Teaching-Learning of Basic Language of Signs through Didactic Games

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ABSTRACT

This article presents the development of a didactic game for the teaching-learning of the basic language of Ecuadorian signs, for the hearing impaired and / or interested in learning the basic sign language of Ecuador. The input device is a Leap Motion, which detects the gestural signals in the Unity3D software. For the processing of the signals, there is a classification system implemented in MatLab for the two types of signal configuration: static and dynamic; correlation is used if the configuration is static (no motion signal) and the DTW algorithm is used for dynamic (motion signal) configurations. Communication between Unity3D and MatLab is done using shared memory. This development core acquires a didactic use with two games, implemented in Unity3D for single player and multiplayer.

CCS Concepts

• **Social and professional topics→People with disabilities**
• **Human-centered computing→Natural language interfaces.**

Keywords

Gestual; sensor; hearing impairment; signal language; teaching methods.

1. INTRODUCTION

Educational models have evolved over the years, adapting to the reality and need of society, involving technology in the teaching-learning processes through multimedia applications, access to information through the internet, virtual classes, communication channels, and more [1]. The growing technological world creates a relationship with education allowing to complement educational models through the acquisition, production, and storage of knowledge with the aim of improving the teaching-learning process [2]. The incorporation of Information and Communication Technologies (ICT) in education has contributed to the enhancement of educational systems by providing greater flexibility and efficiency to teaching-learning methodologies, ICTs have an increasing influence on academic education, allowing the development of environments of teacher-student integration which stimulate creativity respecting the learning pace and abilities of students, as well as strengthening group work [3-5].

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After the touch screens human interaction tech the next step in the human machine interaction suggests the identification of naturally gestures, which already exist in the market devices running at full capacity in various fields as entertainment. Kinect is a good option to do gestural interface recognition, having been the first that was commercialized massively and by the scope of market that Microsoft has, it connects to the XBOX console, one of the most popular game device in the market [6]. One of the specialized hand sensing detectors is the Leap Motion device, which captures the movement of fingers and hands using two monochromatic IR cameras, 3 infrared LEDs and a microprocessor, creates a hemispherical area of coverage of approximately 60 cm. [7].

In the literature can be found different proposals oriented to the detection signs applied to the basic sign language of each region. In [8] review of the Leap Motion sensor's ability to perform Australian, sign language tracking is shown, resulting in accurate tracking of fingers and hands at the time of tracing, but loses accuracy when the hand obstructs the position of other fingers without However, the value of the official API used by Leap Motion is recognized when these obstruction problems are detected. On the other hand [9] proposes the use of Leap Motion for the recognition of Arabic sign language using a stage of extraction of characteristics, processing and classification. In addition, the performance of multilayer perceptron (MLP) neural networks is compared with the Bayes classifier obtaining 99% and 98% accuracy respectively. In [10] shows the development of a system of detection of the 26 letters of the English alphabet in American sign language applying the k-nearest neighbor and support vector and shows results in a range of 72.78% and 79.83%. According to [11], he proposes an intelligent system of translation of the sign language to text, using a glove with contact and inertial sensors and has a classification algorithm k-nearest neighbors, decision trees, and the Dynamic time warping algorithms DTW, this intelligent system is able to recognize static and dynamic gestures, also shows that the system classifier has an accuracy of 91.55%.

This article presents the implementation of a 2D virtual environment focused on improving the teaching-learning process of basic sign language for children. For the teaching-learning process, it is considered educational games developed in the Unity 3D game engine. The developed application allows immersion and interaction of the user in a virtual learning environment through the Leap Motion sign sensor, in order to encourage and complement traditional theoretical and practical education for students with hearing impairment.

The structure of this article is divided into 6 sections, including Introduction. The analysis of the teaching-learning problem of basic sign language for children is presented in Section 2; while the description of the application in 2D is developed in Section 3. Section 4 shows the methodology and the analysis of the results obtained when implementing the didactic games in the process of teaching children as hearing impaired. The conclusions of the paper are presented in Section 5; and finally, in Section 6; the references cited in the document are shown.

