COORDINATION AND COMMUNICATION STRATEGY FOR AUTOMATION COLLABORATIVE SYSTEMS

Ricardo Andrés Castillo
Universidad Militar Nueva Granada, Mechatronics Engineering Department
Cr. 11 101 – 80. Bogotá – Colombia
ricardo.castillo@unimilitar.edu.co

João Mauricio Rosário
University of Campinas, Mechanical Engineering Deparment
Rua Mendeleiev - Cidade Universitária "Zeferino Vaz" Barão Geraldo - Campinas, Brazil
rosario@fem.unicamp.br

Oscar Fernando Aviles
Universidad Militar Nueva Granada, Mechatronics Engineering Department
Cr. 11 101 – 80. Bogotá – Colombia
oscar.aviles@unimilitar.edu.co

Abstract. *In this work is proposed and development an agents based coordination and control strategy for automated production systems composed of collaborative (heterogeneous) manufacturing modules, this strategy will enable these systems to dynamic adapt to changes and disturbances of modern industrial environment. In order to validate the proposed strategy it will be projected a flexible manufacturing system configuration composed by: a hydraulic table, an articulated robot, a robotic hand as a grasping system, a mobile robot with manipulation capabilities and an artificial vision module. In the proposed coordination and control strategy is used an ADACOR holarchic architecture, within this architecture the projected holons (agents) can work either in an independent manner reaching local objectives or in an integrated manner cooperating each other to reach the global production objectives. The coordination between the holons inside the system in order to work in a collaborative form (coordination – cooperation) is developed using an artificial intelligence technique inside each holon to configure its respective Logic Control Device (LCD), thus making automatic the reconfiguration process. The strategy proposed in this work can also be used in other applications that require the collaborative integration of mechatronic systems.*

Keywords: *Automation, distributed coordination and control, holonic systems, stigmergy, collaborative intelligence.*

1. INTRODUCTION

In recent decades it has appeared changes in the manufacturing industrial environment, which has evolved from a local economy towards a global and more competitive economy characterized by high quality products, lower cost and shorter life cycle: this entails a need for of these manufacturing systems to dynamically and quickly adapt to changes and disturbances of the environment (Leitão, 2006). Therefore, to ensure competitiveness, industries require the implementation of integrated manufacturing systems controlled by using a collaborative, distributed and intelligent approach that can ensure flexibility and reconfigurability while maintaining productivity and quality (Colombo, 2004), (Monostori, 2006) (Shen et al, 2006).

So new paradigms such as Collaborative Manufacturing Management (CMM) emerge as an evolution and a response to the need for adaptation to emergencies that is not completely satisfied by the original CIM (Computer Integrated Manufacturing) concept in which the Automated Production Systems (APSs) provide a hardware and software integration based on a strongly hierarchical and centralized control architecture and in a sequential and rigid operational structure (planning, scheduling, execution). Thus, even this control architecture enables the CIM systems for an optimization in production (of one or few products), entails major complications, requiring the interruption of the entire system when a fault occurs at any point in the hierarchy (Colombo, 2006 apud Leitão, 2008), therefore this rigid and hierarchical structure does not allow these systems to adapt efficiently or effectively to disturbances in the industrial environment.

Within this context, Intelligent and Distributed control manufacturing systems arise; those are characterized by a decentralized control architecture which enables them to be robust and adaptable to changes and disturbances. Taking this approach into account, the technological paradigm known as agents-based systems allows the implementation of another paradigm: the holonic systems, which use agent technology. Holonic systems besides to meet the needs previously described provide benefits such as modularity, reconfigurability, autonomy, scalability and reusability (Leitão, 2009).

Taking into consideration that although the distributed agents-based architectures can provide the advantages described above, to obtain them it is necessary to ensure appropriate coordination and cooperation between different agents in order to these achieve global production objectives, each one having only a local vision of the system. Thus it is necessary to develop collaborative strategies that allow individual components of the system to work together cooperatively to achieve global objectives combining its decision and actuation capacities in order to dynamically face unexpected disturbances and changes in system environment (Cioarga and Nalatan, 2008)

Some strategies to achieve effective coordination between agents are used as a command component: heuristics, genetic algorithms, micro-opportunistic techniques, markets based methods, and increasingly distributed artificial intelligence techniques based on bio-inspired algorithms (swarm intelligence) (Jimenez and Ovalle, 2008),(Correa et al, 2010), (Palacios, 2007). Research works using the command techniques above described has been implemented first on hierarchical control architectures (centralized) and then on heterarchical architectures (fully decentralized) (Leitão et al, 2009) in which the appearance of a disturbance is easily overcome through the reconfiguration capability of the system and the consequent redistribution of agents' activities (Pereira, 2009).

The strategy described in this work had taken into account three parts: selection and use of a heterarchical (decentralized) control architecture, the proposal of a technique for coordination and communication between agents based on artificial intelligence and adaptive coefficient inside the holons at the operational and coordination levels. This way, it will be permitted a collaborative work (coordination and cooperation) between the physical resources of a manufacturing system by means of distributed intelligent control and enabled by holonic control architecture ADACOR (ADAptive holonic COntrol aRchitecture for distributed manufacturing systems).

The adaptive component proposed in this research work is implemented inside the Logic Control Device (LCD) of each holon, this will make the system to respond in reactive form reconfiguring and adapting itself physically and logically, as well as also "to learn" each time it is subjected to unexpected changes. Thus, adding speed of response to the system, making it more robust, flexible and agile over time (Weiss, 1999), (Shen et al, 2006).

2. TRADITIONAL APPROACH TO MANUFACTURING CONTROL

Due to the large number of interactions between the different components and the variety of functions performed, the manufacturing control systems are traditionally implemented using a centralized and/or hierarchical structure considering the following components: Planning, Task Scheduling, Execution (routing, monitoring, diagnosis and recovery from an error) and Control of machines and devices; each of those taking a specific time, ranging from weeks in planning to seconds in the factory floor.

