HOLONIC PRODUCTION PROCESS: A MODEL OF COMPLEX, PRECISE, AND GLOBAL SYSTEMS

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Abstract: Nowadays, it is necessary to have a complete description of the production process in order to plan, program, control, and supervise the production process. It is hard to obtain this description due to the existence of two contradictory points of views. First, the precision implicated in the construction of total and complete models, and on the other hand, the need of having a global vision associated with the different views of the process. These views normally show three important aspects: the structural organization of the model, the dynamism between the main components, and the distinct temporal scales and levels, where are taken the main decisions. The holonic approach (Erikson,2004) has been used to manage this complexity, in order to have an abstraction that permit the integration of the mentioned points of views. In this paper we propose, a structure for continuous production process based on holonic approach in order to obtain a global vision and global model less complex of the production process.

1 INTRODUCTION

Nowadays, enterprises can be established in a virtual manner building a dynamic network of enterprises in order to obtain a determined product, in a moment due. The high enterprises' performance is due to the establishment of precise objectives for a determined configuration of the network.

The virtual enterprise, composed in this way follows a set of production agreements, in order to fulfil objectives by trying to diminish the production cost of the product, in a production offer. This virtual enterprise may be composed by a set of enterprises or a set of unit of the enterprise itself. The production agreements implicate the establishment of a logistic, quantities, and qualities of products and sub-products, and synchronization points (E. Chacon,1998), (E. Chacon, 2004), (Juan Cardillo, 2005).

The negotiation is obtained following the existing common knowledge, for which it is necessary to have the following:

- A description language of the production methods
- Protocols for the acceptation of missions among the enterprise participants, following each one of production capacities under a production method of high level.

The enterprises participating in a negotiation know the information services that offer each enterprise by means of a yellow pages service. The global model of a virtual enterprise focused in its mission, can be viewed as an Holon. The knowledge model of the holon follows a Discrete Event Dynamic Systems Model (DEDS), where each one of the steps that conforms the mission is described by means of an operation region. Thus, a conformed enterprise (virtual or not) is considered as an enterprise holon which is composed by a set of Production Units (inside production units or enterprises) conforming the Production Units Holonic System. The coordinator of the conformed enterprise is charged to manage, control, and re-plan each one of the steps of the mission in order to complete it. The established chronogram of the conformed enterprise generates a particular mission for each one of the Production Unit Holon (PUH). Each step of the selected production method by the PUH is associated to an operation region. The coordinator of each PUH is charged to manage, control, and re-plan each one of the steps of the selected production method. In holonic architecture, the groups are managed by itself following its internal resources state knowledge, the production order advance, and the knowing of its production method that permits to obtain the product. Thus, a holon is composed by one or more holons. The advantage of use a holonic approach is due to have a reference model that describes the composition of the conformed enterprise (virtual or not) structure. Here, a conformed enterprise and a holon are modeled by following a business model where the value chain and the product flow both establish the base of the global modelling of a conformed enterprise. In this work, we present a reference model under the holonic approach that permits to have a description of the production process (conformed enterprise) as an embedded system based on its business model, value chain, and product flow. This presents one enterprise (conformed enterprise) as a network of enterprises (production units) composed to follow a production mission. Section 2 is devoted to show the conformed enterprise modelling method. Section 3 describes the holonic approach of the production system, and section 4 presents the conclusions and future works.

2 MODELING OF A CONFORMED ENTERPRISE

A conformed enterprise describes both enterprises composed by several semi-independent units or virtual enterprises. This is due to the utilization of a production model in conjunction with a value chain and a production flow. Both enterprises are modelled in the same manner. Thus, the value chain expresses the sequence of the aggregate value of a product (transformation, storage or transport) by following of the production process itself. The use of the value chains is the base to develop models of the different business process that are specific of an enterprise. A graphics representation of the value chains is shown in figure 1. The product flow can be defined as the different transformation stages, which follows a resource (or a set of them) until the final product achieving. The conjunction of the value chain plus the product flow results the production flow, which is the aggregate of functionalities and transformations of the resources to generate the final product.

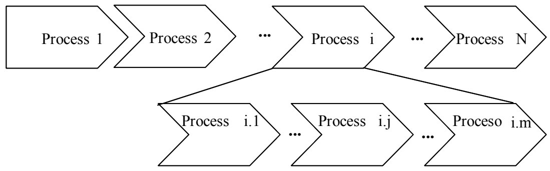

Figure 1: Value chains.

