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# MODELING FOR SIMULATION OF MANUFACTURING SYSTEMS CONTROL

Claire Berchet, Georges Habchi

LLP/CESALP

ESIA – Université de Savoie - 41, avenue de la plaine - BP 806

74016 Annecy cedex, FRANCE

E-mail: Berchet/Habchi@esia.univ-savoie.fr

## ABSTRACT

This article presents basic concepts regarding the modeling for simulation of production systems and in particular the concept of Control Center (CC). The CC is defined then formalized, for its integration in a simulation model. After an overview of the simulation current state of the art, the type of the selected control and structure are specified: an "*interpreted control*" in a "*hierarchical coordinated structure*". The CC is then described by giving its definition, its components and their organization in a simplified manner, as well as a typology of information defining the relations between the CC and the controlled system. Finally, we formalize the internal behavior of the CC in a detailed manner, for its integration in a PPS (Product Processing System)/CC network.

## KEYWORDS

Modeling, simulation, control center, information, manufacturing systems.

## 1. Introduction

The simulation is a powerful tool for manufacturing systems modeling and imitation [1]. The reproduction of physical flows using simulation is nearly perfect. It is also an ideal tool for the follow-up and tracability of the informational flows associated with the physical flow [2]. Thus, the capacities of simulation are broad and make it possible to contribute to the design, management and decision support of industrial systems. It is largely used in the design phase of a production system. Starting with the launching of a project and the analysis of the needs, it is used for validating, justifying and quantifying the necessary investment [3] [4]. But it can also be used during the production system execution, either to modify it (diagnosis, weaknesses detection, implantation,...), or to anticipate the application of decisions and to contribute to the system control [5].

However, the current weaknesses of simulation lie on the one hand in the complexity of the concepts which it applies, and on the other hand in its incapacity to model decisions and consequently, the control system associated with a manufacturing system. In fact, it is almost impossible at the present time to model the pair production system / control system. Nevertheless, in order to have an acceptable system model, the studied system should be modeled according to all its components: operational, informational and decisional. That's why we wish to propose simple concepts dedicated to the introduction of control into simulation. We speak thus about "*active simulation*".

In the first part of this article, we describe the fields currently covered by simulation, its potentials, and its limits. In the second part, we present the framework of industrial control we are using, and the typology of control we adopt. Then, we define the concept of the *Control Center* (CC), by specifying the organization of its components, and by proposing a typology of the information circulating between the CCs on the one hand, and a CC and the controlled system on the other hand. Before concluding, we propose a formalization of the CC by a detailed specification of its internal behavior, and to form: the "*PPS/CC network*" [6].

## 2. The simulation and its limits with respect to the reactivity-issue

A synthesis of various definitions of simulation is proposed in [6]: “*simulation is a method of measurement and study consisting in replacing a phenomenon or a system to be studied by a simpler data-processing model but having a similar behavior*”. Simulation is a tool still little mastered by companies. However, many are those who are concerned by the design or the evolution of manufacturing systems, and are faced with issues like: how to be sure that management applied on this production line is well adapted? How to convince the person in charge of the budget that it is essential to invest in such or such machine, or to take on the personnel? Are the selected parameters of management the best? Etc. Simulation is one of the tools that can help to answer these questions, and others. Its capacities allow the modeling of all flows of the company (physical, informational and decisional), and that, on various hierarchical levels: machine, workshop, production line or factory. Moreover, all the manufacturing system life cycle phases could be covered by simulation: the design, the realization and the exploitation of the system. Abundant literature is available on this subject, particularly on the simulation use in the field of manufacturing systems. Gregor and Kosturiak [8] establish the state of the art in simulation, using various examples of simulation application: studies on FMS (Flexible Manufacturing Systems), a comparative study between a push flow management and a pull one, tests on the reduction in stocks on a production line, etc. We gather here a list of some contributions of simulation in the field of production systems:

- an accelerated implementation,
- an evaluation of profitability by advance (possibility of measuring and of evaluating performance by the help of various performance indicators),
- a design, a modification and a dimensioning by "anticipation",
- a solution of comparison between different alternatives of management,
- a study of the influence of some management parameters; for example, the influence of the variation of management parameters (lot sizing) in the production planning [5] or in the MRP (Materials Requirement Planning) [9] [10],
- a tool for training; the assistance of a simulator can sensitize the user with a new functioning logic of the workshop,
- a tool for mediation; it can be used as a tool for negotiation, a basis for discussions between speakers, by illustrating the consequences of the assumptions under discussion,
- a role of “*macroscope*”; simulation provides a global vision of the studied system, which is particularly interesting when the system is complex and/or when the actual size is very important,
- a role of “*microscope*”; it makes it possible to produce important zooms related to the adapted detail level.

However, concretely today, all possibilities of simulation are not used. The simulator often plays a “*passive*” role that is limited to the representation, the validation or/and the evaluation of a process of production. This is explained by the fact the decision-making and its impact on the production system are not taken into account during simulation. The existing tools are not adapted to model decisions and thus the control process of a production system. It’s necessary to wait for the end of the simulation execution to modify a parameter, and then to remake a simulation, and this, until the results are acceptable. All these cases of application imply many tests before arriving at a certain optimization of the result. It is in fact almost-impossible to react in an automated way on the controlled system, when the simulation is running: we speak thus about “*passive*” use of simulation. In addition, simulation uses complex concepts for the potential user. This does not support the “*democratization*” of this tool, but rather the contrary. Thus, industrial people often ask for the help of specialists external to the company in order to model their systems. Consequently, the use of this tool remains specific and limited.

Thus, in order to use all the capacities of simulation and to make it more “*active*”, our objective is to introduce the generic concept of the Control Center (CC) into simulation. Other researchers work on these aspects, which they name “*reflective simulation*” or “*internal and external*” simulation [11]. Before the definition of the CC, it is important to know which type of control and which structure of control we are using.

## 3. Which control to introduce into simulation?

Since the beginning of the Eighties, we assist at an evolution of the industrial systems, according to the modification of the management methods, the arrival of concepts like “*Just In Time*”, “*Supply Chain Management*”, “*Concurrent Engineering*”, “*Kaizen*”, “*Total Quality Management*”, etc. The control process effectiveness resides in its adaptation to these evolutions. These later result partly in the passage from an “*authorithed*” model in the traditional control

(based on Taylor philosophy) into a contemporary model of "interpreted" control (based on the interpretation of the actors). This "enterprise of the real time" [11] [12] responsabilise indeed the individual decision maker – because of the interpretation capacity of each – and then the control model moves towards an open and integrated model [11] [13] [14]. By extending the control process with new actors (then with new control centers), new variables, we get a richer one but a more complex also. Thus, the decision-making process, approached by some authors [14] [15] [16], becomes more interactive, nonlinear, due to the multiple decision-makers actors. The individual interpretation, unexploited at the operational level within the framework of Taylor philosophy, is requested today in an environment where the management of an event implies real time decision-makings. We take into account this reality and this "interpreted" control in our work.

The decision-maker actor has to use, manage and control his system in coherence with the other actors, in order to meet the fixed objectives. The traditional control process and the traditional hierarchy of the decision system are revised. Indeed, the control process requires a perfect enterprise organization and depends on its type of organization: the information system must be coherent with the physical system, and the decisional system must be coherent with the information system. Finally, the triptych "physical-information-decision" must be organized and operated in real time. Then the decision-making process, which is reflecting the internal organization of the CC, must be relevant and the links between these different autonomous and multiplied centers must be coherent, coordinated and organized, according to a hierarchical axis. Then, among a lot of existing architectures of control [17], we have chosen to work with hierarchical coordinated structures [18]. The framework of our research being established, we describe now the concept of Control Center (CC).

