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The Potential of RFID for Moveable Asset Management

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Abstract
Moveable asset management is still not appropriately supported by existing IT systems. Items are not managed individually, information about location, status and usage is not accurate or lacking. This can cause delays in industrial operations, inefficient use or excess inventory of costly assets, and even lead to damages or accidents. We propose RFID technology as the key to link the necessary data directly with the physical asset. Assets become able to manage themselves, which eliminates many manually tasks, like searching for assets, inspecting for damages or counting them. The article demonstrates the potential of RFID based asset management solutions using the example of tool management in aircraft maintenance. The example includes the smart toolbox and smart tool inventory application as an implemented solution.

1. Introduction

The management of moveable assets is still a major challenge in the industrial environment. Examples for such assets are vehicles, containers, or tools. The goal of moveable asset management is to make assets available when needed and ensure their efficient use. For this reason asset management encompasses activities like locating assets, tracking their usage and ensuring their maintenance. From our daily life we might have experience about how much time we are spending on searching for personal belongings. This problem is much more complex for companies that are dependent on many different kinds of assets that are often used on a shared basis. Workers are wasting much time in searching for assets, which results in increased process costs. For example, if the right container is not available, parts for the assembly cannot be transported to the line and production schedules might be delayed. Improper maintained tools can cause damage or even lead to accidents.

For these reasons companies use asset management systems for such critical assets. Existing standard business software, like ERP-systems, increasingly tend to supports asset management. Good asset management systems should be able to

- manage assets individually,
- allow to locate the right assets,
- provide information about the current physical status (quality) of an asset, and
- keep an information history of an asset.

Typical drawbacks of today's asset management systems are the failure to appropriately support these tasks and a missing direct integration of physical assets with the IT-system. They only manage the number of assets in stock and cannot manage items individually, and they are not designed to store enough related data with an asset, for example, usage data or status information. This results in manual data capturing, which is expensive and error prone. One common practice is to keep safety stocks of critical assets, which is an inefficient and costly solution.

In this paper we want to show that Radio Frequency Identification (RFID) technology [1] bears the potential to overcome these drawbacks. To demonstrate how RFID can improve the management of moveable assets (see Section 2) we developed two demonstrators for the tool management in the business of aircraft maintenance. (see Section 3). It has become common practice in the research area of Ubiquitous Computing to use demonstrators for showing the potentials of the technologies. Examples for institutions that are performing and presenting research in this way are Accenture [2], the Auto-ID center at MIT [3], HP [4], IBM [5], TeCo [6] and the M-Lab [7]. Section 4 closes with a summary about the benefits and challenges in the adoption of the technology. It also provides a prospective how the impact of ubicomp technology on moveable asset management may develop in the future.

2. RFID Enhanced Asset Management

RFID is one of the major technologies that are frequently discussed in the area of Ubiquitous Computing [8]. As shown in Fig. 1, this technology can be seen as the next evolutionary step in automatic identification (Auto-ID) technology. It integrates the digital and the physical world by seamlessly connecting objects in the physical world with their representations in information systems [9]. The avoidance of media breaks bears the potential to improve the efficiency of business processes through automation that leads to reduced cost since less human intervention is required, human errors are eliminated and laborious manual data gathering is avoided. More efficient processes and new services will be the result. [10].

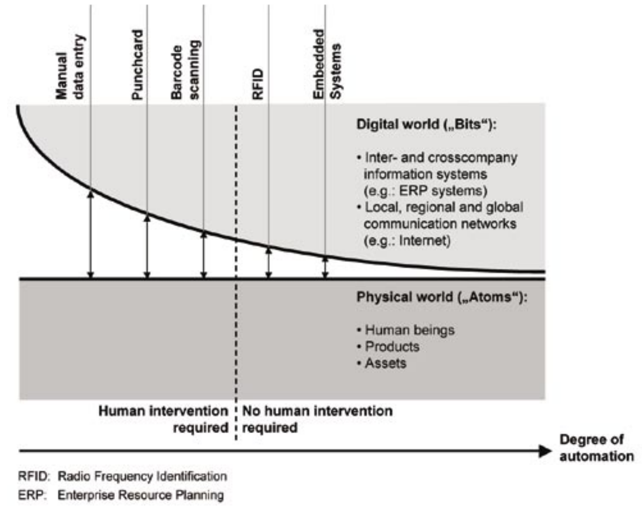

Fig. 1: The media break between the physical and the digital world [9]

