The Politics of Technology and the Governance of Commons

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Abstract

In the 40 years since Hardin's fatalistic pronouncement that privatization and centralized state control are the only two institutional arrangements capable of preventing the tragedy of the commons, there has been considerable research to the contrary. The same could not be said for a similar pronouncement by Lewis Mumford in 1964 concerning the politics of technology in his "Authoritarian and Democratic Technics." Mumford contrasts a technology that is powerful, centralized, and authoritarian with a technology that is distributed, human-centered, and democratic, suggesting that man's autonomy and ability to self-govern hang in the balance between these two stark choices. Institutional arrangements, according to Mumford are "deeply embedded in the technology itself." While Hardin's stark choice between two polar opposites has been refuted in research revealing a great diversity of institutional arrangements for commons governance, there has been little systematic effort in examining the diversity of technological arrangements as they relate to politics in general and commons governance in particular. What this paper undertakes is to begin this effort by borrowing the insights and methods from institutional analysis. I examine a variety of examples in both natural resource and new commons through the lens of the Institutional Analysis and Development framework, highlighting the effect of technologies on access, control, information, and monitoring. As a result, I argue that technological arrangements are more varied and complex in terms of their political effects than suggested by Mumford, and that commons researchers and policy makers should have specific concern with the role of technologies in commons governance.

Keywords: *Technology, commons governance*

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Introduction

"Jens had to cultivate a strong, unified mind to counteract the disparate landscapes, societies, conditions. He jumped from a monthlong spring hunt to a helicopter that would take him to Nuuk to testify in front of Parliament. On behalf of the Hunters' Council, he was working hard to ban the use of snowmobiles and prohibit fishing boats in Inglefield Sound, where the narwhal calve and breed in summer" (Ehrlich 2003 p227). This brief quote concerning a Greenlandic hunter in the early 21st century encapsulates the main thesis of this paper: there are complex interactions between technologies, governance, and commons that have often been overlooked in literatures on both commons governance and the politics of technology.

In "The tragedy of the commons" (Hardin 1968), Hardin indicates that the relentless logic pitting one person's interests against all others will inevitably bring ruin to all in an open access commons. Hardin offers a stark choice between two institutional extremes: "mutual coersion" through a state-enforced social contract, or privatization of the commons. As Matthews and Phyne point out (Matthews, Phyne 1988), this is a political choice that has been discussed since the 17th century, between Thomas Hobbes's Leviathan and John Locke's natural rights view of private property.

Since Hardin's pronouncement, there has been considerable interdisciplinary work in commons governance from the field (e.g. summarized in (Dietz et al. 2002) and (van Laerhoven, Ostrom 2007)) demonstrating that the tragic logic of man warring against man is not inevitable. Human communities in a variety of settings and scales have used considerable ingenuity in crafting effective governance institutions appropriate to the specifics of their bio-physical and cultural embedding. As Dietz el al (Dietz, Ostrom & Stern 2003) point out, Hardin's prescriptions are too simplistic to characterize the considerable complexity of human institutional design.

When looking at the relationship between technology and politics, these simplistic prescriptions are similarly echoed. In an influential article on the politics of technology(Mumford 1964 p2) entitled "Authoritarian and Democratic Technics", Lewis Mumford writes:

> My thesis, to put it bluntly, is that from late neolithic times in the Near East, right down to our own day, two technologies have recurrently existed side by side: one authoritarian, the other democratic, the first system-centered, immensely powerful, but inherently unstable, the other man-centered, relatively weak, but resourceful and durable. If I am right, we are now rapidly approaching a point at which, unless we radically alter our present course, our surviving democratic technics will be completely suppressed or supplanted, so that every residual autonomy will be wiped out, or will be permitted only as a playful

> device of government, like national ballotting for already chosen leaders in totalitarian countries.

According to Mumford, this stark choice is "deeply embedded in technology itself" (p2).

My goals in bringing together the literature on commons governance with that on the politics of technology are threefold. First, I have seen little research that refutes the stark choices that Mumford provides with respect to the relationship between politics and technology. What I attempt to show here is that ; while technologies are political in their efffects, they are designed and used in dynamic interaction in subtle and complex ways by the participants in specific settings. Second, the conceptual and theoretical tools that have been developed for institutional analysis of commons can be brought to bear on issues of technology and governance. Using these theoretical tools provides leverage in discerning these more nuanced uses of technology. And third, I argue that, as with institutions, technologies should be viewed as key degrees of freedom within commons governance settings that are subject to human design and choice. They are not simply relatively fixed constraints, as are the bio-physical world of a particular setting or the cultural norms that prevail amongst resource users. To extend North's sports metaphor (North 1990), while organizations can be considered the players of a game and institutions the rules of the game, I consider technologies to be the *equipment* of the game. People not only change the rules by which they play, they change the equipment. And while Hardin considers commons governance to be a kind of problem for which there are "no technical solutions" (p1243) I instead bring technics back to the discussion of commons, since technologies can both exacerbate commons dilemmas as well as contribute to their solutions, often in complex ways. As objects of intentional human design, a keener awareness of the socio-political implications of technologies within a setting and an understanding of their interactions with the existing and evolving institutions will increase the likelihood that these technologies lead to improvements in the human condition.

The balance of the paper proceeds as follows. In the next section, I provide a review of some of the literature on the politics of technology. I contrast Mumford's "embedded" position with positions of technological neutrality (i.e. technologies themselves are politically neutral) and with a socially constructivist view of technology (i.e. technological designs and uses are largely determined by powerful political actors). By contrast, I take what Friedman and Kahn (Friedman, Kahn Jr 2002) call an *interactional* perspective, that although some technologies carry with them particular political tendencies, most technologies are shaped by actors in interaction with one another in local settings.

