Hospital Robot Module Development in the iWARD Project

School of Mechanical and Manufacturing Engineering, Dublin City University, Dublin 9, Ireland

Dr. Tamas Szecsi

M. Kabir Al Mamun

Muhammad Kamrul Hasan

Md. Anwarul Islam

Colin Griffin

Dr. A.S.M. Mojahidul Hoque

The paper presents an overview of the development of five service modules for the hospital robots developed in the framework of the EU FP6 funded iWARD project. The major tasks of the modules are cleaning, patient guidance, patient condition monitoring, surveillance and delivery. Each robot module is attached to the mobile robot platform using quick-change mechanical connections and standard electrical connections. Upon connection, the plug-and-play modules are recognised by the application software and activate the corresponding client software.

Keywords:

Hospital, Robot, Sensors

1 INTRODUCTION

iWARD is an EU FP6 funded research project with the participation of ten partners form seven different EU countries. Its primary objective is to develop a prototype of a hospital robot swarm that helps to overcome the typical shortages in EU hospitals.

As opposed to currently available specialised robots used in hospitals, the iWARD robots are small, inexpensive, general purpose ones with a modular design. To execute various scenarios in the hospital, inexpensive service modules are installed on the robots. This arrangement has the following advantages over specialised robots:

- Easy configuration
- Easy expansion (with existing and new modules)
- Low cost
- Easy optimisation of mission-schedules

The role of Dublin City University in the project is to lead the development of five service modules for the robot platforms for cleaning, delivery, patient guidance, patient condition monitoring and surveillance. Details of the modules are given below. Any module can be connected to any of the robots using quick-change mechanical connections and standard electrical connections. Each module contains an embedded microcomputer (Gumstix [1]). When a module is connected the Gumstix powers up, informs the hardware manager of the robot about which module is plugged in, and starts the corresponding software for the module. This plug-and-play mechanism enables updating the shared knowledge of the robot system and scheduling and executing the scenarios in the hospital. The modules operation includes powersave mode; when the module is not in use most of its equipment is switched off automatically, thus reducing power consumption from the main batteries of the robot. Software in each service module is organised as an Orca component, which enables communication with other components of the robot system.

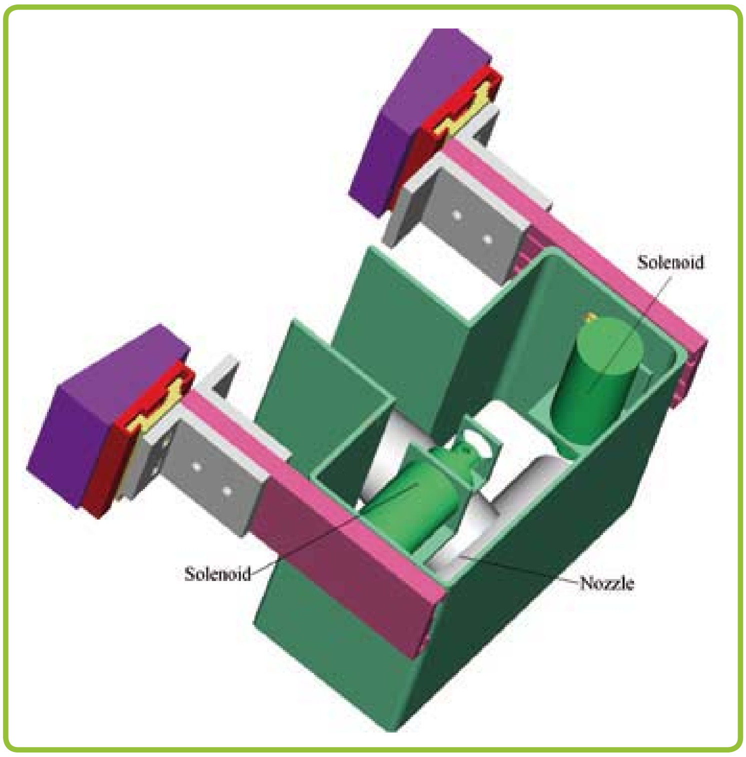


Figure 1: Cleaning nozzle.

