Elderly People Activity Monitoring System

W. Suntiamorntut, S. Charoenpanyasak, J.Sriwan, J.Nopparat, S. Julrat
Centre of Excellence in Wireless Sensor Networks,
Department of Computer Engineering, Faculty of Engineering,
Prince of Songkla University, Hatyai Songkhla Thailand, 90112

{wannarat@coe.psu.ac.th}

Abstract—**This paper proposes an activity monitoring system using accelerated sensors for elderly people. The values from two 3-axis accelerated sensors have been processed using SVM algorithm to classify the activity of elderly people. The classified activity is transmitted via Zigbee protocol to home gateway.**

Keywords; elderly people activity, accelerator, SVM

I. INTRODUCTION

Wireless Sensor Networks (WSNs) use small devices, called nodes, to connect each other wirelessly. The transmission by small devices needs to focus on saving energy. The device consists of several modules such as Digital I/O Analog I/O and communicate module. WSNs transmits data with the radio frequency ISM 2.4 GHz based on IEEE 802.15.4 standard. Wireless Sensor Networks are widely in many popular applications such as smart home and health care monitoring.

Health care system is human health monitoring system. The monitoring system detection human behavior in daily. The system identifies human activities e.g. standing, walking, and sitting and analyzes these results in order to detect the behaviors that are risky to office syndrome. According to the existing researches, there is a complication in classifying human activities between bending forward, backward, left, and right. An inaccurate results cause the system to be unable to detect the behaviors that are risky to office syndrome.

This research presents how to apply the acceleration sensor in order to assist in the identifying of human behavior, especially for elderly people. The behaviors are recorded and transmitted to home gateway for health monitoring. The different direction and movement will help us to assess the elderly people health. In the movement analysis, we use Signal Vector Magnitude (SVM). While the rotation and blending analysis will use Pitch and Roll. Therefore, proposed method can identify the sit or stand of elderly people behavior in any manner and store the activity record for doctor. In addition, it can also alert when fall is detected.

This paper is organized as follows. In the section II, review past work in human monitoring. Next, in the section III, Methodology and system. Some experimental results are shown in the section IV. Finally, conclusions are drawn in Section V.

II. RELATED WORKS

The Office syndrome is the result of unhealthy habits, such as sitting for a prolonged period without sufficient bodily movement. The human behavior monitoring system can be utilized for detecting behaviors that are risky to office syndrome. The system categorizes human behaviors into patterns such as sitting, standing, and walking. Human monitoring system uses 3-axis Accelerometer sensor recording daily activity for human behavior analysis and transmits data to computer server through wireless sensor networks (WSNs).

The human behaviors monitoring system analyzes human behavior in daily life by collecting data from 3-Axis Accelerometer sensors and categorizing the results into different postures e.g. standing, sitting, and walking. The data analysis from the accelerometer sensor involves Signal Vector Magnitude (SVM) [1]-[6] for identifying human behaviors. The system requires multiple sensors for categorizing human behaviors [7]. Each transmits data via wireless sensor network by XBee module [8] and the system will notify the user once risky behaviors to office syndrome [9] are detected relatively to Ergonomic workstation [10]-[13].

The human behaviors monitoring system using wireless sensor network analyzes data from 3-axis Accelerometer sensors by SVM [1]-[6]. The system can detect human behavior such as sitting, walking and standing. But it is unable to specify whether the target is bending forward, backward, left, or right. This causes the data to be insufficient for analysis behaviors that are risky to office syndrome [8] and performing Pitch Roll analysis for detecting rotation direction of the sensors [14]. This research presents how to apply the acceleration sensor in order to assist in the identifying of elderly people behavior for their doctor and fall are detected.

III. METHODOLOGY AND SYSTEM

In this session, the system and each methods which are applied in this work are presented here. The accelerated sensor and classification algorithm are also explained. Two sensor nodes have been used in the system, one is attached on the chest and the other is on the waist. Each node comprises of 3-axis accelerated sensor, XBee module and alkaline battery.

The classification algorithm will be computed on each node and the behavior data will be transmitted wirelessly based on ZigBee protocol to the home gateway. The client can monitor the human activities real-time.

