# Stigmergic Collaboration
## A Theoretical Framework for Mass Collaboration

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# Abstract

This thesis presents an application-oriented theoretical framework for generalised and specific collaborative contexts with a special focus on Internet-based mass collaboration. The proposed framework is informed by the author's many years of collaborative arts practice and the design, building and moderation of a number of online collaborative environments across a wide range of contexts and applications. The thesis provides transdisciplinary architecture for describing the underlying mechanisms that have enabled the emergence of mass collaboration and other activities associated with 'Web 2.0' by incorporating a collaboratively developed definition and general framework for collaboration and collective activity, as well as theories of swarm intelligence, stigmergy, and distributed cognition.

Accompanying this creative arts thesis is a DVD-Rom which includes offline versions of the three Internet based collaborative environments designed, built and implemented in accordance with the frameworks for digital stigmergy and mass collaboration developed in the written work. The creative works in conjunction with the written thesis help to explore and more rigorously define the collaborative process in general, while testing the theory that stigmergy is an inherent component of collaborative processes which incorporate collective material production.

Supported by a range of contemporary examples of Internet activity, including the accompanying creative works, it is found that stigmergy is a deeply rooted mechanism inherent in not only traditional material collaborative processes, but a range of emerging online practices which may be broadly categorised as digital stigmergic cooperation and collaboration. This latter class enables the extreme scaling seen in mass collaborative projects such as Wikipedia.org, open source software projects and the massive, multiplayer environment, Second Life. This scaling is achieved through a range of attributes which are examined, such as the provision of a localised site of individualistic engagement which reduces demands placed upon participants by the social negotiation of contributions while increasing capacity for direct and immediate creative participation via digital workspaces. Also examined are a range of cultural, economic and sociopolitical impacts which emerge as a direct result of mass collaboration's highly distributed, non-market based, peer-production processes, all of which are shown to have important implications for the further transformation of our contemporary information and media landscape.

# Declaration

The following Declaration, signed by the student: Mark Alan Elliott

This is to certify that,

(i) the thesis comprises only my original work towards the PhD except where indicated in the Preface,
(ii) due acknowledgement has been made in the text to all other material used,
(iii) the thesis is less than 100,000 words in length, exclusive of tables, maps, bibliographies and appendices.

_____ Date: _____

# Preface

Many of the concepts developed in this dissertation received collaborative input by numerous individuals by way of review and evaluation of the ideas I produced. These contributions were made via a number of online fora and open research projects. The primary open research project to collaboratively contribute through review and evaluation was MetaCollab.net (this project was conducted as part of this dissertation's creative work component). For a list of registered contributors to this project, see:

<http://collaboration.wikia.com/wiki/Special:Activeusers>

Note: this list only shows registered users as of the current date, and does not list anonymous contributors.

The contributions received were ultimately marginal in comparison to the central, original claims made in this dissertation, namely, the 'general framework for collective activity', and the theoretical frameworks for 'collaboration', 'stigmergic collaboration' and 'mass collaboration', which are of my sole creation.

Mark Alan Elliott
May, 2007

# Acknowledgements

I must begin by thanking Elizabeth Presa, Sean Cubitt and Warren Burt who formed my dissertation committee and provided enormous amounts of encouragement, support and guidance throughout my PhD. The open and explorative environment of the Centre for Ideas and Elizabeth's great insight into and understanding of research within the creative arts made the exploration and development of this thesis possible, and for this I am very much indebted.

I must also extend an immeasurable thank you to Marcus Leonard who has acted as collaborative partner in some way or another for all of the creative projects I have undertaken as part of this PhD. His formidable capacities to wrestle with code, administer web servers and critically evaluate pale in comparison to his warmth and generous nature. I always know there's yet another brilliant solution coming when he says, 'no, you can't do that, it's impossible... wait a minute!'

All of the three creative works submitted with this dissertation were collaborative ventures of fairly large scale and scope, therefore, if I miss your name, know that I realise that without your help, they could not be what they are. Great thanks to all of the many participants, registered and anonymous, of MetaCollab.net, which includes the staff and regulars at Wikia.com as well as the tireless and committed Wikipedians. Thank you also to the many contributors to the Cooperation Commons Google Group (see <http://groups.google.com/group/CooperationCommons/>), our discussions having lent me a great deal of insight into the processes, attributes, ideas and latest research surrounding collective activity.

I also greatly appreciate having had the opportunity to work with a wonderful bunch of students, almost 800 in number over the past four years, as part of my involvement with the Collaborative Contract course and its online component. In working with Simon Terrill on this course for the past three years, our many in depth discussions on and around the collaborative process helped me to see it from totally new perspectives, which is something that I consider to be invaluable. His involvement and feedback was also an important part of the ongoing development of course's online environment. Marcus Leonard also played a critical role in this project, helping build and implement the site, lending the Centre for Ideas a server for the first two years and administering it for the last three. His willingness to share and participate is emblematic of why the Open Source Software movement achieves the incredible feats that it does.

Mimi Marcus and I collaborated extensively on the concept and development of the Australian Bill of Rights Initiative and without her, the opportunity for this particular project would not have existed. She taught and continues to teach me what I believe we all need to know and be a part of creating—our human rights. Marcus Leonard, once again, was instrumental in the development of this project and its online component, spending

many hours with me trying to solve tricky design particulars and nutting out the code to make it work. I am also especially grateful for the more recent involvement of Lucas Maddock, Alex Gibson, Matthew Daniel and Marcus Barber in this project. Drawing on their knowledge, experience and creativity has helped shape an inspiring vision of participatory governance and collaborative policy writing that I hope we continue to foster and develop for some time to come.

No amount of acknowledgment could ever adequately represent what is due to Keri Christensen, with whom I have extended my mind, heart and life. Thank you for your patience and trust in my 'crazy ideas', for your love and support, for your capacity to care, nurture and excite, and of course for the incredible amount of time and energy you have spent looking after our baby boys so I could manifest this vision.

And finally, to my twin sons Cedar and Lucas who came into this world in the final year of this PhD—since you are still too young to understand these words, I speak to your future:

The gift of your life has planted within me a seed that grows in all directions,
It transforms my experience and understanding of everything, everyday.
If you one day read these words, I hope you will know what I mean when I say,
The seed is love, the rain is hope, the sun is creativity and the earth is understanding.

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# Accompanying DVD-Rom

## Instructions for use of DVD-Rom

1. Locate the DVD-Rom attached to the back panel of this dissertation.
2. Load DVD-Rom and click on 'index.html'. This will load an index into your preferred web browser. Or, launch a web browser and from the file menu, choose 'Open file' and select 'index.html' on the DVD-Rom.
3. Navigate to the five different projects via the links on the index page as per normal web browsing.

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1. Collaborative Contract 2005
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## Disclaimer

All environments provided are dynamically generated in their user-contributed material. This means there will be edit links visible, but due to offline archiving, this functionality will not be available. Note: If your computer has an open Internet connection, the archived version of MetaCollab.net will query and retrieve some incidental content (graphics and Google ads mainly), and outgoing links contained within all projects will connect to external sites.

The architecture of the Collaborative Contract sites (especially 2006 and 2007) are more reliant upon dynamically generated requests from logged in users, this means that some functionality will be lost when browsing via the offline archive, specifically, the 'My Blog' links. In this case, they will return Mark Elliott's blog where they would normally return the blog belonging to the logged in student. Additionally, the 2007 iteration has made

considerably more use of Flickr.com and YouTube.com content which the students have uploaded and embedded. In these cases, this content will be unavailable for the offline versions. Also unavailable in the offline version are the blog comments as these are dynamically generated upon browser request.

An online index similar to the one provided on the DVD-Rom can be found at: <http://mark-elliott.net/view/Dissertation>. This index provides links to the active web-based versions of the projects. Additionally, a PDF version of this dissertation may also be found there.

# 0. Prelude: meta contexts

How often I found where I should be going only
by setting out for somewhere else.
—*R. Buckminster Fuller*

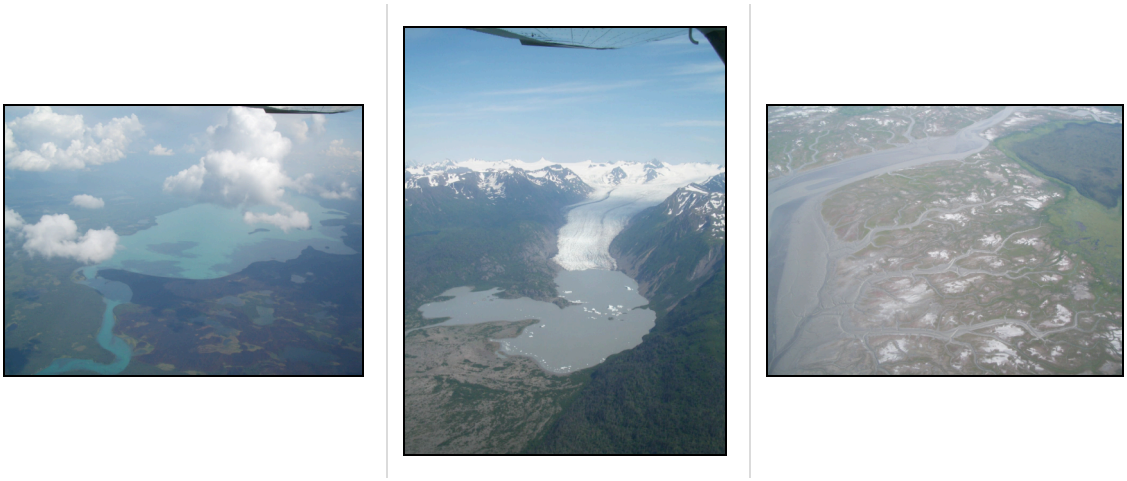

Figure 0.0.
Alaskan south central, aerial view from Cessna 180 light aircraft, mid 2005

Having grown up in Alaska spending a great deal of time in small aircraft (my first fly-in camping trip was at the age of 3 months), I grew up accustomed to seeing and thinking about vast and variegated spaces from an aerial perspective (see figure 0.0). Later in life, I came to realise that this had dramatically shaped my thinking—I still experience a strangely disorienting feeling in new places if I don't know what the terrain looks like from the sky. This desire for aerial, meta, holistic and encompassing understandings has stayed with me throughout my life, evolving in its application and complexity.

After exploring the idea of 'becoming an inventor', I entered the world of music with gusto at the age of 11. Declaring with youthful exuberance that I would never do anything else, I played and wrote music for hours everyday alone and in groups. A decade later, I found my self on the other side of the Earth at the University of

Melbourne's Conservatorium, studying composition. There I applied my capacity for aerial perspectives in the conceptual engagement of works of large scope and high complexity. Inspired by the likes of Bach, Brahms, Ligeti, and Cage, I soon discovered electro-acoustic music, improvised live computer processing, and most importantly, collaboration. In order to push my practice beyond my own understandings I explored the capacity of the ideas I discovered, the technology I could acquire, and the (often cross-cultural) collaborative relationships I forged.

Yet another decade later I found myself to be a practicing composer-performer-collaborator deeply engaged in an inquiry into the nature of reality, collective consciousness and our relationship with the material world which seemed increasingly virtual. The Twin Towers had just been destroyed and despite the largest collective protests the world had ever witnessed, the U.S.A. was invading Iraq. The intersections of the democratic and the unilateral, the civic and the political, the collective and the individual, the open and secret sparked an idea—an Internet driven, large-scale collaborative opera, explicitly devised to subvert the traditionally lofty and dictatorial position of the Western composer while commenting on the assumptions we make when we hand over our individual rights to larger institutions. Further, these ideas and this opera would provide the subject matter for of a PhD.

In commencing my initial research at the Centre for Ideas—a theory and philosophy hub for a multi-disciplinary arts institution (the Victorian College of the Arts)—I discovered much to my surprise that the composition of just such an opera was already underway. What I discovered was the Open Source Software movement, the 'Wikipedians'[1] and Second Life 'residents' who had already established the methodology I was interested in developing, though, not (yet) in the language of music, but rather in computer code, knowledge and virtual 3D worlds. As I continued my research and explorations, I quickly became aware that the issues involved in such collective creative efforts were deeply complex and that the possible outcomes were much broader than a single opera. As a result, my understanding, experience and interests began to shift and expand beyond that of seeing music as the most engaging outcome of the collective efforts I could pursue as part of my PhD.

In fact, my interests had shifted from that of composing music, to *composing collaborations*. Could a collective creative process become a medium in its own right, subject to the design interests of a 'composer'? If so, in what ways might a composer guide this undoubtedly unpredictable and emergent process in order to serve their interests? These initial questions intrigued and inspired me as I realised I had been doing precisely this for years, only on smaller scales. I had been creating musical and artistic instructions for collaborative activities, often through the process of collaboration itself. Situating my collaborative designs online therefore seemed little different—code, conceptual and site architecture felt only a step away from the written language of music and compositional performance planning and design. Bringing people together around a means for collective creation is nothing new for many composers, however the combination of increased scale, 'collaborativity' and the realisation that the output could be anything—even defined by the collaboration itself—was tremendously exciting for me as an artist.

However, a formidable and fundamental question confronted me in theorising this new terrain: '*How* am I to discover just what the nature of this emergent form of collective creativity is?' While the notion of methodology is of course the cornerstone of research, the perplexing issue was that the subject of my research entailed a wide range of topics, many of which are situated in well established paradigms—for instance, information and communication technologies (ICT), media and communication theory, psychology, sociology and the anthropology of collaborative and creative activity, the biological coordinative mechanisms of social populations, emergence and complex adaptive systems to name a few. However it was transdisciplinarity which provided a general methodological approach for the following work, in that the objective was to explore a subject where the problem domain is unstructured and that much of the contributing research exists across and between disciplines, while the theoretical frameworks to be developed may finally reside beyond all existing disciplines (Klein 2002). Transdisciplinarity therefore enabled my 'meta' oriented interests to be engaged on the level of the methodology as well as the subject matter, while reflecting one of my favourite aesthetics—the simultaneous mirroring of form within content and content within form.

Concerning the generation of new knowledge, the objective of every PhD, I will not claim specific allegiance with either constructivist or essentialist positions. My reasons for this are not so much in maintaining a 'trans stance', rather my motivations for pursuing the creation of new knowledge are perhaps more aligned with the evolutionary epistemologists.[1] I am interested in proposing the 'best fit' between my observations, experiences and applications in order that they may aid our collective attempts at making our world a better place—although all such propositions are only provisional, in that through the course of our bio-psycho-socio-material evolution, any and all reference points may and are likely to shift in order to better represent the reality that we experience. The reality I am currently experiencing and sharing with others, and the one I wish to make comment on here, is one of increasing complexity in the domain of collective activity.

As a long time artistic collaborator, I feel my senses are reasonably well tuned towards the participation, or lack thereof, in those around me. In relation to this sense, I have witnessed and been apart of a good deal more cooperation and collaboration in the past five years than in the previous, largely in relation to the Internet and other network-based activities. For instance, I cannot count how many times I have received unsolicited and extremely valuable contributions to my research (often quite serendipitously) via my blog, website or email lists, while many of 'my' ideas have been collaboratively developed in a variety of forums. One such forum being MetaCollab.net, a project founded as part of this PhD, is a cross-disciplinary collaborative research project aimed at building knowledge and theory on and around collaboration. MetaCollab.net has served as a repository for many of the ideas presented in the following chapters, however during their stay in this repository, the ideas have been further evolved by many others—often anonymously.

While this form of anonymous collaboration is one of the many hallmark traits of the increasing capacity some of us have for collective activity (activity that is simultaneously selfless and selfish), the fact that together we are creating more and differently does not mean that what we create or how we apply our creations will all be positive. However ensuring positive outcomes is not the task of scholarship, or art.

[1] See 'Evolutionary Epistemology', Stanford Encyclopedia of Philosophy, (online resource), <http://plato.stanford.edu/entries/epistemology-evolutionary/> retrieved 5 April 2007.

Instead, both pursuits share the task of re-presenting our state of being, individually and collectively, in order that we may do our best to provide a birds-eye-view of terrain which would otherwise be new and 'strangely disorienting'.

# 1. Introduction

> The introduction of many minds into many fields of learning along a broad spectrum keeps alive questions about the accessibility, if not the unity, of knowledge.
>
> —*Edward Levi*

> I like songs that have lots of different parts in them...
>
> —*Sean Lennon*

Creativity, the wellspring of humanity, carries not only the essence and complexity of our mysterious origins, but also the promise of our advancement in the face of rising uncertainty and peril. Those beings with the talent for creative thought and the will to manifest their ideas have driven our cultures, shaped our sense of self, and inspired our capacity to respond to the demands of our times. If there is anything more enigmatic than this—the creative power of humanity and of nature—perhaps it is the fact that somehow we are here, creating ourselves and all of this, together. This is where this thesis begins, with a curiosity, desire, and passion to reach not just towards a deeper understanding of creativity and the collective, but, towards our developing capacities for collective creativity.

By developing original theoretical frameworks, the central aim of this thesis is to show how increasingly large and dynamic groups are coordinating mass collaboration—the process associated with some of the largest collective creative endeavours in human history: Wikipedia.org, the Open Source Software movement and Second Life. In order to provide these frameworks, I make a synthetic connection between the collective activities of humans and those of social insects via the concept of stigmergy. The biological concept of stigmergy (indirect communication between agents which is

coordinated through interactions with their local environment) is utilised to show how mass collaboration is an activity fundamentally dependent upon stigmergy, and how stigmergy is a core component of collaboration more generally.

This intersection of stigmergy and collaboration therefore provides an entirely new way of conceptualising collaboration and thus the emergence of mass collaboration which represents the most well developed and extended collective creative process currently available to humanity. The stigmergic perspective enables the tracing of the evolution of collaboration from the conversational generation and elaboration of ideas, to the extension of this process into the material and digitally networked realms, and finally, to the emergent processes which enable collective creativity to scale into staggeringly large and diverse collections of participants as found in mass collaboration. Such a framework provides not only a means for conceptualising and analysing the bio-socio-cultural mechanisms which underlie and coordinate large-scale collective creative activity, but it also provides the ability to support and engineer them.

## 1.1. Stigmergy

Stigmergy is a class of behaviour in which collective activity is coordinated through the individuals' response to and modification of their local environment—one agent's modification becomes another's cue. Additionally, as agents create such modifications, the medium in which they are encoding (some subset of their local environment) also transforms their encodings in ways that contribute to the agents' work. Thus, 'stigmergic intelligence' is seen to reside not only in and amongst the totality of the agents involved (the traditional notion of collective intelligence), but 'in the interactions among the agents and the shared dynamical environment' (Parunak 2005:5).

Stigmergy has been applied to and is considered a branch of swarm intelligence (SI) by computational intelligence researchers (Bonabeau & Theraulaz 1999), however it was originally conceived to describe the organisation and activities of social insects and how cognitively limited individuals (termites and ants in particular) work together to create complex structures of matter and society (Grassé 1959). Therefore, the empirical study of biology established the mechanisms and features of stigmergy long before its application in the areas of artificial life (AI) and SI.

More recently, research is suggesting that stigmergy is inherent in the workings of the Open Source software movement (Heylighen 2007b; Robles et. al. 2005), the Internet (Gregorio 2002; Parunak 2006), and even the emergence of a global brain (Heylighen 2007a). The breadth of the application of stigmergy provides an indication as to its utility and given the increasing amount of research surrounding the topic, there can be little doubt this framework will continue to expand in its conception and application.

In the context of the present work, stigmergy provides a theoretical framework which explains not only the effects of mass collaboration—the emergence of coordinated structures across and amongst distributed and often disconnected collaborative participants—but it deals with the root dynamics of this activity, providing an explanation for the coordination between the collaborating/cooperating 'produser'[7] and their media of choice.

## 1.2. Collaboration

Collaborative activity underpins a great majority of humanity's collective efforts. While it is receiving an increasing amount of attention from a wide range research fields (such as art, science, industry, business, education, technology, software design and medicine), institutional silos often impede the capacity to discover and synthesise such research. This makes it particularly challenging to develop a cross-disciplinary theoretical framework for collaboration that goes beyond a dictionary definition for the purposes of informing practitioners who wish to utilise collaboration as a problem solving strategy or theorise its application in diverse contexts.

In order to more accurately describe new and existing forms of collaboration, this thesis proposes the foundations for a generalised framework for collective activity. This framework explores the distinctions and the necessary and sufficient conditions for coordination, cooperation and collaboration, providing a context for a more nuanced usage of these terms, especially concerning 'collaboration'.

## 1.3. Stigmergic Collaboration

Illustrated by example, this thesis distinguishes between 'discursive collaboration' and 'stigmergic collaboration', the latter providing a means to theorise the extension of the

collaborative process from the discursive elaboration of shared representations (ideas), to the annotation of material and digital artefacts as embodiments of these representations. Additionally, when stigmergic collaboration is extended by computing and digital networks, a considerable augmentation of processing capacity takes place which allows for the bridging of the spatial and temporal limitations of discursive collaboration, while subtly shifting points of negotiation and interaction away from the social and towards the cultural.

## 1.4. Mass Collaboration

By supporting a shift away from social interactions and towards more site-of-work mediated collaborative interactions, Internet applications[2] and their associated communities are providing participants with rich and powerful stigmergic environments, helping lower barriers to participation while allowing individuals to more easily locate projects of interests. Most notably, the mass collaborative stigmergic 'workspace' allows for the number of collaborative participants to scale from several dozen (at best) in face-to-face contexts (Lipnack & Stamps 2000:180-1), towards tens and even hundreds of thousands.[3] This enables an expansion of project size and scope, epitomised by the Wikipedia.org project.[4]

Therefore, the original linking of stigmergic processes to that of material collaboration, provides the means for tracing the evolution of this process from that of the manipulation of materials for the augmentation of face-to-face collaborative processes, to the emergence of digital workspaces as a mediated form of stigmergic collaboration, to mass collaboration, where the characteristics of the digital stigmergic workspace and other technical, social and cultural aspects enable extraordinary scaling of membership and project scope.

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[2] Applications exemplified by but not limited to the wiki.

[3] 'As of June 2006, the English Wikipedia received more than 120,000 edits a day; more than 67,000 people edited the Wikipedia in that month. As of November 2006, it receives 200,000 edits a day.' Source, 'List of Wikipedians by number of edits', Wikipedia, <http://en.wikipedia.org/w/index.php?title=Wikipedia:List_of_Wikipedians_by_number_of_edits&oldid=121963450> retrieved 19 April 2007.

[4] As of 10 March 2007, there was 1,676,740 articles in the English Wikipedia alone. Source, 'Size of Wikipedia', Wikipedia, <http://en.wikipedia.org/w/index.php?title=Wikipedia:Size_of_Wikipedia&oldid=123161387>, retrieved 19 April 2007.

## 1.5. Contributing Works and Themes

### 1.5.1. Hivish Society as Mind

Stigmergy's origin in the study of social insects provides an obvious metaphor when applied to the collective intellectual efforts of humans—the hive mind. In his classic work, *Gödel Esher Bach: An Eternal Golden Braid* (1979), Douglas Hofstadter compares the total distributed workings of an ant hive, playfully named Aunt Hillary, to the human mind (1979:316-21). In this analogy, Hofstadter compares one ant to one neuron, and the whole hive to the mind. Although unnamed in this work, the mechanisms of stigmergy clearly form an important part of his conception of cognition, as it is stigmergy which coordinates the formation of pathways that enable his 'teams' of ants to carry 'signals' on lower levels, which dynamically combine in such a way so as to lead to the emergence of conceptual structures on higher level of the hive/mind. While this work did not directly engage the notion of collective intelligence, it did explore the mechanics of the individual mind through metaphors of the hive, providing a conceptual mapping for further theorising along these lines.

As a key figure in the development of AI, Marvin Minsky's work, *Society of Mind* (1986), picks up where Hofstader leaves off, providing a detailed thesis outlining how minds are collections of agents and agencies assembled in various configurations on differing levels. In this organisation of cognition, each successively higher level of agency is comprised of a collection or collections of lower level agents, constructing an image of the mind as a society of swarming sub-agents who are themselves composed of further swarms of sub-agents.

Kevin Kelly's work, *Out of Control: The New Biology of Machines* (1994), continues this exploration of emergence and of the hive and minds, providing a prediction that seems to prophesise the emergence of mass collaboration.

> As we wire ourselves up into a hivish network, many things will emerge that we, as mere neurons in the network, don't expect, don't understand, can't control, or don't even perceive. That's the price for any emergent hive mind. (1994:36)

Who could have expected that swarms of online individuals acting without monetary incentive would build through distributed ad-hoc processes the largest and most comprehensive encyclopedic body of knowledge in human history, Wikipedia.org, or one of Microsoft's most aggressive competitors, the Apache HTTP Server? Posing the metaphors of a tree emerging from a seed and a hive from a collection of bees, Kelly ponders, 'what is contained in a human that will not emerge until we are all interconnected by wires and politics? The most unexpected things will brew in this bionic hivelike supermind' (1994:16-7).

### 1.5.2. Swarm Intelligence

Since the time of Hofstadter, Minksy and Kelly's work, new fields of research have emerged around the study of swarm and insect behaviour, mostly with the aim of developing AI. Specifically, swarm intelligence (SI) addresses the distributed, emergent and multiagent aspects that Hofstadter, Minksy and Kelly dealt with, while also incorporating understandings of stigmergy. *Swarm Intelligence: From Natural to Artificial Systems* (Bonabeau & Theraulaz 1999) explores the modelling of stigmergy and insect (primarily ant) behaviours through its re-engineering in AI settings. Of the same name, *Swarm Intelligence* (Kennedy & Eberhart 2001), takes a broader view in its objectives and subject matter, exploring emergence and swarm activity in a variety of organisms and theories of socially constructed intelligence. While Kennedy and Eberhart differ from Bonabeau and Theraulaz on a number of positions (such as the designation of a swarm's membership, the former describing them as particles, the latter as agents), their desire to engineer stigmergy and SI in artificial, computational systems forms a common objective. This objective serves as the primary difference between the concerns of SI practitioners and of those presented here. The concerns explored in the following chapters are focused on the engineering of computationally enhanced collective *human* intelligence and creativity. So while further research and modelling of SI and stigmergy are certainly useful in understanding their human applications, the study and modelling of human collective activities are likely to be better suited to the objectives of this thesis.

### 1.5.3. Smart Mobs

More rooted in the observation and theorising of collective human behaviour and culture, *Smart Mobs* (Rheingold 2002) takes up the themes of emergence and the social mind in the exploration of the potential for the interactions between humans extended by technologies to contribute to the evolution of new forms of collective behaviour. In doing so, he identifies the emergence of 'smart mobs' which are the result of human cooperation amplified by communication and computing technologies. While Rheingold states that 'connections between the behavior of smart mobs and the behavior of swarm systems must be tentative' (2002:179), the frameworks and supporting research (Robles et. al. 2005; Heylighen 2007; Ricci et. al. 2006) proposed in later sections should provide adequate evidence that such connections are valid and warrant further research. Additionally, his observation that 'the right kinds of online social networks know more than the sum of their parts' (2002:179), that is, that they show levels of intelligence emerging above that of their individual members, points to emergent system behaviour, a defining characteristic of stigmergic systems (Parunak 2006:5-7). By developing original theoretical frameworks, a central aim of this thesis is to show how increasingly large and dynamic groups are generating shared emergent representations (i.e. collective intelligence) and how this is a characteristic of mass collaborative smart mobs.

### 1.5.4. What Is Web 2.0?

Since the writing of *Smart Mobs* and the collapse of the dot com bubble, a new conceptualisation of the Internet has begun to take shape. Still nascent, many names have been proposed for this reconceptualisation, such as 'the living Web, the Hypernet, the active Web, the read/write Web' (Tapscott & Williams 2006:19). However, the one that seems to be garnering the most attention to date is 'Web 2.0'. Coined by author and publisher, Tim O'Reilly, in the naming of a conference held to explore the new capacities and opportunities emerging surrounding the Internet post the 2001 dot com bubble, the term, and more importantly the concepts surrounding it have gained ground in the last several years.

*What Is Web 2.0 - Design Patterns and Business Models for the Next Generation of Software* (O'Reilly 2005), describes this conception for a prospective web designer interested in engineering the capacities associated with Web 2.0. While O'Reilly highlights a number of issues, the core theme surrounds designing 'architectures for participation'. In his article, O'Reilly makes a number of suggestions regarding how to to best cater for such participatory architectures, such as engaging the widest possible audience, thinking of the Internet as a platform for applications in order to increase interactivity, and exploiting the network effects resulting from these interactions. Importantly, all of these suggestions can be interpreted as design principles which support the engineering of stigmergy. By including more participants in interactive processes through architectures of participation, designers increase the stigmergic capacity of their applications (the ability for users to respond to and further encode their online environment). Interestingly, O'Reilly's analysis also resonates with social and hive mind metaphors in his commenting that through Web 2.0 associated design principles, we are 'harnessing collective intelligence, turning the web into a kind of global brain'.[5]

### 1.5.5. Wikinomics

*Wikinomics: How mass collaboration changes everything* (Tapscott & Williams 2006) is the first published work to directly address mass collaboration, an often cited example of Web 2.0 and the guiding topic of this thesis. While generally geared towards providing 'examples of how people and organizations are harnessing these principles to drive innovation in their workplaces, communities, and industries' (2006:20), Tapscott and Williams aim to identify new trends and methods of peer production labelling the majority of them as mass collaborative. Tapscott and Williams claim that mass collaboration is associated with 'deep changes in the structure and modus operandi of the corporation and our economy, based on new competitive principles such as openness, peering, sharing, and acting globally' (2006:4). They also suggest that the 'new promise of collaboration is that with peer production we will harness human skill, ingenuity, and intelligence more efficiently and effectively than anything we have witnessed previously' (2006:18).

[5] For more on global brain theories, see (Bloom 2000) and (Heylighen 2005).

However, Tapscott and Williams fail to provide an adequate definition or criteria for discerning collaboration from other collective activities such as cooperation and coordination. This has the effect of lowering the term to that of a buzzword and stripping it of analytical value. In fact, in most cases where authors use the term 'collaboration', it could be exchanged with 'cooperation' to little semantic, effect leaving the discerning reader to wonder why collaboration was used at all. This is not to suggest that there is no difference between the terms, on the contrary, it is precisely the distinctions which forms a key conceptual foundation for this thesis. Rather, in the distinguishing of collaboration from cooperation and coordination, it becomes possible to discern important differences in a range of the collective activities discussed by Tapscott and Williams and others.

Overall, Tapscott and Williams' analysis is typical of inquiries into novel Internet developments in that it deals with the activity in a manner and tone geared towards commercial application. While this is a valid aspect to investigate and one which certainly enhances our understanding of the phenomenon, it generally does not engage the subject deeply enough to provide rigorous conceptual frameworks into the underlying nature, architecture and dynamics of the activity. However, their work does provide valuable examples and anecdotal insights useful in the support and theorising of such frameworks.

### 1.5.6. The Networked Information Economy

A text that does provide a sustained, critical, deeply engaged conceptual framework for peer production is, *The Wealth of Networks: How Social Production Transforms Markets and Freedom* (Benkler 2006). In this work, Benkler, a Yale Law School professor, examines the social, political and economic effects and implications of peer production and mass collaboration, and in doing so describes the emergence of what he calls the networked information economy. He makes a compelling case that there exists multiple modes of public discourse which are qualitatively different from each other depending upon their medium of delivery, and that these differences directly affect the level of social and political freedom available to the public.

In a detailed analysis, Benkler deals with a wide range of criticisms and support for both the mass media and the Internet as platforms for the public sphere. He shows how the mass media as a hub and spoke structure is 'typified by high-cost hubs and cheap, ubiquitous, reception-only systems at the ends' (2006:179). This arrangement suffers from information bottlenecks, is susceptible to concentrations of power (2006:198) and the requirements for supporting the high-cost infrastructure generates an asymmetrical relationship where the recipient's first choice viewing interests are subjugated to the provider's imperative to cater to the highest number of viewers by programming 'second and third choice' content.

With a considerable body of research, Benkler shows how the Internet-based information network as public sphere overcomes these problems through providing a multiplicity of channels for discourse that circumvents information bottlenecks. He also shows how the cost of controlling the infrastructure is higher and the efficacy lower than in mass-media-dominated systems (2006:271-2). He recommends that through granting increased interactivity to the participants, they are encouraged to become active participants in what is otherwise 'a relatively passive cultural model of media consumption' in which the media is not to be treated 'as moves in a conversation, but as completed statements whose addressees were understood to be passive' (2006:179-80).

Importantly, Benkler's argument regarding the potential for increased freedom and autonomy in the networked public sphere is grounded in an attempt at understanding and evaluating '[h]ow a society produces its information environment' (2006:129). In this approach, he lays bare the critical value and efficacy of a well functioning networked public sphere by showing how it is a function of the quality and diversity of one's information inputs which shapes the range of assumptions one can make about what actions and forms of actions are possible (one's freedom) within that information environment. This simultaneously speaks to the subject of stigmergy if one interprets,

- the output of the information environment as the overall emergent behaviour of the stigmergic system;
- the quality and diversity of one's information inputs as the agents' capacity to sense the range of information present in the stigmergic environment; and

- the range and nature of actions one may take as the participants' capacity to modify their information environment *in combination with* the environment's information processing capacities.

Further, Benkler identifies a phenomenon that he terms 'commons-based peer production', which describes the relational characteristics of those involved in mass collaboration. This decentralised process of loosely connected individuals collaborating and sharing resources and outputs with without market signals or managerial commands (2006:60) not only captures the essence of mass collaboration, but also forms the driving force for the emergence of what he terms the networked information economy. This emergent economy is not traditionally recognised for its importance and role in the production of new information which fuels all other subsets of the global economy. Benkler further asserts that in coming years, this component of the world economy will grow in size and strength, super-charging cultural and technological innovation in general.

Benkler's work provides a sociopolitical foundation upon which this thesis will build a different picture of the same landscape. This alternate landscape bears fewer cultural and economic markers, as it is perhaps less familiar to the human perspective. This difference in perspective is perhaps similar to that of viewing peer production as the resulting work of bloggers and Wikipedians, versus viewing it as the product of hives intelligent agents. Or, in another example, that of the Internet as a collection of websites and associated culture, versus seeing it as vast clouds of autonomous, dynamic and interacting points of light swarming around an emerging megalopolis of digitised information and experience. This witnessing and analysis of the emergence of stigmergy within the networked information economy on such vast scales requires a high altitude, multidimensional and non-linear perspective to make sense of what might otherwise,

- look paradoxical—highly complex organisation and structures arising from simple, local contributions,
- look like collectivism—from the outside stigmergic systems may look conformist to the extreme, however within the system individuals have complete

freedom to the point whereby random activity is a necessary part of the system's optimisation (Parunak 2005:4),

- seem unapparent—emergent behaviour exists on levels above that of its constituent parts, so at the 'ground level' the behaviour may not be seen to exist at all (Parunak 2005:6).

## 1.6. The Missing Link - Stigmergy

The theory of stigmergy and its relationship to the human realm represents a potential missing link in the understanding, research and application of the type of large-scale collective activities explored in works such as *Wealth of Networks, Wikinomics* and *What is Web 2.0*. Additionally, theories and intuitions previously described with vague metaphors relating to hive or social minds in the above works, *Gödel, Escher, Bach, The Society of Mind, Out of Control, Swarm Intelligence* and *Smart Mobs,* are solidifying into conceptual frameworks which incorporate stigmergy to explain such collective activities. The body of research linking stigmergy and human activities is a growing area taking place in a number of cross-disciplinary contexts.

### 1.6.1. Social Cognition, Artefacts & Stigmergy

An early work to make cross-disciplinary use of stigmergy is, *Social Cognition, Artefacts, and Stigmergy: A Comparative Analysis of Theoretical Frameworks for the Understanding of Artefact-mediated Collaborative Activity* (Susi & Ziemke 2001). This article explores the inherent connections between stigmergy and other established theories for studying human activity, namely activity theory, situated and distributed cognition. These theories are representative of a growing trend in cognitive research which distinguishes itself from more traditional approaches by moving away from placing the central focus of inquiry on the individual isolated mind, and instead emphasises the role that the wider sociocultural context and material environment plays in the formation of meaning, cognition and intelligence. Susi and Ziemke's analysis shows that the explicit incorporation of the material world and its role in coordinating human cognition strongly links these theories (especially distributed cognition) to that of stigmergy.

### 1.6.2. Human-Human Stigmergy

H. Van Dyke Parunak's *Expert Assessment of Human-Human Stigmergy* (2005), commissioned by Defense Research and Development Canada, a branch of the Canadian Department of National Defence, stands as an excellent and far-reaching evaluation of the mechanisms of stigmergy and its relevance to a diverse range of human activities and potential applications. Parunak designates a number of computational applications as stigmergic, most of which O'Reilly considers flagships of Web 2.0. In fact, not only does he recognise Google's PageRank system, eBay's online auctioning and Amazon's recommender systems as stigmergic systems, but the entire Internet itself.

Such explorative and analytical works have provided a groundswell of research that has enabled a number of novel conceptual frameworks to be proposed which incorporate stigmergy in theories and propositions regarding the collective activities of humanity.

### 1.6.3. Stigmergy, Open Access & Open Source

*Self-Organized Development in Libre Software: A Model based on the Stigmergy Concept,* (Robles et. al. 2005) provides details of a computer simulation created to test the possibility that a stigmergic model (derived from ant behaviour) could generate similar statistical information regarding the allocation of developers to open source projects. Robles et. al. found that 'libre software development can indeed be modelled as a stigmergic one' in regard to 'how developer effort is allocated to projects, and to how this affects the evolution of projects themselves' (2005:8). This research provides strong empirical evidence that stigmergy is in fact a coordination mechanism involved in open source software development.

More recently, Francis Heylighen, a renowned research professor at the Free University of Brussels who's research focus is the evolution of complexity and collective intelligence, has published the exploratory paper *Why is Open Access Development so Successful? Stigmergic Organization and the Economics of Information* (2007a). In this work Heylighen presents a straight forward and compelling case for stigmergy as an underlying mechanism in the expansion of what he terms, 'open access development'.

Heylighen provides three characteristics in order to designate information as open access:

- non-proprietary,
- part of a creative commons free to access, use, and in many cases modify, and
- consisting purely of information that can be duplicated without limit.

In identifying projects such as the Open Source Software movement, Wikipedia and others as open access, Heylighen utilises stigmergy to explain how this activity can successfully contravene business and economic theory in regard to propriety models where there is an apparent lack of incentive and structures for the coordination of activity. Heylighen takes the application of stigmergy even further in a later publication, *Accelerating Socio-Technological Evolution: From Ephemeralization and Stigmergy to the Global Brain* (2007b). In this work he provides explicit connections between stigmergy and the workings of the brain and shows how stigmergy can play a role in the development of the 'semantic web' (increasingly referred to as Web 3.0) by tracing the preferences users 'leave on the paths they have travelled' (2007b:16).

### 1.6.4. Cognitive Stigmergy

Other than the present work, *Cognitive Stigmergy: A Framework Based on Agents and Artifacts* (Ricci et. al. 2006), stands as one of the most comprehensive theoretical frameworks for the application of stigmergy to collective human activities. Ricci et. al. developed the theory for the purposes of 'supporting high-level, knowledge-based social activities' (2006:1) and to bridge the gap between the application of stigmergy in computational multiagent systems where agents are typically simple and of limited cognitive ability, and applications where the systems are composed of societies of high-level cognitive agents. This article lays out a framework based upon the recognition that cognitive agents stigmergically engage their environment largely through the use of engineered artefacts and tools, both of which may be 'annotated' with symbolic information representing the agent's cognition. Their theory provides a useful set of concepts and terms, many of which will be incorporated into the frameworks presented here, specifically that of stigmergic collaboration and mass collaboration.

## 1.7. Mapping Mass Collaboration

Such frameworks will no doubt add positive feedback to the milieux, as more researchers and theorists explore the connections and potential applications for stigmergy in existing and emergent contexts. In particular, the application of stigmergy to phenomenon associated with the Internet, Web 2.0 and interactions utilising networked computers in general provides a great deal of potential. This is because one of the core realisations of stigmergy is that regardless of the size and scope of the environment, if agents interact only locally, their limited capacities are not overwhelmed. Additionally, the dynamics of self-organisation inherent in stigmergy enable coherent, system-level organisation to emerge which provides control while allowing it to be distributed throughout the system (Parunak 2005:2). It is therefore clear that a system requiring distributed control for resource constrained agents who engage locally with a large information processing environment matches quite explicitly both the Internet and that of a classical stigmergic system.

As suggested by Heylighen (2007b), it is also likely that the application of stigmergy to human activity will provide research opportunities into the realm of collective intelligence and the hive/social mind. This research may provide missing links to a large body of research on and around cognition, AI and SI, as the swarming dynamics of stigmergy were already implicit in the earlier works of Hoftstader (1979), Minsky (1986) and Kelly (1994), as well as the theories of situated activity and situated and distributed cognition. As the following chapters shall show, stigmergy provides an invaluable framework for the explication of collective human activity in general and collective creative processes which incorporate material transformation in specific. Figure 1.0 maps the main themes covered with nodes colour coded in relation to their respective chapters.[6]

[6] The icons on some of the nodes are artefacts in the export of this originally dynamic map to that of a graphic file. In its original version, the icon represents a link to another map. In their current representation, I will expand such links throughout the course of the dissertation. For more information on this freely available concept mapping software, see CMap Tools, <http://cmap.ihmc.us/> retrieved 7 April 2007.

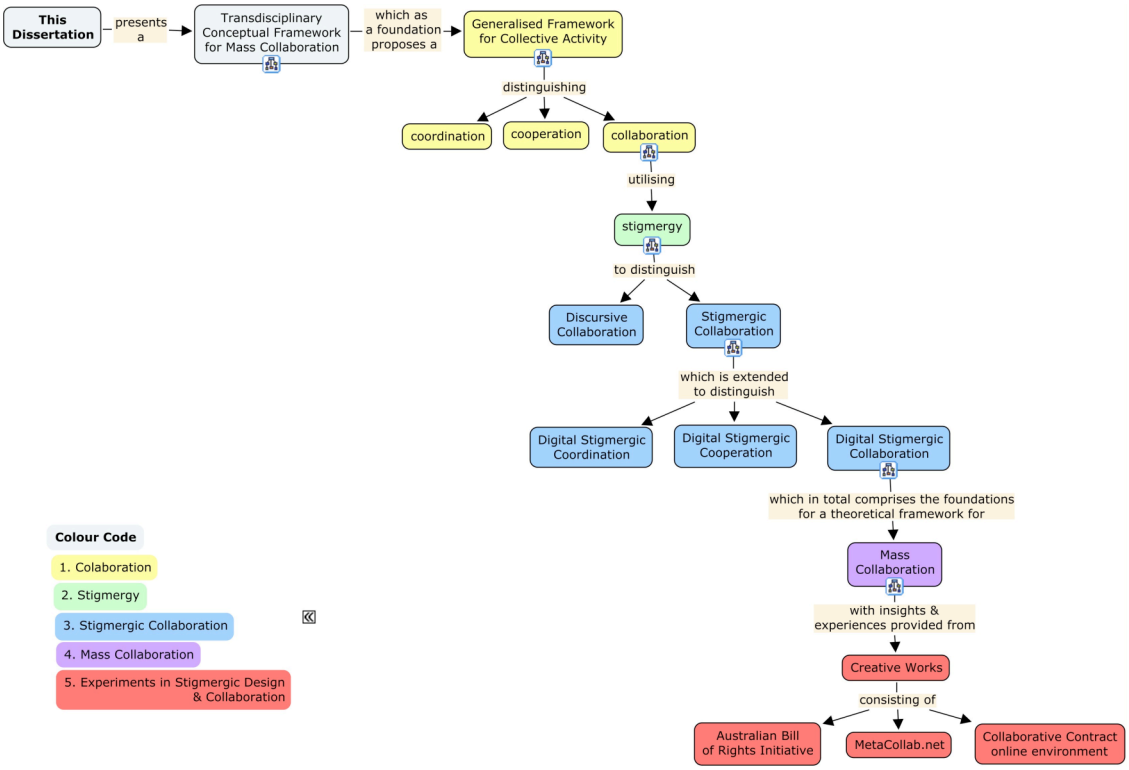


Figure 1.0.
Map of themes covered

Chapter 2, Collaboration, explores the etymology of the term collaboration in order to propose a more specific definition than what is commonly used. This definition then provides a starting point for the development of a general framework for collective activity. This framework contrasts coordination, cooperation and collaboration, showing how there is an intimate and important relationship between the three, the details of this relationship providing core attributes of collaboration upon which I will build a more expanded framework. The expanded framework outlines a generalised process of collaboration and the types of communication structures and forms of technological mediation that may intervene. These distinctions provide the means to discriminate between the collaborative generation of pure ideas through discussion, 'discursive collaboration', and the externalisation of such ideas through various forms of material production, 'stigmergic collaboration'.

Chapter 3, Stigmergy, provides a historical overview of the topic of stigmergy as well as the current state of research and application. The emergent field of human-human stigmergy is explored where several new concepts are proposed before making an in depth analysis of the realm of digital stigmergy. I will further show that the framework

for collective activity outlined in chapter 2 can be applied to the realm of digital stigmergy, providing a powerful means for classifying and analysing newer forms of online collective activity increasingly dubbed 'Web 2.0'.

Chapter 4, Stigmergic Collaboration, brings together the frameworks developed in the previous two chapters, providing an expanded view of the stigmergic collaborative process by incorporating useful concepts from other frameworks for artefact mediated activity. The analysis is then extended to that of digital stigmergic collaboration, showing how in this context different organisations of artefacts emerge, specifically the notion of the 'workspace'—collections of digital artefacts encapsulating coordinative functions of the collaborative activities (Ricci et. al. 2006:5). The provision of a workspace pushes the collaborative negotiation from that of social engagement, to cultural negotiations regarding aspects such as working methods, language and various technological literacies. Significantly, this shift enables the scaling of the collaborative system beyond that of traditional contexts since, in keeping the interaction localised, the capacities of the individual agents are not overwhelmed by the high demands of maintaining social relations with numerous participants across an ever-expanding domain.

Chapter 5, Mass Collaboration, further extends the stigmergic collaboration framework by exploring the technological, sociocultural and legal forms of open access which underpin large-scale digital stigmergic collaborative projects—termed 'mass collaborative'—such as Wikipedia, open source software projects and user-generated massive multiplayer environments such as Second Life. A comprehensive framework for mass collaborative negotiation is developed, exploring the shift that occurs from social negotiation to cultural participation when stigmergic collaboration is mediated via digitally networked workspaces. This framework is supported by the inclusion of the notion of the 'boundary object' (Star 1989) which is utilised to explain the capacities that a digital workspace takes on under such circumstances and how these capacities help stigmergically coordinate the many diverse perspectives involved in mass collaboration. Wenger's theory of 'communities of practice' (1998) provides an understanding of the role that 'participation' and 'reification' play in mass collaborative processes, coordinated via superordinate goals (Sherif 1958), while 'contributor groups'—emergent teaming which occurs at the mid-level between the individual and a

project's collective—are shown to arise from both explicit activities of a community of practice and implicit interactions arising as a result of stigmergy. This is followed by an examination of the relationship mass collaboration has with peer production and its role as a key player in the emergence of Benkler's networked information economy. The chapter concludes with an overview of considerations and principles for supporting and designing mass collaboration informed by research conducted by Stanford University's Cooperation Project.

Chapter 6, Experiments in Stigmergic Design & Collaboration, provides an overview of the creative projects undertaken as part of this candidature, presenting insights into my interests and objectives, while relating their design features back to the frameworks presented in this thesis. Three, originally online projects are provided as offline archived versions on an accompanying DVD-Rom.

- The *Collaborative Contract online environment* was designed to support the teaching and learning objectives of a subject charged with providing cross-disciplinary collaborative experience to 200+ creative arts students from all of the diverse schools at the Victorian College of the Arts, Melbourne University. Providing a 'mini blogosphere' and social networking functionality for students forming collaborative groups which span their disciplines—drama, visual art, film and television, dance and production—this project represents an experiment into 'stigmergic teaching and learning'. The site was iteratively redesigned each year in collaboration with student and staff input from 2004 to 2007.
- *The Australian Bill of Rights Initiative* is an online collaborative venture with the aim of stimulating discussion on and around human rights by providing the means for collaboratively drafting an Australian bill of rights (Australia is currently the only common law country in the world without one). The continually developing online version of this project is available at <http://abri.org.au>.
- *MetaCollab.net* is an online, mass collaborative open research project with the goals of collaboratively developing theory on and around the collaborative process across disciplinary divisions. Like ABRI, this project is open ended and is continually developing. It is located at <http://metacollab.net>.

The above projects represent the result of my attempt to 'compose collaboration' utilising insights from the stigmergic and mass collaborative frameworks presented in the following chapters, while serving to inform these frameworks from a grounded, hands on perspective. This chapter may be read in sequence, or, at any point in order to gain a better understanding as to my practical experience concerning the application of the frameworks presented.

The conclusion provides a detailed, yet concise recapitulation of the material covered as well as placing the current research in context with others investigating peer production from a variety of similar but differing perspectives. It is shown how the level of inquiry for the present analysis describes the underlying mechanisms of mass collaborative activity from a more macroscopic perspective, as opposed to singling out a specific layer of action or application such as the social or political, or new forms of democracy, wealth generation, or the articulation of power. The chapter also looks into the potential future directions for further research and application of the frameworks developed, exploring the domains of emergent governance and stigmergic interface design which might utilise touch screen technologies and brain-computer interfaces. It concludes with a discussion on the possibilities and implications of the emergence of a 'global brain' with the capacities to simulate the collective creative intelligence of mass collaboration.

Finally, the Coda revisits the themes introduced in the Prelude, providing a 'meta vista' of the impacts this research has had on my outlook and inspirations as an artist, as well as providing an insight into my ethical and moral perspective on composing collaboration. In other words, the ethics surrounding the manipulation of a medium which not only includes relationships with real people contributing to projects in good faith and in good will, but the morality involved in attempting to utilise this medium and technology for purposes which enrich the common good through the collective creation of good commons.

# 2. Collaboration

> As far as methodologies go, I think the jazz masters teach collaboration as well as anyone can.
>
> —*Tim Moore*

> You never know when you read a script how it's going to turn out because so much depends on the collaboration between people. If I'd been in some of the movies I turned down, maybe they wouldn't have been a success.
>
> —*Molly Ringwald*

## 2.1. Etymology

The first printed usage of the term 'collaborator' (1802), is attributed to the English philosopher and political radical, Jeremy Bentham (1748-1832). Bentham is well remembered for a number of philosophical contributions including advocating for animal rights, the easing of laws prohibiting same-sex attraction, his contributions to the philosophical branch of utilitarianism and his development of the self-monitoring design of the panopticon (later expanded upon by Michel Foucault).[7] In his discussion of a literary collaborator of Honoŕ Gabriel Riqueti, marquis et comte de Mirabeau (typically referred to as Mirabeau), Bentham becomes perhaps the first in Western culture's print media to identify an individual agency in the context of a co-creative

[7] See *The Bentham Project,* University College London, (online resource), <http://www.ucl.ac.uk/Bentham-Project/info/jb.htm> retrieved 20 April 2007, and the Wikipedia article *Jeremy Bentham,* <http://en.wikipedia.org/w/index.php?title=Special:Cite&page=Jeremy_Bentham&id=123215182> retrieved 20 April 2007.

activity using a 'collab-' term.[8] The *Oxford English Dictionary,* thus defines collaborator as,

> One who works in conjunction with others; esp. in literary, artistic, or scientific work.[9]

It would take another 58 years (1860) for the term 'collaboration' to occur in print, this time by English Novelist, Charles Reade (1814-1884) where in referring to playwrites, he notes that '[o]n the French stage, collaboration has lately become quite common' (1860:180). Defined as,

> united labour, co-operation; esp. in literary, artistic, or scientific work,[10]

this second usage expands the term to identify the agency of the collective—that is, it recognises that something creative is happening which requires a collection of agencies.

1871 saw the first printed instance of 'collaborate' by J. H. Appleton, this usage taking on a more objective tone, referring to the overall process as opposed to just the agencies involved. It recognises that not only are people acting individually and together in a creative fashion, but that there is a unique process involved. The *Oxford English Dictionary* defines 'collaborate' as,

> to work in conjunction with another or others, to co-operate; esp. in a literary or artistic production, or the like.[11]

Apart from distinctions regarding aspects of agency and process, it is important to note that all of these early mentions were in relation to literary collaboration—a form of collective activity which not only incorporates the creative process, but that of stigmergy as Parunak confirms in his *Expert Assessment of Human-Human Stigmergy:*

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[8] Collaborator, *Oxford English Dictionary, Second Edition,* (1989). (Eds.) J. A. Simpson & E. S. C. Weiner. Oxford: Oxford University Press.
[9] Collaborator, *Oxford English Dictionary, Second Edition,* (1989). (Eds.) J. A. Simpson & E. S. C. Weiner. Oxford: Oxford University Press.
[10] Collaboration, *Oxford English Dictionary, Second Edition,* (1989). (Eds.) J. A. Simpson & E. S. C. Weiner. Oxford: Oxford University Press.
[11] Collaborate, *Oxford English Dictionary, Second Edition,* (1989). (Eds.) J. A. Simpson & E. S. C. Weiner. Oxford: Oxford University Press.

> Joint authorship has always been a stigmergic activity, mediated by the emerging document itself. Each author is stimulated by what previous authors have written to add main-line content or marginal comments. (2005:11)

That stigmergy is integral to the etymological origins of collaboration provides a critical insight into the material nature and process of this collective activity. Additionally, its connections with creativity represents the primary distinction between collaboration and cooperation. Both of these etymologically informed observations will be focal points for the present work, supported and developed from a number of perspectives.[12]

## 2.2. Defining Collaboration

Commonplace dictionary definitions are often more broad than even the *Oxford's*. The *Macquarie International English Dictionary,*[13] defines collaboration as, 'the act of working together with one or more people in order to achieve something'. The breadth of this definition indicates that anything from a friendship, to a university, a city or nation may qualify. In fact, upon further reflection, one may even wonder whether or not collaboration should be limited to humans—many other social creatures work together to achieve common goals by some means or another.

Largely in response to such generalisations, and over the course of several decades as a practicing artist, I have built up an understanding regarding the activities and modes of collective thinking that I must engage in, in order to collaborate. These skills, understandings and experiences stand out as some of the most complex and finely nuanced of my practice and provide definite contrast to other terms associated with collective activity such as cooperation and coordination—often used interchangeably with collaboration.

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[12] A historical, sociocultural analysis of this term's progressive emergence (including the fact that the usage of the term in wartime didn't appear until the 1940s) would likely yield valuable insights into the development of Western culture in relation to the perception and activity of collaboration. Indeed such an analysis could be connected to the present and extended into the future, providing considerable scope for the theorising of the history and future development of collective creativity more broadly.

[13] *Macquarie International English Dictionary*. (2004). Bloomsbury Publishing.

In order to provide a more directed and useful definition of collaboration with which to ground this thesis, I have explored many varying definitions from numerous research contexts such as fine art criticism (Green 2001), IT and organisational theory (Black et. al. 2003), network theory (Newman 2001), educational theory (Gifford 1999) and artificial intelligence (Grosz & Kraus 1999). The principal finding is that the definition of collaboration tends to vary depending upon the contexts, interests and applications of those who are defining it. While this may not present problems for those investigating from a mono-disciplinary perspective, it is problematic in developing a general understanding of the process which is required when 'composing collaboration'—that is, designing for and employing collaboration as a problem solving strategy across disciplinary outcomes.

For example, below is an idealised definition from the context of education and research:

> The principles in a true collaboration represent complementary domains of expertise. As collaborators, they do not only plan, decide, and act jointly, they also think together, combining independent conceptual schemes to create original frameworks. Also, in a true collaboration, there is a commitment to shared resources, power, and talent: no individual's point of view dominates, authority for decisions and action resides in the group, and work products reflect a blending of all participants' contributions. (John-Steiner et. al. 1998)

A curter, dictionary-like definition from the context of information technology:

> Active participation between two or more people to achieve a common goal such as co-authoring literature.[14]

A more process oriented definition from the context of child abuse research and prevention:

[14] UC Davis Information & Education Technology Glossary, <http://distauth.ucdavis.edu/glossary.html> retrieved 12 February 2007.

> A mutually beneficial well-defined relationship entered into by two or more organizations to achieve common goals. Collaboration is the process of various individuals, groups, or systems working together but at a significantly higher degree than through coordination or cooperation. Collaboration typically involves joint planning, shared resources, and joint resource management. Collaboration occurs through shared understanding of the issues, open communication, mutual trust, and tolerance of differing points of view. To collaborate is to 'co-labor'[15]

Therefore, in trying to avoid the inherent danger of creating a definition that is either too broad or too narrow in its scope, the following represents a consolidation of many definitions like the above incorporating insight from the following frameworks as well as my own experientially based understanding of artistic collaboration.

> Collaboration is the process of two or more people collectively creating emergent, shared representations of a process and or outcome that reflects the input of the total body of contributors.

While a theoretical framework for collaboration will be developed that expands considerably upon this definition, it represents the core characteristics of a process that remain relevant across the applications examined in this thesis. Therefore, it will serve as the referent for the term 'collaboration' any time it is used. By focusing on the process of the collective creation of emergent shared representations in general, both internalised (e.g. conversational) and externalised (e.g. material), realms of co-creation may be addressed. While this definition also stipulates that the output of collaboration may be an ongoing process (such as in the case of business partners) and or a final outcome (such as a coauthored paper) it is also necessary to recognise that for all participants whose activity is deemed collaborative, their input must be represented in the process and the outcome. However, a collaborator's contribution may be subsumed within the process and thus undetectable while its effects are still present in the overall process and outcome. Through the specification of unique, yet universally applicable

[15] Yale University's National Center for Childeren Exposed to Violence website, <http://www.nccev.org/resources/terms.html#Collaboration> retrieved 12 January 2007.

processes and concepts, this definition aims provide a transdisciplinary framework applicable to collaboration in any and every field of human endeavour.

## 2.3. The Non-Zero-Sumness of Collaboration

Prior to continuing, it must be mentioned that while undoubtedly competition, antagonism and conflict are an inherent part of human interaction which may even contribute to the motivations and objectives of cooperation and collaboration, they form part of a branch which in specific ways places them in a somewhat separate category than that of the current investigation. The dynamics of collective creativity entail a particular form of collective outcome whereby there is some form of net gain across those participating. These types of situations have been formalised as 'non-zero-sum' outcomes in the domain of mathematics known as game theory.

First developed by John von Neumann and Oskar Morgenstern (1944), zero-sum and non-zero-sum outcomes relate to the net loss or gain across participants which can be seen to be engaging in an activity governed by the dynamics of game theory. In the case of a zero-sum game (which might not be a game in the common usage of the word) 'players' are engaged in an activity which entails that the participant's net outcomes will have an inverse proportion to one another resulting in a zero sum. In other words, 'my gain is your loss', or more explicitly, this dynamic describes a win-lose situation where there can be only one winner and one loser. Examples include two-player tennis, a duel or a game of chess. Non-zero-sum outcomes on the other hand describe win-win scenarios where every 'point' that is made by one of the participants counts towards the collective—'my gain is your gain'. Examples of this form of interaction include the outcome of team efforts (a team's collective loss is still a non-zero-sum, just a negative one), the participation in the collective formation and management of various types of commons (environmental, informational, et cetera), and organisations where the members work together to achieve some form of shared reward or outcome (Wright 2000).

In practice, zero-sum and non-zero-sum dynamics are often mixed, as in the case of team sport and entrepreneurial business. The teams must internally cooperate (and possibly even collaborate) in order to compete across their grouping's external

boundaries. This model provides a familiar example of collective competition ranging from ritualised conflict in the form of team sport, to business and even warfare. In the case of sport and business (and any other form of ritualised conflict), the collectives and individuals involved may compete, but only if they are compliant in a set of institutionalised or agreed upon procedures—in other words, their cooperation enables their competition. Even in the case of many violent conflicts, there is often still a code abided by, be it 'gentlemanly' or institutional (such as the *United Nations Convention against Torture and Other Cruel, Inhuman or Degrading Treatment or Punishment*). Such codes limit and thus restrain the actions of those in conflict, effectively enclosing the boundary of competition within that of cooperation (to better or worse effect depending upon the compliance of those involved).