I then turn my attention to commons, first focusing on how technologies can affect the "type of good" of particular resource units because of the technology's impact on excludability and subtractability. I argue that the type of a good is not immanent in the good itself, but crucially depends on technology. Changes in technology are often accompanied (after a period of time) by changes to institutional arrangements. I close this section by arguing that new technologies can create new types of goods, exemplified by the vigorous markets for virtual real estate in such online games as Second Life.

Following this, I provide a brief overview of the Institutional and Analysis and Development Framework (IAD), enumerating the elements that comprise an *action situation* (i.e. a setting in which actors engage in collective action). Through discussion of particular examples, I show how technologies can impact these action situation elements. I end with a return to the three purposes with which this paper started, arguing that viewing technology's impact on commons governance through the conceptual framework of institional analysis operationalizes an interactional view of technology in which technologies are political in a wide variety of forms.

Theories Relating Technology and Politics

In Mumford's view, technological artifacts embed within their very structure particular political qualities. Under this belief, rather than being used differently in different socio-cultural settings, technologies exert their own political stamp on society regardless of context of use. Feenberg (Feenberg 1991) calls this perspective *substantivist,* associating it with the writings of Martin Heidegger (Heidegger 1977) and Jacque Ellul (Ellul 1964). Ellul, Feenberg writes, argues "that the 'technical phenomenon' has become the defining characteristic of all modern societies regardless of political ideology. 'Technique' he asserts 'has become autonomous'" (p7).

Feenberg contrasts the substantivist view with an *instrumental* view, in which technologies are instruments in the control of whomever wields the technology. This instrumental view is typical of discourse within engineering communities, and can be seen in the following quote from the paper published by the General Fisheries Council for the Mediterranean (Fiorentini, Paschini & Cosimi 1987 p23) "At the present point of the study the increase of the mesh sizes of the front part (from 200mm to 800mm) is strongly recommendable for pelagic trawls. The savings obtained were as much as expected and, as mentioned earlier, they might be even higher for the commercial fleet. At the same time the fishing efficiency is not reduced even for fish of small dimensions like anchovies, sardines, and sprats."

Although he views himself as a social constructivist (see below), Hughes nonetheless espouses significant elements of an instrumentalist view in his conception of *large technological systems* (LTS's) (Hughes 1987). Under this view, the technologies of interest are those at large (and usually national) scale: electrification (Hughes 1987) and irrigation (Ravesteijn 2002) to name two of many which have been studied using the LTS approach. Technologies are viewed as *problem solving systems* "using whatever means are available and appropriate … concerned with the reordering of the material world to make it more productive of goods and services" (Hughes 1987 p53). The builder of large technosocial systems is characterised by "the ability to construct or to force unity from diversity, centralization in the face of pluralism, and coherence from chaos," (p52). Efficiency and productivity are the central concerns of the instrumentalist, and technologies are seen as being without inherent political qualities.

In his paper entitled "Do Artifacts Have Politics?", Langdon Winner highlights the central claim of the substantivists. "At issue is the claim that the machines, structures, and systems of modern material culture can be accurately judged not only for their contributions of efficiency and productivity, not merely for their positive and negative environmental side effects, but also for the ways in which they can embody specific forms of power and authority" (Winner 1980 p121). And although Winner acknowledges the contribution of the substantivists for abandoning a naïve instrumentalist view, he believes that there are only a small subset of technologies, nuclear power being one, that "are in their very nature political in specific ways" (p128). Winner instead claims that most technologies are political in that "the design or arrangement of a device or system could provide a convenient means of establishing power and authority in a given setting" (p134). As an example, he cites Cyrus McCormick's use of pneumatic molding machines in his manufacturing plant in the middle 1880's, not because they were more efficient, but because they displaced skilled labor who could engage in such things as work stoppages and labor demands. In (Noble 1986) Noble takes a similar position in arguing that technologies are fundamentally shaped and wielded by social forces, and that actors with political power will use technologies to consolidate this power. Through detailed historical analysis of the development of automated machine tooling in the 20th century, Noble argues that management increased automation not because of corresponding increases in productivity, but because this technology centralized power, moving it from the shop floor into the hands of management. Noble's argument thus elaborates a predominantly Marxist analysis of the relationship between labor, power, and technology in capitalist countries, such as that of (Braverman 1974). Friedman and Kahn (Friedman, Kahn Jr 2002) call this the *exogenous* position, in that any politics associated with technology is shaped by social forces that are external to the technology itself. This is also sometimes called the *social constructivist* (Bijker, Hughes & Trevor 1987) or *social determinist* position.

The position that I elaborate in the balance of this paper is consistent with what Friedman and Kahn (Friedman, Kahn Jr 2002) call the *interactional* position. In this position, there is recognition that technologies can have political *effects,* but that these effects are only partly a result of intentional design. These effects are, more importantly, subject to mediation and control by individual users within particular local settings. So, for instance, though the planners of Brasília might have had goals to create a thoroughly regularized and rationaled modern city through the very structure of the built environment—its immense (and largely empty) plazas, rectangular apartment blocks, separation of traffic from pedestrains, and segregation of places of work, commerce, and home—the actual residents had other plans. Incrementally constructing an "other" Brasília on the outskirts of the "built" Brasília , originating as squattor settlements of laborers, this non-planned Brasília came to contain 75% of the population of the city, winnning political recognition and city services only through ongoing political action (Scott 1998).

