Morse code-based communication system focused on amyotrophic lateral sclerosis patients

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Abstract

This application is based on face recognition and facial features techniques to extract Regions Of Interest (ROI) by applying Haar filters and cascade classifier with OpenCV implemented in Visual Studio C#. Likewise, a software program was developed to transform blinkings into words, along with a graphical user interface, in which the spanish language alphabet letters and predifined phrases are displayed., as a consequence, the ALS patient has the possibility to structure sentences, thus, facilitating his/her communication process with relatives and medical staff.

Several tests were applied to five ALS patients (50 years, on average) with an advanced stage of the disease, that's to say, they have lost their speech ability and movement in both upper and lower extremities. They were trained in how to use the application software by means of simple tasks such as reading the spanish alphabet. A first group was formed to help them out with the Morse code, what made them easier to understand the spanish alphabet and its assignment to each blinking. This test was done by using two different environments, namely, one environment with low light intensity and the other one with normal light intensity. A second group was formed with patients without any previous knowledge.

1. Introduction

Humans are by nature social beings, and that capability has been developed thanks to the verbal and non-verbal communications, through which feelings, thoughts and needs are expressed, as well as, problems are solved. For humans, therefore, expressing their preferences, opinions and feelings is part of their daily life and makes them easier to satisfy their basic needs.

Speech is an activity that demands a combined action of motor processes, such as respiration, phonation, articulation and resonance. In turn, those processes need an optimal operation of systems and organs involved in: generating an air column that causes the vocal cords to vibrate, making strong, precise and coordinated movements to articulate correctly and to emit intelligible sounds; directing the air column onto the resonant chambers (mouth and nose). Our quality of life and the way as we communicate to each other will be impacted and altered respectively, when any of the systems involved in phonation is malfunctioning.

Diseases such as amyotrophic lateral sclerosis (ALS) in humans produce a progressive loss of voluntary movement, consequently resulting in immobility of the patient, affecting, among others, those processes related to speech. The lack of communication between the patient and his/her environment, affect his/her quality of life, making him/her feel isolated and depressed. The use of new technologies contributes to improve the quality of life of the patients with severe speech impediments caused by diverse diseases [1]. A clear example of this contribution is the fact that the scientist Stephen Hawking (ALS patient) thanks to a personal computer has written more than 10 books with a finger [2]. Like him, other patients use alternative communication systems such as OnScreenKeys, Iriscom, and Tobii C12 whose high cost prevents its widespread use [3]. This article describes the development of a communication System focused on ALS patients under Morse code, called CodeBlink This application is a response to address the communication needs of low-income patients with this disease that affects motor neurons and communication, between the patient and his environment, between them and their relatives, doctors, nurses, etc.

CodeBlink, was developed in Visual Studio C # .net and uses modern technologies such as intelligent agents that facilitate the interpretation and communication of these patients, because it incorporates default images and words which can be identified and selected quickly. The algorithm captures patient's face, eyes and blinking to achieve communication through the system by using Morse code, considering that the cells of the eye are the last to deteriorate in the advanced stages of amyotrophic lateral sclerosis (ALS).

Since Morse code is used, the algorithm discriminates, the type of blinking from time duration, coding a short blinking with a dot and a long blinking with a dash, which

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are the symbols used to represent the spanish alphabet letters in this code, that is a system that represents letters and numbers by means of signals sent intermittently. The graphical user interface facilitates the communication process because it has a predictive keyboard and default words that use the voluntary ocular position as an alternative communication media

1.1. Amyotrophic Lateral Sclerosis - ALS

Amyotrophic Lateral Sclerosis (ALS) is a disease that occurs in the nervous system that attacks the nerve cells found in the brain and spinal cord. These cells are responsible for transmitting messages from the brain and spinal cord to the voluntary muscles, such as those found in arms and legs. This chronic and degenerative nervous system disease is characterized by the progressive death of motor neurons (neurons involved in voluntary movement), central and peripheral, causing muscle weakness and atrophy leading to paralysis. Hence, ALS produces dependence, isolation, fear and depression [4].

In the initial phase, the patient may have mild muscle problems that can manifest when walking, writing and reading, because the muscles responsible for speech, swallowing and respiration are the first affected by the disease. In the final stage, the patient loses force which prevents him from moving, relying only on his eyes to communicate. According to the Colombian Association of Amyotrophic Lateral Sclerosis (ACELA), ALS affects adults, that's to say, people over 18 years. The risk increases as you get older and men are at greater risk of contracting the disease than women. From 25 to 30 people in a million develop this disease.

