

# HOLONIC ARCHITECTURE FOR A MULTIAGENT-BASED SIMULATION TOOL\*

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**Abstract:** In the last few years Holonic Manufacturing Systems (HMS) have been used to improve some areas such as control systems of manufacturing systems, monitoring and diagnosis systems, and Computer Integrated Manufacturing architectures. This paper presents an application of the holonic approach together with the Multi-agent Systems (MAS) to develop a Simulation Tool for manufacturing systems. The architecture for this tool is related to functionalities that support the Manufacturing Model created by the User. This proposal allows the User to take advantage of these two approaches to simulate a manufacturing environment according to the manufacturing requirements.

## 1 INTRODUCTION

Current simulation tools usually offer useful techniques to simulate manufacturing environments in static models. Their main feature is the simulation process based on static models. Some tools offer an optimization function to improve the model before executing the simulation process, and other tools allow the User to modify the model “on-the-fly”. However, since manufacturing modeling changes according to customer needs, simulation tools must also adapt to them (Nikoukaran and Paul, 1999). To the best of our knowledge, there are currently no simulation tools that provide this kind of flexibility (Klingstam and Gullander, 1999). However, we assume that if there is a Simulation Tool that provides additional features such as proactivity, flexibility, agility and reconfigurability it is possible to improve the Manufacturing Model Creation and the Simulation Process for a User (Law and McComas, 1999). Therefore, we propose the application of Multi-Agent Systems (MAS) theory and the Holonic Approach (HMS, 2004) to add flexibility to manufacturing system simulation (Miller and Pegden, 2000). The proposal is based on the unity of two notions: holon and agent. On one hand, a holon refers to a system (or phenomenon) that is both

a whole in itself as well as part of a larger system. It can be viewed as systems that are nested within each other (Koestler, 1990). On the other hand, an agent is an autonomous and flexible computational system that is able to act in an environment (Wooldridge and Jennings, 1995). Based on a comparative study of these two notions made by Giret (Giret and Botti, 2004), in this work it can be concluded that an Agent can be treated as a Holon. Since MAS is an extensive approach that can be used for the distributed and intelligent control of general systems, and since the Holonic Manufacturing System (HMS) is a specific manufacturing approach for distributed control systems, thus, it is possible to conclude that the development of a Simulation Tool based on a Multi-agent Methodology for Holonic Manufacturing Systems is viable. In this Work the ANEMONA methodology (Giret et al., 2005) is used for the tool specification. Section 2 of this paper presents the basis of the approach of the HMS architectures and the MAS that will support the Simulation Tool. Both the Model of the shop floor and the Simulation Tool are treated as a MAS that interact to provide additional features such as flexibility and proactivity during the Simulation Process. The proposed Simulation Process is composed of two phases: Model Creation and Model Simulation. Section 3 presents the HMS Architecture for the Simulation Tool. Finally, some conclusions and further research are outlined.

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## 2 A MAS BASED SIMULATION TOOL

This paper presents an extension of a previous work (Ruiz et al., 2006) in which a brief study was made to identify the manufacturing simulation process. The study distinguished two main phases in the simulation process of a manufacturing system: Model Creation and Model Simulation. The goal of the first phase is to create a model that represents a real manufacturing environment, the goal of the second phase is to simulate this model where the user can observe the system behavior, detect bottle necks, and adjust the system to improve its functionality based on the simulation results. The purpose of the Simulation Tool is to provide a Service Platform that executes specific system processes that can be automatically improved by adding proactivity and flexibility features. These features will help the User during the Simulation Process. The descriptions of the functional blocks associated to the Simulation Process is presented below: In *the First Phase*, the User builds a model while a Manager coordinates the model creation by monitoring when it is necessary to execute specific tasks according to the current state of the system. The first step is the importation and analysis of information from the real world. This information is included in the elements to be used by a Modeller to create the Model. The Model can be edited by the User whenever necessary, and the User can specify the behaviour (attributes) of each one of the model elements as desired. In *the Second Phase*, the simulation of the model obtained in Phase 1 is configured by the User (event type, speed, and type of animation). Then, the simulation is executed according to the established configuration, taking into account the attributes of each model element. The User can add events in order to include additional information during the simulation process. When the simulation process is finished, the results are analyzed. The analyzed results are incorporated into business reports and graphics to be viewed by the User and can be reused by the system. It is also possible to export the analyzed results for external analysis.

