# Context Awareness of Human Motion States using Accelerometer

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*Abstract*—**The proposed context awareness system is composed of acceleration data acquisition part and fuzzy inference system that processes acquired data, distinguishes user motion states and recognizes emergency situations. Two-axial accelerometer embedded in SenseWear $PRO_2$ Armband (BodyMedia) on the right upper arm collects input data containing the longitudinal acceleration average (LAA), the transverse acceleration average (TAA), the longitudinal acceleration-mean of absolute difference (L-MAD), and transverse acceleration mean of absolute difference (T-MAD). Fuzzy inference system is a tool imitating the human ability of decision making. In our system, the fuzzy inference system was used to distinguish the user motion states and to recognize emergency situations. In an experiment using eight subjects, the recognition rates of lying, sitting, walking and running were 98.9 %, 98.9 %, 99.7 % and 99.9 %, respectively. Recognition rate for lying after walking and lying after running was 100 %.**

*Keywords*— **context awareness, motion states, accelerometer, fuzzy inference system**

## I. INTRODUCTION

This paper describes a context awareness system of user motion states, which is one of the most essential technologies in ubiquitous health care system. Context comprehends all relevant information when service is provided to a person using an actual system such as a mobile communication devices or any device embedded in environment. A system, that detects such information automatically and provides appropriate information or service according to the current context of the user, is called context awareness system. In the present study, the final goal of context awareness system in medical environment for the application of ubiquitous health management is a system that collects information on the patient in the form of 5W, namely, who, when, where, what and why and, based on the information, provides medical services fit for each situation. With the increase of the aged population as well as medical costs for the aged, we need to implement preventive medicine customized to individuals, going beyond existing medical service in hospital. In this situation, context awareness system is a type of health management technology that makes healthcare services available at any time and in any place. Recently the technology is being applied to health management in several countries.

The proposed context awareness system is composed of acceleration data acquisition part and fuzzy inference system that processes acquired data, distinguishes the user motion states and recognizes emergency situations. Two-axial accelerometer embedded in SenseWear® $PRO_2$ Armband (BodyMedia) on the right upper arm collects input data containing the longitudinal acceleration average (LAA), the transverse acceleration average (TAA), the longitudinal acceleration-mean of absolute difference (L-MAD), and transverse acceleration-mean of absolute difference (T-MAD). The system can process ambiguous information of how suitable the measured data is for the specified user motion states by representing it in probability. In addition, it uses fuzzy inference system that monitors the subject through simple calculation without precise mathematical modeling and allows parallel processing, which speeds up the control. Using the fuzzy inference system, we implemented a context awareness system that can distinguish the human motion states into four states (lying, sitting, walking and running).

## II. METHOD

### A. Context awareness

Context awareness system of user motion states is one of the most essential technologies in various application services of ubiquitous health care system. Discussion on the term 'context awareness computing' was made first by Schilit and Theimer in 1994. Context awareness system is a system that can manage users' context, namely, their position, information on people and available objects around them, and even changes in these entities over time, when providing information or services relevant to their works. Pascoe defined context as physical, conceptual and state information of specific objects, in which users show interest. Dey defined it as all types of information that characterize beings (persons, places, things, etc,) related to the interaction between users and the system. The ultimate goal of context awareness system in medical environment to be applied to ubiquitous health management system is to acquire information about patients composed of 5W, namely, who, when, where, what, and why in order to diagnose users' health condition and provide any medical service. In this study, the function of the context awareness system is limited to distinguishing four types of body motion –lying, sitting, walking and running–and recognizing emergency situation.

*B. Data acquisition part*

In the armband are a 2-axis accelerometer, heat flux sensor, galvanic skin response sensor, skin temperature sensor, and a near-body ambient temperature sensor. Data acquired from each sensor can be recorded into the storage device in the armband. The acceleration sensor embedded in the armband is ADXL202AE of Analog Device. It can measure acceleration in 2-axis directions, its measuring range is ± 2 g, and its sensitivity is 167 mV/g when 3V power is applied. From the sensor are acquired the longitudinal acceleration average (LAA), the transverse acceleration average (TAA), the longitudinal acceleration-mean of absolute difference (L-MAD), and transverse acceleration mean of absolute difference (T-MAD).

