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An Agent-Oriented Model for Complex Decision Making Support*

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Abstract

Our work deals with complex decision support in management and competitive intelligence area. Our approach of decision aid is based on the conception of an intelligent system providing needed informations for (human) decision. In complex domains, planning is an efficient cognitive and economic way to face complexity. Therefore complex decision support is here apprehended through planning support scope. Our analysis emphasises of domain representation models as complex decision support models. Adopting an agent-oriented approach as a conceptual basis, we present models and architecture of a tool developed to build such decision models.

1. Introduction

Our work focuses on firms strategic management and competitive intelligence support through (individual) decision making. We intend to conceive information systems able to (intelligently) assist this activity. The existing systems have several shapes and they can be analysed in various ways. However these analysis are generally based on three dimensions : data, models and human-machine interaction. According to our meanings, human is the *site* of the decision. Therefore the aim of decision support consists in *well-informing* decisions in a given situation and in a human-machine scope. Complex decisional domain are those marked by a large set of linked elements to take into account in order to make decision. Accordingly the *occurrences uncertainty* (what to do ? or what to choose ?) and the *definition uncertainty* of domain events, fields and objects (what is it about ?) are increased. In these cases, decision making takes the shape of plan elaboration processes. Supporting this activity leads to assist its two main functions according to our definition of complexity that concern *modelling* and *anticipation* [1]. First we'll define Planning Support System and then we'll propose *domain representation models* as complex decision support models. We'll suggest an agent-oriented modelling approach to conceive such models and we'll describe the architecture and the models of a tool developed to build planning support systems.

2. Planning support system as complex decision support system

Decision support is at the conjunction of various research fields. Therefore the related analysis depend on the adopted point of view. However when we deal with management information systems as decision support system, these analysis focus generally on three dimensions : data, models and dialogue system. Following Turban typology [2], we define four categories of systems (Fig 1):

- Executive Information Systems (EIS) : provide useful and relevant information to decision makers by improving the access and the manipulation of the existing information in order to confront objectives and observations.
- Executive Support Systems (ESS) : include communications, analysis and intelligence capabilities. They allow data analysis

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and give an appreciation of the organisation future.

• Decision Support Systems (DSS) : provide, in addition, informations about decisions to make for achieving a given goal.

• Planning Support Systems (PSS) : allow in addition an arrangement, an analysis and an evaluation of the decisions or the procedures adopted. They provide *intelligent assistance* at various stages of the decision making process, according to Blanning and King definitions [3]. They mainly help decision makers in : formulating problems and models, interpreting and diagnosing situations, formulating plans of actions, evaluating proposals, monitoring differences between action results and expectations, and providing justifications and explanations.

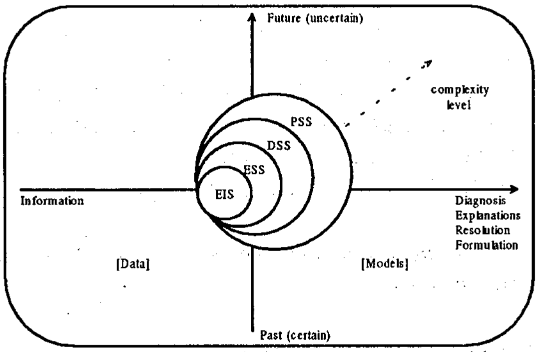

Fig. 1 : EIS, ESS, DSS, PSS dimensions[1]

We define a complex decisional domain as a domain where there are many linked elements to take into account in decision making. Therefore we introduce the notions of informational and decisional *structures* to denote respectively a set of closely linked and (or) interdependent informations and decisions. Each information get its total meaning only if it is apprehended through these structures. Decision structure complexity is a consequence of informational structure one. But it arises also from the difficulty to consider each decision independently of the others [4]. Planning as a hierarchical and (or) a schematic representation activity of an object (procedure or state) elaborated and (or) used as a decisional string reduce such complexity. Through anticipation, planning guides real choices by taking into account possible or probable future events. *Modelling* means the activity of representation (or abstraction) of relevant data among the various details of a situation

