RESOURCE SPACE, INDIVIDUALS AND ECOSYSTEMS: EMERGENCE AND REPRESENTATIONS

Francois Bousquet

C1RAD-GREEN
42 rue Scheffer, 75116 PARIS
Email: Bousquet@green.cirad.fr

For the last four years we have conducted a multi-agent modelling experiment within a pluri-disciplinary team made up of biologists, ecologists, anthropologists and economists whose objective is to understand how fishing is organised in the Niger Central Delta. We have created a platform of multi-agent simulations called AtomTalk in order to model agent interaction in a fragmented space (Bousquet 1994, Cambier 1994). We have also examined the problem of modelling diverse representations, ranging from those of the actors of the world being studied to disciplinary points of view of the researchers involved.
The problem of representation is inherent in the creation of artificial worlds where agents interact with their natural and social environment. In this paper we discuss the representation problem from our modeller point of view. We give some examples of the models we have created. More precisely, we will examine the question of the place and status of representations when an attempt is made to simulate circular relationships linking individual and social group levels within the ecosystem. For that purpose we introduce the concept of "mediator" objects, or "common" objects.

1. Representations and modelling of the environment

Examining the question of representation implies tackling a vast and highly diversified area of research. Even if one fixes as limits human sciences and their representations discussed since the era of Descartes (Ladrière 1990, Revol 1995), one is confronted with a polysemy resulting from the different approaches of philosophy, biology, psychology and sociology. This polysemy is also found in the area of cognitive sciences which have made representations one of their main subjects of research. Our reflection developed here is the point of view of a researcher working in the area of modelling with systems provided by Artificial Intelligence who collaborates with social scientists engaged in environmental research.

1.1. Representations in the area of environment

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."* (Cailie.. 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).

1.2. Modelling of representations

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.

1.3. Representation, emergence and ecosystem

Ecosystem modelling is a fairly well-established type of research. The traditional method is to model the dynamics of one or several populations in competitive or predatory interaction. The formalism of differential equations is used in most cases. The goal is to sum up the dynamics of a system on the level of the populations concerned. Human intervention in these ecosystems is simply represented by a mortality imposed on the population.

In the last few years, different approaches have been developed in order to take into account the complex structure of ecosystems. These modellings are oriented more and more towards the individual level (Individual-based Modelling). The goal is to understand how ecosystem properties can emerge from interaction between entities on a more microscopic level.

At the same time, the human agent has appeared as an element in the ecosystem. Previously, human actions were considered in terms of resulting mortality. Now attention is being focused on the decision-making processes and on actions of humans in the ecosystem. We propose to represent human agents as entities in the ecosystem which also themselves act on a microscopic level, thereby entering the network of interactions, out of which we want to see forms emerge.

In the study of humanized ecosystems, our goal is to understand the viability of interactions by observing the emerging organizations. Consequently, this is a connectionist approach searching for intelligibility (in this case viability in the sense of Aubin (1993)) not in a part of a system, but in the entire system (Bateson 1984). Considering man in this way, as an interactional cell exposes one to criticisms : " *To the degree that the system is conceived as a cybernetic order as is frequently the case in ecological studies, the act of including culture in a unified science Mill lead to a displacement of mental properties from humankind to the ecosystem* " (Sahlins 1980). Our position as modellers is that it is possible to credit human agents with a culture and at the same time consider them as elements of a whole that they help construct through their interactions. This is a very functionalist conception of culture, close to the work of Malinowski, as described by Sahlins. Therefore it is possible to study the behavior of human agents on a microscopic level, crediting them - or not - with representation and to observe an organization on a macroscopic level. The mind remains a property of humankind, but viability is a property of the ecosystem.

But what representations are involved here ? We, the modellers, want to know how actors perceive and act in their environment. The paradigmatic models are varied. Certain economists conceive of man's action on resources as a utilitarian calculation, while other researchers see this interaction as the expression and consequence of cultural traits. More exactly, (Sahlins 1980) *"culture appears simply as a mediator, or an environment of the constitutive dynamics of human intentions. By mediation, we mean a totality of means available to the subject by which he reaches the goals he has established ; it is an environment not only in the sense of a ensemble of external constraints on the individual, but also something on which he forges his intentions and, in doing this, organizes the properties of the milieu .* " Modelling can be an interesting tool to compare different hypotheses - utilitarian vs. social. We will give several examples in §5.2.2.

