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GESTURE-BASED REMOTE-CONTROL SYSTEM USING COORDINATE FEATURES

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ABSTRACT

To date, the most effective way for HCI (Human Computer Interaction) is dependend on intermediate device – remote control, teach pendant or computer mouse, data glove and many others. The use of human gesture as an input to a computer system has the advantages in terms of its flexibility and ease of access. We proposed a gesture based control system for effective HCI interfaces based of coordinate features. The focus is on using the proposed coordinate features to correctly classify a number of human gestures corresponding to specific functions. The system was setup based on Kinect 360 and Labview interfaces to control four specific functions based on four human gestures using coordinate features. The feasibility and the performance of the system was examined in terms of its accuracy, operational distance and lighting condition. Our experimental results showed that the proposed coordinate features could be used for gesture based remote control.

Keywords: gesture, human computer interaction, coordinate features.

INTRODUCTION

Human computer interaction (HCI) is one of the important fields of both Engineering and technology. With the advance of the technology people are looking for an easy interactive with technology, availability of variety of choices and freedom of selection. In recent development of tablet, gesture based products and touch based devices it became necessary to make in depth analysis how the gestures interact with the twenty first century technology, technology that provides machines which can meet the demands of the users. The technology is needed to provide a very flexible and interactive machines for humans. There are different types of physical expressions that humans make which can easily interface with machine, these expressions can either be hand gesture, voice or speech gesture and vision or facial gesture (Tam & Li, 2012).

Gesture is one of the non-verbal communications that we use every day, giving instructions, pointing directions are all important daily gestures. Movements of gesture stands in place of speech, instead of talking or moving lips showing in action through gesture is much easier and flexible. So far the use of mouse for interacting with personal computers and remote control device for Television (TV) interaction has been achieved, however the demands are growing higher from the users along with technology, to be independent from the mechanical devices. Currently, the mouse and keyboard provides means of input, other options like virtually grasping an objects through head, hand, and other parts of the body is becoming the popular gesture, as the adults give a way for the technology generation it is important to focus meeting their technological demands through more work on research (Bhuiyan & Picking, 2009), (Ren, Meng, 2011). The most effective way that is being used recently for gesture communication is either by wearing a remote control device at user's hand, or by wearing a gloves that is instrumented (Ren, Yuan, 2011), (Caputo 2012). However, the tools for capturing hand gesture are magnetic sensing devices (data gloves) or electro-mechanical device, in this process the tools use sensors attached to a glove that senses finger flexion into electrical signals to determine the hand gesture. The most complete, application-independent set of real-time measurements of the hand in HCI is delivered through this tools (Ren *et al.*, 2011), (Shan, 2010).The researches demonstrates that the gesture based applications can be used for many different things, such as home appliance, controlling, entertainment, caring for elderly or disable individuals, browsing public information, gaming and remote control for home appliances such as TV (Chang & Wu, 2010), (Bhuiyan *et al.*, 2009).

BACKGROUND

Related works

In the purpose of communication, human uses different types of gestures, and there is a greater interest in the fields of researches regarding how best human can use the gesture with their interaction towards machines. This leads development of multisensory machines for communication with new applications for efficient way of communication. The development and use of human interfaces with machines starts years back, in particular interest of in-depth analysis in 1980 "Put-That-There": Voice and Gesture, research study is carried out to address how voice and gesture can inter-orchestrate actions, the applications is used to point items on the large screen with voice, large screen technology is used for it, a space-sensing cube on wrist, & microphone, to interface large screen display, the result that is needed to achieve is to combine the voice and gesture recognition to command on a large display (Bhuiyan *et al.*, 2009).

As recently as 2008 Select-and-Point, general gesture based control research delivered a unit that composes of three parts a presence server, controlling peer & controlled peer using cameral, software tools, applications such as Microsoft Office, multi-media programs in multiple devices and web browser is controlled under the Select-and-Point device. It interfaces with mobile, large screen personal computers and Table top (Bhuiyan *et al.*, 2009). It has addressed to limit the different cumbersome processes in the meeting among groups, it also delivered an easy interaction style based on pointing gesture, and it resulted group meeting rooms to be more intelligent based one. Furthermore, latest version of speech and voice recognition made user interface in commercial vehicle more easier, resulting driving to be comfortable and safer (Bailly, 2011).

