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Human Activity Recognition using Single Accelerometer on Smartphone Put on User's Head with Head-Mounted Display

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Abstract

Abstract— Human activity recognition has been applied to many areas of healthcare to the entertainment sector. The accelerometer sensor on a smartphone is used as the primary sensor to recognize the movement of the user. The smartphone put onto user's head using the head-mounted display as a new experience on entertainment access like virtual reality or game application. The proposed method for human activity recognition with MLP on classification, achieved 85,1% accuracy in identifying six different movement type.

Keywords: *accelerometer, head mounted display, activity recognition, artificial neural network.*

1 Introduction

Mobile devices, especially smartphones have become an essential part of everyday human life. Smartphones are no longer just as a tool for communication but also helps in many activities, ranging from a device to assist the work, sports activities, and also as a means of entertainment.

One significant influence that makes smartphones are becoming popular is the role of the operating system. The most popular operating systems today are Android, which is indicated by a market share of nearly 85% [1].

The smartphone is sophisticated not only because the operating system but also the support of powerful internal hardware, like built-in sensors. For example, an internal sensor like accelerometer which serves to calculate the movement acceleration of the smartphone, that can tell when the smartphone screen needs to change between portrait and landscape [2].

The impact of the smartphone developments attracted a lot of attention to do research in the field. One of the research topics that are quite familiar with the use of sensors in smartphones, namely recognition human activity (HAR). This topic has been studied due to the many benefits and can be applied to many fields ranging from health, military, security, and entertainment [3][4]. In the previous study, human activity recognition as virtual reality game controller using user’s head rotation and body movement detection [5] is proposed, but the research is limited to detection of the user walking activity and head movement.

Previous studies that discuss human activity recognition using accelerometer has been widely considered. Some studies only use the accelerometer sensor is available on smartphones [6][7]. In these studies, they compared several algorithms to train the model that will be used to identify patterns of activity data, some of these algorithms is a multilayer perceptron, SVM, random forest, simple logistic and logit boost[6]. The best results are obtained when using multilayer perceptron with around 90% accuracy results. In this study also tried combining several algorithms and results in an increase in the accuracy value with a reduction of error value about 18% but it takes a long time compared to using only one algorithm alone.

Head-mounted displays (HMD) is one of the new innovations in the field of information technology, especially in the field of augmented reality. HMD is a device that is placed on the user's head, it can resemble a helmet or glasses shaped like google glass. The emergence of this tool opens up many opportunities of research and development of systems that can be built therein. More over with the google cardboard which is an alternative to HMD, adding additional opportunities because these tools are cheap and only requires smartphone as the primary computing media.

This research proposed a novelty on recognizing human activity based on single accelerometer built in a smartphone that put onto user’s head by using head-mounted display (HMD) to recognize several different activity using neural network. The result of this study can be applied to virtual reality or game controller.

2. Proposed method on Activity Recognition Process

There are four steps that are necessary to build a human activity recognition system as follows: sensing, preprocessing, feature extraction, training, and classification, as shown in Fig. 1 [8].

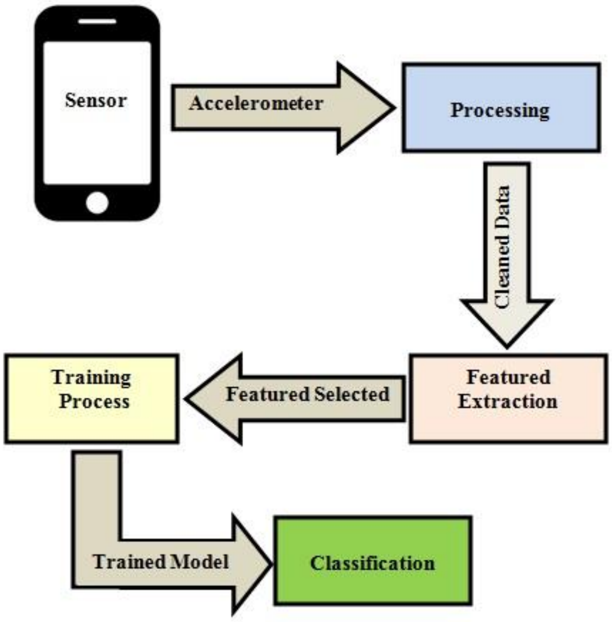

Fig. 1 Activity recognition flowchart

From the Fig. 1 can be explained in detail starting from sensing stage is the process to collect sensor data by the specified sampling rate from the smartphone which commonly each device has a different rate than other.

