IN-BED POSTURE CLASSIFICATION

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Abstract: The growing trend of the population age contributes to the accumulation of patients in social facilities and in-home care, which leads to growing chronic diseases. Modern systems try to improve the effectiveness of health care interventions. Our work aims to create a widely applicable platform that combines the measurement of in-bed position with another's negative states. All these physical influences are mainly the cause of chronic tissue damage (pressure ulcers). Processing of the pressure distribution on the bed is a more dimension problem. The mentioned data are multi-modal. Therefore, we used the machine learning (ML) method to obtain the properties.

Keywords: Decubitus, Matrass, Machine Learning, Body posture classification

1 INTRODUCTION

The thesis aims to create a simple and reliable classification system for monitoring the condition of the patient who is lying on the bed. The main reason for the research was the requirement of the modernization and automation medical or rehabilitation devices. IoT devices and modern data processing methods are the only option for maintaining a high quality of life for patients who are prone to pressure ulcer development. In developed countries with an aging population, it is necessary to work on the care of these patients. The number and age of patients in need of after-care facilities are increasing. The high standards that are placed on this care require based on large staff resources. Moreover, the qualification of new paramedics is expensive and requires a lot of time. The lack of paramedics who can care about such aging patients increases. It affects the quality and availability of care provided, forcing hospitals to close parts of their wards, overburdened and exhausted nurses cannot perform all the procedures that would be necessary for patients. Some foreign studies even show that the lack of paramedics increases the likelihood of complications and death of patients. [1] This fact is evident in crises such as today's pandemic situation. Therefore, more and more attention are being paid to technical solutions in these areas of human activity. The overall trend of innovation in health care is desirable for society and necessary in the future.

However, as result of these trends, we must also ask ethical questions. After all, human contact and care are irreplaceable, and no machine can replace them. Despite the shortcomings, other than technical solutions do not yet appear relevant. Pressure ulcers are a major problem in bedridden care. There are several causes of development, and the only effective method of their treatment is prevention. Prevention of the emergence of pressure sores is based on the general experience of nursing and medical practice. It consists of the repetitive activity of paramedics and depends on the not always telling scales. These actions seek to optimize so-called smart sensors, which should be capable of early warnings or even intervention. This work's result is the classification process of sensitizing systems designed for both institutional and home care. The benefit of the work will be optimizing nursing tasks and minimizing the risks of complicating conditions. Another important aspect of this work is how measured data are processed and classified. The result of the pressure image classification will be the input for the data fusion and analysis of the overall state of the monitored entity.

2 PRESSURE ULCERS

Pressure ulcers, also known as decubitus, are a high-priority problem in everyday nursing. This is local damage of the skin, tissue, and at the worst stage, bone structure degradation. The cause of the formation of decubitus is high and stable pressure on the tissue in the areas of bone growth. Among other described side effects are increased humidity or temperature. Significantly affected points include the coccyx, heel, tulle, or scapula area when positioned on the back. The damage has the character of an ulcer with severe inflammation. In case of neglect, there is also a risk of blood poisoning and death. [2]

However, the problem is not only the prerogative of institutional care. In in-home care, the risk depends on the nurse's experience. Decubitus is not only the prerogative of gerontic patients, but younger patients who suffer from chronic pain are also at risk. The consequences can be tragic, and the solution is only an invasive procedure with long-term regeneration. Recovery is painful and time-consuming, so the best solution to a degrading state is to overcome prevention. The overall severity of the decubitus is also the reason for the emergence of therapeutic products that reduce or eliminate the risk of developing it completely. [2]

2.1 PREVENTION

The scientific literature lists the procedures and scales of assessment of the occurrence and damage already incurred. Pressure ulcers are classified into four categories (phases). Each phase represents physiological changes in skin, tissue, and bones in areas of adverse effects. [3]

Risk Assessment Scales for Pressure Ulcers Prevention (RAPs) have been introduced as a preventive risk assessment in patients. However, this is an objective evaluation, and there is no consensus among the professional public about the correctness of the individual criteria. All these scales are based on the point assessment of the physical and mental state of the evaluated patient. The result is an overall rating and a scale cut-off of the risk score. We can select three basic scales from the list of the most used scales. [4]

- Braden Scale
- Norton Scale
- Waterlow Scale

Depending on this assessment, the intervals of the treatment are individual. Such a system is highly dependent on the objectivity of its assessors [4]. It is a knowledge-based (vessel) system that could be integrated into the surveillance system. By eliminating the ambiguity of the evaluation, it is possible to optimize the physical actions of paramedics while also increasing the patient's safety.