The execution of manufacturing plans are always subject to disturbances (faults in machines, no operators, ordain to produce faster, delay the suppliers) which diminish the productivity of the system. In this case the system should respond quickly and dynamically, executing correctives actions in order to complete the production orders within the scheduled time, minimizing the impact of these disruptions, through a reformulation of plans. If an error is detected it is necessary to make a diagnosis in order to identify the cause of failure or of uncertain operating conditions. This treatment of disturbances during the execution of the plans turns the manufacturing control a complex and interesting. The control of machines and devices is the lowest level in the control hierarchy involving initiation, coordination and monitoring of the different functions of the machines (Leitão, 2006).

3. INTELLIGENT AND DISTRIBUTED MANUFACTURING CONTROL SYSTEMS

The traditional approach to manufacturing control system does not meet the modern requirements for dynamic adaptation to changes in the environment (in terms of flexibility, scalability, agility and reconfigurability), which today constitutes a key feature for competitiveness and survival of firms (Shen et al., 2006) (Leitão, 2009). The distributed manufacturing control systems arise as an evolution and response to emerging needs not fully satisfied by the original and centralized CIM concept. These systems besides improving the previous features, add agility, modularity, fault tolerance, reusability, component interaction and profitability management to Production Systems. Thus, the CSAPs can achieve global and local manufacturing objectives, based on a structure no longer hierarchical but heterarchical.

Associated with this concept distributed and intelligent manufacturing (see Figure 1) control systems have redundancy of functions and responsibilities (Monostori, 2006) and its operation is based on distributed and parallel activities performed by autonomous entities or units.

By introducing artificial intelligence techniques, these systems are enhanced with the ability to quickly and appropriately adapt to emergencies or unforeseen events without external intervention. Currently there are two approaches that exemplify intelligent and distributed manufacturing systems' concept: agent-based control systems, and holonic control systems, considering agents as a technology and holonic systems as an implementation methodology of this technology (Shen et al, 2006).

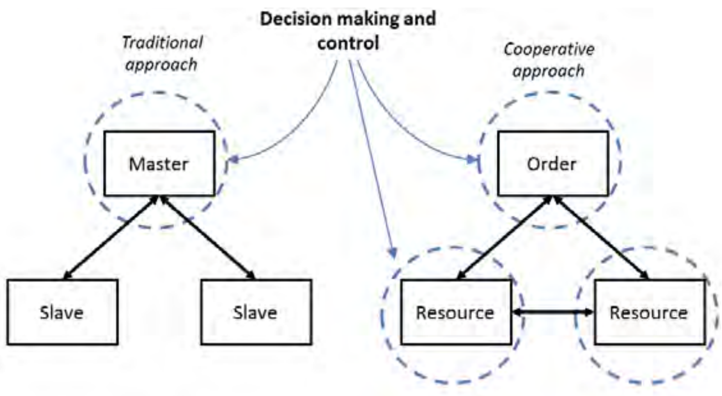

Figure 1. Traditional and distributed approaches to decision making in manufacturing control systems (Marik, 2005 apud Leitão, 2008)

3.1 Agents and holonic based systems (Holonic Systems)

These systems (Multi Agent Systems - MAS) are derived from the concept of Distributed Artificial Intelligence (DAI), a MAS can be defined as a set of agents representing the resources within a manufacturing system (Shen et al, 2006), being organized by a heterarchical architecture that is characterized by a high level of autonomy and coordination. The necessary collaboration to obtain agents coordination and/or or cooperation requires a regulated flow of information between agents and their environment. The communication between agents which is a constant requirement in these systems can be direct (exchange of information between specific agents) through a language with determined syntax and semantics or indirect (using the environment) (MONOSTORI, 2006). These manufacturing control systems can be easily expanded, requiring only the modification of certain agents operation or the addition of new agents to the control system (Leitão, 2009).

Multi agent systems have been widely used in transportation, telecommunications and health systems besides its application in manufacturing (Monostori, 2006), (Agentlink, 2005 apud Leitão, 2008). Into manufacturing field an agent can represent both a physical resource (CNC machines, robots or products) or a logical entity as an order. Using suitable distributed control algorithms, the agents representing products or machines can make manufacturing decisions itself, which are related to resources location and coordination, this using a kind of "automatic-negotiation".

The architecture of holonic manufacturing systems is based on a concept knew as Holarchy, defined as a set of holons organized under a hierarchical structure which allow those for cooperate to achieve the global system objectives by combining the knowledge and skills of each holon (holarchy is a type of architecture between heterarchy and hierarchy). Unlike a traditional hierarchy in a holarchy a holon can simultaneously belong to more than one hierarchy, so the holonic architectures may enclose temporal and permanent hierarchies. So even integrated in a holarchy a holon not lose their autonomy or individuality. Thus, manufacturing control systems (HMS) combine heterarchical control´s adaptation to unexpected events (disturbances) and hierarchical control´s predictability and high performance (Bongaerts, 1998 apud Leitão, 2008).

The robustness of the system is based on the distribution, not being the control centralized on only one element, the lost of one of them does not mean inoperability, stop or restart of the system, so the production can be reorganized even using different components. Moreover, you can also add, subtract or easily modify hardware and software modules while the system keeps running.

One of the proposed architectures in order to illustrate the HMS approach is the collaborative ADACOR (ADAptive holonic COntrol aRchitecture for distributed manufacturing systems) architecture (Leitão and Restivo, 2006).

