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MAS and PLC: a comparison on applications of manufacturing systems

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Abstract: The requirements of industrial manufacturing indicate a need for reconfiguration and reprogramming process flow, in order to meet changes in the product with the changing market requirements. These changes imply changes in the manufacturing process, which in many cases means changing the layout, reprogramming the systems, etc. The sizes of production lots are getting smaller and the variety of products on the same line has increased. This makes the preparation time of manufacturing devices an important factor in the formation of the final cost. Devices with more autonomy, able to manage themselves and allow a rapid exchange of features are still to be desired in a manufacturing environment, where conventional systems with centralized scheduling, with defined sequence in the central controller and array of features still fall short. But new solutions must be compared in performance with traditional solutions as there are features that traditional systems are performing well, and that are still on the market. Comparing a solution using multi-agent systems and using a solution centric management on a Programmable Logic Controller can clearly define which metric systems have better performance.

Keywords: MAS, Multiagents Systems, Industrials Manufacturing, PLC, Automation.

1. INTRODUCTION

The manufacturing industry has been facing a market need which refers to the consumption of products highly customized. For several years the concept of mass production, characterized by production of the few products on a large scale has been widely implemented, but nowadays it is unable to deal with the variations of the type of goods and no longer able to respond to the challenges of modernity and dynamism. Large production batches, production lines with identical machines and processes and standardization of products no longer exist. The high-volume production continues to be processed, however, there is a tendency to mass production of highly customized goods.

The business environment in the future would be characterized by constant changes in market demand and global competitiveness would press the entry of new products (James, F. and Smit, H.,2005).

Centralized management on a Programmable Logic Controller (PLC), integrated manufacturing, flexible manufacturing systems, manufacturing systems evolvable stand as proposed in order to attend to this market need. But there are management systems with better performance than other.

Specifically, this paper compares management systems focused on PLC and management system based on mult-agent systems, with focus on comparing metrics that can define the system with better results compared to the production requirements that the market demands.

2. CONCEPTS OF MANUFACTURING SYSTEMS

2.1. Centralized control of processes

Traditionally the control in an automation system is performed in a centralized and hierarchical (Colombo, A. et al. 2008). A component capable of processing information is responsible for receiving data from input devices (sensors, switches, keypads, etc.), and trigger output devices (actuators and solenoid valves, motors, solenoids, etc.), according to a logical relation and previously defined in an automation program.

One of the most used components in control automation systems is the Programmable Logic Controller (PLC). A PLC is a component that meets all points of input and output signals, which controls the flow of the process and manages the manufacturing process. The PLC inspects the signs of all inputs (Georgini, M., 2000), performs the logical process predefined, and sets the logic state of the outputs, as the logic of the process. This is repeated in cycles. (Fig. 1) shows the structure of the centric management system by PLC, where the signals from all system components are connected to central controller.

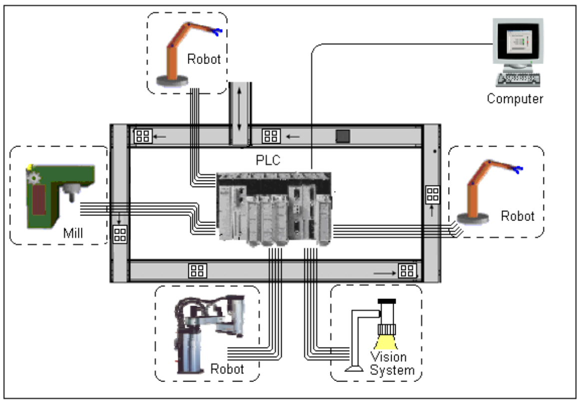

Fig. 1. Management process focused on PLC

The traditional view of manufacturing systems have good features in terms of productivity (Leitão, P., 2009), however, dynamic and adaptive responses are not reached. Changes in the production system mean reprogramming the software and hardware, that causes a waste of time that would be necessary to implemente the new system.

2.2. Computer Integrated Manufacturing - CIM

With an insight into the manufacturing process, we see a CIM as the union of the devices that have a local management interfaced to a central computer that manages the process flow and controls algorithms executed on each machine.

