ABSTRACT: This paper proposes an agent-oriented model as a way to face the lack of understanding and development of Decision Support Systems dedicated to Distributed Manufacturing Systems. Such model is mainly stemming from a modeling paradigm called Agent Oriented Programming Paradigm for Production Systems (AOP3S) which is based on Multiagent Systems (MAS) and CIMOSA concepts.

Keywords: multiagent, modeling, Decision Support Systems, Distributed Manufacturing Systems, CIMOSA.

1. Introduction

Due to the globality of the economy, new approaches such as Extended Enterprise, Virtual Enterprise, Holonic Manufacturing Systems, etc., were born to support the required increasing of competitiveness [AMICE 93] [Browne &al. 95] [Walton &al. 96]. These approaches characterizes, with more or less intensity, the distribution of functional, decisional and informational means of the enterprise into cooperative units. Usually, the whole of units dedicated to manufacturing actions is called by Distributed Manufacturing System (DMS). In a such context the development of Decision Support Systems (DSS) ascends in significance.

This paper proposes an agent-oriented model as a way to face the lack of understanding and development of DSS. Such model is mainly stemming from a modeling paradigm called Agent Oriented Programming Paradigm for Production Systems (AOP3S) which is based on Multiagent Systems (MAS) and CIMOSA concepts.
Initially, the DMS as well as some decision-making processes with which this DMS can be confronted are characterized. Such situations and such decision-making processes become the requirements for the DSS model definition. After that, the AOP3S and the proposed DSS model are introduced.

2. Distributed Manufacturing System

Several configurations can characterize a DMS which can be conceived as being a set of units able to decide, to act and to use shared resources. Usually, the units are placed at the organization's control level; each unit is associated to a set of manufacturing resources (but not necessarily in a bi-univocal way); each unit is an autonomous actor able to execute interdependent manufacturing tasks in cooperation with other actors; the manufacturing resources are placed at the organization's execution level. See Fig. 1.

More precisely, a DMS can be considered as made up by (Fig. 2):

- a set of autonomous and intelligent units, where any unit, known as $U_i$, is a structure engaged in the execution of manufacturing tasks. $U_i$ has four components: $P_i$ representing the functional means, $D_i$ representing the decisional means, $I_i$ representing the informational means, and $In_i$ representing the communication means. Together these means are capable to realize the manufacturing tasks associated to $U_i$.
- a set of resources, where any resource, known as $R_r$, represents a means such as an NC machine, some raw material, etc. The resources are possibly shared by units.
- an organization which associates resources to units, resources among other resources and units among other units.

Note that the definition of $U_i$ is based on two essential interdependent properties: autonomy and intelligence.

Autonomy endows $U_i$ with the capability to realize the manufacturing tasks by itself. More precisely, is when $U_i$ has a part of $D_i$ and a part of $I_i$ to realize $P_i$. More $D_i$ and $I_i$ are important more the unit $U_i$ will be endowed with autonomy.

Intelligence endows $U_i$ with the capability to decide face to different situations. It is associated to $D_i$ and the more important these means are the more the unit will be endowed with intelligence. It is noticed that the intelligence here is strictly defined from the operational viewpoint and not from the psychological, philosophical, etc., viewpoints.

3. Requirements for a Decision Support System (DSS)

The Decision Support System (DSS) is an essential component of the DMS. Its major objective is to help the various decision making processes undertaken in the DMS. Thus, to define the DSS requirements, we should first to identify such decision-making processes.

The DMS decision-making processes: (i) observe the distributed nature of
manufacturing systems; (ii) aim at good functioning of the functional flow, and; (iii) are based on a form of cooperation among the units called coordinated collaboration (which considers that the manufacturing tasks are compatible and the resources and units' capabilities are limited).

The DMS decision-making processes are mobilized in four precise situations:

- **kick-off situations** when an unit must or want cooperate with other units.
- **normal situations** concerning the execution of units' tasks;
- **abnormal situations previously defined** concerning foreseeable events which appear during normal situations, and
- **abnormal situations not previously defined** concerning unpredictable events which appear during normal situations.