Hand based gesture

Hand is a closely mimic, which human communicate to each other, accompanied by either actions or speech (E.g. speaking while demonstrating on hand). Besides being quite convenient, hands provide communications of a lot of thought or emotion, with about 29 degrees of freedom. All hand/arm movements are categorized into two major class of gestures and unintentional movements. Unintentional movements are those hand or arm movement that do not convey any meaning. Most of the systems that have been developed so far are targeted for face/or hand detection as the first step, followed by tracking and gesture recognition.as explained in classifications of the hand/ arm movements which categorically is divided into two Gesture and unintentional movements, under the gesture it can be either manipulative gestures which is the ones used to act on objects in an environment or communicative gestures which have an inherent communicational purpose (Ren *et al.*, 2011).

Gesture recognition systems

Gesture recognition uses variety of different systems in order to process the detection, tracking and recognition of the gesture. The systems implements different devices and tools in order to process the gesture, one example is that of Thomas G. Zimmerman (Wan & Nguyen, 2008) who developed Z-glove and the Date Glove, which are gloves that uses flex sensors for measuring the bending of fingers, their position, orientation and tactile feedback vibrators and aimed to provide a visual programing language. Another system is gesture recognition based on Radio Frequency Identification (RFID) (Shan, 2010) technology which uses captured radio wave information which is stored on a tag attached to an object. Third system that is based on gesture recognition is Hidden Markov Models (HMM) (Lee & Park, 2009), which is based on a statistical modelling to extract efficiently the gesture expressions. Finally, there is a gesture recognition based on Kinect

Camera (Le, 2014) system Xbox Kinect camera proves to be extremely good in recognition of human body. The following four subsections explains the detailed research of the different systems for gesture recognition.

Gesture recognition based on gloves

Gestures have different expression which is based on different systems, one system uses data information gathered from glove to implement gesture recognition of the system. The glove have motion capture sensor or flex sensor and accelerometer sensors on each of the hand fingers and that makes easy the system to understand the movement and gestures of American Sign Language (ASL) for finger spelling by using the decision making process of neural network and artificial intelligent (Cabrera, 2012).

The glove approach provides the exact location and orientation of the finger, coordinates of palm and hand configuration (Dan & Mohod, 2014). The glove uses flex sensor that bends whenever the hand finger makes particular gesture and it gives variety of resistance then the accelerometer measure the motion of the hand, the flex sensor produces analogue output which are converted into digital output using ADC converter (Ghotkar *et al.*, 2012). The converted digital signals are then sent to computer to process further the gestures into a more meaningful way to the virtual of world, even though the glove based system is expensive it has advantage over the other systems because of its high accuracy and fast speed reaction (Kumar, 2012) (Parvini, 2009)(Dan *et al.*, 2014). However, the use of data glove is cumbersome to the user as it has to be worn anytime to implement gesture remote control, and that makes it less independent system. Figure 1 shows Data glove with flex sensors, which gives variable resistance data from the glove as it is bended, the more sensor bends, the more resistance it generates, needles and threads are used to attach the flex sensor to the gloves (Ghotkar *et al.* 2012).

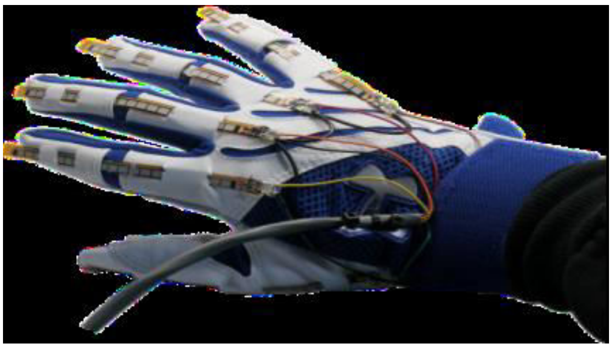

Figure-1. Data glove with flex sensors (Ghotkar *et al.* 2012).

Gesture recognition based on RFID

Gesture recognition is a broad range topic it involved different types of systems with different meaning of expression and application. Radio-Frequency Identification (RFID) is used to read data from a tag attached to an object, it is a wireless of non-contact system that uses radio frequency electromagnetic fields for the purpose of automatic tracking and identification. It has been previously applied in surveillance of products, supply chain, telemedicine and parts tracking of automobiles

(Kriara, 2013). The RFID mostly composes of three systems tag, reader and middleware, tag contains several data of electrically stored information that can be read several meter away.