In the case of collaborative non-zero-sum outcomes, the dynamic is slightly different. In defining collaboration as being dependent upon the emergence of collectively created shared representations, this seems to imply that the representations generated are of collective benefit, i.e. win-win. However, when collaborating it is possible to compromise 'too much' in relation to one's contributions, but to still continue engaging in the activity. In such a case, and as a result, a participant may afterwards feel as thought they did not actually share in the supposed collective benefit. So in the present context, the way in which I define collaboration as a strictly non-zero-sum outcome, is one perhaps more technical in nature. This definition has to do with the emergent character of collaboration in that as contributions are made, a new whole is forming, one which could not have been generated if the efforts had been individualistic. This means of defining the 'non-zero-sumness' of collaboration therefore does not stipulate that such an outcome is greater or better, but rather different. This difference is quantifiable in its cognitive composition of integrated contributions from multiple participants, and qualitatively different in relation to the character of its whole in relation to its component parts.

Of course there are may other positive outcomes which may and typically arise from collaboration aside from shared representations, such as new relationships, experiences and access to resources, however, in the strictest sense it is the emergent shared representation which is at the very least the non-zero-sum outcome. Therefore, the non-

zero-sum collaborative outcome in respects sets the wide-range boundary of analysis for the present work.

As a final note on collaboration and antagonism, in my experience, the fitness of a given collaborative system is often connected to the amount of tension it can bear.[16] That is, a collaborative group can achieve a toning effect upon their overall output if they feel comfortable to engage in vigorous debate concerning their contributions. However such debates seem to be of less constructive value when directed from a purely self-interested perspective, i.e. one's pride or vested interests. Rather, when the debate is oriented around achieving the most individualistically *and* collectively satisfying outcome, the results tend to be better all round. Having said this, too much debate can of course bog the creative process down. Therefore a healthy balance is ideal, this balance perhaps in some ways being generally indicative of 'healthy relations'.

## 2.4. Frameworks for the Study of Social Activity

Before elaborating original frameworks for collective creativity, it is necessary to review pre-existing frameworks which may offer insights into the collaborative process and cater to such theorising.

Although some researchers have expressed the need for a 'general theory of collaboration' (Wood 1991), no specific field of research has attempted such a formulation. If one were to though, it would need to first and foremost account for the collective generation of ideas—that is, cognition where the agents involved are in some way synchronised during the creative process. While the cognitive sciences provide an obvious body of knowledge to draw upon, the traditional approach in this area tends to theorise cognition as information processing individual minds, often disconnected from the environment, culture and sociality (Hollan et. al. 2000:5).

However, a number of disciplines have broken away from this more traditional view of the mind, namely activity theory, situated action, distributed cognition and actor-

[16] Thank you to the Australian artists Jacqueline Riva and Geoff Lowe who put words to this notion for me in a Centre for Ideas lecture given by them at the Victorian College of the Arts in 2005. For more on their practice, see <http://www.uplandsgallery.com/artists_details.php?id=4> retrieved 29 April 2007.

network theory. These alternative frameworks acknowledge and even emphasise the role that the wider social, cultural and material context plays in the formation of cognition, meaning, relevance and intelligence. This extended, more holistic approach provides a linkage for theorising collaborative production, a process that is also simultaneously social, cultural and material. Specifically, the incorporation of material concerns in the accounting of cognition provides a link between the above theories and that of stigmergy and its role in coordinating the creative contributions to a shared collaborative outcome. In fact, the connection between the above research disciplines and stigmergy is not entirely original.

In their work *Social Cognition, Artefacts, and Stigmergy: A Comparative Analysis of Theoretical Frameworks for the Understanding of Artefact-Mediated Collaborative Activity,* Susi and Ziemke (2001) make an excellent inquiry into this linkage and conclude that stigmergy offers a minimal common ground between activity theory, situated and distributed cognition (2001:16). Via the connection between these fields of research and stigmergy, I have imported a number of concepts and terms into the proposed frameworks for collaboration and mass collaboration which I will expand upon throughout this thesis. The following section provides a short summary of each field investigated, highlighting their relevance to collaboration, stigmergy and the objectives of the present work.

### 2.4.1. Actor-network Theory

Actor-network theory (Latour 2005) provides in many respects a broad frame for one of the central themes of this thesis—the interplay between the agent (dubbed 'actors' in this framework) and its environment. This theory simultaneously poses an ontology and epistemology of sorts by describing how agency emerges from a larger undifferentiated network comprising both the environment and agents in totality. According to actor-network theory, agency is an effect of patterned networks of interacting, heterogeneous materials including all objects and 'objects-and-people' networks that mediate interaction (Law 1992:381).

This view of agents (who are sub-networks themselves) merely as 'punctuations' of heterogeneous materials therefore does not presume primacy of the agent over or in

relation to the environment. Rather, it sees them as ultimately equivalent (Law 1992:383). This is because the perception and definition of the nature of an agent and the meaning associated with it, is contingent upon and generated from the intricate web of relations manifesting in the moment and not some a priori assumption. For instance, the actions and agency of a PhD candidate are contingent upon the enacting of appropriate activities (researching, developing ideas, completing work satisfactorily) and relationships (peers, supervisors, administrators) on a daily and even moment-to-moment basis.

In relation to the present work, actor-network theory will therefore provide the foundations for the development of an approach to agency specific to human collective activity and one which will be defined by the demands of its context. For instance, it will be shown that the agency required to participate in collaborative activities will be different, and in some ways, greater, than that of a cooperative enterprise.

### 2.4.2. Activity Theory

Activity theory, a foundational approach for research theories concerned with social-situation and artefact-mediation (Tarja & Ziemke 2001:5), focuses less on agency and its formation, and more on analysing specific activities along three primary lines:[17]

- the mediation of activity by cultural artefacts,
- internal activity (thought) as originating in the social plane (contextualised activity), and
- the necessity of analysing activity at levels of diminishing scope, i.e., activity->action->operation
    - (Gifford & Enyedy 1999:4).

Artefact mediation forms a key theme for this thesis as a means of linking the external activity of collaboration to that of stigmergy. The second point, the presumption that the external in various ways cues the internal also supports a core understanding of

[17] Activity theory has been developed considerably since its origins in Vygotsky's cultural-historical psychology (1978) in the end of the 1920s. The theory was picked up and developed by Leont'ev (1979, 1981) and Sergei Rubinshtein in the early mid twentieth century, and was later extended by many at the cue of Yrjö Engeström's paper: *Learning by Expanding: An Activity - Theoretical Approach to Developmental Research* (1987). This overview incorporates elements from this overall evolution.

stigmergy—that the environment provides stimulus which prompts agents to (re)modify it. The final point, the necessity to analyse activities on various levels, also plays a role in the present framework, as inquiring into collaboration and stigmergic mass collaboration is one fundamentally composed of multiple levels. Useful generalisations regarding the components of the activity can be made about collaboration utilising the above levels of diminishing scope as illustrated in table 2.0.

| **Level** | **Current Application** | **Example 1** | **Example 2** |
|---|---|---|---|
| Activity | some form of collaboration | *collaborative discussion (discursive collaboration)* | *mass collaboration (stigmergic collaboration)* |
| Action | substrate encoding of creative elements | *emergent shared representation of the subject (cognitive substrate)* | *wiki page editing (digital substrate) -and- shared emergent representation of the subject (cognitive substrate)* |
| Operation | means of annotating the substrate(s) | *verbal and other associated forms of communication and interaction* | *submission of data to web server via browser-based text editing capacity* |

Table 2.0.

Levels of collaborative activity

Therefore, the above levels provide a means of conceptualising the domain of collaborative activity in a very generalised form. While this arrangement does inform the present understanding of the activity (and in some respects forms a broad conceptual backdrop), the framework is ultimately too simplistic for a fully detailed analysis of the collective activity manifesting on the scale of mass collaboration.

### 2.4.3. Situated Action

Generally, situated action[18] considers the changing state of the environment to be the primary determiner of the agents' actions, with these actions consisting of improvised responses to such environmental changes (Suchman 1987). This theory therefore considers the unit of analysis to be the relationship between the individual and the environment.

[18] Also referred to in some sources as 'situated activity'.

Once again, a strong emphasis on the role of the environment as agent stimulus provides a possible foundation for discussing stigmergic approaches to collaboration. However, the theory's shortcoming in the present context is that its primary concern is of the individual and therefore does not explicitly address aspects of collective activity.

### 2.4.4. Distributed Cognition

Informed by activity theory and reacting against the internalised, mind-in-isolation approach common to traditional cognitive sciences (Susi & Ziemke 2001), distributed cognition provides one of the more promising frameworks in regard to the support and explication of stigmergic mass collaboration. Not only did earlier work in cognitive sciences start from the idea that the solo mind was the central driving force in human cognition, but it also left culture, history, emotion and context out of its theoretical frameworks, seeing them as secondary aspects to be dealt with after a sound theory of mind had been developed. Distributed cognition is therefore seen as a remedy, in that it deals with the mind from the outside-in, linking culture, history, emotion and context to cognition via the starting point of a social and material settings (Hutchins 2000:10).

This focus on the material, sociocultural and contextual aspects and implications of cognition covers many of the elements necessary when theorising collaboration. By providing more specific analytical components than actor-network theory and filling the social gap of situated cognition, it goes further than activity theory in the scope of its unit of analysis and in the range of mechanisms involved in the cognitive process (Hutchins 2000:1). Specifically, open for analysis is the entire distributed socio-material-technical system within which 'representations of information are propagated and transformed' (Susi & Ziemke 2001:287). Resonating with actor-network theory, the notion of such a system blurs the boundaries between agent and artefact, and inline with stigmergy, distributed cognition supports the evidence that such socio-material-technical systems give rise to collective cognitive properties which differ from those of its individual constituents (Hutchins 2000:4).

The recognition of cognitive properties which are above that of the individual agent distinguishes distributed cognition as a theory and provides connections with the notion of 'stigmergic intelligence'—intelligence which resides amongst and across the total

number of participating agents *as well as* the information processing and coordination capacities the environment provides. Recognition of such higher-level dynamics points to notions of emergence, collective intelligence and the hive mind.[19]

### 2.4.5. Stigmergy

In conclusion, the above theories provide several useful concepts for the exploration of collaboration and material mediation that contribute to the activity of mass collaboration. Specifically, and in agreement with Susi and Ziemke (2001), the above frameworks display a strong common thread with stigmergy in their incorporation and reliance upon the external environment for the coordination of activity and cognition. This common thread provides a rich source of insight and concepts for the further theorising of stigmergy in human contexts. In particular, distributed cognition provides a sound framework for contributing to the conceptualising of the artefact mediated, distributed creative processes associated with mass collaboration, and how these process are coordinated via stigmergic interactions with the material/digital world.

## 2.5. Coordination, Cooperation & Collaboration - a generalised framework for collective activity

In describing the broadest distinguishing characteristics of collaboration,[20] it is useful to contrast the term against others which are also attributed to collective activity. Specifically, I have found that conceptualising collaboration in relation to cooperation and coordination provides an excellent basis for explication, and as a result, these relationships constitute a major theme for a proposed generalised framework for collective activity.

As a starting point for distinguishing collaboration from cooperation, the *Oxford* definition and etymology confirms the artist's intuition that there is a considerable

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[19] The general realm of collective intelligence is a growing field of study with many new projects emerging, for instance, see Harvard's, *Group Brain Project,* <http://groupbrain.wjh.harvard.edu/Home.html> retrieved 26 March 2007, and MIT's *Center for Collective Intelligence,* <http://cci.mit.edu/> retrieved 10 March 2007.

[20] At this point it must be stressed that this thesis only strives to engage collaboration (and cooperation and coordination) in the context of human agency. This is not to say that these behaviours are exclusive to the human realm, rather it is beyond the scope of this work to provide an adequate examination and evaluation of current AI, SI and animal cognition research in order to form such conclusions. However, it is hoped that the present research might help provide insights which will assist in the exploration of such distinctions.

difference. Cooperation, 'working together towards the same end, purpose, or effect'[21] varies little to that of collaboration, except with the latter's stipulation of 'esp. in literary, artistic, or scientific work'.[22] This subtle difference is reflected in the term's etymology as all instance of its first usages was in reference to literary collaboration. The early usages of cooperation on the other hand are true to the above definition in that they refer to collective activity aimed at a shared pursuit without a creative component. The main distinction between these two terms is therefore the addition of creation in the case of collaboration. Put another way, collaboration is cooperation with the addition of collective creativity.

While creativity provides a concise point of distinction between collaboration and cooperation, the theorising of creativity is a large and diverse field in itself, a detailed exploration of which it is well beyond the scope of this work. Nonetheless, the notion of convergent and divergent production as formulated by Guilford (1950; 1962) (considered to be the grandfather of creativity research and psychometric intelligence testing) does capture a fundamental difference in creative ideation. Convergent production is a cognitive process whereby an agent seeks a single best solution (mathematics, logic, scientific method), whereas divergent production develops multiple solutions to the same problem domain (creative arts, lateral thinking, brainstorming).

Applied to collective problem solving activities, convergent production relates to cooperative processes where agents are complicit in some procedure, but not engaged in the generation of alternative processes, objectives or ideas. Conversely, collaboration is characterised by divergent production where participants are required to generate multiple solutions which must be developed and selected by the collective. Coordination on the other hand is not characterised by some form of problem solving and is thus neither dependent upon convergent or divergent production. Rather, it is a fundamental enabling requirement for all collective activities (even those competitive in nature).

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[21] Cooperation, *Oxford English Dictionary, Second Edition,* (1989). (Eds.) J. A. Simpson & E. S. C. Weiner. Oxford: Oxford University Press.
[22] Collaboration, *Oxford English Dictionary, Second Edition,* (1989). (Eds.) J. A. Simpson & E. S. C. Weiner. Oxford: Oxford University Press.

To coordinate is to 'place or arrange (things) in proper position relative to each other and to the system of which they form parts; to bring into proper combined order as parts of a whole.'[23] Therefore if cooperation is to take place, a cooperative system's wide range of potential components (biological, material, conceptual, cultural) must be arranged 'relative to each other and to the system' in order for the components to form the relationships which are meaningful in context to the cooperative objective. For instance, it does me no good to ask someone to help push my car to a gas station if they are not near enough to hear or interact with me. Similarly, our values, cultural and social norms must also be coordinated, otherwise they might not be interested in helping even if our verbal and body languages are coordinated enough for us to understand one another.

Therefore, collaboration, cooperation and coordination form a set of human behaviors, each necessary (but not sufficient) for one another. Another way of conceptualising this arrangement is to say that cooperation transcends and includes coordination, as collaboration does to cooperation.[24] Figure 2.0 and its subsequent expansions (figures 2.0-2.4.) outlines these relationships as a proposal for a generalised framework for collective activity.

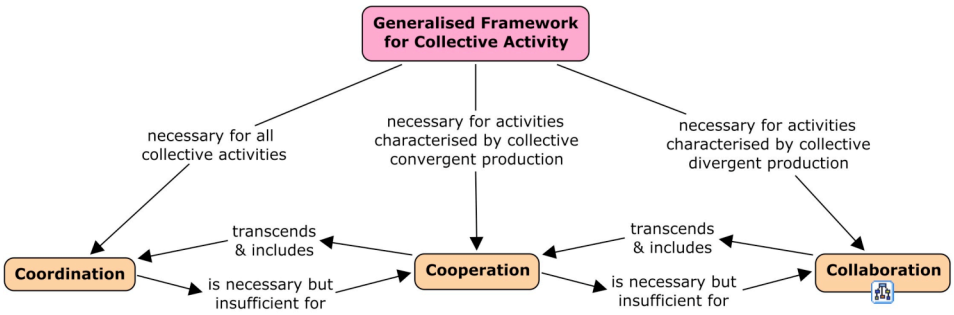


Figure 2.0.

Generalised framework for collective activity, the relationship of coordination, cooperation and collaboration in the context of collective activity

[23] Coordinate, *Oxford English Dictionary, Second Edition,* (1989). (Eds.) J. A. Simpson & E. S. C. Weiner. Oxford: Oxford University Press.

[24] These relationships bear a strong resemblance to the cybernetic, 'metasystem transition theory'. This theory describes the evolution of organisation and complexity through the emergence of successive levels of control, each new level transcending and including the former (Heylighen & Campbell 1995; Joslyn, Heylighen & Turchin 1997; Turchin 1995).

### 2.5.1. Coordination - harmony of proximal relations

The following expansion of the coordination node refines the notion of 'arranging parts relative to one another and to an overall system', highlighting the idea that a harmonisation of proximal relations provides the distinguishing and sufficient conditions for coordination.

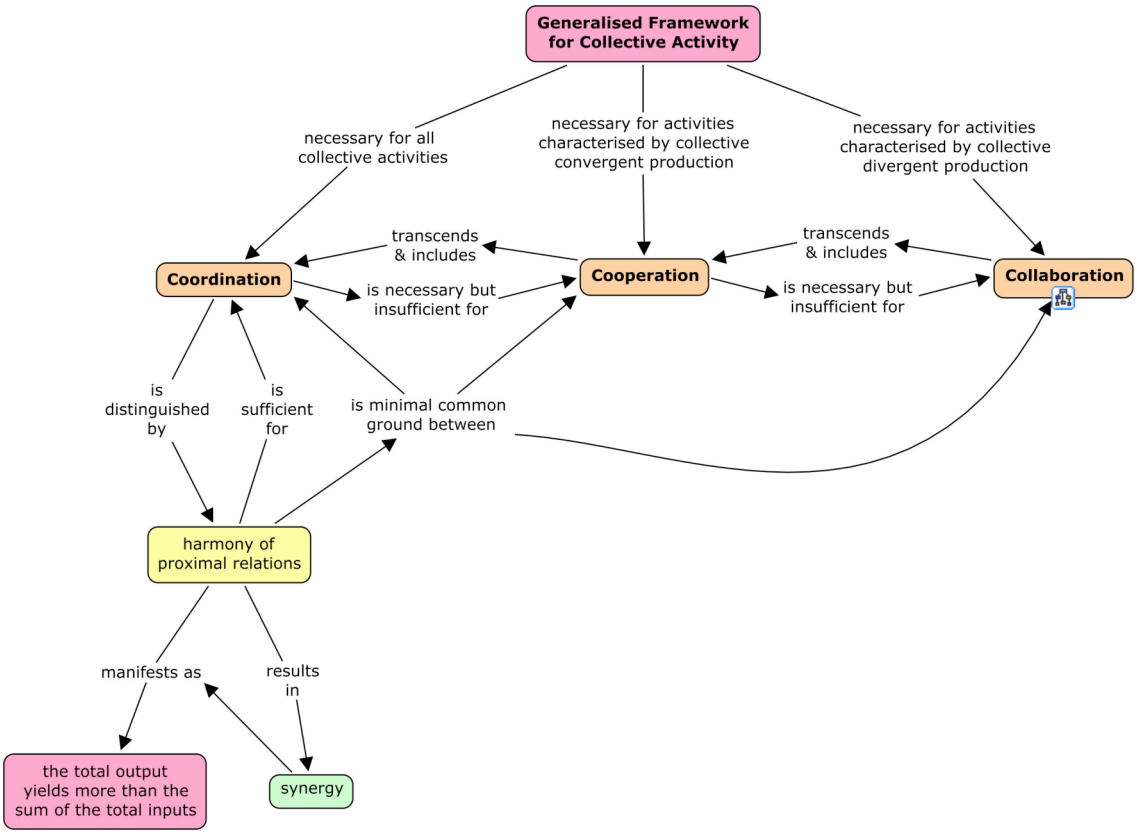


Figure 2.1

Generalised framework for collective activity, coordination, harmony of proximal relations & synergy

A harmonisation of proximal relations therefore provides in the most basic sense the minimal common ground between coordination and cooperation. In other words, the relationships connecting the individuals and elements of a potential cooperative group must achieve some form of proximity and level of harmonisation before cooperation can occur. A theoretical dynamic that captures and develops this coordinative resonation is synergy.

#### 2.5.1.1. Synergy

Applied to a wide range of phenomenon, Corning broadly defines synergy as 'the combined or cooperative effects produced by the relationships among various forces, particles, elements, parts, or individuals in a given context—effects that are not otherwise possible' (2003:2).[25] Another way of describing the effects of synergy is to say that the totality of the interactions in a synergistic system produces something more, or different than their individualised sum. That is, (to use the cliché) the whole is greater and or different than the sum of its parts.

For example, the synergy involved in a corporate organisation allows for greater and different results than if each employee were doing business on their own. In addition, since synergy is an effect of coordination, and coordination is necessary for cooperation as cooperation is for collaboration, then it stands to reason that synergy is also an inherent part of collaboration. In fact, synergy's role provides one of collaboration's most important effects—the capacity for the collective creative output to be greater and or different than if the individuals were working alone. Not only then is a harmony of proximal relations (the coordinative enabler of synergy) a minimal common ground between coordination and cooperation, but also collaboration.

### 2.5.2. Cooperation - procedural compliance in a shared pursuit

Cooperation provides a middle ground between the more mechanistic nature of coordination, and the nuanced, conceptual, social and cultural subtleties of collaboration. Wrapped up in the *Oxford* definition of cooperation (working together towards the same end, purpose, or effect) are a number of attributes which upon unfolding, can be found to rest upon several notions, without which the activity could not operate.

The first relates to the preconditions of the capacity to 'work'. In order for humans to work together, there must be some form or set of procedures, whether they are implicit (e.g. social norms, histories, pre-established methods) or explicit (e.g. a discussed and agreed upon set of operations, objectives or the like). However, perhaps most commonly, forms of explicit and implicit procedures are combined. The second

[25] Corning's use of the term 'cooperation' relates to the working together of elements of various forms of systems both animate and inanimate. I will steer away from such usages, using instead the term synergy itself to describe such positive gains resulting from the system-wide effects of interaction.

precondition is that of a compliance of will. Not only must there be a set of formalised or 'informalised' procedures, but the participants must also be compliant in the process of enacting them. For instance, it is precisely when one does *not* provide compliance through force of will, or to a lesser extent, through lack of agreement in procedure that one describes an individual or group as 'not cooperating'.

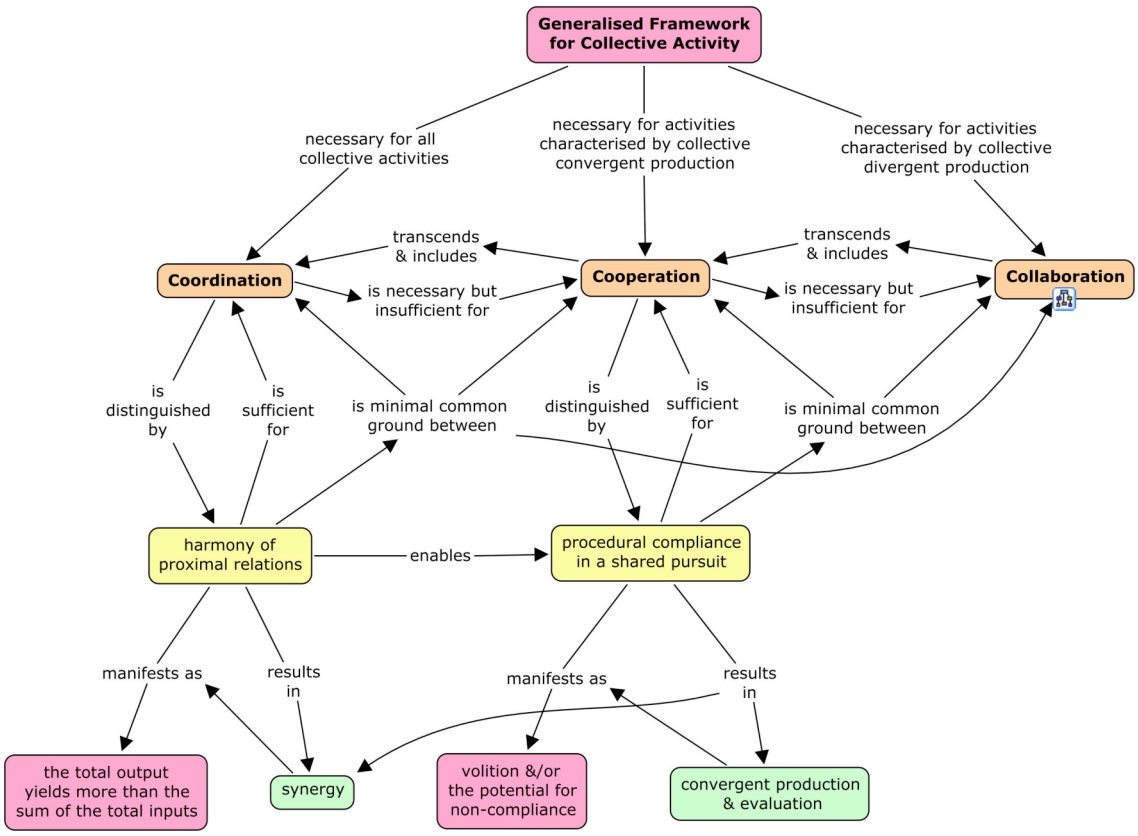


Figure 2.2.

Generalised framework for collective activity, cooperation, procedural compliance in a shared pursuit & convergent production

It is therefore the combination of agreed procedure and compliance of will which gives cooperation its defining character (see figure 2.2). Interestingly, while a shared pursuit is the obvious outcome of cooperation, a shared pursuit is not always characterised the same objectives and motivations on the part of its individual constituents. Participants may have many varying motivations and objectives for cooperating (and collaborating). For instance, in some contexts, one may cooperate in order to further their social standing while another in the same group does so in order to receive monetary reward.

In larger-scale cooperative situations, a smaller group or individual generally withholds the generation, evaluation and selection of concepts and materials subject to divergent production (such as the details and methods of procedures, the proposed outcome and even ongoing development issues) from the collective enterprise. The initial and ongoing development of such aspects are typically provided by a sole creator or a smaller collaborative group—such as board members in the case of organisations, or policy writers in that of governance. This arrangement opens up the door for cooperative enterprises to increase their numbers as larger groups may be frustrated by the distribution of the creative process throughout its membership (no doubt many who work in or with organisations have had this experience).

The creators therefore typically provide to the wider group the procedures for achieving an outcome not possible by the independent individuals working alone. Often the procedures involved are so well defined that outcomes can be reverse engineered, as in the case of a franchise, employment position or government office. Once in place, the collective then provides compliance in executing the planned procedures in a relatively linear, convergent fashion, working collectively towards the charted objective. Even if objectives differ along various lines and among different individuals and groups within the organisation, the scope of the objectives as defined by the procedures tends to provide clarity of intent which functions to coordinate the interests of those involved. However, it is important to remember that in practice, collective activities of any sort are always characterised by a complex web of social and cultural interactions and relationships.

### 2.5.3. Collaboration - co-created emergent shared representations

While, co-creation is the essence of the *Oxford Dictionary's* distinction between cooperation and collaboration, in contemporary practice this creativity cannot be restricted exclusively to processes of material production such as 'literary artistic or scientific' composition. Even if the sole outcome were a single manuscript or a work of art created between several participants, a comprehensive theory of collaboration must account for the co-conceptual realm, which coordinates the interplay of the multiple creative contributions. This shared dimension is perhaps one of collaboration's most complicated aspects to describe and theorise, as not only does it incorporate one of the

more elusive and complex aspects of the human experience—emergent cognition (it is difficult enough to described one's own let alone another's), but also creativity. Additionally, during the process of collaboration this shared realm consists of individual minds somehow synchronised in their creative production.

As previously mentioned, the notion of the *representation* provides a means for engaging this multifaceted and multidimensional process. The concept of the representation from which the present application of the term derives, is a cornerstone of the cognitive sciences and cognitive psychology and thus distributed cognition (DC). According to Hollan et. al.,

> Minds are not passive representational engines, whose primary function is to create internal models of the external world. The relations between internal processes and external ones are far more complex, involving coordination at many different time scales between internal resources—memory, attention, executive function—and external resources—the objects, artifacts, and at-hand materials constantly surrounding us. From the perspective of distributed cognition, the organization of mind—both in development and in operation—is an emergent property of interactions among internal and external resources. (2000:177)

There are several points to reinforce here. The first is the distinction DC makes in order to distinguish itself from more traditional cognitive science approaches where the representation acts as a cognitive symbol whose 'primary function is to create internal models of the external world' (above). DC does not consider the emergence of representations to be wholly 'encompassed by the skin or skull of an individual' (Hutchins 2000:1). Rather, the representations and the cognition which generates them is distributed across and amongst the social, and the material domain as represented by our cultural interactions with the external world.[26] The second is that since the mind's

[26] The underpinning of the cognitive sciences by representationalism (the notion that one cannot ultimately perceive reality, only representations of it) makes it vulnerable to the philosophical problem known as the 'homunculus argument' or 'Ryle's regress'. In this argument, it is presumed that some agency (a 'homunculus') is internally present interpreting the sensory input, and thus generating the representations that we take to be reality. However, if this were the case, then there must be some additional 'homunculus' (i.e. some cognitive subcomponent of the homunculus) interpreting first homunculus's input, thereby resulting in an infinite regress. The position posed here (and supported by

development and operation, and thus its generation of representations, 'is an emergent property of interactions among internal and external resources' (above), the representation therefore has the capacity to connect and coordinate the internal cognition of multiple agencies via its distribution across and amongst the collective and the environment. This distribution of such shared representations throughout collections of individuals and their environment is the very essence of DC.

Therefore, as collaborators share each other's presence and communicate, interact and negotiate their social and cultural relations, positions and motivations, as they share and exchange their creative contributions towards the group's objectives, they are generating emergent, shared representations. These are representations of the collective's understandings of every aspect relevant to the collaborative domain, including the state of the collaborative objective, the participants' relationships and wellbeing, the surrounding environment and any other factor or aspect which is perceived to be of importance. These representations may also be externalised, projected onto the wider environment as material extensions of their internal representations, such as a shared document, artwork, or a 'solution' which is represented by the state of the environment, such as an arrangement of earth, objects or individuals.[27] The shared representation, whether internal or external, provides a platform upon which the creative cognition of multiple collaborative participants may

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DC) is that there is a fundamental flaw in the logic that generates the homunculus argument, specifically, its reliance upon centralised executions of linear logic. Rather, as proposed by Hoftstdater (1979) and Minsky (1986), cognition is an emergent phenomenon constituted by the aggregation of vast collections of sub-agencies producing nonlinear interactions which in total yield the experience of our individual interpretation of the representations of reality. (Hollan et. al. (2000:177) also cites Minsky's conception of this architecture in direct support of DC.) In other words, representationalism in regard to DC and stigmergic collaboration is still assumed, however the means in which it is conceptualised is distinguished from that of the cognitive sciences in that the representation of reality is distributed amongst the individual, the collective and the environment. However, since the individual is on a lower level than that of the collective and the environment, there is not necessarily the capacity to directly experience the higher levels (Parunak 2005:6) and consequently, the representation of reality tends to appear only on this individual level. Therefore the notion of the infinite regress is not so much refuted as embraced, in that a fractal-like, 'emergence of the hive from the workings of the ants in conjunction with their environment' conception of the representation of reality seems a much more probable state of affairs with systemic emergence providing the means of arriving at higher levels of representation. In other words, the hive's homunculi are teams of agents, theirs being the individual agents, theirs being the multiple agent-like nonlinear workings of their own minds with each of their cognitive process being distributed among their 'peers' and the wider environment (i.e. the substrate of the brain et cetera).

[27] This is precisely the domain of stigmergy (expanded upon in the following two chapters) which provides an understanding of how such externalised representations coordinate creative cognition, as well as how the cognition of the collective is extending into the environment, beyond 'skin and skull'.

be coordinated. Figure 2.3 incorporates these insights in relation to the overall framework for collective activity.

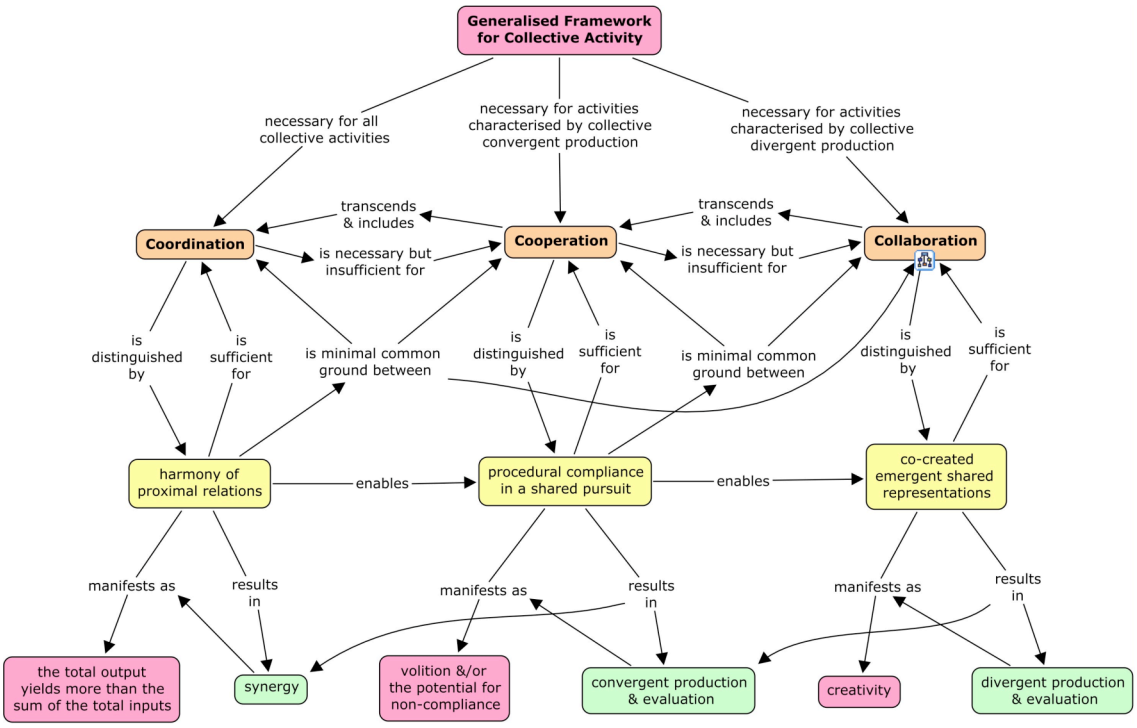


Figure 2.3.

Generalised framework for collective activity, collaboration, co-created emergent shared representations & divergent production

The DC conception of the representation is also useful in the context of collaboration in that it does not ultimately distinguish between the shared internal and external collaborative domain, as in practice, both are clearly linked and dependent upon one another. Instead, internal and externalised representations of the co-creative output become differing dimensions of a single emergent fabric. Existing within the minds of the participants as well as in the material world, the two realms of this single fabric are mutable to the modifications and transformations of one another by both the participants and any inherent transformational capacities a collaborative media may possess. Additionally, this conception of the representation allows for the known as much as the unknown to be re-presented in the minds and work of collaborators, even if they do not understand or perceive that this is occurring. This is important because since collaboration is common to all humans everywhere (like individual creativity), it must therefore operate below the level of conscious understanding—that is to say, the

generation of such shared representations is less a cultural capacity and more one of biology.

#### 2.5.3.1. Emergence in the process of collaboration

It is necessity to include 'emergent' in the description of co-created shared representations as it addresses two critical aspects of collaboration:

- the appearance of structures at a higher level that are not explicitly represented in lower-level components (the basic definition of emergence) (Parunak 2005:6); and,
- nonlinearity—multiple simultaneous events which impact each other, enabling and contributing to the overall state of the emergent process (Holland 1999:225).

The formation of new structures or 'wholes', which cannot be reverse engineered or fully accounted for by a description of their parts, describes very well the nature of collaboration. The output of a collaborative group is always somehow different than what the individuals might generate if working alone, while it is also impossible to describe ahead of time the exact details of what a collaborative group might produce. The fact that one may produce something more or different through collaboration than when working alone, provides for a wider and greater scope of output and is typically associated with the positive side of this emergent process. However, as Kevin Kelly notes, 'the word "emergent" has its dark side' (1994:30). Many practitioners are wary of the collaborative process since not only is it somewhat unpredictable, but it requires the individual to relinquish some amount of control to the collective. For many this can be tantamount to loosing the ability to guide the outcome's formal and content oriented development, these choices being precisely that which defines the authorship and thus creative identity of the maker (and for artists especially, this identity is often a very conscious construction as in many respects it represents their creative currency). The relinquishing of one's sole authorship, exclusive control and the subsumption of individualistic identity into that of the collective is a required part of collaboration. However, the process of emergence may transform this potential loss into a gain.

In his work *The Third Hand: Collaboration in art from conceptualism to postmodernism* (2001), Charles Green shows how artists employ precisely this

characteristic of collaboration to blur, de-emphasise and reconstruct individual identity and authorship. This reconstruction becomes an artistic strategy, enabling a reactive mechanism against the traditional (and especially modernist) notion of the artist as creative individualistic monolith. Green also explores how 'a third artistic identity superimposed over and exceeding the individual artists' (2001:179) emerges and how many artists consciously strive to invoke this meta-entity. As collaborating artists, Melamid and Komar[28] put it, '[w]e invented that third person, the third artist, but we never specifically named that third artist' (Green 2001:179). The recognition of this 'third hand' is emblematic of emergent structures or wholes above that of the constituents, and one which in its unpredictability provides an exciting and often 'super-charged' dynamic to one's otherwise familiar practice and output.

The second aspect in the definition of collaboration addressed by the concept of emergence is nonlinearity. Nonlinearity is an inherent part of emergence in that it provides for the necessary complexity required for the appearance of that which is on a level above and thus qualitatively distinct from its parts (Holland 1999:225). In contrast, a linear process by definition involves a direct proportional change in related quantities—that is, 2+2=4. Therefore, 4 is in fact the sum of its parts and as such, may be reverse engineered.

Due to the nature of nonlinear systems (the change of one component may have 'butterfly effects' upon the state of many others), collaborative output requires constant attention and redevelopment throughout the process. As participants incorporate modifications from their own contributions and each other's (sometimes simultaneously), they affect the entire semantic state of the collaborative domain to greater or lesser degrees. Continuing the theme of collaboration in art, performance artists Gilbert and George[29] who's work and day to day life since the late 1960s consists entirely of one lifelong artistic collaboration, have recognised this need for continual maintenance stating that '[e]very day we have to be sure that the purpose is set in the right direction. It needs redefining every day, every second.' (Green 2001:187).

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[28] For examples of Melamid and Komar's work see <http://www.diacenter.org/km/> retrieved 8 April 2007 which highlights their series 'Most Wanted Paintings on the Web', for more general information on their practice, see <http://www.komarandmelamid.org/chronology.html> retrieved 8 April 2007.

[29] See Wikipedia article, 'Gilbert and George', <http://en.wikipedia.org/w/index.php?title=Gilbert_and_George&oldid=130583844> retrieved 14 May 2007.

In addition to potential system-wide effects of small and or local changes in nonlinear systems, the nature of collective divergent production implies that a multiplicity of ideation occurs on both the level of the individual and the collective simultaneously. Therefore, participants must confront nonlinearity constantly as they generate shared representations of the output. This nonlinearity also includes the rich multiplicity of sociocultural information perceived simultaneously at any one time by the collective. This information informs the individual's choices via their regard for the other participants and the state of the wider context, as well as informing the group as a whole, helping set the tone and shape the directions for the collective. Therefore, nonlinearity occurs on and across a number of levels within the collaborative process, providing for the rich levels of complexity that yield the emergent outcomes.

As a final note concerning emergence and divergent production in collaboration, it is important to stress that this process also depends up on convergent production and thus linear dynamics, especially regarding formal procedural considerations. Prior to collaborative contributions being incorporated into the emergent output, procedural methods must be previously agreed upon through individual proposition, collaborative development or implicit means (such as working methods associated with certain practices, cultures or histories that the participants are connected to). Such procedures, the basis of cooperation, provide the framework upon which participants can make 'valid' collaborative contributions.

For instance, academics collaborating on an article would employ the research procedures and formal frameworks associated with their disciplines, as well as those associated with their relationships and histories—e.g. they might use telephone communication in favour of email based upon past experience. In such a context, it would be unlikely that one of the participants would provide his or her contributions in the form of chalk drawn on a busy city street, however this could be a perfectly legitimate procedure for collaborating artists. In other words, collaboration's reliance upon convergent cooperative production (a restricted set of possible formal and or procedural considerations) supports divergent production and emergence. In addition, while such procedural compliance in effect limits the form or type of contribution acceptable, it increases the level of coherence and efficiency within the system through providing a common framework for the development and exchange of representations.

In summary, contrasting the terms coordination, cooperation and collaboration provides a great deal of insight into the processes and relationships regarding collective activity. Coordination (which is not dependent upon either convergent or divergent problem solving) provides synergistic potential through the harmonisation of proximal relationships, thereby forming the sufficient conditions for cooperation and all other forms of collective activity. Cooperation on the other hand relies upon procedural compliance in a shared pursuit (enabled by the synergy of coordination), which in turn provides the collective convergent production mechanisms necessary for 'well formed' contributions to a collaborative venture.

Collaboration transcends and includes cooperation in its reliance upon procedural compliance and is distinguished from the 'shared pursuit' of cooperation by the inclusion of collective creation (and thus divergent production). Similarly, cooperation transcends and includes coordination in its reliance upon synergy, and as a result, coordination is also nested within collaboration, enabling the synergistic output of collectively created, emergent, shared representations. These representations differ qualitatively and quantitatively from those produced by individuals working creatively alone through the emergence of a new whole comprising the synergistic interrelations of the individual contributions.

This generalised framework for collective activity provides an elegant means of conceiving the broad forms of non-zero-sum collective activity and will act as the foundations for the following general theory of collaboration.

## 2.6. Towards a General Theory of Collaboration

The above broad framework for collective activity provides a means for distinguishing coordinative and cooperative enterprises in relation to collaboration, as well as an entry point for a more in depth discussion of collaboration. Expanding the above diagram's collaboration node (see figure 2.4), the remainder of this chapter will focus on an approach towards a general theory of collaboration—one intended for application, adaptation or extension into any field of endeavour in order to provide a theoretical foundation for that of mass collaboration.

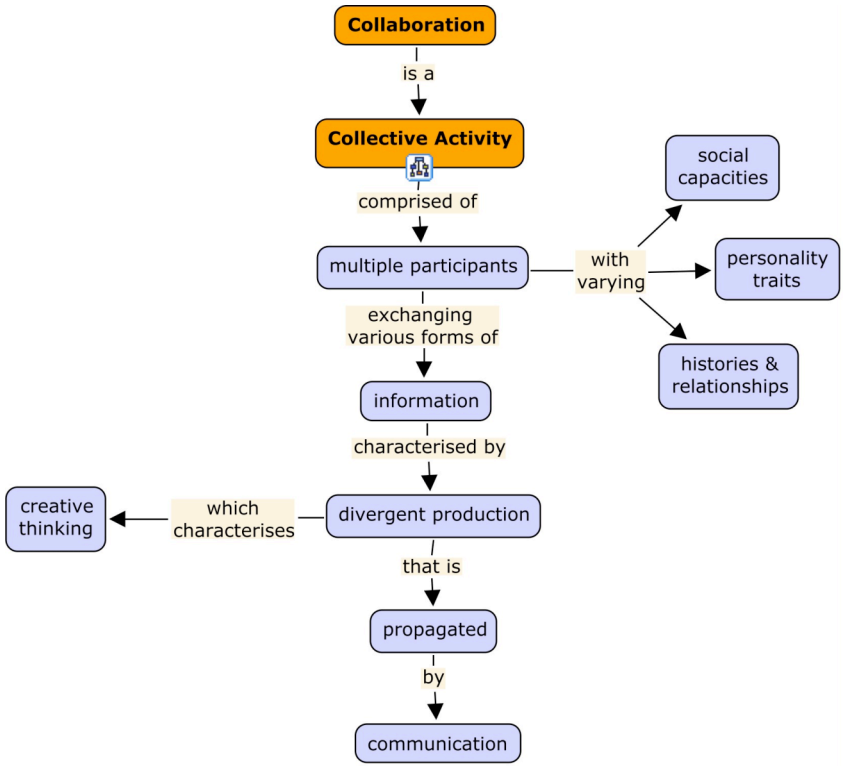


Figure 2.4.

Collaboration, personality, relations, creativity & communication

## 2.6.1. Personality & Relations

The primary component of any collaboration is of course its participants. An individual's personality traits and their capacity to engage socially must surely impact upon their ability to collaborate, however what traits, skills or capacities are the 'most collaborative' and how to measure these are by no means clear. An online survey conducted by Dave Pollard, Mitch Ditkoff, Tim Moore and Carolyn Allen asked 108 respondents[30] 39 questions regarding what qualities, attitudes and skills help make a good collaborator. The top six responses are as follows.[31]

[30] The researchers note that while they considered expanding their samples size, the average scores for each question did not change significantly after the first 50 responses had been collected and therefore took this to indicate that the sample size was adequate to gauge the responses of the online population as a whole.

[31] The survey in its entirety can be found at <http://blogs.salon.com/0002007/stories/2005/11/18/theIdealCollaborativeTeamAndAConversationOnTheCollaborativeProcess.html> retrieved 27 February 2007.

An ideal prospective collaborator...

1. is enthusiastic about the subject of our collaboration.
2. is open-minded and curious.
3. speaks their mind even if it's an unpopular viewpoint.
4. gets back to me and others in a timely way.
5. is willing to enter into difficult conversations.
6. is a perceptive listener.

In contrast, the bottom six responses were:

34. has experience as a collaborator.
35. is a skilled and persuasive presenter.
36. is gregarious and dynamic.
37. is someone I knew beforehand.
38. has an established reputation in field of our collaboration.
39. is an experienced business person.

These responses show that what many people consider valuable in an 'ideal' collaborator are not necessarily obvious (considering for instance responses 3, 5, 34, 37 and 38).

Histories and relationships also play a considerable role in the collaborative process, both of which I divide into two broad categories: types and qualities.

Types of histories refer to experiences that may affect one's collaborative experience, such as whether or not one has had experience as a collaborator in some field or in utilising a specific procedure (like email or coauthoring). The quality of such histories is perhaps equally important, as someone may have had a traumatic experience as a coauthour communicating via email, making it less likely that they will readily engage in this process.

Types of relationships (ultimately as subset of histories) define a wide range of socioculturally acceptable and expected behaviour in collaborative scenarios. For instance, if participants are husband and wife, their engagement is likely to differ

considerably than if they were employer and employee. Once again, if the quality of the participants' relationships is good, then it is likely they will have an easier time of collaborating than if it is fraught with misalignments, miscommunication and arguments.

Since the aim of the present work is to describe frameworks for collaboration on large scales where direct social engagement is mediated by the site of work, the following will focus less on an analysis of the psychological qualities of good collaborators and more on an inquiry into the basic mechanisms which enable such activities.

### 2.6.2. Communication & Information Exchange

Of such enabling mechanisms, perhaps the most crucial is communication—collaboration cannot be a solo venture. In the context of the present work, I will define communication as,

> the explicit and implicit exchange and propagation of various types of information which forms and informs the co-creation of emergent shared representations and their material externalisations.

Information which is communicated during a collaboration may serve a wide variety purposes, providing ideas and opinions regarding the work at hand, understandings about those who we are working with and how to better relate to them, and may even appear unnecessary, only becoming important at some later date. Some information may not enter the conscious realm, such as the social and cultural cues which guide us in the application of tacit routines in reciprocating a subtle act of goodwill like a smile or an encouraging tone for instance. Other examples of communication often below our conscious awareness include the activation of sets of norms associated with sociocultural groupings like those of gender relations or those unique to a some practice associated with a certain community context. Such forms of implicit communication are likely to run even deeper in the case of body language and pheromones.

In addition to there being many forms of communication and informational exchange (with potentially more forms and effects than we can be aware of), it is important to remember that because a message was articulated and received in one particular

medium, does not ensure that the best response will also be in that same medium. For example, in the case of a hypothetical collaborative choreography of a dance routine, a contribution may be spoken by one person, transcribed and sent via Internet chat relay by another person, read by the recipient to a group who then discusses and responds with bodily movements which are relayed via web cam back to the original speaker. Because of this capacity of humans—the ability to process a message in one medium and respond with another—collaborative environments (especially in electronic realms) are ideally media rich, as such lateral responses are never more prevalent than in creative production.

#### 2.6.2.1. Social, Tech & Bio Networks

In addressing communication as a fundamental aspect of collaboration, it is important to remember that communication is a network phenomenon. That is, while it might be obvious that communication makes use of channels that connect sender and recipient nodes, it is important to consider that communication also generates networks through its very being. Entities communicating using any medium *become* connected nodes. Therefore, collaboration may be especially well suited to the Internet's hyperlinked network structure and even subject to aspects of technical and social network theory.

#### 2.6.2.2. Types of Communication

It is understood that the communication which flows through and generates collaborative networks comes in many forms, such as spoken word, visual signs, electronically encoded text, et cetera. However, overarching these subsets, are larger patterns that syntactically organise such exchanges.

##### 2.6.2.1.1. Turn-taking

Theorised by Sacks et. al. (1974) as an underlying, context-free rule set constituting a coordination mechanism for social interaction, turn-taking orders interactions in a wide array of situations such as moves in gaming, regulating traffic at intersections, serving customers in businesses, and talking in interviews, meetings, debates, conversations and the like. Without going into undue detail, turn-taking was identified through conversation analysis and is described as a 'speech exchange system' comprising

mechanisms which govern features such as turn construction, turn allocation, speaker-change, transitions, turn order and turn size. In their conception, it is claimed that the act of speaking requires intimate collaboration and 'is sustained through the particular turn at talking, and that this state of talk involves a circle of others ratified as coparticipants' (1974:3).

#### 2.6.2.1.2. Indirect Communication

Turn-taking is a widely regarded theoretical framework (Google Scholar showing some 1,666 citations to the original article by Sacks et. al. (1974) as of March 2007) and is no doubt a powerful analysis of the features which underlie and organise conversation. However, there are additional realms of communication not wholly governed by these mechanisms. Because this framework caters for conversational communication only, it does not examine mechanisms which govern conversation where the message is received and responded to by numerous participants in nonlinear fashion (as in the case with stigmergy). That different mechanisms are possible is evident when considering the asynchronous, large-scale collaborative exchanges in projects such as Wikipedia.org, or even a simple email list where one emailer is addressing the entire subscription base. In both cases turn-taking may emerge, however numerous participants may reply simultaneously or never at all and this would not violate the norms or syntax associated with these forms of communication.

Additionally, participants contributing to the communicative exchanges which constitute mass collaborative production such as Wikipedia article editing, or an email list discussion, are not necessarily 'ratified as coparticipants'. In fact, in the case of wiki editing, their contributions as related to their identity may be unknown to the wider community. Similarly, when taking part in an email list discussion, one often replies or reads replies from participants unknown regarding their background or identity beyond their name (and in some cases, not even a full or real name is known as aliases are often employed). This provides for a radically distributed model of communication, one which relies much less on specific hierarchies for ratification and participation and instead invokes more 'equipotential' relations such as those described in peer production literature (Bauwens 2005).

Therefore a second broad class of communication coordinating mechanisms may be discerned which shall be designated as 'indirect communication'. Indirect communication is the encoding of a message in some aspect of the environment that serves the function of a medium, granting it increased permanence and the capacity for the message to reach a wider audience and span a greater timeframe, while also lessening the communication's reliance upon turn-taking. This form of communication may incorporate any form of exchange which may be encoded in some media (i.e. text, imagery, sound, et cetera), while its dynamism will be dependent upon the capacity for recipient response. Figure 2.5 expands the communication node, showing the different processual paths of communication in collaboration depending upon the form it takes.

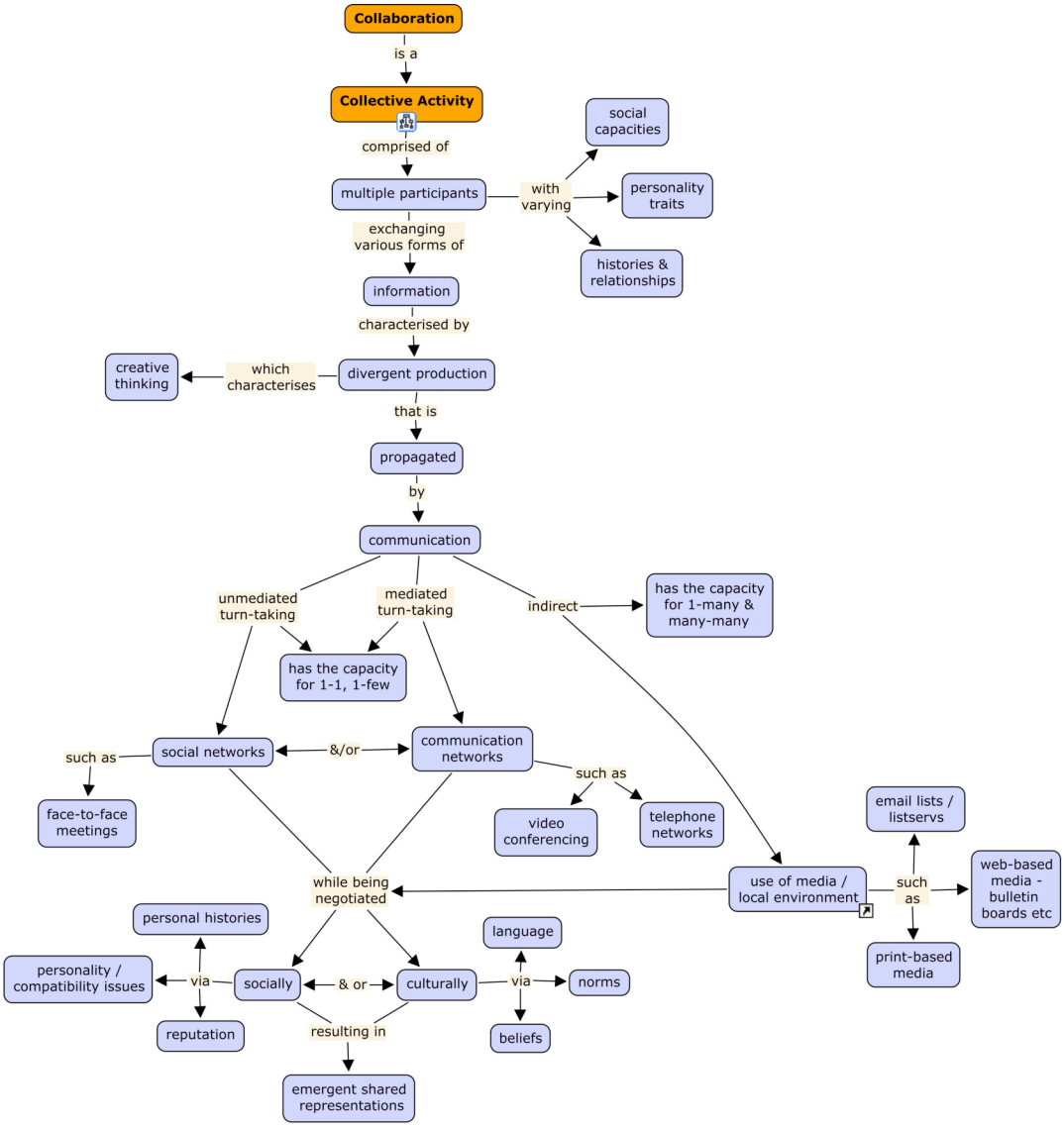


Figure 2.5.

Collaboration, turn-taking, indirect communication & negotiation of shared representations

In the case of conversation, if it is encoded in some media distinct from its original source that provides some element of permanence and accessibility to multiple recipients, then the necessity for turn-taking in the responses is lessened. For instance, when writing to an email list, neither does one expect the entire subscriber base to feel obliged to respond in turn-taking fashion, nor is there inherent mechanisms to coordinate such interaction—who should respond and when et cetera. This is not to suggest that there are not turn-taking like elements involved, but rather that there is less reliance upon such structures in indirect communication and that it is precisely their absence which enables communication in these contexts to function—i.e. the system would be overwhelmed if all were to respond as if each were spoken to directly.[32]

Since it is possible for some form of infrastructure to mediate communication while enabling turn-taking (as in the case of a telephone call) it is useful to make the following distinctions:

- **Unmediated turn-taking** describes the realm of face-to-face communication, where there is no added artifice augmenting the capacities of the communicative individuals involved. This form of exchange is perhaps the most limited in regard to time and space constraints (everyone must be present in the same place at the same time and are subject to turn-taking), however it is without doubt the most rich, allowing for all senses to be simultaneously engaged, catering to many forms of exchange both conscious and unconscious.
- **Mediated turn-taking** extends the spatial and temporal capacities of conversational dialogue via some network and or infrastructure allowing for and preserving turn-taking as the basic organisation of exchange. Such extensions in space affects transmission time to varying degrees, ranging from undetectable delays in phone conversations, to longer interruptions while one waits for an email or letter message to arrive at its destination and then return.
- **Indirect** communication is extended in space and time via some encodable medium such as print, broadcast or web-based forms (websites, blogs, email lists, et cetera). This has the multifaceted effect of allowing for turn-taking

[32] It may be speculated that the closer the ratio of possible recipients to possible respondents is to 1, the more likely turn-taking will be cued. However, empirical research is required to confirm this intuition.

syntax to be bifurcated into numerous asynchronous conversations, dispensed with all together (as in the case of broadcast or 'push' media), or some mix thereof.

While indirect communication is perhaps less obvious as a regular form of exchange than turn-taking, it is no less present in our daily lives. It relates to exchanges in which the sender has no specific recipient in mind, or is focused on communicating to a group, or to an individual but where the message is also open to others to receive as well—essentially, one to many, or many to many. While examples include bulletin boards (on and offline), street signs and signals, graffiti, advertisement breaks on broadcast media, broadcast media itself and print media, the forms which concern the present analysis are those related to collaborative activity.

Indirect communication associated with collaborative activities may take a number of forms depending upon the nature of the collaborative objectives and context. For example, if it is a face-to-face session aimed at generating a small group's creative objectives, then paper, white board and pen may be employed which effectively broadcasts communication to the whole group indirectly. Similarly, if this group wished to extend its activities in time and in membership (e.g. to a larger subset of its organisation), it might post the outcomes of the meeting on an intranet, email list or monthly newsletter, thereby broadening its participants as well as the process's communicative and information processing capacities.

In the case of collaboration, perhaps the most important requirement of indirect communicative media, is that it must be multi-pathed, or at the very least, two-way in order for the exchange and co-development of ideas to take place. Therefore, in the context of this discussion, broadcast and various forms of push media are of less concern. However, before exploring the implications and applications of indirect communication in collaborations utilising stigmergy, it is important to introduce several other aspects central to the collaborative process.

### 2.6.3. Negotiation

A core component of collaborative communication is negotiation, both social and cultural. In the case of direct and mediated direct collaborative exchanges, social

interaction is the first line of engagement. That is, social negotiation is the result of continually assessing one another's developing state of being, personal histories, reputation, understandings of psychologies/personalities and any contextual factors which influence these. On the other hand, cultural negotiation is the realm of beliefs, norms, values and other traits and practices such as language, fashion and accepted behaviours. While such cultural aspects are also continually assessed, in direct and mediated direct exchanges they tend to recede to the background, serving a secondary role unless the participants are specifically dislocated culturally or confronted with some previously unknown trait or practice.

In the case of indirect collaborative communication, this primacy tends to reverse, with cultural negotiation becoming the first line of engagement. For example, if a collaborative exchange were taking place through coauthoring a Wikipedia article, foreground concerns would be principally technical and language oriented, followed by aspects of methodology, procedure and 'netiquette', all of which are understandings primarily associated with particular on and offline cultures as opposed to specific social exchanges. This reversal from social to cultural as the front line of interaction forms an important distinction in collaborative process, one which plays a central role in enabling mass collaboration by reducing the demands of large-scale social negotiation which would otherwise be placed on participants.

### 2.6.4. Human Agency in Coordination, Cooperation & Collaboration

In order to collaboratively negotiate on a social or cultural level, agency on the part of the participant is clearly required. While in some respects the details as to this agency are somewhat incidental (in that it just happens), it is worth noting that the demands upon participants increase as the complexity of collective activity rises. This is important as it contributes to the load on the participant and as such requires consideration when conceptualising engagement and communication at the human level of experience.

In following from the view of agency as proposed in actor-network theory (Latour 2005; Law 1992), agency can be understood as a contextually defined manifestation, consisting of effects generated by 'patterned networks of diverse (not simply human)

materials' (Law 1992:380). In this light and in the context of the above framework for collective activity, the extent and nature of human agency (the faculty of an agent or of acting[33]) can be seen as varying depending upon its context within coordinative, cooperative or collaborative activities. Enacting each of these levels of collective activity demands differing forms of agency, each of which increases in complexity with the context of the activity.

