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DE MONTERREY®

INSTITUTO TECNOLÓGICO Y DE ESTUDIOS SUPERIORES DE MONTERREY

CAMPUS CIUDAD DE MÉXICO

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1. Introduction

Every day, technology grows faster in order to make people's life easier and becomes a factor that is a support for people who are affected by this situation giving them a beneficial change in the social, economic and cultural fields.

People who have disabilities have found in technology a major step towards a more self-sufficient life. The use of computer controlled devices allows these people to handle several activities at home. This allows people to extend their capabilities by giving them several additional utilities that extend the level of support to patients than in earlier times.

A specific kind of patients with special needs that requires full-third person aid for any activity are the quadriplegic patients. The complete loss of the four extremities compels them to remain at rest all the time. The creation of dependence for any activity in quadriplegic patients, has originated the manufacturing of many devices that can solve this problem. In 1976 a wheelchair that could help this kind of patients was created and was described on its article "*Design and evaluation of head unit for wheelchair control by quadriplegic patients*". In it, they explained how a control unit works for people who have lost hand and arm functions and help them manipulate the speed, steering reversal and on-off switching of a electric wheelchair by means of backward movement and rotation of the head. When possible (depending on the patient's capabilities), the wheelchair can be manipulated using shoulder movements. In more recent advances there has been the development of a technology that enables individuals to drive a powered wheelchair or control a mouse cursor using simple tongue movements can be operated by persons with high-level spinal cord injuries.

On the other hand, the use of artificial neural networks to differentiate signals generated by the human being is the main innovation that we are offering to quadriplegic patients. Although indications for patients are to get a chair that promotes moving the unaffected muscles and not buying a wheelchair that is completely autonomous, our chair integrates features that can include patients with less sever impediments, which makes it perfect for any kind of patients.

In order to offer more efficient options for quadriplegic patients, the following investigation is based on an eye-controlled wheelchair. The system is based on previous work developed by Dr. Pedro Ponce Cruz on a commercial Quickie wheelchair. The implementation of the system includes the manipulation of two motors, the detection and differentiation of the signals generated by ocular movements and the computing of distances detected by three ultrasonic sensors.

The project proposed is creating a wheelchair that includes four major features. The first is being able to control the chair by moving the eyes, the second is having the possibility of reproducing prerecorded voice messages, the third is being able to control the chair with voice commands and the last feature is an avoidance system based on the data collected with the ultrasonic sensors.

1.1 Global view for motor disabilities patients

Around the world, a lot of countries are worried about defining the meaning of a "person with a disability" on a way to create a law that could help them on their social and employment lives. On the United Nations website, exist a paper that shows the actions taken by some countries, starts in 1981 with Argentina and ends with Germany on 2001, and each one decide that a person with a disability is a person who has a physical, emotional or mental disability as a result of which, that person's functioning is substantially limited in one or more of their activities.

In 2001, the European Union had a 14.5% of people who had a disability only on the first fifteen members (except Sweden). The age of these people varies between 16 to 64 years old. This number increased to 25% with addition of the ten next members. An important issue refers to the percentage of this people who has a work is only the 42%, (in comparison to a 65% of people employed who do not have any disability).[1]

On a study made in the USA the statistics about the motor disability show that:

- The average age of injury is 31.7 years.
- Males account for about 75% of those with spinal cord injuries.
- The leading causes of spinal cord injury are as follows:
    - Motor vehicle accidents: 44%
    - Acts of violence: 24%

[1] Anonymous, *"Igualdad de oportunidades para las personas con discapacidad: un plan de acción europeo (2004-2010)"*, http://europa.eu/legislation_summaries/employment_and_social_policy/disability_and_old_age/c11414_es.htm , (accesed October 28, 2009)

- Falls: 22%
- Sports: 8%
- Other: 2%[2].

The people want to know about issues that any person with a disability could have, so the first real action to do that was that the year of 2003 year was called the "European Year for the people with disability". Over that year, the people could hear their problems and their necessities on a way to take actions on their benefits. Actions like creating symposiums, conferences and debates that results on promoting their rights and also, promoting their participation on the social, political and economic ambits. These results were made by the Ministers of Social Affairs and Employment on July. In the cases like Denmark, they take actions immediately on give enough budget to create on the next two years, 1200 homes specialized to support persons with a disability.

Another real action in favor of this cause was the International Convention about the Rights of the Person with a Disability on the United Nations on December 13, 2006 where the countries started to establish legally and politically actions to help this persons. Also, the European Union uses these talks as a base to create their own treats to prohibit and punish the discrimination with laws like 2000/78/CE that refers to the equal treats on employment and occupations. On this issue, if a person with a disability is affected by any kind of discrimination, the person could take actions on a judicial organ or another type of

2 WebAIM, *"WebAIM: Motor Disabilities – Types of Motor Disabilities"* , http://www.webaim.org/articles/motor/motordisabilities.php , (accesed October 23, 2009)

legal action in a way to protect their rights to work in the case that the individual was capable to do the work[3].

Particularly, Spain created the "Estrategia global para el empleo de las personas con discapacidad"[4] that is a paper that covers ideas and actions to take with this situation. The Spanish people discussed and used part of the next principles to create a more useful strategy:

- Improve the labor activity of the people who has a disability.
- Promote these actions on a global view.
- Equal opportunities to a man and a woman with a disability.
- Improve the work of a person with a disability.
- Create a better environment between patients who have a disability and the persons who have not, including their families.

All of these points were the basis of the two main objectives that the government would review:

- Increase the activities, occupations and the labor inclusion of persons who have a disability.
- Improve the occupations quality and dignify the workstations of a person with a disability on a way to fight the discrimination of this people.

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3 Anonymous, *"Directiva 2000/78/CE"*, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:303:0016:0022:ES:PDF, (accesed October 28, 2009)

4 M. A. Cabra, *"Empleo y Discapacidad"*, http://www.juntadeandalucia.es/empleo/revistaempleo/revista/RevistaEmpleo/Galerias/Descargas/PDF_Secciones_Revistas/Revista_18/adebate_18_00.pdf, (accesed October 27, 2009)

On different scale, all the countries around the world take different kind of actions like the implementation of special parking slots for these people, also the creation of a law to define this type of persons and create norms referring to the right of accessibility to workstations. This makes sure that an individual with a disability could go to every place on a building like a school, hospital, hotel etc. because it should have elevators, ramps or another type of equipment for this cause. In countries like USA, there are special inspection reviews on the different buildings to make sure that a person with a disability could work efficiently.

1.2 Statistics of disabilities in Mexico

In Mexico, the number of people with a disability (data taken from the National Institute of Statistics, Geography and Informatics, also known as INEGI) show that 1 795 300 peoples have a disability which represents 1.84% of the population of the country in 2000. Within the count of disabled persons, INEGI classifies the different disabilities on motor, visual, mental, primarily auditory and language. The next graph illustrates data from INEGI, which estimates rates of several disabilities of Mexican population[5] .

5 Anonymous, *"Consulta Dinámica de Cuadros Estadísticos"* , http://www.inegi.org.mx/est/librerias/tabulados.asp?tabulado=tab_di01b&s=est&c=11516 , (accesed April 6, 2009)

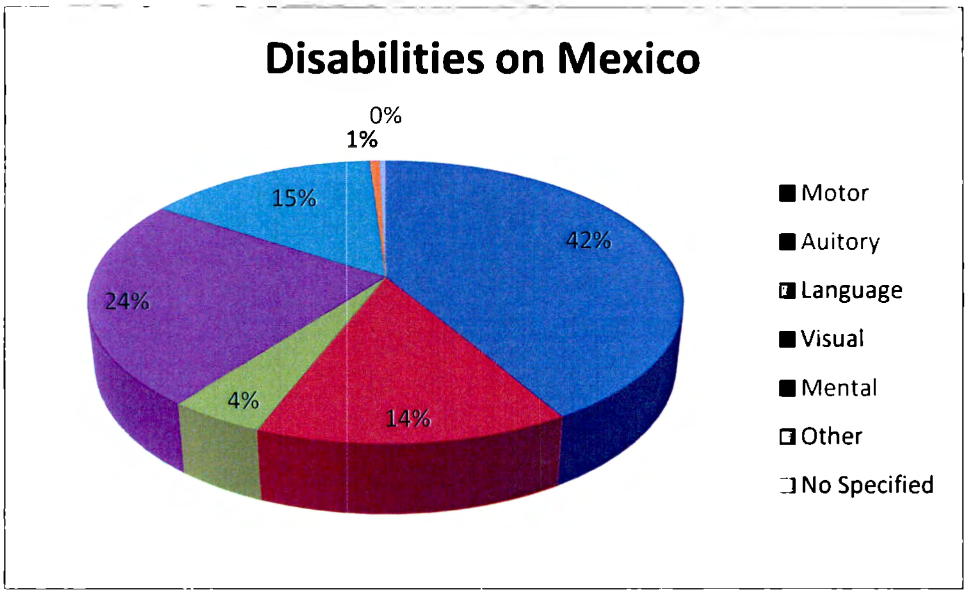

Fig 1.2.1 Percentages of people with a disability in Mexico

With these values obtained by INEGI, you can see that for every thousand individuals that live in Mexico, eight have a motor disability. This numbers can help to understand that 813 867 persons have a disability across the country, from which an estimated 76.2% of these people live in urban areas and the remaining 23.8% in rural areas. Another important factor in these values, is the age of people that are most affected by this incident, which are those between 65 and 69 years with an estimated 288 869 people with motor disabilities. This represents about 35.5% of people with motor disability.

You should consider the fact that people who have a low level disability, have enough mobility to be able to move with a common wheelchair, but people who have a major disability require a power wheelchair to move. Throughout this project, we will investigate and work to the extent of supporting the improvement of instruments used by people who have a disability, making a considerable driving electric wheelchair that has intelligent control. This is done with the purpose of giving a sense of freedom of action significantly improving the quality of life of the patient.

