AN INTELLIGENT HAND GESTURE RECOGNITION SYSTEM USING FUZZY LOGIC

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Abstract

Hand gesture recognition is a developing technology that makes the human machine interaction through meaningful physical movement. Several devices have been developed in the past using the camera for recognizing hand gestures and communicating with the machine. This paper explains about a new system called fuzzy based hand gesture recognition (FHGR) to avoid the use of camera which has several disadvantages like lighting, making proper hand movements before camera, less range, etc. This paper explores the possibility of having the intelligent control unit in a wearable form like a hand watch or a wrist band, etc. For stable displacement, estimation filtering is used. With the sensors placed in the form of a watch or a band in our hand, any motion made by the hand will be detected by these sensors and transferred to a control unit to take the required actions. Experimental results shows that the stability and accuracy of the proposed system is more.

1 Introduction

Hand gestures are one of the most commonly used gestures in day- to- day life. When systems to recognise these gestures are developed, they can be used to perform human machine interaction. Such interactions enhance the quality of life for hearing impaired people as their communication with common man improves. A very widely used theory for computational intelligence is the fuzzy set theory. This theory deals with the designing systems for processing flexible information [1]. This theory can be applied in control systems for decision making. The fuzzificator of the fuzzy system computes the membership degrees of the input values to the fuzzy sets associated to each fuzzy variable. The rule base consists of the rules bounded by these fuzzy variables. The information manager searches the rule base for the appropriate rule to be applied. The output values are determined by the inference machine. Lastly, the defuzzificator determines a single output as a function of the output values. There are different methods used for determining the input values (hand variables) to the fuzzy logic system. To implement hand gesture inputs into the fuzzy system various methods have been used in the past. Some methods use cameras to capture the shape of the hand and picturise the required inputs to be acted upon in order to get the required interpretation of the gesture [2]. Such vision based systems are the most commonly used systems due to their low cost. The captured images are interpreted using different algorithms like finite state machine, interval mathematics, etc. Some other methods involve the use of sensors [3]. A system for hand gesture and sign language recognition occurs based on the intensity of the signals produced by the electromyography sensors. Information from the accelerometer and the electromyography sensors are fused and given to the Markov models to obtain the final results [4]. The hand gesture recognition is achieved by fusing the RGB-D cues. The hand is detected by a course to fine synchronisation method. A Gaussian Mixture Model(GMM) skin model is used to detect the skin candidate areas on the color image and the hand region is determined by combining the depth information of the hand with respect to the camera [5]. A unified set of hand gestures are framed. The system interprets the user's hand gesture and converts them into a predefined command which is given to the control system. The control system thus controls many devices based on the user's hand gesture. This system omits the problems which are created due to the control features of the control system [6]. A micro inertial measurement unit is framed based on the micro Electro Mechanical Systems (MEMS) sensors. The sensors sense the motion information produced by characters written by the user. The measurement unit records the accelerations and velocities of the motion during hand-writing. These values are then processed using methods like FFT and DCT [7]. In this system a micro inertial measurement unit based on the MEMS sensor is created to analyse the motion done by the users by converting them into electrical signals. These data are processed using FFT and DCT. Also a Hidden Markov Model (HMM) is used to classify the gestures [8]. Vision poses a 3D application where the object can be moved and rotated by simple motion of the user's hands. This method involves using the hand direction to achieve human computer interaction [9]. A fuzzy c-means clustering based mixture-of-experts (FME) model is used to perform enhanced hand gesture recognition. Multiple local experts are obtained through a fuzzy c-means clustering and the decisions from them are grouped using a gating network [10]. In this vision based system a Cam-shift algorithm is used to track the skin colour. The starting point of the boundary (obtained by the BEA) is transformed using Fourier transform. The nonlinear non-separable type of data's outline features are classified using a SVM [11]. TRS moment invariants combined with Viola-Jones object detection framework is used for hand gesture recognition which involve very complex backgrounds like the ones at houses. This combined system provides a user friendly robust recognition [12].

The novelties of the proposed idea are summarized as follows:

1, FHGR recognize the hand movement produced by the MEMS accelerometer with the specified direction and processes immediately.

2, Kalman filtering is used for increasing the reliability and accuracy of the system.

