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Conference Paper · October 2003

DOI: 10.1109/IEMBS.2003.1280534 · Source: IEEE Xplore

Proceedings of the 25th Annual International Conference of the IEEE EMBS
Cancun, Mexico • September 17-21, 2003

A Study on the Activity Classification Using a Triaxial Accelerometer

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Abstract— **This paper describes a design of an algorithm for analyzing human activity using a body-fixed triaxial accelerometer on the back,. In the first step, we distinguish static and dynamic activity period using AC signal analysis. Then five static activities were classified by applying the threshold in DC signal corresponding to the static activity period. Also, after taking AC signal and negative peak signal in the dynamic activity period, the four dynamic activities were classified by adaptive threshold method. To evaluate the performance of the proposed algorithm, the measured signals obtained from 12 subjects were applied to the proposed algorithm and the results were compared with the simultaneously measured video data. As a result, the activity classification rate of 95.1% on average was obtained. Overall results show that the proposed classification algorithm has a possibility to be used to analyze the static and dynamic physical activity.**

Keywords—**Physical activity, 3-axis accelerometer, static and dynamic activity**

I. Introduction

Accurate analysis of human activity is important for analysis of physical activities or walking. Recently, a new method attaching sensors to several parts of human body, e.g. chest, waist, wrist, thigh, and ankle, to measure various human activities with more accuracy and efficiency was developed, and algorithms by which lying, sitting, standing, and dynamic activities are classified are being introduced, and also researches on more detailed activity classification using wavelet transform, fuzzy clustering method, neural network, etc. are being conducted [1][2]. In this paper we designed an activity analysis algorithm using adaptive threshold method which can possibly detect various activities more accurately and is adaptively applicable to subjects.

II. METHODOLOGY

A. Experimental Method

In this study, we used 3-axis piezoresistive accelerometer to measure acceleration. Measured acceleration is converted to digital signal by A/D converter with sampling rate of 32Hz using multi-functional microprocessor ADuC812, and saved to 32Kbyte memory. The characteristic of the accelerometer was sensitivity of 500±25mV/g, input range of 4g, and bandwidth of DC~100Hz. 24 subjects in their twenties (age range 21-28 years, 20 man and 4 woman) with no severe disease were participated. Data from 12 subjects were used for signal analysis and algorithm development and data from another 12 subjects were used for algorithm evaluation. Signal from two groups was obtained from different activity protocol, and by means of filming subjects activity during data acquisition. We compared the result from data analysis using activity classification algorithm with that of data analysis using filmed videotape. 3-axis accelerometer was attached on subjects back, on the vertebrae and the X-axis measured right and left direction, Y-axis measured up and down direction, and Z-axis measured back forth direction of acceleration signal and three direction of acceleration of human body was measured simultaneously. Obtained data was transmitted to PC through serial port and analyzed by MatLab.

B. Activity Classification Algorithm

In this study we developed activity classification algorithm by which we can classify 5 static activities: standing up, sitting down with lowering subjects head, sitting down and leaning against, lying down straight, and lying upside down, and 4 dynamic activities: walking, going up the stairs, going down the stairs, and running, by analyzing measured 3 directional acceleration signal.

Static activity and dynamic activity can be classified by comparing the amplitude of extracted AC signal from the measured data because static activity which has no movement are represented as DC signal and dynamic activity which has movements are represented as AC signal.

Piezoresistive accelerometer changes the DC value of the signal according to the incline difference with regard to gravity direction. Therefore, classification of 5 static activities is possible by applying DC value difference due to the difference of body incline which originates from posture change. Standing up DC value is different for each subjects because body standing posture is different for each subject standing posture. Hence, we applied reference of standing DC signal to make a decision of the threshold.

Among dynamic activities, running signal is much more larger than other dynamic activities. Hence, running signal is classified by applying threshold to the moving average to the absolute value of AC value extracted from Y-axis signal.

