Design of Mobile Application Control based on Hand Gesture
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Abstract— In recent years, we have seen dramatic progress in the field of Hand Gesture Recognition, yet these applications have some drawback. Keeping in view the trend of making application more interactive and simple, easy to use as well as cost efficient, a Hand Gesture Recognition based system is developed to allow interactive control of application using hand gesture. This paper presents a framework for hand gesture recognition based system which controls the mobile application. The working of this framework is based on the information fusion of 3 Axis Accelerometer (ACC) and Surface Electromyography (SEMG) sensors. A Gaussian Mixture Model (GMM) and Fast Dynamic Time Warping Algorithm (FDTW) are utilised to get the final result. In addition the system also includes a wearable hand gesture sensing device which is worn on the forearm and an algorithmic framework for the smart phone to recognise the hand gesture. The Armband which is worn on the forearm is able to manipulate 11 predefined gesture or even the personalised ones. The results suggest that the developed prototype responded to each gesture within 300 ms on the mobile phone, with average accuracy of 96%.

Keywords: Accelerometer; Armband; Fast Dynamic Time Warping Algorithm; Gaussian Mixture Model; hand gesture; surface electromyography

I. INTRODUCTION

Can we have a simple, interactive and intuitive way of interacting with the mobile applications? In an attempt to answer this question, this study signifies the use of hand gesture to generate a control input for the application.

Since many years there has been much more ongoing research on how to facilitate more interactivity between human and computers. With the rapid development of computer technology contemporary Human Computer Interaction (HCI) devices have become essential in individual’s daily use. HCI devices have also dramatically changed our living habits with computer, consumer electronics and mobile devices. The simplicity with which an HCI device or technique understood and operated by user is a major consideration in selecting such a device.

Gesture is a non-verbal communication technique generated by a movement of body that involve physical movement of hands, head, fingers, head, face, arms performed for transmitting meaningful information or interacting with the environment.

Hand gesture is a movement fingers, palm, hand and it can be recognised using different technologies such as computer vision, sensing electric field, touch screen etc. In this system hand gesture will be recognised using 3 axis accelerometer and Surface Electromyography (SEMG) sensing.

In early technology camera is used for sensing the hand gesture. It includes a challenging problem of changing light and background. So using accelerometer and SEMG sensor technology problem of previous technology can be overcome. Accelerometer can be able to measure accelerations from vibrations and the gravity. Because of these characteristics accelerometer gives better result while capturing noticeable actions with more accuracy and large scale gestures which is expressed in paper [1] [3]. Surface ElectroMyoGraphical signals [7] [14], which recognize the motion of related muscles during a gesture execution as given in paper [7]. Surface ElectroMyoGraphical signals are able to capture fine motions such as wrist and finger movements and can be utilized to realize human–computer interfaces. In our system armband is designed that is use to recognise the hand gesture. Armband is a wireless device that communicates with the smartphone. Whereas, using both accelerometers [6] and SEMG sensor have their advantage in capturing hand gestures. Combination of both sensors improves the performance and accuracy of hand gesture recognition. The armband is wearable gesture capturing device which consist of gesture based interface to present feasibility of gesture based interaction in the mobile application which is given in paper [8]. The wearable wireless armband which is presented through this research paper based on the fusion of both ACC and SEMG signal. Where as an extension to [1]–[3], there are four main contribution.

1) A wearable gesture based real time interaction prototype for mobile devices using the fusion of ACC and SEMG signal is presented.

2) Small, lightweight and power efficient wireless wearable devices which recognise the gestures using Accelerometer and surface electromyography (SEMG) signals from forearm.

3) Fast dynamic time warping and Gaussian mixture model scheme is applied in this system.

4) An evaluation with a gesture based interaction application on a mobile phone demonstrates the feasibility of the interfaced system because of the application of smartphone can be controlled through hand gestures.

5) The system becomes easy to understanding and operating the applications.

