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Mobile Agent PLM Architecture for extended enterprise

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Abstract

Nowadays manufacturers are under increased pressure to have an add value for their products to struggle the low-cost production in emerging countries. Distributed control and Intelligent Product are a new and exciting opportunity to build more effective process networks for a wide range of applications in logistics and product development, Radio Frequency Identification is applied increasingly; this technology applied in conjunction with the Mobile Agent system can bring more values in managing and control the lifecycle of products by optimizing the three essential factors: cost, quality and deadline for the survival of a company in the competitive manufacturing world. In this paper we propose Mobile Agent PLM Architecture for extended enterprise, based on Mobile Agent and RFID or, more generally, Product Embedded Information Devices (PEID), for tracking and managing the information of the whole product lifecycle in the extended enterprise, and to satisfy new requirements for increased integrability, traceability, adaptability, extendibility, and closed-loop PLM. Mobile Agents are suitable for tracking information in distributing environment and the mobility aspect, at any time and any place. This paper proposes a first architecture based on these technologies.

Keywords: *Intelligent product, PLM, closed-loop PLM, traceability, Mobile Agent, RFID.*

1. Introduction

The decentralized information context, the distributed decision-making authority, the integration of physical and informational aspects, and the cooperative relationship among product lifecycle management, make the Intelligent Product a new and interesting paradigm, with great potential for meeting today's agile manufacturing challenges. Critical issues to be investigated include how to define intelligent product for a given problem within a specific context, what should be the appropriate system architecture, how to design effective cooperation mechanisms for good system performance, inspired by what happen in nature with us as human beings and the way we develop intelligence and knowledge [1] . In this paper, a new approach based on Mobile Agent which manages and controls the Intelligent Product is proposed and developed for extended enterprise.

However, equally or more importantly, Auto ID systems provide the basic infrastructure for reconsideration and possible alterations of the product and agent product. This is based on the observation that a physical product connected to a network can potentially access and affect its own functions. That is, through this network connection, a product (or a set of products) can interact indirectly with those operations that they come in contact with. In order to convey any status changes in real time, the PLM mobile agent uses radio frequency identification (RFID) technology to transform the physical processes and statuses into information flow. Receiving data from RFID middleware, the system conveys all changes to corresponding mobile agents automatically. We refer in this document to such products being 'intelligent' in a loose sense; we also introduce the concept of an Intelligent Product and we consider its potential impact on the entire product lifecycle.

This paper is organized as follows; section 2 will analyze different proposals for defining Intelligent Products; a classification of intelligence will be also presented. Section 3 present related technologies (RFID and Mobile Agent). In Section 4, we present our proposed approach for Intelligent Product. Finally, Section 5 provides some concluding remarks and future work.

2. Intelligent Product: Background review

In this section, we give an overview on the concept of Intelligent Product by presenting the recent principal definitions in the literature. All these definitions focus on certain aspects of Intelligent Products and on certain application areas or parts of the product lifecycle.

According to the Oxford English Dictionary an intelligent device or machine is one which is" able to vary its behaviors in response to varying situations, requirements and post experience". McFarlane [2] defines an Intelligent Product- as a product whose information content is permanently bound to its material content and which is able to influence decisions made about it; McFarlane formalizes the concept of an intelligent product with the following working definition:

An intelligent product is a physical and information-based representation of a product which:

- Possesses a unique identification;
- Is capable of communicating effectively with its environment;
- Can retain or store data about itself;
- Deploys an adequate language to display its features, production requirements, etc.;
- Is able to participate in decisions relevant to its own destiny.

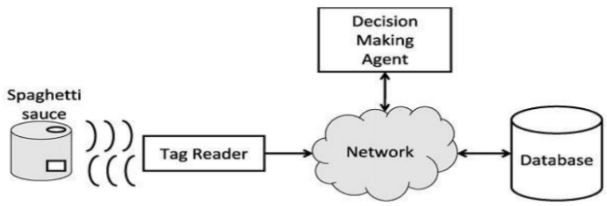

Fig. 1 Intelligent jar of spaghetti sauce [3].

