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A Review on Human-Computer Interaction using Smartphone's Inertial Sensors

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Abstract: ***Nowadays mobile phones have become minicomputers equipped with inertial sensors due to advancement in microelectronics, which increases the processing power of these devices and has made possible new forms of input interfaces like gesture-based user interfaces. Because of this, a new type of interaction has been introduced in which the user interacts with the computer using movements or gestures made while holding a device. A gesture recognition system has been proposed for mobile devices using the measurements of accelerometer and gyroscope. The system has been set in which predefined gestures are loaded and they are recognized in a user-independent way, without the need of learning phase. The system has low computational complexity so that the events can be executed in real-time on devices with limited capabilities. Using this system, we are trying to reduce the dependability on conventional input devices which are used to control computer system.***

Keywords: Human-Computer Interaction, Interaction devices, Pointingdevices, Interaction Techniques, Pointing, Gestural input, HCI, Gesture Recognition

1. Introduction

Gesture recognition is a part of computer science in which different mathematical algorithms are used to recognize movements made with hand or even the entire body. With the help of gesture recognition, a person is able to control the given system without any physical contact. Gesture recognition is implemented in systems which accept input in the form of hand movements, taps or swipes on the interface.

The evolution of mobile phones has made it possible for them to be made powerful enough to have the processing power to make their own decisions or perform tasks which might have been impossible 5 or 10 years ago. Mobile phones have become the most ubiquitous wearable computers available and have the capability to change our surroundings. Every mobile phone these days has a plethora of sensors like accelerometer, gyroscope, microphone etc. These sensors act as a feedback system which alerts the user about his surroundings. Using smartphone sensors and gesture recognition allows the user to interact directly with the system in a way which is precise and also easy to learn.

The advancement in MEMS (Micro-Electromechanical System) has led to the use of inexpensive 3-linear accelerometers which are used in a gesture recognition system. Wearable inertial sensors are a low-cost, low-power solution to track gestures. Mobile applications in the field of HCI (Human-Computer interaction) can be used by optimizing theaccelerometer-based gesture recognition system.

Gesture recognition using accelerometers is a relatively new topic and many problems are yet to be solved. There are a large number of gestures which can be used for certain tasks and can be implemented and used in our day to day life. However, the accuracy of the gesture recognition needs to be very high so as to minimize the incorrect inputs given to the system.

The review follows the following order:

Section 2 is used to describe the different phases observed in the HCI system.
Section 3 reviews the previous work done in this field.
Section 4 Compares the results obtained from previous work.
Section 5 presents the conclusions.

2. Techniques

2.1 Data Gathering

In data gathering, the data generated due to gestures is recorded with the help of accelerometers and gyroscope. The data needs to be accurately read because even a slight mistake can cause disruptions in the output generated.

2.2 Pre-Processing

The transmitted data may contain some noise or unwanted inputs. In pre-processing the collected data undergoes smoothing, filtering and normalization so that the algorithm for gesture recognition can run smoothly and correct output is generated.

2.3 Vector Quantization

Vector quantization is used to convert the collected three-dimensional data to a one-dimensional prototype vector which make the algorithm easier to implement. The prototype vectors are collected in thecodebook. The vector quantization is done using k-means algorithm.

2.4 Recognition

The gesture recognition system has two phases – training and recognition. Hidden Markov model is used in the phase to recognize the gestures. This phase is critical to the working of the entire system and to generate the desired output.

3. Literature Survey

3.1Gesture Recognition Using Mobile Phone's Inertial Sensors

Xian Wang[1]et-al have discussed the various methods which are available for implementation of a gesture recognition system. They have postulated the merits and demerits of the different methods which are available. In this approach, the authors have achieved an average accuracy of 93.2 %. The gesture recognition system that has been implemented has a theoretically low computational complexity as compared to other methods that have been mentioned.

3.2 Accelerometer Based Gesture Recognition Using Continuous HMMs

Timo Pylvanainen[2]et-al presented a new gesture recognition system which used Hidden Markov models. In this system, the gestures were done using hands and were recorded using 3-D accelerometer which was set in a hand-held device. In the pre-processing stage, the effects of device orientation were removed from the collected data. Hidden Markov model was used to recognize gestures as it is the most basic tool available for recognizing sequences of variable length. They used a system in which the recognizer was tested on a set of ten gestures with twenty samples used per gesture used by 7 people making it a total of 1400 samples. The data was normalized using constant scaling. They achieved 99.76 % accuracy in gesture recognition.

3.3 Gesture recognition as ubiquitous input for mobile phones

GerritNiezen[3]et-al presented a ubiquitous system using input mechanism which utilized gesture recognition techniques on a mobile phone. They suggested possible applications for this system which could be used using commonly available hardware. The effects of mobile gaming system on theperception of a person are discussed. In this system, they have optimized the algorithm so that only a small amount of mobile phone resources will be used so that the video game can utilize most of the resources available. The mobile phone's inbuilt accelerometer was used to create a dataset which would be used in gesture recognition. They considered a total of 80 samples out of which 77 were correctly recognized using gesture recognition. The overall accuracy of 96.25 % was achieved in the testing of the proposed system. The recognition time was reduced to 200ms from 1000ms. The system was tested on Symbian Series 60 devices.

