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INTELLIGENT SOFTWARE AGENTS FOR DECISION MAKING IN ENTERPRISE

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Abstract: This paper will attempt to highlight the complexity of decision-making mechanisms as well as the interest of integrating the cognitive dimension into the simulation models, with a view to evaluate the impact of technological reality (flow, individual production feedback) over the results of enterprise decisions. Therefore, we will review a simulation model using discrete events simulation techniques, which integrates the agent-based decisional system modeling.

Keywords: decision, multi-agent system, discrete event, enterprise simulation.

1. INTRODUCTION

In today's industrial context (variable markets, competition, crisis, etc.) which strongly separates the mass production processes (Taylor-isms), enterprises need to become "reactive" (Adler, 1997). The key of this reactivity is to be found in a different vision over the enterprise, described by larger autonomy and more flexibility related to decisional actors, which means re-distribution of designing and making decisions at enterprise level. We will research the informatics concepts that allow the „dynamic" and „distributed" modeling of the enterprise based on the paradigm described above. That will supply an evaluation mechanism which will support quick and accurate measurement of the performances associated to a specific decisional area (strategic, financial, commercial, productive, organizational, etc.), with a view to improving production (Li S and Li J.Z, 2009), (Ferber, 1994).
This mechanism may contribute significantly to the economic diagnose of the enterprise and to the decision-making process regarding the choice of corrective actions.
We will consider the enterprises – entities that produce material goods - as systems undergoing a transformation of resources and involving human behaviors ranging from simple execution phenomena („piloting" in a cybernetic sense), to motivation, rational decision-making and personal intentions.
In order to be able to build a descriptive model of these organizations, we will use a methodology of representing systems designed by Van Gigch (1991), to which we have made additions.
The organizational hierarchy is represented as an encapsulation on different levels of module integration which present a certain degree of autonomy and in which the behavior orientation phenomena are modeled by means of reasoning.
The enterprise's decisional structure implies co-existence of two types of reasoning:

- Structural Reasoning – Rs – which refers to the "type" of decision to be made, "when", "how" and "by whom";
- Evaluative Reasoning – Re - which refers to the objects taken into consideration by decision-makers as criteria of evaluating results.

These concepts are the foundation of the systemic model that we propose. Upon each level of the enterprise there are associated flows (technological and informational) which will circulate crossing models such as Management Decision Center and Activity Center

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(Fig.1).

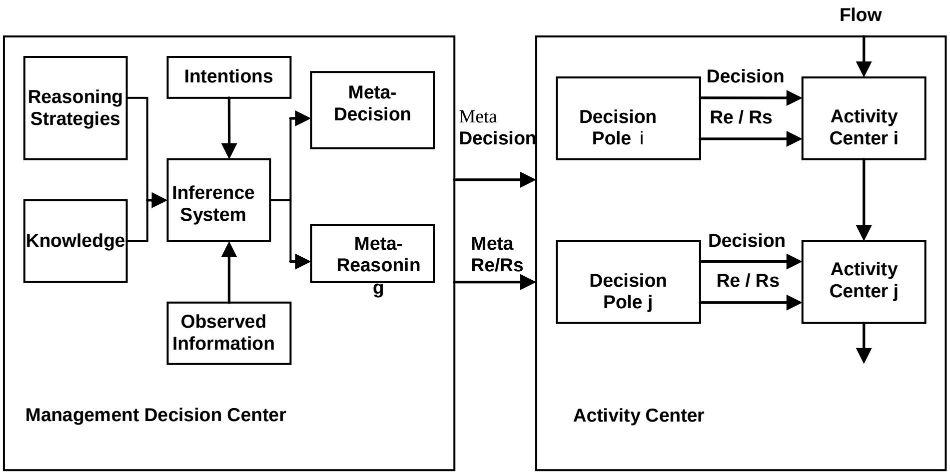

Fig.1. Systemic Model of the Enterprise

The first is responsible for management, organization and decision-making, while the second presents the operational processes of the enterprise, either physical or informational. The Activity Center has its own decision poles for each activity. Modeling and implementation of this vision over the enterprise will become possible by adapting the informatics' concepts from the Distributed Artificial Intelligence (DAI) (Duffy and Unver, 2008).

2. THE DISTRIBUTED DECISION IN A MULTI-AGENT SYSTEM

Research on the industrial systems' behavior has shown the importance of considering all know-how that intervenes in the decision-making process. An industrial issue is indeed naturally distributed and decomposed on abstract levels. One takes into account complex organizations that abandon standard hierarchical schemes in favor of a wider distribution of responsibility levels.

