Pressure Ulcer Monitoring and Intervention: A Software Platform

M. Farshbaf, S. Ostadabbas, R. Yousefi, M. Nourani
Quality of Life Technology Laboratory
The University of Texas at Dallas, Richardson, TX 75080
{mxf104020, sarahostad, rxy091020, nourani}@utdallas.edu

M. Pompeo
Presbyterian Wound Care Clinic
4500 S Lancaster Road, Dallas, TX 75231
healerone@aol.com

***Abstract*—Pressure ulcer is a significant problem for bed-ridden and wheelchair-bound patients, diabetics, and the elderly. These patients need to be regularly repositioned to prevent excessive pressure on a single area of their body, which can lead to ulcers. In this work, we develop a software platform that facilitates monitoring at-risk patients and suggests preventive steps that all can lead to less pressure ulcer formation incidents in the hospitals.**

I. Motivation

Soft body tissues are sensitive to prolonged compressive loading, eventually leading to tissue necrosis in the form of pressure ulcers (PUs). PUs are often developed on skin that covers bony areas of the body, such as the heel, ankles, hips or buttocks [1]. PUs severely affect patients' quality of life since the ulcers are painful, difficult to heal, and often extend hospitalization periods. Once developed, PUs represents an acute health condition that results in increased costs and suffering over many months and even years. Effective ulcer prevention and early detection will greatly reduce patient suffering/discomfort. Strong motivation for this work comes from the growing shortage of trained health care providers and the ever-increasing cost of health care.In 2000, the shortage of nurses was estimated at 6%. This shortage is expected to grow to 20% by 2015 and, if not addressed, to 29% by 2020 [2].

We have developed a software platform for PU monitoring and intervention system that recognizes different limbs of patient, computes risk of ulcer for each limb and suggests the next posture turn to the nurse. A Force-Sensing Array (FSA) [3] is used to collect pressure data from a hospital bed. The sensor mat is light, thin and flexible and with the sampling frequency of 1.7 Hz. The data from this pressure mat is used as the input to our ulcer prevention platform. This software interface has five major parts to be discussed next.

II. Software Components

1) Raw Data acquisition: This software module collects data of 2048 pressure sensors which is embedded in bed through USB port and stores it in a list for further processing. Data is shown in color-coded graph for recognizing spots that are under high pressure and stress. The other feature is limb-detection module which allows us to label (see Fig.1) and track at-risk regions of the body such as sacrum over the hip bones, heels, back of the head, heels and shoulder and assess those parts more accurately with associated pressure statistics. The module can also show statistics of sensors data such as max, min, and variance.

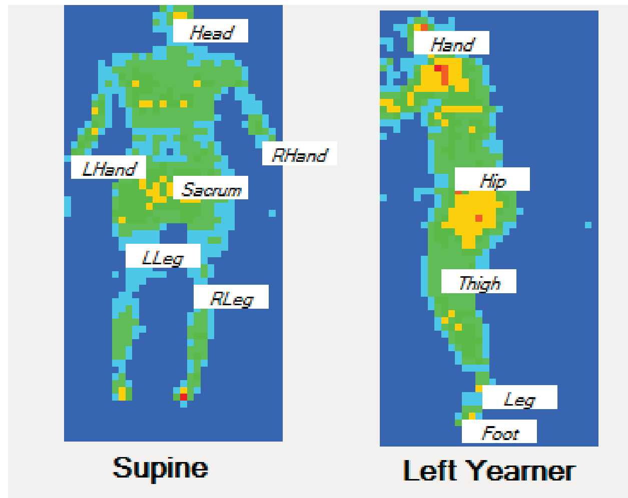

Fig. 1. Pressure Image and Labeled Limbs

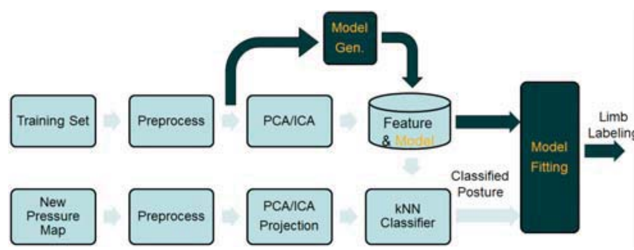

Fig. 2. Posture Classification and Limb Detection Model

2) Patient's Status and Biometric Data: In this part, there is a space for nurses to fill Braden-Chart data which helps software in calculating risk of ulcer. The Braden pressure ulcer risk assessment chart is widely used by hospitals to informally estimate the risk of developing pressure ulcers for bedbound and chairbound patients.Typically, a nurse manually records his/her judgment as a number between 1 (highest risk) and 4 (lowest risk) for six categories: (1) sensory perception, (2) moisture, (3) activity, (4) mobility, (5) nutrition and (6) friction & shear. Patients with a total score of 12 or less are considered to be at risk of developing pressure ulcers, (i.e. 15-16=low risk, 13-14=moderate risk, 12 or less=high risk) [4]. Blood pressure and other biometric factors can be optionally added.