Though an instrumental position is dominant in the discourse among practicing engineers, there is an influential minority taking an explicit interactional approach to the design of technologies. These include *participatory design* practitioners among software system designers (Bjerknes et al. 1987, Greenbaum, Kyng 1991, Nardi, O'Day 1999, Schuler, Namioka 1993) and organizations such as *Engineers without Borders* (Anonymous), all of whom situate users of local communities or organizations as primary actors in the design, use, and lifecycle of technologies.

To summarize, views of technology have ranged from an instrumenalist position that technology is politically neutral, to a substantive position that technology has politics immanent within its very structure, to a social constructivist position that technology affects power and authority through its use within existing arrangements of socio-political power. My position is interactionalist, in that I view technology as having political effects, that, while infuenced by the intentional embedding by the designer is nonetheless reshaped by users within the practical settings of their everyday lives. In the next section, I turn from an examination of theories of technology to the ways in which technologies influence the governance of commons. Following this, I operationalize the interactionist perspective in providing a number of examples of ways in which local participants have shaped technologies within their local settings.

Types of Goods

Ostrom and Ostrom (Ostrom, Ostrom 1977) identify two key dimensions along which to describe goods: *excludability* and *rivalry* (sometimes called *jointness of use* or *subtractability*). *Private* goods are those with both high excludability and high rivalry, *toll* goods are those with high excludability and low rivalry, *common pool resources* (CPR’s) are goods with low excludability and high rivalry, and *public* goods are those with low excludability and low rivalry. *Commons* have traditionally been defined (e.g. as in (Buck 1998)) as areas of physical extent that contain CPR’s.

One of my key claims is that type is not immanent in the good itself: As a consequence of changes in technology, goods can “shift” from one type to another. I examine each of the factors of rivalry and excludability in turn.

Rivalry

New technologies can increase rivalry. Safina comments “The 19th-century naturalist Jean-Baptiste de Lamarck is well known for his theory of the inheritance of acquired characteristics, but he is less remembered for his views on marine fisheries. In pondering the subject, he wrote, ‘Animals living in... the sea waters... are protected from the destruction of their species by man. Their multiplication is so rapid and their means of evading pursuit or traps are so great, that there is no likelihood of his being able to destroy the entire species of any of these animals.' Lamarck was also wrong about evolution" (Safina 1995 p45). Prior to a technological innovation, what was once effectively a public good (i.e. there was always enough for the demand) becomes a highly subtractible common pool resource. This resource scarcity can lead to human conflict (Bennett et al. 2001), including war (Ember, Ember 1992)). Changes in technology can have the same effect as increases in population by changing the rate at which resource units can be appropriated from a CPR.

Safina considers technological advances as the primary reason for the collapse of fisheries worldwide.

> How did this collapse happen? An explosion of fishing technologies occurred during the 1950s and 1960s. During that time, fishers adapted various military technologies to hunting on the high seas. Radar allowed boats to navigate in total fog, and sonar made it possible to detect schools of fish deep under the oceans' opaque blanket. Electronic navigation aids such as LORAN (Long-Range Navigation) and satellite positioning systems turned the trackless sea into a grid so that vessels could return to within 50 feet of a chosen location, such as sites where fish gathered and bred. Ships can now receive satellite weather maps of water-temperature fronts, indicating where fish will be traveling. Some vessels work in concert with aircraft used to spot fish.
>
> Many industrial fishing vessels are floating factories deploying gear of enormous proportions: 80 miles of submerged longlines with thousands of baited hooks, bag-shaped trawl nets large enough to engulf 12 jumbo jetliners and 40-mile-long drift nets (still in use by some countries). Pressure from industrial fishing is so intense that 80 to 90 percent of the fish in some populations are removed every year (Safina 1995 p46).

Technologies can also reduce the rivalry of goods. For instance, White (White 1962) details how the development of the heavy plough enabled the cultivation of wetter, heavier soil in Northern Europe. White explains that the heavy plow opened richer, "alluvial bottom lands" to cultivation that had been previously unavailable. Further economies were realized in the use of this plow by changing field sizes from roughly square fields to long, narrow "strip fields", which increased drainage. White states that the resulting savings of peasant labor over the predecessor *scratch* plow "together with the improvement of field drainage and the opening up of the most fertile soils, all of which were made possible by the heavy plough, combined to expand production and make possible that accumulation of surplus food which is the presupposition of population growth, specialization of function, urbanization, and the growth of leisure" (p44).

This reduction of rivalry can most dramatically be seen with technological changes associated with knowledge. Using Hess and Ostrom's terminology, *ideas* manifest in *artifacts* that are stored in *facilities* (Hess, Ostrom 2001). In the scribal culture of early modern Europe prior to the development of printing in the late 15th century, written artifacts were highly subtractable. Written artifacts were scarce and costly to produce. As Eisenstein argues (Eisenstein 1983), moving from a scribal to a print culture resulted in profound changes in Europe, particularly with respect to the Protestant reformation and the growth of scientific knowledge. With lowered costs of production, books, folios, images, charts, and all types of printed matter became widely though not uniformly diffused throughout Europe in the 16th century. What was once scarce in a scribal world became abundant in a print world. And with the advent of the Internet, manifestations of knowledge are now hyper-abundant, with a variety of facilities distributed across the world for storage and access. Any artifact that can be digitized, including images, text, music, and video, that exists wherever there is ubiquitous infrastructure for digitization can be considered a non-subtractible resource.

