Hand Data Glove: A Wearable Real-Time Device for Human-Computer Interaction

Piyush Kumar[1], Jyoti Verma[2] and Shitala Prasad[3]

[1]Department of Information Technology, Indian Institute of Information Technology, Deoghat, Khalwa, Allahabad, India
[2]Department of Electronics and Communication Engineering, Galgotia College of Engineering and Technology, Greater Noida, India
[3]Department of Electronics and Computer Engineering, IIT Roorkee, India
{piyushkumariiita, jyoti.gcet, sheetala.god.prasad}@gmail.com

Abstract

In this paper, a real-time Human-Computer Interaction (HCI) based on the hand data glove and K-NN classifier for gesture recognition is proposed. HCI is moving more and more natural and intuitive way to be used. One of the important parts of our body is our hand which is most frequently used for the Interaction in Digital Environment and thus complexity and flexibility of motion of hands are the research topics. To recognize these hand gestures more accurately and successfully data glove is used. Here, gloves are used to capture current position of the hand and the angles between the joints and then these features are used to classify the gestures using K-NN classifier. The gestures classified are categorized as clicking, rotating, dragging, pointing and ideal position. Recognizing these gestures relevant actions are taken, such as air writing and 3D sketching by tracking the path helpful in virtual augmented reality (VAR). The results show that glove used for interaction is better than normal static keyboard and mouse as the interaction process is more accurate and natural in dynamic environment with no distance limitations. Also it enhances the user's interaction and immersion feeling.

Keywords: *Data Glove, Gesture Interface, Gesture Recognition, K-NN, Machine Learning, Virtual Reality, Augmented Reality, Air Writing, Human-Computer Interaction*

1. Introduction

The new generation computer technology is expanding and surrounding humans and computers communicating as naturally as a human with other human. The Ubiquitous systems are more common and controlling them is a task. The technology in user-interfaces (UI) has changed to gesture interface, capturing the motion of our hands and controlling the devices is more natural and realistic. Hand gesture may include multi-touch screen interface, MS Surface computing, or camera based gesture recognition, adding new interactions in shopping applications and even in gaming industries [1]. Gesture recognition is more common to Virtual Augmented Reality (VAR) as the main input device and become more popular with films like Minority Report [2].

Human-Machine Interaction time-to-time keeps moving more closer towards the natural and intuitive user interfaces. Human beings have a good grasping and manipulating ability with their hands and thus interfaces like keyboard and mouse are more popular. Currently, in

most of the HCI interfaces hand is used including static gesture recognition [3] and dynamic gesture recognition [4]. The gesture based on data glove is been used in sign language processing and training [5], but now it is also used in robotics to control the robot arms wearing the glove [6]. The Gesture-Based Computing is also discussed in the Horizon Report of 2011 edition [1]. In this edition it describe the interacting devices with the computer as Nintendo Wii, the Apple iPhone and the iPad, SixthSense device by Pranav Mystry of MIT lab, the Kinect system for the Xbox and Time-to-adaptation [7].

In this paper, we mainly focus on the real-time input and output of the data from the data glove and successfully and accurately grasping the actions. Hand Data Glove is an electronic device equipped with sensors that senses the movements of hand and finger's individually, and pass those movements to computer in analog and/or digital signal continuously. Thus now a day's hand data gloves are used in many research fields including virtual reality, gaming [1], robotics [6], character recognition and verification [8], and in shopping applications. The most important used of data gloves are in medical surgery due to its high accuracy rate and the most practical device used. Even iPod/iPhone/iPad are using gestures in mobile video game platform [9]. Here we will use hand data glove to make paintings and air-write characters in more real-time environment and with less complexity. Also it is used to interact with 3D models and fetch information such as 3D Google Earth.

This paper is divided into six sections. The first heading was introduction, the second section is the proposed research, the third section tells about the gesture and gesture definition used in this paper. The third last section is about the implementation and tuning the system and conclusion is the last section followed by future work.

