Engineering Science Programme

ESP3903 Major Design Project II

Creating Sensor systems and Energy Harvesting

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Design and Test of Autonomous Sensor in Early Warning System for Fall-Risk Patients
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Abstract

Monitoring of seated patients using autonomous sensors, forewarning caretakers of falls and allowing them to take the appropriate measures. The autonomous sensor proposed, carries out force measurements in a protected environment and will trigger an alarm autonomously, if fall-risk behaviour is detected. Data can also be collected to further understand fall-risk patterns, as well as provide data for new designs, techniques, and implementation. The weight distribution across a chair during different behaviours can be directly measured. Furthermore, the data can be used to improve the design of geriatric furniture, caretaking methodologies as well as detect activities that may overload the device.

1. Introduction

For our project, we first met with the staff at Tan Tock Seng Hospital (TTSH) to determine the problem that patients faced, as well as to discuss how we would be able to help engineer a solution to their problem.

At Tan Tock Seng, one of the areas in which patients were identified as being vulnerable is when they are seated in the chair in Figure 1 below. The tray shown is locked in place, and can only be removed by the cooperation of two people (usually the patient and the nurse). We tested the chair, and discovered that there were two egress methods from the chair without removing the tray: sliding out leg-first under the tray, and a much more challenging one which involved supporting the entire body weight with the arms and climbing out.

We conjectured that the second method was unlikely to happen as it required a degree of athleticism that was not present in most of the patients. As expected, when we asked nurses, the most common occurrence of falls happened with patients sliding from under the chair, and subsequently injuring themselves.

Figure 1: Stationary Geriatric Chair with Tray

Falls resulting in injury are a prevalent patient safety problem. Elderly and frail patients with fall risk factors are especially vulnerable to falling in healthcare facilities. They are especially at risk for a fall due to physiological changes from medical conditions, medications, surgery, procedures, or diagnostic testing that can leave them weakened or confused[1]. While statistics are not available in Singapore, here are some relevant facts about falls in medical facilities in the United states:

- Every year in the United States, hundreds of thousands of patients fall in hospitals, with 30-50 percent resulting in injury[2]

- A fall with injuries costs, on average, USD14,000[3]

When we spoke to the staff at TTSH, we learnt that many patients assessed to be at risk for falls are not physically restrained because such restraints cause significant reductions in their freedom to move about. However, the understanding when restraints are not used is that patients will call nurses (for supervision or assistance) as and when they want to move about their environments.

During the course of hospitalization, some of these patients with unsteady gaits will be seated in chairs next to their beds. While often these chairs have a foldable table that ensure the patients can remain in the chairs, there are instances when they will try to get out of the chairs unsupervised by nurses and risk injurious falls.

During our visits to TTSH, we saw that there was a daily routine check on the fall risk patients and the equipment that was implemented to alert the nurses in the event that they are falling of the bed, through the use of a fall risk sensor underneath the mattress. In order to test if the fall risk system is working, the nurse will get the patient to stand up and sit on the chair to see if the alarm activates, before allowing them to get back onto the bed. This poses a risk

[1] Sentinel Alert Event The Joint Commission Issue 55, September 28, 2015
http://www.jointcommission.org/assets/1/18/SEA_55.pdf
[2] Fischer I, et al: Patterns and predictors of inpatient falls and fall-related injuries in a large academic hospital. Infection Control & Hospital Epidemiology, 2005;26(10):822-827
[3] Galbraith J, et al: Cost analysis of a falls-prevention program in an orthopaedic setting. Clinical Orthopaedics and Related Research, 2011;469(12):3462-3468. doi:10.1007/s11999-011-1932-9.

to the patients should they try to get up while the nurses are busy.

While additional methods of restraining are available, such as a belt around the waist of the patient, it is avoided as far as possible. Research studies indicate that the use of restraint carries with it the risks of both psychological and physical injuries: in this specific case, perhaps pressure ulcers and chafing and feelings of humiliation and embarrassment[4].

Our task then, is to design a sensor system that can forewarn nurses when patients are attempting to slide off the chair, and are at risk of falling. This warning system will enable nurses to be able to intervene and prevent falls and the injuries resulting from them.

2. Aim

The aim of building this sensor is to alert nurses early before the patient leaves the geriatric chair.

