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# Development of a New Wearable Monitoring System for Posture Changes and Activities and its Application to Rehabilitation

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*Abstract*— **In order to evaluate the efficacy of rehabilitation for persons with hemiplegia, a therapist usually makes judgment by directly observing posture changes, walking speed, activities not only in hospital, but also during daily living. Therefore, quantitative assessment of activities is most desirable. From this viewpoint, we have developed a device for ambulatory monitoring of posture changes, walking speed and activity scenario and evaluated its measurement accuracy by simultaneous recordings of a digital video camera. In order to investigate its applicability to a patient's activity monitoring, we have further developed a new monitoring system which can display static and dynamic motion pictures as well as detailed angle changes of the trunk, thigh and calf. This system makes a therapist to easily understand the patient's motion during training in rehabilitation center and activities during daily living. By evaluation on 6 patients with hemiplegia, the patients' motions were successfully monitored during walking in the rehabilitation center and daily living at their own home. The results clearly demonstrated that the system could detect detailed motion characteristics, indicating that the system appears useful for evaluating quantitatively the efficacy of rehabilitation.**

*Keywords*— **Wearable monitoring system, Posture changes, Activities, Walking speed, Rehabilitation**

## I. Introduction

Importance of activity monitoring is well recognized in the fields of health care, gerontology and rehabilitation. For example, in the field of gerontology, it is one of the key subjects for the elderly to maintain their activity in daily life in high condition to avoid becoming bedridden. Therefore, an objective measurement of activity is essential [1].

Activity monitoring is also well recognized as being useful in the field of rehabilitation. In order to evaluate the efficacy of rehabilitation, a therapist must evaluate motion characteristics during standing-up, walking, and so on. However, the therapist must usually make assessments subjectively using direct observation. Therefore, quantitative assessment of activities is most desirable. One method employed is to make recordings using a 3D motion capture, but the range over which such recording is possible is usually limited and data analysis is complicated. Therefore, these methods are generally not useful in rehabilitation.

Some wearable instruments capable of monitoring activity using accelerometer, gyro-sensor, and so on, have been developed [2~8]. But, it is difficult for the therapist to evaluate the patient's posture changes from the data obtained from these devices. Therefore, the wearable system has not yet become practical in rehabilitation field.

On the other hand, we developed a portable device measuring the trunk, thigh and calf angle to the gravitational direction to improve of quality of life for the elderly persons [9]. At the beginning of development, we used miniature electromagnetic inclinometers to measure angles, but had problems with limited measurement range and inertial artifacts of the weight built in the sensor. To solve these problems, we used the accelerometer and gyro-sensor for angle measurement [10], and developed our system to measure the posture changes together with walking speed including the slowness of elderly persons (50 cm/s or less) with high precision (r=0.99) [11~13].

In order to investigate its applicability to a patient's activity monitoring, we have been carrying out the clinical evaluation in rehabilitation center [11~13]. In this study, we have further developed a new monitoring system which can display motion pictures as well as detailed angle changes. By evaluation on 6 patients with hemiplegia, the patients' motions were monitored during walking in rehabilitation center and daily living at their own home.

## II. System overview

Fig. 1 shows the outline of the sensor system for monitoring posture changes on sagittal plane together with walking speed. Lower part shows the block diagram of sensor unit. The accelerometer, gyro-sensor, amplifier, Micro SD card, transmitter, Battery, CPU, and so on, are installed in the sensor unit, and this unit is attached on the subject's trunk, thigh and calf, respectively. The patient's motion in the rehabilitation center is monitored using the telemetering system and their activity during daily living at home is recorded using micro SD card.