After sensing phase has been completed then the next step is the pre-processing stage, the raw signal data is processed in several ways to obtain certain required value. The data generated from the preprocessing stage need to be processed further to choose the features that suit the needs of the system, this phase is called feature extraction. The training phase is a stage of training the system to be used to identify the correct activity. In this study, we build the model in the personal computer environment. The last stage is a classification using the results of the previous phase of training that has been trained to recognize the activities conducted. In this section describes the process flow of human activity recognition system which is divided into several parts as follow.

2.1 Data Acquisition

Sensor data is gathered from a smartphone that put on user's head with the head-mounted display to capture the data. Smartphone is placed on the HMD as shown in Fig. 2 while the system on smartphones preparing to record accelerometer sensor based on user movement.

The output of the accelerometer sensor available on smartphone devices consist of three axis values, there are x, y, and z. These values represent the acceleration that occurs in on each axis that are supported by the corresponding sensor that often called the pitch, yaw, and roll.

Fig. 2 Smartphone placed on head mounted display

The data used in this study was obtained by using a smartphone xiomi Redmi 1s that has a processor Quad-core 1.6 GHz Cortex-A7, 1 GB memory and battery capacity of 1900 mAh. We built an android application to log the accelerometer data while the user performs several activities that presented in Table 1.

Table 1. The Activity List

Activity	**Initial condition**	**Description**	**Movement repetion**
Walk	Stand	Walking straight	50 step
Run	Stand	Running straight	50 step
Lower half	Squat	Humped-squat	8 times
Upper half	Stand	Humped-stand	10 times
Jump	Stand	Jumping	14 times
Full vertical	Stand	Squat-stand	13 times

There are six activities that will be recognized by the system, these activities have been selected because is often encountered in a game. The detail about the activity is presented in Table 1. Any changes made by the user movement will be accompanied by a silent condition for 0.5 seconds. The conditions necessary for the observed data to make it easier to analyze.

Results of the data collection process show that each activity has done illustrate the accelerometer data changes are relatively different in each activity, in detail shown in Fig. 3 to Fig. 8.