Due to it is a degenerative disease, there is a progressive worsening of symptoms, which vary from one person to another depending on the brain area affected. ALS affects, initially, the voluntary movement of the upper and lower extremities. Later, feeding and speaking difficulties appear.

Affected people end up with disabilities that make them highly dependent about everyday activities, deteriorating their quality of life, demanding external help, even to breathe [4].

According to ACELA, patients also have difficulty in language because speech therapies are not enough and an advanced communication system is required for them. However, those systems are not available to the institutions because of their high cost.

For these reasons, a need arises to develop a low-cost application that facilitates communication between the patient and medical staff or family members. In this paper, a low-cost technological alternative is presented, which is easily adaptable to patients in the early stages of the disease, who, when being trained in Morse code, are able to make use of the system.

1.2. Augmentative and alternative communication aids for patients with ALS

Communication is essential for humans to maintain relationships with family and environment; certainly, the loss of speech is a serious limitation that profoundly affects anyone. It is therefore crucial that the patient faces this disease quietly and be motivated to continue to live.
So, there are a variety of research works related to communication alternatives in patients with Amyotrophic Lateral Sclerosis.

Firstly, there may be mentioned the development of a prototype software to support communication for ALS patients, created by Dr. Miguel A. Sanz Bobi and engineer Maria Luisa Tavera Otero in 2002, is a game mode software oriented to ALS patients, who do not have computer skills that enable them to create a digital photo album; the prototype was designed to be used by people with different types of disabilities. By using a computer, patients are able to interact with devices as the joystick movement, by pressing keys or by a simple flicker, they could carry out tasks of communication with others. The application was developed using programming languages like C ++ and Borland C ++ compiler [5].

The Basque company Iriscom Systems, S.L., designed a system from infrared lights connected to a computer, which are the basis for the use of the software. The application incorporates a camera with an infrared light emitter that produces a focused reflection toward the user's eyes. This beam of light guides the computer to interpret the exact place the patient is looking at, in order to move the mouse pointer to where you want to direct it. Only by moving your eyes, you can gain access to all computer operations, including the ability to browse the web, use email or interact in social networks.

Thanks to those functionalities, this Iriscom's communication system received the Prince of Viana de Dependencia Prize in 2011 as entrepreneurship initiative for having developed this alternative communication system for people with greater disabilities [6].

Commercially, Tom Weber Software Company developed a communication system called OnScreenKeys in 2001, to help ALS patients. This application allows them to write and speak by using a computer and its mouse, touch screen and an eye-tracking device. This system has a virtual keyboard to type the words, which, when moving the cursor over each letter will write it automatically after a few seconds. Additionally, it has a virtual voice which is used to play the text written by the patient [7].

It may also be mentioned that Tobii Technology Company, in 2008, created Tobii C12 Communicator, an eye-controlled communication system which facilitates ALS patient's communication via text or symbols, which are played through a synthesized or digitized voice. You can also write and edit text, browse the web, listen to music and access games, control your environment and manage some tasks of daily life [8]. In this sense, communication systems are part of the contributions of biomedicine to ALS patients, by offering a simple form of communication to those who have lost this ability.

1.3. Morse code

This is a code or communication system, based on the transmission and reception of messages using an alphabet consisting of dots, dashes and spaces that, when combined with each other, can form words, Figure 1 [9].

A	·–	N	–·	1	·––––
B	–···	O	–––	2	··–––
C	–·–·	P	·––·	3	···––
D	–··	Q	––·–	4	····–
E	·	R	·–·	5	·····
F	··–·	S	···	6	–····
G	––	T	–	7	––···
H	····	U	··–	8	–––··
I	··	V	···–	9	––––·
J	·–––	W	·––	0	–––––
K	–·–	X	–··–		
L	·–··	Y	–·		
M	––	Z	––··		

Figure 1. Morse code

2. Computational interpretation

The algorithm consists of five parts: acquisition, processing, coding, interpretation and visualization. During the acquisition process, the user (doctor or relative) identifies and chooses one camera from those ones connected to the computer. After choosing the camera, the system starts capturing images to then proceed with processing phase, where filters are applied to those images in order to obtain gray-scale images, whose contrast is maximized by applying Histogram equalization technique, without information loss, to avoid failures due to light conditions. In addition to this, eyes and face detection are carried out in this stage, selecting regions of interest to be taken into account in the next phase. In the coding phase, each blink is captured by considering its duration, to decide if it is long or short. Finally, the coded word is built, which will have to be interpreted by using Morse code. In this project, a long blink is coded as a dash (600 to 1200 milliseconds) and a short blink is coded as a dot (less than 600 milliseconds). When coding each patient's blink into Morse code, each word or alphabet letter is shown to the doctor or relative as a patient's message in his/her native language -spanish language- in the visualization stage. The application software was developed using C#.NET programming language along with Visual Studio IDE from Microsoft. Figure 2 depicts three out of five stages. Image processing was done by using EmguCV libraries.

