Simulating the management of renewable resources with multi-agent systems.

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Nowadays the economic and alimentary wellbeing of most societies is related to a sustainable use of their natural environment With the environmental changes and with increasing human needs, population growth and economic growth this interaction is often upset. Therefore there is a need to build new resource sharing rules. The sustainability of society-resource interaction is often controled by regulating access to space. One of the major problems concerning resources such as wild fauna or fish communities is that the resource may move or migrate among the differents parts of space, following the different seasons of the year. The dynamics of this space-resource must be taken into account. Modelling and simulation may be an efficient tool to explore the consequences of diverse modes of collective appropriations on the dynamics of the resource. In this paper we present and discuss a modelling methodology (multi-agent systems) in the field of renewable resource management

1 Some modelling problems

Research in environment involves several actors First of all, it involves actors within the ecosystem whose interactions with the environment are studied Secondly, it involves the researchers themselves

This is important, because environmental research is carried out more and more by research groups made up of representatives of different disciplines A different representation of reality can be seen in each of these disciplinary research approaches (Friedberg 1992) In order to avoid confusing these representations with those of the actors we will refer to these disciplinary representations as points of view They constitute a certain vision of reality The goal of the interdisciplinary research is, if not to create an integrating point of view, at least to find links between these points of view.

Another series of problems inherent in environmental research, particularly in the use of renewable resources, are the problems of access to these resources, appropriation modes and decision-making processes. The environment is therefore something which is individually and collectively built. Access to resources often implies representations produced by common values and categories constructed and shared by a community. This ensemble expresses the relations that this community and its individuals have with the world. How do men conceive their relation to the environment ? This question leads to another : the relationship with others *"Levi Strauss has clearly shown that cultures mythical representations are not imposed on them by the ecological milieu or their material base ; on the contrary, they choose their mythical representations in differentiating opposition to those of neighboring cultures."* (Caillé, 1992) The two aspects of representation - natural and social - are linked, because, for the anthropologist representations made by individuals generally arise out of " systems of representation " which are rooted in the totality of their society 's ideas and values *"All relations between individuals and groups concerning things involves a relation of control or authority .This relation is itself established and organized on the basis of a representation of reality (ideology), whether it involves ethics, morale or a religious reference "* (Weber 1988)

Thus the problem is to modelize the individuals and their representations We propose to investigate this problem with simulation methodology coming from artificial intelligence field.

2. Artificial Intelligence and simulation.

2.1. Modelling knowledge.

The modelling we refer to here is that of Artificial Intelligence, an area concerned with modelling of knowledge There are two principal schools of modelling in cognitive sciences the cognitivist school and the connectionist school. Without going into the ongoing debate between these two schools (Varela 1989&1993, Bourgine 1993, Andler 1992, Dupuy 1994), we should note that :

- the cognitivists consider representations as interpretations of the world. These representations exist physically in the form of a symbolic code in the brain or in a machine (computational theory of the mind) Here cognition becomes manipulation of symbols according to rules. The cognitivist hypothesis is the basis of symbolic AI

- the connectionists consider cognition as the emergence of global states in a brain made up of simple components It is the global state of the system which is identified with a given faculty The roots of connectionism lie in the neurosciences. The associated methods are those of the neuron networks

Thus on one hand, there is an approach which could be described as ascending, since its goal is to understand the macroscopic properties resulting from interactions on a microscopic level, and on the other hand, an approach which considers knowledge at a high degree of abstraction and which aims at manipulating this knowledge

2.2. Multi-agents systems.

The knowledge modelling that we propose is based on the use of multi-agent systems (Ferber 1994). In order to model complex phenomena multi-agent systems represent agents of the observed world and their behavior Creating a multi-agent system means reproducing an artificial world resembling the observed world, in that it is made up of different actors, in order to conduct diverse experiments. Each agent is represented as a computerized independent entity capable of acting locally in response to stimuli or to communication with other agents.

Agents can be more or less complex There are models of very simple agents which simply respond to stimuli · this is " reactive " agent modelling. For example, different given agents are studied interacting to exploit a resource or share work (Drogoul and Ferber 1994). There are also models of more complicated agents which can have goals, representation of others, reasoning capacity and memory (Doran 1994) In each case, modelling by multi-agent systems is interested in the emergence of global behavior out of local interaction (communication, influences , negociation).