A society of agents should be able to represent different decisional actors within the enterprise. Therefore, we will redefine the "Decision Centers" specified in the Systemic Model (Fig.1) as intelligent agents named "Cognitive Agents", autonomous and inter-dependent.

They are autonomous because they enjoy certain degrees of freedom in decision-making. They are inter-dependent because they make the decision sharing the same know-how over the enterprise (which continuously evolves with each agent's decisions), while the decisions are sometimes competing and consequently conflict generating.

We will focus on three main directions when describing this society: organization, architecture of a generic agent and cooperation between agents.

In production systems, the social tendency which implies the agents' capacity to cooperate and integrate in the life of a group is very strongly connected to the enterprise's organization (processes, workflows, etc.) as well as to degrees of freedom the agents have related to decision-making terms. Therefore, we will define three organizational structures for modeling the important concepts related to this approach of the enterprise.

This layered organizational structure will facilitate the specification of coordination and synchronization protocols for the cognitive agents (Fig. 2).

- ***Hierarchical Organizational Structure –*** it depicts the standard hierarchy of responsibility within the enterprise, defining a number of levels on which the objectives, performance metrics and decisional items are all known.
- ***Dependency Organizational Structure –*** it overlaps the hierarchy and allows definition of communication / synchronization protocols for the agents on the same level, consequently setting up a potential cooperation network.
- ***"Effect-Group" Type Organizational Structure,*** is closer to the modern enterprise vision (teamwork, reflection group). Indeed, the objectives are defined by a team and do not depend upon the hierarchy in any other way except the connection with the global performance indicators. The structure will be defined by the Meta-Agent Concept which will be described in the systemic vision (Fig.1) by the virtual representation of the Group notion (meaning the team of agents participating in a collective action), symbolizing the principle: „the ensemble represents more than just the sum of its parts".

The meta-decisions that will generate this meta-agent (the Cognitive Agent) will involve many agreements of the "who, what, when" type.

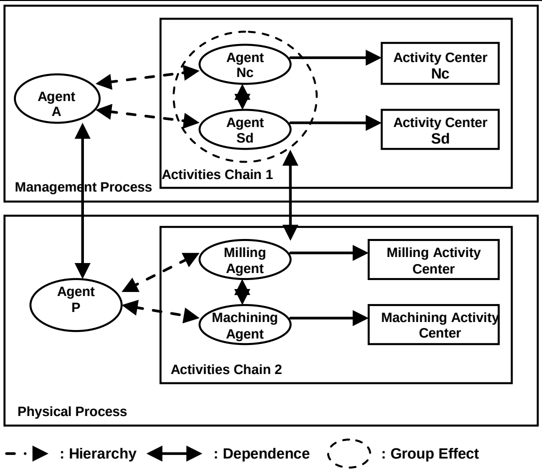

Fig. 2. Organization within the Enterprise

This paper focused upon a certain enterprise organizational structure, as presented in Fig. 3.

The structure involves two processes:

1. The Management Process, with two main activities: projection / calculation of needs and scheduling;
2. The Physical Process, with two main activities as well: milling and machining.

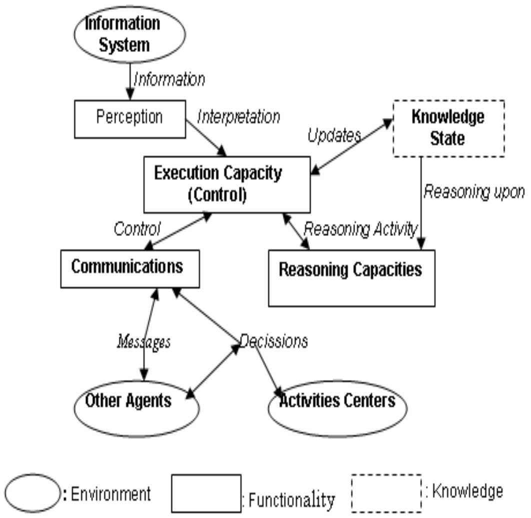

Fig. 3. The Functional Approach

2.1. The Cognitive Agent Model

As we started in section 1 (Fig.1.), we have redefined the Pole Decision that a meta-intelligent agent called "cognitive agents". The cognitive agents have as main mission organization and management of enterprise, from a functional point of view. In other words, they must manage the means of production towards meeting objectives, taking the place of those normally in charge with this. That will imply negotiations and agreements with other agents, management of activity centers already in place, intentions and personal reasoning (Mitkas, 2005).

Agents evolve in a particular environment and acquire know-how for problem solving. They research the environment with a view to gathering information, communicating with other agents and making decisions for the entities within the system. The main functionalities (Fig.3.) evolve around the execution module that supervises the agent's cognitive capacities, updates its know-how and beliefs, controls its interactions with the other agents and the environment.

