RFID Uses for Prosis Ambient Control

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Abstract. Product traceability is now an obligation in terms of observability and flexibility of manufacturing systems and logistics chains. RFID technologies are due to be more and more integrated into existing communication networks. New infotronics technologies will enlarge the capabilities to interact, to react and to customise control systems with innovative possibilities. New control approaches should be proposed based on the use of emerging technologies that would allow their operability in manufacturing sites. A model for ambient control production systems is proposed, based on a set of holonic entities interacting through set of entities that offer ambient service. After describing the PROSIS model, the ambient services that can be provided are presented.

1 Introduction

Ambient intelligence applied to manufacturing systems will deeply transform approaches to production organisation and control. Infotronics technologies [4] will enlarge the capabilities to interact, to react and to customise control systems with innovative possibilities that should already be envisaged and thoroughly studied.

Indeed, future production needs are already expressed through emerging paradigms such as mass customisation requiring individualised and flexible product tracking, lean approach leading to drastic stock reduction and enhanced flow control, Six sigma approaches bringing more rigour and requirements in the results to be achieved, or product traceability obligation, in particular for safety and maintenance needs.

In order to address these objectives, new control approaches should be proposed, based on the use of emerging technologies that would allow their operability in manufacturing sites. Indeed, in a highly competitive international environment, the control of production system with efficiency is a key point for a company. Traditional management and control methods show their limits against the increase of production constraints, and it becomes essential to study new control approaches. We propose, for the control of production systems, architecture without any hierarchical decision-making dimension. The proposed approach uses holonic paradigm and multicriteria model in the decisional process.

After presenting the actual research works in infotronics technologies applied to control systems, we will propose a model for ambient control systems in production, based on a set of holonic entities interacting through set of entities that offer ambient service. Finally, we will describe the various parts of this model, whether nomadic or

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not, in general interaction or in specialised interaction. We will then present some of the ambient services that can be provided.

2 Manufacturing Ambient Control

The ambient intelligence concept comes from the federation of topics that are of apparent different nature, like nano and micro systems, wireless technologies, distributed computation or sensor technologies. One objective of the convergence between these technologies is to provide new users services, such as home automation, Smart Objects… This ambient intelligence concept, also called ubiquity, gives users the possibility to interact from any place with many interconnected infotronics devices, sensors and actuators, embedded around them and operating through ad hoc networks with distributed architecture. Intelligence is referred to as ambient because of the omnipresence of wireless communicating non apparent computing agents. The common point between future production imperatives as those mentioned above is the increasing need of ad-equation between the current manufacturing system and its associated information system [19], combined with deeper granularity in which the detail level is at part unit. Infotronics technologies offer a large scope of solutions to answer these imperatives and find already many applications in the manufacturing system area, changing usual operating modes. According to [10], the impact of introducing such technologies in manufacturing systems is considerable. It concerns for instance fast improvement of product tracking allowing stock level reduction and improved exploitation of product availability, due to real time reliability of product data. On a longer term, more advantages can be developed for mass customisation management [6], product secureness [3] or collaborative production-distribution organisation [17].

