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Unsupervised Clustering for Abnormality Detection Based on the Tri-axial Accelerometer

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Abstract: Today's society confronts the aged problem by the reason that the rate of the population over age 65 increases rapidly in world wide. One important problem is how to manage them effectively from the dangerous emergency like falling, slipping or unintended activity. Such activity is required to be detected as the abnormal behavior to predict the dangerous emergency of elderly people so that they are protected from more fatal situation. There are many researches to classify the behavior but it is evaluated that it is not proper to detect just only the abnormal behavior. We propose the method of unsupervised learning to overcome the disadvantage of the supervised learning method only for abnormal activity detection. In experiment, we show that the unsupervised learning can be used to detect abnormal behavior from three subjects.

Keywords: activity, abnormality, abnormal behavior, accelerometer, unsupervised learning

1. INTRODUCTION

Due to developing medical sciences and decreasing born rates, we are getting into aging society rapidly. In the United States, 13% of population was aged 65 or older by 2000 [1] and it's expected to increase up to 20% by 2030.

It is not only the problem of United States but also the problem of the entire world. Consequently, the elderly health care problems have appeared in our society. For example, elderly people are more prone to get accidents and it might make matters worse because they do not have a sufficient ability to overcome the dangerous situations caused by abnormality like falling or slipping by themselves. In addition, the populations unbalance between the young and the old makes the elderly management harder. In this regard, the more efficient healthcaring system is required. If the developing system can detect the abnormality with the reliable recognition rate, it is expected that we can find out effectively whether they are in the dangerous situation with only help from few caregivers.

This paper proposes the method how to find the abnormal activity automatically. When the old or handicapped people have a dangerous situation, we can let them avoid the worst situation if the signal related to activity has been transmitted and analyzed properly. Even though many researchers reported about abnormality detection based on the vision system [2-4], the vision system applications have the limitation of relatively more expensive costs, large processing time and especially, spatial fixture. Therefore we propose the method based on the tri-axial acceleration signal.

2. RELATED WORK

There have been some researches for activity detection based on the accelerometer. Ravi et al. were the one of the group who proposes the activity detection system based on the accelerometer [5]. In this paper basic eight activity like walk, run, climb up, climb down, vacuum, rush, sit-ups were classified. Beak et al. tried to improve the recognition rate through higher order statistical model [6]. Mean, standard deviation, skewness, kurtosis and eccentricity were used as a feature vector and multilayer perceptron was used as a classifier. Bao et al. tried to find the various type activities based on the five accelerometers which are attached at important joints [7].

Previous works whose purposes are to recognize the various activities adopt supervised learning model and the authors have insisted that it can be regarded as a solution to detect the abnormality. Theoretically they aim to classify all activities by supervised learning but practically there must be many problems in real application for abnormality detection. First, it is required to gather the data representing all activities we have undergone for training in supervised learning. Second, suppose we succeed in acquiring all activities data, the transition between activities can be hardly trained for classification. Third, the same activity is even likely to show different patterns between users. Therefore it is concluded that the use of supervised learning model has serious limitations for abnormality detection. To overcome the problems mentioned above, we suggest unsupervised learning method only to detect abnormality instead of the detailed activity classification by supervised learning. In this approach, the abnormality detection can be achieved in ways below. First, new activity that is not registered during training session can be classified into the abnormalities. Second,

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even though the activity is registered past, we can recognize as an abnormal behavior when the duration of the current activity last long than the past activity. In this paper we concentrate on how to find the abnormal activity behavior by whether current activity pattern is registered past or not and try to evaluate the performance of this method.

3. IMPLEMENTATION

To detect the abnormal behavior we need to recognize whether the pattern is registered past. For applying proposed method we need to follow the step bellow.

- Hardware design
- Pre-processing
- Feature extraction
- Classification

3.1 Hardware design and Pre-processing

The signal from the accelerometer has four kinds of information: time, acceleration data along the x-, y-, and z-axis. The x-axis is anteroposterior, y-axis is vertical and z-axis is lateral direction. Tri-axial accelerometer MMA7260QT marketed by Freescale Semiconductor Technologies is used. It senses acceleration up to $\pm$6g by the selected mode but we used only $\pm$1.5g resolution. The processor used in this experiment is ATmega8L and Micro SD card is used to store the data. Sampling rate is 512Hz but by applying 5th-order median filter, 8th-order mean filter and down sampling by factor of 8 to reduce the memory updating rates, the total transmission rate from the processor to the memory is 512/8=64Hz. The acceleration data has 8-bit resolution for each axis and is stored sequentially. Fig. 1 is the block diagram of this system.