## 3 USE CASE INTERACTIONS IN THE SIMULATION TOOL

The ANEMONA methodology (Giret et al., 2005) was used for the specification of the Simulation Tool which includes the specification of System Goals, Use Cases, and Holons related to the architecture of the

Simulation Tool. The identification of the System Goals is made by using the HMS-CU Guidelines from 1 to 6 (Giret and Botti, 2006). **1.** Importation of the information from the real manufacturing system to be modelled in order to analyze and associate it to the specific icons of the Library Icons; **2.** Creation of a Model using an icon library by providing functional schemas that will help the User to customize each icon; **3.** Simulation of a Model based on a specific configuration made by the User; **4.** Supervision of the simulation process by the automatic creation or elimination of instances according to the needs of the current state of the system; **5.** Automatic analysis of the results to be viewed by the User (Reports and Graphics); **6.** Reuse of the analyzed results by associating them to the corresponding icon behavior in the Icon Library; **7.** Exportation of the analyzed results to external analysis tools; **8.** Editing of interfaces to extend the current framework.

### 3.1 Use Cases

The cooperation domains (-Use Cases- required to satisfy the System Goals) are specified using the HMS-CU Guidelines from ID 7 to 13 of the ANEMONA methodology (Giret and Botti, 2006).

**Specification of Use Cases and their Roles:** As result of using the HMS-CU guidelines, the identified roles that appear during the Simulation Process are: the Import/Export Manager (IEM); the Input/Output Data Analyzer (IODA); the Synchronization Manager (SYNM); the Modeller (MOD); the Icon Manager (ICOM); the Model Checker (CHECK); the Speed Manager (SPEM); the Animation Manager (ANIM); the Event Generator (EVEG); the Simulation Planner (SIMP); the Report/Graph Manager (REGM); and the Interface Manager (INTM).

In order to fulfil the communication needs among entities in a Use Case, the following interaction relations (Fig. 1) have been detected.

- *Manage the Data Importation.* According to a User request, the Synchronization Manager (SYNM) asks the Import/Export Manager (IEM) to import data from a real manufacturing system. Then the SYNM asks the Input/Output Data Analyzer (IODA) to analyze the imported data, and asks the Icon Manager (ICOM) to associate this data to the corresponding icons;

- *Manage the Model Creation.* When the data of the real manufacturing system has been included in the system, the SYNM generates instances of the Modeller (MOD), the Model Checker (CHECK), the ICOM and the Interface Manager (INTM) which all cooperate with the User during Model Creation;

- *Model Creation.* The User creates a model using the Modeller (MOD), which communicates with the Icon Manager (ICOM). The ICOM provides the icons that represent specific elements of the system (human, machinery, tool, etc.). Then, the Model Checker (CHECK) verifies that the model is free of mistakes, and the Interface Manager INTM provides the appropriate interfaces;

- *Model Simulation Configuration.* When the Model has been created, the User requests the configuration of the model simulation and the SYNМ activates the Modeller (MOD). The User requests the speed, type of animation, and type of events required from the MOD. The MOD communicates the selected speed to the Speed Manager (SPEM), the type of selected animation to the Animation Manager (ANIM), and the selected type of events to be associated to the Model during the simulation process to the Event Generator (EVEG);

- *Model Simulation.* When the configuration of Model Simulation has finished, the SYNМ activates the Simulation Planner (SIMP). The SIMP receives the Model and starts to plan the simulation. It communicates with other components during model simulation: the Speed Manager (SPEM) indicates the speed at which events and their animation must be generated; the Event Generator (EVEG) generates events according to the type of events selected and speed indicated by the SPEM; and the Animation Manager (ANIM) animates the icons according to the events generated by the EVEG;

- *Manage Analysis of Results Simulation.* When the simulation has finished, the SYNМ generates instances of the Input/Output Data Analyzer (IODA), and the Report/Graph Manager (REGM), which both cooperate during the Results Analysis and the Report/Graph Generation;

- *Analysis of Simulation Results.* The Input/Output Data Analyzer (IODA) analyzes the simulation results to extract valuable data to be reused by the system and delivers the analyzed results to the Icon Manager (ICOM) which then associates this data to their corresponding icons in the Icon Library;

- *Report/Graph Generation.* When the analysis has finished, the Input/Output Data Analyzer (IODA) delivers the analyzed results to the Report/Graph Manager (REGM) which then generates reports and graphs for the User;

- *Results Exportation.* When the User requests the exportation of the results, the Synchronization Manager (SYNM) generates an instance of the Import/Export Manager (IEM), which then exports the results into files for external analysis.

- *Interface Edition.* When the User requests to extend

an interface to improve system functionality, the Synchronization Manager (SYNM) generates an instance of the Interface Manager (INTM), which allows the User to edit the selected interface. When the Synchronization Manager (SYNM) detects that an instance is no longer required it eliminates it.