Presently, research concerns essentially the migration from simple use of infotronics technologies (like RFID: Radio Frequency IDentification) to the concept of intelligent product and its induced applications in heterarchical control. [14] propose the concept of self scheduling driven by the product or by the interaction product-process. This interaction allows local and contextual generation of tasks oriented trade used for real time control of the resource. A product carries information that it is able to communicate to the decision centres associated to resources. In that, a product can be qualified as active. The entity managing immaterial aspects (information, communication and decision) is called I-product. This definition is closed to that given by [9], which defines an intelligent object by only its communication ability, completed by its associates' service delivery, communication transparency and environment adaptability to intelligence. In parallel, [10] defines the intelligent object concept as a dual object (physical and virtual) with information processing capability (memory, communication, computing, action …). A complementary concept is the one of extended product [18] which associates a provided service to the product. This service, more and more intelligent, should be compliant with customers' needs. In order to offer high value added services related to a physical product, this one should be associated to an immaterial component carrying information and knowledge and made of services, engineering, software… According to Hribernik [5], this immaterial component, called Avatar, allows implementing the global concept of distributed production and decentralised information management specific to each product. In this context, the use of new technologies, such as RFID, wireless networks and ubiquitous processing allows linking the product to a network of applications related to production, maintenance… In France, Product Driven Systems are subject to new investigations dealing on one hand with the control of interactions between fabrication process and product and on the other hand, with the integration of new technologies such as Wireless Sensor Networks and Radio Frequency Identification in the cybernetics loop. These technologies should provide the product with memory, computation and communication capabilities: it thus becomes 'active' within the manufacturing system that processes it. This 'active' product can be given means for capturing environment variations, making decisions and thus fully interacting with its environment (process resources, other products, human operators, etc.) [12]. Finally, whatever name given, I-product, virtual product, extended product, avatar or other, future operation of manufacturing systems will rely on this type of entity. However, objects of different nature will have to inter-operate: the holonic paradigm [7] is not restricted in the Holonic Manufacturing Systems [8] to an oriented product vision only; there exist other types of holonic entities with a role as much important. Among proposals from the HMS community [2], Product, Resource and Order Holons are three types of basic Holons that are most recurrent [15]. We are referring to the most known holonic architecture: PROSA [20]. Starting from there, the control of manufacturing systems by products only is not enough. Indeed, the product as such does not carry all the operational constraints and all related information that would allow making optimal, or at least satisfactory, control decisions. Each of the two other Holon types (Resource and Order) brings its own set of data and constraints, making a different viewpoint. To take into account these data and constraints, we propose control that integrates different viewpoints coming from different interacting entity types.

3 Prosis Model

3.1 PROSIS Model Presentation

PROSIS (Product, Resource, Order, Simulation Isoarchical System) [13] proposes a holonic and isoarchical approach that facilitate the implementation of ambient control solutions for manufacturing systems. We wish to study and develop decision mechanisms with architecture and information system being as close as possible of the material system, even to the image of the organisation of this system, and directly interconnected to it via infotronics technologies. This approach objective is to gain in terms of structural and decisional flexibility, and thus in terms of reactivity and adaptability.

Initially thought for modelling complex social systems, holonic systems are made of entities (the Holons) in mutual interactive dynamic relationships. A Holon should be seen as a whole or a part of a whole: this is the Janus effect expressing among others recursion notions. This approach marks a break with previous hierarchical models in which components are of the type 'master - slave' following a tree like and not varying topology of decision centres. This is reinforced with the respect of orders by the slave decision centre. Indeed, a Holon has a decisional intelligence giving the possibility to act on its own behaviour and also to act on the behaviour of the systems it belongs to [15]. Hierarchical decomposition is replaced by Holon recursion and implementation of the Janus effect. This opens a wide level of freedom for the implementation of a control system according to an heterarchical architecture, that is able to mix centralised and non centralised parts.

Different holonic architectures are proposed in the literature for control HMS [2]. These architectures present however the inconvenient of giving an important place to the hierarchy concept in decision making. For example, when basic Holons cannot find in PROSA a scheduling solution, a solution is derived by a Staff Holon which uses a centralised processing algorithm. In order to simplify the implementation of an ambient control system, we suggest that all interacting entities be at the same decision level. Thus, there is no possibility of decisional hierarchy leading to manage complicated decision making rights. This means an isoarchical architecture. The isoarchy concept (word made from Greek iso (equal) and archy (power)) refers to the same decision power and thus to a complete absence of hierarchy. In a decision system made of several decision centres, a decisional architecture can be qualified as isoarchical when each decision centre has the same decision capability. This property can easily be obtained when decision mechanisms are duplicated in each decision centre and appropriately parameterised. Isoarchy appears as a particular specification of the concept of heterarchy and as the opposite of the concept of hierarchy [11]. However, within this category it expresses an even concept that can be applied only to truly and totally equalitarian architectures. This particular situation between Holons has been foreseen in holonic systems through the concept of ‘flat holonic form’ [1]. However, this architecture in which relationships between Holons makes a complete graph was not really deeply studied.

