

Estimation of Human Movement by Fuzzy Reasoning Method Using a Triple Axes Accelerometer

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Abstract - Movement of humans when walking and going up and down the stairs has been estimated using the Fuzzy reasoning method. In order to estimate that movement, the frequency distribution is determined for each variable using the obtained data from accelerometer. After this determination, strategic values are decided. The membership function for each value is defined based on experience and each adjusted membership function is weighted and then combined, with the resulting rules is determined by 36 patterns. The rules and membership function is examined against the movement to reach validation for daily use. Although more adjustment for membership function is required, this study enables the application of daily use of movement. The results can also be used to estimate the daily consumption of calories for our lifestyles.

I. Introduction

Method for estimating the movement of humans have been studied by the Fuzzy reasoning method using a triple axes accelerometer. In previous research, posture and movement have been studied [1, 2, 3, 4]. In order to further develop the estimation of moving movement, this study analyzed the individual components of moving movement, and additionally applied to them the Fuzzy reasoning method. To keep a healthy body, our body weight has to be kept at a suitable level, and the consumption of calories should be known, but there are many kinds of calorie meters in the market. Additionally, the consumption of calories varies among the moving movement. The consumption of calories is 3 times different between walking and going up the stairs. To find the differences among the moving movement, this study used a simple detector, the triple axes accelerometer, which detects movement. Then the movement of walking and going up and down the stairs are analyzed by Fuzzy reasoning method.

II. Method

An accelerometer with a triple axis made on an IC chip is attached to the right side of the hip, as shown in Figure 1. The axis in the direction of gravity is defined as Z, the second axis for the direction of progress is defined as X and the direction transverse to the direction of progress is defined as Y, denoting the rotation of the hips. For the standing movement, the acceleration values should be 1.0 G in the Z axis, while the other values of X and Y should be 0 G. The data are obtained on the X, Y and Z axes, and the angle of the hips of the participants is controlled for movement. A calibration is made at 1.0 G along the Z axis, and 0 G along the X and Y axes, respectively. These three axes detected the acceleration of gravity. The signal from the accelerometer is sampled at 0.01 sec, and stored into a laptop computer.

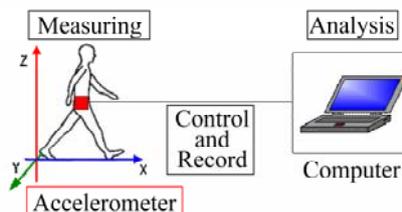


Figure 1. System Configuration

A walking velocity for slow, medium and fast is obtained. The slow speed is defined less than 84 steps / min, the medium speed ranged defined from 85 to 110 steps / min, and the fast speed is defined faster than 110 steps / min.

II.1 G_{sj} is the moving average value of acceleration

Figure 2 shows the obtained data from the accelerometer. G_{sj} is the average values of acceleration G_j to compensate for the angle of the accelerometer with respect to the direction of gravity, the obtained data G_j shifted by 0.01 seconds to calculate for the moving average value of G_{sj} . The strength value G_{Mj} is calculated by Equation (3) as follows.