2. Proposed Research

In past few years many research have been carried out in virtual reality and on data glove. Data glove based interface are designed and researched for replacing static and fixed keyboard and mouse to have more natural way of communication as human being does by making gestures while communication. But have this, the gesture must be recognized first and thus data glove is used. It provides data based on the angular measure of the bones in hand. Gestures are the first most interactive module for game control, Wiimote [1, 10]. Komura and Lam [11] have proposed a method to control a small robot walking motion using the data glove. They actually proposed a mapping system between finger motion and 3D characters location. In this proposed paper, we are mapping the finger motion with the 3D mouse pointer to sketch something useful on the computer screen. Basically the mapping is between the real world and the digital world, connecting each other. The data glove used for the experiment is an electronic device with motion capture sensors, i.e., flex sensors, capturing the movements of each individual finger from physical world and converts them to digital signal using analog-to-digital convertor. This digital signal is then passed to the computer to further process and paints the digital or virtual world, as it is the mimic of physical or real world.

To mimic the real physical world the virtual digital world has to recognize all the gestures performed in the real world wearing the data glove in real-time with high accuracy. The Spatio-Temporal pattern can be both static and dynamic realizing real-time gestures with an accuracy of 93% and is user independent [3]. This paper has achieved to generate and train the various gestures to the system successfully. These gestures are clicking, dragging rotating and the most important is pointing. These gestures are explained in the next section.

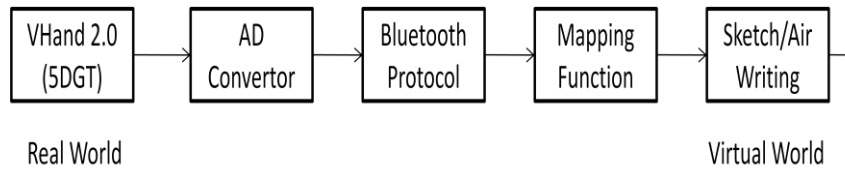The complete block diagram of the system proposed is shown in Figure 1, below.

VHand 2.0 (5DGT) → AD Convertor → Bluetooth Protocol → Mapping Function → Sketch/Air Writing

Real World   Virtual World

Figure 1. Hand Data Glove-Based Digital Sketching and Air-Writing System

The gesture-based user interaction (GUI) can be used in fields such as 3D animation to interact and manipulate with the models, visualizing large dataset on large screen output display device useful for medical data and/or gaming. GUI used in controlling machineries with Dexterous Telemanipulation techniques with the help of bots in field.

In this paper, the main task is to map the digital signal with the task performed or wanted to perform in the virtual environment. The mapping system used in this paper is simple a cluster based gesture recognition. The data is received and sampled and then passed to K-NN clustering algorithm. The K-NN cluster classifies the data based on Euclidean distance formula and on the basis of the result the gesture is recognized and so the related action is performed.

3. Gesture Definition

Gesture is a way of communication used to communicate with others without the speech which involves the body language. Gesture can be defined with or without spoken words. It includes movements and positioning of hands, the face, and the whole body. But in this paper, only hand gesture is considered for the experiments. The basic goal of gesture recognition is to have an automated system that can identify the specific human gestures and also use these gestures to control the devices/virtual environment. In this world of computerization, gesture is building a very richer and strong bridge between the human beings and machines with no limitations. It provides an enabled interface for human to interact with machines in most friendly way as with the other human beings. The online gestures used in this paper for experiments are: clicking, rotating, dragging, pointing and air-writing (path tracking).

3.1 Clicking Operation

The gesture performed for clicking is very simple and straight forward. The finger should bend downwards to make an angle of ≈90° or in general,

$$xy\_angle1^o < click\_angle > xy\_angle2^o \qquad \qquad …(1)$$

Figure 2 clearly show the click operation. In mouse there are two different click operations, i.e., Left Click and Right Click.

Figure 2. Simple Click Operation Gestures

3.1.1   Left Click Operation: For the left click gesture the threshold angle must be between 45° - 90°. And the fingers used in left click are thumb or index finger.

$$45^o < th\_left\_angle(thumb/index) > 90^o \qquad ...(2)$$

In starting, around 70 to 80 samples are used as garbage because of previously bend of flex sensors (explained in next section) of thumb/index finger.

