TOWARDS AUTOMATIC CONTROL FOR MICROFACTORIES

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Abstract: Microfactories are new specific and flexible systems to produce and assemble micrometric products. These systems are different of standard production platforms because they are confronted with a lot of constraints without influence at human-scale systems. This approach will lead to the development of an architecture of the technical information system adapted to a modular, reconfigurable and evolutionary microfactory. In such a context of production of microproducts, the technical information system is the spinal cord of the microfactory. The definition of the data, their architecture and their organization will build up the base of the control structure. To efficiently and surely control the set of cells, the traditional control scheme must be integrated in a global information model. This paper presents the design of an information model dedicated to microfactories and its advantages.

Keywords: Microfactory, Manufacturing Execution System (MES), technical information system, Unified Modelling Language (UML)

1. INTRODUCTION

Microfactories are automated units designed to produce products composed of micrometric components. Today, microfactories are made of elementary modular cells able to carry out basic operations. The size of modules participating to a microfactory is generally greater than the components they are assembling. To perform new operations, few elementary modules may be grouped in a new cell. The realization of one of these cells is still a scientific challenge but several research projects have already get significant results in this domain. These results show very promising functionalities as the ability to configure or reconfigure a cell, by changing an active element for instance. However, the set of operations carried out by a cell is still limited. Now, we need to put several cells together and make them cooperate to produce complex assembled microproducts, as done for mesoscopic productions. The next generation of microfactories will increase ability and complexity more by adding numerous elementary actuators than by developing complex robots. In this context, the control will evolve to become more cooperative and distributed.

To achieve this, we have set up collaboration between two laboratories. On one hand, the "Laboratoire d'Automatique de Besançon" has a high level in production engineering and in the practical expertise of handling components at micrometric scale. Therefore this laboratory has defined the schedule of conditions of an adapted microfactory and its corresponding model. On an other hand, the "Laboratoire d'Informatique de l'Université de Franche-Comté" has an expertise in the modelling field, in model checking, in scheduling activities and distributed systems, for execution in microfactories.

This paper presents the information model of multi-cells microfactories. The model is expressed with the Unified Modelling Language (UML) and is used as connecting link between the robotic and computing researchers. The context of our model is the Manufacturing Execution System (MES) level of the Computer Integrated Manufacturing (CIM) pyramid. In a first part we make precise the micro-factory context and its properties. Then, we present the information model in the third part and justify its use in the forth part.

2. SPECIFICITIES OF THE MICROFACTORIES

The organization of several productions into a sub-contracting workshop leads to set up a flow management and a stock management because the big weight machines are established for a long time. At the opposite, microfactories allow to manufacture only one type of product, in the same time, and we can move the cells to an optimal place, in goal to facilitate the movement of the components. The consequence is to minimize the scheduling problem.

However, one of the specificities of microfactory is the impossibility for the operator to have a direct (manual) access inside the celles. We have to introduce a new kind of data support. For example, to support the production follow-up and experimental tele-operation, the technical information system must manage important data flows (control of robots with great degrees of freedom, feedback with three-dimensional real time videos, etc). In addition, the unusual indeterminist behaviour of components at this scale [1] led us

to integrate an assistance to the operator starting from a permanent management of gradually acquired knowledge.
Finally, the feeding and transport of microcomponents between cells are not easy, because the problem of the position and the orientation become more difficult with a status of ultra precision. Moreover, usual linear production lines will become, in microworld, a three dimensional organization of the manufacture. Moreover, as the production takes place in a controlled environment with modularity and light weight cells, we can organize the microfactory by tuning the position and the orientation of each cell. This approach will lead to the development of modular, reconfigurable and evolutionary microfactories, as described in fig. 1. However the design of such microfactories is complex at the cell level as well as at the information system level. Due to the computing power needed to control a cell, we consider that several computers will be mandatory to achieve an automatic control of the production platform. In such a context of production of micro-products, the technical information system is the spinal cord of the microfactory due to the distributed aspect of the computing and scheduling functions. The control structure, i.e. the definition of the data, their architecture and their organization, must be clearly defined to ease the interactions between several cells and the global management. Moreover, as the complexity of the control increase with the distribution of the control and the scheduling information, it is necessary to use software engineering techniques to ensure the quality of the information model.

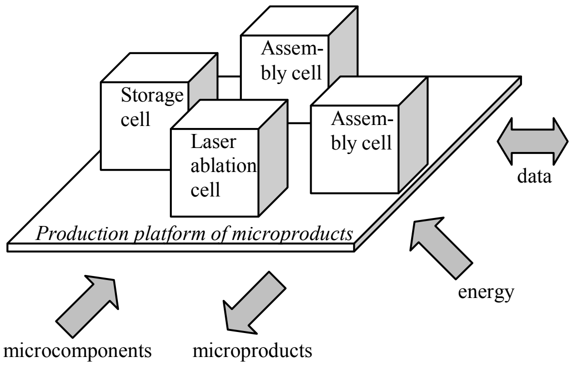

Fig.1: Microfactory structure

The object of our study relates to microfactories able to produce successively various types of microproducts into small or average quantity, for which the development and the installation of a production dedicated line are not financially profitable. For this reason, we work with a modular, flexible and evolutionary architecture which make it possible to have a reconfigurable and reorganizable production equipment [2].