"This opposition of cognitive and reactive should not be taken too literally, although it does help situate the problems. There is a graduation from the purely reactive agent who only reacts to stimuli to the totally cognitive agent who possesses a symbolic model of the world that he constantly updates and on which the planing of all his actions is based. " (Ferber 1994)

3. Some experiments.

The experimentation that we present here consists of representing a river fishery and submitting it to demographic growth of fihermen We implemented two biotopes representing a river and its adjacent floodplain. We simulate about one thousand groups of fish comprised of three species, two preys and one predator

Each simulation begins with ten fishermen Each year, three fishermen are added These fishermen own fishing gear and an amount of money. They catch fish, sell them at fixed prices, buy fishing gear and spend money for the household consumption.

3.1 Simulations

We present three simulations comparing three hypotheses concerning the fishermen's decision making process . common sharing rules, economic rationality, regulation of access by taxes. For the first scenario the fisherman is constrained by rules These rules concern the access to space and the use of various fishing gear They are given by anthropologic studies of the common knowedge of the fishermen society. In the second scenario each fisherman tries to maximise its expected benefits (bounded rationality) He can go wherever he wants and use any kind of fishing gear along the year Thirdly we consider the same scenario, but a small tax has to be paid in order to access the floodplain

3.2 Results.

We chose to observe two criteria·

- The benefits of the fishermen (see figure 1). The results are much better with common rules because these rules are well adapted to the dynamics of the resource When the structure of the resource changes then these rules become unefficient, from an economic point of view. The economic rationality gives worse results. We see that the existence of a tax, by protecting the resource, make the fishery last longer

- The biomass (see figure 2) For the three simulations the fishermen first exploit one specie, then another one. For the economic rationality, the resource collapse after a while With taxes the resource is protected. With common sharing rules, the resource is maintained at a higher level.

Figure 1

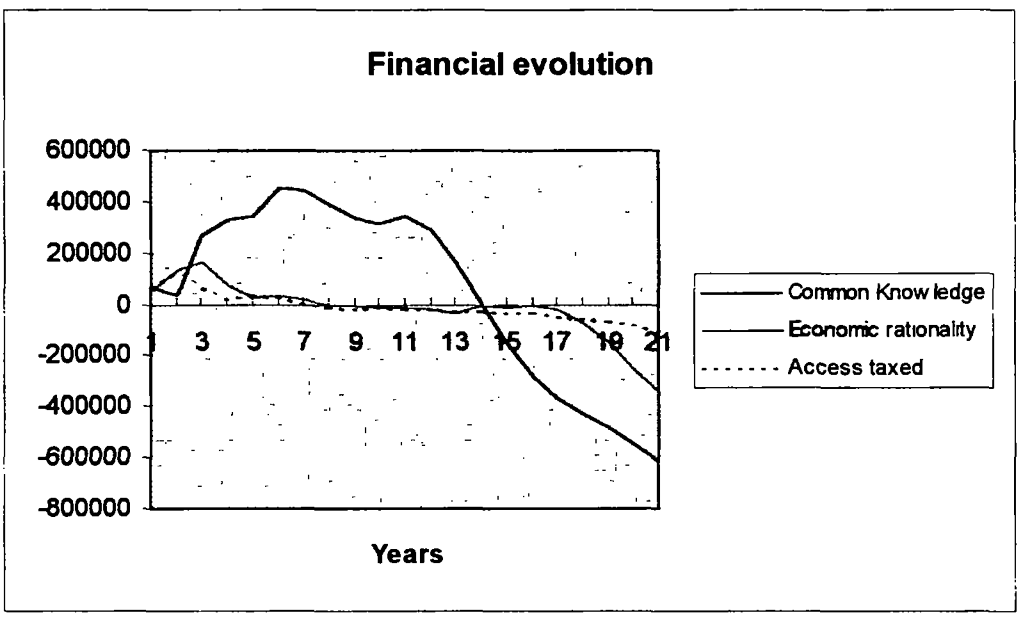
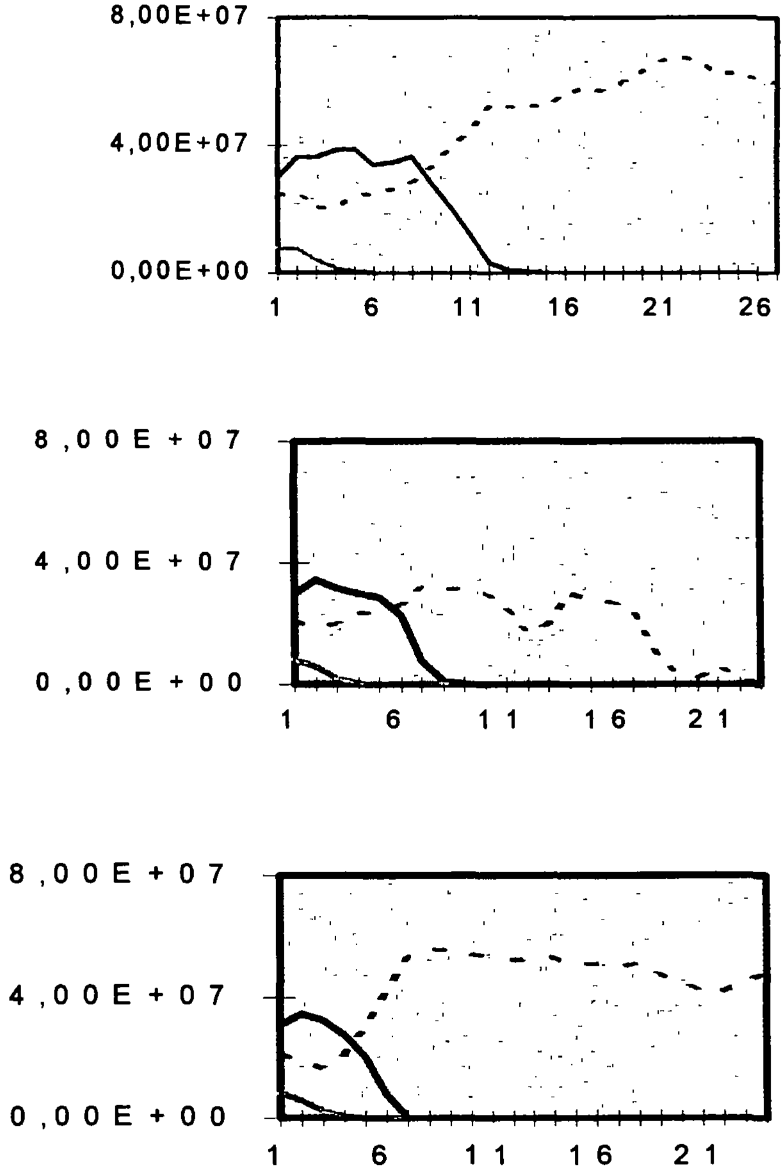