Each stage of the value chain (Input resources, processing or transformation and storage) of the production flow is also viewed as a Production Unit (PU), where the characterization of each PU depends on how the resource (or a set of them) evolves, such as: continuous, batch, manufacture, or hybrid. Additionally, each PU does a specific transformation depending on the properties of the resource (or resources). However, it is possible to found common or generic elements that characterize a PU in a production flow. Each element is viewed as a process inside of the PU. These processes are as follows:

- A process to take hold of resources
- A process of transformation/transport
- A process of storage between each PU process

Initially, resources are located and obtained for the PU. The process to take hold of PU resources warrants resources for a determined production recipe. After, the PU selects a production method required to transform the raw material. The selection of the production method depends on the resources properties, and then it is carrying out the transformation process. When the transformation process is finished, the transformed resource is storing and waiting for the need of another PU.

Figure 2 shows a structural model of a PU. This model not only presents the controlled and supervised system (control and supervision process plus the production process) that makes the transformation, also beholds the product plan, production methods, configuration, and management of the resources that are needed in the production process. This structural description is the base to extract the main information to do a planning of the PU by considering which values or variables permit the description of the PU state, such as: performance indicators, reliability, and so on. Other variables that may be taken into account are: quality of the product, expected quantity of product, production capacity, storage capacity (minimal and maximal), etc. For example, PU production capacity is related to the transformation process capacity, and also to the storage capacity, if and only if raw material and the rest of the resources are guaranteed.

An object-oriented structural model of the PU drawing by means of the Unified modeling Language (UML) (JçI. Jacobson, www.rational.com/uml), (A. Muller, 1997) is presented in figure 3. The class diagram uses rectangles to represent classes and lines to represent relationships among classes. This diagram includes three kinds of relationships, such as: generalizations/specializations (arrows not fulfilled), associations (lines), and compositions (line finished in a filled diamond).

Figure 3 shows different entities or classes in the PUH and how they are related. In particular, it is highlighted a special class which is related to an association between the classes ProductionPlan and Product, named ProductPlan. Also, the class Configuration which is charged to register all of the different configurations of resources, production process, control and supervision software, and production method, as an association class between the four aforementioned entities. It is viewed the classification of the resources managed by the PU in order to accomplish its production plan that support the enterprise plan.

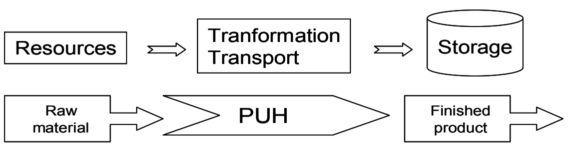

Figure 2: Model of a Production Unit.

For lack of space, this class diagram is showed in a concise form; each class has a set of properties (attributes and relationships) and operations, which support the behavioural model of the PU.

The embedded model of figure 4 shows the decisions scheme needed for each path of the value chain of a PU. Our proposition uses an embedded model that is based on the description of a Holon.

This model presents level works composed by the production process and each one of the established control loop. The designed controllers (that takes decisions) are inside the communications and information architecture, which needs applications and industrial networks in order to capture actual variable values, by means of sensors, and to indicate controller actions, by means of actuators. Thus, the controlled productive process is viewed as a system that need to be controlled (supervise, monitor, manage) by a supervisor. This permits to view the whole productive system as an embedded system conformed by a path of the value chain that takes products, transform-them to generate another derived product.

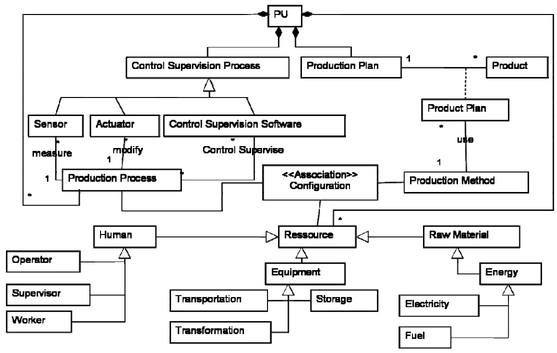

Figure 3: UML Class Diagram of a Production Unit.