The RFID technology provides the utilization of un-intrusive and inexpensive passive RFID tags can easily be attached into the user's clothes, and therefore the gestures made by user can be sensed from a distance of up to few meters and several centimeters away. To implement the localization of the system based on active RFID technology that calculates the received signal strength (RSS) to estimate a tag's location, the RSS shows that it is more accurate. On the other hand, in order to locate the passive RFID tags it has been suggested by researchers the use of angulation technique to approximate the arrival direction of a tag signal is the best options (Asadzadeh, 2011). The disadvantage of having this system is that is can only read when it senses the presence of tag within their detection fields, which suggest luck of accuracy and very low tracking system, therefore it is considered too imprecise and limited to achieve, and for gesture based it is hardly feasible to use RFID for smart home assistance (Kriara, 2013).

Gesture recognition based on hidden markov models (HMM)

A Hidden Markov Models (HMM) is a group of limited states connected by transitions. Each of the finite state is characterized by sets of two probabilities: probability transition and either continues or discrete output probability distribution density function, which defines the probability condition of emitting symbols of output from a continuous random vector of a finite alphabet.The HMM have wide range of application which includes the use of gesture representation. Nhan Nguyen, Sungyoung and Donghan (Nguyen-Duc-Thanh, 2012) developed a system in which humans interact with the robots in which the robots understands the gesture and the actions it takes via the control of human hand gesture, they used two stages of HMM, firstly the HMM is used to recognize the prime command like gesture, and secondly the HMM recognizes and executes the gesture, they have included Mixed Gaussian distribution as mean of increasing the recognition rate in HMM. Another method of implementing hand gesture detection and recognition is developed by Nianjun Liu and Brain C. Lovell (Liu & Lovell, 2003), who used sequence observation to characterize HMM states which are obtained from HMM based framework for detection and recognition of hand gesture and extraction of segmented hand image by Vector quantization and in the process of recognition system they have tried several training algorithm method for higher recognition rate.

Gesture recognition based on kinect camera

Microsoft Kinect Camera is a modern technology device developed by Microsoft for Xbox 360 interactive video game with the user. The Kinect camera interprets specific body gestures completely into hands free controls, it composes of RGB camera, depth sensor and multi-array microphone, and it has the capability of providing 3D motion capture, voice and facial recognition. The depth sensor has infrared laser projector with monochrome CMOS sensor, which is capable of capture video in 3D under any available light conditions.

Using Kinect camera's depth image and skeletal point tracking, a virtual touch screen system is constructed which makes the user easier to perform interaction with the screen from a certain distance, the result thus suggests a success in robustness and effectiveness for interactive human computer (Jing & Ye-peng 2013), similarly using Kinect camera's depth information and employing Hidden Markov Model as classification method for the gestures a tele-operation robot for Server/Client is developed, the system enables the user to manipulate the robot and also make it available the reusability of the software in a networked system of robots (Qian 2013).

The gesture recognition systems that has been studied in this section provides sufficient information and proves that Kinect camera is much more suitable to be used in design and analysis of gesture based remote control system.

METHODOLOGY

The design of the system uses Kinect camera as a medium of gesture detection to achieve precise hand trajectory tracking. Although there are different types of depth camera that is available for image detection, the preferred camera for this project is a Kinect camera. This is due to, Kinect camera system is able to provide a gesture detection and recognition at relatively low cost and ease of interfacing as demonstrated in (Ren, Meng, 2011) (Tam & Li 2012) (Le 2014).

Additionally, we have simulated the output of our setup to control a television or personal computer (TV/PC). However, the setup remained general and it could also be used to control other devices. In order for Kinect interfacing, we have used publicly available tool kit based on LabVIEW. Flow chart in Figure-2 shows the proposed system design. We denoted green LED in our graphic user interface (GUI) to represent detected function. The LED would turn ON when a specific gesture is detected and OFF when there is no gesture detected.

Hand gestures is used generally by the users for expression of their feelings and notifications of their thoughts. Hand posture and hand gesture are the terms related to the human hands in hand gesture recognition. Their difference is that hand posture is considered to be a static form of hand poses (Scholar & Engineering 2013). Gestures are divided into two, static gestures and dynamic gestures. Static gestures are generally recounted in terms of hand shapes, and dynamic gestures are described according to hand movements.