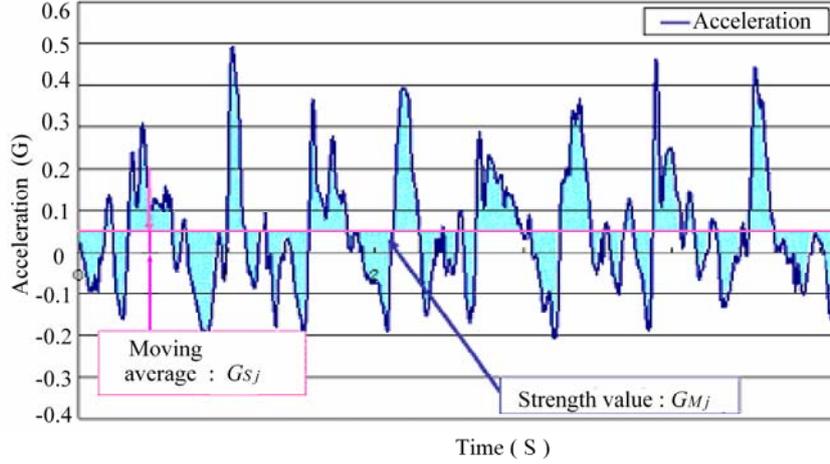


Figure 2. Obtained and calculated values of G_j , G_{sj} and G_{Mj}

$$G_{sj} = \left(\sum_{i=1}^{512} (G_j(i)) \right) / 512 \quad (1)$$

Figure 3 shows an example of the average acceleration for the X axis, as defined by Equation (1) which is dependent on the measurement number of times, respectively. Although the values for G_{sx} suggest estimation for going up the stairs, the values of G_{sy} and G_{sz} are not available for the estimation of the movement.

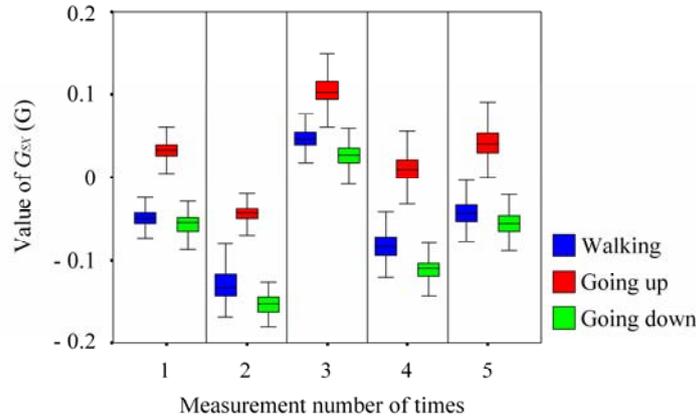


Figure 3. Distribution for the average values of the X axis depending on measurement number of times

The obtained data might have different values during each time of measurement. There is slight different position for attachment of position on the hip among measurement number of times. Those differences should be minimized depending on a slight inclination of the sensor attached on the hip. Although the obtained data for Z axis is compensated as the declination of direction gravity when the participants installed on the hip, but it is disenable for compensation of the direction for progress to movement as X axis and direction to transverse movement as Y axis, because there are no suitable calibrating index for X and Y axes. The compensation method should be applied from obtained data. In order to compensate from obtained data, the median values in the deviation of data is calculated as shown in Equation (2). The result of compensation of obtained data, the range of for G_{sj} is distributed on same range as shown in Figure 4. Where $Me(S_j)$ is median values for walking movement.

$$G_{dj} = G_{Sj} - Me(S_j) \quad (2)$$

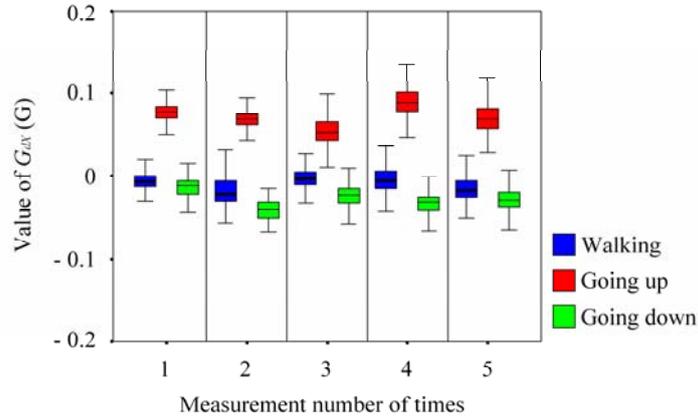


Figure 4. Distribution for compensated values of G_{dx} depending on measurement number of times

II.2 G_{Mj} represents the strength of acceleration on the j axis

Figure 5 and Figure 6 show the strength of acceleration values depending on the movement of G_{MX} and G_{MZ} which is shown the strength of kinetic movement. Those are called the strength values, G_{Mj} and calculated as follows:

$$G_{Mj} = \sum_{i=1}^{512} |G_j - G_{Sj}| / 512 \quad (3)$$

The obtained data are analyzed by Equation (3). The results are shown in Figure 5 and Figure 6, respectively. Figure 5 shows the distribution of the strength of acceleration on the X axis, depending on measurement number of times. For walking values of G_{MX} have larger strength than for going up and down the stairs. The difference suggests that the walking strength is accurately estimated.