II. SYSTEM ARCHITECTURE

This hand gesture based system can control the specified application of the smartphone without touching it. The system consists of a wearable gesture capturing device which recognises the different hand gesture and an interaction application program which runs on a smartphone. Wearable gesture capturing device i.e. armband is worn on the forearm. For recognising hand gesture Accelerometer (ACC) and SEMG sensor is attached into the wearable device. When it receives the gesture in the form of signal interaction application program process these signal and convert that each gesture into instruction and it performs the action related to that gesture command. Ultimately it gives the feedback in the form of action which performs on the smartphone.
A. Gesture Vocabulary:

B. Gesture Recognising Module:

A gesture recognising module is designed to capture the hand gesture. It captures the SEMG and ACC signals synchronously. It consists of accelerometer with SEMG sensor which is embedded into the board. These sensors are connected to the main board using wires to share the same battery and the controller. AVR controller, Battery and Bluetooth module are embedded into the main board. All four modules are strung with the elastic band. Because of the elastic band gesture capturing device can be worn on the users forearm.

Figure 2 shows the architecture of the gesture recognising module which is also named as armband. Three axis accelerometers with SEMG sensor is attached to it which capture the signal amplifies it and filter them within 0.5 Hz to 1600 Hz bandpass. Three axis accelerometer measures acceleration along three axes (x, y, z) and give three axis ACC signal in output. The signal received from the sensor is pass on to the AVR controller which digitized the signal using 10 bit A/D converter that is embedded with the controller (ATmega 8) and then sent out via Bluetooth serial port protocol module (HC05) which is connected within the main board as explained in [10].

C. Interfaced Application Program:

In an interfaced application program smartphone is used to demonstrate the feasibility of the hand gesture based interaction. An interface application program that is implemented in java which includes Bluetooth interface of wearable device with the smartphone, hand gesture recognition, translation and phone operation modules.

Figure 2 shows the architecture of the application program interface module. It consists of four modules i.e., Bluetooth interface module, gesture recognition module, phone translation module and phone operation module. Bluetooth interface module (HC 05) receives data from Bluetooth API (application program interface) and stores them into buffer. Gesture recognition module read the data from the buffer and recognises it for getting appropriate result according to the data received. Phone translation module maps the gesture which is received from the recognition module to instructions. The interactive supported gestures are less as compare to the interactive task but it can be increased as per user requirement. Different gestures can be added into the system. User is allowed to modify different gesture related to specific task. The phone operation module executes the instructions received from the recognition module by calling system API’s or sending keyboard message, which are used by the operating system to notify program of key events. Phone operation module able to execute this instruction and maps it with phone operation. In this system gesture recognition module consists of two states.

- Training state.
- Testing state.

In training state system is trained for specific work using hand gesture related to the action to be performed by that gesture.

In testing state system is tested for the action that is allocated to the specific task.

In the system gesture can be added as per user’s requirements.

The gesture sequence cannot be changed only the gestures are possible to change their action. In the system before changing the gesture action the gesture that is already stored in the database of the system that must be cleared. This makes the database update with the new gestures.

III. HAND GESTURE RECOGNITION

In the system the controlling of mobile operation using multiple hand gestures with the help of interfaced wearable computing module. This wearable computing module is responsible for taking all decision according to the hand gestures.

A. Hand Gesture Vocabulary:

Hand gesture vocabulary consists of 12 gestures and according to that gesture specific action is performed. Gestures are nothing but the movements of wrist and arm. All the gestures are combination of small scale gesture and large scale gesture. In small scale gesture user should move only wrist and fingers without movement of arm. In large scale gesture consist of movement of arm along the predefined trajectories in the vertical plane and one more movement that is user can also grasp or open his hand. User can define predefined gestures by repeating the gestures in
the training mode of the interfaced application program. The repetition of the gesture depends on the user’s fulfilment. It may be 5 times or it may be 10 times.

B. Algorithmic Framework:
The algorithms described here are implemented in a gesture identification module. Recognition accuracy and action response time are two basic requirements for algorithm working on the smartphone device with moderate computational resources. In the system accelerometer with SEMG sensor is used to recognise the small scale and large scale gesture. Gaussian mixture model [2] is used to recognise the gestures performed by the wearable device.

IV. CLASSIFICATION
There are 12 gestures in the database of the system. To classify the different gestures movement received from the hand wearable device Gaussian mixture model [2] and fast dynamic time warping algorithm [13] is implemented in the system.