The Architecture of the Cognitive Agent is made out of: Agent's Memory, Supervisor, Reasoning Agent, Communication Agent and Sensor (Fig. 4).

This generally represents a specific expertise corresponding to the agent's own know-how.

Example: "one must maximize production in order to meet the needs of the market".

- **Relationships**, namely the enterprise actors that our agent is in contact with. Example: Agent Sd has relationships with agent A, agent Nc and agent Milling (Fig. 2).
- **Intentions and Reasoning,** which represent the intentions (execution of orders, overtime, lack of cooperation, etc.) and reasoning (objectives, decision-making manner) of the agent at a certain point in time.

The Supervisor synchronizes the ensemble of agents, depicting the situations that require agent's reaction (message received, performance indicator changed, etc.) and suspension / suppressing / introduction of (new) information in Agent's Memory (knowledge, intentions, reasoning), needs-based.

The Supervisor allows the agent to observe own behavior and choose actions that must be taken (reasoning, message interpretation), to consolidate the information supplied by the Sensor and the Communication Agent, to coordinate modules. In this case we have taken over the control mechanism of the Blackboard-based systems (Oztemel and Tekes, 2009), (Shoham, 1993), in which different modules communicating different data flows (information, message, signals) allow communication of own state to the Supervisor. This will receive the events, will process them and will re-send them as control flows (activation /termination) (Fig. 4).

The Reasoning Agent will start from the Agent's status, the level of interaction with other agents and the type of decision that must be made, consequently inferring an action sequence suitable to the new objectives. It is a software module that consists of:

- A Rules Database that presents the operations which are applicable to different tasks. Example: IF the stock becomes void, the stock becomes void THEN previous Agent starts the questioning.

- An execution procedure (inference mechanisms) that synchronizes the rules and avoids the incoherence that is usually related to competing executions of more rules.

The Communication Agent is directly responsible for receiving, interpreting and giving feed-back on the messages of other agents using communication protocols. It allows sending out messages and decisions to the Activity Centers and agents on lower levels. This it is an interface between an agent and its relationships to the message interpretation and communication channel.

The Sensor: the Cognitive Agent (evolving in a constantly changing environment) benefits of perception devices that are administered by an agent called Sensor. The primary objective of this agent is to examine the external variables (performance indicators, global variables, etc.) and to allow updating of the Agent's memory. The enterprise global information system may then be consulted by means of this Sensor Agent.

2.2. Cooperation

Cooperation between agents is done through voluntary language actions of each agent. A cooperation policy is needed in order to model these language actions, which means define the circumstances leading to message delivery, the dialogue content and dialogue participants (Lopez et al, 2008).

2.3. Communication Principles

The organizational structure defined for modeling the enterprise reproduces a communication network between agents functioning on different levels. The agents involved in different processes are often supposed to negotiate in order to improve productivity (Pellizari and Dal Forno, 2007).

For example, at administrative process level, agent Sd must take into account the Milling Agent point of view and consequently must negotiate, keeping in mind reasoning and intentions for each part. Moreover, in the case of the "Group-Effect" type of structure, communication is everybody's business.

The Meta-agent will be responsible with the interactions' brief and decision-making in case of conflict.

Messages that are to be communicated to the agents must have a format that enables common language for everyone. They allow the exchange of information, enable the Q&A processes and communicate decisions and reasoning.

- **Decisions.** The activity centers need a number of specific information resulted from decision-making. For example: frequency and quantity produced, type of product, size of lot.
- **Reasoning.** Be it evaluative or structural, reasoning is a particular type of information. It is generally tied to the hierarchical structure of organization, which means it is communicated from one decisional level to the other, by means of cognitive agents.

Example:

Rs: production type;

Re: meeting the needs of the market (delays, price, quality), job performance evaluation.

- **Demand – Response.** The content is specified starting with the moment when the message is interpreted as a request. A certain number of possibilities is defined (as issues related to the request), once the agents are created and the liaisons specified.
  The request is two-folded: with or without a response (choosing the response is usually related to the intentions and reasoning of the agent).
- **Information.** The classic informational messages represent a formula such as Production = min ((Quantity, Stock), etc.), which an agent communicates to its connections.

2.4. Conflict Resolution

The agents are active in an environment dominated by organizational and functionality imperatives, being tied down by a social contract in which the prime notion is the common good. Despite it all, conflicts may arise whenever an agent negotiates with another one, very similar to it (Lopez et al., 2008).

It is therefore important to design a mechanism capable of conflict arbitration with a view to making a final decision.

The mechanism was introduced at the level of agent society organization, the "Group - Effect" Structure. The changes inherent to the process impose representation of an ensemble of meta-knowledge and meta-rules that will allow judging and resolving incompatibility-generated conflicts.