Coordination therefore demands a range of agency—from very little when it takes place as a result of innate biological forces (such as gregariousness) to more so when consciously arranging aspects, objects or individuals in order to capitalise on synergy. Cooperation on the other hand requires at minimum a level of coordinative agency, plus that of wilfully providing compliance in the execution of some procedure that leads to a collective outcome. As a result, the complexity of agency required will depend upon the complexity of the procedures in addition to that of social and contextual aspects. Similarly, collaboration demands at minimum the level and nature of agency involved in cooperation (which includes coordination) in addition to the added complexity required to collectively create and negotiate the emergence of shared representations.

A full account of the specific natures and characteristics of these forms of agency is beyond the scope of the present work, however this framework provides the broad details required to gain a sense of the demands placed upon individuals engaged in these levels of collective activity. In the context of mass collaboration, it can be seen then that those who participate in this activity (collaboratively drafting a Wikipedia article for instance) must dedicate a level of agency which is considerably above that of participating in the cooperative practice of social bookmarking (meaningfully tagging webpages so that a filtered common pool is created[34]) and certainly above that of conducting a web search (coordinating a range of websites based upon their relevance to a search term).

This conceptualisation of agency provides a way of gauging the demands placed upon the participants in various collaborative and cooperative scenarios. It also underscores

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[33] Agency, *Oxford English Dictionary, Second Edition,* (1989). (Eds.) J. A. Simpson & E. S. C. Weiner. Oxford: Oxford University Press.

[34] See for instance the social bookmarking web-based application, <http://del.icio.us> retrieved 19 April 2007.

the role which indirect forms of communication can play in reducing the load of negotiative complexity during mass collaborative contexts where the high number of participants would otherwise render managing such negotiation impossible. Such reductions in effect amount to a reduction in agency demanded of the participants on the social level which frees up more time, energy and agency for creative contribution.

### 2.6.5. Discursive & Stigmergic Collaboration - internalised & externalised representations

Through the process of manipulating some shared material as a point of negotiation, the levels of agency demanded of the participant can be reduced in some areas—i.e. social negotiation and memory—while being increased in others—more direct and uninterrupted engagement with the creative site of work. This effect is the result of providing a stigmergic platform upon which the participants may externalise their otherwise internalised emergent shared representations, these representations being arrived at (when there is no such stigmergic platform) through some form of direct social interaction—i.e. discourse. Therefore, it is possible to distinguish between two interrelated, yet distinct forms of collaboration.

- *Discursive collaboration* is the collective divergent production of internal representations (ideas) through the exclusive use of mediated or unmediated turn-taking conversation, which consequently forms the sole collaborative output.
- *Stigmergic collaboration* utilises external media as a feedback mechanism in cuing and coordinating further creative contributions which are linked to and representative of shared internal representations. Figure 2.6 shows how stigmergic collaboration emerges as an externalisation of otherwise internalised emergent, shared representations.

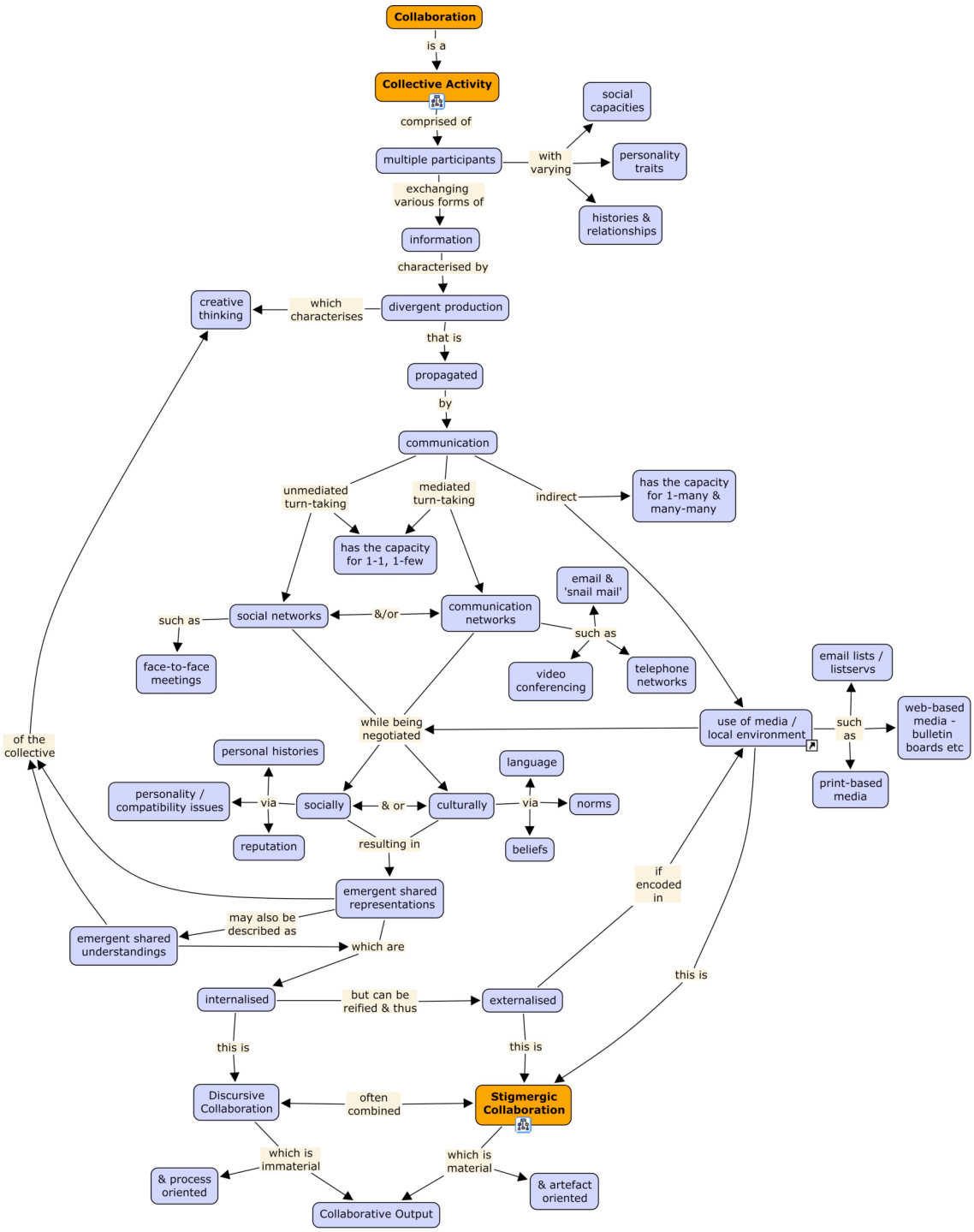


Figure 2.6.

Collaboration, discursive & stigmergic collaboration

This distinction establishes the important proposition that while all cases of collaboration must generate emergent collectively created internalised representations (which may be done so through conversation alone), stigmergic collaboration may occur without the need for conversation—two people can collaborate by drawing a

picture together without ever saying a word and without taking turns by drawing simultaneously. However, common collaborative practice typically combines these two methods which reinforce, augment and stimulate one another. The nature and objectives of the collaborative project typically determine how they are combined, with the levels of discursive versus stigmergic components being optimised depending upon the complexity of the process and objectives. For instance, members collaborating on a large-scale scientific research project will require much more stigmergic (i.e. material) components than participants collaborating on the co-creation of their understandings surrounding a shared experience of an artistic performance.

Before the further expansion of the stigmergic collaboration framework and applying this knowledge to that of mass collaboration, the framework of stigmergy requires revisiting. Drawing from recent research into stigmergy from a wide variety of contexts provides considerable scope for more deeply understanding and integrating its themes and characteristics with that of collaboration.

# 3. Stigmergy

> Weblogs, Neighborhoods, and Google are all phenomena of the World-Wide Web. All of these are fairly new and they are all very powerful. Weblogs are successfully taking on large publishers on their fact checking. A minor shift in Google's ranking algorithms creates huge ripples. Warchalking swept through the web and onto street corners in a matter of days. Is there any connection between them? I want to convince you that they are all intertwingled, all the result of the same phenomenon, and that we have much more interesting and powerful phenomenon on the horizon.
>
> —*Joe Gregorio*

> When many work together for a goal,
> Great things may be accomplished.
> It is said a lion cub was killed
> By a single colony of ants.
>
> —*Saskya Pandita*

## 3.1. Solving the Coordination Paradox

Prior to the recognition of the mechanisms of stigmergy, understandings regarding the organisation and coordination of activity in social insect colonies were largely dominated by various attempts to resolve the *coordination paradox*—while each individual appears to pursue their own agenda, somehow the colony as a whole exhibits high levels of organisation (Theraulaz & Bonabeau 1999; the following summary of the history of stigmergy is largely based upon Theraulaz and Bonabeau's article on the subject). Prior to stigmergy, the main argument for explaining this paradox was mainly oriented around organismic metaphor. This approach argued that there must be laws governing the coordination of societies that are the same or equivalent to those which govern an

individual organism, and thus any society could therefore be considered an organism (Spencer 1882). In the late 1880's Herbert Spencer fuelled this approach by identifying a set of characteristics that seemed to be common to both individuals and societies. These characteristics included 'growth, progressive and joint differentiation of structures and functions, mutual shaping of the parts they are made of, division of labour, and finally similar properties between the social organism and each of its constituent units, with the exception that the former has a greater lifetime' (Theraulaz & Bonabeau 1999:98). The entomologist William Morton Wheeler continued to develop this perspective in his famous paper, *The Ant Colony as an Organism* (1911), which outlined one of the first systemic approaches to the study of social phenomena in insects. However the scientific concepts and technology of the time were unable to identify any such laws which might link the governance of individuals to that of societies, and in 1926, he abandoned his efforts concluding that,

> ...we can only regard the organismal character of a colony as a whole, as an expression of the fact that it is not equivalent to the sum of its individuals but that it represents a different and at present inexplicable emergent level. (Wheeler 1926 via Theraulaz & Bonabeau 1999:98)

Those who continued to follow the organismic approach achieved very little as their frameworks were essentially reliant upon a metaphor, and as such, yielded little explanatory value. However at this same time, an opposing perspective was forming, one reflective of a more individualistic and reductionist bent aimed at ridding science of mentalism and anthropomorphism. French biologist Etienne Rabaud championed this tact, the majority of his work on insect societies attempting to show that individual insects behave as if alone, and that any assertion of collective activity was unfounded.

In spite of his extremism (which was later shown to be erroneous through numerous examples of social coordination in insects (Theraulaz & Bonabeau 1999:100)), Rabaud did contribute two theoretical components which provided the springboard against which stigmergy was formed. The first was *interaction,* which stipulated that for social animals who live continuously in close proximity, an individual's actions may influence another's and as a consequence, modify their behaviour. The second was *interattraction,* which

pointed to the fact that any animal of a social species is attracted to another of the same species in specific ways (Rabaud 1937).

It was the implication of these propositions—that individuals bear a stimuli that can trigger a specific interaction (such as the nonrandom distribution of individuals in their environment), upon which Pierre-Paul Grassé and his students later developed stigmergy. In addition, they also provided the first synthetic view to combine the specificity of interactions among social individuals and coordinated collective behavior at the colony level in explaining collective behaviour.

Specifically, he and his students recognised that not only does an individual produce specific stimuli upon its fellows, but that the group (which can be reduced to a single member) also produces stimuli which influences the behaviour of the individual (Grassé 1963). Therefore, sociality was not some trivial by-product of interattraction, but was instead a biological characteristic rooted deeply in the ethological history of every species. For instance, a social animal behaves differently alone than when in the presence of its social members, and when alone, differently yet again than nonsocial animals (Theraulaz & Bonabeau 1999:101).

Concepts developed by Grassé which led directly to that of stigmergy include *social appetition,* the drive a social animal displays to seek its nestmates which may render it unable to survive without them (as in bees) and *group effect* where the behavioural state and sometimes an animal's whole physiology is altered when exposed to a critical threshold of stimuli from its fellow social members (1946; 1958) (for example the social phase in locusts triggered by stimulus exchanges (Chauvin 1941)).[35] When such group effects do occur, integrative and regulatory processes may emerge, leading to what Grassé termed *social regulation*—the coordination of collective performance surrounding a task, or of the re-establishing of population equilibrium once disrupted through psycho-physiological and psycho-motor mechanisms. Such processes are the result of idiosyncratic characteristics of individualistic behaviour reliant upon stimulus-response sequences where the stimulus is an

[35] Perhaps this was what Kevin Kelly was referring to when he questioned what effects might be triggered in humanity as we are increasingly 'interconnected by wires and politics' (1994:17).

action of one individual and the response an action triggered in another, which may trigger yet another stimulus, et cetera.

This provided the necessary conceptual framework to support the proposition of stigmergy, as not only do individuals provide stimuli for other individuals, but the individuals' activity also has the effect of reorganising the environment in such a way which produces structures that also serve as stimuli. Termites roll mud balls impregnated with pheromones, cuing others to roll further mud balls which lead to mounds, sophisticated arches and ventilation systems (Grassé 1984; Kennedy et. al. 2001:103). Similarly, ants lay pheromones in the environment as they work, indicating to their nestmates who and how to best help (Deneubourg et. al. 1989). This allows highly complex structures to self-organise due to the collective input of large numbers of individuals performing extraordinarily simple actions in response to configurations of and encodings within their local environment.

These realisations provided the final pieces in the puzzle that led Pierre-Paul Grassé to coin the term stigmergy from the Greek words stigma 'sign' and ergon 'action' (1959) in order to capture the notion that signs left in the environment may produce action from agents.

## 3.2. Elements of Stigmergy

The stigmergic system consists of primarily two components, a collection of agents, and the environment in which they interact. Through the agents' modification of this environment by physical manipulation or encoding signs directly into or upon it, the environment plays the role of medium for a message which acts as a cue, stimulating further actions from agents.

### 3.2.1. Agent Attributes

In order to make such changes to their environment, agents must have the capacity to sense and assess its state, as well as faculties to actuate changes in response to their assessment. Therefore, we may say that stigmergic agents are comprised of three simplified components as illustrated in figure 3.0. They have sensors, actuators and some internal program for sensing and responding to their environment (Parunak 2005; the following summery outlining the basic architecture of stigmergy draws heavily on Parunak's work as it

represents one of the most up to date and comprehensive overviews of the topic). These attributes as developed through the process of co-evolution between the agent and its environment give rise to a set of dynamics unique to the specific stigmergic system.

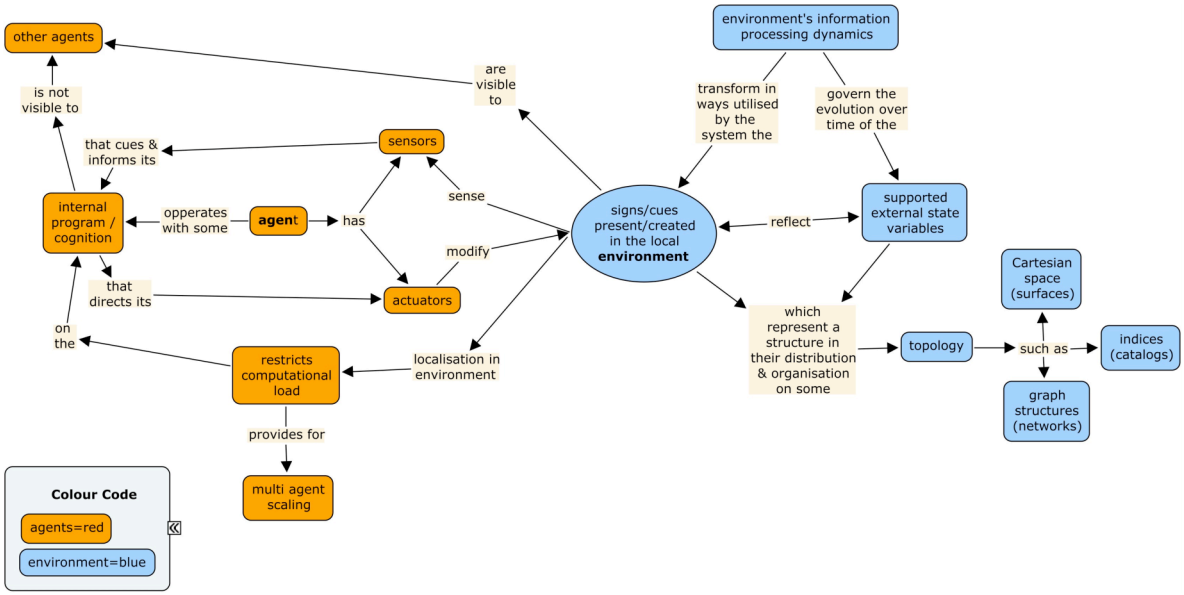


Fig. 3.0.

The stigmergic system, agent and environment relationship

Due to the agent's situated activity within an environment, their sensors and actuators engage only a restricted portion of this environment. This has the effect of limiting the horizon of their senses and engagement thereby ensuring that their capacities are not overwhelmed. This enables the system to scale no matter how large the environment grows since there is no centralised organisation or regulatory network needed to span it. Rather, the coordinative and information processing dynamics are distributed throughout the environment and individual agents, forming emergent patterns relevant to the interaction of the agents and environment. For instance, in ant trail systems, trails appear and disappear in the environment according to their usage—pheromones are deposited and build up in intensity and complexity while the trail is useful. As it becomes less so, the environment evaporates the pheromones in accordance with the dwindling deposits.

### 3.2.2. Environmental Attributes

The environment plays a critical role in the coordination of activity and communication in the stigmergic system. Its role is equally as important as that of the agent's, this differing

markedly from traditional notions of cognition where stimulus-response reactions are seen to reside completely within the agent's internal program, independent of any role the environment might play in transforming or affecting these reactions. In stigmergic systems (like activity theory, situated and distributed cognitive theories), the environment plays an integral role in the construction of meaning and memory in that its configurations and reconfigurations act as an extension of the cognitive process.

The environment in a stigmergic system can be broadly characterised by the three following components as illustrated in figure 3.0.

The environment's *structure* reflects the organisation of its features on a particular topology that provides the agent with a sense of locality. Stigmergic systems may employ any form of topology, including graphs (networks), indices (catalogues) and Cartesian coordinates (space). While the environment's structure may very, it is important that the agent's activities are situated within some form of spatial domain that provides for the agent's experience of localisation—an experience which in restricting their engagement and senses, limits the demands placed upon their interactive capacities and thus enables system-wide scaling (Parunak 2005).

The environment's *dynamics* govern its evolution through time with the stigmergic system typically incorporating these dynamics to its advantage, thereby providing the function of additional information processing capacity to the agent-environment interactions. This notion is summarised well by Ricci et. al.,

> ...the environment is not a mere passive 'container', but it embeds mechanisms and (reactive) processes that promote the emergence of local and global coordinated behaviours. It has not only a state that can be observed and modified by agents, but it encapsulates some laws that can be triggered by agent actions (or, by events such as a change in location, or the passing of time), and that alter the environment state independently of the agent intentions.' (2006:7)

For example, the aggregation and evaporation of pheromones in insect systems has the effect of 'truth maintenance and discarding obsolete information' (Parunak 2005:6). Similar

effects can be observed in animal trail systems where trodden earth, erosion and dying vegetation produces the trails, while regrowth and continued erosion maximises fidelity through diminishing those which are unused.

The combination of an environment's structure and its dynamics give rise to a certain set of *state variables* which represent the perceivable, meaningful variations the environment provides for. For example, in pheromones systems, states include the environment's capacity for pheromone deposit (permeability of soil/vegetation et cetera), while in animal trail systems, obstacles, ground cover and terrain mutability contribute to the possibility of encoding trails.

## 3.3. Types of stigmergic interaction

Interactions in stigmergic systems may be classified into four broad categories that can be further divided into two sets of two. The first set of interactions relates to the interpretation of *collections* of signs which I term 'gestalt focus' and is comprised of 'marker-based' and 'sematectonic' cues. The second grouping I designate as 'sign type' and regards the interpretation of *individual* signs being either 'quantitative' and 'qualitative' in nature.

**Gestalt Focus**—what level of the environment is being considered meaningful.

- *Sematectonic stigmergy* relates to agent interpretation of certain configurations of environmental and or agent placements comprising the actual content of the environment.
- *Marker-based stigmergy* concerns whether agents base their interpretations and actions on specialised markers deposited in the environment (similar to the notion of 'metadata').
    - (Parunak 2005; Brueckner 2000)

**Sign Type**—what form the sign takes.

- *Quantitative* signs are scalar and of a single type, representing varying intensities of cues.
- *Qualitative* form a unique, discrete set of cues.

- (Parunak 2005; Theraulaz & Bonabeau 1999; Kramer 2005).

Gestalt foci are often mixed, with both sematectonic and mark-based interpretations being available within the same overall domain. Similarly, both sematectonic and mark-based interpretations may be comprised of quantitative and or qualitative signs.

I suggest that the terms, 'gestalt focus' for the first set (sematectonic and marker-based) and 'sign type' for the second (quantitative and qualitative) are helpful in discriminating between differing levels of stigmergic interaction. In this conception, the agent's attention decides the gestalt focus, which determines what level of the environment the agent considers meaningful at that moment, while the sign type deals with two distinct groups of characteristics individual signs may posses.

These four types of interaction will serve as valuable distinctions in later discussions of human-human stigmergy and mass collaboration, providing a means of discriminating and classifying stigmergic activity in a wide range of contexts. For instance the stigmergic collaboration of coauthoring a Wikipedia article entails for the most part sematectonic/qualitative interpretation of the current state of the article's semantic content (Parunak 2005:10), however tools such as the 'recent changes' functionality provide marker-based/quantitative feedback through positive and negative counts of characters added or deleted during past revisions (see figure 3.8).

Figure 3.1 illustrates the how the above types of stigmergic interaction are related to one another and the agent-environment system, as well as providing several examples of their existence in biological settings.

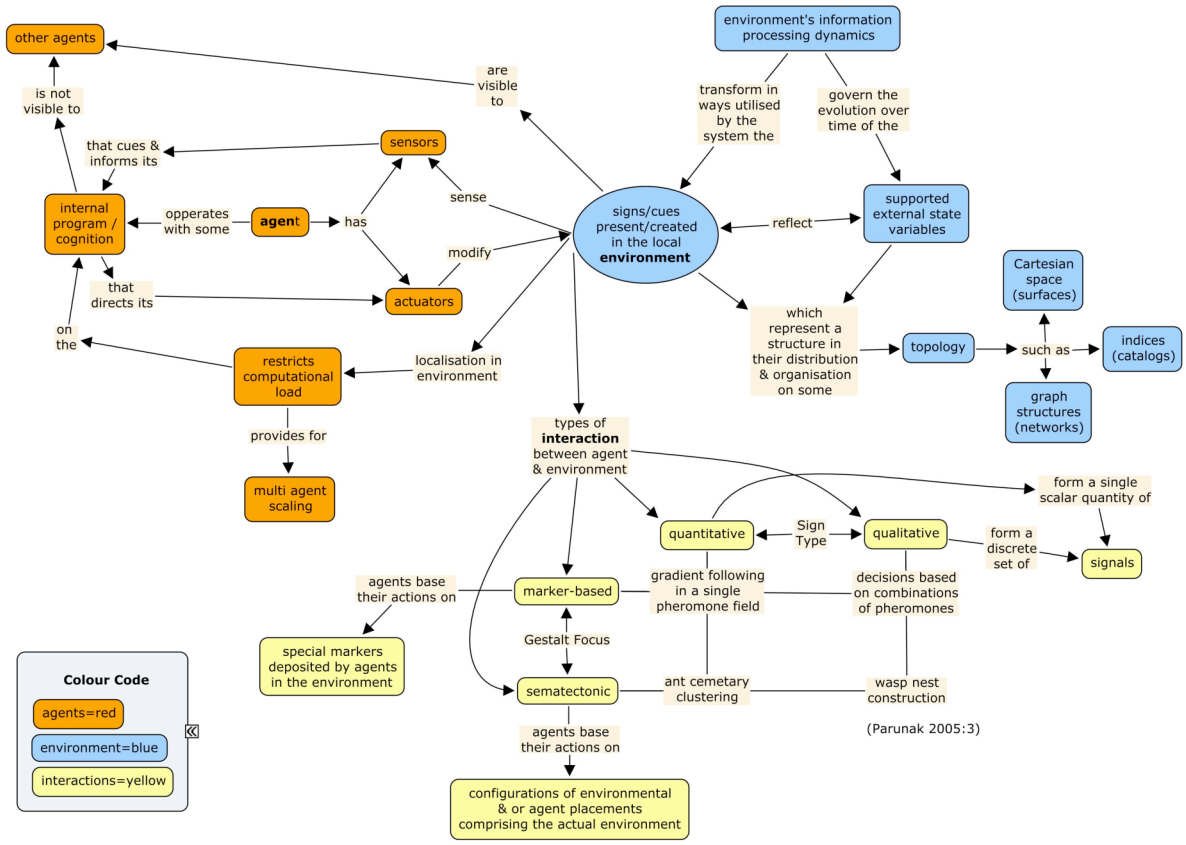


Fig. 3.1.

The stigmergic system, the interactions of

Note: ant corpses are moved to the largest perceived pile - the decision to move a corpse being based only on pile density (Bonabeau et. al. 1998); paperwasps deduce the state of nest construction in relation to internal templates in order to determine the next best step in building (Karsai 1999).

## 3.4. Emergent System-level Dynamics

The stigmergic system functioning as a whole (all agents plus the environment) produces emergent, system-level dynamics. These dynamics are a distinguishing factor of stigmergy and appear on a level above that of the local interactions of agent and environment. For instance, regarding the above example of Wikipedia article coauthoring, the emergent system-level behaviour is the expression of a jointly held consciousness (Parunak 2005:10). In termite mound building (the placement of single, pheromone impregnated mud balls upon one another) the system-level behaviour is the construction of complex nests and architectures such as arches and ventilation systems (Theraulaz & Bonabeau 1999). The

emergent capacities of stigmergy also mean that such systems are evolvable, adaptable and able to develop new behaviors (Parunak 2005; Kelly 1995), an ideal feature for collaborative groups seeking multiple solutions in a continually changing environment. Kevin Kelly provides an excellent metaphor for the system-level effects of emergent systems which may appear 'logical' on the outset (such as the hunt and gather behaviour of ants) but which are ultimately unpredictable (whether or not they will show up in your kitchen):

> No matter how intimately you know the chemical character of H2O, it does not prepare you for the character of a whirlpool. (1995:30)

Stigmergic systems also display autocatalytic, threshold oriented tipping-points in which coordinated phases are triggered by a critical density of activity, for example, the formation of pillars in termite mounds (Theraulaz & Bonabeau 1999). Below such thresholds, amplification mechanisms fail and potential emergence does not appear due to lack of coordination.

## 3.5. Applications: Computational Intelligence & Robotics

A brief survey of the applications of stigmergy provides considerable empirical confirmation as to its explanatory power and utility.

Perhaps the first field to explore the potential in consciously engineering stigmergy was artificial intelligence (AI) and its application of stigmergy in computer simulation and modelling. Deneubourg et. al. (1991) was able to reproduce various ant behaviours such as the sorting of objects based upon the recognition of object types and their densities in given areas (i.e. ant corpse piling), while Mason (2002) wrote an algorithm which incorporated the use of virtual pheromones in order to simulate the clustering behaviour that leads to the creation of complex structures in termite societies. As the above examples demonstrate, many researchers now consider stigmergy to be an accepted branch of AI and is generally referred to under the subset known as swarm intelligence (SI) (Kennedy et. al. 2001) or multiagent systems (Ricci et. al. 2006).

Researchers are also exploring a wide range of stigmergic applications in the realm of robotics (which in many respects represents a consecutive step in application from computer simulation). Beckers et. al. (1994) developed a small robot team that reproduced stigmergic sorting behaviour, this time with real objects, while Steele and Thomas (2007) successfully developed a control system, *Directed Stigmergy,* which enables and facilitates the collective remote control of a team of robots. Similarly, Parunak et. al. (2002) have developed and tested a method which utilises digital pheromones to coordinate not just robots, but flying swarms of robots (unmanned aerospace vehicles—UAVs) 'enabling a single human to monitor an entire swarm of UAV's' (2002:1).

Robots have even been programmed to stigmergically produce works of art as illustrated in figures 3.2 and 3.3.

Figure 3.2.
400 x 500 cm artwork produced by a group of 10 robots[36]

[36] Artist website, <http://www.lxxl.pt/artsbot/newkind.html> retrieved 8 April 2007.

Figure 3.3.
'Mbots' drawing and interacting stigmergically via the medium of the canvas[37]

Leonel Moura and Henrique Garcia Pereira's robots achieve paintings that emerge from the combined effects of randomness and stigmergy:

> The algorithm that underlies the program uploaded into each robot's microcontroller induces basically two kinds of behaviour: the random behaviour that initialises the process by activating a pen, based on a small probability (usually 2/256), whenever the colour sensors read white; and the positive feed-back behaviour that reinforces the colour detected by the sensors, activating the corresponding pen. ... The collective behaviour of the set of robots evolving in a canvas (the terrarium that limits the space of the experience) is governed by the gradual increase of the deviation-amplifying feed-back mechanism, and the progressive decrease of the random action, until the latter is practically completely eliminated. During the process the robots show an evident behaviour change as the result of the 'appeal' of colour, triggering a kind of excitement not observed during the initial phase characterized by a random walk. This is due to the stigmergic interaction between the robots, where one robot in fact reacts to what other robots have done.[38]

[37] Artist website, <http://www.lxxl.pt/artsbot/newkind.html> retrieved 8 April 2007.
[38] Taken from artist website, <http://www.lxxl.pt/artsbot/newkind.html>, for more images see <http://www.lxxl.pt/artsbot/index.html>, retrieved 8 April 2004.

In fact, there are many examples of the application of stigmergy in AI and robotics, and it is likely that the coming years will see many more with the ongoing miniaturisation of technology—especially in the realm of nanotechnology and innovations such as 'smart dust' (Pister 2001). Stigmergic systems are especially well suited to such situations where construction and or coordination is required and a high volume of participating agents is available. Three core strengths of stigmergy support its application in these types of contexts:

- **Simplicity**—stigmergic systems may achieve complex tasks through the collective efforts of relatively simple agents.
- **Scalability**—not only do stigmergic systems typically require multiple agents to function, but their performance tends to increase with scaling agents and expanding environments.
- **Robustness**—through high redundancy and constant self re-organisation, a stigmergic system may tolerate loss of membership with out significant reduction of its capacity.
    - (Parunak 2005:4)

Stigmergy's realm of application continues to expand, even into the domain of coordinating conceptual material (once again resonating with Hoftstader (1979) and Minsky's (1986) explorations). Specifically, researchers have used these techniques in the emergent generation of hypothesis corroboration and problem solving (an area connected to evolutionary and genetic programming). Kennedy et. al. (2001) developed an algorithm called 'particle swarm optimization' which evolves optimal or 'near-optimal' solutions to a problem by flying 'particles' (population members) through a problem hyperspace, the swarms eventually converging on the most 'fit' solution as defined by parameters set by the user. Weinstein et. al. (2004) applied similar swarming and stigmergic techniques in the development of an algorithm for their system *Ant CAFE*. This system utilises multiple swarm and stigmergic methods which emulate ant behaviors such as foraging, nest sorting and nest construction in order to extract information from massive intelligence sets (data measured in petabytes) for the purposes of conducting 'indications and warnings' analysis on potential terrorist attacks. While it is no doubt early days for such applications, it is clear

that there are many and that the connections with cognitive aspects, including collective and individual intelligence, are well founded.

## 3.6. Stigmergic Intelligence

With many notions of intelligence in existence (artificial, swarm, collective, emotional, social, lateral, musical, et cetera), it is not without some trepidation that I introduce another, 'stigmergic intelligence'. However, I believe it is important to draw specific attention to the nature of this form of intelligence as it is unique and differs considerably from most previous conceptions.

Utilising the framework of stigmergy, intelligence is understood to reside 'in the interactions among the agents and the shared dynamical environment' (Parunak 2005:4). This is also perhaps the archetypal example of the hive mind analogy, finally providing a well-documented, evidence based framework for the musings of Hofstadter (1979), Minsky (1986) and the swarm-like nature of individual and collective consciousness for Kelly (1995). Similarly, it also provides a framework for Rheingold's exploration into the behaviour of ICT media and the coordination of 'smart mobs' (2002) as well as O'Reilly's (2005) inquiries into the architectures of participation associated with 'Web 2.0'. The distribution of intelligence across a constituency and their surrounding environment also provides strong links with distributed cognition. The following observation by Hutchins illustrates these connections.

> The potential of the material environment to support memory is very widely recognized. But, the environment can be more than a memory. Cognitive activity is sometimes situated in the material world in such a way that the environment is a computational medium. (2000:7)

This less differentiated view of agent, collective and environment as represented by the notion of 'stigmergic intelligence' is also reminiscent of Latour's actor-network theory where agency, cognition and intelligence are seen as punctuations of interacting heterogeneous materials interconnected by patterned networks (2005). Applied to humanity, this union of the collective and environment suggests the traditionally controversial (if not somewhat cliché) claim that we really are 'all one'. As Parunak states,

'[i]t would be more difficult to show a functioning human institution that is not stigmergic, than it is to find examples of human stigmergy' (2005:1) implying that this form of intelligence is endemic in human activities and that our intelligence in some ways not only comprises each other's, but also the wider environment. In the current context, this notion of stigmergic intelligence (perhaps a subset of collective intelligence) provides a crucial conception in providing a concrete and well-defined framework for the phenomenon of mass collaboration.

## 3.7. Human-Human Stigmergy

There are many examples of human-human stigmergy, and as Parunak mentions above, once one begins looking, they seem to crop up all around and in every institution. Some more obvious examples include trail and track formation (Helbing et. al. 1997a; Helbing et. al. 1997b), graffiti and illegal garbage dumping,[39] however the impact of stigmergy can be seen across the breadth of human interaction. On the larger-scale, applications comparable to nest building in social insects include the constraints and impositions placed upon development in urban areas by previous building works—both in regard to location and orientation of subsequent buildings, as well as historical overlays designed to coordinate new works with the existing themes. On the smaller-scale, applications blend into our day-to-day without our notice, such as a practice common in Italian espresso bars where waiters place empty saucers on the counter next to the espresso machine which communicates to the barista that these are to be filled with cups of coffee.[40]

All of the above examples are of the sematectonic variety (interpretations based upon the state of the solution as represented by the environment) with trail formation, garbage dumping and saucer placement being quantitative (of a single scalar quantity) while graffiti and building works being largely qualitative (unique, discrete cues). However types of stigmergic interaction in human activity tend to be nested, reflecting the complexity of human culture and engagement. For instance while graffiti might on the outset appear

[39] Garbage dumping as stigmergy is mentioned by Dylan Shell on comment to Joe Gregorio's (2002) Stigmergy and the world-wide web. *Bitworking,* (web log), <http://bitworking.org/news/Stigmergy> retrieved 20 December 2005.

[40] Both of the above examples were provided by Parunak (personal communication), the former (building works) communicated to him by Fabien Michel of the University of Reims, France, the latter (saucer placement) by Franco Zambonelli.

qualitative to those who engage in the art (a good work's techniques and or subject matter inspiring a response) from outside the graffiti community it would seem to be an activity governed more by quantitative means (the more works existing on one particular wall, regardless of merit, the more likely it is that more will be attracted). Of course, both are correct. Additionally, many applications of stigmergy mixes marker-based with sematectonic mechanisms. For instance, a marker-based phenomenon that can be occasionally witnessed in zones where graffiti is frequent, is when one artist makes a textual comment to another (such as pleading with others not to continue painting over his or her work). Such comments place a marker outside of the content of the activity (i.e. creating graffiti works), the equivalent of making a note in a document's margins when coauthoring.

While such forms of non-computational stigmergy are pervasive in our communities and activities, the objective of this thesis is in the theorising of mass collaboration, which is currently restricted to digital means. Therefore in the efforts of economy, the following will focus primarily on computational forms, the variety and scale of which are both massive and important in their implications.

## 3.8. Digital Stigmergy

Digital stigmergy—stigmergic behaviour that emerges when humans work within digital environments—is (as far as we know) human specific and occurs in a wide range of contexts on a wide range of platforms. While two people may interact stigmergically via a single digital device, (e.g. by passing a laptop back and forth), the most notable forms of digital stigmergy occur in networked contexts such as the Internet, intranets and mobile/handheld networks. In fact, a number of researchers argue that the growth of the World Wide Web itself is the result of stigmergy, with new websites providing the stimulus for others to create further websites (Elliott 2006; Gregorio 2002; Heylighen 2007b). While this assertion is correct (Parunak provides a brief case study on the World Wide Web as stigmergic system (2005:12-3)) there are many subsets of the World Wide Web which have taken stigmergy to a far greater level than simply providing stimulus for new sites. However, in order to grasp the nature and scope of these developments, it is first necessary

to consider how humans have evolved stigmergy through the ongoing development of media as an extension of their stigmergic environment.

### 3.8.1. The Evolution of Media: Extending & Transforming the Environment

Since early humanity, we have explored the representational capacities of environmental subsets. In the first instances, the distinctions between these subsets and the wider environment were fuzzy. Cave and rock paintings[41] provide some of the first examples of humanity adapting the natural environment around them to more specific stigmergic applications. In other words, these are early prototypes of media with the capacity to communicate indirectly thereby providing stimulus to others to modify their behaviour, shape their culture and reproduce and evolve further media usage.

In this view of human stigmergy, the common usage of the term 'medium', actually describes quite well the nature and purpose of the environment for stigmergic systems, both in its most broad and oldest usages.[42]

- Circa 1573-4: An 'intermediate between two degrees' [i.e. the stigmergic environment connecting and coordinating two agents].
- Circa 1941: 'Any physical material (as tape, disk, paper, etc.) used for recording or reproducing data, images, or sound' [thereby providing an 'environment' for the inscription and conveyance of signs from one agent to another].
- Circa 1595: 'An intervening substance through which a force acts on objects at a distance or through which impressions are conveyed to the senses' [in capturing stigmergy, this definition only leaves out the notion that once impressed upon the senses, such a 'force' may instigate a change in the behaviour of the recipient].

In light of these definitions (especially the latter) it is posed that the term medium and its plural, media, more accurately describes these environmental subsets which have been specifically cultivated by humanity for the purposes of indirectly communicating

[41] No doubt before such developments, annotations in environmental media such as wood and earth took place, these now lost in time.
[42] The following definitions and etymologies are taken from the 'Medium' article, *Oxford English Dictionary, Second Edition,* (1989). (Eds.) J. A. Simpson & E. S. C. Weiner. Oxford: Oxford University Press.

impressions and representations to wider audiences, thereby providing an 'environment' for stigmergic interactions (this view is also supported by Heylighen (2007b:12)). Subsequently, throughout the remainder of the present work, I will use of the term media to signify these stigmergic environmental subsets in the context of human activity, digital or non.

### 3.8.2. Digital Media as Stigmergic Environmental Processor

Pre-digital media exhibits stigmergic-like capacity in its coordination of culture over more extended timeframes and geography, but usually with less agent-environment interactivity. Early stigmergic media such as cave and rock paintings were more limited in their coordinative capacities (especially in regard to geography) by their monolithic, situated nature, rendering them less able to reach a wider audience. Print media on the other hand is considerably more capable in this regard due to its portability and its comparative ease of reproduction, this combination providing for a wider range of stigmergic interactions. For instance, increased numbers of readers raises the likelihood that both a book and the ideas it contains will be further reproduced (i.e. more printings of the original and new books inspired by it) and that these reproductions will reach yet wider audiences thereby increasingly coordinating culture. It is not difficult to think of how other pre-digital media provide cultural, economic and social coordination through the flow-on effects of conceptual stimulation and the reproduction of these concepts in further media incarnations—i.e. radio, film, television, commercials, billboards, graffiti, markets et cetera.

However, a significant shift occurred through the digitisation of media. Digitisation has enabled features which are generating more capacity for the coordination of culture through rapid iterations of an increasingly interactive and malleable computational environment—specifically that of multi-path interaction and increased ease of copy, modification and dissemination. This equates to not only elevated levels of feedback, but more deeply, increased power of the system's capacities and interactions along a number of stigmergic dimensions:

- the environment's structural capacities: state variables, dynamics and topology, and

- the system's interactional capacities: marker-based, sematectonic, quantitative and qualitative.

#### 3.8.2.1. Enhanced Structural Capacity

When media is digitised, a fundamental transformation takes place in its nature and fabric, one that enables increased stigmergic capacity. Not only is the material which conveys the representation[43] transformed (from paint to pixel for instance) but so to is the platform for those materials (e.g. from canvas to computer). It is the latter point that carries the greater transformational capacities concerning stigmergy, as the computational platform enables extensions of the media's structure, dynamics and state variables.

The digitisation of media affects its structure (the stigmergic dimension which provides the agent with a sense of locality upon some topology) in a number of possible ways. Networking protocols and standards, such as TCP-IP, HTTP and HTML in the case of the Internet, extend the topological fabric of a digital stigmergic medium across a network of computational platforms. The primary result of this is the provision of multiple loci for agents distributed geographically, such as the Internet's capacity to provide a potentially unlimited number of sites for website construction anywhere on the global network. However, perhaps the most important effect of this expansion is the extension of locality.

Through networking and various innovations in web-based software applications, the site of locality that an agent experiences at a particular locus can be replicated indefinitely, thereby providing multiple simultaneous instances of the *same* site of work to many agents. This is one of the most profound evolutions of media regarding stigmergy as it provides a multiplicity of the spatial dimension effectively allowing *more than one agent to occupy the same site of work at the same time*. This capacity is a clear development from that of insect stigmergy in that insect agents are limited by the spatial displacement of their physical forms which correspondingly limits the numbers which may simultaneously engage a single site of work. An excellent example of this extension applied to the digitised print medium is Wikipedia's capacity to provide a single article for viewing and editing to a

[43] This usage of 'representation' also includes instances abstract and non-figurative in nature.

great many people simultaneously.[44] This same effect occurs in the visual drawing medium, with Flash-based software developed by Drawball.com. Drawball's site enables multiple users to work on the same region of a much larger overall digital canvas simultaneously. Figures 3.4—3.7 show the successive levels of zoom required to arrive at the level where drawing may happen. Note the 'ink pot' in the lower right corner of figure 3.7—the amount of ink may be increased (or decreased) as a user increases their history and profile on the site (in figure 3.7 my ink is all used up).


Figure 3.4.
Drawball, full zoom[45]

[44] Wikipedia provides dynamic web pages through the use of wiki software, a type of website which enables visitors to add, edit and delete content. For more information on wikis in general, see Wikipedia article, 'Wiki', <http://en.wikipedia.org/wiki/Wiki> retrieved 9 April 2007.
[45] Screen shot from Drawball.com, <http://www.drawball.com/> retrieved 9 April 2007.


Figure 3.5.
Drawball, 33% zoom[46]

[46] Screen shot from Drawball.com, <http://www.drawball.com/> retrieved 9 April 2007.

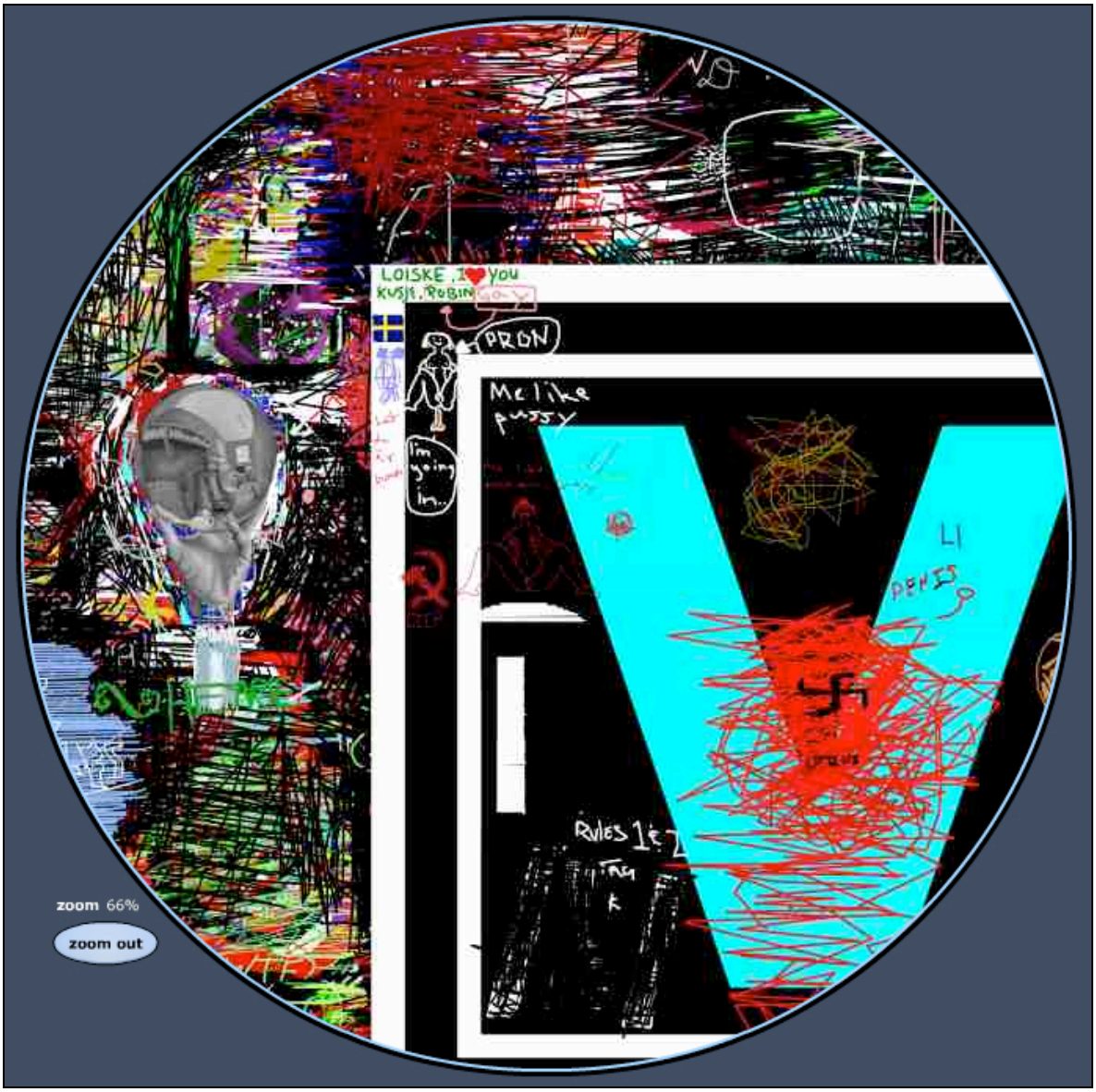


Figure 3.6.
Drawball, 66% zoom[47]

[47] Screen shot from Drawball.com, <http://www.drawball.com/> retrieved 9 April 2007.

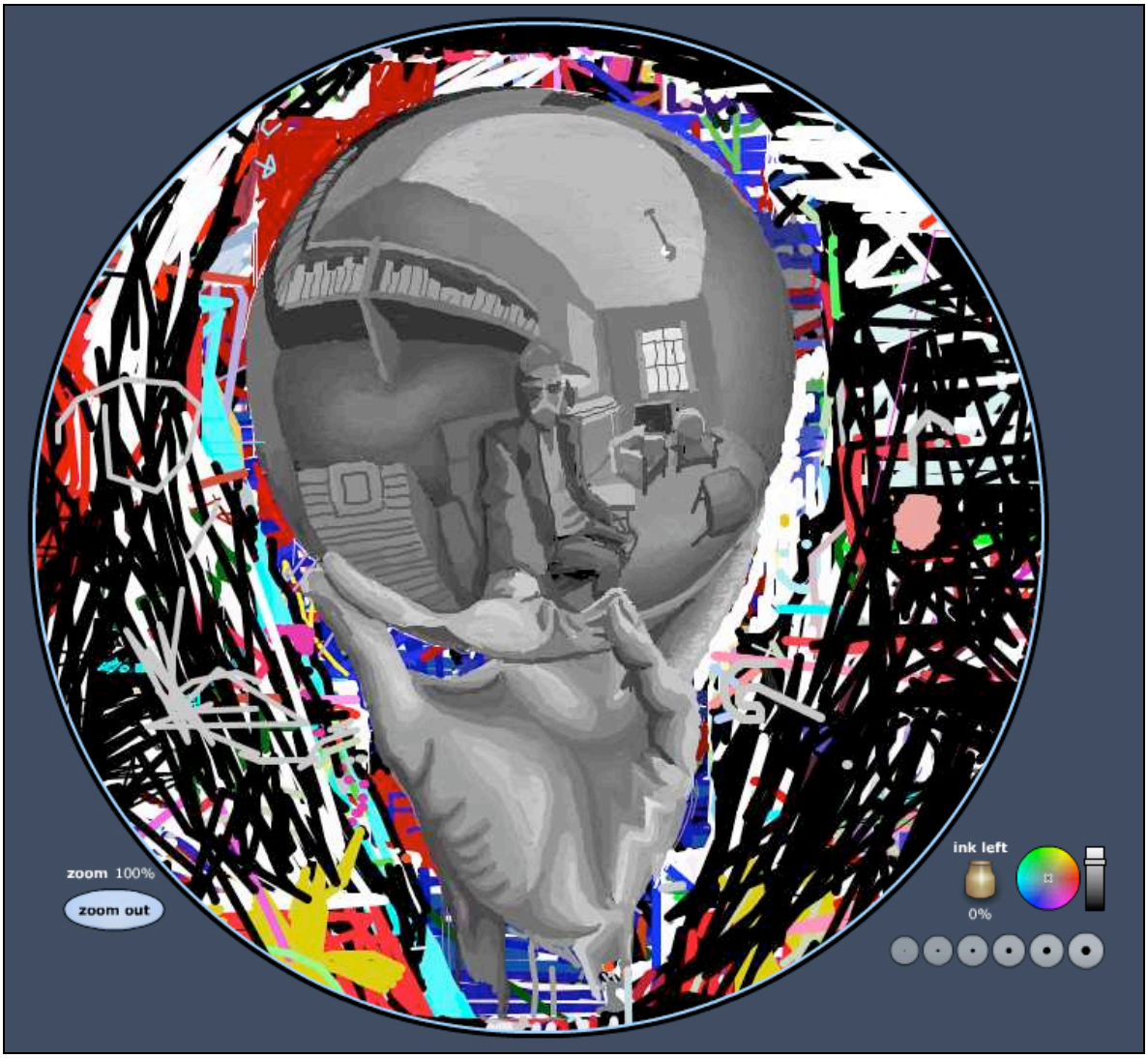


Figure 3.7.
Drawball, 100% zoom, level of drawing[48]

Another important consequence of the digitisation and subsequent networking of media is that the same media content may be easily re-presented upon different topologies, often simultaneously. This provides multiple pathways through the same content, naturally optimising different semantic ontologies through the emergent pathways generated. For instance in the case of most wikis (such as Wikipedia), pages are organised in and may be browsed via categories,[49] thereby forming the topology of an index. However, a user may browse the same pages via cross-referenced hyperlinks, forming more of a graph-like

[48] Screen shot from Drawball.com, <http://www.drawball.com/> retrieved 9 April 2007.
[49] See Wikipedia article, 'Wikipedia: Categorical index' <http://en.wikipedia.org/wiki/Wikipedia:Categorical_index>, retrieved 9 April 2007.

experience. This capacity for multi-topological representation is likely to become increasingly important as the capacity for new digital topologies emerge. Examples of such newer topologies include the recent development of the 3D, stigmergically encodable environment of Second Life (a massive multiplayer online environment constructed by its participants), and the exploration of more radical multi-dimensional representations such as mixed and augmented reality where real world and virtual realms are overlayed and interact.[50] In the case of Second Life, the stigmergic topology is that of 3D Cartesian space, however various aspects (objects, locations, residents) may also be browsed in an index form, while it is also possible to list locations (and 'teleport' to them) with Internet-based URLs.[51]

The dynamics associated with stigmergic environments which govern their evolution through time are also present in stigmergic media, these dynamics being considerably expanded by the ongoing development of media's computational platforms. Some examples of the information processing dynamics associated with Wikipedia's software platform, Mediawiki,[52] include the generation and maintenance of contributor and revision histories, the coordination and resolution of edit conflicts (when two people edit the same article at the same time), and the automatic listing of articles in categories and the inclusion of templates when the correct code is entered on a page. These examples should make it clear that a digital stigmergic medium's information processing dynamics will evolve and improve as technological capacity and understanding of related software engineering improves. It is in precisely such areas where increased understanding of stigmergy in digital and mass collaborative contexts will help focus engineering and project objectives.

Finally, the combination of a stigmergic medium's structure and dynamics give rise to its state variables—the variations in the medium which are perceivable and meaningful to the agents interacting with it. Such variables may be toggled or manipulated by the agents, others by the environment itself, and yet others by both. Examples of such state variables in

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[50] Interestingly, standards and technologies which may serve to link the digital world to that of the real are currently under development in the realm of wireless sensor networks (see Wikipedia article 'Sensor network' <http://en.wikipedia.org/wiki/Sensor_network> retrieved 9 April 2007) which has the potential to generate a massive extension in the stigmergic, multi-topological experience.
[51] See <http://slurl.com/about.php> retrieved 14 May 2007.
[52] Mediawiki is freely available open source wiki software. See <http://www.mediawiki.org/wiki/MediaWiki>, retrieved 9 April 2007.

Wikipedia's Mediawiki software include encoding pages with ASCII characters (text), creation of text headings, uploading and embedding images and specifying hyperlinks to other wiki and wider web pages. Similar to the linked development of media dynamics with evolving technological and engineering abilities, state variables are also subject to such increasing capacity. However, state variables are perhaps more limited to the syntax, ontologies and practices inherent in the given media. For instance, it is unlikely that the Mediawiki software will develop to incorporate the variable of drawing (like Drawball.com) on article pages, as this would not fit Wikipedia's established objectives and practices associated with encyclopedia writing.

#### 3.8.2.2. Enhanced Interactional Capacity

As the structure of stigmergic media undergoes continued evolution in tandem with technology and engineering practices, so to does agent-environment interactions. With this evolution, interactions between agent and environment are becoming increasingly fluid and of finer resolution, while the fidelity of representation becomes more sharp and accurate.

Digital stigmergic media provides many forms of marker-based and sematectonic gestalt foci. For instance, Wikipedia's Mediawiki environment provides for more or less standard document editing, which in itself consists of sematectonic interpretation of internal semantic relations that evolve with individual modifications and contributions (Parunak 2005:11). On the other hand, Mediawiki's author and history tracking serves as a marker-based means of interpreting the various states of the document through time, while hyperlinks and even edit buttons provide marker-based cues for performing various actions within the media environment.

In similar fashion, digital media contexts provide well for the sign types, quantitative and qualitative. For instance, as previously mentioned, Wikipedia's recent changes page (see figure 3.8) has a feature that displays a positive or negative value depending upon how many characters a participant adds or deletes in any given revision. This allows the participant to make an immediate evaluation as to whether or not the article has undergone a considerable revision and thus demands their attention. This very same function also incorporates qualitative cuing by colour coding positive values green for additions and red

for deletions, thereby providing two distinctly different messages which combine in order to allow one to scan the page quickly for either type of change.

**9 April 2007**

- (diff) (hist) . . Uwais al-Qarni; 00:09 . . (-169) . . Tom harrison (Talk | contribs) *(→Life - rm honorifics)*
- (diff) (hist) . . User talk:Jerry/Archive 2; 00:09 . . (+16,877) . . Jerry (Talk | contribs) *(transfer comments from main talk page)*
- (diff) (hist) . . Jean-Luc Godard; 00:09 . . (-128) . . BettinaSen (Talk | contribs) *(→"Cahiers" and early films)*
- (Upload log); 00:09 . . M Johnson (Talk | contribs) *(uploaded "Image:Canine-Mutiny.png": Marge, Lisa and Bart quickly fall in love with a dog named Canine Mutiny. == Fair use for The Canine Mutiny and The Simpsons (season 8) == Although this ima)*
- (diff) (hist) . . Guillermo Franco; 00:09 . . (0) . . 189.133.54.30 (Talk)
- (diff) (hist) . . Wikipedia talk:Articles for deletion/StartCom; 00:09 . . (+681) . . Hu12 (Talk | contribs) *(→coi spa clutter on afd - moved from main page)*
- (diff) (hist) . . User:Kid Sonic; 00:09 . . (-288) . . 75.53.36.13 (Talk) *(→Favorite Shows)*
- (diff) (hist) . . Wikipedia:Request an account/April 2007; 00:09 . . (+20) . . AccReqBot (Talk | contribs) *(Adding SBaL)*
- (diff) (hist) . . User talk:VirtualSteve; 00:09 . . (+450) . . VirtualSteve (Talk | contribs) *(→Ganmain - response)*

Figure 3.8.

Mediawiki's recent changes features[53]

Developing our understandings of how digitised stigmergic media incorporates and elaborates on such mechanisms for interactivity, as well as the structural capacities of the media itself, will help us understand how to more successfully engineer stigmergic activity in the digital domain. Such engineering ability is already a vital part of the success of mass collaborative ventures such as Wikipedia, and as more people integrate Internet usage into their daily lives, and as technology and culture provides for more accessibility to mass collaborative projects, such engineering knowledge and skills can only become more important and valuable.

## 3.9. The Internet as Stigmergic Medium

The Internet is fundamentally a stigmergic system in that it supports mediated indirect communication and inspires users to respond to its encoding by further encoding it (Gregorio 2002; Kramer 2005:6; Parunak 2005:12). Bootstrapping methods employed in the early phases of the Internet's architectural development also supports this general observation. In order to facilitate interoperability between network nodes, the Advanced Research Projects Agency (ARPA) chose the Berkeley Software Distribution (BSD) of the UNIX operating system as a standardised platform for interconnection. By distributing the source code along with the software application, ARPA enabled users of potential nodes to

[53] Screen shots taken from the Wikipedia page 'Special: Recentchanges', <http://en.wikipedia.org/wiki/Special:Recentchanges> retrieved 9 April 2007.

customise the operating system in order to meet the needs of their specific hardware configurations (Pedersen 2001).

The distribution and collective modification of computer code is essentially the same stigmergic process inherent in collaborative document editing mentioned above—sematectonic interpretation of internal semantic and syntactical relations which evolve with individual modifications and contributions, thereby affecting subsequent interactions and encodings. This stigmergic custom of distributing and editing a software application's source code (typically in a text file) in order that the application might be customised, has become a cornerstone of much of the Internet's growth via the Open Source Software movement, especially through the Apache HTTP Server—open source software which runs some 70% of the Internet's web servers.[54]

Increasingly companies and organisations are recognising the inherent potential in enabling stigmergy by distributing source code and programming methodologies. IBM's early alliance with the Open Source Software movement and Apache in 1998 helped pave the way for private corporations to explore such symbiotic relationships (Rheingold 2002) and more recently, Internet search engine giant, Google, has launched Google Code (http://code.google.com). This service provides support for user driven innovation by providing open source applications (http://code.google.com/projects.html) project hosting (http://code.google.com/hosting) and tool kits (http://code.google.com/webtoolkit) for designing and building cutting-edge dynamic content applications.

Through stigmergic methods (hosting services which via indirect interaction feed and fuel the developments which these services support and host) Google empowers users and programmers alike with the ability to participate in the further redesign of their digital environment. This provides the opportunity to attempt to harness the collective's potential to serve Google's development interests by sparking new areas and instances of innovation upon which they may build.

[54] 'Apache has been the most popular web server on the Internet since April 1996. The November 2005 Netcraft Web Server Survey found that more than 70% of the web sites on the Internet are using Apache, thus making it more widely used than all other web servers combined.' Taken from: 'Apache HTTP Server Project', (online resource), <http://httpd.apache.org/> retrieved 17 April 2007.

It is important to remember however that while such stigmergic methods offer a wide variety of positive opportunities for many, there will no doubt be increasing uses of the process for more malevolent, malicious and criminal applications. A recent example of stigmergy utilised for just such an outcome was the posting of a message on the popular Craigslist website advertising that the contents of a particular apartment were freely avalible to be taken. The result was that an innocent person's apartment was 'stripped of appliances, windows, light fixtures and even the kitchen sink'[55] by a crowd stigmergiclly responding to the Craiglist ad. As it is ultimately impossible to prevent all such cases of misuse, there is the possibility that such activities might provide a negative feedback force on the growth of stigmergic Internet activity if such instances continue to rise.