2. ANALYSIS OF THE PROBLEM

The process of teaching and learning is tedious and presents difficulties in schools, especially not being familiar with several elements involved, forming a fundamental part of this process, teacher and student. In order for learning to be meaningful, it is necessary in large part for the student to assimilate the knowledge imparted by the teacher; however, the majority of students with hearing impairments come from family listeners, so they are relatively deprived of language development and living in a less efficient communicative environment compared to the listeners. This linguistic deprivation has consequences on their emotional and social development. The traditional model of teaching is focused on the task of the teacher, who delivers monotonous texts and therefore are text of little interest to students [12].

The continuous advances of technology have been emerging new systems that allows us to interact with applications without the need to use conventional controls or input devices, but is based on gestures of the hands or the body itself as a form of communication, which gives step to educational development, the teaching-learning process of sign language should be immersive that link to a graphic environment and the gestural interaction that is created by a computer so that the teaching-learning process is developed in the best way.

The proper device in the development of the gestural interface is Leap Motion offers several advantages, the main the detection of fingers, hands and arms, which is the basis of sign language and immersion and multiplayer interaction, *i.e.* two students can use the same graphical environment focused on a game at the same time, that is to say establishes a methodology of teaching that allows the feedback.

The creation of a game is used as a privileged instrument to facilitate and stimulate individual or group teaching-learning processes. From the teaching part, the different aspects are combined: participation, dynamism, entertainment, collectivity, feedback and competence. From the learning aspect it is related through the academic environment and entertainment. There can be no greater value event than finding that the game can be creative and motivate the learning of sign language and enjoyment between teacher and student. Introducing students to activities teaches that learning is easy and that you can generate qualities such as creativity and interest in participating [13].

3. PROPOSAL DESCRIPTION

The developed system is a didactic game based using gestural sensors for tracking the fingers of the hands in order to allow the interaction between one or two users with an attractive interface that facilitates the language teaching-learning process to hearing impaired people. Figure 1 shows the schema of development that allows in real time the interaction and user attention with the 2D virtual scene. The entire application can be subdivided into five sub-processes: *i)* data processing, *ii)* bilateral communication, *iii)* feature extraction, *iv)* classifiers and *vi)* game scene.

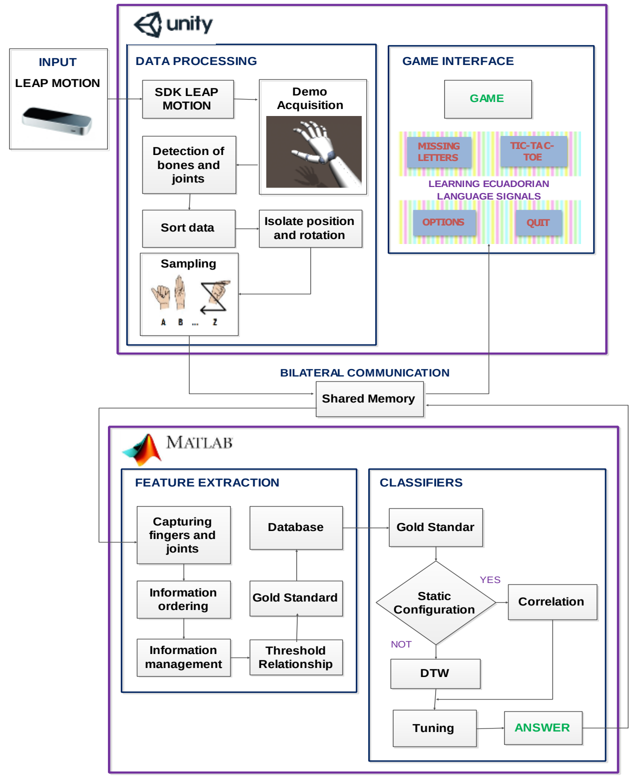


Figure 1. System operation scheme.

i) Data Processing, the process of data treatment is considered as input the sense of position and orientation of the user's fingers, that data are processed in real time in order to interact with the virtual scene. The tracking of the fingers is done through the Leap Motion gesture sensor using two infrared cameras in conjunction with the official application programming interface (API) of the device which are also compatible with some common programming languages, e.g. C ++, C #, Java, Python, etc. [7] [14].