3, The proposed method is more efficient for tracking and locating the direction with variable speed. This system is much suitable for physically challenged.

The rest of this paper has the following sections

Section 2-System overview

Section 3-Experimental results

Section 4 -Conclusion

2 System Overview

The system proposed in this work, utilizes three major components: The sensors, Controller, and GSM modem. Micro Electro Mechanical System (MEMS) sensor (ADIS16220) is used to measure the vibration. The block diagram of wearable module (WM) is shown in fig. 1. The signal were conditioned and converted by an analog to digital converter and the converted signals were Kalman filtered. In addition, the movement signal was measured and stored synchronously, so that it could be used for comparison with the filter coefficients. The ADIS16220 is a wide-bandwidth sensor which collects data autonomously and makes it available to any processor system that supports serial peripheral interface (SPI). It has one fixed frame and one moving frame to form a differential capacitance network that responds to linear acceleration.

A modulation signal on the moving plate feeds through each capacitive path into the fixed frame plates and into a demodulation circuit, which produces the electrical signal that is proportional to the acceleration acting upon the device. The analog acceleration is converted into digital and the digitized data is passed through the controller. The controller processes the acceleration data, stores it in the capture buffer, and manages its access using the SPI. Measurement tests were carried out by wearing the accelerometer in the hand and checks the four possible directions. The measurement result is given in section 5. Based on the signal received, the processor sends the control signal through GSM modem for accessing the hardware. Different functions of hand gesture with the corresponding hardware control are given in table 1.

Table 1: Different hand gesture control

Hand Gesture	GSM	Operation
Exist	Exist	Send the Information
Exist	Not Exist	Store and Forward
Not Exist	Exist	Waiting for Input
Not Exist	Not Exist	No Operation

The receiver is interfaced with a GSM modem for accessing the corresponding applications. The micro controller (Arm 7 core) in the receiver processes the commands which are received from the wearable module. The block diagram of the receiver module is shown in fig. 2. A computer system, Intel pentium dual core, and a 2.2 GHz are interfaced with the controller for accessing the internet. The NetBeans IDE 7.1.2 and a high level programming language, java, is used to build up the codes. Interfacing the hardware device by using a communication port (RS 232) is used for performing a specified action like taking a snap and sending an email in the PC mode.

FHGR has intelligence to operate the system properly and it always watches the signal level of GSM. It will send the information only when the signal is in the required level. The operations for various states are given in table 1. In case the GSM signal is not present or the level of the signal is less than the required level of sensing, the controller stores the information and forwards it when the required level is found.

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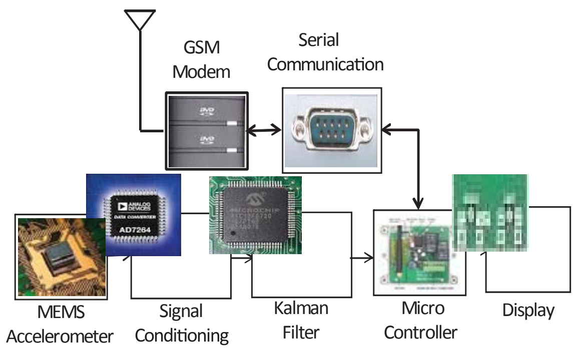

Figure 1. Block diagram of wearable module

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2.1 MEMS Accelerometer

MEMS or micro electro mechanical systems are used to intervened the electronic and mechanical systems to improvise on the scope of the respective fields. MEMS provide an interaction between the electronic and mechanical worlds of research resulting in improved technologies. Using MEMS complex mechanical elements like cantilevers or membranes can be easily manufactured. In some cases the manufacturing of such objects using MEMS is relatively easier than lathe machining. MEMS are produced by micro fabrication of silicon materials. MEMS are characterized by their intimate mechanical parts like holes cavities etc.

One such widely used MEMS is the MEMS accelerometer. Accelerometers generally use the piezo electric effect. Another commonly used accelerometers measure acceleration as a change of capacitance. Since capacitors can operate both as sensors and actuators, they possess excellent sensitivity and a high temperature tolerance. Capacitive sensing depends upon the variation of capacitance due to the changes in the physical geometry of the capacitor. The general equation for capacitance of a parallel plate capacitor is given by:

$$C_0 = \varepsilon_0 \varepsilon \frac{A}{d} = \varepsilon_A \frac{A}{d} \tag{1}$$

where A-area of the electrodes; d-distance between the parallel plates; ε- permittivity of the material in between the plates. .A variation in any of these parameters results in the variation of the capacitance. Hence the MEMS sensing uses the changes in each of the three parameters.