The simple duality between individualism and holism can be questioned. Gilbert (Gilbert 1994) generalizes this impression : " It *is now possible to argue that while there was some truth in both* (individualist and holist approaches), *neither was a particularly helpful or revealing way of conceiving the relationship between global and local behavior.* " Thus, Dupuy (1992) speaks of complex individualism, and Giddens speaks of the *"recursive nature of social life "; "social practices reflect the ability of humans to modify the circumstances in which they find themselves, while simultaneously recreating the social conditions practices, knowledge, resources) which they inherit from the past."* (Layder 1994)

This point seems very important to us. On one hand, the question of the viability of a resource access system can be studied by associating it with the different actors' representations of the environment. But, on the other hand, it seems equally important to investigate the dynamics of the representations. How do they evolve ? How does the actor represent to himself the whole which he is part of and how can this representation change ? The collectivity is not only a constraint for the individuals in it : it is also constructed by them. In societies referred to nowadays as being " in transition " - which means that they refer both to traditional structures and an economic rationality which is becoming universal - this problem is particulary acute. But how do individuals construct this collectivity ?

To sum up, the modelling of artificial ecosystems composed of various entities among which humans, leads us to ask the following questions.

Where are the representations situated ? Should they be considered as symbols inside the agents's heads ? Are environmental objects attached to these representations ? What are the mechanisms which permit the representations to last ? How can collective referencials be modelled ? How should the role of the observer, or even observers, be taken into account ?

These are the problems that we have to study in order to create artificial systems. Without of course, being able to give complete answers, we will show, in the second part, how we have approached some of them and how we intend to pursue this research.

2. Formalizations

2.1. Multi-agent 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,

2.2.2. Human agents : individualism and holism

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 3) 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 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.

It is possible either to confer an individualistic attitude on individuals or to consider them as actors in a collective context. Figures 4 and 5 show an experiment which is based on both

---

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

approaches. Different statistical shapes which characterize ecosystem functioning are observed and compared on the scale of the ecosystem. The goal is to explain them through the structure of the system, and particularly through representations of human agents. This functionalist approach is an attempt to create links between representations and ecosystem viability.

2.3. 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.

The multi-agent simulation platform AtomTalk corresponds to this theoretical framework (figure 6).

2.4. "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. 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 in paragraph 1.3. 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.

3. Discussion: Representation of knowledge or emergence of representations

We have proposed a modelling framework with two purposes :

- to represent resource space dynamics,
- to model the decision-making process of the actors, carried out according to the representations they make of their environment.

What can these multi-agent model be used for ? As Lenay has observed, we can consider that there are two different approaches in the creation of multi-agent systems :

- the phase of knowledge representation,
- the phase of simulation.

At the current stage of our reflection and as a function of our past experience, two approaches can be distinguished. One stresses representation of knowledge, the other is concerned with the generation of representations.

In the first approach representation of knowledge is very important. Construction of artificial universes requires implementation in the computer of a considerable quantity of knowledge about the real world. There is a movement from " naturalist " knowledge towards multi-agent systems. When this naturalist is a social scientist, the problem is the implementation of agents of the artificial world. This leads to questions about the relations between the representations and actions and practices. Consequently, representation of knowledge catalyzes reflection on the problems of individual or collective choices, as they come up in an actual, specific case. This is a functionalist approach. The purpose of the the simulation which follows the knowledge representation phase is to confront different functions under consideration with the natural environment. Natural environment dynamics are themselves often simulated with the use of functions: biologists and ecologists often describe biodiversity through functions or groups of functions (Barbault 1993). The goals of simulation are twofold : to understand the links between different ecological functions and social representations, and to explore the viability of these interactions. What functions should be assembled to understand the behavior of a humanized ecosystem ? Here we are in agreement with Doran : *"There is an important sense in which our work is more theory building than it is modelling. The aim is to discover more about certain processes and how they interact. "*. This approach is designed to open a permanent channel of communication between observation of the real world and theorization.

