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A PROACTIVE SYSTEM TO PREVENT PRESSURE ULCERS ACQUIRED VIA PROLONGED HOSPITALIZATION

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Abstract— Pressure ulcers are a serious problem affecting over a million patients every year. These ulcers often occur when patients have limited mobility and cannot change positions in bed on their own. Eventhough there are accepted guidelines for attending and repositioning high-risk patients, the rate of pressure ulcers continues to rise . This paper presents a wearable, wireless vital sign monitor capable of continuously measuring the duration and orientation of a patient's posture throughout . Patient posture is determined using a tri-axial accelerometer attached to a patient's torso. A set of algorithms are used to process the accelerometer signals to adaptively identify accelerometer alignment on the patient, and classify patient orientation and enables alerts to be sent to the caregiver when a patient turn is due in accordance with the protocol adopted by the hospital. A novel method to address the need for improved pressure ulcer prevention is presented. The patient's position is continuously monitored and the turning procedure carried out is logged and updated on the hospital's cloud system, thereby enabling centralized monitoring. Under a controlled setting, system was able to continuously monitor patient's position and can accurately detect standard patient positions.

Keywords—pressure ulcers , repositioning , wearable , tri axial accelerometer , cloud system

I.INTRODUCTION

Hospital acquired pressure ulcers (HAPUs) also known as **bedsores , decubitous ulcers** are injuries that are localized damage to the skin and underlying tissue resulting from prolonged pressure on the skin [1]. Pressure ulcers develop when soft tissue is compressed between a bony prominence and an external surface for a prolonged period of time, leading to tissue necrosis.This causes some damaging and detrimental effects on skin and its underlying tissue due to insufficient blood circulation. Patients with reduced mobility, reduced perception of sensory information and malnourished and dehydrated geriatric patients [2]. Pressure ulcers can also lead to other complications such as sepsis, cellulitis, bone and joint infections [3]. Additional risk factors include impaired sensory perception, friction, shear stress, and inactivity

HAPUs are classified into 4 stages based on their severity. Recovery time may take from few weeks to months depending on the severity.The current recommended healthcare guideline is that patients get assessed for pressure ulcer risk every 24 hours and at-risk patients be repositioned every 1-2 hoursto alternating lateral and supine positions by the caregiver and a manual log of the changed position is recorded. [4].To augment manual healthcare practices non-invasive monitoring solutions have been developed to measure the pressure distribution. the patients get assessed for pressure ulcer risk every 24 hours and at-risk patients be repositioned every 1-2 hours [4]. Because of a low caregiver compliance to turning protocols in ICUs and hospital wards such a turning procedure is not always followed strictly .Difficulty in continuously monitoring patient position, lack of a system which can provide turn reminders/alerts and suboptimal caregiver staffing ratio increases the occurrence of HAPUs.

A Proactive method is presented in this paper to address the need for improved pressure ulcer prevention. The patient's torso is mounted with a tri axial accelerometer and the patient's orientation with respect to gravity is measured. The accelerometer measurements can be processed with a real-time algorithm to estimate the duration and orientation of a patient's posture .The risks are analyzed and the information is wirelessly transmitted to the central nursing station. The performance of the patient posture measurements calculated with algorithms are evaluated using human subject data collected with the wireless device. It consists of a wearable device which continuously monitors the position of the patient and updates it on a digital log on the hospital's cloud system An alert is given to the caregiver at regular intervals.

II.HARDWARE DESIGN

The device has a 9 axis MEMS Inertial Measurement Unit (IMU) which consists of a 3 axis accelerometer, a 3axis gyroscope and a 3 axis magnetometer in a single package. Full scale values of each of them are as follows:

Accelerometer: +/- 2g
Gyroscope: +/250rad/sec
Magnetometer: +/- 1200uT

ViSi Mobile is a wireless body-worn vital signs monitor that continuously measures Heart Rate, SpO_2, Respiration Rate, Pulse Rate, and skin temperature. The system is comprised of a wrist module, an upper arm module, and a chest module. Each module contains a three-axis accelerometer to provide information about the patient's orientation and activity. Fig. 1 depicts how the ViSi Mobile attaches to the patient's body.

Fig.1 ViSi Mobile attaches to the patient's body.