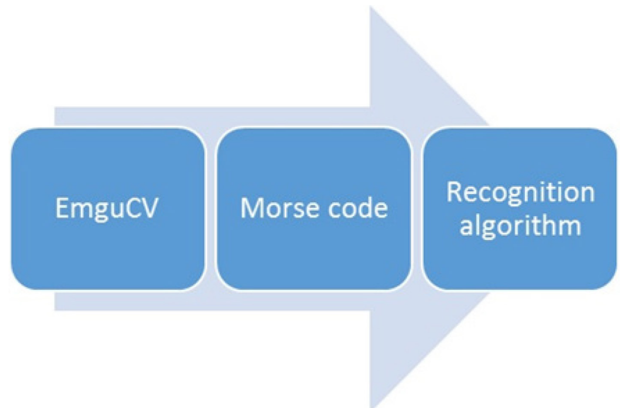


Figure 2. System components.

Due to this system is designed for end-users, it is not required to illustrate step by step the image conversion process. Figure 3 shows gray-scale conversion process and image internal normalization and, as a reference, only appears the final result when a user (doctor or relative) is setting up the application.

Figure 3. Internal conversion process image

The algorithm design is expressed through use case diagrams shown in Figures 4 and 5, where you can identify the interaction between user and system, in this case, patient and assistant. Patients interact with the system when writing text by means of blinkings. In the system, they have two default options. Firstly, they can write words by using Morse code; secondly, they are able to choose default words through a writing prediction technique based on letter combinations to ease phrases construction. The assistant person interacts with the system via a configuration window to select the camera type, to set default values so that the system can identify face and eyes, activate blinkings and, finally, to assess that the system was correctly configured.

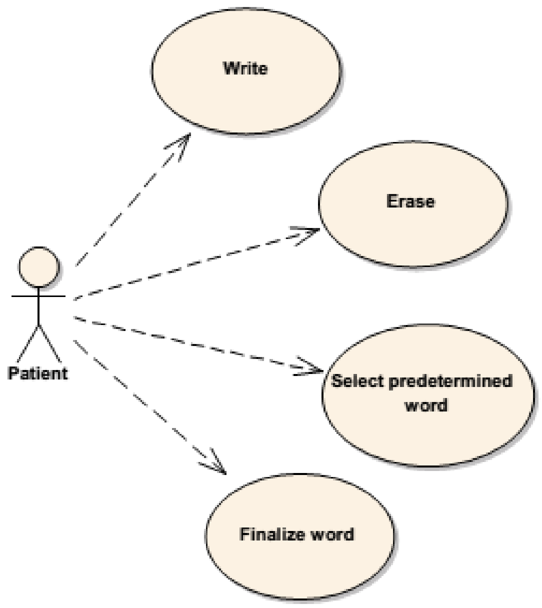


Figure 4. Patient use cases.

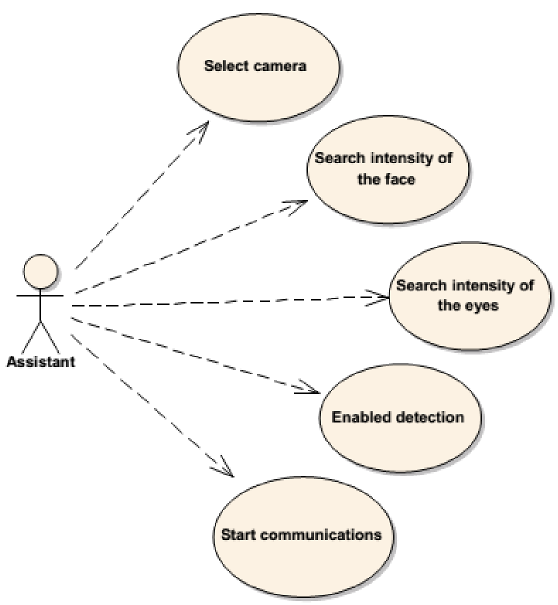


Figure 5. Assistant use cases

In figure 6 you can see the flow diagram developed for the patient's image processing until the final result, consisting of the coding of a patient's blink into a message over the user interface.