The second approach consists of focusing on the dynamics and transmission of representations and especially their generation (Varela 1989). The dynamic of representations and their epidemiology (Sperber 1992) is a research subject in cognitive sciences. Bases drawn from this research can be used to study the question of cultural transitions frequently evoked in environment problems. As for the emergence of representations, this is above all a subject for the Artificial Life area, in which researchers seek to understand the generation of life and of representations. What is involved here is the progressive reconstruction of mechanisms which permit the creation of Artificial Life, the generation of representation by robots. It is only then that the problems of language and transmission will be posed.

These two approaches to representation, manipulation of functions or generation of representations, can be seen as the extreme limits of an area in which diverse muti-agent modelling experiments can be proposed.

4. Conclusion.

The modelling of complex ecosystems with multi-agent systems leads to the problem of agents representations of their natural and social environment. Our past research has consisted in modelling the representations of these artificial agents. One can model representations corresponding to an individualistic behaviour or a behaviour constrained by social norms. The methodology is interesting for defining the representations and establish a link between these representations and the functioning of the whole ecosystem. One define global indicators and discuss the emerging patterns.

In order to go further in the modelling of a collective cognition we propose to study the relations between the agents and special objects of the environment. We call these objects "mediator" or "common" objects. Market, symbolic goods, symbolic places are examples. These objects can be modelized as objects of the environment or mental representations.

In the future we will try to develop and improve our framework by testing it on various cases such as hunting societies (Cameroon) or farmers communities inSenegal.[2]

[2] I wish to thank C.Lenay, J.P.Treuil, M.Antona, J.Weber and the two anonymous reviewers for their comments.

REFERENCES

Andler D. Calcul et représentation : les sources. In *Introduction aux sciences cognitives,* Folio essais 1992.

Aubin J.P. *La mort du devin, l'émergence du démiurge. Essai sur la contingence et la viabilité des systèmes.* 1993

Barbault. R. Une approche écologique de la biodiversité. *Natures, Sciences et société,* Voll,N°4, 1993.

Bateson G. *La nature et lapensée,* Seuil, 1984.

Berkes F., Feeny B., McKay B., Acheson J.M. The benefits of the commons, *Nature* 340, July 1988.

Biennenstock E. Une approche topologique de l'objet mental. Actes du colloque de Cerisy, *Les theories de la complexite autour de l'oeuvre d'Henri Atlan,* Seuil 1991.

Bourgine P. What is knowledge? 1993

Bousquet F., Cambier C, Mullon C, Morand P., Quensiere J. Simulating fishermen's society. In *Simulating societies, the computer Simulation of social Phenomena.* N. Gilbert and J. Doran (ed),UCL Press 1994.

Bousquet F., Cambier C. Simulating the interaction between a society and renewable resources. Proceedings of The World Congress of Sociology, Bielefeld, 1994.

Bousquet F. *Des milieux, des poissons, des hommes: étude par simulations multi-agents. Le cas du Delta Central du Niger.* Thèse de l'Université Lyon 1, 1994.

Caillé A.. Sujets individuels et sujet collectif. In *Philosophie et anthropologie,* Editions du centre Pompidou, 1992.

Cambier C. *SimDelta, un système multi-agents pour la modélisation de la pêche.* Thèse de l'Université Paris 6, 1994.

Changeux J.P. *L'homme neuronal.* Fayard 1983.

Denis M., de Vega M. Modèles mentaux et imagerie mentale. Ehrlich, Tardieu et Cavazza (eds), *Les modèles mentaux, approches cognitives des représentations,* Masson 1993.

Drogoul A., Ferber J. Multi-agent simulation as a tool for studying emergent processes in societies. In: *Simulating Societies, the computer simulation of social phenomena.* N. Gilbert and J.Doran (ed), UCL Press, 1994.

Doran J., Palmer J., Gilbert G., Mellars P. The EOS project: modelling Upper palaeolithic social change. In: *Simulating Societies, the computer simulation of social phenomena.* N. Gilbert (ed), UCL Press, 1994.