Based on this definition, Wong and al. [3] have defined a two levels classification of intelligence. When the Intelligent Product only covers points 1–3, it is information oriented, and is called a product with level 1 product intelligence. A product with level 2 product intelligence covers all points, and is called decision oriented. Even though this Intelligent Product classification is quite generic concerning the level of intelligence of an Intelligent Product, it is based on a separation between the actual product and its information-based counterpart (as seen in Fig. 1). Therefore, it is mainly intended for describing the use of RFID technology in for example manufacturing and supply chain purposes, without covering for instance products with embedded processing and communication capabilities.

We also found in the literature another definition complementary to previous ones, given by Karkkainen and al.; the fundamental idea behind an Intelligent Product according to Karkkainen and al. [4] is the inside-out control of the supply chain deliverables and of products during their lifecycle. In other words, the individual products in the supply chain themselves are in control of where they are going, and how they should be handled. To move to inside-out control of products, the products should possess the following properties:

- Globally unique identification code;
- Links to information sources about the product across organizational borders, either included in the identification code itself or accessible by some look-up mechanism;
- Can communicate what needs to be done with them to information systems and users when needed (even pro-actively).

Another definition of Intelligent Products is given by Venta in [5]. Venta refers by intelligence to products and systems that:

- Continuously monitor their status and environment.
- React and adapt to environmental and operational conditions.
- Maintain optimal performance in variable circumstances, also in exception cases.
- Actively communicate with the user, environment or with other products and systems.

Based on these definitions, a novel three-dimensional classification of Intelligent Products is introduced [6], which covers all the main aspects of the field. This classification model is shown in Fig. 2.

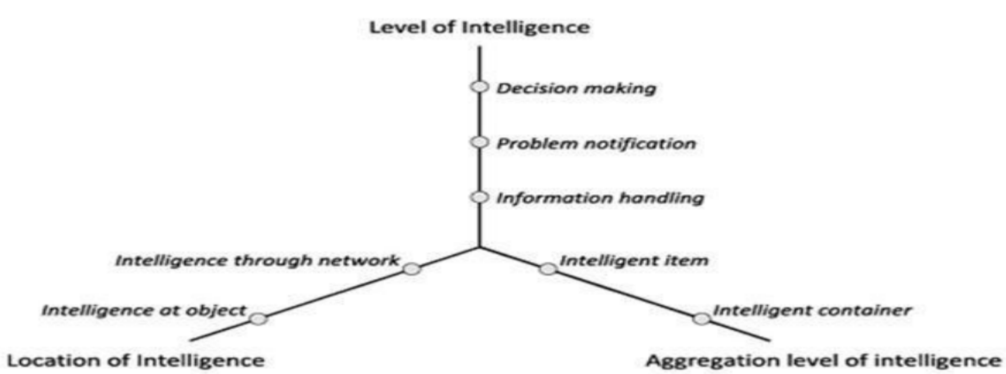

Fig. 2 Classification model of Intelligent Products [6]

3. Technologies enabling intelligent product

In this section we analyze the technologies behind Intelligent Products from two main points of view, the Mobile Agents technology and the Radio Frequency Identification.

3.1 Mobile Agent technology

Agents can be loosely defined as 'software that assist people on their behalf…and are delegated to perform task(s), and given constraints under which they can operate'.

In other term, in [7] Mobile agent is a kind of software. It is autonomous, and it migrates from one host to another in diverse network environments, and can be used in distributed architecture for the decision-making process [8]. It can transmit messages, distribute resources, and interact with other mobile agents or distributed resource systems. The mobile agent accepts tasks assigned by its owner, and then move onto the Internet to platforms that provide related services to carry out its task. When the work is complete, the mobile agent reports back to its owner. A mobile agent must have the following properties [9]:

(1) It should be able to achieve one or more goals automatically.
(2) It should be able to clone and propagate itself.
(3) It should be able to collaborate and communicate with other software and agents.
(4) It must have a scope of competence.
(5) It should have some evolution states to record the computation status.

