Digital Assisted Communication

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Keywords: Sign Language, Blind, Deaf, Kinect, Sensor Gloves, Translator.

Abstract: The communication with the deaf community can prove to be very challenging without the use of sign language. There is a considerable difference between sign and written language as they differ in both syntax and semantics. The work described in this paper addresses the development of a bidirectional translator between several sign languages and their respective text, as well as the evaluation methods and results of those tools. A multiplayer game is using the translator is also described on this paper. The translator from sign language to text employs two devices, namely the Microsoft Kinect and 5DT Sensor Gloves in order to gather data about the motion and shape of the hands. This translator is being adapted to allow the communication with the blind as well. The Quantitative Evaluation Framework (QEF) and the ten-fold cross-validation methods were used to evaluate the project and show promising results. Also, the product goes through a validation process by sign language experts and deaf users who provide their feedback answering a questionnaire. The translator exhibits a precision higher than 90% and the projects overall quality rates are close to 90% based on the QEF.

1 INTRODUCTION

Promoting equal opportunities and social inclusion of people with disabilities is one of the main concerns of the modern society and also a key topic in the agenda of the European Higher Education.

The emergence of new technologies combined with the commitment and dedication of many teachers, researchers and the deaf community is allowing the creation of tools to improve the social inclusion and simplify the communication between hearing impaired people and the rest.

Despite all the efforts there are still a lot of improvements to be done for this matter. For example, in the public services, it is not unusual for a deaf citizen to need assistance to communicate with an employee. In such circumstances it can be quite complex to establish communication. Another critical area is education. Deaf children have significant difficulties in reading due to difficulties in understanding the meaning of the vocabulary and the sentences. This fact together with the lack of communication via sign language in schools severely compromises the development of linguistic, emotional and social skills in deaf students.

The VirtualSign project intends to reduce the linguistic barriers between the deaf community and those not suffering from hearing disabilities.

The project aims to improve the accessibility in terms of communication for people with disabilities in speech, hearing and also the blind. ACE also encourages and supports the learning of sign language.

The sign language, like any other living language, is constantly evolving and becoming effectively a contact language with listeners, increasingly being seen as a language of instruction and learning in different areas, a playful language in times of leisure, and professional language in several areas of work (Morgado and Martins, 2009).

2 LINGUISTIC ASPECTS

The sign language involves a set of components that make it a rich and hard to decode communication channel. Although it is not as formal and not as structured as written text it contains a far more complex way of expression. When performing sign language, we must take account of a series of

Escudeiro, P., Escudeiro, N., Norberto, M., Lopes, J. and Soares, F.
Digital Assisted Communication.
DOI: 10.5220/0006377903950402
In *Proceedings of the 13th International Conference on Web Information Systems and Technologies (WEBIST 2017)*, pages 395-402
ISBN: 978-989-758-246-2

parameters that define the manual and non-manual components. The manual component includes:

- Configuration of the hand. In Portuguese sign language there is a total of 57 identified hand configurations.
- Orientation of the palm of the hand. Some pairs of configurations differ only in the palm's orientation.
- Location of articulation (gestural space).
- Movement of the hands.
- The non-manual component comprises:
- Body movement. The body movement is responsible for introducing a temporal context.
- Facial expressions. The facial expressions add a sense of emotion to the speech.

3 RELATED WORK

In the last two decades a significant number of works focusing on the development of techniques to automate the translation of sign languages with greater incidence for the American Sign Language (Morrissey and Way, 2005), and the introduction of serious games in the education of people with speech and/or hearing disabilities (Gameiro et al., 2014) have been published.

Several of the methods proposed to perform representation and recognition of sign language gestures, apply some of the main state-of-the-art techniques, involving segmentation, tracking and feature extraction as well as the use of specific hardware as depth sensors and data gloves.

The collected data is classified by applying a random forests algorithm (Biau, 2012), yielding an average accuracy rate of 49,5%.