3.4 gRmobile: A Framework for Touch and Accelerometer Gesture Recognition for Mobile Games

Mark Joselli [4]et-al proposed a new framework for touch or accelerometer-based gesture recognition that uses Hidden Markov model for gesture recognition. The framework can be used in mobile application development with the implementation of gestures. The paper also proposes a way to present the performance and the tests conducted on the framework which can be used in real time. The framework was able to get an accuracy of 89 % for motion gestures and 98 % for touch gestures. This framework was mainly designed to help developers get acquainted with this kind of input obtained through gestures. The framework is built in Java to ensure cross platform compatibility and also for ease of implementation across most of the devices like Symbian, Android, Ubuntu, and BlackBerry.

3.5 Evaluating andoptimizing accelerometer-based gesture recognition techniques for mobile devices

GerritNiezen [5] et-al evaluated a number of algorithms which algorithms which are being used in gesture recognition. Based on the research they chose the most suitable and most optimized algorithm which can be implemented on a smartphone. The mobile phone's inbuilt accelerometer was used to create a dataset which would be used in gesture recognition. The algorithms were evaluated by considering computational efficiency, recognition accuracy, and storage efficiency. The algorithm was implemented in C so that it could be used on various devices without any problem. An accuracy of over 90% was achieved using the Hidden Markov Model.

3.6 Georgia Tech Gesture Toolkit: Supporting Experiments in Gesture Recognition

Tracy Westeyn[6] et-al have proposed a toolkit which is based on Cambridge universities speech recognition toolkit to provide tools which will be helpful in gesture recognition research. This toolkit allows a user to get both user time and off-line gesture recognition. The main motivation behind this was to help developers and also to implement Hidden Markov Model in a simple way. With the help of this toolkit, an accuracy of 99.2 % is achieved when 249 out of 251 samples were correctly identified.

3.7Accelerometer Based Gestural Control of Browser Applications

MikkoKauppila [7]et-al have discussed the use of accelerometer-based gesture control which can be used in browser applications. The system which is proposed is based on HMM and contributes to tilt compensation and gesture segmentation. The results of the system have shown a promising alternative to conventional input devices used with computers. The way described in the paper has a natural and intuitive way to control browser applications. The system has an accuracy of 99% when the dataset is gathered from a single user.

3.8 uWave: Accelerometer-based Personalized Gesture Recognition and Its Applications

Jiayang Liu [8] et-al have presented uWave which is an efficient gesture recognition algorithm used for Human Computer Interaction using a 3D accelerometer. In this system, the user has a training phase in which the gestures are input to the database. They have used a large library of gestures which contains over 4000 samples collected by eight users. This system has an accuracy of 98.6 %. The library provided by them is the largest which is openly available. They have highlighted the importance of user dependent and adaptive recognition.

3.9 Gesture Recognition with a 3-D Accelerometer

Jiahui Wu [9] et-al have presented an acceleration based gesture recognition which is called Frame-based Descriptor and multi-class SVM. In this system, they have first collected the data and then represented by the frame based descriptor to extract the necessary information. They have then used anSVMbased classifier for recognition of the gestures. This approach is better than DTW, Naïve Bayes, C4.5,and HMM. FDSVM has an accuracy of 99.38 % for direction gestures and 95.12 % for all the gestures.

3.10 Magic Wand: A Hand-Drawn Gesture Input Device in 3-D Space with Inertial Sensors

Sung-Jung Cho [10]et-al have proposed a system which implements an input device called Magic wand with which a user can give input to the system using gestures. This system works in 3-dimensional space and uses inertial sensors to generate acceleration signals along with angular velocity signals. The recognition algorithm is based on the Bayesian algorithm matches the gesture which matches to the closest one in the system. The system achieved an accuracy rating of 99.2 % making it a very good prospect for further research.

3.11 Mobile Phone Controller Based on Accelerative Gesturing

MikkoKauppila [11] et-al have mentioned that the input sensor data is sent to PC via a Wi-Fi/Bluetooth connection. Using PC allows for more freely estimating a parameter (PC's having move computational more). HMM parameters are sent to mobile, a gesture recognizes running on the mobile phone use this parameter to recognize a gesture from continuous acceleration data produced by phone's inertial sensor. Mapping of recognized gesture into various phone commands is done by gesture controller. The Controller internally is implemented as a Finite state machine. Thus the authors have presented a controller based on continuous gesturing for S60 mobile phones.