4. DESCRIPTION OF THE PROPOSED STRATEGY

The strategy proposed in this work is composed of three main parts:

a) Study and selection of a heterarchical (distributed) control architecture.
b) A manufacturing control system and a communication model between agents.
c) An adaptive component within agents to enable an automatic knowledge acquisition.

4.1 ADACOR Heterarchical Architecture

The selected architecture to be used within the proposed strategy responds to approach HMS, this ADACOR architecture was proposed, developed and implemented at the Polytechnic Institute of Bragança (Portugal) (Leitão et al, 2009). This architecture is selected in order to enable the implementation of a intelligent manufacturing control system based on a configuration with a high degree of flexibility, adaptability and robustness when a change or disturbance appears, easily adapting itself within a stochastic environment (Leitão et al, 2005).

A Collaborative Automated Production System (CAPS) with ADACOR architecture organizes its holons synchronizing the use of resources, thus becoming dynamically reconfigurable and therefore able to produce a large number of products and /or families of parts with minimal effort in changing its physical components (flexibility). In addition, a ADACOR architecture causes the system to allow a quick and easy integration of any new device as well as the improvement of existing holons without having to reset or reprogram the entire process, meaning in greater flexibility and reconfigurability of the designed system (Leitão et al, 2005), (Colombo, 2004).

The ADACOR architecture adds the Supervision Holon (SH) and the elements for control, self-organization and learning capabilities to generic holonic architecture PROSA (Van Brussel, 1998), (Monostori, 2006), (Leitão et al, 2009). The SH introduces coordination, group formation and optimization to the system, thus defining in four classes in the architecture in order to create objects (holons): Product Holon (PH), Task Holon (TH), Operational Holon (OH) and Supervision Holon (SH), the last introduces cooperation and global optimization within the decentralized control.

The CAPS /ADACOR are neither completely decentralized nor hierarchical, but have a dynamic balance between centralization and full distribution. These systems can change its state from steady to transient or the contrary depending on the appearance of disturbances. At steady state, even each operating holon (OH) has a partial view of the system, they can work cooperatively with each other when they are integrated via a network interface, beeing commanded by the control and supervision module. The SH along with the TH will manage the actions of each holon in order to develop a complete process comprising machining, quality control and products transport, thus achieving the overall objectives (centralized operation in the absence of disturbances). When a disturbance appears, the system switches to a heterarchical architecture (transient state), in this case the Supervision Holon disappears and direct connection between the TH and OH is created, in this case is performed a market based schedule (taking offers and rewards into account) until the system returns to its steady state.

According to the concepts of ADACOR holonic architecture that is selected in this work four levels are considered:

a) Operational level with the Operational Holon (OH);
b) Coordination level of with the Supervision Holon (HS);
c) Management Level considering the Task Holon (TH);
d) Planning Level considering the Product Holon (PH), (see Figure 2).

4.2 Distributed and Intelligent Control Manufacturing System

This intelligent and distributed system is based on the coordination of agents using stigmergy in order to solve the Manufacturing Dynamic Scheduling problem (Scheduling Job Shop Problem - JSP). This problem will be addressed with two purposes:
• Develop optimized manufacturing plans to be sent to the Supervision Holon (SH);
• Generate new plans while the system is in its transient state after a disturbance, in order to send them to the operational holons when the recovery time is over and the system returns to a normal operation, in this stage a high speed response is required.