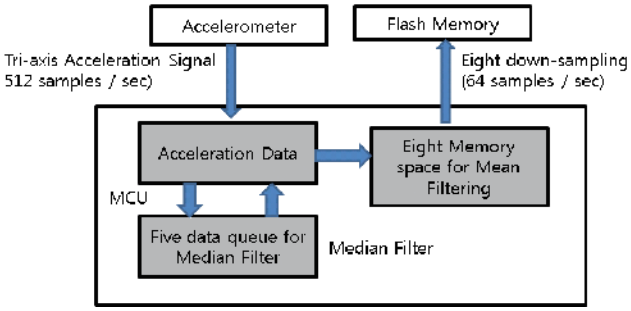

Fig. 1 Block diagram of the procedure of signal processing

3.2 Feature extraction

Features are extracted in a moving window signal with size of 128 samples every 32 samples from the signal preprocessed based on the method above. We should choose the feature vector simply because the purpose of this research is just detecting the abnormality, not classify each pattern. From this data, the features extracted were;

- Mean
- Standard Deviation

for each three axis.

3.3 Classification

The aim of this paper is to find whether current activity is registered past. To detect whether a pattern is registered or not probability model based on the past activity pattern is created. To make the probability function of activity, the Expectation-Maximization (EM) algorithm is used with the feature vectors above [8]. However, in general several parameters of EM algorithm should be initialized to enhance fast evaluation and to avoid local minimum, so the rough set theory is used to initialize mean, covariance matrix and weight of the Gaussian Mixture Model (GMM)[9]. Also we apply the Bayesian Information Criterion (BIC) method for determining the number of class k [10]. Simply speaking, BIC method is to find the number of class k which minimizes Eq. (1) :

$$BIC = -2L\left(\mathbf{X}_1, \mathbf{X}_2, ...\mathbf{X}_n | \mathbf{\Theta}^{ML}\right) + k\lambda \log n \qquad (1)$$

where $L\left(\mathbf{X}|\mathbf{\Theta}\right)$ is the likelihood of the probability function, n is the number of data and λ is the variable to optimize the equation.

Using this probability density function, if the random variable of the current activity instance has less probability than a threshold, we can assume that it is more likely to be an abnormality. By experiment, we should find the proper threshold value to decide the abnormality.

4. EXPERIMENT & RESULT

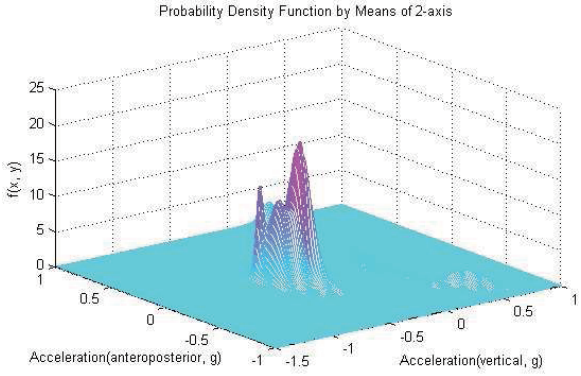

Fig. 2 Probability density function of daily routine activity

4.1 Experiment

We have collected data from three subjects for three days. The accelerometer is attached at each subjects pelvic region. With respect to the collected data, probability density model of activity signal is formed using the EM algorithm. Fig. 2 represents the probability density function described by mean value of two axes (anteroposterior, vertical) as an example. After constructing the model, we acquire another one day signal of daily routine as a normal behavior and we collect the acceleration signals which contain the abnormal behaviors to evaluate the performance of the system. Falling straight ahead, falling backward, rolling and falling down from 120 centimeter are chosen as the abnormal behaviors. Getting

