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Interoperability for a dynamic assembly system

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Abstract

There are many challenges for the manufacturing industry when building and maintaining interoperable information systems. Automation and related information systems are often implemented in controlled and secure environments that lead to autonomous disconnected islands. This study presents two innovative solutions that exemplify both horizontal and vertical systems integration. The solutions have been implemented and tested on a flexible and mobile assembly system with equipment from different suppliers.

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1. Introduction

Manual work tasks are common in assembly systems today. It is also the recommended approach for assembly systems with high product variety [1]. Automated assembly systems to exist and they are often highly specialized equipment designed for high throughput and volume. Desired characteristics for flexible assembly systems are mobility and the ability to quickly change automation levels [2]. Totally manual work relies on human skill and flexibility but generic automation solutions require easy to use interfaces together with highly knowledgeable operators. Human robot collaboration is an example of dynamic automation that could increase productivity without reducing the flexibility.

Dynamic assembly systems add new requirements on the information systems that serve humans and equipment. Equipment diversity or heterogeneity requires common standards of both communication and implementation. Mobility means a more distributed system with requirements on communication protocols and infrastructure. The automation implementations, together with its operator, will need to be self-reliant and with decentralized decision-making. Future dynamic assembly systems is therefore a good example of heterogenetic highly distributed systems of components with high autonomy, concepts that all complicates systems integration [3]. Interoperability, which is the possibility of a systems components to interact, is also a key design principle for future smart manufacturing systems [4]. New technologies like Internet of Things and Cloud computing paradigms are supposedly going to solve many interoperability issues for future systems. This will not happen automatically and there is a need to understand what the current state is and what can technically be done today.

Through a lab experiment a dynamic assembly system of three mobile workstations have been designed and implemented. A chosen constraint of the system was that the workstations have to use equipment from different suppliers. The product that is assembled is chosen because it is a medium volume product that would benefit from a more automated assembly but it would be too expensive to build a totally automatic system. This study describes and discusses the process and results of designing and implementing the information system for this assembly system. Two innovative solutions have been implemented and will be described in more detail.

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Fig. 1. The product is the coupling part of a quick connection for pneumatic applications. Workstation 3 does the final assembly and Workstation 1 and 2 do part assemblies.

2. The project

One goal of the research project MOTION is to show that it is possible to build dynamic and mobile automation solution with products and solutions from different suppliers and integrators. The purpose is to achieve a flexible and efficient assembly system. The project utilizes research-integrated education by incorporating system implementation with the learning objectives of a course for third year students of the mechatronics bachelor program at Chalmers University of Technology in Gothenburg. The product to assemble is the coupling part of a quick connection for pneumatic applications (Fig. 1) produced by CEJN AB. It is a relatively complex product and CEJN wants to reduce the cost for assembling it, however the volumes are not high enough to allow for expensive purpose build equipment.

Today the coupling is assembled on a shop floor with functional setup of ten separate stations. The final assembly system consists of three mobile workstations, two for part assemblies and one for the final assembly. Two of the workstations utilize robots from Universal Robots that are approved for an open environment. The details behind this choice and results of human robot evaluations are further described in [5].

3. Technologies

This chapter will shortly explain important concepts and technologies that the results are based on.

3.1. OPC UA

Vertical integration, or communication between enterprise level and the field level networks, requires interfaces and standards between these levels to be aligned. This has been a problem for manufacturing companies since these two domains have very different requirements [6]. The Open Platform Communication Unified Architecture is a protocol for Machine to Machine (M2M) communication that was designed for interoperability between different platforms and systems [7]. One reason for this is because it scale well with support for both small simple devices through the binary type protocol and more advanced implementations through HTTP/XML type protocol [8]. Any embedded system that support OPC UA can act as a server that exposes chosen values that can be read by clients. The clients may then be a server on it’s own and extend the client-server tree.

3.2. RFID

RFID could be said to be a forerunner for IoT. The IoT paradigm converge three different visions: things-, internet- and semantic-oriented [9]. In industrial applications the things-oriented vision was adopted early through RFID technology [10]. RFID allows for easy identification of tagged objects and combined with SOA close in on the IoT vision of seamless communication [11]. The RFID communication has been extensively formalized by ISO/IEC standards. A RFID system consists of readers and tags and they can operate on different set frequencies. RFID tags can often hold more information other than its identification number. This can be used for decentralized information during production or as a way to improve products unique information over its full life cycle. It allows for a decentralized information storage approach.