Downs R.M., Stea R. *Maps on Minds , Reflection on Cognitive Mappings,* New York. Harper and Row 1977.

Dumouchel P. Systèmes sociaux et cognition. In *Introduction aux sciences cognitives.* D.Andler (ed.), Folio, 1992.

Dupuy J.P. *Introduction aux sciences sociales, logique des phinomènes collectifs.* Ellipses 1992.

Dupuy J.P. *Aux origines des sciences cognitives,* Editions La Decouverte 1994.

Fay C. Systèmes halieutiques et espaces de pouvoirs: transformation des droits et des pratiques de pêche dans le Delta Central du Niger (Mali) 1920-1980. *Cahier des sciences humaines,* 25, 1989.

Ferber J. La kénétique : des systèmes multi-agents à une science de l'interaction. *Revue international de systemique,* Vol. 8, n°l, 1994.

Friedberg C. Représentations, classifications: comment l'homme pense ses rapports au milieu naturel. M. Jollivet (Ed.), *Sciences de la nature, Sciences de la société. Les passeurs de frontières,* CNRS Editions, 1992.

Gilbert N. Emergence. *Artificial Societies,* UCL Press In press.

Hardin G. The tragedy of the commons, *Science,* 162, 1243-1248, 1968.

Havelange V. Sciences cognitives et tradition sociologique. *Revue international de systémique,* Vol. 8, n°l, 1994.

Johnson-Laird P.N. La theorie des modeles mentaux. Ehrlich, Tardieu et Cavazza (eds), *Les modèles mentaux, approches cognitives des représentations,* Masson 1993.

Kareiva P. Population dynamics in spatially complex environments: theory and data. *Phil Trans. R. Soc. Lond. B,* 1990.

Laasri H. et Maitre B. *Coopération dans un univers multi-agents base'e sur le modèle du blackboard: etudes et realisations.* These de l'universite Nancy l, 1989.

Ladrière J., Représentation et connaissance, *Encyclopedia Universalis* 1990.

Lardon S., Deffontaines J.P., Baudry J., Benoit M. L'espace est aussi ailleurs. In Brossier J., Vissac B., Le Moigne J.L. (eds), *Modelisation systemique et systeme agraire,* INRA editions 1990.

Layder D. *Understanding social theory,* SAGE publications 1994.

Lenay C. Introduction. *Revue Internationale de systémique.* Vol. 8, n°l, 1994.

Livet P. Normes. In *D'une science à I'autre, des concepts nomades.* Stengers (ed.), Seuil, 1987.

Minsky M. A framework for representing knowledge. In P.H. Winston (ed.). *the psychology of computer vision,* McGraw Hill 1975.

Morand P., Bousquet F., Cambier C. Un modele d'ecologie des peches. *Forum Halieumetrics,* ORSTOM editions, in press.

Revol B. Naissance de la re-présentation chez Descartes et ses représentations dans les Méditations Métaphysiques, *Actes du Séminaire Genèse des représentations,* 23-27 Janvier 1995, Compiègne.

Sahlins M. *Au coeur des sociéte's, raison utilitaire et raison culturelle,* Gallimard 1980.

Smith A. *Recherches sur la nature et les causes de la richesse des nations,* Paris GF-Flammarion. (1776). 1991.

Sperber D. Les sciences cognitives, les sciences sociales et le matérialisms In *Introduction aux sciences cognitives.* D.Andler (ed.), Folio, 1992.

Varela F. *Connaitre les sciences cognitives, tendances et perspectives,* Seuil, 1989.

Varela F., Thompson E., Rosch E. *L'inscription corporelle de I'esprit,* Seuil 1993.

Weber J. *Cours d'anthropologie économiqut,* multigr. EHESS, 1988.

Weber M. *Economie et société,* Paris, Plon, 1971.

Zeigler B.P. Knowledge representation from Newton to Minsky and beyond. *Applied Artificial Intelligence,* 1, 1987.