By alerting the nurses early, they can reach the patients in time to assist them in their movements.

This project aims to reduce fall rates by providing timely assistance to patients when needed.

As such, we have designed a sensor system to be placed on the seat of the chair that will sound an alarm should the patient be trying to slip off the chair. The system can be switched on and off by the nurse as and when the chair is required to be used by the patient.

3. Description of the system

3.1 Mechanical Design

The sensor system is constructed using a conductive metal piece with dimensions 40 x 40 cm, as the baseplate with 9 holes of diameter 4mm drilled into it. This is to allow for M4 screws to be put through the holes. 3 acrylic pieces with dimensions 20 x 10 x 0.2cm with 3 holes each will be placed through the screws on the base plate. The screws are then bolted in place.

[4] The characteristics of physically restrained patients in intensive care units, International Journal of Human Sciences, Vol 4, No 2(2007), *İsmet Eşer, Leyla Khorshid, Gülendam Hakverdioğlu*

We then cut acrylic tubes of 2 different radii into 9 smaller pieces each, with the smaller tube being able to fit through the larger tube. This will form the structure of our "buttons". The pieces from the larger tube will be glued onto the acrylic boards, centred around the screws.

9 circular pieces of the smaller radii was also cut out from acrylic, with holes of 4mm diameter drilled in the middle to be glued onto the remaining 9 small tubes, which forms the "button". Screws are then placed through the holes and bolted in place

Every "button" in the seat is constructed by placing a spring between two screws.

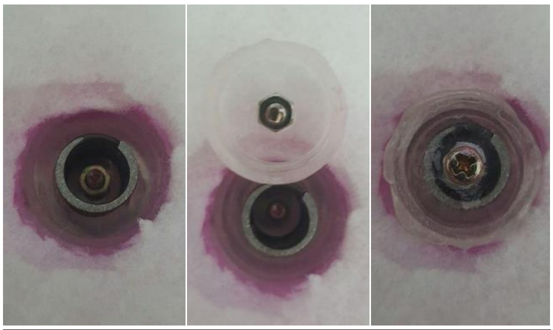

Figure 2: Images of "buttons"

Figure 3: Spring held in place by screw

Buttons are placed in a three by three grid near the front of the seat, the first row 7.5cm from the front and the second and third row 10cm behind the first and second respectively.

A spring of spring constant 9.8N/mm with a maximum load of 58.8N is placed between the two screws such that they are not in contact with each other.

Initially, the two screws are not in contact, but when sufficient pressure is applied to the top button, the spring between the top and bottom screws is compressed from 20mm to a minimum length of 14mm and the screws touch, thus creating a complete circuit and sounding the buzzer.

For every button, the top screw is connected to the circuit via an insulated wire completing the circuit, thus when contact is established, this is the signal that the sensors has been triggered.

Buttons are mounted on a metal board for a sturdy base. Layers of foam are placed between the buttons as well as above the buttons for the comfort of the user.

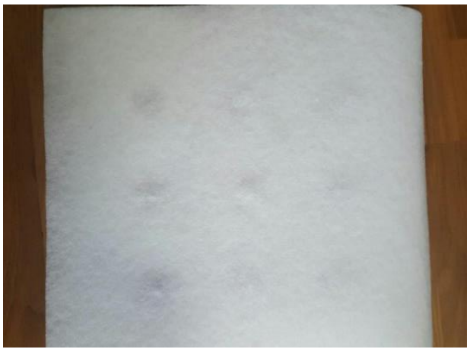

Figure 4: Cushioning of sensor system

3.2 Electronics Design

The circuit is powered by a 6V battery holder connected to a switch and buzzer which is then connected to the metal base plate. The 6 buttons in the front 2 rows will be connected to wires with each 3 in the same row connected in parallel. We are excluding the back 3 buttons as it is to provide the spring effect and distribution of load.