The CIM concept is broader and aims at integrating all stages of the process: sales, supplies, design and development, production and delivery. The paradigm CIM is the integration of all activities of the company through the use of information technology (Leitão, P. et al., 2001), such as databases, networks, etc., that allow the exchange and sharing of data between business units and its applications. Computer integrated manufacturing (Fleischhauer, L., 1996) is the efficient use of information technology in manufacturing to increase productivity and efficiency of businesses.

2.3. Flexible Manufacturing Systems (FMS)

The need for diversity of production imposes limits on the time required to set the machinery or equipment from one product to another. Changing the manufactured product usually involves the modification of its production system, making the necessary adjustments to the new manufacturing. The flexible manufacturing systems have to present the possibility of equipment perform more than one task. For the same equipment being able to perform more than one operation in manufacturing, it should be resourced to enable, through feeding device, change its functionality, providing distinct processes being performed by the same equipment.

A FMS is distinguished from other forms of automated manufacturing by considering the diversity of the products they want to produce (product flexibility) and adaptive characteristics of the machines (flexibility of the equipment) (Cavalcante, A. et al. 2010), (Peixoto, J., 2012) and (Peixoto, J. at al., 2012).

The increased level of equipment utilization, improved the level of product quality, reducing production cost and time to prepare the machine (setup) and tracking of products throughout the production are some of the advantages that a flexible manufacturing system have.

These systems impose a challenging problem, which results in the correct allocation of resources to the various processes required to produce a range of products, as well as programming the sequence of activities to achieve the best system performance.

2.4. Reconfigurable Manufacturing Systems (RMS) and Evolvable Assembly Systems (EAS)

Reconfigurable manufacturing systems are integrated systems with equipment that allow modularity, adaptability and scalability of the product (Colombo, A., et al., 2008). But to be fully operational, these modules should provide open hardware and software architecture with plug and play functionality, the connection is made without the other equipment is disconnected or reconfigured.

The reconfiguration of systems allows the manufacture is evolvable. The EAS are based on the need to make changes in a system where the environment changes. The mounting system of evolution is based on simple systems, reconfigurable elements with specific tasks (system modules), which allow a continuous evolution of the system (Barata, J., et al., 2001). An EAS can co-evolve with the product and assembly process (Ferreira, B. et al., 2009).

Mult-agent Systems (MAS) are presented as a good alternative for the implementation of EAS (Barata, J. et al., 2008) and (Peixoto, J., 2012), proposing the decentralization of management of manufacturing, and the autonomy for every workstation to manage the process. Stations (agents of process) and parts (agent of product) negotiate among each other the services to be offered, scheduling and executing them. The (Fig. 2) shows this structure.

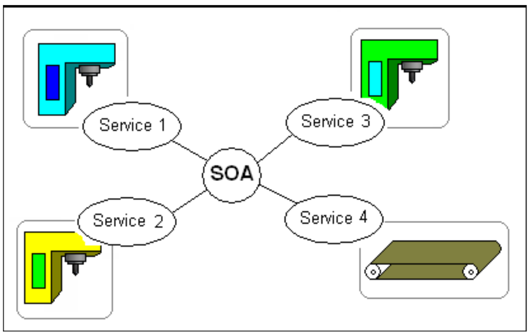

Fig. 2. Composition of Multi-Agent System

3. INDUSTRIAL MANUFACTURING MANAGED BY MULTI-AGENT SYSTEMS

Industrial manufacturing managed by mult-agent systems is a proposal to have reprogrammable systems, self-managed and autonomous, which share information and negotiate the tasks to be performed.

This approach to manufacturing systems adds functionality reprogramming of process. Each step is negotiated between manufacturing subsystems (agents), so that the order in which the manufacturing is performed is defined through negotiation and availability of each agent of the system. The proposal combines features of this point pluggability, the capacity of each subsystem (agent) to connect or disconnect the manufacturing system, having no need to be reprogrammed or stop the process.

The implementation of manufacturing systems using MAS begins of a vision of decentralized processes. Can be performed in 5 steps:

• Identify the components that have the ability to work autonomously;

• Checking if the elements of transport must be mapped as carriers (TUA);

• Consider each product or set of products as agent of product (PA);

• Promote the implementation of devices such as agents, each agent implementing a module interconnection with the hardware, a logic module that manages the device and a communication module that enables the exchange of messages with other agents;

• Connecting agents on a platform of communication between agents.