Among the external factors that affect the development of the project, there is the fact that Mexico is considered a third world country; this issue affects the estimated income of a person compared with developed countries. Therefore, it is very difficult obtain an electric wheelchair because it has a high price for most of the Mexican population. Additionally, Mexico still does not have a concrete structure that concerns to the necessities and proper type of considerations toward people who have a disability, such as ramps and transit zone.

On the other side, this workgroup wants to complete the project and show that Mexico is not behind on technological innovations. We would also like to present a truly beneficial project that could achieve real results and would cause the cost of some instruments to be lowered.

1.3 Types of disabilities

On this days, the issues referring about people who got a disability have taken more importance thank to the human conciseness and the technology improvements made it on the past decades.

On this project, you need to know on particular about motor disability. A motor disability is impairment on the movement of some part or parts of the body. A person with this problem needs more concentration and more control on the movements of his or her body than a normal person. There are two main kinds of motor disabilities, Diseases or Congenital Conditions and Traumatic Injuries.

Diseases or Congenital Conditions have eight sub kinds of disabilities. One of them is Cerebral palsy, this occurs on the fetal development most of the cases and the results are a decreased muscle control and a person could see it when a patient does involuntary movements or impaired speech for example. Severe cases could degenerate their disability on paralysis. This type of patient can do activities with special and normal items like a computer keyboard but with the difference that they need to put their hand first on the area around the key and with a calm move type with the finger.

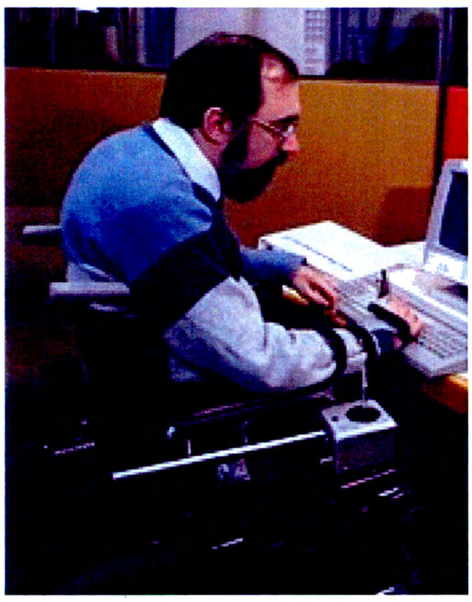

Fig. 1.3.1 Cerebral palsy

Another one is the Spine bifida, this is a case when the spine fails on close properly. This caused the membrane around the spine to protrude through the back creating a visible bulge. The result of this case is motor difficulties, learning and languages difficulties and in some cases paralysis. On the worst cases, the fluid could accumulate causing damages to the brain.

On the Traumatic Injuries, it has two sub types of disabilities, one of them refers to the lost or damage of a limb. On this case, a patient has the option of using the Biotechnology to use a mechanic limb to substitute the lost one or create objects on a way to compensate the lack of the limb, like a special one-hand keyboard as shown on Fig. 1.3.2 to work with a computer.

Fig. 1.3.2 One-hand keyboard

The other one is a Spinal cord injury that causes a trauma showing paralysis of the limbs. If a patient has paralysis on the legs, is called paraplegia, if the patient also has paralysis on the arms it is called quadriplegia. The quadriplegia, also called Tetraplegia, occurs when a person has a spinal cord injury above the first thoracic vertebra. The paraplegia occurs when the level of the injury happens below the first thoracic vertebra[6].

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[6] Apparelyzed.com, *"Quadriplegia Paraplegia Tetraplegia and Types of paralysis"* , http://www.apparelyzed.com/paralysis.html , (accesed October 28, 2009)

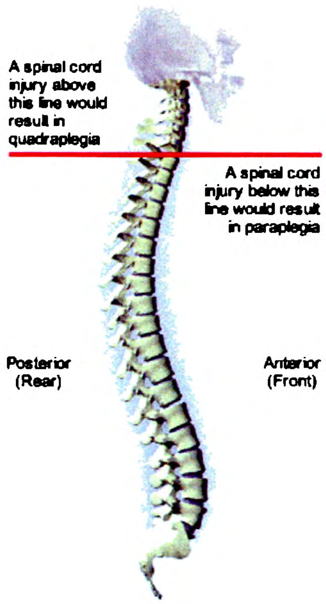


Fig. 1.3.3 an affected spine

The paralysis is a where the brain send messages from the body, but this message is blocked and the body does not response and also cannot move a muscle.

Some types of partial damage on the spinal cord:

- Anterior Cord Syndrome.- The damage presents on the front of the spinal cord and the effect of this damage is the loss of pain, temperature, and touch sensations below the level of the injury but the patient could still have a little movement and in the best case can recover it.

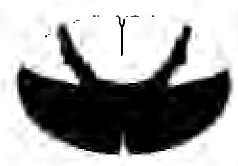


Fig. 1.3.4 Anterior Cord Syndrome

- Central Cord Syndrome.- A damage made on the central cord will affect the movement of arms and the legs, but the lasts ones could be prevented.

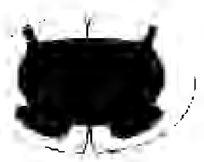


Fig. 1.3.5 Central Cord Syndrome

- Posterior Cord Syndrome.- A damage done on the part toward the back of the spinal cord. Despite the patient still has muscle power, pain and temperature sensations, the patient could experience difficulty on the coordinating movement of their limbs

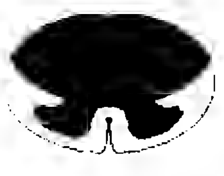


Fig. 1.3.6 Posterior Cord Syndrome

- Brown-Séquard Syndrome.- When a person received a damage on one side of the spinal cord, the patient would eventually loss the movement of the injured side but the patient can still preserved the pain and temperature sensation.

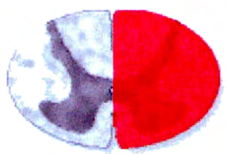


Fig. 1.2.7 Brown-Séquard Syndrome

1.4 Justification

This project started in order to make a difference for people with a complex motor disability, which makes simple activities, into actions that cost a lot of work and even sometimes interaction with the environment is hampered by this same situation.

During various courses that are taken for members of various college student groups that participated in this project, was found on this an opportunity to apply various aspects of academic history of each, and learn more.

A key tool in communication between patients and the system was developed programming language LabVIEW of National Instruments because it has been the platform on which interface has made all the eye movement detection and navigation system. One reason why this program was chosen to work on the project was that LabVIEW provides many options in the development between the programmer and the result you want to see, either with simulations of data acquisition at real time.

1.5 Project's reach

Among its achievements throughout the project development progress, it can be expressed referring to the conjunction of the sub – projects done around the wheelchair.

Now, it has two ultrasonic sensors functional that work on detecting approaching objects the chair, so that they send signals that can receive and interpret in a computer to review and decide between a selection of cases on a way to select how to avoid the object sensing.

Another advance made on the system refers to the electro oculography system, its functional in all senses and it's a system that works on receiving signals from the patient's eye movement so that emits signals to indicate direction or voice messages.

Recently, another system was done and has the function to give direction orders which is based on the creation of a program which has the feature to receive voice signals so that the patient may have another option to interact with the wheelchair. Note that all these systems are operating in conjunction with the chair motion.

1.6 Objectives

1.6.1 Main Objective

Create a useful alternative for people who has a motor disability on a level that they can´t use a joystick to move a normal electric wheelchair.

To get this goal. this project concrete their works on the use of a electric wheelchair that works with intelligent control to do an adaptable system capable to support a patient recognizing the instruction that the patient gave to the wheelchair. on electro oculography system or voice command as a communication way in order to do a comfortable experience on a normal day.

1.6.2 Secondary Objectives

- Create a system that could comprehend signals received from electro oculography thanks to the program made to identify and understand a direction command and a voice command.
- Make a Navigation system that supports the patient with the move of the directions in a way to avoid static and dynamic objects.
- Give direction commands with a interface that works with voice.

1.7 Background

1.7.1 Introduction

Our Project focuses on resolving motion and communication problems for quadriplegic patients. Research the field started on 1898 with the first eye tracking system. History has taught us that with every discovery a new technology is developed. Discovering the way in which the eye moves has opened a door for the development of a vast variety of technologies.

Some of the newly developed technologies for eye tracking are: Electro-oculography (EOG), searching coil lenses, Dual-Purkinje trackers and image processing techniques. Every one of them has advantages and disadvantages when compared to one another. For our project we were searching for a low cost, user friendly, non-invasive dispositive.

The most popular technique for eye movement detection is EOG, because of its simplicity and low cost. Having that in mind, we decided to use this technique in our project.

Eye movement detection is commonly known as "eye tracking". In general there are two kinds of techniques used to monitor the eyes: in the first one the position of the ocular globe in relation to the head is measured; the second one refers to the measurement of the orientation of the eye in space.

