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ORIGINAL PAPER

Awakening Event Detection for Fall Prevention Among Bedridden Using Kinect-Like Depth Image

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ABSTRACT

Falls among bedridden would increase in number if they are left unsupervised by the caregivers. This aim of this study is to evaluate the features from the Kinect-like depth image representing the bedridden in detecting the awakening event as the event that falls might occur. The images from 20 subjects performing six sleeping activities including the awakening events were obtained before image segmentation based on horizontal line profile was computed to these images in localizing the bedridden as the region of interest. After that, the biggest blob selection was executed in selecting the biggest blob (blob of bedridden person body). Finally, blob analysis was formulated to the resultant image before boxplot was used to present the output features. From boxplot analysis, centroid-x shows significant non-overlap between the awakening event and other sleeping activities as compared to other features which can be used to recognize the awakening event.

INTRODUCTION

Bedridden is referring to a person who is confined to bed or unable to leave bed due to medical orders, illness or psychological misfortune [1]. There is possibility for bedridden to fall out of bed when left unsupervised which might cause serious injuries [2]. However, 24/7 hour supervision of bedridden by the caregivers might be quite difficult to be done especially when the caregiver is handling a huge number of bedridden patients. Thus, the risk of bedridden to fall when there are no caregivers around might increase. This is why an automated bedridden monitoring system is vital to recognize the awakening events of bedridden and further alert the caregivers to instantly give assistance to prevent falls.

Nowadays, there are many technology interventions for the monitoring system in healthcare industries. One of the technologies that are used for health-related purposes is Microsoft Kinect that was used for recognizing human gestures [3], head detection for fall prevention [4] and other application due to the promising potentials in term of accuracy rate [5]. However, little study has been done in using Kinect to monitor bedridden in fall prevention especially by utilizing the occurrence of awakening event [6-10]. The awakening event is considered since such event is the high potential event that fall might occur for bedridden person.

Thus, the aims of this study is to evaluate the features from the Kinect-like depth image representing the bedridden for detecting the awakening event toward development of an automated system for fall prevention among the bedridden.

RELATED WORKS

There are several works were proposed in developing the automated monitoring system for a bedridden person. One of the existing systems is called MovinSense [10] that used a single tri-axial accelerometer attached to the patients' chest to monitor bedridden patients. The work in [7] used Kinect to monitor the bedridden by estimating the bed occupancy, body localization, body agitation and sleeping positions from the depth image while the study in [11] detected the sleeping posture and movement in obtaining the overall sleeping information. Furthermore, work in [12] focused on the detection of patient's bed status using the depth information, the 3D bed edges, bed height and bed chair angle which are estimated from the Kinect-like depth image to monitor bedridden position and status.

There are also several studies focused on bedridden monitoring which is not for detecting or preventing a fall but the proposed systems were designed for preventing the pressure ulcer among the bedridden. Pressure ulcers is caused when the bedridden lying on the same sleeping posture for long periods of time. For example, a study in [13] used pressure mapping system to create a time-stamped and whole-body pressure map while a study in [14] proposed the Kurtosis and skewness estimation extracted from signal obtained from the cost-effective pressure sensitive mattress in preventing the ulcers. Other than that, work in [14, 15] used wearable wireless transceivers, support vector machine and K-nearest neighbour methods in order to recognize the position of bedridden.

Thus, since there are only a few works focused on fall prevention among the bedridden, the evaluation of Kinect as vision sensor for fall prevention system among bedridden person was proposed in this study. This is also due to the Kinect has many advantages such as portable, low-cost, high frame-rate at 30 Hz, fast 3D information, and accurate depth information [16] as well as compared with other existing 3D motion capture system available in the market which is suitable to be used in this project.

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MATERIALS AND METHOD

Data Acquisition and Collection

In this study, the depth image dataset of 20 subjects performing six sleeping activities including awakening events (See Fig. 1) were established. Fig. 2 shows the recommended experimental setup whereby the Kinect was placed at the centre of the front side of bed with distance of 1.5 metres and at a height of 2.94 metres. The corresponding depth images of the subject are shown in Fig. 3.

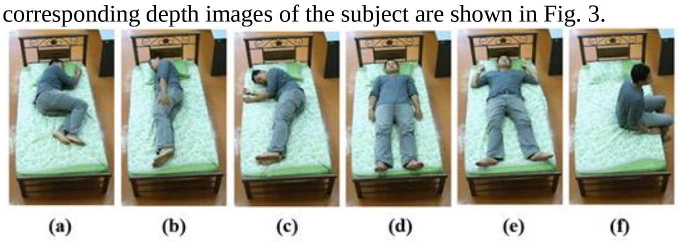

Fig. 1 Sleeping activities done by subject: (a) Feotus (P1); (b) Log (P); (c) Yearner (P3); (d) Soldier (P4); (e) Starfish (P5); (f) Awakening Event (PL).

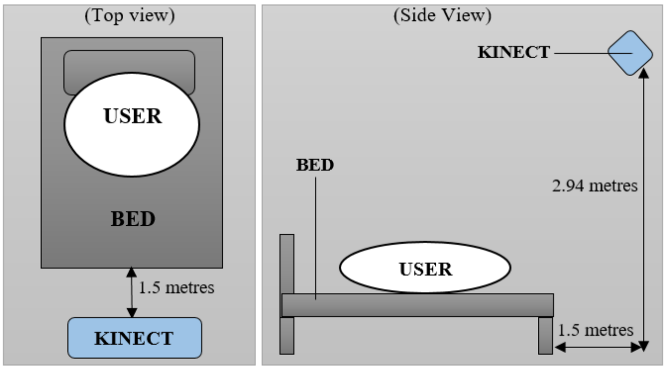

Fig. 2 Experimental Setup for Data Acquisition and Collection

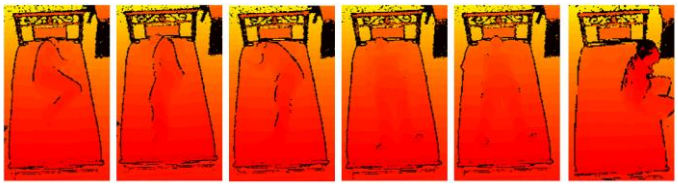

Fig. 3 Data acquisition and collection for sleeping activities.

Image Segmentation

Before segmentation was computed, one time calibration needs to be executed. In this calibration process, the image of empty bed was obtained (See Fig. 4) and the bed region was manually cropped from the depth image. From this process, the cropping coordinates were stored in the system (for the segmentation process) and the horizontal line pixels of the entire line in the cropped region (the empty bed) were collected. After that, the mean of each line was calculated and stored into the system (for the segmentation process). Then, the collected image from the previous section was cropped using the same coordinates that are stored before and the cropped image was segmented using the following equation:

$$g(x,y) = \begin{cases} 1, & f(x,y) > \textit{horizontal line mean} \\ 0, & \textit{elsewhere} \end{cases} \quad (1)$$

Whereby the horizontal line mean or horizontal line profile was used to determine the threshold value. The depth image of an empty bed was as shown in Fig. 4 while Fig. 5 (a) and (b) shows the image of subject after segmentation for sleeping activities awakening event.

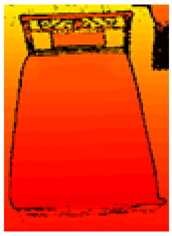

Fig. 4 Image of an empty bed.

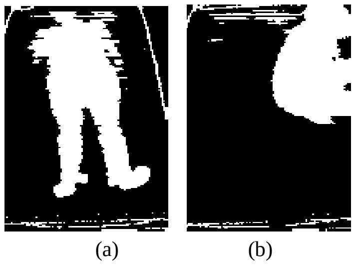

Fig. 5 Image of subject after segmentation doing sleeping activities: (a) sleeping on bed (P4); (b) awakening event (PL).

Morphological Process

After that, the morphological process consists of four times erosion with 'disk' structure element and two times dilation with 'square' structure element were executed to the segmented image. in order to remove noise from the image especially the white pixels in the background which can be considered as false detected object pixels. By eroding the image, the background noises including the bed were removed, leaving only the image of the subject (the object). Next, the image of the subject was dilated twice to ensure the continuity of the image, so that the output image will not have separated pieces of body parts. Fig. 6 (a) and (b) present the segmented image after morphological process:

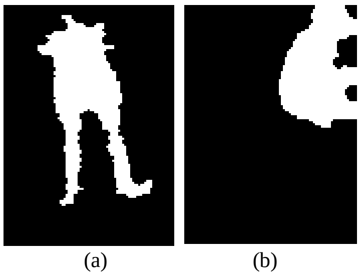

Fig. 6 Image of subject after morphological process doing sleeping activities: (a) sleeping on bed (P4); (b) awakening event (PL).

Biggest Blob Selections

Although the image has been dilated to ensure its continuity, there were still several images sample that has separated body parts. This problem can be seen in Fig. 7 whereby the image consists of several blobs. As a result, the complexity of the extracted feature will increase if more than one blob exists in the image. Thus, blob selection was done in order to get only the biggest blob and remove another blob in the image. Fig. 7 (b) illustrates the resultant image after the blob selection was formulated to the image in Fig. 7 (a). This function retains the biggest blob and removes other smaller blobs; by assuming the biggest blobs represent the image of the subject.

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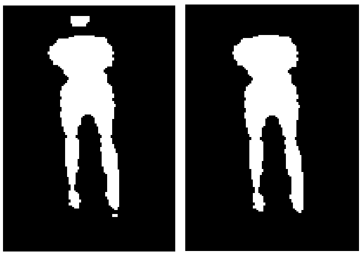

(a) (b)

Fig. 7 Image of subject doing sleeping activity: (a) before biggest blob selection; (b) after biggest blob selection.

Blob and Feature Analysis

At this stage, blob analysis was computed to evaluate the features from Kinect-like depth image that can represent the awakening event of the 20 subjects. Six features were extracted from the biggest blob which are area, perimeter, major axis length, minor axis length, centroid-x and centroid-y of the subject's blob. Then, these features are analyzed using boxplot technique to find the most significant features that can differentiate between awakening events with other sleeping activities. Six boxplots are presented in the results and each represents each feature against the type of sleeping activities including awakening events that were performed by the 20 subjects. The pattern of the boxplot of each figure are analyzed and the most significant features that did not have any overlapping between the awakening events and other sleeping activities are considered to be the best feature to be used for detecting the awakening events of the subjects.

Decision Making

Once the best feature was selected, the feature will be used in this process to recognize the awakening event of the subject. Rule-based ('If else') function was applied in this last stage to indicate the activities of the subjects of whether they are doing other sleeping activities or they perform the awakening event (See Fig. 8). The system will display 'AWAKE' if the feature shows awakening event or otherwise, it will display 'Other Event'.

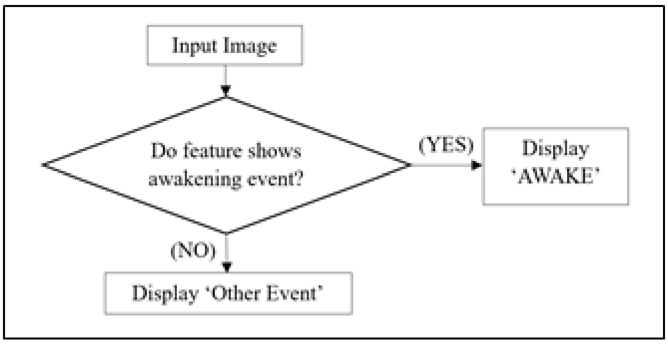

Fig. 8 Flowchart of decision making process.

RESULTS AND DISCUSSION

The results obtained in feature analysis stage based on box plot are presented in Fig. 9-14 that indicate the each feature for sleeping activities including awakening events done by 20 subjects.

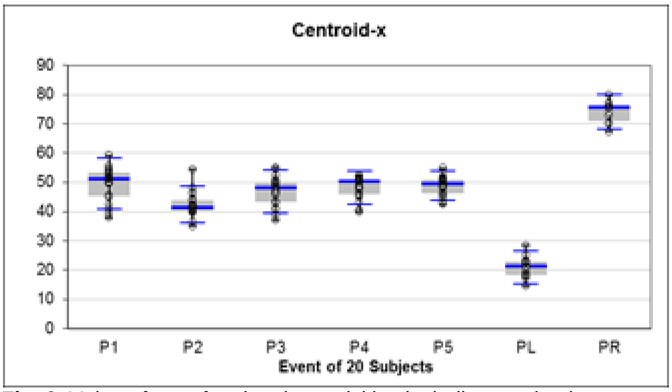

Fig. 9 Value of area for sleeping activities including awakening events.

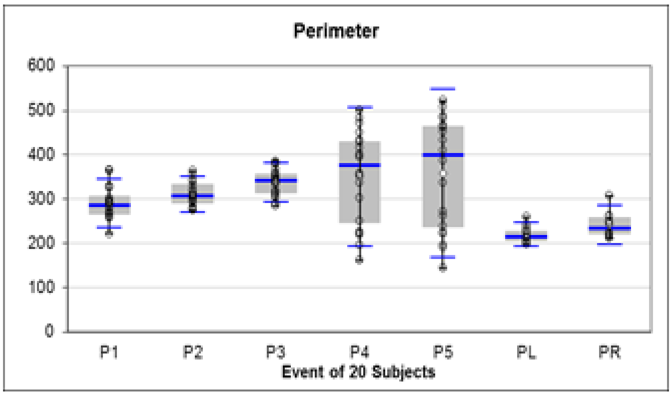

Fig. 10 Value of perimeter for sleeping activities including awakening events

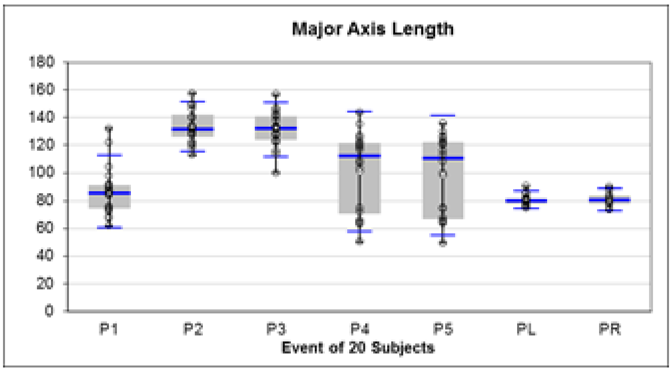

Fig. 11 Value of minor axis length for sleeping activities including awakening events.

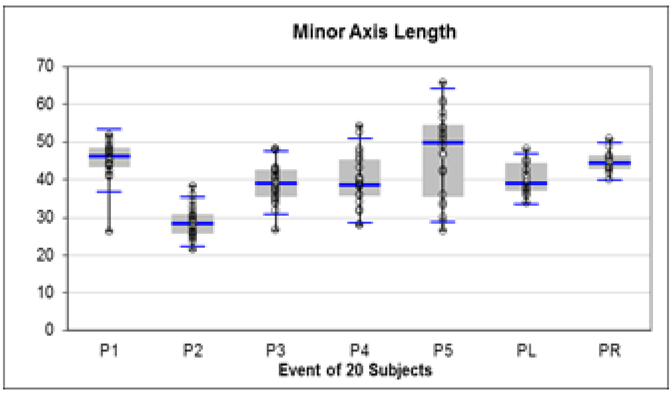

Fig. 12 Value of major axis length for sleeping activities including awakening events.

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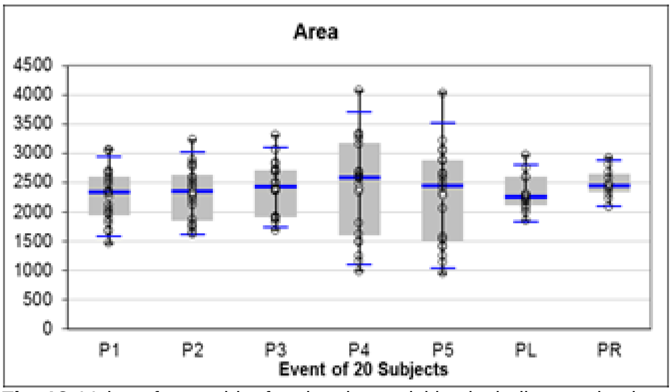

Fig. 13 Value of centroid-y for sleeping activities including awakening events.

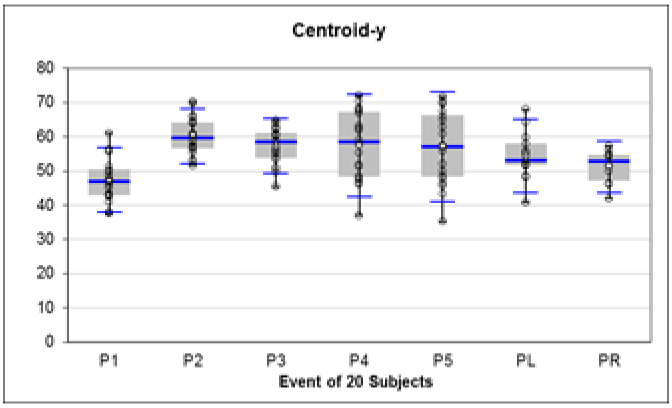

Fig. 14 Value of centroid-x for sleeping activities including awakening events**.**

Box plot technique was used to analyze which features can differentiate between awakening events and other events (other sleeping activities). This is because this technique is simple and suitable for visual representation of large data distribution. Overall, based on the results in Figure 9-14, almost all features were slightly overlapping between each other which might be due to the different body size, height and gender among different subjects. However, it can be seen in Figure 14 that the centroid-x that represents 20 subjects performing the awakening event (PR and PL) were not overlap other sleeping activities (P1-P5). Thus, this feature was selected to detect the awakening events of the subjects.

CONCLUSION

As a conclusion, the features from Kinect-like depth image have been analyzed to identify and differentiate between awakenings with other events. Based on the results from the boxplot technique, it seems that centroid-x can be used as a feature to recognize awakening event successfully with the accuracy of 100%. Therefore, an automated system that can detect a pre-fall (awakening event) have been developed in this project. This system can prevent a fall by alerting the caregivers when the awakening event occurs.

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