3.1.2   Right Click Operation: Similarly, for the right click the finger used is middle finger bending more than 50°. The limit is defined such that the middle finger can bend properly and the change in the numerical value is clear. And also bending the middle finger more than 80° is not common with all the users.

$$50^o < th\_left\_angle(middle\ fingre) > 80^o \qquad ...(3)$$

Figure 3. Left and Right Click Operations Gesture

3.2   Dragging

To define the gesture of dragging in 2D, again we need to do the gesture of left click and need to change the x-axis and y-axis together in either direction. Only changing the x-axis results in dragging in x-axis and similarly in case of y-axis. In initial position the x-axis and y-axis are the same that of middle of window defined of size 640x480, in 2D graphics. In this operation the value of the z-axis is always equal to zero.

Fig. 4. Simple Drag Operation Gestures

$$(change\_x\_position \leftarrow previous\_x\_position) \,\&$$
$$(change\_y\_position \leftarrow previous\_y\_position) \; with$$
$$45^o < th\_left\_angle(thumb/index\ fingre) > 90^o \qquad ...(4)$$

3.3   Rotating

Rotation is a 3D operation and is always performed around and imaginary axis called a rotation axis. A rotation is a translation keeping a fixed point or line. Rotation about any new imaginary axis can be performed by taking a rotation around x-axis and then around y-axis followed by the z-axis in 3D space. In 2D space z-axis is neglected. To define this gesture the fingers are kept straight and only the axes are changed. As the bend in figures disturbs data glove value and results in conflict. Rotating in this manner the 3D/2D virtual object rotates in the virtual environment. Use of 3D rotation is mainly in animation and designing and to test 3D Max, CAD, Maya, and 3D Studio 3D packages are used.
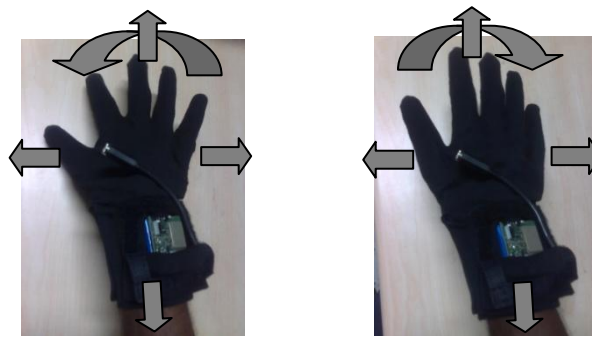

Figure 5. The Rotating Operation Gesture (anti-clock-wise and clock-wise)

3.4   Pointing

The gesture defined for the pointing is very simple and easy. All the fingers are folded and only the index finger is straight. This deactivates all the other gestures like left click and right click and only tracks the path of the x-axis, the y-axis and the z-axis. The old axes position is changed with the new axes position and this shows that the pointer is pointing the object in that environment. The main application of this gesture is in presentation where a large gathering is collected and we need to present and point out something on the screen.

Figure 6. The Pointing Pperation Gesture

$$(\ 0^o < th\_left\_angle(thumb/index\ fingre) > 20^o \ ) \ and$$
$$(\ angle\_all < 90^o \ ) \qquad\qquad ...(5)$$

4. Implementing and Tuning

In this section, we will talk about how the data glove is installed and trained and tuned according to our gestures defined above. The data glove used in this experiment is DG5 VHand 2.0, which is a wireless data glove based on the latest Bluetooth technology for high bandwidth. VHand data glove works on a single chargeable battery of $3.5V - 5V$ and has connectivity up to a range of 10 meter. In this data glove 5 proprietary flex sensors are used for a high sensibility. The Bi-Flex Bend Sensor is a sensor that changes resistance when it bends [12]. The bending can take place in either direction. Flex sensor also senses the presser under the temperature -45F to 125F, shown in figure 7 below. There is 3 degrees of integrated tracking with 3 axes, i.e., roll, pitch and yaw, measuring each movements of figure having 1024 different position per figure. Each position is represented with 10 bit data. The VHand data glove is totally platform independent. The device is connected via a COM port to a computer and at backhand a driver is running to read the data from sensors and control the actuators.
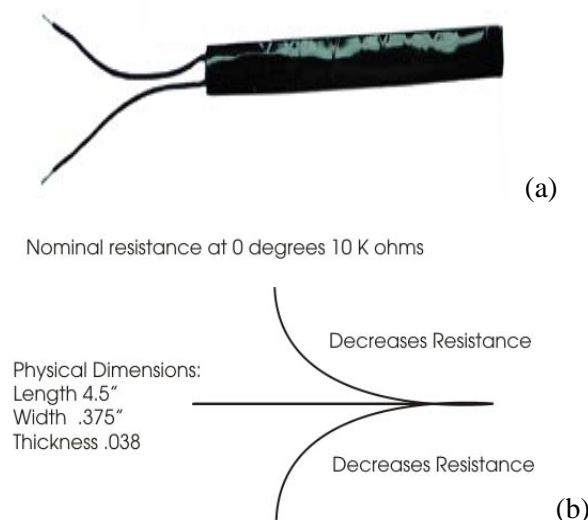