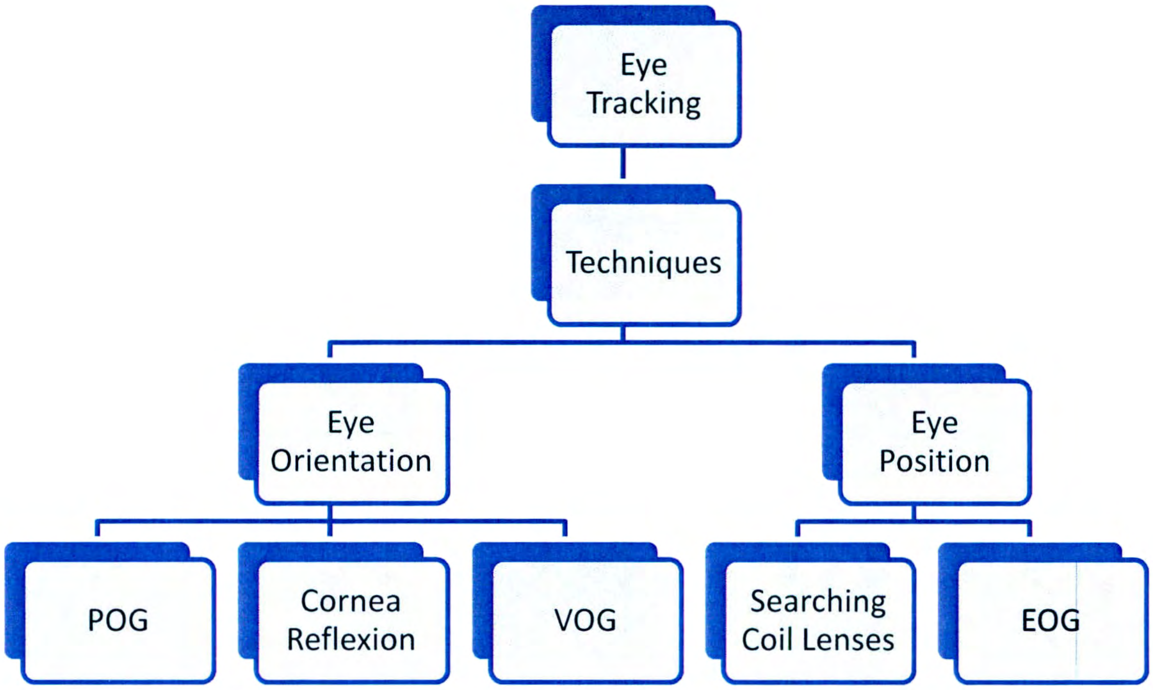


Fig. 1.7.1.1 Different types of eye tracking

1.7.2 Infrared Oculography

This technique is based on the theory that says that any surface will reflect light in a given proportion. Commercial devices have been developed using this technique, this kind of devices have a precision of one tenth of degree. One of the disadvantages of using this is that the horizontal precision is lower than EOG; the most important one is that this system cannot detect blink movements.

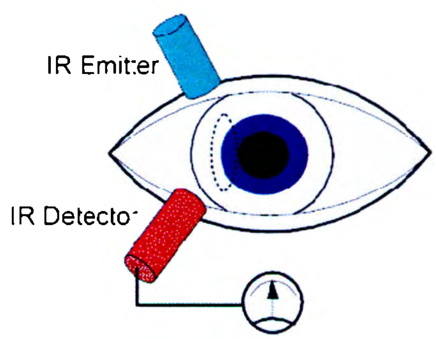


Fig. 1.7.2.1 An Infrared Oculography diagram

1.7.3 EOG

The electro – oculography technology is a method that detects the eye movement by registering the voltage created between the cornea and the retina. The values of these voltages range between 15 and 200μV with a 20μV per eye movement degree sensibility.

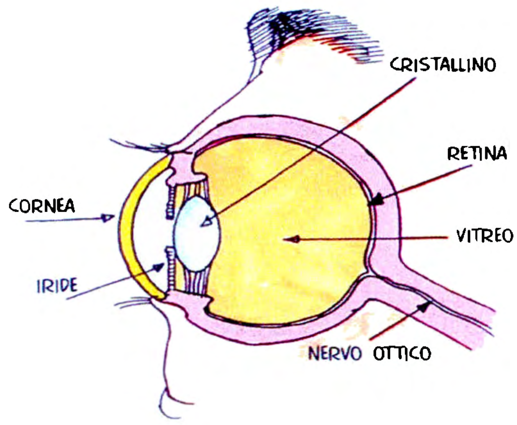


Fig. 1.7.3.0.1 The voltage created between the cornea and the retina (Reference: Barea, 200)

The voltage produced between the retina and cornea is caused by a hyperpolarization and depolarization of the retina nervous cells. The retina and the cornea create a dipole on the back of the eye: positive in the cornea zone and negative in the retina zone.

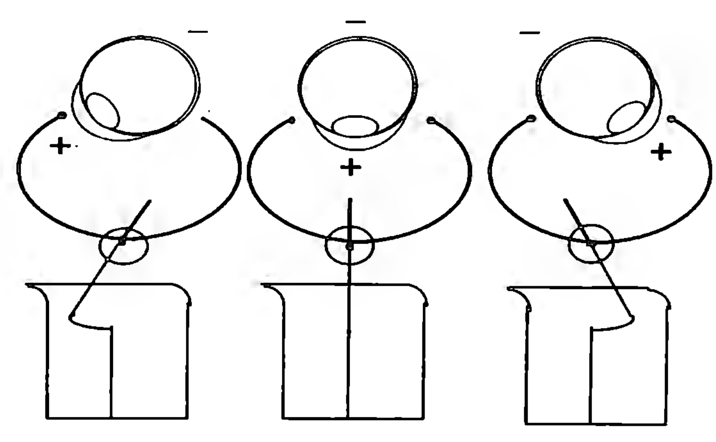


Fig. 1.7.3.0.2 An horizontal view of the voltage cornea – retina (Fuente: Barea, 200)

To receive the eye-movement signals we use common medical electrodes. Five of them are placed in a specific way on the face; this will allow us to receive the signals in two separate channels. The vertical channel will receive blink, up and down movements. The horizontal channel will receive the left and right movements.

The ideal positioning of the electrodes are shown in Fig. 1.7.3.0.3

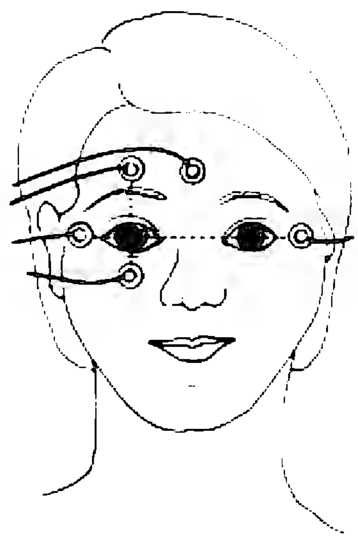


Fig. 1.7.3.0.3 An ideal location for the electrodes for a EOG work (Reference: Barea, 200)

1.7.3.1 Acquisition circuit for signals coming for de eyes EOG (Electro- Oculography)

The signals acquisition circuit is the one that let us to measure the voltage corneal retinal originated by the movement of the user, by this way we can acquire a signal that enable us to manipulate it by using LabVIEW algorithms. There will be used one of these circuits for each channel of movement, so we enhanced two circuits due we have two eye-movements channel: vertical and horizontal.

This circuit has two main stages:

1. Signal Acquisition that let us to obtain signals in micro volts through a differential operational amplifier.
2. Signal Amplification using a no inverting amplifier.

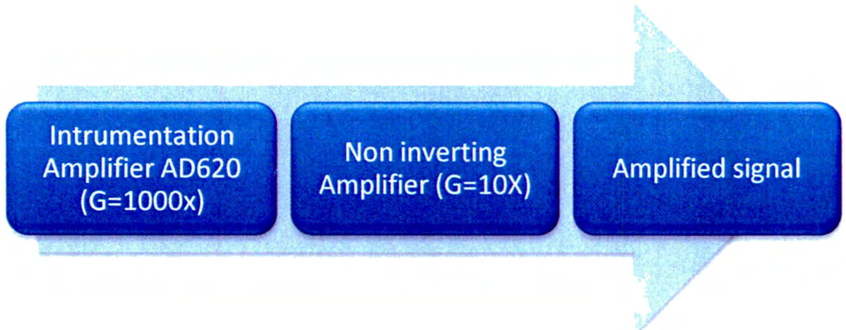


Fig. 1.7.3.1.1 Blocks diagram for the acquisition circuit and signals processing for the EOG

On the first stage there is used the Operational amplifier AD620 (instrumentation amplifier), commonly used for biomedical applications due it has high gain for working with low voltages.

On the second stage we are using a non inverting amplifier implemented with a the circuit LF411 by the way we can get usable signals that let us to read and manipulate with the acquisition device

As following we can see the schematic diagram implemented:

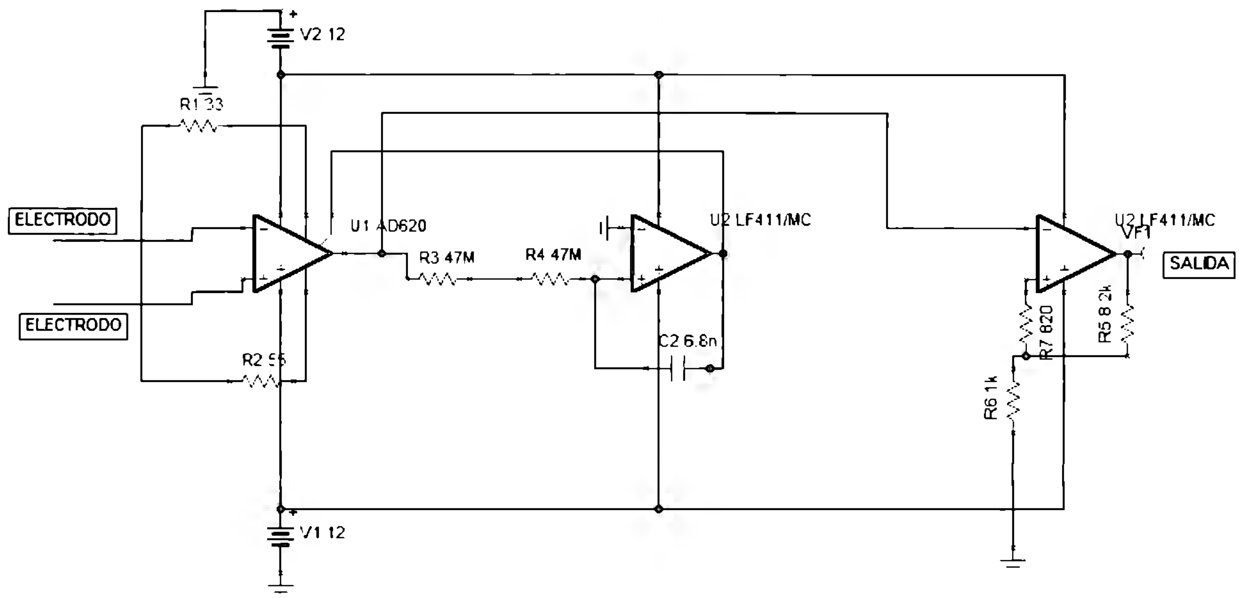


Fig. 1.7.3.1.2 Implemented EOG circuit

Specifications of the devices we were using:

- AD620: instrumentation difference amplifier
  - Extremely High common mode, infinite ideally and entrance´s impedance in differential mode.
  - Accurate and stable gain in the range from 1 to 1000.
  - Very low exit impedance, ideally zero.
  - Common mode reject differentiation extremely high

The advantage that this amplifier offers is the simplicity that the user has to obtain an accurate gain with very low noise level, which are basic characteristics for working and manipulating the low voltage signals. With this first acquisition step we used the highest gain allowed for the amplifier due the original emitted signal is over the range of micro volts, that let us with a wished gain with at least 10000x, that is a desirable value.

