Mobile Hand Gesture Recognition System for the Portuguese Sign Language

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***Abstract*—Gesture Recognition is a fundamental technology nowadays. Not only is it applied in games and medicine, but also in Sign Language Translation. This tool assists the deaf community since it allows them to communicate with people who do not understand Sign Language. This paper describes the development of an automatic Translator of Portuguese Sign Language (PSL) which comprises a glove that is supported on wireless sensors, an android application and a machine learning algorithm to associate a gesture to a letter. A survey of all the related work is described, followed by a description of the architecture that is being implemented for this project.**

***Index Terms*—Portuguese Sign Language, Wireless System, Gesture Recognition, Human Computer Interaction, Bluetooth, Machine Learning, Android.**

I. Introduction

Nowadays, technology simplifies and increases the services quality provided, but despite its constant advance, the conditions provided to the deaf community are far from the best, since the most widely used form of communication between a deaf person and a non-deaf person is by written text, which is not very efficient.

There are approximately 100.000 Portuguese who suffer from hearing loss [1]. This translates into 100.000 people who face daily difficulties in simple quotidian tasks involving interaction with a non-deaf person. In addition, the younger age group of this community still finds education difficulties, which translates into a slower linguistic and social development in relation to the students who listen [2].

Even though Portuguese Sign Language (PSL) is one of the official Portuguese Languages since 1997 [3], its integration in the society is far from perfect. Although there are some projects connected to PSL translation these are not portable, involving a Kinect camera [2], [4], which limits the use of the system outside a home.

In order to solve this communication barrier, it is the objective of this work, the development of a portable system capable of translating PSL using a sensor based glove.

Advanced human-computer interaction (HCI) is under the spotlight these days. The gesture recognition is an important step in that direction, since gestures made by the user are recognized by the machine [5]. The gesture recognition, can be divided into five stages: Data Acquisition, Pre-Processing, Segmentation, Feature Extraction and Classification.

Combining these elements it is possible to create a system that recognizes PSL. The proposed system will be supported on a low-cost wireless glove, an android application and employing Machine Learning algorithms. Together they will be able to associate PSL to Portuguese Language.

II. Related Work

There are already Gesture recognition systems using Sign Language, however, most parts of these systems are applied only for American Sign Language [6].

Sign Language recognition can be done in many ways, so the various approaches will be separated into two areas, those that use video-based sensors and those that use motion-based sensors [7]. The big difference from one approach to the other lies in data acquisition [8].

The systems that rely on video-based sensors have the advantage of not requiring the use of accessories. The images collected in this approach can be done by single cameras, stereo-cameras, active techniques and invasive techniques [8]. Reference [6] proposes a system based on Kinect, wich is a depth camera, that makes 3D-reconstruction in real time. After the camera detects and tracks the hand it collects the data, that is classified using Markov models. In the first results it was possible to obtain an accuracy rate of 97%, showing that depth cameras are effective for Sign Language recognition.

Reference [9] describes a system based on Leap Motion for Australian Sign Language. Leap Motion was shown to be capable of providing accurate tracking of hands, fingers, and movements. The disadvantages of this system is that Leap Motion can not capture the finger positions that are hidden from the viewpoint of the camera and when two fingers are brought together the detection fails. Both reference [6] and reference [9] make part of the active techniques.

The systems that rely on motion-based sensors have many advantages when compared to video-based sensors such as: direct linking with the user; more coverage provided; not influenced by the environment; and most important is a wireless system. The data in this approach can be collected by an inertial measurement unit (IMU), electromyography (EMG), wifi and radar, and others like flex sensors and haptic technologies [7].

The system presented in [10] uses a glove with flex sensors and an IMU to track the motion of the hand int three-dimensional spaces. The purpose was to convert Indian Sign Language to voice output.

Reference [11] proposes a glove based in capacitive touch sensors, that translates American Sign Language. This system recognizes gestures from A to Z and numbers from 0 to 9 with an accuracy rate over 92%. The advantages of this advice are the low-cost hardware used and the portability of the device. Although there are systems that translate Portuguese Sign Language [2], [4], [12], they are not portable or have high costs. This work intends to answer these limitations, using low-cost and wireless hardware.

The purpose is to create a system for the translation of the LGP based on methods used for the translation of other languages.

III. Proposed System Architecture

The system is aimed at a single user, containing a sensor based glove, a bluetooth module and an Android App, represented in Fig. 1. When the user represents a gesture, the machine learning algorithm compares a set of predefined values that are associated with a letter with the measured values received from the flex sensors and accelerometer, and if those values are close to the predefined ones, it tries do identify the letter. This information will be sent to the Android App via Bluetooth. In the first phase of the work, which is described in this paper, the collected data is obtained solely from the flex sensors. In a later phase, the accelerometer will be integrated and the data of this sensor will also be collected. In the work developed in this article the Android App is not yet fully implemented. It already receives data provided by LilyPad but the algorithm has not yet been implemented directly in the app. At this stage the translation done is displayed in the graphical interface of the processing program, that is an open- source graphical library and integrated development environment (IDE). To develop the proposed system architecture, it is necessary to consider two fundamental parts, the glove and the algorithm. Both parts will be described in detail in subsection A and B, respectively.