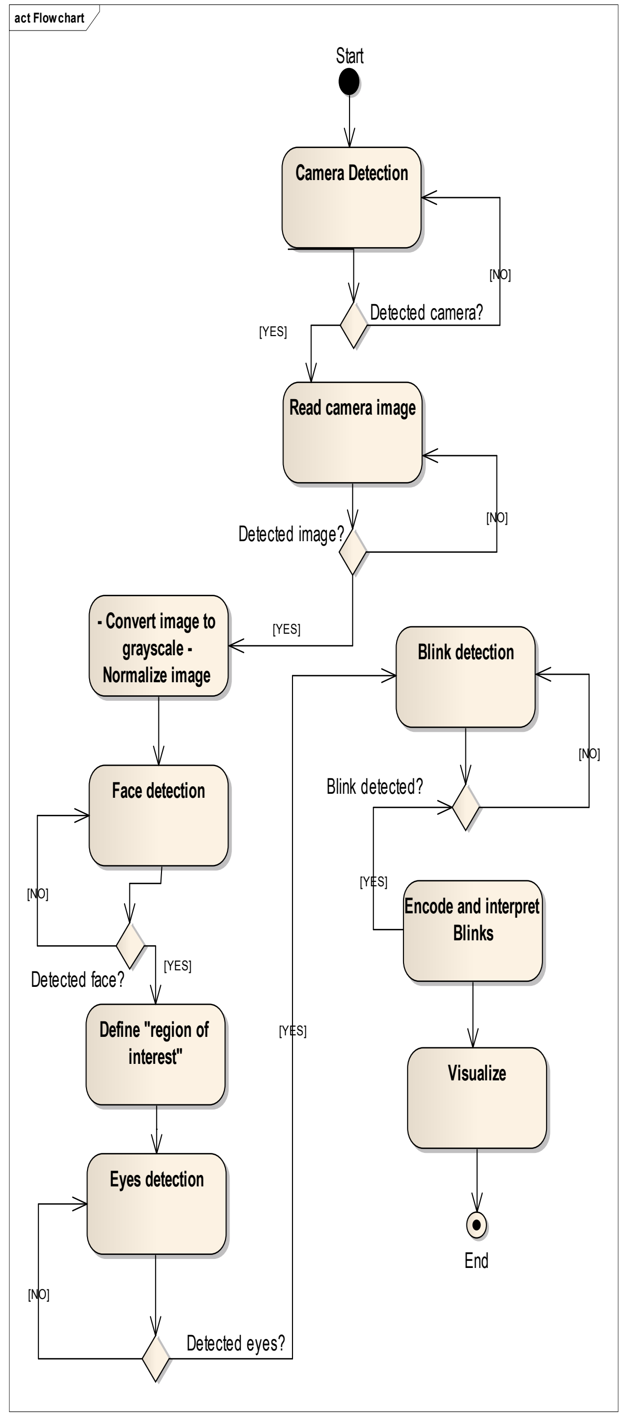
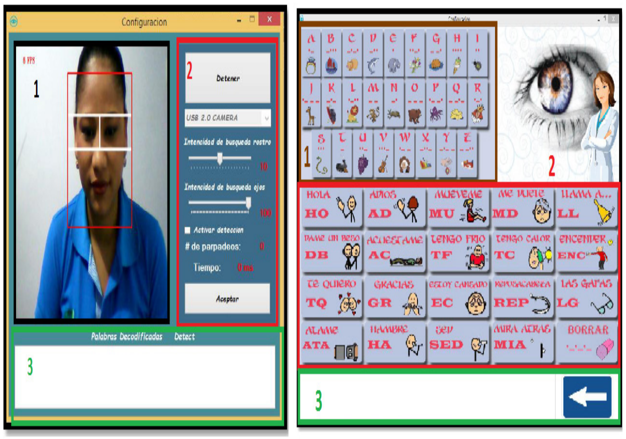


Figure 6. Flow diagram

3. Evaluations and results

This research resulted in a computational tool capable of performing the tasks necessary for blinking interpretation, starting with images capture from a webcam in real time, to display the words or letters interpreted, in Spanish language.

This tool has two interfaces: one interface for system setting, for an assistant person, and the other for the interaction with the patient. The configuration interface is divided into three regions: 1. detected picture 2. System setting, 3. Text display (see Figure 7 a). The display interface is also divided into three regions: 1. alphabet, 2. default words, 3. text display (see Figure 7 b).



(a) (b)

Figure 7. System interface. (a) Setting window. (b) Display window.

The system operation starts with an image capture. Afterwards, it checks whether a face has been recognized in that captured image; if so, it selects a box face and delimits the eye area, then the system checks that within this image area there is an open eye and thus detect when he/she performs a blink.