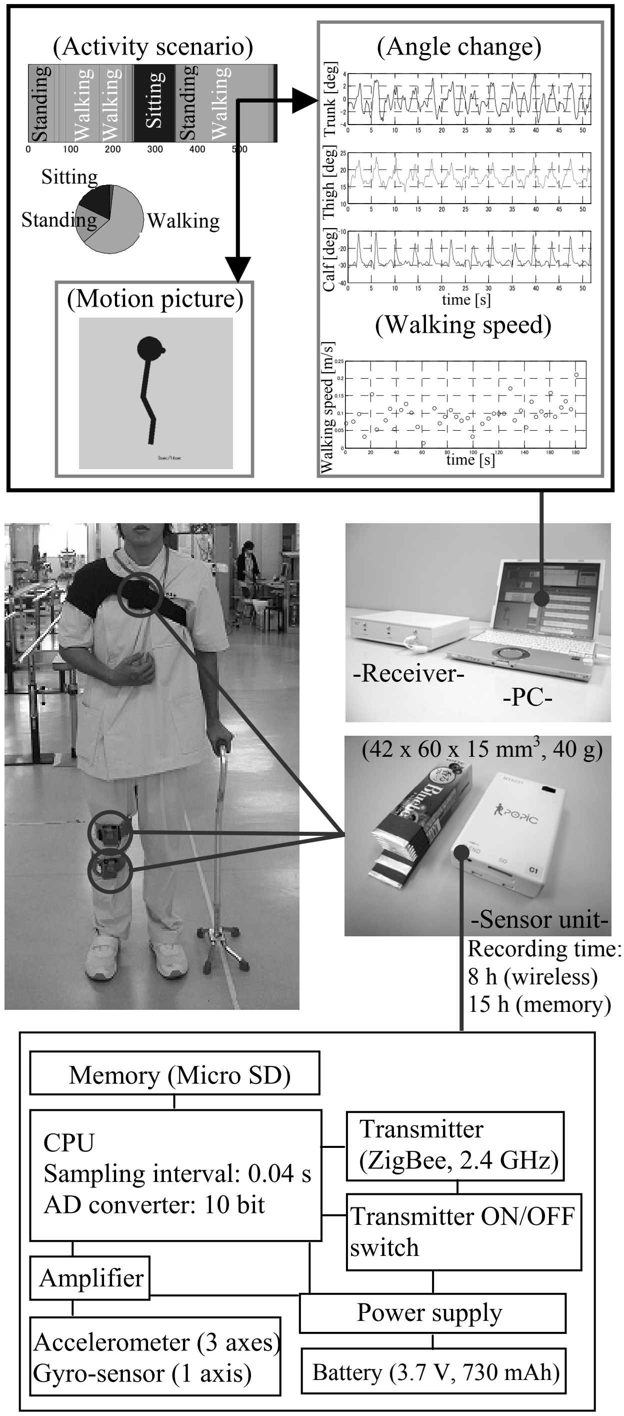


Fig. 1 Outline of the monitoring system

Firstly, it discriminates among postures from walking, sitting, lying and standing using the angle changes on the sagittal plane calculated from low frequency signals (DC~0.5 Hz) of the accelerometers of each part. Specifically, each posture is determined using the angle thresholds. In the static posture such as standing, sitting and lying, the angle to the gravitational direction of each part is obtained from these low frequency signals of the accelerometers. On the other hand, to calculate the angle changes in the trunk, thigh and calf during dynamic posture such as walking with high precision, angular velocity outputs (0.1~10 Hz) of the gyro-sensors of each part are integrated. The initial angle value is obtained from the sensor signal of accelerometer just before walking. Using the thigh and calf angles in heel contact and off and subject's leg length, walking speed for one walking cycle is calculated using the two link gait model. We previously reported details of calculation methods described above and its measurement accuracy [10~13].

Upper part of Fig. 1 shows the outline of data display for the therapist. Firstly, activity scenarios are displayed as 5 color bars (standing, walking, sitting, lying and standing-up and sitting down). The detailed angle changes, walking speed and motion pictures can be displayed by clicking the bar of activity scenario. These make a therapist to easily understand the patient's activity and motion characteristics.

## III. Subjects and Methods

4 subjects with hemiplegia (50~85 yrs) had measurements of posture changes during walking in the rehabilitation center. Posture change and walking speed were measured during 10 m-walking. The posture changes of subjects were also recorded using a digital video camera.

2 subjects with hemiplegia (80, 84 yrs) had measurements of activities during daily living at home after leaving the hospital. The measurement are carried out for two hours after home visiting rehabilitation, and activity scenarios, posture changes, walking speed were evaluated. The lower limb sensors were fixed on the paralyzed side.

Before measurement, we acquired permission from the ethical review board at the hospital and the informed consent had been obtained in each patient.