The calculation of gain could be obtained by the following way:

$$R_G = \frac{49.4k\Omega}{G-1} \qquad \text{Equation 1}$$

By this way they obtained value for the gain resistance placed between pin 1 and pin 8 in the AD620 is equal to 49.35Ω, this value was approximated with two precision resistances of 33 Ω and 22 Ω to reach an approximated value of 55Ω. By this way, the obtained gain is about 1000.

The second and last stage is the electronic processing that is used due we still needed to amplify the signal, to reach the desirable value. We could reach this value by configuring an operational amplifier with a gain of 10x using a non inverting topology. As following we present an image of the used configuration:

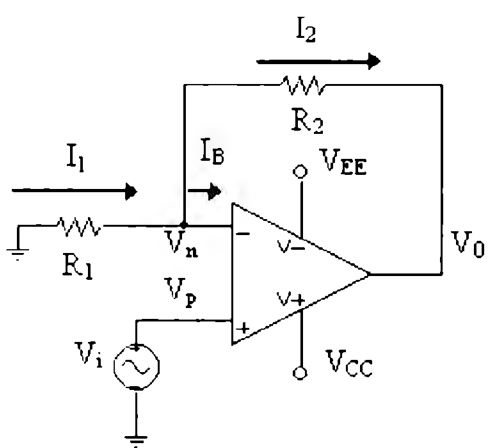


Fig. 1.7.3.1.3 Non-inverting configuration

This topology was implemented due the advantages it presents due it enables:

- To amplify, but not attenuate.
- To hold the signal in phase.
- In the circuit on Fig. 1.7.3.1.3, there is not virtual ground, although VN=VP. We can look that for this case VP is not zero (VP=VI).

In order to obtain a gain of 10 using this configuration we made the following calculus according with the topology previously indicated knowing that the exit gain is AF =Vo/Vi. The required resistance can be calculated as following.

$$A_f = \left(1 + \frac{R_2}{R_1}\right)$$

$$10 = \left(1 + \frac{R_2}{R_1}\right)$$

Equation 2

If we consider the resistance R1 equal to 1KΩ, we can get the R2, that was adjusted to commercial values by the following way: R2= (8.2KΩ + 820Ω) by this way we can obtain an approximated gain to 10x.

$$10 = \left(1 + \frac{8.2k\Omega + 820}{1k\Omega}\right)$$

$$10 = 10.02$$

Equation 3

Once implemented the previous circuit, there were executed tests that showed amplitudes approximately in ranges of 2 to 3 volts, as we can see in the following figure:

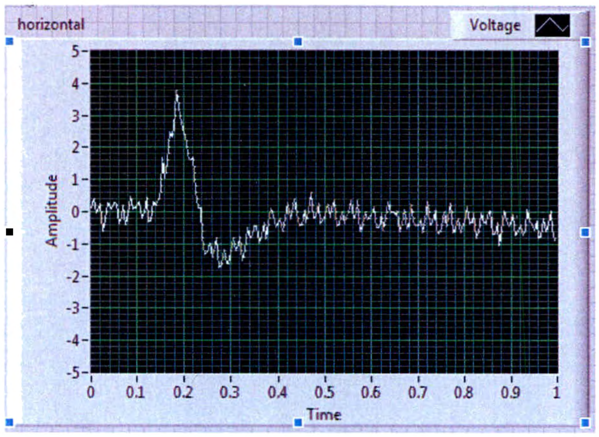


Fig. 1.7.3.1.4 Corresponding signal for a non inverting amplifier coming from the ocular movement

Also we can appreciate that the obtained signal is not very clear, this is due there are noises coming mainly from the environment. Due this noise have high frequency components we implemented a filtering stage that can "clean the signal". By this way, it will be able to obtain a cleaner signal that let us manipulate it by a better manner. This is because the neural networks utilized to acquire and differentiate the diverse eye movements are interfere with this kind of noise originating errors and non desirable results.

1.7.3.2 Filtering the input signal

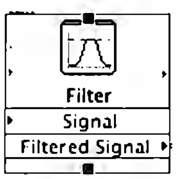
For manipulating the signals first things to do is filtering. Digital filters are used for attenuating or amplifying some signal characteristics. In order to apply a digital filter we must digitalize the analogical signal and process it mathematically for further reconstruction. In this case LabVIEW makes this easy for us because it can read the voltage signals from the DAQ hardware used for digitalizing and generating signals making it easier to manipulate through programming without having to build a complex set of analogical amplifiers.

The digital filters are classified based on their transfer function. By analyzing a signal's transfer function we can determine the behavior of the filter and by knowing this we can select the correct characteristics of the filter according to our signal.

In the variety of filter types we can find two main different groups which are IIR and FIR. In the case of the IIR (infinite impulse response) as it is said by the name, indicates that if the input is an impulse, its output is going to be an infinite number of terms, this means the signal never gets back to a resting state. In the other hand we have FIR (finite impulse response) if the input is an impulse the output will be a finite number of terms. Therefore we can say that the IIR types are better because they produce a more efficient filtering. This is very important when applying filters because we look for the lowest computing cost that will be reflected in a quicker response of the system. We selected the IIR filters because of their low computing cost.

Another important point to consider when designing are the specifications for the filter, either low pass, high pass, band rejection or band pass should be selected. In our case we use a low pass filter with a cut off frequency of 5Hz. This is because the period of our signal is around 0.25s, in other words it has a fundamental of 4Hz, so we are giving a little range space being aware of some problems with the computer. In this way we reject any other frequencies in which we are not interested like the high frequency noises which introduce unneeded oscillations to our desired signal.

The implementation of filters in LabVIEW is relatively easy because there are filtering Vis that can be used and posterior configured to the desired parameters. The signal simply goes into the filtering VI and the output is the filtered signal, an image of the filter and its configuration panel is shown below.



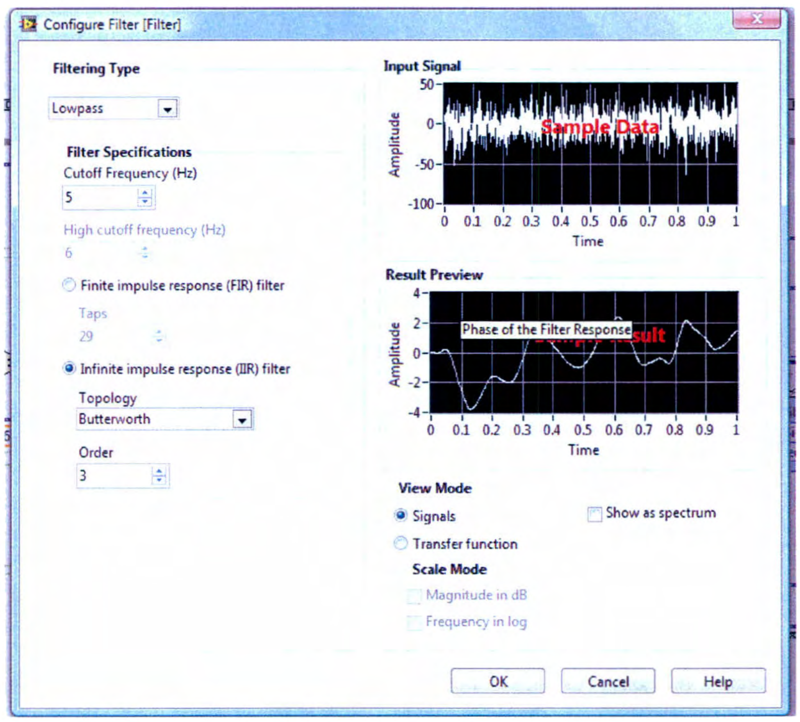


Fig. 1.7.3.2.1 Filter configuration window

- Cut off frequency of 5 Hz
- Low pass filter
- IIR filter
- Topology: Butterworth
    - Order 3

The filtering parameters were decided after a few tests where the better results were obtained at a low pass cut frequency of 3hz a clear signal, afterward it was changed to one between 10 and 15 Hz because some of the information was lost. It is important to say that a clear signal will require less number of neurons in the ANN to be reproduced. After finding the clear signal with a properly configured filter we proceeded with the next steps in programming.