The acceleration sensor, which has one axis, hangs on the spring in housing and its weight is m. If the sensor, the mass of which is m, moves, the inertia (F) is in proportion to ma by Newton's law of motion, and the force applied to the spring (F) is in proportion to kx, where k is spring constant and x is spring displacement, by Hook's law. The relation between acceleration a and displacement x is as in Equation (1).

$$\mathbf{ma = kx}$$
$$\mathbf{a = \frac{kx}{m}} \qquad (1)$$

Using this equation, we can acquire acceleration (a) signal data corresponding to spring displacement (x).

*C. Fuzzy inference system*

Fuzzy inference system is to map input data vector to scalar output, and its structure is as in Fig. 1, composed of four components – fuzzifier, fuzzy rules, inference and defuzzifer.

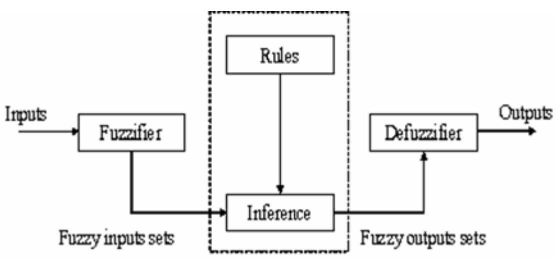


Fig. 2 Structure of fuzzy inference system

Step 1: Divide input/output space into membership function

The section where most of the values of variable x and y exist is divided into several areas. Each area is named lying, sitting, walking or running, and is assigned a fuzzy membership function. x (LAA, TAA, L-MAD, T-MAD) is divided into four areas (Low, Middle, High, Very High) and y (membership for states) into four areas (Low, Middle, High, Very High). In this process, the shape of membership functions was trapezoid (Fig. 2, Fig. 3).

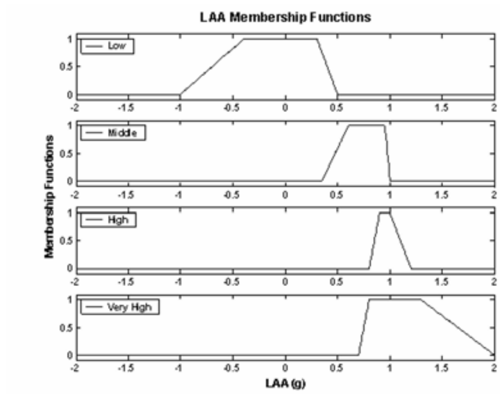


Fig. 2. LAA membership functions

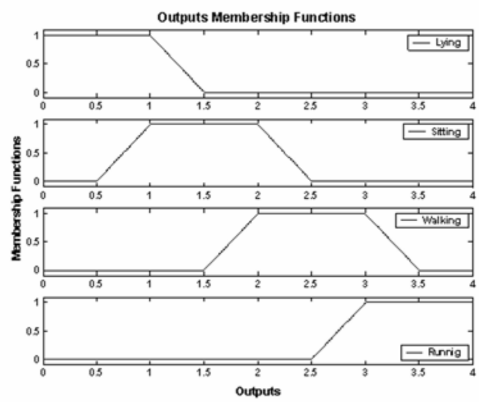


Fig. 3. Outputs membership functions

Step 2: Generate fuzzy rules from data pairs

Fuzzy rules are generated from the membership degree of input/output data pairs in each area and numeric data obtained through experiment. Rules as follows are generated by applying fuzzy operators such as AND and OR to available input/output data pairs.

