Mobile and Ubiquitous Technology in Remote Controlled Robotic Applications

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Wireless sensors, robotics, mechatronics, safety

Abstract

In last few years new applications utilizing ubiquitous computing has been introduced in advanced manufacturing, home automation and health care. Ubiquitous computing is also coming into robotic applications e.g. via usage of RFID technology and wireless sensor networks. Remote monitoring and safe remote control is important in many robotic applications. It is especially crucial in mobile robot applications. In this paper, we present our work carried out in remote controlled robotic applications where mobile and ubiquitous technology is used. First we present a framework for hardware and software in remote monitoring and control of robots. Then we discuss about HMI and safety issues and present our experiences with a mobile map-based user interface. We also present our experiments on RFID utilization and indoor or outdoor positioning of a mobile work machine or a ubiquitous mobile robot.

1 Introduction

During the latest decade there has been a major change going on in the field of robotics. The amount of service robots is growing rapidly. In the end of 2005 it was first time bigger than the amount of industrial robots [1]. Industrial robots have been traditionally used in structured environments where the level of interaction between human and robot is quite low. Service robots and many work machines are becoming increasingly mobile and autonomous. Therefore remote monitoring and control together with advanced environment sensing is increasingly important. There are however many challenges in developing remote control including control delay, usability and safety issues.

Lately there have been forecasts that we are going towards ubiquitous era where everyday objects are networked to each other enabling new forms of communication [2], [3], [4]. Even if ubiquitous technology is not coming first on everyday production work in factories, RFID technology and wireless sensor networks (such as ZigBee) offer new chances to expand environment sensing of mobile robots and work machines. This can lead to new innovations not only in advanced manufacturing but also in home automation and health care.

Main reasons for environment sensing in mobile robot applications include recognizing people nearby, object and obstacle detection and autonomous navigation in working environment. There are many possible ways for environment sensing, e.g. computer vision, laser scanners and variety of other sensors. Positioning has often crucial role in mobile robotics. For navigation purposes the position of the robot is updated continuously. That is often done by combining dead reckoning (e.g. pose and speed estimation) with environment sensing. There are a lot of mobile robot positioning experiments using different sensors, such as odometer and angle measurements, ultrasonic sensors, inertial sensors, computer vision and GPS satellite positioning. [5]. In last few years there have been also experiments where RFID technology has been used to help positioning and navigation [6, 7].

2 Remote Control Framework

In many robotic applications remote monitoring and control is needed; that is e.g. the case in mobile robotics. The progress of web-based technology and mobile user interfaces provide many possibilities for remote monitoring. On the other hand, remote monitoring and control is needed in many robotic applications. Safety issues play often crucial role in remote control of robots. [8], [9], [10].

In our previous research we have presented a framework for teleoperation and maintenance of industrial robots [11]. The idea of the framework is to provide a rapid change of products to be manufactured and safely monitor and carry out the maintenance remotely. General platform of this framework should be similar in all applications and have the main software/application information of the system. The framework (see Fig. 1) includes definition for hardware and software parts of the robot system including both general and device dependent part.