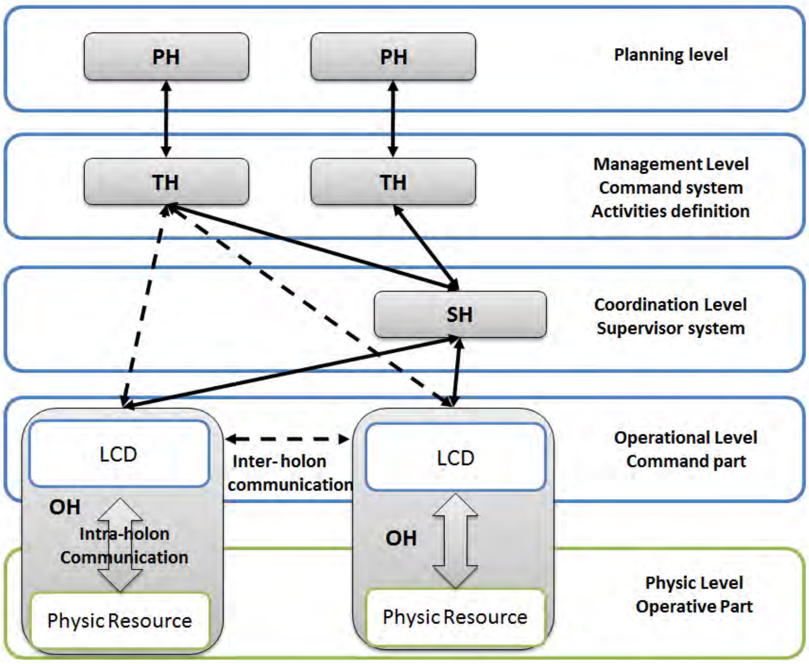

Figure 2. Levels in ADACOR Architecture

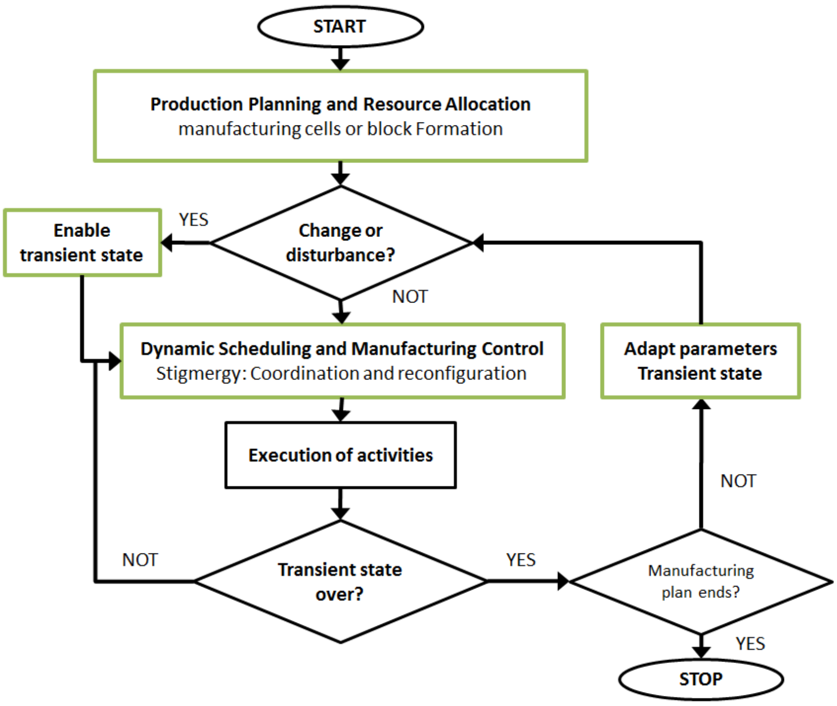

Figure 3. Diagram of Operation - Manufacturing Control System

Manufacturing control system operation whose flowchart is shown in Figure 3 takes advantage of characteristics of ADACOR heterarchical and distributed architecture on which this system is implemented, this combination means a system adaptation capability so that it can effectively deal with the following disturbances:

- Need to schedule new operation and/or cancellation of already scheduled operations;
- Failure of Manufacturing Resources or introduction of new devices in the system;
- Unexpected events such as faults in machines, absence of operators, emergency tasks, delay of suppliers in raw materials delivery;
- Smaller or larger Times in fulfilling previously scheduled tasks.

According to the diagram of the proposed strategy shown in Figure 3 can be identified the following steps.

4.2.1 Production Planning and Resource Allocation

This stage is performed by the Product Holon (PH) within the planning level; the operations to be performed in order to obtain the final product are identified and placed in a matrix called PFA Matrix Effect (Production Flow Analysis). In this matrix the rows represent the machines or available manufacturing resources and the columns represent the parts to be manufactured. This way it can be applied a clustering method to "organize" the operations within the incidence matrix and thus identify possible manufacturing cells on the factory floor in the production system. The grouping or clustering algorithm used for the proposed strategy is the ROC (Rank Order Clustering) algorithm.

At this stage it is very important to notice that even having an organization of activities that can reflect a formation of manufacturing cells, there is no obtained a sequence of these activities or work plan that can suggests a way to produce the desired product. In Figure 4 is shown the process for obtaining the manufacturing cells starting from the original incidence matrix and applying the ROC algorithm to implement the clustering process.

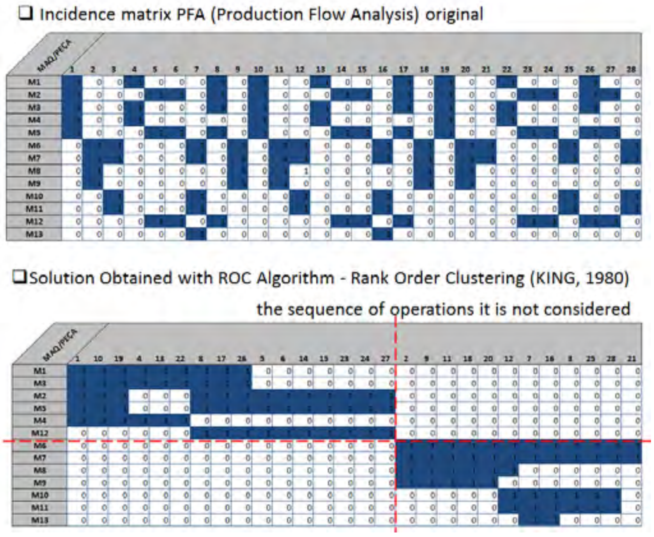

Figure 4. Obtaining Manufacturing Cells in the Resource Allocation Process

4.2.2 Scheduling and Manufacturing Control

After the planning and resource allocation stage it is mandatory to calculate the sequence of operations required within each cell to obtain the product, which means obtaining the manufacturing plan. In the traditional approach to manufacturing control these plans are sent without modification to the task scheduling component, but in the proposed strategy described in this work these plans have to dynamically change every time a disturbance occurs inside or outside the system.

Thus manufacturing plans have to be modified so that the tasks initially assigned to manufacturing resources will now be re-scheduled to other resources taking advantage of the redundancy feature in underlying CAPS hardware. These plans aim to assign resources and time to the operations of the plan to satisfy a set of constraints and minimizing or maximizing an objective function, see Figure 5.

4.2.3 Coordination and Reconfiguration for Tasks Scheduling

The technique used for dynamic and agile manufacturing scheduling uses concepts of distributed artificial intelligence (DAI) and is known as *stigmergy*, this technique makes available locally the global knowledge of the system. Thus is obtained not only cooperation, but also coordinating between the holons comprising the ADACOR the system.