3. Supporting planning activity

The *modelling* support consists generally on providing graphical figures. These figures don't only reproduce purely and simply an object but they express non directly perceptible contents that a cognitive activity have to reconstruct. The interpretation and the conception of these diagrams find their foundations into cognitive psychology work and especially into cognitive maps theory. But as several experimentations lay it [1], the reading and the efficiency of such figures depend on the draw properties but as well on the knowledge that users have about its coded contents. Therefore the efficiency and the expected effect cannot be generalised. The anticipation support is mostly linked to the simulation. It takes generally the shape of a prospective research of decision procedures (operating from a initial state) or the shape of plans evaluation. However it is sometimes relevant to allow a complementary retrospective research (operating from a goal). Furthermore a plan evaluation requires sometimes an anticipation of various sub-plans independently of the current resolution step. This means that, at a given step of the planning activity, the resolution can be based on more than one *abstract space* to consider and to represent.

4. An agent-based approach for planning support system model

Traditional planning system models like operational research ones have been generally conceived in a global resolution vision. However some complex problems are too large to be analysed globally. Therefore a different approach based on a distributed resolution vision has been developed. It uses distributed artificial

[1] Adapted from [2].

intelligence and multiagent techniques. In decision support framework, a large part of the agent-based models are based on the concept of *cooperative problem solving* [6] in which intelligent agents work together to resolve a problem or to produce a design, a plan, a decision etc. Our approach is different because we consider decision makers as the « producer ».of the design, plan or decision. This means that our agents are not designed to directly produce a desired plan or decision but they are conceived in assistance perspective. Moreover complexity advocates anticipation capabilities as essential to an efficient support. However an action cannot be anticipated if a strategy is not already decided and defining a strategy means to plan the future by adopting options (decisions). This dialectic leads us to an approach based on the use of multiagent techniques to conceive a *domain representation model* and particularly an *environment model*. Such models represent characteristics and dynamic behaviours of a domain constituents. Therefore according to represented elements, agents vary from simple « unix-like » processes to very sophisticated cognitive and social agents. Through simulation these models allow *ex ante* an evaluation and a formulation of less uncertain plan or decision and then an anticipation of phenomena [8][10]. However this approach is principally adequate when application fields presents general characteristics such as a natural decomposition of entities, an evolutive and metric universe, a system in which the exploration by classical methods leads to an excessive combinatory [5].

5. SimEco: an agent-oriented tool to build environment model

To illustrate our main ideas, we have developed a prototype called SimEco[2]. Its implementation under WINDOWS on PC (Pentium) has been done with several languages[3]: CLIPS with its C++ library WxCLIPS[4] and C. For graphical figures, we have also used the VCG Tool[5].

5.1 SimEco architecture

The figure (Fig. 2) illustrates the general architecture of SimEco. SimEco provides mainly :

- functions to integrate applications with relational databases tools where data are generally stored,
- libraries of routines containing some general functions like user-interface, mathematic and graphical ones
- control functions which constitutes the skills of a specific agent (supervisor) which deal with concurrency, truth maintenance, user interaction, etc.,
- shared (or not) temporary database(s) to store informations.
- functions to define the agents, their properties and skills
- functions to define the relations between environment objects and between agents.
- libraries of predefined plans that are sets of meta-rules defining organisations mode, communications protocols and associated constraints.

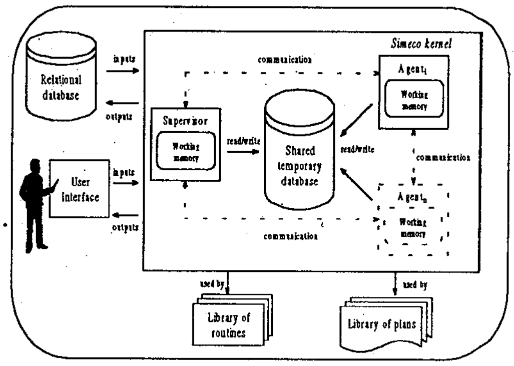

Fig. 2 : General architecture of SimEco

[2] For Simulating Economy and Simulating Finance.
[3] It is entirely writing in C++ .