The tracking of the hand through the Leap Motion device, installed in the Unity 3D graphic engine, allows to detect the movement of the hand and locate the bones and joints of each of fingers in a defined point of interest. The setup tracking is as follow: 3 bones and 3 joints pear finger for each hand (30 points), results in a total of 60 points of interest; In addition, there are some bones and joints that detects the device but are not used in the signal detection algorithm, see Figure 2.

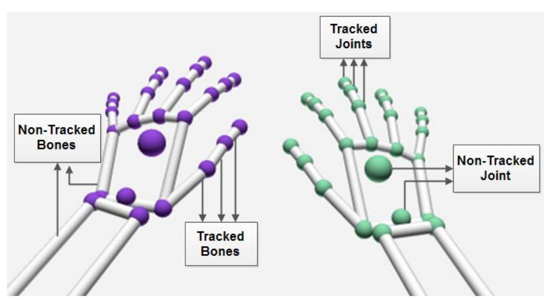


Figure 2. Hand tracking with LeapMotion.

For sampling each language signal, there is a graphical interface in Unity that allows to visualize and capture the position and rotation of bones and joints of the fingers, see Figure 3.

Figure 3. Hand tracking.

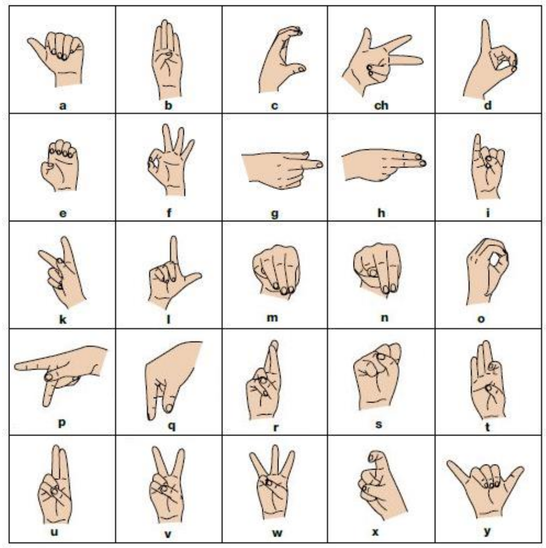
ii) Bilateral Communication, the classification algorithm of gestural signals is implemented in MatLab in real time. MatLab considers as input the tracking data obtained from the Unity game engine and the output is the result of identification of the realized gesture. The communication between Unity and MatLab is bidirectional, *i.e.*, both development environments can simultaneously read and write data. In order to meet this requirement, the shared memory is implemented. According to [15], the Shared Memory (SM) is performed by a Dynamic Link Library or called .dll. This method manages the SM space, provides permissions for the applications, labels the RAM space, provides functions to get-set shared information and free space when the app is closed.

iii) Feature Extraction, the values of position and rotation coordinates of the gestural signals for reference are obtained through the Leap Motion device. The data are grouped into a symmetric matrix R^{mxn}. It contains the values of each bone of fingers and joints; where $m = 15$ represents the thumb, index, middle, ring and pinky fingers, each one of them is divided into 3 parts called: distal, intermediate and proximal bones, for simplify they are abbreviated with the greek letters ooo respectively; and $n = 12$ represents the space coordinates (x,y,z) of position and rotation features of bones and joints, see table 1.