1.7.3.3 Circuit tests and visual analysis

With the circuit built and working properly we preceded to get familiarized with the signals generated for each type of eye movement. The first signal analyzed was the blinking signal shown below in the Fig. 1.7.3.3.1

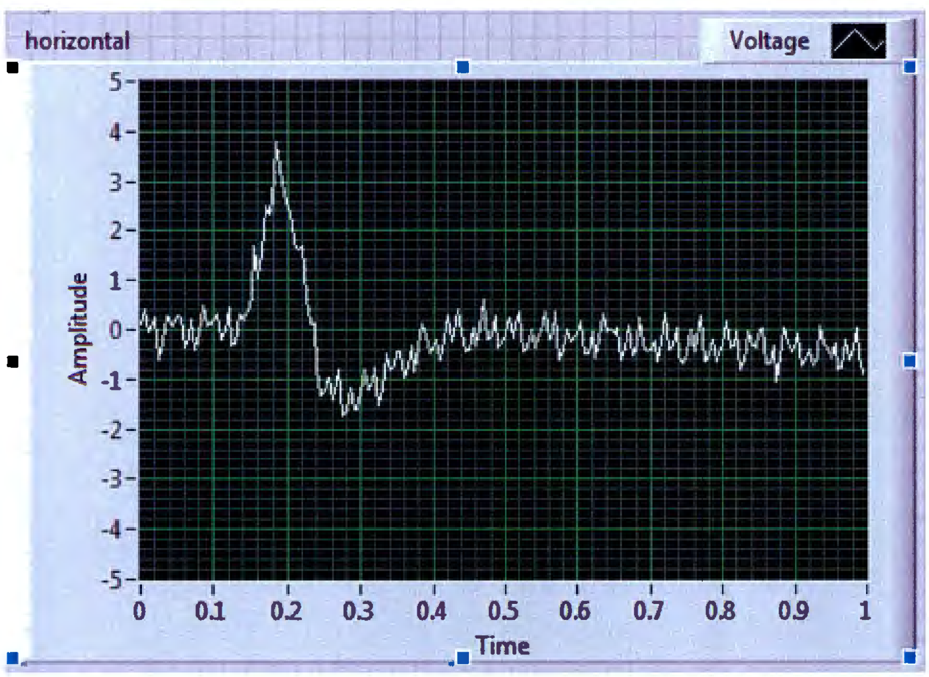


Fig. 1.7.3.3.1 Blink movement

If we visually discriminate the high frequency noises we can se something very similar to sine waveform with a period of around 400ms that has a variation of around 100ms depending on the blinking speed. Another important observation is the amplitude; in the image we can see how the signal reaches an upper limit of 4V and an inferior of -4V. This amplitude is variable between each person tested, but the signal is still clear.

With the same channel we took some samples of the generated signals when moving the eye upward and downwards shown below.

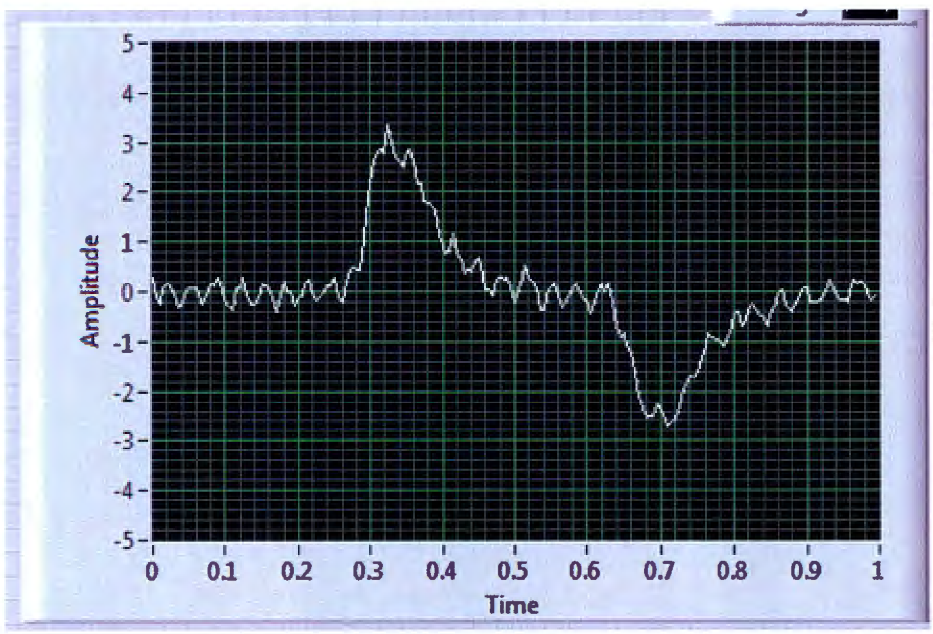


Fig. 1.7.3.3.2 Oscilogram for look "up"

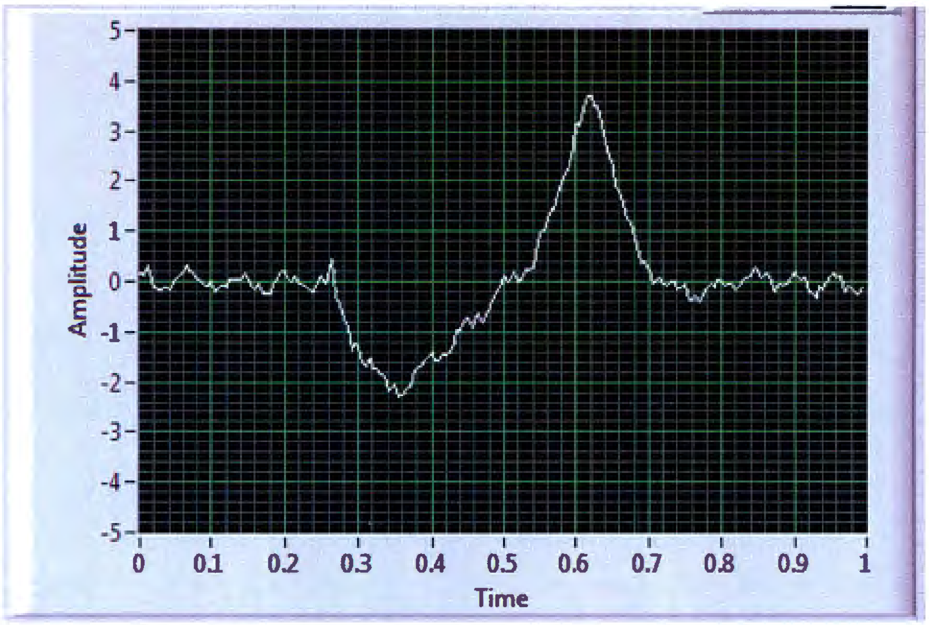


Fig. 1.7.3.3.3 Oscilogram for look "down"

For the up and down movements we can see almost the same characteristics than in the blinking with the difference of a slight space when movement is not detected because the first oscillation is due to the going up movement and the second is the coming back to the center point. It is important to mention that the variation of velocity of the movement upwards can make the signal look the same as the one measured when blinking. It is also important to say that the peak to peak amplitude is smaller for the eye globe movements than the one of blinking.

In the other hand we have the analysis of the horizontal channel in charge of measuring the left and right glove movement. In this case the firs observation is that the blinking is not detected unless the blinking is made intentionally hard. Next we show the oscilograms of the acquired signals for the horizontal channel.

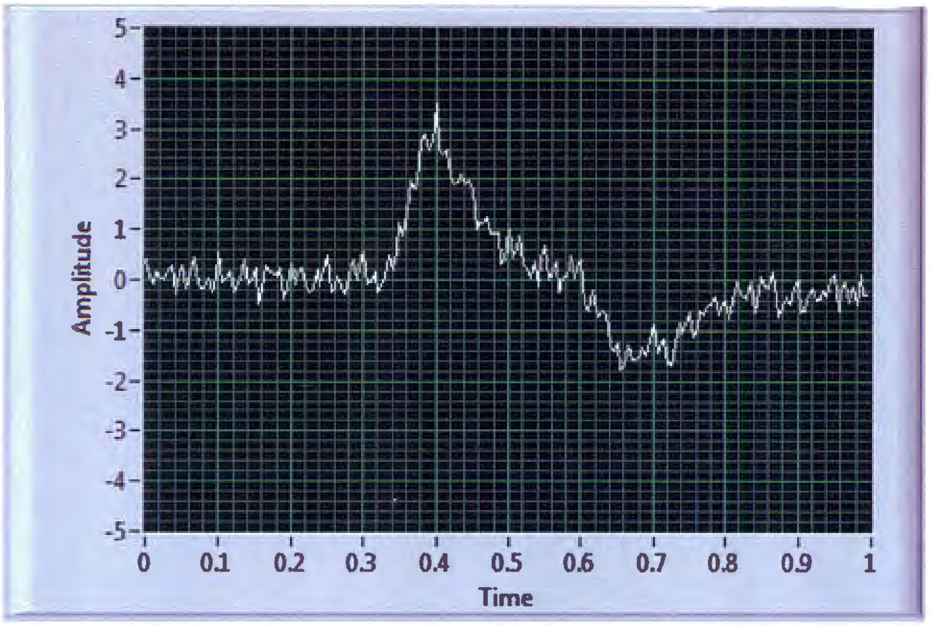


Fig. 1.7.3.3.4 Oscilogram for look "right"

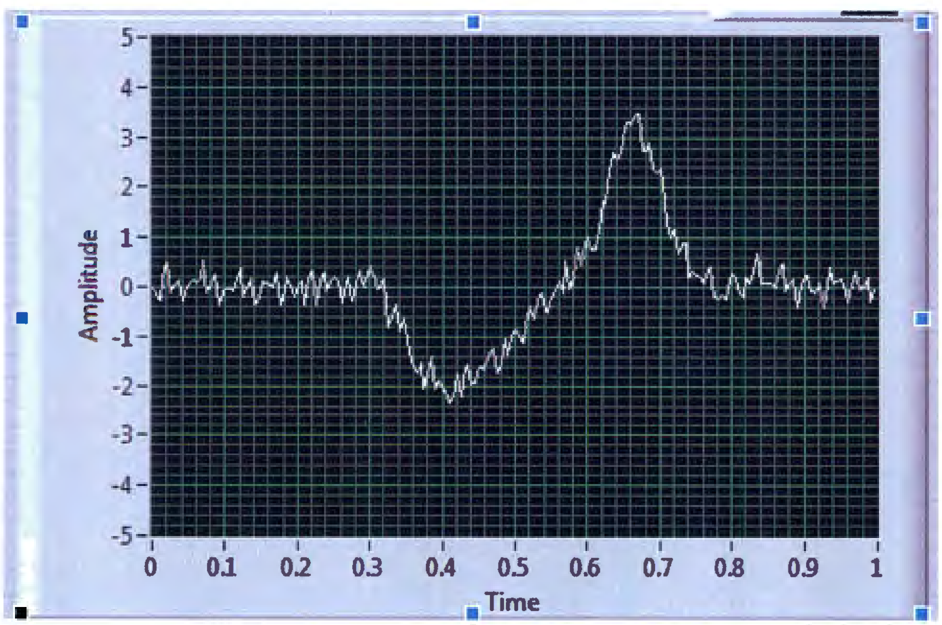


Fig. 1.7.3.3.5 Oscilogram for look "up"

In all of the above images we can distinguish by simple observation that the signals are almost the same as the ones in up and down movements. This fact will allow us to treat them the same way when digitalized without the need of generating different programming or methods for their manipulation. Once having the specs of each movement and comparing each other we can see that the direction of the eye movement is firmly tagged by the polarity of the measurement. When moving upwards we get a positive signal and when moving down we get a negative measurement. In the same way it happens with the horizontal channel.

