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To cite this version:
João Peixoto, José Oliveira, André Rocha, Carlos Pereira. The Migration from Conventional Manufacturing Systems for Multi-Agent Paradigm: the First Step. 6th Doctoral Conference on Computing, Electrical and Industrial Systems (DoCEIS), Apr 2015, Costa de Caparica, Portugal. pp.111-118, 10.1007/978-3-319-16766-4_12 . hal-01343472

HAL Id: hal-01343472
https://hal.inria.fr/hal-01343472
Submitted on 8 Jul 2016

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The Migration from Conventional Manufacturing Systems for Multi-Agent Paradigm: the First Step

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Abstract. The consumer market ever more calls for diversified products in small batches and the industry lacks production systems that meet the demands with efficiency and ability to adapt quickly. Integrated manufacturing systems implemented have their management for programmable logic controllers and electrical interconnections, control logic and satisfactory robustness, but they do not attend the needs of diversity and flexibility in production. The solutions to these needs refer the company to migrate to the use of new technologies of control, circuit and logic. But, for an industry migrates is a very big and expensive step. Then, there is an urgent need for methods that implement the interface between logic controllers and multi-agent systems in order to evolve an integrated manufacturing system taking advantage of all electrical circuitry, control logic and the logic controller that installs itself, taking advantage of the self-adapting characteristics that the multi-agent systems provide.

Keywords: multi-agent systems, industrial manufacturing, agility, self-adaptive systems.

1 Introduction

The modern consumer behavior is in constantly changing and the industry is facing the big challenge of accompanying these changes. On the one hand, consumers are seeking ever more customized products which represent their individuality, on the other hand, the industry, to remain competitive, needs to meet this demand of large-scale variety.

The study of James [1] has pointed out that the business environment in the future would be characterized by constant changes in market demand and the global competitiveness would push the entry of new products.

The high-volume production continues to be processed however, as pointed out [2], there is a tendency to mass production of highly customized product. And it leads to a large volume of small lots. And the speed that the market demands products highly customized to be delivered is important. The production line space to adapt to a new product is smaller and significant to the final cost. As stated in [3], to cope with this new reality and achieve a competitive advantage over competitors, future productions systems must provide solutions to: long time for system design, commissioning and
setup; complex variations requirements; inflexible implementations; scalability; fault-
tolerance or redundancy; and incompatibility between different technologies.

But, what method it is necessary to industries will migrate to new paradigms that
attend the market requisites? One cannot simply dismantle the existing production
systems and build new ones, with new paradigms. This work will be discussing the
steps to migrate from a conventional manufacturing to a system self-adaptive, making
use of all existing infrastructure and local logical.

This work shows a study of manufacturing industrial and the possible solution for
new necessities of market. In section 2 approach how cloud-based can be used for
support to self-organized systems. The section 3 shows de concepts of industrial
manufacturing management. The section 4 shows the approaches this problematic by
academics and researches groups. The section 5 discusses a need of method to
migrate of conventional system to self-organized systems. And section 6 shows the
conclusion of this work.

2 Contribution to Cloud-based Engineering Systems

The requirements of diversity in production lead the industry to need versatile
systems that use shared resources. One way is to share resources through Cloud-
based. This concept computing systems applied in manufacturing, such as multi-agent
systems, recourse to cloud environments to seek methods, algorithms, and means for
obtaining a skill required by a new production process that is presented. The multi-
agent systems need not have all the variants of a production process to serve it with
the diversity it needs, just to have these variants seek in a cloud environment, sharing
resources with all agents in the system.

With the computing resources evolution available to the manufacturing
management, solutions using the “cloud” concept have emerged as a good alternative
to systems which have high power of communication, but do not have elevated power
to local processing. In [4] the application of multi-agent solutions with cloud systems
is approached and can be seen in Figure 1.

![Fig. 1: Mult-agents using cloud concept, based on [4].](image)

In Figure 1 the Process Agents resorting to the cloud environment (Cloud Storage)
to obtain data on the process as well as the Task Agent resorting to cloud environment
(SaaS) to learn skills with humans.
3 Manufacturing Systems Management

The management system has been constantly the subject of research and to every new demand that arises new paradigms are researched and implemented. This work mentions what it thinks to be the most significant in terms of solution presented to industry.

