Smart Wheel Loader Based on RFID and Positioning Technologies

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Abstract—**In this study we introduce our experiments from smart wheeled transporters where RFID and positioning technologies have been applied. Indoor applications include a forklift truck in a warehouse of a shopping centre and a mobile robot developed for laboratory tests. The smart wheel loader is an outdoor application where RFID and GPS technologies have been integrated in positioning using location aware platform. Our location aware architecture enables the use of geographic information system data in mobile devices and can deal with information coming from local sensors, and which can be used in different kind of environments and indoor and outdoor conditions.**

Keywords: RFID; smart systems; industrial applications; location-aware systems; positioning;

I. Introduction

Wheeled transporters such as forklift trucks and wheel loaders are key elements of material handling and transport in warehouses and factories. These material handling and transport operations are often integrated to information systems of the company. However, data entry has to be done manually, which increases possibility of errors. Bar code readers and data collecting devices are used to automate data entry of material handling operations but still the operator usually has to leave his transporter to scan barcode labels. This can be a time-consuming process that slows down loading or unloading process, thereby decreasing the number of pallets that can be moved and increasing the amount of labour required. In harsh industrial environments barcode labels often become unreadable. Radio frequency identification (RFID) and positioning technologies give possibility to build smarter transporters which help the operator and decreases mistakes in data input.

Over one billion RFID tags were sold worldwide in 2006 according to European Commission [1] and by 2016 it might be over 500 times this number. The European markets in these estimations will grow from €500 million to €7 billion by 2016. Tags are already relatively cheap and usable not only in an effective automatic identification of objects, humans, and other species but also locations, and increasingly mobile services and media content. Industrial applications of RFID technology are currently more and more interesting research and development issue [2].

II. Related Work

There have been many research and development projects where RFID technology has been integrated either indoor or outdoor mobile robot applications. For example MIT's Auto-ID Lab has presented LibBot, a robot equipped with an RFID reader, that automates the otherwise automated shelf-reading process and finds misplaced books autonomously [3]. Japanese and Korean research institutes AIST and ETRI has made cooperation to develop methods for RFID-enabled tracking and following a target moving unpredictably with mobile robot [4].

In last few years there have been some research and development projects to utilize RFID technology in forklift trucks. Many warehouses employ currently bar-coding solutions to help ensure that correct pallets are moved. In these solutions usually the operator manually scans bar codes located on pallets and shelves. This can be a time-consuming process that slows down loading or unloading process. RFID technology together with location aware technologies can greatly increase productivity, accuracy and efficiency in warehousing and material handling. The Institute of Transport and Automation Technology in University of Hannover has been developing RFID equipped forklift trucks with a consortium in Identprolog project [5, 6]. They have presented also some solutions for the obvious problems in industrial environments, such as magnetic disturbances in metallic environments, mechanical strains, reader collision problems and economic aspects. Some vendors have already launched RFID equipped forklifts into market [7, 8, 9] while others have recently started to offer customers possibility to retrofit existing forklift trucks smarter with RFID technology [10]. Even if there are nowadays some RFID equipped forklift trucks available, they can not be considered as general purpose equipment but they need usually tailoring in every case.

We have studied in RFMedia Laboratory RFID and WSN (Wireless sensor network) technology earlier in many cases both indoor and outdoor conditions [11, 12, 13]. Our research applications have included mobile robots and work machines. Location aware technology has been used earlier for example for route visualizations, collaborative communication techniques and selecting locations [13, 14, 15].

III. EQUIPMENT AND SYSTEM ARCHITECTURE

A. *Equipment Used in Our Case Applications*

In our research we have gathered experiences how RFID technology and positioning technologies can be combined to create smarter transporters. Indoor applications include a RFID equipped forklift truck in a warehouse of a shopping centre and a laboratory mobile robot where positioning is based on hybrid technology including a floor plan, internal measurements and RFID. In outdoor application we introduce a smart wheel loader which has been tested in wood industry. That wheel loader is based on a location aware system platform, which has a map about the outdoor warehouse area, a GPS system for localization. RFID technology is used both for pallet identification and positioning inside the covered warehouse buildings.