In Y-axis signal, Going down the stairs signal is also larger than other dynamic activities except running signal. To make a decision of threshold to detect going down the stairs, walking signal was used the reference. The difference in signals can be divided into two kinds according to the magnitude of walking signals. If walking signal level is large, the difference between going down the stairs and walking is relatively small. On the contrary, if the magnitude of walking signal is small, the difference between going down the stairs and walking is large. Therefore, applying single threshold in activity classification will generate large error according to subject action. To minimize error and obtain consistent detection rate regardless of subjects action , two thresholds are applied to classify walking and going down the stairs according to the magnitude of walking signal.

At the action of going up the stairs, upper body inclines at front of body. Therefore, DC level of Z-axis signal increases in the action of going up the stairs and acceleration signal level increases. Hence, negative peak of going up the stairs signal is relatively increases compared to other walking or going down the stairs signals. From the original signals of Y-axis and Z-axis, signals from static and dynamic activity that include walking, going up the stairs and exclude running and going down the stairs signal are extracted. Among the extracted signals, standing signal in static activity is determined as reference and the signals larger than the reference are eliminated and the absolute values of the signals smaller than the reference are taken to get negative signal. Threshold to classify going up the stairs was determined 1/3 of moving average of walking negative signal.

In order to get the reference value of standing and walking which are the two values to classify activities, certain period of standing and walking is included in the beginning of the data measurement.

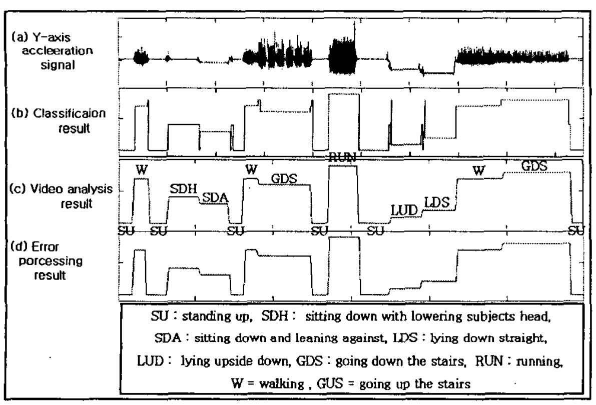

Fig. 1. Example of the classified results

Fig.1 is an example of the classified result of human body acceleration signal by applying activity classification algorithm. In comparison with result using the algorithm and results from the video, error occurred from acceleration signal during posture changing process in static activity, and from walking period during stair change in stair activity. Hence, error handling algorithm is designed to eliminate the errors: in video analysis, static activity, that is, posture changing process is not considered as dynamic activity but as static activity, walking period between stair activities is considered as stair activity, so dynamic activity less than 5 seconds in posture changing process is considered as the next classified static activity, and walking period between stair activities is not considered as walking, but as successive stair activity until there is any activity more than 5 seconds after the stair activity. Fig.1 (d) is an example of results after the error handling process. It shows that after the error handling process, result that is more similar to the video analysis data can be obtained by adjusting the error in posture changing process or stair activity.