## IV. Results and Discussion

Fig. 2 shows typical recordings of the angle changes of trunk, thigh, knee and calf before and after rehabilitation in male patient using T-cane and MAFO (62 yrs, paralyzed side: right, rehabilitation: 21 days). The patient had measurement during 10 m-walking before and after rehabilitation program. From these results, the range of knee angle changes obtained after rehabilitation became larger than those obtained before rehabilitation, and cyclic angle changes of trunk, thigh and calf were also detected. These results show that the subject could control the gait by flexion and extension of the knee after rehabilitation, indicating that the efficacy of rehabilitation program could be evaluated by the quantitative data obtained from the system.

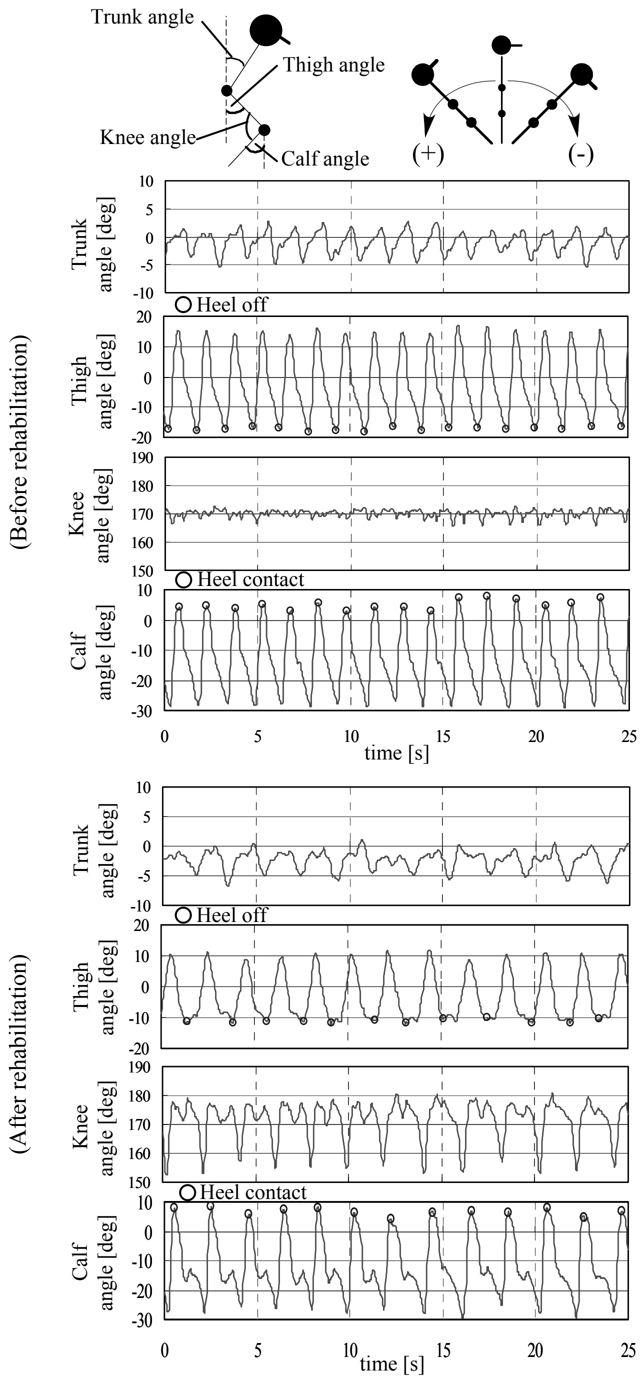


Fig. 2 Typical recordings of the angle changes of trunk, thigh, knee and calf during walking before and after rehabilitation

Fig. 3 shows analytical results for a long-term rehabilitation in male patient with non-cane and non-brace (56 yrs, paralyzed side: right). Each plot denotes the average value during 10 m-walking after rehabilitation. Each plot denotes the average value during 10 m-walking after rehabilitation. 20 walking cycles were accumulated in standard deviation: SD of the thigh angle in heel contact.