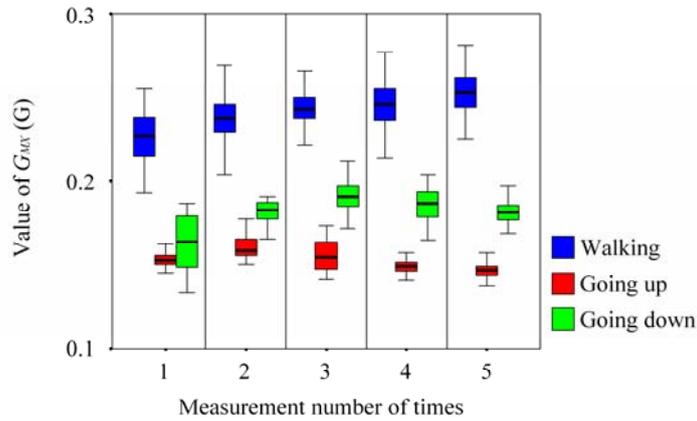


Figure 5. Distribution for strength values of the X axis depending on measurement number of times

Figure 6 shows the distribution of the strength of acceleration on the Z axis depending on measurement number of times calculated by Equation (3). For going down the stairs, the strength is larger than in other movements. This suggests the strength of the movement of going down the stairs can be estimated. However, the values of G_{MY} are not available for discriminate this movement.

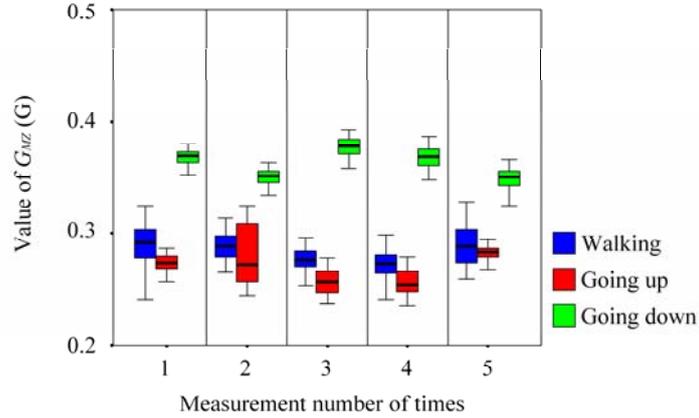


Figure 6. Distribution for the strength values of the Z axis depending on measurement number of times

II.3 Estimation method for movement using FFT analyse

The FFT method is applied to the obtained data in order to estimate movement. The reason is movement of our body is periodic. It suggests us suitable to apply frequency analysis method. That is because X and Z values come from each step of right and left foot. But the S_y value is cause by the twisting our body. The waist goes through one full twist during two steps. The result of FFT processed for obtained data is shown in Figure 7. However the values of FTT for the X and Z axes are not available for estimating the movement. Figure 8 shows the distribution S_y values for each movement measurement number of times. The result shows to enable to estimate of the movement for going up the stairs.