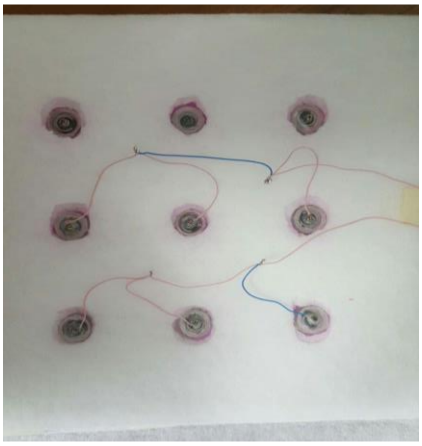

Figure 5: Wiring under the foam

The circuit is connected as shown below:

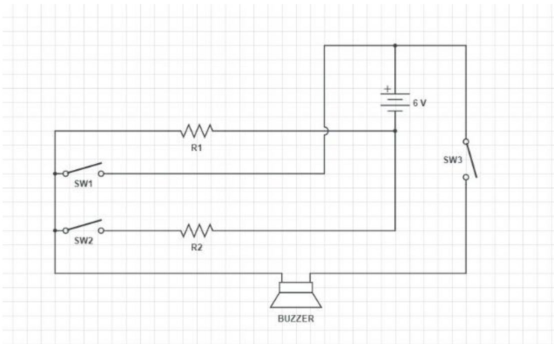

Figure 6: Circuit diagram

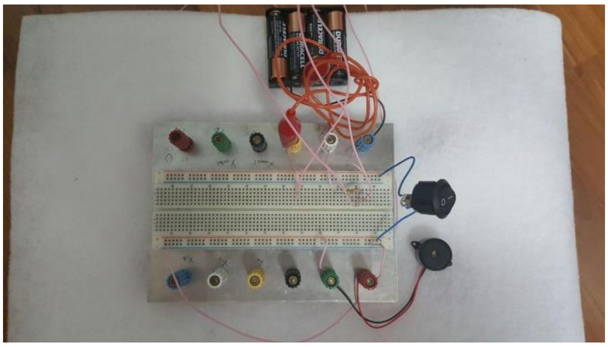

Figure 7: Electronic circuitry

SW1 and SW2 represent the middle and front row of buttons on the seat respectively. When any one of the buttons in a row are pushed, the switch is closed and the circuit is completed.

When all switches are closed, the buzzer will not sound as R1 and R2 has a resistance, thus the current will travel in the path of least resistance so most of the current flows through SW1, SW3 and the buzzer will not sound. This is the case whereby the user is sitting on the chair normally.

When SW2 and SW3 is closed, the buzzer sounds as the current flows through SW2, R2, R1, SW3 and the buzzer. This is the case whereby the user is starting to slide off the chair and in possible danger, thus the buzzer activates and alerts people to this situation.

When SW1 and SW2 are opened, current can only flow through R1, SW3 and the buzzer thus the buzzer will also sound. This is the case whereby the user is no longer sitting on the chair and has possibly fallen to the ground. The buzzer will continue to sound to alert any nearby staff or personnel until they turn off SW3.

4. Results

As the patient attempts to slide off the chair, the buzzer will be triggered as weight is concentrated on SW2, leaving SW1 opened.

It takes approximately 10 seconds for a user to slip out from the seat and 8 seconds for a nurse to reach the chair from the workstation where the nurse is usually seated. Thus, there will be sufficient time to reach the patient after the buzzer has sounded.

5. Conclusion and discussion

5.1 Conclusion

The sensor system can detect movement of the patients when he/she is trying to slide off the chair and alert anyone in the proximity of a possible fall to allow for intervention to prevent such a fall from occurring.

The sensor will be installed in geriatric chairs in hospitals, especially in wards where there is a high concentration of fall-risk patients.

By providing timely assistance, we hope to reduce the fall rate of patients and prevent subsequent injuries.

5.2 Possible future improvements

As this is just a simple setup of a sensor system, much can be done to improve the entire system, such as increasing the no. of springs to be able to detect a wider range of movements, possibly in the horizontal direction, and not just vertically. The sound of the buzzer could also be made to vary according to how much pressure is applied to the buzzer and how many buttons are depressed.

The durability of the system can also be improved on and using other more durable material instead of our current materials, which are cheap and easy to source. The scale of the setup can also be scaled down including the electronics and packaged better. Better cushioning can be used in future as well, to provide more comfort to the user.

The alarm system can also be integrated into the current alarm system implemented in the hospitals, although that would require much more work and planning.

6. Acknowledgements

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