Figures

Figure 1 : 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 2 : Resource agents and ecological emergence

A space made up of two milieus is represented. About a thousand agents of three different species interact, in competition or predation, within this space. The entire group of agents is subjected to a fishing mortality which increases each year. As a result, the evolution of the total catch can be observed an ecosystem level : first it increases, then it levels out and remains stable for a long time before a final, definitive plunge.
This underlines the resistance of the ecosystem.

This response curve is found in the case of several different African rivers. Through the interplay of local interactions, a global form appears, which was not predictable from the sum of individual behavior.

Figure 3 : 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.

Figure 4 : Simulation of intensified exploitation by adding more fishermen.

We have created an ecosystem composed of 4 milieus in which three different fish species interact. Every year we add three fishermen to this ecosystem. We have simulated three different scenarios corresponding to three decision-making hypotheses :

a) Access to all the milieus is free : each fisherman chooses the activity which maximizes his income.

b) Two social groups share access to the space and to use of equipment. There is a set of rules attached to each social group. Each agent is member of one of the social groups. One group represents 2/3 of the population.

c) Conditions are the same as a) but we have added a global constraint: access to milieus 3 and 4 is limited. No more than 5 agents can fish at the same time.

Figure 5 : Results

The rows represent the three scenarios. The columns represent three types of indicators that can be observed in the evolving artificial ecosystem.

1) The total catch. Note that the simulation with free access and economic rationality is shorter-lived.

2) specific composition of catches. Note that the evolution of specific compositions is very different according to the envisaged decision-mlaking process. Thus the link is made (Bousquet 1994) between, on one hand,

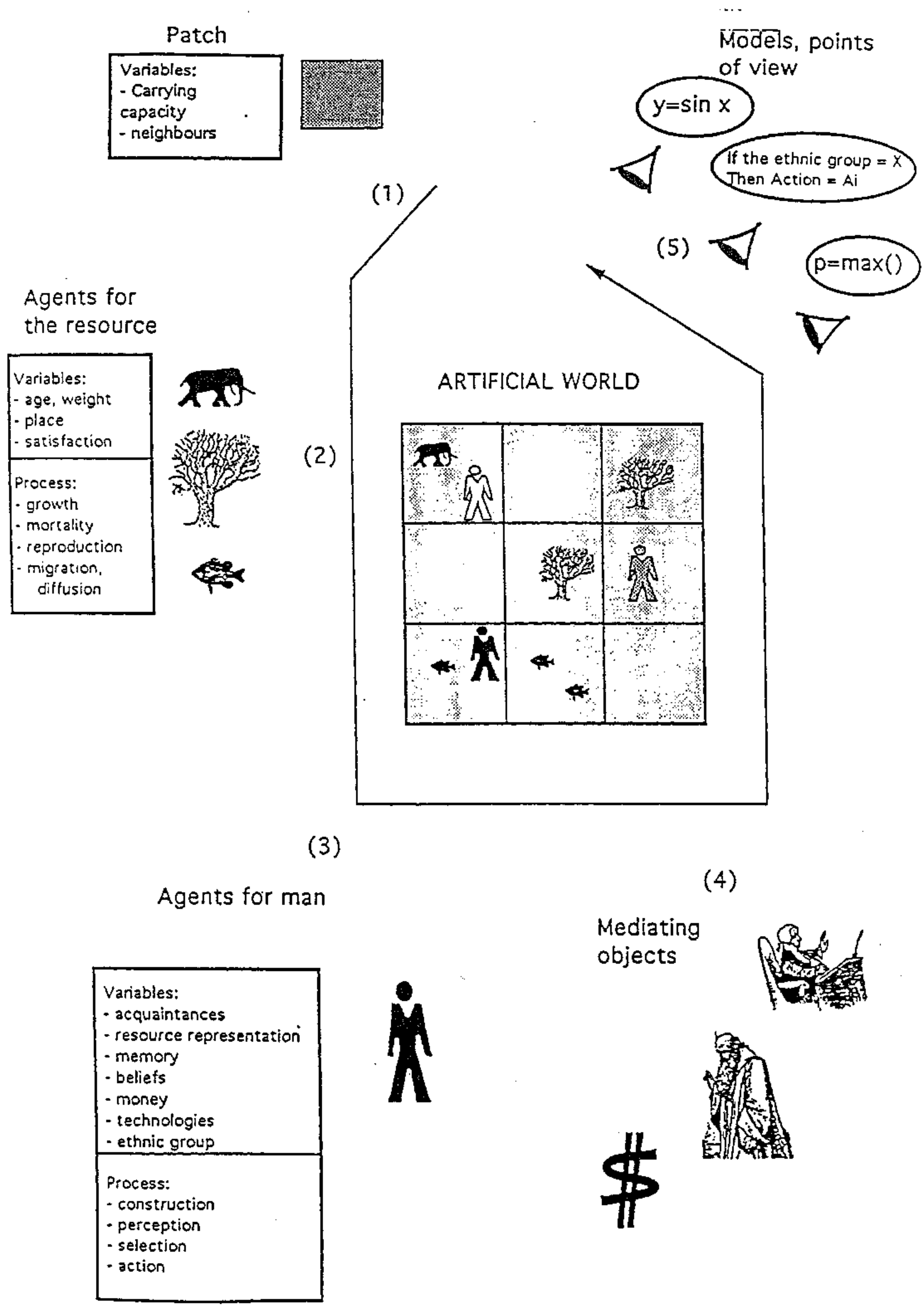
- The decision-making processes and the representation they imply, and on the other hand,