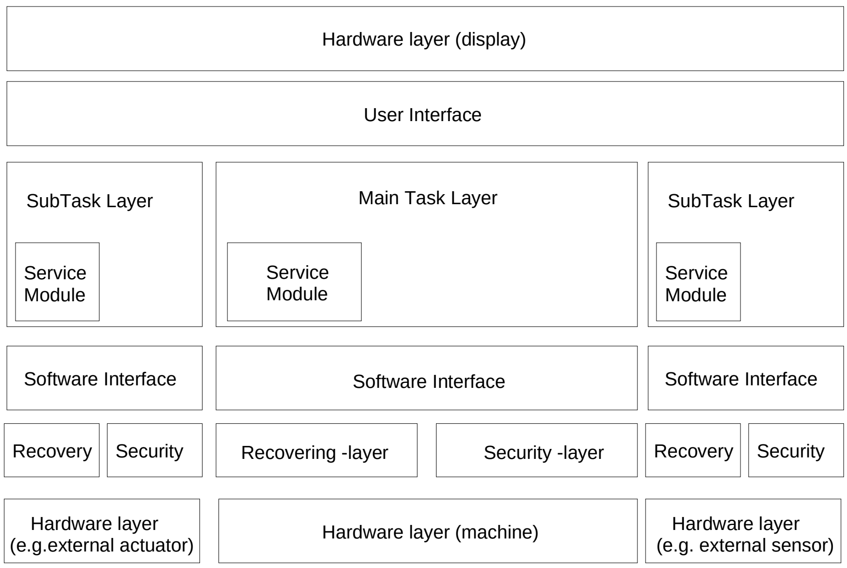

Fig. 1. A framework for remote monitoring and control of robots

General part is aimed to be similar for all the same-functioning machines when device dependent part is specified for each machine separately. General part consists of hardware layer, user interface and task layer. These layers are similar in most of the devises and machines in the system. It is built based on modular structure which enables increasing and decreasing of properties flexible. Device dependent part includes software interface, recovering layer, security layer and hardware layer. This layer is device and hardware specific. It utilizes special features of recovery if they are provided in the platform. Recovery properties are integrated in very close to HW to avoid situations with system crash. In the security layer most important information will be stored. This can be passwords for data encryption in the network, recognition codes of different units and modules etc. Architecture for remote connection enables also flexible updates of new software versions. Modern machines have to be designed such that on-site software updates are minimized.

3 User Interfaces and Safety Issues

3.1 Easy-to-use HMI

One goal of our work has been in providing an easy-to-use HMI for user of the robot. First experiences were made with web-based user interface in a laptop which to operate remotely a robot work cell with industrial robot. We have later also tested handheld mobile devices based HMIs, such as the map-based user interface in a Tablet-PC (Fig.2) which was used in remote control of a mobile robot.

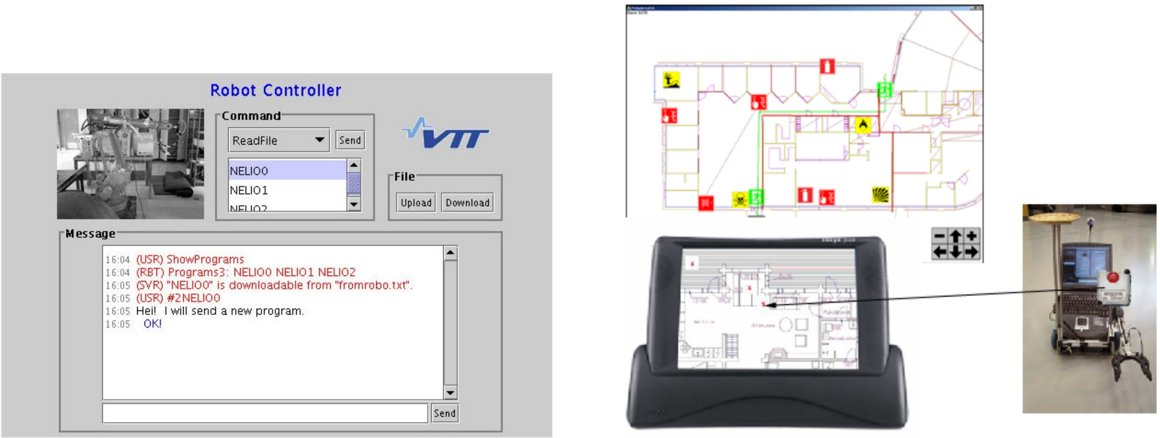

Fig. 2. User interfaces used in our remote control experiments.

3.2 Safety issues in teleoperation

There are several safety issues when using teleoperation of the robots due to strict regulations. The current assumption is that user of the robot will stand beside the robot and make all the operation locally. When using teleoperation, simplest approach is to have similarly the user standing beside the robot. However, this is not very economical solution when the cost of the work is such a high level in European countries. Operation of the robot is safe because of the safety constructions such as cabin around the robot. However, there are many potential hazards when using teleoperation and off-line programming. These include incorrect simulation model, time delays, person in robot workspace, data corruption during the information transfer and hackers outside to system [11].

Telemonitoring can be provided as a teleservice by system integrators and developers. Developed technology provides possibilities to keep constant production and fast recovery from the failures. This draws into new way of building up systems where system integrators will sell capacity, not separate robot arms or work cells. This trend can be seen from the other machine builders and it will come also to robot systems [12], [13].