[4] Graphical interface to the NASA CLIPS language, developed by Julian Smart at Artificial Intelligence Applications Institute (University of Edinburgh).
[5] Graph generator from specifications, developed by Georg Sander at the University of Saarland.

- SimEco Developer: a methodology, an interpreter and an interface to define new specific applications which consist in defining (without coding) all above-mentioned elements and in packaging the application (cf. Fig. 3). A module supporting knowledge acquisition and based on CommonKADS methodology should be added in the future.

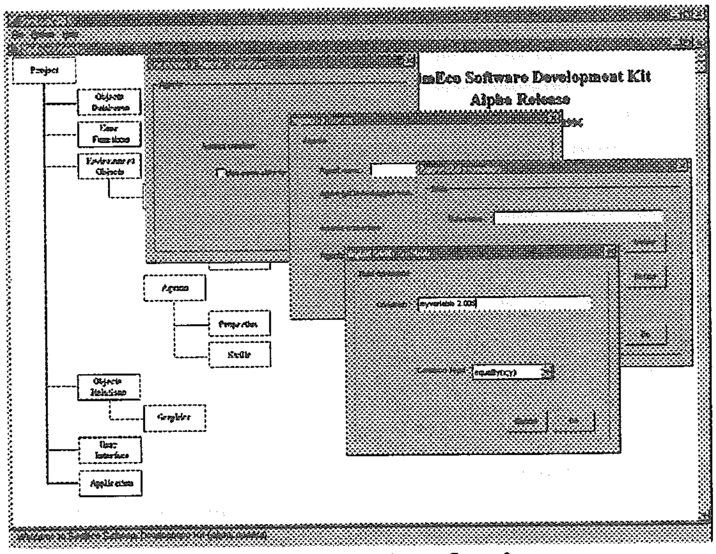

Fig. 3 : SimEco Developer Interface

5.2 SimEco object model

Objects manipulated in SimEco are partially defined in the object model of figure 4. It is based on Object Modelling Technique (OMT) notation [7] and it is based on the concepts of plan, agent and agents organisation.

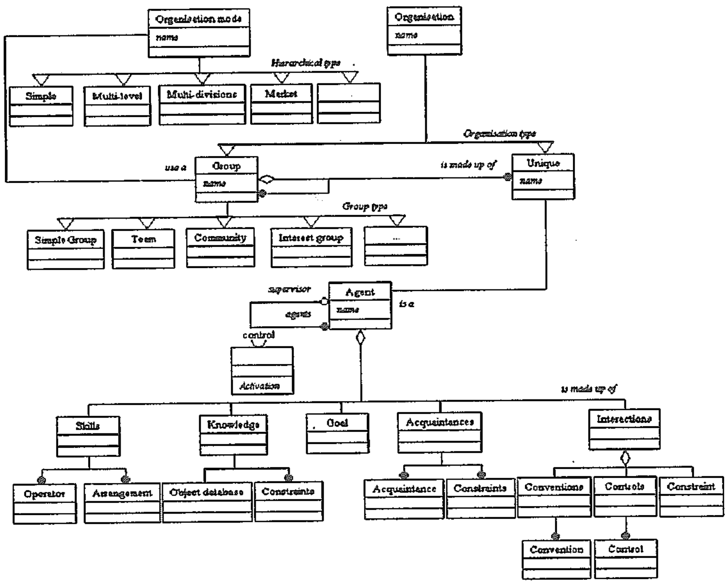

Fig. 4 : Object environment model of SimEco

Agents are the basic elements of the SimEco architecture. Formally an agent is an autonomous entity defined by its :

• knowledges : the set of environment objects that it knows and the associated constraints,

• acquaintances : the set of others agents that it knows with corresponding social constraints,

• goals which should be defined explicitly in order to use some SimEco functions,

• skills : a set of rules with constraints like an arrangement in a plan. According to our objectives, these behaviours are based on particular decision makers expertise.