Excludability

Physical features, such as mountains and rivers, have served as natural barriers to access of particular resources. Excludability, however, is significantly impacted by the technologies available for restricting access. Developing new technologies has often been a significant concern for those relying on resources for their livelihood. In writing about the development of barbed wire in the western prairies and plains of the 19th century United States, Basella writes that "Between 1870 and 1880, newspapers in the region devoted more space to fencing matters than to political, military, or economic issues" (Basella 1988). Keeping agricultural plots from free-ranging animal herds was such a concern for the frontiersman of the westward expanding United States, that the infant barbed wire industry saw explosive growth in the 1870's. From 10,000 pounds of barbed wire in 1874, the first year of commercial production, production jumped to 600,000 pounds in 1874, to over 12 million pounds in 1877, and 80 million pounds in 1880 .(Basella 1988). Barbed wire not only keeps cattle from crops, but visually signals to other people that a plot of land is owned by another.

What can be enclosed depends crucially upon techologies of exclusion. What might have previously required human monitoring of boundaries can be replaced by technological artifacts that dramatically reduce the costs of enclosure. With such things as razor wire, and electric fences, not only monitoring, but sanctioning of the trespasser can be "automated" without requiring human intervention. Technologies of exclusion can thus be thought of as embodying specific rules of exclusion. The "no trespassing" sign that is ubiquitous in the United States might signal the rule, but it is the fence that enforces.

And in some cases, it is the law, not the fence that provides exclusion. "The technology that protects DVD movies is an incompetently designed stream cipher known as

Content Scrambling System (CSS) [3]. The law, not the cipher, provides the real protection" (Touretzky 2001 p23).

It is this near-equivalence of effects between laws and technologies of exclusion that Lessig refers to when he talks about "code and other laws of cyberspace." Computer code (i.e. software) that is used for exclusion and monitoring is, in Lessig's view, equivalent to law, or nearly so. "We live life in real space, subject to the effects of [computer] code. We live ordinary lives, subject to the effects of code. We live social and political lives, subject to the effects of code. Code regulates all these aspects of our lives, more pervasively over time than any other regulator in our life" (Lessig 1999 p296). With the advent of computer code, this dual between technology and rules is easily conflated, since computer code in most conventional computing languages is constructed from a series of *if/then* rules.

Even Lessig, however, recognizes that fences are not laws. "Should we remain passive about this regulator? Should we let it affect us without doing anything in return?" (p296) He argues, instead, that laws are centrally important for preventing further enclosure of the digital commons, a position argued by many others (e.g. (Boyle 2003) (Hess, Ostrom 2001)). And Edward Felten, a computer scientist at Princeton university, argues that computer code can never embed the context-sensitivite judgement that people employ when applying laws to the situated experiences of social life, in this case the application of "fair use" exceptions to US copyright. "The legal definition of fair use is, by computer scientists' standards, maddeningly vague. No enumeration of fair uses is provided. There is not even a precise algorithm for deciding whether a particular use is fair. … Accurate, technological enforcement of the law of fair use is far beyond today's state of the art and may well remain so permanently. Technology will not obviate the need for legal enforcement of the copyright rights of both copyright owners and users" (Felten 2003 p58).

Such exceptions to the understood rules-in-use within a community are not uncommon. But when there are human monitors, such as "detectives" in the Japanese villages that McKean (McKean 1984) describes who patrol the village forest lands for harvest violations in rural Japan, they can allow exceptions, particularly when people need access to resources under times of emergency or duress. Computer code and electric fences cannot respond with a wink, or collect a bottle of sake in exchange for turning a blind eye in the way that a human monitor can. Technological exclusionary controls can thus change patterns of social interaction, solidifying and rendering context-independent what was previously fluid and context-sensitive.

The Interaction between Institutions and Technologies

The philosopher James Moor argues that there is a time lag between the introduction of new technologies and the institutional response to these technologies, what he calls a *policy vacuum* (Moor 1985). According to Moor, institutional responses are often required because changes in technology not only have important socio-political effects, but challenge existing conceptual frameworks, concerning such things as the nature of property, speech, labor, and what it means to participate.

Stable technologies can give rise to well understood institutions that are fit to the technology and the situation of use. This is often the case with particular appropriation technologies. Ehrlich cites Knud Rasmussen's account of this phenomemon from his journeys in Greenland in the early 20th century. "To catch fish, the Netsilik built a stone dam and put a weir in the little stream that connected the large and small lakes. Rasmussen observed that the river trout that swam into the trap could easily get out, but the salmon, swimming upriver, never turned around once in the weir and were easy to catch. There were rules about the time of day for fishing" (Ehrlich 2003 p208).. In her comparative study of 33 subgroups of fishers worldwide, Schlager (Schlager 1994) states that "Twenty-two groups (67 percent) limit access to their fishing grounds on the basis of type of technology used. … Limiting both the number of individuals who can access a ground and the type of technologies they can utilize reduces the amount of fishing effort applied in harvesting, thereby possibly affecting the magnitude of appropriation externalities. … For example, the cod fishers of Fermeuse, Newfoundland, described by K. Martin (1973, 1979), have 'divided their own fishing grounds, as have many inshore fishing communities, by setting aside certain fishing areas (usually the most productive) for the exclusive use of certain technologies' (1979, 285)." Allocating specific technologies to specific locations also reduces what Wilson .(Wilson 1982) calls "technological externalities", i.e. when the gear of one appropriator interferes with the gear of another.

What the above examples point out is that changes in subtractability (e.g. increases in appropriation) often result in institutions that increase excludability. Boyle points out how this is occuring with digital goods. "The difficulty comes because of the idea that information goods are not only non-rival … they are also assumed to be non-excludable … Thus, the law must step in and create a limited monopoly called an intellectual property right" .(Boyle 2003 p42) As the economist Michael Perelman points out, since technology has made certain goods non-rival and abundant, those who previously derived economic gain from the relative scarcity of the good seek to create artificially scarcity with stronger exclusionary institutions (Perelman 2002).