However, agents come in a myriad of different types, usually depending on the nature of their environment. What has been needed in a classification scheme to distinguish between different types of agents?

This paper does not propose a further definition of what an agent is, but will adopt the Franklin and Graesser [10] classification scheme and categorize the agents dealt with here as goal-oriented, communicative, mobile agents.

Franklin and Graesser definitions are as follows:

- goal oriented agents - agents that do no simply act in response to the environment;
- communicative agents - those able to communicate with other agents;
- Mobile agents - those able to transport themselves from one host to another.

Our interest in mobile agents should not be motivated by the technology per se, but rather by the benefits they provide for the creation of distributed systems, such as extended enterprise in paper. So there are seven reasons to use mobile agents [12]:

(1) reduce network load;
(2) overcoming network latency;
(3) encapsulate protocols;
(4) asynchronously execution and autonomously;
(5) dynamic adaptation;
(6) naturally heterogeneous;
(7) robust and fault-tolerant.

Table 1 List of commonly used mobile agents [11]

name	***developer***	***Language***	***Application***
Agent Tcl	R. Gray, U Dart.	Tcl Tk	Information management
AgentSpace	Ichiro Sato, O. U.	Java	General purpose
AgentSpace	Alberto Sylva	Java	Support for dynamic and dist. Appl.
Aglet	IBM, Tokyo	Java	Internet
Ajanta	Minoseta U.	Java	General purpose
Ara	U Kaiserslautern	C/C++, Tcl, Java	Partially connected c. D.D.B.
Concordia	Mitsubishi E.I.T.	Java	Mobile computing, Data base
JATlite	Standford U.	Java	Information retrieval, Interface agent
Kafka	Fujitsu Lab. Japan	Java, UNIX-based	General purpose
Kali Scheme	NEC Research I.	Scheme	Distributed data mining, load balancing
Knowbots	CNRI	Python	Distributed systems/Internet
Messengers	UCI	C (Messenger-C)	General purpose
MOA	OpenGroup, UK	Java	General purpose
Mole	Stuttgart U. Germany	Java, UNIX-based	General purpose
OAA	SRI International, AI	C, C-Lisp, Java, VB	General purpose
Odyssey	General Magic	Telescript	Electronic commerce
Plangent	Toshiba Corporation	Java	Intelligent tasks
Tacoma	Norway & Cornell	C, UNIX-based,	Client/Server model issues/OS support
The Tube	David Halls, UK	Scheme	Remote execution of scheme
Voyager	ObjectSpace	Java	Support for agent systems

Various projects applied the Mobile Agent paradigm to add the values in manufacturing intelligent product:

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Holonic Manufacturing Systems (HMS) [13], in the manufacturing context, a Holonic Manufacturing System is seen as an autonomous and co-operative building block of a system for transforming, transporting, storing and/or validating information and physical objects.

Ubiquitous manufacturing, agent system paradigm to collaborative negotiation in a global manufacturing supply chain network [14].

Timon C. Du and al. in [15] propose a framework for using mobile agents to demonstrate autonomous behavior in the electronic marketplace.

Mobility and autonomy are keys characteristics when considering Mobile Agent technology as a component of intelligent product. This implies that agents can move around a network according to some itinerary. Various mobile agents systems (frameworks) support both mobility and itinerary, such as Aglet software development kit and framework. The Aglets software development kit conforms to the MASIF (Mobile Agent System Interoperability Facility) standard [16]. MASIF is a standard for mobile agent systems which has been adopted as an OMG technology.
Once created, an aglet object can be dispatched to and/or retracted from a remote host, deactivated and placed in secondary storage, then activated later(fig. 3).