3.3. Automation ML

Automation Markup Language (AML) is a standard to support and align information regarding design of automation solutions [12]. Developed by several different German automation companies and research institutes it aims to increase interoperability between different engineering tools. It has five different features: Object identification, class libraries, role class libraries, system unit classes and instance hierarchies. An editor for the Windows platform can be downloaded to simplify the development of AML files.

3.4. Web service

A web page provides both data and graphical interface, via HTML, to a visitor. A web service can also act as a web page but resources can also be represented in other ways. In accessing a web service that follows the REST (REpresentational State Transfer) architecture it is easy to find the correct resource when knowing the identification and service structure [13].

3.5. Raspberry Pi

The Raspberry Pi is a computer that resulted from the idea that future computer scientists should have a simple machine to learn the basics on [14]. Since it is small, cheap and nowadays has a large user community, it is very useful for DIY hacks. It has easy access I/O pins and there are many add-on boards for various implementations. Since this product aims at end-consumers information is freely shared in the community and most projects are open source.

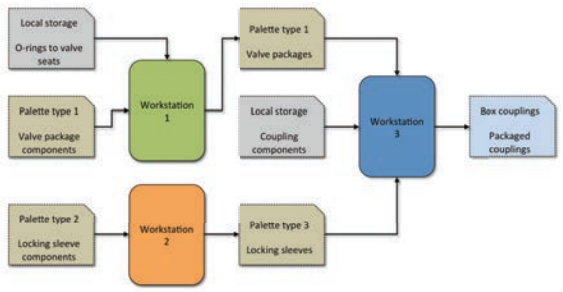

Fig. 2. Assembly system.

4. Results

This chapter describes the outcome of the planning and implementation during the MOTION project regarding information and communication with focus on the more innovative solutions with scientific value.

4.1. System overview

An early decision of the project was that we wanted to go for a palette system with RFID tags on each palette. The tags should contain information about what type it is and how many components or parts it carries. As mentioned above the new assembly system consists of three mobile workstations. Fig. 2 shows the overall workstation layout including the palettes. Since mobility is important, a wireless network connects them together but there are wired IP-networks within each station. Each station has a tablet connected to the Internet. Separate from the workstations an HMI is used for monitoring the production flow and it utilizes OPC UA protocol.

One chosen constraint of this project is that the workstations have to utilize equipment like programmable logic controller (PLC) and human machine interface (HMI) from different suppliers. These constraints complicate the implementation phase since the chosen equipment utilizes different development platforms that make code reuse more difficult (Table 1). One thing that needed to be implemented on all three workstations was the communication with the RFID reader. After realizing that there was no one implementation that would fit both platforms, a different solution was tested. The new solution utilizes the Raspberry Pi computer for the RFID management.

Table 1. Equipment suppliers and their development platforms.

Station	Supplier	Platform HMI	Platform PLC
1:1, 1:2, 3	Beijer Electronics	IX HMI	CODESYS
2	B&R	Automation Studio	Automation Studio

There are two sets of information in that are needed for the assembly operators in this system. First are work instructions and second are instructions and management regarding the machines and equipment. Work instructions are distributed as simple documents to the tablets at each workstation. Regarding machine management information a web service was developed that enables information in Automation ML to be utilized at an operational level.

4.2. RFID solution

The RFID solution includes one Raspberry Pi at each workstation instead of the PLCs from each supplier. Two problems had to be solved for the system to work. First problem was the actual reading and writing to the RFID tags and the second problem was how the Raspberry Pis were going to communicate with the other equipment. For the first problem the MIFARE reader RC522 [15] was used. Several projects can be found on the forums including this reader and a Raspberry Pi computer. One of these projects [16] was utilized but further development was necessary in order to get the needed functionality.

The second problem regarding the communication with other equipment was easier to solve. There is a python implementation of OPC UA [17] that was utilized and combined with the RFID code. The final solution provides tags over OPC UA that can be used to trigger reads and writes of the currently active tag. Fig. 3 shows the setup without any covers.