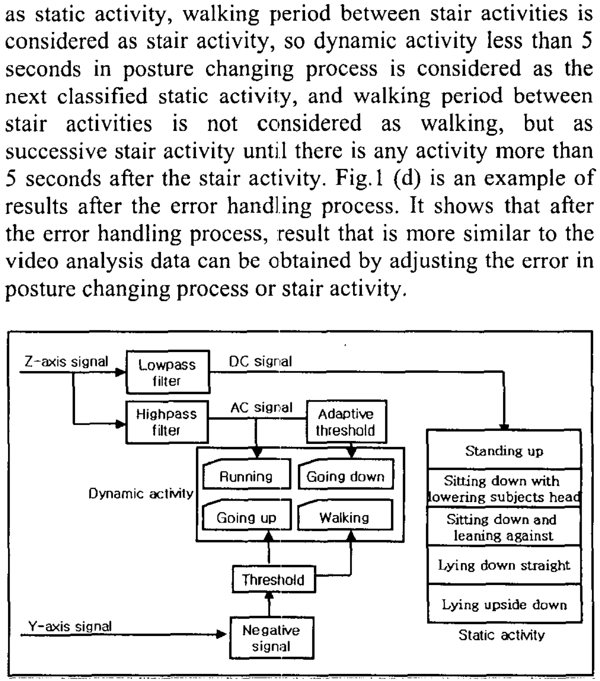

Fig. 2. Block diagram of designed activity classification algorithm

Fig.2 show the block diagram of designed activity classification algorithm based on above-mentioned acceleration signal analysis.

III. Results and Discussion

For the evaluation of designed activity classification algorithm, the algorithm was applied to the data from 12 subjects. To test the usefulness of the algorithm, Data from 12 subjects were obtained by different activity protocols, and also, standing and walking signals were obtained and we used them as the reference values in data analysis. The classified result from activity classification algorithm was compared to the image data from videotape recording and the activity classification rate of the system was evaluated. The rate is expressed as percentage using following formula:

$$\textit{Classification rate} = \frac{\textit{classification}\ \text{time applying algorithm in video analysis peroid}}{\text{classification time in video analysis period}} \times 100(\%)$$

TABLE I
Classification results according to activities

Classification activity		video analysis (sec)	algorithm analysis (sec)	classification rate (%)
Static activity	standing up	1020	975	95.6
	sitting down and leaning against	184	173	94
	sitting down with lowering subjects head	234	226	96.6
	lying upside down	259	245	94.6
	lying down straight	268	256	95.5
Dynamic activity	walking	651	589	**90.4**
	going up the stairs	543	537	**98.9**
	going down the stairs	483	465	**96.3**
	running	238	225	94.5
Total		3,880	3,691	**95.1**

Table 1 shows classification results according to activities. In classification results according to activities, walking show the lowest rate of 90.4% and going up the stairs show the highest rate of 98.9%, and the classification rate is consequently 95.1% in average. In all activities, classification rates were over 90%, which verify high accuracy of the designed algorithm. Also, in preceding research, walking, going up the stairs, and going down the stairs had similar activity patterns which resulted in low classification rate[3], but in this study, classification rate was very high.

In activity classification algorithm, signal gets flattened during activity changing process in applying moving average, and this causes error in applying threshold and classifying the exact starting point and ending point. In this study, error occurring rate is diminished, but not completely eliminated. However, error in activity changing process when applying this algorithm to longtime activity is considered to be out of the question because no error occurred during proceeding activities.

In a special subject case, amplitude of going down the stairs signal was smaller than walking signal but it is rare. Because our algorithm will not be applied for this subject, another approach to analyze of activity of those subjects should be tried.

Activity monitoring systems based on posture and activity classification are applied in many quarters like cardiac disorder, activity analysis of the elderly, geriatric dementia, chronic fatigue syndrome, rehabilitation medicine, sports analysis system, and etc. [4]. In this study, a short time activity protocol including 9 various activities was established to design algorithm. Long time data acquisition during daily life and application of the algorithm is needed for further research to evaluate usefulness because most activity state monitoring is used in daily long time activity analysis.

IV. CONCLUSION

In this study, classification algorithm of 9 typical activities occurring in daily life using 3-axis single accelerometer was designed. Acceleration data from 12 subjects were acquired, designed activity classification algorithm was applied and the result was compared to video data result and analyzed and consequently, classification rate of 95.1% was obtained. Moreover, classification performance was improved by applying adaptive threshold method.

ACKNOWLEDGMENT

This study was supported by a grant of the International Mobile communications 2000 R&D Projects, Ministry of Information & Communication, Republic of Korea. (01-PJ11-PG9-01HT00-0026).

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