These situations characterize the two next decision-making processes:

- **Reactive decision-making process** that convey a reasoning that one could classify as based on empirical knowledge (facts and reasoning). These decision-making processes mobilize the expertise issued from the experience of production system operators. Such expertise are known prior the events apparition and take into account the following situations:
  - normal situations implementing coordination mechanisms which guide $U_i$ to execute $P_j$.
  - abnormal situations previously defined implementing urgent and well known mechanisms which guide $U_i$ to return to a normal situation.

- **Reflected decision-making process** that bring about more elaborated reasoning based on new knowledge. These decision-making processes are partially known prior the events apparition and they take into account the following situations:
  - abnormal situations not previously defined implementing "intelligent" reasoning mechanisms to guide $U_i$ to return to a normal situation, and
  - kick-off situations implementing "intelligent" reasoning mechanisms which guide $U_i$ to accept/agree with initial cooperative attributions.

Note that the reactive decision-making processes are associated to the DMS lower control level. The reflected decision-making processes concerning the abnormal situations previously defined are associated to the DMS intermediate control level. The reflected decision-making processes concerning the kick-off situations and the abnormal situations not previously defined are associated to the DMS higher control level.

The decision-making processes follow a precise activation sequence. The reflected decision-making process are often realized when reactive decision-making processes can’t face events.

4. **AOP3S**

In order to define the DSS model based on the above requirements it was used the Agent Oriented Programming Paradigm for Production System (AOP3S) [Spinosa 96].

AOP3S is a modeling paradigm stemming from a cognitive approach, which is, AOP3S considers the processing of decision-making processes and consequently the intelligence. AOP3S has three major components: the conceptual framework, the representation language and the representation methodology.

4.1 **The conceptual framework**

It represents the AOP3S theoretical aspects, in which are found the CIMOSA [CIMOSA 93] and Multiagent Systems (MAS) concepts issued from the Distributed Artificial Intelligence [Ferber 95] [Avouris &al. 92] [Bond &al. 88] [Huhns 87].

CIMOSA concepts have a double interest. On one hand CIMOSA synthesizes an important number of case studies, on the other hand, CIMOSA is adapted to the modeling of industrial areas.

MAS concepts are particularly important due to their aptitude for knowledge modeling. They provide techniques and methods which allow to model complex, distributed, cooperative and intelligent systems.

Basically, the conceptual framework defines that $U_i$ is an agent.

4.2 **The representation language**

It corresponds to the means through which the DSS model is described. The representation language materializes the conceptual
framework on an object base as postulate by the object oriented (OO) approach. This base comprises two major object groups (Fig. 3):

- A group of objects which represents an essential DMS (a generic system from which specific systems can be generated). Note that this essential DMS is conceived as been a MAS.

- A group containing objects belonging to the CIMOSA architecture (more precisely, they belong to the modeling framework of CIMOSA architecture).

5. The DSS model

The entire DSS model corresponds to the union of the units' decisional means defined inside the DMS model. More precisely, each $D_i$ in the DMS is represented by a decisional system model (DEC-S) which interacts with others (Fig. 4).

![Figure 4 - The DSS general model.](image)

5.1 The decisional system model (DEC-S)

The decisional system ($D_i$) of each $U_i$ is modeled by a an object called DEC-S which in turn is composed by three other object models: REACTIVE-DEC representing the reactive decision-making processes, REFLECTED-DEC representing the reflected decision-making processes and COOP representing the cooperation process. See Fig. 5.

DEC-S gathers these objets, translating the idea that the resolution of manufacturing problems takes into account the operators' experience and, only in case of defeat, it takes into account more elaborated decision-making processes. The former concerns already acquired expertise and it is represented by the REACTIVE-DEC object model. The later concerns new expertise and it is represented by the REFLECTED-DEC object model.

In case of failure of reflected decision-making processes, the human intervention is always necessary. This situation is considered in the COOP object model.
Figure 5 - The DEC-S model.