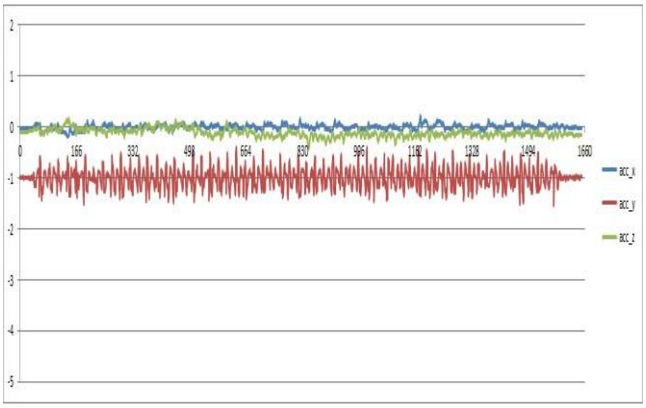

Fig. 3 Walking activity

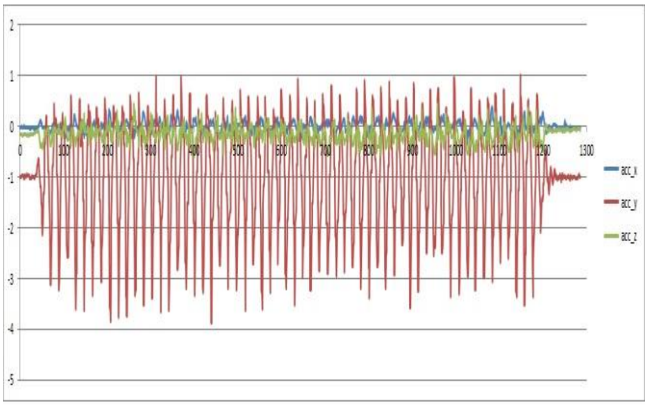

Fig. 4 Running activity

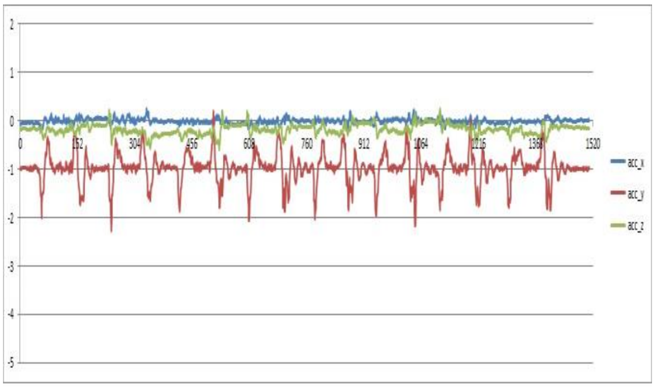

Fig 5. Lower-half activity

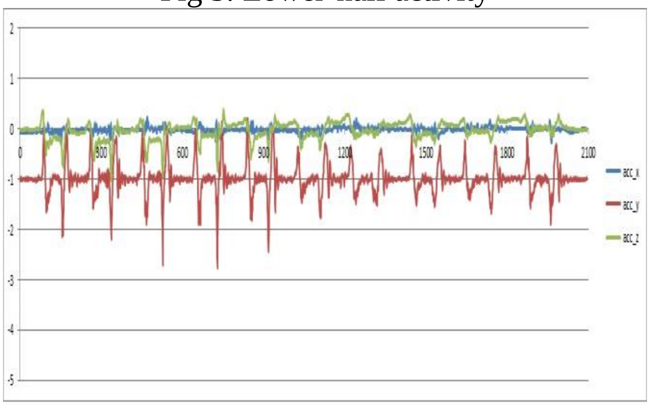

Fig. 6 Upper-half activity

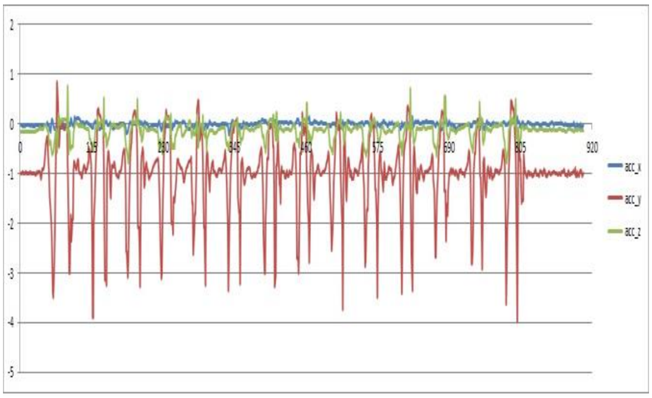

Fig. 7 Jump activity

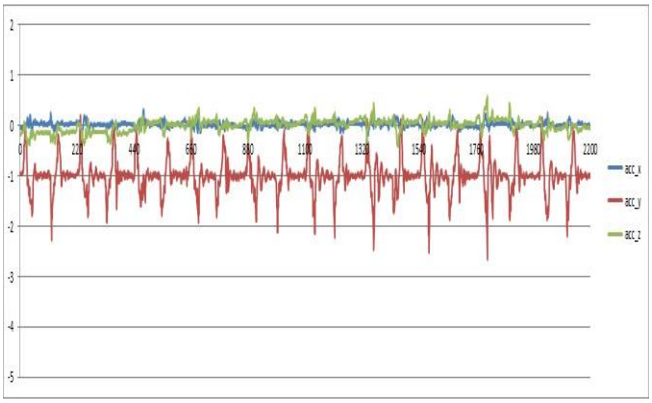

Fig. 8 Full vertical activity

2.2 Preprocessing

Due to data obtained from early stage still needs to be cleaned from an unwanted factor that commonly called noise then at this stage of preprocessing aims to obtain better data. At this stage of the filtering process to separate between the gravity and the movement of the actual value carried out. The method used filter is a low pass filtering function to capture the value of the gravitational effects shown by the following formula

$$y_i = \alpha x_i + (1 - \alpha)\, y_i - 1 \qquad (1)$$

After the data is collected, the next step is to process the data is carried out at the preprocessing stage, three-dimensional data obtained from the accelerometer need to be combined to get the value of the acceleration vector magnitude using Euclidean magnitude formula is:

$$a = \sqrt{x^2 + y^2 + z^2} \qquad (2)$$

The merger process of the three axes is needed due to simplifying the extraction and to overcome noise derived from changes in orientation that may occur due to the position of the device which is placed on the user's head to change position. And also, even though the value of some axis are combined no impact on the pattern recognition process because the direction of the signal change has little effect on the recognition process.