A. Gaussian Mixture Model:
A Gaussian Mixture Model (GMM) is also known as a parametric probability density function [2]. The parametric probability density function can be depicted as a weighted sum of Gaussian component densities. To estimate the GMM parameter from training data using the repetitious Expectation Maximization (EM) algorithm or Maximum a Posteriori (MAP) estimation from a well-trained antecedent model.

In equation form Gaussian mixture model i.e. a weighted sum of M component Gaussian densities can be written as

\[ P(x/\lambda) = \sum_{i=1}^{M} w_i g(x|\mu_i, \Sigma_i) \]

where \( x \) is a D dimensional continuous valued data vector (i.e. measurement or features), \( w_i, i = 1, \ldots, M \), are the mixture weights, and \( g(x|\mu_i, \Sigma_i), i = 1, \ldots, M \), are the component Gaussian densities. Each component density is a D variate Gaussian function of the form,

\[ g(x|\mu_i, \Sigma_i) = \frac{1}{(2\pi)^{D/2}|\Sigma_i|^{1/2}} \exp\left(-\frac{1}{2}(x - \mu_i)^T \Sigma_i^{-1}(x - \mu_i)\right) \]

With mean vector \( \mu_i \) and covariance matrix \( \Sigma_i \). The mixture weights satisfy the constraint that \( \sum_{i=1}^{M} w_i = 1 \).

The complete Gaussian mixture model is parameterized by the mean vectors, covariance matrices and mixture weights from all component densities. These parameters are collectively represented by the notation,

\[ \lambda = \{w, \mu_i, \Sigma_i\} \quad i = 1, \ldots, M \]

There are several variants on the GMM shown in Equation (3). The covariance matrices, \( \Sigma_i \), can be full rank or constrained to be diagonal. Additionally, parameters can be shared, or tied, among the Gaussian components, such as having a common covariance matrix for all components. The choice of model configuration (number of components, full or diagonal covariance matrices, and parameter tying) is often determined by the amount of data available for estimating the GMM parameters and how the GMM is used in a particular biometric application.

It is also important to note that because the component Gaussian is acting together to model the overall feature densities, full covariance matrices are not necessary even if the features are not statistically independent. The linear combination of diagonal covariance basis Gaussians is capable of modelling the correlations between feature vector elements. The effect of using a set of M full covariance matrix Gaussians can be equally obtained by using a larger set of diagonal covariance Gaussians.

GMMs are often used in biometric systems, most notably in speaker recognition systems, due to their capability of representing a large class of sample distributions. One of the powerful attributes of the GMM is its ability to form smooth approximations to arbitrarily shaped densities.

In the system Gaussian mixture mode is implemented in such a way that it recognises the hand gesture accurately. In the system it compares the values of three axis such as x axis, y axis, and z axis which is received from the 3 axis accelerometer. After comparing values are initialised to the x, y and z axis accordingly. This process repeats for every gesture performed by the hand wearable device.

B. Fast Dynamic Time Warping Algorithm:
To find out the optimum alignment between two time series Dynamic Time Warping (DTW) algorithm is use [13]. To determine time series similarity it is frequently used, also it is used for classification, and to find out the corresponding regions between two time series. Use of DTW limits to only small time series data sets because it has a quadratic time and space complexities. To overcome this problem Fast Dynamic Time Warping (FDTW) algorithm is implemented in the system. Fast DTW is an estimation of DTW that has a linear time and space complexity. Fast DTW uses a multilevel approach. The multilevel approach recursively stick out a solution from a coarse resolution and rectify the projected solution.

Fast DTW algorithm is able to find out an accurate estimation of the optimum warp path between two time series. By using a multilevel approach the Fast DTW algorithm head off the brute force dynamic programming approach of the standard DTW algorithm. The time series were initially sampled down to a very low resolution. For the lowest resolution warp path is found and sticking onto an incrementally higher resolution time series. The sticking out warp path is processed and projected again up to a higher resolution. The process of refining and projecting is repeated until warp path is found for the full resolution time series.

Effectiveness in Fast DTW algorithm is O(N) time and space complexity. Fast DTW gives a perfect minimum distance warp path between two time series than optimum. Fast Dynamic Time Warping algorithm uses a multilevel approach which include three levels such as

1) Coarsening: - In this level reduce the time series into a smaller time series that interpret the same curve as accurately as possible with fewer data points.