B. *Locawe – A Platform for Location Aware Systems*

In our pilot we have used our location aware system architecture. This architecture enables the use of geographic information system (GIS) data also in mobile devices and can deal with information coming from local sensors, and which can be used in different kind of environments and indoor and outdoor conditions. A simplified architecture is described in Figure 1 and it has been introduced in details in [16].

Based on our architecture we have designed our location aware system platform called Locawe. This platform has been tested in several field experiments and industrial pilots reported in [16]. In Locawe, it is possible to use different positioning technologies, in outdoor case typically GPS. GPS receivers are nowadays usually integrated in mobile devices. So the use of this sensor is relatively easy without any extra components. GPS receiver declares location information in World Geodetic System 1984 (WGS 84) geographic coordinate system. This has to be converted like all spatial data before the rendering process.

Locawe supports also indoor positioning, and it has been tested with both WiFi and ZigBee positioning. WiFi positioning information provided by Ekahau's Positioning Engine (EPE) can be integrated to our location-aware systems. This means that in the floor plan it is possible to visualize tracked or traced objects like persons and vehicles. The accuracy of WiFi positioning varies a lot, and it is depended on the environment itself. Due to the influence of metal surfaces and continuous changes in the environment, it is typically not possible to achieve high level accuracy in industrial conditions. [11, 17, 18].

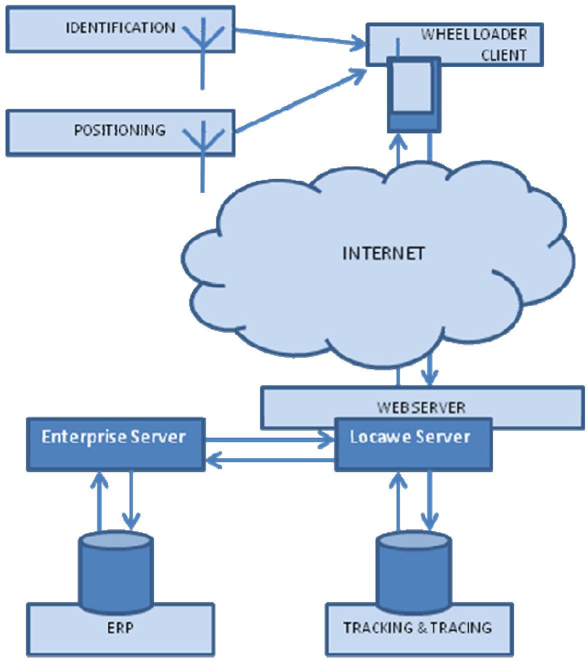

Figure 1. An architecture for smart wheel loaders based on RFID and positioning technologies.

IV. INDOOR APPLICATIONS

Indoor applications include a RFID equipped forklift truck in a warehouse of a shopping centre and a laboratory mobile robot where positioning is based on hybrid technology including a floor plan, internal measurements and RFID.

A. *RFID Equipped Forklift Truck in Warehouse*

UHF-based RFID-technology was tested for automatic identification in a warehouse with a forklift truck equipped with RFID reader and antenna (Figure 2). These tests were promising and showed that RFID-technology can be used if the reader, antennas and tags are placed in appropriate locations. However, in these test we found that long cables and loss of signal intensity will be a real problem if the forklift truck must lift objects high, for example to shelves which are situated many meters high.

Figure 2. RFID equipped forklift truck in warehouse.

B. *Mobile Robot with Safety Scanner, Positioning and RFID Technology*

We have developed a remotely controlled robotic system for our laboratory tests (Figure 3). In these experiments we have used a mobile robot (Evolution Robotics' ER-1) with remote controlling features over internet. The robot is equipped with web-camera, infrared collision avoidance sensors, speech recognition and speech synthesizer systems. We have supplied the robot with WLAN-connection and RFID reader with three antennas. The robot has also a safety scanner which can bring information about obstacles for the user (Figure 4) and it can be integrated to RFID technology.