Figure 2: Evolution of the biomass



3.3 Discussion

A complete interpretation of these results would require a lengthy discussion (Bousquet 1994) The simulation results show that the evolution of species abundance may depend on the decision-making process By representing knowledge at the individual level and by simulating interactions, we reproduce ecosystemic patterns which can be qualitatively compared to ecosystemic observations from reality.

With this experiment we try to give an example of the use of multi-agent systems. It is possible to represent artificial agents and their decision-making process One can consider an individualistic decision making process or a collective one. It is also possible to represent agents who negociate in order to adopt collective rules of access to the resource.

4. A general framework

We propose a framework for the modelling of resource-human interaction (Bousquet&Cambier 1994) We have divided this modelling approach into several stages (figure 3) The first two stages consist of creating a "resource space " (Morand et. al 1994, Lardon et al 1990) in which human agents evolve.

Our description of this stage will be relatively short, so that we can examine human agent modelling in greater detail During the description we will illustrate abstract considerations with realizations resulting from our work.

4.1. Creation of a resource space : emergence of ecological forms

In the first stage of modelling, space is considered as a support surface : usually fragmented, space is represented by several interconnected milieus. There are many different ways of representing a space : grids, networks, continuums, etc. (Kareiva, 1990) . Each of these portions of space is a life support for the agents which represent the resource. Traditionally, pluridisciplinary models are constructed around one or several interface variables which insure circulation of data and results. Here it is the space which supports circulation of objects and is the scene of their interaction The totality of milieus constitutes a veritable object of interface between social and ecological dynamics

Resource modelling necessitates modelling of reactive agents or groups of agents. These agents are characterized by variables of weight, species, size, age, etc. The individual processes concern growth, mortality, reproduction and displacement (movement, migration, diffusion) in the fragmented space. These agents are in interaction . in ecology the main interactions considered are predation and competition

Examination of local interactions between fish agents reveals an organisational pattern with characteristic properties (response to a disturbance, statistical breakdown) This global property, this observed phenomenon, cannot be explained as the sum of the properties or behavior of the elements

4.2. Human agents

In order to simulate interaction between human and the renewable resources they exploit, the decision making process of the agents must be modelled. The agents must decide what part of the space they are going to displace in, what resource they are going to exploit, and who they are going to cooperate with The agents are first of all characterized by descriptive variables (size of household, age, ethnic group, amount of money possessed, etc.), but also by the variables in the agents' representations of their environment. An example is the concept of acquaintances, which serve both as an address book and as representation of others. During our work we have also introduced the notion of technotopes (figure 4) which is a model of the fishermen's representation of its natural environment.