Cooper et al. (Cooper et al., 2011) use linguistic concepts in order to identify the constituent features of the gesture, describing the motion, location and shape of the hand. These elements are combined using HMM for gesture recognition. The recognition rates of the gestures are in the order of 71,4%.

The project CopyCat (Brashear et al., 2010) is an interactive adventure and educational game with ASL recognition. Colorful gloves equipped with accelerometers are used in order to simplify the segmentation of the hands and allow the estimation of motion acceleration, direction and the rotation of the hands. The data is classified using HMM, yielding an accuracy of 85%.

ProDeaf is an application that does the translation of Portuguese text or voice to Brazilian sign language (ProDeaf, 2016). This project is very similar to one of the main components used on the VirtualSign game, which is the text to gesture translation. The objective of *ProDeaf* is to make the communication between mute and deaf people easier by making digital content accessible in Brazilian sign language. The translation is done using a 3D avatar that performs the gestures. *ProDeaf* already has over 130 000 users.

Showleap is a recent Spanish Sign language translator (Showleap, 2016), it claims to translate sign language to voice and voice into sign language. So far Showleap uses the Leap motion which is a piece of hardware capable of detecting hands through the use of two monochromatic IR cameras and three infrared LEDs and showleap uses also the Myo armband . This armband is capable of detecting the arm motion, rotation and some hand gestures through electromyographic sensors that detect electrical signals from the muscles of the arm. So far Showleap has no precise results on the translation and the creators claim that the product is 90% done (Showleap, 2015).

Motionsavvy Uni is another sign language translator that makes use of the leapmotion (Motionsavvy, 2016). This translator converts gestures into text and voice and voice into text. Text and voice are not converted into sign language with Uni. The translator has been designed to be built into a tablet. Uni claims to have 2000 signs on launch and allows users to create their own signs.

Two university students at Washington University won the Lemelson-MIT Student Prize by creating a prototype of a glove that can translate sign language into speech or text (University of Washington, 2016). The gloves have sensors in both the hands and the wrist from where the information of the hand movement and rotation is retrieved. There is no clear results yet as the project is a recent prototype.

4 VirtualSign TRANSLATOR

VirtualSign aims to contribute to a greater social inclusion for the deaf through the creation of a bi-direction translator between sign language and text. In addition a serious game was also developed in order to assist in the process of learning sign language.

The project bundles three interlinked modules:

- **Translator of Sign Language to Text:** module responsible for the capture, interpretation and translation of sign language gestures to text. A pair of sensors gloves (5DT Data Gloves) provides input about the configuration of the hands while the Microsoft

Kinect provides information about the orientation and movement of the hands. The Figure 1 shows its interface.

Figure 1: Sign to text translator interface.

- **Translator of Text to Sign Language:** (Figure 2): This module is responsible for the translation of text to sign language. The gestures are performed by an avatar based on a defined set of parameters that are created using the VirtualSign Studio (VSS). The VSS provides an interface to the users to create all the gestures and that information is stored on the VirtualSign server and is reused for the translations.

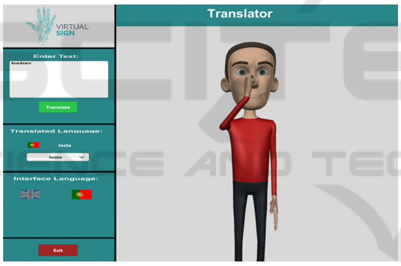

Figure 2: Text to sign translator interface.

- **Serious Game:** Module responsible for the didactic aspects which integrates the two modules above described into a serious game. The system architecture as a whole has two main components. The main component is the game client that includes the game module and the VirtualSign translator. Then there is the Web Server component that hosts all the web services needed for the game. Those web services have access to the server database where the players' information is kept. The game clients communicate with each other using Unity network commands and with the web server through HTTP requests.

5 SIGN LANGUAGE TO TEXT

The translation process between gesture and text is done by combining the data received through the Kinect and the data received from the 5DT gloves.