However, another stigmergic dynamic likely to continue positively influencing the ongoing growth of the Internet is the simple and commonplace capacity to 'view page source'—the HTML code used to 'mark up' webpages. As anyone who has spent time learning to build websites knows, the capacity for most browsers to display a webpage's source code provides the would-be web designer with the capacity to simply view, copy and paste the relevant code from a page which displays the desired functionality (O'Reilly 2005).[56] This type of approach points to a valuable area for future research and development—'stigmergic teaching and learning', which could provide pedagogical approaches well suited to the Internet in its capacities for 'view/copy/paste' and distributed individualised learning (in contrast to the centralised and collectively situated classroom model).[57] In fact, stigmergic teaching and learning forms the underlying premise for one of the three creative works provided, the Collaborative Contract online environment profiled in chapter 6.

### 3.9.1. Web 2.0 - The Internet as Programmable Stigmergic Environment

Following the dot com bubble and its subsequent collapse in 2001 (see figure 3.9), an approach to utilising the Internet's architecture and capacity began to emerge, one that

[55] See, 'Home emptied after hoax online ad', BBC News, (online service), <http://news.bbc.co.uk/2/hi/americas/6532231.stm> retrieved 9 April 2007.
[56] This method is commonly (stigmergically) listed on 'how to' websites such as Internet4Classrooms.com, <http://www.internet4classrooms.com/chp_source.htm> retrieved 4 April 2007.
[57] Stigmergic learning is also the means employed by Google mentioned above in hosting resources such as their tool kits (http://code.google.com/webtoolkit), this up-skilling enabling Google to 'crowdsource' components of their innovation cycles.

represents a movement away from the static webpage / broadcast model towards more dynamic multi-path interaction (O'Reilly 2005). 'Web 2.0' is increasingly becoming the buzzword of choice used in association with this new approach, one recognised for its community, participation and peering focus (Tapscott & Williams 2006:19).[58] Figure 3.10 shows a timeline of the emergence of some of the software application oriented buzzwords associated with Web 2.0.


Fig. 3.9.

The technology-heavy NASDAQ Composite index peaked in March 2000, reflecting the high point of the dot-com bubble[59]

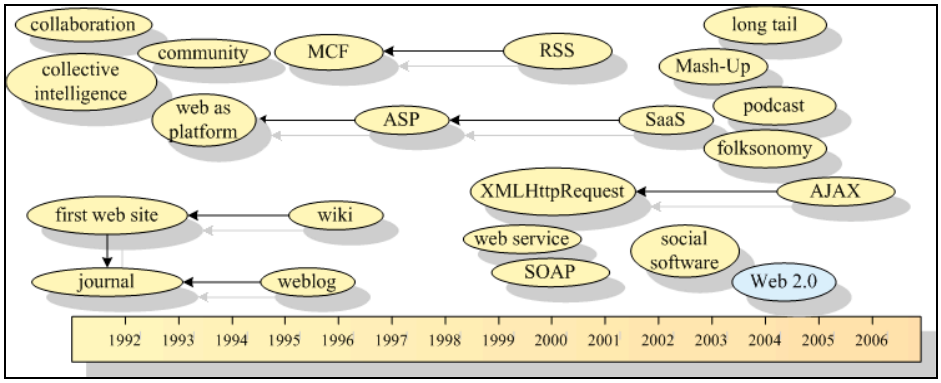


Fig. 3.10.

Time bar of Web 2.0 buzz words[60]

[58] It should be noted that some are critical of the hype surrounding Web 2.0 and interpret it not as 'a second-generation of either the technical or social development of the internet, but rather as the second wave of capitalist enclosure of the Information Commons' (Kleiner & Wyrick 2007).

[59] Image and description taken from the Wikipedia article, 'Dot-com Bubble', <http://en.wikipedia.org/w/index.php?title=Dot-com_bubble&oldid=120258441> retrieved 5 April 2007.

Tim O'Reilly's *What Is Web 2.0 - Design Patterns and Business Models for the Next Generation of Software* (2005) sets out to describe and catalogue the characteristics of this emergent design methodology which he associates with Internet enterprises and activity such as eBay, Amazon, Google, open source, BitTorrent and the blogosphere. Below are some of the characteristics he identified as core attributes of Web 2.0, followed by an explanation linking each one directly to the mechanisms of stigmergy.

### 'Architectures of participation'

Architectures of participation are seen to be one of the fundamental concepts involved in Web 2.0 approaches with O'Reily stating that added value can be gleaned from user interaction not only by encouraging direct user participation, but by setting 'inclusive defaults for aggregating user data and building value as a side-effect of ordinary use of the application'. Direct interactions (like Amazon's user-generated reviews) correlate to the design of stigmergic environments where user-generated, marker-based and sematectonic contributions are provided for by the user's direct interactions (e.g. reviews). Similarly, indirect interactions, which often occur without the user's knowledge, equate to increased environmental information processing on the structural level (e.g. recommender systems such as Amazon's 'Customers who bought this item also bought' feature).

### 'Rich user experiences'

Programming methods such as 'AJAX'[61] enrich user experiences by enabling webpages to dynamically update content without reloading the entire page, provide a more fluid interactive experience by reducing time between iterative content changes and thus tend to garner more interaction. This same technique also increases the variety of smaller interactions possible which were once too time consuming to make practical—for instance YouTube.com provides functionality where one simply clicks a rating level on the page

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[60] From Jürgen Schiller García's blog post 'Web 2.0 Buzz Time bar', <http://www.scill.de/content/2006/09/21/web-20-buzz-zeitstrahl/> (retrieved 9 April 2007), via Wikipedia 'Dot-com bubble' article <http://en.wikipedia.org/w/index.php?title=Dot-com_bubble&oldid=120258441> (retrieved 9 April 2007).

[61] Shorthand for 'Asynchronous JavaScript and XML', see, <http://en.wikipedia.org/w/index.php?title=Ajax_%28programming%29&oldid=124366075> retrieved 21 April 2007.

(marker-based quantitative) which requires no page reload for instant display and incorporation into other users' ratings, thereby providing collaborative filtering.[62] Both reducing the time involved in iterative content development and increasing the diversity and granularity of interactive possibilities are critical to the evolution of more responsive stigmergic systems, the consequence of this for the user being a more rich interactive experience.

### 'Users as co-developers'

That the individual agent in a stigmergic system should co-develop the state of the environment is inherent to the process. Therefore, if web services are to be stigmergic, then the user must be allowed to contribute in some way to the state of the application presenting the procedures / shared representations. Another way of conceptualising this arrangement is the notion of 'user-generated content' (often touted as a core Web 2.0 attribute), while yet another is 'crowdsourcing'—the enticement of large collections of contributions from users which ultimately benefits the organisation to which they are contributing.

### 'The service automatically gets better the more people use it'

As previously mentioned, stigmergic systems provide for agent scaling through localised interaction, and like a hologram, they increase fidelity with larger areas of encoding. This is an example of what Dan Bricklin described as the 'cornucopia of the commons' in his paper of the same name (2001) as well as what Cory Doctorow playfully describes as 'sheep that shit grass' (via Rheingold 2002:77). It is likely that all such examples of positive feedback which manifest through collective engagement with a shared environment are attributed to stigmergy—even in the case of wireless mesh networks (Rheingold 2002) where gradients of coverage increase with the number of nodes, and whose agents respond to this increased gradient by further increasing the node number (the dynamics produced in this case are very similar to that of pheromone systems).

[62] Utilising this thesis's conception of collaboration, the popular use of the term in 'collaborative filtering' is a misnomer. In such circumstances there is no divergent, collective creation of representations, rather the process simply makes use of compliance in procedure towards a shared outcome (the collective rating) and therefore would be more aptly described as 'cooperative filtering'. However, in accordance to custom, the term will be utilised in its common form.

### 'Reach out to the entire web'

O'Reilly makes the point that through the aggregation of a high volume of small contributions, large profits of various sorts can be generated. For instance, eBay's enterprise amasses billions of dollars via small transactions, or Amazon's recommender system being generated by multitudes of incidental individual interactions. Such high yields via small contributions are precisely the way gains are made in stigmergic systems—each ant deposits a disproportionately small amount of pheromone, however the hive as a whole provides enough to accurately guide its multitudes over vast amounts of time and space.

### 'Software written above the level of the single device'

Designing and writing software above the level of the single device is crucial to the formation of the networked environments that enable stigmergic interactivity. By treating the web as an application platform, designers are able to leverage the interactivity of great numbers of people via a single infrastructure. In attempting to achieve Google's corporate mission, 'to organize the world's information and make it universally accessible and useful,'[63] Google provides web-based applications in order to capture the interactions and information of its users such as their email client (http://mail.google.com), online collaborative document and spreadsheet functionality allowing interoperability with Microsoft Word and Excel (http://docs.google.com), online collaborative calendering (http://calendar.google.com) and the above mentioned code repository (http://code.google.com). This enables Google to reorganise these contributions in potentially meaningful ways[64] and create opportunities for further interaction and informational encoding. In addition to generating a common, standardised platform/environment for stigmergic interaction which would ideally manifest a 'cornucopia of the commons' effect, they also generate and ensure the market share of would-be clients for their future ventures and advertising (a major source of Google's revenue).[65]

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[63] Taken from Google's 'Corporate Information, Company Overview', (online resource), <http://www.google.com.au/intl/en/corporate/index.html> retrieved 5 April 2007.
[64] However, Google is also known for reorganising information in un-meaningful ways (for the searcher), as in their selective search returns for Google China, omitting returns censored as per the views of the government. <http://news.bbc.co.uk/1/hi/technology/4645596.stm> retrieved 5 April 2007.
[65] See Google's 'Corporate Information, Company Overview', (online resource), <http://www.google.com.au/intl/en/corporate/index.html>, retrieved 5 April 2007.

### 'Harnessing collective intelligence'

The point made here by O'Reilly is essentially that with the right (stigmergic) architecture, the collective contributions of hundreds, thousands, even millions of people yield extremely useful and valuable information (basically a reiteration of 'The service automatically gets better the more people use it'). Below is a list of organisations describing how they are harnessing collective intelligence through leveraging large collections of many small stigmergic interactions.

- Massive numbers of users provide eBay.com with an online market place which exhibits cornucopia of the commons dynamics enabling more transactions and better merchandise;
- Amazon.com makes use of a great variety of informational sources gleaned from the interactions of its users, which in turn provides its users with valuable information via its recommender system;
- The numbers of links pointing to any given website provides Google's PageRank system with the information it needs to direct the majority of web users to their destinations;
- Through hundreds of thousands of smaller contributions, the English Wikipedia alone has over 1,728,321 articles with a total of over 609 million words, (roughly fifteen times as many as Encyclopedia Britannica);[66]
- Open source projects listed on SourceForge.net attract and coordinate the input of multitudes of developers, which drives the creation and development of software which runs a majority of the web (i.e. the Apache HTTP Server).

The above examples and discussion should make it clear that stigmergy is playing a fundamental and enabling role in the ongoing evolution of the global network. However, while notions of Web 2.0 continue to be a popular means of designating newly available stigmergic capacity, this designation's demise is built into its very conception, in that the possibility for Web 3.0 is invoked in the notion sequential of versioning. Of course, this does not necessarily mean that the functionality and approaches attributed to Web 2.0 will

[66] From Wikipedia article, 'Wikipedia: Size comparisons', <http://en.wikipedia.org/w/index.php?title=Wikipedia:Size_comparisons&oldid=111330758>, retrieved 9 April 2007. These statistics are of course no indication of quality, however the main point is that interactions captured in the form of small contributions may scale up to very large outcomes.

disappear, but rather that they are likely to evolve, and or be subsumed and transcended by yet further developments (such as the notion of the 'semantic web', typically touted as 'Web 3.0'). How such future evolutions are to take place still remains unapparent, however if the current pace and trajectory of technological and social development continues, not only are they likely to be already emerging on the horizon, but they are also likely to be inextricably reliant upon and probably even further extensions of the mechanisms of stigmergy. As these future and present extensions of the mechanisms of stigmergy take place, they may also catalyse the expansion of other yet unknown and unwitnessed capacities, perhaps through Grassé's 'group effects' which trigger morphogenic transformations at critical transition points. I would like to suggest that we are in fact entering such a phase, with the morphogenesis taking place at the level of our capacity for collective activity through the coordination and expansion of digital stigmergy.

## 3.10. Digital Stigmergic Coordination, Cooperation & Collaboration

The framework for collective activity posed in the previous chapter—coordination, cooperation and collaboration—provides not only a means for differentiating forms of collective activity, but it also presents a framework for conceptualising the recent expansion of humanity's stigmergic capacity. Specifically, the framework can be extended to incorporate the notions and interrelations of 'stigmergic coordination, cooperation and collaboration' (see figure 3.11). This extension enables a means of organising and conceptualising the growing amount of stigmergic activity online by providing a generalised framework for classifying various forms of digital stigmergy. Mirroring non stigmergic coordinative contexts, stigmergic coordination[67] provides the initial conditions for stigmergic cooperation (the harmonising of proximal relations through indirect interactions), as stigmergic cooperation does for stigmergic collaboration (providing procedural compliance in a shared pursuit for the co-creation of emergent shared representations via indirect interaction). While this thesis is aimed at theorising mass collaboration (a subset of stigmergic collaboration), a brief description of stigmergic

[67] In some respects, the term 'stigmergic coordination' represents a tautology in that the term stigmergy describes a certain class of coordination. In fact, it may be that 'stigmergic coordination' as being described here is simply traditional stigmergy as found in insect societies. However, the term provides useful means of contrast to that of 'stigmergic cooperation' and 'stigmergic collaboration' since these phenomenon are quantifiably different than that of the former type found in colonies of ants and termites.

coordination and cooperation is provided in order to help describe this emerging realm of collective activity, as well as to help set the stage for the further expansion of the frameworks for stigmergic and mass collaboration in the following chapters.

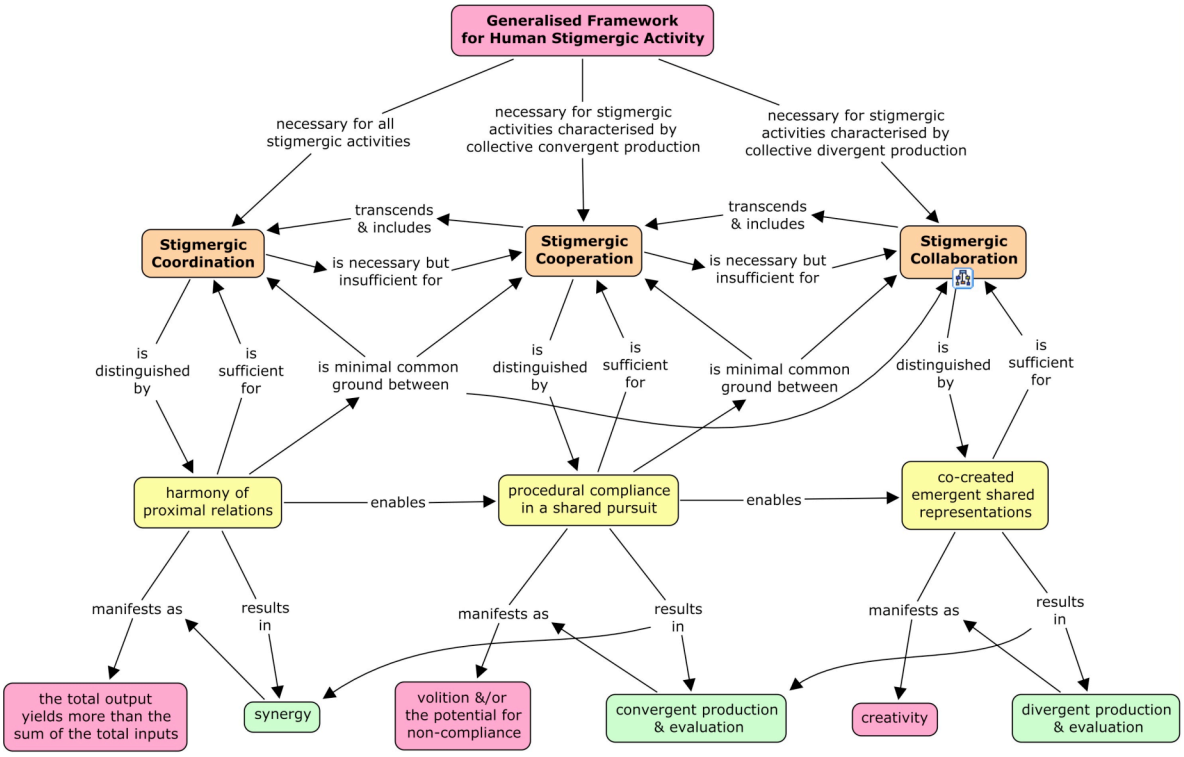


Figure 3.11.

Framework for Human Stigmergic Activity

## 3.10.1. Digital Stigmergic Coordination

Two primary examples of stigmergic coordination, the hyperlink structure of the Internet and Google's PageRank system, provide a great deal of the functionality which enables navigation of the web's terrain (a precondition for interacting with its finer details as well as enabling stigmergic cooperation and collaboration).

The hyperlink structure of the Internet—links which interconnect sites and pages with a single mouse click—is constructed stigmergically in a manner similar to that of tracks, trails and roads in that they are created and reinforced by the traffic which they cue (Heylighen 2007a). Therefore, hyperlinks provide a fundamental method of navigation to and through what would other wise be largely unknown sites of information.

Google's PageRank algorithm is the second 'clear example of an emergent phenomenon generated stigmergically' (Parunak 2005:14). Providing much of the Internet's functionality in recent years through a tight stigmergic relationship with the web's hyperlink structure, PageRank rates a webpage and thus Google's search returns by determining how many links point to it from other webpages, as well as how many links point those pages pointing to the initial page.[68] Not only is this an example of straight forward stigmergy, but the principles inherent in pheromone systems can be clearly seen here, namely marker-based/quantitative (Heylighen 2007a). By embedding a page with a link to another page, the site designer is effectively depositing a sort of pheromone which is 'sniffed out' by Google's 'spider' applications as they index the web in order to apply PageRank. Conversely, if a link to a page is removed, like pheromone evaporation, the page's rating is lowered. This functionality provided by Google effectively adds to the environmental information processing capacities of the Internet, which manifests as marker-based/quantitative cues for users when returning search results (i.e. a site with a higher rank and therefore listed closer to the top of the search returns is more likely to be visited).

Such examples of stigmergic coordination in the digital domain provide for the harmonization of proximal relations required to cluster websites into groupings of mutual relevance, thereby coordinating human activity in time and space and providing the preconditions for stigmergic cooperative and collaborative activities online.

### 3.10.2. Digital Stigmergic Cooperation

Stigmergic cooperation on the other hand is characterised by procedural compliance in a shared pursuit, mediated by a stigmergic medium (such as the Internet). Since the Internet provides one of the first global, standardised dynamic environments capable of bridging time and space and coordinating activities and perspectives while catering for most media, it should be of no great surprise to find a wealth of stigmergic cooperation taking place. In fact, as table 3.0 shows, stigmergic cooperation is clearly a big trend.

[68] See 'Our Search: Google Technology', Google, (online resource), <http://www.google.com/technology/> retrieved 5 April 2007, and Wikipedia article 'PageRank', <http://en.wikipedia.org/w/index.php?title=PageRank&oldid=120406955> retrieved 5 April 2007.

| Example | Procedure(s) | Objective / Emergent System Behavior |
|---|---|---|
| Del.icio.us | Tag webpage with meaningful label. | A shared, continuously updated and collaboratively filtered catalogue of webpages. |
| YouTube.com | Upload videos to site, rate and comment on videos. | A free resource of fresh, collaboratively filtered video content. |
| Flickr.com | Upload pictures to site, rate and comment on pictures. | A free resource of fresh, collaboratively filtered pictorial content. |
| Wikimapia.org | Identify and comment on locations. | A free global mapping resource with user-relevant annotations. |
| Stumbleupon.org | Establish user profile; identify websites of interest via browser-based add-on. | Return sites matching your interests based upon sites identified by others whose profiles match yours. |
| DotSub.com | Provide subtitles for video content. | A free resource of subtitled video content. |
| Geni.com | Enter familial relations and invite other family members to do so. | Family members generate a family tree drawing on the collective efforts of the many. |
| MoveOn.org, GetUp.org.au | Subscribe to email list; execute instructions provided in emails. | Large-scale, grassroots political lobbying.[69] |
| RottenTomatoes.com | Rate and review movies. | A free resource of movie reviews and collective ratings. |
| Digg.com | Submit and rate various sections of web content. | A free resource of collaboratively filtered and rated Internet content. |
| Technorati.com | Assign blog posts with relevant Technorati HTML coded tags. | A free, shared resource of blog tags which may serve as a filtered search of blog posts as well as potential promotion for one's blog. |
| Trailfire.com | Meaningfully annotate webpages, link to other annotated webpages. | Users collectively create meaningful 'trails' across websites by annotating pages. |

Table 3.0.

Examples of digital stigmergic cooperation detailing their procedures and outcomes

[69] For example see 'Hicks Lobby Group Delivers 65,000 Protest Letters', *ABC Online,* (online resource), <http://www.abc.net.au/news/newsitems/200704/s1890677.htm>, retrieved 7 April 2007.

There are many more such examples,[70] however the above should provide adequate illustration of the stigmergic cooperative approach:

1. Define a procedure designed to ensure an outcome which gains value with user contribution.
2. Develop an online interface and cultivate a community which supports the procedure.
3. Compliant participants execute procedures and benefit from collective efforts.

Notice that while the first and second steps may be collaboratively developed (and no doubt they often are), it is the final step which stigmergically generates the emergent outcome utilising convergent production—the contributions made by the participants are linear and procedural in nature and or non-collaborative in their creative content (e.g. reviews, lobbying emails, comments). This new form of large-scale collective activity is growing fast with great scope for development regarding its process and outcomes and no doubt the coming years will see an expansion of its application domains.

### 3.10.3. Digital Stigmergic Collaboration

Stigmergic collaboration in digital contexts, as shown in figure 3.11, takes on many of the features which characterise collaboration in more traditional contexts in its building upon coordination and cooperation. However, in the context of digital stigmergic collaboration, since the environment is responsible for the coordination of the emergence of collectively created shared representations, the digital environment requires the incorporation of specific attributes to do so. Therefore, the above 'recipe' for digital stigmergic cooperation can be adapted to that of digital stigmergic collaboration, typified by ventures such as Wikipedia:

1. Define an objective for which collective *creative* contribution is required in order to build value through user contribution.

[70] For an impressive and regularly updated index of such sites, see <http://www.go2web20.net/>, retrieved 5 April 2007.

2. Define a set of procedures designed to provide the capacity for participants to make such contributions.
3. Develop an online environment which caters for these contributions and enables the emergence of collectively created shared representations, and cultivate a community which supports the objectives.
4. Compliant participants make creative contributions and benefit from collective efforts.

These design requirements enable the stigmergic collaborative process to be extended into the digital domain, not just in its procedural and coordinative components, but also in its actual output. In other words, the collaborative output becomes a shared digital artefact which may span in scope and distribution the Internet's world-wide network. This capacity not only enables collaboration to transcend spatial and temporal borders and limitations, but it also presents a unique, humanity-first situation—that the subject of a collaborative endeavour may span the Earth, while also providing simultaneous co-locality to the locus of creative engagement to a near infinite number of collaborative participants.

Therefore, this transition of stigmergic collaboration into the virtual realm represents an immense shift in our collective creative capacity on a number of fronts, not the least of which being the potential for dramatic scaling in regard to project membership. When digital stigmergic collaborations achieve such scaling in participation, new effects take place which transform yet again the process and elements of the collaboration, giving rise to the new and quantifiably different set of dynamics and possibilities of mass collaboration. This overall evolution, from discursive collaboration, to stigmergic and digitally stigmergic collaboration, to that of mass collaboration, in respects represents transitions similar to those that take place when several trees growing together multiply to become a grove, and then eventually a forest. At each transition point, new dynamics are triggered by the wider environment and the trees' innate capacities giving rise to distinctly different ecologies and making possible the emergence of ever greater complexity and diversity among the collective interactions of the trees and their environment (Kelly 1994).

The following chapter provides an extensive framework for digital stigmergic collaboration, the enabler and midway transition point between traditional forms of

collaboration and mass collaboration—the most radical extension of collective creativity yet seen by humanity.

# 4. Stigmergic Collaboration

**Please help me with a quote!** - Posted by Eleonore (131.211.80.219) on 17:21:49 16/03/04

Dear all, I am to publish an article on online collaboration on writing. I saw this quote:

*How do I know what I think until I see what I say?*

It is supposed to be written by Forster, and I would like to use it. Can anybody help me with the complete reference (title, page, year, publisher, location)? I'd be ever so grateful!!!

---

**How do I know what I think** - Posted by Jon Scaife (81.152.20.87) on 22:30:35 10/06/04

This is quoted by Daniel Dennett in Consciousness Explained and by other authors. I've seen a reference to it as being in Howards End but so far I haven't found it. I don't think it appears in the screenplay of the Merchant-Ivory film of Howards End. If you find a definite source I'd be interested!

---

**quote** - Posted by Laura (board editor) on 16:45:11 11/06/04

It is definitely Forster's, but not from Howards End. It is used in an essay - I don't know which one I'm afraid - and the highest chance of finding it would be in Abinger Harvest or in Two Cheers for Democracy. If not in one of these, it could be in The Prince's Tale and Other Unpublished Writings. But the best candidate would be the former two. I will have a look at it myself as well. Best wishes, Laura

---

**How do I know...** - Posted by Judith Seaboyer (130.102.204.211) on 05:57:26 07/07/04

I've sought this site because I too was trying to track down this quote! My "source" says it's *Aspects of the Novel* but that's all. So we're still not there, but maybe closer!

---

**How do I know ... attribution** - Posted by Michael Harvey (204.193.6.90) on 21:42:01 11/10/04

I've been looking for the original source of the quote as well and have found it attributed to Forster, W.H. Auden, and Isak Dinesen; but I have never seen any credible indication of the actual work from which it comes.

---

**How can I tell what I think till I see what I say?** - Posted by Heiko (editor) on 18:59:25 14/05/05

As dicussed this is a misquote from *Aspects of the Novel*, the whole thing goes like this:

> "Another distinguished critic has agreed with Gide—that old lady in the anecdote who was accused by her niece of being illogical. For some time she could not be brought to understand what logic was, and when she grasped its true nature she was not so much angry as contemptuous. 'Logic! Good gracious! What rubbish!' she exclaimed. 'How can I tell what I think till I see what I say?' Her nieces, educated young women, thought that she was passée; she was really more up-to-date than they were." (EMF, *AN*, ed. Oliver Stallybrass (Harmondsworth: Penguin, 1976) 99)

---

**How can I tell what I think till I see what I say?** - Posted by John (86.137.33.222) on 01:00:32 04/08/06

Does this mean the quote comes originally from Gide, and Forster popularised it? That would explain how Graham Wallas manages to use the phrase in 'The art of thought' in 1926, a year before Aspects of the Novel was published.

---

**how can i tell...** - Posted by matt48170 (216.234.119.27) on :22:13:45 10/04/07

I thought this was from Alice in Wonderland.

—http://emforster.de/hypertext/template.php3?t=thread&thread=145

Stigmergic collaboration arises when two or more people utilise some form of material media for the encoding of their collective creative endeavour. The shared media provides a domain within which the contributor's annotations are subject to the standard forms of stigmergic interactions—sematectonic, marker-based, qualitative, quantitative, et cetera—while also being subject to any information processing capacities which the media may possess. This dynamic provides a potent combination of features that contribute to considerable extensions of collective creativity in the material world and radical expansions of distributed, collocated creative spaces in the digital. This chapter will expand upon the basic attributes which enable such expansions, followed by an exploration of the structures and elements which characterise digital stigmergic collaboration.

## 4.1. Extensions in Space, Time, Mind & Emergence

The extension of the potential for collaborative creation derives somewhat counter intuitively from the further separation of the participant's direct communicative exchange. The employment of some mediating, malleable media provide a site for the encoding of collaborative exchanges which simultaneously records the creative contributions of the individuals involved, while coordinating the shared representations of the collaborative output emerging between them. This extension of collaboration via the stigmergic encoding of media extends the participants' collaborative capabilities across four primary lines, space, time, mind and the process of emergence.

### 4.1.1. Space

The externalisation of co-created representations provides localisation in space for collaborative participants to manifest their work. This localisation enables stigmergic dynamics, expanded capacity for the materialisation of the shared representations, and a space for creation that may accommodate more contributors. Of course, 'local' can mean different things in different contexts, but regarding stigmergic collaboration, local refers to that which participants can engage with their 'sensors and actuators' (Parunak 2005:4)—in other words, their senses and physical faculties. Even in the context of digital stigmergy, while the effect of an annotation might be a change in a web server on the other side of the world, the 'actuation' occurs at one's fingertips. It is through this localisation of work that the capacities of resource restricted agents (collaborative participants) are limited from information and processing overload while enabling self-organisation and emergence through the media's coordination and processing of large numbers of comparatively small but contextually meaningful contributions.

The coordination of such contributions may take place at a wide variety of points throughout the collaborative process. More obviously, stigmergic collaboration supports the creation of an artefact which represents the collaborative output itself, e.g. a document, artwork, object, et cetera. However, stigmergy may also support the planning and coordinating of activities surrounding the creative activities through:

- providing memory aids (taking notes and writing memos)

- developing procedures (templates and frameworks for creative contribution)
- brainstorming (sketching out possible objectives and approaches)
- supporting organisational communication (email lists, message boards, memos et cetera.)

Primarily, the combination of reifying aspects of the procedural components as well as the collaborative output provides an increased space for the interaction of a greater number of participants than would have otherwise been possible.

### 4.1.2. Time

The formation of material representations of the collaborative output provides an increased level of permanence to the participants' contributions. This expands their influence and presence beyond short and long-term memory (on the levels of both the individual and collective) enabling the participants to extend their shared representations beyond the interactions of those immediately present. Material representation also provides added stigmergic impact through the potential for the creators to share their process and result with others, thereby influencing and coordinating a wider audience.

### 4.1.3. Mind

Material encoding of collaborative contributions enable the participants to 'see what they think', providing them with enhanced capacity to remember, review and reflect upon their shared contributions, both individually and collectively. According to Baars (1997), as laid out in his Global Workspace theory, by externalising our otherwise internalised representations, we enable the possibility for our consciousness to subject these representations to the workings of components of the brain which are otherwise less connected internally. In collaborative contexts, not only does this avail such representations to the wider capacities of the individual mind, but also to those of the other participants, thereby distributing the cognitive load as well as optimising for the specific skills and resources individual members may posses (i.e. leveraging the division of labour).

The engagement with media environments also opens up the possibility for taking advantage of any transformational dynamics the environment may possess or make

possible. Such dynamics may include calculating, correcting, reformatting, connecting, synthesising, visualising and distributing, thereby extending mind and cognition into the wider environment and opening it up to further stigmergic interactions from the environment itself.

### 4.1.4. Emergence

This combination of extended space, time and mind through stigmergic material engagement also contributes to perhaps the most important component of collaboration, the process of emergence. By providing local areas for individual encoding which interact on the higher level of the collective's shared cognition, stigmergy enables a synergistic exchange among the individual contributions, yielding a wider range of parts which may contribute to a correspondingly more complex whole. The experience of witnessing this emergence can be exciting and stimulating (as most with collaborative experience would likely attest) contributing positive feedback to the activity.

Therefore, through these combined extensions of space, time, mind and emergence, stigmergy functions to coordinate the externalised extensions of the participants' emergent, shared representation of the collaborative domain. This material coordination of collaborative efforts enables numerous forms of collective creation which would otherwise be beyond the scope of mental capacities unassisted by material coordination, such as coauthoring books, novels, plays and films, or the collective creation of sculptures, murals, dramatic performances, scientific and academic papers.

However, even greater potential is unleashed when stigmergic collaboration is further amplified with digital media situated upon network infrastructures. Space, time, mind and emergence take another great leap in expansion, extending the collaborative domain to that of the entire Earth, instantaneously connecting to millions of minds, the emergent result of which, positive or negative, has only just begun to be exploited.

## 4.2. Digital Stigmergic Collaboration

As discussed in the preceding chapter, the digitisation of stigmergic processes enhances its power and potential by augmenting the information processing capacities of the media

employed, as well as by extending the locus of encoding across time and space while simultaneously retaining its localised character. Although the dynamics inherent in traditional conceptions of stigmergy remain intact when transferred into human digital applications, we find several unique additions. Namely, the added complexity resulting from the annotations and modifications when utilising symbolic language and the way in which collections of artefacts function in digital contexts. The cognitive stigmergy framework (Ricci et. al. 2006) provides a well-developed outline for the addition of these features to the collaborative stigmergic domain.

Figure 4.0 and its subsequent expansions (figures 4.3 and 4.4) provide a map of the conceptual relationships that form the basis of the proposed framework for stigmergic collaboration.

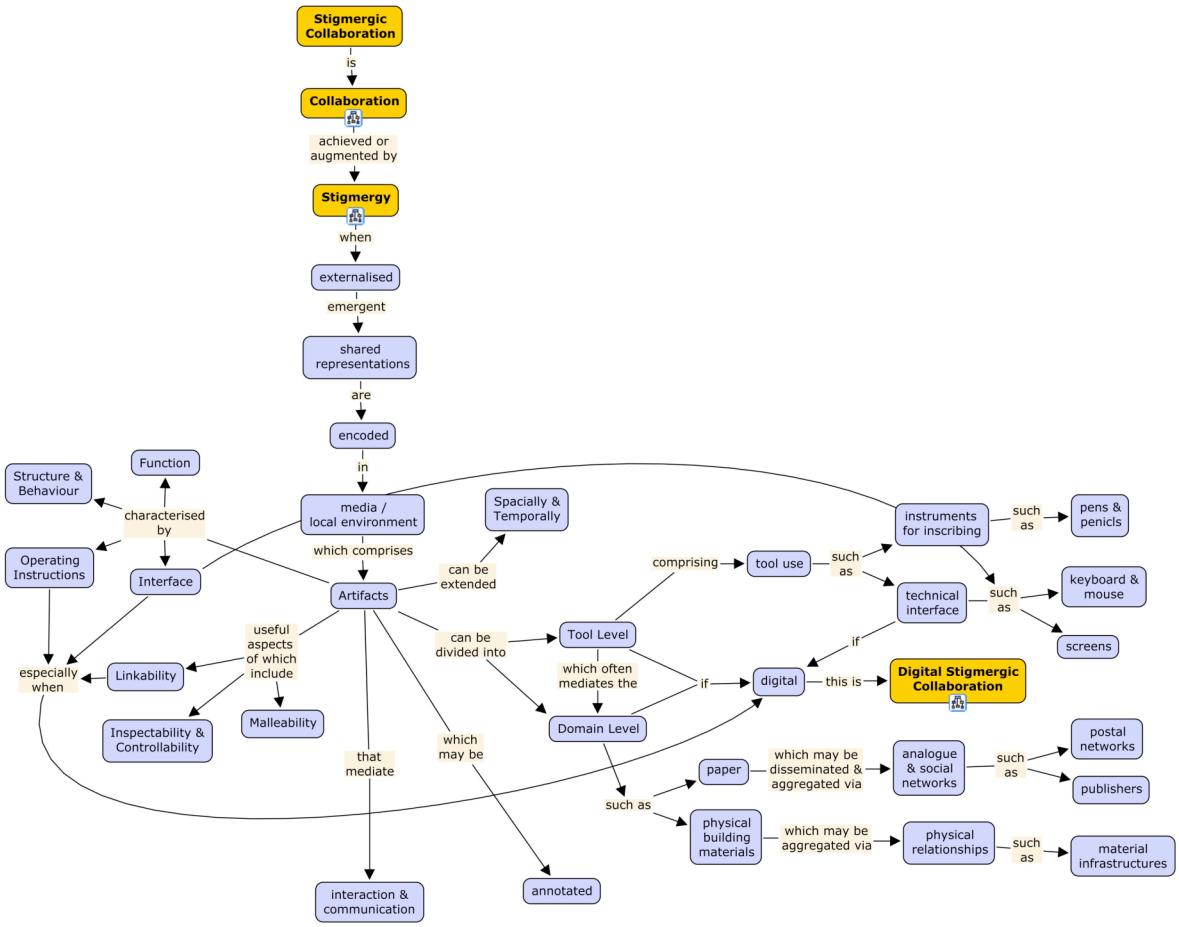


Figure 4.0.

Stigmergic collaboration, artefacts

### 4.2.1. Cognitive Stigmergy

In the exploration and research of cognition (especially in the realms of cognitive science and psychology) it is becoming increasingly clear 'that individuals are socially and culturally situated and that the environment needs to be considered in order to understand cognition' (Rambusch et. al. 2004:1). This realisation has become formalised in the studies of situated and distributed cognition (Rambusch et. al. 2004) with researchers becoming increasingly aware of and interested in the relationship between such theories and stigmergy. For instance, Susi and Ziemke's *Social Cognition, Artefacts, and Stigmergy: A Comparative Analysis of Theoretical Frameworks for the Understanding of Artefact-Mediated Collaborative Activity* (2001), concludes with the assertion that the conceptual framework of stigmergy offers a compelling minimal common ground in the comparison of activity theory and situated and distributed cognition. They claim that in accordance with Occam's Razor, 'before resorting to more complex phenomena, such as consciousness and free will' the simplest theory (stigmergy) should be examined first (2001:16). The result has been the convergence of theoretical frameworks and terms that help bridge the ostensibly distant fields of entomology, artificial intelligence and human cognition.

The most notable representation of this convergence, *Cognitive Stigmergy: A Framework Based on Agents and Artifacts* (Ricci et. al. 2006), was developed for analysing and engineering stigmergic systems where the agents involved operate on a cognitive level. Written from the perspective of researchers working in the field of multiagent systems (MAS)[71] and informed by distributed cognition and the comparative analysis of the cognitive frameworks listed above, this work is an attempt to extend the domain of stigmergy from that of social insects and multiagent computational systems into the realm of human and higher intelligence agents.

Through the provision of a number of useful theoretical components, the cognitive stigmergy framework provides a number of elements for the following framework for stigmergic collaboration.

[71] Multiagent systems is a branch of artificial intelligence and computer science that deals with programming the interactions and intelligence of many simple agents towards some goal or objective (Wooldridge 2002).

### 4.2.2. Artefacts

The notion and study of the 'artefact' spans a wide range of research contexts, including distributed cognition (Rambusch et. al. 2004), activity theory, situated cognition (Susi & Ziemke 2001), computer supported cooperative work, human computer interaction, cognitive science and multiagent systems (Ricci et. al. 2006). Rambusch et. al. (2004) reported in their work *Artefacts as Mediators of Distributed Social Cognition: A Case Study*, that artefacts functioned 'as mediators of distributed social cognition, i.e., they constitute or facilitate shared memory, coordination, communication, and sharing of information' (2004:5). Additionally, functionality may vary depending upon who is using them (their social context) and where they are used (their relationship to other artefacts) (2004:1). It has also been noted that while artefact mediation may appear to reduce agent interaction through increasing distance between agents, in many cases (such as stigmergic contexts) mediated interaction is indirect and thus the artefact takes on a social nature (Susi & Ziemke 2001).

While the conception of the artefact varies somewhat from discipline to discipline depending upon how the concept is being employed, in regard to the present application the following description provided by Ricci et. al. (2006) will serve as a generalised definition.

> Artifacts are first-class entities representing the environment that mediates agent interaction and enables emergent coordination: as such, they encapsulate and enact the stigmergic mechanisms and the shared knowledge upon which emergent coordination processes are based. (2006:1)

In this view, the notion of the artefact incorporates material and virtual media, as well as the tools that comprise the participants' environment that can be selected and used for any purpose, including those collaborative (Ricci et. al. 2006:2). Ricci et. al. (2006) further identify a number of more fine-grained properties and functions of the digital artefact:

- **Function**—the intended (or adopted) functionalities the artefact provides;
- **Structure and behaviour**—in regard to the internal and or material aspects of the artefact and how it is implemented in order to provide it function;

- **Usage interface**—a set of operations that participants can invoke to use the artefact and exploit its functionality;
- **Operating instructions**—a description of how to use the artefact to achieve its functionality.

In addition to explicit operating instructions, many instructions are largely implicit, such as how to use a mouse and computer interface, and may even be improvised, contributing to new and unintended functionality.

Additional aspects listed by Ricci et. al. (which also serve to define the domain which distinguishes artefacts from that of the agent) are:

- **Inspectability and controllability**—the capability of observing and controlling artefact structure, state and behaviour.
- **Malleability**—the capability of changing and adapting artefact function to new requirements or unpredictable events occurring in the wider environment.
- **Linkability**—the capability of linking together at runtime distinct artefacts as a form of composition, in order to scale up the complexity of the function the artefacts are to provide. Through their modularity, this capacity also supports the dynamic reuse of artefacts.

The distinction between artefacts (the material realm) and agency (wilful activity) entails a fuzzy line as per actor-network theory (Latour 2005; Law 1992), however there are useful distinctions. While Ricci et. al. claim somewhat prescriptively that '[d]ifferently from agents, artefacts are not meant to be autonomous or exhibit a pro-active behaviour, neither to have social capabilities' (2006:8), it is worth noting that the above features, inspectability, malleability and linkability are not typically those associated with agency. On this topic of distinguishing agency, Parunak makes the point that in contrast to the environment, agents tend to be structured monolithically with a well-defined boundary, and that the internal state of the agent is hidden, while that of the environment 'is accessible to an agent with appropriate sensors' (2005:3).

Ricci et. al. also reinforce the point made in the previous chapter that artefacts in the digital domain may be distributed across a topology which enables a single artefact to be extended

across multiple sites of work, thereby bridging spatial, temporal and conceptual distances (e.g. a single Wikipedia article simultaneously accessible by multiple individuals). A final point about the nature of artefacts in stigmergic systems is that they tend to act as points for feedback generation, both positive and negative. In fact, Ricci et. al. recognised this capacity as promoting 'awareness' of the work and practices of other agents which may be effective in driving or improving their own activities (2006:10). However, the notion of feedback (common to all cognitive systems) seems to better describe the point they are trying to make and underscores the role which artefacts play in stimulating collaborative contribution.

### 4.2.3. Tool & Domain Levels

Another feature of the artefact as identified by the cognitive stigmergy framework is that in (and potentially outside of) digital contexts, artefacts may be generally divided into two categories:

- **Domain level**—consisting of artifacts representing the target of the agent's work, or an objectification of such a target.
- **Tool level**—consisting of artifacts representing the tools which facilitate agents in doing their work.
    - (Ricci et. al. 2006:8)

Examples of this division include pencil versus paper in the analogue realm, while in that of the digital, this conception of a domain and tool level provides a means for further differentiating aspects of media as a stigmergic subset of the wider environment as posed in the preceding chapter. For instance, the read versus edit views when using a wiki such as Wikipedia's (see figures 4.1 and 4.2), or Drawball.com's canvas versus its ink and mouse-pointer-as-paintbrush (see figure 3.7). Moreover, this distinction provides a useful means of conceptualising digital collaborative environments regarding the objective (domain level) and the functionality required to achieve this objective (tool level). Such distinctions are also helpful in the analysis of existing environments for the purposes of their further and ongoing development.

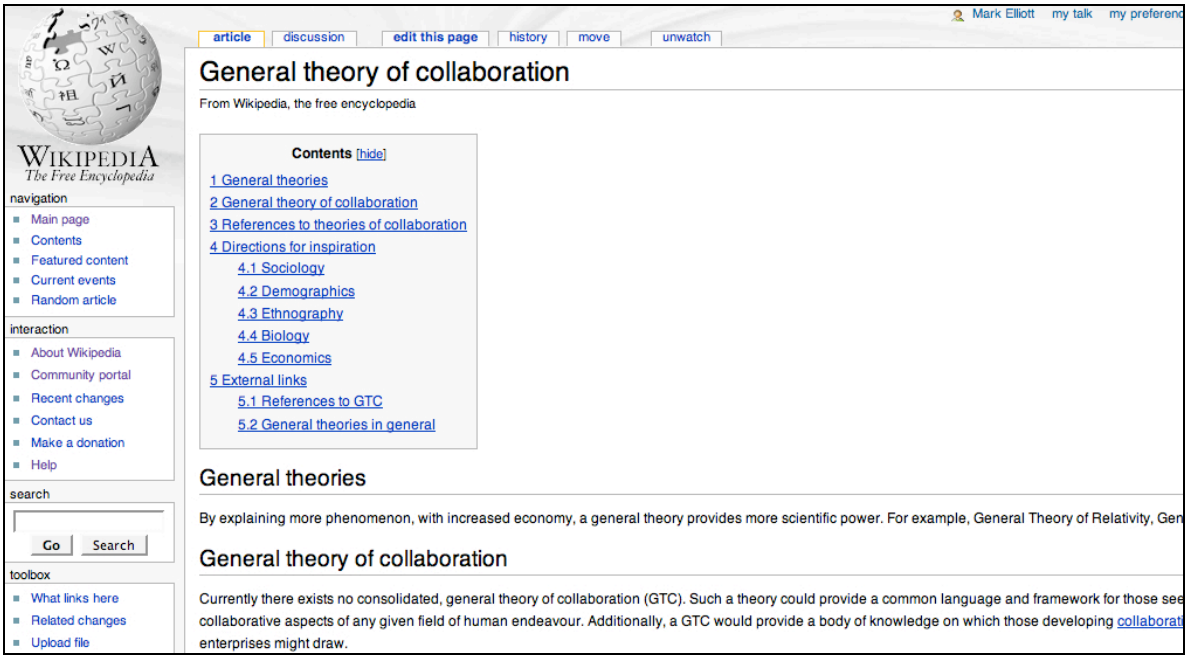


Figure 4.1.

Wikipedia's domain level (read view)

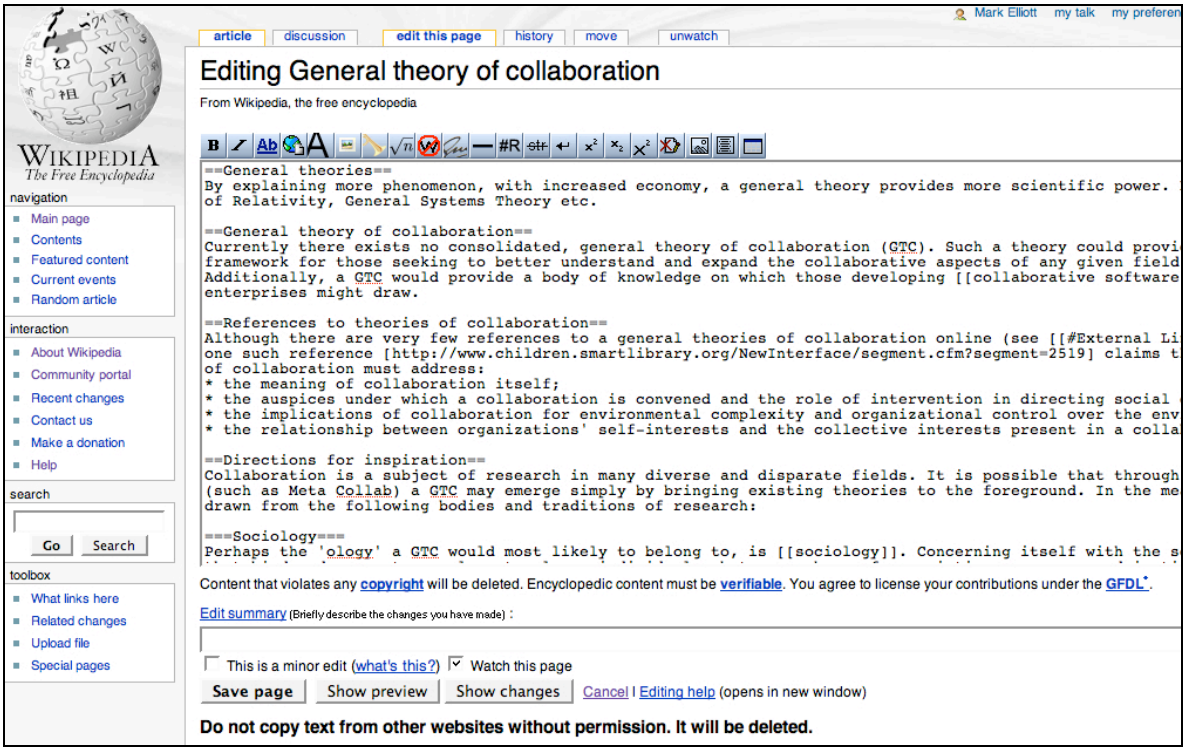


Figure 4.2.

Wikipedia's tool level (edit view)

### 4.2.4. Annotations

As discussed in the previous chapter, within stigmergic systems, the changes agents make to their environment are understood as signs that provide cues for various forms of activity. However, the signs created by human agents typically possess rich symbolic value embodying some type of information adhering to a formal or informal semantics, which in turn refers to some ontology (Ricci et. al. 2006:9). The cognitive stigmergy framework designates this type of sign as an 'annotation'. This delineation of the sign and the symbolic annotation is valuable as it provides for the further distinguishing of types of annotations specific to cognitive agents. While Ricci et. al. (2006:10) proposed the following four separate forms of annotation, it is suggested that they form two classes, 'formation' and 'properties':

**Formation**—the means in which the annotation was created.

- Intentional—generated as the direct result of agent action.
- Automatic—generated as the result of the information processing capacities on the tool or domain level.

**Properties**—aspects of an annotation which convey meaning.

- Form—the annotation's implicit shape or force (such as the use of capitals in text as emphasis).
- Content—the annotation's explicit symbolic content (e.g. the referent of a word).[72]

These classes form an orthogonal relationship, providing a means of analysing individual annotations in applied contexts. Table 4.0 illustrates this relationship and provides several examples:

[72] In Riccci et. al.'s conception, these two classes were termed 'explicit' (form) and 'implicit' (content).

| | | FORMATION | |
|---|---|---|---|
| | | **Intentional** | **Automatic** |
| **PROPERTIES** | **Content** | The semantic content of a textual contribution made to a Wikipedia article. | Wikipedia's recent changes feature (see figure 2.8) displaying a positive or negative value depending upon how many characters were added or deleted in a given revision. |
| | **Form** | Bold, italic, punctuation, et cetera used for emphasis in a textual contribution. | The colour coding of the above values green for additions and red for deletions. |

Table 4.0.

Variations and features of symbolic annotations in cognitive stigmergy

The combination of the above classes with those outlined in the previous chapter regarding the gestalt focus and sign types of stigmergic interaction provide considerable detail for the analysis of annotations in cognitive stigmergic systems. This increased level of scrutiny also provides designers with more conceptual power in designing collaborative environments for stigmergic interactivity. Figure 4.3 shows the stigmergic collaboration concept map expanded to include the processes and elements involved in collaboratively annotating artefacts.

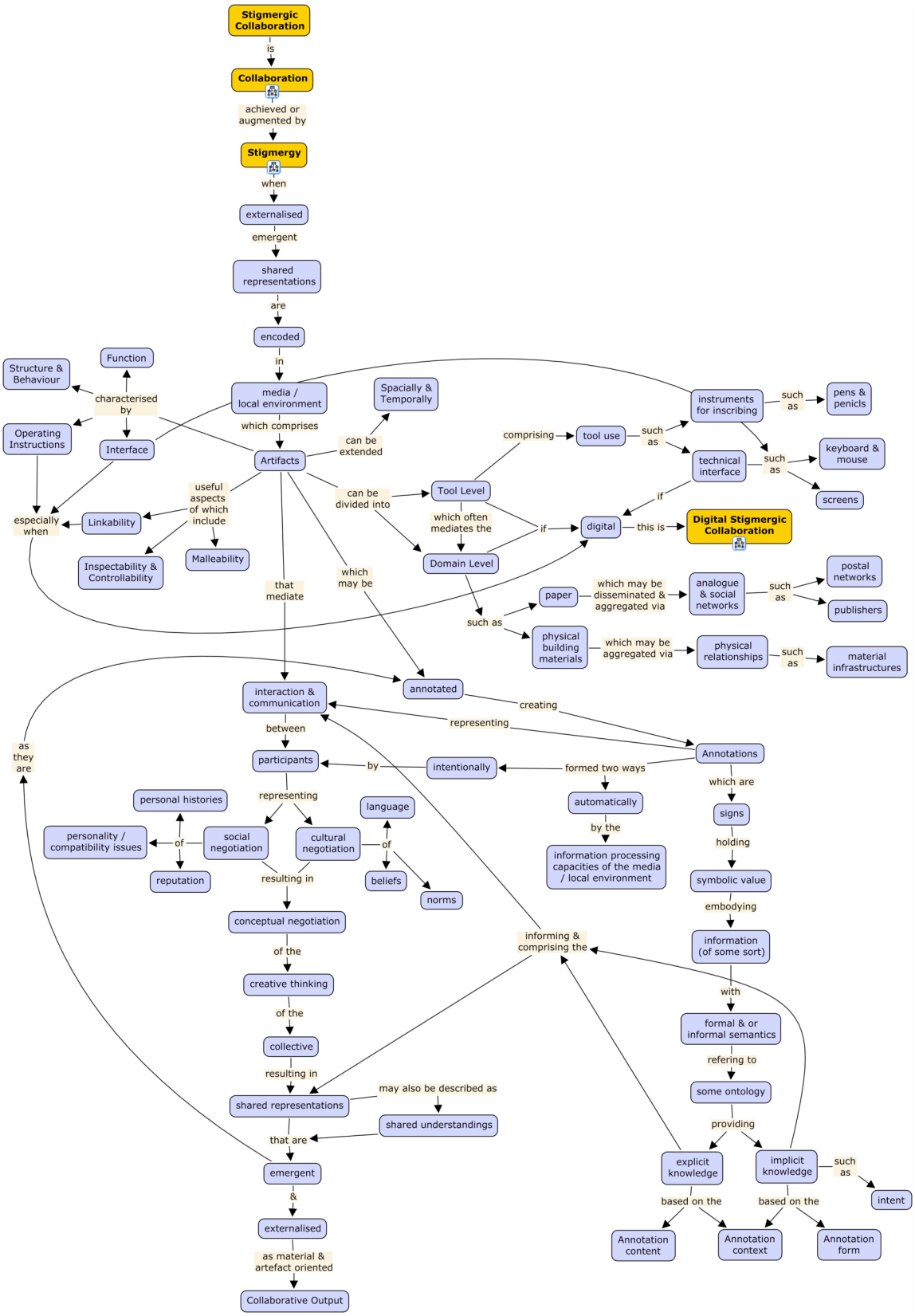


Figure 4.3.

Stigmergic collaboration, annotating artefacts

### 4.2.5. The Social Workspace

A central observation made in the cognitive stigmergy theory, is that through the process of stigmergic activity, digital artefacts and their corresponding annotations tend to build up, forming a field of work or a social 'workspace' (Ricci et. al. 2006:2,5).[73] The artefacts comprising a digital workspace such as a collaborative environment mediate interaction, encapsulate coordinative functions (2006:5) and may be linked and or shared across workspaces. Workspaces themselves may overlap, sharing both participants and artefacts and can be nested recursively. The workspace concept therefore provides a means to rigorously describe and define the characteristics of a shared interactive topology (2006:9).[74] Figure 4.4 shows figure 4.3's 'Digital Stigmergic Collaboration' node expanded and focuses on the characteristics and features of the digital stigmergic collaborative workspace.

[73] This theory of a social workspace comprised of digital artefacts also bears strong connections with the Global Workspace theory (Baars 1997) previously discussed. It may be that the manifestation of such digital workspaces is a naturally arising structure resulting from our cognitive ability's needs to externalise our internal representations.

[74] While the workspace as conceived in the cognitive stigmergy framework is a digital one, there are grounds to extend this idea into the realm of the analogue—think of the artist's studio, or even one's desk, both places comprise artefacts and tools which under the right conditions can support multiple participants in some collaborative endeavour.

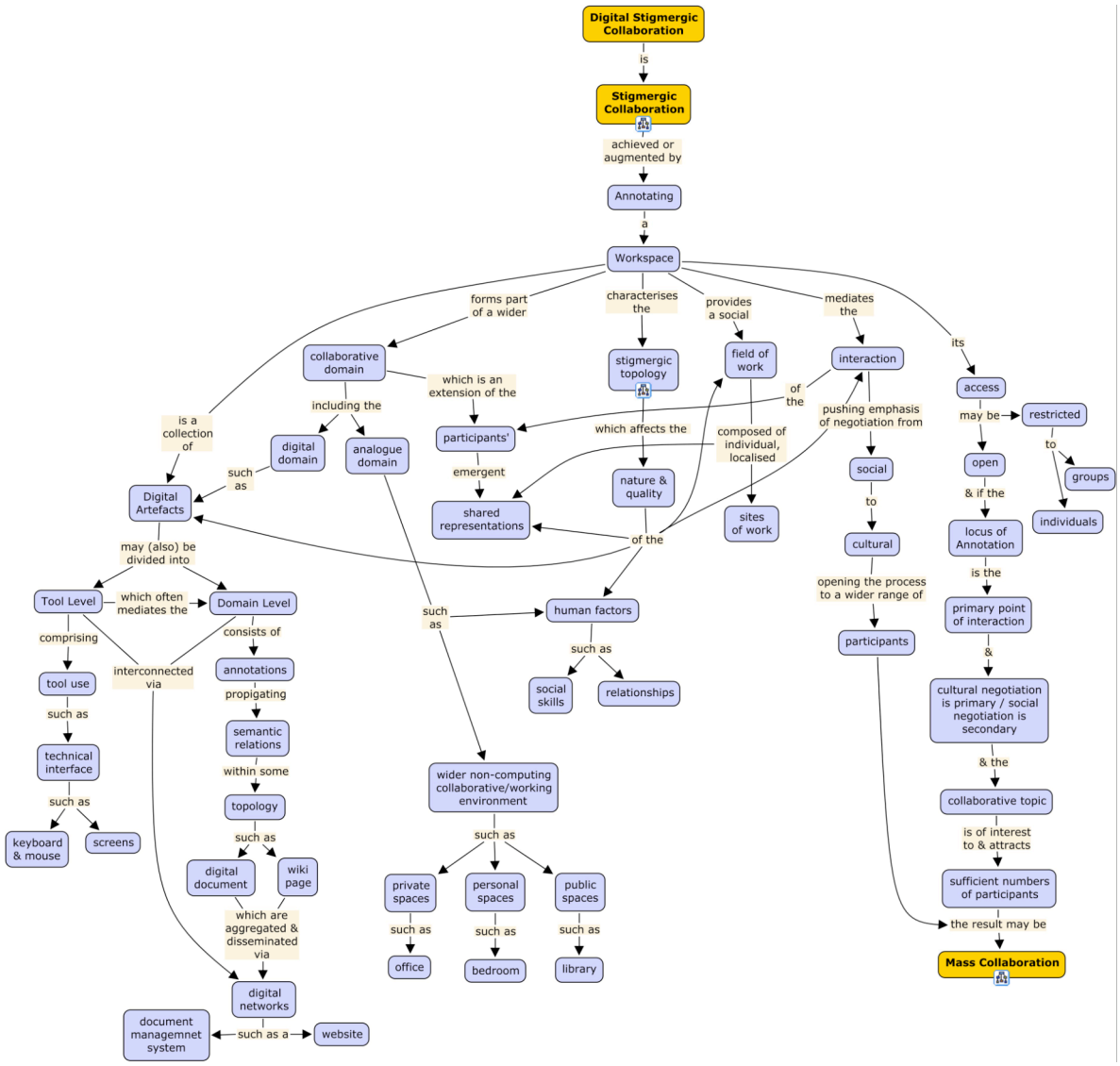


Figure 4.4.

Digital stigmergic collaboration, workspace

It is important to remember that while the digital workspace comprises digital artefacts and mediated interaction, this activity is subsumed within a larger analogue workspace—one of interfaces, non-virtual artefacts, spaces, people and physical interactions. Exploring this domain represents an area of research which is beyond the scope of the present work, but likely to produce insight into digital stigmergic collaboration through the ethnographic examination of its real world context. In fact, several works have come very close to this type of investigation, *Designing Collaborative Systems: A Practical Guide to Ethnography* (Crabtree 2003) and especially Hutchins' exploration of distributed cognition in *Cognition in the Wild* (1995a). This work provides a detailed analysis of groups and individuals

engaging with their surrounding artefacts and environment while involved in maritime navigation. Extending and applying the insights and methods developed by Hutchins and Crabtree (and of distributed cognition and ethnography in general) to the realm of stigmergic collaboration would no doubt provide a valuable source of insight in helping expand our understanding of the wider context of the digital workspace in application.