Our goal in modelling agent representations is to study their role in the decision-making process. It is not simply a question of reproducing value systems and classifications It is an attempt to articulate agents' representations and actions within the decision-making process itself, for it is through these actions that they transform their environment To accomplish this we have chosen to sequence the decision-making process in different phases . construction, perception, selection and action

The construction phase. During this phase agents construct their environment . They create a " mental map of the environment " which can be made up of mental objects " [1]. This is the resource

[1] Research in cognitive sciences is based on several concepts which are at the same time close in concept and quite different mental object (Changeux 1983, Bienenstock 1991), mental models (Johnson-Laird 1993), mental maps (Downs and Stea 1977), mental images (Denis and de Vega 1993), schemas (Minsky 1975) and others we have perhaps forgotten Here we simply want to indicate that the agent makes a representation of

space in the fisherman's mind, and the representation of other human agents as well (Doran 1994). Later in the text we examine the question of these mental maps

The perception phase. During this phase, agents perceive information about the environment and complete their mental map on the basis of observed facts or beliefs about the environment The perceived information only exists from the point of view of the observer's mental map and not from the point of view of an objective environment.

The selection phase. During the selection phase the agent chooses an action among the different possibilities. He will choose a place of action, a social collaboration, a technology of action, etc

The action phase. The agent displaces, acts on the resources - thereby transforming the environment - memorizes the results and possibly revises his beliefs (about the resource, society).

It must be noted a decision-making process does not necessarily involve these four phases, which imply cognitive agent We carried out experiences with mimetic and repulsive agents (Bousquet et al 1994). In these cases, only the selection and action phases were activated : relations between action and perception and perception of the natural environment were not conceived

4.3. The observer or the observers

A large number of researchers who use MAS, especially the scientific community which is interested in artificial life, postulate autonomous systems An important research axis is based on research in robotics

In our experiments described above, it is clear that the agents cannot be credited with an intentionality of their own The agents are perceived and modelized through scientific theories The variables and the behaviour of the agents reflect the various observers points of view " *It is the observer who injects intentionality into the system, which is after all, only a sophisticated mechanism combining physical elements* " (Sperber 1992)

The agents we have presented correspond to knowledge supports The dynamics of interactions, movements and different processes involved correspond to the models proposed by the different scientists involved There are different points of view held by researchers on the functioning of the entities Our proposition is to explicitly represent these points of view. The artificial universe that we represent is made up of a world consisting of agents who exploit a resource as well as represent the points of view of the actors who observe this system These points of view are made up of knowledge of the dynamics of the artificial ecosystem We propose to explicitly represent this knowledge The result is a separation of the entities of the observed world from the base of models which can be applied (Ziegler 1987) We try to underline the role of the observer Thus the results of the simulations and the behaviour of the artificial ecosystem are related, not only to the structure of the ecosystem, but also to the various points of view

4.4. "Mediator " objects and " common " objects"

Generally multi-agent systems are associated with the current of methodological individualism (Lenay 1994, Havelange 1994) which considers the single individual as the elementary unit, the atom of society (Weber 1971). Methodological individualism tries to reconstitute the whole by aggregation of the parts. We recognize here the ascending approach characteristic of multi-agent systems. However, it is also possible to consider the given social groups with their norms and rules of group functioning (Livet 1987) The agents are led by constraints and rules expressed on a group level . they are merely acting entities that we place in a dynamic environment

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his environment, a representation which is a model of space made up of objects or agents.

The simulations that we present, either with an invididualistic or nore holistic scenario, bring out properties of the whole. The agents have particular representations which induce a global behavior The whole is observed through indicators which exhibit patterns that we can interpretate

However, as we mentioned it appears important to envisage the dynamics of representations. It is of particular importance to understand how the agent individually participates in the creation or reinforcement of the social systems which subsequently will orient him in his decisions. How can this phenomenon be taken into account in multi-agent systems ? And, since our methodology leads us to create agents and objects, which objects (mental or physical) are attached to these representations ?