### 3.2 Holon Identification

The refinement of the Organization Model is done by following the ANEMONA's PROSA Guidelines from 1 to 13 and 22 to 25 to define holons (abstract agents). **a) Specification of Holons:** Both the definition of holons and the refinement of the Organization Model are done by following the PROSA Guidelines from 1 to 13 and 22 to 25. Figure 1 shows the main interactions between the specified holons. *Resource Holons and their Roles:* The Import/Export Holon plays the Import/Export Manager (IEM) role; the Analysis Holon plays the Input/Output Data Analyzer (IODA) role; the Icon Holon plays the Icon Manager (ICOM) role; the Modeller Holon plays the Modeller (MOD) and Model Checker (CHECK) roles; the Simulation Holon plays the Simulation Planner (SIMP) role; the Results Holon plays the Report Generator (REGM) role; the Event Holon plays the Event Generator (EVEG) role; the Animation Holon plays the Animation Manager (ANIM) role; the Speed Holon plays the Speed Manager (SPEM) role; and the Interface Holon plays the Interface Manager (INTM) role; *Staff Holon and their Roles:* Synchronization Holon plays the Synchronization Manager (SYNM) role. *Product Holons:* Model Holon, Report Holon, Graph Holon, Event Holon, Icon Holon, and Interface Holon; *Work Order Holons:* Importation Order Holon, Model Order Holon, Report/Graph Order Holon, Event Order Holon, Exportation Order Holon; **b) Refinement of Interactions:** The specification of new interactions is identified by using the PROSA guidelines 26 to 28. PROSA guideline 25 is also used to complete the definition of the new interactions. The refinement of interactions includes the identification of goals that the interactions pursue, the identification of exchanged messages, the identification of source and receiver of that messages, and the identification of temporal constraints.

## 4 CONCLUSION

This work presents a new holonic architecture for a multiagent-based simulation tool. The specification of the Holonic Architecture of the Simulation Tool has been made possible by the Analysis Phase

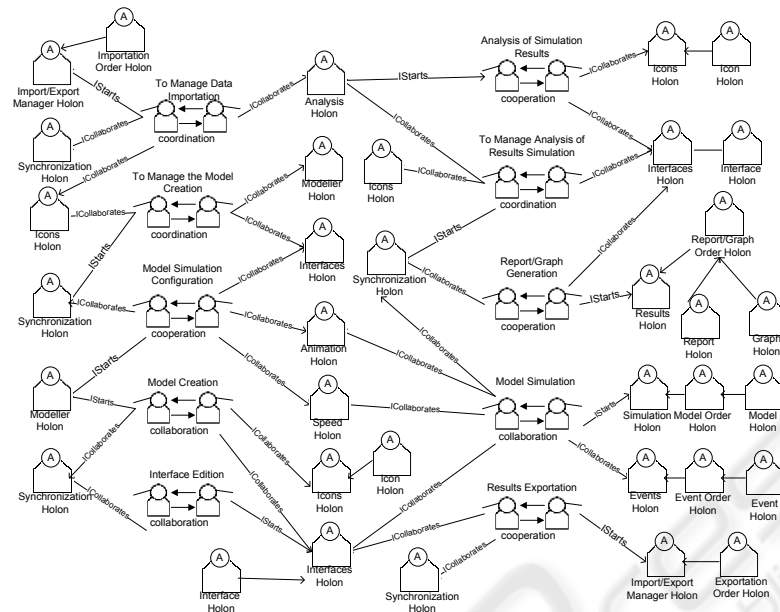


Figure 1: Holon Interactions.

of the ANEMONA Methodology (Giret et al., 2005). The architecture takes advantages of the benefits of two representative approaches, HMS and the MAS to propose a more powerful tool than current simulation tools. The Simulation Tool includes features such as flexibility, scalability, reconfigurability, and adaptability that can be observed during the Model Simulation and also offers additional features such as: *a) Simple Architecture:* Since a Holon can play more than one role, it allows the system to reduce the risk of having a great number of entities that are not required all the time. Control can be distributed thereby avoiding bottle necks which slow the system performance down. *b) Synchronization:* Due to the supervision of the Synchronization Holon, it is possible to detect needs that are related to the generation or elimination instances of a specific holon or holons according to the current state of the system. *c) Modelling:* The Modeller Holon provides flexibility when the User is creating the Model avoiding possible omissions (Checker role). *d) Negotiation Processes:* To optimize the use of current resources holons perform negotiation processes during the whole simulation cycle based on their goals, beliefs, and tasks. We are currently working on the documentation of the design phase of the Simulation Tool, which is also based on the ANEMONA methodology.

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