A final and important point to be made about the general characteristics of the stigmergic workspace is that while a fundamental function they provide is to coordinate the activities of multiple participants, like any stigmergic media, they may also coordinate the activities of individuals working alone, or, without direct reference to one another (Ricci et. al. 2006:7). This is due to the optimisation of localisation through providing a workspace were one may work as if alone by providing a site of work unmediated by social negotiation. The creative process is therefore streamlined while still enabling participants to engage with and gain from the input of other contributors through the workspaces' wider context and features if they wish. In following sections this will serve as a vital feature helping to explain how digital stigmergic collaboration enables the system to scale, allowing multitudes of participants to take part in a single mass collaborative project without being overwhelmed by having to socially interact and negotiate their contributions with thousands of participants.

### 4.4.6. Technologies of the Stigmergic Collaborative Workspace

A detailed account of specific technologies in use is perhaps of less importance than grasping the fundamentals of what these technologies provide, as the rate of emergence for such technology is currently very rapid and thus identified benchmarks are likely to be replaced in a very short time. Therefore, the core functionalities some technology must provide in order to enable stigmergic collaborative functionality is,

> the provision of a site of work accessible to a number of participants that enables one to work as if alone via the ability to add, edit and delete annotations.

Another way of saying this is that the technology must provide for individual contributions to a larger unified work consisting of dynamic content. It must be stressed that this entails

not just additive content contribution (however this capacity might satisfy the needs for many stigmergic *cooperative* ventures), but the ability to dynamically incorporate additions, edits and deletions into preexisting material. This functionality is necessary in order to reflect the ongoing emergence of the shared representations involved in any collaborative pursuit (digital or non), a process which in effect mirrors that of the participant's emerging internalised shared representations of the process and outcome.

A forerunner of this form of technology is of course the wiki[75] with its capacity to act as a 'blank page' upon which unlimited participants may contribute new content while constantly updating existing material. However, with increasing software engineering knowledge and the technological infrastructure which supports it, a wide range of other examples are emerging which exploit this same parameter of functionality but within a number of other media subsets. The following section details some of these developments with examples while avoiding technical specifics in order to emphasise the nature of the stigmergic collaborative workspace across differing forms of media.

### 4.4.7. Examples of Stigmergic Collaborative Workspaces

Due to technical limitations, the formative years of digital computing restricted annotations (collaborative or otherwise) to that of the alphanumerical, ASCII type (text, numbers, code, et cetera). Consequently, anything beyond this strained the capacities of not only the means of annotation (e.g. keyboards), but also its representation (e.g. screens). The Open Source Software movement provides an early example of digital stigmergic collaboration in the 'ASCII medium' utilising code repositories as a workspace. One such workspace, SourceForge.net, provides many examples of code-based stigmergic collaborations with its 146,583 projects consisting of some 1,566,219 registered users as of April 22nd, 2007.[76] However, as computing and interface technology expands so does the scope for engaging more variety of media and more senses through stigmergic collaboration. As already highlighted, online ventures such as Drawball.com are exploring the stigmergic capacity exploited everyday on many city streets—graffiti—through the medium of drawn imagery

[75] 'A wiki is a website that allows visitors to add, remove, edit and change content', see the Wikipedia article, 'Wiki', <http://en.wikipedia.org/wiki/Wiki>, retrieved 13 April 2007.
[76] Source, SourceForge homepage, <http://sourceforge.net/> retrieved 22 April 2007.

(see figures 2.4-2.7). However there is a wide and growing range of potential forms of media for stigmergic collaboration to explore.

Several new ventures are making progress into online stigmergic collaboration in the musical realm. Of special interest to me as a composer is online dynamic collaborative score editing—which, to my knowledge has not yet emerged. However there is Wikifonia.org which represents a transition point from emailing score based files between participants to that of an online repository. Wikifonia's architecture allows for an online representation of an uploaded score and the ability for others to download, contribute to the score and then re-upload it. While this is a good example of stigmergic collaboration, the intervening steps required to make an annotation significantly restricts interactivity, especially in light of the fluidity of sites like Wikipedia.org. Kompoz.com supports somewhat more fine grain musical collaboration via providing an online track mixer—each participant is able to upload an individual part of an overall musical fabric (a guitar part, a vocal track, percussion, et cetera). Regarding Wikifonia's collaborative score editing, this would be the equivalent of being able to contribute an individual instrumental staff to a larger score (which would enable considerably more dynamism). However, Kompoz does not focus on score editing functionality, rather the medium for contribution is various formats of audio file (WAV (Waveform Audio Format), MP3 (MPEG-1 Audio Layer 3) and WMA (Windows Media Audio)).

Jumpcut.com provides an increased level of interaction and dynamism by enabling users to edit video online after its upload. This enables participants to collaborate on a film by uploading and 'remixing' portions, thereby providing most functionality of a simple video editor online (see figure 4.5). The addition of such online editing to Kompoz's functionality (editing individual tracks within the site once added) would enable yet another level of interaction—especially if more than one person could synchronously edit a track, seeing the changes another was making in real time.

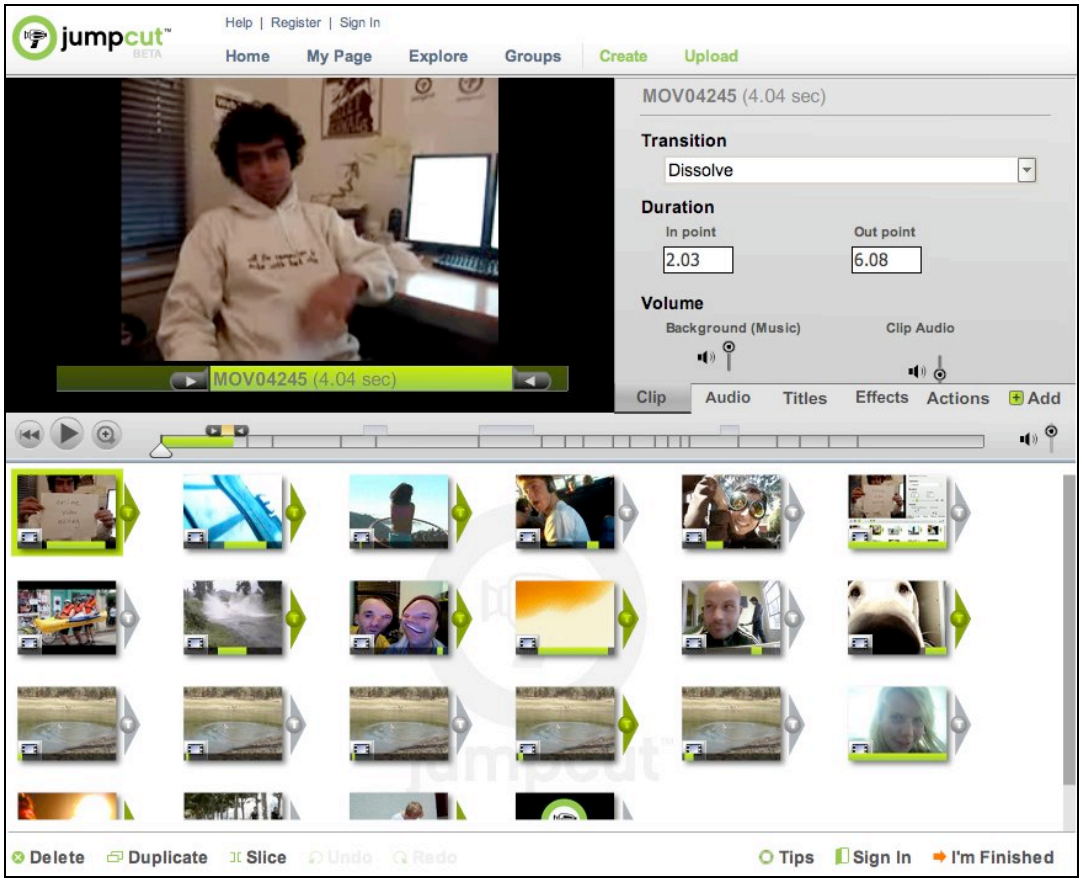


Figure 4.5.

Screen shot of Jumpcut.com's 'remix' online video editor demo

An excellent example of a stigmergic collaborative workspace that caters for a range of media and forms of annotation is Thinkature.com. Thinkature provides a rich environment for collaborative concept and mind mapping, including text and voice chat, while being enabled by AJAX-like programming (the page dynamically changes content without a full page reload). Figure 4.6 illustrates a number of its features.

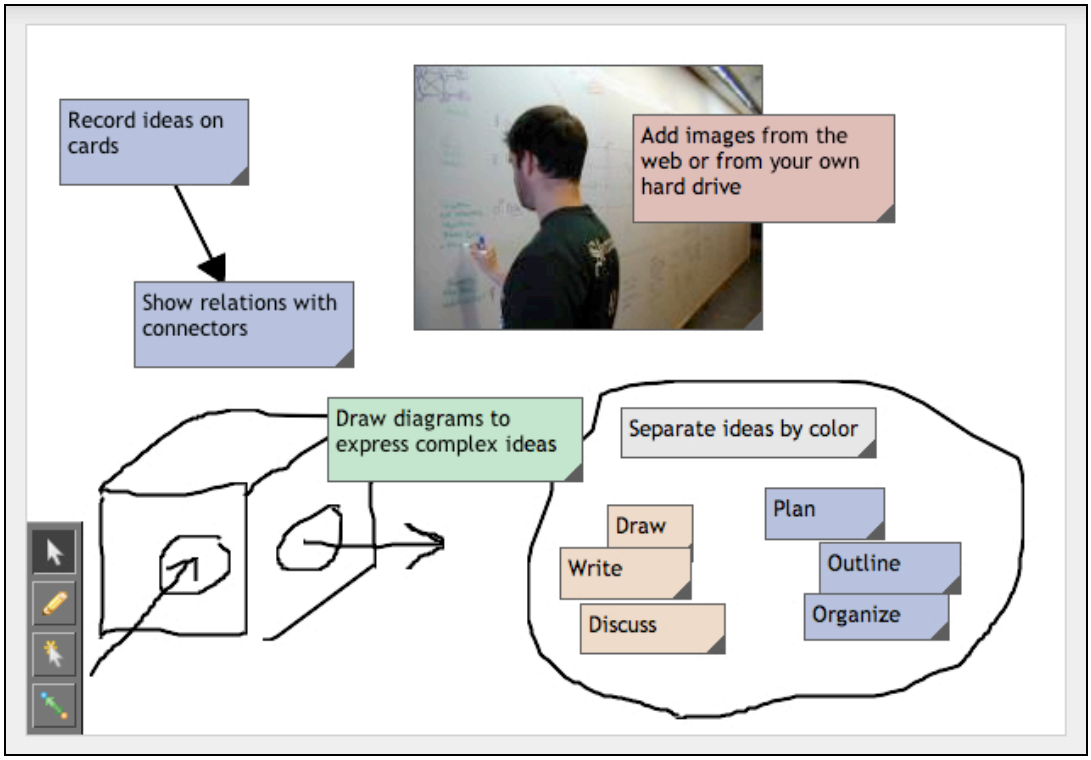


Figure 4.6.

Screen shot of Thinkature.com's homepage demo

Another example of collaborative concept mapping is the IHMC CmapTools[77] server network. CmapTools is open source concept mapping software (the same software used to create the maps for this dissertation) with the additional functionality of allowing for maps to be collaboratively accessed via the Internet. Once accessed (if permissions are granted by the map owner) additional collaborators can add/edit/delete the contents of a map or link to another map in a similar way that an editor might in wiki collaboration, linking from page to page. The Cmap software also allows for synchronous collaboration, functionality which goes beyond the current asynchronous editing of wikis, providing the participant with a more connected sense of their collaborator's engagement through increased real time feedback.

It must be said however, that the value of synchronous, indirect stigmergic collaboration (in any medium) has yet to be significantly evaluated (such functionality is currently nascent) as it might be that such features will change the dynamics of interaction, returning them to a more traditional collaborative process by stimulating direct social engagement between

[77] See the 'CmapServers' node at <http://cmap.ihmc.us/> retrieved 11 April 2007.

contributors. In my opinion it is more likely that the ability to edit synchronously in such contexts will only produce more novel collaborative dynamics, as the engagement is still indirect, thereby ensuring the site of work remains is the primary level of engagement.

The nature of the above examples of digital stigmergic collaboration therefore (to date) hold true with the notion of providing a site of work accessible to a number of participants that enables the individual to work creatively as if alone via the ability to add, edit and delete annotations. In essence, this relatively simple functionality represents the provisions for full stigmergic engagement with an environment while restricting modifications to a localised region in order that the agent's capacities are not overwhelmed.

The ability for stigmergic collaboration to be extended into online environments can be seen as an innate capacity which collaboration possesses, allowing it to be augmented through its capacity for stigmergic interaction. This capacity is evident even in small face-to-face settings through the ability to incorporate material extensions of the collectively created, emergent shared representations. One might say that the seeds for digital stigmergic collaboration and thus mass collaboration have lay dormant, patiently awaiting the arrival of the technological and social innovations required to bring them about.

In any case, the above provisions for digital stigmergic collaboration in combination with open access on a number of fronts, enables a second level of powerful and fundamental stigmergic effects to take place which are the distinguishing features of mass collaboration, namely, the unlimited scaling of collaborative membership and project size.

# 5. Mass Collaboration

> The power of intelligence stems from our vast diversity,
> not from any single, perfect principle.
>
> —*Marvin Minsky*

The emergence of digital stigmergic collaboration has led to one of the most significant evolutions in collective activity that humanity has yet witnessed—the expansion of collaborative membership beyond the marginal limits of approximately 25 participants (Lipnack & Stamps 2000) towards the potentially unlimited contributor base of mass collaboration. This has the effect of augmenting in scale and scope the process and outcomes of creativity, a human capacity which defines our ingenuity, comprises much of our culture, and opens the door to the future while addressing the challenges we are confronted with as we cross its threshold.

The term mass collaboration is being increasingly used to describe this expansion of collective creativity and its associated projects, with a number of popular online magazines helping fuel its uptake and currency from 2005. *Business Week's* online magazine published the article, *The Power Of Us—Mass Collaboration on the Internet is Shaking Up Business* (June 2005), which looked at Wikipedia, Second Life and open source software among other Web 2.0 oriented phenomenon, proclaiming that '[u]ltimately, all this could point the way to a fundamental change in the way people work together.'[78] In December 2005, another online magazine, *Red Orbit,* published the article 'Web Denizens Contribute to Do-It-Yourself "Wikimania"', a profile on wikis and their uptake in a wide range of applications. This time the term mass collaboration was used in a quote by Jimmy Wales, Wikipedia co-founder, 'It's a mass collaboration

[78] See, The Power Of Us—Mass collaboration on the Internet is shaking up business. *Business Week,* (online magazine), <http://www.businessweek.com/magazine/content/05_25/b3938601.htm>, retrieved 13 April 2007.

to build all kinds of things... It's becoming a new model for doing things on the Internet.'[79]

With the recent publication of Tapscott and William's *Wikinomics: How Mass Collaboration Changes Everything* (2006), use of the term has exploded online with Google showing about 234,000 returns as of April 2007. As previously mentioned, Tapscott and William's analysis is largely geared towards the commercial application of mass collaboration (as intimated by the reference to economics in the title) and less on underlying mechanisms and dynamics. However they do canvas a wide range of issues relating to the phenomenon from this perspective. In arguing for more open, cooperative and collaborative approaches to online business methods, models and beliefs (i.e. against exclusive digital rights management et cetera), they make a strong case for the emergence of mass collaboration as a 'new business paradigm', one which embraces the notion of open access (2006:276).

That the mass collaborative process has yielded the likes of *Wikipedia* and the Apache HTTP Server has for many brought into question the traditional bedrocks of Western civilisation at the end of the 20th century: ownership and authorship (Forte & Bruckman 2005; Stewart & Gosain 2006). The corporation as the most efficient means of wealth creation and the accredited expert as the only individual endowed with the authority to generate quality knowledge are important assumptions for our contemporary culture to engage. However, the analysis presented here is perhaps on a level below that of the implications of distributed ownership and authorship in mass collaborative contexts. Rather, the present investigation is concerned more with the distributed coordinative processes which *enable* this multiagent composition of authorship and ownership and as a result, will focus less on arguments as to its validity as an alternative and in some respects counter-institutional mode of production.

Understanding *how* stigmergy, in combination with collaborative activity and the Internet, has enabled mass collaboration to shatter the glass ceiling of collaborative membership (and thus authorship and ownership) is crucial for the further development of this activity and our understanding of collective production in the 21st century. The

[79] See, Web Denizens Contribute to Do-It-Yourself "Wikimania". *Red Orbit,* (online magazine), <http://www.redorbit.com/news/technology/320436/web_denizens_contribute_to_doityourself_wikimania/>, retrieved 13 April 2007.

potentials that lie in harnessing mass collaboration in order to provide solutions to specific problems requiring the creative capacity of a great many people are vast and pressing, such as developing solutions to climate change, alternative energy and sustainability, tracking and combating potential pandemics, leveraging micro finance and volunteerism in order to address poverty, eliciting large-scale cultural shifts through the creation and provision of free information and software resources, et cetera. This chapter will explore a range of the core factors which govern the transition from stigmergic collaboration, to that of mass collaboration in order to illuminate its underlying mechanisms as well as to provide design considerations for the further engineering and analysis of such ventures. Figure 5.0 charts out this conceptual terrain, outlining their relationships and processes.

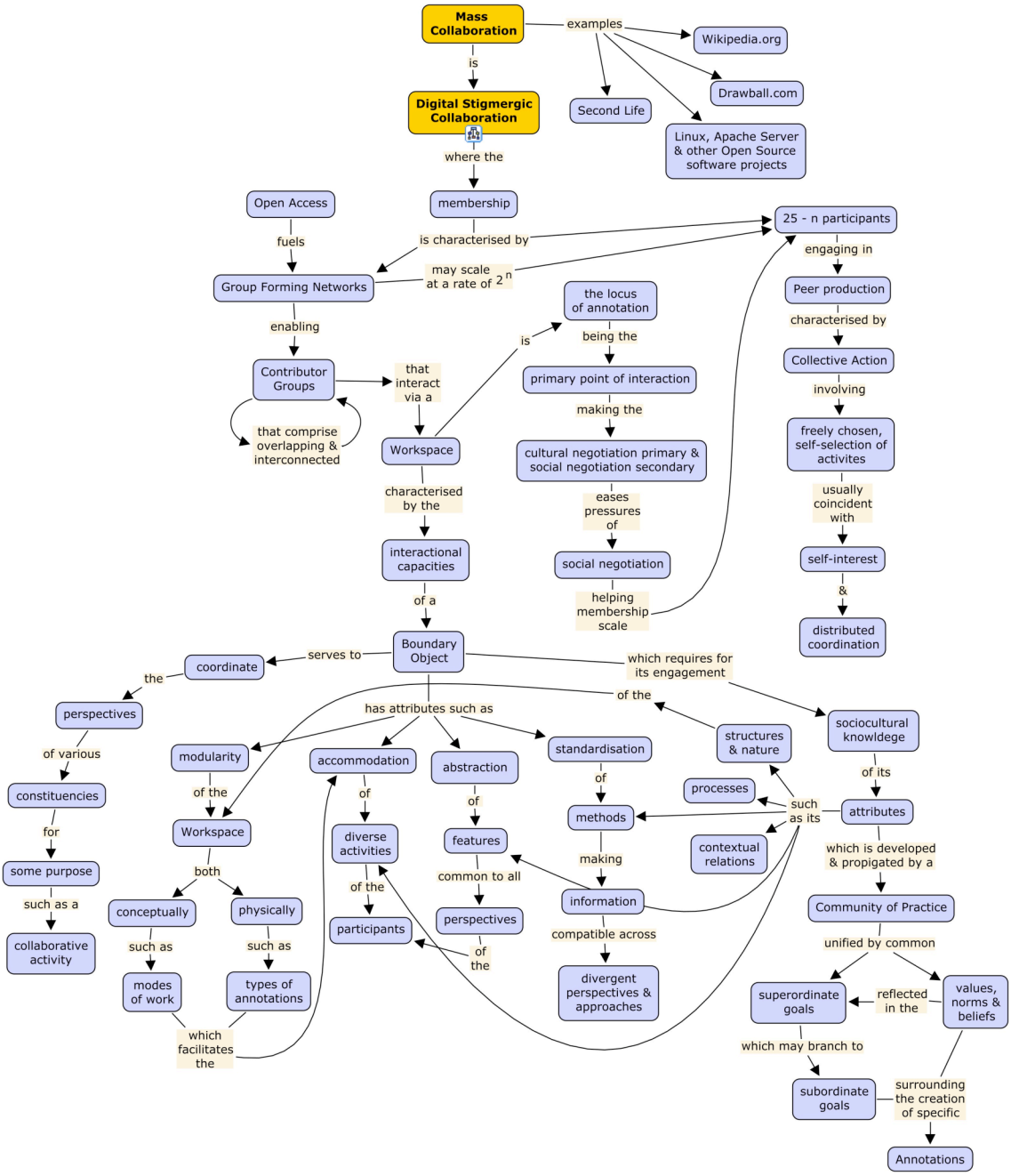


Figure 5.0.

Mass collaboration, elements and process of

## 5.1. Enabling Mass Collaboration

### 5.1.1. The Development of Open Access

In its original conception, ‘open access’ refers to the provision of free and unrestricted access to scientific and scholarly research texts as formalised by the Budapest Open

Access Initiative (BOAI) in 2002.[80] The Budapest Open Access Initiative's definition also stipulates that authors should retain copyright in order to maintain control and integrity over their works and that this is the only role copyright should play. This movement was instigated in direct response to the realisations that free access to knowledge could only bootstrap more knowledge, and that for the first time, the Internet provided such a means for more or less free distribution.

Heylighen (2007b) also uses the term to designate a state of information associated with mass collaborative projects such as Wikipedia and open source software projects. He stipulates that open access is non-proprietary, part of a 'creative commons' and free to access, use, and in many cases modify, and which consists purely of information enabling unlimited duplication. Similarly, in the present context, the term takes on a somewhat more radical character as it refers to a considerably wider range of access than in the original BOAI. This wider range plays a crucial role in enabling digital stigmergic collaboration to transition into that of mass collaboration through mechanisms that facilitate open access along three primary lines, the technological, the sociocultural, and the legal.

#### 5.1.1.1. Technological

The technological enablers for mass collaborative activity are primarily those of digital stigmergic collaboration (the provision for individualistic contribution to a shared common pool of dynamic content) but with a few additional features. The most common of such features is software infrastructures that provide open access to participation, in that anyone who happens to find them self at the workspace may participate. This stands in contrast to the BOAI definition of open access, in that the membership of those writing the scientific and academic articles are vetted (typically) by journal publishers and the peer review process, not to mention that once the articles are published, copyright is retained in order to prevent someone from modifying an article's content without permission. However, making such an unvetted modification is of course precisely the point of mass collaboration.

[80] See 'Budapest Open Access Initiative', (online resource), <http://www.soros.org/openaccess/> retrieved 30 April 2007.

It is possible to imagine mass collaboration taking place where the membership is restricted (i.e. open access to participation is not granted), however there would need to be a pool of participants to draw on of a considerably large size. A large pool is required in order to provide for enough active contributors (as opposed to 'lurkers' or 'free riders') with a wide enough range of perspectives, interests, skills, time and motivation to contribute to the various aspects of the collaboration.

Additional technological aspects that often (but not always) accompany mass collaboration are the features and functionality of social software. Specifically, identity representation in relation to contributions and general activity helps support the moderation of activity. For instance, new and especially anonymous users may be more heavily scrutinized by the community for quality of their contributions. Explicit and implicit reputation systems may also play a part in mass collaborative projects, allowing the tracking of a participant's contribution quality and allowing the community or the technological infrastructure to gradually increase or decrease their rights and responsibilities in accordance with this quality. In the case of Wikipedia, reputation is tracked implicitly by the community itself using the system's capacity for identity representation along with a number of permission levels, 'steward', 'bureaucrat' and 'administrator' which are granted by community consensus and or regular elections.[81]

It is also worth mentioning that the technology which has underpinned Wikipedia is that of the open source variety. Ward Cunningham, who created the very first wiki, 'WikiWikiWeb' in 1994[82] soon wrote another wiki, 'WikiWikiGoesPublic', which hosted its own source code. This act of providing open access to the software's source code effectively spawned the hundreds of variety and huge success the wiki enjoys today, thereby leading directly to the technological functionality which enables Wikipedia.[83] It is also this very same open source technological capacity that enables Wikipedia's software, Mediawiki, to continue to evolve alongside the project's interests and requirements.

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[81] See Wikipedia article, 'Wikipedia', (online resource), <http://en.wikipedia.org/w/index.php?title=Wikipedia&oldid=122333781> retrieved 13 April 2007. See also 'Requests for Adminship,' *Wikipedia* <http://en.wikipedia.org/wiki/Wikipedia:Requests_for_adminship> retrieved 13 April 2007.
[82] See 'WikiWikiWeb', (online resource), <http://c2.com/cgi/wiki> retrieved 13 April 2007.
[83] Source, 'Wiki History', (online resource), <http://c2.com/cgi/wiki?WikiHistory> retrieved 13 April 2007.

#### 5.1.1.2. Sociocultural

The development of sociocultural trends which support the underlying processes of mass collaboration—i.e. the free sharing of information, authorship and ownership, as well as open access to the outcome—is a necessary component to the activity's ongoing uptake and further development. According to research into value systems (Beck & Cowan 1996; Cowan & Todorovic 2005), the emergence of human value systems, and thus ideology, norms and beliefs, form an inseparable union with our living conditions. In light of such theories, it is probable that the sociocultural structures which support mass collaboration (e.g. values surrounding cooperation and sharing and forms of open access et cetera) are emerging in tandem with the technology itself.[84]

O'Reilly (2005) perceives a shift on the sociocultural domian towards an 'ethic of cooperation', while Stewart and Gosain's work *The Impact of Ideology on Effectiveness in Open Source Software Development Teams* (2006) shows how ideology motivates behaviors that enhance trust and quality of communication and identification with the project's team. This identification positively enhances effectiveness within developer teams along a number of lines. Of specific interest are some of the open access beliefs identified as being core concerns to open source developers, for instance, the belief that 'outcomes are better when code is freely available' (2006:4) as illustrated by the following quote.

> Restrictions on the distribution and modification of the program cannot facilitate its use. They can only interfere. So the effect can only be negative. (Richard Stallman 1992 via Stewart and Gosain 2006:4)

The above belief is reflected in the expression often heard in online communities involved in open source and Wikipedia-like contribution, 'information wants to be free'.[85] This expression underscores the necessity in mass collaboration to have unrestricted, open access to copy, edit and transform information within the domain level of the workspace for the purposes of creative development, without necessarily even providing credit to original authors. This is due to the fact that during the process

[84] This view is also lent support by Luhmann's essay, *The Autopoiesis of Social Systems,* (1990).
[85] Generally attributed to Steward Brand as mentioned at the first Hackers' Conference in 1984 and subsequently published in the *Whole Earth Review,* Point Foundation, May, 1985:49.

of collaboration, it is often difficult if not impossible to trace whose idea or words originated exactly where and when, and that in the case of collaboration (as opposed to cooperation), the point is to contribute to the creative development of a shared representation, be it material or conceptual. Therefore, as new capacities for collective creation emerge, it is reasonable to assume that the sociocultural values, beliefs and norms must also develop in order to support the necessities of the collaborative process as it expands to new scales and engages new contexts.

#### 5.1.1.3. Legal

Irrespective of social and cultural beliefs surrounding open access, the default copyright laws in the West are 'all rights reserved' and as a result, information is not free and requires explicit licenses in order to liberate it. While designating content as existing within the 'public domain' does not require elaborate licensing, this does not ensure against its appropriation by some proprietary venture. In such a case, access to this material could be restricted to paying customers only, regardless of whether or not those selling the material actually composed it. In order to ensure that such proprietary appropriations do not occur which might lock the collaborators off from access to the very material they created, the development of a license was required to ensure the complete freedom of information from exclusive proprietary claims. Such a license would have to protect information in not only its current state, but also its derivations. This would provide for protection against someone making a slight modification or adaptation to such content in order to claim it as his or her intellectual property.

In relation to his work with the GNU Project and the development of the first open source operating system, Richard Stallman developed just such a licensing agreement for software, known as the General Public License (GPL) (Weber 2004). The GPL led directly to the creation of the GNU Free Documentation License (GFDL) which applies to textual works (originally developed for software documentation). The GFDL grants readers the right 'to copy, redistribute and modify' so long as all subsequent copies and derivatives are available under the same license.[86] It is this agreement under which

[86] GNU Free Documentation License. *Wikipedia, The Free Encyclopedia*. Retrieved 01:47, April 14, 2007, from <http://en.wikipedia.org/w/index.php?title=GNU_Free_Documentation_License&oldid=119925363>.

Wikipedia licenses its content, enabling it and all of its derivations to be free from exclusive proprietary appropriations.

A similar and subsequent development is the advent of the Creative Commons organisation founded by Lawrence Lessig, a professor at the Stanford Law School. This organisation provides licenses which enable creators to specify which rights they may wish to retain and which they would like to release, thereby enabling greater flexibility in regard to media sharing and collaboration.[87] Similarly, in the user-generated massive multiplayer world, Second Life, 'residents' are provided with a number of copyright options for the objects they create: 'no copy', meaning no copies are permitted to be made by others, 'no trans', which means the object cannot be given to any other residents, and 'no mod' meaning the objects may not be modified by others.[88] By providing residents with increased copyright control over the content they produce,[89] as well as providing an 'in-world' currency (the 'Linden dollar') a 'virtual economy' is enabled, helping drive the mass collaborative generation of the environment's fabric. This example makes it unclear as to how important pure open access (i.e. unrestricted intellectual property) is to mass collaborative ventures, as it may be that some amounts of restriction enables creations to be imbued with monetary or exchange value which may actually help stimulate the activity of mass collaboration in the right context.

However, there can be no doubt that licensing agreements which enable the open access of information will become more important as 'precompetitive sharing' plays an increased role in larger scale industrial ventures. Recently the Swiss pharmaceutical company, Novartis, released freely online the results of its genomic analysis of type 2 diabetes in order to encourage further development,[90] while major mining company Goldcorp considerably amplified its prospecting cycles by posting proprietary data online with monetary encouragements for participation via open submission (Tapscott and Williams 2006:7-10). As corporations and governments discover the potential for

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[87] Source, Creative Commons website, (online resource), <http://creativecommons.org/> retrieved 14 April 2007.
[88] Source, Second Life website, (online resource), <http://secondlife.com/> retrieved 14 April 2007.
[89] See 'Second Life Terms of Service,' Linden Lab, <http://secondlife.com/corporate/tos.php> retrieved 14.04.07.
[90] See 'Pharma Goes Open Access' by Stephen Pincock in *The Scientist,* (online magazine), <http://www.the-scientist.com/news/home/52891/> retrieved 14 April 2007. Thank you to Lise Lévesque who provided this information via the Cooperation Commons Google Group.

open access, powerful motivations and forces will step into play in helping develop the legal means and methods for enabling what Benkler describes as the emergence of the 'networked information economy', an economy which makes more efficient use of human and physical capital when sharing and collaboration are provided for (2006:116).

### 5.1.2. Mass Collaborative Negotiation

#### 5.1.2.1. Shifting the Collaborative Gestalt: from social negotiation to cultural participation

As discussed throughout this work, a critical shift in the collaborative gestalt takes place in the transition from that of social negotiation conducted via turn-taking communication as the means of collaborative participation, to immediate engagement with a shared site of work through indirect communicative exchanges. In freeing up energy that participants would otherwise use in negotiation, more is available for contribution to a workspace's domain level creative objectives. This has the effect of exploiting the potential inherent in stigmergic systems for globally coordinating localised input, thereby providing the capacity for the integration of a great number of individualistic contributions into that of a collective whole. A mediating collaborative workspace therefore effectively sidesteps social negotiation, fast-tracks the creative gestation period, removes social boundaries, and as a consequence, lowers the 'costs' of contribution by eliminating the need to become acquainted, maintain relationships and negotiate with fellow participants as contributions are made.

This is not to say that social negotiation does not take place in mass collaborative contexts or that developing and maintaining relationships with co-contributors isn't a valuable thing to do—it may even be essential to growing and supporting the collaborative community. Rather, that during mass collaboration, negotiation takes a back seat in terms of the creative process. Most (if not all) mass collaborations have discussions associated with the content being developed, but it is possible to contribute (to Wikipedia.org or Drawball.com for instance) without discussing what you are creating. In more traditional collaborative scenarios this would be impossible as all contributions would require turn-taking direct communicative negotiation. Interestingly, it is also possible to take part in discussion without editing by contributing to a

Wikipedia article's 'talk page'[91] or contributing to a MySpace group dedicated to Drawball which means that traditional collaborative exchanges are not so much excluded from the process, but are instead subsumed.[92] Other forms of direct mediated communication also commonly support mass collaboration such as bulletin boards, IRC (chat) and email lists, and in some cases, unmediated face-to-face communication.[93]

Therefore, such methods of direct turn-taking communicative exchanges are most certainly an important and perhaps crucial form of contribution, however they are typically secondary to the objectives of the overall project. The primary objective is of course the product of the workspace's domain level—in the case of Wikipedia, this manifests as encyclopedic articles, for Drawball it is the evolving mural, for the Apache HTTP Server, it is the software application. This embodied objective forms the collaborative gestalt, one that differs qualitatively from that of collaboration primarily coordinated via direct and mediated direct communication. In the case of the later, the domain level is embedded within that of the relationships, discussions and personal exchanges involved in negotiating the contributions, and while there certainly may be personal relationships involved in mass collaboration, the domain level of the workspace is outside the ownership or domain of any personal relationships which may be involved. Because one cannot know all the many contributors (due to high volume and or anonymity), this creates a sense of sharing the work with a larger unknown constituency. In this context, the workspace becomes a shared point of exchange which in some respects must do the work of mediating the contributions itself.

#### 5.1.2.2. Boundary Objects

In mediating, integrating and providing for the contributions of a large constituency, mass collaborative workspaces tend to reflect the attributes of a 'boundary object' as

[91] For an example of a discussion accompanying mass collaboration, see the English Wikipedia's 'Israel talk page', complete with extensive archives, <http://en.wikipedia.org/wiki/Talk:Israel> retrieved 14 April 2007. See also Wikipedia's 'Talk page' article, <http://en.wikipedia.org/w/index.php?title=Wikipedia:Talk_page&oldid=122587339> retrieved 14 April 2007.

[92] See, <http://groups.myspace.com/drawballfans> and <http://groups.myspace.com/drawball>, retrieved 16 April 2007. See also the wiki-based coordinated collective attack on Drawball, dubbed by the attackers as 'The Great /B/lackout', <http://www.encyclopediadramatica.com/index.php/The_Great_/B/lackout> retrieved 16 April 2007.

[93] See Wikipedia's 'Meetup' article which helps coordinate the physical meeting of Wikipedians, <http://en.wikipedia.org/w/index.php?title=Wikipedia:Meetup&oldid=122456312> retrieved 14 April 2007.

identified by sociologist of science, Leigh Star (1989). Boundary objects serve the function of coordinating the perspectives of multiple constituencies for some purpose or activity and traditionally may be conceptual or tangible artefacts, simple or complex in their structure (Star 1989; Star and Griesmer 1989). Star identifies four main features of the boundary object:

- **Modularity:** each perspective can attend to one specific portion of the boundary object.
- **Accommodation:** the boundary object lends itself to various activities.
- **Abstraction:** all perspectives are served at once by deletion of features that are specific to each perspective.
- **Standardisation:** the information contained in a boundary object is in a pre-specified form so that each constituency knows how to deal with it locally.
    - (Star 1989 as summarised by Wenger 1998:107)

Table 5.0 provides several examples of these characteristics as represented in mass collaborative project workspaces.

| Project | Modularity | Abstraction | Accommodation | Standardization |
|---|---|---|---|---|
| **Wikipedia** | any number of people can edit any number of articles at any given time | contributors can attend separately to issues of content, layout, technical infrastructure, community discussion et cetera | encyclopedias are abstractions by nature; attempting to represent a 'neutral point of view'; the 'no original research' rule | community defined standards for content layout, drafting procedures (no copyright material), neutral point of view |
| **Drawball** | any number of people can contribute simultaneously to differing loci of the mural | multiplicity of drawing activities such as repairing work overdrawn by others, starting original work, working on projects with others | drawing tools are restricted to the same common set for everyone | all previously existing work is subject to a common means of modification and adaptation to new work |
| **Second Life** | any number of people may inhabit and build objects in any number of places | many activities are open to participants: building objects & the environment, organising events, exploring, socialising | the environment's underlying rules (its 'laws of physics') provide a uniform and common experience by restricting all other possibilities | there is a single set of procedures, software code and copyright rules regarding the modification and adaptation of existing work which is uniform for all residents |
| **Open source repositories** | modular by nature, sections of code may be developed by any number of different participants | various activities are open to participants: writing original functionality, bug fixes, testing | the objectives of the project (i.e. to provide software with 'x' functionality) unifies perspectives by restricting and focusing possibilities | specific coding languages and programming methods are agreed upon or are present as existing code, thereby standardising ongoing contributions[94] |

Table 5.0.

Boundary object features associated with mass collaborative projects

[94] For example, see Apache HTTP Server style guide, (online resource), <http://httpd.apache.org/dev/styleguide.html> retrieved 17 April 2007.

The details of these attributes are defined by the participants either when establishing the collaboration's cooperative procedures (such as in the case of standardisation and abstraction), or through the emergent activities of its participants (as in modularity and accommodation). In either case, the workspace must provide the capacity for these attributes in their representation and continued emergence in order to offer a common framework for the coordination of the stigmergic contributions by numerous individuals with differing perspectives. Further, the boundary object coordinates the stigmergic contributions from members with different perspectives and approaches to the collaborative activity via the ability of such reified representations to 'bridge disjoint forms of participation' through both connection *and* disconnection among the participants (Wenger 1998:107). This ability to disconnect the idiosyncratic aspects of perspectives from members of differing constituencies while connecting their contributions via the fabric of a boundary object workspace is the essence of stigmergic mass collaboration. The mediation of the workspace reduces social friction associated with differences in perspectives by increasing the capacity for direct creative participation. This circumvents social negotiation and instead shifts the negotiation to the level of the integration and interrelations of the actual contributions themselves.

#### 5.1.2.3. (Virtual) Communities of Practice

First proposed by Jean Lave and Etienne Wenger (1991) and further developed by Wenger (1998) as part of an expanded theory of social learning, the term 'communities of practice' (CoP) refers to 'groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly.'[95] In recent years there has been increasing speculation as to the existence of virtual communities of practice (VCoP) as a valid form research in its own right. Some researchers are critical of the capacity for the virtual (online) environment to provide the requirements necessary to qualify as CoP (Kimble & Hildreth 2004; Lueg 2000), however many others argue that while new effects are produced as a result of digitally networked mediation, this domain is a legitimate form of CoP (Kim 2004; Trabinger 2004; Zarb 2006). The view that CoP exist virtually is now reasonably well supported (Johnson

[95] 'Communities of practice: a brief introduction' Etienne Wenger, (online resource), <http://www.ewenger.com/theory/communities_of_practice_intro.htm> retrieved 16 August 2005.

2001; Kimble et. al. 2001) with additional research continually emerging (Zarb 2006). A large and well developed theory integrated into both on and offline organisational learning and knowledge management (Hildreth & Kimble 2002, 2004; Wenger 2004), a full account and mapping of the CoP theory is beyond the scope of this work, however a number of the key concepts and how they relate to mass collaboration are reviewed. Specifically, the key concepts of CoP, 'participation' and 'reification', provide connections with stigmergy and its capacity to play an integral role in such communities on and offline.

Wenger's CoP theory sees the construction of identity and the negotiation of meaning taking place through the dialectal interplay of participation and reification as central to the process of learning (1998). The interplay between participation and reification represents an important distinction which provides a means of theorising the fuzzy line which simultaneously separates and connects stigmergy with mediated and direct forms of interactions associated with mass collaboration. Described as 'a duality, not opposites' (1998:66) these two interacting dimensions compliment each other and contribute to the negotiation of meaning through,

- *participation* as the experience of our everyday social interactions and their attendant relations (1998:55), and
- *reification* as 'the process of giving form to our experience by producing objects that congeal this experience into "thingness"' (1998:58).

In this conception, these two dimensions support a range of shortcomings that each other possess, in that participation addresses the inability for the 'stiffness' of reification to encapsulate all instances of understanding and meaning, while reification provides the sense of objectivity, permanence and co-location required to enable coordination beyond subjective and local interactions (1998:64). Kimble and Hildreth (2005) also note a linkage which exists between tacit, or 'soft knowledge', which cannot always be articulated and must instead be experienced via participation, and 'hard knowledge', which can be structured and codified and therefore may be reified. This leads to the presumption that a balanced alignment of participation in order to convey the experience of soft knowledge, and of the reification of hard knowledge in order to promote system-wide coordination, might be required for the successful coordination of

mass collaboration. In practice it is interesting to note that some mass collaborative workspaces provide for the participation in CoP (as in the case of Wikipedia with its many varying forms of participation[96]) and others do not. However even in cases where mass collaborative workspaces do not directly provide for the growth of a community of practice, one tends to form nonetheless, as in the case of MySpace groups associated with Drawball.com.

In light of the forms of participation and reification associated with mass collaborative ventures, a core distinction can be made between traditional CoP—originally conceived in relation to situated experience in co-located settings (1998:13)—and VCoP, which is that most forms of participation in the latter context take place via the coordination of stigmergy (i.e. reification). This suggests that participation in relation to online CoP is perhaps more fundamentally oriented within the 'reificative' process of stigmergy (i.e. all forms of online participation depend upon their reification). This also suggests that like Susi and Ziemke's finding that stigmergy provides a minimal common ground between activity theory, situated and distributed cognition (2001:16), stigmergy may also form a linkage with reification as described in the CoP theory. The expansion of this linkage offers a potential direction for future research, in that it presents an excellent opportunity for exploring human-human stigmergy while drawing upon the breadth and depth of the CoP theory, which provides a substantial grounding in the organisation of communities surrounding particular practices such as those associated with mass collaboration.

#### 5.1.2.4. Superordinate Goals

Mass collaborative projects and their associated communities of practice are often associated with what may be described as 'superordinate goals'. Superordinate goals serve to coordinate and focus the collaborative efforts of the participants while helping moderate conflict surrounding confusion as to the project's objectives. Muzafer Sherif showed in his seminal article, *Superordinate Goals in the Reduction of Intergroup*

[96] See Wikipedia's 'Community Portal', <http://en.wikipedia.org/w/index.php?title=Wikipedia:Community_Portal&oldid=123006057> retrieved 16 April 2007, which lists a very wide range of ways to participate in the project and the community (see 'Ways to communicate'). See also, 'Signpost', Wikipedia's regularly published, community written newspaper <http://en.wikipedia.org/wiki/Wikipedia:Signpost> retrieved 16 April 2007, an excellent testament to a thriving community of practice.

*Conflict* (1958), that conflict can be significantly reduced in group interactions by the introduction of goals compellingly shared by group members and which require the collaborative efforts of all. In mass collaborative contexts such goals often appear in the form of mission statements, taglines, project descriptions, instructions or guidelines which attempt to communicate the objectives and or primary concerns of the group. Superordinate goals in this context also tend to communicate something of the core values, beliefs and norms associated with the project, this having the effect of attracting and unifying like-minded participants and even marshalling their contributions.

Most mass collaborative projects surveyed tended to have a collection of such goals represented within their workspaces, providing stigmergic cues for participants in their collaborative activities and their community interactions. Some of the superordinate goals from four mass collaborative projects are listed below, followed by commentary.

**Wikipedia.org**

- *the free encyclopedia that anyone can edit* (Wikipedia.org's tagline) [97]
- *encyclopedic content must be written from a neutral point of view, representing views fairly, proportionately and without bias.* [98]

These two superordinate goals illustrate the nested relationship such goals may possess. While Wikipedia's tagline serves as an overall project description informing visitors and potential participants as to its nature and objectives, the neutral point of view, or 'NPOV' as it is more widely known by Wikipedians, is specifically targeted to participants and serves to marshal and focus their contributions. While not made explicit in these examples, it may be argued that that the tagline speaks to the project's underlying values, beliefs and norms in regard to notions relating to freedom of information, participatory organisations, 'flat hierarchies' and open access. The NPOV on the other hand is more direct in its insistence as to fairness, proportionality and the avoidance of bias. It goes without saying that superordinate goals in the context of stigmergically mediated projects exist only as ideals in their reified state, as it is only in their expression through the participation of the collaboration's constituency that they

[97] Wikipedia, 'Main Page', <http://en.wikipedia.org/wiki/Main_Page> retrieved 16 April 2007.
[98] Wikipedia article, 'Neutral point of view', <http://en.wikipedia.org/wiki/Wikipedia:Neutral_point_of_view> retrieved 27 January 2007.

are subjectively interpreted and applied (to better or worse effect). This also underscores their role as goals, in that they represent an ideal state or approach for the mass collaboration, not necessarily the reality of the situation. The tone of the following qualification of the NPOV reflects the fact that such goals are potential flash points for boundary pushing by contributors.

> Neutral point of view is a fundamental Wikipedia principle. According to Wikipedia co-founder Jimmy Wales, NPOV is "absolute and non-negotiable."[99]

**Drawball.com**

- *Draw something cool to be added to the artist hall of fame!!!*[100]
- *Show off your skills on the enormous circle of potential art known as drawball.*[101]

In contrast to Wikipedia's more idealistic tone and overarching objectives, Drawball's superordinate goals take an individually oriented, informal, simple and suggestive approach, with an accent on being cool and showing off. While this example may not appear to qualify as a superordinate goal in that it does not directly reference a goal which requires the collaborative efforts of all, it could be argued that this is achieved indirectly by suggesting how one's contributions relates to the overall project—i.e. by providing contributions to a domain which allows for relativistic rating and evaluation in relation to the works contributed. (The tone of these suggestive goals is also likely to be designed to target youth with the time and interest in participating in a graffiti-like project in order to ensure maximum activity—the more activity, the more site traffic and the more likely users are to click the advertising links which flank the drawing domain.)

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[99] Wikipedia article, 'Neutral point of view', <http://en.wikipedia.org/wiki/Wikipedia:Neutral_point_of_view> retrieved 27 January 2007.
[100] Drawball homepage, <*http://drawball.com*> retrieved 16 April 2007.
[101] Drawball homepage, <http://drawball.com> retrieved 16 April 2007.

**Apache.org**

- *The Apache projects are characterized by a collaborative, consensus based development process, an open and pragmatic software license, and a desire to create high quality software that leads the way in its field. We consider ourselves not simply a group of projects sharing a server, but rather a community of developers and users.* (Apache.org's homepage welcome message)[102]
- *While there is not an official list, these six principles have been cited as the core beliefs of philosophy behind the foundation, which is normally referred to as "The Apache Way". All of the ASF [Apache Software Foundation] projects share these principles.*
    - *collaborative software development*
    - *commercial-friendly standard license*
    - *consistently high quality software*
    - *respectful, honest, technical-based interaction*
    - *faithful implementation of standards*
    - *security as a mandatory feature*[103]

The high level of specificity in Apache.org's homepage welcome message suggests a well-developed and highly refined collaboration. The superordinate goals listed provide a description of the project (in its capacity as an umbrella for sub-projects), its process and objectives (developer and user-led open licensed collaborative software projects) as well as suggesting inherent values, beliefs and norms (consensus based processes, open licensing / open access, leaders in the field, community-oriented). 'The Apache Way' takes a step further in detailing their technical objectives as standard and security focused while listing more value, belief and norm oriented points, adding 'respectful, honest, technical-based interaction' and 'commercial-friendly'. From the perspective of a potential contributor, it is fairly easy to grasp the nature of the project and the likely character and tone the interactions might take, however once again, these are goals only able to represent an idealisation.

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[102] Apache.org homepage, <http://apache.org/> retrieved 16 April 2007.
[103] 'Project Management and Collaboration', 'Philosophy', Apache.org, (online resource), <http://www.apache.org/foundation/how-it-works.html#management> retrieved 16 April 2007.

**Second Life**

- *Your world. Your imagination.* (Second Life's tagline)[104]
- *Second Life is a 3-D virtual world entirely built and owned by its residents.*[105]
- *We are a global community working together to build a new online space for creativity, collaboration, commerce, and entertainment. We strive to bridge cultures and welcome diversity. We believe in free expression, compassion and tolerance as the foundation for community in this new world.*[106]

Both the tagline and the description from their website communicate the user-generated nature of the collaboration, though the tagline is markedly more idealised, possibly reflecting an advertisement orientation similar to Drawball.com. The third set of goals taken from the community page of the Second Life website, imparts a strong sense of the project's idealised values outlining notions of creativity, collaboration, entrepreneurial innovation, play, cultural diversity, compassion and tolerance, thereby setting a tone for participation and providing a touchstone for expected conduct and interaction.

The importance of the superordinate goal in mass collaborative projects should not be underestimated as they play a crucial part in forming the collective identity, expectations and procedures of the community as it participates in an ongoing collective attempt at the goal's reification. The further analysis of the successes and failures in achieving the stated objectives of such goals present an important opportunity for future research. It is likely such analysis would yield valuable insights into the internal workings of existing mass collaborative projects, while providing directional pointers for designers in engineering new ventures.

### 5.1.2.5. Contributor Groups & Emergent Teaming

Numerous annotations to the domain level of a mass collaboration coordinated and marshalled by superordinate goals naturally forms clusters of annotations, linking

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[104] Second Life homepage, <http://secondlife.com/> retrieved 16 April 2007.
[105] 'What is Second Life', SecondLife.com, (online resource), <http://secondlife.com/whatis/> retrieved 16 April 2007.
[106] 'Community', SecondLife.com, (online resource), <http://secondlife.com/community/> retrieved 16 April 2007.

participants who are attracted to the same areas of content in accordance with their interests. As participants generate shared representations, their contributions are likely to overlap, mix and meld with others', confusing authorship to the point where disentanglement may become impossible. This has the effect of generating 'contributor groups' linked via their contributions, personal interests, discourse and shared representations.[107] This powerful combination of linkages may lead the individuals to work together, forming emergent teams attracted by the stigmergic signs and signals emitted by their reifications. However even if members of a contributor group have no explicit knowledge of one another (which in many cases may be the norm), from a 'birds-eye' perspective they would still appear as if their group's work were consciously coordinated. It is at this level that the stigmergic coordinative mechanisms are perhaps most apparent, bearing much resemblance to pheromone coordinated activity in insect societies. Their annotations provide the cues for one another to 'add/edit/delete' at the domain level while naturally optimising team efficiency through self-selection according to individualistic interests and strengths.

In fact, fuzzy lines between implicit and explicit coordination within contributor groups is perhaps most common in mass collaboration. For example, Wikipedia's 'Community portal'[108] provides a wide range of suggestions as to potential contribution, such as 'New project pages seeking contributors', 'Things to do' and 'Good Article Collaboration of the week'. None of these link-based suggestions demand that the groups contributing communicate directly, however histories and 'signatures' may inform members of whom they are working with, even if they do not directly interact. All one needs to do to take part in such a contributor group is follow the links like pheromones (marker-based/qualitative) to the site of work and contribute. The high number of options for contribution classified under categories such as those listed above increases the likelihood that a prospective contributor will find a site of interest. This aspect reflects the autocatalytic nature of stigmergy—the more activity and

[107] For example, see the discussions on the Wikipedia talk page for the article 'Transdisciplinarity', <http://en.wikipedia.org/w/index.php?title=Talk:Transdisciplinarity&oldid=89010495> retrieved 17 April 2007, which illustrates a contributor group of four members engaged in a complex discussion as to what approaches to take with the drafting of the associated article.

[108] See Wikipedia article, 'Community portal', <http://en.wikipedia.org/w/index.php?title=Wikipedia:Community_Portal&oldid=123313389> retrieved 17 April 2007.

contributions that take place, the more likelihood the project is to attract those interested in partaking in the activity.

With workspaces which do not directly provide for the support and formation of a community of practice, such as Drawball.com, that contributor groups are working together at the domain level (sematectonic/qualitative) may not be so apparent. However even in such cases, that individuals are attracted to areas of work with content representing their interests (whether to work alone or together) is highly likely, and in fact the previously mentioned MySpace groups[109] confirms this suspicion. Even in such cases that do not support authorship and social networking, the stigmergic effects of individual annotations are strong enough to inspire users to seek alternative means of forming explicit contributor groups. Although, even when groups explicitly coordinate, this does not necessarily ensure that all activity will be coordinated through mediated direct communication. It is quite possible that a Drawball contributor might 'lurk' on one of the afore mentioned group sites and not contribute to the conversation, but still be stigmergically compelled from reading the discussions to take part (even if disruptively) in the contributor group's objectives.

Several researchers have identified some of the processes that lead to the formation of contributor groups from differing perspectives. In his influential article, *That Sneaky Exponential—Beyond Metcalfe's Law to the Power of Community Building* (1999), David Reed identifies what he calls 'group-forming networks' (GFNs). GFNs are networks that support the formation of communicating groups, creating 'value' which scales exponentially with network size (this scaling occurs at a rate of 2 to the power of N where N is the number of nodes in the network). The value increased by such networks is,

> 'the value of potential connectivity for transactions. That is, for any particular access point (user), what is the number of different access points (users) that can be connected or reached for a transaction when the need arises'. (1999:1-2)

GFNs have therefore been identified in research as being one of the more powerful drivers of network value which may have contributed significantly to the growth of

[109] See <http://groups.myspace.com/drawball>, <http://groups.myspace.com/drawballfans> and <http://www.encyclopediadramatica.com/index.php/The_Great_/B/lackout> retrieved 16 April 2007.

giants such as Ebay, the popularity of chat rooms and even the Internet itself (1999). This effect is now generally referred to as 'Reed's Law'.

Applied to mass collaborative contexts, workspaces which support the explicit formation of contributor groups via social networking functionality, tend to exhibit high rates of group forming. For instance Wikipedia's Mediawiki software provides functionality so that a link to an author's user page[110] is displayed on contributions listed in the 'recent changes' or on an article's 'history page'. This enables contributors to connect with one another in order to coordinate activities and or to simply discover what other articles users may be working on who express similar interests based upon their contributions.[111] It is the provision for identity in Wikipedia's workspace that enables contributors to explicitly self-organise and mobilise as groups within the environment, thereby providing for a wide range of contributor group dynamics. Second Life's provision for identity through unique names given to 'residents', in combination with social networking like functionality, enables similar dynamics, including the formation of a great many groups, such as those geared around building objects within Second Life.[112]

Closely related to GFNs, Michael Zarb identified in his thesis, *Modelling Participation in Virtual Communities-of-Practice* (2006), a dynamic which he terms 'splicing'. Splicing refers to the capcity some technology has which allows 'the community to segregate and form sub-communities' (2006:12). Zarb argues that the capacity for splicing enables the reduction of 'off topic' noise to be reduced through the formation of sub-groups which enables them to indulge their more specific interests without distracting the wider community (2006:30). Such an example of splicing in mass collaboration is Apache.org's capacity to host numerous software development projects,

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[110] See Wikipedia article, 'User page', <http://en.wikipedia.org/w/index.php?title=Wikipedia:User_page&oldid=123416158> retrieved 17 April 2007.

[111] A great deal of information may be listed on a user page such as skills, language competencies, philosophical interests and physical 'meetup' dates and places. For example, see 'User:Jimbo Wales' (co-founder of Wikipedia), <http://en.wikipedia.org/w/index.php?title=User:Jimbo_Wales&oldid=123320159> retrieved 17 April 2007.

[112] Within the Second Life environment, see the group, 'Builders of SecondLife', which as of 17 April 2007 had 1303 members.

enabling the wider pool of developers to take part in and create new projects (sub-groups) which are of direct relevance to their interests, applications and skills.[113]

In summary, the capacity for the formation of contributor groups through emergent teaming (whether implicitly or explicitly coordinated) is a defining feature of mass collaboration. It is also this phenomenon which displays some of the more potent and interesting mechanisms of mass collaborative stigmergy—the coordination of collective creative activity on levels between that of the individual and the collective. The concept of emergent contributor groups also bears significant resemblance to the notion of Hofstader and Minksy's teams of agents which contribute to the emergence of the higher level agency of individual cognition, perhaps suggesting the potential for forms of collective intelligence emerging on top of and as a result of collaborative contributor groups.

On a more applied level, providing increased self-reflexivity for members of contributor groups who are working on specific aspects of a large-scale collaborative workspace may increase incentives towards activity by helping convey the experience of the sub-group they are apart of but may not be aware of. It also seems apparent that the provision of group-forming and splicing capacities as per Wikipedia and the Apache Software Foundation helps to coordinate the membership, stigmergically directing the flows of user experience toward applications more focused on specific contributor interests, skills and competencies.

### 5.1.3. Peer Production & the Emergence of the Networked Information Economy

Peer production, referred to by a number of terms such as peer-to-peer, commons-based peer production, peering, social production and collaborative production, is a growing area of contemporary research focusing on Internet-based production methods, exchanges and relations of individuals, often approached from or informed by a political and or economic perspective. The following will highlight and explore several points of relevance, specifically Bauwens notions of 'peer-to-peer' and 'use-value' (2005), and Benkler's 'commons-based peer production' in relation to his identification of the

[113] See <http://projects.apache.org/> retrieved 17 April 2007.

emergence of a networked information economy (2006) of which mass collaboration plays a key role.

In his essay *The Political Economy of Peer Production* (2005), Michel Bauwens defines peer-to-peer as relating to 'participation by equipotential participants' which is characterised by the process of the production of 'use-value through the free cooperation of producers who have access to distributed capital'. Further, the 'peers' are governed by a community which they themselves constitute (as opposed to an external hierarchy) and who tend to utilise new common property regimes to provide open access to their resulting work.[114]

This definition of peer production describes much of the practices involved in mass collaboration, however the central distinction between this field of inquiry and that of the present, is the level of analysis. The peer-to-peer outlook largely focuses on the political and economic interests of the transactions and relations amongst individuals engaged in production outside of traditional organisational models. In contrast, the view of mass collaboration presented here is concerned more with the dynamics produced as a result of large-scale interactions between peers and their online environment—perhaps on a level below that of politics, economic interests and organisational models. However, the peer-to-peer and stigmergy perspectives compliment each other well, each providing insight into the different strata of a common terrain.

An important point made by Bauwens regarding mass collaboration is that of 'use-value' as the primary form of value produced through peer production. Use-value is a term borrowed from Marxist economics designating a form of value characterised by a labour-product's capacities to satisfy a human need or want.[115] Use-value appears to be a primary form of value generated in mass collaborative contexts at the domain level of production. Specific use-value is often inherent for the producers (the work they contribute to is in the realm of their interests) but it also tends to extend beyond that of the original creators towards a wider group of consumers. For instance, the utility provided by Wikipedia as a general source of knowledge to those who use it as a

[114] See also 'The Foundation for P2P Alternatives', <http://p2pfoundation.net> (retrieved 10 April 2007), a substantial wiki and blog-based Internet collective founded and guided by Bauwens.
[115] Wikipedia article, 'Use Value', <http://en.wikipedia.org/w/index.php?title=Use_value&oldid=121496281> retrieved 17 April 2007.

reference, the software produced by the Open Source community for clients, the fabric of Second Life's world for its residents, and the aesthetic enjoyment provided by the art at Drawball, goes considerably beyond that of the contributors.

Additionally, use-value is precisely what drives the long-term viability of mass collaborative projects—if the output is of no use or interest, the project garners no contributions and consumers. This indicates that the higher the project's use-value, more likely its associated community of practice will remain coherent and active concerning the project's workspace. In this manner, the use-value helps determine a project's lifespan, pointing to the fact that for all well established mass collaborations, the output tends to be open ended in nature.[116]

Bauwens makes another observation relevant to mass collaboration, which is that through legal frameworks such as the GPL, the collective output of peer production generates an information commons. With the potential for residents of Second Life to retain intellectual property rights over their creations, an open access commons may not necessarily be the exclusive case in regard to mass collaboration, however it may be that there are subsets within Second Life—some contributing through peer production to such a commons and some which contribute to a market style economy through leveraging IP rights. In any case, the pervasiveness of the creation and contribution to an open information commons through mass collaboration utilising licenses such as the GPL and GPDL (especially in regard to Wikipedia and open source software projects) make it an important attribute worth consideration.

Yochai Benkler develops this theme of the generation of an information commons through peer production in his work, *The Wealth of Networks: How Social Production Transforms Markets and Freedom* (2006). Benkler describes 'commons-based peer production' as,

> ...radically decentralized, collaborative, and nonproprietary; based on sharing resources and outputs among widely distributed, loosely connected individuals who cooperate with each other without relying on either market signals or managerial commands (2006:60).

