Abstract: This paper presents our work on a simulator for testing and validating holonic control solutions for manufacturing systems. The IEC 61499 specifications were chosen for modeling and visualization of the manufacturing equipments, the simulator providing thus a good integration with high level control solutions developed upon the same specifications.

Key-Words: - holonic, manufacturing systems, simulator, dynamical scheduling

1 Introduction
An important part of the current research in the area of manufacturing control systems is on developing intelligent distributed control solutions, consisting of autonomous and cooperative entities, with potential in overcoming the reconfiguration limitations of traditional (centralized or hierarchical) control systems. These solutions are often referred as agent-based control systems. Among them, the holonic control systems attracted significant interest from researchers, concretized in different international research projects (like the Holonic Manufacturing Systems project) and important conferences.

The holonic manufacturing paradigm originates from the Arthur Koestler’s principles about the internal organization of living organisms and social communities. In the manufacturing domain, a holon is defined as “an autonomous and cooperative building block of a manufacturing system for transforming, transporting, storing and/or validating information and physical objects”. The holon consists of an information processing part and often a physical processing part. A holonic manufacturing system includes a number of holons, organized in holarchies and cooperating to achieve the global goals of the system.

Given the complexity of the distributed manufacturing systems and the important implementation costs, simulation may represent a viable solution for validating the control systems and for the analysis of its performance in complex scenarios, before the actual implementation.

Simulation may be also used during the operation of a physically implemented system as a method for analyzing in advance different system’s evolution paths and thus supporting the decision-making entities with information for choosing the best ones. To initialize this on line simulation with the current system’s state, [1] proposes three solutions: (a) by acquiring current status information from all devices in the system, (b) by using a simulator running in parallel (and at the same pace) with the physical system or (c) by combining this two solutions in a such called observer.

Our work, presented in this paper, focused on the development of a simulator for manufacturing systems, enabling the validation of different holonic control strategies in complex scenarios, difficult and costly to be implemented in reality.

Although there are different platforms that can be used for simulation of agent-based manufacturing systems (like MAST [2], NetLogo [3], Repast [4], Mason [5] etc.), we chose to develop an IEC 61499 function block – based simulator, for a better integration between the simulated devices and the intelligent agents, also encapsulated in IEC 61499 function blocks.

2 The simulator

2.1 IEC 61499 basics

The IEC 61499 standard defines a modular open architecture, for the next generation of distributed control and automation systems. The standard incorporates advanced software technologies, such as the functionality encapsulation, modular design,
event-driven execution, and distribution Error! Reference source not found., Error! Reference source not found.

The basic element of the architecture is the function block, defined as a compositional unit with a specific interface and some functionality elements, which can be implemented both by software and hardware. The standard defines three types of function blocks: basic, composed and service interface.

A basic function block represents a software structure, with role of executing an elementary function within the control application, such as reading a sensor or setting an actuator state. The functionality embedded into a composed function block is determined by a network of interconnected function blocks. The blocks that form the network can be basic, service interface, or even composed function blocks. The service interface function blocks allow the abstracting of the services specific to a platform, such as reading of inputs, setting of actuators or communication services.

Even designed mainly for low-level control in industrial automation, IEC 61499 function blocks can also be used for encapsulation of high-level control of industrial equipments (in form of intelligent agents, for example), as suggested and exemplified in [6] and [7]. Graphical visualization functions for building, for example, human-machine interfaces, or for simulating manufacturing processes, could also be encapsulated in IEC 61499 service interface function blocks (SIFBs) [8].

2.2 Function blocks for simulating manufacturing devices
To build the simulator we started from a function block based visualization package (vhmi), developed at Auckland University (www.fb61499.com). In its basic form, this package include an IEC 61499 device, a resource, and two function blocks for moving and rotating an image on a graphical surface. Instead of using this general purpose FBs for moving and rotating images, we developed new FBs, modeling the behavior of different manufacturing equipments and capable to display one or more images, representing work pieces. The emulated manufacturing equipments include till now conveyors, buffers, diverters and work stations.

2.2.1 Function blocks for conveyors and buffers
The work pieces are transported in our simulator by conveyors and buffers. Besides the function of transporting parts (like a conveyor), a buffer is able to provide them to a workstation in a random order.

