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THE HOLONIC PARADIGM AS A NEW METAPHOR FOR THE COORDINATION PROBLEM OF VIRTUAL ENTERPRISES

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Many scientific developments are based on the observation of natural phenomena. The studies of the Hungarian journalist Arthur Koestler proposed a neologism based on a new word, holon, to describe social systems and live beings. This paper will explain the holonic paradigm as a metaphor for the coordination problem of a virtual enterprise. The intentional stance will be used as a cognitive analysis tool, lending typically human intentions (believe, desire, intention) to the individuals of a system and explaining their holonic behavior. Thus, it will be possible to discover important issues to be questioned when a virtual enterprise environment is being designed.

1. INTRODUCTION

The evolution of new technologies is enabling a more effective sharing and exchanging of information across individuals and organizations. Adding the availability of information technology to the challengers of the 21st century, a new paradigm is emerging: the virtual enterprise. According to Walton & Whicker (1996), "*the Virtual Enterprise consists of a series of co-operating 'nodes' of core competence which form into a supply chain in order to address a specific opportunity in the market place.*"

To form a virtual enterprise, enterprises from selected skills and assets are necessary. In fact, the establishment of cooperative agreements between enterprises is not new; the innovation is the use of information technology based on computer network to support the operation of this system.

Many scientific works have been done in order to develop and implement the necessary infrastructure of a virtual enterprise, its protocols, network devices and software agents. But a special effort should be done in the study of its social behaviour. The coordination of a virtual enterprise is a special issue once it is a collection of parts, enterprises that belong to the system, but that have the behaviour of wholes. The selected enterprises should attend to the system goals, but each enterprise has its own culture, organization and politic. Some of them have been established in a mature market for many decades. Thus, the management of this heterogeneity is a problem to be solved.

The original version of this chapter was revised: The copyright line was incorrect. This has been corrected. The Erratum to this chapter is available at DOI: 10.1007/978-0-387-35399-9_52

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A motivating belief is that the information processing phenomena that occur in the natural world are a source of a number of useful metaphors for virtual enterprises in particular. In the Distributed Artificial Intelligence, sub-field of the AI that has many answers to the virtual enterprise, many metaphors have been used, leading to solutions of many problems [Chandrasekaran, 1981]. This paper purposes the study of the social behaviour of virtual enterprise by way of holonic metaphors. The main issue will be the coordination problem applied to a virtual enterprise. Firstly, the holonic paradigm will be presented. Then, the virtual enterprise will be characterized as a social organization, using societies of animals, insects and live organisms to illustrate it. The coordination problem will be defined and a path to find holonic solutions will be structured.

2. THE HOLONIC PARADIGM

The holonic paradigm is a result of the work done by the Hungarian journalist Arthur Koestler in the late 60's [Koestler, 1990b]. He has undressed the comfortable clothing of ideological, psychological and philosophical mystification, and emerged into the real reasons of the evolution. The first conclusion done by Koestler was that complex systems are easier achieved if composed by intermediate forms. In fact, the Nobel Prize in Economy Herbert Simon had already illustrated this in his watchmaker parable [adapted from Simon, 1962]:

"There once were two watchmakers, named Hora and Tempus, who made very fine watches. The phones in their workshops rang frequently; new customers were constantly calling them. However, Hora prospered while Tempus became poorer and poorer. In the end, Tempus lost his shop. What was the reason behind this? The watches were consisted of about 1000 parts each. The watches that Tempus made were designed such that, when he had to put down a partly assembled watch (for instance, to answer the phone), it immediately fell into pieces and had to be reassembled from the basic elements. Hora had designed his watches so that he could put together stable subassemblies of about ten components each. Ten of these subassemblies could be put together to make a larger subassembly. Finally, ten of the larger subassemblies constituted the whole watch. Each subassembly could be put down without falling apart."

The method of Hora has two great advantages. When the building of a subassembly had to be interrupted he just had to rebuild that subset, and not the whole watch. In the worst situation, if the perturbation had happened when he was about to finish a subassembly, he should repeat nine operations. Furthermore, this method leads to a more resistant and easier to fix finished product than the unstable mosaic of subatomic fragments of Tempus.

It is possible to demonstrate with some calculus [von Bertalanffy, 1976] that the whole existence in Earth should be impossibly developed, unless Tempus converted himself to the method of Hora. A complex system can be faster enhanced from simpler structures if there are stable intermediate forms. Between the possible complex forms, the hierarchy is the only one that can evolve in an able time. Thus, Simon noticed the omnipresence of hierarchies in real world: "*where there is life, it is hierarchically organized*".

It is important to understand the meaning of hierarchy in the holonic paradigm. Etymologically, this word has narrower and much more stunted meaning,

representing systems where there is the subordinate and the foreman, the employee and the employer. In fact, this is the basis for comprehensive but often unsuccessful developments of manufacturing systems in the past. In the holonic context, a hierarchy is an opened system of interrelated and recursively hierarchic subsystems, decomposed in a process that does not stop until a elementary (but never final) subsystem is reached.

Any social organization with a coherence and stability degree is hierarchically arranged. But this principle could be disturbed once there is no human society with a monolithic structure, shaped in just one feasible hierarchy. However, the complex structure of the social life can be dissected in its variety of hierarchical frameworks. Therefore, complex societies are structured in many types of hierarchies, linked in its social cohesion. A individual can participate of different societies, belonging to many hierarchies. For instance, a virtual enterprise can be modeled as a hierarchy of its enterprises. Each enterprise has its own hierarchy, and the linkage of these hierarchies according to its social cohesion forms the virtual enterprise. An element of an hierarchy can belong also belong to other hierarchies, as if it was a expert that performs services in many enterprises, or a machine that is shared by many factories.

The second conclusion done by Koestler was that, although parts and wholes are easily identified in complex systems, parts and wholes in their absolute sense do not exist anywhere. Koestler proposed the word holon (connection of *holos*, whole in Greek, with the suffix *on*, that indicates part or particle as in proton and neutron), describing the hybrid nature of these components. In the holon, the wholes are assertive holistic elements in relation to their subordinated parts, and the atomic parts are dependent on higher levels.

3. SOCIAL BEHAVIOUR

A set of enterprises constituting a unique entity can be called social, whereas an enterprise acting alone in the market is solitary. Although 'social' indicates that there is more than one individual (at least two), not all aggregations however are social. The 1973 Nobel Prize in physiology or medicine Nikolaas Tinbergen, one of the ethology founders, illustrates it using the social behaviour of insects and animals [Tinbergen, 1964]:

"When, on a summer night, hundreds of insects gather round our lamp, these insects need not be social. They may have arrived one by one, and their gathering just here may be clearly accidental; they aggregate because each of them is attracted by the lamp. But Starlings on winter evenings, executing their fascinating aerial maneuvers before settling down for the night do really react to one another; they even follow each other in such perfect order that we may be led to believe that they have superhuman powers of communication. This keeping together on the basis of reacting to each other, then, is another mark of social behaviour."

Analyzing this short instance, it is possible to conclude that not all aggregations of enterprises are social. To be social, it is not enough for a group of enterprises to have the same attractions, as in the case of the insects rounding the lamp. In contrast, Starlings cooperate when flying around, executing the same turnings and clustering together and rising to avoid predators as the Peregrine Falcon. Hence, aggregation is merely a prelude to closer cooperation.

Traditionally, the individual is defined as a indivisible and self assertive unit, with a separated and independent existence. However, this absolute sense is not found anywhere; in fact, there is cooperation and interdependency. Koestler called this property Janus effect; a god that, according to the roman mythology, has two faces looking at different direction. The down-directed face represents the whole, while the upper-directed face is the dependent part. The Janus effect is a fundamental characteristic of any hierarchical element.

The social part that an embedded in such a environment enterprise plays in a distributed process is defined by its roles. Typically, roles include permissions and responsibilities associated with specific behaviour patterns. According to the holonic paradigm, each holon can be defined as a canon of fixed rules and its abilities to accomplish flexible strategies, as shown in figure 1. The rules prescribe the specification over permissions that define behaviour that is allowed to occur, prohibitions that define behaviour that is not allowed to occur and obligations that define behaviour that must occur. The flexible strategies map from state history to action, assigning the ability to deal with uncertain situations. In other words, the canon determines the rules of the game, while the selected strategy decides the course of the match.

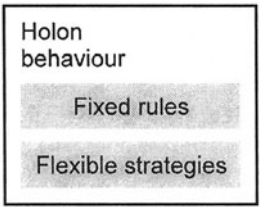

Figure 1 – The behavioral model of an holon

4. COORDINATION IN A DISTRIBUTED BUSINESS PROCESS

In the virtual enterprise paradigm, individuals interact to achieve better their own goals and the goals of the society. As an interactive individual, each enterprise may be affected by other enterprises in pursuing its goals and executing its tasks. A main focus may be attached to the coordination as a form of interaction related to goal accomplishment and task completion.