3.1 Management with Programmable Logic Controllers (PLC)

Manufacturing system has evolved from craft production with low volume, high variety and general purpose machines to production lines, dedicated machines and large enterprise, which enable the mass production [5]. Mass production brought the concept of a manufacturing with a viewpoint centered on Programmable Logical Controllers (PLC), which operates in a loop: (i) read all inputs; (ii) execute defined logic (the process) to generate the outputs from the inputs; (iii) trigger the outputs conform the processing logic;

3.2 Flexible Manufacturing Systems (FMS)

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 to be 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) [6] e [7];

3.3 Computer Integrated Manufacturing (CIM)

CIM is a concept where the approach aims at integrating all process stages: sales, supplies, design and development, production and delivery. The paradigm is the integration of all the company activities through the use of information technology [8], such as databases, networks, etc., that allows the data exchange and sharing between business units and its applications. Computer integrated manufacturing is the efficient use of information technology in manufacturing to increase productivity and efficiency of businesses;

3.4 Evolvable Assembling Systems (EAS)

EAS are the integrated systems with equipment that allow modularity, adaptability and scalability of the product. They are modules who should provide open hardware and software architecture with plug and play functionality; the connection is made without the other equipment being disconnected or reconfigured. The reconfiguration of systems allows the manufacture to be evolvable. The mounting system of the evolution is based on simple systems, reconfigurable elements with specific tasks (system modules), which allow a continuous evolution of the system. An EAS can co-evolve with the product and assembly process [4]. The EAS can be implemented by Service Oriented Systems (SOA), that is the basic element in the abstraction of
services which has properties of autonomy, interoperability, platform independence, encapsulation and availability [9], or by using Multi-agent Systems (MAS) defined as a paradigm derived from the distributed artificial intelligence field, characterized by decentralization and parallel execution of activities based on autonomous entities, called agents [10].

The table 1 shows a comparison among the proposed manufacturing management system, linking the paradigm employed, the main feature and the ability to use cloud approach.

**Table 1.** Comparison among the systems of manufacturing management.

| Management system | Paradigm used     | Main Feature                     | Cloud Solutions  |
|-------------------|-------------------|----------------------------------|------------------|
| Centralized       | Logic control     | All control of process           | -                |
| FMS               | Logic control     | Idle resources                   | -                |
| CIM               | Computer control  | Require availability resources   | Possible         |
| EAS               | SOA or MAS        | Adaptation to manufacturing      | High             |

### 4 Approaches to New Paradigms for Manufacturing

#### 4.1 Academic Approaches

The self-organizing systems researches are increasing, but there are still few studies with real industry application. But the fact the academics take care of this problem is a big step to find new forms of applying concepts and get new solutions. The table 2 shows some research in doctoral thesis that approaches the topic.

**Table 2.** Comparative approaches in academic research.

| Ref. | Problematic Description                                                                 | Method                                                                 | Application Details                                                                 |
|------|-----------------------------------------------------------------------------------------|------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| [11] | Need for agility on the factory floor to handle disturbances and uncertainty          | Multi-agent systems for interface between generic and physical environment | Integrated manufacturing plant with 2 robots                                         |
| [12] | Properties of self-x to implement self-organizing systems                               | Product fits into modules, forming coalitions, generating optimized layouts | Plant with 3 robots, 5 conveyors, and 3 parts feeders                             |
| [13] | Diagnostics in complex industrial installations with a large number of components     | Agents make the diagnosis of component failure and estimate its propagation | Manufacturing plant with 2 conveyors, 2 robots and pallets                        |
| [14] | Attending the diversity production requirements to market demands                      | Agents in layers, one for deliberation and one for rapid reaction       | Manufacturing cell with axis of rotation and translation                          |
| [15] | Replace the component automation interconnected with distinctive technology          | Converting the functionality of a device existing in a service offering | Plant with 2 dosage machine and 1 transport line                                    |
| [16] | Necessity of use dynamic allocation of resources to changing production                | Situation analysis, objectives and adaptation of system behavior        | Implementation of power drives using MatLab                                    |
Production attend a series of small lots, sometimes a unique lot of one product. Defines a semantic link among the concepts of agent, environment and organization. Production line for small series of assembling boards. Case study in industries to support decision making.