Proposed coordinate features

In this work, we focused on using four different hand gestures and these gestures correspond to four specific TV/PC functions – ON/OFF or volume up or

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down. In order to differentiate each gesture, we proposed a recognition based on coordinate features corresponded to joints and body parts – shoulder, elbow, wrist and palm joints, in this project the palm joint is ignored since it is close to the wrist joint. Table 1 summarizes all gestures with their corresponding functions and proposed equation to represent them – (where stands the X coordinate of the Shoulder, similarly stands the elbow's Y coordinate and finally the represents the Z coordinate of the wrist).

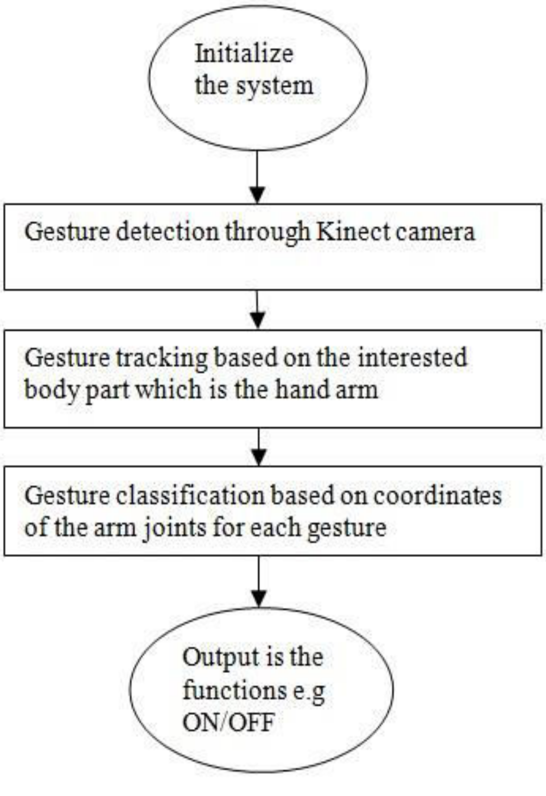

Figure-2. Proposed system design flow chart.

For both volume up and down the arm pose of the user stretches either the left or right hand straight or horizontal which creates the Shoulder-Elbow and Wrist to be in line with each other, the arm is stretched. Along the X-axis which gives different values of coordinates between the shoulder, elbow and wrist for the X-coordinates, however the value of Y and Z are the same for the shoulder, elbow and wrist. Since the value of X varies from each joint of the arm and the X-axis is along the horizontal extension of the arm the absolute value of the X-axis is greater than the other two axis Y and Z which have same displacement value of almost 0 at each joint of the shoulder, wrist and elbow, but since the arm position cannot exactly be adjusted straight and may alternate the absolute value of the three joints for Y and Z-axis is assumed to be 0. The reason behind taking absolute value is to avoid negative value as the arm movement goes up and down, therefore the value should remain positive, the equations used are list next to each gesture on Table-1.

As can be seen from the equation of X-axis is different from the Y-axis and Z-axis in terms of > 0, For example if the origin which is the shoulder S let be 0 and as it displaces the elbow E assumed to be 2 and finally the Wrist is equal to 4, the absolute value of the $|X_s - X_e|$and $|X_e - X_w|$ of X-axis is not equal to 0 but that of Y-axis and Z-axis is approximated to be almost 0.

From the equations it is noticeable that only Z-axis have same absolute value, the extension of the arm with shoulder and elbow stretched and therefore, the X-axis's absolute value of the $|X_s - X_e| > 0$ since the X-axis varies with displacement from the origin of the shoulder to the elbow, while the $|X_e - X_w| < 0$ since the value of the X-axis of elbow did not change when the arm's wrist is perpendicular to the wrist.

But Y-axis have $|Y_s - Y_e| < 0$ as there is no displacement of Y-axis for the shoulder and Elbow but Y-axis varies the displaced value when the wrist is perpendicular to the elbow $|Y_e - Y_w| > 0$, and finally the Z-axis does not change for the variation of the joints and its value remain the same for arm pose of the gestures for system ON and OFF.