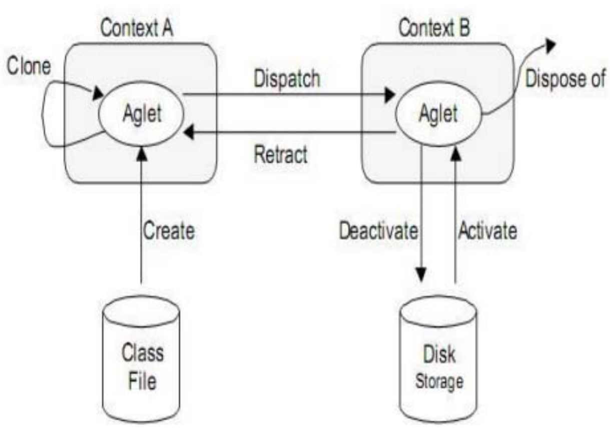

Fig. 3 Aglet Life-Cycle Model [15].

In the literature there are many available mobile agent systems (frameworks) for developing mobile agent. Table 1 summarizes the commonly used mobile agent systems for research and applications. Java Agent Development framework (JADE Framework) [17] is also used to develop agent applications in compliance with the Foundation for Intelligent Physical Agents (FIPA) specifications.

3.2 RFID technology

In this part we present Radio Frequency Identification (RFID) technology and its potential applications in industry. RFID technology offers wireless communication between RFID tags and readers with non line-of-sight readability. These fundamental properties eliminate manual data entry and introduce the potential for automated processes to increase project productivity, construction safety, and project cost efficiency.
RFID can increase the service and performance of the construction industry with applications in materials management, tracking of tools and equipment, automated equipment control, maintenance and service, document control, failure prevention, quality control, field operations, and construction safety.

The number of radio frequency identification (RFID) applications in different industries increases continuously. Cumulative sales of RFID tags up to the beginning of 2006 reached 2.4 billion. In 2005 alone, 600 million tags were sold, which presents the trend in RFID allocation [18]. While the initial RFID application areas were generally industrial, applications like retail sector, supply chain management, warehouse management, logistics, manufacturing, military applications, and service sector also present potential applications for RFID technologies [18]. Radio-Frequency Identification (RFID) technology is a wireless sensor technology which is based on the detection of electromagnetic signals. They operate with up to 1MB of memory and have longer reading ranges because of the internal power supply. Their operating power is obtained from the transceiver device. However, they have shorter reading ranges and require a higher-powered reader than active tags.

The RFID is an automatic identification technology, relying on storing and remotely retrieving data by using devices called RFID tags or transponders. RFID provides a contact-less data accessing solution. If a product is attached with RFID tag, then the tag information will be read by the RFID reader and feedback to the backend PLM mobile agent system. Thus, the manual data input can be eliminated. When a RFID reader detects a tag, the mobile agent will receive the tag content and the reader ID. Then, the agent will determine an event type and initiate a RFID event message.
An RFID system is constituted by:

- an RFID device (tag);
- a tag reader with an antenna and transceiver;
- and a host system or connection to an enterprise system (Fig. 4).

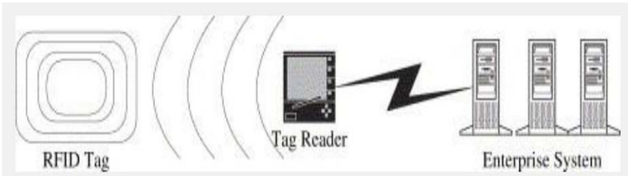

Fig. 4 A typical RFID system

Currently there is a considerable work being undertaken in the rationalization of frequency spectrum allocation between countries, development of standards and the introduction of many commercial applications. There are now over 350 patents registered with the US Patent Office related to RFID and its applications (Table 2).

Table 2 The decades of RFID [19]

Decade	***Event***
1940/1950	Radar refined and used major World War II development effort. RFID invented in 1948.
1950/1960	Early explorations of RFID technology, laboratory experiments.
1960/1970	Development of the theory of RFID. Start of application field trials.
1970/1980	Explosion of RFID development. Tests of RFID accelerate. Very early adopter implementations of RFID.
1980/1990	Commercial applications of RFID enter mainstream.
1990/2000	Emergence of standards. RFID widely deployed. RFID becomes a part of everyday life.