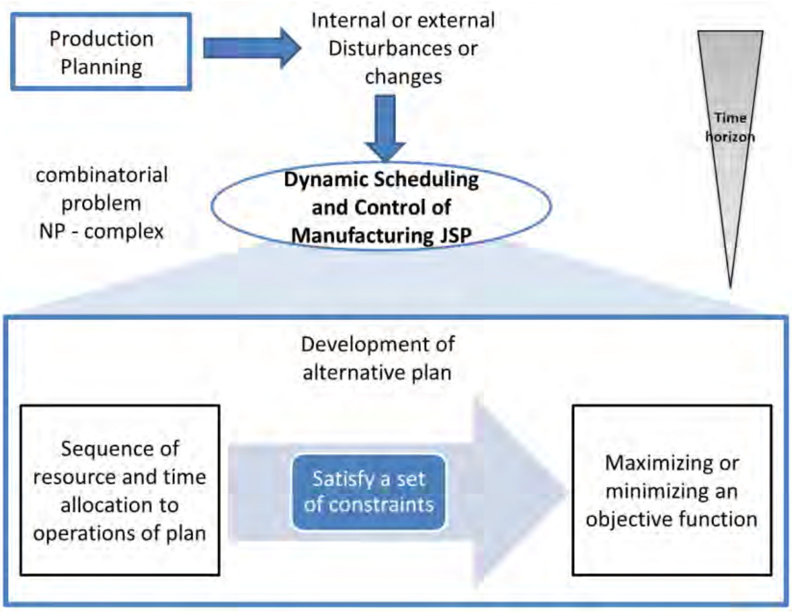

Figure 5. Dynamic Scheduling Process and Manufacturing Control

The coordination of agents based on stigmergy aims not only the allocation of resources and time to activities of the manufacturing plan, but also the coordination of resources within the same cell to complete a selected activity. The stigmergy model proposed to be used to satisfy those requirements is based on communication between agents using local extra-task mechanisms (signals) that is a subtype of stigmergy known as Based on Signs Stigmergy (Kollingbaum, 2001 apud. Hadeli et al. 2004).

In this type of stigmergy the agents base their communication and coordination in non-permanent signals known as pheromones, the combination of these pheromones produces a Dissipative Field in the environment, triggering actions on other agents without the need for direct communication (computational cost). Thus, agents will not have to deal with the complex dynamics of the system but can combine its computational power and local knowledge in a coordinated manner to achieve a collective, orderly and effective behavior.

4.2.4 Reconfiguration Process of Manufacturing Control System

When a disturbance appears in the system the agents deposit pheromones creating, maintaining and enhancing the dissipative field while another disturbance appears, those agents stop to produce pheromones causing disappear the dissipative field and allowing the system to return to its steady state. Taking into account these pheromones agents running in a local manner can know global information in the system. This makes that it may be obtained semi-optimal solutions in a short time, which serve as support for obtaining optimal plans for the system in its steady state.

Global information of the system made available through pheromones may not only be taken into account within a reactive operation, but also it allows the holons to adjust certain variables in a type of an automatic knowledge acquisition (learning).

4.3 Automatic Knowledge Acquisition

This feature is the third part of the proposed coordination and control strategy and aims that agents embedded inside the operational (OH) and supervision (SH) holons may not only have a reactive behavior, but also acquire knowledge that can improve their performance and response speed in the steady state of the system, and especially in its transient state. Taking this into consideration some variables responsible for this process might evolve via an adaptive algorithm. The continuous adaptation of these variables causes the system to improve its performance over time without leaving a range that prejudices its stability.

The integration of the adaptive component within the agents to be coordinated will cause these not only have a reactive behavior, but also "learn" by inserting therein a deliberative characteristic further reducing the coordination algorithm complexity. The values that will be adapted continuously inside the system are:

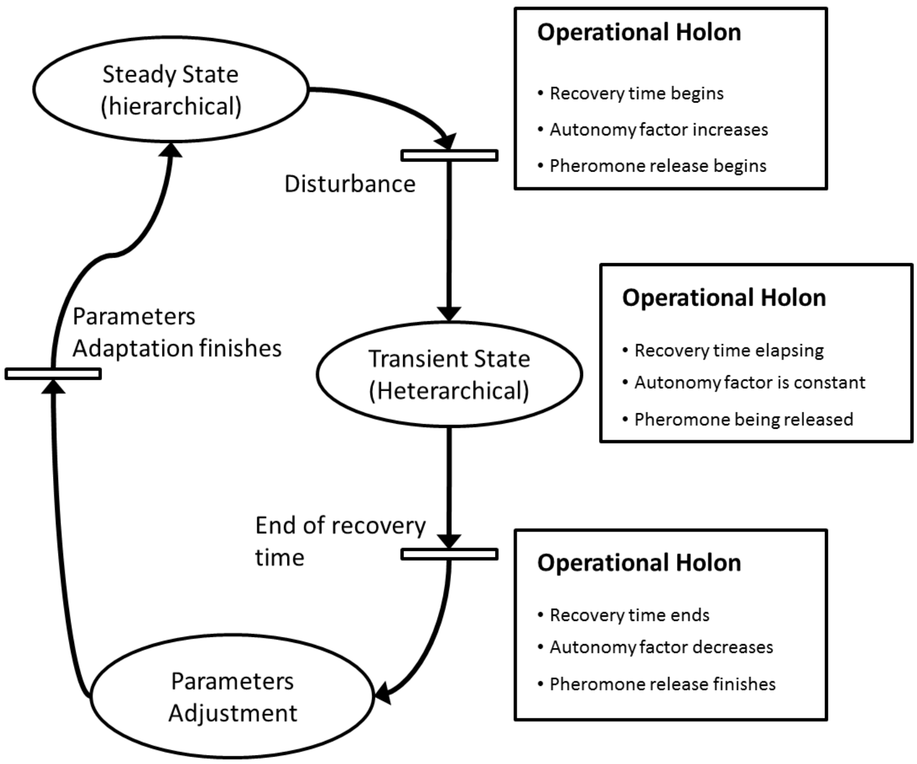

Figure 6. Reconfiguration Process of Manufacturing Control System

Autonomy Factor: Variable within the LCD (Logical Device Control) of operational holons (OH), which determines its autonomy to run manufacturing operations scheduled by itself at times also determined by itself (they are scheduled by supervision holon). This factor has to increase when any disturbance appears in the system (so the OH does not depend on the plans scheduled by supervision holon) and decreases after finishing the recovery time, been again adapted. Initially the autonomy factor is determined by a based on rules algorithm and then it modifies its value through an algorithm that takes into account: its current value, the recovery time and the pheromones values (these variables are presented below).