Multi-agent systems used to be described as a set comprising a space, agents, and objects which form the environment. In order to go further in the characterization of the individual-society loop, we propose to proceed by the modelling of " mediator " and " common" objects These objects are both individual and shared representations which tend to create the social group and at the same time to be the expression of its existence. Markets, symbolic places or goods all these are objects constantly being constructed by humans in ritualization Then these objects orient the perception or constrain human action Through the perception of these objects each agent perceives himself as a member of the whole and thus contributes to the creation or the sustaining of this whole There is reification, not of the collectivity as the holistic point of view maintains, but of objects which are signs of the whole

How should these objects be represented ? Are they exogenous representations, outside of the mental space ? Or endogenous entities ? Or endogenous and exogenous entities, common but specific to each individual ? How are these objects shared ? What are their dynamics, is language an indispensable vehicle for the exchange of representation ? We do not have ready-made answers to these questions. They depend on the contexts, on the objects and social group under consideration. Why would the creation of artificial worlds resolve a fundamental sociological problem ?

Creation of an artificial world is a writing exercise, a re-creation of the world as observed by the researcher The multi-agent systems play a useful role if they enable the observer to make his point of view, his ideology, explicit. As modellers our proposition here is to create a class of particular objects which to us seems important for the representation of artificial societies built up from the individuals that make up them up.

5. Conclusion.

Multi-agents systems seems to be an interesting methodology in order to study the interaction between the renewable resources dynamics and the social dynamics One can consider two phases in the modelling process . the knowledge representation phase and the simulation phase. If the interest of the first phase is well known, the multi-agent systems gives an original methodology for the study of common properties By focusing on the links between indivdual autonomy and collective cognition, multi-agents systems are an efficient tool for theory building

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Figures

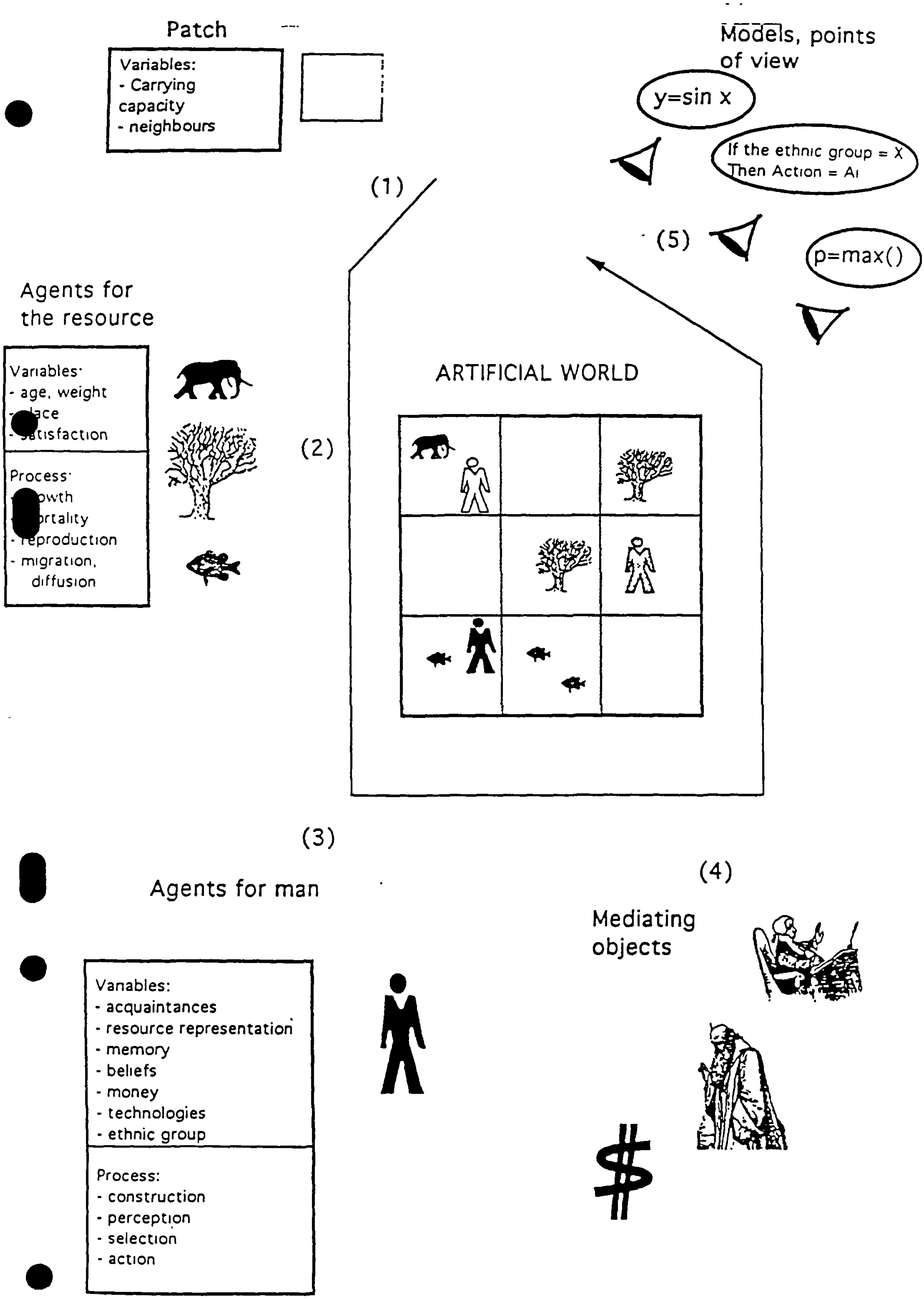
Figure 3 : A multi-agent modelling framework for modelling resource-human interactions