PROSIS aims to explore this approach which is specially suited to ambient control systems: indeed, a single hierarchy level permits Holons to directly and simply access entities offering ambient services. The absence of a central decision system forbids any predefined or forecast organisation of manufacturing system operations. These should thus be progressively organised by the Holons themselves with the support of ambient service entities. This self-organisation assumes real-time characteristics considering all information characterising each Holon contributing to define the operations. We then talk about self-organised control functions. These functions are integrated into the intelligence associated to each Holon. For that, we define a Holon as a conceptual entity based on the association of a Material Structure (the M_holon), an Information System and a Processing System (the I_holon) that provides a decisional intelligence allowing interaction with other Holons. This structure allows recursive decomposition of manufacturing systems, in compliance with the holonic paradigm, by clearly showing the duality and parallelism between the real world (material) and the informational world (immaterial, in which data and decision making stands).

For a nomadic Holon, the main problem is synchronisation between material and immaterial parts of this Holon. This is solved with infotronics technologies: The M_holon has an ID tag containing at the minimum a unique identification number associated to the Holon whose value is stored in the information system of the I_holon.

A network of I_holons can be associated to a set of Holons making a manufacturing system to create an I_holon hyper graph following recurrent composition rules. We shall describe the different base Holons: the Product Holon (PH), the Resource Holon (RH) and the Order Holon (OH) which feature evolutions with respect to PROSA. Management of production related knowledge results from interactions between these three types of Holons.

PH-RH interactions provide process knowledge: resource operating methods, capacity, reachable quantities and possible results. PH-OH interactions indicate production knowledge: batches description (quantities to deliver, product reference, delivery schedule …). RH-OH gives execution process knowledge: follow up of process execution by resources, monitoring of progress, of process interruptions …).

However, a major difference with PROSA is the disappearance of the Staff Holon which is not needed in an isoarchic context. We replace it by a Simulation Holon having a totally different objective: starting from the manufacturing system status obtained by analysing interactions between the other Holons, the aim is to simulate the manufacturing system evolution, to provide evolution indications to the workshop manager and to anticipate eventual failures via diagnosis actions.

This Holon does not contribute to self organisation, but it facilitates the role of the workshop manager: it provides control with proactive properties. The Simulation Holon is not addressed in this paper.

3.2 Product, Resource & Order Holons

A Product Holon is made with a M_product (the material object) and an I_product containing the fabrication process (knowledge needed to perform product manufacturing and to obtain appropriate quality) and also its state model and all traceability information; in other words containing respectively a product future, present and past. Therefore, there exist in PROSIS as many PH instances as manufactured products or/and Work In Progress products. This is a major difference with respect to PROSA in which the Product Holon acts as an information server to the other Holons of the HMS, delivering technical information for a given type of product but not containing products state information. By definition in manufacturing, a product is a nomadic entity. It is thus necessary to identify it and, for that, to tag it. Unit identification goes through the deployment of ad hoc technologies linking each M_product to its I_product. A good example of these technologies is RFID with an ID tag attached to the M_product carrying at least an identification number, eventually completed with key information of the I_product. Other information stored in the central database and accessible through a network can be associated to this nomadic information.

The Resource Holon is conceptually similar to the definition proposed in PROSA: it includes a material part, like automated equipment (NC machine tools, industrial robot), making an M_resource, and an information processing part, the I_resource, which drives the equipment and contributes to allocate tasks to the resources. Resource allocation methods for the I_resource are not the same as those in PROSA since interactions with the other types of Holons are defined in an isoarchical context. Furthermore, RF identification is implemented only in the case of nomadic resources, like mobile robots, shuttles, etc.

An Order Holon represents a task in a manufacturing system: a manufacturing order concerning in general a set of PH. It is responsible for the performance of assigned work within specified times. It is thus closely linked to the concept of batch, WIP and delays / lead time. This is a nomadic entity with a strong link with one (or several) Product(s) Holon(s). The I_order checks dates satisfaction during work performance and about the consideration of economic factors (batch size, WIP (Work in Progress) volume, minimisation of production changes, batch partition, etc.). The M_order will be, according to the case, the manufacturing order with an ID tag, or the container also tagged, allowing the manipulation of one or several M_products.