With this we conclude the tests and analysis of the signals, the fact that will allow us to discriminate between each type of movement is the one about polarity difference between eye movements. When we get a negative start we know it can only be a downwards or left movement depending on the channel. In the vertical channel we have the problem of having two signals that are almost the same, therefore the importance of identifying half periods. Another important conclusion is made through a rough calculation where we can say that we generate a signal around 300uV that will correspond to the theoretical value 20uV per degree.

2. Structural Design

2.1 Wheelchair main instruments

Although there will be a better control of all the variables if we design the entire wheelchair, we were not focused on the mechanical design. As it was previously specified we were working on an already tested wheelchair, the commercial Quickie P222-E.

On the original wheelchair's control, the Quickie wheelchair offered to the patient a joystick that could be manipulated to control the wheelchair in any direction. The operation principle implemented on Quickie's direction control, consisted in a lever with two electromagnetic sensors.

When sensing certain amount of field, the wheelchair can be driven to the direction determined by both electromagnetic sensors, one of them controls left or right and the other forward or backward.

The controller was built with a magnet placed on one end of the lever, in order to go in one direction, the patient must move the lever, so the magnet could be closer or further away from any of the electromagnetic sensors generating an electromagnetic field proportional this relation. Depending on the intensity of field, the wheelchair could be moved in any direction. In order to control the wheelchair, we required to generate a magnetic field emulating the one induced by the magnet placed on the lever. We placed two coils in front of each sensor at a distance of 5 mm to generate one field for each sensor, using a NI cRIO 9014 with two Full H-Bridge Brushed DC Servo Drive Modules 9505, we sent PWMs in order to use the coils as electro-magnets.

The pulse's amplitude was constant with a value of 25 V (this value depends on the voltage of the power battery of the whole system), but we were generating two electromagnetic fields in opposite directions in a space of 4 cm. The combination of both fields produced unexpected results because the sensors identified random values then the directions could not be executed by using single coil polarization, which could produce the four directions. We solved this problem by searching configuration values that could proportionate us the four possible directions (forward, backward, right and left).

The signal was controlled by two variables per coil, one of them indicated the frequency of the pulse and the second lead the direction of the current. We can observe on Fig. 2.1.1 both variables: *PWM DC (%) RIGHT C* and *DD Right* which are connected to a Case Structure, depending on the boolean value selected on *DD Right*, the current will flow in one direction with a duty determined by *PWM DC (%) RIGHT C*.

These variables were used for the right coil, the left coil has its own variable and both regulate the same values as in the right one.

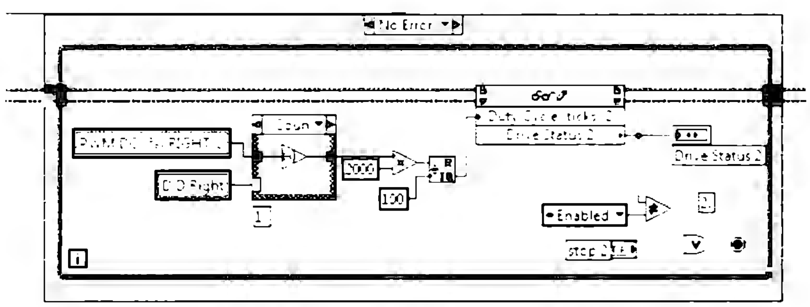


Fig. 2.1.1 The configuration for the frequency and direction of the signal is controlled by introducing numerical values from 0 to 100 in the "PWM DC (%) RIGHT C" variable. The current direction depends on "D D Right" Boolean value.

In the configuration for the case structure and depending on the selection of the variable "D D Right", the introduced value of "PWM DC (%) RIGHT C" will be inverted or not, this means that the current will flow in one sense or in the opposite. The "Read/Write Control" will lead the previous values to the outputs of the CRIO.

In order to drive the wheelchair with constants values in any direction, we found values for the four variables as following:

	PWM DC (%) LEFT C	PWM DC (%) RIGHT C	DD T	DD F/B
Forward	100	44	CCW	CCW
Backward	100	40	CW	CW
Left	10	80	CW	CCW
Right	5	70	CCW	CW

Fig. 2.1.2 Configuration values to indicate the four possible directions for the control.

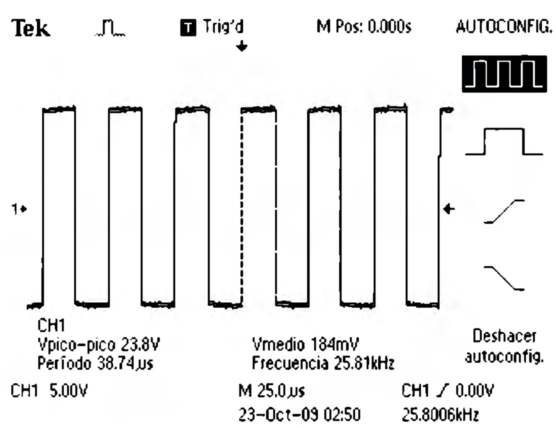


Fig. 2.1.3 PWM for the polarization of the coils to induce a magnetic field

As we mentioned, these values determined the PWM's duty for each coil. By doing current measurement we got the following values:

Direction	Duty (%)	Frequency (kHz)	Amplitud (V)	Current (A_{RMS})
Forward	60	20	24	0.58
Backward	60	20	24	-0.51
Left	80	20	24	1.04
Right	70	20	24	-0.9

Fig. 2.1.4 Data obtained from the different configurations of the coils.

On experimental results, the behavior for the sensed values originated by the coils we found that it is not linear. By manipulating the signal's duty, there were configurations that saturated the sensors avoiding any kind of movement, so the different values cannot be controlled linearly.

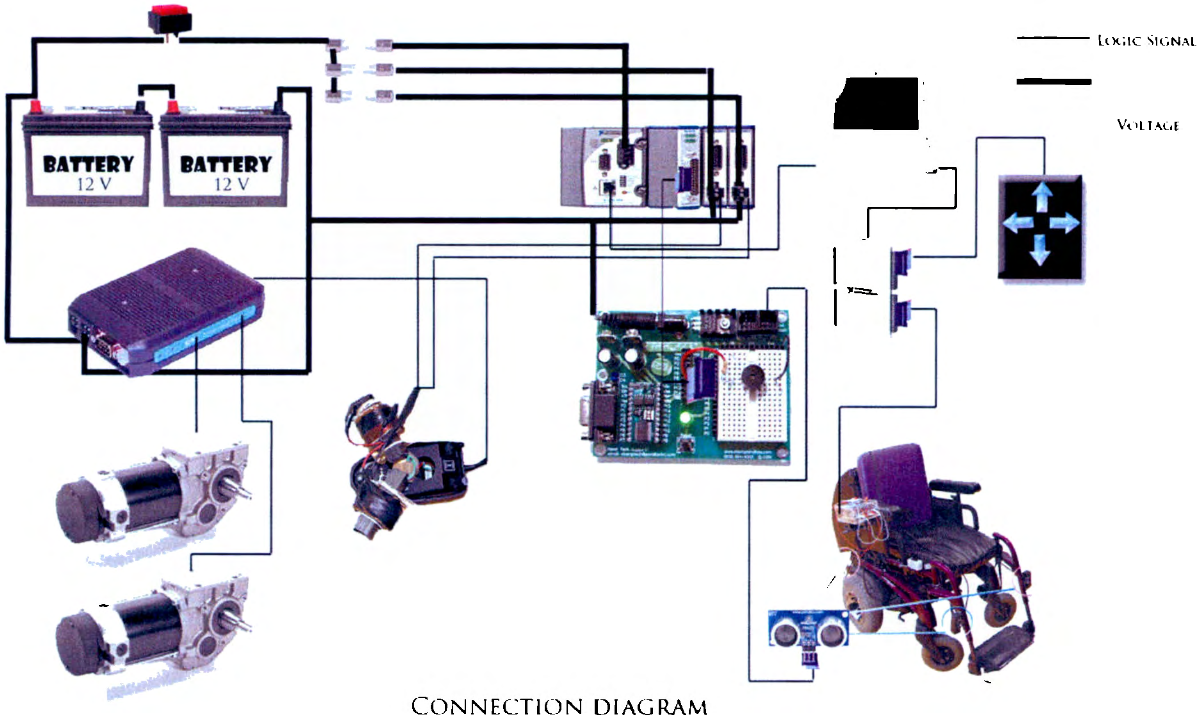


Fig. 2.1.5 Electrical diagram

2.2 Electrodes

Electrodes detect the magnetic field generated by the body movements. Constitution of the electrodes is very simple; materials are the conductor, which is in contact to the body, through electrolytic foam and an adhesive material which is used to position the electrodes.