(a)

Nominal resistance at 0 degrees 10 K ohms

Decreases Resistance

Physical Dimensions:
Length 4.5″
Width .375″
Thickness .038

Decreases Resistance

(b)

Figure 7. The Flex Bend Sensor and its Working Characteristics [10]

As in figure, it shows that when the flex sensor is bending the resistance in it is bending and results in resistance break. That is if the original length of the sensor is *L* of *R* Ω after bending the length of the sensor changes to *L1*, which is always less than *L* and hence the resistance decreases to *R1* Ω, which is always < *R* Ω and a change is seen in the volt meter. Again when it comes in its original shape the length changes to its original length *L* and resistance to *R* Ω.

After this a simple C++ code is written to retrieve the data and use it to train the system. Only one hand data glove is used to test the system, i.e., right hand data glove. The data received is in format shown below:

ax	ay	az	thumb_f1	index_f2	middle_f3	ring_f4	little_f5

Figure 8. Data Type to Feature Vector

where, first 3 data are the three axes values ranging -32767 to 32767 and next 5 data are the five finger data values ranging from 0 - 100. The axes value is calculated by the simple mathematical formula given by

$$ax = 2(ax_1 + ax_h + 128)\sin(ax_h)/32767 \quad \dots (6)$$
$$ay = 2(ay_1 + ay_h + 128)\sin(ay_h)/32767 \quad \dots (7)$$
$$az = 2(az_1 + az_h + 128)\sin(az_h)/32767 \quad \dots (8)$$

The number of data samples collected per minute is around 2000. The next step is to cluster these data values after applying a uniform sampling to various different gestures defined. Here the dataset *D(R)* is uniformly sampled to *R* sets at every time interval for each eight fields in the feature vector. The clustering is done by simply using *K*-NN cluster algorithm written in C++.

K- Nearest Neighbor is a method for classification of objects based on the closest features. *K*-NN is used in this paper as it is very simple and easy to implement among all other machine learning algorithms. Here, k is the number of clusters formed. To classify an unlabeled test vector is classified by assigning the label which is most frequent in k training. For example, the data value for left click is different with the data value of right click as in left click thumb and/or index finger is used and in right click operation gesture of bending of the middle finger is used. Collecting these values and forming clusters. Label these clusters by users at the time of training only. Then when test feature vector is present in the same feature space it is classified using a simple Euclidean Distance formula. Similarly, the same process is followed for the other gestures too. It has a very good accuracy rate in recognizing these gestures.

After training and classification the last step is the sketching and air-writing action performed in the virtual environment. The graphics library used to program the graphics are 'BGI' – C 2D graphics library and 'OpenGL' – 3D graphics library. The C graphics library is used to test the data glove in 2D environment, air writing in our case and OpenGL graphics library is used for testing the hand data glove in 3D virtual environment, painting and interaction with 3D objects in our case.

The gestures are chosen in such a way that they conflict very less with the other gestures used. See the Table 1 below for detailed information about the gesture and gesture conflict. The matching matrix clearly shows that the gesture used is independent from the other fingers gesture having a good accuracy rate.

Table 1. Matching Matrix for Different Gestures Used. Each Gesture is performed 10 times.