• interactions : skills to communicate with others agents : conventions of interactions with acquaintances and rules to manage these conventions.

• SimEco agents have in addition cognitive capabilities such as decision making and plan generating mechanisms. They do some actions corresponding to operators execution that produce new states. A plan is an arrangement of these actions towards a defined goal.

• They are *pseudo-anticipative.* In fact they possess local working memory that allow *ex-ante* an evaluation of the plans or decisions before their adoption and their execution.

• They are *social-capable* which means that they are able to determine their inferences from informations on the others agents and on the organisational environment.

• They are *goal-oriented* which means that they achieve personal or collective goal depending on the organisation that they belong to. An organisation is constituted of several agents and is ruled on a particular mode. This mode determines the conditions and the modalities of a plan execution. For example if two agents belong to a same organisation ruled by a hierarchical mode, the main agent can order the second one to do some actions to achieve a goal. Organisations instances can evolve with agents actions.

• They are *situated* agents that means they can adopt various attitudes depending on the current problem-space. The way they work is described in the functional model of figure 5 and is closed with Oquendo and al. [9] definitions.

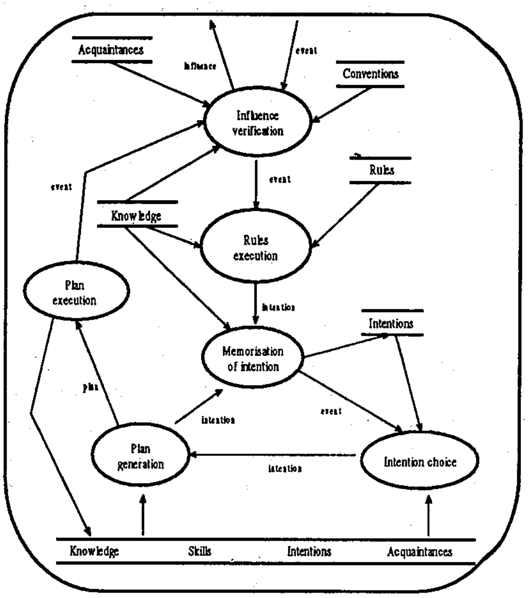

Fig. 5 : Partial functional model of SimEco agents

5.4 Planning support provided by SimEco-based systems

Planning support takes two shapes according to the two functions defined above. Concerning anticipation : this kind of systems support mainly decision makers prospective reasoning processes to elaborate plan through hypothesis tests and plan evaluation. A retrospective reasoning is supported when decision aims can be effectively formulated. Concerning *modelling* : SimEco provides routines allowing graphical diagrams (Fig. 7) to be defined according to an user defined convention. Moreover a trace of situation evolution, data evolution and some analysis routines are available for further analysis.

More generally, SimEco-based systems improves :

• problems comprehension by giving a precise model of the situation with the various hypothesis,

• possible solutions generation through the manipulation of the implemented models by providing explanations and ideas on the possible solutions of a problem,

• solutions feasibility : which are analysed in term of impact on the environment.

The value of such a support can essentially be appreciated through the occurrences uncertainty (what to do ?) and the definition uncertainty (what is it about ?) reduction that it could provide.

5.4 The SimFin example

As an application of SimEco Developer, we have implemented SimFin an agent-oriented system which deal with financial control strategies. Each agent represents a firm with its own properties (budget, etc.). They can : sell some stakes, buy directly some stakes, order another agent to buy some stakes, negotiate a purchase price, propose appropriate selling price related to a situation, cooperate with other agents towards a given goal etc. They can also use financial structures side effects to achieve their goals. The relations between agents (control, group, etc.) arise from the various capital-sharing that they hold between them. We have also defined different situations and hypothesis to test. Globally the obtained results are closed to those obtained through an experimental laboratory. Moreover in the cases with many agents the simulation results show complex financial structures and processes that it would be difficult to reconstitute manually. In the partial and simple process defined below we want to know the consequences of an eventual purchase of holdings by the agent A3 to the agent A2 related to the agent A1 financial control.