The programming of the agent can be performed on JAVA [18], which brings the functionality of using the JADE platform for interconnection of agents and protocols FIPA Request and FIPA Contract Net, that provide safe and consistent communication almost agents (Bellifemine, F. et al., 2004).

To simulate the functionalities of the transport system, the assembly stations and pallets in a mounting system using mult-agent systems, was developed a graphical interface in the Java language, which contains classes and methods that simulate the physical devices. This interface is called the agent display and runs on a computer connected to the JADE platform, as well as every computer that instantiates the resource agents, forming the assembly stations. This virtual system is shown in (Fig. 3), the simulation environment of the monitor agent, which will hold the animation of the simulation of resource agents, product and conveyor. Each assembly station is modeled in a process agent, coded in java, JADE platform connected to it and communicating with the other agents through the protocol FIPA Request and FIPA Contract Net. When instantiated, the agent puts its services in the yellow pages of the JADE platform. The communication is initiated by search piece in the yellow pages to identify the agents, who have the capacity to provide the service requested, then makes contact with them to schedule and run the service.

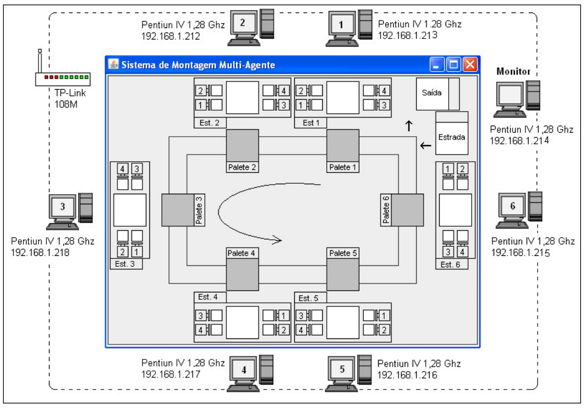

Fig. 3. System emulator mult-agent system applied in industrial manufacturing

4. INDUSTRIAL MANUFACTURING MANAGED BY PROGRAMMABLE LOGIC CONTROLLERS

The simulation of the assembly system with management centered on a PLC is implemented through the IsaGraf3.3 software, developed by CJ International, which provides a graphical interface that links all the element flags accessible by the programming language that meets the IEC61131 (Georgini, M., 2000) and (Silveira, P. and Santos, W., 1999). With The five languages on this standard, we chose the sequencing function graph (Sequential Function Chart-SFC). By the product requirements it was concluded that the system assembly stations allocated around a circular track, with a continuous drive, it would be more feasible the implementation of the manufacturing management centered with the PLC. (Fig. 4) presents the simulation environment proposed for management centered on a programmable logic controller.

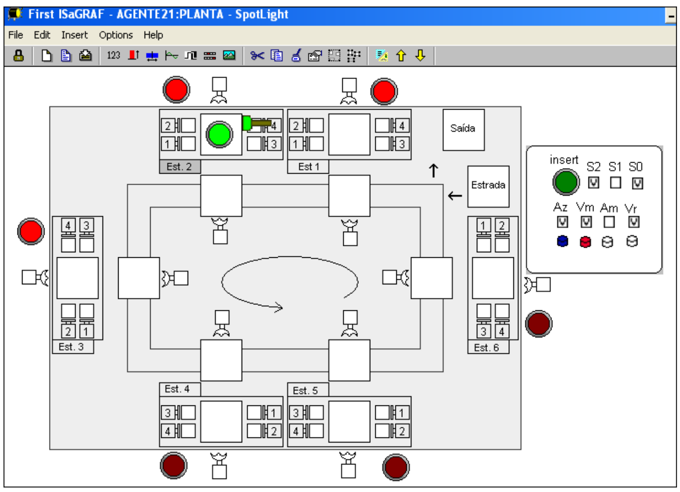

Fig. 4. Didactic plan virtual of assembly system centered PLC

This implementation consists of an interface that has the hardware components. For each component there is one object that simulates the behavior of the component, by inserting a variable linked with an image. The request for production is carried out by defining the type of installation and the command button insert.

5. CHOOSE THE METRICS

The definition of metrics or characteristics qualifies a system requirement, allowing for comparative analysis. When it is said that they measure the metrics are quantitative (Sato, D., 2007). Qualified when it is said that the metrics are qualitative, no possible measure them. The metrics can be measured directly (cost, effort, lines of code, execution speed, memory, number of errors, etc.) or indirectly (functionality, quality, complexity, efficiency, reliability, maintainability, modularity, and others) (Pereira, C. and Carro, L., 2007).

