Proceedings of the 2010 International Conference on Industrial Engineering and Operations Management
Dhaka, Bangladesh, January 9 – 10, 2010

Application of a Plug-and-Play Guidance Module for Hospital Robots

M.K. Hasan, A.S.M. Hoque and Tamas Szecsi
School of Mechanical and Manufacturing Engineering
Dublin City University, Dublin, Ireland

Abstract

This paper explores the design and development of an intelligent plug-n- play guidance module for hospital robots to recover the shortage of healthcare personnel in hospitals and healthcare centres in EU countries. The module is developed by using Orca which is an open-source framework for developing component-based robotic systems. Active RFID system is used in this module to guide patients or visitors to any known place in the hospital. If the patient or visitor is lost the robot will automatically notify the authorised hospital personnel. It is hoped that this robot swarm system will contribute to better patient care in hospitals.

Keywords
Robot Swarm, Hospital Guidance Robot, Active RFID, Orca, Player

1. Introduction

The Intelligent Robot Swarm for Attendance, Recognition, Cleaning and Delivery (iWARD) is a European Union funded research project where the primary objective is to overcome the typical manpower shortages in EU hospitals and healthcare centres by developing a hospital robot swarm. Each iWARD robot contains a mobile, self-navigating platform and several modules attached to it to perform their specific tasks. The Guidance module is one of the five service modules installed on the mobile robot platforms to guide patients and visitors in the hospital. For example, a patient can be guided to the X-ray room, or a visitor to a patient's ward. In order to ensure that a patient is able to follow the robot, the speed control system of the robot may slow down or stop waiting for the patient by measuring the distance between the moving robot and the patient. This simulates a virtual electronic rubber-band between the robot and the patient. The robot is able to measure distance regardless of the orientation of the patient relative to the robot. In this paper it is described how the guidance module identifies the follower and guides them to their destination using Active RFID reader and tags.

There are a variety of guidance robots like Xavier, RHINO, MINERVA, Nursebot and RoboVie etc. [1-5] currently on the market. Although those robots can perform a wide range of guidance and related activities, they do not fit into the modular concept of the iWARD project. These robots are standalone devices and cannot be coupled with other service modules. Their price is considerably out of line with the budget constraints of the project. In order to minimise the cost of such a system and to make it affordable to hospitals, the iWARD robot swarm heavily relies on low-cost, standard components and plug-n-play sensors. As opposed to the large individual robots that are currently available in some hospitals, the robot swarm is based on smaller robots. This should cause less interference with persons and objects in the hospital.

The remainder of the paper is organized as follows. Section 2 clarifies the reasons for speed adjustment in the guidance task. Section 3 describes the detailed scenario of the patient guidance task in a hospital environment. Section 4 outlines the background related to the theme of the paper. Section 5 describes the prototype development steps including experimental results. Section 6 describes the software architecture. Finally, Section 7 and 8 list future works and conclusions.

2. Scenario: The Robot Guides a Patient to a Specified Location

The Guidance module starts work when an authorized staff member calls a robot for guidance. Different input devices like voice adoption, keyboard, and touch screen are used to call the robot, specifying the start and end locations. The robot management system selects a suitable robot and sends it to the start point. When an emitter tag is placed on the person to be guided then the robot identifies the signal from the emitter tag .The patient's ID is linked to this tag and the robot only guides a patient with this tag. The robot moves to the final destination; the patient follows the robot with a ‘virtual elastic band’. The Patient Guidance Module (PGM) measures the distance between the robot and the patient. The speed of the robot is adjusted according to the following distances.

- 0 -3 meters: the robot keeps the human walking speed
- 3-5 meters: the robot slows down and waits for the tag to come within the 3 meter range
- 5+ meters: the robot stops and waits for the tag to come in its range.

If within certain time period the patient is still in the 5+ meter zone, he is considered to be lost. For the patient guidance module Active RFID sensors were selected for the following tasks: identification of the patient and speed control of the robot. The PGM continuously measures the distance between the robot and the patient so that the robot speed can be controlled during the guidance operation.