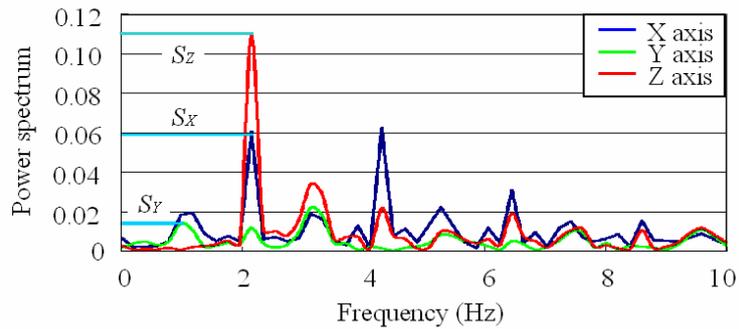


Figure 7. Results after FFT processing

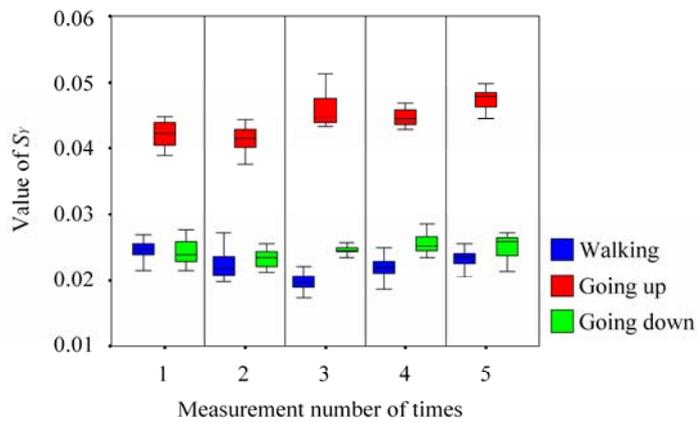


Figure 8. Distribution for S_y values depending on measurement number of times

Some of the participants might have small values for S_Y as shown in Figure 9, but some of participants might have large values. The value of only is depending on hip twist of the participants. The result is gotten the small values of S_Y group and large values of S_Y group. The result shows that S_Y values are tending to mostly have same distribution during the movement for walking, going up and down on the stairs. The values have to compensate using $Me(S_j)$ for applied the data for walking movement using Equation (4).

$$S_{dj} = S_j - Me(S_j) \quad (4)$$

The values of S_Y and S_{dY} are compared in Figure 9, and it shows the data goes to be easily estimating values for movement. Zone A shows walking, Zone B shows going up and Zone C shows going down. The data on the left indicates S_Y , and on the right S_{dY} , respectively.

The data S_Y in Zone A the normal group and in Zone B the small group, overlapped each other. However, S_{dY} calculated by Equation (4), is discriminating as shown in Figure 9. Further, as the dispersion of S_{dY} declines and the reliability improves.

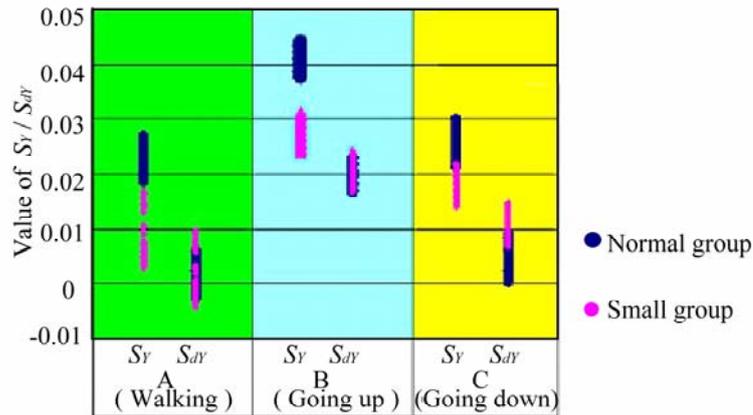


Figure 9. Comparison for S_Y and S_{dY} values

III. Fuzzy reasoning analysis

1) Applying Fuzzy reasoning

Firstly, the membership function for each element is defined by experimental findings, then individually weighed and combined. These adjusted variables become the applied values of G_{dX} , G_{MX} , G_{MZ} and S_{dY} . Figure 10 shows the resulting strategic values and their contribution for making rules. Figure 11 shows the frequency distribution and the membership function of G_{MZ} for the movement of walking traced in blue, going up traced in red and down traced in green, respectively. After determining the frequency distribution for G_{MZ} , the membership function for G_{MZ} is decided. Other membership functions are also decided similarly as that of G_{MZ} . To validate the estimation of each movement the participants numbered 13. Moreover as the 4 adjusted variables of velocity are applied, it goes to 12 rules and with 3 original velocities ranged and total Fuzzy rules goes to 36. Subsequently, the membership function is adjusted using the Mandani Method. Each membership function is weighed based on the estimations of the data as shown in Figure 11. Finally, the Fuzzy reasoning system goes to a defuzzy system.

