Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
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DAAAM Symposium

OUTLINE OF AN AUTONOMOUS CONTROL CONCEPT FOR CONTINUOUS FLOW PRODUCTION USING RFID AND AGENT-BASED SERVICES

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Abstract: *Next generation manufacturing systems will need to be able to adapt to prevalently changing conditions in order to remain cost effective and competitive. One promising approach to achieve this goal is to increase autonomy through software agents. Combined with RFID technology, agents form a powerful tool to enhance both existing and prospective manufacturing systems. This paper will propose an outline of an autonomous control concept using RFID technology and agent services with respect to continuous flow production.*
Key words: *e-manufacturing, agent-based services, continuous flow production, RFID, intelligent manufacturing systems*

1. INTRODUCTION

With globally increasing competition, frequently shifting markets and continuous emerging of new technologies, prospective manufacturing systems must be able to cope with these new conditions in order to remain competitive. Such manufacturing systems will need to integrate into heterogeneous software and hardware systems, allow seamless extensibility to accommodate new sub-systems, automatically adapt and reconfigure according to the product currently being worked on, cooperate with various departments within an enterprise and quickly react to unexpected faults or changes in order to minimize possible impacts on the working environment.

Agent technology provides a way to satisfy these requirements. Multi-agent systems enable the manufacturing system to become distributed and intelligent. For example, agents can be implemented to encapsulate manufacturing activities or wrap existing software systems in an open, distributed and intelligent environment. Additionally, agents can also be implemented to represent physical manufacturing resources like machines, robots and products.

Recently, agent technology has been considered as an important approach for developing industrial distributed systems. It has particularly been recognized as a promising paradigm for next generation manufacturing systems (Weiming et al., 2006).

2. AGENTS AND MULTI-AGENT SYSTEMS

An agent is typically a small, lightweight computer program that is able to achieve tasks autonomously in a dynamic environment. Such tasks can be achieved either by agents equipped with the appropriate individual capabilities or by efficient interaction among agents of different types that have complementary capabilities. Agents address autonomy and complexity as they are adaptive to changes, incorporate a certain level of intelligence and are distributed by nature. Interaction between agents could even be regarded as a kind of social activity (Monostori et al., 2006).

Even though different definitions from various authors exist, agents are generally defined by the following four characteristics (Wooldridge & Jennings, 1995):

- *Autonomy:* Functionality of an agent is independent from human-interaction or other agents. They are able to make their own decisions and are thus operating autonomously.
- *Social ability:* Agents may communicate with other agents or components using some kind of agent-communication language (ACL). They may even collaborate on a task.
- *Reactivity / intelligence:* Agents perceive their environment and respond appropriately to changes that occur in it. Some may even learn or use knowledge to achieve their goals.
- *Pro-activeness:* Agents do not simply act in response to their environment but are able to exhibit opportunistic, goal-directed behaviour by taking the initiative when appropriate.

Usually, not a single agent but multiple agents are used in an environment. Such an environment or system in which several agents communicate and interact with each other is called Multi-Agent System (MAS).

3. RADIO FREQUENCY IDENTIFICATION

Radio-frequency identification (RFID) is a generic term for technologies using radio waves for the identification of objects. The RFID system generally uses a reader and a tag component, where the tag comprises at least an integrated circuit and an antenna. In general, RFID is similar to barcode systems. However, the main difference is that barcodes use optical identification and must therefore be in direct line of sight with the reader whereas RFID tags must not. Additionally, RFID tags are resistant to various environmental influences like rain, snow, dirt, oil, paint, etc. It is possible to read up to hundreds of RFID tags simultaneously and even through objects. This does, however, depend on the type of RFID tag used.

RFID tags are typically characterized by features like frequency, power supply and the ability to store and/or process information (Treytl et al., 2006). Providing various configurations, tags can either be read-only or also be able to store custom data. Basically, there are two common types of RFID tags (PPC, 2006):

- **Passive:** Passive RFID tags are designed to be small and low cost. A passive tag only contains an antenna and circuitry that stores data, but no internal power source. Its power supply is detracted from the electro-magnetic energy field generated by the reader. However, this makes it suitable for short-range communication only.
- **Active:** Active RFID tags only use their own internal battery to send data. Their battery allows them to transmit data at a greater range (up to several hundred meters). Active tags are able to continuously broadcast signals. Depending on the configuration of the tag, they may also have a CPU and memory to store user-defined data.