2 CLEANING MODULE

The aim of the cleaning module is to provide cleaning of the hospital floor in the wards, corridors and other rooms. The cleaning device is a small motor operated vacuum cleaner. The cleaning nozzle is attached to the front of the robot and is operated by two solenoids. (Figure 1).

In order to prevent the nozzle from hindering the movement of the robot during transportation it is normally locked up a couple of millimetres above ground level using the solenoids. During cleaning the nozzle is lowered to the ground automatically. The nozzle is spring-loaded in the horizontal direction and is able to absorb impacts when the robot bumps into an obstacle. Once this happens the nozzle activates the bumper of the robot. Two major cleaning tasks are considered: scheduled cleaning and spot cleaning.

2.1 Scheduled cleaning

Scheduled cleaning in the hospital is performed according to predefined cleaning plans. The plan (schedule) contains all daily cleaning activities. After a robot with the cleaning module attached to it navigates to the specified location, the cleaning module is activated and general cleaning using cleaning patterns is performed. Figure 2 shows a cleaning pattern using parallel cleaning motions. Another option is to use a random cleaning pattern and time limit to finish the scenario.

2.2 Spot (spillage) cleaning

The task of the spot cleaning cycle is to remove spillages from the floor. This type of cleaning is not scheduled but rather initiated by a staff member who recognises the spillage. The person marks the spillage area with a cone. Since during spot cleaning it is not necessary to clean the whole room, the robot needs to recognise the position of the spillage by finding the cone in the room. To facilitate this, the cone is equipped with an infrared light emitter (LED) (Figure 3). The camera on the robot has infrared filters that only pass lights in a narrow bandwidth, corresponding to the bandwidth of the infrared LED. This way the images from the background and from other light sources (sun, light bulbs) can be filtered out and do not interfere with the LED's light emission.

Once in the room, the robot attempts to locate the IR LED block vie random movements and rotations. If the LED block is found, the orientation of the robot relative to the cone is calculated based on the horizontal position of the image from the infrared LED in the frame of the camera (Figure 4).

Since the vertical position of the camera relative to the robot is fixed, distance measurement between the robot and the cone can be based on the vertical position of the image of the infrared LED in the frame (Figure 4). Assuming the vertical viewing angle α of the camera is constant, the distance between the camera and the robot L can be calculated based on the vertical position of the light spot from the LED in the picture frame:

$$L = H \cdot (n + 1) \cdot tg\alpha \quad (1)$$

where H is the height of the light spot relative to the camera and n is the ratio between the space below and above the light spot (H and A) in the picture frame:

$$n = \frac{A}{H} \quad (2)$$

Once the robot is close to the cone it is guided around locally to clean up the spillage.

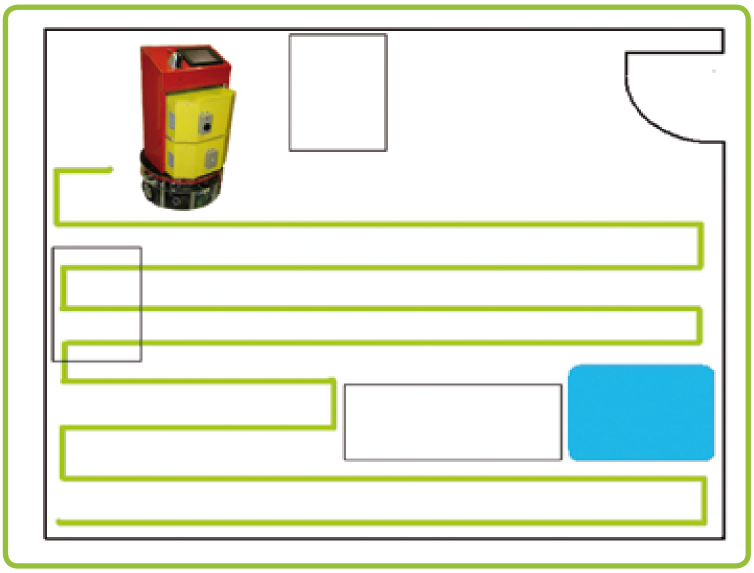


Figure 2:

Scheduled cleaning plan.