Recovery Time: This time is determined by the operational holon that detects a failure in the case that he cannot overcome the disturbance. All holons close to those that detected the failure will have their autonomy factors increased while the recovery time is not over. After that, the autonomy factors of OHs are decreased and recovery times within the OHs are adapted according to the type of disturbance presented and its historical value;

Pheromone: It is a variable within the OH that indicates the influence or impact of the disturbance on the system, depending both on the type of problem that caused it and on its historical values. The pheromone will be only propagated by OH that detects the failure, being maintained during the recovery time. This variable should have a value that ensures rapid response without making the system unstable.

Rejection Factor: Contains information related to the operational holon´s reliability to perform a task scheduled by the supervision holon (at steady state), its value is adjusted inside the SH taking into account the number of times a that a OH has rejected an assigned task, so aiming at a greater speed in the process of tasks scheduling.

The process of adapting each parameter of an ADACOR system is described in Figure 7. This process is implemented throw a MLP neural network trained by a supervised learning algorithm (Backpropagation).

5. EXPECTED RESULTS

The coordination and control strategy based on stigmergy, and enhanced with the integration of an adaptive component within the agents to be coordinated (OPERATIONAL AND COORDINATION LEVELS) allows that these not only have a reactive behavior, but also "learn" by inserting a deliberative characteristic into them.

This allows that operational holons not only have a reactive behavior, but also "learn" by inserting a deliberative characteristic into them, also enabling a time reduction in system transient state. In this work it is intended to get results showing that the cost (time, computation) to reach the steady state after a disturbance is less when using the coordination strategy described above than using a centralized or a PROSA architecture and based on markets scheduling techniques.

The efficiency level of system reconfiguration depends on the learning mechanism and the number of parameters that will modify their values through this learning (Leitao, 2006). Furthermore, the system stability depends on the variables previously described and the number of holons designed for the system.

Figure 8 shows the strategy proposed with its three main components described above.

5.1 Validation of the proposed strategy

The proposed coordination and control strategy will be validated in two ways: First through dynamic modeling, analysis and simulation of processes within the holon without the coordination system and then with the coordination and control system coupled, in order to validate the stability and performance of the system, with the purpose to compare these results with those obtained with other traditional strategies (based on hierarchical architecture and based on heterarchical architecture).

The other part of the validation will take into account the implementation (hardware - software) of the strategy described above with its three characteristics, using for this the manufacturing resources of the Laboratory of Automation and Robotics at UNICAMP in order to integrate them in a collaborative manufacturing system, configured according to a heterarchical architecture ADACOR, on which will be implemented the coordination and control system, and adaptive component described above.

The resources used in the configuration of the architecture are:

- A hydraulic base with 3 DOF, one for translation and two for rotations, it is able to position and orient the parts to be machined;

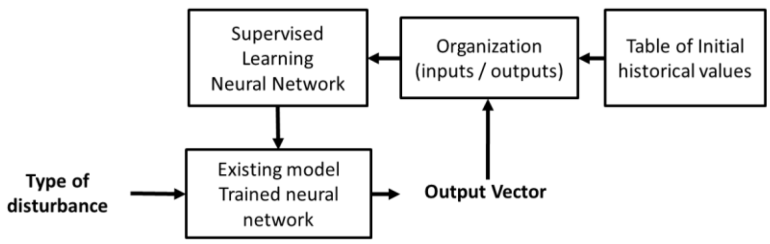

Figure 7. Parameters Adaptation Process - Supervised Training Algorithm

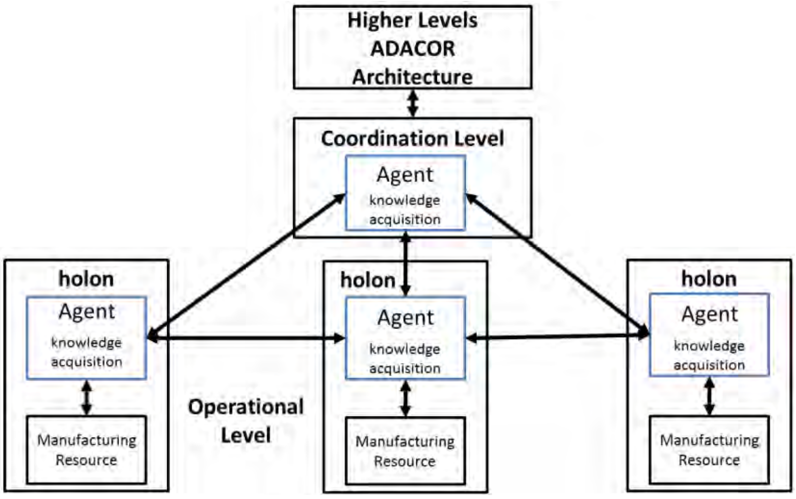

Figure 8. Proposed Coordination and Control Strategy

- An anthropomorphic manipulator (ABB IRB 140 with 6 DOF) capable of performing handling, machining and transport of parts processes;
- A camera (260X KOCOM, model: KZC-261) responsible for quality control process;
- A gripping system composed by a robotic hand with 6 DOF, with capacity for grasping flat, spherical and cylindrical objects.
- A mobile robot Robotino FESTO, in order to transport the non-machined parts to hydraulic base, and then the machined parts from the hydraulic base to the storage area.