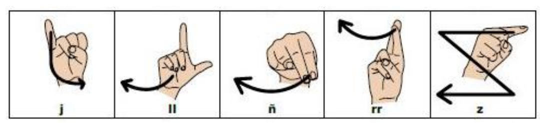
Table 1. Matrix Rmxn

Left/Right Hand													
Fingers		Bone						Joint					
		Position			Rotation			Position			Rotation		
		x	*y*	*z*	*x*	*y*	*z*	*x*	*y*	*z*	*x*	*y*	*z*
Thumb	ρ	1	2	3	4	5	6	7	8	9	10	11	12
	σ	2											
	τ	3											
Index	ρ	4											
	σ	5											
	τ	6											
Middle	ρ	7											
	σ	8											
	τ	9											
Ring	ρ	10											
	σ	11											
	τ	12											
Pinky	ρ	13											
	σ	14											
	τ	15											

To perform the collection of characteristics of each letter of the Ecuadorian basic language sign, it is necessary to consider that the sign is divided according to its type of execution in: dynamic signs, which possess movement to express the gesture (j, ll, ñ, rr and z) see Figure 4 (a); and static signs (remaining of the alphabet), which no needs motion to do the signal, see Figure 4 (b). [16]



a) Static signs



b) Dynamic signs

Figure 4. Ecuadorian Basic Language Signs.

To obtain the reference characteristic of letters of static configuration, 9 samples are collected, with which the correlation coefficient between them is realized. Each result must be greater than 0.8 to be considered a valid representation of the letter, otherwise the sampling is performed again. Table 2 shows an example of the correlation matrix for the letter B.

Table 2. Correlation values for letter B

	B1	B2	B3	B4	B5	B6	B7	B8	B9
B1	1	0.9996	0.9994	0.9355	0.9355	0.9688	0.9851	0.9771	0.9862
B2	0.9996	1	0.9997	0.9349	0.9969	0.9718	0.9858	0.9790	0.9880
B3	0.9994	0.9997	1	0.9356	0.9977	0.9691	0.9859	0.9763	0.9869
B4	0.9355	0.9349	0.9356	1	0.9381	0.8992	0.9257	0.9039	0.9194
B5	0.9975	0.9969	0.9977	0.9381	1	0.9599	0.9886	0.9648	0.9807
B6	0.9688	0.9718	0.9691	0.8992	0.9599	1	0.9553	0.9948	0.9935
B7	0.9851	0.9858	0.9859	0.9257	0.9886	0.9553	1	0.9558	0.9703
B8	0.9771	0.9790	0.9763	0.9039	0.9648	0.9948	0.9558	1	0.9925
B9	0.9862	0.9880	0.9869	0.9194	0.9807	0.9935	0.9703	0.9925	1

The final phase of feature extraction is to apply the GoldStandar average to the correlation values obtained in Table 2. This method is a benchmark trend, because it is the best sample and serves as a basis for comparison, this value is obtained by averaging the 9 valid samples [17].

To obtain the dynamic configuration letter reference feature, the entire trajectory is sampled with a total of 5 samples, the first sample will be the beginning and the fifth will be the end of the sequence; to complete the path of the letter Z, to finally obtain a 12 x 60 matrix containing the 5 samples info in sequence to create the final trajectory, see Figure 5.

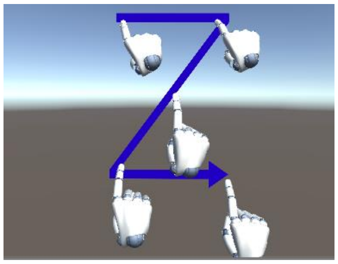


Figure 5. Stroboscopic image of dynamic signals.

iv) Classifier, in this subsection the information delivered by the database is analyzed in order to determine whether the gesture performed by the user's hand is similar to the reference signal. Two processes are implemented in real time according to the configuration of each letter, *i.e.*, static letters and dynamic letters.

A) *Static features,* the appropriate classifier for the static letters is the correlation coefficient, it value determines the relation that happens between two variables. This process is performed between the stored reference data and tracked data in real time by the gestural sensor. The correlation response is determined according to the following conditions

- If the value approaches 1, then there is a positive correlation and the data is related.
- If the value approaches 0, then there is no correlation and the data have no degree of relationship.
- If the value approaches -1, then there is negative correlation and the data are inversely related [18].