A. System Overview

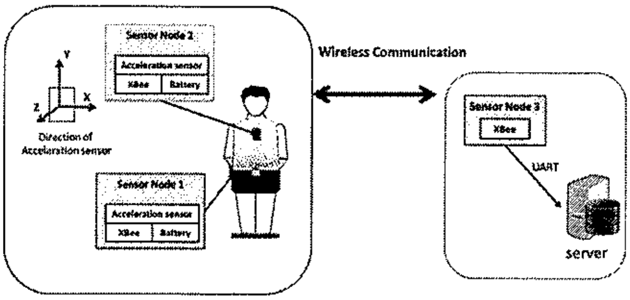

Figure 1. Human activity monitoring system

In order to establish the human activity monitoring system, two sensor nodes are applied as shown in Figure1. Sensor node 1 on the waist is used to detect the regular human activities such as sitting, walking and standing. In this paper, we propose to attach another accelerated sensor (sensor node 2) on the chest in order to understand the body movements such as blending up, down, left or right whilst the human is sitting or standing. These two sensor nodes perform independently and transmit the body activity to record at the home gateway wirelessly based on ZigBee protocol. The advantage of using this system is we can monitor many human in the same time due to each node is distributed computing. However, there is a limitation of the wireless connectivity. From our simulation experiences using NS2 we suggest not to apply more than 30 peoples on the same gateway which is enough for one family deployment.

For classifying human activities from a 3-axis accelerated sensor, we propose two states of classification. Firstly, Signal Vector Magnitude (SVM) is applied for behaviors such as sitting, standing or walking. This SVM algorithm is run on sensor node 1 (attached on waist). The calculation is shown in Equation(1). The second state is a measurement of pit and roll orientation angles using the data from accelerated sensor's at the chest. The Equation(2) is utilized to analyze data from acceleration sensor for classifying between bending left or right whilst we are sitting or standing. The Equation(3) is used to classify the body movement between bending up and down. Whereas fx_g, fy_g, fz_g is gravitational field in axis X, Y and Z from accelerated sensor, respectively.

$$SVM = \sqrt{fx_g^2 + fy_g^2 + \ fz_g^2} \qquad (1)$$

$$\text{Pitch} = \tan^{-1}\left[\frac{fY_g}{\sqrt{(fx_g^2+fz_g^2)}}\right] \qquad (2)$$

$$\text{Roll} = \tanh^{-1}\left[\frac{-fX_g}{fZ_g}\right] \qquad (3)$$

The pattern classification of human activity requires both two sensors' position. After sensor node 1 that running SVM analysis has got the result, the behavior is sent to sensor node 2 to combine the results and finally transmit the activity to gateway in order to store the result in database.

B. Accelerated Sensor

For an analysis acceleration data of axis X, Y and Z for detecting physical human activity in daily life, we used a MMA7361L (Freescale Co. Ltd., USA) acceleration sensor that can measure 3-axis acceleration. The acceleration sensor is a low power, low voltage and low current consumption. As its current consumption is 3 uA under sleep mode operation, the sensor is applicable to wireless sensor networks where low power operation is essential. The result of data analysis form acceleration sensor can classify human activity.

In order to startup acceleration sensor, we used 3.3V power input, which is supplied from the battery of a wireless sensor node, set sensitivity gravity range 1.5g and set acceleration sensor to operate at sleep mode for saving power. Data output of axis X, Y and Z from acceleration sensor is sent to wireless sensor node device for classifying data human activity.

C. Wireless Sensor Networks

For the wireless transmission of measured data from the acceleration sensor, we used XBee from Digi-company. XBee module transmits data based on IEEE 802.15.4 Personal Area Networks standard. The XBee module operates within Industrial Sciences Medicine (ISM) bands at a maximum data-rate of 250Kbps. XBee module used UART or RS-232 for communicating to personal computer. The modules include RF module for transmitting data through wireless network, Digital I/O for controlling XBee module and analog I/O for reading analog data from other sensors. Operation voltage input range is between 2.7V and 3.6V. In addition, this programmable XBee module has micro-controller so we can program it for controlling operation of XBee module and other sensors.

The XBee modules with programmable option have a processor with 2K of RAM, and 32k of flash. The module includes processor EM250 or MC9s08qe for development of the program, unlike other versions of XBee which requires micro controller for processing. EM250 processor is responsible of processing, controlling Digital I/O, controlling Analog I/O and serial port. We can use programmable XBee module for analysis data from acceleration sensor and transmission data through wireless network.