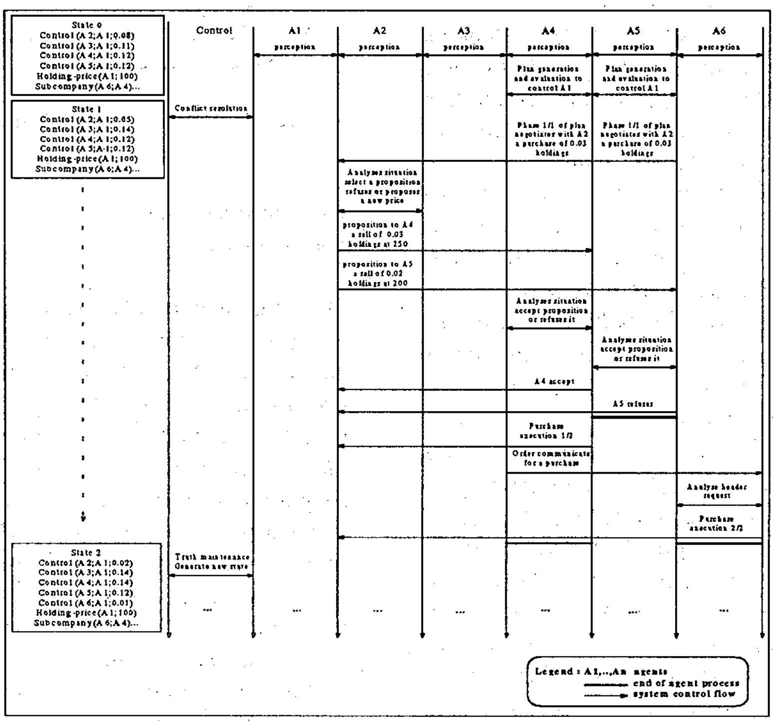

Fig. 6 : An example of SimFin process

Furthermore SimFin displays diagrams describing the various environment states (Fig. 7). These diagrams follows the default graphical convention based on the notions of *proximity* and *centrality*.

That means that organisations and organisations members are respectively placed according to their relationships and their importance. SimFin provides also explanations about each agent behaviour in a textual and (or) graphical shape.

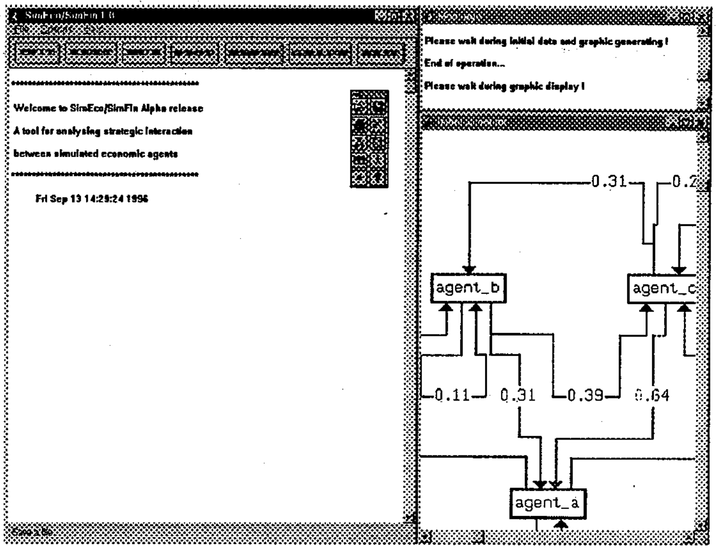

Fig 7 : An Interface of SimFin

6. Conclusion and perspectives

In this article, we deal with the decision support aspects in complex universe. We propose an agent-oriented modelling approach to define decision support environment model. To illustrate this approach, we have briefly presented a still incomplete platform called SimEco. It provides various functions allowing simulation and production of relevant *information* in a decision support scope. A tool called SimFin which deals with financial control strategies has been implemented using SimEco and the results already obtained by confronting laboratory experiments results and the system ones, lead our work to two immediate perspectives : knowledge acquisition in order to build more « realistic » agents, the validation and an efficiency analysis of such a system in decision arena.

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