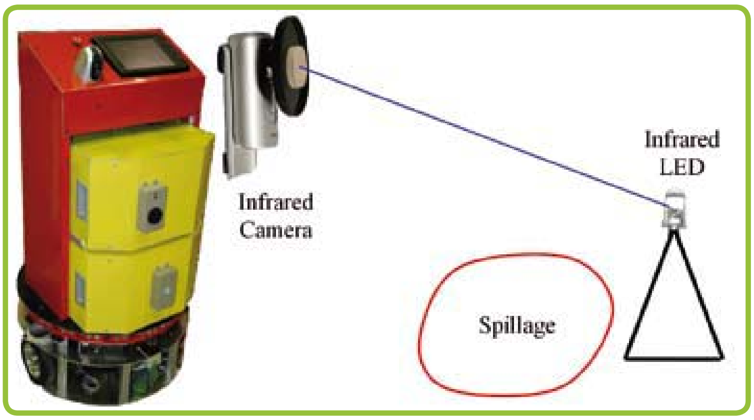


Figure 3:

Spillage cleaning.

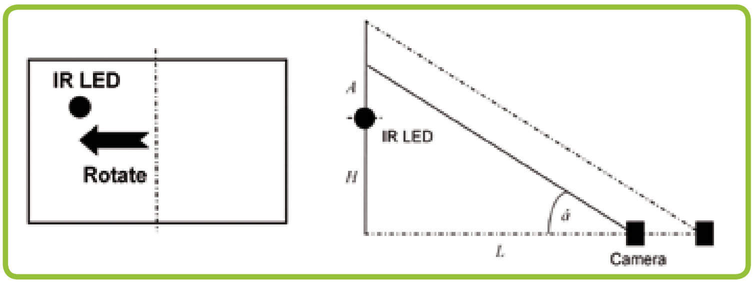


Figure 4:

Orientation and distance of the robot relative to the cone.

3 DELIVERY MODULE

The delivery module is used to transport small items like X-rays, medicines, medical records and small personal belongings of patients in the hospital. The module contains a delivery box with automatic control. The locking mechanism is controlled by an electrical lock (Figure 5) through a digital power relay. Once the spring-loaded door is closed the box is locked automatically. It can only be opened after successful authentication using an iButton [2] interface.

A microswitch, installed on the delivery box gives feedback information about the status of the box (open/closed). This prevents the robot from being sent away before the box is actually closed.

Figure 5 shows the delivery box opened and with all electrical connections exposed.

4 PATIENT GUIDANCE MODULE

The aim of the patient guidance module is to provide assistance of patients by guiding them between pre-defined locations in the hospital. The patient follows the moving robot. Since the normal walking speed of people can widely vary, it is essential that the speed of the robot is adjusted to that of the patient. This is done by permanently measuring the distance between the robot and the patient (Figure 6).

Distance measurement is performed by using a radio frequency identification system (RFID). A Wawetrend [3] RFID reader (Figure 9) is installed on the robot, and the patient carries two active RFID tags with different ranges. The distance between the robot and the patient is related to the signal strength from the tags.

The speed of the robot is constantly adjusted based on the calculated distance.

Besides distance measurement the RFID is also used to identify the patient. When a staff member instructs the robot to guide a patient to a location, he/she introduces the tags of the patient to the robot. The robot then only guides the patient with these tags and ignores signals from other possible tags.