According to the definition of smart objects [11, 12], smart assets have a unique ID, may use sensors, have a memory and are able to communicate. Using these features they are able to meet the requirements for good asset management systems that were stated in the previous section. An attached RFID chip makes it is possible to identify and manage smart assets individually. With an infrastructure of reading devices in place they can be tracked and localized. Sensor enhanced RFID devices enable them to monitor their physical context (awareness) such as temperature or moisture. The memory of smart assets can be used to store history information that can be requested later (e.g. about usage). As a result most tasks in asset management, like identification, tracking, monitoring can be done automatically. From a users point of view the smart assets seem to manage themselves. Decisions that affect the asset can be made on the object itself. Information technology that indeed is empowered by a ubiquitous computing infrastructure is directly linked to the movable assets.

On top of the more efficient asset management, additional services around asset management can be created by using this infrastructure [13]: The ability to many moveable assets anywhere and anytime facilitates the outsourcing of asset management to logistics service providers. Accurate information about usage enables pay per use-models that also support this trend. Providing information about status and location of assets can also be seen as independent services (e.g. track & trace).

The following examples show how some companies are using RFID to enhance asset management:

- Scottish Courage had to face 3-5 % shrinkage of their aluminum kegs per year. To solve this problem the brewery decided to use the RFID-technology to individually identify their kegs and to track to what customers they are lend out. The system enabled the brewery to get their asset back or claim for refund [14]. Later the brwery decided to outsource the management of their beer kegs to the company Trenstar, who adopted the system and introduced a pay per use model to bill for their service.
- A gas dealer attached RFID tags to his gas bottles that store the basic weight, the type of gas and the filling date. As empty gas bottles have different weights, knowing the base weight of a gas bottle makes it easy to determine exactly how many gas needs to be refilled [15].
- Nortel Networks uses expensive test equipment, which needs to be accessed by many engineers. To avoid searching for the equipment, Nortel implemented a RFID based local positioning solution. Since Nortel has introduced the system most devices can be found in less than five minutes [16].

3. Smart Solutions for Aircraft Maintenance

Section 3.1 describes the problems that arise in tool management in the aircraft maintenance business. For the execution of MRO (Maintenance, Repair and Overhaul) of aircrafts, many requirements by law regarding quality, safety and documentation exist, which leads to extensively standardized processes within the industry (see e.g. ATA iSpec 2200). The presented problems are therefore similar throughout the aircraft maintenance industry. The solutions that are presented in Section 3.2 are based on the concept of RFID enabled smart assets and were developed by the M-Lab in cooperation with a major company from the aircraft industry[1] and SAP SI.

3.1 Challenges in the Tool Management in Aircraft Maintenance

Each mechanic in the aircraft maintenance company is assigned to a personal toolbox that contains the most often used tools. The mechanic is personally liable for the tools, for example, in case of loss he or she needs to pay for the tools. The mechanic is also liable for any damage that is caused by a tool, which was forgotten in an airplane after a maintenance task. The following processes could be identified as labor intensive and cumbersome tasks for the mechanics:

[1] The Project was carried out at FairchildDornier, Oberpfaffenhofen, Germany

- *Marking process.* Tools in a new toolbox are marked by engraving the identification number of the toolbox. This task is done manually and can take up to two days. Since the marking fades it needs to be replaced every two years depending on the usage even earlier.
- *Routine completeness check process.* After each maintenance task the mechanic is requires to check the completeness and correctness of the toolbox, this means, the mechanic needs to check that all tools are in the box and that all the identification numbers on the tools that were put back are equal to the identification number of his or her box.
- Base completeness check process. Once a week each mechanic has to perform a cross check of his or her toolbox together with a colleague, which can take several hours. Both completeness and correctness of all tools has to be checked. A tool list acts as a written protocol to facilitate the check and needs to be signed after completion.
- *Lookup process.* If a tool is missing after a maintenance task the aircraft in question needs to be searched until the tool is found. In the worst case this can lead to a delayed delivery of the aircraft to the customer, which results in costly penalties.