New Types of Goods

Changes in technology can also create new types of goods. These include such things as pharmaceuticals, electronics, durable medical supplies, and machine tools. The ubiquity of technologically-created goods has likely become taken for granted in general, since goods other than those that are directly appropriable in their natural state can be considered technologically-created goods.

An example that strikingly illustrates the good-creation property of technology is the emergence of virtual property in Massively Multiplayer Online Games, such as Second Life (Grimmelmann 2004). In one sense, this technologically-created property only exists within a technologically-mediated virtual world. And yet this virtual property is bridged to the non-virtual world, the world of physical stuff through the labor used to create these goods and the markets that are now developing for selling these goods. Meehan reports that “In the game Project Entropia, a virtual island sold for over $26,000 and a virtual space station sold for $100,000” (Meehan 2006 p3) and that virtual property regularly sells on online auction sites such as eBay. New types of goods are often followed by new institutions to structure their governance.

Applying the Tools of Institutional Analysis: The IAD Framework

The Institutional Analysis and Development (IAD) Framework developed at the Workshop for Political Theory and Policy Analysis at Indiana University (Ostrom, Gardner & Walker 1994) provides an analytical tool for unpacking the structure of collective action settings. The main borrowing from the IAD is the set of elements that comprise a collective action setting, which I use to categorize technological effects. In the exposition that follows, I use the definitions from (Ostrom 2005).

An *action situation* exists ``[w]henever two or more individuals are faced with a set of potential actions that jointly produce outcomes'' (Ostrom 2005). The internal structure of action situations consists of the following seven elements (italicized). There are *participants* who hold *positions* who can select with some amount of *control* using a given amount of *information* over a set of *actions* that yield *outcomes* with particular *costs and benefits*.

Participants

The participants are the actors within a particular setting. A key issue facing commons concerns the set of actors who can appropriate, derive benefit, and who might be required to provision public goods associated with a commons. New technologies of transportation, such as the snowmobile in Greenland with which I opened this paper, can bring new appropriators into a setting. Ironically, it is also a technology of transportation—the helicopter—that enables Jens, the Greenlandic hunter, to be a participant in another action setting: Parliamentary deliberations concerning the banning of the snowmobile. Another example in which technology affects participation is the personal water craft (or *jet skis*), whose introduction in coastal settings has led to conflict and controversy (Walker 1994) (Davenport, Davenport 2006).

Technologies of communication can likewise impact participation. For instance, with increasing digital bandwidth and technologies of virtual presence, the very meaning of membership within particular communities is being challenged. These technologies can enable individuals not physically present to participate in interactions with one another. Depending on the resource, technologies might also enable remote use and appropriation of resource units. For example (Querci, Querci 2000) reports on the use of the Internet for the remote control of the scarce viewing time available in high-quality telescopes in observatories around the world by students in distal locations.

Technologies can also impact the number of participants interacting within an action situation. One way they do so is by increasing the technical complexity of a task, thereby *requiring* several participants to operate the technology. For example, the boat technology available for several thousand years to native micronesian navigators, coupled with their culturally transmitted knowledge about star patterns, geography, wave action, and the flight of shore birds, enabled a single individual to take voyages of several days duration far out of the the sight of land (Hutchins 1983). Modern, ocean-going vessels, on the other hand, require the participation of a number of different people with differentiated skills in order to operate: "no single person could make all of the observations and do all of the computations required to complete the [bearing fix] cycle in the amount of time available" (Hutchins 1995 p43).

In addition to requiring coordinated action for their operation, technologies can also *enable* coordinated action by a large numbers of participants in an action situation. A few examples taken from outside the literature on commons exemplifies how this can occur. Suchman describes the way in which various displays are used to coordinate actors in the planning of baggage handling at a busy US airport (Suchman 1997). Paper flight progress strips ("which are strips of card approximately 8 inches by 1 inch, and which are divided into fields containing information for a particular flight") have also been closely studied as technologies of coordination within flight control towers (Hughes, Randall & Shapiro 1992). Ueno examines "technologies for making social organization, work, and mass production mutually visible in collaborative activity" within a modern manufacturing factory (Ueno 2000). And Hutchins describes how a team of six people (bearing-takers, bearing timer-recorder, plotter, keeper of the deck log, fathometer operator) navigate an amphibious helicopter transport using a number of role-specific technological tools (Hutchins 1995).

Positions

Positions specify roles associated with participation, where different roles are linked to different action possibilities. Technologies are related to entry and exit into particular roles. For example, access to transportation technologies can allow individual appropriators entry into resource domains and new markets, thereby reducing their dependence on local markets. These same technologies, however, can also increase the externalities on existing sellers within local settings. Communication technologies such as the Internet and the cell phone can also facilitate the entry and exit into non-local markets.

The introduction of particular technologies into a setting can also give rise to a new class of roles: those associated with having the requisite *technical knowledge* to use and maintain these technologies. This technical knowledge might not be distributed uniformly across all of those sharing a commons which can sometimes lead to power inequalities. For instance, the technical knowledge associated with carrying out open ocean trips of several days' duration in micronesia was carefully safeguarded and transmitted only through long apprenticeship (Thomas 1987).