Confusion Matrix	Ideal Position	Left Click	Right Click	Dragging	Rotating	Pointing
Ideal Position	8	0	0	0	1	1
Left Click	0	9	0	1	0	0
Right Click	0	0	10	0	0	0
Dragging	0	3	0	7	0	0
Rotating	0	0	0	1	9	0
Pointing	4	2	0	0	0	4

According to this Table 1, the left click, right click, dragging and rotation operation gestures are more accurate and efficient then other gestures. The left and right click gesture graph is shown in Figure 9, below.
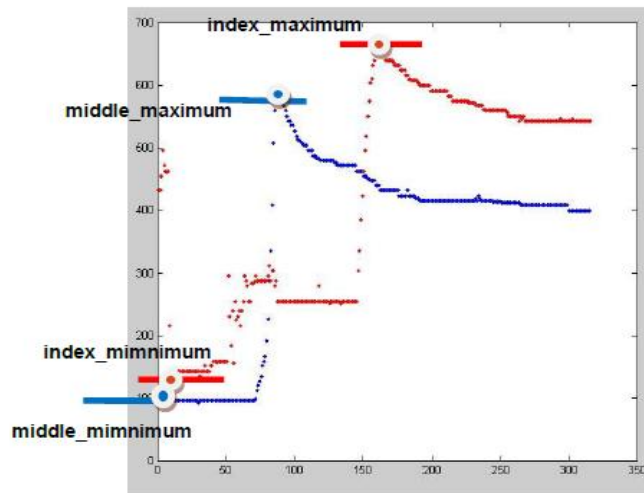

Figure 9. The pattern of Left click (Red) and Right click (Blue) using Hand Data Glove

4.1 Mapping

But how does the mapping take place? What is the function used? The pseudo code below explains the whole concept of left click and right click using the above pattern.

1. calculate the *minimum* and *maximum* values of both *index* and *middle finger*
2. *right = middle_maximum – middle_minimum* and
   left = index_maximum – middle_minimum
3. *if (right > left)*

then
  gesture = right_gesture
  perform right click
else
  gesture = left_gesture
  perform left click

In the similar way the other mappings are performed with little modifications in the above code. In rotation gesture the complexity is bit more because more data are involved in it.

4.2   Applications

The applications areas tested are air-writing, sketching, 3D gaming and 3D animation. The confusion matrix between different gestures is used for measuring the accuracy. The gestures are chosen such that there is no conflict between other gestures.

In Figure 10.a, there are some of the screenshots of the actions performed by the glove in virtual reality. The first screenshot shows the result of air writing in 2D environment. The second figure 10.b shows the output of sketching in OpenGL 2D environment. And in figure 11, a 3D earth made in OpenGL manipulation is performed using data glove
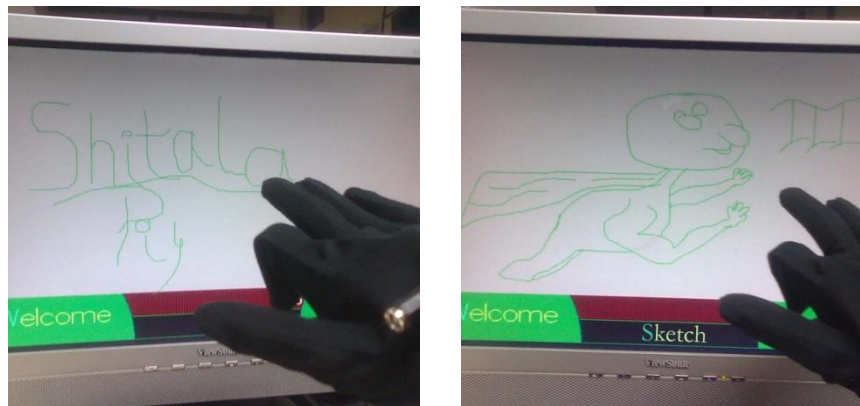

Figure 10. a) Air Writing in BGI 2D Graphics Environment; b) Sketching in OpenGL 2D Graphics Environment

Figure 11. 3D Earth Manipulation using Data Glove

5. Conclusion

This paper is designed to research on how a DG5 VHand Data Glove works and how it is used to interface between human and machine. It is found that the static keyboard and mouse are having many limitations with them, while in the case with data glove can be used for the same purpose without any limitations. The degree of freedom (DoF) of data glove is more than mouse resulting better inputs in the world of virtualization. *K*-NN here is used to train the data and recognize the gestures and take the appropriate actions. The resulting found to be very good and efficient with real-time. This experiment proves that such devices are a good technological for interacting and controlling the devices, software or hardware. The air writing and sketching with 3D game are the software applications that involved data glove as input device.