3 HOLONIC APPROACH IN PRODUCTION SYSTEMS

A holon for a manufacturing enterprise is defined as a constructor block; cooperative and autonomous for transforming, transporting, storing and/or validating physical objects and information (H. Brusel, 1998). A holon has the autonomy to create and control the execution of its owns plans, it may cooperate with other holons to jointly develop an acceptable plan to reach the system mission. The cooperation among holons is accomplished by one evolution of the holarchy in the organization (a holon system).

In a Holonic system production, the objective is to achieve a complete spectrum of the range of the control function that goes from the production plans, that controller at the highest level, until the process/machine that control the lowest level.

A Holon possesses two constituent elements: a connected transformation system and a system of taking of decisions. The decisions system monitors the resources and the evolution of the order that are being controlled in the plant floor, by associate elements for such an end.

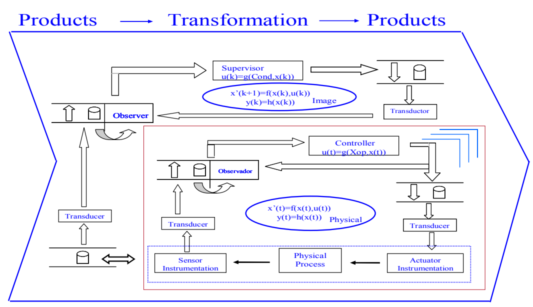

Figure 4: Production process embedding model.

The integral automation of systems outlines a global vision of the productive process, where each element that intervenes in the production should be taken into account to be able ***to control***, **to supervise**, and **to management** the production, to see figure 5. The automation scheme is based on the construction of models that represent the ***Unit of Production*** so much in its structural aspect, like in its dynamics. The control schemes assure that the behavior of the system is inside that wanted, for that which the knowledge that one has of the state of the system allows to evaluate which should be the viable control actions with the purpose of assuring that the system reaches the wanted state.

In the productive system, the control is subordinated to the objective fixed to the **Unit of Production**, and the objectives are determined for what the Unit of Production can make.

The process has a proper behaviour that depends on the physical and chemical laws in particular in a condition of given operation. This behaviour it can describe formally as a Hybrid Dynamic System.

When having the description of the dynamics, the behaviour can be controlled by a automatic supervisory system or by means of the intervention of a human being.

The product of the production process is obtained by means of a group of resources that can suffer changes in the time, thus the information of the state of the process, and of the resources should be continually monitoring with the purpose of determine, if the system completed the production objective, or on the contrary it could not complete the production objective by failure in some of the resources. This change should be management to define a new production scheme in the Unit of Production or to verify in another level if it is possible to have a form of assuring the objective fixed for the set of Units of Production.

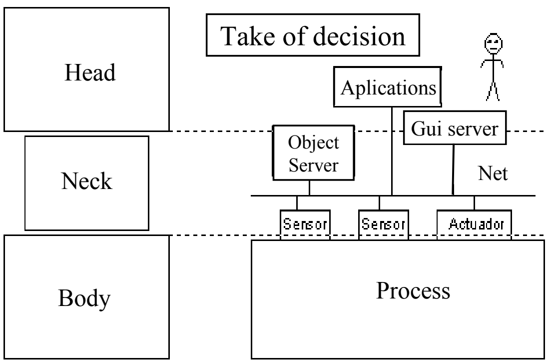

Figure 5: Integral automation of systems.

Considering the Unit of Production with the capacity to have autonomy (a Holon: Holon Unit of Production, HUP). HUP is composing of a BODY, NECK, and HEAD. In the body is where the processes: of transformation of the matter, of storage or transport are developed. This it is carried out by a group of physical devices as reactors, compressors, store, etc.. In the head are the mechanisms of taking of decisions, based on the knowledge of the production process and the necessary resources. These mechanisms of taking of decisions are developed by the classic techniques of supervisory control or by approach of intelligent systems. The neck is the interface between both, this is composed by the whole infrastructure tele-informatics that stores and transports the information. Thus, in the head are the applications of taking of decisions that determine the behaviour that should have the body. In the neck is the communication mechanism between the head and the body (process), their implementation is all the mechanisms that allow to capture information of the process and to send commands to the process. See figure 6.