5 PATIENT CONDITION MONITORING MODULE

The patient condition monitoring module serves several major scenarios: remote collection of data from patients related to their condition, virtual consultation between patients and doctors, and situation recognition.

5.1 Remote data collection from patients

In this scenario the robot remotely collects data from patients related to their condition and behaviour. The patient wears an Equivital belt [4] with built-in sensors (Figure 7). The belt is able to measure vital parameters like body (skin) temperature, heart rate, respiration effort rate, body position and acceleration. The coded signals from the sensors are transmitted with a radio frequency transmitter to a receiver connected to the Gumstix computer of the module. The sensory information is then analysed and the patient's condition and behaviour is defined. If necessary the programme can inform a doctor or nurse that the patient requires medical attention. The system can also be used for routine collection and storage of patient data in a database.

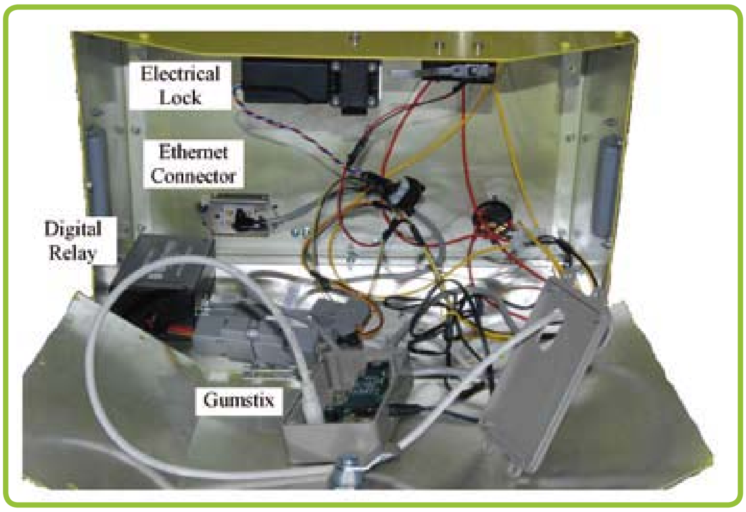


Figure 5: Delivery box.

Figure 6: Patient guidance

The accelerators in the sensor belt can be used to detect a person falling and also to recognise if a patient is feeling uneasy in their bed.

Since all measurements are taken during usual patrolling of the robots, it eliminates the necessity to install permanent data transmitters in every location in the hospital.

5.2 Virtual consultation

In this scenario a doctor instructs a robot to go to a patient's bed. The robot is equipped with a camera, microphone and speaker system. The Canon VC-C4 pan/tilt/zoom video camera [5] can be teleoperated by the doctor from a remote terminal (Figure 8). The image quality and settings can also be controlled remotely. Through opened audio/video channels the doctor and the patient can have a virtual consultation. The doctor's image appears on the touchscreen of the robot.

5.3 Situation recognition

In this scenario certain situations, connected to the condition and/or behaviour of the patients can be recognised. An example is to recognise a patient lying on the floor. For this scenario a Canon VC-C4 pan/tilt/zoom camera [5] and a PMD3D laser scanner [6] is installed on the robot (Figure 9). Using imaging techniques, the module recognises if a patient is lying on the floor and warns the nurses through their terminal about this. In order to gather more information a nurse can teleoperate the video camera similarly to a virtual consultation session.

6 SURVEILLANCE MODULE

This module has two major tasks: to monitor the environment in the hospital and to provide security information and recognise intruders.

6.1 Environmental monitoring

The aim of this scenario is to constantly monitor major environmental parameters (like temperature, humidity, smoke/fire) in the hospital. Sensors measuring these parameters [7] are connected to a Gumstix computer through an RSIOADXR [8] data acquisition card (Figure 10). The data acquisition card is controlled through an RS232 serial port. The computer analyses the collected data and warns the corresponding staff

Figure 7:

Equivital sensors transmitting data to the robot.

