APPLICABILITIY OF A GESTURE DETECTION GLOVE FOR HUMAN-COMPUTER INTERFACE

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Resumo:

The use of portable electronic devices, such as smartphones and tablets, is diffused around the world. However, because of the reduced size, the interaction with the human being is difficult, especially the data input by typing on virtual keyboards in the screen. We proposed a glove system for capturing gestures. This system consists of six accelerometers and six gyroscopes located at the fingertips and over the posterior part of the hand, allowing precise detection of movements in threedimensional space. This paper describes the development of some applications for the glove system. A series of applications were developed, such as the recognition of gesture patterns of sign languages, allowing people with some kind of special needs (blind or deaf-mute, for example) to interact efficiently with a computer or smartphone. The glove may replace conventional joysticks and mice devices with the advantage of inserting more degrees of freedom to the control. We also developed a 3D virtual hand model controlled by the glove. The glove is specially suitable for blind or deaf-mute people to interact with a computer or smartphone in a more efficient way. The development of applications such as mouse movement, joystick control, key recognition and 3D model shows the potential of the glove as an input device. The social impact is clear, since the proposed system can mitigate the difficulty of people with physical deficiency in communicating.

Palavras-chave: HCI, Glove, Gesture detection

Modalidade de Participação: Iniciação Científica

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1 INTRODUCTION

The use of portable electronic devices, such as smartphones and tablets, is diffused around the world. However, because of the reduced size, the interaction with the human being is difficult, especially the data input by typing on virtual keyboards in the screen. Also, it is necessary to develop new interfaces that allow a more agile human-computer interaction with less effort to the user.

We proposed a glove system for capturing gestures. This system consists of six accelerometers and six gyroscopes located at the fingertips and over the posterior part of the hand, allowing precise detection of movements in three-dimensional space. The sensors are read by a microcontroller, which processes the values of linear and angular acceleration and sends the information to the final device (a computer, a smartphone or a tablet) (ROMANSSINI, 2018).

This paper intends to show some applications for the glove system. One of them is the recognition of movement patterns of sign languages for writing on digital equipments. It allows people with some kind of special needs (blind or deaf-mute, for example) to interact more efficiently with a computer (CHOUHAN et al., 2014). Also, the glove may replace conventional joysticks and mice devices with the advantage of inserting more degrees of freedom to the control. Another uses can also be cited, such as virtual reality interface, motion detection for physiotherapy exercises, training for health academics and remote control of surgeries. Also, the glove can be used as a platform for teaching activities through the development of applications that can exploit its functionalities.

2 HARDWARE

Figure 1 - Developed glove for capturing gestures.

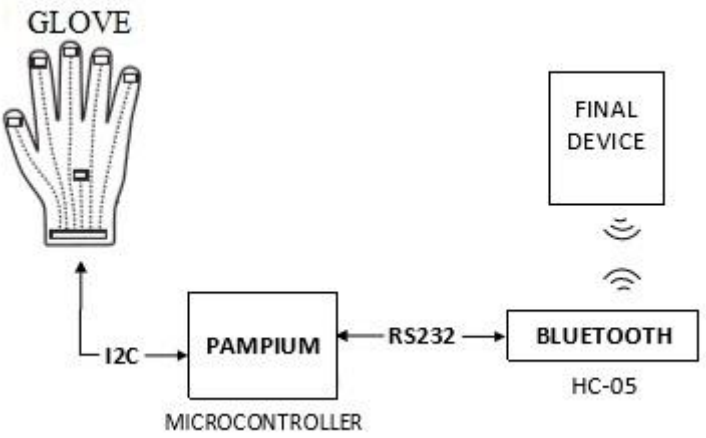


The gesture detection glove used in this work was developed by our group at UNIPAMPA. It is composed of six sensors, a microcontroller, a Bluetooth module and some wires. Figure 1 depicts the prototype of the gesture capture glove. Hand movement data is captured by six MPU 6050 sensors arranged at each fingertip and at the dorsal area of the

hand. Each MPU 6050 has an accelerometer and a gyroscope, providing linear and angular acceleration data on three-axes (X, Y, Z), which allows good precision for motion capture (INVENSENSE, 2013).