To simplify, we consider that a word corresponds to a gesture in sign language.

A gesture comprises a sequence of configurations from the dominant hand, each associated with (possibly) a configuration of the support hand, and a motion and orientation of both hands. Each element of the sequence is defined as an atom of the gesture. The beginning of a gesture is marked by the adoption of a configuration by the dominant hand. In the case of a configuration change, two scenarios may arise: the newly identified configuration is an atom of the sequence of the gesture in progress or the acquired atom closes the sequence of the gesture in progress and signals the beginning of a new gesture that will start with the following atom.

5.1 Hand Configuration

When we speak of sign language, we must mention that each Country, sometimes each Region, has its own Sign Language. In Portuguese Sign Language(PSL), there are a total of 57 hand configurations, reduced to 42, since 15 pairs differ only in the orientation, as is the case of the letters M and W.

The configuration assumed by the hand is identified through classification – a machine learning setting by which one (eventually more) category from a set of pre-defined categories is assigned to a given object. A classification model is learned from a set of labelled samples. Then, this model is used to classify in real time new samples as they are acquired.

5.1.1 Hand Configuration Inputs

In order to obtain the necessary information to identify the configuration of each hand, 5DT data gloves (5DT, 2011) are used. Each glove has 14 sensors, placed in specific places of the joints of the hand and it is possible to obtain data at a rate of 100 samples per second.

To increase robustness in reading data and reduce the weight of that noise, a set of sensor data is only maintained (for further classification) if that data is stable for a pre-defined period of time, after having detected a significant change.

5.1.2 Classification

The classification is made from labelled samples, and then the program classifies the new samples in real time. After the sample is obtained the data is passed thought the classification.

To improve the result of this classification process, the 42 hand configurations were divided into different groups. The differential factor between each group was the fingers with greater relevance for this group of configurations.

As seen in Figure 3, in group 3, the configurations similar to the hand-opening gesture were grouped. On the other hand, in Figure 4, we see that in group 2, the configurations related to the thumb raising.

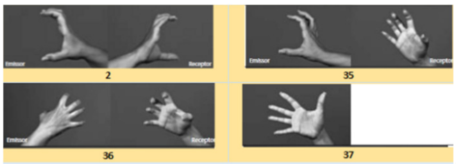

Figure 3: Group 3 - Open hand related configurations.

Figure 4: Group 2 - Thumb raising hand configurations.

Three individuals, named A, B and C performed the tests. Each with a dataset with 10 samples for each existing configuration, with a total of 1260 samples. This samples were then crossed with datasets, using 2 of the individuals as training and the remainder as test, using a k-nearest neighbors (KNN) classifier (Zhang et al., 2006).To reduce the variance of our estimates we have used 10-fold cross validation.

In the following tables we see the results of the tests performed.

Table 1: Correct prediction rate in the group classifier test.

		C
A_B	1	1
	2	0,566
	3	0,542
	4	0,741
	5	0,54
	6	0,8
	7	1
	8	0,71
	9	0,754
	10	0,54
	11	0,73
	12	0,8

		B
A_C	1	0,68
	2	0,57
	3	0,4
	4	0,759
	5	0,833
	6	1
	7	0,7
	8	0,78
	9	0,73
	10	0,56
	11	0,757
	12	0,82

		A
B_C	1	1
	2	0,71
	3	0,525
	4	0,92
	5	0,42
	6	0,723
	7	1
	8	0,6
	9	0,75
	10	0,54
	11	0,73
	12	0,84

A point to take into consideration is the fact that intermediate (fake) configurations that constitute only noise may occur during the transition between two distinct configurations.

As example we can see in Figure 5 the transition from the configuration corresponding to the letter "S" to the configuration corresponding to the letter "B", where we obtain as noise an intermediate configuration associated that matches the hand configuration for number "5" in PSL.

Figure 5: Transition from configuration S to configuration B, through the intermediate configuration (noise) 5.