- The ecological functions represented by the three species of fish modelled .

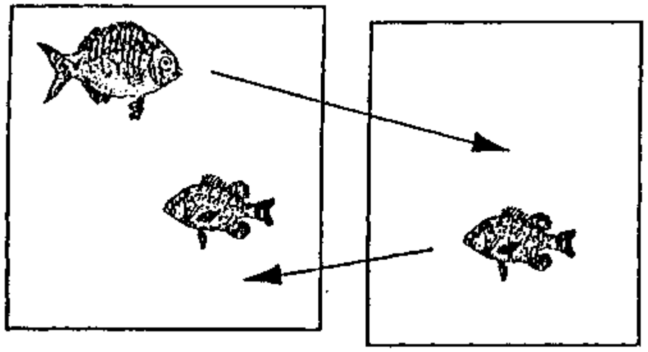
3) The income of each fisherman. Each curve represents the evolution of a fisherman. In the first simulation, evolution of income is quite homogenous. In the second simulation it can be noted that the incomes are higher overall, but at the end of the simulation there is a very marked economic differentiation between the two social groups.

Figure 6 : AtomTalk

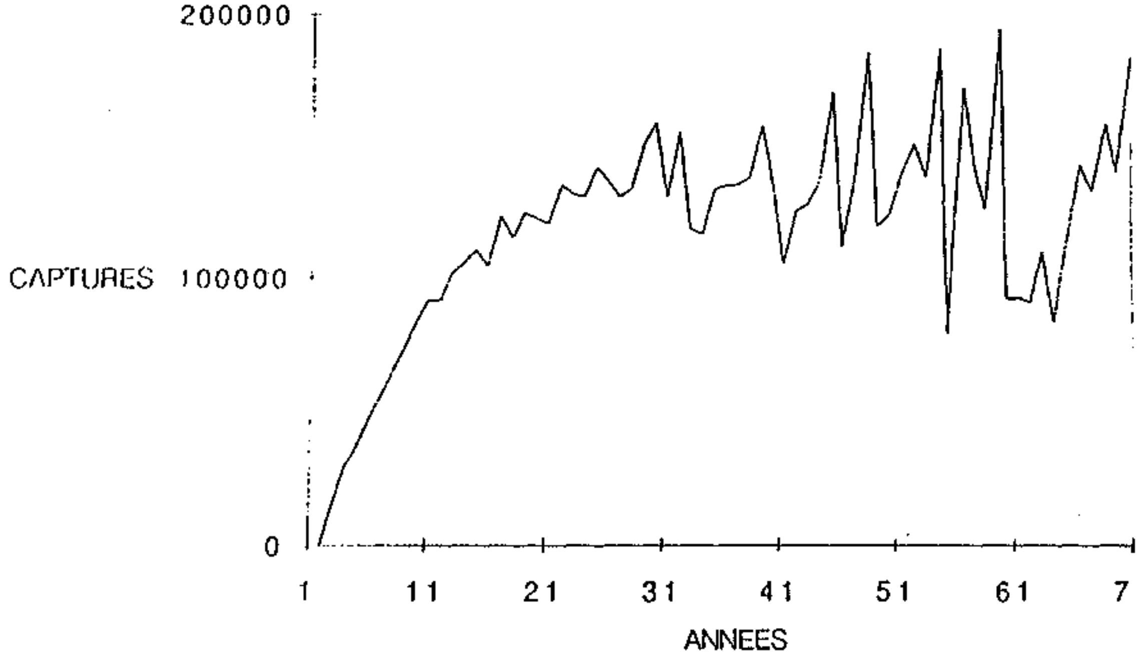
AtomTalk is a platform of simulations inspired by the Atom Blackboard developed at the CRIN (Laasri and Maitre 1988). It is implanted with [3] Smalltalk language. The blackboard part is considered as the artificial world where different agents move about. Specialists, implanted by means of production rules, make it possible for the points of view of the different observers - who manipulate the agents of the artificial world - to be expressed. The control structure organizes the simulation.