The control of the glove is performed by the PAMPIUM microcontroller (ENGROFF, 2010), which is responsible for configuring and reading the sensor data. Both the microcontroller and the communication interfaces are implemented in FPGA. A Bluetooth module is used to transmit the data read from the sensors to the final device (a computer or a smartphone). This wireless transmission allows great mobility for the user. Figure 2 shows the general scheme of the entire system.

Figure 2 - General scheme of the entire system of the gesture capture glove.



3 APPLICATIONS

We implemented an interface driver for reading and processing data from the glove by a computer or smartphone (final device). This interface receives accelerometers and gyroscopes data from the glove through Bluetooth protocol and processes the information according to the application. A pre-treatment of the data is necessary for noise suppression and rotation detection. We normalize the sensor data to a range of -10 to +10 for the accelerometers and from $-\pi$ to $+\pi$ for the gyroscopes. The following subsections describe the developed applications for the implemented glove.

3.1 – Glove as a mouse pointer

A direct application of the gesture capture glove is the control of the cursor movement in a computer. It is the simplest application, but it demonstrates the capability of the glove interacting with the machine. In addition, it allows access to any application that has the mouse as a control device. The movement in the direction of the x and y axes of the screen (hand in the horizontal position) allows smooth and intuitive control of the mouse cursor. The accelerometer values read from sensor number 2, located at the index fingertip, are converted to cursor offset and transmitted to the operating system through the interface implemented in Java programing language.

The transfer function relates the velocity of the index finger (in arbitrary unit mickey/s) to the actual mouse speed (in pixel/s). It is divided in four regions delimited by five points: (0, 0), (0.45, 1.8), (1.25, 5.5), (3.9, 24), (40, 570). The inclination of the first line segment produces a small physical gain in the screen, allowing precision movements and the ability to reach each pixel on the screen (HAN, 2013). If the index finger movement is not sufficient to move the pointer one pixel on the screen, this value is stored and added in the next count. The

gain is increased for higher speeds, in order to afford a natural movement sensation for large cursor displacement.

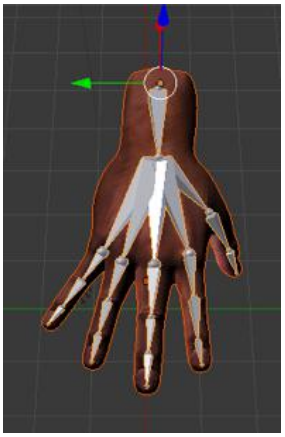
Mouse click is implemented moving the index finger down. What differentiates the click movement and cursor movement on the y-axis is the position of the thumb. When stretched, it permits movement of the pointer. When leaning next to the index finger, it freezes the pointer movement and the click is performed if the index finger moves down. The detection of the position of the thumb is easily performed through the z-axis value of the accelerometer in the sensor number 1.

3.2 – Virtual 3D hand model

The full glove capability can be demonstrated with a hand 3D model. This virtual model reproduces the real hand movement by means of the values read from the accelerometers and gyroscopes. Each finger movement is independent from the others, which provides a realistic control of the 3D model.

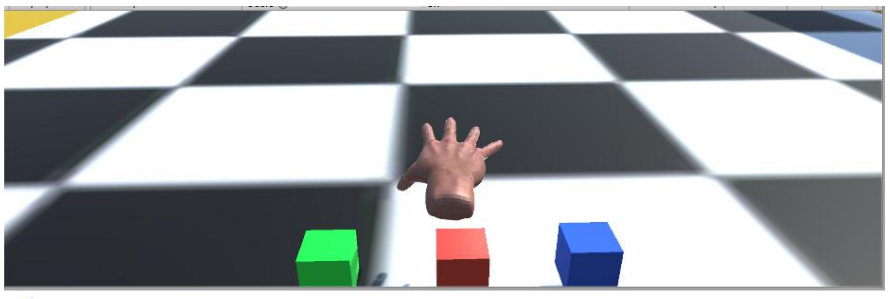
The 3D model was implemented in Unity framework. It is composed of bones for the assembling of each part of the finger. Figure 3 shows the figure of the virtual model of the hand, where the bones are indicated in white.