3. Obstacle avoidance system

3.1 Fuzzy logic

The concept of fuzzy logic is known since some decades before and it is referred to the comprehension of the input values using what is called "fuzzy Set" with the aim that these can give a level of interpretation of the receives data in a way that the output values are the closest to the needs of the problem.

We must say that fuzzy logic is very adaptable, because it allows the creation of simplified control systems in the way they are more autonomous with the capacity of adapting to many control systems because it has the particularity that there is no need to know the mathematical model of the plant in which it is working. In classical control the system is designed based on the mathematical models, therefore not usable for other plant.

Fuzzy logic is about the handling of linguistic variables that any person can use in a daily life, the system can generate a response without the need of punctual values, thing that is not possible in common control systems witch in deed require defined values for working. The fuzzy logic control has the capacity of knowing the punctual output values by making relationship with a membership value.

In a more understandable way, the common case is to receive values between 0 and 1 in the X_1, X_2 etc. for considering a significant value for every X data obtained. The way fuzzy logic works is that we know the value for the x data like 0.2, 0.7 etc. that allows us to know how much does it belong to the condition 1 or the condition 2, these conditions affect and improve the comprehension of what we want to obtain from the system.

Fuzzy logic can be divided in three different process that take data into each other for the control to give the more useful values to the system, this base processes are called *Fuzzyfying, IF_then rules and defuzzyfication*. On the next extract we will talk about how each one works.

The firs process is called fuzzyfing. This refers to the moment that the values are received, this values called neat values obtained directly from the physical systems acquired by sensors. Here is where a mapping is made in order to convert the received values into fuzzy data, the way to do this is by the means of membership functions, some of them very commonly known as saturation, shoulder, triangular, or trapezoidal depending on the desired membership for each case. In this way we can get a visual understanding on how the values are going to change with respect to the function points.

In a written way the fuzzy values have a tilt on the upper side of the letter, in the ecuation 4 a discrete representation of the fuzzy values is shown.

$$\tilde{A} = \{a, b, c\} = \left\{\frac{\mu_A(X_1)}{X_1} + \frac{\mu_A(X_2)}{X_2}\right\} \qquad \text{Equation 4}$$

From these values we must understand that the plus sign doesn't represent an addition between values, it Works as a union between them. The other thing to consider is the interpretation of the values because the denominator values, X_1 for example, is the neat value in the input side, and the values in the numerator ($\mu_A(X_1)$) are the membership values obtained from the membership function.

In the second process, also known as evaluating of the IF-Then rules, the input condition is evaluated in order to generate a fuzzy output via the interpretation of the rules. Many values can be measured and evaluated as the input conditions to generate an output condition with the base evaluating structure of: IF___is__ then___is __ using the membership values from the fist fuzzyfying step.

Once we have the significant value we proceed with the last step called defuzzyfing. In this step a filter is used for having a better perspective, the filter used is called min- max which refers to the comparison between cases for each pint in order to make an AND between all values in each case of the causes (leaving the minimum value in which all values are present) and a or in the case of the consequences (leaving the maximum value of all consequences on each case). This works to make an evaluation for the output and obtaining a real value, it is done by adding all the input values multiplied by their membership value and dividing it by the addition of all the membership values. Equation 5 shows the output equation.

$$Salida = \frac{\sum X * \mu_X(X)}{\mu_X(X)} \qquad \text{Equation 5}$$

Given the basics on fuzzy logics we can explain how the obstacle evasion system Works.

With the three ultrasonic sensors we will acquire values between 0 and 255 that represent the distance in centimeters between the sensor and an object close by. Once having the input values we can proceed with the fuzzyfing step for establishing its membership value according to the designed rules. With our project there are 3 rules for each sensor that indicate if the chair is close, mid distance or far. Since there are 3 inputs and 3 rules for each ones there are many combinations of membership functions that determine the value introduced into the parameters programmed as D T, D D F, MAX T and MAX F/B. once this values are determined analogical impulses are sent to magnetic inductors that control the wheelchair movement so it moves away from the obstacle.

3.2 System developed to avoid obstacles

In order to avoid collisions and give to the patient more freedom in movements, we developed a system that can avoid dynamic and static objects. The system was integrated with three ultrasonic PING sensors developed by Parallax. The programmed algorithm on LabVIEW is as following:

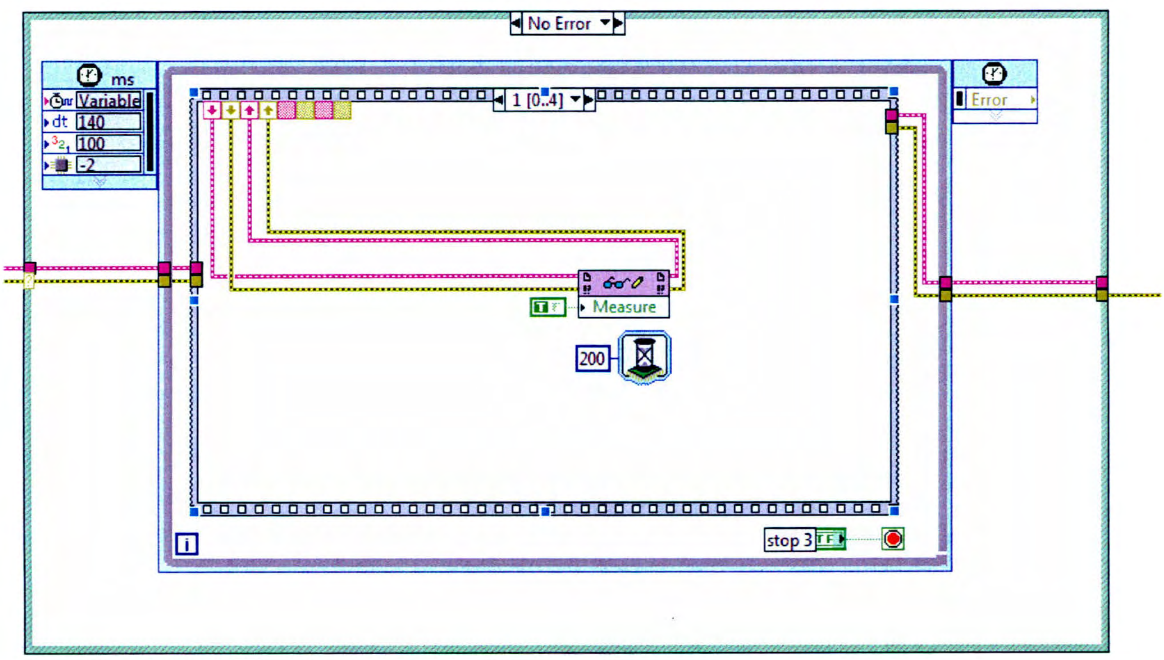


Fig. 3.2.1 Timed loop that enables the measurement obtained by the three sensors.

On Fig. 3.2.1, we can see the timed loop that enables the acquisition of the three distance measurements

The structure to manage the different situations where the wheelchair can be, were considered by indicating the different combinations that the ultrasonic sensor could have in a logic table. This combination would indicate to the wheelchair what to do. For example, considering that the two frontal distance sensors are indicating a distance closer than ten centimeters, then the wheelchair will go back else the system could crash.

	Left Sensor	**Right Sensor**	**Back Sensor**	**Then**
Proximity	Close	Close	Far	Backwards
	Close	Far	Far	Turn Right
	Far	Close	Far	Turn Left
	Far	Far	Close	Forwards
	Far	Close	Close	Turn Left
	Normal	Far	Far	Forwards
	Close	Far	Close	Turn Right
	Close	Normal	Far	Turn Left
	Normal	Far	Close	Forwards
	Close	Close	Close	Stop

Fig. 3.2.2 Different possibilities that the wheelchair could face in a real situation.

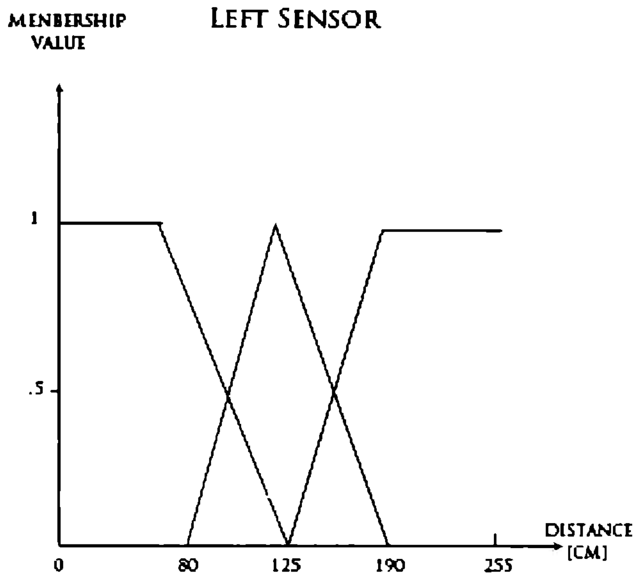


Fig. 3.2.3 Membership values for the left sensor, these values are also the same for back and left sensors.

On Fig. 3.2.3 we can see the different values where begins the different positions: far, close or normal. These values can be changed by the user depending on its own criterion. This fuzzy controller determines how the wheelchair will be moved by controlling the pulses sent to each motor.

Fig 3.2.4 Ultrasonic sensor locations on the wheelchair

As we can see on figure 3.2.4 there are three ultrasonic sensors that support the fuzzy control implemented over the wheelchair. In our tests we can conclude that may be necessary more sensors, this is because with some objects placed on any of both sides, the wheelchair cannot "see" this objects originating crashes or absolute stopping of the wheelchair. There will be also needed, at least two sensors that can detect the presence of floor for future improvements.