3 DATA

The subject of this article is not the discussion of data collection, but its processing. However, it is necessary to show what raw data will look like. In addition to external sensors, the most important is the pressure image, which is universally scalable according to the resolution of the pressure image. The entire classification framework is created and tested in the *MATLAB R2020a development environment.* An image resolution data model (36 x 11) pressure point matrix was created. The pressure point is represented as an 8-bit unsigned integer. The image is colour-converted into a heat map, where the greatest pressure is represented by a dark red to black and areas with low or zero pressure are represented by white followed by yellow.

3.1 DATA SIMULATION

A dataset of three test patterns was created for testing in the initial phase. The use of simulated data for learning methods is not yet foreseeable. Data is designed to debug simple decision structures. A real dataset will be created after the sensory part is put into operation. The first test patterns are:

- Position on your back
- Position on your stomach
- Position on the left side

By transforming the columns of the pressure image horizontally, the data are complemented by a fourth position (position on the right side). By augmentation of the original images, the simulated dataset is extended by other images. The pressure matrix is pre-processed by trash hold filtering, and for presentation, values between points are interpolated in (Figure 1).

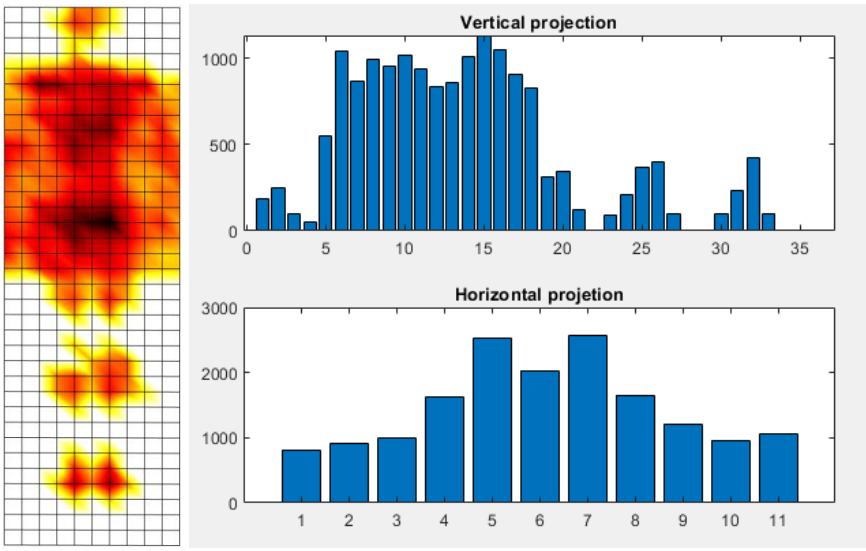

Figure 1: Heat map projection

4 FEATERUE EXTRACTION

In this chapter, we will deal with the design of pressure image processing. The features detected in the image are forwarded to the master application, which will be the output interface of the system.

4.1 HARD-FEATURES

Properties that can be precisely, mathematically defined from the input pressure image. They do not require a learning process and are not dependent on the training set. These methods are more robust and based on the physical nature of the measured data. The use of the computing capacity of a marginal facility is nowadays very desirable regarding the ecological footprint of the facility. One possible solution in the future appears to be edge devices in standalone working mode.

Energy

Kinetic energy is expressed as the sum of the maximum values of dynamic load change around the pressure point. The result is a time-consuming quantity that represents the patient's activity in the bed. This feature is crucial for us due to the further processing of the pressure image. If the patient is in motion (changing his position), it is not appropriate to classify his position. The activity score (AS) defines it as: [7]

$$AS(t) = \sum Max\{P_i(t),\ P_i(t-1)\} \cdot \left(\frac{\Delta P_i}{\Delta t}\right)^2 \qquad (1)$$

where P_i represents the *i*th pressure point at time *t*. [7]