[116] This concept resonates with the Web 2.0 design principle of the 'perpetual beta' as identified by O'Reilly (2005).

This description of the mode of production which he claims is a primary driving force in the emergence of a new global economy, the 'networked information economy', stands remarkably well as a depiction of the collaborative stigmergic activity associated with mass collaboration. Bauwens, Benkler and myself are in fact discussing the very same realm of phenomenon, but from differing perspectives. Through commons-based peer production (i.e. stigmergic cooperation and especially mass collaboration), Benkler is recognising the emergence of a new global economic force that represents the 'dark matter of our economic production universe' (2006:117). This activity's contribution to information production as an underlying and considerable component of the global economy can also tap into psychological motivations that money cannot—the innate desire to share, cooperate and collaborate (2006:116).

But what is perhaps most important in regard to Benkler's analysis, is that the shift to this new economy has potentially profound implications for our conceptions of freedom and our capacity to understand and respond to the world emerging around us. Benkler argues that through the emergence of the networked information economy—which relies almost exclusively on mass cooperative and collaborative stigmergic production—our cultural information inputs become increasingly diversified. This has the direct and proportional effect of broadening and diversifying our cultural outputs, the result being that the range of assumptions we can make about our environment and what actions and forms of actions are possible within that information environment are equally increased and diversified (2006:129).

In fact, Benkler is quite specific and detailed as to the ways in which a shift in the structure of the cultural information environment produces this phenomenon. Using as an example Google's PageRank algorithm in contrast with commercially driven search engines such as Overture, he shows how Google's search returns provide a more transparent view of the cultural knowledge surrounding a given subject. In the case of his example, Overture's first ten returns on the search 'Barbie' provided only commercial sites while the same search using Google provided at least seven critical cultural commentaries on the role of the Barbie doll in impacting the self image of young girls, one scholarly work on Barbie and its cultural history, and three commercially oriented sites (2006:285-94). This increased diversity is a direct result of the structural configuration of both the creation of the information environment by

creating links (marker-based/qualitative) to sites of use-value, and its filtering and accreditation (2006:68) via following ranked returns from search engines (marker-based/quantitative). Put more simply, stigmergic information environments allow you see and respond to the paths that civic culture is actually taking and making, and less of those constructed to direct you towards specific market and or politically motivated outcomes.

Benkler also shows how this relationship between market and nonmarket forces shape the transparency and diversity of culturally oriented information in the five most popular online encyclopedias (2006:287-9). Of the five, four are commercial while one 'is a quintessential commons-based peer production project—Wikipedia' (2006:287). Most of the commercial encyclopedias had no specific entries on Barbie, while they did briefly mention Barbie under their 'dolls' entry. Only Britannica and Wikipedia had specific entries, the one written for Britannica being by a sole author who had written a book on the subject. Wikipedia's article was according to Benkler's analysis equally if not more informative, which also included references to the book by the author of Britannica's article. More importantly, Wikipedia's revision history functionality renders the drafting of the article transparent. In doing so, it is apparent that the number of contributing authors is significant enough that the likelihood of skewing the article towards that of a bias perspective (such as Barbie manufacturers or an author with a book on the market) becomes significantly less likely.

In fact, since the time of Benkler's analysis of the encyclopedias (2003-4), the Barbie article continues to undergo reshaping and updating by a wide range of authors who make an edit every week to two days as of mid April 2007 (see figure 5.1). This illustrates that not only does commons-based peer production (mass collaboration) result in increased diversity and transparency, but also the possibility that the sources of information being created may react and evolve along with culture in real time.

article | discussion | edit this page | history | move | watch

Barbie

From Wikipedia, the free encyclopedia

Revision history
View logs for this page

(Latest | Earliest) View (previous 50) (next 50) (20 | 50 | 100 | 250 | 500).
For any version listed below, click on its date to view it. For more help, see Help:Page history and Help:Edit summary.
(cur) = difference from current version, (last) = difference from preceding version, **m** = minor edit, → = section edit, ← = automatic edit summary

Compare selected versions

- (cur) (last) 20:56, 18 April 2007 lanmacm (Talk | contribs) **m** *(→Biography - rvv.)*
- (cur) (last) 20:44, 18 April 2007 Donreed (Talk | contribs) *(→Biography)*
- (cur) (last) 06:20, 16 April 2007 DHN-bot (Talk | contribs) **m** *(robot Modifying: ru:Барби)*
- (cur) (last) 20:21, 13 April 2007 Acalamari (Talk | contribs) **m** *(→Parodies and lawsuits - Slight correction in a source.)*
- (cur) (last) 20:20, 13 April 2007 Acalamari (Talk | contribs) *(→Barbie versus Bratz - Unspacing.)*
- (cur) (last) 20:19, 13 April 2007 Acalamari (Talk | contribs) *(→Controversies - Unspacings.)*
- (cur) (last) 20:17, 13 April 2007 Acalamari (Talk | contribs) *(→Biography - Unspacings.)*
- (cur) (last) 20:16, 13 April 2007 Acalamari (Talk | contribs) *(→Development - Unspacing.)*
- (cur) (last) 19:04, 11 April 2007 MartinBot (Talk | contribs) **m** *(BOT - rv Pinkflipflop66 (talk) to last version by Woohookitty)*
- (cur) (last) 19:03, 11 April 2007 Pinkflipflop66 (Talk | contribs) *(←Replaced page with 'barbie is a slut! Ken broke up with her because she slept with john v Dont buy barbie!')*
- (cur) (last) 09:20, 10 April 2007 Woohookitty (Talk | contribs) *(per cfd/speedy)*
- (cur) (last) 06:45, 9 April 2007 Pascal.mr (Talk | contribs) *(rv)*
- (cur) (last) 06:26, 8 April 2007 SieBot (Talk | contribs) **m** *(robot Modifying: da:Barbiedukke)*
- (cur) (last) 18:32, 7 April 2007 lanmacm (Talk | contribs) **m** *(→Parodies and lawsuits - slight rewording.)*
- (cur) (last) 12:59, 7 April 2007 Lexein (Talk | contribs) **m** *(→Parodies and lawsuits - rm copyvio, add news link)*
- (cur) (last) 07:06, 7 April 2007 lanmacm (Talk | contribs) *(→Barbie versus Bratz - add note on countersuit.)*
- (cur) (last) 06:49, 7 April 2007 lanmacm (Talk | contribs) **m** *(→External links - rv, the full lyrics of the song are too long and cannot be included for copyrigh*

Figure 5.1.

Wikipedia's 'Barbie' article revision history on 19 April 2007

While the above examples focus on popular culture (i.e. Barbie), the domain of mass collaborative 'open research' is already being employing to similar effect. One such example is MetaCollab.net, one of the creative projects developed in conjunction with this PhD (profiled in the following chapter). This project provides an open access repository for the collaborative creation of theory surrounding the process and practice of collaboration itself (see figures 6.13 and 6.14). Another project similar to that of MetaCollab.net, this time in the field of biology, is Open Wetware (see figure 5.2). The superordinate goal of this wiki-based project states that it 'is an effort to promote the sharing of information, know-how, and wisdom among researchers and groups who are working in biology & biological engineering.'[117] With this project offering resources, labs, courses, contributor groups and of course encyclopedic information, it isn't hard to imagine how mass collaboration (or commons-based peer production in Benkler's terminology) can offer increased freedom through open access to not just less biased,

[117] See 'Main Page', OpenWetware.org, <http://openwetware.org/index.php?title=Main_Page&oldid=70777> retrieved 19 April 2007.

more diverse sources and forms of information, but to individual involvement in the participation of its very creation.


Figure 5.2.

OpenWetWare.org's home page as of 19 April 2007

### 5.1.4. Critical Evaluation of Mass Collaboration

In his article, *Digital Maoism: The Hazards of the New Online Collectivism'* (2006), Jaron Lanier expresses the concern that mass collaborative processes (wiki usage in particular) may fall prey to the trappings of collectivism. However it is my opinion that this assessment misses the mark somewhat, as the process of mass collaboration (especially in open access contexts) necessitates collective action as opposed to collectivism—in other words, individuals are not bound to contribute content which is not of direct interest, relevance, or use-value to them (Rheingold 2006). This tends to ovoid the potential pitfall that individuals might subjugate their interests through the

pressures of the collective. In wiki contributing contexts, instead of collectivism manifesting, individuals with differing perspectives tend to 'fork' projects, as the ease of creating new mass collaborations is relatively easy. For instance, see Conservapedia.com, the superordinate goals of which state,

> Conservapedia is an online resource and meeting place where we favour Christianity and America. Conservapedia has easy-to-use indexes to facilitate review of topics. You will much prefer using Conservapedia compared to Wikipedia if you want concise answers free of "political correctness".[118]

The social nature of the communities of practice which form around mass collaborations do not however exclude the potential that individuals will be excluded or marginalised based upon their particular interests, i.e. it is possible for those with more administrative powers to block the contributions of those who are perceived to not fit in. Once again though, this form of administrative restriction is likely to catalyse more diversity in the information domain through the forking of projects or at the very least to spark open discussion and debate as to the reasoning behind such restrictions.

One particularly common criticism of mass collaborative projects, especially those geared towards knowledge construction such as Wikipedia, is a lack of authority, creditability, verifiability and accountability. In many respects, these are valid concerns, as the mechanisms that tie the 'real' identity of participants to their contributions are less rigorous than those in traditional publishing practice are. However, it is my opinion that such issues will be 'auto-corrected' by the wider community, and or accepted in general. For instance, similar arguments have been levelled at open source software, and yet despite such potential problems, it is the use-value which ultimately determines the overall value of a given piece of software. To date, acceptance by various governmental and commercial institutions has served to establish open source software as a valid and well used form of process (Weber 2004). Similarly, in the case of Wikipedia articles, it is also likely that through the course of time, existing and emergent institutions will evaluate the use-value of this process, ultimately stipulating and possibly restricting its applications. This of course may not restrict people from still gaining knowledge from

[118] Conservapedia.com homepage, <http://www.conservapedia.com/Main_Page> retrieved 14 May 2007.

such sources, however if such institutions impose limitations on the applications of such sources (e.g. through restricting their citation in academic contexts) this may affect the long-term adoption of the process. In the short term, such criticisms levelled at mass collaborative process and outcomes are likely to have a toning effect as the communities involved move to counter and address them. This is perhaps evident in Wikipedia's increasing vigilance regarding monitoring copyright infringement and in the use of warning messages such as 'The neutrality of this article is disputed', 'This article or section may be confusing or unclear for some readers' and 'This article needs additional references or sources to facilitate its verification'.[119]

On a more infrastructural level, a definite barrier in the capacity for mass collaboration to reach out to the entire world's population are of course 'digital divides'. From the Organization for Economic Cooperation and Development (OECD), the digital divide refers to,

> ...the gap between individuals, households, businesses and geographic areas at different socio-economic levels, with regard both to their opportunities to access information and communication technologies and to their use of the internet for a wide variety of activities. The digital divide reflects various differences among and within countries.[120]

While there can be no doubt as to the existence of digital divides and their contribution to cultural under representation, economic, educational and technological disadvantage, there are increasing signs that the gap is narrowing, and that issues of addressing this divide lie more in social rather than technological development (Curry & Kenney 2006; Santoyo 2003). However, current estimates place the number of Internet users at 1,114,274,426 as of March 2007, implying that upwards of 7% of the Earth's population now has network access.[121] This growth rate is exponential (see figure 5.3) and unless unforeseen events influence this curve (such as sudden disruption to energy supplies) this trend suggests continued and accelerated network penetration rates.

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[119] For examples see, <http://en.wikipedia.org/w/index.php?title=Transdisciplinarity&oldid=108555831> and <http://en.wikipedia.org/w/index.php?title=T-shirt&oldid=131209427> retrieved 14 May 2007.
[120] OECD website, 'Digital Divide', <http://stats.oecd.org/glossary/detail.asp?ID=4719> retrieved 30 April 2007.
[121] InternetWorldStats.com, <http://www.internetworldstats.com/stats.htm> retrieved 30 April 2007.

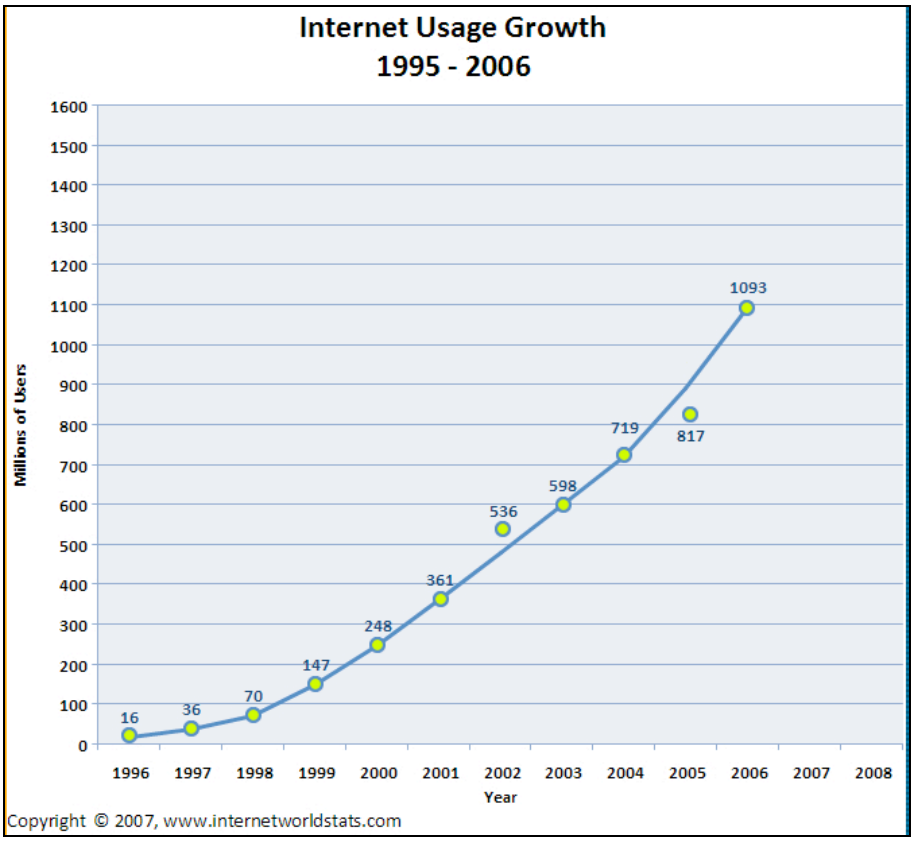


Figure 5.3.

Internet usage growth, 1995-2006[122]

A fourth occasional criticism of not just mass collaborations such as Wikipedia, but of email lists, blogs and other forms of participatory media, is that only a small proportion of those who regularly consume the resources actually contribute the majority of the work involved in creating them. While this trend may be used as a point of criticism (Nielsen 2006), it is my opinion that while participation is likely to rise with the social and technological development of the media involved, this dynamic is ultimately none other than the Pareto principle, or the '80/20 rule'.

The Pareto principle, first observed by Joseph M. Juran, states that 'for many phenomena, 80% of the consequences stem from 20% of the causes'.[123] However, the exact proportion is generally not 80/20, and in fact it is often much closer to 90/10 in the case of wiki collaborations.[124] This principle applies to a wide range of phenomenon

[122] Image source: 'Internet Growth Statistics', *InternetWorldStats.com*, <http://www.internetworldstats.com/emarketing.htm> retrieved 30 April 2007.
[123] Pareto principle. In Wikipedia, The Free Encyclopedia. Retrieved 05:08, April 30, 2007, from <http://en.wikipedia.org/w/index.php?title=Pareto_principle&oldid=125453488>.
[124] See Wikia.com, 'Page views', <http://www.wikia.com/wiki/Page_views> retrieved 30 April 2007.

including computer programming,[125] relationships and business,[126] biodiversity on land masses[127] and wealth distribution.[128] So while increasing participation in mass collaboration is in many ways an underlying aim of this thesis, it is also recognised that for any valuable resource, the majority will be primarily concerned with its consumption, while the minority will likely be the ones maintaining and developing it. The crucial aspect regarding digital resources is of course the fact that they may be infinitely reproduced with little to no effort or energy, so despite the number of 'free riders', the commons does not diminish. One important observation this criticism does highlight however is that a reasonably large number of overall participants are required for a mass collaboration to establish a diverse and robust core of contributors if it must contend with the Pareto principle at any and all scales.

Despite the above criticisms, the strengths of mass collaboration remain its decentralised, participatory, open source, collective action and use-value oriented structure. Only society's long term collective reasoning of the merits or lack thereof regarding its capacities, as well as the associated online communities' response, will determine the validity of such criticisms. However, like most other forms of media, now that mass collaboration has emerged, it is unlikely to disappear regardless of its pros or cons. Rather, it is more likely that this emergent form of collective activity will continue to play a considerable role in the ongoing transformation of the cultural and economic landscape of the future whether we happen to like it or not.

## 5.2. Engineering & Supporting Mass Collaboration

As the mass collaborative process becomes increasingly woven into the fabric of our daily lives in regard to its applications, the consumption of its products and participation in the activity, the necessity to better understand this phenomenon on its many levels will only intensify. Improving our understandings will help us to fine-tune existing

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[125] Free Online Dictionary of Computing, <http://foldoc.org/?eighty-twenty+rule> retrieved 30 April 2007.
[126] Pareto's Principle: The 80-20 Rule'. *Notes to Self: Thoughts on psychology, productivity and soft skill development for personal improvement,* (web log), <http://spiritize.blogspot.com/2006/02/paretos-principle-80-20-rule.html> retrieved 30 April 2007.
[127] Megadiverse countries. In Wikipedia, The Free Encyclopedia. Retrieved 05:23, April 30, 2007, from <http://en.wikipedia.org/w/index.php?title=Megadiverse_countries&oldid=124674841>.
[128] Pareto principle. In Wikipedia, The Free Encyclopedia. Retrieved 05:08, April 30, 2007, from <http://en.wikipedia.org/w/index.php?title=Pareto_principle&oldid=125453488>.

cases as well as better engineer new instances in order to leverage the emergent potential which lies in our capacity to collectively create on ever increasing scales. The following section provides an overview of the various theoretical components proposed throughout this thesis, revisited in the context of engineering and supporting mass collaboration. While there can be no doubt that our understandings of stigmergic, software and community engineering practices will develop very rapidly in the coming years, it is hoped that the following insights will help spur our early attempts towards the support and expansion of our collective creative abilities.

### 5.2.3. Levers of Collective Activity

The Cooperation Project,[129] a collaboration between Stanford University, The Institute for the Future[130] and Howard Rheingold, has published several sets of analytical tools based on their multi disciplinary research into collective processes as applied to a wide range of activity. Of specific relevance, is their proposal of a set of cross-disciplinary clusters of behaviours and concepts which through their analysis may help us to better understand the dynamics of collective activity as associated with specific instances and contexts. These clusters, dubbed 'levers', suggest ways to alter, adjust and tune the dynamics of collective activity in groups, organisations and communities (Saveri et. al. 2004). Such adjustments may be made by the consideration and application of principles the levers convey, or, by increasing or decreasing their application based upon a continuum within which they manifest (see table 5.1).

Not all levers are necessarily present or applicable in all contexts (2004:30) however, I feel that while some are more relevant to mass collaboration, they all provide some insight into the concerns and considerations relevant to engineering the process. These levers will be used to structure an overview of the engineering concerns in regard to mass collaboration, with specific attention paid to the design and support of stigmergy, open access, collaboration within online workspaces, and aspects of interaction and

---

[129] See *The Cooperation Project's objectives, accomplishments and proposals,* (online resource), <http://www.rheingold.com/cooperation/CooperationProject_3_30_05.pdf>, retrieved 25 November 2005. See also the activities of the linked project, the Cooperation Commons <http://cooperationcommons.com> retrieved 19 March 2007.

[130] Institute for the Future is located in Palo Alto, California. See its website, <http://www.iftf.org/> retrieved 18 December 2006.

negotiation considered to be of particular importance. Table 5.1 represents a summary of these seven levers as presented by Saveri et. al. (2004).

| Lever | Continuum | Description |
|---|---|---|
| **Structure** | *static—dynamic* | Structure refers to the configuration of human and non-human actors and processes in an organisation, and their inter-relationships. |
| **Resource** | *public—private* | Property regimes for resources set up conditions and relationships that effect production, wealth creation and innovation in different ways. |
| **Rules** | *internal—external* | Rules provide a framework for interaction in a cooperative system; they set a boundary that delineates what constitutes acceptable behaviour and mediate between self and group interest. |
| **Identity** | *individual—group* | Identity is at the core of many human and biological systems in which cooperative behaviour and collective action emerges. Reputation, trust, affiliation and membership are all manifestations of identity that affect such contexts. |
| **Feedback** | *local—systemic* | Feedback is a way of describing the knowledge horizon of actors in a system in which collective behaviour emerges. |
| **Memory** | *ephemeral—persistent* | Memory is a form of stored knowledge which may be useful only for a short time (ephemeral), or create long-term records of choices and interactions (persistent). |
| **Thresholds** | *high—low* | Thresholds reflect transition points in the status of resources, organizational systems, and in the behaviour of actors within systems. Thresholds can act as triggers and valves that set cooperative behaviour in motion or suppress it. |

Table 5.1

Levers for analysing, engineering and fine-tuning collective activity

While the various levers do refer to unique aspects of collective activity, the features highlighted below may be of some relevance across more than one category.

#### 5.2.3.1. Structure, *static—dynamic*: the stigmergic workspace

### Indirect Interactions

In regard to mass collaboration, the structure lever—often thrown to its more dynamic extreme—is perhaps one of the most important. In order to enable mass collaboration it is critical to structure the project's workspace so that indirect interaction provides for stigmergic collaboration through the addition, deletion and modification of content. In most cases, the domain level of the workspace (where collaborative contributions are made) should be separate from mediated direct interactions (discussion) regarding collaborative contributions in order to maximise available creative energies while minimising distraction from individualistic interests (and the possible feelings that one cannot express themselves naturally). However having said this, such determinations should ultimately be made on a case-by-case basis, as it is conceivable that the product of such direct interactions could contribute explicitly to the collaborative output.

### Workspace Environment

In general, the nature of both the tool and domain levels of a workspace will depend upon the objectives of the project and what forms of media and annotation tools it supports. For some projects, media rich environments will be ideal (e.g. Wikipedia's support for text, image and sound contributions), while the objectives of others will be more focused and thus restrictive (such as Drawball's support for drawn imagery only). Depending upon what forms of media are utilised and to what ends, designers may take differing approaches to the environment's state variables (the forms of annotation possible). Balancing functionality with usability is crucial regarding the provision of such variables, as it is important to provide contributors with enough capacity to make contributions of sufficient quality and complexity while no overwhelming them with too much functionality.

The representation of the stigmergic environment should where possible and relevant be re-presented upon a variety of topologies, as it is recognised that 'the ability to position resources across multiple structural perspectives increases the likelihood of cooperation and the perceived value of the resources' (Saveri et. al. 2004:33). Examples include the re-representation of hyperlinked documents in categories, or collaborative contributions

made to semantic content as revisions listed in an index (such as Wikipedia's 'recent changes' or 'history' functionality).

### Workspace Annotations

Annotations to collaborative workspaces can accommodate a wide range of forms and modes of symbolic expression providing a rich pallet to draw from in both existing precedents and the generation of annotations idiosyncratic to available participant skills, the project's objectives and the available workspace and end-user technologies. Fundamentally, annotations can be divided into four groups, each consisting of two sub-groups:

1. **Gestalt focus** is determined by the participant's attention as to what level of the domain is being considered as meaningful. If it is the state of the domain level itself, it is *sematectonic*. If it is some type of metadata place within or on top of it, it is *marker-based*.
2. **Sign type** is determined by whether the annotation is a unique, discrete cue of non-scalar attributes, in which case it is *qualitative,* or if it is of a single scalar quantity that may be increased or decreased accordingly, in which case it is *quantitative*.
3. **Formation** of the annotation may be achieved *intentionally* by an agent exerting its will, or *automatically* by the workspace's information processing capacities.
4. **Properties** of the annotation consist of its *content,* the formal or informal semantics it possesses in relation to some ontology and or literacy, and its *form,* the force or shape the annotation is given.

### Agent Capacities

When engineering for the above annotation attributes, designers must be conscious of the specific capacities of participants concerning annotation creation, observation and interpretation. In particular, agents within stigmergic systems have three primary capacities to cater for:

1. **Cognitive abilities** which may vary between individuals and groups, as well as between different contexts (some groups or individuals may be highly skilled at performing a certain annotation, but require considerable support with others—

for instance, high capacity when using a word processing program, but no understanding of how to edit a wiki). This component also includes the wide range of sociocultural aspects and issues which may affect, limit or enhance a participant's ability to engage with and contribute to a mass collaborative workspace.

2. **Sensors** in human agents relate to both biological and technological capacities. It is critical to remember that both of these capacities may vary between individuals and their access to various forms of technology, and that on the most basic level, the participant must be able to sense a change to the environment in order for the environment to provide a cue to continue its creative development. Conversely, sometimes it might be beneficial for contributors *not* to sense some change in the workspace, as it may distract from contribution to or consumption of the created resource. For instance, it might be distracting for readers and editors of Wikipedia articles to see edits by other participants taking place in real time.
3. **Actuators** also relate to both biological and technological capacities. While conventional computing standards (e.g. the hardware interface) limits the forms of actuation which may take place, standardisation across computer hardware and software provides the capacity so that many can perform the same types of annotations. The creation of digital tools at the tool level of the workspace can help overcome potential hardware limitations as well as considerably augment the possibilities for annotation generation not otherwise possible. Catering for both sensor and actuator capacities is very much the realm of standardisation and accessibility and no doubt there will be considerably more possibilities in these areas over the coming years as the modes and methods for human-computer interaction develops.

### Collaborative Negotiation

More generally, while keeping in mind that the most fundamental level of negotiation accomplished during mass collaboration is the indirect negotiation of co-created emergent shared representations, it is also important to consider supporting other forms of communication. Other forms might include indirect communication such as blogs and bulletin board approaches, or mediated turn-taking such as email, chat, video

conferencing and even unmediated face-to-face engagement (i.e. 'meetups'). By providing opportunities for discursive as well as stigmergic collaboration, participants may gain a greater sense of membership, purpose and trust in relation to the overall project (Zarb 2006; Kimble et. al. 2001; Lipnack & Stamps 2000).

### Contributor Groups & Emergent Teaming

Designers can facilitate structural support for contributor groups through providing for group-forming networks and 'splicing'—the forking of discussion and project development activities (Zarb 2006). Group-forming can be supported through provisions for identity (allowing participants to identify others working in similar domains via their presence and or contributions) and 'group spaces' which allow individuals to annotate a collective space apart from the main site of collaboration such as Wikipedia's 'talk pages', 'community portal' and bulletin board.[131]

Supporting emergent teaming in its own right (teaming without explicit member coordination) is a feature of stigmergic activity in general, in that through providing high profile and well-organised links to sites of work, contributors may find their own way there to contribute. However, deciding what components of the project to link to and where to put such links may depend on a wide range of factors that are likely to change through time with the project. Therefore, the ideal solution is to support user-driven organisation of such marker-based links (as in the case of Wikipedia). Participants stimulated to create these links in relation to their own interests tend to have a stake in maintain them, and are more likely to accurately anticipate the interests of like-minded contributors.

### Workspace as Boundary Object

It is important to consider the shared workspace as a boundary object that links various individuals and constituencies through forms of connection and disconnection. In other words, the workspace acts as a type of neutral space which caters for differing perspectives by restricting some aspects of individual specificity through *abstraction* and *standardisation.* However it is still reasonable for workspaces and communities to

[131] The Bulletin Board is located on the 'Community Portal' page in Wikipedia, <http://en.wikipedia.org/w/index.php?title=Wikipedia:Community_Portal&oldid=123434554> retrieved 17 April 2007.

provide specialised capacities for particular members or forms of membership (such as Wikipedia's 'stewards', 'bureaucrats' and 'administrators') as by providing varying levels of participation and experience, the workspace may achieve *modularity* and *accommodation.* Restated below are these four attributes with brief descriptions.

- **Abstraction:** all perspectives are served at once by deletion of features that are specific to each perspective
- **Standardization:** the information contained in a boundary object is in a pre-specified form so that each constituency knows how to deal with it locally
- **Modularity:** each perspective can attend to one specific portion of the boundary object
- **Accommodation:** the boundary object lends itself to various activities
    - (Star 1989 as summarised by Wenger 1998:107)

#### 5.2.3.2. Resource, *public—private*: open access

##### Open Content

The most important aspect of resource allocation in mass collaboration is that through licensing options such as the GPL, GFDL, the Creative Commons licenses, or some similar agreement, the content developed is for the most part made public. This is critical as '[t]he rate of innovation depends on the degree to which diverse populations can build on other's work' (Saveri et. al. 2004:37) and the ability to freely copy and modify this work is imperative to its collaborative development.

##### Membership

Access to the project's shared domain is of course critical, and projects with open membership tend to attract more activity. However, this must be balanced with quality of content and extraneous factors such as spam and vandalism. Regarding Wikipedia, its vibrant community of participants and technological infrastructure ensures that it 'costs' less time and energy to fix and revert poor quality or destructive contributions than to restrict access. Drawball on the other hand has no explicit membership, however administrators can reduce or increase one's ink, or blacklist users via their IP address in

relation to the quality of their work.[132] Other projects such as Second Life, limit access via the necessity for explicit membership, although in this case it is still possible for anyone to register.[133]

### Open Source Software

While it may not necessarily be imperative for the success of mass collaboration, open source software may greatly facilitate the capacity for the workspace to develop in tandem with a community's interests and objectives. Through the benefits of being able to make changes to the software via access to its source code, as well as the possibilities of tapping into a large development community, Wikipedia is able to continually improve their Mediawiki software in ways meaningful to the project and as suggested by its user's input and interactions. Such interlinked development between the participants and the software platform greatly increases the likelihood that the state variables and the specific types of annotations possible will best suit the collaborative objectives of the given project.

### Use-value

The use-value of a particular project may provide an important means for ensuring project uptake and lifespan. However precisely what use-value to design for is challenging, as this is largely the realm of culture and collective taste (and perhaps ultimately left to those generating the content). Regardless, identifying the broad strokes of a project's potential use-value(s), and then better positioning them in relation to communities that may be interested can help garner exposure and contributors to the project. Such evaluations and re-positionings of use-value is likely to be ongoing as the project's outcome and constituency develops and evolves through time.

### 5.2.3.3. Rules, *internal—external*: superordinate goals

Superordinate goals provide the primary unifying and persistent feature in relation to internally developed and enforced rules for interaction in mass collaborative contexts.

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[132] Drawball.com also protects itself from spambots through presenting the participants with a graphic puzzle, requiring the user to connect a number of dots in a particular sequence in order to gain access to drawing functionality.

[133] Those under the age of 18 are required to provide a parent's valid credit card for identity security purposes, however the basic account is still free. See <http://teen.secondlife.com/> retrieved 14 May 2007.

Superordinate goals provide rules by acting as reified proxies of the project's individual or collective authority figures which set the community's tone and values through the statement of objectives, project descriptions, guidelines or instructions. Such goals should be thought through carefully when commencing a mass collaborative project as superordinate goals may require specific tailoring for distinct constituencies and contexts.

Regarding more specific rules that govern mass collaborations, projects such as Wikipedia and most open source software projects determine and govern much of their more specific rule structures internally (with superordinate goals helping to marshal this process). However this is not always the case as Drawball and Second Life are both private organisations and as such, the general creation, administration and enforcing of rules comes from the authoritative base of the commercial organisation in its need to protect and maintain its monetary investments and interests.

#### 5.2.3.4. Identity, *individual—group*: communities of practice

The support for identity on the individual, participant level in mass collaboration takes a wide range of approaches, from none in the case of Drawball, to being more or less identity based in the case of Second Life (although one's 'in-world' representation of identity does not necessarily correspond to one's in the real world). In designing and supporting mass collaborative projects, the approach taken to participant identity must be decided on a case-by-case basis as it is dependent upon the projects objectives. However, from a theoretical, communities of practice perspective, the support of individual identity provides a means for participants to organise communities of practice surrounding their more specific interests. The formation of such communities provides for more opportunities to temper the high amounts of reified contributions associated with stigmergic, indirect interactions with community participation and interaction.

Apart from participant identity, identity on the collective level is likely to be largely influenced by superordinate goals, as well as by the emergence of contributor groups and communities of practice in mass collaborative contexts where participants are

involved in their own governance. The 'Wikipedians' page[134] is an excellent example of emergent collective identity formation generated through a community of practice.

#### 5.2.3.5. Feedback, *local—systemic*: witnessing annotation

Feedback is a fundamental, systemic component of stigmergic systems—changes in the environment which stimulate agent activity to make more changes is a form of feedback in its own right. Therefore perhaps the most fundamental and obvious design support for mass collaboration in relation to feedback is the provision for participants to witness the effects of their annotations as they contribute them. While perhaps obvious in this context, designers and researchers should not underestimate the power of this experience—some workspaces even augment it in various ways. In Second Life, the process of creating or modifying an object is accompanied with local feedback by way of avatar movements and 'particle effects' which lends a 'superpower' association to the process.

Responsiveness of the workspace is another key means of increasing systemic and local feedback to the contributor. With recent developments in programming, especially regarding AJAX oriented programming approaches, the time between making a change within a workspace and its effect upon the wider domain level is reducing. In workspaces such as Second Life it is for most intents and purposes, simultaneous.

Marker-based feedback presents many opportunities for enriching and stimulating the interactive experience, in that provisions can be made for adding metadata to the collaborative workspace without explicitly affecting the semantic flow of the collaborative work. Examples include Wikipedia's categories and template tags, recent changes and revision information, while Second Life's 'minimap' enables local navigation and identification of other residents while still viewing and creating within the main domain. Marker-based metadata can also be particularly helpful in communicating indirectly the state of progress on various components of a mass collaboration through alerts posted in marginal areas of the workspace or through the provision of links designed to catalyse emergent teaming by advertising differing locations for contribution. Additionally, the digital environment allows for designs such

[134] See Wikipedia article, 'Wikipedia: Wikipedians', <http://en.wikipedia.org/wiki/Wikipedia:Wikipedians> retrieved 14 may 2007.

that marker-based annotations can be rendered visible or hidden from view based upon designer or contributor discretion. For example, Mediawiki provides a logged in user with notification when someone has left a message for them on their user page. This message is displayed on an article but only seen by the user to whom it is directed (see figure 5.4).

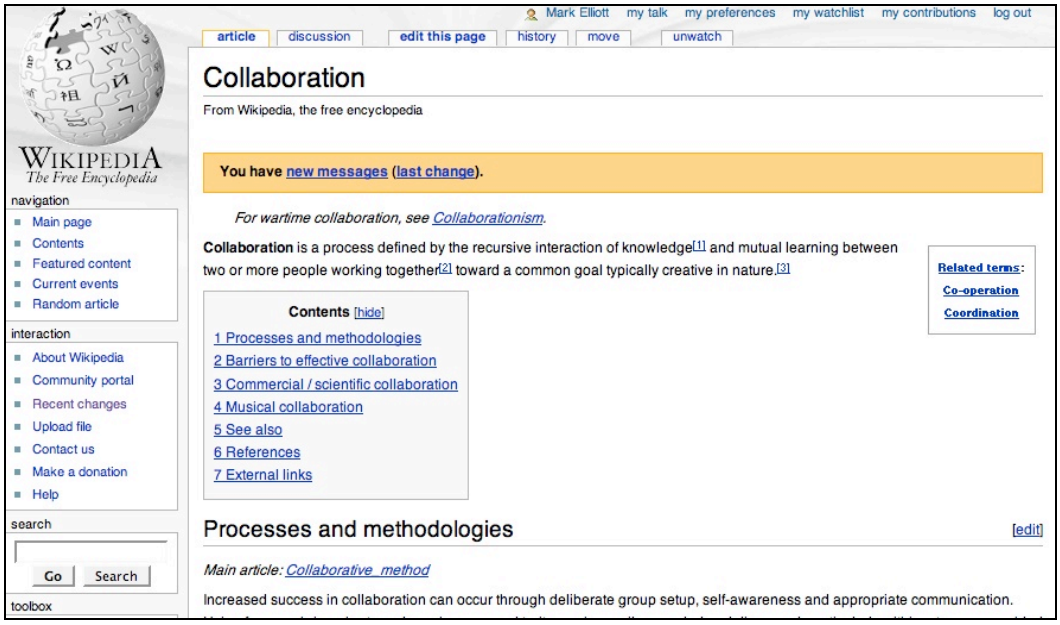



Figure 5.4.

Wikipedia, 'You have new messages', example of marker-based/qualitative stigmergy

It should also be mentioned that a critical form of systemic feedback required to start any open access mass collaboration is that associated with member attraction—participating members autocatalytically attract more participating members through the added value of their contributions, by creating links pointing to the site (raising its PageRank), and through their social communications. This is generally known as positive feedback (the process of returning part of the output to the input, thereby further augmenting the input) while this particular type of 'members attracting members' effect is more specifically known as increasing returns (Arthur 1989).

Increasing returns can also be seen in the high ranking of mass collaborative sites when using the Google search engine—sites which add interlinked pages as a component of their collaborative creation improve their PageRank as a function of the increasing

number of pages which point to other pages within the collaborative space. This is sometimes referred to as the 'Google effect' or Google or link bombing when done intentionally. The hallmark example of this dynamic is Wikipedia, which often tops Google search returns, thereby driving increasing returns by stigmergically guiding more consumers and contributors to their site.

#### 5.2.3.6. Memory, *ephemeral—persistent*: individual & collective

Mass collaborations tend to exhibit an interesting characteristic regarding memory as represented by the participant's contributions. As the workspace presents the current state of the collaboration, participants often overwrite or modify existing contributions and thus current and past contributions quickly become subsumed within the collaborative process. This has the effect of creating *collectively persistent* while *individually ephemeral* memory on the level of the system. However most mass collaborations track individual participant contributions to some extent (e.g. Wikipedia's history functionality and Drawball's playback feature), which in some respects pushes the memory level towards persistence on both the collective and individual levels.

Designers might consider expanding the memory capacities of a mass collaborative workspace by providing more detailed views of aspects of the process of contribution as it unfolds (which also functions to provide increased feedback). One particularly compelling example is that of the History Flow visualisations produced by Viegas et. al. (2004).[135] By graphically mapping the activity of Wikipedia contributors, a wide range of activity becomes explicit, especially additions and deletions of content and 'edit wars' where editors battle back and forth for primacy of their contributions. The incorporation of such visualisations could provide participants with considerably more detailed views of the ongoing collaborative process, providing increased feedback and knowledge as to the development of the collaborative process. Figure 5.4 shows a visualisation using the History Flow software of the edits made to the 'Chocolate' article on Wikipedia. Entrances and exits of various colours show new material being

[135] For a gallery of images, see the 'History Flow: Gallery' on IBM's Collaborative User Experience Research Group website, <http://www.research.ibm.com/visual/projects/history_flow/gallery.htm> retrieved 23 April 2007.

added and deleted, while the zigzag pattern shows the back and forth pattern of an edit war where editors repetitively delete and replace content (2004:580).

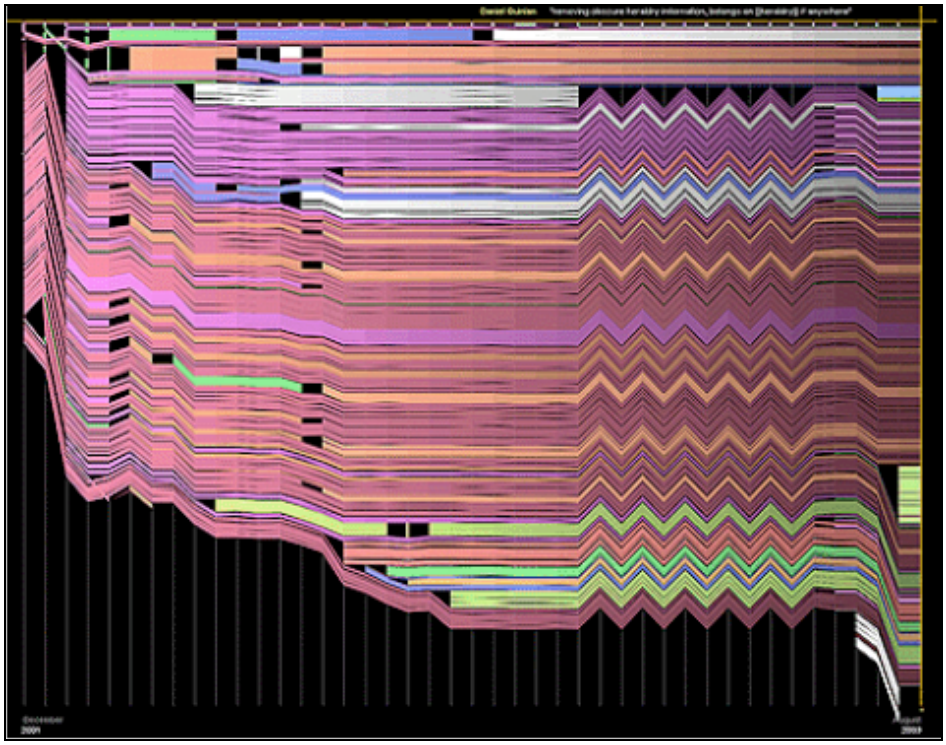


Figure 5.5.
Reprinted from Viegas et. al. (2004:580) - The History Flow visualisation of Wikipedia's 'Chocolate' article

### 5.2.3.7. Thresholds, *high—low*: tipping-points

While threshold oriented tipping-points have been observed in stigmergic systems—for instance the coordinated phases triggered by a critical density of activity in the creation of pillars within termite mounds (Theraulaz & Bonabeau 1999), details as to specific thresholds in mass collaborative projects are still unclear, however their existence is almost certain.

How to best design in order to encourage the positive triggering of tipping-points at various thresholds requires more empirical research into the actual events, however triggering such tipping-points is likely a function of feedback resulting from effects such as increasing returns. Perhaps the best rule of thumb is to iteratively redesign for increasing contributions of reasonable quality, as higher volume of lower to moderate

quality contributions can help drive participation by cuing 'clean up' activities by participants who are so inclined.[136]

The lack of knowledge surrounding the specific details of the thresholds involved in mass collaboration is emblematic of the research still required to be undertaken in order to better understand and engineer these emergent superorganisms of the collective creative ecology. In some respects, such knowledge will emerge along with the activity, however I feel that this development can be accelerated and expanded upon by targeted and coordinated research activities in the area. In fact, I would like to suggest that the undertaking of such research represents a prime opportunity for the application of the activity itself. By drawing upon the collective knowledge and experience of those involved in the daily enacting of mass collaboration across its wide range of applications, a high level of use-value could be brought to the project, further fuelled by academic and pure research oriented involvement. In such a case, the fruit of the project's labours would be immediately fed back into its further enacting, providing an interconnected and interrelated domain for experimentation, reflection and application of the theories generated.[137]

[136] For instance see Wikipedia's 'Wikipedia:Cleanup Taskforce' page, <http://en.wikipedia.org/w/index.php?title=Wikipedia:Cleanup_Taskforce&oldid=124923818> retrieved 22 April 2007.

[137] The exploration and development of such a project is planned as an extension of the activities of MetaCollab.net (one of the projects undertaken as part of this PhD and profiled in the following chapter).

# 6. Experiments in Stigmergic Design & Collaboration

> A designer is an emerging synthesis of artist, inventor, mechanic, objective economist and evolutionary strategist.
>
> —*R. Buckminster Fuller*

The following chapter presents an overview of the creative projects instigated as part of my PhD candidature. Having undertaken the conception, design and management of three online collaborative projects, the following accounts provide insights into my interests and objectives. Here I relate their design features back to the frameworks presented in the previous sections. All of these three projects are situated within contexts which are traditionally *not* considered apart of the creative arts—educational course design, human rights policy writing, and transdisciplinary theoretical research. The decision to not draw on my musical and artistic training was a very conscious and deliberate one, as my interests for this PhD lay distinctly in the notion of 'composing collaboration'—that is, treating the collaborative process as a medium in its own right. In wanting to test the limits of this idea, it seemed that if collaboration could be interpreted as an artistic medium, then the output of this process should be of less concern than composing processes and structures which facilitate the emergence of the collective objectives of those collaborating.

An accompanying DVD-Rom has been provided containing offline versions of the below projects, however it should be stressed that these projects are open ended and dynamic in nature. In the case of the Australian Bill of Rights Initiative (ABRI) (http://abri.org.au) and MetaCollab (http://metacollab.net), please feel free to browse their online versions. The most recent iteration of the Collaborative Contract course site

(2007) was archived just prior to the student submission deadline, so much of the final works are missing from the offline version (online access to the site is password protected). While the shift to online submission was not complete in 2006, some examples of final collaborative works can be seen in the 'Group Studios' of the 2006 version.

Finally, it must be mentioned that while I designed the below environments, Marcus Leonard, played an invaluable role as collaborative partner in the execution of the designs as well as in providing ongoing technical administration and assistance for the Collaborative Contract and ABRI sites.

## 6.1. The Collaborative Contract Online Environment

Upon commencing my PhD, Dr. Elizabeth Presa, head of the Centre for Ideas (CFI), presented me with the opportunity that I could incorporate the development and design of the course, Collaborative Contract, into the outcomes of my research. The general objectives for the Collaborative Contract course are to connect students from across the diverse faculties of the Victorian College of the Arts (music, visual arts, dance, film and television, production and drama) and provide them with a context for developing cross-disciplinary collaborative projects. Through developing such projects, a range of disciplinary divisions in practice, languages and approaches must be engaged, representative of those commonly existing in the professional world of the creative arts and the skills required to address them.

I began the first of what would be four years of iteratively redesigning aspects of the course by acting as a 'collaborative facilitator', providing guidance and advice for the students engaged in collaborative projects. In taking this role, I was interested in gaining a better perspective of the subject from the inside out before suggesting any substantial revisions or additions. In fulfilling this role, I was immediately struck by the immense potential of the course—200 arts students involved in small, cross-disciplinary collaborative projects (on average 2-5 members per group) the outcomes of which typically falling outside of disciplinary boundaries. Additionally, the details of their project ideas, experience and outcomes went largely unknown to one another as the formation of their groups and the ongoing development of their projects was their

responsibility, with course contact limited to lecture style presentations by professional collaborating artists.

### 6.1.1. Interests, Objectives, Outcomes & Reflections

After this first year, my lasting impression was that there was a wealth of learning opportunities available in the cross-group exposure of the many ideas and projects the students were developing. This led directly to the vision of an online environment, which through stigmergic principles might generate a microcosm of discursive collaboration. The model I initially drew upon was that of social networking. It was imagined that through the provision of basic social networking capacities such as fora, student directories, bulletin boards and most importantly, a 'group studio' (a place for groups to discuss and coordinate their activities), learning opportunities might be generated through cross-group exchanges.

This design led to the creation of a trial website for the 2005 iteration of the course, participation within which was voluntary and non-assessable in order to test software and design principles, as well as to gauge student interest and technological capacities. While a primary restriction was that of budget, the decision to utilise open source software, specifically TWiki (wiki enterprise collaboration software[138]) was arrived at almost immediately after receiving a quote for the proprietary building of the initial site design (some $20,000 Australian dollars). Open source software reduced the budget enough so that the first year could run with the only cost being to my and Marcus Leonard's time. The server was, and still is, a slightly refurbished desk top PC connected to the College network via the photocopier room in the Centre for Ideas (see figure 6.0) which provides password-protected access to the site from any Internet location.

[138] See <http://twiki.org> retrieved 22 April 2007.


Figure 6.0.
Mark Elliott with Centre for Ideas server

The first iteration of the online environment (see figure 6.1) attracted interactions from half the course, approximately 100 students, who expressed enough interest to spur a redevelopment the following year. For the second and third iterations (2006 and 2007), the online component was integrated as an assessable component of the course work with its redevelopment supported by an internal Teaching and Learning grant. Figures 6.1 through 6.3 show screen shots of the home page illustrating the evolution of the site's visual design over the last three years.

The Centre for Ideas
The Victorian College of the Arts
Search

Collaboration

Home Page

Teams
About Teams
Collab Summaries
Blog index
TeamGenesis
TeamAmrita
TeamAmy
TeamBen
TeamBox
TeamBumford
TeamChange
TeamChristianGunn
TeamConfusion
TeamContagion
TeamCrash
TeamDance
TeamEloquence
TeamExhibition
TeamGlobal
TeamGogo
TeamHaIJimboTige
TeamHole
TeamJustBrowsing
TeamKronosBound

You are here: Collaboration > WebHome
Edit Printable topic end

754-301
Collaboration Contract Online Network

Welcome to the Collaboration Contract Online Network. This is a collaborative network created especially to facilitate and expand the collaborative opportunities for the students enrolled in Collaboration Contract, a course offered by the Centre for Ideas at the Victorian College of the Arts (VCA). The VCA is an affiliate of the University of Melbourne.

New Course Wide Forum

CollabContractForum is open to everyone across all the tutorials. This forum is wide open for any discussion topic relating to collaboration, your group, your experience with this course, your hopes, dreams and desires for a collaborative utopia... whatever! – This is an excellent opportunity to explore and expand your understandings through tapping the many minds of the talented artists enrolled in this course.

Tutorial Forums

Figure 6.1.

Collaborative Contract online environment, 2005, home page

Centre For Ideas Online

Search:
MarcusLeonard Print
Diffs More

home
» my blog
» blog index
» group studios
» message board
» collabopedia
» my student page
» directory
» gallery

» course links
» help
» resources
» student code of conduct

» Admin

754-301

Center for Ideas

Collaborative Contract

Welcome to the course's online component.

**Please see the Student Code of Conduct – guidelines for using this site.**

If you have not filled out your student page, go here.

**Slow?** Our server is getting busy. If you can, avoid the really busy times – especially Friday around midday after the class.

What's New

- See CollabOPedia for **free grant money** (of course you have to apply and be selected).
- Please use me, I'm the Message Board
- Post useful information regarding collaboration on CollabOPedia for extra credit.
- You might be interested in this study which surveyed people to discover the traits of AN IDEAL PROSPECTIVE COLLABORATOR. Check out the table of results.
- Interested in starting your own free public blog on the internet, click here.

The PARTY

- **Friday May 12, 7pm** – Grant Street Theatre, VCA
- Calling for Collaboration groups to perform and show work – contact jordeez@hotmail.com
- Outside bands, djs and drinks, people, fun, oh baby!

Contacts

- Course coordinator: Dr Elizabeth Presa – e.presa@vca.unimelb.edu.au
- Network facilitator: Mark Elliott – m.elliott@vca.unimelb.edu.au
- Network facilitator: Simon Terrill – s.terrill@vca.unimelb.edu.au
- Technical problems with this site: Marcus Leonard – marcus@marleo.net

Figure 6.2.

Collaborative Contract online environment, 2006, home page

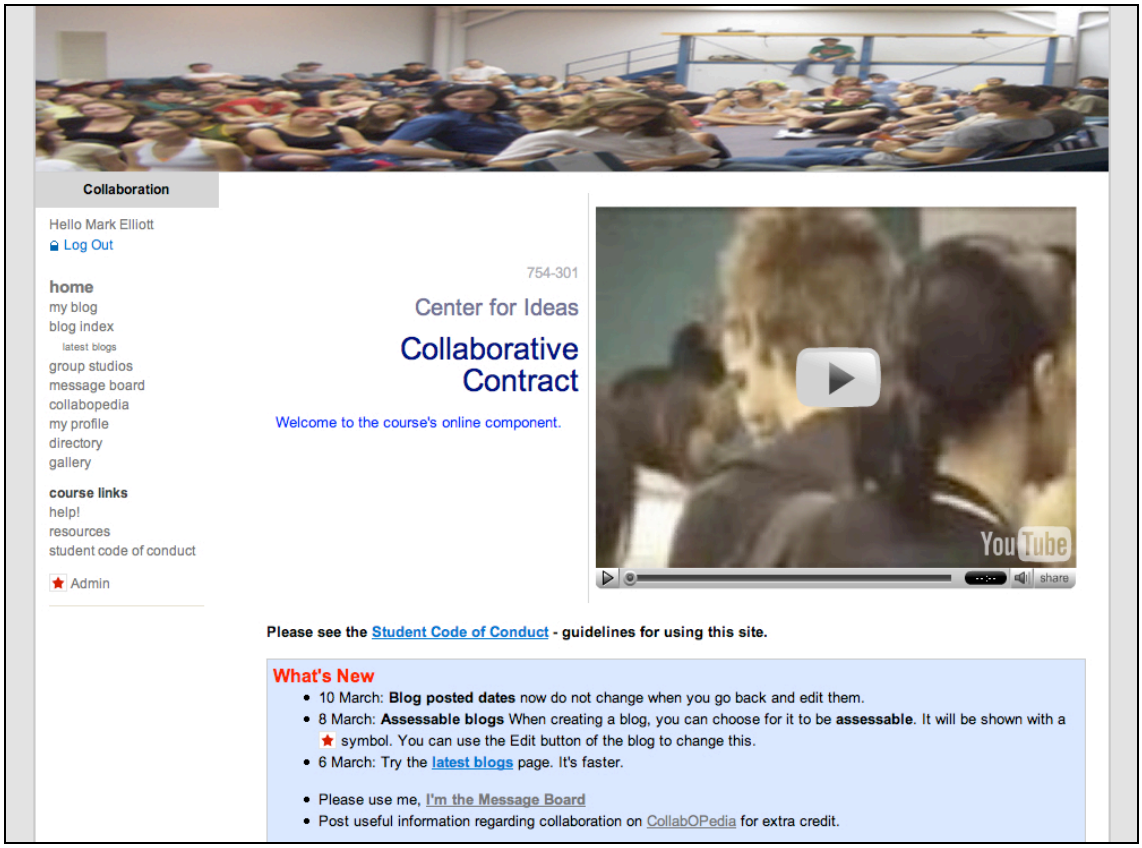



Figure 6.3.

Collaborative Contract online environment, 2007, home page

Upon reflecting and redesigning for 2006, the only major change was the decision to add another level of social networking, a mini blogosphere.[139] While we did have some support for blogging in the 2005 version, it was *very* basic. In combination with the fact that the nature of the blogosphere seemed to fit well with the idea of creating a 'microcosm of discursive collaboration', and after having seen it tried out in other educational contexts, I made the decision to expand this component. It was hoped that the relationships between individual blogs (in this case, journal-like postings of the students' experiences and thoughts in relation to collaboration) might generate additional learning experiences through the proximity of their blogs as being part of the same website, as well as by the common experience the course provided. This choice proved well and the blogging functionality is now one of the environment's core features. The blogosphere is driven largely by assessment—the students post one fifty word blog post per week for ten weeks, the subject of which being on, about or around

[139] The usual application of the term 'blogosphere' is the notion of the wider collection of blogs forming an ecology or community of interactions. For more information, see the Wikipedia article, 'Blogosphere', <http://en.wikipedia.org/wiki/Blogosphere> retrieved 22 April 2007.

collaboration. Since the blogosphere spurs some students to write more than the requirement, we incorporated a feature that allows the students to identify which blogs they wish for us to assess (marked with a red star in the 2007 installation).

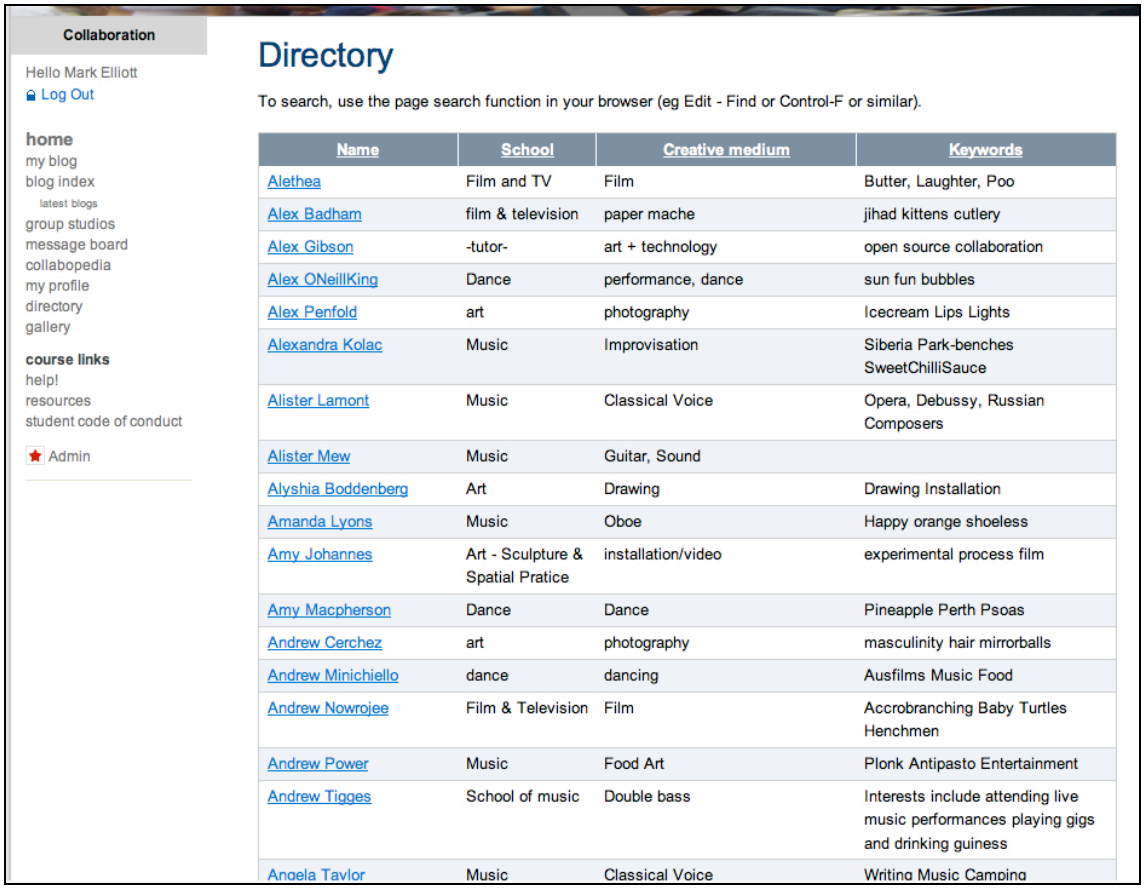
This type of marking of posts is representative of marker-based/qualitative stigmergy and interestingly, this raises the prospect of 'stigmergic teaching and learning'. Reviewing blogs marked for assessment and leaving occasional comments in response provides teachers with an indirect means of engaging and imparting instruction. While this is by no stretch of the imagination a substitute for direct interaction with the students, it does provide a means for new and additional forms of interaction in resource restricted teaching environments. In asking a late arrival to the course if she was clear on how to approach the writing of her blogs, her answer reinforced the concept of stigmergic learning—she replied, 'can't I just read other peoples"? This indicates that stigmergy may already be a part of the younger generation's approach to learning online (similar to the 'view page source' example provided earlier). Of course, the very notion of engineering a blogosphere for the educational dissemination of information relating to student experience and reflection is stigmergic teaching in itself. However the leveraging of the collective intelligence and indirect interactions generated by the group to help inform and teach itself requires a level of trust in the process as well as a 'hands off' teaching approach which differs considerably from more traditional methods.

Apart from blogging, the site is currently exploring a range of functionality, all of which also falls under the rubric of stigmergic teaching and learning. There are currently two main categories of functionality to the site.

The site provides social networking opportunities (primarily through identity support) through the functionality of:

- A directory of the student body listing email (linked to from their name), school, creative media and interest key words, enabling students to contact one another individually or collectively and to have some sense of each other's artistic interests and orientations (figure 6.4);

- Identification of blog authorship and navigation via an index, enabling students to quickly look up their friend's or view the most recent postings (figure 6.5; see navigation links to 'blog index' and 'latest blogs' in the left hand column);
- Identification of their association with a collaborative group and its work (see figure 6.7);
- Fora with the capacity for students to create new threads for discussion as well as advertising of their creative projects (see left hand navigation links).
- Basic coordination tools for each of the collaborating groups, a message board, wiki note pad and calendar (located on each group studio page).




| Name | School | Creative medium | Keywords |
|---|---|---|---|
| Alethea | Film and TV | Film | Butter, Laughter, Poo |
| Alex Badham | film & television | paper mache | jihad kittens cutlery |
| Alex Gibson | -tutor- | art + technology | open source collaboration |
| Alex ONeillKing | Dance | performance, dance | sun fun bubbles |
| Alex Penfold | art | photography | Icecream Lips Lights |
| Alexandra Kolac | Music | Improvisation | Siberia Park-benches SweetChilliSauce |
| Alister Lamont | Music | Classical Voice | Opera, Debussy, Russian Composers |
| Alister Mew | Music | Guitar, Sound | |
| Alyshia Boddenberg | Art | Drawing | Drawing Installation |
| Amanda Lyons | Music | Oboe | Happy orange shoeless |
| Amy Johannes | Art - Sculpture & Spatial Pratice | installation/video | experimental process film |
| Amy Macpherson | Dance | Dance | Pineapple Perth Psoas |
| Andrew Cerchez | art | photography | masculinity hair mirrorballs |
| Andrew Minichiello | dance | dancing | Ausfilms Music Food |
| Andrew Nowrojee | Film & Television | Film | Accrobranching Baby Turtles Henchmen |
| Andrew Power | Music | Food Art | Plonk Antipasto Entertainment |
| Andrew Tigges | School of music | Double bass | Interests include attending live music performances playing gigs and drinking guiness |
| Angela Taylor | Music | Classical Voice | Writing Music Camping |

Figure 6.4.