Among the studies reported can be seen that the problems are similar, the methods are different and the results refer to the same path: industrial manufacturing. Thus, the academy has solutions by attend the need of industry to diversity of market demand.

4.2 Project Groups

The multi-agent paradigm systems used in industrial manufacturing has been the subject of research projects, sometimes there is in the group companies tendency to apply these concepts. This interest demonstrates this topic importance, and the fact of industry assumes that it finds solution to varieties of products required by the market. The table 3 cites some project groups who work among with companies and research institutes. These groups are predominating in Europe when the topic is more development in research and industries appliance.

| Table 3. | Groups of projects that approaches multi-agents systems in industrial manufacturing |
|-----------|---------------------------------------------|
| Project   | References | Approach                      | Some Partners | |
| SOPRO    | [19]       | Self-organizing systems        | Fraunhofer IZM |
| COSMOS   | [20]       | Self-adapte of product variance| UNINOVA, Phoenix Contact, OST, EDAG |
| EUPASS   | [21]       | Self-integrated modules of flexible production | UNINOVA |
| IDEAS    | [22]       | Self-adapte to changing of technologies components | UNINOVA, Nottingham University, FESTO, KTH, MASMEC |
| XPRESS   | [23]       | Design of production based on self-organizing | University of OULU, Fraunhofer, Airbus, KUKA |
| PRIME    | [24]       | Plug-and-produce systems in self-organizing concepts | UNINOVA, Siemens, Nottingham University, Introsys, Asyril, TQC, Simplan |

Here it’s possible to observe the importance of the self-organizing for central researches and manufacturing industries.

4.3 Gaps among Approaches

The cited approaches, either in theses either for research groups indicate solutions to the need of quickly respond the change in the product industry, but they point the way to the deployment of a new technology. Considering the industry has controllers installed, mounted with their hardware and their defined logic locations, the proposed solutions do not take advantage of it, which is present on the factory floor.
Fig. 2 Paradox between the current technologies installed in industry and solutions that academics offer, two would with different approaches.

And this is a big gap in application terms, it is a fact that the industry does not want to eliminate the controllers they have and with known characteristics. But one needs to migrate to new concept, because of what not answers the new demands of the market. This is the paradox the academy is responding and has been a big gap to be studied and resolved.

5 Discussion of a Method to Migration

The solutions proposed by academy to attend the need of self-adaptation with multi-agent systems require computer systems with high capacity, which makes the controllers that manage machines today in the industry, do not support this technology. But abandoning these controllers seems, in the industry eyes of the something unacceptable face every investment already made in installation.

The Figure 3 shows the first step proposed for migration.

Fig. 3: Proposed migration from the existing system of automation to self-adaptive systems

For the industry to join the new paradigm will require several intermediate steps. And the first step is to develop a method that can migrate the conventional management system for managing a multi-agent system.

The method can be abstract the functionality of a controller existing in an envelope, disposing in the multi-agent system to supply and request services, beyond the capability of interaction and negotiation. The method will have to define how to access controller existing, which can be learned by agents assigned in the cloud (cloud learning).

Inspection requirements and the database can also be modeled in the cloud, in order to provide specifications of the items that should be targeted in specific
manufacturing agents (cloud maintenance) and storage of knowledge about the
colligations system to attend a specific demand (cloud storage).

The method under discussion must then be connected in a multi-agent platform and
interfaced with the hardware controller by one communication form, translate the
features of each station in services and their needs must be translated into requests.

6 Conclusions and Future Work

Market demand is a reality that the industry must attend and that this work has
examined solutions that academic and research groups had presented and took part in
proposing an intermediate method between the management of current and future
manufacturing. A conclusive research that refers to a method that helps to evaluate a
management system for logic controller to migrate to a multi-agent platform is
something wanted by the industry as the first step to adherence to new paradigm.

Once the first step is given, more multi-agent systems begin to work in and more
results will be reviewed and for directing the path. As future work this paper suggests
the implementation of methods that interfacing existing controllers on the factory
floor with management modules of the agent in order to abstract functionality. These
methods may be validated and defined its comparison of efficacy. Also suggests the
search of agents that act in the cloud and can support maintenance inspection.

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