B) *Dynamic features,* refers to the letters of the alphabet has movement, so, it is not appropriate to implement the correlation coefficient between it values, as it presents difficulties when comparing several points that form a trajectory. In order to solve this problem, it is implemented the Dynamic Temporal Alignment DTW algorithm, which allows to measure the similarity between two sequences that can vary in time and space. At the moment of making a gesture does not always make a movement of the same duration and exact trajectory as the signal pattern, so that measure the homogeneity of the information in the sequences of the gesture becomes useful in the dynamic configurations.

- If the value is small, then there is great similarity.
- If the value is large, then there is no similarity [19].

The identification of the letter is done by tuning, *i.e.* the coincidence of interest by defining a value of relation between the gold standard factor and the letter that the user makes.

v) Game Scene, the development of the game interface considers the interaction and immersion between the user and the 2D virtual scenes. Attencion and interaction is a psychological process that is triggered when the person leaves their clear perception of their environment tasks by placing all their attention on an object, narration or image that immerses them in an artificial medium, in this case in a game. The developed application considers a main menu that allows access to the games and user options, as shown in Figure 6. The interactive menu allows to select the game, options and difficulty of the game.

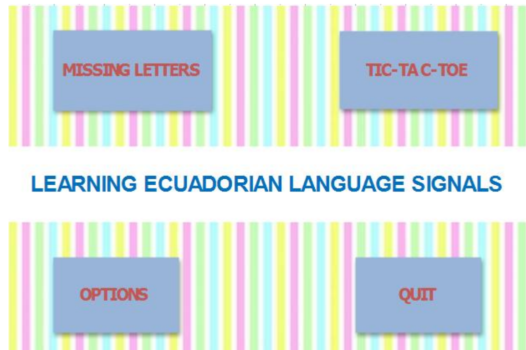


Figure 6. App start menu.

Missing Letters is an agility game that presents an animated image and a word, the goal is to complete the letters that are missing in the word, through sign language. For each missing character has 10 seconds maximum to respond correctly and then goes to the next word. Each success earns 10 points out of a total of 100 possible points, the player with the highest score and least time is the winner, see Figure 7.

Figure 7. Missing Letters scene.

Tic Tac Toe is a traditional game, played by turns, the player must put an X or an O, trying to make a vertical, horizontal or diagonal line. You can only choose the boxes where it is free, to get to a box should be made the number that is there by the sign language and overlaps the X, can end with a winner or a tie, see Figure 8.

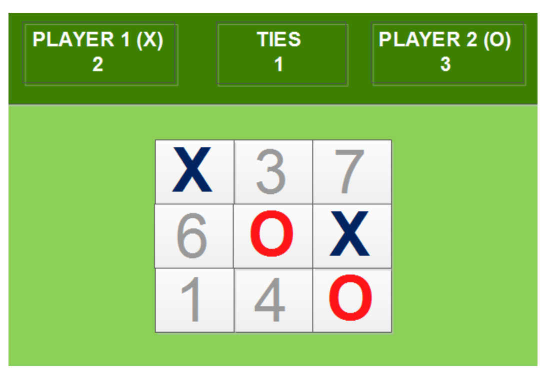


Figure 8. Tic tac toe scene.

4. METHODOLOGY AND ANALYSIS

In this section we define the didactic specifications to design each of the components of the game, the same that are in function of teaching-learning process that they wish to develop in the students that interact in the game with an immersive interface that helps and facilitates the process. To do this it is important to include the characteristics of the color that stimulate and benefit the retention of information for longer when the color is used as educational material. Warm colors: red, orange and yellow stimulate and increase brain activity. The cool colors: green, blue and violet induce relaxation. The design of the graphic environment of the game combines both styles of teaching, activation and relaxation [20].

Combining a game scene through the benefits of color psychology in teaching-learning and Leap Motion input device allows you to interact with the environment. To analyze the functionality, the teaching-learning process of the game is practiced with two groups of students 1 and 2, who have previously completed the theoretical conception stage on basic sign language. Group 1 performs the practice with the game. In contrast, group 2 does not practice the game.