Figure 3. Mobile robot with RFID and safety scanner equipment.

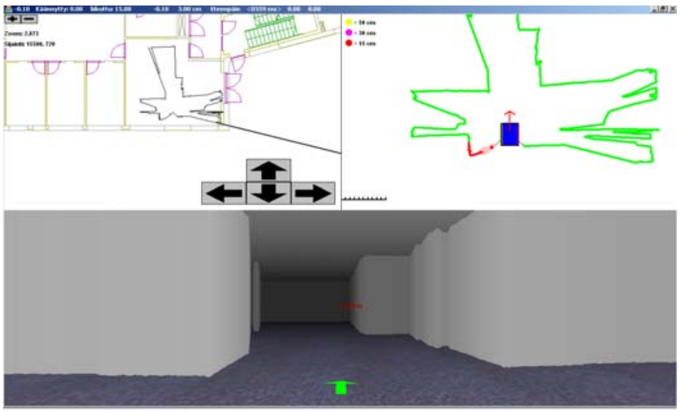

Figure 4. Overview of the user interface of the mobile robot with safety scanner and RFID.

V. OUTDOOR APPLICATION: SMART WHEEL LOADER

A. *Main Idea for the Smart Wheel Loader*

In outdoor application we introduce a smart wheel loader (Figure 5) which has been tested in wood industry both in summer conditions and in harsh winter conditions. That wheel loader is based on a location aware system platform, which has a map about the outdoor warehouse area, a GPS system for localization. RFID technology is used both for pallet identification and positioning inside the covered warehouse buildings.

The main idea in the developed solution is that operator neither has to leave his wheel loader to scan the product labels nor give manually information about the unloading point and package leaved there. Currently the operator must first halt the wheel loader, hop off and manually san the bar codes located on product packages before loading or unloading them. The user interface of the smart wheel loader can be seen in Figure 6.

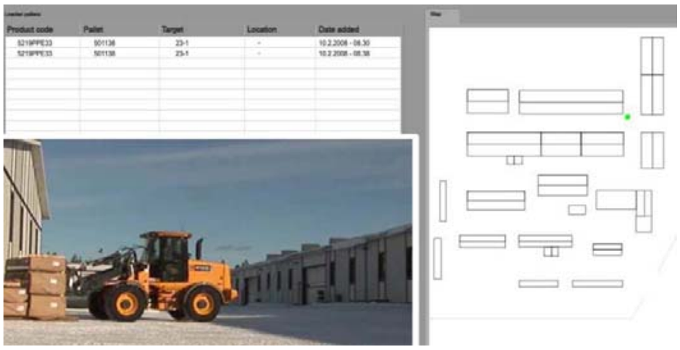

Figure 5. Smart wheel loader working with positioning and product information

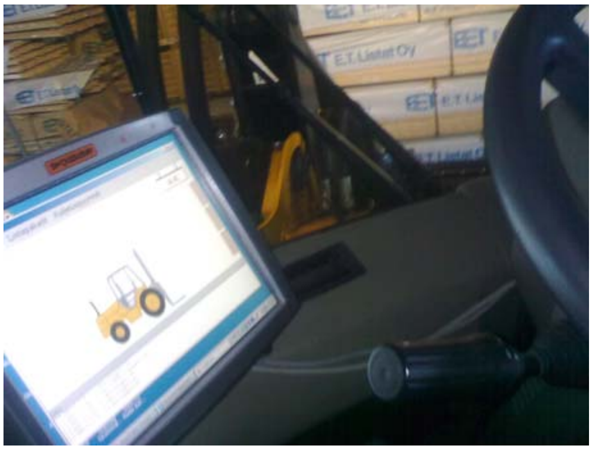

Figure 6. User interface of the smart wheel loader.

B. *Problems and Solutions Found in Identification of Products*

One problem we encountered has been presented in Figure 7. The RFID tags could be read in picking place with no problem even if there were three packages in the gripper. When these packages were lifted up, only the lowest one could be read anymore. For the solution we had to add an extra antenna and test different placements for it. Figure 8 shows the best solution we found for antenna placement in our test.