Intermediate configurations differ from the others by the time component, i.e., intermediate configurations have a shorter steady time, which is a constant feature that may be used to distinguish between a valid configuration and a noisy, intermediate configurations. Thus, we use information about the dwell time of each configuration as an element of discrimination by setting a minimum execution (steady) time below which configurations are considered invalid.

5.2 Hand Motion and Orientation

To obtain information that allows characterizing the movement and orientation of the hands we use the Microsoft Kinect.

The skeleton feature allows tracking up to four people at the same time, with the extraction of characteristics from 20 skeletal points in a human body, at a maximum rate of 30 frames per second.

Of the 20 points available only 6 are used, in particular the points corresponding to the hands, elbows, hip and head.

The information about the motion is only saved when a significant movement happens, i.e. when the difference between the position of the dominant hand (or both hands), and the last stored position is greater than a predefined threshold.

Therefore, when a significant movement is detected we save an 8-dimensional vector corresponding to the normalized coordinates of each hand (x_n, y_n, z_n) and the angle that characterizes its orientation. If the gesture is performed just with the dominant hand, the coordinates and angle of the support hand assume the value zero. The coordinates are normalized by performing a subtraction of the vector that represents the hand position (x_m, y_m, z_m) by the vector that defines the central hip position (x_a, y_a, z_a).

$$(x_n, y_n, z_n) = (x_m, y_m, z_m) - (x_a, y_a, z_a)$$

To be capable of getting the orientation made, the angular coefficient is defined to a straight line of the intersection of the hand and the elbow.

In summary, for each configuration assumed by the dominant hand, a set of vectors characterizing the motion (position and orientation) of the hands are recorded.

5.3 Evaluation

The main focus in performance is in the capacity of the model to predict correctly the words being represented through sign language.

This evaluation counts with 15 words, these 15 words have 2260 samples, but only 750 samples were used to train the SVM (Steinwart and Christmann, 2008). Each one of the 15 words has 50 examples, the same number was used for all of them to ensure a uniform distribution of the classes.

This gestures have been obtained by different users. The recall is a measure to select all the instances of a particular class and the precision is the percentage of correct predictions to a particular class. The classes (words) used are “Olá”(1), “Adeus”(2), “Sorrir”(3), “Segredo”(4), “Floresta”(5), “Sol”(6), “Flor”(7), “Aluno”(8), “Escola”(9), “Casa”(10), “Aulas”(11), “Desenho”(12), “Amigo”(13), “Pais”(14) and “Desporto”(15).

The confusion matrix shown in Table 2 clearly shows the effectiveness of the classifier that achieves an average precision above 99% for this test scenario.

Table 2: Confusion Matrix.

Classes	1	2	5	6	10	7	8	3	4	9	13	14	15	11	12	Class precision
1	**97**	1	0	0	0	0	0	0	0	0	0	0	0	0	0	98,98%
2	3	**99**	0	0	0	0	0	0	0	0	0	0	0	0	0	97,06%
5	0	0	**98**	0	0	0	0	0	0	0	0	0	0	0	0	100,00%
6	0	0	0	**100**	0	0	0	0	0	0	0	0	0	0	0	100,00%
10	0	0	0	0	**98**	0	0	0	0	0	0	0	0	0	0	100,00%
7	0	0	1	0	0	**10**	0	0	0	0	0	0	0	0	0	99,09%
8	0	0	0	0	1	0	**102**	0	0	0	0	0	0	0	0	99,03%
3	0	0	0	0	0	0	0	**101**	0	0	0	0	0	0	0	100,00%
4	0	0	0	0	0	0	0	0	**100**	0	0	0	0	0	0	100,00%
9	0	0	0	0	0	0	0	0	0	**99**	0	0	0	0	0	100,00%
13	0	0	0	0	0	0	0	0	0	0	**100**	0	0	0	0	100,00%
14	0	0	0	0	0	1	0	0	0	0	0	**100**	0	0	0	99,01%
15	0	0	0	0	0	0	0	0	0	0	0	0	**97**	0	0	100,00%
11	0	0	0	0	0	0	0	0	0	0	0	0	0	**104**	0	100,00%
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**100**	100,00%
Class Recall	97 %	99 %	98,99 %	100 %	98,99%	99 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	

6 TEXT TO SIGN LANGUAGE

The translation of any text to sign language is a quite demanding task due to the specific linguistic aspects.

Such as any other language, the sign language has its own grammatical aspects that must be taken into consideration. Those details are taken into consideration in the VSS.

A server based syntax and semantics analyser is being developed to improve the accuracy of the translation. Deaf people usually have a hard time reading and writing their language. The avatar used for the translations was created with Autodesk Maya as well as its hand animations.

The Figure 2 shows the avatar body that has identical properties to a human one in order to get the best accuracy possible performing the gestures.

Other aspects were taken into consideration, such as the background that must create a contrast with the avatar. That contrast is needed so all the gestures and the movements can be easily understood by the deaf.

6.1 Structure

The text to sign language translator module is divided in several parts. In order to improve the distribution and efficiency of all the project components their interconnections were carefully planned.

The connection to the Kinect and data gloves is based on sockets. This protocol was also used for the PowerPoint Add-in, the text from the powerpoint will be sent to the translator, thus the avatar will translate all the text to sign language. The Add-in will send each word on the slide, highlighting it and waiting for the reply in order to continue so that the user knows what is being translated at the time.

The database contains all the parameters and the corresponding text. During the translation process the application will search the database for the word that came as input. When the text is found in the database the parameters containing the data required for the avatar to translate will be sent to the application. If there is no match in the database, the avatar will then translate the word letter by letter.

6.1.1 Architecture

The Figure 6 shows the two main modules, which carry out the steps needed in the translation process: The first module (text recognition) converts the written text into signals, which is represented by an animated character.

The second module translates the gestures of sign language into text. In this process we used two devices: The Kinect for motion recognition and the gloves for the recognition of static hand configurations.

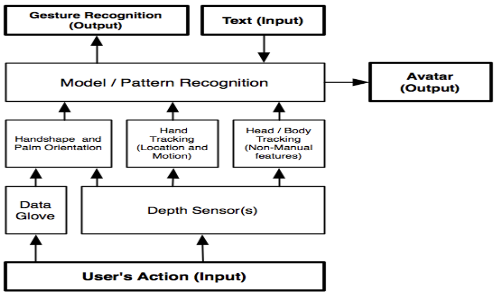

Figure 6: Translator architecture.

6.2 VirtualSign Studio

The VSS is the tool where users can create the gestures for each word. VSS main interface is represented on Figure 7.

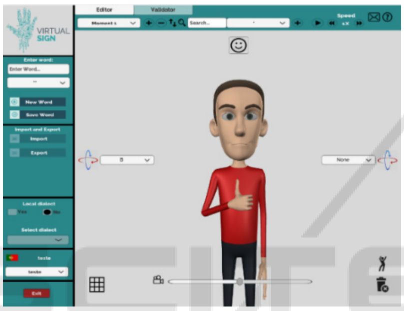

Figure 7: VirtualSign Studio interface.

In order to use this application the user only needs to put the user and the password to login. There are two types of users, editors and validators.

The editor is capable of creating words to be introduced in the data-base. To create the words the editor has access to all the linguistic aspects represented by the avatar. There is also a possibility to import a word already made.

The validator has the possibility of validating words, the validator imports words that need to be validated and can then use the preview system to see if the word is correct, if the word is correct then the validator only needs to click in the validate button and after that moment this word starts to be used to translate the texts.

The validator can also set a word in a review state where the editor can fix it.

6.3 Text to Sign Results

Anonymous questionnaires were made to obtain information about the quality of translation of the translation between gesture to text and text to gesture. The text to gesture already has a large database with arround 600 words.

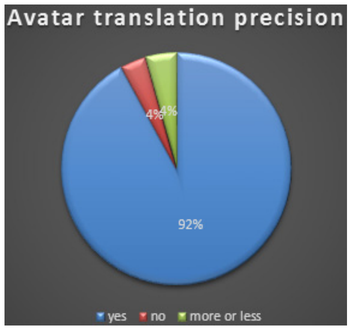

Figure 8: Text to sign results.

The Figure 8 presents the results obtained about the precision of the 600 gestures that have been analyzed by four specialists of PSL. The range of ages of the specialist that have answered these questionnaires went from 39 to 64 years old.

7 SERIOUS GAME

The digital games provide a remarkable opportunity to overcome the lack of educational digital content available for the hearing impaired community. Playing a game as the name suggest has a great leisure aspect that can't be found in conventional educational means. Educational game researcher James Gee (Gee, 2003) shows how good game designers manage to get new players to learn their long, complex, and difficult games.

Two games were created for the project.

A single player game where the player controls a character that interacts with various objects and non-player characters with the aim of collecting several gestures from the Portuguese Sign Language (Escudeiro, 2014).

The first game is played in first person view in which the player controls a character on the map. Each map represents a level and each level has several objects that represent signs scattered through the map for the player to interact with.

The second game created is a multiplayer game. The game consists of a first person puzzle game and requires two players to cooperate in order to get through the game.

7.1 Game Concept

VirtualSign games aim to be an educational and social integration tool to improve the user's sign language skills and allow them to communicate with others using those skills.

The game is a first person puzzle game, where the puzzles are based on simple form objects such as cubes and spheres. The Player will be motivated into solving the puzzles using the surrounding environment. The objects can be moved by the user and there is also intractable objects such as buttons and switches. However, some of those objects are only accessible to one of the players, thus, creating the need to cooperate with each other in order to finish each level.

After the players complete the level, the time they took to complete will be registered on an in game worldwide ranking table with others players times to incite competition. There is also a personal score that each player achieves so there is competition between the two players as well.

The communication between the players is shown as gestures in real time but there will be also a text chat where the previous messages can be accessed.

The Figure 9 shows the input application and the avatar translating after receiving a message.

Figure 9: VirtualSign Cooperation game interface during gameplay.

7.2 Game Results

Ten testers (8 male and 2 female) aged between 23 and 65 tested the game and answered surveys. However, due to the need of using the VS translator only 5 of those testers were able to try that feature and answer one of the questions. The link with the form and instructions was given to the testers. The forms were answered anonymously. The survey of the beta test phase had 20 questions of which the last one was an optional written answer about possible improvements to the game.

The questions graded the game between 1 and 5 with 1 being the worst and 5 being the best. The final average was 4.5 out of 5 at the end of the testing phase.

8 VISUAL IMPAIRED INCLUSION

Besides the social inclusion of the deaf with the VirtualSign translator, the ACE project also aims to reach visually impaired people. With the use of voice as input and output for the translator ACE aims to provide the means for a deaf person to talk with a blind one and vice-versa.

So far there is a game under development ACE for the blind, which gives the player feedback trough sound. The voice features are also being integrated in VirtualSign in order to achieve ACE final goal.

9 CONCLUSIONS

The VirtualSign system is prepared to work with several distinct sign languages making it possible to have deaf people from different countries understanding each other.

The machine learning techniques used to process the inputs from Kinect and the 5dt Gloves are able to identify the signs being represented with high accuracy.

VirtualSign can be applied in places with public attendance to facilitate the communication among deaf and non-deaf people. It is naturally accepted that having assistance to understand sign language in places like fire departments, police stations, restaurants, museums and airports, among many others, will be of clear added value in the promotion of equal opportunities and social inclusion of the deaf and hearing impaired.

The VirtualSign translator was tested by several users. The estimated accuracy of the conversion from gestures to text reaches values of 97%.

For future work on the translator gesture to text a system with the same precision and accuracy without using gloves is being planned.

Also an intermediate system of semantics between sign language and the written text is being created. The semantic and syntax are very important because the translation between the languages is not direct.

There is also the blind voice recognition and synthetization that is being developed as mentioned before and there is a game for the blind under development. We also aim to create a way for both deaf and blind to create digital arts through an application using all the progress made so far.

ACKNOWLEDGEMENTS

This work was supported by FCT - ACE - Assisted Communication for Education (ref: PTDC/IVC-COM/5869/2014) and European Union- Erasmus + I-ACE International Assisted Communication for Education 2016-1-PT01-KA201-022812.

REFERENCES

Morgado, M., Martins, M., 2009. Língua Gestual Portuguesa. *Comunicar através de gestos que falam é o nosso desafio, neste 25. º número da Diversidades, rumo à descoberta de circuns-tâncias propiciadoras nas quais todos se tornem protagonistas e interlocutores de um diálogo universal.*, 7.

Morrissey, S., Way, A., 2005. An example-based approach to translating sign language.

Gameiro, J., Cardoso, T., Rybarczyk, Y., 2014. Kinect-Sign, Teaching sign language to "listeners" through a game. *Procedia Technology*, *17*, 384-391.

Biau, G., 2012. Analysis of a random forests model. *Journal of Machine Learning Research*, *13*(Apr), 1063-1095.

Cooper, H., Pugeault, N., & Bowden, R., 2011. Reading the signs: A video based sign dictionary. In *Computer Vision Workshops (ICCV Workshops), 2011 IEEE International Conference on* (pp. 914-919). IEEE.

Steinwart, I., & Christmann, A., 2008. *Support vector machines*. Springer Science & Business Media.

Brashear, H., Zafrulla, Z., Starner, T., Hamilton, H., Presti, P., & Lee, S., 2010. CopyCat: A Corpus for Verifying American Sign Language During Game Play by Deaf Children. In *4th Workshop on the Representation and Processing of Sign Languages: Corpora and Sign Language Technologies*.

ProDeaf, 2016. *Solutions.* [Online] Available at: http://www.prodeaf.net/en-us/Solucoes [Accessed December 2016].

Showleap, 2015. *Showleap blog.* [Online] Available at: http://blog.showleap.com/2015/12/2016-nuestro-ano/ [Accessed December 2016]. 79.

Showleap, 2016. *Showleap.* [Online] Available at: http://www.showleap.com/ [December July 2016].

Motionsavvy, 2016. *Motionsavvy Uni.* [Online] Available at: http://www.motionsavvy.com/ [Accessed December 2016].

University of Washington, 2016. *UW undergraduate team wins $10,000 Lemelson-MIT Student Prize for gloves that translate sign language.* [Online] Available at: http://www.washington.edu/news/2016/04/12/uw-undergraduate-team-wins-10000-lemelson-mit-student-prize-for-gloves-that-translate-sign-language/ [Accessed December 2016].

Gloves, 5DT., 2011. *Fifth dimension technologies.* [Online] Available at: http://www.5dt.com/?page_id=34.

Zhang, H., Berg, A. C., Maire, M., & Malik, J., 2006. SVM-KNN: Discriminative nearest neighbor classification for visual category recognition. In *Computer Vision and Pattern Recognition, 2006 IEEE Computer Society Conference on* (Vol. 2, pp. 2126-2136).
IEEE.

Gee, J. P., 2003. What video games have to teach us about learning and literacy. *Computers in Entertainment (CIE)*, *1*(1), 20-20.

Escudeiro, P., Escudeiro, N., Reis, R., Barbosa, M., Bidarra, J., Baltasar, A. B., ... & Norberto, M. (2014). Virtual sign game learning sign language. In A. Zaharim, & K. Sopian (Eds.), *Computers and Technology in Modern Education, ser. Proceedings of the 5th International Conference on Education and Educational technologies, Malaysia*.