For a more efficient building of different systems configurations we developed two types of conveyors: linear and corner conveyors. Linear conveyors are straight horizontal or vertical conveying lines, the transportation direction being settable through a parameter. Corner conveyors can be thought as two coupled linear conveyors, a horizontal and a vertical one. Its orientation is settable through a parameter, as illustrated in Fig. 1.

![Fig. 1. Linear (a) and corner (b) conveyors](image-url)

The input parameters of the function blocks emulating these conveyors allows the user to set their position, lengths, orientation, and the ID of devices they are connected with. Fig. 2 presents the interfaces of the function blocks emulating the linear and corner conveyors.

![Fig. 2. Interfaces of the function blocks emulating the linear and corner conveyors](image-url)
order to attend its destination. Diversers are instructed beforehand about the destination of each piece in the system. The pieces are identified on the base of a unique ID transmitted to diversers by the input conveyors. Fig. 3 contains the visualization of a diverter, along with the interface of the function block emulating it.

Beside the communication with the connected simulated devices, a diverter is able to communicate with an intelligent agent in charge to transmit diversers their routing tables and instructions on work pieces destinations.

### 2.2.2 Function blocks for work stations

The work stations are responsible for processing the work pieces according to their processing plan. These processing plans are predefined for each type of product the system can build, the only unknown information being represented by the addresses of the work stations that will process the components. This information is determined when the order is launched through negotiations with the work stations. The result is a receipt containing both the operations to be done to a work piece and the work stations committed to them. These receipts are accompanying the work pieces during their moving through the system so as they can be autonomously transported and processed. In a real system, these receipts can be stored on RFID tags, attached to the work pieces.

When a piece attends a work station its receipts is examined, the station looking for the first unexecuted operation, which is supposed to be identical with the operation committed to the work station for that work piece. If true, the station will process the component, will change the status of the operation as *executed*, and will release the component. The images for visualization of work pieces are selected according to the number and types of executed operations in their receipts.

![Diverter visualization and the emulating function block](image)

#### Fig. 3. Diverter visualization and the emulating function block

Similar to the diverter, the function block emulating a work station is able to communicate both with the connected simulated devices and with the intelligent component of the holon it is part of.

### 3 A working scenario

To illustrate the operation of the simulator we considered a manufacturing system containing three work stations, named M₁, M₂, and M₃. Three operations can be executed by the system, O₁, O₂, and O₄, associated to the stations as follows: M₁ (O₁, O₂), M₂ (O₂), M₃ (O₁, O₄). O₁ is a boring operation; O₂ colors a work piece from yellow to green, and O₄ attaches a drilled piece to a peg component. Four product types can be built, as illustrated in Table 1. The system’s interface allows users to launch individual orders for each product type.

#### Table 1. Product types

<table>
<thead>
<tr>
<th>Type</th>
<th>Picture</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Type A product</td>
<td><img src="image" alt="Yellow ring" /></td>
<td>Yellow ring</td>
</tr>
<tr>
<td>Type B product</td>
<td><img src="image" alt="Green ring" /></td>
<td>Green ring</td>
</tr>
<tr>
<td>Type C product</td>
<td><img src="image" alt="Yellow peg-ring combination" /></td>
<td>Yellow peg-ring combination</td>
</tr>
<tr>
<td>Type D product</td>
<td><img src="image" alt="Green peg-ring combination" /></td>
<td>Green peg-ring combination</td>
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</table>

The operation of the system is illustrated in Fig. 5. Fig. 6 presents the network of the function blocks emulating the physical devices.
Fig. 5. A working scenario: a) the interface for launching orders; b) the human interfaces of the order holons; c) the human-machine interface of the work stations; d) the simulator visualizations

Fig. 6. The network of the function blocks emulating the physical devices
4 Conclusion
An IEC 61499 function block based simulator was introduced, mainly intended for validation and performance analysis of different holonic control strategies for manufacturing systems. The use of IEC 61499 specifications allows a seamless integration between the emulated devices and intelligent agents encapsulated in function blocks as done in other research works [9].

References: