A Method for Monitoring Body Motion in Bed via Luminous Marker Attachments

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Abstract. *For the care of people in bed, the assistance or support for their body motion is an essential task. In the absence of helpers or at night, however, preventive measures are being required to avoid sudden accidents such as a fracture of bone due to a fall from a bed or suffocation due to turning over in bed. In this paper, a method was proposed for monitoring three-dimensionally their body motion, which is able to supply 24-hour monitoring with a low cost and high accuracy. Being different from previously developed methods in which a television camera is used to monitor the three dimensional (3D) motion of the body with reflective marker attachments via sequential image processing, this proposed method employs luminous markers and their two-dimensional positioning detectors to determine the 3D coordinates of the markers via a perspective view transformation. Based on the idea, a prototype system was developed, and its measurement accuracy was evaluated for a fixed marker and a repetitive circular motion marker. An application of the system to a subject turning over in bed demonstrated its feasibility for 3D body motion monitoring from the movement tracks of the subject rolling angles and breathing.*

Keywords: The Care of People in Bed, Monitoring the Body Motion, Turning Over in Bed, Breathing Movement

1. Introduction

In Japan, the shortage of helpers supporting senior citizen's daily life becomes a serious problem [1]. For the care of people in bed, its essential task is to avoid sudden accidents such as a fracture of bone due to a fall from a bed or suffocation due to turning over in bed. A method commonly used for this aim is to monitor three-dimensionally the movement of a body with reflective marker attachments using a television camera and irradiation light [2]-[3], while it requires sequential image processing and allows only the movement measurement from the direction in light. In this paper, a new method was proposed for monitoring the three-dimensional (3D) motion of the body with infrared luminous marker attachments via two-dimensional (2D) positioning detectors. It enables one to monitor the body motion simultaneously from many directions due to the hemispheroidal radiation of the infrared rays. Based on the above idea, we developed a prototype system. Applying the system to a subject turning over in bed, we demonstrated its feasibility for monitoring the 3D body motion from the movement tracks of the subject rolling angles and breathing.

2. Method

For 3D body motion monitoring, two luminous makers are attached to the left and right sides of a subject. Denote by $[u_L\ v_L\ 1]^T$ and $[u_R\ v_R\ 1]^T$ 2D camera coordinates for the left and right makers, respectively, and by $[x\ y\ z\ 1]^T$ 3D homogeneous coordinates of each luminous maker.

We then have the following relationship between both the coordinates with arbitrary real number λ:

$$\begin{cases} \lambda_L\,[u_L\ u_L\ 1]^T = P_L[\ x\ y\ z\ 1]^T \\ \lambda_R\,[u_R\ u_R\ 1]^T = P_R[\ x\ y\ z\ 1]^T \end{cases} \qquad (1)$$

where P_L and P_R are the projection matrices of three rows and four columns for the left and right luminous makers, respectively. If the projection matrices P_R and P_L are known, measuring the 2D camera coordinates of each luminous marker yields the corresponding 3D coordinates from Eq.(1).

Figure 1 shows the measurement environment for monitoring the body motion of a subject in bed.

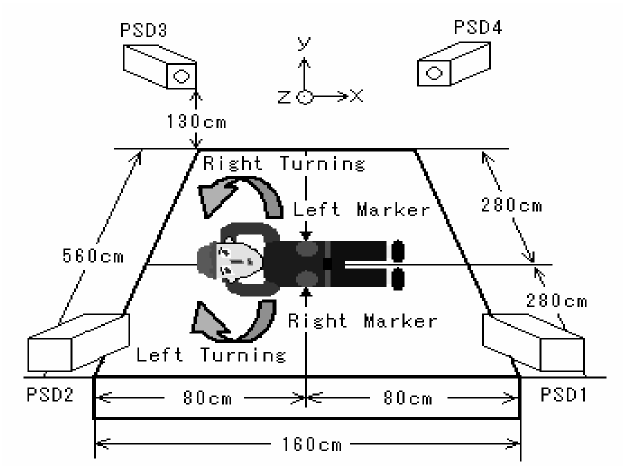

Fig. 1. Measurement environment for monitoring the body motion of a subject in bed.

Two luminous markers are attached to the left and right portions around the abdominal region of a subject, and their movements are simultaneously detected as 2D camera coordinates by four position-sensing detectors (PSD). The 3D locus of each luminous marker is then calculated from the 2D camera coordinates via a perspective view transformation. Figure 2(a) shows the appearance of a luminous marker emitting infrared rays. The luminous marker consists of an infrared light-emitting diode being manufactured by Hamamatsu Photonics K.K. of high brilliancy type and a miniature holder with an adhesive double-coated tape and a hook-and-loop fastener for the installation to the subject's body.

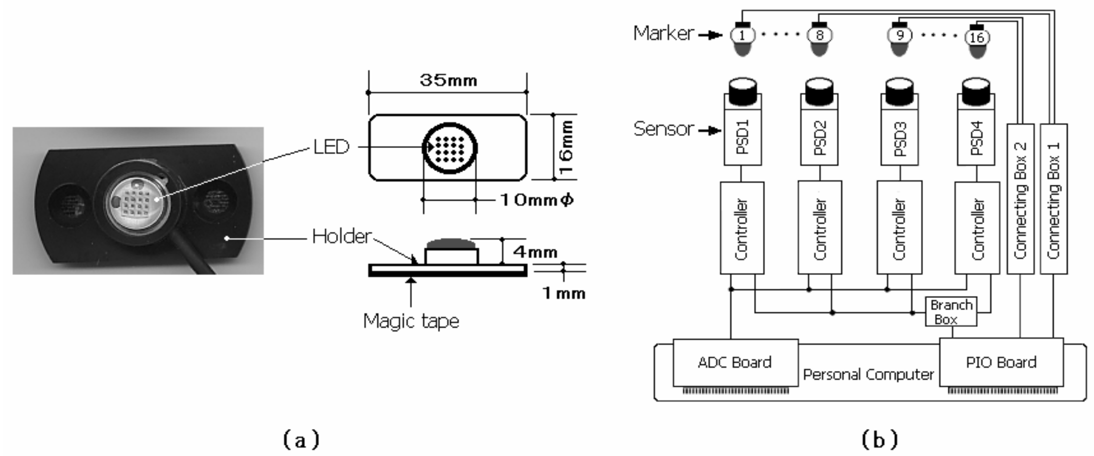

Fig. 2. Appearance of a luminous marker and block diagram of the measurement system.

The marker has a weight of 40 g and is still light with a connecting cable of about 5 m. The block diagram of the prototype system is shown in Fig. 2(b). The system consists of four 2D PSDs for measuring the marker's locations. The PSDs are controlled by a personal computer so that they allow the 3D measurement for 16 markers at most. Each PSD's output voltage is analogue-digital converted and transferred to a personal computer in order to calculate the 3D locus via a perspective view transformation.

3. Results and Discussion

Figure 3(a) shows the calibration frame with multiple luminous maker attachments for obtaining the projection matrices P_R and P_L of the prototype system. The locations of the calibration makers can simultaneously be detected as 2D camera coordinates from four PSDs.

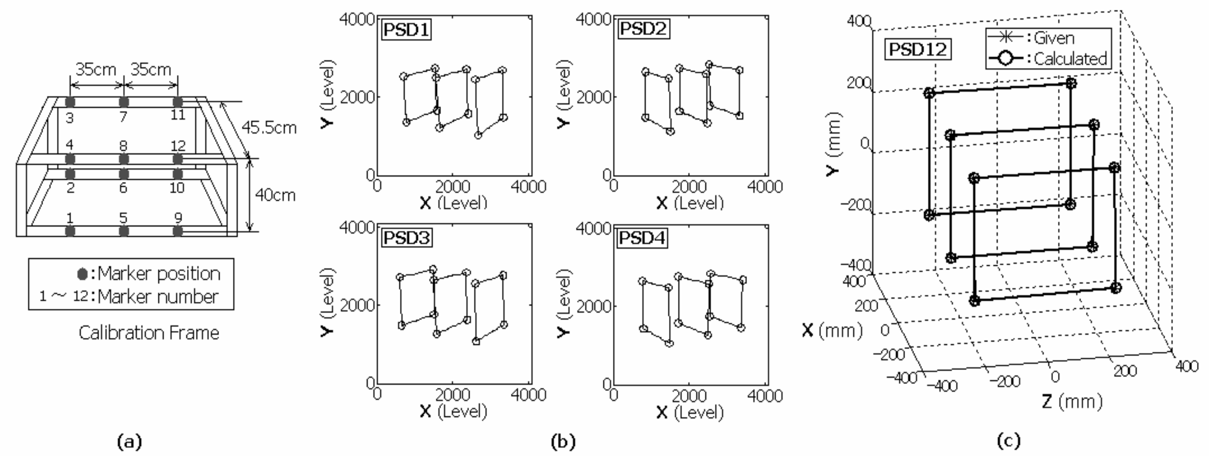

Fig. 3. Three-dimensional coordinates calculated from two-dimensional camera coordinates measured for the calibration frame.

Figures 3(b) and 3(c) show the 2D camera coordinates measured with four PSDs and the resultant 3D coordinates, respectively.

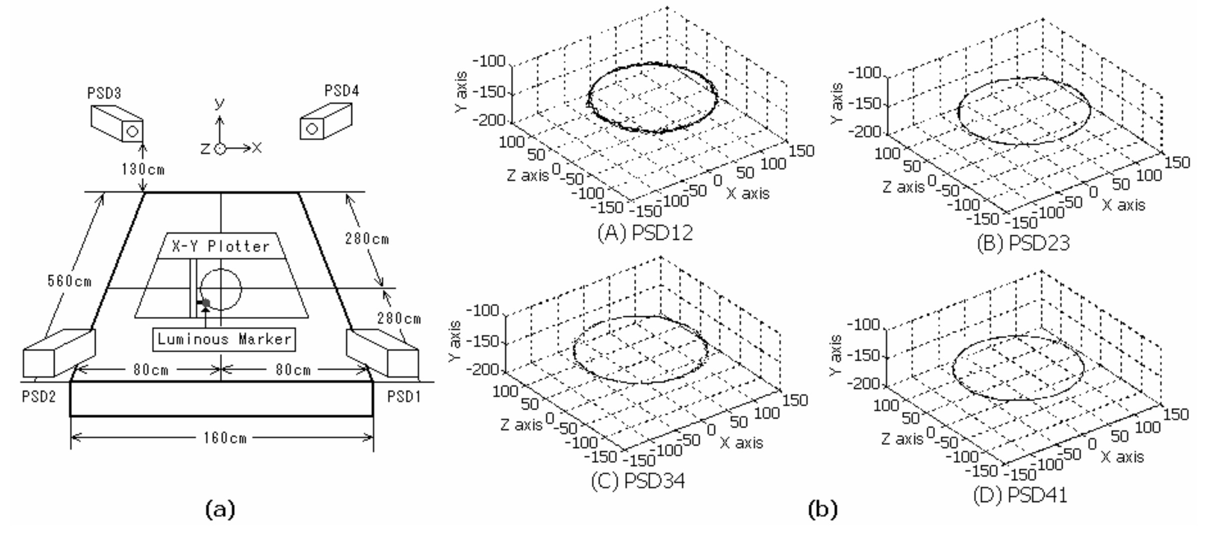

Fig. 4. Experimental results for the circular movement of the luminous marker.

The measurement accuracy of the system was evaluated for a fixed marker and a repetitive circular movement marker. For the fixed maker, we found that its location can be detected within an error of 1 %. Figure 4(a) shows the measurement environment for a luminous marker that moves along with a circle, which was realized by using the marker attached to the penholder of a X-Y plotter. Figure 4(b) shows the results obtained for the repetition circular motion with a radius of 100 mm, which demonstrates that the locations can be detected with an error of ± 3.6 mm for the repetitive circular movement marker with a swing of ± 100 mm.

In order to confirm the above system's feasibility for monitoring the body motion, we measured a subject turning motion in bed. Figures 5(a) and 5(b) show the results simultaneously detected for the rolling angles and breathing movement, respectively, when the subject turns over in bed. We found from the figure that the system can detect the body motion in bed together with the breathing movement.

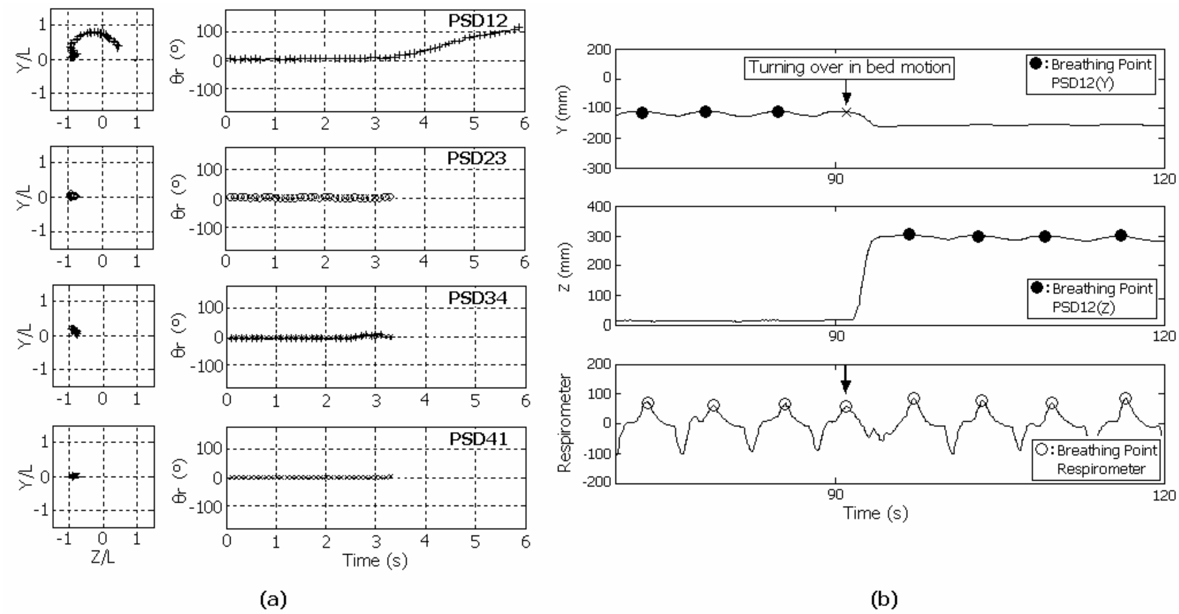

Fig. 5. Detection results for the rolling angles and breathing movement of a subject in bed.

4. Conclusion

A method has been proposed for monitoring three-dimensionally the motion of the body with infrared luminous marker attachments. A prototype system has been developed, which has demonstrated its feasibility for monitoring the body motion of a subject in bed and the breathing movement as well.

The future subject is to apply the proposed system to the body motion monitoring for an actual senior citizen in bed.

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