Patch
Variables:
- Carrying capacity
- neighbours
Models, points of view
y=sin x
If the ethnic group = X
Then Action = Ai
p=max()
(1)
(5)
Agents for the resource
Variables:
- age, weight
- place
- satisfaction
Process:
- growth
- mortality
- reproduction
- migration, diffusion
(2)
ARTIFICIAL WORLD
(3)
(4)
Agents for man
Mediating objects
Variables:
- acquaintances
- resource representation
- memory
- beliefs
- money
- technologies
- ethnic group
Process:
- construction
- perception
- selection
- action



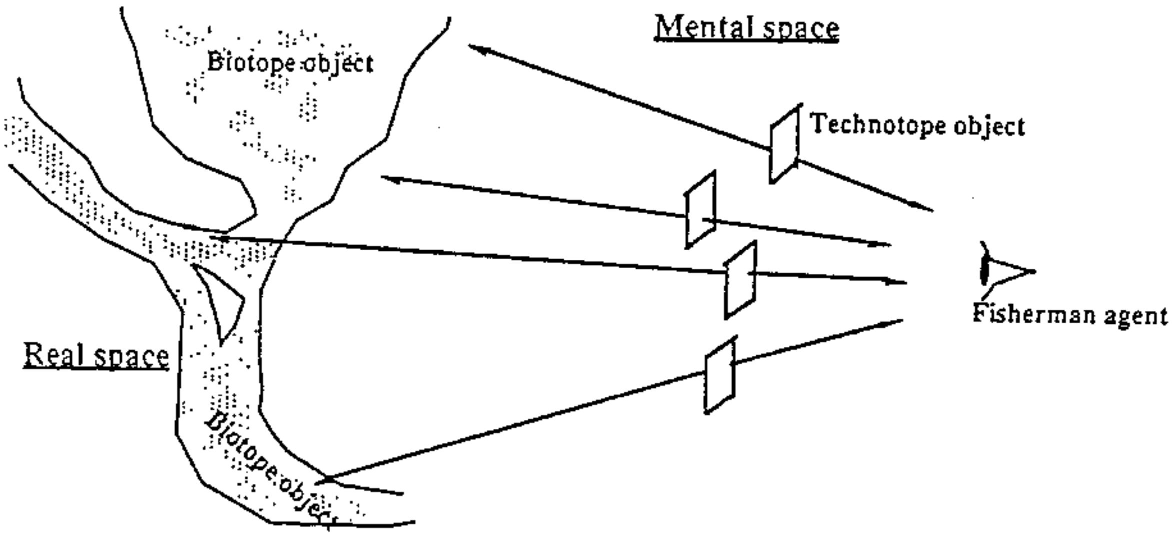
PRÉLÈVEMENT
CROISSANT



- Croissance,
- Mortalité,
- Reproduction,
- Migrations.

HYDROBIOLOGIE

HALIEUTIQUE


Mental space
Biotope object
Technotope object
Fisherman agent
Real space
Biotope object