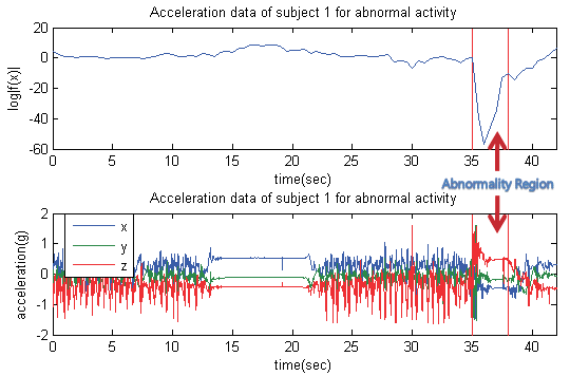

Fig. 3 Probability density function of activity which consists of abnormality(up) and raw signal(down)

activity data from elderly people can be better but in the procedure of getting abnormal data, they may undergo the dangerous emergency so we get the data from the subject with age from 24 to 26. Each abnormal activity is repeated five times so each subject performs twenty abnormal activities totally. The raw signal and the probability density function of abnormal behavior for No. 1 subject is represented in Fig. 3

4.2 Result

To evaluate the performance, we need to choose the proper threshold as a standard to decide whether current activity is normal or not. The proper threshold value is chosen heuristically by this experiment. In ideal case, all normal activities should be higher than threshold and abnormal activities should have the point below the threshold.

Table 1 Result of the number of error for activity detection

Subject	False Positive	Action	False Negative
S1	7sec/1day	F. A.	0/5
		F. B.	2/5
		R	0/5
		F. D.	2/5
		Total	4/20
S2	0sec/1day	F. A.	0/5
		F. B.	0/5
		R	0/5
		F. D.	0/5
		Total	0/20
S3	6.5sec/1day	F. A.	0/5
		F. B.	0/5
		R	0/5
		F. D.	0/5
		Total	0/20

The result of total error for activity detection is shown in Table 1. To evaluate the performance, first, we show the time that normal activities are lower value of the probability density function than threshold as a false positive. In real situations, the total period of abnormality during one day can be important factor, so the table shows the total period. Much of the false positive makes the system not efficient because it makes caregiver use another certification method like calling to user but it can little affect to find the dangerous emergency to the user. Second, we also show the number of times which is in the case of that the each 5 abnormal activities does not contain the lower value of the probability density function than threshold as a false negative. It is very important because it can affect directly to whether we can find the dangerous emergency. When abnormal activity appear, if it does not find the abnormality, it is possible to make them worst situation. In this experiment, the result of false positive is shown in column 2 and false negative is shown in column 4. In the case of the false negative, each activity is represented with the result of the abnormality error because of evaluating the effect of each abnormal activity. The kind of the activities is shown in third column. F.A, F.B, R and F.D represented falling straight ahead, falling backward, rolling and falling down in order.

5. DISCUSSION & FURTHER WORKS

The objective of this paper is to propose the method to detect the abnormal behavior. For that, we use the past activity information and construct the activity probability model based on Gaussian Mixture Model with the EM algorithm. Every activity is decided whether the activity is abnormal behavior or not based only on whether the current activity is registered past. In this method abnormality is detected without detailed classification and its needless to consider user-independent case because probability density function is constructed by the corresponding users data. It is clearly shown that the detection rates are different from every subject.

Generally speaking, abnormal activity may have very steep acceleration change given that the main subjects could be the elderly who do not move much. In this regard, the results in the previous section can be promising in that many false positive errors will be reduced. In addition, it is noted that the accelerometer will be used as an auxiliary of care because direct involvement through communications should be guaranteed in the case of abnormality detection. However, it is required to reduce the false positive errors. Clearly too frequent wrong alarms deteriorate the reliability of the system. We will try to choose another feature vector, sampling method or change the period of collecting the learning rate. Furthermore, it is required to acquire more data enough to construct well-fitting probability density function. We will obtain more data from the elderly people through longer period and show that it can be adopted by the elderly well. Lastly, we should evaluate the time duration of each activity as quantitatively but in this paper there is not. However, we show that each pattern has the different duration and we expected that it can show the abnormality of user. Comparing weekend and weekday activity is the one choice of method to be shown that different activity pattern can have the different time duration. As a

future work, we will approach this method and evaluate quantitatively.

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