3. INFORMATION MODEL

We have developed the information model on the level of the MES activity (Manufacturing Execution Systems) of the technical information system of the decision model of the CIM (Computer Integrated Manufacturing) pyramid [3], [4], as you can seen in the fig. 2.

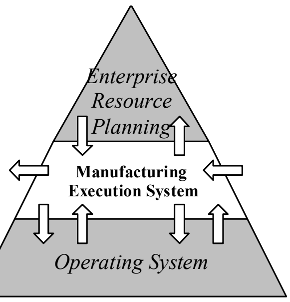

Fig.2: context of CIM model

Among the eleven functions of the MES system indexed by the ISA-95 [5], six are concerned with our framework of application: scheduling of the tasks, management and piloting of the processes, collection and data acquisition, feeding of the products and the batches, analysis and optimization of the performances, stock management, the statute and the allocation of the resources.
To satisfy all these functions, this approach leads to a very dynamic technical information system ready to use tools of representation, filing, handling, exploitation, and communication of information. All the data of production and the blaming of the process will be necessary to sort and capitalize in order to extract some know-how in the microfactory or more specifically in a cell [6].
The UML case diagram in the fig. 3 represented the various cases of uses for the operator who organizes the production.

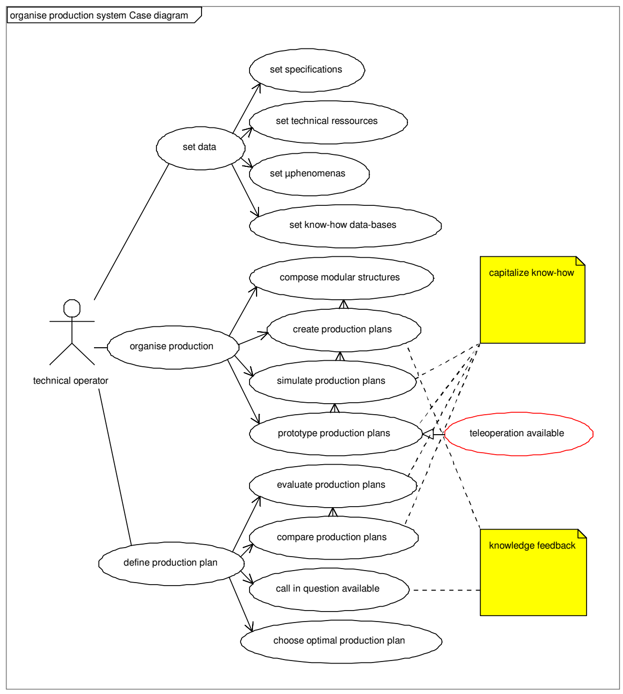

Fig. 3: UML use case diagram

The modularity is defined into the cell. In first, the plateform of production has a basic cell store at one's disposal; a basic cell is composed of a physical structure to connect different type of equipment, as active elements (actuators, sensors, …) and passive elements (fingers, tools, …); each element is parameterize with its position, its action and its environment. An assembly cell is so composed (fig. 4) with some grippers to move and to put on position, a laser source to polymerize glue during the assembly operation, an optical sensor to control the precise moving of the object.

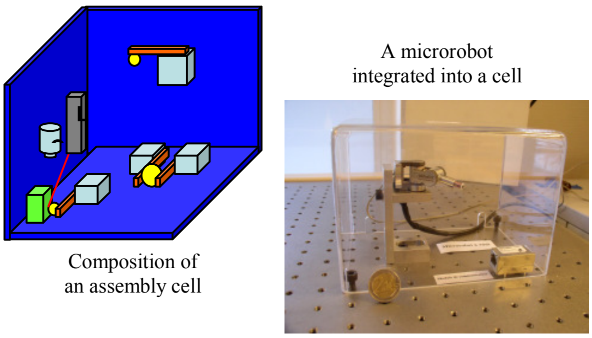

Fig. 4: example of an assembly cell

Our concept of microfactory is based on the design of cells of production. Each "basic cell" is the subject of thorough design engineering and research [7]. It has micro-actuators and/or microsensors arranged between them in a precise way to allow specific functionalities. The cell comprises parameters of inputs and outputs naturally accessible from the organization system and the operator. As far as possible, modeling of the behavior of the cell is provided with the cell in particular to allow its simulation. The models are enrich progressively with the acquisition of new knowledge resulting from the use of the cell.
In addition, if needed such a basic cell will be modified by the addition of active elements and/or passive elements. We define a "active element" as a body having input(s)-ouput(s) (example: sensor, or actuator), and a "passive element" as a body not having input-output (a simple tool). This modularity obtained by active or passive elements is illustrated under UML by the following diagrams (fig.5).
Each cell used for the implementation of a task of the assembly plan is initially the subject of a simulation and/or an experimentation in order to validate its parameter setting.
After the validation of the use of various cells, the initial organization of the production is defined while being based on multiple criteria coming from the specifications of the production.
The organization of the obtained cells form the Platform of the Production of the Microproducts (abbreviation PFPM). Contrary to the often linear lines of production of the meso-world, the PFPM can be spread while following two dimensions (organization in matrix, triangular, circular, etc), or even in three dimensions (organization cubic, spherical, cylindrical, conical, pyramidal, by layers, etc).
The architecture of the PFPM is articulated around three standard bodies of connection being used as interface of communication, energy and products. Three flows corresponding are based, according to cases, on a material or immaterial support.
If need be, the PFPM has a specific environment (clean room, antivibratory enclosure, fluid environment, black room, etc).