The purpose of this work is points to more qualitative aspects, which refer to the system performance (performance tends to be qualitative), which implies that the metrics are of a qualitative nature. Some metrics are listed and defined as not relevant to the proposed analysis, as suggested: cost (more focused to the hardware than the software on a production system), number of errors (longer about systems that are already in production), reliability (very subjective for this proposal), among others.

The metrics defined as appropriate and relevant to the analysis are presented in Table 1, along with their technical justification, how to obtain and evaluation criteria.

Tabel 1. List of metrics used in the experimental validation.

Metrics	Technical justification
Time variation of the production increase with the seasons.	The increased production stations should not cause an increase in production time.
Maintenance of the production with the removal of stations.	In case of failure in one season, the mounting system should continue the process, leaving the other station absorb the task missing.
Maintenance of the production to the insertion station.	In case of bottleneck formation, the system should allow that more stations are inserted in aid of the mounting system.
Amount of memory occupied by the program by adding the entire system.	The amount of memory occupied defines the need for computing capacity of the system to deployment.
Skills required to operate and implement changes in the assembly system.	Increased complexity in the implementation of changes refers to the need for specific knowledge of the operator / system programmer.
Lines of programming code.	The number of lines of program code denoting the programming effort.

6. RESULTS

Analyzing the results of each metric was observed that can be attributed advantages and disadvantages to each of the concepts, using the comparison. Table 2 describes the analysis and shows which concept had the best perform.

Tabel 2. Analysis of the metrics observed

Analysis of Metrics	Best
In PLC the additional stations are not significant for the production time, unlike MAS, where the addition of stations affects the production time.	PLC
The withdrawal of stations in both systems does not affect the continuity of production, provided that other stations have similar abilities to those that came out of the station.	Equal
In the PLC to insert a new station was necessary to disconnect and reprogram again. MAS is sufficed instantiate the new season.	MAS
In the PLC with the addition of some stations interferes with the amount of memory used (4% from 1 to 6 stations). Already MAS there is a more significant difference (82% from 1 to 6 stations).	MAS
In MAS, the operation of the system requires a basic knowledge of the operating system, even for insertion and removal of stations. In the PLC is required to make changes to the system.	MAS
In MAS, because its instances, the programming effort is unique, regardless of the station number. Already in each PLC insertion station becomes necessary to add codes, higher cost programming effort.	MAS

This is not define which one system is the best, but to indicate which system responds best to a given metric. The application is that if one set of metric requirements are more important than others.

With all news technology that provides automation systems, there is still systems requirements of manufacturing in the classical view has better performance. And this is why this vision still occupies a good space in the implementation of manufacturing systems.

Comparing manufacturing systems is not trivial, because each system has concepts and management devices implemented in different technologies. It would be difficult to compare the memory space occupied on a managed system for a computer and a managed system in a PLC, because the result would indicate the ability of the technology and not the manufacturing system. But, to compare the extra memory with the addition of subsystems (agents) gives more meaning in terms of effort system to absorb another subsystem.

The definition of specific metrics allows a significant correlation between the systems and become feasible and meaningful the comparison. And this is the point that deserves special attention in order to compare characteristics that represent meaning for the production desired. And here it is clear that depending on the desired characteristics, a system would be more appropriate either another.

7. CONCLUSION

In the scenario of industrial manufacturing, the need for highly customized goods refers to the search of new paradigms for management of automation of production. But it does not mean the previous paradigms disuse , since these are still found in implementations with its features and functionalities.

In this context, multi-agent systems applied to industrial manufacturing intended to be an alternative management automation production device, offering features more appropriate for the diversification of production, not intended to replace other technologies.

As future work, proposes deploying physical prototype demonstration, which would support teaching, assisting students in their learning and providing data for the analysis of works and concepts in these systems. It also proposes the design of mult-agent system that can inspect other agents and assist in its transformation (evolution) to compose another service that originally lacked.

REFERENCES

Barata, J., et al. (2001). Integrated And Distributed Manufacturing: A Multi-Agent Perspective. In: Workshop On European Scientific And Industrial Collaboration - WESIC, Enschede. Proceedings… Enschede : WESIC. pp. 27-29.