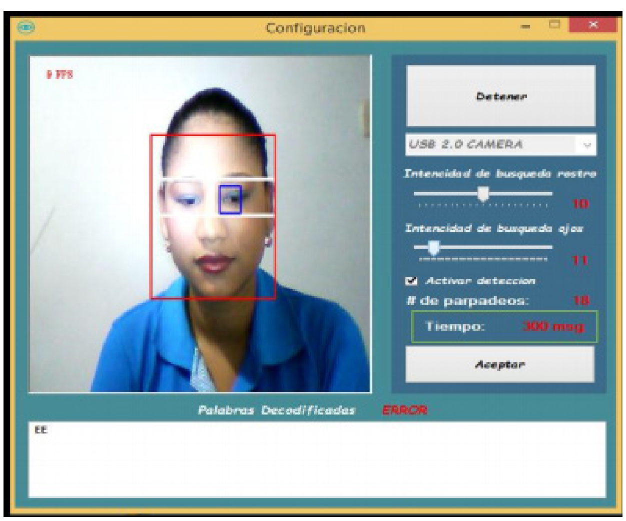


Figure 8. Face recognition. Capture and processing.

In face detection stage, you must first add an image on which the detection is done. In this case, a continuous stream of images coming from the camera is loaded into the system. After loading the images, next steps apply:

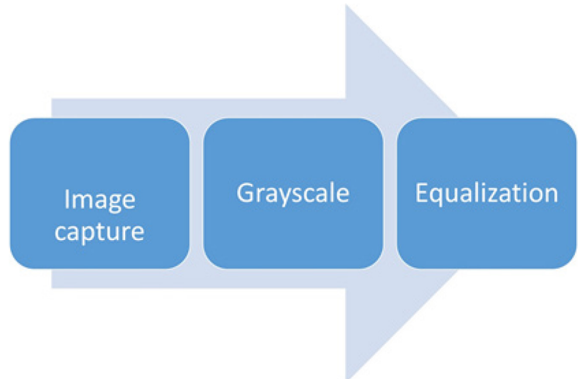


Figure 9. Capture and processing of detected face

As seen in Figure 9, it is necessary to convert the image to grayscale is necessary for the proper functioning of the face detection algorithms used by openCV; histogram equalization is applied to the greyscale image to standardize the image's contrast and brightness. This is done so that different lighting conditions do not face detection in the image.

Once the face has been detected, the region of interest is obtained with OpenCV for eye capture, which are located on the face detected. Such detection is performed using cascade classifiers previously trained, which detect open or closed eyes, or only open eyes. In this case, it is necessary to detect if the eyes are open, because when the detection is negative, it means that the patient has blinked.

In order for the eye detection process to properly work, the search is defined within the region of interest, i.e. the face, from which the values are taken to determine the corresponding region for each eye.

To perform the test, the letter A is selected, which in Morse code is represented by a point and a dash, an within the system is represented by a short blinking followed by a long blinking

Patient	Brightness (100%)	Brightness (50%)
1	27 de 27	5 de 27
2	19 de 27	3 de 27
3	22 de 27	3 de 27
4	9 de 27	1 de 27
5	6 de 27	0 de 27

Table 1. Brightness condition per patient

The first test was done with enough light for both groups, it was found that those patients with knowledge in Morse code, could recognize 22 of the 27 letters of the alphabet, i.e., a recognition of about 80% of the characters compared to a 30 % obtained with patients who had no previous knowledge on Morse code. See Table 1.

Moreover, in poor lighting conditions, patients in the first group reduced their percentage of correct answers to

15% against 3% of the second group. The final test demanded that one of the patients could write a complete sentence, however, at the end of it, the patient experienced physical fatigue after 2 hours, including the time involved in tool training.

4. Conclusions

Amyotrophic Lateral Sclerosis is a degenerative disease of the nervous system characterized by progressive death of motor neurons, which are responsible for voluntary movement, causing muscle weakness and atrophy leading to paralysis. In addition, it also affects phonation, preventing the patient from communicating through speech. This situation affects the patient due to it makes him/her feel lonely and isolated, which in turn, impacts him/her because it is more difficult to cope with the disease.

In order to improve the quality of life of patients with ALS, In order to improve the quality of life of patients with ALS, the design of a low-cost communication system using Morse code -to transform blinkings into a mean of communication between the patient and its environment- is addressed.

By implementing an algorithm to capture face, eye detection and eye blinking, it was possible to encode the alphabet using Morse code, using the blinking time. This algorithm was developed in C # .NET, a programming language used in Microsoft Visual Studio IDE, with which the patient with sufficient training can build words and phrases to communicate. Additionally, the system has a writing prediction strategy, which starting from the first identified letters forms complete words, simplifying sentence construction.

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