3. Related Works

There are many sensing options available on mobile robots to identify and track humans, including the use of artificial markers and light emitting devices. Others make use of laser range sensors, identifying people as moving objects. Although these systems are quite efficient, the drawback is that the human to be tracked has to carry an “attractor” device. On the other hand, many applications use the robot’s on-board camera for human detection, often concentrating on the face or other regions of the human body. Some researchers have worked on “multimodal” systems, in which visual data is combined with laser range data or thermal images data to enhance human detection and tracking performance of the system. In several cases, speech recognition is also integrated only with vision or with both vision and laser data [6]. Image processing is a complex task and environmental conditions largely affect its performance. However, in the above systems the optical line of sight is mandatory. This might not be possible for the IWARD guidance scenario as the patient or the robot may turn around while cornering and avoiding obstacles. Also, other persons might come in between the robot and the follower while guiding. RFID seems to be an available option as it can penetrate through walls and nowadays it is extensively used in identification purposes. Kartoun [7] developed a system where a robot follows a human using Parco UWB RFID Tags where active tags are worn by both a man and the robot. He has achieved tracking based on dynamic calculations between the X and Y coordinates of a tag located on the human and the X and Y coordinates of a tag placed on the robot. But in his experiments, the speed of the robot was kept constant. To locate a specific tag requires triangulation from multiple readers that are placed in very specific patterns. A large number of readers are required to provide locations in a large area [8]. This approach has the problem of cost and space with the number of stations and the interval between the stations affected the accuracy [9]. For the PGM only the distance between the robot and the follower is sufficient rather than getting their dynamic location. Moreover, all the sensors and devices required for the IWARD project should only be on to robot. It is not possible to install several readers in the various locations within the hospital due to project limitations. Kim and Chong [9] have developed a prototype system that guides an RFID based mobile robot to a stationary target. Their system consists of a 315MHz RFID reader that reads the tag data simultaneously and picks up the direction of the tag using the received signal strength pattern. Based on the angle of signal arrival they have developed a guidance strategy that enables a robot to find its way to the tag position. In the IWARD project, both the robot and the patient wearing the tag move around. However, the received signal strength indication (RSSI) value for distance measurement is not reliable, as it can vary and be distorted significantly depending on several factors [8]. To deal with the problem of getting the dynamic distance between the robot and the follower one should consider the system’s ease of use and range of applicability. Hence the proposed system employs only active RFID tags and a reader without additional external sensors and/or reference stations. This application is able to continuously identify the follower and to calculate the distance between the robot and the follower.

4. Prototype Development

4.1 Active RFID kit

The Wavetrend 433 MHz, L-RX201 Reader [10] is used for the PGM which detects and decodes RF transmitted signals from the Wavetrend family of tags. The reader is powered through a PS300 Power Supply Unit. The reader incorporates a BNC connector to allow for attachment of an external antenna to extend the reader's range.

4.2 Hardware Setup

The hardware connection diagram is shown in Figure 2. The active RFID system is installed in a box shown in figure 4. The Guidance module box is powered through a Strix female power jack (Figure 4b).