2.3 Feature Extraction

After the data has been through the preprocessing phase of the data is ready for further processing which is looking for the features required of the data. The first step in this phase is to break into a window signal obtained based on a particular time range commonly called the time window within each second that contain 50 sampling rate from the device. Once the data is managed to be broken apart for each window, then it can be used to find the average acceleration value and the last value that is required to get the value of maximum amplitude and the minimum amplitude.

2.4 Training Process

Results Features of the previous stages need to be included at this stage of training for the system to recognize the activities of the user. Algorithms used for this study using a multi-layer perceptron (MLP) for this algorithm showed pretty good results to recognize patterns of human activity [6] [7]. MLP is a neural network comprising an input layer, hidden layer, and output layer. MLP is utilizing backpropagation to train the network to find the best weight for its network. In the process performed sigmoid activation functions are listed as follows:

$$o = sig(s) = \frac{1}{1+ e^{-s}} \quad (3)$$

While for the backpropagation formula as below

$$\Delta w_{ij} = - \alpha \cdot \frac{\partial E}{\partial w_{ij}} = \alpha \cdot \delta_j \cdot x_i \quad (4)$$

3. EXPERIMENT

Total overall patterns ranging from walking, running, jumping, lower-half, upper-half and full vertical that will be tested is 145 data patterns. The testing result for the activity recognition system is presented in Table 2. We use confusion matrix to show the actual activity compared with the predicted activity. For the left side of the table is the actual activity while the top side of the table is the predicted activity from the system.

Table 2. Confusion matrix from recognition testing

Predicted / Actual	Walk	Run	L. half	U. half	Jump	Full Vert.
Walk	50	0	0	0	0	0
Run	0	49	0	0	1	0
L. half	0	0	3	3	1	1
U. half	0	0	0	10	0	0
Jump	2	5	0	0	6	1
Full Vert.	4	0	0	1	4	4

Accuracy evaluation is important to evaluating the performance of the system output. A common method used to measure the accuracy of a system is the precision and recall parameters. Accuracy is the adjacency value between the measurements of the value and the actual one[9]. Whereas precision is a fraction of the items were taken that are relevant compared to all items were taken, in other words, precision is the probability that an item is considered to be relevant, and recall is a fraction of the relevant items being taken compared to the overall relevant items in the database[10].

Table 3. Accuracy evaluation

Subject	**Rate**
True-positive	0.821
False-positive	0.059
Precision	0.762
Recall	0.821

For the first three activity, walk, run, and upper half achieve a good accuracy that above 90%, this accuracy is based on the successful prediction from the pattern data. Walk and run result almost perfect because both activities have a very distinct movement data. While the other activity shows not very satisfy due to just depend on an accelerometer sensor to recognize a similar activity such as lower half, jump, and full vertical. The system can be predicted 122 patterns of 145 total pattern.

4 Conclusion

In this paper, we present an approach to recognizing human activity by the help from smartphone accelerometer sensor that put on the head-mounted display. We use MLP to train the recognition model because this algorithm has proved to get a good accuracy. The result from using MLP in this paper has achieved precision total around 76% whereas the recall is 82%.

By using smartphone sensor especially, an accelerometer is possible to recognize movements made by the user. Therefore, it can be used as a controller for virtual reality game by using a smartphone that is placed on the HMD device. Our method is succeeded to recognize the user movement where the walking activity and upper-half activity can be 100% recognized.

For further development is needed more training data to adopt a diversity of users and devices. We look forward to further research, the system can achieve better accuracy by using other feature and segmentation method while maintaining the fast response time of the system. Another alternative to improve the accuracy of the system can take advantage of advanced methods such as artificial neural network combined with evolutionary algorithm [11].

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