Collaborative Contract online environment, 2007, student directory

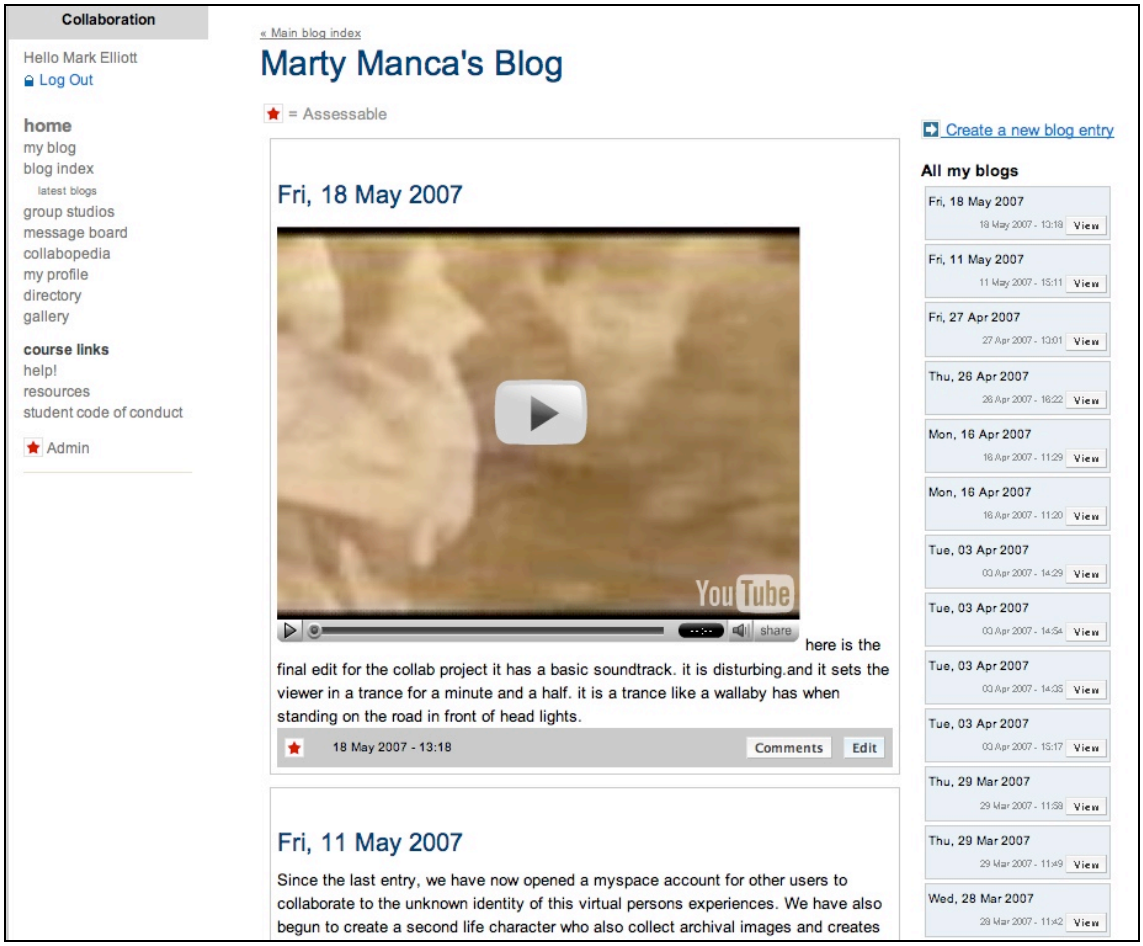



Figure 6.5.

Collaborative Contract online environment, 2007, blog

Project documentation is an important aspect of the current version as this component serves as the primary means of assessing the groups' work (each student's marks are divided between 50% blogs (individual), and 50% group project (collective).

- 'Group studios' provide a localised point of interaction for collaborative groups, listing a summary of the project, the group's members and tutor, upload capacity for assessable documentation of the projects,[140] and a basic wiki page for the collaborative drafting of a 500-word report written by all group members (see figures 6.6-6.8).

[140] The full incorporation of online assessment has only taken place as of 2007, with 2006 being a transition period when students were strongly encourage to upload their assessment but it was not mandatory. Even this year, as the student's ability to digitise their work is not evenly distributed across the VCA and there is not enough resources for it to be fully supported within the course. As a result, it is likely we will be accepting some submissions in some form of 'hard copy'. The teachers will then upload this material themselves for the purposes of archiving.

- An experimental knowledge base, 'Collabopedia', is also provided for cataloguing information that might be helpful for collaborating students in future years. Its use is optional, but with the reward of one to two points extra credit for considered entries. Each year's postings are rolled over to the next year's installation (see left hand navigation links).

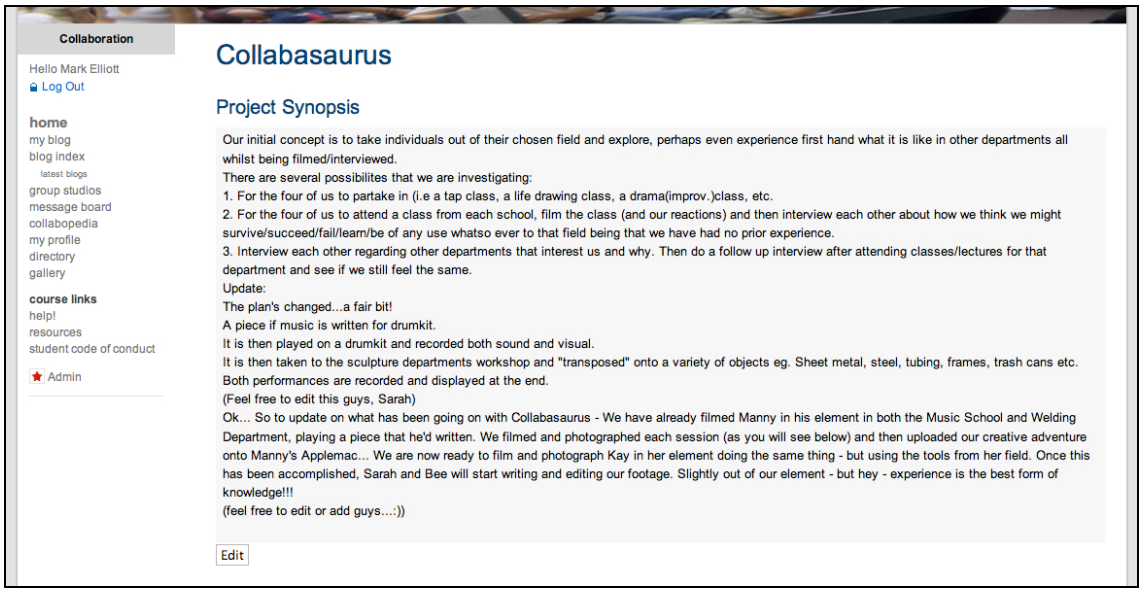



Figure 6.6.

Collaborative Contract online environment, 2007, group studio synopsis

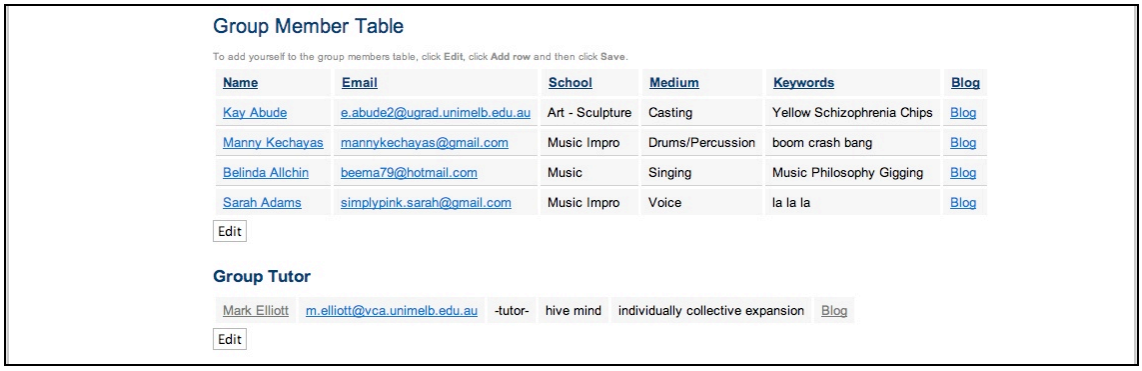



Figure 6.7.

Collaborative Contract online environment, 2007, group studio members

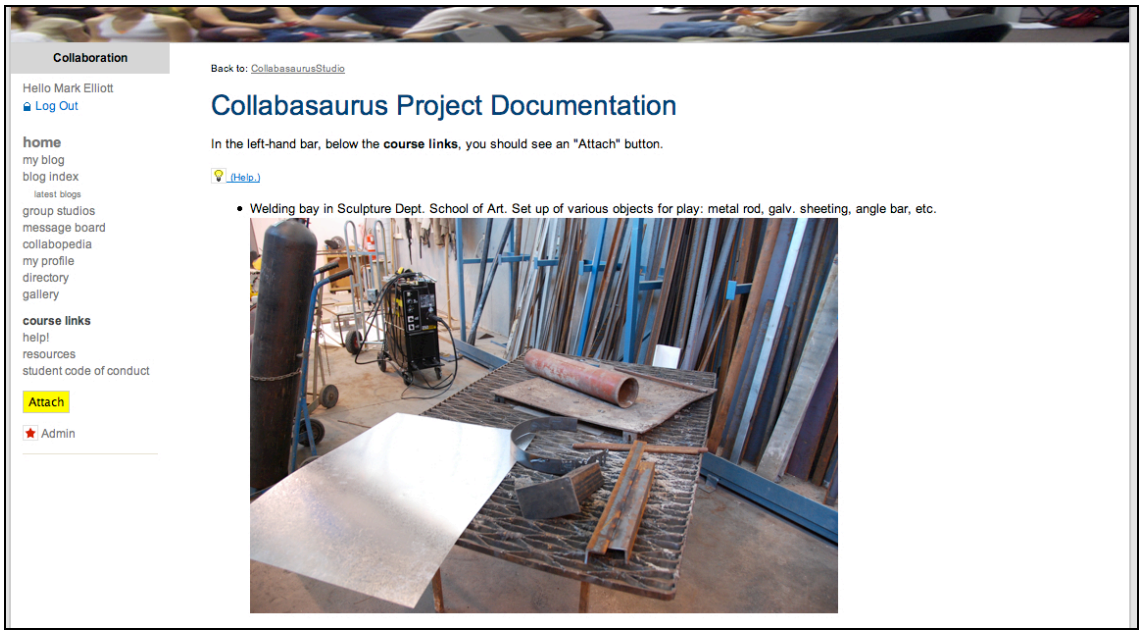



Figure 6.8.

Collaborative Contract online environment, 2007, group studio documentation

Aside from the design and implementation of the online environment, the other major course structure change suggested was weekly tutorial style consultations with the students. Prior to this addition, the students had no regulated contact regarding the development and communication of their projects. Additional changes to the course structure include supporting group mixing across faculties in the early weeks of the course as students have a particularly difficult time engaging across the boundaries of their community of practice. From the perspective of the communities of practice model, as communities engage in their practice (i.e. the students learn about and enact their chosen disciplines within their differing school context), they forge a group identity which tends to form a powerful boundary of membership, often acting as a barrier to cross-practice interrelations (Wenger 1998:104).

These early experiments in stigmergic teaching and learning (as well as teaching collaboration) have impressed upon me a number of key points:

### The importance of superordinate goals in self-moderation

With some two-hundred blog posts being written each week and upwards of two thousand being generated over the period of the ten week course, moderating is crucial but difficult if not impossible to be conducted as the posts are being published (this may

happen any time of the day, any day of the week). Moderating posts prior to publication was initially considered, however we felt that much of the connection with the act of publishing would be lost if they had to wait for approval, and more importantly, it would signal to the students that they were not free to express themselves in a natural way. Moderation (and especially self-moderation) in this context is of particular importance as a number of creative arts students (and artists in general) base their practice upon pushing boundaries and challenging assumed freedoms. While this is of course a valuable aspect of artistry, the practice may be employed to better or worse effect. In the first year of running the blogosphere as part of the curriculum (2006), we had a small number of students being abusive in their blogs, both indirectly (towards groups of people in specific faculties) and directly (to named individuals). However, as soon as these posts were discovered, they were removed and replaced with a notice explaining why such behaviour was unacceptable, as well as how it infringed the wider College code of conduct and what disciplinary measures could be expected if such activity continued. This had the immediate effect of rallying students against those who had been abusive, eliciting apologies from the offenders within days. In other words, by stating clear goals as to what the course was trying to achieve in terms of its approach to its interactions, students began to moderate not only their own content, but other student's activities as well. It is also worth noting that this year (2007), since the clear posting and discussion of such goals for conduct from the start of the course, we have had no further cases of abusive behaviour (to our knowledge) within the blogosphere.[141]

### Cross-boundary collaboration: flattening hierarchies

Since incorporating the online environment into the course material, I have received a considerable amount of input in the course development from students, this having the effect of instigating a type of cross-boundary collaboration between students and the teaching staff. This collaboration has occurred both indirectly, through incorporating and discussing student suggestions posted to the site's fora, as well as directly, via emails, conversations and even explicit collaborative projects designed to collaboratively address such development. In one case, the site acted as a boundary object between the teaching objectives and that of a student's collaborative interest's. In

[141] However, it has recently come to my attention that a group's members has used their blog postings as a means of finger-pointing and blaming one another for their project's apparent failures. While this is perhaps not ideal conduct, it is fairly representative of less successful collaborative ventures.

2005, a student's inquiry prompted the formation of a student/teacher group that collaborated on the system from a bird's-eye view, thinking about how to better facilitate the course and system objectives from a both perspectives. Figure 6.9 illustrates a prototype outcome of this collaboration, attempting to devise a method for representing the individual and group relationships within the course (this component is yet to be implemented due to lack of resources, however it is hoped that it will be in coming years). In writing about his experience, this particular student felt that '[w]hile...the traditional teacher/student relationship still existed online, freedom of expression became more of a level playing field, resulting in a new learning experience.' And that for him, 'this method of teaching was much preferred over the standard one-way teacher/student relationship...' Such experiences represent a shift from traditional top-down teacher/student roles, to a more 'flattened hierarchy' which is characterised by real time response and collaboration in regard to student/teacher interaction and course design. It is also worth emphasising here that it was the decision to utilise open source software that enabled the capacity to redesign aspects of the collaborative environment in response to student suggestion.

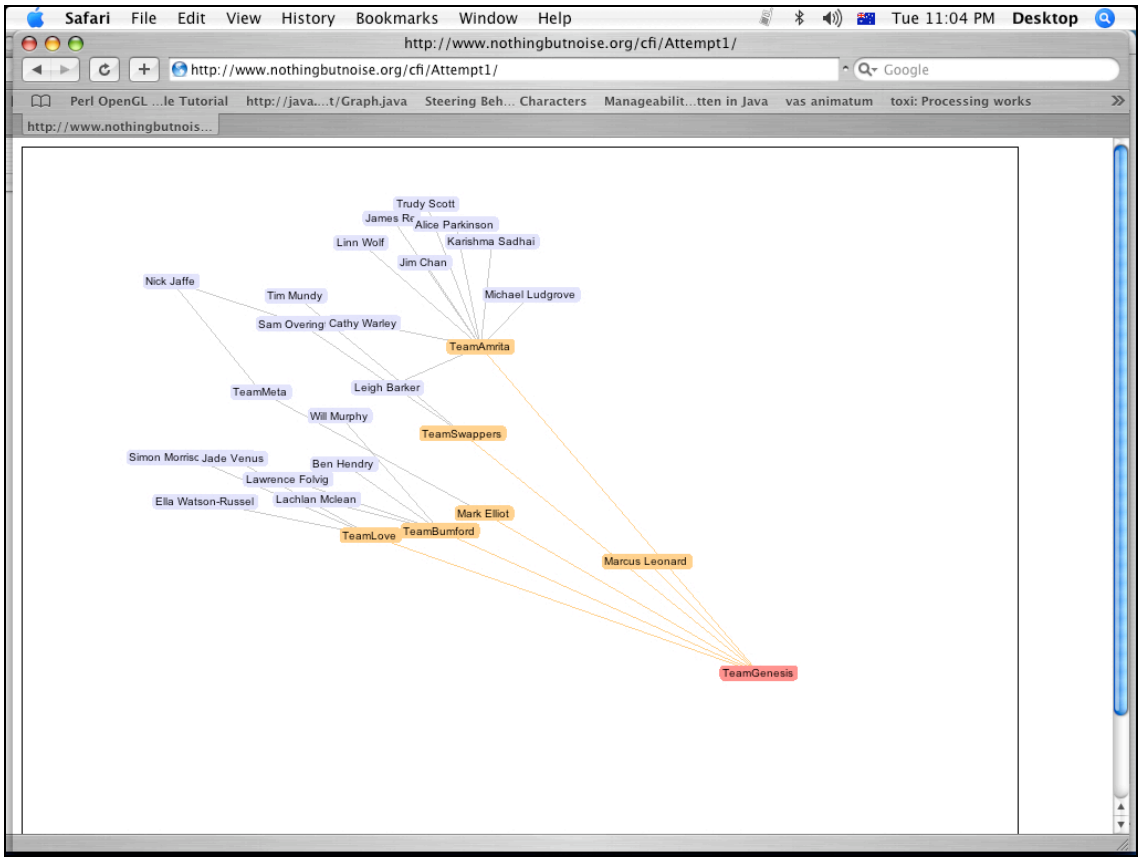



Figure 6.9.

2005 Collaborative Contract student, Nick Jaffe's, social network visualisation tool, designed in collaboration with course teacher, Mark Elliott

## Don't prescribe the nature of collaboration to artists!

Our initial attempts at conveying current research on and around the subject of cooperation and collaboration were met with rather fierce resistance amongst some students. While many were receptive to such research and expressed a strong interest, it appears that a reasonable proportion have their own strong ideas in relation to collaboration and cooperation, and or do not want to be engaged directly on the topic, preferring instead to leave it unscrutinised. However this year has seen a far less resistance to the notion of 'forced collaboration' (the course is a common curriculum hurdle for the VCA's undergraduate degree across all schools). This is likely the result of leaving more of the discovery of what collaboration is and means up to the students, as well as by providing the option for the few students set firmly against collaborative exploration to take another course.

More generally and critically, (as previously mentioned) the sheer scale and pace with which the blogosphere blooms presents definite challenges regarding moderation—in terms of keeping up with it and finding the necessary time to review the posts as they are published. Additionally, user participation could be better, although with each passing year, the students seem to make significant leaps towards becoming more adept and interested in engaging online activities. On the whole, the experience of designing and implementing stigmergic teaching and learning has been a valuable and productive experience, and represents a growing area certainly meriting further research and application.[142]

## 6.2. The Australian Bill of Rights Initiative

The idea for the The Australian Bill of Rights Initiative, an experiment in the collaborative generation of an Australian bill of rights, arose as the result of discussions in 2005 with a lawyer who is a good friend of mine, Mimi Marcus. With no federal bill of rights to speak of, the Australian justice system does not have explicit mechanisms for the protection of even basic freedoms such as speech, association, expression and movement. In discussing the advice provided by the Australian high court judge, Justice Kirby and others who advocate for such a bill, we began exploring the idea of developing a website and an associated organisation geared towards stimulating discussion on and around human rights through engaging both everyday civilians and legal experts in the process of drafting a bill of rights. It took some months before concrete plans were formed, but not long after they were, we began constructing a wiki-based website to explore the possibilities. One year later (mid 2006) we had a functional collaborative site with a well-developed set of resources for interested parties to engage in the collaborative drafting of a bill of rights. Figure 6.10 shows the current design and home page, while 6.11 illustrates the bill of rights 'MasterDocumentView' which enables a participant to view all current articles in one document including links to the individual articles as well as their associated discussion pages. (See accompanying DVD-Rom for an offline version of the site, or visit <http://abri.org.au>.)

[142] See also the Global Modules program offered by Champlain College in Burlington, Vermont, USA, within which CFI students have successfully participated, <https://my.champlain.edu/public/global.modules/mBoard/> retrieved 27 April 2007. A description of the program can be found on the 'Global Modules Blog', <http://globalmodules.blogspot.com/> retrieved 6 May 2007.

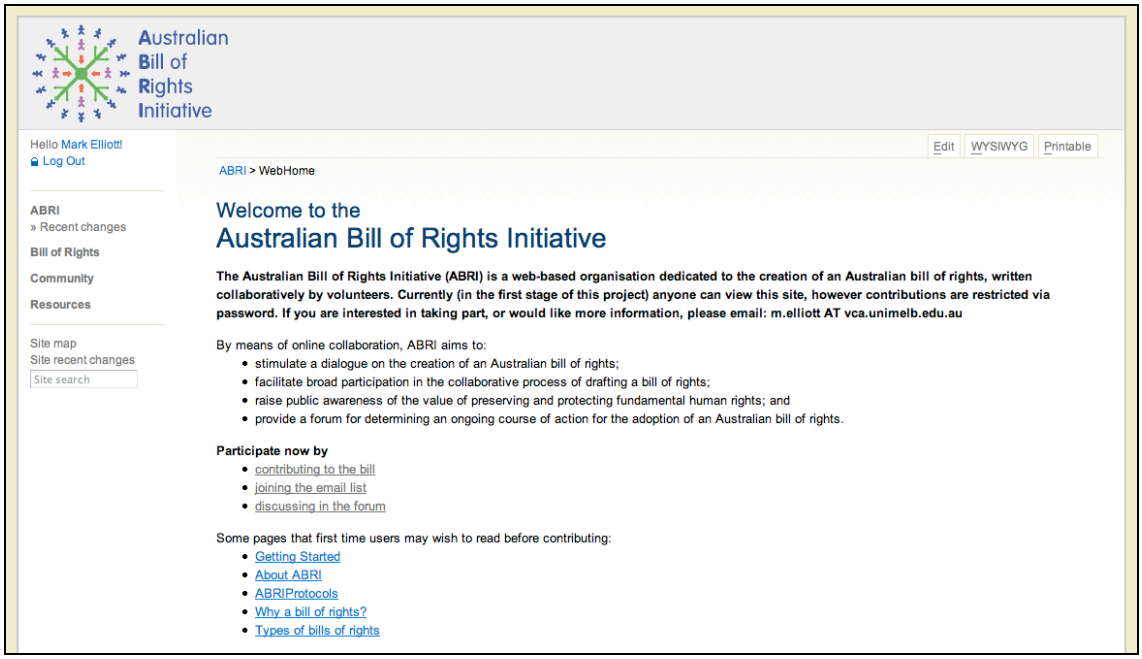



Figure 6.10.

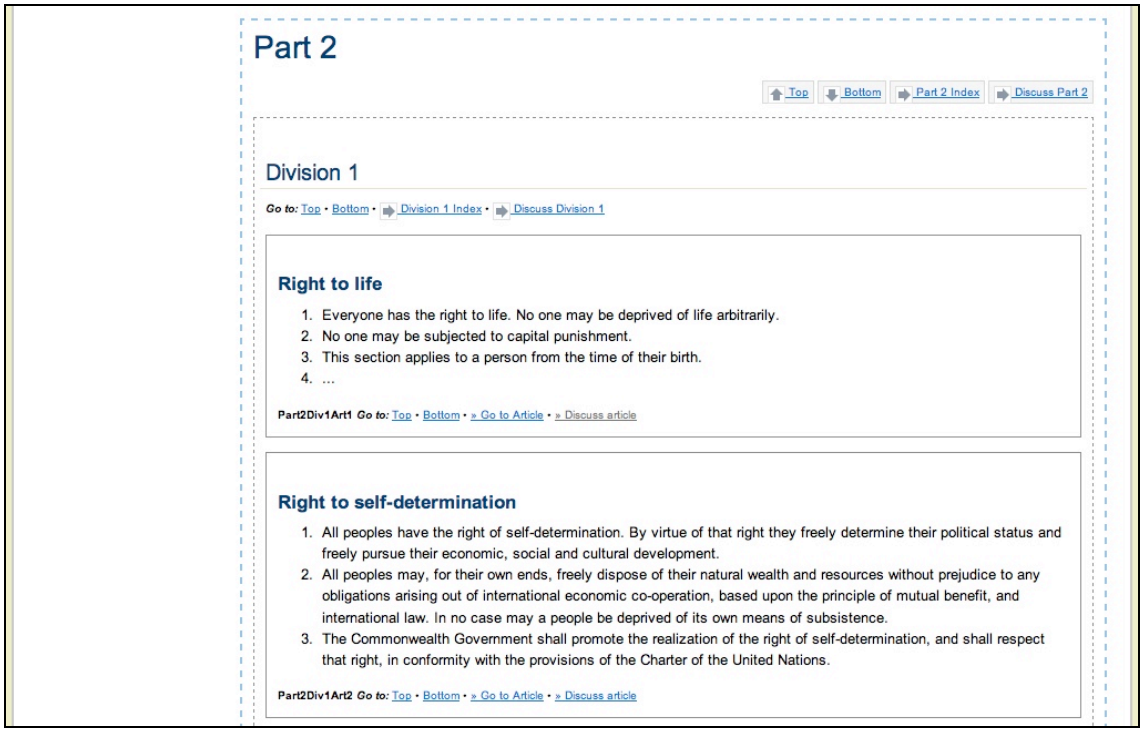
Australian Bill of Rights Initiative, home page

### 6.2.1. Interests, Objectives, Outcomes & Reflections

While I am personally very interested in the ongoing development of human rights and the exploration of a bill of rights for Australia, my deeper interests lie in the potential role that mass collaboration might play in the open access, collaborative development of public policy and governance in general. In a simplified analysis of the current state of Western democracy, the gap between the civilian's vote and the execution of political office seems to be growing, at times to the point of disconnect. Within Australia such concerns include, powerful lobbying organisations influencing governance outside of the democratic process, politicians who promise whatever is needed to gain office but do not follow through once elected, majority sentiment unable to halt unilateral international invasions, closed door caucuses determining policy and legislation which violates the rights of asylum seekers, refugees and indigenous communities according to our obligations as signatories to the UN's *Universal Declaration of Human Rights*, et cetera.

Drawing upon models provided by the Open Source Software movement, Wikipedia and other mass collaborations, it might be possible to employ similar processes in

governance allowing interested individuals to stigmergically contribute to a great variety of tasks, decisions and creative endeavours involved. Further, if threshold tipping-points were achieved it is likely such activities would engender emergent communities of practice which could operate in conjunction with expert/elected consultation. While it is unclear how such activities might reshape our notions of freedom, civic participation and political rights and responsibilities (to say nothing of our very conception of democratic governance) such questions were, and still are, my artistic motivations for composing this particular collaboration.



Part 2

Top | Bottom | Part 2 Index | Discuss Part 2

Division 1

Go to: Top • Bottom • Division 1 Index • Discuss Division 1

Right to life

1. Everyone has the right to life. No one may be deprived of life arbitrarily.
2. No one may be subjected to capital punishment.
3. This section applies to a person from the time of their birth.
4. ...

Part2Div1Art1 Go to: Top • Bottom • » Go to Article • » Discuss article

Right to self-determination

1. All peoples have the right of self-determination. By virtue of that right they freely determine their political status and freely pursue their economic, social and cultural development.
2. All peoples may, for their own ends, freely dispose of their natural wealth and resources without prejudice to any obligations arising out of international economic co-operation, based upon the principle of mutual benefit, and international law. In no case may a people be deprived of its own means of subsistence.
3. The Commonwealth Government shall promote the realization of the right of self-determination, and shall respect that right, in conformity with the provisions of the Charter of the United Nations.

Part2Div1Art2 Go to: Top • Bottom • » Go to Article • » Discuss article

Figure 6.11.
Australian Bill of Rights Initiative, bill of rights

While we have had ABRI's framework for participation build for almost a year now which enables contribution to a draft bill, fora, email list access and extensive resources on the subject, the directions and activities of this project have take a few slight twists and turns. Primarily, the central issue through out 2006 was one of process and participation. Initially we had conceived of drawing upon Mimi's legal contacts in order to include experts in the discussion and drafting process, in the hopes to collaboratively establish the scope, general structure and legitimacy of the project before opening it up to the general public. However, we have since discovered that while many people

expressed enthusiastic interest in the project, this did not necessarily correspond to action. In fact, it seems that very few of the practitioners we approached in Australia's legal community have the time or inclination to take part in such a project. Perhaps this may change in coming years.

This realisation sparked a change of tact, with Mimi, Marcus Leonard and myself deciding to go back to the drawing board, but this time with an expanded core group of collaborators. As of early 2007, we began tapping our networks and drawing together a handful of particularly interested and dedicated participants in the hopes of forming an expanded core group for the purposes of broadening our perspectives, ideas and resources. This has proven to have been a wise decision as there is renewed progress regarding the directions of the project, with new members instigating structured investigations into the project's objectives, mission, visual branding and the exploration of widening participatory structures for added inclusivity (see figure 6.12). Specifically, by providing a sliding scale of possible interactions, annotations and activities, we hope to engage a wider cross-section of Australia's constituency in hopes of reaching a tipping-point towards larger scale participation. Upon determining the specifics of newer approaches to interaction, we plan to conduct a usability study before a full redesign of the site (currently planned for mid 2007).

Figure 6.12

Core ABRI members collaborating, left to right: Adam Mills, Alex Gibson, Lucas Maddock, Mark Elliott, Keri Christensen, Mimi Marcus and Matt Daniel; photograph by Marcus Leonard

While this project has yet to reach its full potential as a mass collaborative enterprise, the emergence of similar projects in other parts of the world suggest that this approach may bear fruit. Specifically, the experiment of Wikocracy.com, which aims to 'see what happens when everyone can write and revise the law',[143] and especially the activities of MorePerfect.org. MorePerfect.org's superordinate goals state that they strive to enable 'more direct public involvement and participation' and to create 'a marketplace of ideas where we, the people, can collaborate with each other on matters that affect our daily lives'.[144] Of particular note is their recently commenced wiki-based projects providing participants the ability to edit a version of the United States bill of rights and constitution.[145] While these projects have also yet to garner significant activity (although based upon the bill of rights history page, there has been a reasonable amount of engagement), such processes are very new and may require more time and development to establish themselves through gaining the public profile needed to reach a tipping-point of participation.

From a critical perspective, the online situation of ABRI presents a possible barrier to entry for those who may be interested in participating but who do not have the confidence, skills and or access to online infrastructure. This issue has prompted ABRI's members to discuss the possibility of developing programs which seek to include members of the Australian community who may fall into this category via on location, print and discussion based engagement.

Another potential criticism is that the project's open access approach to participation may lower the quality of a resulting bill due to the lack of experience, knowledge or skills of the participants. This concern is being addressed through the inclusion of participating legal experts and practitioners. In addition, the project's secondary aims are to promote awareness regarding human rights and therefore, the quality of the a

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[143] Wikocracy home page, <http://www.wikocracy.com/wiki/index.php/Main_Page> retrieved 22 April 2007.
[144] MorePerfect home page, <http://www.moreperfect.org/wiki/index.php?title=Main_Page> retrieved 22 April 2007.
[145] See 'Bill of Rights', MorePerfect.org, <http://www.moreperfect.org/wiki/index.php?title=Bill_of_Rights> and 'Constitution of the United States', <http://www.moreperfect.org/wiki/index.php?title=Constitution_of_the_United_States> retrieved 22 April 2007.

resulting bill is in some respects secondary to stimulating debate and awareness surrounding the topic. However, the trained legal participants have so far successfully achieved translating the contributions from laymen into that of the legal framework.

A final concern is that of the technological demands that are made upon the participants. Even though the wiki is fast becoming a commonplace web tool, there are a great many who do not yet have such skills. This represents a considerable barrier to participation (mainly it appears as a result of lack of confidence in engaging an unknown process). This concern has become a central focus for the newly formed core group's exploration of 'layers of participation'—the provision of varying means of contribution through different channels, media and methods which cater for varying levels of interest, access and capacity. This approach is also tantamount to providing the boundary object attributes 'accommodation' and modularity'.

With Google's Chief Executive, Eric Schmidt, recently citing user-generated services such as Goolge Video[146] and YouTube.com in his advice to Republican governors that those who most effectively take advantage of the new capacities of the Internet will be the 'the winners of the next election',[147] the role of online participatory activities can only play an increasing part in the politics of tomorrow. From the broader vantage point of reviewing, analysing and taking part in the emerging capacity associated with stigmergic coordination, cooperation and collaboration (as well as my own perspective on the efficacy of contemporary Western democracy) I tend to agree with Benkler that, 'there is more freedom to be found through opening up institutional spaces for voluntary individual and cooperative action than there is in intentional public action through the state' (2006:22). However, only time will tell if participatory democracy can bootstrap itself into existence through the utility of mass collaborative processes. As the authors of *Wikinomics* ask,

> Why not open source government? Surely we would make better decisions if we were to tap the insights of a broader and more representative body of participants. (Tapscott & Williams 2006:25).

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[146] See <http://video.google.com/>, retrieved 28 April 2007.
[147] See, 'Google CEO calls Net key to White House', posted on ZDNet.com, November 29, 2006, <http://news.zdnet.com/2100-9588_22-6139518.html?tag=zdfd.newsfeed> retrieved 28 April 2007.

## 6.3. MetaCollab.net

In commencing my research for this PhD, the distinct lack of theory surrounding the process of collaboration immediately struck me as an incredible opportunity for original exploration. As mentioned in chapter 2, there have been small amounts of research conducted within various disciplines, however, this research remains hidden within institutional silos and disconnected from wider discourse. Additionally, there has been no concerted attempts at formulating a generalised theory of collaboration which might serve to inform practitioners interested in developing methods and frameworks for employing this process as a strategy for problem solving in a variety of settings. These understandings contributed to the conception of MetaCollab.net, an open research project aimed at providing a repository and collaborative workspace for existing and emerging theories and understandings surrounding collaboration. In providing such a workspace, it is hoped that connections might be drawn between and amongst the various contributions, thereby leading towards more generalised insights into the process across differing applications and perspectives.

### 6.3.1. Interests, Objectives, Outcomes & Reflections

As an artist, the notion of a union of form and content provided a compelling aesthetic in this collaborative composition, in that the process of collaboration might lead towards theories and understandings regarding this very same process. Another explorative interest for this project is that of mass collaborative open research in general. By developing a commons of knowledge through collective investigation and creation, such processes lead to a generation of contributions embodying a high level of use-value for the participants as well as external consumers, while providing a pathway for such consumers to contribute based upon the responses to their consumption. This of course embodies the academic and scientific process in general, but with much shorter production cycles as well as increased input into peer review and the potential to draw upon more perspectives in the formulation of the ideas at stake. While the value and utility of mass collaborative research is still yet to be recognised or determined by the larger research community, it is hoped that experiments such as MetaCollab.net will help instigate such input and evaluation. Figures 6.13 and 6.14 show the site's home

page and its featured article. (See accompanying DVD-Rom for an offline version of the site, or visit <http://metacollab.net>.)

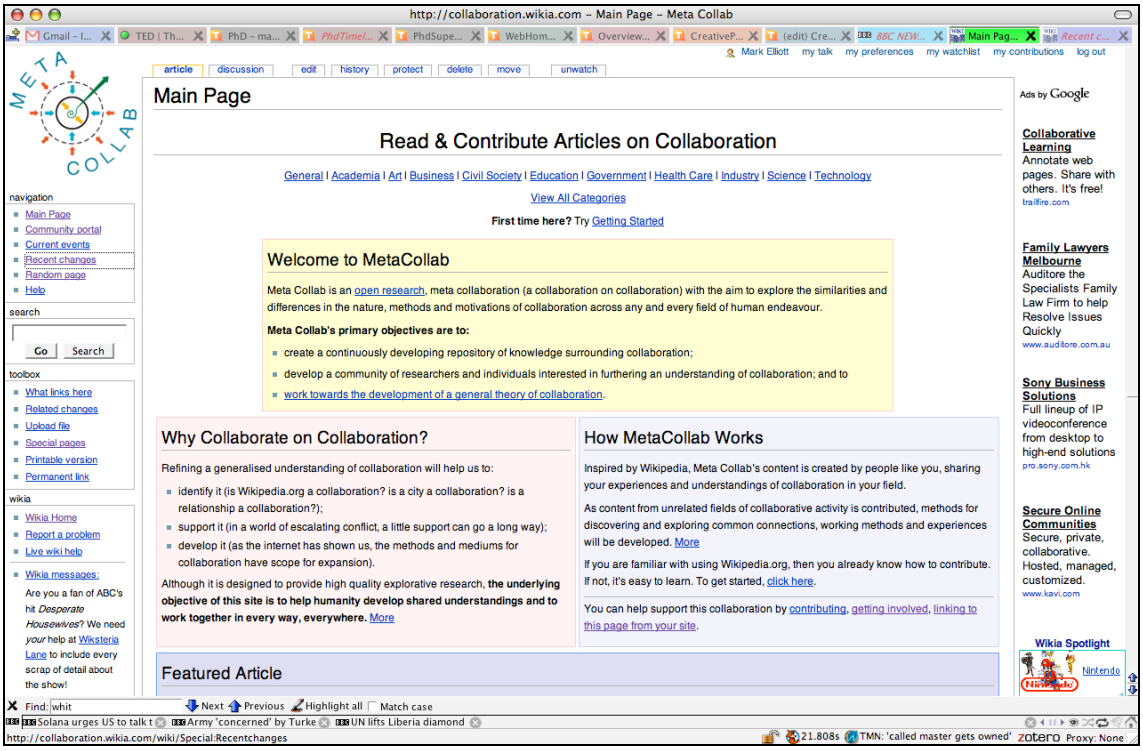


Figure 6.13

MetaCollab.net home page


Figure 6.14

MetaCollab.net home page, featured article

Soon after developing the first prototype of the project's site in early 2005, it was decided to migrate the content to the hosting of Wikia.com, a commercial spin-off of the Wikipmedia Foundation (the foundation which administers Wikipedia.org and her sister projects). Wikia.com provides a service they call 'wiki farming', where the costs of hosting and administering a wiki-base collaborative project is covered in exchange for the input and management efforts of the project's 'founder', as well as the listing of 'Google ads' in the sites' margins. Wikia.com also provides a pool of some 122,000[148] possible participants from its 2,600+[149] wikis who often contribute across the wiki projects interconnected by the system's workspace and community of practice. While all of Wikia.com's 2,600+ wikis would not necessarily qualify as mass collaboration (many are at this point very small endeavours and thus represent digital stigmergic collaboration), a great number of them do.[150] This incredible amount of activity is testament to the success and viability of the stigmergic and mass collaborative process in the wiki medium.

While the objectives of collaboratively developing a general theory of collaboration are yet to be realised, the project has matured to the state of a functioning mass collaboration. Soon after migrating to Wikia.com (then called Wikicities.com), MetaCollab.net began receiving regular contributions which it still garners at a varying rate ranging from one per day to one per week with the 'Active Users' page listing 64 registered contributors as of 24 April 2007 (bearing in mind that this count does not include anonymous editors of which there have been many).[151] With Google registering approximately 28,400 returns for the search 'metacollab' and 9,310 for 'meta collab', the site now hosts nearly four hundred pages (of which 150 are likely to be legitimate content pages), while there has been 10,489 page views and 3,619 page edits since the wiki was migrated to Wikia.com on the 3rd of October, 2005.[152]

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[148] Accurate as of 23 April 2007. For current statistics see <http://www.wikia.com/wiki/Special:Statistics> retrieved 23 April 2007.
[149] Message from 'John Q' on the Wikia-l email list, 'We have 2600+ wikis, each with their own Local Settings file and configuration info...' received 27 April 2007.
[150] See Wikia.com's 'Popular Wikia Wikis' article, <http://www.wikia.com/wiki/List_of_Wikia> retrieved 1 May 2007.
[151] See <http://collaboration.wikia.com/wiki/Special:Activeusers>, retrieved 22 April 2007.
[152] These figures are accurate as of 22 April 2007. For up to date statistics, see <http://collaboration.wikia.com/wiki/Special:Statistics>.

The experience of founding and developing MetaCollab has taught me many important lessons regarding the engineering of mass collaboration. Perhaps the most valuable of these is the necessity of 'tending the garden'. As stigmergy is an autocatalytic activity—its activity generates more activity—I have observed distinct patterns associated with my interactions with the site. Specifically, the more I engage with it, the more others tend to. This is probably the result of a number of dynamics, not the least of which being my own tendency to communicate to others about my activities, however the pattern remains just the same. No doubt this pattern influences the activities of participants involved in many other mass collaborative projects, as the feedback provided by seeing others contribute to a project you care deeply about and have invested many hours in provides quite a 'buzz'.

While spam, vandalism and malicious attack are always a part of such open infrastructures (MetaCollab requires no registration to participate), the ability to respond to and repair such damages is made fairly easy by its software (Mediawiki[153]). Ensuring that it is easier to 'rollback' a damaged page and or block a disruptive user or 'spambot' than it is to create the disruptive annotations in question, skews the activity in favour of positive development. Additionally, various user access levels exist within Wikia.com's infrastructure which, depending upon the level, enables a participant to delete and protect pages from further edits by those who are deliberately hindering the project's progress or misusing the site.[154] While those who administer such wikis generally avoid this practice in the spirit of open access, occasionally pages such as a home page may attract a high level of vandalism and thus warrant edit protection. Currently no pages in MetaCollab.net are protected, although many IP address have been blocked, primarily due to spamming.

Other than such aspects of routine maintenance, another key observation concerning the administering of mass collaboration is that of community building. Maintaining and contributing to email lists provides a valuable means of community building through promoting activities and stimulating interaction, as does engaging in discussion on 'talk pages' associated with specific articles. Many contributors, whether 'newbies' or

[153] This is the same software that us utilised by Wikipedia. For more information, see <http://www.mediawiki.org/> retrieved 1 May 2007.
[154] See 'Help:User access levels', <http://www.wikia.com/wiki/Help:User_access_levels> retrieved 23 April 2007.

'oldies', tend to post to talk pages when unclear of the article's direction or of the relevance of their contributions. Sometimes participants post to these pages when they are unsure as to the best location for their ideas. In any case, responding to and encouraging such ongoing engagement seems to go a long way in the building of a 'community of participation'.

Perhaps most importantly, MetaCollab.net has provided me with the potential to expand my cognitive capacities in regard to collaboration theory not only into the wider material world through the reification of my ideas into webpages, but into the minds of many others. These others remain largely unknown to me, in that of the sixty-four registered contributors, I have only had conversations with a small fraction of them, the rest being essentially anonymous. Irrespective of this anonymity and our no doubt differing perspectives and different locations around the Earth, we have still managed to establish quite specific and high level points of mutual interests in order to collaboratively develop our understandings through the process of mass collaboration.

## 6.4. Overall Reflections

Upon reflection, the experience of the above projects underscores most significantly the capacity that such stigmergic interaction provides in expanding our capacities to become more direct participants in contributing to our collective understandings through the intersection of our individual pursuits. This capacity is governed by institutions of collective action (as opposed to collectivism) generated through individualistic contributions as participants develop, and as a consequence, share their ideas and experience. This represents a shift away from media channels which are dominated by political or commercial bias, while still allowing for the fact that the interests of the individuals involved and even the hosts of these activities might be political and or commercial in nature (e.g. Wikia.com is a commercial entity). Returning to Benkler's analysis, architectures of stigmergic coordination, cooperation and collaboration,

> ...enable anyone, anywhere, to go through his or her practical life, observing the social environment through new eyes—the eyes of someone who could actually inject a thought, a criticism, or a concern

> into the public debate. Individuals become less passive, and thus more engaged observers of social spaces that could potentially become subjects for political conversation; they become more engaged participants in the debates about their observations. (2006:11)

# 7. Conclusion

> From the beginning, we living beings have been modules of something current evolutionary theory fails to see, a collective thinking and invention machine.
>
> —*Howard Bloom*

Collective creativity and its capacity to reshape the production of our culture in its content, methods and ability to redefine our understandings of the individual and collective, is nowhere more pronounced than in 'mass collaboration'. Through original theoretical frameworks, the central aim of this thesis is to show how mass collaboration is an activity fundamentally dependent upon 'stigmergy', and how stigmergy is a core component of 'collaboration' more broadly. The intersection and synthesis of stigmergy and collaborative activities provides a novel means of conceptualising collective creative *material* production through the process of 'stigmergic collaboration'—participants responding to the creative annotations of others by making further creative contributions.

Stigmergic collaboration, in combination with digital networks and associated technology, provides the necessary conditions that enable collective creativity to scale into the extraordinarily large size and scope that is associated with mass collaboration. These mass collaborations are collections of creative contributions, deletions and modifications made by widely distributed individuals who participate for no reason other than their own individualistic interests. The frameworks developed in this dissertation provide a means for the interrogation, analysis and engineering of the mass collaborative process, which in coming years can only further bloom into an extensive and interconnected network of communities building a diverse and dynamic commons for the enrichment of the wider public.

Following an introduction to the themes involved including a brief literature review, the second chapter, Collaboration, investigates the etymology of collaboration and determines that this activity is distinguished from cooperation by the incorporation of a collective creative component. Using this distinction as a basis, as well as research into definitions arising in disciplinary specific contexts and my own long history of collaborative artistic experience, I provide a definition of collaboration designed to more narrowly restrict the term's usage and conception:

> Collaboration is the process of two or more people collectively creating emergent, shared representations of a process and or outcome that reflects the input of the total body of contributors.

In light of this definition, a number of frameworks for the analysis of social activity are evaluated for their capacities in relation to building a framework for collaboration and mass collaboration, and it is found that a range of theories are of relevance with the notion of stigmergy providing a minimal common ground between them. In order to enable a wider contextualisation for the investigation into the nature of collaboration, I provide a generalised framework for collective activity. This framework sets out primary distinctions between coordination, cooperation and collaboration showing how there is an interrelated and important relationship between the three with coordination providing the necessary conditions for cooperation as cooperation does for collaboration. This framework provides the basis upon which the core nature of collaboration can be elucidated—the collective creation of emergent shared representations. The identification of these characteristics as well as the consideration of the types of communication structures and forms of technological mediation that may intervene, provides the means for a deeper investigation into the process and fundamental elements of collaborative activity. These distinctions provide the means to discriminate between discursive collaboration—the collaborative generation of pure ideas through discussion, and stigmergic collaboration—the externalisation of such ideas through various forms of collective material production.

Chapter 3, Stigmergy, explores and expands upon the framework of stigmergy, tracing its historical and contemporary developments in both theoretical and applied contexts. The framework of stigmergy is reviewed in detail and it is found that this mechanism plays an

active role in not only our day-to-day lives, seamlessly integrating itself into our communities through trail and road formation, building works and even practices within cafés, but in providing the central coordinative mechanism in the rapid evolution of the World Wide Web. This coordinative capacity of stigmergy, that an 'environmental change brought about by one agent's action incites another agent to act in turn, thus unconsciously contributing to their common benefit' (Heylighen 2007a:11), is shown to provide for a wide range of Internet activities. Examples include web navigation through hyperlink placement and selection, Google's PageRank search engine, the capacity for stigmergic learning, the stimulation of the creation of websites based upon their content related existence and the capacity to 'view page source', as well as the gleaning of valuable information from user interactions such as Amazon.com's recommender systems.

More significant still is the emergence of digital stigmergic cooperation and collaboration, thereby representing an extension of the generalised framework for collective activity into that of digital stigmergic contexts. Digital stigmergic cooperation is shown to be characterised by complicity in the procedural requirements of a shared pursuit (the same conditions of non-stigmergic cooperation) with examples provided such as social bookmarking, collaborative filtering, user-generated media sites and political e-lobbying. Digital stigmergic collaboration is introduced, showing how digital stigmergic coordination and cooperation form its enabling conditions and providing the capacity for collaborative output to become a shared digital artefact which may span the Internet's world-wide network, providing simultaneous co-locality to a locus of creative engagement to a near infinite numbers of collaborative participants. Overall, stigmergy is found to play a central role in not only the structure, nature and ongoing expansion of the Internet, ranging from the coordination of its most basic navigational features to the emergence of cutting-edge practices increasingly referred to as 'Web 2.0', but in the evolution of humanity's collective creative abilities.

The fourth chapter, Stigmergic Collaboration, narrows the focus to collaboration in stigmergic contexts, primarily of those taking place within digitally networked environments. I present a framework which shows how stigmergy extends the collaborative process in space, time and mind while increasing its capacities for emergence. Specifically, these capacities are expanded through providing a platform for collocated activity upon

which the creative contributions may dynamically mix and blend via the participants collective consciousness towards the formation of more complex wholes than would otherwise be possible without externalised support. Drawing upon various frameworks for digital, artefact mediated activity, the framework is further developed. Specifically, the theories of distributed cognition and cognitive stigmergy (Ricci et. al. 2006) are utilised in their conception of the 'workspace' as collections of digital artefacts that encapsulate coordinative functions of the collaborative activities (2006:5). The details of the workspace theory are expanded upon, drawing upon contemporary stigmergy research in order to further develop the features of the tool and domain levels of interaction, as well as the various forms and features of the stigmergic annotations and interactions which may occur.

Chapter 5, Mass Collaboration, begins by exploring the forms of technological, sociocultural and legal open access which underpin mass collaborative projects. This is followed by a detailed framework for mass collaborative negotiation which explores the shift that occurs from social negotiation to cultural participation when stigmergic collaboration is mediated via digitally networked workspaces. I expand the framework utilising a number of imported and original theories, including:

- The boundary object (Star 1989), utilised to explain the capacities which help stigmergically coordinate the many diverse perspectives involved in mass collaboration through modularity, accommodation, abstraction and standardisation.
- Wenger's theory of 'communities of practice' (1998), provides an understanding of the role that participation and reification play in the formation of communities in and around mass collaborative ventures;
- Superordinate goals (Sherif 1958) act as a means to coordinate and focus the collaborative efforts of the participants while helping moderate conflict.
- Contributor groups which result from emergent teaming at the mid-level between the individual and the collective that emerge from explicit activities of the community of practice and or implicit interactions arising as a result of stigmergy.

This chapter continues with an examination of the relationship mass collaboration has with peer production and its role as a key player in the emergence of Benkler's networked information economy. This is followed by an overview of considerations and principles for

supporting and designing mass collaboration, structured by a template for analysing collective activity developed through research conducted by the Institute for the Future, Howard Rheingold and Stanford University's *Cooperation Project*.

Finally, the sixth chapter, Experiments in Stigmergic Design & Collaboration, provides an overview of the creative works produced as part of this PhD, providing insights into my interests and objectives in their development, while relating these interests back to aspects of the frameworks presented in the previous sections. I also provide reflections as to their capacity to test the frameworks of stigmergy, collaboration and mass collaboration as well as recommendations made in light of lessons learned through their design and implementation.

## 7.1. On Stigmergy, Power & Politics

The critique of network and innovation based activities is a widespread and important domain of contemporary scholarly activity. The thrust of such criticism is often based in one of two central approaches, the critical analysis of progress as the goal of history, or, the concern that innovation is capturable by social forces which strive to maintain the status quo. Rather than single out a specific layer of cultural action for analysis, such as power relations or the political, this dissertation has driven below such inquiries in an attempt to establish the systemic grounds upon which such activity takes place. Therefore, in relation to other contemporary authors investigating network-based collective activity, this dissertation differs not so much in its general subject matter (i.e. new forms of 'second generation' Internet activity) but at the level in which it describes this behaviour. Instead, it offers a macroscopic view of the underlying structures that enable these behaviours, regardless of whether the goal is new forms of democracy, the generation of wealth, or the articulation of power.

While definitions of 'progress' may differ greatly in various critical contexts, any suggestion that history (material, biological or cultural) may possess some inherent goal tends to garner criticism by a number of authors often representative of the 'postmodern' outlook (Gould 1996; Lyotard 1984). This perspective is easily understood in the context of countless brutal regimes that have, and continue to suppress cultural subsets—even

committing genocide under the assumption that certain branches of biological and cultural 'progress' are more valuable than others. However, a growing number of authors are formulating an alternative perspective to that of the postmodern, one typically characterised by the belief that structures and processes of biology and culture are on a generalised, progressive path towards ever increasing complexity (Bloom 2000; Heylighen 2007a; Wright 2000). My personal understandings and intuitions place me in the latter group, however I did not construct this dissertation's account of stigmergic mass collaboration to support or refute either stance. Rather, its aims are more functional in the desire to further enable an activity that has the capacity for the ongoing extension of collective creativity, regardless of its progressive nature or lack thereof.

The concerns of the second critique, that such innovations may be further extensions or appropriations of a powerful elite with the aim of maintaining or manipulating the status quo are also understandable in today's context where the corporate and governmental structures are predicated on the exploitation (in the most objective sense of the word) of the consumer/voter. However, a number of authors have argued that mass collaborative processes represent a new form of activity which is much less susceptible to such forms of exploitation, manipulation and control (Bauwens 2005; Benkler 2006; Lessig 2004; Moody 2001). While these authors argue in favour of the strengths of mass collaboration (its decentralised, participatory, open, use-value orientation) as well as point to the importance of free access to culture and information, there is the potential that power may be disproportionately exerted at the lower level of code.

Lawrence Lessig's, *Code and Other Laws of Cyberspace* (2000), points to a potential problem which is stressed by Alex Galloway in *Protocol* (2004). This is the problem that, where code is law, it is important that legal minds address the question of code. Galloway's argument further develops this theme, forming the thesis that code as protocol is the form that power takes in the contemporary world and unlike more traditional conceptions of power, is not easy to locate. Protocol cannot be identified as an instrument of some power elite, as might have been the case in earlier periods when power was wielded by kings or by state bureaucracies. Instead, protocol proliferates and reproduces within the network's deep structure. In Galloway's work, any kind of network-based social activity, political struggle or creative activity, takes place under this condition. As a result, mass collaboration cannot

escape its reliance upon protocol at the code level, let alone its generation of additional layers of protocol in the definition of processes and mechanisms for annotation. Therefore, Galloway's criticism is accepted—those who control protocol at its code level, in respects control mass collaborative activity. This concern is perhaps most present and threatening in the struggles for network neutrality—the ability for members of a network to connect and communicate in ways not segregated and or restricted by economic or political institutions or interests.[155]

However, the same argument may be made for a number of other activities that we engage in daily, suggesting that while such concerns are warranted, they do not invalidate the activity. According to the linguist Roman Jakobson (1960), language is a rule-governed system which enables additional forms of activity such as the creation of poetry by adding extra rules, such as rhyme and metre. This builds a picture of the mechanisms of language as a framework that enables connection and communication through building upon successive layers of rules, while restricting users to a prespecified and even institutionalised sets of protocols. Similarly, Heylighen (2007a) argues that stigmergy builds structures which initially enables the coordination of a wide range of activity through the building of pathways reinforced by usage, but which may ultimately restrict, elicit and direct such activity through the pathways it forms. Both systems, language and stigmergy, therefore allow users to say and do anything, so long as they abide by the appropriate rules, the rules of syntax on the one hand, and the pathways established by communities of participants on the other.

Therefore, while the protocol that enables mass collaboration is not necessarily exempt from manipulation and restriction, it does provide an emergent domain which enables new forms of activity, which, like poetry, encourages invention and creativity. Additionally, mass collaboration inherently provides a critique as to the assumptions of sociopolitical power concerning the necessity for the exclusion of participation in order to generate well-formed and informed contributions to culture. The individual stigmergic and mass collaborations instigated as part of this dissertation are examples of just such critiques,

[155] For example, a recent study found that 25 of 41 countries surveyed showed signs of state-sponsored content flitering, see, 'Global Net Censorship "Growing"', BBC News, (online service), <http://news.bbc.co.uk/2/hi/technology/6665945.stm> retrieved 18 May 2007.

which through the invention and addition of protocols, offer new ways of stimulating creativity, innovation and collaboration.

## 7.2. Future Directions: Participatory Governance, Neurohacking & the Global Brain

In reviewing possible future research and application directions for the theories and methods for collective creation reviewed in this thesis, the scope is both diverse and far-reaching. More obvious applications include areas already tapping into stigmergy research, namely that of AI and SI. Such applications include the design of both software and robotic swarming agents for a whole host of activities including terrestrial, planetary and space exploration, data mapping on and offline, as well as genetic and evolutionary computing applications. Similarly, the nascent realm of nanotechnology will no doubt take advantage of the potential of stigmergy (if it isn't already) in its capacity to support the activity of large numbers of simple agents interacting within an environment. Additionally, modelling existing Internet-based stigmergic activities could provide a wide range of data to draw on for the purposes of further simulationing various forms of stigmergy.

As illustrated with the Australian Bill of Rights Initiative and MorePerfect.org, mass collaborative processes offer new and unique means of enabling collaborative participation within the realm of governance and policy writing. It is suggested that this form of interaction, as well as the self-governing forms of communities of practice which emerge surrounding it (i.e. the 'Wikipedian's' and the Open Source Software movement), might point to more abstracted applications in the realm of governance in general. Realms where collective creativity, decisions and consensus are required are candidates for those that might be explored for mass collaborative application. Examples include organisational and business management (as highlighted by Tapscott and Williams (2006)), local community organisations, artist collectives,[156] academic and scientific research communities,[157] and numerous special interest groups.

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[156] For such an example see Polyopticon.org, a community-based, free online tool and resource for artists, <http://polyopticon.org> retrieved 26 April 2007.

[157] See the *Encyclopedia of Life,* 'The Encyclopedia of Life (EOL) is a collaborative global project designed to catalog the complete proteome of every living species in a flexible reference system.' <http://eol.sdsc.edu/> retrieved 28 April 2007. See also the *Earth System Grid,* a project aimed at creating a virtual collaborative

However, future investigations that could more directly contribute to the continued development of mass collaborative engineering are likely to be oriented towards various forms of interaction studies. Developing more advanced means of modelling and visualisation of the interactions and activity which mass collaborative sites not only garner, but record on their servers, is likely to produce new conceptions of the activity as well as new understandings as to its more successful engineering. For instance, dynamic, multidimensional representations of past activity could provide insight into understanding various thresholds and tipping-points, enabling project designers to more accurately plan and design for the numbers and types of participant activity required to kick start a project such as Wikipedia. Additionally, developing real time visualisations of mass collaborative activities could provide critical tools for both future project managers and participants in order to better direct their activities through gaining feedback from the collective's overall efforts as they are occurring.

Interaction studies might also be extended to include the non-computational realm of real world human activities that support and surround their online activities. Ethnographic research which engages theories of distributed cognition (Hutchins 1995a) could be of particular relevance in a humanistic exploration of what it means to contribute to such mass collaborations on the ground level. Such a study might shed light on how to better support participant activities as well as provide important insight into the participant's 'hands-on' usage of the workspaces—how a designer and how a user interact with such sites might be very different in their conceptions and manifestations.

Such insights could help contribute to the design of interfaces and operating systems that encourage and leverage stigmergic interactions. An example of a system beginning to employ such features is the *Sugar* operating system designed by the One Laptop Per Child program.[158] Figure 7.0 shows a screen shot of the networking interface, displaying the status and activities of other users.

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environment which would link distributed centres, users, models, and data in their attempts at visualising and addressing global warming, <http://www.earthsystemgrid.org/> retrieved 28 April 2007.

[158] For more information on this project see <http://laptop.org/> retrieved 26 April 2007.