System ON and OFF

It is one of the important and fundamental functions for any system that is remotely controlled to have it switched on or off by the remote control, using the predefined equations and Kinect camera with interface of Labview in order to meet the proposed four hand gestures. The approach of the gesture that has been used is to make sure its accuracy and proves vital for locating the hand gesture location based on coordinate of the hand joints. the specific poses of the gesture is performed each of the four gesture, AND gate is used to select the value from the respective inputs of the either the shoulder, elbow or wrist and its output is connected to the LED to light on once the conditions set is met. As can be seen from Figure 3a the green LED turns on as the user makes the hand gesture, The absolute non negative value of the shoulder, elbow and wrist for the coordinates is important in this calculation to determine the exact position in which they are located.

To implement system On gesture, the user poses right hand as described in Table 1, the subtracted absolute value of the shoulder and elbow for X coordinates give a value greater than 0, because the hand extension along the X-axis does give different value in both shoulder and the elbow. However along the vertically perpendicular elbow the X-axis value is the same since the hand is not extended along the X-axis but along the Y-axis. For the Y coordinate it has the same value in both the shoulder and elbow but as the hand vertically stand on the elbow and stretch straight along the Y-axis the absolute value differs. However, the Z coordinate does not change in terms of its absolute value since it is has same value on the shoulder, elbow and wrist hence the system turns on.

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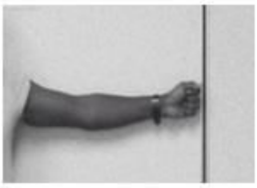
Table-1. Proposed coordinate features.

Input Gesture	Equations	Gesture details	Output Function
	$\lvert X_s - X_e \rvert > 0$ $\lvert X_e - X_w \rvert > 0$ $\lvert Y_s - Y_e \rvert < 0$ $\lvert Y_e - Y_w \rvert < 0$ $\lvert Z_s - Z_e \rvert < 0$ $\lvert Z_e - Z_w \rvert < 0$	Horizontal extension of the left hand" The user extends his/her left hand along the shoulder making the Shoulder-Elbow-Wrist in straight line, when the system detects the static gesture posted then it will increase the volume of the TV/PC.	Volume up
	$\lvert X_s - X_e \rvert > 0$ $\lvert X_e - X_w \rvert < 0$ $\lvert Y_s - Y_e \rvert < 0$ $\lvert Y_e - Y_w \rvert > 0$ $\lvert Z_s - Z_e \rvert < 0$ $\lvert Z_e - Z_w \rvert < 0$	Horizontal extension of Shoulder-Elbow and vertical extension of Elbow-Wrist of the left hand, as the user performs the specified gesture the system turns on the TV/PC.	System off
	$\lvert X_s - X_e \rvert > 0$ $\lvert X_e - X_w \rvert > 0$ $\lvert Y_s - Y_e \rvert < 0$ $\lvert Y_e - Y_w \rvert < 0$ $\lvert Z_s - Z_e \rvert < 0$ $\lvert Z_e - Z_w \rvert < 0$	Horizontal extension of the right hand" The user extends his/her right hand along the shoulder making the Shoulder-Elbow-Wrist in straight line, when the system detects the static gesture posted then it will decrease the volume of the TV/PC.	Volume down
	$\lvert X_s - X_e \rvert > 0$ $\lvert X_e - X_w \rvert < 0$ $\lvert Y_s - Y_e \rvert < 0$ $\lvert Y_e - Y_w \rvert > 0$ $\lvert Z_s - Z_e \rvert < 0$ $\lvert Z_e - Z_w \rvert < 0$	Horizontal extension of Shoulder-Elbow and vertical extension of Elbow-Wrist of the right hand", as the user performs the specified gesture the system turns off the TV/PC.	System on
Lagend	➢ X, Y and Z denoted coordinate axes ➢ Subscript s, e and w denoted corresponding human joint – shoulder, elbow and wrist		

System OFF uses the hand gesture pose of the left hand, it is almost similar to that of system ON, the calculations and formula used remains the system, but the value of each coordinate joint depends how accurate the arm is posed to create the exact gesture it starts by the user posing the hand gesture in Figure-3a, the green LED lights only when the gesture is successful.