A. Hardware Description

The sensor glove is composed of three hardware elements, as shown in Fig. 2: five flex sensors, a LilyPad USB and a bluetooth. When combined, these sensors allow hand gesture recognition.

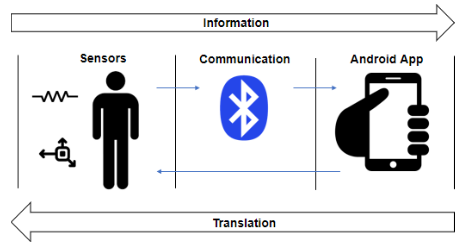

Fig. 1. System Architecture

Fig. 2. Glove seen from the front and back

Each one has its own function, such as:

- **LilyPad Arduino USB:** This is a wearable board, that is the central component of the system [13]. It is responsible for powering the system. Every hardware component will be connected to LilyPad USB by conductive threads and sewable snaps. The LilyPad USB only has four analog outputs, however observing the datasheet of the central microcontroller (ATmega32U4) we were able to understand that the LilyPad has two digital outputs (pins 9 and 10) that can also be programmed as analog outputs. Since each finger will have its own analog output it was necessary to program pin 9 through the ADC.
- **Bluetooth RN41:** This bluetooth is responsible for sending the arduino data to the android application. This module use simple secure pairing (SSP) if it is attempting to pair with devices that supports the bluetooth specification version 2.1 + EDR [14]. Since the bluetooth can not be sewn directly on the glove, a Lilypad XBee was used and the bluetooth attached. This board includes easy-to-sew tabs and all the necessary power regulation to run on the LilyPad system.
- **Flex sensor:** This sensor is responsible for tracking the finger orientation. In order to obtain a low-cost design, it was implemented using velostat, which is a opaque material made of a polymeric foil impregnated with carbon to make it electrically conductive. The velostat measures the amount of deflection or bending allowing to understand which position the finger is [15], and the conductive thread carries the current allowing to create a circuit. The glove is composed by five flex sensors, each one on one finger [16].

Since the flex sensor acts as a resistor, it was necessary to

measure the value of this resistance when it is stretched and flexed. For this, values were taken with the help of the multimeter for both situations. The values presented an average of 7 kΩ when the finger was stretched and an average of 100 kΩ when the finger was flexed.
In order to obtain more accurate values of the five flex sensors it was necessary to use a conditioning circuit, like the one show in Fig. 3.

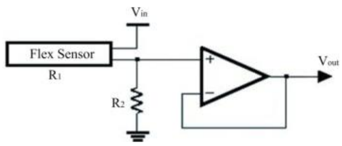

Fig. 3. Flex Sensor

The choice of resistance to be used (R_2) is calculated by the following (1),

$$R_2 = \frac{R_1(Vcc - V_0)}{V_0} \quad (1)$$

where the parameters are defined as:

- V_0: Output Voltage [V]
- R_2: Resistance limiting [kΩ]
- R_1: Variable resistance that is given by the flex sensors [kΩ]
- V_{cc}: Reference Voltage [V]

The R_2 resistance will assume a value of 10 kΩ.

B. Software Description

- **Learning Algorithm:** To implement the letter detection task we explored the use of Neural Networks. First five gestures were performed for each letter. This data was collected by one person with LGP knowledge.

  Since a person never makes a gesture in the same way, there were small variations of values in the five tests of each letter. For each sampling phase, a thousand samples were taken and their respective avereage. Then the ten samples closest to this average, based on the Euclidean distance (2), were considered. For each letter, 50 samples were obtained.

$$d(a, b) = \sum_{i=1}^{N} (a_i - b_i)^2 \quad (2)$$

Parameters in (2) defined as:

- a: Average of one sampling
- b: Every values of the corresponding sampling

Since there are 26 letters in the alphabet, there are 26 files with the respective values for each letter. In each of these files were placed all the letters, marking with 1 the own letter and the remainder as 0. This way the instruction for the neural network is only given 1 when it finds its letter and 0 when it finds another one. A portion of the data set of the letter 'A' is shown in Fig. 4.
For this algorithm Neuroph Studio was used to train the various neural networks [17]. In this case, since there is a neural network for each letter, we had to define 26

```
65,177,13,50,7,1
68,176,14,50,6,1
65,176,13,50,7,1
65,177,12,50,8,1
35,180,141,71,14,0
36,180,142,72,13,0
34,178,143,72,13,0
```

Fig. 4. Data preparation

different sets of data, where 70% was used for training and 30% to validate the results (Fig. 5).