Another problem with certain kinds of technical knowledge is that it might be invisible to many members who provision the commons, and hence sufficient resources might not be allocated for the support of technical knowledge. As an example, Nardi and Oday (Nardi, O'Day 1999) discuss how a high-tech company underestimated the importance of librarians within an in-house "information commons" and how this had negative impacts on the subsequent research within this company. Through training and socialization in becoming librarians, the librarians developed practices of performing a number of valuable services, but did so unobtrusively and invisibly to upper management.

Control

This element concerns the amount of control individual participants have to affect outcomes. "Action situations may involve differential distributions of control and opportunity to different individuals in the situation. Consequently, individuals may differ in the amount of power they have in the situation" (Ostrom 2005).

With the advent of computer technologies and the contested outcome of the 2000 presidential election in the United States, technologies associated with voting—from paper ballots to punch cards, optical scanners and graphical user interfaces—are increasingly recognized for their role related to political control. Voting technologies impact the amount of error in vote counting (The Caltech/MIT Voting Technology Project 2001), the security and reliability of the ballots and the voting process (Felten 2003), and the transparency and auditability of the voting process (Felten 2003). Technical constraints can also affect what kinds of voting "algorithms" are even possible. For instance, after Pierce county citizens of Washington State, USA approved *ranked choice voting* (sometimes known as *instant runoff voting*) in 2006, they were asked to approve an amendment that permitted the county vote administrators to limit the ranking to the top three candidates, since the existing federally certified voting software was unable to handle more than three candidates (Pierce County Auditor 2008).

Technologies can also control human behavior in their operation (such as cutting guides) and organization (e.g. assembly lines). Braverman (Braverman 1974) describes how Frederick Taylor first studied the ergonomic micro-structure of human action in work settings in order to build machines to structure the work and to centralize the control of this work. The new technologies and institutional regimes were mutually entwined so as to move control over production from the shop floor to management.

Information

Technological changes affecting information can have far reaching effects on a commons and its governance, since information is associated with each of the other elements of the IAD framework. These include information on markets (including information markets), resource system state (e.g. resource unit levels, pollution), the reputation of participants, appropriation technologies, population demographics and group membership, and compliance with existing rules. Rheingold discusses ways in which emerging information technologies affect cooperation, resulting in such things as "smart mobs" of individuals who spontaneously come together in coordinated action (and as spontaneously break apart) that emerge through a viral spread of information amongst the participants using real-time internetworked technology (Rheingold 2002).

The impact of technologies on the different kinds of information is so vast that any survey here would necessarily only scratch the surface. I instead highlight two non-obvious (but what I believe are important) technological impacts on information. First, technologies (and computational technologies in particular) can affect the visibility of certain techno-social processes through their partial automation. "There is an important fact about computers. Most of the time and under most conditions computer operations are invisible" (Moor 1985 p272). Part of the controversy surrounding the use of many computerized voting systems concerns the fact that the computational invisibility, when coupled with legally-enforced ownership of program source code that excludes all but the owners and their agents from looking at the program internals, makes these systems inherently inauditable by disinterested third parties .(Massey 2004).

Invisibility, however, can also be a charateristic in non-computational technologies. Technologies that do not enable transparency for such things as monitoring other participants' resource use can result in the abandonement or destruction of the technology. Lansing's example related to rice irrigation in Indonesia is telling.

> "This method [the flooding of rice fields on a careful schedule] depends on a smoothly functioning, cooperative system of water management, physically embodied in proportional irrigation dividers, which make it possible to tell at a glance how much water is flowing into each canal and so verify that the division is in accordance with the agreed-on schedule. … Modernization plans called for the replacement of these proportional dividers with devices called "Romijn gates …. The use of such devices makes it impossible to determine how much water is being diverted" (Lansing 2006 p8).

Despite the $55 million dollars that the government spent on installing the Romijn gates, "new irrigation machinery installed in the weirs and canals at the behest of the consultants was being torn out by the farmers as soon as they felt that it was safe to do so" (p7).

There is another important class of technologies that I highlight, what I term *technologies of representation*. By this I mean technologies that enable information to be externalized in persistent form and transmitted to others. Eisenstein (Eisenstein 1983) argues that technologies of representation, such as the the printing press, are unlike other technologies: “One cannot treat printing as just one among many elements in a complex causal nexus, for the communications shift transformed the nature of the causal nexus itself … It is of special historical significance because it produced fundamental alterations in prevaling patterns of continuity and change” (p275).

One way in which these technologies affect the “causal nexus” is the role that they play in propogating knowledge from one generation to the next. As Hess and Ostrom state concerning Popper’s conception of reified scientific knowledge “knowledge contained in scientific reports, articles, and books comes to have an autonomous existence as it affects the thinking and research of the next generation of scientists” (Hess, Ostrom 2001).

One particularly important form of reified knowledge for issues of commons governance is the geographical map. Black points out that “[t]he choice of what to depict is linked to, and in a dynamic relationship with, issues of scale *and* purpose, and the latter issue is crucial. A map is designed to show certain points and relationships, and, in doing so, creates space and spaces in the perception of the map-user and thus illustrates themes of power” (Black 1997). Problems can arise, for instance, in how borders are mapped, because “the [border] lines betoken frontiers and these frontiers are the cause, course and consequence of conflict” (p121).

Maps do not simply reflect, but can create a sense of space, place, and ownership among those who perceive them. And, as James Scott argues, they can also simplify complex social realities in an attempt to centralize and rationalize power and authority (Scott 1998), especially by states in the process of modernizing. For example, cadastral maps used in administering a taxation system over a given geographical area are necessarily clear in their specification of borders and owners, ignoring such things as variations in soils, yield, drainage, and the countless other subtleties associated with land that are known by local inhabitants. Such maps, Scott argues, not only simplify *representationally*, but in doing so, reflect back on the inhabitants through the introduction and enforcement of institutional rules based upon these representations. They are thus key elements in the *creation* of the simplified reality that they represent.