These resources will be associated as the physical part of the three designed Operational Holons (OHs), and integrate different technologies in order to obtain a flexible manufacturing system able to perform processes such as: positioning and orientation, machining, quality control, grasping and transport.

The resources used and the configuration of the manufacturing system are shown in Figure 9. The operational level of this architecture consists of three holons each composed of a logical component LCD and a physical resource (Figure 9). For the organization at the operational level is taken into consideration that each holon has sensors and actuators in order to be self-sufficient in case of any disturbance executing actions autonomously (without dependence on another holon sensors or actuators). In Figure 10 is presented the distribution of physical resources to form holons, the arrows leaving the LCDs bring orders to the actuators and the arrows arriving symbolize the signals gathered from sensors.

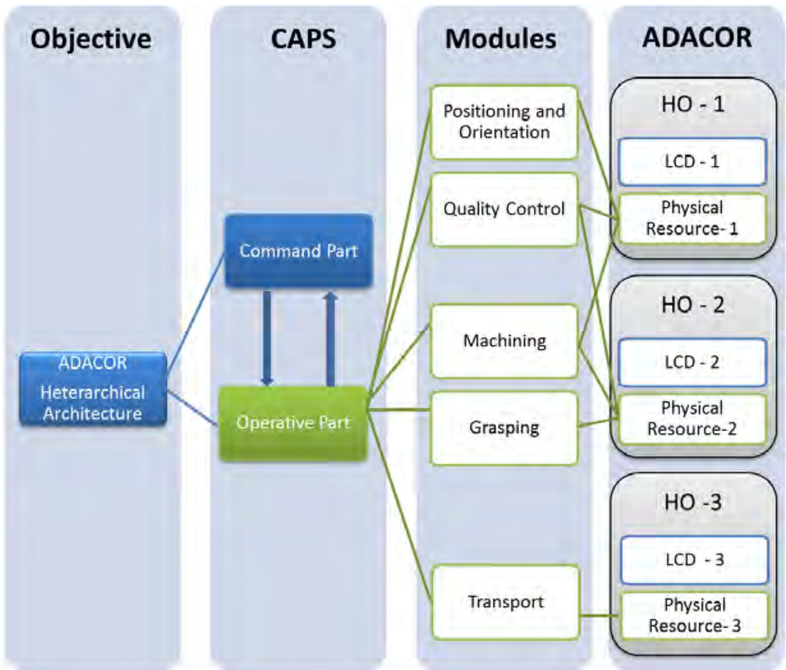

Figure 9. Configuration of designed ADACOR Architecture

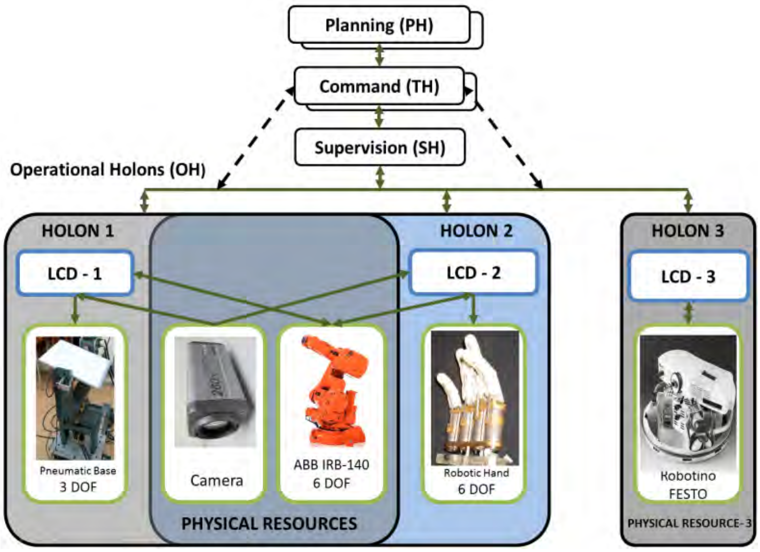

Figure 10. Configuration of Collaborative Manufacturing System used for Validation

It is very important into designed heterarchical configuration that these manufacturing resources be able to effectively perform more than one process, so the integrated system can have redundancy that allows flexibility in the development of different sequences to perform the same task. Thus it can enable the system to create alternative plans that do not always use the same resource. Consequently the system can be robust to faults or damage to any of its components without affecting the development of the activities previously scheduled, therefore, the workspace of a physical components should be maximum coincident with other resources. In figure 11 it can be observed the configuration of the physical connections in the designed system.

The strategy proposed in this paper not only allows cooperation at the operational level, but also it means a decrease in recovery time (reconfiguration) of the system and therefore in increased performance and agility.

5.1.1 Activities with holon 1

- Form Identification (Base, camera).
- Positioning and relative orientation between piece and tool (robot manipulator with tool, hydraulic base)
- Machining (manipulator robot with tool, camera, base).