System volume down/up

The volume down gesture of the remote control can be executed when the user poses a gesture in which the shoulder, elbow and wrist of the left hand are stretched along the horizontal and creates the three joints to be in line with X-axis. Figure-3c shows how the gesture is performed, the skeleton 3D display follow how the user demonstrates the gesture, the green button of LED turn on only when the gesture as specified coordinate features is met, since the current position of the arm is along X-axis the value of the shoulder, elbow and wrist joints are different as the hand displacement increments from the origin of the shoulder as defined in table 1 $|X_s - X_e| > 0$ and $|X_e - X_w| < 0$ the value of X coordinate is ignored and the other two coordinates are used to

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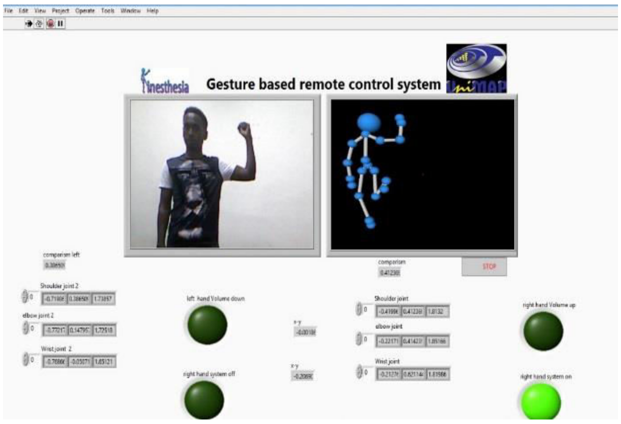
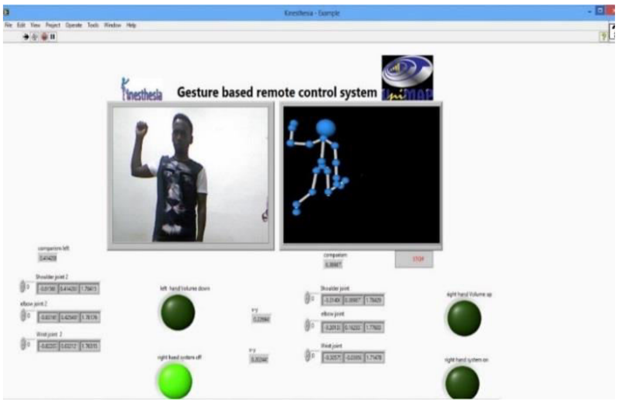
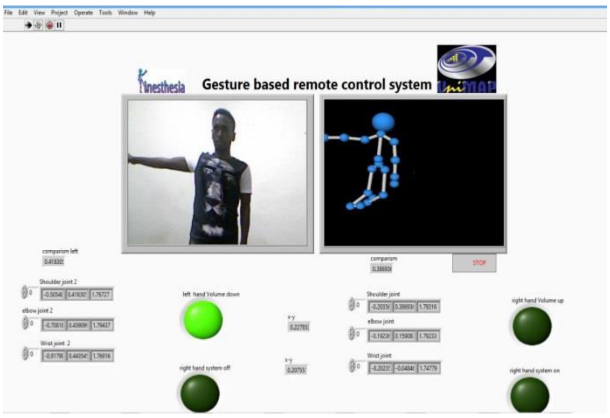
calculate the position of the interested joints, the Y coordinates at the shoulder, elbow and wrist is the same and its absolute value is almost 0 likewise the Z coordinates of the three joints. The system volume up of the remote control is similar to that of volume down in terms of the joints coordinates and results, the only difference is that the right hand is used in volume up. The values of the coordinates may change based on the user's hand positioning. The Figure 3d demonstrates that the green button lights up as the gesture is made, and this can only happen if the requirements of coordinate features are met. Even though the hand position may be different but the system is similar to that of the Volume down hand gesture expression.



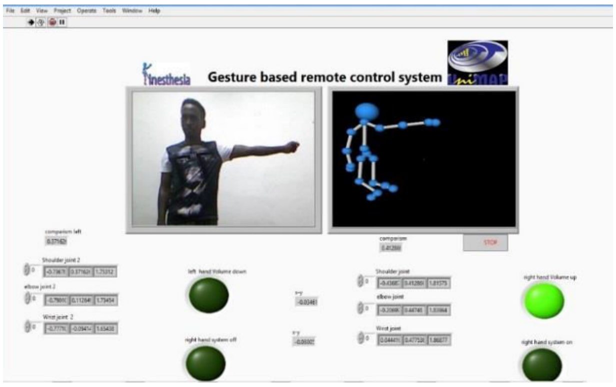
(a)System on



(b)System Volume down.



(c)System off.



(d)System volume up.