### 3. The Control Center (CC)

#### 3.1 Definition

We define the concept of control center (CC) as "an autonomous structure, depending on the enterprise global strategy, having a decisional authority, associated with an entity and having necessary resources to apply actions and to achieve the defined goals within the global framework of the enterprise".

#### 3.2 Components

The components of CC are: *actors, referents, objectives, intrinsic and extrinsic information, decisional tools, measures and performance evaluation, decision, actions and resources* for their implementation. These components are organized according to the simple diagram presented in figure 1, which is the base of the CC internal process. We detail the specifications and the modeling of this behavior in the following part.

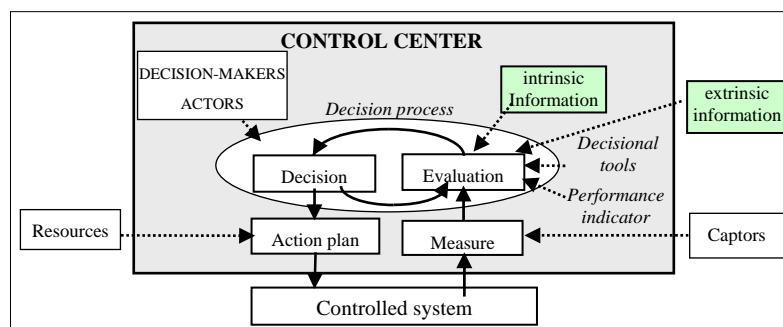


Fig.1. Internal structure of CC

#### 3.3 Typology of information circulating between CCs

We propose in a no exhaustive way a typology of information, which is exchanged between these CCs or between a CC and the controlled system. The coherence of the whole system depends on this information. The goal of this typology is to structure the information used during the CC internal process. The information which is not used for control will not be represented in this typology.

- *Structural information* is related to products, resources, customers, etc. To avoid redundancies, it can be stored on a common data-base. It is available for the CC which might need it (purchase, planning management,...), and the qualified CCs are responsible for its update and its reliability.

- *Decisional information* corresponds to decisions emitted by a CC following a decision-making process, in the form of objectives, towards one or more CCs of the same level or of lower hierarchical level. Thus, in an "interpreted" control, it's the CC receiving this information which have to achieve the given goal by setting action variables, and building itself its performance indicators. Decisional information can come only from one CC.
- *Control information* (management priorities in a queue, lists of Product Order for MRP, tickets for Kanban, etc.) generally relates to the controlled system at one operational level. It is stored by each CC, because it can be different from one CC to another one, and can change according to the system state.
- *State information* (breakdown, set-up, stop, etc.) informs the CC in real time about the state of the controlled system (resource and physical flow) according to time. It is induced by events and is used in a "reactive control by anticipation". It has process indicators as a support.
- *Feedback information* is obtained from the controlled system (resource and physical flow) in a periodic way. It has result indicators as a support and are useful in the case of an "a posteriori control".
- *Environment information* relates to the CC of the higher hierarchical level, in the case of strategic decisions (market research, launching of a new product, etc.).

The research presented in this article will complete precedent works of our research team on the physical flow modeling and simulation of manufacturing systems by the help of the PPS concept (Product Processing System) [6] [7]. The current work lies the CC to the PPS, formalizes the CC behavior and the links between CC and PPS. This formalization enables us to integrate industrial control in simulation at the operational level of manufacturing systems.

#### 4. Modeling of the Control Center

##### 4.1 Modeling the physical and informational systems

Let us take the simple example of a production process composed of a raw material stock, a welding operation, a correction operation and a finished product stock (see figure 2). The physical flow is modeled by a generic structure called "entity" and the resources by another one called "PPS" (Product Processing System). The PPS has the same structural and behavioral characteristics as a resource (machine, stock, operator, etc.). It carries out mainly the three basic functions: "reception", "transformation" and "supplying". In addition, it is able to have the different resource states: idle, busy, blocked, broken down, etc. For more information on the physical process modeling, readers could refer to other articles [6] [7].