IV. EXPERIMENTAL RESULTS

Development of human activity monitoring system using wireless sensor networks for analysis of risky behavior that might cause the office syndrome e.g. sitting or standing for long time period. The Experiment monitoring system includes SVM method for classified posture activity and analysis Roll and Pitch measurement for classifying human activity. An additional feature is a warning: The system collects a period of time taken by each body movement and raises a caution if the period is too long according to the Ergonomic in Table 1.

TABLE I. ERGONOMIC TIME FOR EACH ACTIVITY

Activity	Time(sec)
Sitdown not body movement	60
Sitdown and body movement	120
Stand not body movement	60
Stand body movement	120
walking	None

In order to evaluate the possibility of monitoring Human activity such as sitting standing and walking, we can classify the result from data axis of X Y and Z acceleration sensor at user wearable waist. We developed an algorithm that assesses the output characteristic of 3-axis acceleration sensor by SVM method. Table 2 shows the statistic value of the SVM. Detection posture activity while the users are sitting or standing can be classified relatively to the Roll and Pitch value. Table 3 shows the statistic value of the Roll and Pitch measurement.

TABLE II. STATISTIC VALUE OF SVM FOR HUMAN ACTIVITY DETECTION

Activity	SVM
Sitting	0.773 to 0.81
Standing	0.716 to 0.768
walking	0.611 to 0.875 (swing)

TABLE III. STATISTIC VALUE OF ROLL AND PITCH MEASUREMENT

Activity	Pitch	Roll
Normal	37.85 to 38.60	-54.50 to -53.80
Down	29.97 to 38.11	-54.09 to -51.16
Up	43.76 to 45.0.2	-55.59 to -53.03
Left	32.44 to 42.22	-66.87 to -61.64
Right	30.73 to 44.27	-46.94 to -41.21

The Result of human activity by SVM method and Pitch Roll measurement. We can classify human behavior in daily. The Experiment of human activity monitoring system can define activity such as walking and sitting or standing in pattern bend down, up, left, right and normal. Each takes one minute for testing. As shown in Figure 2 graph 1 presents a result of the test. At the beginning, sensor node 1 detects sitting and sends data to sensor node 2 for analyzing pitch and roll, for classifying bending normal, down, left, right and up. Then sensor node 1 detects standing and sends data to sensor node 2 for analyzing pitch and roll, for classifying bending normal, left, right, down and up. At the end, sensor node1 detects walking. In this case, Pitch Roll measurement will not be performed by sensor node 2. In order to verify the correctness, we have done the experiments by changing the activity every a minute. The accuracy of the classifying in the activity of tests is shown in Table IV. By using this information we can observe and suggest the better activity for elderly people in order to have a good health.

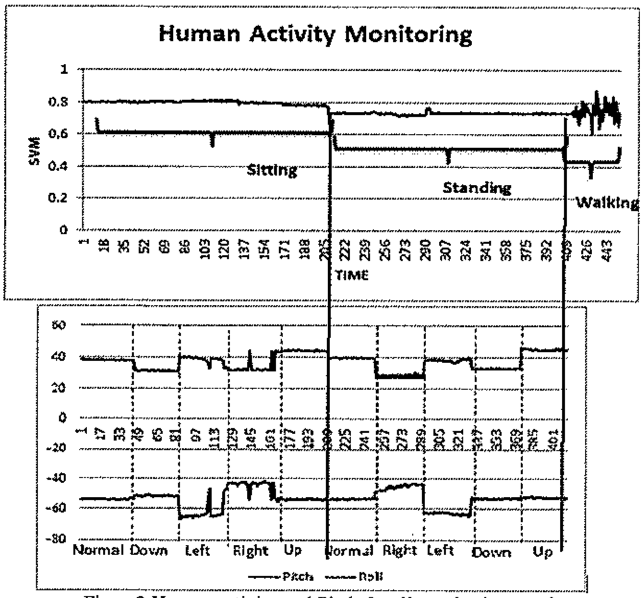

Figure2 Human activity and Pitch & roll monitoring graph

TABLE IV. RESULTS OF EXPERIMENTS

Activities	Task	No. Tests	Overall Correct	Overall Incorrect	Accuracy (%)
Sitting	Normal	150	148	2	98.67
	Bending Down	150	147	3	98.00
	Bending Up	150	147	3	98.00
	Bending Left	150	146	4	97.33
	Bending Right	150	147	3	98.00
Standing	Normal	150	148	2	98.67
	Bending Down	150	148	2	98.67
	Bending Up	150	147	3	98.00
	Bending Left	150	145	5	96.67
	Bending Right	150	148	2	98.00
Walking	Walking	150	143	7	95.33

V. CONCLUSION

By using our proposed system, we can classify the human activity in more detail which we can suggest the better activity for elderly people in order to have a good health. Because of our proposed system, we can classify the human movement while he is sitting or standing still. Moreover, we have classified the human activity embedded on each sensor node.