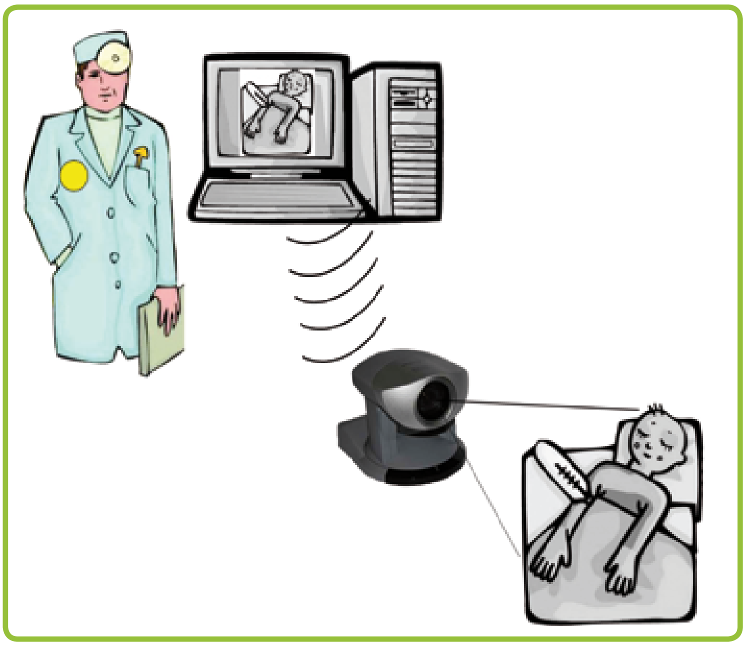


Figure 8:

Remote consultation.

Figure 9:

Recognising a patient lying on the floor.

Figure 10:
Sensors connected to the computer through a data acquisition card.

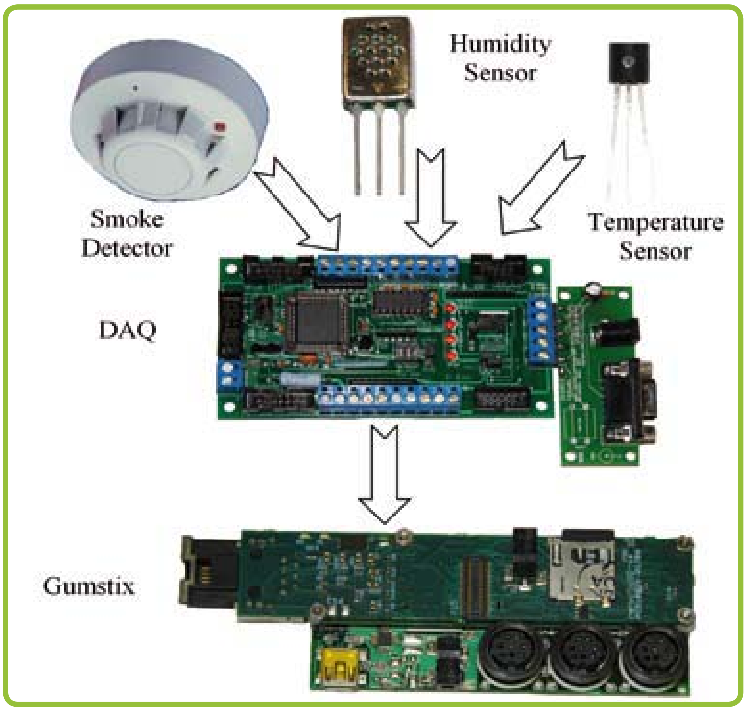
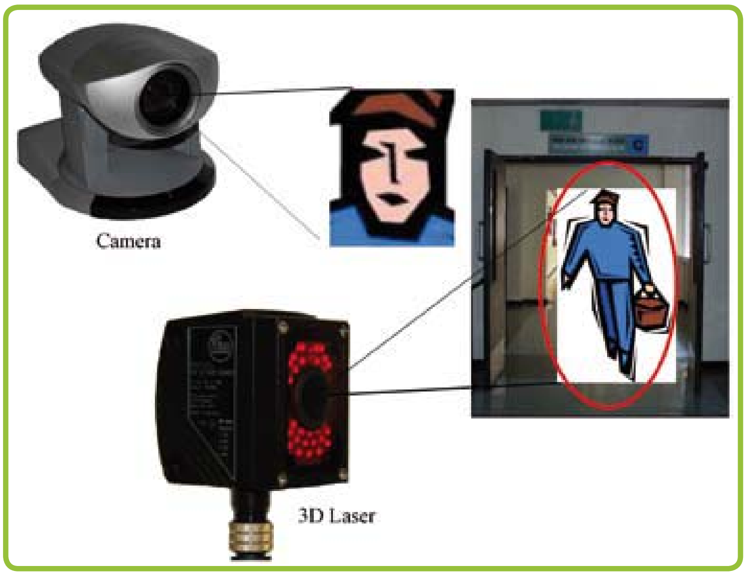