4 Mobile and Ubiquitous Applications

4.1 Experiments with Ubiquitous Mobile Robot Application

We have implemented ubiquitous prototype of mobile robot using Evolution’s ER-1 platform. This Elviira-robot (Fig.3) is equipped with a web camera, sensors (RFID and ZigBee) and WLAN positioning. Using these equipments it is possible to control remotely this mobile robot with mobile devices like Tablet-PC or PDA (Fig. 4). The communication between the user and the mobile robot is implemented with socket communication when the robot can be controlled remotely using textual commands (like “Move 100 c” to move robot one meter forward). Based on video information provided by remote desktop connection, it is possible to steer the robot in normal conditions. We found this way to be more efficient way than video streaming. RFID- and ZigBee-technologies are used to get first experiences how to improve remote controlling in complicated environments. In our field experiments the subjects got information concerning the environment where the robot is currently moving based on RFID identification and dead reckoning. Usage of UHF technology provides us longer reading distances. By three antennas it is possible to identify objects from floor and from walls. Especially the antenna pointing downwards could be used to update exact position.

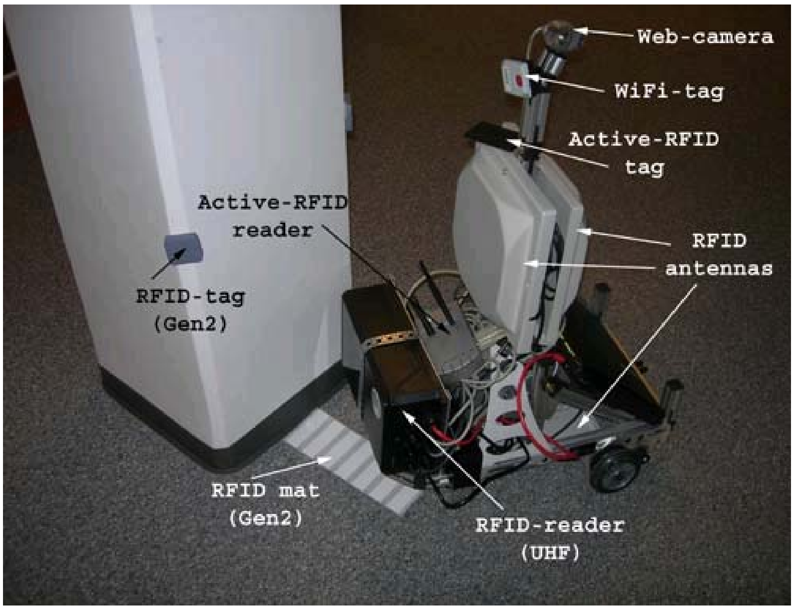

Fig. 3 Elviira-robot equipped with ubiquitous technologies.

We have lately carried out an experimental comparison of three techniques for displaying information about the position and movements of a remote mobile robot to the user. [14], [15]. The experimental techniques displayed the position of the robot on an indoor floor plan augmented with 1) a video view from a camera attached to a robot 2) displaying nearby obstacles (identified using RFID technology) on the floor plan, and 3) both features. 10 subjects controlled the mobile robot through predetermined routes in an indoor environment as quickly as possible avoiding collisions. The results showed that all three developed techniques were successful. The technique without a camera view was the fastest, and number of steering motions made was smallest using this technique, but it also had the highest need for physical human interventions. The technique with both additional features was subjectively preferred by the users.

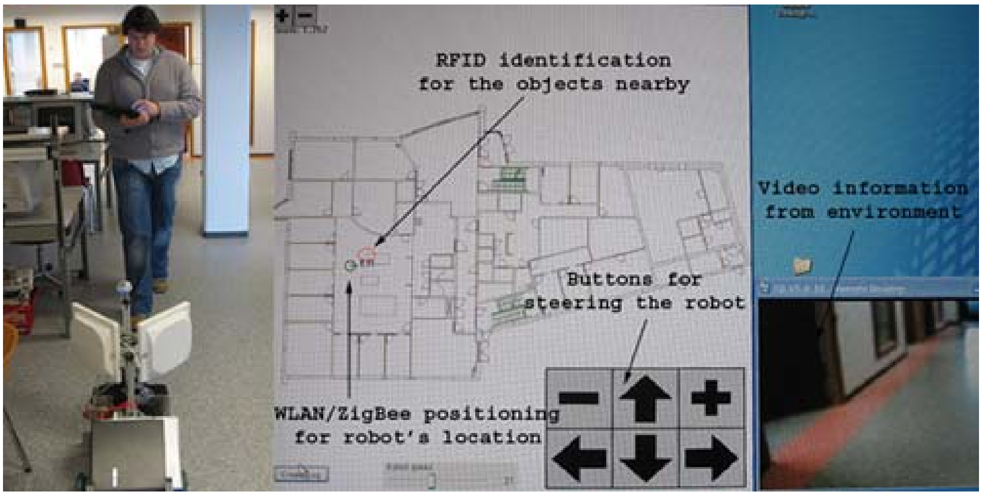

Fig. 4. Controlling mobile robot with map-based user interface.