Figure 3 - 3D hand virtual model. Bones are indicated in white.



The bones are connected to each other so that the articulations reproduces a realistic hand movement. The fixed reference is located at the wrist. This model is a prototype for any project using a 3D space, like virtual reality games, simulations or remote control. Figure 4 shows the figure of the rendered virtual 3D hand controlled by the glove in the Unity framework.

Figure 4 - 3D hand model in Unity Framework.



Unity is a very popular tool for building games. It makes it easier to work because much of the game scenario is done by dragging and dropping objects. In addition, it provides

native methods for the control of the hand's bones, which allows the fingers to move a given distance while keeping the hand integrity.

The movement of each finger is calculated by the difference between the current and the previous values read by the related gyroscope. This difference is added to the current position of the bone at the fingertip. Each finger has three phalanges, except for the thumb, which has two. The position of the bones are estimated in order to give the impression of hand closing or opening. This estimation is made by the multiplication of the bone position by a coefficient of the calculated gyroscope difference. The coefficients were defined as 1.3 for the distal, 1 for the middle and 0.7 for the proximal phalange. The movement of the entire hand is calculated according to the value read from the accelerometer located at sensor 4 on the posterior part of the hand.

To catch an object, we use a collider method as a trigger that is activated when the hand is open and it closes near to an object. The object local axes become child of the hand, thus following the hand movement. When the hand is opened, the object axes stop being a child, causing the hand to release the object.

3.3 – Recognition of LIBRAS alphabet

A suitable application for the developed glove is the recognition of letters from gestures, in which the user makes a certain movement and the application understands it as a key pressed in the keyboard. We adopted the alphabet from the Brazilian sign language (LIBRAS) (FELIPE, 2007), as standard for the gesture recognition. LIBRAS is the official Brazilian sign language and its use is widespread along the country. With the combination of various gestures it is possible to spell complete words and phrases.

The automatic recognition of the gestures with the glove and the translation to a letter in the keyboard allows the typing in a portable device (a smartphone, for example) in an easy and intuitive way for a blind or a deaf-mute person.

The gesture recognition is made by the use of classification algorithms. There are several algorithms for this purpose in the literature, so it is important to make an analysis of classification algorithms to determine the more suitable for this application. The training of these algorithms requires the division of data into classes. The design space is divided in 28 classes corresponding to all letters of the alphabet plus the symbols for "space" and "idle". The input data has 18 features, composed of the measurements of six 3-axes gyroscopes previously described, captured from the glove at a given instant.

We selected six machine learning algorithms in order to evaluate which one adapts better to our application and produces the best performance in terms of accuracy and prediction time. They are the following: Support Vector Machine (SVM), K-Nearest Neighbors (KNN), Linear Discriminant Analysis (LDA), Quadratic Discriminant Analysis (QDA), Logistic Regression (LR) and Random Forest (RF) (JAMES, 2013).

The metrics for evaluating classification algorithm performance are precision, recall, F1-score and the delay of prediction. A predicted class can result in four cases: true positive (TP), false positive (FP), true negative (TN) and false negative (FN). These metrics define precision (PPV), recall (TPR) and F1-score (F) (POWERS, 2016). For the delay it is necessary that the algorithm takes less than 10 ms because this is the sensors update time.

Table 1 shows the comparative for precision, recall, F1-score and prediction time for the implemented algorithms. The SVM and LDA reached greater precision with 94% of correct predictions. Worst result was obtained by KNN, with 88%. Considering F1-score and recall, SVM and LDA presented again the best values. SVM achieved 0.93 for TPR and F_1, and LDA obtained 0.91 for both metrics. The high F1-score demonstrates that few classes have the high error rate and that the remaining present low error rate. These results demonstrate that all heuristics can be used for real-time prediction on the target glove.