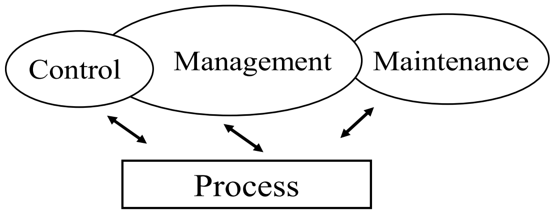

Figure 6: Relation ships between Holon and TIC infrastructure.

3.1 Holonic Control Loop

The basic functional unit for the automation of a production system is the control loop. This control loop is redefined how the Holonic Control Loop (HCL), it possesses all the characteristics of a Holon.

The HLC is conformed by a body that contains the physical process that possesses implicit the actuator and the set of sensors and whose model, without losing generality, we can describe as a dynamic system in state equations. The neck of the HCL this conformed by the architecture tele-informatics and proper applications that are able to capture, to try, to store, to adapt, and to transfer so much information of the sensor as toward the actuator. The head of the HCL (controller) is conformed by the mechanism of taking of decisions, this mechanism can have a rigid form (PID, etc.) or not (neuronal net, etc.). This controller, that is able to regulate to an operation point, is designed using the physical model of the process (knowledge model), its can be described by dynamic equations and /or algebraic that dependent of the operation point, of the state or output and of parameters that belong to an operation region. In definitive the Holonic Control Loop is an autonomous system that possesses two input and two outputs characterized by products and information. Input Product: products supplies and resource. Input Information: Controller's type, Operation Point, Parameter of Controller. Output Product: sub-product or finished product. Output Information: State of the controller process. To see figure 7.

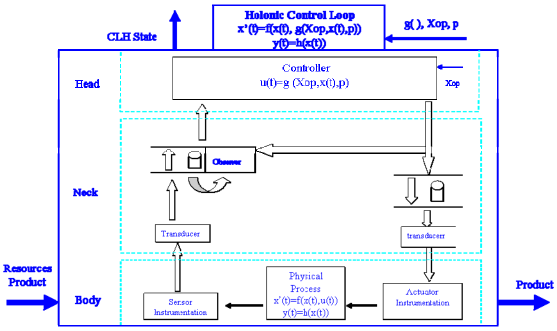

Figure 7: Holonic Control Loop.

3.2 Supervisor Holon

As we know, a process possesses more than a control loop. To each control loop we have redefined as the HCL. The management of all the loop control relapses in a supervisor. The supervisor possesses all the characteristics of a holon. Thus, when composing all the loops control we obtain the Controlled Holonic Systems. See figure 8.

The Controlled Holonic System is a system that has i models (maybe one for each control loop), each model has a set the m of nominal values of operation that can be reached with a set the j types of controllers which are adjusted under an approach determined with n parameters. Just as it shows it the figure 9

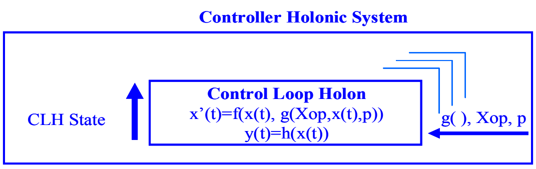

Figure 8: Controller Holonic System.

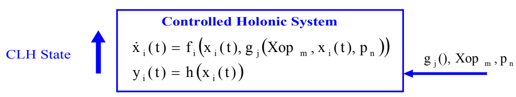

Figure 9: Embedding Controlled Holonic System.

In the same manner that the previous sub-section the Supervisor Holon (SH) is conformed by a body, a neck and head. The Body of SH is conformed by the Controlled Holonic System which generates state values of the process (as sensors), and possesses implicit actuator given by: g (), Xop, p. The neck of SH is conformed by the tele-informatics architecture and set of applications that allow to detect events (they are able to capture, to try, to store, to adapt, continuous information of the state variable in events) as generating the set point (g (), Xop, p) toward the loops control. The head of the SH this conformed by the mechanism of taking of decisions, that is design using approach of modelling of Discrete Event Systems generated by the Controlled Holonic System.

In definitive the Supervisor Holon is an autonomous system that possesses two input and two outputs characterized by products and information. Input Product: products supplies and resource. Input Information: recipe, scheduling of Operation. Output Product: sub-product or finished product. Output Information: State of the supervisor process. See figure 10.

3.3 Holonic Production Unit

It is possible that a production process has more than a supervisor. To each supervisor we have redefined it as the Supervisor's Holon. The management of all the supervisors relapses in a coordinator; this coordinator possesses all the characteristics of a holon: Production Unit Holon. Thus, when we compose all the supervisors, we obtain the Supervised Holonic System. (See figure 11).