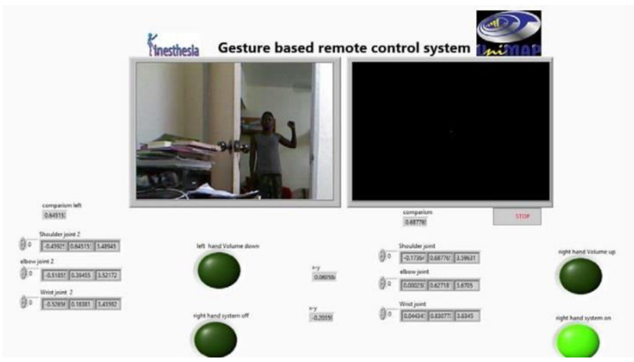
Figure-3. System on, off, volume down and volume up gestures.

Analysis of the system's performance

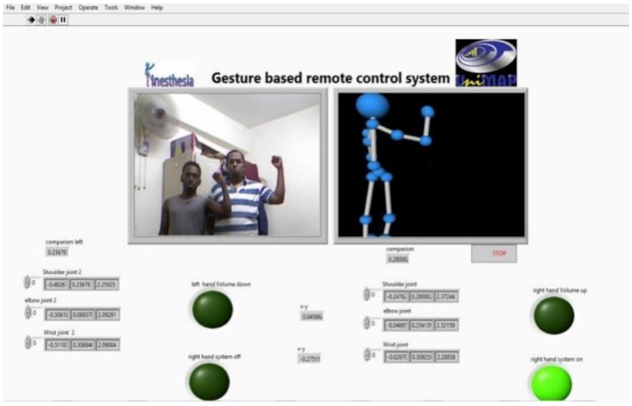
The performance of the system was also tested under the variation of environmental parameter to simulate practical application. Environmental parameters including lighting variation, operational distance and interference for additional users.

Our experimental results showed that the system was able to detect the correct gesture and function from operational distance (perpendicular distance measured from kinect to user) at least 3meter to maximum of 6 meter. Figure-4a shows user posing distance of 6 meters away from the system. This showed that the system could be used in a relatively small space or indoor environment.

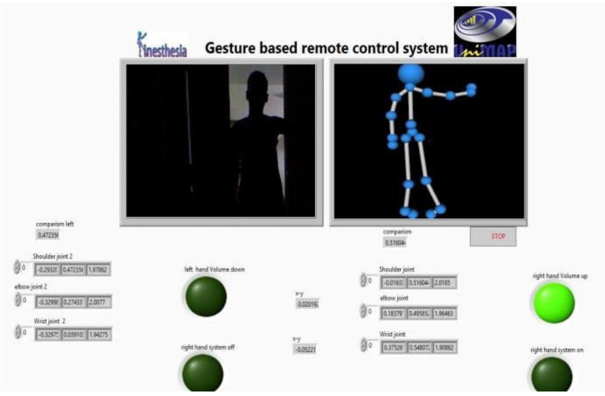
When the the lighting environment was varied, we noticed that the system was able to provide correct gesture and function classification even though the room is dark, as shown in Figure-4c. However, the correct classification in dark environment could only be achieved when operational distance is equal or less than 6 meters. This is due to the limitation of Kinect camera. Repeating the experiment with additional user, correct classification of gesture and function was still achieved. Sample of experimental result is shown in Figure-4b. This is due to the system is setup to detect only the first user, since, in the practical scenario HCI is operated by one user (but not the same user) at a time.



(a)User posing gesture 6m away from the system.



(b)two users posing gesture at the same.



(c) user posing gesture with dark room.

Figure-4. The system's distance, lighting and number of user.

CONCLUSIONS

We have developed a gesture-based remote-control system using coordinate features of human hand joints namely – shoulder, elbow and wrist. Four different hand gestures was selected and the coordinate's features of each gesture corresponded to control four specific functions. An experimental setup was developed based on kinect camera, LabVIEW interfaced to examine the performance of the proposed coordinate features in gesture recognition.

Our experimental results showed that the proposed coordinate features could correctly classify the gesture and its corresponding function. Additionally, the performance of the developed system remained good, under variation of environmental parameters; such as lighting condition, operational distance and number of user.

The development and experimentation provided information of suitable features for hand gesture recognition. There also provided a valuable insight for us to enhance the system to include additional gestures and their corresponding functions. It would be interesting to developed a new coordinate features for finer gestures and their corresponding functions.

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