Not only might these technologies contribute to further rationalization and concentrations of power (as Scott argues), but they can have the opposite effect: they can give “voice” in increasingly larger forums to those who have been previously marginalized. This is what Cleaver calls the “Zapatista effect,” named for the Zapatista’s use of the Internet to forge an “electronic fabric of opposition” to Mexican government policies (Cleaver Jr 1998). The fact that externalized representations reflect back on the subjects of knowledge indicates the dual role that these technologies play in both representing and creating social reality.

What all of this implies is that more pervasive forms for externalizing information can profoundly affect the way in which knowledge, identity, and culture are conceptualized, all of which have political implications.

Actions

Actions are undertaken by participants in specific positions in order to affect outcomes. Some actions can only be undertaken in the presence of technologies: the swinging of a scythe, the sawing of a tree. The actions that are available to participants can both expand and restrict as a result of technologies. Examples of restrictions are discussed above concerning **control**, while expansions can be seen with the technologically-mediated coordinated action as discussed above in the **participants** section.

What I wish to highlight in this section, however, are emerging concepts of human-machine interaction that view people as being biologically constructed to be technologically extended: who we are is fundamentally determined by the actions that we can engage in, which is largely determined by the technological materials at hand. "We humans have always been adept at dovetailing our minds and skills to the shape of our current tools and aids. … [The mind] is a structure whose virtue lies in part in it's capacity to delicately gear its activities to collaborate with external, non-biological sources of order so as (originally) to better solve the problems of survival and reproduction" (Clark 2001 p18). Cultural-historical theorists of mind, starting with Vygotsky (Vygotskiĭ, Cole 1978), take *activity* between agents and objects as central units of analysis. Such activity is mediated by cognitive and technological tools. "An enormous number of artifacts has been developed by humankind to mediate our relationship with the world. Using these artifacts is the hallmark of living the life of a human being." (Kaptelinin, Nardi 2006 p42). These views of man as *homo faber* contrast with the *homo economicus* models typically used in Commons research (Ostrom, Gardner & Walker 1994) (Ostrom, Walker 2003). The activity-centered view, to a large extent, provides a philosophical rationale for the interactionalist perspective I outline above. Tools are not only shaped by people, but as well shape who people become. Technology and human action cannot be separated.

Outcomes

Regardless of whether one takes an instrumental, substantive, or interactionalist position, technologies are *intentionally designed* for achieving specific effects on the state of the world: nets for catching fish, saws for felling trees, cell phones for making phone calls. Herb Simon defines designing as "courses of action aimed at changing existing situations into preferred ones" (Simon 1996). People have displayed astonishing ingenuity in their shaping of materials at hand to bring about envisioned futures.

But because of the complex interconnections in socio-ecological systems (Janssen, Ostrom 2006, Wilson 2002), technological innovation, human activity, and the complexity of the natural world can have unintended effects across a large span of space and time; such effects can be difficult to predict when technological and institutional choices are being made. The case of the horseshoe crab (limulus polyphemus) in the eastern United States illustrates this point. The harvesting of horseshoe crabs in the early 1990's increased more than tenfold from their averages between 1950--1990 (Walls, Berkson & Smith 2002) as a result of two primary factors. The first is their use as bait for eel and whelk, which experienced significant growth in world demand (p50). Second, as a result of advances in science and technology, "[t]he biomedical industry uses blood from horseshoe crabs in the production of Limulus ameobocyte lysate or LAL, which is the standard test used to detect endotoxins pathogenic to humans in all injectable drugs and implantable medical devices" (Kurz, James-Pirri 2002 p261). Although the bled crabs are returned to the wild, the resulting mortality rates are estimated in the 8-15% range (p267). The complexity of natural systems is evidenced by the impact of increased horseshoe crab harvesting on the Red Knot, a shore bird with a 30,000 kilometer annual migration between its wintering site at Tierra del Feugo and its summer breeding ground in the Canadian arctic. Due to the length of this migration, the Red Knot makes a brief stop at Delaware Bay to feed on the nutrient rich horseshoe crab eggs that had been abundant until recently. With no other major refueling stops on route to the arctic, Red Knot survival is now threatened with extinction due to the increased harvesting of horseshoe crabs (Baker et al. 2004). Thus, increases in world demand for one good increased demand for another, when coupled with technological advances in the biomedical industry have reduced the population of one species in a particular location, resulting in the near extinction of another species that spends most of its lifetime thousands of kilometers distant.

There is complexity as well in the way that technologies have far-reaching social effects that extend beyond their functional, intrumental effects. Technologies have what Sclove calls *non-focal* effects, the "pervasive, latent tendencies" of technologies to "shape patterns of human relationship" (Sclove 1995 p89). To illustrate, Sclove provides the example of Ibieca, Spain, where residents had indoor plumbing installed during the 1970's, replacing their mutual dependence on a village fountain. As a result, "women stopped gathering at the washbasin to intermix scrubbing with the politically empowering gossip about men and village life" (p86) Further, by introducing indoor water pipes, donkeys were no longer used for hauling water. This reduced donkeys' marginal benefit, so that they were more likely to be replaced by tractors for work in the field, which led to a higher dependence of the villagers on outside jobs.