Histogram projection

Horizontal and vertical projection of pressure image values is an effective way to obtain information about the pressure image. Each pressure point value is added up in the vertical and then horizontal direction. As can be seen in (Figure 1) the result is further used to find out extra information about the position of the center of gravity. If the center of gravity in the x-axis occurs outside the specified operational boundaries, a request for intervention arises. The subject could fall out of bed. Another use of the center of gravity is the segmentation of the pressure image. The gravity center position divides the pressure image into four sub-images. The upper and lower parts are secondarily divided to produce six partial images. These are then used to analyse Body Symmetry Diagnostic (BSD). [5]

4.2 SOFT-FEATURES

Generally, there are methods based on machine learning and artificial intelligence carried out over a larger data volume. The results depend on the quality of the teaching set. An example of such a feature is the recognition of gestures, objects, or the position of a lying figure. In the meantime, we expect to teach the classifier from the first test data. Our next step is a test with real data in real conditions. The accuracy of classification methods can range from 80% to 90% according to the specified method and the quality of learning. [6][7]

5 CLASIFICATION

The raw data after pre-processing are usable only for the presentation of the heat map, but they are not sufficiently descriptive for posture recognition. The task of recognizing the position from this type of data correlates with recognizing the written text. This technique so-called optical character recognition (OCR). In such a case, OCR techniques are used to obtain image properties, which also contain machine learning methods. Some methods could be categorized as pre-processing because they only transform the input space and transfer it clarified to the classifier. A relatively direct method is the use of convolutional neural networks. Convolutional neural networks (CNN) or deep networks also hide transforming convolutional layers. However, the disadvantage is learning methods, rely on a large dataset. Standard CNNs can still converge to similar solutions in OCR, but we do not have many options to moderate them. OCR methods such as histogram-oriented gradient (HOG) serve not only as pre-processing for extracting image properties but also as a sub-scaling method that reduces the size of the input. We can reduce the classifier, such as a standard neural network (NN), or other machine learning methods like (random forest, k-NN, other) [6]. The adopted method deals with segmentation by region of interest (ROI). Fuzzy C-mean clustering, which is based on standard k-means clustering. For example, in an article *Hung* [7], successfully used this method in combination with a neural classifier. Subsequently, the authors improved it to solve a low-cost infrared sensor. Even with low resolution and two-state output of the measuring point, they were able to achieve sufficient feature separability.

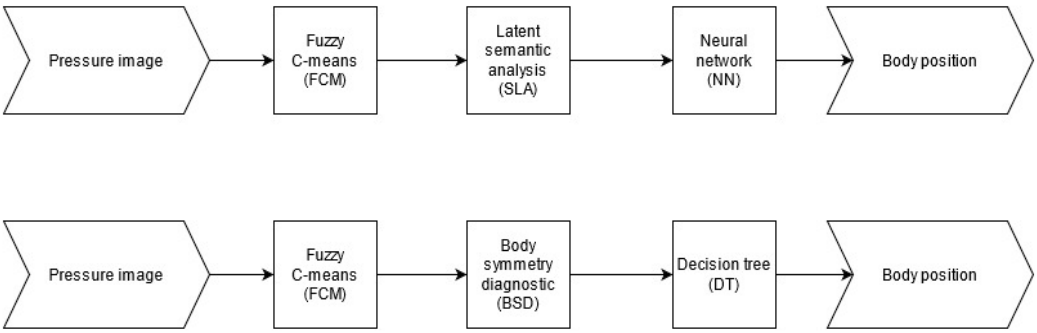

Figure 2: Two models of classification chain

Figure 2 shows two classification strings. The top string provides for the use of OCR methods in combination with FCM and SLA. The resulting properties are separated by a standard neural network. The second string uses symmetric analysis. The properties of the symmetry are separated by the decision tree. The output is a classification vector of four positions, mentioned in chapter (3.1).

6 CONCLUSION

This work has presented the design of on-bed activity classification. Nowadays trend in health care shows the very high priority of technic solutions for complex health condition diagnostic. Two classification methods for posture recognition based on machine learning were selected. V virtual dataset with four main positions was made.

Further work will be focus on experimental testing and system integration. The same performance and stability test will be performed with real data. The classification vector will be extended with new sleeping positions after the real data come. The case study demonstrated the potential and practicability for pressure ulcer prevention and evaluation of fall risk. Another possible usage of application is the detection of sleep apnoea or somnambulism.

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