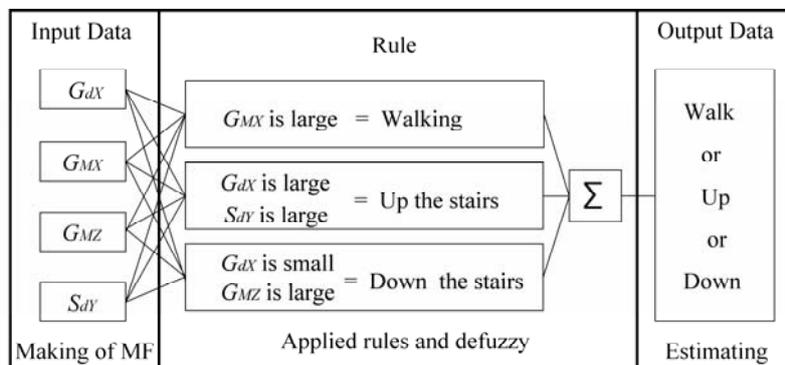


Figure 10. Strategic values for establishing Fuzzy reasoning rules

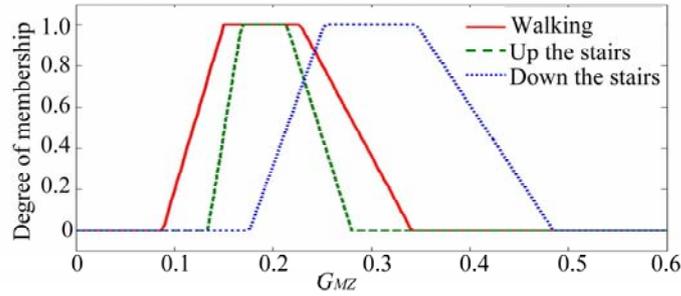


Figure 11. Membership function of G_{MZ}

IV. Results

Table 1 shows the agreement with the applied Fuzzy method for each movement. The result shows the discriminability including all velocity ranges and participates ranging from 90% to 94%. The mis-discriminability is estimated with other movements ranging from 6% to 10%. The mis-discriminability is dependent on the participant population. Figure 12 shows the result the discrimination for walking, going up and down for continuously movement. For the next step, a study should apply a continuum from walking, going up the stairs, going down the stairs, respectively.

Table 1. Result of discriminability of the movement

		Output Movement		
		Walking	Going Up	Going Down
Input Movement	Walking	91.8%	2.0%	6.2%
	Going Up	2.8%	94.7%	2.5%
	Going Down	8.4%	0.9%	90.7%

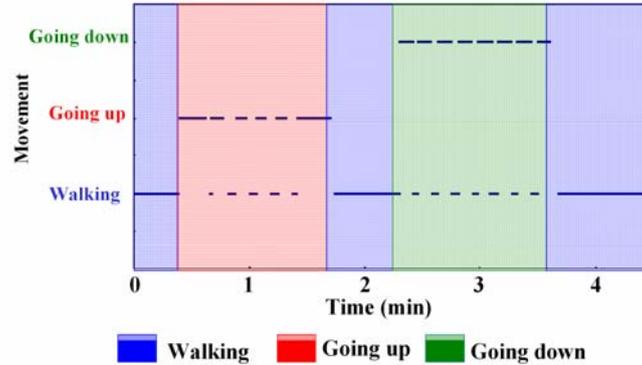


Figure 12. Result of discrimination for continuous movement

V. Conclusions

Moving movement has estimated using Fuzzy reasoning and the results show us that discriminability is acceptable for actual use. However, a wider region of the membership function needs to be accounted for in future research.

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