In her ethnography of an Iraqi village, Fernea (Fernea 1989) provides another example of how technologies can restructure social relations. When a new bridge was built in the small village of El Nahra, the American engineer repositioned the bridge from its old site between the tribal settlement and the mosque, to a new site linking the centers of the settlement and village. "What the engineer did not know, and of course no one dreamed of telling him, was that the old bridge was inefficiently situated for a very good reason: to allow the women to pass over unnoticed, to either side of the canal, to visit friends or pray in the mosque without being exposed to the stares of the strange men who always filled the coffee shops or lounged at the entrance of the bazaar." As a consequence, "women went out much less often after the new bridge was finished and the old bridge was dismantled and sold for firewood" (p50).

In short, changes to technology result in outcomes that differ not only from the intended, instrumental uses of these technologies. But they can have as well far-reaching effects at different scales of space and time on complex socio-ecological systems, altering patterns of natural and human life.

Costs and Benefits

Under an instrumental view, most technologies are developed so as to reduce the costs and increase the benefits associated with production. New efficiencies that reduce appropriation and transaction costs are certainly important, and several have been mentioned above. What I wish to highlight, however, is that changes in technology not only create efficiencies along predicted dimensions, such as labor or energy cost, but *shift* costs and benefits and who pays and receives these. For example, the snowmobile in a hunting community in Greenland might reduce time costs associated with hunting, but also increases noise, air and water pollution, all of which are externalized, and increase dependence on a cash economy to pay for the ongoing costs of ownership. In addition, the increased competitive pressure that might result from lowered labor costs realized by snowmobile-using hunters can lead to a technological arms race among the different participants. And, as indicated above, the costs and benefits associated with non-focal and complexity effects can change dramatically with changes in technology, none of which may be obvious or predictable at the outset.

Conclusion

It would be strange to inquire whether institutions are political. Whether we view politics as fundamentally concerned with *power over* or *power with* social relations (a distinction made by Vincent Ostrom (Ostrom 1997 p53)), the political nature of institutions is simply taken for granted; how could institutions not be political? The literature on commons governance reveals the great variety of institutions that people have crafted in response to the contingent aspects of the biophysical and cultural contexts in which they act. Such institutions reveal the range of choices that lie between the poles of privatization and centralized coercion that Hardin claimed were the only institutional choices.

And yet it is easy to overlook or misunderstand the political nature of technologies, the concern of this paper, and I return to three original purposes that I stated at the outset. The first is to argue that technologies *are* political, but in a much greater variety of ways than the two choices of *democratic* and *authoritarian* that Mumford asserts, or alternatively, of the extremes of the non-political instrumentalist or the social-determinist. One of the problems of much previous analysis is that if we look at states as the only viable political actors, then our technological analysis will be of Large

Technological Systems. We can inquire into whether such technologies are centrifugal or centripetal, simplifying or diversifying, much as Mumford did in 1964. What will escape our gaze is the way in which individuals on the ground participate in the shaping of technologies to fit the contingencies of the specific circumstances they face. Small and medium-sized technological systems may be as important as large technological systems in the creative governance of commons. Jens is *not* concerned with the development of a pan-Greenlandic infrastructure for the automation of various aspects of hunting. Nor does he take a uniform anti-technology stance ("On his tiny radio, Greenlandic music played—soft country-western with lyrics about dogsleds and ice rather than cowboys, horses, and sunsets" (Ehrlich 2003 p174)). He is, rather, concerned with the effect of snowmobiles on the narwhal population in Inglefield Sound. To ask whether snowmobiles (in the abstract? In general?) are democratic or authoritarian is beside the point. The key point is how Jens and his fellow Greenlanders will respond to the specifics of their lived interactons. Such a response might be technological (e.g. with exhaust mufflers), institutional (with a general ban), or some combination (a requirement to use mufflers at certain times and dates). Which response that they choose is an open question; regardless, the technical *and* the institutional choices are political.

Substantiating the claim concerning the variety of politics of technological things requires achieving the second primary purpose of this paper, which is to use the tools of institutional analysis that had been so useful in arguing that Hardin's institutional extremes were but two among many. In particular, I use the taxonomy of goods along the dimensions of excludability and rivalry, along with the elements of action settings as provided by the Institutional Analysis and Development framework. These serve as lenses for looking more deeply at technological impact. Not only does this lead to a conclusion that technologies are political by virtue of their effect on each of the elements of the IAD, but examining each element more closely reveals *how* these technologies are political: in determining who and how many people participate in an action setting, what positions they take, the amount of control that participants have to affect outcome variables, the information that is available for choice and action, the set of action possibilities available, and the costs and benefits associated with outcomes.

As Ostrom points out (Ostrom 1997), the "material" of institutional design is human language. *Technological* design, on the other hand, is carried out with material from the biophysical world. My treating technologies as institution-like, using the same language and analytic framework is thus no accident—it too is a designed choice. Technological "code," i.e. the knowledge of the world that is built in to the very design of technology (the way the hand forms around the hammer's handle, the way the hammer exploits gravity and the density and weight of the head), can sometimes function much like institutional code. Hobbes could just as well have been defining technological design as institutional design when he defined power as "the use of present means to achieve some future apparent good" (quoted in (Ostrom 1997) p9). Institutions and technologies interact, mutually shaping one another. New technologies can give rise to policy responses that in turn shape subsequent technological development.

But neither rules nor institutions function autonomously; human agency has not disappeared. And this relates to the third purpose for this paper: to underscore the importance of the role that technology plays in collective action settings. This is not only because institutional artifacts must be shaped in response to technological developments. But it is important because, unlike the biophysical setting and shared culture of participants that are largely fixed within any particular action arena, technologies represent degrees of freedom for human agents, amenable to creative design.

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