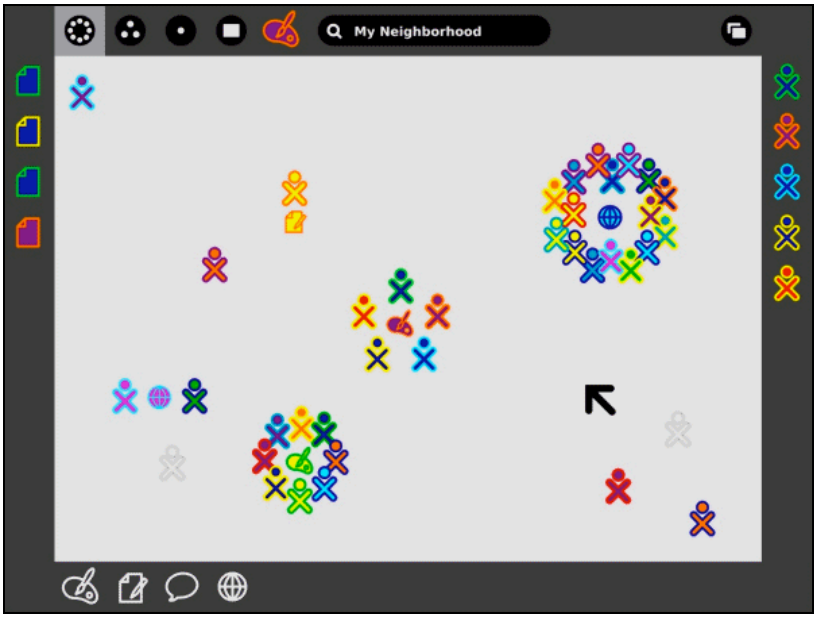


Figure 7.0.

Screen shot of the *Sugar* operating system's networking interface[159]

Another quickly developing interface-oriented area likely to benefit from stigmergy research is that of touch screen technology. The capacity to annotate a workspace by simply touching it is likely to yield many new forms of interaction and annotation, especially in relation to 'multi-touch' technologies. Multi-touch enables multiple points of contact to be registered, i.e. more than one finger or more than one participant working simultaneously on the same screen.[160] As such applications are likely to become common place in the near future with their incorporation into such products as Apple's iPhone,[161] they are likely to trigger completely new forms of stigmergic interactions within individualised networked contexts and public spaces.

Improving various forms of interface with digital stigmergic systems may reach in some respects an apex with the eventual popular adoption of brain-computer interfaces (BCIs). BCIs enable the inputting of signals directly to the brain, most commonly used to restore sight or hearing (Chorost 2005), or, to output signals in order so that computers may receive some form of command. While two-way information exchange has not yet been

[159] Image from the post 'The Sugar UI', *Coding Horror,* (web log), <http://www.codinghorror.com/blog/archives/000762.html> retrieved 26 April 2007.
[160] See Jeff Han's 'Multi-Touch Interaction Research', (online resource), <http://cs.nyu.edu/~jhan/ftirtouch/> retrieved 26 April 2007.
[161] See, <http://www.apple.com/iphone/> retrieved 26 April 2007.

successfully demonstrated[162] Leuthardt et. al. (2004) has shown how a non-invasive system can record electrocorticographic signals from the scalp, enabling users to 'control a one-dimensional computer cursor rapidly and accurately' with a training period of 3-4 minutes (2004:1). No doubt, such technologies will continue to advance, and as they do, the possibility for stigmergic interaction directly via 'brainware' and 'neurohacking' (the design of software engineered to interface with a brain via some form of BCI) becomes an increasing reality. How mass collaboration might manifest if enabled through such technologies certainly falls within the realm of speculation. However given the connection between increased interface and application processing power and increasing variety of annotation (as illustrated by the recent rise of non-textual mass collaborative platforms such as Second Life and Drawball), one can imagine that more direct interface with the brain will at the very least make more diverse and complex forms of annotation possible.

Through the coming years, as our stigmergic intelligence rises with the complexity and diversity of our interactions with each other and the environment, a simple extrapolation reveals that this process is the equivalent to our collective consciousness improving and expanding upon its creative abilities. In other words, we are becoming more creative as a collective—our mobs are not only becoming smarter, but are gaining increasing capacity to creatively express themselves in a manner previously only available to individuals and small groups. What this implies is that not only are we seeing the appearance of new processes that enable such activity, but we are also witnessing the emergence of a new form of agency, one clearly of the collective variety. If Latour and Law are correct in their conception of actor-network theory, then what constitutes agency is not only the volition of a bounded, monolithic 'processor', but also its interactions with the wider network of 'heterogeneous materials', including all objects and 'objects-and-people' networks that mediate interaction (Law 1992:381). Therefore, in the actor-network conception, there is ultimately no need to discriminate between individual and collective agency—it's all just emergent agency in the final analysis. This new form of collective creative agency associated with mass collaborative activity may then be conceived of as not only a creative smart mob, but a collectively composed yet *singular* agent.

[162] 'Brain-computer interface', in Wikipedia, The Free Encyclopedia. Retrieved 08:08, April 26, 2007, from <http://en.wikipedia.org/w/index.php?title=Brain-computer_interface&oldid=124494608>.

Drawing once again on Hofstader and Minsky's hive/society as mind, we may now invert their original thesis (that individual mind is composed of a collectivity). This inversion being that the collectivity may possess attributes of the individual mind—agency, intelligence, creativity and the like. Drawing upon and applying stigmergy, the semantic web, swarming, open access mass collaboration and 'metasystem transitions'[163] to current and potential means of extending the Internet, Heylighen (2007a) outlines just such a possibility. His thesis is that not only is collective intelligence increased through the application of these processes, but more directly, it is also indicative of the emergence of a global brain with operational structures and functionality which mirrors that of the brain on an individual level:

> An analysis of the stigmergic mechanisms that seem most effective in supporting such distributed intelligence shows that they are virtually identical to the mechanisms used by the human brain. The quantitative stigmergy exemplified by 'ant algorithms' is nearly identical to the process of Hebbian or reinforcement learning that differentially strengthens connections between neurons in the brain. The 'ants' that trace and explore the quantitatively weighted network formed in this way correspond to human or software agents searching the web, or to bursts of activation spreading across the brain. Qualitative stigmergy, which is the true motor of innovation, can be seen as the basis of symbolic consciousness in the brain. It is exemplified on the web by a variety of collaborative, 'open access' sites where people freely improve on each other's contributions. (Heylighen 2007a:23)

Of course the nature of this emergent global brain is yet unknown, and may remain so, as it is difficult for lower-level entities stigmergically interacting with locally available information to reason explicitly about the higher-level emergent structures of which they are a lower level component (Parunak 2005:7). However, it may be said that the way we are currently experiencing this emerging intelligence is through the ways in which it works for

[163] A metasystem transition is the process whereby higher levels of control emerge, coalescing around lower level groupings of similarly natured control—such as the formation of multicellular entities from the single cellular (Heylighen & Campbell 1995; Joslyn et. al. 1997; Turchin 1995).

and with us—that is, the increasing utility we experience provided by our engagement with it. For example, if I am interested in some new topic of which I know nothing other than a few key words, within seconds I may have before me a raft of information describing this topic in detail based upon the stigmergic annotating of webpages, links and their interpretations and rankings (i.e. the basic conception of the Internet). An extension of this utility provided through mass collaboration is the synthesis of knowledge otherwise returned in the form of a web search. This is perhaps one of Wikipedia's greatest strengths and promise—instead of synthesising numerous information sources myself via the review of my many web search returns (which may also direct me to many offline sources as well), this work has already been done allowing me to proceed directly to either new interests thus informed, or, to continue with more fine-grained inquiries based upon links and references supplied in the mass collaborative synthesis.[164] Therefore, while we may never truly know the nature of a global brain from the perspective of *its* level of experience and existence, if current trends are any thing to go by, the experience of such a global brain from our human level is likely to be one of ever increasing information availability and utility. Of course, human interest is not limited to that of informational inquiry, but neither is mass collaboration as it spans ever more methods and media of collective production.

Extending this conception yet further, it is conceivable that one day the capacities of machine, environmental and human computation might reach the point where the process of mass collaboration could be modelled based upon the many past and present manifestations thereby allowing the equivalent of collective creative synthesis and production to happen automatically. This would be tantamount to artificial *collective creative* intelligence. Such an agency could generate incredible amounts of feedback to human activity, providing ever expanding pools of knowledge and information creation,

[164] As a specific example, say someone mentioned to me that a project called 'Freenet' existed, and while they did not know the specifics, they thought I might be interested in the project. Searching Google for this project (with a single key word) I am stigmergically directed towards the Wikipedia article as it is the third highest ranking return and more specifically I am ideally interested in a synthesis of knowledge surround the query—including critical viewpoints (which is generally the experience I have of Wikipedia). At Wikipedia I find a well-referenced article of high detail, pointing me also to the project's website, as well as many other information sources and similar ideas and projects. With this example (which occurred this morning, 27 April 2007) I am not suggesting that Wikipedia specifically will provide the 'ultimate answer machine' in its most idealised and realised expression, or that I do not lose something in the process of others synthesising material for me. Rather, I believe that the process of mass collaboration is making this type of synthesis possible, and like the many trips to the library that the Internet has replaced, such synthesis enables more rapid acquisition and processing of information at a lower expense of energy.

fuelled by our further engagement with and expansion of it. This type of outcome, as fanciful as it may seem, is representative, even if only by metaphor, of 'a level of intelligence, awareness and complexity that we at present simply cannot imagine' (Heylighen 2007a:20) resulting from the emergence of a global brain and or of some future 'singularity' of technological innovation (Kurzweil 2006; Vinge 1993). Perhaps the best way to conceptualise such imagined outcomes is with a thought experiment:

> Imagine: all the answers to all of the questions you and everyone else can formulate are instantly available.

While such a situation might seem to auger the 'death of inquiry' and a corresponding atrophy of creativity and even volition, further engagement with the thought experiment indicates that this may not be the case. Even when one is provided with a 'correct' answer, one is presented with the potential complication of integrating this answer with one's existing and unfolding knowledge, experience and understandings. Additionally, while this integration may provide in some instances resolution, in the long run it is more likely to only generate additional questions—even if the answers to the questions generated are also present (as can often be experienced when surfing the web in its current form). This result is because the integrative process is at its core a creative act—the creation of new representations/understandings. Due to creativity's divergent nature, it is likely to generate not just one additional question, but many (and of course there may be more than one answer to a question even in more absolute contexts). The point being that following the process of inquiry through its nonlinear branches and fogs of questions and answers is by no means easy, even when all of the answers are provided to the questions as they arise.

As a consequence, one's ability to engage in this process of inquiry and integration must also be relative to one's capacities to do so. Therefore, wouldn't these capacities require ongoing development in order for one to continue to comprehend and integrate the answers to one's questions? Isn't this the very same process which life-long education and self-development currently embodies, and isn't there already a volume of answers instantly available to anyone with Internet access far beyond the scope of any single individual to synthesise?

Aside from an assumed radical explosion of technological advancements and variety of new experience made available, perhaps the emergence of a global brain wouldn't be that different from the growing and inquiring individual's currently existing reality after all. Or, perhaps this apparent lack of difference (and today's current explosion of technological advancements and new varieties of experience), is simply because such a global brain has already arrived.

# 8. Coda: meta vistas

Our duty, as men and women, is to proceed as if limits to our ability did not exist. We are collaborators in creation.

*—Pierre Teilhard de Chardin*

I wish we will work together to help create the key tools that we need to inspire preservation of Earth's biodiversity, and let us call it the Encyclopaedia of Life.

*—Edward O. Wilson*

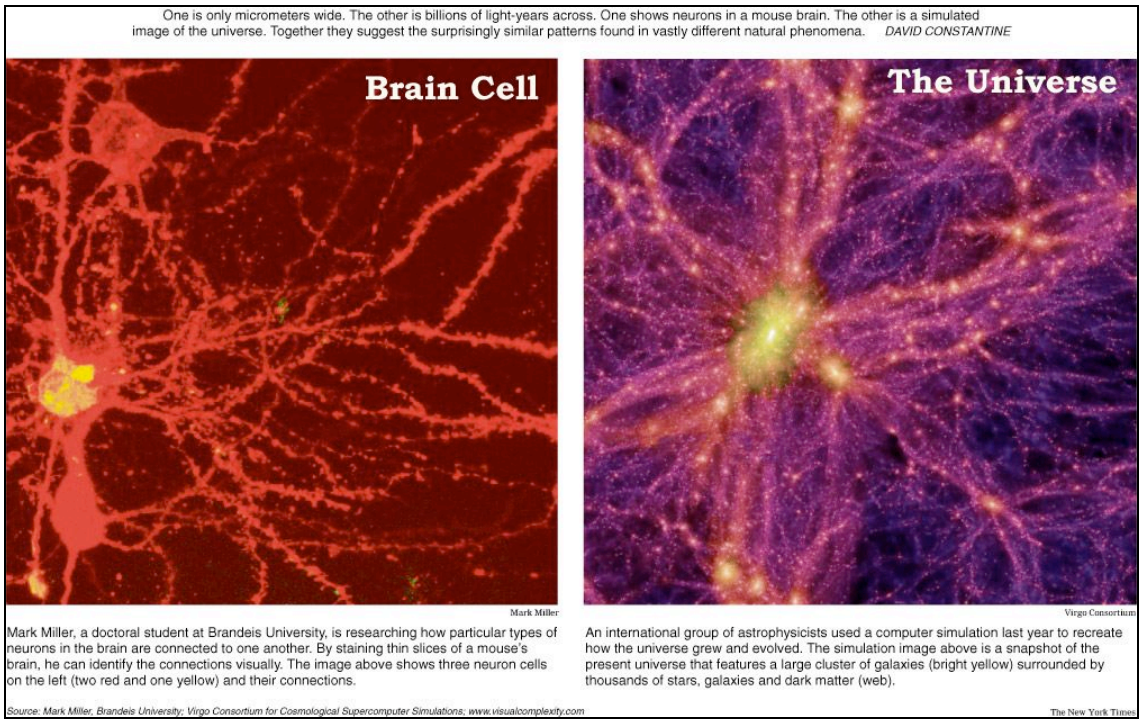


Figure 8.0.
Visual comparisons of neurons in a mouse brain and a simulation image of the present state of the universe[165]

[165] Source, Constantine, D. (2006). Science Illustrated; They Look Alike, but There's a Little Matter of Size. *The New York Times,* August 15.

This journey began with an artist's curiosity (which might be better described as a burning desire) to explore the potentials and possibilities for composing collaboration. In my interest to reach out to the widest contributor base possible, I envisioned a large-scale, collaborative, Internet-based opera. What I ended up composing was however, something quite different. Instead of restricting my scope, methods and orientations to that of musical composition, I forged relationships with many around the world through embracing the process and spirit of collaboration, and composed works (both discursively and stigmergically), which yielded outcomes and lessons far exceeding my own individual resources and capacities. While the processes I employed to achieve these outcomes were often composed in the traditional sense—through the creation of original ideas, planning and annotations—the output was of course not that of music. Had I known this before commencing my PhD, I might have been somewhat disconcerted. However, having such prior knowledge is not how my life works.

Rather, my life seems to follow the pattern of an ever-expanding spiral, with fractal eddies spinning off in all directions, and from the vantage point of retrospectively analysing the progress of this spiral, it now seems to make perfect sense. How else could my compositional interests have had the opportunity to merge so fluidly with my ever-deepening exploration into the nature of reality, life and relation? So in effect, the spiral of my life did not leave music behind but rather transcended it. Moreover, this experience has renewed my wonder of the power, depth and complexity of the medium of music which moves a large portion of the Earth's population in coordinated action or experience every day (Benzon 2001).

Also renewed was my appreciation for the aerial perspective. However, as figure 8.0 and its accompanying text illustrates, the notion of the aerial view may occur across all scales, and that patterns may also repeat themselves across these scales. Of course, it may not be that these patterns are actually reoccurring (and providing us with a universal capacity to generalise), rather this may simply be the shape our human, bio-psycho-socially limited lens gives them. In any case, the truth of the matter may be in the end, less interesting than the pursuit of its discovery. Translated by Paul Reps and Nyogen Senzaki (1957:39) a short Zen story relates this notion:

> Daiju visited the master Baso in China. Baso asked: 'What do you seek?'
>
> 'Enlightenment,' replied Daiju.
>
> 'You have your own treasure house. Why do you search outside?' Baso asked.
>
> Daiju inquired: 'Where is my treasure house?'
>
> Baso answered: 'What you are asking is your treasure house.'

The pursuit of the discovery of, now becomes the discovery of the pursuit. This particular pattern (human or universal) is one of the classic inversions of perspective. In essence, it is seeing the negative of an image, enabling that which was the background to become the foreground. It is seeing the journey rather than the destination, it is understanding rhythm as the space between the notes, or recognising the environment as the source of all life.[166] This inversion is of course at the root of many great discoveries, such as some of the most important images ever created in the study of the universe. By investigating what, if anything, lay within a tiny dark spot amongst a universe of bright stars and galaxies, the Hubble Deep Field image was produced, spurring some 400 research papers[167] and a wide array of subsequent images, theories and questions (see figure 8.1).

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[166] 'I finally figured out that the way to get wonderfully lifelike behaviour is not to try to make a really complex creature, but to make a wonderfully rich environment for a simple creatures.' - David Ackley discussing the engineering of AI, via Kevin Kelly (1994:130-1).

[167] Hubble Deep Field. (2007, April 21). In Wikipedia, The Free Encyclopedia. Retrieved 05:35, May 3, 2007, from <http://en.wikipedia.org/w/index.php?title=Hubble_Deep_Field&oldid=124621485>.

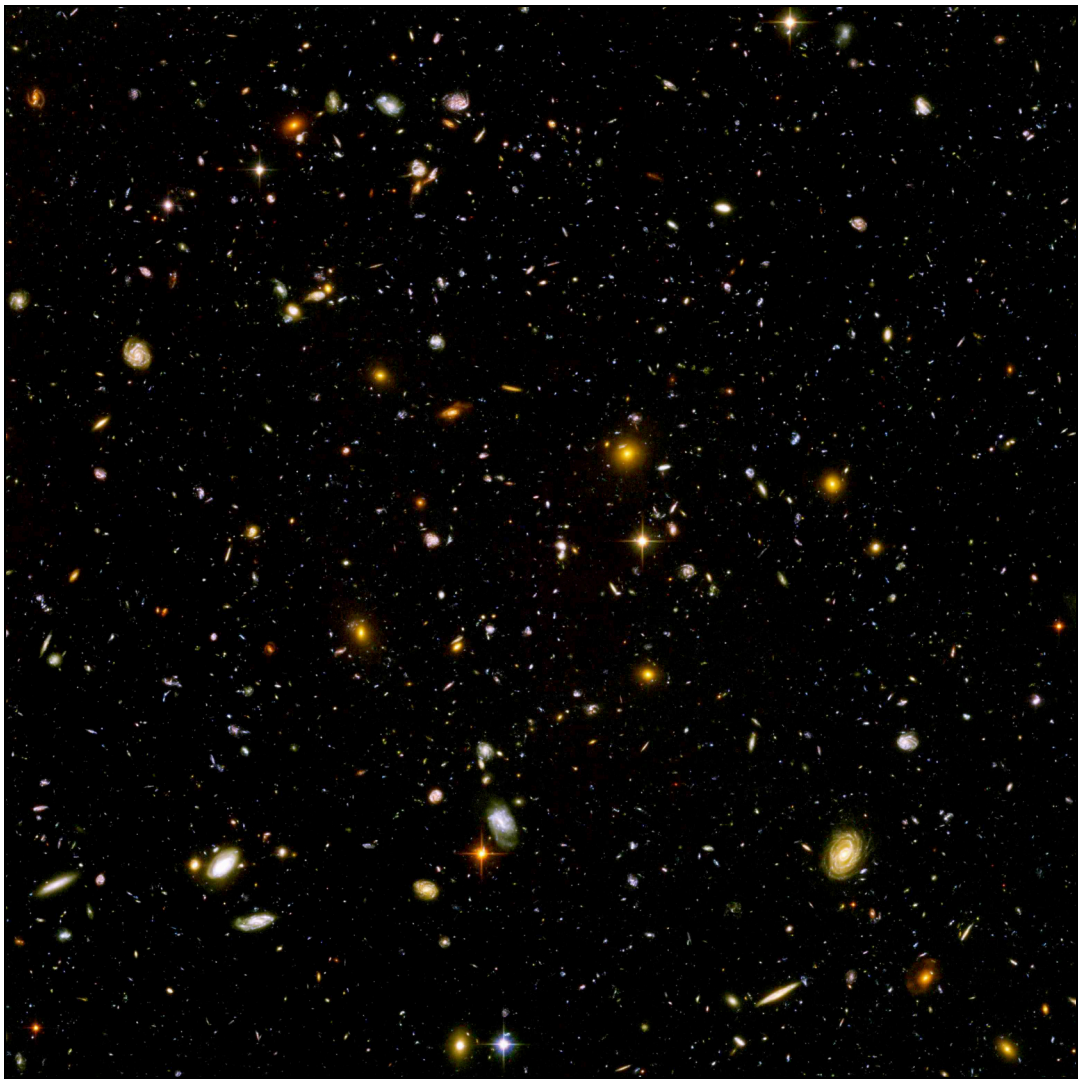

Figure 8.1.
Hubble Ultra Deep Field, 'This view of nearly 10,000 galaxies is the deepest visible-light image of the cosmos'[168]

This age old inversion of perspective is also that which has guided me towards peering into the seemingly small dark space between those who create together. Like the Hubble Deep Field images, what I have encountered is not just a number of distant stars to chart, but a massive collection of galaxies, previously obscured by the bright lights of creative individuals and work they collaboratively produce together. Zooming out to the perspective required to accommodate the breadth and depth of mass collaboration further augments these galaxies, the investigation of a number of them having fundamentally shifted the way I see the world I inhabit in regard to collaborative and

[168] Image and text source, Hubblesite.org, <http://hubblesite.org/newscenter/archive/releases/2004/07/image/a> retrieved 3 May 2007.

mass collaborative activity, as well as the nature of life, interaction and consciousness. I now see a world teeming with intelligence that extends beyond our individual and collective minds and reaches out into the wider environment as it plays a part in the manifestation of distributed creative cognition. As I magnify the fuzzy borders that confine the agency enacting this cognition, the fuzziness dissolves into fields and gradients of potential and energy.

This recognition of the existence of cognition distributed throughout our wider environment and the creative capabilities this distribution possesses, represents the emerging recognition of seeing and valuing collaboration as a resource. Like seeing and valuing energy efficiency as a resource, the full potential wrapped up within this shift of perspective will take some time to unfold as we continue to gradually invert our perspectives from a person and outcome focus, to one directed more towards process and interaction. Of course, in the discovery of this pursuit, we must not forget the fact that the process of collaboration always comprises people and outcomes, especially as our capacity for designing collective creativity increases—the practice of engineering is not one traditionally known for specific ethical or moral sensitivity. However, I believe such issues will become increasingly important to confront as we progressively reveal the nature of our interactions with each other and the environment, especially as the scope for engineering these interactions broadens. In this dissertation's focus on the development of a particular framework for understanding mass collaborative interactions, it is hoped that future studies might continue this exploration while simultaneously expanding the scope of enquiry to include that of the ethical and moral concerns of such engineering and applications. It is my intuition that such studies might reveal yet further galaxies reflecting deeper understandings as to what it means to be one of the many collaborating on the emergence of the shared representation we call reality.

When looking at mass collaboration through the lens of stigmergy one sees the backdrop, or a negative image of this activity and its creative production. This view reveals our environment to be a non-passive, reactive medium responding synergistically to our interaction. This dynamic therefore displays characteristics resembling in ways a living entity. However this entity's vitality is derived less from the bounded nature of an organism conserving its energy in the face of entropy, and more

from the synergy produced by collections of individuals extending and projecting their cognition upon and throughout the environmental substrate. Therefore, if such a substrate is going to have the capacity to react and respond in such a manner which best reflects the interests of the participants *and* the environment, great care must be taken in the cases where engineering is the starting point—as illustrated by today's often calculated destructive exploitation of the environment and various populations which inhabit it. Of course, a primary strength of mass collaboration is that the success and failure of such projects is almost entirely determined by evolutionary principles that depend upon a project's use-value, relevance and interest to the participants, not to mention that the constituency has the capacity to reshape the project in their interests as it unfolds.

In reflecting upon one of the initial motivations for what was originally to be a mass collaborative opera—the intersections of the democratic and the unilateral, the civic and the political, the collective and the individual, the open and secret—I have learned a number of lessons from the inclusive and adaptive nature of mass collaboration. Designs for collective activity which fail to incorporate mechanisms of inclusion and feedback from those who form a part of its fabric, run the risk of manifesting the interests of the engineers at the expense of the wider constituency and the shared environment. This notion is represented well in Benkler's concern for the capacities of our media environments (2000:178), however, such design lessons may also be imported into the realms of national and international policy. As explored by the Australian Bill of Rights Initiative, inclusive processes may provide increased capacity for the participant to represent more explicitly their interests within the processes that governs them. Similarly, as we design processes for collective action that extend our will upon those who do not reside within the boundaries we call nations, inclusivity plays an even more crucial role. This is perhaps at the heart of the reservations the majority of Australians and myself had for the unilateral invasion of Iraq (of which the Australian government was a collaborator).

However, for the first time in human history, the technological capacity to achieve such inclusivity exists like never before. And of course, while human history also teaches us that all instruments of collective activity are subject to the will of the often self interested powerful minority, the playing field of this activity is undergoing a rapid

transformation. As previously mentioned, this transformation has shattered the glass ceiling of collaborative membership and increasingly with it our bedrock assumptions of authority and ownership. In the long run, the shattering of such assumptions may be even more important than any technological development, as it is always our assumptions which restrict our visions of what we may do and who we may be. In many respects, it is precisely these assumptions and this vision that we must confront if we are to apply this newfound capacity for inclusivity and collective creativity to its full capacity.

With a growing host of immanent disasters prepared to thrust us into a world the likes of which we'd rather not imagine, our balance on the razor's edge is wavering. Bird flu pandemic, abrupt climate change, sudden collapse of fossil fuel supplies—if even one of these events occur, let alone multiples thereof, we will have to work together in ways unprecedented on projects unimaginable and with every bit of our collective creativity. In fact, we will to need to work together in such ways and on such scales even if to simply maintain our shaky stance on this razor's edge we call 'progress'. Stigmergic, mass collaboration is likely to be the primary means with the capacity to achieve the levels of large-scale creative coordination required to address such challenges. Not only is mass collaboration providing such opportunities, but it is simultaneously giving rise to new forms of community, interaction, creation, ownership, authorship, governance and art.

I am increasingly seeing mass collaboration as one of Edward O. Wilson's 'key tools', not just for the *inspiring* of the preservation of Earth's biodiversity, but a tool for actually *doing* the work which must be done in order to help ensure humanity's ongoing place within this diversity. While tools and technologies often fail in their promise of a new and better tomorrow, mass collaboration is more than the emergence of a new tool, it is also representative of the emergence of new ways of thinking, being and doing which have the potential to provide new models and precedents in our never ending quest for a more equitable and enriching today.

# Bibliography

Abbott, R. (2006). *Emergence Explained: Getting epiphenomena to do real work.* arXiv.org, (online database), <http://arxiv.org/abs/cs.MA/0602045> retrieved 16 January 2006.

Arthur, WB. (1989). Competing technologies, increasing returns, and lock-in by historical events. *The Economic Journal,* 99 (394): 116-131.

Auchter, D. (2000). The Evolution of the encyclopaedia britannica: From the macropaedia to britannica online. *Journal of academic librarianship,* 26 (1): 74.

Aunger, R. (2002). *The Electric Meme: A New Theory of How We Think.* NY: The Free Press.

Baars, B. (1997). *In the Theater of Consciousness: The Workspace of the Mind*. Oxford University Press.

Bauwens, M. (2005). The political economy of peer production. *CTheory,* (online journal), <http://www.ctheory.net/articles.aspx?id=499> retrieved 28 January 2006.

Beck, D. (c. 2002). *Stages of Social Development: The Cultural Dynamics that Spark Violence, Spread Prosperity, and Shape Globalization*. Available at <http://humanemergence.org/essays/stages_of_social_development.htm> retrieved 20 August 2005.

Beck, D., & Cowan, C. (1996). *Spiral Dynamics: Mastering Values, Leadership, and Change*. Oxford: Blackwell Publishing.

Beckers, R., Holland, O. E., & Deneubourg, J. L. (1994). From local actions to global tasks: Stigmergy and collective robotics. In R. Brooks & P. Maes (Eds.), *Artificial Life IV: Proceedings of the Fourth International Workshop on the Synthesis and Simulation of Living Systems,* Cambridge, MA: MIT Press, 181-189.

Benkler, Y. (2006). *The Wealth of Networks: How Social Production Transforms Markets and Freedom*. London: Yale University Press.

Benkler, Y. (2005). *Common Wisdom: Peer Production of Educational Materials*. Center for Open and Sustainable Learning. Available at <http://www.benkler.org/Common_Wisdom.pdf> retrieved 4 January 2007.

Benzon, W. (2001). *Beethoven's Anvil: Music in Mind and Culture*. Perseus Books.

Bertalanffy, L. (1969) *General System Theory: Foundations, Development, Applications*. NY: George Braziller, Inc.

Black, L.J. Cresswell, A.M., Luna, L.F., Pardo, T.A., Martinez, I.J., Thompson, F., Andersen, D.F., Canestraro, D.S., Richardson, G.P., Cook, M. (2003). A dynamic theory of collaboration: a structural approach to facilitating intergovernmental use of information technology. *Proceedings of the 36th Annual Hawaii International Conference on System Sciences, 2003*.

Bloom, H. (2000). *Global Brain: The Evolution of Mass Mind*. Canada: John Wiley & Sons, Inc.

Bollier, D. (2006). *When Push Comes To Pull*. Aspen Institute. Available at <http://www.aspeninstitute.org/atf/cf/%7BDEB6F227-659B-4EC8-8F84-8DF23CA704F5%7D/2005InfoTechText.pdf> retrieved 16 December 2006.

Bonabeau, E., Theraulaz, G. (1999). *Swarm Intelligence: From Natural to Artificial Systems*. Oxford: Oxford University Press.

Bonabeau, E., Theraulaz, G., Fourcassié, V., & Deneubourg, J.-L. (1998). The phase-ordering kinetics of cemetery organization in ants. *Physical Review E,* 4: 4568-4571.

Bricklin, D. (2001). The cornucopia of the commons: how to get volunteer labor. In A. Oram (Ed.), *Peer-to-Peer: Harnessing the Power of Disruptive Technologies,* O'Reilly and Associates, Inc. Available at <http://www.bricklin.com/cornucopia.htm> retrieved 11 December 2006.

Broderick, D. (1997). *The Spike: Accelerating Into The Unimaginable Future*. Melbourne: Reed Books.

Brown, J.S., Duguid, P. (1991). Organizational learning and communities-of-practice: toward a unified view of working, learning, and innovation. *Organization Science,* 2 (1): 40-57.

Brueckner, S. (2000). *Return from the Ant: Synthetic Ecosystems for Manufacturing Control*. Dr.rer.nat. Thesis at Humboldt University Berlin, Department of Computer Science. Available at <http://edoc.hu-berlin.de/dissertationen/brueckner-sven-2000-06-21/PDF/Brueckner.pdf> retrieved 4 February 2007.

Bryant, S. L., Forte, A., Bruckman, A. (2005). Net communities: becoming wikipedian: transformation of participation in a collaborative online encyclopedia. *Proceedings of the 2005 international ACM SIGGROUP conference on Supporting group work GROUP 2005*.

Capra, F. (2004). *The Hidden Connections: A Science for Sustainable Living*. NY: Anchor Books.

Chauvin, R. (1941). Contribution á l'étude physiologique du Criquet pélerin et du déterminisme des phénomènes grégaires. *Annales de la Société Entomologique de France,* 110: 133–272.

Chorost, M. (2005). *Rebuilt: How Becoming Part Computer Made Me More Human*. Boston: Houghton Mifflin.

Coleman, S. (2004). Whose conversation? engaging the public in authentic polylogue. *The Political Quarterly,* 75 (2): 112-120.

Corning, P. (1998). The synergism hypothesis: on the concept of synergy and it's role in the evolution of complex systems. *Journal of Social and Evolutionary Systems,* 21 (2). Available at <http://www.complexsystems.org/publications/synhypo.html> retrieved 7 January 2007.

Corning, P. (2003). *Nature's Magic: Synergy In Evolution And the Fate of Humankind*. Cambridge: Cambridge University Press. Available at <http://www.complexsystems.org/magic.html> retrieved 14 January 2007.

Cowan, C., & Todorovic, N., (Eds.). (2005). *The Never Ending Quest: Dr. Clare W. Graves Explores Human Nature*. Santa Barbara, CA: ECLET Publishing.

Crabtree, A. (2003). *Designing Collaborative Systems: A Practical Guide to Ethnography*. London: Springer-Verlag.

Curry, J., & Kenney, M. (2006). Digital divide or digital development? the internet in Mexico. *First Monday,* 11 (3), (online journal), <http://firstmonday.org/issues/issue11_3/curry/index.html> retrieved 30 April 2007.

Deneubourg, J.-L., Goss, S., Franks, N. R., & Pasteels, J. M. (1989). The blind leading the blind: Modeling chemically mediated army ant raid patterns. *Journal of Insect Behavior,* 2, 719–725.

Deneubourg, J. L., Goss, S., Franks, N. R., Sendova-Franks, A., Detrain, C., & Chretien, L. (1991). The dynamics of collective sorting: robot-like ant and ant-like robot. In J. A. Meyer & S. W. Wilson (Eds.), *Simulation of Adaptive Behavior: From Animals to Animats,* Cambridge, MA: MIT Press, 356-365.

Désilets, A., & Paquet, S. (2005). *Wiki as a Tool for Web-based Collaborative Story Telling in Primary School: a Case Study*. National Research Council Canada. Available at <http://iit-iti.nrc-cnrc.gc.ca/publications/nrc-48234_e.html> retrieved 25 February 2006.

Elliott, M., Marcus, M., Barber, M., Leonard, M., Gibson, A., Maddock, L., & Daniel, M. (2007). Australian bill of rights initiative: collaborating on public policy. *Re-public,* Wiki politics - part II, (online journal), <http://www.re-public.gr/en/?p=142> retrieved 11 May 2007.

Elliott, M. (2006). Stigmergic collaboration: the evolution of group work. *M/C Journal: A Journal of Media and Culture,* 9 (2), (online journal), <http://journal.media-culture.org.au/0605/03-elliott.php> retrieved 10 December 2006.

Elliott, M. S., Walt S., (2004). *Mobilization of Software Developers: The Free Software Movement*. Free / Opensource Research Community, (online database), <http://opensource.mit.edu/papers/suzorfitzgeraldbasset.pdf> retrieved 19 August 2005.

Emigh, W., & Herring S. C. (2005). Collaborative authoring on the web: a genre analysis of online encycolopedias. *Proceedings from the Thirty-Eighth Hawaii International Conference On System Sciences 2005*. Available at <http://csdl2.computer.org/persagen/DLAbsToc.jsp?resourcePath=/dl/proceedings/&toc=comp/proceedings/hicss/2005/2268/04/2268toc.xml&DOI=10.1109/HICSS.2005.149> retrieved 21 February 2006.

Engeström, Y. (1987). *Learning by Expanding: An Activity - Theoretical Approach to Developmental Research*. Helsinki: Orienta-Konsultit. Available at <http://communication.ucsd.edu/MCA/Paper/Engestrom/expanding/toc.htm> retrieved 15 February 2007.

Forte, A., & Bruckman, A. (2005). Why do people write for Wikipedia? incentives to contribute to open-content publishing. *GROUP 05 workshop: Sustaining community: The role and design of incentive mechanisms in online systems*. Sanibel Island, FL. Available at <http://www-static.cc.gatech.edu/~aforte/ForteBruckmanWhyPeopleWrite.pdf> retrieved 22 February 2007.

Galloway, A. (2004). *Protocol, How control exists after decentralisation*. Cambridge, MA: MIT Press.

Garreau, J. (2004). *Radical Evolution*. NY: Doubleday.

Gifford, B. R., Enyedy, N. D. (1999). Activity centered design: towards a theoretical framework for CSCL. *Proceedings of the 1999 Conference on Computer Support for Collaborative Learning*. Available at <http://portal.acm.org/ft_gateway.cfm?id=1150262&type=pdf&coll=&dl=&CFID=15151515&CFTOKEN=6184618> retrieved 11 May 2007.

Giles, J. (2005). Special report: internet encyclopeidas go head to head. *Nature,* (online magazine), <http://www.nature.com/news/2005/051212/full/438900a.html> retrieved 2 July 2006.

Gould, S. J. (1996). *Full House: The Spread of Excellence from Plato to Darwin*. Harmony Books.

Granovetter, M. (1982). The strength of weak ties: a network theory revisited. In P. Marsden & L. Nan, (Eds.), *Social Structure and Network Analysis,* California: Sage Publications.

Grassé, P.-P. (1946). Sociétés animales et effet de groupe. *Experientia,* 2: 77–82.

Grassé, P.-P. (1958). L'effet de groupe sur l'animal et sur l'homme. *Journal de psychologie normale et pathologique,* 55: 129–150.

Grassé, P.-P. (1959). La Reconstruction du nid et les Coordinations Inter-Individuelles chez Bellicositermes Natalensis et Cubitermes sp. La théorie de la Stigmergie: Essai d'interprétation du Comportement des Termites Constructeurs. *Insectes Sociaux,* 6: 41-84.

Grassé, P.-P. (1963). Les phénomènes sociaux chez les Animaux. *Cahiers de l'Institut de Science économique appliquée,* Suppl. 139 (5): 7–23.

Grassé, P.-P. (1984). Termitologia. tome II, *Fondation des Soci´et´es Construction,* Paris: Masson.

Green, C. (2001). *The Third Hand: Collaboration in Art from Conceptualism to Postmodernism*. Minneapolis, Minnesota:University of Minnesota Press.

Gregorio, J. (2002) Stigmergy and the world-wide web. *Bitworking,* (web log), <http://bitworking.org/news/Stigmergy> retrieved 20 December 2005.

Grosz, B. J., & Sarit K. (1999). The evolution of SharedPlans. In M. Wooldridge & A. R. Dordrecht (Eds.), *Foundations of Rational Agency (Applied Logic Series),* Netherlands: Kluwer Academic Publishers.

Guilford, J.P. (1950). Creativity. *American Psychologist,* 5: 444-454.

Guilford, J.P. (1962). Creativity: its measurement and development. In S. J. Parnes & H. F. Harding, (Eds.), *A Source Book for Creative Thinking,* NY: Scribners.

Helbing, D., Schweitzer, F., Keltsch, J., & Molnár, P. (1997b). Active walker model for the formation of human and animal trail systems. *Physical Review E,* 56: 2527–2539.

Helbing, D., Keltsch, J., & Molnár, P. (1997a). Modeling the evolution of human and trail systems. *Nature,* 388: 47–50.

Hennessey, B. A., Amabile, T. M. (1988). The conditions of creativity. In R. J. Sternberg (Ed.), *The Nature of Creativity: Contemporary Psychological Perspectives,* Cambridge: Cambridge University Press, 11-42.

Heylighen F. (2005). Conceptions of a Global Brain: an historical review. *Principia Cybernetica Web,* (online database), <http://pespmc1.vub.ac.be/Papers/GBconceptions.pdf> retrieved 9 December 2006.

Heylighen F. (2006). Mediator evolution: a general scenario for the origin of dynamical hierarchies. In D. Aerts, B.D'Hooghe & N. Note (Eds.) *Worldviews, Science and Us,* Singapore: World Scientific.

Heylighen F. (2007a). Accelerating socio-technological evolution: from ephemeralization and stigmergy to the global brain. To appear in G. Modelski, T. Devezas & W. Thompson (Eds.), *Globalization as an Evolutionary Process: Modeling Global Change,* London: Routledge.

Heylighen F. (2007b). Why is open access development so successful? stigmergic organization and the economics of information. To appear in B. Lutterbeck, M. Bärwolff & R. A. Gehring (Eds.), *Open Source Jahrbuch 2007,* Lehmanns Media.

Heylighen F., & Campbell, D. T. (1995). Selection of organization at the social level: obstacles and facilitators of metasystem transitions. *World Futures: the Journal of General Evolution,* 45: 181-212.

Hildreth, P. M., & Kimble, C. (2002). The duality of knowledge. *Information Research,* 8 (1).

Hildreth, P. M., & Kimble, C. (2004). *Knowledge Networks: Innovation through Communities of Practice*. London/Hershey: Idea Group Inc.

Hofstadter, D. (1979). *Gödel, Escher, Bach: An Eternal Golden Braid*. GB: Basic Books.

Hollan, J., Hutchins, E., & Kirsh, D. (2000). Distributed cognition: toward a new foundation for human-computer interaction research. *ACM Transactions on Computer-Human Interaction,* 7 (2): 174-196.

Holland, J. (1999). *Emergence: From Chaos to Order*. Perseus Books Group.

Hutchins, E. (1995a). *Cognition in the Wild*. Cambridge, Massachusetts: MIT Press.

Hutchins, E. (1995b). How a cockpit remembers its speeds. *Cognitive Science,* 19: 265–288.

Hutchins, E. (2000). Distributed cognition. In N. J. Smelser, P. B. Baltes. (Eds.), *International Encyclopedia of the Social and Behavioral Sciences,* Kidlington Oxford: Elsevier Sciences Ltd. Available at <http://www.telelearning-pds.org/coa/distributed_cognition.pdf> retrieved 16 February 07.

Izquierdo-Torres, E. (2004). *Collective Intelligence in Multi-Agent Robotics: Stigmergy, Self-Organization and Evolution.* University of Sussex. Available at <http://www.informatics.sussex.ac.uk/users/eji21/master/ei_ami_jan2004.pdf> retrieved 16 November 2006.

Jakobson, R. (1960). Closing statements: linguistics and poetics. In T. A. Sebeok (Ed.), *Style In Language,* Cambridge Massachusetts: MIT Press, 350-377.

Johnson, C. M. (2001). A survey of current research on online communities of practice. *Internet and Higher Education,* 4 (1): 45-60.

Johnson, S. (2001). *Emergence: The Connected Lives of Ants, Brains, Cities, and Software*. NY: Scribner.

Johnson, J., Dyer, J. (2005). User-defined content in a constructivist learning environment. In the conference book of the m-ICTE 2005, A. Méndez-Vilas, B. González-Pereira, J. Mesa González, J. A. Mesa González (Eds.), *Recent Research Developments in Learning Technologies,* Badajoz, Spain: Formatex, ISBN Vol. II (pp. 448-893): 609-5996-1. Available at <http://www.formatex.org/micte2005/169.pdf> retrieved 13 June 2006.

John-Steiner, V., Weber, R., & Minnis, M. (1998). The challenge of studying collaboration. *American Educational Research Journal,* Winter, 35 (4).

Joslyn, C., Heylighen, F., & Turchin, V. (1997). Metasystem transition theory. *Principia Cybernetica Web,* (online database), <http://pespmc1.vub.ac.be/MSTT.html> retrieved 22 February 2007.

Karsai I. (1999). Decentralized control of construction behavior in paperwasps: an overview of the stigmergy approach. *Artificial Life,* 5: 117-136.

Kelly, K. (1994). *Out of Control: The New Biology of Machines*. London: Fourth Estate Ltd.

Kennedy, J., Eberhart, R. C., & Shi, Y. (2001). *Swarm Intelligence*. San Francisco: Morgan Kaufmann Publishers.

Kim, A. J. (2004). Emergent purpose. *Musings of a Social Architect,* (web log), <http://socialarchitect.typepad.com/musings/2004/01/emergent_purpos.html> retrieved 16.04.07.

Kim, E. E. (2003). *An Introduction to Open Source Communities*. Free / Opensource Research Community, (online database), <http://opensource.mit.edu/papers/blueoxen.pdf> retrieved 19 August 2005.

Kim, E. E. (2004). *A Manifesto for Collaborative Tools*. Blue Oxen Associates, (online database), <http://www.blueoxen.com/papers/0000D/> retrieved 2 February 2006.

Kimble, C., & Hildreth, P. (2004). Communities of practice: going one step too far? *Proceedings 9e colloque de l'AIM,* Evry, France.

Kimble, C., & Hildreth, P. (2005). Dualities, distributed communities of practice and knowledge management. *Journal of Knowledge Management,* 9 (4): 102-113.

Kimble, C., Hildreth, P., & Wright, P. (2001). Communities of practice: going virtual. In Y. Malhotra (Ed.), *Knowledge Management and Business Model Innovation,* York, UK: Idea Group Publishing, 220-234.

Klein, T. J. (2003). Unity of knowledge and transdisciplinarity: contexts of definition, theory and the new discourse of problem solving. In G. H. Hadorn (Ed.), 'Unity of

Knowledge in Transdisciplinary Research for Sustainability', in *Encyclopedia of Life Support Systems* (EOLSS), developed under the auspices of the UNESCO, Oxford, UK: Eolss Publishers.

Kleiner, D., & Wyrick, B. (2007). InfoEnclosure 2.0. *Mute Magazine,* Mute Publishing Ltd, (online magazine), <http://www.metamute.org/en/InfoEnclosure-2.0> retrieved 21 April 2007.

Kollock, P. (1998). Social dilemmas: the anatomy of cooperation. *Annual Review of Sociology,* 24: 183-214. Available at <http://www.sscnet.ucla.edu/soc/faculty/kollock/classes/cooperation/resources/Kollock%201998%20-%20Social%20Dilemmas.pdf> retrieved 6 May 2006.

Kramer, R. S. S. (2005). *Stigmergic Communication: Achieving So Much Without Saying a Word*. Sussex, UK: Author. Available at <http://www.kramer.me.uk/robin/Files/AMI.pdf> retrieved 2 January 2007.

Kurzweil, R. (2005). *The Singularity Is Near*. NY: Viking Adult.

Kuznetsov, S. (2006). Motivations of contributors to Wikipedia. *ACM SIGCAS Computers and Society,* 36 (2).

Lanier, J. (2006). Digital maoism: the hazards of the new online collectivism. *Edge,* 185, (electronic journal), <http://www.edge.org/3rd_culture/lanier06/lanier06_index.html> retrieved 8 January 2007.

Latour, B. (2005). *Reassembling the Social: An Introduction to Actor-Network-Theory*. Oxford, New York: Oxford University Press.

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. Cambridge: Cambridge University Press.

Law, J. (1992). Notes on the theory of the actor-network: ordering, strategy, and heterogeneity. *Systemic Practice and Action Research,* 5 (4): 379-393.

Leont'ev, A. (1979). The problem of activity in psychology. In J. Wertsch (Ed.), *The Concept of Activity in Soviet Pyschology,* Armonk, New York: M.E. Sharpe, Inc.

Leont'ev, A. (1981). *Problems of the Development of Mind*. English translation, Moscow: Progress Press. (Russian original 1947).

Lessig, L. (2000). *Code and Other Laws of Cyberspace*. NY: Basic Books.

Lessig, L. (2004). *Free Culture: The Nature and Future of Creativity*. NY: Penguin.

Leuthardt, E., Schalk, G., Wolpaw, J. R., Ojemann, J. G., & Moran, D. W. (2004). A brain–computer interface using electrocorticographic signals in humans. *Journal of Neural Engineering,* 1: 63-71.

Lipnack, J., & Stamps, J. (2000). *Virtual Teams*. Canada: John Wiley & Sons.

Lueg, C. (2000). Where is the action in virtual communities of practice? *Proceedings of the workshop Communication and Cooperation in Knowledge Communities at the German Conference on Computer-Supported Cooperative Work (D-CSCW) "Verteiltes Arbeiten - Arbeit der Zukunft",* Munich, Germany.

Luhmann, N. (1990). The autopoiesis of social systems. In N. Luhmann (Ed.) *Essays on Self-Reference,* NY: Columbia University Press.

Lyotard, J.-F. (1984). *The Postmodern Condition: A Report on Knowledge*. translation, Geoff Bennington and Brian Massumi, Manchester: Manchester University Press.

*Macquarie International English Dictionary*. (2004). Bloomsbury Publishing.

Mark, G., & Abrams, S. (2005). Differential interaction and attribution in collocated and distributed large-scale collaboration. *Proceedings of the 38th Hawaii International Conference on Systems Sciences 2005*.

Mason, Z. (2002). Programming with stigmergy: using swarms for construction. In R. K. Standish, M. A. Bedau & H. A. Abbass (Eds.), *Artificial Life VIII: Proceedings of the Eighth International Conference on Artificial Life,* Sydney, Australia: MIT Press, 371-374.

Minsky, M. (1986). *The Society of Mind*. NY: Simon and Schuster.

Moody, G. (2001). *The Rebel Code: The Inside Story of Linux and the Open Source Revolution*. Cambridge, MA: Perseus Publishing.

Neumann, J.-V., & Morgenstern, O. (1944). *Theory of Games and Economic Behavior*. Princeton: Princeton University Press.

Newman, M. E. J. (2001). The structure of scientific collaboration networks. *Proceedings of the National Academy of Sciences of the United States of America, 2001,* 16; 98 (2): 404-409.

Neus, A. (2001). Managing informational quality in virtual communities of practice. *IQ 2001: The 6th International Conference on Information Quality*. Available at <http://opensource.mit.edu/online_papers.php> retrieved 19 August 2005.

Nielsen, J. (2006). *Participation Inequality: Encouraging More Users to Contribute*. Useit.com, (online resource), <http://www.useit.com/alertbox/participation_inequality.html> retrieved 30 April 2007.

Olson, G. M., Malone, T. W., & Smith, J. B. (2001). *Coordination Theory and Collaboration Technology*. Lawrence Erlbaum Associates.

O'Reilly, T. (2005). *What Is Web 2.0: Design Patterns and Business Models for the Next Generation of Software*. O'Reilly Media, (online resource), <http://www.oreillynet.com/lpt/a/6228> retrieved 4 April 2007.

Ostrom, E. (1990). *Governing the Commons. The Evolution of Institutions for Collective Action*. Cambridge, MA: Cambridge University Press.

p2pFoundation.org, *Defining P2P as the Relational Dynamic of Distributed Networks,* (online resource), <http://p2pfoundation.net/Defining_P2P_as_the_relational_dynamic_of_distributed_networks?title=Defining_P2P_as_the_relational_dynamic_of_distributed_networks&oldid=9667> retrieved 15 December 2006.

Parunak, H. V. D. (2005) *Expert Assessment of Human-Human Stigmergy*. Altarum Institute / Defence Research and Development Canada. Available at <http://www.newvectors.net/staff/parunakv/HumanHumanStigmergy2005.pdf> retrieved 12 October 2006.

Parunak, H. V. D., & Brueckner, S. (2003). Swarming coordination of multiple UAV's for collaborative sensing. *Proceedings of Second AIAA "Unmanned Unlimited" Systems, Technologies, and Operations Conference,* San Diego, CA, AIAA. Available at <http://www.altarum.net/~vparunak/AIAA03.pdf> retrieved 1 November 2006.

Parunak H. V. D., & Brueckner, S. A. (2004). Stigmergic learning for self-organizing mobile ad-hoc networks (MANET's). *Proceedings of Third International Joint Conference on Autonomous Agents and Multi-Agent Systems 2004,* Columbia University, NY.

Parunak, H. V. D., Purcell, M., & O'Connell, R. (2002). Digital pheromones for autonomous coordination of swarming UAV's. *Proceedings of First AIAA Unmanned Aerospace Vehicles, Systems, Technologies, and Operations Conference,* Norfolk, VA, AIAA.

Parunak, H. V. D., Brueckner, S. A., & Odell, J. (2004). Swarming pattern detection in sensor and robot networks. *Proceedings of 10th International Conference on Robotics and Remote Systems for Hazardous Environments,* Gainsville, FL, American Nuclear Society (ANS). Available at <http://www.altarum.net/~vparunak/ANS04.pdf> retrieved 10 November 2006.

Pedersen, S. T. (2001). *Open Source and the Network Society*. Free / Opensource Research Community, (online database), <http://opensource.mit.edu/online_papers.php> retrieved 19 August 2005.

Pister, K. (2001). *Smart Dust: Autonomous sensing and communication in a cubic millimeter*. University of California at Berkeley Robotics Lab. Available at <http://robotics.eecs.berkeley.edu/~pister/SmartDust/> retrieved 5 March 2007.

Rabaud, E. (1937). *Phénomène social et société animale*. Paris: F. Alcan.

Rambusch, J., Susi, T., & Ziemke, T. (2004). Artefacts as mediators of distributed social cognition: a case study. *The 26th Annual Conference of the Cognitive Science Society,* Chicago.

Reed, D. (1999). That Sneaky Exponential—Beyond Metcalfe's Law to the Power of Community Building. *Context Magazine,* Spring. Available at <http://www.reed.com/Papers/GFN/reedslaw.html> retrieved 19 July 2005.

Reps, P., & Senzaki, N. (Eds.) (1957). *Zen Flesh Zen Bones, A collection of Zen annd Pre-Zen writings*. Penguin Books.

Resnick, M. (1998). *Turtles, Termites and Traffic Jams: Explorations in Massively Parallel Microworlds*. Cambridge, MA: MIT Press.

Resnick, P. (2003) *Where Locality Meets Virtuality, Making the Net Work: Sustainable Development in a Digital Society*. Middlesex England: Xeris.

Rheingold, H. (1985). *Tools for Thought*. 2nd rev edition (April 18, 2000), Cambridge, MA: MIT Press.

Rheingold, H. (1993). *The Virtual Community*. 1st edition (November 1, 2000), Cambridge, MA: MIT Press.

Rheingold, H. (2002). *Smart Mobs*. Cambridge MA: Basic Books.

Rheingold, H. (2006). Collective action is not collectivism. *Smartmobs,* (web log), <http://www.smartmobs.com/archive/2006/06/02/collective_acti.html> retrieved 17 May 2007.

Rhine, N., & Figall, C. (2001). Tapping the grapevine: user-generated content. *EContent,* 24 (3): 38-43.

Ricci, A., Omicini, A., Viroli, M., Gardelli, L., & Oliva, E. (2006). Cognitive stigmergy: a framework based on agents and artifacts. *The Third International Workshop on Environments for Multiagent Systems*. Available at <http://www.cs.kuleuven.ac.be/~distrinet/events/e4mas/2006/> retrieved 3 January 2007.

Riehle, D. (2006). Invited talks: how and why wikipedia works: an interview with Angela Beesley, Elisabeth Bauer, and Kizu Naoko. *Proceedings of the 2006 international symposium on Wikis WikiSym 2006,* ACM Press.

Robles, G., Merelo, J.J., & Gonzalez-Barahona, J.M. (2005). Self-organized development in libre software: a model based on the stigmergy concept. *Proceedings of 6th International Workshop on Software Process Simulation and Modeling*.

Rogers, Y., Ellis, J. (1994). Distributed cognition: an alternative framework for analysing and explaining collaborative working. *Journal of Information Technology,* 9 (2): 119-128.

Sacks, H., Schegloff, E., & Jefferson, G. (1974). A simplest systematics for the organization of turn-taking in conversation. *Language,* 50: 696-735.

Sanger, L. (2005). The early history of Nupedia and Wikipedia: a memoir. In C. DiBona, M. Stone, & D. Cooper (Eds.), *Open Sources 2.0 Sebastopol,* CA: O'Reilly Press.

Santoyo, A. S. (2003). Estimation and characterization of the digital divide. *2003 Round Table on Developing Countries Access to Scientific Knowledge,* The Abdus Salam ICTP, Trieste, Italy.

Saveri, A., Rheingold, H., Pang, A. S-K., Vian, K. (2004). *Toward a New Literacy of Cooperation in Business: Managing Dilemmas in the 21st century*. Davis, M. (Ed.). Institute for the Future, Technology Horizons Programs. (Report SR-851-A). Available at <http://www.iftf.org/docs/SR-851A_New_Literacy_Cooperation.pdf> retrieved 8 June 2005.

Sherif, M. (1958). Superordinate Goals in the Reduction of Intergroup Conflict. *The American Journal of Sociology,* 63 (4): 349-356.

Simpson, J. A., & Weiner, E. S. C., (Eds.), (1989). *The Oxford English Dictionary, Second Edition*. Oxford: Oxford University Press.

Spencer, H. (1882). *The Principles of Sociology*. NY: Appleton.

Star, L. (1989). The structure of ill-structured solutions: boundary objects and heterogeneous distributed problem solving. *Distributed Artificial Intelligence,* 2: 37-54.

Star, L. & Griesemer (1989) Institutional ecology, 'translations' and boundary objects: amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science,* 19 (3): 387-420.

Steele & Thomas (2007). Directed stigmergy-based control for multi-robot systems. *Proceeding of the ACM/IEEE international conference on Human-robot interaction*. ACM SIGCHI/SIGART Human-Robot Interaction, 223-230.

Stewart, K. & Gosain, S. (2006). The impact of ideology on effectiveness in open source software development teams. *MIS Quarterly,* 30 (2): 291-314.

Suchman, L. (1987). *Plans and Situated Actions: The Problem of Higher Psychological Processes*. NY: Cambridge University Press.

Susi, T., & Ziemke, T. (2001). Social cognition, artefacts, and stigmergy: a comparative analysis of theoretical frameworks for the understanding of artefact-mediated collaborative activity. *Cognitive Systems Research,* 2 (4): 273-290.

Tapscott, D., & Williams, A. (2006). *Wikinomics: How Mass Collaboration Changes Everything*. NY: Portfolio.

Theraulaz, G., Bonabeau, E. (1999). A brief history of stigmergy. *Artificial Life*, 5: 97-116.

Trabinger, K. (2004). Resources and links. *Communities of Practice Online,* (web log), <http://coponline.blogspot.com/2004/12/resources-and-links.html?CFID=5166467&CFTOKEN=91093269> retrieved 16 April 2007.

Turchin, V. (1995). A dialogue on metasystem transition. *World Futures: the Journal of General Evolution,* 45: 5-57.

Viegas, F., Watternberg, M., & Dave, K. (2004). Studying cooperation and conflict between authors with history flow visualizations. *Proceedings of CHI'04,* (Vienna, Austria), 575-582.

Vinge, V. (1993). The coming technological singularity: How to survive in the post-human era. *Vision 21: Interdisciplinary Science and Engineering in the Era of Cyberspace NASA,* Lewis Research Center, 11-22.

Vygotsky, L. (1978). *Mind in Society: The Development of Higher Order Psychological Processes*. (Eds.) M. Cole, V. John-Steiner, S. Scribner and E. Souberman. Cambridge, MA: Harvard University Press.

Watts, D. J. (2004). *Six Degrees: The Science of a Connected Age*. GB: Vantage.

Weber, S. (2004). *The Success of Open Source*. Cambridge, MA: Harvard University Press.

Weinstein, P., Parunak, H. V. D., Chiusano, P., & Brueckner, S. (2004). Agents swarming in semantic spaces to corroborate hypotheses. *Proceedings of Third International Joint Conference on Autonomous Agents and Multi-Agent Systems* (AAMAS 2004, New York, NY), 1488-1489.

Wenger, E. (1998). *Communities of Practice: Learning, Meaning, and Identity.* Cambridge University Press.

Wenger, E. (2004). Knowledge management as a doughnut: Shaping your knowledge strategy through communities of practice. *Ivey Business Journal Online,* 68, (3), (online journal), <http://www.iveybusinessjournal.com/article.asp?intArticle_ID=465> retrieved 17 March 2007.

Wertsch, J. (1979). The concept of activity in Soviet psychology: an introduction. In J. Wertsch (Ed.), *The concept of Activity in Soviet Psychology,* Armonk, New York: M.E. Sharpe, Inc.

Wheeler, W. M. (1926). *Les Sociétés D'Insectes, Leur Origine, Leur Évolution.* Paris: Librairie Octave Doin.

Wood, D. J., & Gray, B. (1991). Toward a comprehensive theory of collaboration. *The Journal of Applied Behavioral Science,* 27 (2:) 139-162.

Wooldridge, M. (2002). *An Introduction to Multiagent Systems*. Chichester, England: John Wiley & Sons.

Wright, R. (2000). *Nonzero: The Logic of Human Destiny*. NY: Pantheon Books.

Wurr, A., & Anderson, J. (2004). Multi-agent trail making for stigmergic navigation. In A. Y. Tawfik & S. D. Goodwin (Eds.), *Advances in Artificial Intelligence,* 17th Conference of the Canadian Society for the Computational Studies of Intelligence (pp. 422-428). London, ON: Springer.

Zarb, M.P. (2006). *Modelling Participation in Virtual Communities-of-Practice*. LSE MSc ADMIS Dissertation: Distinction. Available at <http://www.mzarb.com/Modelling_Participation_in_Virtual_Communities-of-Practice.pdf> retrieved 16 April 2007.