In contrast to the typical use of RFID technology today in warehouse management and supply chain applications, the paper proposes a Mobile AGENT PLM Architecture for extended enterprise, it combines Mobile Agent and RFID or, more generally, Product Embedded Information Devices (PEID), for tracking and managing the information of the whole product lifecycle in the extended enterprise, and to satisfy new requirements for increased integrability, traceability, adaptability, extendibility, and closed-loop PLM. Multi Mobile Agent and Radio Frequency Identification systems have been commonly recognized as enabling technologies for designing and implementing next generation of industrial control systems featuring.
After discussing the concepts of Intelligent Product and the technologies behind, the next section focus on our proposed approach, and its contribution in product lifecycle management.

4. Proposed approach

Currently, the manufacturing industry is moving more and more from a supplier-driven to a customer-driven market. Due to the growing industrial capacity, customers are provided with a greater choice, and competition between suppliers is increased. As a result, companies must shorten product life cycles, reduce time-to-market, increase product variety and instantly satisfy demand, while maintaining quality and reducing investment costs. This is a great challenge to the manufacturing process itself; it must be more flexible and robust as well as demonstrate enhanced scalability. Therefore, the ends for introducing the Intelligent Product concept in manufacturing are to improve production planning and control, to enable customized products and to make change-over between product variants more effective.

This section is focused on our proposed approach, which is based on the next postulate “the product is an actor who manages its evolution in cooperation with the various actors of the life cycle, equipped with Intelligent Data Unit using Radio Frequency Identification (RFID), and the Mobile Agent”. This approach combines the Mobile Agent and RFID technologies for overcoming the challenge described above.
The system architecture is shown in Fig. 5. In this architecture, the physical product is a material object, identified and characterized by the intrinsic information, such as geometric parameters. The Mobile Agent product is an artifact of the product represented by the information system, resources and decision-making mechanisms.
Our approach involves the mutation of the simple physical product to an ambient product or actor capable to communicate with the others players throughout its lifecycle with the property of having the ‘inside-out’ control. The main advantage of this architecture the flexibility provided to the enterprise. A mobile agent is an active object that has certain capability to perform tasks, and communicate with other agents in a given environments for cooperation. We use RFID-based product information management, to enabling item-level “track and trace”, and to complete, accurate, and timely information to support lifecycle decisions (LEVEL 1 INTELLIGENT PRODUCT), and we use the Mobile Agents, for enabling “active” decision-making capability (LEVEL 2 INTELLIGENT PRODUCT).