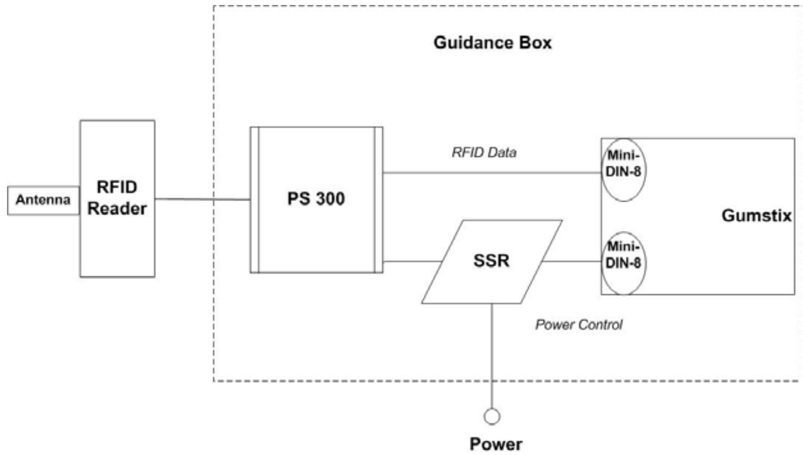
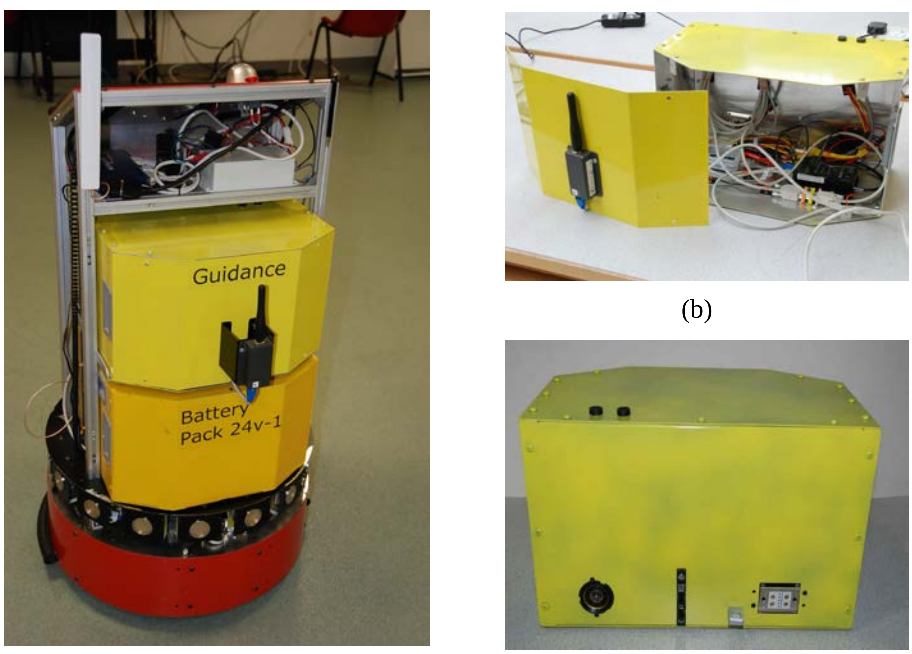


Figure 2: Reader connection diagram

The Strix hot plug supplies the power required for the electrical devices inside the box, drawn from the robot's main power supply unit. The RFID reader is connected to a PSU 300 power supply unit which is connected to the reader and the gumstix. The Ceep connector (Figure 4c) is used to implement an Ethernet connection with the robot's computer. The reader and a solid state relay are connected to the embedded computer (gumstix) via an RS232 serial mini din 8 ports. When the guidance module is plugged into the robot it automatically turns on the gumstix and the gumstix opens the RFID reader via a solid state relay when necessary.



(b)

(a) (c)

Figure 3: (a) Mobile base with Guidance Module box. (b) Inside the Box. (c) Back panel of the box.

4.3 Experiments and Results

Tests were carried out in an effort to relate the RSSI to distance. First, tests were carried out in a wide room and second one in a narrow corridor; the readings were taken at 1m up to 8m at 1m intervals. Testing environments are showing in figure 4.

(a)Wide Corridor (b) Narrow Corridor (c) Wide Area

Figure 4: Different testing environment

Figure 5: Graphs showing the influence of moving different tags away from the reader on the RF signal, wide room(left),narrow corridor(right)