Special tools, which are not included in the toolbox, can be checked out from a central tool inventory. The tools are stored in automated shelves and a service operator is taking requests for tools. Every mechanic can have up to 10 tools checked out the same time. To ensure this limit a tool is handed out only in exchange for a metal token that has the personal identification number of the mechanic inscribed. The following three processes describe the tasks of the operator:

- *Checkout process.* If a mechanic requests a tool it is handed out to the mechanic in exchange for a metal token. If the tool is not on its shelf position the operator should find a metallic token instead which shows who has lent out the tool.
- *Return process.* In exchange for the returned tools the mechanic gets the metal tokens back. The service operator receives the tool and puts it back into the respective shelf position. Often tools are returned late and are not available to other mechanics since there is no accessible information about the tools the mechanics have checked out.
- *Lookup process.* Often a mechanic only knows the number of tools he or she checked out. If a mechanic wants to know the checked out tools, the service operator must search for the tokens of the mechanic on all shelves. This lookup process can take up to three hours.

Concluding, the weaknesses in these processes are based on missing documentation of checkouts and human errors. This leads to searching for tools that are checked out, misplaced tokens, exchanged tools, forgotten completeness checks and time consuming tool marking. The smart toolbox and the smart tool inventory that are described in the following sections address these weaknesses.

3.2 The Smart Toolbox

The Smart Toolbox was introduced in [17] in the context of the Smart Box Concept. We implemented the Smart Toolbox (see Fig. 2) to demonstrate the concept of automatic and unobtrusive content monitor using RFID technology. RFID tags are attached to all tools and the boxes are equipped with RFID readers and antennas. The identification of the toolbox in addition to the identification of the tool is written on each RFID tag, this means, the toolbox can uniquely identify all tools that are in the toolbox at any required moment and automatically perform the routine and base completeness check. To check for completeness, this is done by comparing all identifications on the tools with a list of identifications of tools that should be in the toolbox to check for completeness. By comparing all toolbox identifications on the tools with its own identification the toolbox can automatically check for correctness. The smart toolbox operates autonomously and sends data about tool usage and checks wirelessly to the tool management system.

The state of the toolbox is visualized (see Fig. 2) in two ways corresponding to the two conditions: (a) Missing tools are shown by empty spaces, and (b) tools that belong to a different toolbox are highlighted with a special indicator. The mechanic easily recognizes if a tool was forgotten in an airplane or if tools were mixed up between different mechanics. He can take the appropriate actions right after he finishes a maintenance task avoiding or reducing the lookup process.

Fig. 2: Setup and screenshot of the Smart Toolbox demonstrator

It is important to emphasize that the way the mechanic handles the tools and the toolbox does not change by introducing the smart toolbox application. The automatic monitoring happens unobtrusively relieving the mechanic of annoying checking procedures. In addition, the smart toolbox identifies the mechanic who interacts with the box by detecting the RFID badge of the mechanic. If he is not the owner of the box a warning will be displayed to help avoid mixing up of tools in advance. Another additional benefit is the usage history of the tools that is inferred by keeping the times a mechanic takes out a tool and puts it back in. The time until the next maintenance or exchange of a tool can be visualized by combining the usage history with the expected lifetime or maintenance frequency of a tool. This usage history also allows optimizing the content of the toolbox, this means, tools that are used infrequently can be removed from the toolbox and placed in the tool inventory.

Instead of manually marking the tools the toolbox can initially write its identification on the RFID tag of all tools in the box. However, this requires RFID tags attached to the tools. This is done ideally during the manufacturing process of the tools, which is a non-trivial task and requires a high knowledge of tool manufacturing and RFID technology.

A real world implementation of the smart toolbox faces the following challenges: (a) Most of the tools are made out of metal, which require specialized RFID hardware (e.g. low frequency systems or ferrit coated tags), (b) the toolbox itself is made out of metal, which can be solved by placing RFID antennas in each drawer of the toolbox, and (c) some of the tools have a small size, which make it difficult to attach a RFID tag.