Figure 11:
Face detection..



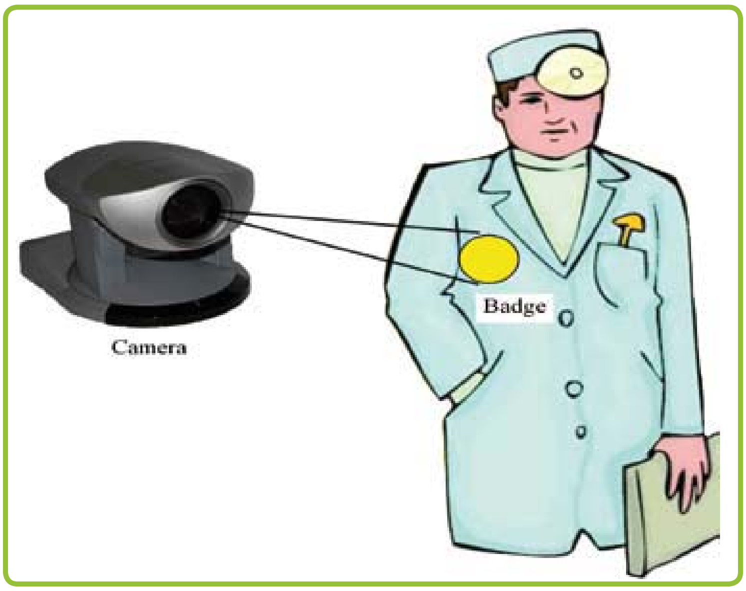


Figure 12:
Staff recognition.

member if the measured values are outside their normal range.

6.2 Intruder recognition

The intruder recognition scenario is mainly used during the night when there is a limited only presence of staff in the hospital. The aim is to identify a person in the hospital who could be a potential intruder.

When a passive infrared (PIR) sensor [9] on the robot senses the presence of a person it activates the image recognition software of the module to try to identify if that person is a legal one in the hospital or is a potential intruder.

The recognition system is equipped with a video camera and a 3D laser scanner (Figure 11). These two devices attempt to locate a person by recognising a face and body in the images.

Once the person is located the camera searches for an identification badge on the clothing of the person relative to his face (Figure 12). All legal persons in the hospital (patients, doctors, nurses, ...) should wear a badge that is recognisable by the system. If this badge can not be located it is an indication that the person could be a potential intruder and the surveillance module focuses and zooms the camera onto the person and using the pan and tilt mechanism follows the movement of the face, thus providing detailed security information. At the same time the module warns the security staff that a potential intruder is found. A staff member, analysing the video images, decides if intervention is required.

7 SUMMARY

This paper gives an overview of five service modules developed for a hospital robot swarm within the iWARD project. The modules are successfully integrated into the system and are easy to install and remove without restarting the robots' computers.