The first graph in figure 5(left) shows the results of moving the tags away from the reader. The graph shows unexpected results since moving away from the tag reader should result in a noticeable linear decrease in the signal strength. The results obtained were not reliable because the signal strength stayed in the same range and in some cases as shown the detection increased after a decrease which should not happen. Some tags disappeared and weren't detected at further distances. Detection of some tags was better in the second experiment. It was concluded that both experiments gave non-reliable results, but also it was noticeable that the results obtained from carrying out the experiments in a narrow corridor were better than the results from the wide room. The reason was that in narrower environments the signal reflections against the walls increases as shorter distances were required for the signal to reach the wall and reflect. Reducing the signal travelling distance increases the signal strength which results in a better detection. Also it was obvious that the detection of the tags differs from one tag to another; in the first experiment at 1m and 2m all tags were detected , at 3m, 4m, 5m,6m and 7m tags 124,187,193,194 were detected and at 8m only tag 187 was detected . And in the second experiment at 1m, 2m and 3m all tags were detected by the reader, at 4m tags 124 ,187,193 and 194 were detected , at 5m tags 124 ,187, 193 and 66 were detected, at 6m and 7m all tags were detected and at 8m only tags 124 and 187 were detected.

Active RFID systems seem applicable only to detect whether the tags are in their range and are not reliable to calculate the exact distance using RSSI value. The RSSI will vary significantly depending on the spatial configuration of line of sight impediments from tag to reader. It also varies based on the CW configuration or modulation technique utilized by the manufacturer. Additionally, objects to which the tag is mounted and the orientation of the tag to the reader depending on antenna configurations will dramatically impact the RSSI output [4]. There are several types of active tags and each type has a certain range. We took TG 800 tags which have the highest range. We wrapped them with a thin foil paper in a way that it is only detectable within 0 to 3 meter range (+-1m tolerance). Several tests were carried out in different location as shown in figure 4 to ensure these wrapped tags are always detectable in the required range. A pouch made using two wrapped tags which would be worn by the follower. Using two tags improves the reliability of readers reading. The PGM detects whether any of the tags is present as long as it starts moving and in any stage if it loses the signal it waits for a certain time interval and if the tags are found again it resumes its operation. If it can not detect the tags within a pre set time limit it stops and waits for a certain interval to notify the system that the patient is lost. Figure 6 shows the scheme of distance measurement and robot speed control.

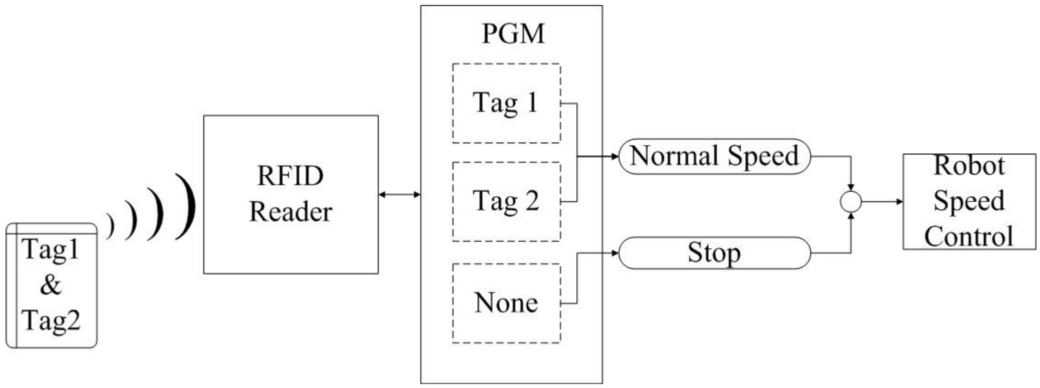


Figure 6: Scheme of distance measurement and robot speed control.

5. Software

5.1 Module computing

The guidance module is equipped with a gumstix [12] embedded computer .It comes with a Linux kernel installed in it. All module computing is performed by this computer: plug -n-play of the module, drivers for the solid state relay, communication of the module with the robot's computer. All module software is cross-compiled for the gumstix XScale processor. The gumstix is powered up automatically once the module box is inserted into the robot.

5.2 RFID driver

As with all other module software, the driver software of the RFID reader was programmed in C++ for Linux. The driver ensures two-way RS232 communication between the gumstix and the relay.