The purpose of coordination is to achieve or avoid states of affairs that are considered as desired or undesired by one or several enterprises. As illustrated in figure 2, two contrasting patterns can become visible: cooperation and negotiation. Cooperation, pre-requisite for social behaviour, is coordination among nonantagonistic individuals, while negotiation is coordination among competitive or simply self-interested individuals. Cooperating enterprises try to accomplish as a team what as individuals they cannot. Competitive enterprises try to maximize their own benefit at any expense of others.

The challenging issue is to build and maintain a system in which each individual is a already established enterprise. In a parallel with Distributed Artificial Intelligence, the elementary question faced by virtual enterprise paradigm is: when

and how should which enterprise interact – cooperate and compete – to successfully meet their objectives?

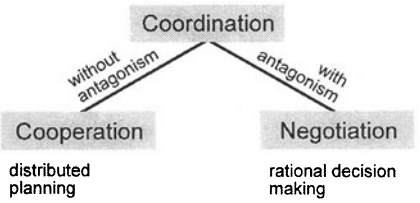

Figure 2 – Different aspects of coordination

5. PLANNING IN DISTRIBUTED SYSTEMS

Planning is essential for the social behaviour of individuals that share the same environment. In virtual enterprises, planning means the achievement of a cooperative system through the coordination of the actions of each enterprise that performs tasks in a distributed business process.

There are two possibilities when planning in a distributed process, as shown in figure 3: centralized planning (a central coordinator receives individual plans from each enterprise) and distributed planning (the individuals model the plans of each other).

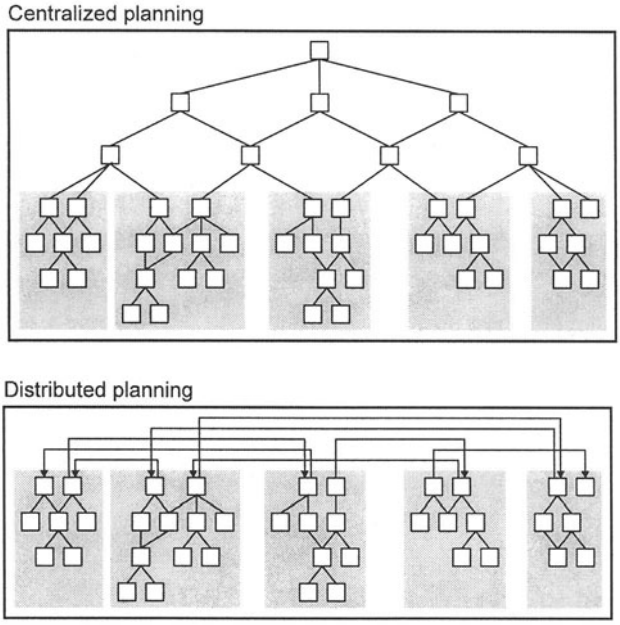

Figure 3 – Planning possibilities in a distributed process

In fact, the centralized planning looks like the Cartesian Materialism model of consciousness, debated by the philosopher and cognitive scientist Daniel Clement

Dennett [Dennett, 1997], [Dennett & Kinsbourne, 1995]. According to this orthodox model, wherever there is a conscious mind, there is a point of view, an observer that takes the information available and places them in the universe. It is the same as Descartes idea of a central point in the brain (the pineal gland) linking the brain (body) to the conscious mind. This erroneous dissociation was aptly surnamed "the ghost in the machine" by the oxfordian philosopher Gilbert Ryle [Ryle, 1984]. Nowadays, this is clear that it is a non-solution to problems of mind (there is no centralized gateway).

It is a mistake to believe that the brain has any deeper headquarter, but it is possible to model the brain, with no intention to solve the problems of mind in this work, as a headquarter itself, a place where the ultimate observer is. However, the distributed planning in a virtual enterprise is a challenge, because not only the planning process, but also its result, is distributed. As there is no final plan represented in its entirety, the distributed pieces should be compatible. It means that the enterprises should not conflict with each other when executing their plans. Furthermore, they should help themselves in their plan completion.

Many possible techniques that aid the completion of the distributed planning process are based on search algorithms. In the same sense as some of these algorithms, Arthur Koestler built a parallel to the scientific evolution [Koestler, 1990b]:

"*Newton (...) adopted the Kepler's law about the free fall, but rejected his Astronomy. He accepted Kepler's planetary laws, but demolished the rest of the keplerian building. He didn't take Kepler's complete and adult theory as starting point, but turned his development back over its own steps until achieving the point where it lost the path. Neither it was the kleperian building constructed over the Compernico's building. (...) Copernico didn't continue to construct from the point where Ptolomeu had stopped either, but returned two thousand years, until Aristarco. All the great revolutions show a notable 'pedomorphic' feature. They demand cancellation and re-execution.*"

It illustrates why sometimes it is necessary to move backward to enable a significative enhancement, as in some search algorithms [Yokoo & Ishida, 1999]. It is the *reculer pour mieux sauter*.