**Rule 1**: IF LAA is Low and TAA is Low, and L-MAD is Low and T-MAD is Low, THEN y is Low.

**Rule 2**: IF LAA is Middle and TAA is Middle, and L-MAD is Middle and T-MAD is Middle, THEN y is Middle.

**Rule 3**: IF LAA is High. and TAA is High., and L-MAD is High. and T-MAD is High, THEN y is High.

**Rule 4**: IF LAA is Very High. and TAA is Very High, and L-MAD is Very High. and T-MAD is Very High, THEN y is Very High.

Table 1. Fuzzy rules

| | LAA | TAA | L-MAD | T-MAD | Results |
|---|---|---|---|---|---|
| Rule 1 | Low | Low | Low | Low | Low |
| Rule 2 | Middle | Middle | Middle | Middle | Middle |
| Rule 3 | High | High | High | High | High |
| Rule 4 | Very High | Very High | Very High | Very High | Very High |

Step 3: Determine output correspondence based on fuzzy rules

First, for four inputs, the degree of fulfillment (DOF) for each state is found from each membership function. Then, to determine the membership degree of output $m^i_{o^i}$ , the equation below is used for the 'if' part of the i$^{th}$ rule using the max-min operation.

$$\mathbf{m}^{\mathbf{i}}_{\mathbf{o}^{\mathbf{i}}} = \mathbf{m}_{\mathbf{I}^{\mathbf{i}}_{1}}(\mathbf{x}_1) \bullet \mathbf{m}_{\mathbf{I}^{\mathbf{i}}_{2}}(\mathbf{x}_2) \quad (2)$$

Here, $o^i$ and $I^i_1$ indicates the output area of each rule and the input area of the i$^{th}$ condition respectively, and $\bullet$ is the min operator. For example, the case of rule 1 is:

$$\mathbf{m}^{1}_{\mathbf{Low}} = \mathbf{m}_{\mathbf{Low}}(\mathbf{x}_1) \bullet \mathbf{m}_{\mathbf{Low}}(\mathbf{x}_2) \quad (3)$$

In a fuzzy system, the internal expression of data is a usual fuzzy set but the output must be a definite number. For this, we use the center-of-area method (COA) that finds the center of a fuzzy set or the mean-of-maxima method (MOM) that takes the mean of largest values. To determine output, this study used MOM because it can determine state quickly through a small number of operations and its performance in distinguishing body motions is high. MOM is expressed by the equation below. First, the membership function value finds the area with the largest value, and the values on the horizontal axis of the output area data are summed, and the sum is divided by the number of values.

$$y = \sum_{i=1}^{K} \frac{\overline{y}^i}{K} \quad (4)$$

## III. Results

We put the data acquisition system on the upper arm of eight healthy adult subjects as in Fig. 4, and had the subjects perform body motions in order of walking (10 minutes) – sitting (10 minutes) – running (10 minutes) – lying on the back (5 minute) – lying on the face (5 minutes). At each second, we collected one sample containing the average value of vertical signal (LAA), the average value of horizontal signal (TAA), the average value of change in the acceleration of vertical signal (L-MAD), and the average value of change in the acceleration of horizontal signal (T-MAD).