##### 4.2 Modeling the decisional system

According to the definition suggested above, the CC is associated with the controlled entities (PPS), and allows to represent the control of a manufacturing system, like in the example below.

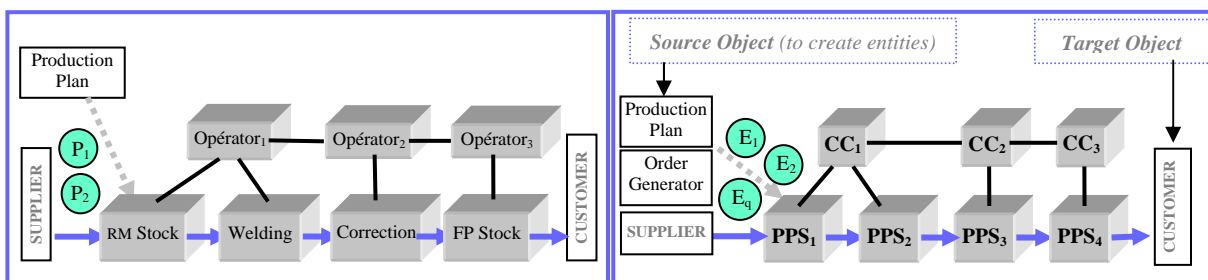


Fig.2. Using PPS-CC network for manufacturing systems modeling

In order to formalize in more detail the PPS-CC network, we describe the internal behavior of the CC. Indeed, the behavior of the PPS being already formalized in precedent work [7], our research tries to formalize the decisional system with the CC. As we described previously, the CC components organization is a simplified one. In figure 3, we look further into this internal behavior process of the CC. We find in this diagram, the principal phases of figure 1

- at "exit" of the controlled system: event or periodic measure;
- the decision-making process;
- in "entry" of the controlled system: the application of the action plan on the system.