These meta-knowledge and meta-rules will facilitate defining strategies with regards to pre-defined negotiation scenarios. In order to be able to represent them we will take into consideration a meta-agent who will react in situations of group communication and will have the same structure as the cognitive agents but also knowledge of meta-level domain and rules.

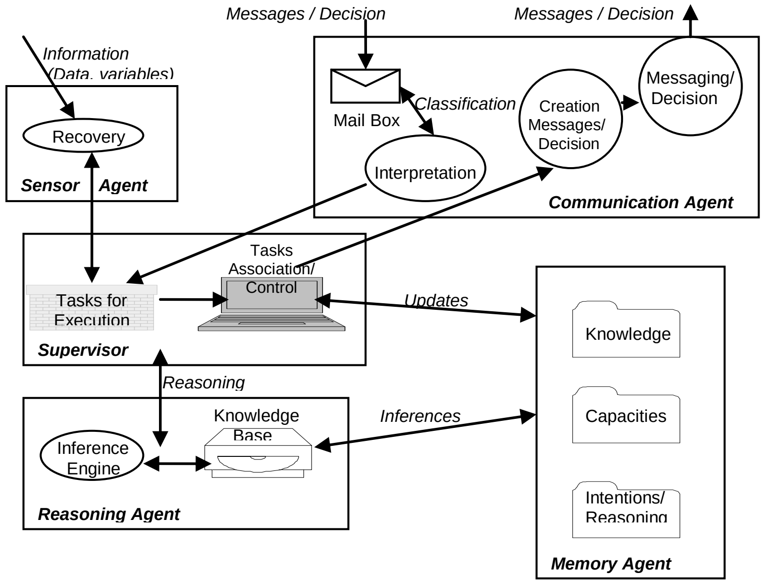

Fig.4. The Cognitive Agent Architecture

For implementation of the case-study in question we have built a simulation model representing two processes, management and physical, which allowed us to develop a specific emerging phenomenon (Kadar et al., 2005).
The initial configuration determined by Agent A decides upon the size of the production lot: 35 pieces. Moreover, each agent has his/her own knowledge and reasoning that will guide his/her behavior accordingly:

- Agent Sd will be evaluated by delays of delivery to clients (Re). It has amongst its competencies two pieces of knowledge: "smaller lot – less delays" and "all technological parameters considered – type of product, tools – a 5 pieces increase per lot will allow progressive amelioration of physical efficiency".
- Agent Milling will be evaluated by physical efficiency: working time/preparation time (Re). One of its pieces of knowledge says that "improving efficiency means limiting the changes in tools, which in turn leads to a bigger lot".
- Each agent has every intention to respect the reasoning set out to him, which leads to a win-win negotiation process directed towards success for both parties involved.

Result observation (Fig. 5) indicates convergence towards an "optimal" size of 50 pieces per lot. This result is partially tied to the satisfaction threshold established within the enterprise. A different context (delay in delivery limited to 3 days, for example) will generate a conflict whose resolution will imply the intervention of a meta-agent.

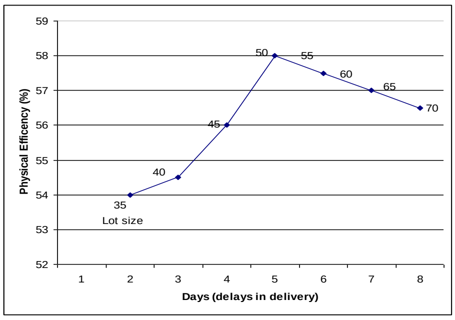

Fig. 5. Simulation Resuts

4. CONCLUSIONS

Within this paper we have proposed integration of the concepts of multi-agent systems/object-oriented simulation models/agents' databases, focusing these concepts upon the capacities, communication and organization perception of these agents, with a view to studying the production organization behavior.
The presented system is a proposed architecture of a multi-agent system that has been only partially implemented to allow carry out the simulations whose results was presented in section 3.
The multi-agent systems provide solutions for the decision-making problem within organizations (Oztemel and Tekes, 2009), (Nissen, 2001), (Wang et al, 2002), (Guo et al, 2004), by means of agents (each actor involved in the operational processes being modeled as an agent). In this context the agent has a point of view and participates in the objective setting and global performances of the enterprise. This simulation has a

direct impact on the decision-making process and supplies the expertise that may nurture the learning process.

Through the capacity of quick research of the change opportunities, it may intervene in the enterprise's organizational development sequences, as a turning point between the need for change and the action of change.
All experience acquired through simulation favors the collective setting of operational programs designed to guide every change actor and provides a vision on the impact of individual action upon global performances.

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