5.3 User interface software

The user interface software was developed by another iWARD partner (Warwick University) in Java. It contains menu systems through which users of the system (nurses, doctors, and pharmacists) can access the guidance module. It allows, for example, entering the tag ID and the start and end locations. Orca contains different type of interfaces which allow implementing orca functions in different languages (for example, java, python etc). While doing so, the Java code calls the external C++ functions (through Orca) of the guidance module to operate the guidance module.

5.4 Orca interfaces

In line with the general software architecture of the iWARD project, the guidance module's software implements Orca interfaces to communicate to other software modules in the system. The plug and play interface allows the guidance module software to inform the hardware manager of the robot to be made aware of the existence of the module on the robot. As soon as the module is inserted into one of the drawers of the robot, the gumstix is powered up and sends a message to the hardware manager with the code of the module. Similarly, if the module is removed from the robot the hardware manager is updated. The command to start the guidance operation comes from the mission controller of the system.

6. Future Works

Currently the PGM can only able to guide patients at one speed. So far, a speed control technique is not implemented as RFID can not provide exact distance required for this purpose .The research team is currently working on multimodal systems in which visual data will be combined with RFID.

7. Conclusion

Using the guidance scenario for guiding a patient from one place to another place in a hospital using the mobile platform and the guidance module, all aspects of the guidance module were tested. The first tests were performed in a real hospital environment at the Newcastle University nurses' training centre. The test showed that the guidance module was fully functional and performed according to the expectations. The final test will be performed in the Matia Hospital in San Sebastian. In an iterative implementation process the sensor selection, mechanical and software design will be evaluated and improved continuously.

Acknowledgements

Dublin City University is a partner of the EU funded FP6 project called Intelligent Robot Swarm for Attendance, Recognition, Cleaning and Delivery (iWARD) (www.iward.eu), and the Innovative Production Machines and Systems (I*PROMS) Network of Excellence (www.iproms.org).

References

1. R. Simmons, J. L. Fernandez, R. Goodwin, R. Koenig, and J. O'Sullivan, "Lessons learned from xavier," IEEE Robotics and Automation Magazine, vol. 7, pp. 33–39, June 2000.

2. W. Burgard, A. B. Cremers, D. Fox, D. H¨ahnel, G. Lakemeyer,D. Schulz, W. Steiner, and S. Thrun, "Experiences with an interactive museum tour-guide robot," *Artificial Intelligence*, vol. 114, no. 1-2, pp.3–55, 1999.

3. S. Thrun, M. Bennewitz, W. Burgard, A. Cremers, F. Dellaert, D. Fox, D. H¨ahnel, C. Rosenberg, J. Schulte, and D. Schulz, "Minerva: A second-generation museum tour-guide robot," in Proc. of the IEEE International Conference on Robotics and Automation (ICRA), Las Vegas, NV, Oct. 1999, pp. 1999–2005.

4. M. Montemerlo, J. Pineau, N. Roy, S. Thrun, and V. Verma, "Experiences with a mobile robotic guide for the elderly," in Proc. of the AAAI National Conference on Artificial Intelligence. Edmonton, Canada: AAAI, 2002.

5. T. Kanda, H. Ishiguro, T. Ono, M. Imai, and R. Nakatsu, "Development and evaluation of an interactive humanoid robot" RoboVie"," in Proc. Of the IEEE International Conference on Robotics and Automation (ICRA), 2002, pp. 1848–1855.

6. N. Bellotto and H. Hu, Multisensor Integration for Human-Robot Interaction, The IEEE Journal of Intelligent Cybernetic Systems, vol. 1, 2005.

7. Kartoun U. Human-Robot Following Using Parco UWB RFID Tags. Ben Gurion University of the Negev, Israel. 2005

8. Smith R. RFID: A Brief Technology Analysis CTOnet.org. 2007

9. Kim M and Chong N .RFID-based mobile robot guidance to a stationary target. Mechatronics .vol. 17(4-5). pp. 217-229, 2007.

10. Active RFID Manual. Wavetrend. USA

11. RFIDTalk. http://www.rfidtalk.com/showthread.php?

12. Gumstix, http://www.gumstix.com/