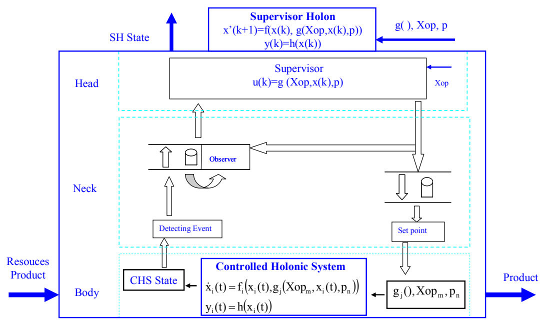

Figure 10: Supervisor Holon.

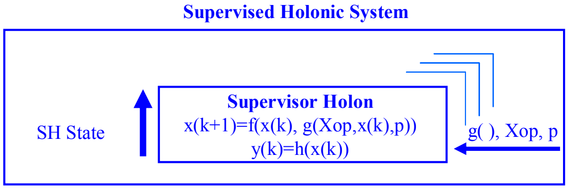

Figure 11: Supervised Holonic System.

The Supervised Holonic System is a system that has i models (maybe but of one for supervisor), each model has a set m of nominal values of operation that can be reached with a combined j of types of recipes which are adjusted under an approach determined by supervisor with n of parameters. Just as is shown it the figure 12.

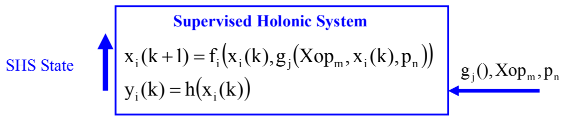

Figure 12: Embedding Supervised Holonic System.

In the same manner that the previous sub-section the Production Unit Holon (PUH) is conformed by a body, a neck and head. The Body of PUH is conformed by the Supervised Holonic System which generates state values of the supervisor process (as sensors), and possesses implicit actuator given by: g (), Xop, p., i.e. recipes, scheduling, etc.. The neck of PUH is conformed by the tele-informatics architecture and set of applications that allow to detect events (they are able to capture, to try, to store, to adapt, information of the state variable of the supervised process in events) as generating the set point (g (), Xop, p) toward the supervisor. The head of the PUH this conformed by the mechanism of taking of decisions, that is design using approach of modeling of Discrete Event Systems generated by the Supervised Holonic System.

In definitive the Production Unit Holon is an autonomous system that possesses two input and two output characterized by products and information. Input Product: products supplies and resource. Input Information: negotiated production demand. Output Product: finished product. Output Information: State of the productive process. See figure 13.

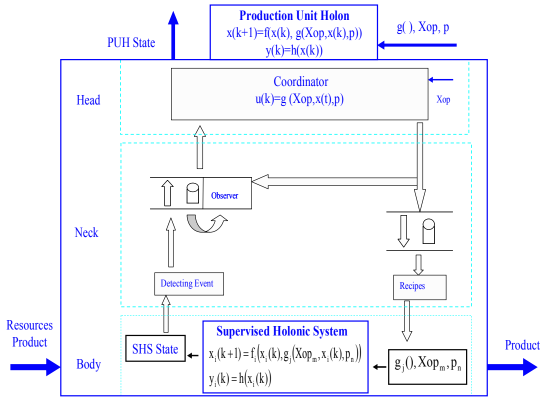

Figure 13: Production Unit Holonic.

4 CONCLUSION AND FUTURE WORK

In the work, we show an implemented architecture that allows to have a recursive (embedded) structure, represented by each Holon. The information stays up-to-date by means of mechanisms topologically equal. The coordination is carried out by means of supervisors generated for each built configuration based on a production mission. The stages for the supervisor's construction are defined like one of negotiation. This negotiation to define the objective and the generation of synchronization points based on the defined configuration. Once finished the stages of selection of the configuration and establishment of the synchronization points the supervisor you instance for the duration of the mission.

It is necessary to establish negotiation mechanisms for the establishment of the mission, since the global knowledge of the production capacities is known internally, and the configuration is obtained after the evaluation of the different arisen alternatives of each participant's internal capacities. The protocol Contract Net of the FIPA appears as the most suitable mechanism for the establishment of a common mission.

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