The posture of a patient's torso can be characterized using a set of three angles.The angle between each basis vector and the gravity vector measured by the accelerometer can be calculated and posture angles are defined with respect to the ground plane orthogonal to the gravity vector.Therefore, if a patient were standing perfectly erect the torso angles would equal, 0°, 90°, and 0° for the horizontal vector, vertical vector, and normal vector respectively. The three torso angles can be incorporated into a posture classifier to aggregate the angles over specified ranges into discrete posture states.

For Posture estimation the three basis vectors are unique to the individual patient and therefore, an adaptive identification procedure with algorithms and several assumptions with regard to patient posture to where and how the housing is placed on the torso is carried out and the positions and orientation is found.

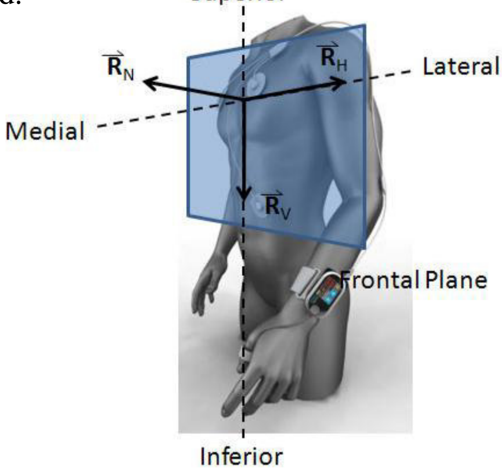

Figure 2. Basis vectors that define a patient's torso plane.

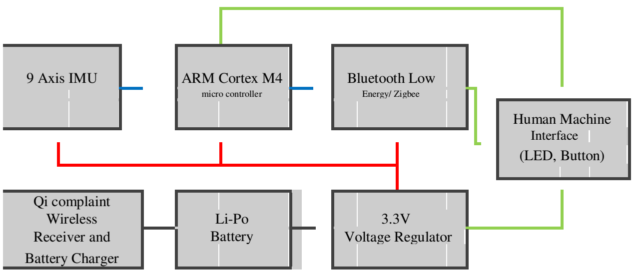

Figure3. Wearable device block diagram

The IMU(Inertial Measurement Unit) communicates with the MCU using I2C protocol and an interrupt mechanism is implemented to wake up the MCU only when the data is ready, thereby saving power. An ARM Cortex M4, 32-bit microcontroller (MCU) runs the algorithm and interacts with the other modules.MCU and thegateway (tablet) communicate wirelesslyusing Bluetooth low energy (BLE) protocol. A Li-Polymer battery with a capacity of 170mAh, a 3.3V low drop-out voltage regulator. Thedevice is designed with power efficient components and an intelligent algorithm which enables the device to run for at least 10 days on a single charge. Figure 3. Wearable device block diagram

III. SOFTWARE DESIGN

Software design for the overall system can be divided into 3 sections:

3.1.GATEWAY INTERFACE

This software component runs on the tablet and provides an interface for the caregiver to interact with the wearable device. The first step in the interface is entry of basic patient details. The next step involves risk assessment using Braden scale. Fig. 4represents the interface for Braden scale assessment. The condition which describes the state of the patient in each of the parameters is selected by the caregiver and considered. Once the assessment is completed the overall Braden scale score is displayed. Based on the score, patient's risk level is also displayed.

If the score falls in the risk categories, the interface displays a message asking the caregiver to attach the wearable device on the patient. Once it is attached, gateway connects to the wearable device and starts continuous patient position monitoring. The caregiver is then asked to set a threshold from a list of preset values in degrees to identify a turn from other movements (turn threshold). The preset values will be set by the caregiver, specific to the patient based on patient's movability. The software intelligently alerts and guides the caregiver through the turn protocol using a color code system as follows:

Green color – no need of repositioning
Blue color – Patient due for repositioning
Red color – Patient turn long overdue, reposition as a matter of priority

Braden Risk Assessment Scale

Sensory / Mental	Moisture	Activity	Mobility	Nutrition	Friction \ Shear
Totally limited	Constantly moist	Bedfast	100% immobile	Very poor	Frequent sliding
Very limited	Very moist	Chairfast	Very limited	< 1/2 daily portion	Feeble Corrections
Slightly limited	Occasionally moist	Walks w/ assistance	Slightly limited	Most of portion	Independent Corrections
No Impairment	Dry	Walks w/ out assistance	Full mobility	Eats everything	