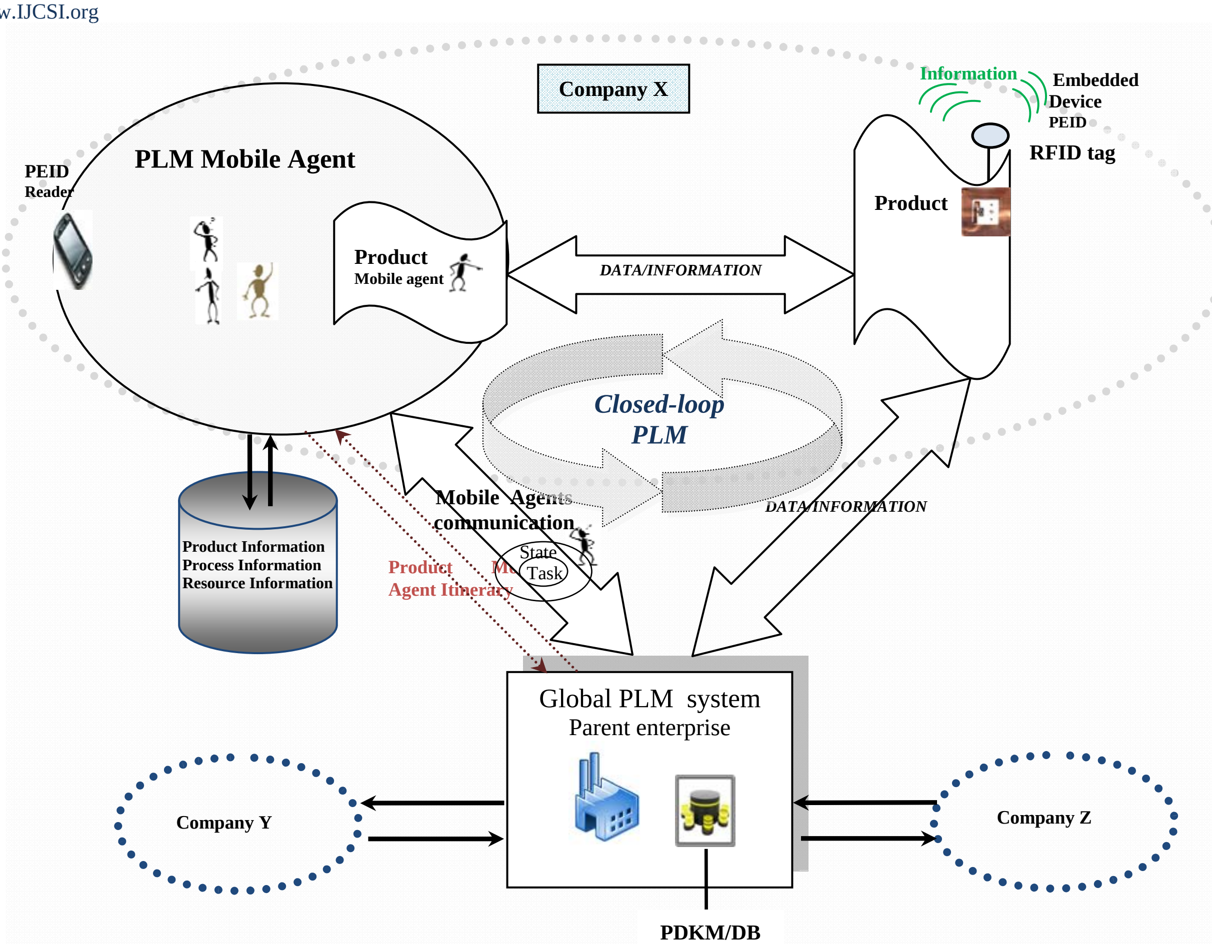

Fig. 5 Proposed architecture

PLM: Product Lifecycle Management
PEID: Product Embedded Information Devices
RFID: Radio Frequency Identification
PDKM/DB: Product Data Knowledge Management/Database

The complete architecture includes a Mobile Agent for each product. In our scenario, the main actor is the Product. It will be obviously consider as an active actor (RFID property, Mobile Agent party). But other Mobile Agents are acting in the same environment for cooperation. In the first second of our scenario, each Mobile Agent involved will have its unique identification (the same identification as product). These agents could easily act on behalf of the owner (e.g. responsible designer). When the product is delivered for company X to the parent enterprise, the corresponding Mobile Agent migrates to accompanying her counterparty physical Product, with the possible feedback to its environment in the real-time, when there is a change in the product information.

Therefore the proposed architecture makes possible the tracking and managing the information of the whole product lifecycle in extended enterprise, with an automatic feedback of information about all product lifecycle phases, to build the knowledge database, manage and re-use the information.

5. Conclusion and future works

In this paper we reviewed the concept, the definitions, the classification of intelligence, and practical ends of Intelligent Products. As discussed above, the Intelligent Products combines many disciplines and could be used in many ways. We proposed a new architecture based on the Mobile Agents and the Radio Frequency Identification (RFID), for tracking and managing the information of the whole product lifecycle in the extended enterprise, and to satisfy new requirements for increased integrability, traceability, adaptability, extendibility, and closed-loop Product Lifecycle Management.
The architecture proposed in this research is the first step for a generic, « intelligent », layer interface based on mobile agents and RFID technologies with existing

Product Lifecycle Management (PLM) systems. In the future work, we will model and implement the mobile agent architecture by using a framework. It must be able to communicate in real-time, and also able to interact with existing PLM systems and other information systems such as Enterprise Resource Planning (ERP), Advanced Planning and Scheduling (APS), Manufacturing Execution System (MES).

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