6. Future Work

In future work, the data glove can be used to type the characters and operate all the applications of computer making it keyboard and mouse independent and many high dimensional applications can run on the system or in the virtual environment. Also there can be a combination of two or more gestures to form a new complex gesture for a complex task to perform using HMD.

References

[1] T. Shiratori and J. K. Hodgins, "Accelerometer-based user interfaces for the control of a physically simulated character", ACM Transactions on Graphics, vol. 27, no. 5, **(2008)**, pp. 1–9.

[2] P. K. Dick, S. Frank, "Minority Report", http://www.imdb.com/title/tt0181689/, **(2009).**

[3] S. P. Priyal, P. K. Bora, "A study on static hand gesture recognition using moments", In Proceedings of International Conference on Signal Processing and Communications (SPCOM), **(2010)**, pp. 1-5.

[4] J. Lee-Ferng, J. Ruiz-del-Solar, R. Verschae and M. Correa, "Dynamic gesture recognition for human robot interaction", In Proceedings of 6th Latin American Robotics Symposium (LARS), **(2009),** pp. 1-8.

[5] T. Takahashi and F. Kishino, "hand Gesture Coding based on Experiments using a Hand Gesture Interface Device", SIGCHI Bull, vol. 23, no. 2, **(1991)**, pp. 67-74.

[6] C. Lee and Y. Xu, "Online, Interactive Learning of Gestures for Human/Robot Interfaces", In IEEE International Conference on Robotics and Automation, **(1996)**, pp. 2982-2987.

[7] The new media consortium, The Gesture-Based Computing, Horizon Report **(2011)** Edition.

[8] S. Sayeed, N. S. Kamel and R. Besar, "Virtual Reality Based Dynamic Signature Verification Using Data glove", in International Conference on Intelligent and Advanced Systems, IEEE, **(2007)**, pp. 1260-1264.

[9] W. Stewart, "Gestures, 3D, Mobile Changing Gaming Market", in International CES Daily, Gaming, **(2011),** January 6-8, pp. 104.

[10] The new media consortium, "The Gesture-Based Computing", Horizon Report 2011 Edition, http://net.educause.edu/ir/library/pdf/HR2011.pdf.

[11] T. Komura and W. C. Lam, "Real-time Locomotion Control by Sensing Gloves", Computer Animation and Virtual Worlds, vol. 17, no. 5, **(2006)**, pp. 513-525.

[12] Two-Directional Bi-Flex Sensors™. http://www.imagesco.com/sensors/flex-sensor.html.

Authors

Piyush Kumar

He is presently pursuing his Ph.D. in Information Technology from IIIT Allahabad, India. He received his M.Tech. degree from IIITA in year 2011 and B.Tech. degree in year 2009 from KNIT, Sultanpur, Uttar Pradesh, India. His major interest is in Image Processing, Gesture Recognition, Data Glove, Virtual Reality and OCR.

Jyoti Verma

She has completed her B.Tech. degree in Electronics and Communication in year 2011 from Galgotia College of Engineering and Technology, Greater Noida, India. Her major areas of interest are Robotics, Data Glove, Visualization and Image Processing.

Shitala Prasad

He is currently pursuing his Ph.D. from Indian Institute of Technology Roorkee, Uttarakhand, India. He has received his M.Tech. degree from IIIT Allahabad, in Information Technology in year 2011 and B.Tech. degree in Computer Science in year 2009 from IILM Greater Noida, India. He is specialized in Human Computer Interaction. His major research work interest is in Image Processing, Face Recognition, Gesture Recognition, Virtual Reality and OCR. Along with this he also works on Image Processing in Mobile Computing and Cloud Computing.