5.2 The reactive decision-making processes model

The reactive decision-making processes are modeled by the REACTIVE-DEC object. Such object makes up a knowledge base containing reactive solutions for precise problems. This base is built thanks to four main notions:

- endogenous sources of reactive decision-making: these sources are demands (dispatches of messages) of $U_i$'s internal decision-making processes. The demands are produced during the verification of the final state of events concerning the realization of $P_i$. These sources are modeled on one hand by the PHY-AC object model which is considered as the demand sender and, on the other hand, by the REACTIVE-DEC object model which is considered as the demand receiver;

- exogenous sources of reactive decision-making processes: these sources are demands of decision-making processes generated by the $U_i$ interface (INTERFACE object). These demands come from other $U_i$ and are formulated to reply to a specific and often urgent need. These sources are modeled on one hand by the INTERFACE object that sends the demand, and on the other hand, by the REACTIVE-DEC object considered as the demand receiver;

- selector: to each elaborated demand it is evaluated the system current situation (the reason for the demand) and the concerned reactive decision making-process is activated. The evaluation is modeled by the REACTIVE-DEC object and active an REACTIVE-AC object;

- reactive decision making-process: it corresponds to methods (programs in OO approach) that describe solutions to recover the system normal situation. Each solution is modeled by one REACTIVE-AC object.

5.3 The reflected decision-making processes model

The reflected decision-making processes are modeled by the REFLECTED-DEC object. This object is the main component of the $U_i$ decisional system and it has as objective to endow $U_i$ with intelligence. The definition of this object is articulated thanks to the following notions:

- endogenous sources of reflected decision-making processes: these sources are the demands generated during the reactive decision-making processes. They are in $U_i$ and are essentially modeled by the REACTIVE-DEC object;

- exogenous sources of reflected decision-making processes: these sources are demands of decision-making processes sent by the $U_i$ interface which treats the messages coming from other units. These sources are modeled by the INTERFACE object;

- the selector: each request elaborated by the above sources is associated to selection means which evaluate the system current situation and activate the corresponding reflected decision-making process. This notion is modeled by the REFLECTED-DEC object;

- the reflected decision-making processes: it corresponds to procedures based on Artificial Intelligence methods which are described thanks to cognitive aspects (described below). Each reflected decision-making process is modeled by one REFLECTED-AC object.
• Cognitive aspects: these aspects are modeled by a set of objects (BELIEF, INTENTION, etc.) gathered in the COGNITIVE-ASPECTS object. The reflected decision-making processes use the cognitive aspects to evolve the $U_i$ mental state (conscience) which is represented by the MENTAL-STATE object.

Note that although the REACTIVE-DEC object and the PHY-AC object seem to be similar, the former manages abnormal situations, while the later manages normal situations. The REACTIVE-DEC object appears thus as the $U_i$ process functioning control.

5.4 Cooperation model

The cooperation model is mainly modeled by the COOP object. The COOP's goal is to implement the cooperation among the different units through the definition of a cooperation protocol. The cooperation protocol is committed when individual and/or common actions are attributed to $U_i$. The cooperation protocol is composed of five main phases: (a) the launching; (b) the recognition of individual and common action; (c) the formation of unit groups of to realize a set of processes and (d) the execution. During the execution of these phases, the cooperation protocol causes the evolving of $U_i$ mental state by mobilizing $U_i$ cognitive aspects (object ASPECTS-COGNITIVE).

Note that the proposed object structure allows the definition of several variants of the cooperation protocol.

6. Conclusion

A multi-agent and CIMOSA oriented model has been proposed taking into account various situations whose a Decisional Support System can be confronted in a Distributed Manufacturing System.

It is clear that the proposed model is a contribution that remains on a conceptual level. To consider an operational level, the proposed DSS model should be implemented.

This implementation will be made easier thanks to the representation means provided by AOP3S. More precisely, an OO language can be directly employed to implement a MAS, where each $U_i$ is an agent running in an autonomous and interactive workstation.

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References