The plug-and-play capabilities of the system ensure that the robot management system is aware all the time which robot is equipped with which modules. The modules are currently undergoing extensive testing in both laboratory and real hospital environments.

8 ACKNOWLEDGMENTS

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).

9 REFERENCES

[1] Gumstix, [Online], http://www.gumstix.com/, (Accessed November 2007).

[2] Maxim, [Online], http://www.maxim-ic.com/products/ibutton/ibuttons/, (Accessed November 2007).

[3] Wavetrend, UK, [Online], http://www. wavetrend.co.uk/ (Accessed December 2007).

[4] Equivital, [Online], http://www.equivital.co.uk/ index.html#ClassTwo, (Accessed December 2007).

[5] Canon Corporation, (Online), http://www.usa.canon.com/, (Accessed December 2007).

[6] Ifm-electronic, [Online], http://ifm-electronic.com., (Accessed March 2008).

[7] Futurlec, [Online], http://www.futurlec.com., (Accessed December 2007).

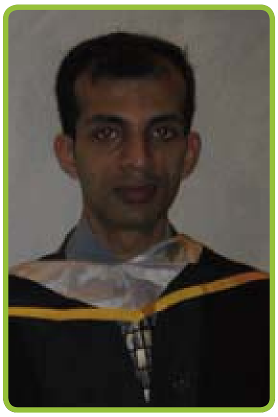
[8] Controlanything, [Online], http://www.controlanything.com., (Accessed December 2008).

[9] Parallax Inc., [Online], http://www.parallax.com., (Accessed November 2007).

Dr. Tamas Szecsi

tamas.szecsi@dcu.ie

Dr. Tamas Szecsi was born in Hungary. He graduated with an MSc degree in Manufacturing Automation from the Technical University 'MOSSTANKIN', Moscow. Research in the area of Cutting tool condition monitoring lead him to a Ph.D degree in Manufacturing Engineering which he received from the University of Rousse. Currently he is a senior lecturer in Manufacturing Processes and Systems at the School of Mechanical and Manufacturing Engineering at Dublin City University.



M. Kabir Al Mamun

mamunk2@mail.dcu.ie

In 2003 M. Kabir Al Mamun received his Bachelor of Science degree in Mechanical Engineering from the Islamic University of Technology (IUT), Dhaka, Bangladesh. In 2007 he received an MSc. degree in Mechanical & Manufacturing Engineering from Dublin City University, where he is currently working on his PhD thesis on developing hospital robot modules for surveillance and patient monitoring.

Muhammad Kamrul Hasan

hasanm3@mail.dcu.ie

Muhammad Kamrul Hasan received his B.Sc. degree in Mechanical Engineering in 2003 from the Islamic University of Technology (IUT), Dhaka, Bangladesh, and his MSc. in Computer Aided Mechanical and Manufacturing Engineering from Dublin City University in 2006. Currently he is working on his Ph.D thesis on developing hospital robot modules for guidance and delivery.

Md. Anwarul Islam

md.islam5@mail.dcu.ie

Md. Anwarul Islam graduated in 2002 with a BSc degree in Mechanical Engineering from the Islamic University of Technology, Bangladesh. He received his MSc. degree in Computer Aided Mechanical and Manufacturing Engineering from Dublin City University in 2006. Currently he is working on his PhD thesis on developing a cleaning module for hospital robots.

Colin Griffin

colin.griffin22@mail.dcu.ie

Colin Griffin recently completed a Masters degree in Mechanical engineering at Dublin City University. Prior to that he successfully earned a Bachelors Degree in Mechatronic Engineering. Most recently he has entered the area of 3D CAD design.

Dr. A.S.M. Mojahidul Hoque

asm.hoque2@mail.dcu.ie

Dr. A.S.M. Mojahidul Hoque obtained his PhD degree from Dublin City University in 2010. His research interests include design-for-manufacture, manufacturing feature-based design, hospital robots, simulation, and sensoring