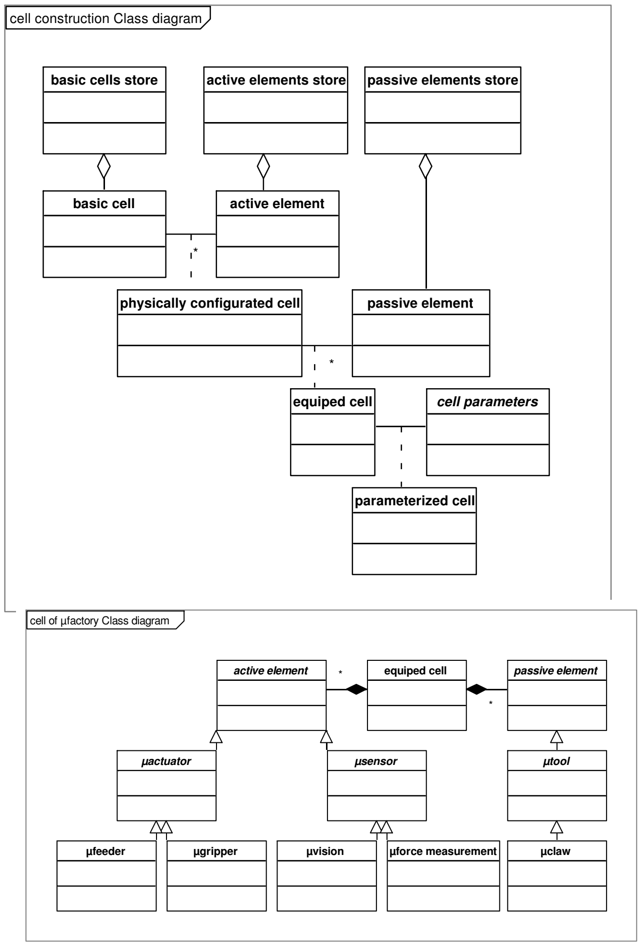

Fig. 5: examples of microfactory class diagram

Lastly, the definition of an advanced "human machine interface" must amongst other things make it possible to make available the microworld to the operator for the observation, or the remote-control.

4. WHY USING A MODEL?

The modelling of the microfactory focus on three topics: the factory design and behaviour, the factory components and interactions between those components.
Models can be used for multiple activities (to simulate normal or alternative behaviours, to validate tasks scheduling, to check intrinsic properties, to cope with functional complexity) but any model has a cost. It should be justify by its feedback to the physical level [8].
The first benefit of a formal model is the ability to provide a non ambiguous definition for every elements present in the

system to be modelled. But that's not enough and starting from the conception phase we must use several kinds of model to validate microfactory properties.

We must focus on the specific goals associated with an activity to reduce the modelling complexity. Typically, for the microfactory, model should gather information on architecture validation, system organization and functional description. Those several activities will produce a possibly large model.

To manage it, we introduce a concept called View. A view is the projection of a model for a specific activity. We use this concept to ensure coherence between microfactory activities.

Furthermore, microfactories deal with really small parts that are sensible to their environment. This specificity leads us to model this environment and its interaction with the microfactory. This approach is known as dedicated model to be linked with works on DSM (Domain Specific Models).

We have a view dedicated to functional specifications of the microfactory. This view should help us to verify and to validate a set of properties applicable to the factory. We want to be able to confront a factory's model to its realization by:

- Animating behaviours described in the system's model. In that case, we will be able to capture actions and reactions of the system even before realization.
- Validating a realization of the system. There, we will compare the realization with the model, by applying a same action on both and check the result. A script of actions can be compute by automatic test generation [9].
- Checking that intrinsic properties of the system are present in the model. First, we have to formulate hypothesis on the environment and we must identify intrinsic properties of the system. Those hypothesis and properties should be verified on the model. And in a second time we must be sure that they are respected or present in the realization of the system, i.e., the microfactory [10].

After verifying the properties of the system, the model may be used as a base to the design of the information management architecture of the physical micro factory. For instance, as the interactions between the factory components are identified in the model, this information may be used to realize the communication network between the cells and the controlling components. The model may also be used in the development of tools helping engineers during the design phase of a microfactory: simulators, automatic generation of the cells command, etc. In all these cases, the model will serve as a reference for the factory architecture and, thus, guarantee the coherency of all the works done.

5. CONCLUSION

The approach towards automatic control for microfactories needs the data representation. The specificities of these production system lead to a development of a new method to organise and to optimise the functionalities. In such a context of production of microproducts, the technical information system is the spinal cord of the microfactory

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