In addition to passive and active RFID tags, there are also two hybrid forms: semi-passive and semi-active tags. Just like active tags, both types include an internal battery. However, semi-passive tags do not use this battery to send data to the reader. Energy needed for data transmission is still induced by the reader as it attempts to read the tag. On the other hand, semi-active tags use the battery for sending data, but they do not remain active all the time. Instead, they are switching into a sleeping-mode when not used. Compared to active tags, lower costs and longer battery life are motives for using these two types (PPC, 2006).

4. AGENTS AND RFID IN MANUFACTURING

Agents become increasingly important in manufacturing because they help to implement important characteristics such as autonomy, responsiveness, redundancy, distribution and openness. Many tasks related to manufacturing could be conducted by agents. Hence, combining agents with RFID tags on products is a natural progression which increases flexibility and scalability in production. Doing so allows each agent to autonomously react to various influences and configure production line parameters according to the particular product.

The architecture of PABADIS'PROMISE – a research project of the European Union – connects shopfloor level, Manufacturing Execution System (MES) and Enterprise Resource Planning (ERP) using agents. ERP is the level responsible for taking orders, which are then processed and executed at MES and shopfloor level. In PABADIS'PROMISE, a multi-agent system lies at the core of MES which generally consists of product agents and resource agents. Machines and devices of the MES are represented by resource agents, which in turn provide services to product agents. Product agents are the intelligence of the system. They execute orders and decide on how to reach their goals best (PPC, 2006).

Agents on RFID tags could be implemented in the following four ways (Treytl et al., 2006):

4.1 Product Identification Tag

A simple Product Identification Tag (PIT) is the most cost effective approach as it uses a passive RFID tag that only provides a unique identification number. Using this ID, the associated product agent that handles further operations is loaded from the network at each step of the production line.

There are a few drawbacks, though: With passive tags, communication range is limited (about one meter) and storage for custom data is usually not available. Therefore, agent code and product data always have to be loaded from the network.

4.2 Product Data Tag

The Product Data Tag (PDT) is a slight enhancement to the PIT. It does not only carry an ID but also stores order and other product specific data. Depending on the storage capacity required, passive or active RFID tags could be used. It must be noted that active tags and increasing memory will make this approach more expensive than the first one, though. The agent itself, however, still needs to be loaded from the network.

4.3 Product and Agent Tag

Another approach called Product and Agent Tag (PAT) contains ID, product data and agent code. Although the tag stores the agent code, it is not able to execute it. This means that the agent will remain inactive most of the time and cannot process or monitor production tasks. Agent code will only execute once loaded by a machine. However, this approach allows self-contained execution as no additional data is required from the network.

4.4 Product and Agent Host Tag

Product and Agent Host Tag (PAHT) is the most expensive approach. Its huge advantage is that it allows direct execution of agent code. This represents the most ideal implementation of the agent concept as the agent will always run regardless of its current location and is tightly coupled with the product. Thus, it can communicate with other agents and monitor progress constantly, enabling it to react to certain conditions. However, this can only be achieved by active RFID tags capable of processing data. Due to the high costs involved with these tags this solution is not suitable for continuous flow production.

5. CONCLUSION

In continuous flow production, cost effectiveness is essential as large amounts of products have to be considered. Thus, given the four previously introduced ways of implementing agents on RFID tags, only PIT seems appropriate for continuous flow production from an economical perspective, although PDT and PAT could also be used under certain circumstances. Nevertheless, the concept provided here will only take PIT into account.

This concept describes a multi-agent system distributed across MES. Its purpose is to allow autonomous control of manufacturing systems by reducing complexity and decentralizing intelligence in dispersed agents. Basically, the concept makes use of two types of agents: resource agents and order agents. Resource agents are tightly coupled with production hardware. Each machine is represented by a resource agent who controls machine parameters and provides certain services like other agents. Order agents represent active orders from the ERP system. These agents are the core component of the system and incorporate the business logic required to complete the order. It is important to understand that order agents are slightly different from the product agents used in PADABIS'PROMISE. Instead of creating an agent per product, there is only a single agent per order. The reason for this change was to decrease the overall amount of agents in the system. In order to allow easier integration in existing manufacturing infrastructures, agents are implemented using intranet web service technology. Additionally, the concept includes various other information services (e.g. indexing and database services) whose purpose is to supply agents with data.

Every order from ERP consists of a certain number of parts, each identifiable by a unique ID on a passive RFID tag (PIT). By creating a new order, a new order agent is also instantiated. It remains on the agent pool service until activated the very first time. Activation happens as soon as a machine reads a tag whose ID belongs to an inactive order agent. From this moment onwards, the agent handles operation for this and all succeeding parts also belonging to that order. It calculates schedules and resources, sets machine parameters and organizes transportation. Of course, further research still has to be done regarding the concrete implementation details of the system.

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