Barata, J. Mendes, P. and Ribeiro, L. (2008). MAS And SOA: Complementary Automation Paradigms. In: IFIP International Con-Ference On Information Technol-Ogy For Balanced Automation Systems, Porto. Proceedings… Porto: IFIP.

Bellifemine, F., Caire, G. and Greenwood, D. (2004). Developing multi-agent systems with JADE . West Sussex: John Wiley, pp. 303.

Cavalcante, A., (2012). Arquitetura baseada em agentes e auto-organizável para a manufatura. 140 f. Thesis (Doctor degree in Electrical Engeneering) – Programa Pós-graduação em Engenharia Elétrica, Federal University of Rio Grande do Sul – UFRGS, Porto Alegre.

Cavalcante, A., Pereira, C., Barata, J. (2010). Component-Based Approach to the De-velopment of Self-X Automation Systems. In: IFAC Workshop on Intelligent Manufacturing Systems, Lisboa. Pro-ceedings... Lisboa: IFAC. pp. 239-244.

Colombo, A., et al. (2008). Service-Oriented Control Architecture for Reconfigurable Produc-tion Systems. In: The IEEE International Conference on Industrial Infor-Matics, Daejeon. Proceedings… Daejeon: IEEE. pp.13-16.

Ferreira, B. et al. (2009). An architecture for self-managing evolvable assembly systems. In: IEEE International Conference on Systems, MAN, and Cybernetic, San Antonio. Proceedings… San Antonio: IEEE. pp. 2707-2712.

Fleischhauer, L. (1996). O uso da tecnologia de agentes na integração da Programação da Produção. 102f. Dissertation (Mester Degree in Engeneer), Federal University of Santa Catarina - UFSC. Florianópolis.

Georgini, M. (2000). Automação aplicada: descrição e implementação de sistemas sequenciais com PLCs. São Paulo: Érica, pp.216.

Guimarães, H. (2005). Norma IEC61131-3 para programação de controladores programáveis: Estudo e aplicação.. 86f. Monografia (Final work of Electrical Engeneer) Federal University of Espírito Santo, Vitória .

James, F. and Smit, H. (2005) Service-oriented para-digms in industrial automation. IEEE transac-tions on industrial informatics, Nova York, v. 1, n. 1, pp. 62-70.

Leitão, P. et al. (2001). Trends In Agile And Co-Operative Manufacturing. In: LOW COST AU-TOMATION SYMPOSIUM - LCA, Berlin. Pro-ceedings… Berlin: IFAC. p. 156-165.

Leitão, P. (2009). Agent-based distributed manu-facturing control: A state-of-th-art survery. Engi-neering Applications of Articial Intelligence, v. 22, issue 7, pp. 979-991.

Peixoto, J. (2012). Desenvolvimento de sistemas de automação da manufatura usando arquiteturas orientadas a serviço e sistemas multi-agentes., 134 f. Dissertation (Mester Degree in Engeneer) – Electrical Engeneer Institute, Federal University of Rio Grande do Sul, Porto Alegre.

Peixoto, J., Pereira, C. and Cavalcante, A. (2012). When agents meet manufactur-ing: paradigms and implemations. In: XIX Brazilian Congress of Automatic – CBA2012, Campina Grande. Proceedings… Campina Grande: [S. e.]. pp. 957–964.

Pereira, C. and Carro, L. (2007). Distributed real-time embedded systems: Recent advances, future trends and their impact on manufacturing plant control. Annual Reviews In Control, Ox-ford, 2007, v. 31, pp. 81–92.

Sato, D. (2007). Uso eficaz de métricas em métodos ágeis de desenvolvimento de software, 155 f. Dissertation (Mester Degree in Computer Science) – Institute of Mathematics and Statistics, University of São Paulo, São Paulo.

Silva, L. (2003). Estudo e Desenvolvimento de Sistemas Multiagentes usando JADE: Java Agent Development framework. 97 f. Monograph (Final work for Bachelor in Computing) – Sciences and tecnologies center, University of Fortaleza – UNIFOR , Fortaleza.

Silveira, P. and Santos, W. (1999). Automação e controle discreto. 2. ed. São Paulo: Érica, pp. 229.