3) Processed Data: We used a two-phase posture classifier. During training phase, pressure image quality is enhanced and database of features is generated by reducing dimension of

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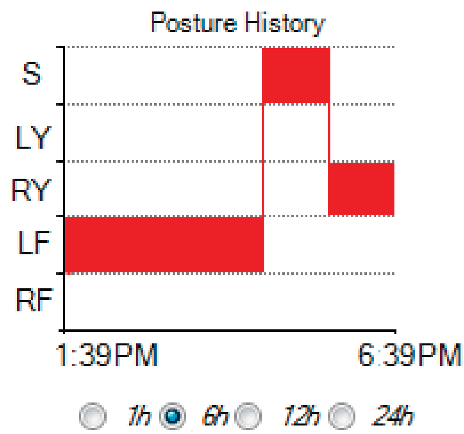

Fig. 3. Postures Classifications Graph

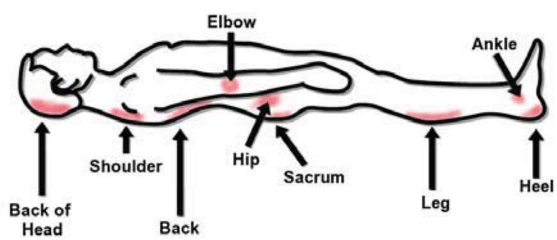

Fig. 4. Most Common Body Sites to Develop Pressure Ulcers

input data using principal component analysis (PCA). During test phase, pressure image is projected to a new feature space and KNN classifier is used to classify different postures (see Fig.2). Based on detected posture and skeletonization techniques, limbs are extracted and labeled in pressure map graph. Fig. 1 show examples of limb detection and posture classification, respectively [5].

Classified postures is recorded and shown in a graph to help nurses decide on patient's status. By using this data, nurses can have a more controllable treatment process. Fig. 3 shows posture history graph.

4) Ulcer Risk Assessment: Every posture exposes the body to a different set of pressures. The high risk regions for developing pressure ulcer are often over bony areas of the body such as lower back (sacrum), over the hip bones, heels, and even the rims of the ears. Fig. 4 shows some of these at-risk regions considered in our study.

Our approach is to track the risk level independently for each at-risk area of the body using a time-pressure stress-recovery model. Pressures above a certain minimum pressure, P_{min} will eventually cause a pressure ulcer, and therefore cause the risk to increase. Pressures below P_{min} result in recovery and lower risk. The risk assessment diagram for 6 hours of monitoring is shown in Fig. 5.

5) Resource-Efficient Turning schedule: The optimal strategy to deal with pressure ulcers is prevention. The

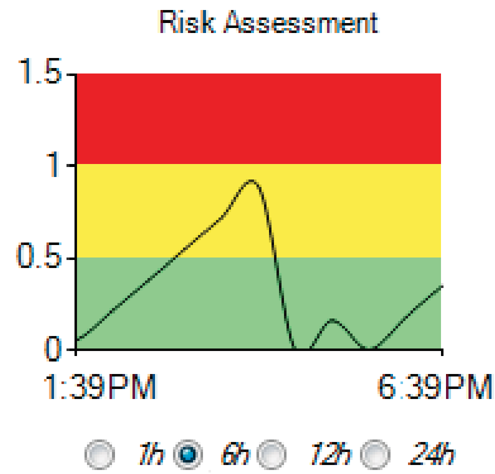

Fig. 5. Snapshot of Risk Assessment Graph

current standard for prevention is to reposition at-risk patients every two hours. But, each patient has different needs based on overall vulnerability and damaged skin areas. A fixed schedule may either result in some patients getting ulcers, or nurses being overworked by turning some patients too frequently. Our platform employs an efficient algorithm to find a repositioning schedule for bed-bound patients based on their risk of ulcer development. Our algorithm uses data from the pressure mat and provides a sequence of next safe positions and the time of repositioning for each patient. This patient-specific turning schedule minimizes the overall cost of nursing staff involvement in repositioning the patients while simultaneously minimizes the chance of pressure ulcer formation [6].

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