2) Projection: - In the second level it finds a minimum distance warp path at a lower resolution. Using that warp path as a initial guess for a higher resolution’s minimum distance warp path.
3) Refinement: - In the third level it refines the warp path sticking from lower resolution through local adjustments of the warp path.

The time complexity required to make the resolutions which are proportionate to the number of points in all of the resolutions. Time complexity in the fast dynamic Time Warping Algorithm in equation form is given as:

Fast DTW time complexity = N(8r+14) .............(4.1)

Which is O(N) if r (radius) is a small constant value.

Space complexity of Fast DTW be composed of the space necessary to stack away the resolutions (other than the full resolution input time series), at any one time the maximum amount of cells that were used in a cost matrix, and the size of warp path stored in memory. The space complexity of storing the warp path is equivalent to the longer one warp path that can exist at full resolution. In equation form Fast DTW space complexity can be written as:

Fast DTW space complexity = N(4r+7) ............(5.1)

Which is also O(N), if r (radius) is a small (<N) constant value.

In the system Fast DTW applied to find an accurate minimum distance warp path. So that the recognition accuracy in hand gesture is getting better result.

V. RESULT

Experiments were performed to evaluate the performance of the hand wearable device based on the hand gesture recognition. In the database for every gesture 10 values are stored so that the accuracy of the recognition is increased. The application framework is familiar with the user who had smartphone, so that user can understand the complete operations of the device. In the hand wearable gesture recognition device (10*12=120) gesture values are stored in the database.

A. Algorithmic Performance:

The performance of the wearable hand gesture based recognition system consists of three steps.

1) Train
2) Store in database
3) Test

In the device on starting time user must train the device with all the gestures, so that according to gesture specific action which is stored in database is executed in the smartphone by recognising the gesture. For every gesture 10 repeats are stored in the database. After completion of training user can test the system by doing the same gesture that is stored in the database. Sometimes it may be possible specific action is not performed because of the same action repeated in two gestures i.e. same position of hand gesture recognise in that condition. Performance of the system also depend on the size of training set if size of training set is larger then it provides more accuracy, but sometimes it may cause an error if the size of training set extra larger then it may produce time latency which affect on accuracy and delaying the execution of the operation.

Main advantage of an algorithmic framework is making use of less computing resource so that real time interaction on the smartphone device can be assured. As compared to Digital pen [3] this framework performs better.

In digital pen only 10 gestures are possible in our framework 12 gestures are supported.

B. Interaction Performance:

In the interaction performance include the main concept is that the gesture which is stored in database that must be matched with the testing gesture while testing so that specific action is executed related to that gesture. Figure 3 shows the hardware of the wearable hand gesture recognition device and figure 4 shows the interaction framework on the smartphone. The framework is designed to control the following smartphone operations such as:

1) Camera.
2) Dialler.
3) SMS Screen.
4) Full Brightness
5) Sound Mute.
6) Wi-Fi Enable.
7) Wi-Fi Disable.
8) Google Map.
9) Google Page on Browser.
10) Medium Brightness
11) Low Brightness.
12) Sound Unmute

Fig. 3: Wearable Hand Gesture Recognition Device. (Armband)

Fig. 4: Interaction framework on Smartphone.
VI. CONCLUSION

A wireless wearable hand gesture based recognition framework presents the real time interaction prototype using smartphone that is based on the combination of the SEMG and ACC signals. Using this application operation of the smartphone can be controlled by performing the specific hand gestures which is stored in the database of the system. Algorithmic framework is responsible for classification of the different gestures and performing the actions related to that gesture. Algorithmic framework consists of 12 gestures which control the operations of smartphone through hand gesture. As compair to the Digital Pen implemented framework is better because Digital Pen can recognise only one kind of gestures. In implemented framework small scale and large scale gestures can be recognised. The designed framework is easy to handle. This application is very user friendly to understand. From gesture vocabulary user can easily perform all the actions using wearable hand gesture recognition device. The gesture vocabulary can be redefined by the user if user not comfortable with the gestures stored in database. This framework can be use in daily life, Emergency condition, Gaming for better experience.

REFERENCES

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