A MEMS accelerometer consists of movable proof mass with plates which is attached to a reference frame through a mechanical suspension system. Here the movable plates and the fixed outer plates act as capacitors. Consider the free space capacitances between the movable plate and the two stationary outer plates be C_1 and C_2 respectively. C_1 and C_2 are a function of their corresponding displacements x_1 and x_2:

$$C_1 = \varepsilon_A \frac{1}{x_1} = \varepsilon_A \frac{1}{d+x} = C_0 - \Delta C \tag{2}$$

$$C_2 = \varepsilon_A \frac{1}{x_2} = \varepsilon_A \frac{1}{d-x} = C_0 + \Delta C \tag{3}$$

where x- proof mass displacement due to acceleration

When there is no acceleration the two capacitances become equal making x zero. When x is not equal to zero, the difference in capacitance is given by:

$$C_2 - C_1 = 2\Delta C = 2\varepsilon_A \frac{x}{d^2 - x^2} \tag{4}$$

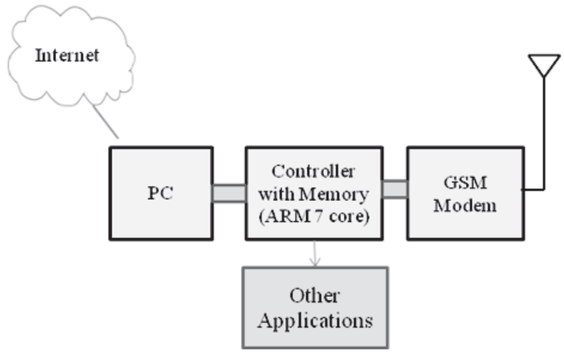

Figure 2: Block diagram of receiver

This capacitance difference and the displacement x are related by the following nonlinear algebraic equation:

$$\Delta C\, x^2 + \varepsilon_A x - \Delta C d^2 = 0 \tag{5}$$

When the displacement is negligible x_2 term can be neglected. Hence the resltant expression for displacement is:

$$x \sim \frac{d^2}{\varepsilon_A} \Delta C = d \frac{\Delta C}{C_0} \tag{6}$$

Hence a conclusion can be made that the displacement is proportional to the difference in capacitance.

The capacitance C_1 corresponds to the overall capacitance of the upper capacitors of the system and the capacitance C_2 corresponds to the overall capacitance of the lower capacitors of the system.

In order to find the output voltage i.e., the voltage of the proof mass, we use the following expression:

$$(V_x + V_0)C_1 + (V_x - V_0)C_2 = 0 \tag{7}$$

On simplifying using equation 2 and 5 the output voltage can be given by:

$$V_x = V_0 \frac{C_2 - C_1}{C_2 + C_1} = V_0 \frac{x}{d} \tag{8}$$

2.2 Kalman Filtering

A computational algorithm which processes the measurements to deduce an optimum estimate of the past, present, or future state of a linear system by using a time sequence of measurements of the system behaviour, along with a statistical model that characterizes the system and measures errors, with the initial condition information. The Kalman filter is used majorly for the purpose of reducing noise in input data resulting in an increased performance.

Considering a standard discrete filtering model several assumptions are made, a state transition matrix F is applied to the known previous input X_{t-1}, A control matrix B is applied to the control vector U, A process noise vector W_t is present, an observation vector named Y_t is present for input X_t, an observation matrix H and observation noise vector is represented as V_t.