1 Representation of space
2. Representation of resource agents
3 Representation of human agents
4 Representation of mediator or common objects
5. Representation of different points of view

Figure 4 : Space representation and technotope objects

On one side an artificial space, composed of different biotopes, is represented. On the other side, there is a mental space composed of different technotope objects (Fay 1989) Each of these objects correspond to the use of a technology in a particular place, as imagined by the agent

The technotope notion designates the relationship between technological temporality, spaciality and technological imagination


Patch
Variables:
- Carrying capacity
- neighbours
Models, points of view
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If the ethnic group = X
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Agents for the resource
Variables:
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Agents for man
Mediating objects
Variables:
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- resource representation
- memory
- beliefs
- money
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- ethnic group
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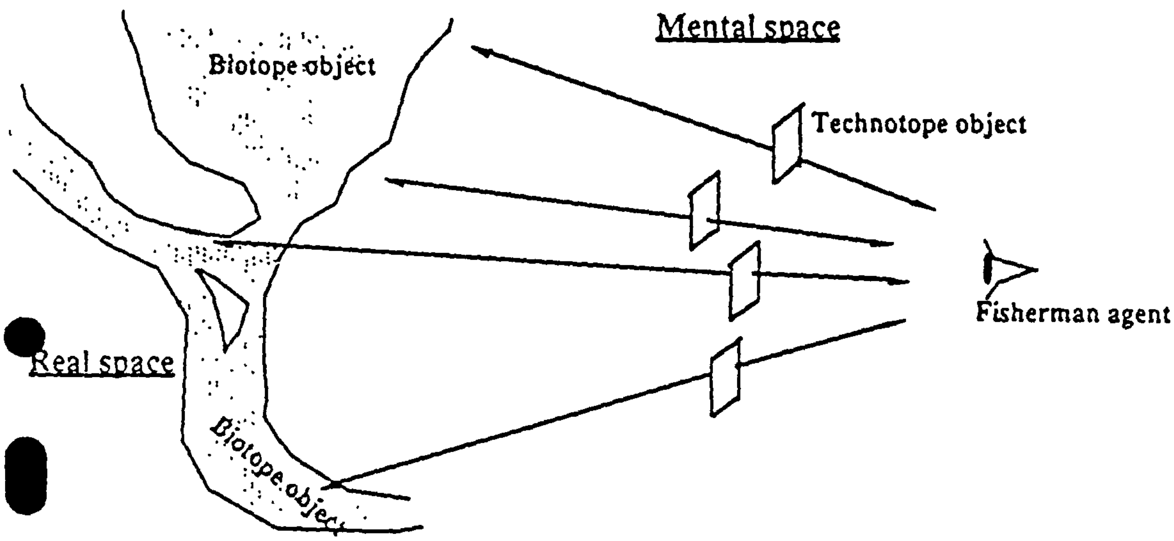
Mental space
Biotope object
Technotope object
Fisherman agent
Real space
Biotope object