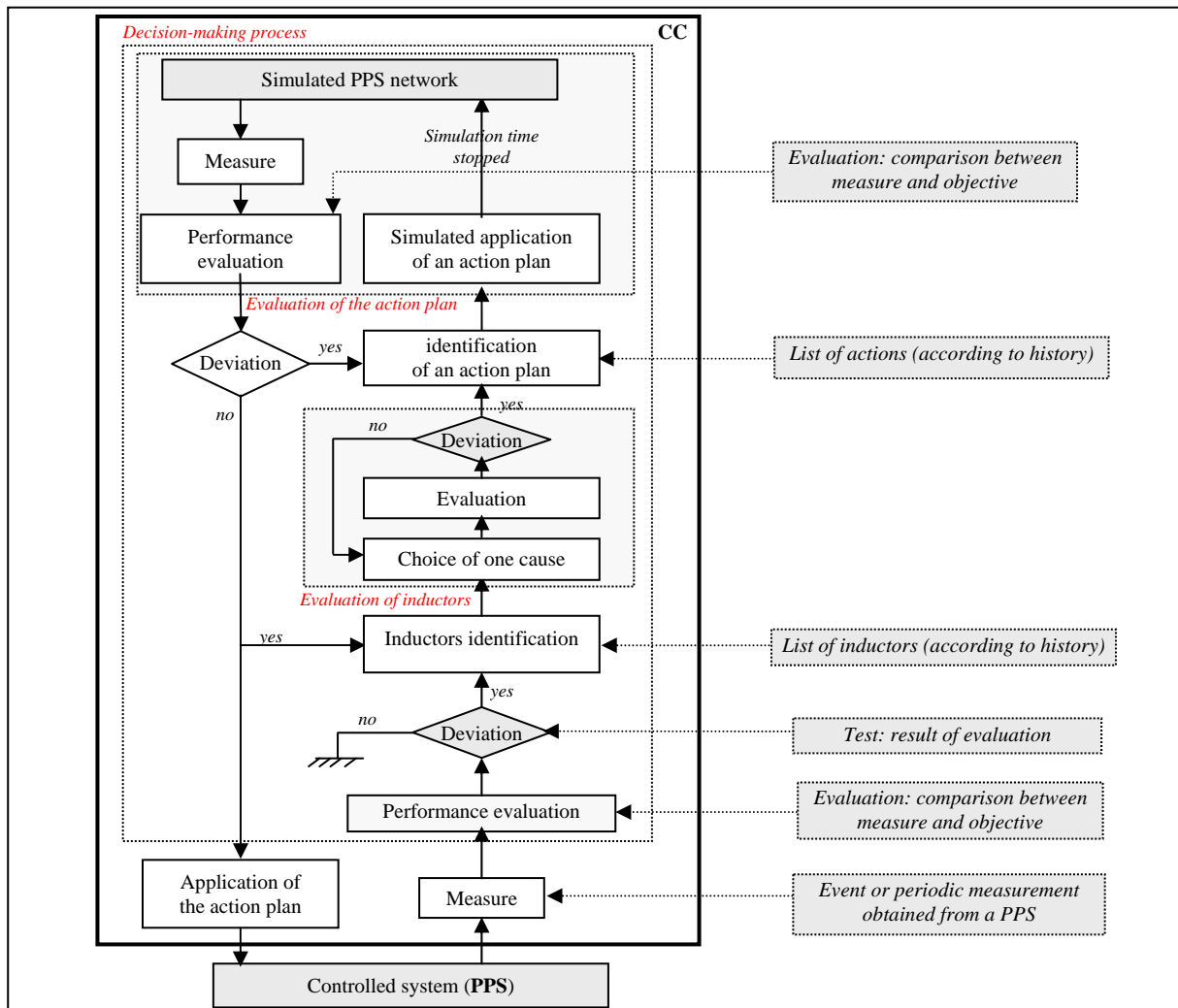


Fig.3. Detailed internal behavior of a Control Center

After having obtained the measure concerning the PPS state and its flow, by the help of process or result performance indicators [19] (according to the type of selected control [20]), our objective is to describe the decision-making process of the CC [21]. This process is divided into three stages:

a) **Performance evaluation of the controlled system and its physical flow**

This stage consists to analyze the measure obtained from the controlled system (a PPS), to compare it with the CC local objective, and then to conclude if a deviation exists. During this evaluation the information (referred in § 3.3) is taken into account for the co-operation relations between CCs.

b) **Evaluation of the inductor responsible of the deviation**

The second stage concerns the identification of the inductor responsible of the deviation from a list of inductors. The choice of inductor is realized according to a history of the controlled system. Each inductor corresponds to a performance process indicator or a performance result indicator of a lower level of the decision global structure. As each inductor is associated to an objective, the evaluation at this stage consists on the determination of the deviation of each one and its impact on the controlled system.

c) **Evaluation of the action plan or “internal and external simulation”**

The third stage of the decision-making process consists of testing the actions determined at the preceding stage, by internal simulation using the controlled system (the PPS is simulated at the moment when measurement was made). This is a performance evaluation in a simulated manner, in order to define the adequate action plan. If the deviation is always reached after simulation of the action plan, other possible actions are tested, until the deviation is eliminated. If the target level of performance indicator is not reached any more (no deviation), the action plan to be adapted is found and can be applied “really” to the controlled system.

#### 4. Conclusions and perspectives

We have proposed in this article the concept of CC which allows to introduce “*reactive control*” into simulation. Also, this research work permits:

- to make simulation more “active”,
- to react in a structured manner on the controlled system in the case of deviation with respect to its expected behavior during the simulation,
- to widen and benefit more from the potentials of simulation.

Actually, we are working on the performance evaluation phase concerning the behavior of the CC, by developing the cooperation and coordination relations between CCs. We will propose in future articles a UML (Unified Modeling Language) model of the different objects composing “PPS-CC network”: the PPS, the CC, the entity, the generator of order, etc. A prototype implementing the proposed concepts is actually under development and will be tested at Alcatel. This prototype will be used as an assistance tool for the industrial control of a production line.

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