To be a semi-autonomous subset, each holon must be equipped with auto-regulating mechanisms. Its operations, guided by its canon, must be coherent to its environment. The auto-regulating properties uphold its balance when it is under variable conditions, pointing out the directions to be followed. An illustration is the role of a steersman, keeping the boat on the correct path. Based in such a principle, Norbert Wiener (1972) created the term cybernetics (from Greek, *cibernitos*, that means steersman).

Mechanisms like this are essential in a virtual enterprise, once it is inserted in a very dynamic environment. The needs of a market must change the objectives of an enterprise, and a virtual enterprise should be able to respond to that changes. Only with agility it is possible to seek opportunities.

The planning process of a virtual enterprise, in all the hierarchic levels, should be continuous and iterative. In addition, there must be a vertical communication process, where higher levels speak with lower ones.

A planning process can be divided according to the hierarchy of a supposed business process. As well as the illustration, the strategic level, breeder of the virtual

system, is the top level. It is the responsible to recognize the market necessities and transform them into opportunities. The virtual enterprise should be formulated according to the strategies adopted in this level.

A virtual enterprise is constrained in its planning intention according to the definitions of the strategic level (plans, objectives, politics, etc). This limiting process spreads the whole hierarchy, compelling the functional planning of each inferior holon (for instance, the operational, financial and marketing plannings of each enterprise) to be in agreement with all upper levels. In the holonic paradigm, holons have different equilibrium points when balancing its canon and flexibility, as illustrated in figure 4. In the higher levels, there is a tendency in having more flexibility, whereas in the lower ones predominate a canon of fixed rules.

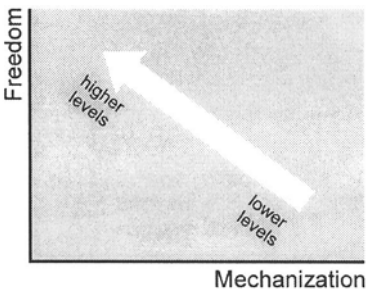

Figure 4 – Degrees of freedom and mechanization

Once a set of plans is defined, an agile organizational structure might be achieved, and the plans might be implemented. As the feedback in a control system, the auto-regulating property uses a process of measurement, diagnosis and correction to set a new direction in the whole planning process. Thus, each plan in all hierarchic levels can be modified according to a new state in the environment.

6. CONCLUSIONS

The holonic paradigm aims to a suited method to model and interpret social systems. This method can set out from Koestler (1990a) discovery that, in its structural and functional aspects, any organism is a hierarchy of auto-regulated holons that:

- works as autonomous wholes in supra-ordination of its parts;
- works as dependent parts in subordination of upper control levels;
- works in coordination with its local environment (other holons and external environment).

It is important to reinforce the concept of hierarchy that is used. It is not related to the common relationship of boss and employee that is also synonymous of rigidity. In the holonic context, an hierarchy is an opened system of interrelated and recursively hierarchic subsystems, decomposed in a process that does not stop until a elementary (but never final) subsystem is reached, as shown in the section 3.

Translating all of this to the virtual enterprise paradigm, it is possible to notice that such a company is a set of enterprises that have an assertive behaviour, as an already constituted subsystem, but in which each enterprise has a social (and legal) compromise with the other ones, being a part of it. To be successful, these

enterprises should attend to the external necessities (for example, the market demand) and should work in accordance to each other. In a competitive aspect, the virtual enterprise can be seen as sets of self interested enterprises that work together (with a cooperative behaviour) to achieve common goals. This should lead to a great differential to the whole enterprise and also to its individual members.

The coordination of such a system is a challenging issue. The design of the elements that makes a virtual enterprise possible should consider social aspects of the entire system. The cooperation can only be achieved with an adequate planning process. To be enhanced, its elements should show some assertive behaviour, causing conflicts. A rational negotiation mechanism should, thus, be implemented.

The communication is a core aspect. As the information technologies are becoming more and more sophisticated, it is getting easier to implement a big network linking enterprises spread around the world. But will such a net be a social entity, or will it be a bunch of insects attracted by a source of light? Is it clear enough that the enterprises should interact in a cooperative system?

As it could be seen, the holonic paradigm is useful since it discovers innovative questions about the needs of an organism, even if it is a colony of animals or an enterprise. Doing so, many coordination problem-solving techniques can be developed. In this sense, with the answers to questions such as these, retrieved by this or other metaphors, an effective virtual enterprise environment can be implemented.

7. ACKNOWLEDGEMENTS

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