Figure 4. Braden scale assessment interface

3.2 WEARBLE DEVICE

As soon as the device is attached on the patient, a software timer is started.The inputs entered by the caregiver in the tablet The patient's position is continuously monitored and is synchronized with the gateway (tablet) for centralized monitoring.The intelligent algorithm running inside the device computes patient position by converting raw 9 Axis sensor data to Quaternion [6]. Sensor's current orientation is compared with the preset turn thresholds to estimate whether the patient has been turned or not. To avoid false alarms caused by sudden jerks, patient position is updated only after 15 seconds of detecting a change in position. The wearable device estimates the patient position based on the following conditions.

- Left turn: |current orientation| > |Left side turn threshold|
- Right turn: |current orientation| > |Right side turn threshold|
- Supine: Lower bound turn threshold < current orientation < Upper bound turn threshold

The caregiver is intimated of the patient position once in every two hours along with alert message to take appropriate steps.

3.3 CLOUD SYSTEM

The application running on the hospital's cloud system interacts with the gateway (tablet) and provides centralized monitoring and continuous digital logging of the patient's position. The application provides the option of reviewing all previous patient positions whenever necessary. It also provides a centralized console to view and monitor all the patient position in real time connected through the gateway (tablet). The various subsystems of the proposed method are pictorially represented inFig 5.

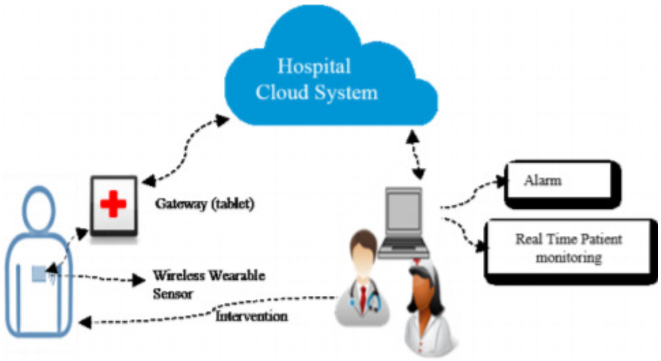

Figure 5.System architecture

IV.TESTING AND VALIDATION

A set of experiments were carried out to evaluate the performance of the accelerometer alignment and posture measurement algorithms. Posture data were collected from Device testing and validation were carried out in a controlled setting, to understand the effectiveness of the algorithm in accurately monitoring patient's position. An experiment was set up to simulate a patient who has limited mobility. Experiment was performed with the help of two volunteers; volunteer 1 acting as the caregiver and volunteer 2 acting as the patient. Wearable device was attached on the patient's chest. The patient position was continuously logged through the gateway(tablet). Turn thresholds were set before the experiment started. Length of a single experiment spanned 5 minutes. Table I represents the patient's position with time

TABLE

Time (seconds)	Patient's actual Position	Patient's position reading from System
50	Supine	Supine
110	Left	Left
170	Right	Right
230	Supine	Supine
290	Left	Left

Experiment started with patient lying down on the bed in supine position. Then for every one minute until the end of the experiment, caregiver was asked to change patient's position following the sequence given in table I. Table 1 shows the patient's position recorded along the sequence followed at regular time intervals.

V.CONCLUSION

A novel method to address the need for improved HAPU prevention was developed, working in collaboration with intensivists. A wearable device and gateway (tablet) interface was developed and a preliminary test was carried out in a controlled setting, to validate the efficiency of the system in accurately monitoring the position of the patient. The results obtained shows that the device can continuously monitor the patient's position and identify the various standard positions. A large scale clinical validation to assess the efficiency of the proposed method in an ICU setting is being planned. A risk index was proposed to fuse the calculated posture variables into a **P**ositional **P**ressure Ulcer **R**isk **I**ndex (PPRI) to provide real-time feedback to healthcare workers. Future work based on clinical data collected from hospitalized patients will be required to tune the model and assess the efficacy of the index to guide care and reduce the incidence of pressure ulcers.

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