3.3 The Smart Tool Inventory

Similar to the smart toolbox, RFID tags are attached to all tools in the tool inventory and a RFID reader and antenna is placed in the checkout counter of the tool inventory (see No. 1 in Fig. 3). The RFID hardware allows to uniquely identify tools that are placed on the checkout counter. In addition to the tools, each mechanic can be identified using the security badge, which is also based on RFID technology.

The implementation consists of two parts, (a) the RFID client application that handles the identification of the tools and mechanics, and manages the checkout and return process, and (b) the Web application that allows the service operator to access information about the checkout state of tools, this means, the lookup process can be performed in seconds using the Web application. The RFID client application is connected via the intranet to the tool management system. In this case, the tool management system is part of an SAP R/3 system and the connection is done using the Business Connector interface of the SAP system. The data to and from the client application is sent as XML messages.

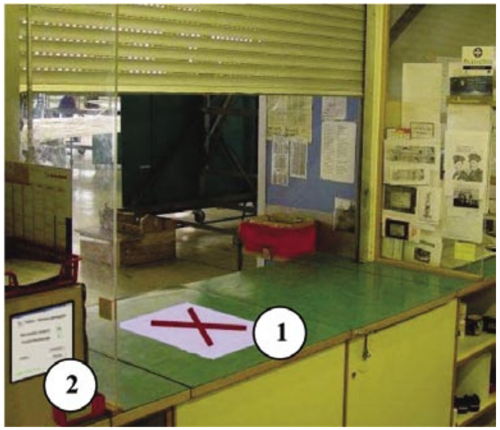

Fig. 3: Smart Tool Inventory setting with RFID reader and antenna (No. 1) and display (No. 2)

It is important to highlight that the checkout and return processes do not get more complex using the smart tool inventory application. In contrary, since the metal tokens can be omitted the process is optimized. No explicit user interaction with the system by the service operator is needed, since the tools trigger all processes: If a tool is placed on the counter, its identification is checked in the tool management system. If the tool is currently checked out a return process is initiated and the identified tools are marked as returned in the tool management system, otherwise a checkout process is initiated where the tools are marked as checked out by the identified mechanic in the tool management system. To avoid missing tools due to RFID errors, a visual feedback about the process is given to the service operator (see No. 2 in Fig. 3).
In addition to the current state of a tool the history of checkout and return processes is stored. This allows detailed statistics of tool usage and can lead to an optimized tool inventory.

The implementation of the smart toolbox faces the following challenges: (a) Most of the tools are made out of metal, which can be solved using specialized RFID hardware, (b) the RFID tags need to be attached to the tools. As in the previous smart toolbox application, this should be done during the manufacturing process of the tools.

4. Conclusion

In this paper we have shown that RFID technology has a high potential to improve moveable asset management in several ways based on automatic and unique identification. The following benefits are the result of avoidance of media breaks by automating or reducing manual tasks: (a) identification of the right assets (b) locating of assets (c) monitoring the quality or state of assets, and (d) keeping the history of assets.

There are still several challenges to overcome when using RFID to enable smart assets. First the technology has some major drawbacks as long as it is used in metallic environments. These problems can be solve using specialized RFID systems, however engineering know how is needed in addition to IT know how. Second there is a lack of standards in product identification. A concept for a ubiquitous Auto-ID infrastructure is currently developed by the Auto-ID center at MIT. This concept not only focuses on the numbering schema but also on technical aspects like frequency and middleware aspects. This will also help to address the third challenge, that traditional ERP-systems are not ready to manage all those assets individually. ERP-vendors like SAP are also supporting the Auto-ID center and working on smart items infrastructures.

In addition to the improved asset management, innovative services can be created by using this infrastructure: (a) outsourcing of asset management to logistics service providers, (b) pay per use-models, or (c) realtime information about status and location of assets. More research needs to be done in refining the solutions and developing scenarios that are using Ubiquitous Computing technologies beyond RFID. In order to fully implement the vision of smart assets sensor technology can be incorporated.

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