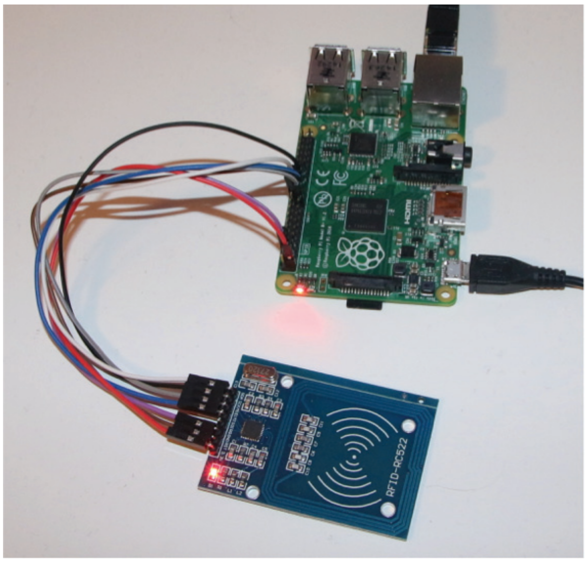

Fig. 3. A Raspberry Pi with the MFRC522 board.

4.3. Web service for equipment management

A web service was developed using the Play Framework [18], which is RESTful by default. It also provides a powerful template platform to create dynamic web pages. These pages are a useful interface for the users that are everyone working with the equipment like operators, technicians, or managers. It connects information such as text, pictures and movies to object imported from the AML structure. Two types of information are supported, instructions and issues. The issue handling also connects to users so that issues can be assigned to different individuals. New issues or instructions are easily created and attached to desired object. The objects are found by navigate through the hierarchy. Since AML utilizes unique ids it is possible to change the structure completely in the AML file, upload it again, and the hierarchy will be changed but without loosing any other information.

5. Discussion

The diversity of communication protocols and equipment for this relatively small system can be seen in Fig. 4. OPC UA is useful and enables vertical integration, it should not be overlooked if supported [19]. However only the high level controllers supported OPC UA even if the protocol can be embedded into very simple sensors and actuators. The implementation would probably have been easier and better if more of the hardware supported the OPC UA architecture.

The RFID implementation utilizing Raspberry Pi and OPC UA was successful. The end result is not as stable as a traditional solution and the hardware is not designed for harsh environment. However it is a working proof-of-concept and it shows that open source community software and standardization allows for low cost solutions that are easy to implement.

Utilizing a structured tool such as Automation ML during the implementation phase is not only useful during the automation design, it does also provide a tool directly useful for other implementations such as web services. If production systems development tools can be directly utilized in operational work the communication between these different functions could improve, which is an increase of horizontal interoperability. In this case it was only the hierarchical structure from AML that was used but there is definitely a huge potential to explore.

6. Conclusions

Within the research project MOTION a flexible assembly system consisting of mobile workstations has been developed. The process of implementing an information and communication platform for this assembly system have been described and discussed. Two innovative solutions have been presented that enable vertical and horizontal integration.

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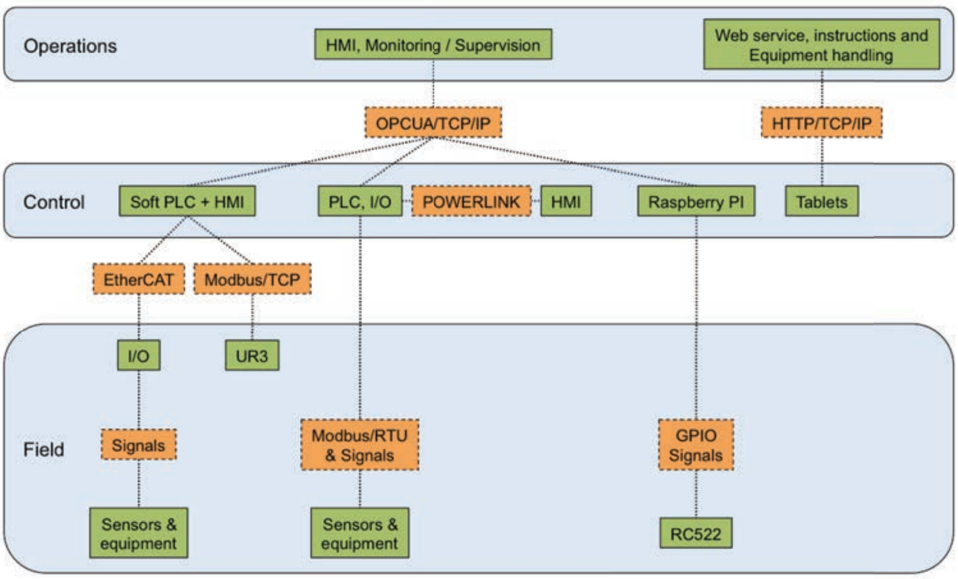

Fig. 4. System overview with equipment and communication protocols.

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