4 RFID Functions in Ace

Self organisation of a set of Holons suggests that control decisions must be taken locally. PROSIS naturally reflects the physical organisation of Holons: around each M_resource are physically placed p M_products and k M_orders. These k M_orders are related to the p products (k less or equal to p). Self organised decision making in control requires the participation of all the locally implicated entities: resource, orders and products.

For that, local and specific interactions will be established between the I_holons of the (1+p+k) concerned Holons. These I_holons make a local 'Flat Holonic Form'. It is clear that these Holons do not all have the same objective: some trade-off should be found to facilitate the emergence of a good control solution.

In order to manage this, an ACE (Ambient Control Entity) providing I_holons with various ad hoc services is associated to each resource. The ACE also offers services to the Holons making the WIP associated to this resource.

The first type of ambient service offered by an ACE is reception of the (1+p+k) I_holons, made each of their information system (own data, reconstruction of the current Holon state) and of an instantiation of their decisional system. An ACE contains mechanisms allowing the management and the access to the information related to these I_holons. Also, an ACE has a RFID coupler allowing managing the information related to resource WIP according to input/output products. Synchronisation between the I_holons and the M_holons ensures compliance between the physical world and the information system. When a product or a products batch arrives in the resource WIP (or leaves it), the corresponding ID tag is read and the whole set (I_product, I_order) is updated (added to or taken out the ACE information structure).

When an I_product or I_order is activated, its internal thread starts, triggered by the RFID event (figure 1). This thread becomes then the decisional system of the I_holon. It can for example decide to move to another resource if the current one become too slow or if it is down. It is stopped and destroyed when the RFID coupler indicates that the M_product or M_order has leaved the resource WIP.

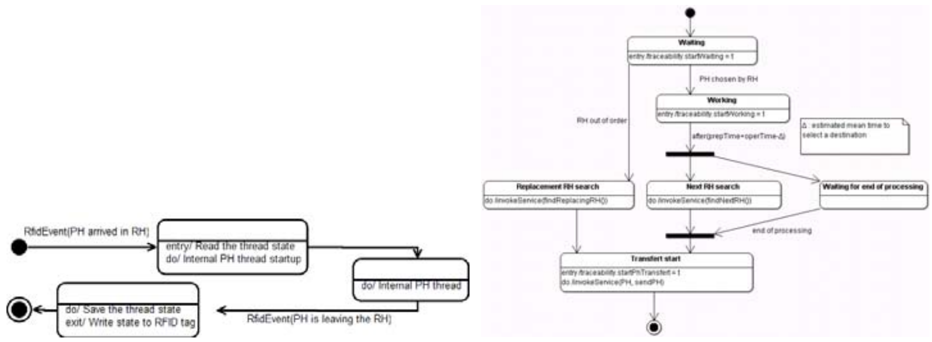

Fig. 1. Thread control via RFID events.

Our RFID hardware is composed of 13,56MHz couplers compatible with both ISO 14443 (all subtypes) and ISO 15693 cards, with a 4cm R/W range. We have chosen 4Kb memory ISO 14443-2 B chips with 106Kb/s transfer rate and anticollision functions. They use Calypso technology.

Among ambient services also proposed by an ACE, we find visualisation through a Human-Machine Interface (HMI), real time self organisation through mono- or multi-criteria heuristics, real time indicator calculation, performance analysis, archiving or traceability.

5 Conclusions

The future needs of the production systems lead to introduce more intelligence in the core of these systems. The PROSIS model gives an answer by bringing decisional intelligence to the products, resources and orders, via a holonic approach. To support the holons, ACE are used. They propose ambient services to the holons, like hosting, instantiation, or synchronization between I_holons and M_holons, using RFID technology.

This allows the improvement of the real time control of the production system, using multicriteria decision algorithms of AHP type.

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