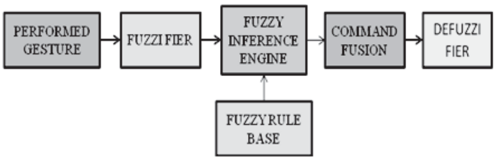

Figure 3: Proposed Fuzzy Controller

Initial state X_0 and noise vectors $W_1,\ldots W_t\ldots\ldots V1,\ldots\ldots V_t$ are mutually independent. Δt is the difference between t and t+1. The Kalman filter equations are as follows,

$$X_t = F_{X_{t-1}+} BU_t + w_t \tag{9}$$

with

$$F = e^{\Delta tA} = I + \sum_{i=1}^{\infty} \Delta t^i A^i/_{i!}$$

$$y_t = HX_t + V_t \tag{10}$$

In order to determine the predicted phase of filter, we have to calculate the predicted state and variance matrix as

$$\hat{X}_{t|t-1} = F\hat{X}_{t-1|t-1} + BU_t \tag{11}$$

$$P_{t|t-1} = FP_{t-1|t-1}F^T + Q_t \tag{12}$$

Where F is transition matrix, B-control matrix and - process noise variance matrix.

2.3 Fuzzy Logic Controller

The mechanism of a fuzzy controller used in the FHGR is illustrated in fig 3. The fuzzy controller performs the following functions on the input signal:

1) Measures the input values from the accelerometers and assigns variables.
2) Performs a scale mapping on the input variables and converts them into the corresponding universe of discourse.
3) Fuzzifier performs the fuzzification function, i.e.:- conversion of the input data into suitable linguistic values. The values can be viewed as labels of fuzzy sets.

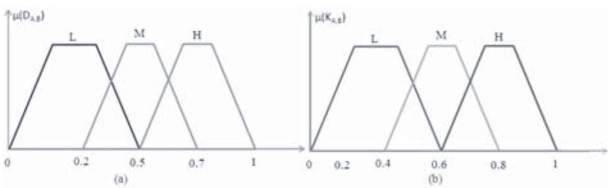

Figure 4: Membership function (a) Displacement (b) Distance

4) Inference engine determines a mapping between the input signal and the output fuzzy set using fuzzy reasoning techniques.
5) The defuzzifier performs scale mapping by using max criterion, or mean of maximum method.

Fuzzy logic controller has two input variables and one output variables. The input variables are: irregularities, displacement KH, GSM coverage VG.

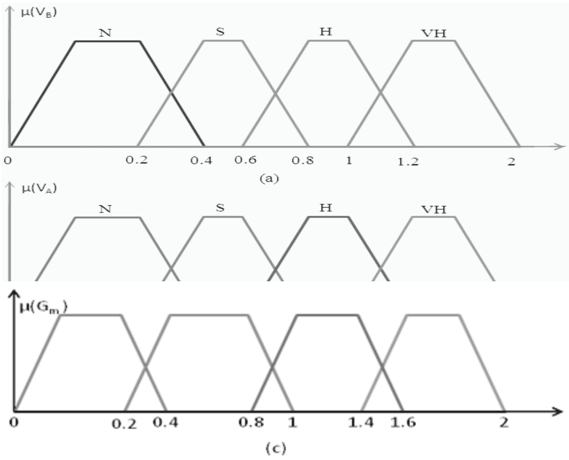

Figure 5: Membership function (a) amplitude of V_d (b) amplitude of V_k (c) amplitude of G_m

The output variable is the displacement voltage Vd. The membership function for displacement and distance are LOW, MEDIUM, or HIGH as shown in fig 4(a) and (b) respectively. The membership function for output voltage is: Small(S), Medium (M), High (H), or Very High (VH). The membership function of V_d and V_k are shown in fig 5. The fuzzy controller obeys the following rules:

The displacement of hand movement produces a considerable output voltage and the signal level V_G is always measured by the controller. Based on the hand movement, the information is sent through the GSM.

If displacement is high and V_G is high then output is very high. If displacement is medium and V_G is high then output is high. If displacement is small and V_G is high then output is low. If displacement is very small and V_G is high then output is low. If displacement is high and V_G is low then output is low. The rule base for the fuzzy system is given in table 2.