Cabling causes often problem when RFID technology is used with transporters such as forklift trucks or wheel loaders. In smart wheel loader tests we did not have to lift the product packages so high that there would have been problems for loss of signal strength. However, that is often the case with forklift trucks and sometimes also with wheel loaders. Therefore we developed a solution for wireless communication between the reader and antenna in the smart wheel loader. Wireless communication is based on 6LoWPAN technology (IEEE 802.15.4 based radio node). It has been working well in our tests but it has not yet integrated into the wheel loader.

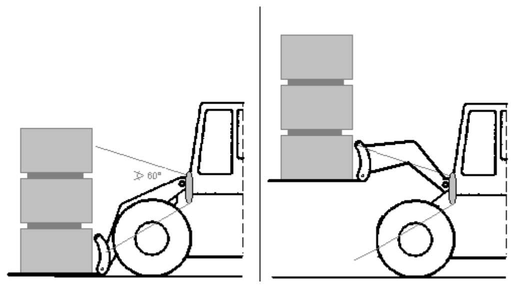

Figure 7. The problems due to the antenna placement.

Figure 8. Wheel loader with two antennas.

C. *Identification of Storage Positions Inside Warehouses*

When the wood packages were left inside the warehouse, GPS technology could not be used. Therefore, the location of that storage point was read from the RFID tags placed in the ceiling (Figure 9). One antenna was placed in the roof of the wheel loader's cabinet. In the tests all RFID tags could be read from the ceiling. In first experiences there was some overlapping with neighbouring storage point's RFID tags but that could be solved by decreasing signal level of the transmitter.

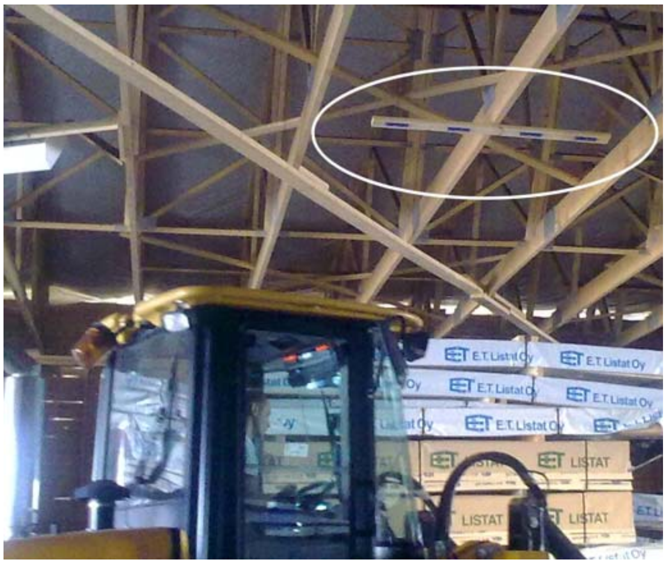

Figure 9. RFID tags in the ceiling used for indoor positioning.

VI. DISCUSSION AND FUTURE DEVELOPMENT NEEDS

RFID technology has been used with mobile work machines for object identification and as a part of localization systems together with other positioning technologies. Based on our experiments RFID technology is applicable for both tasks. We have also considered the cost effectiveness of current technology and found that RFID technology is in that application not cost-efficient for tagging individual objects but that is possible for containers or collected product packages.

One development need which was found in our application is inventory management of different wood products. That is currently made with bar codes and handheld readers and to read every package operators must get close to packages which are often in awkward positions, for example high in the upper shelves. RFID technology could solve the problem if the product packages would be marked with UHF-type RFID tags. Then RFID tags could be read from longer distance. If a special reader would still be needed to reach also for upper shelves in warehouse that could be developed for example based on paddle-type device. Psion has presented lately [19] an example of a paddle-type RFID reader (Figure 10) for HF tags.

Figure 10. A paddle-type RFID reader (Psion Teklogix).

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