In the future we have plans to continue HMI experiments with UWB and active RFID technologies. About active RFID we have already got first experiences by testing ActiveWave's Standard reader and cardTags. These tags seem to be possible to read in indoor conditions with the distance more than tens of meters without line of sight. So this kind of solution could be ideal for example for the places where robots need a wide range of working place without any disturbing factors like human beings.

4.2 Indoor and Outdoor Positioning Experiments

Implementing location based services one of the cost factors with spatial databases is so called map engine. This software development tool is needed to handle spatial databases and GPS positioning. We have developed in research projects our own map engine (Fig. 5). This engine is used for example in a mobile service for fire inspectors. In the recent projects this map engine has been used in various implementations of smart environments and it is nowadays called as a Locawe platform (location aware platform). This platform is used in a couple of field experiments reported in our previous studies [16], [17], [18], [19].

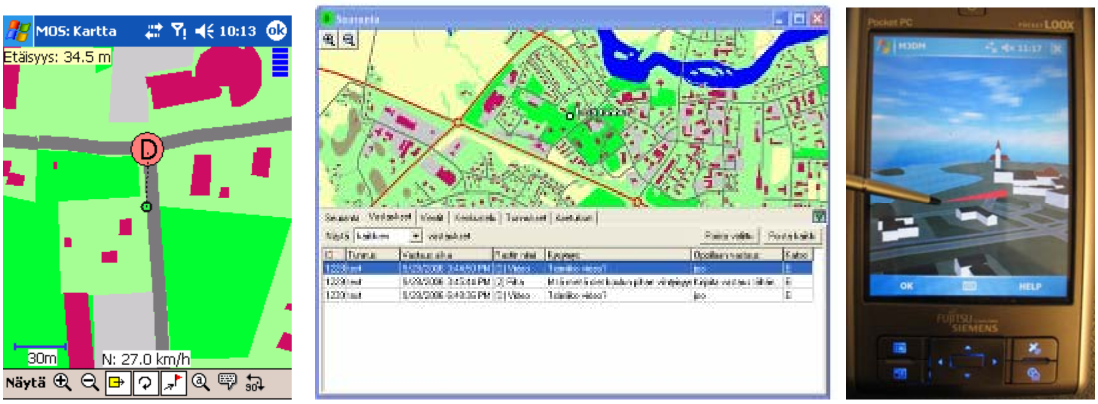

Fig. 5. Map engine used in location aware field experiments.

Locawe can be also used for creating indoor positioning solutions. In this case spatial data can be replaced by floor plans of the buildings in dxf format (see Fig. 5). In floor plans the moving objects have been shown based on WLAN positioning with Ekahau's engine. Just lately we have managed to include 3D features in our platform both indoor and outdoor conditions. Also when using 3D models it is possible to localize the user and identify objects nearby.

We have participated in the development of prototype machine automation application (see Fig. 6) utilising GPS positioning. The proof of concept demonstration version of upgraded control system in a direct seeding drill enabling precision cultivation is reported in [20]. The modifications allowed the seeding drill to know exact position and enabled easy link between the control system and the cultivation management program. This kind of approach can be used for coarse position of outdoor mobile robots. Another example of our pilot location experiments uses indoor radio position methods in a mine. In this demonstration we have used both ZigBee and WLAN networks for positioning. The primary goal for this development task is the safety of workers in hazardous situations. The secondary target for the same concept is the coarse positioning for unmanned vehicles.