Table 2: Rule base for hand gesture

(a)

K_H	V_E	V_H	o/p
LOW	LOW	HIGH	LOW
LOW	MEDIUM	HIGH	HIGH
LOW	HIGH	VERY HIGH	HIGH
MEDIUM	LOW	HIGH	LOW
MEDIUM	MEDIUM	HIGH	HIGH
MEDIUM	HIGH	VERY HIGH	HIGH
HIGH	LOW	HIGH	LOW
HIGH	MEDIUM	HIGH	HIGH
HIGH	HIGH	VERY HIGH	HIGH

(b)

K_H	V_E	V_H	o/p
LOW	MEDIUM	LOW	LOW
LOW	MEDIUM	LOW	LOW
LOW	MEDIUM	LOW	LOW
MEDIUM	HIGH	MEDIUM	HIGH
MEDIUM	HIGH	MEDIUM	HIGH
MEDIUM	HIGH	MEDIUM	HIGH
HIGH	HIGH	HIGH	HIGH
HIGH	VERY HIGH	HIGH	HIGH
HIGH	VERY HIGH	HIGH	HIGH

3 Simulation Result

In this experiment we used a single portable accelerometer for measurement of hand movement. The proposed system is very compact and wrist mounted and operating with the help of small two AA batteries.

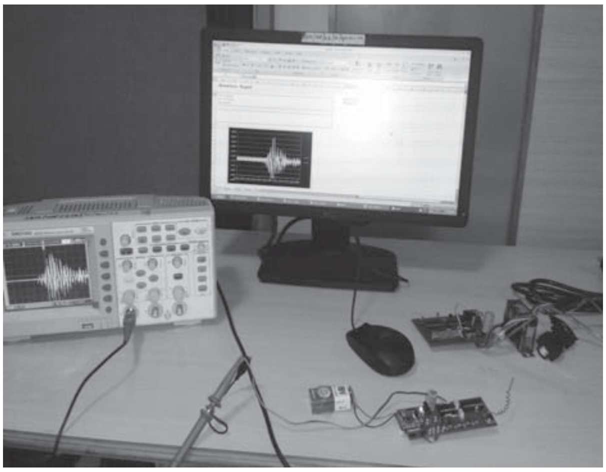

Figure 6: Hand gesture measuring setup

The proposed real-time tracking system identifies the movement of hand with four different directions. We have tested the FHGR with four different direction of sensing and the setup is shown in fig. 6. Capacitive type accelerometer was used for measuring the vibration through hand movement. The signals which were received from the accelerometer were processed in the time domain and the same will be transformed into the spatial domain by using filtering. The measurement setup was installed in hand and different control functions were verified.

For low frequency vibration measurement, a capacitive type accelerometer is used. It is the most common type of high performance MEMS acceleration with wide range. The ADI16229 is a dual axis acceleration sensor with advanced frequency and time domain signal processing. A programmable decimation filter with windowing function is used in time domain signal processing. We measured the output from the accelerometer by using a digital storage oscilloscope SMO1060. Based on the hand movement it will generate the signals and the different signal which generate by the accelerometer is given in fig. 7.

Each hand gesture consists of a signal which is received from the accelerometer, filtering and processed by the controller. A frame of the test sequence and the corresponding signals are shown in Figure 7. Figure 7(a) depicts the result of the movement of forward direction. In order to achieve real-time performance, the signal is filtered before processing. The amplitude of the signal will vary according to the movement of the accelerometer. A significant reverse movement is clearly observed and is shown in fig. 7(b).

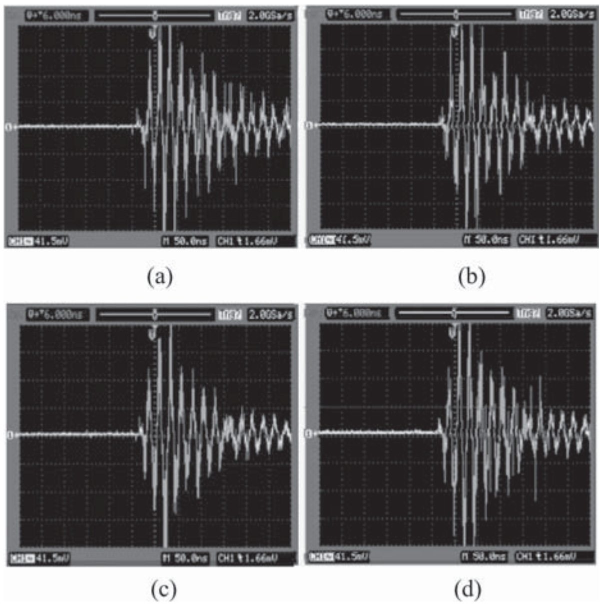

Figure 7: Different gesture measurement a) forward b) reverse c) left d) right

This is presumed to be the impact that the movement of hand from forward to reverse direction and the signal variation due to forward to reverse direction was identified by the processor and the exact gesture was calculated. Fig.7(c) and (d) shows the left and right gesture recognition.