From these results, the walking speed became faster by 57 rehabilitation days and then keeping about 0.7 m/s. Therefore, the performance of walking could improve and keep by the rehabilitation. The range of thigh angle changes became larger by the rehabilitation, therefore joint motion improved. SD of the thigh angle in heel contact, i.e., repeatability of motion was getting worse by 57 days while the walking speed was increasing, but those were improving with keeping walking speed by 71 days. It is demonstrated that the present system appears useful for quantitative evaluation of the efficacy for a long-term rehabilitation.

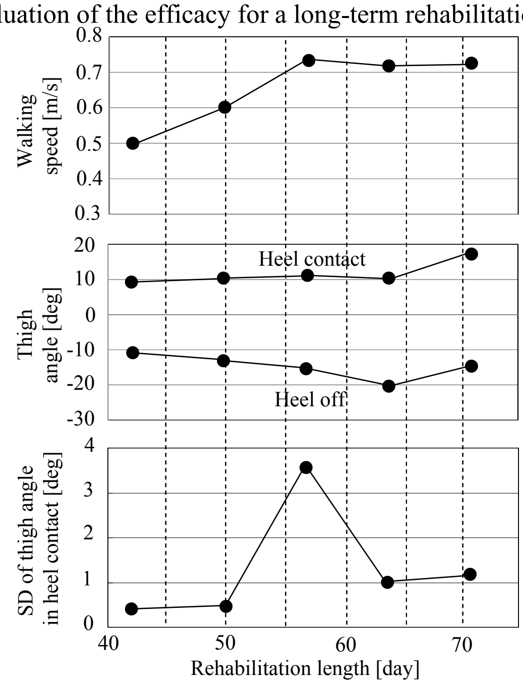


Fig. 3 Analytical results for a long-term rehabilitation

Fig. 4 shows typical recordings of the activity scenario, stick picture during sitting, and the thigh angle change and walking speed during walking in female subject with hemiplegia (84 yrs, paralyzed side: right), in 13 and 34 days after leaving the hospital. From these results, the subject was almost living with sitting and lying position. In 13 days after leaving the hospital, cyclic thigh angle change and walking speed were not detected, showing that the subject's gait was unstable. But, in 34 days, cyclic angle changes and stable speed-up and slowing-down in walking speed, were detected. From stick pictures, detailed posture in sitting position could be evaluated, indicating that the system appears useful for evaluating activities during daily living and the efficacy of home visiting rehabilitation.

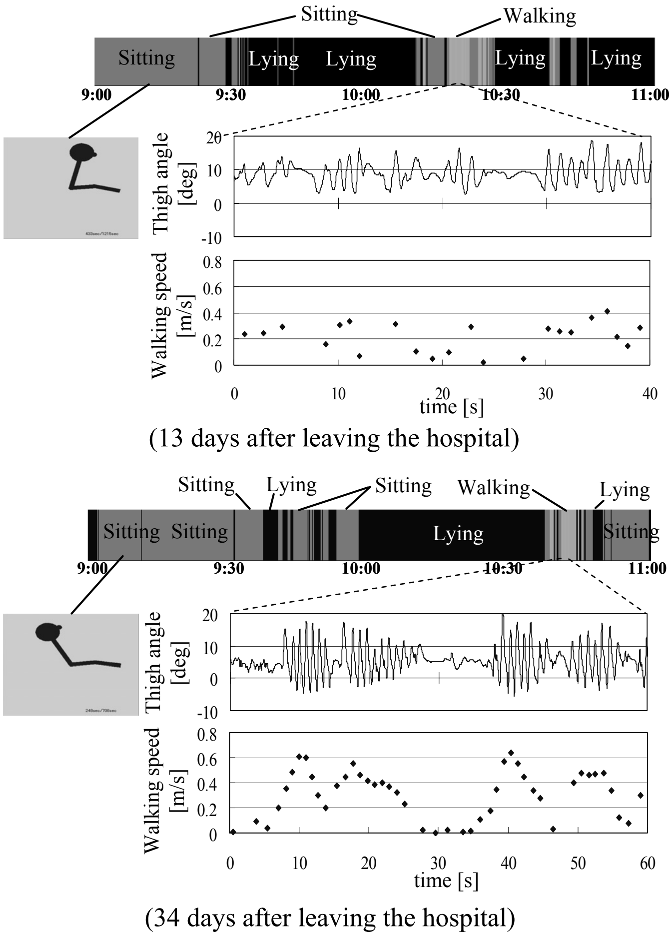


Fig. 4 Typical recordings of the activity scenarios and the thigh angle change and walking speed during walking in daily living at patient's home