Fig. 4. The subject wore an SenseWear PRO$_2$ Armband on the right upper arm

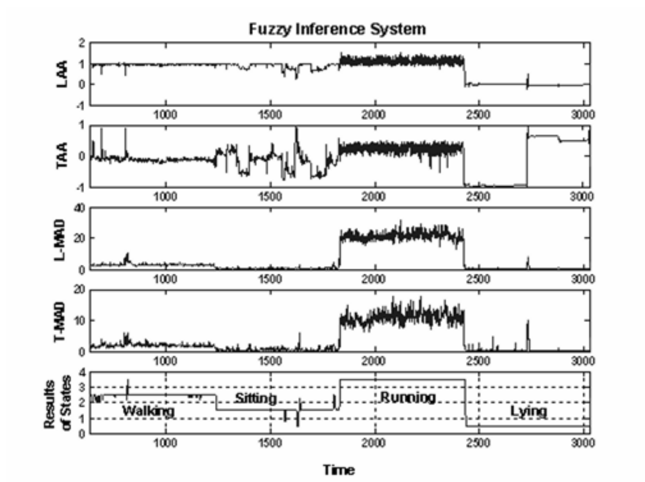


Fig. 5. Context awareness results of human motion states

Fig. 5 shows experimental data given as input data for, from the top, the longitudinal acceleration average (LAA), the transverse acceleration average (TAA), the longitudinal acceleration-mean of absolute difference (L-MAD), and transverse acceleration mean of absolute difference (T-MAD). 'Results of States' on the bottom shows the result of motion states lying (~1), sitting (~2), walking (~3) and running (~4), which were obtained by analyzing LAA, TAA, L-MAD and T-MAD data using the fuzzy inference system. The motion state recognition rate for the experiment data of walking (10 minutes) – sitting (10 minutes) – running (10 minutes) – lying (10 minute)were 98.9 %, 98.9 %, 99.7 % and 99.9 %, respectively. Recognition rate for lying after walking and lying after running was 100 % (Fig. 6.).

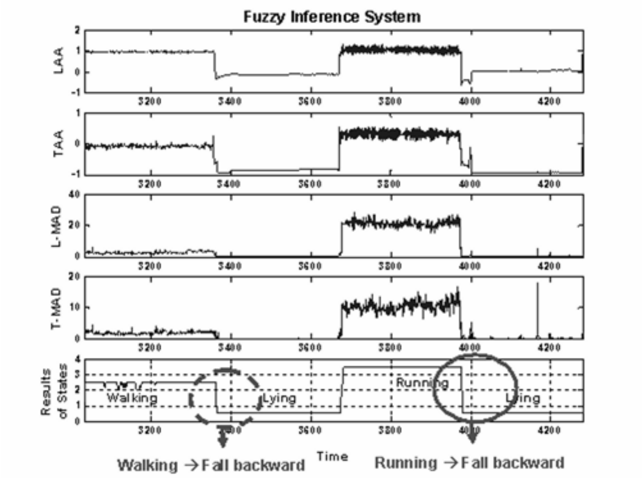


Fig. 6. Context awareness results of emergency

## IV. Conclusions

Fuzzy inference system is a tool imitating the human ability of decision making. In our system, the fuzzy inference system was used in distinguishing the user motion states, and recognizing emergency situations. In an experiment using eight subjects, recognition rates of lying, sitting, walking and running were 98.9 %, 98.9 %, 99.7 % and 99.9 %, respectively. In addition, the emergency situation recognition rates obtained from an experiment of eight subjects were all 100 %. In these experiments, however, we limited emergency situations as falling on walking and falling on running.

The results of experiments with subjects performed in this study suggest that the context awareness system proposed in this study for distinguishing the user motion states and recognizing emergency situations can be used in ubiquitous health management system to diagnose health condition and get medical services at any time and in any place.

## Acknowledgment

This study was supported by a grant of the Korea Health 21 R&D Project, Ministry of Health & Welfare, Republic of Korea (0405-ER01-0304-0001).

## References

1. http://ubdc.re.kr
2. A. K. Dey (2001), "Understanding and Using Context," Personal and Ubiquitous Computing J., Vol. 5, No. 1, pp 4-7
3. http://www.ap-soc.com/c/pdf/200410/IT-SoC5_2.pdf
4. BodyMedia White Papers (2002), "Characterization and Implications of the Sensors Incorporated into the SenseWear Armband for Energy Expenditure and Activity Detection"
5. http://www.analog.com/UploadedFiles/Data_Sheets/53728567227477ADXL202E_a.pdf
6. http://doc.utwente.nl/fid/1331
7. G. H. Jin, S. B. Lee, T.S. Lee et al (2005), "Ambulatory System for Context Awareness Using a Accelerometer", J. KCA, 5(5), 287-295

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