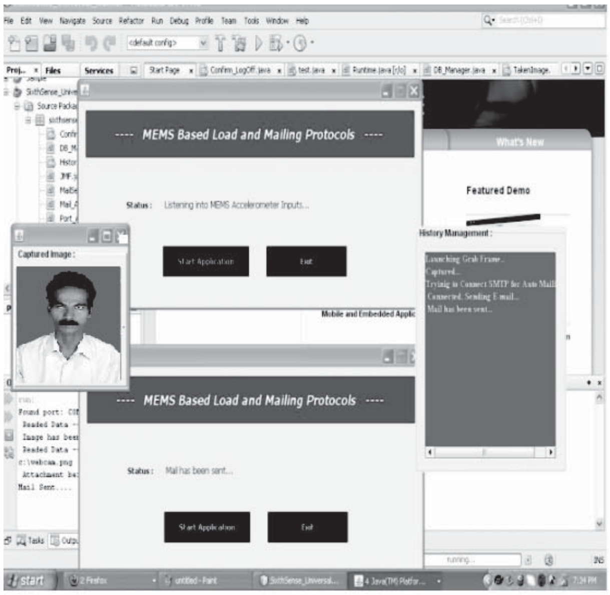

Figure 8: Screen shot of mail transfer

In our proposed model, the software module coding is developed using java language. The NetBeans IDE 7.1.2 is the tool used and a high level programming language like java is used to build up the codes furthermore it is interfaced with the hardware device by using a communication port (RS 232) used for performing the specified action like taking a snap and sending an email in the PC mode. In the software realm a virtual port is used called the hyper Terminal.

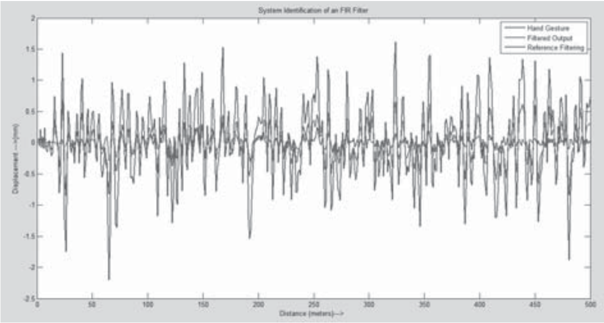

Figure 9: Comparison of reference filtering with Kalman filtering

The hyper Terminal is an input–output port .The input given at one end can be received as output at the other end and vice versa. In the proposed FHGR system forward direction is the input for the operation of taking a snap and sending email (PC mode), we write the coding accordingly by using Java in the software module and interface it with the hardware device .When the forward direction is given as an input by the MEMS accelerometer from the wearable device, the PC recognizes it and specified operation is performed.

To validate the effectiveness of the proposed filtering approach, the results are compared with the reference filtering. The signals which are received from the accelerometer are estimated and compared with the reference and Kalman filtering approach is shown in Fig. 9.

4 Conclusion

Hand gestures are a common mode of expressing emotions and information in any conversation. Hand gesture being an important integral part of the conversation even for physically able persons, such hand gesture recognition systems provides marvellous scope in communication for the physically disabled. This paper presents yet another method of recognising hand gestures. Since the latest technologies involve high end micro controllers, algorithms can be easily made to recognise the hand gestures based on the inputs to the micro controller and the rules on which the algorithms act upon. Using MEMS accelerometer, we can draw a direct relation between the electronic and mechanical systems. This relation proves handy as hand gestures being mechanical can be converted into electric signals which can be easily analysed. The Kalman filtering process rejects most of the noise giving a noise free input for the microcontroller. This paper provides a new paradigm in the research of hand gesture recognition. This system at present can be directly employed in the biomedical industry to improve the abilities of the hearing impaired. By doing suitable modifications in this system, it can be used for the betterment of the abilities of the other impairments and also can serve as a research topic by itself.

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