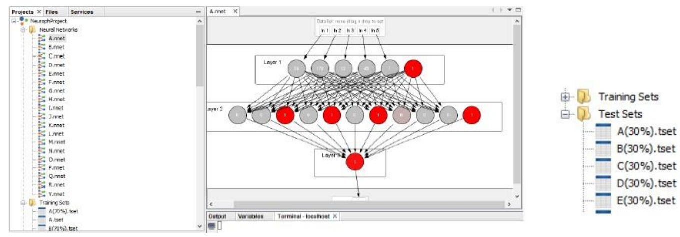

Fig. 5. Neuroph Studio

Initially there was no normalization of the input values, so the neural networks were not training well. The weights were not being initialized with a value low enough by Neuroph Studio. In order to do this it was found the highest and lowest value in the data of the all letters and applied the (3). In this case the highest was 197 and the lowest 0.

$$V' = \frac{value - min}{max - min} \quad (3)$$

Parameters in (3) defined as:

- value: Real time value of flex sensor
- max: Higest value
- min: Lowest value

This way it was possible to obtain the data in a format suitable for training (Fig. 6).

```
0.3299,0.8934,0.0660,0.2538,0.0355,1
0.3299,0.8985,0.0609,0.2538,0.0406,1
0.1777,0.9137,0.7157,0.3604,0.0711,0
0.1827,0.9137,0.7208,0.3655,0.0660,0
0.1726,0.9036,0.7259,0.3655,0.0660,0
0.1777,0.9086,0.7259,0.3706,0.0660,0
```

Fig. 6. Normalized Values

- **processing application:** The processing application has the purpose of displaying a letter associated with a gesture using the machine learning algorithm which takes input from the values of the flex sensors. The end result is represented in Fig. 7. The five fields on the left correspond to the values of the fingers, beginning in the little finger and finishing in the thumb, by their respective order. The field on the right corresponds to the letter given as translation.
- **Android application:** The app consists of four buttons, the first to turn on the bluetooth, the second to turn

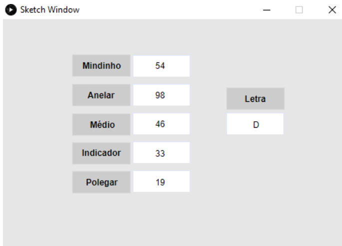

Fig. 7. processing application

it off, the third to show paired devices and the fourth to discover new devices. The “Status” field correspond to the Bluetooth status (On/OFF) and the “Text” field will display the data received from LilyPad. RNBT-9B10 represents the bluetooth glove that we are trying to pair (Fig. 8). The app, developed in Android Studio, is not yet fully implemented, the next step is to implement the algorithm in it.

Fig. 8. Android application

IV. Results and Discussion

The first tests were done with the Arduino Uno instead of the LilyPad USB. This way it was guaranteed that the five flex sensors were working properly before the LilyPad was sewn to these sensors.

Since the hardware has not yet been fully implemented the results obtained from the 30% validation, were not the most desired, reaching a hit rate of 65.3%, when tested for the translation of the alphabet:

- Correct letters: C, D, E, F, G, I, K, N, O, P, S, T, U, W, Y, Z
- Wrong letters: A, B, H, J, M, Q, R, V, X

Although was not an optimum hit rate it was the excepted one since the system is not fully implemented.

This percentage corresponds to a single test attempt, done by a person with LGP knowledge, in which each letter was tested only once. In the final system each letter will be tested several times to see what is the correctness of each hit. However, there is still a long way to go, where the next step is the implementation of an accelerometer. With this implementation it is expected that the rate of accuracy will increase since this sensor will allow to distinguish gestures with equal configurations and with different orientations, as is the case of ”M” and ”W”.

In the test we performed with android app, we paired the mobile phone with bluetooth RNBT-9B10 and the bluetooth status was changed to connected. LilyPad then sent the app, via bluetooth, the phrase ”receiving data” that was printed in the Text field of the app, from 200 ms in 200 ms (Fig. 8).

In the final system the processing program will be replaced by a mobile application, where it will be possible to observe, in real time, the translation of the gesture. The transfer of data from the LilyPad USB to the android application will be supported through a Bluetooth connection, allowing the system to be totally wireless.

V. Conclusions and Future Work

This article introduced a low-cost and wireless sensor based glove capable of translating Portuguese Sign Language. The hardware and software were selected taking into account the characteristics and requirements of the system. Future work consists on implementing an accelerometer and complete the mobile application in order to display the letter associated with the gesture in real time.

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