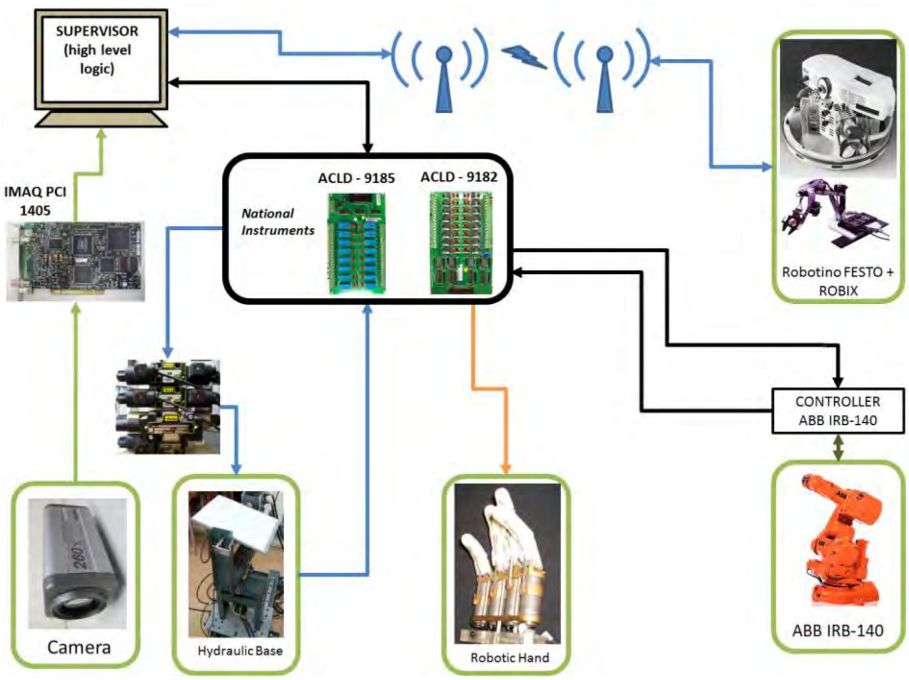

Figure 11. Configuration of connections in the designed system

5.1.2 Activities with holon 2

- Grasping of different form pieces (manipulator robot, robotic hand, and camera).
- Moving of parts for re-positioning or transport between mobile robot and machining area (manipulator robot, robotic hand, camera).

5.1.3 Activities with holon 3

- Grasping, trajectory planning and transport of pieces between stock and machining areas (mobile robot with grasping device).
- Grasping, trajectory planning and transport of pieces between machining area storage areas (mobile robot with grasping device).

5.2 Analysis of Experimental Data

The approach that will be used to evaluate the proposed strategy aims to compare performance between proposed strategy and scheduling strategies based on "traditional" hierarchical and heterarchical architectures. (Brennan and Norrie, 2003). To achieve that some performance measures for the proposed strategy will be calculated to be then compared with a heterarchical architecture (Soldberg and Lin, 1992) and with a hierarchical architecture (Rabelo and Camarinha, 1996). Performance measures or indicators to be considered in the evaluation are (See Figure 12):

5.2.1 Quantitative Indicators

- **Execution time (lead time):** total time to process a product.
- **Throughput:** Relationship between the number of parts produced in an experiment and the total time of the experiment.
- **Repeatability:** half of the standard deviation of the percentage utilization of each resource in many experiments.

5.2.2 Qualitative Indicators

- **Agility:** The ability to react in a short period of time to the occurrence of a disturbance. Comparison between values of throughput with and without disturbance.

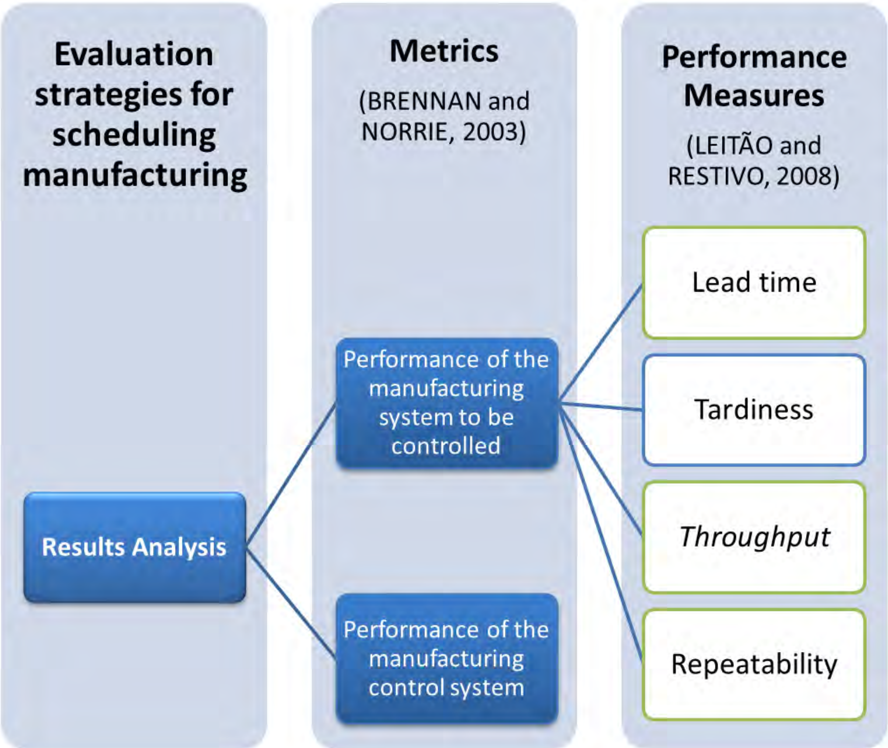

Figure 12. Evaluation of the Proposed Manufacturing Strategy

6. CONCLUSIONS

The coordination in addition with cooperation developed in the proposed strategy means an emerging collective behavior of homogeneous agents that only require local knowledge of the system to achieve overall goals.

Signs or pheromones may contain information expanding dissipative field as a form of indirect communication lighter in terms of time and processing than direct negotiation between agents.

A strategy based on adaptation "learning" and quick (dynamic) reconfiguration of the control system will enable the controlled manufacturing system to be agile and robust in uncertainty and environment complexity.

The conception of the physical resources of a manufacturing system as the operational part of a holonic manufacturing control system can reduce the complexity to divide, organize, configure, program and validate the autonomous structures or operational holons within an ADACOR architecture.

The parameters adaptation of ADACOR manufacturing control system will take into account the autonomy factor and recovery time in operational level but also the rejection factor in coordination level. These parameters will be adapted with an artificial neural network (multilayer perceptron) according to a set of historical values, so improving the efficiency of control system through the time.

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