## V. CONCLUSIONS

In this study, we have developed a new monitoring system which can display motion pictures as well as detailed angle changes of the trunk, thigh and calf. By evaluation on 6 patients with hemiplegia, the patients' motions were successfully monitored not only in rehabilitation center, but also during daily living. These results clearly demonstrated that the present system could detect detailed motion characteristics, indicating that the system appears useful for evaluating the efficacy of rehabilitation using quantitative data. Further investigations will be needed through measurements for a longer period of time in many patients.

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## REFERENCES

1. A. Hendry, W. Gilchrist G. Duncan, A. L. Evans and D. C. Smith (1990) Measurement of walking speed in elderly inpatients. Med. Biol. Eng. Comput., vol. 28(6), pp. 602-604
2. R. E. Mayagoitia, J.C. Lotters, P. H. Veltink and H. Hermens (2002) Standing balance evaluation using a triaxial accelerometer. Gait and Posture, vol. 16, pp. 55-59
3. M. Sekine, T. Tamura, M. Akay, T. Fujimoto, T. Togawa and Y. Fukui (2002) Discrimination of walking patterns using wavelet-based fractal analysis. IEEE Trans. Rehab. Eng., vol. 10(3), pp. 188-196
4. M. Makikawa and H. Izumi (1995) Development of an ambulatory physical activity memory device and its application for the categorization of actions in daily life. In Proc. Medinfo. '95, pp. 747-750
5. B. Najafi, K. Aminian, A. Paraschiv-Ionescu, F. Loew, CJ. Bula and P. Robert (2003) Ambulatory system for human motion analysis using a kinematic sensor: Monitoring of daily physical activity in the elderly. IEEE Trans. Biomed. Eng., vol. 50(6), pp. 711-723
6. S. Miyazaki (1997) Long-term unrestrained measurement of stride length and walking velocity utilizing a piezoelectric gyroscope. IEEE Trans. Biomed. Eng., vol. 44(8), pp. 753-759
7. R. Williamson and BJ. Andrews (2001) Detecting absolute human knee angle and angular velocity using accelerometers and rate gyroscopes. Med. Biol. Eng. Comput., vol. 39, pp. 1-9
8. H. Dejnabadi, B. M. Jolles, E. Casanova, P. Fua and K. Aminian (2006) Estimation and visualization of sagittal kinematics of lower limbs orientation using body-fixed sensors. IEEE Trans. Biomed. Eng., vol. 53(7), pp. 1385-1393
9. S. Tanaka, K. Yamakoshi and P. Rolfe (1994) New portable instrument for long-term ambulatory monitoring of posture change using miniature electro-magnetic inclinometers. Med. & Biol. Eng. & Comput., vol. 32, pp. 357-360
10. K. Motoi, S. Tanaka, M. Nogawa and K. Yamakoshi (2003) Evaluation of a new sensor system for ambulatory monitoring of human posture and walking speed using accelerometers and gyroscope. SICE Annual Conference 2003 Proceedings, pp. 563-566
11. K. Motoi, Y. Higashi, Y. Kuwae, T. Yuji, S. Tanaka and Y. Yamakoshi (2005) Development of a wearable device capable of monitoring human activity for use in rehabilitation and certification of eligibility for long-term care. Proceedings of the IEEE Engineering in Medicine and Biology 27th Annual Conference Shanghai, CD-ROM
12. K. Motoi, K. Ikeda, Y. Kuwae, T. Yuji, Y. Higashi, M. Nogawa, S. Tanaka and Y. Yamakoshi (2006) Development of an ambulatory device for monitoring posture change and walking speed for use in rehabilitation. Proceedings of the 28th Annual Conference of the IEEE Engineering in Medicine and Biology Society, CD-ROM
13. K. Motoi, S. Tanaka, Y. Kuwae, T. Yuji, Y. Higashi, T. Fujimoto and K. Yamakoshi (2007) Evaluation of a Wearable Sensor System Monitoring Posture Changes and Activities for Use in Rehabilitation. Journal of Robotics and Mechatronics, vol. 19(6), pp. 656-666

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