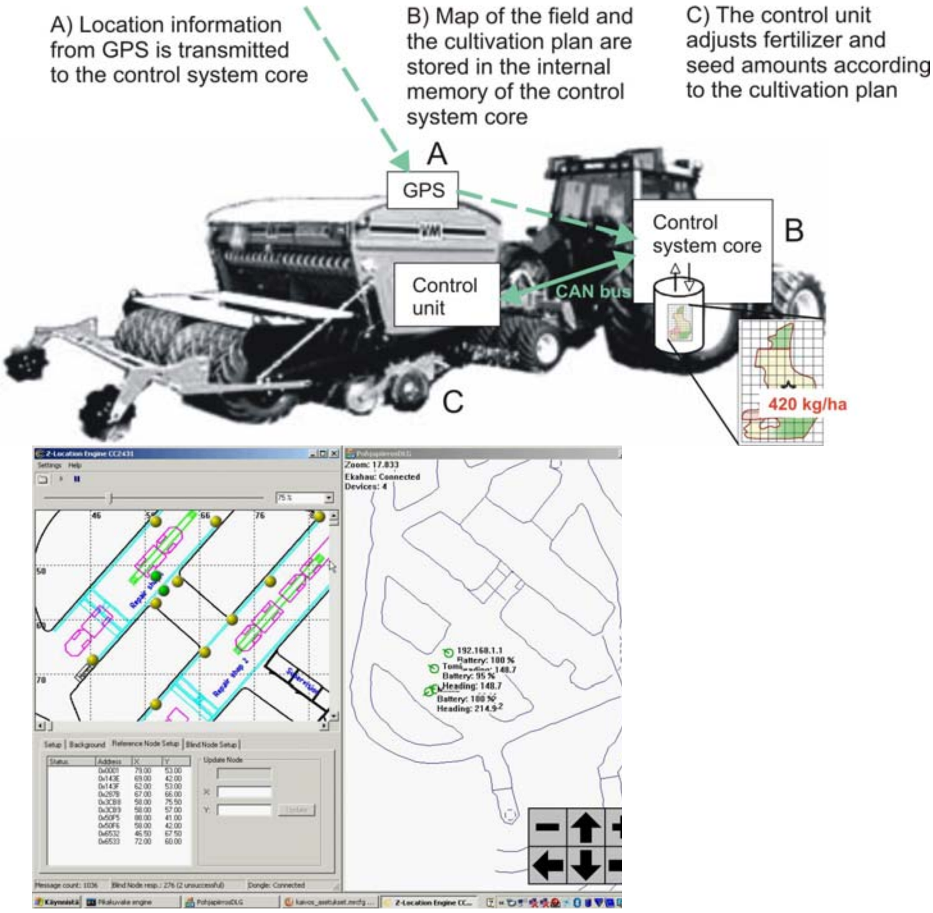

Fig. 6. Outdoor (GPS) and indoor (ZigBee, WLAN) positioning experiments.

4.3 Utilizing RFID in mobile devices

In the field experiments we found that the system build on Locawe platform can be used with or without video information even that it is much more complicated to navigate based on information visualized on floor plan. Experiments of indoor positioning of mobile robots have shown the need to use hybrid positioning systems [6], [7]. Even that our system uses a hybrid positioning with WLAN, sensors and dead reckoning we can see that the quality of positioning is not high enough for critical environments like in mines. We consider focus on next studies in active-RFID and UWB positioning. About active-RFID we have already a novel experiment. In the case that a reader is used in robot itself it is possible to build a system which can guide robot to stay in a sandbox based on tags in environment. Because the reading distance can be tens of meters this kind of solution is better for outdoor conditions or big halls. Another way to use active-RFID with mobile robots is to attach the robot with a tag. In this case it is needed to use client-server architecture for controlling robot when in the first case the robot can move autonomous. With UWB technology the accuracy for positioning could be even less than 30 cm. Even that this technology is very promising it is still very expensive to use and it is needed to take care license policies because the frequency area between 5 and 6 GHz seems to remain out of free use.

UHF-based RFID-technology has been tested also for different applications in a shopping centre. Fig. 7 presents examples of testing automatic identification in warehouse with a transporting truck equipped with RFID reader and antenna. These tests were promising and showed that RFID-technology can be used if the reader, antennas and tags are placed in appropriate locations.

Fig.7. Automatic identification in a transporting truck equipped with RFID technology.

5 Conclusions

In this paper, we have presented work carried out in remote control, mobile and ubiquitous robotic applications. We have shown examples how mobile and ubiquitous technology can be utilized in different kind of applications both in outdoor and indoor environments. RFID technology and sensor networks offer new chances to expand environment sensing of mobile robots and work machines. That can lead to new innovations in advanced manufacturing, home automation and health care. HMI and safety issues are crucial in these new application areas. In mobile applications hybrid positioning systems can in the future bring solutions to current positioning inaccuracy problems.

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