3.12 Velocity Profile Based recognition of Dynamic Gestures with Discrete Hidden Markov Models

Frank G. Hoffman[12] et-al present a method for dynamic gesture recognition using discrete Hidden Markov Model (HMM) from an uninterrupted stream of gesture input data. A gesture from both hand and fingers are captured in three-dimensional using TUB-Glove sensor. From the gesture data, two velocity based profiles are extracted to address the segmentation problem. The system works in two phases training and recognition phase. A minimum distance classifier is used to classify the feature vectors and to minimize the number of dimensions and to make output that is acceptable for classification with discrete HMM. To evaluate the performance of the system, set of 500 same gesture were entered into the system by two persons A and B. The System achieves 95.6% recognition rate, for a set of 100 gestures

3.13 Gesture Recognition with a Wii Controller

Thomas Schlomer [13] et-al have proposed that user interaction in many application is becoming pervasive and much more tangible and physical. The author aims to use gesture recognitions to interact with the application. For gesture input, Wii-controller is used. Accelerometer sensor in Wii-controller, independent of a gaming console is used for gesture recognition. The System allows for arbitrary training of gesture by the user and can be used for a system like a photobrowsing on home TV. For training and recognizing user gesture, employs Hidden Markov model. Gesture in a system is not restricted to apredefined gesture, but allowing theuser to train and use individual gesture for a tailored user interaction with gestures. To evaluate the performance of the system they collected quantitative data of gestures trained by the user. Five gesture are performed by each participant for fifteen times resulting in a total of 75 gesture per participant. The result of recognition varied from 85% to 95% and the average rate for recognition was 90%.

3.14 Enabling fast and effortless customization in accelerometer-based gesture interaction

Jani Mäntyjärvi [14] et-al have mentioned that Gestures are an intuitive communication channel, which has not yet been fully utilized in human-computerinteraction[13]. Proposed a complimentary interaction procedure for handheld devices using gesture control based on the accelerometer. Gestures command should be customizable, quick, easy to learn and train, to support flexible gesture commands. The paper presents a method to train and recognize tailored gesture commands with less amount of effort from the user for training. The authoremploys Discrete Hidden Markov model. Gesture commands are presented to control DVD player, from the result of recognition. A method based on the inclusion of noise-distorted signal duplicates to the training set and resulting in increasing the recognition accuracy and decreasing training efforts by the user. The Average recognition accuracy for a set of eightgestures each having two original and two gaussian noise distorted duplicates, for each training, was 97%. And average accuracy with two original and four gaussian noise distorted duplicate was 98%, cross verified from a total data set of 240 gestures.

3.15 An Accelerometer-Based Gesture Recognition Algorithm and its Application for 3D Interaction

Jianfeng Liu[15] et-al have discussed that the VR systems have a variety of the application ins different domain as E-learning, CAD, digital entertainment and sports simulation. Human-Computer interaction in VR environment is a 3-DImentional Interaction. 3D interactions are defined as any user action directly performed in 3D spatial context to achieve the interaction. A vivid interaction technique and the multimodal user interface are required for 3D interaction. In order enhance the 3D interaction author presents an accelerometer based interaction technology and applied it to a VR system as the main interaction system. The raw data output the accelerometer is preprocessed i.e quantized, then train and recognize them using discretely hidden Markov model. Using recognition algorithm they treated gestures as a technique of human-computer interaction and use it in 3D interaction system. The experimental result shows that the system quickly and with reliable recognition rate, can recognize the gesture input. They got a 90-95% recognition rate for their training data set.

4. Result

In this section, the accuracy of the different methods has been discussed. Table 1 shows the accuracy of all the different methods used. Out of all the methods that have been reviewed, it is seen that the Hidden Markov Model is the most preferred method to implement a gesture recognition system. However, compared to HMM, Frame-basedDescriptor, and multi-class SVM gets better results for user-dependant and user-independent cases. Georgia Tech Gesture Toolkit has made the implementation of a gesture recognition system relatively easier and also faster.

Table 1: Comparison of methods based on accuracy

Sr. No.	*Method*	*Accuracy*
1	Accelerometer Based Gesture Recognition Using Continuous HMMs	99.76 %
2	Gesture recognition as ubiquitous input for mobile phones	96.25 %
3	gRmobile	89 %
4	Evaluating and optimizing accelerometer-based gesture recognition techniques for mobile devices	90 %
5	Georgia Tech Gesture Toolkit	99.2 %
6	Accelerometer Based Gestural Control of Browser Applications	99 %
7	uWave	98.6 %
8	Frame-based Descriptor and multi-class SVM	95.12 %
9	Magic Wand	99.2 %
10	Velocity Profile Based recognition of Dynamic Gestures with Discrete Hidden Markov Models	95.6 %
11	Gesture Recognition with a Wii Controller	90 %
12	Enabling fast and effortless customization in accelerometer-based gesture interaction	98 %

Conclusion

Most of the methods which can be used for implementing a gesture recognition system which uses 3-d accelerometer and gyroscope for getting input data have been discussed in this paper. Most of the papers mention that the methods have a good accuracy rating. However, it can be still improved further. Another problem the can be seen is the time required for the gesture to be recognized. As a part of our future work, we are planning to implement a gesture recognition system which will make use of inertial sensors present in mobile phones and then will be used to control a computer. Our aim will be to get the highest accuracy percentage and decrease the time required to recognize the isture.

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