4.1 Evaluation

The evaluation of the application of the game is made considering the groups of students mentioned above, to whom two modes of evaluation are applied. The first is through the i) evaluation module, which weights the results of the experimentation based on the variables: time and correct configuration of the letter and ii) usability test, which establishes through a questionnaire the level of satisfaction of the users when using the game.

A) Evaluation Module

The objective is to correctly perform the configuration of the hand in each letter of the alphabet that is presented in each word, for it the game has several options that facilitate interaction in-game. Once the practice with the game is concluded, the data of the evaluation module are obtained and in Table 3 the register of the values obtained in the students of group 1 of the analyzed variables is observed.

Table 3. Player ́s Score

Player	Time	Words Success	Points
Player 1	1:00	4	80
Player 2	1:00	2	40
Player 3	1:00	3	60
Player 4	1:00	2	40

To establish a comparison between groups, the same parameters are identified in students at the time of performing the basic sign language. Table 4 shows the data provided by the teacher.

Table 4. Session Score

Player	Time	Words Success	Points
Player 1	1:00	1	20
Player 2	1:00	2	40
Player 3	1:00	1	20
Player 4	1:00	1	20

According to the data obtained it is observed that group 1 has better results in the recorded variables, this is due to the practice performed by the interactive game with an immersive interface, so that they become familiar with the basic sign language, facilitating their development at the time of making the settings of the hand in each letter.

B) Usability Test

The application developed has a didactic approach and is based on results that are desired to be obtained in the teaching-learning process, therefore the evaluation of the use of the application involves: to students and teachers, the tasks they are going to carry out, the environment. The SUS summary evaluations method [21] is used using a single number on a Likert-style scale [22]. Table 5 contains the results obtained from the evaluation according to the questions posed to the evaluated ones.

Table 5. Questionnaire Results

Questions	Score	Operation
1. Do I think I would like to use this system frequently?	5	5-1=4
2. Do I find this system unnecessarily complex?	1	5-1=4
3. Do I think the system is easy to use?	5	5-1=4
4. Do I think I would need technical support to make use of the system?	3	5-3=2
5. Do I find the various functions of the system fairly well integrated?	4	4-1=3
6. Is there too much inconsistency in this system?	1	5-1=4
7. Do I think most people would learn to use the system quickly?	4	4-1=3
8. I found the system quite uncomfortable to use?	1	5-1=4
9. Have I found the system too cumbersome to use?	4	4-1=3
10. Would I need to learn a lot of things before I could manage the system?	2	5-2=3
Total		34
SUS Result		85

The total number obtained according to the results processing of the SUS questionnaire indicates that it must be multiplied by a factor of 2.5, giving rise to 80. This result centered on usability indicates that the app offers an acceptable user experience, however, it also indicates the improvements that must be implemented at the user level to achieve a better result usually greater than or equal to 90. In order to validate the improvement of the learning-teaching process, two working groups 1 and 2, who have previously completed the stage of theoretical conception of basic sign language. Group 1 performs the practice with the game. In contrast, group 2 does not play practice. The first group has better results in the registered variables, this is due to the practice of the interactive game with an immersive interface, so that they become familiar with the basic sign language, facilitating their development at the moment of making the configurations of the hand in each letter.

5. CONCLUSION

This article presents the development of a didactic game for the teaching-learning of the basic language of Ecuadorian signs, for the hearing impaired and / or interested in learning the basic sign language of Ecuador. The input device is a Leap Motion, which detects the gestural signals in the Unity3D software. For the processing of the signals, there is a classification system implemented in MatLab for the two types of signal configuration: static and dynamic; correlation is used if the configuration is static (no motion signal) and the DTW algorithm is used for dynamic (motion signal) configurations. Communication between Unity3D and MatLab is done using shared memory. This development core acquires a didactic use with two games, implemented in Unity3D for single player and multiplayer.

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