This will help to reduce the amount of data transmission in the wireless system. Finally, we are able to know each activity in detailed by using another accelerated sensor attached on the chest. Thus we can still observe the human even he is sitting or standing still. In addition, we can know whether the human has any movement or not whilst he is sitting.

ACKNOWLEDGMENT

The author would like to thank to BTFP, Office of The National Broadcasting and Telecommunications Commission (NBTC) for research grant supportive.

REFERENCES

[1] D. M. Karantonis, M. R. Narayanan, M. Mathie, and N. H. Lovell," Implementation of a Real-Time Human Movement Classifier Using a Triaxial Accelerometer for Ambulatory Monitoring," IEEE Transactions on information technology in biomedicine, vol. 10, 2006, pp. 156-167

[2] Z. He, and L. Jin, " Activity Recognition from acceleration data Based on Discrete Consine Transform and SVM," in IEEE International Conference on Systems, Man , and Cybernetics San Antonio, TX, USA, 2009, pp. 5186-5189

[3] M. Nii, K. Nakai, and Y. Takahashi, "Extraction of Human Behavior from Human Activity Monitoring Data using MEMS Sensors," in IEEE, 2011

[4] D. Naranjo-Hernandez, L. M. Roa, J. Reina-Tosina, and M. A. Estudillo-Valderrama, "SoM: A Smart Sensor for Human Activity Monitoring and Assisted Healthy Ageing," in IEEE Transaction On Biomedical Engineering, Vol. 59, NO. 11, 2012, pp. 3177-3184

[5] M. R. Narayanan, S. J. Redmond, B. G. Celler, and N. H. Lovell, "Longitudinal Falls-Risk Estimation Using Triaxial Accelerometry," in IEEE Transaction On Biomedical Engineering, Vol. 57, NO. 3, 2010, pp. 534-541

[6] N. Wang, S. J. Redmond, E. Ambikairajah, B. G. Celler, and N. H. Lovell, "Can Triaxial Accelerometry Accurately Recognize Inclined Walking Terains?," in IEEE Transaction On Biomedical Engineering, Vol. 57, NO. 10, 2010, pp. 2506-2516

[7] D. Naveen Babu, P. Veeranath, and K. Bhaskar, "NOVEL SYSTEM FOR MONITORING OF PATIENTS HEALTH CONDITION USING MOBILE 3-AXIS ACCELEROMETERS SENSORS," in International Journal of Advanced Engineering Technologies, VolI-IssueI-2013, pp.25-31

[8] Digi International Inc. (2013), "XBee®/XBee-PRO® ZB RFModules,"[Online].Available:http://ftp1.digi.com/support/documentation/90000976_P.pdf

[9] PRLog, "Office workers syndrome: a new condition to focus on with your massage therapist," [Online], Available :http://www.prlog.org/12145934-office-workers-syndrome-new-condition-to-focus-on-with-your-massage-therapist.html, [September 30, 2013].

[10] Professional and Specialized Services, "COMPUTER ERGONOMICS: WORKSTATION LAYOUT AND LIGTING," Available: http://www.labour.gov.on.ca/english/hs/pdf/gl_comp_erg.pdf

[11] OSHA, "OSHA fact sheet : laboratory safety ergonomics for the prevention of musculoskeletal disorders," [Online], Available : https://www.osha.gov/Publications/laboratory/OSHAfactsheet-laboratory-safety-ergonomics.pdf, [October 2, 2013].

[12] Stanford Environmental Health & Safety, "Ergonomic microbreaks," [Online], Available : http://www.stanford.edu/dept/EHS/prod/general/ergo/microbreaks.html, [October 2, 2013].

[13] C. Liebenson, "Micro-Breaks," Journal of Bodywork and Movement Therapies, July 2002.

[14] Freescale Semiconductor, "Tilt Sensing Using a Three-Axis Accelerometer," [Online]. Available: http://cache.freescale.com/files/sensors/doc/app_note/AN3461.pdf