The obstacle avoidance system worked with three main devices: ultrasonic sensors, BasicStamp and the algorithm that had the function to avoid obstacles. The system worked as following:

1. Two ultrasonic sensors placed in the front of the wheelchair, both were connected as following to the basic stamp as following:

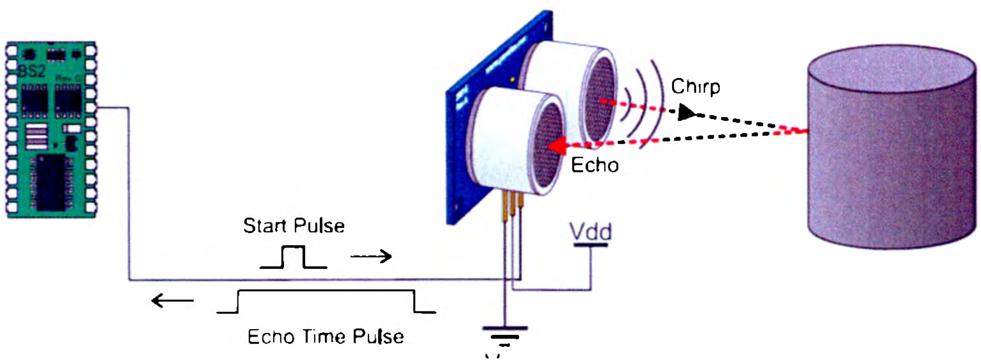


Fig. 3.2.5 Ultrasonic sensors working

Two of the three pins were connected to Vcc and ground respectively. The third pin was used to perform the communication, this pin sent the measured distance. The ultrasonic sensors sent the appropriate signal in 40 KHz. The BasicStamp obtained the sensed value but its processor speed, when it was ready for been sent, the compactRIO obtained the 8 bits value and using the fuzzy logic control it can develop the avoidance control.

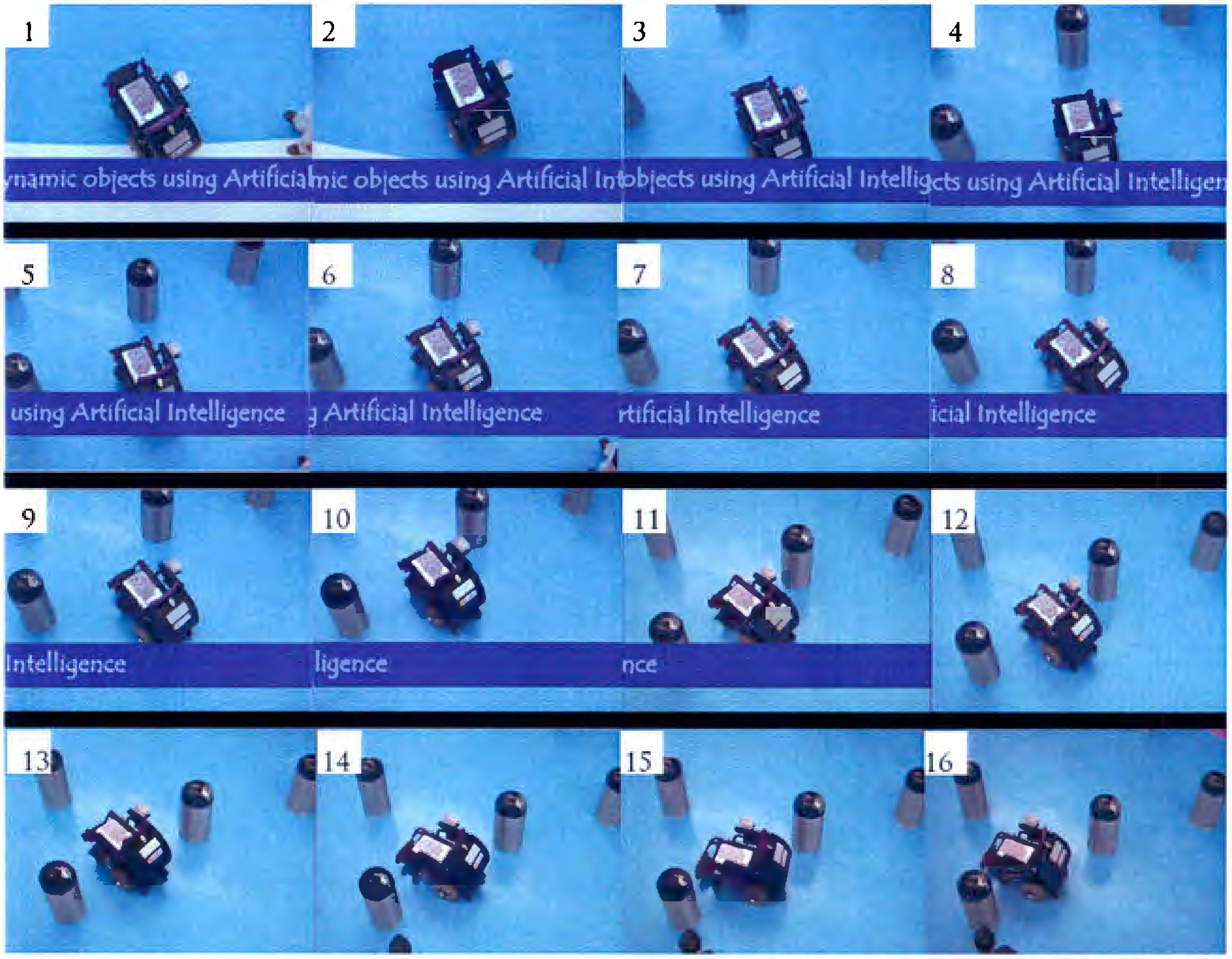


Fig. 3.2.6 An story – board that presents the avoid system working

4. Voice Control System

The Voice Control system is planned for patients that do have severe motion impediments, but can talk. Controlling the chair with speech is much easier than controlling it with the eyes, therefore for this kind of patients the chair can also be controlled with four basic commands. The chair is programmed in Spanish or English or any other language that works with Windows recognizer and will respond to *Derecho, Derecha, Izquierda* and *Atras*.

To create this system we decided to use software that already existed. The first one is Windows Speech Recognition; this will receive the spoken word through the computers microphone and will try to execute some command already programmed in it. The recognized word will generate a message that is in .NET format, which means that we can capture the message from Windows and execute our own command. To capture the .NET message we used Speech Test 8.5 by Leo Cordaro, this is a VI for LabVIEW, and this will help us capture the recognized word.

Fig. 4.1 shows the Front Panel of Speech Test 8.5, the phrases to the left will be the phrases that we will recognize to control the chair. Once both softwares have recognized the spoken command a variable is sent to the general control of the chair and the chair will move as the patient speaks.

The way this works is:

First the message is captured by the windows recognizer software that usually generates an events further handled by the event handler which is a tool used by the OS to know whenever the system shall react to something, like a mouse click. The message is generated by the windows recognition software when an instruction is detected, these instructions are made in .net programming which can be also used in LabVIEW. Therefore this vi creates an instance for giving the new variables ("phrases") to the methods in speech recognition. Afterwards, when the given word is recognized the event handler lets us know when one of our words has been spoken and return the string associated with it. Once we have a string return variable we use case selection to assign a different action to each word trough the motion control system.

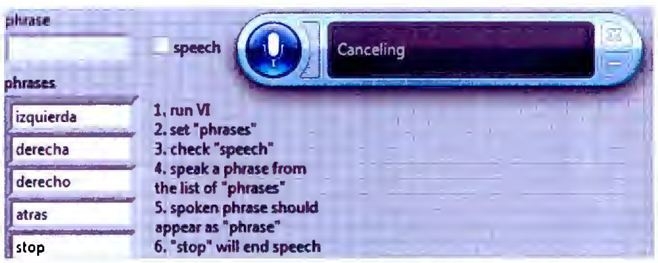


Fig 4.1 Speech Test 8.5

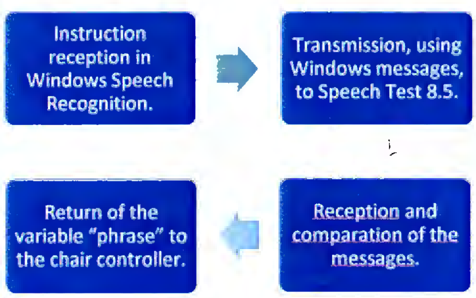


Fig 4.2Front Panel of Speech Test 8.5 and Function Diagram

5. EOG Control

5.1 Introduction

The brain can be interpreted as an information processing machine. Information comes in through electrical signals with which the 100 to 500 billion cells, called neuron, process to create a reaction output. The system forms networks and these can be hierarchical or layered.

The neurons are composed by a central body, the axon and the dendrites. Information comes through the dendrites, which are connected to the synapse section of another neuron's axon terminations. The synapse is a chemical procedure in which the neurons transmit information. Knowing that the number of dendrites can vary helps us to understand the way in which these cells communicate. One, none or multiple variables or electrical impulses can be received through the dendrites. These impulses are added in order to be compared to a fixed threshold of activation. If the threshold is exceeded by the addition then the neuron is activated and will communicate this activation to other neuron through its axon. The process will repeat itself in each neuron on the networks giving a reaction as result. Fig. 5.1.1 shows a schematic drawing of a neuron.

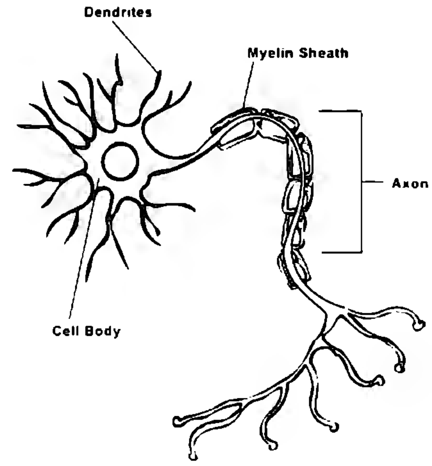
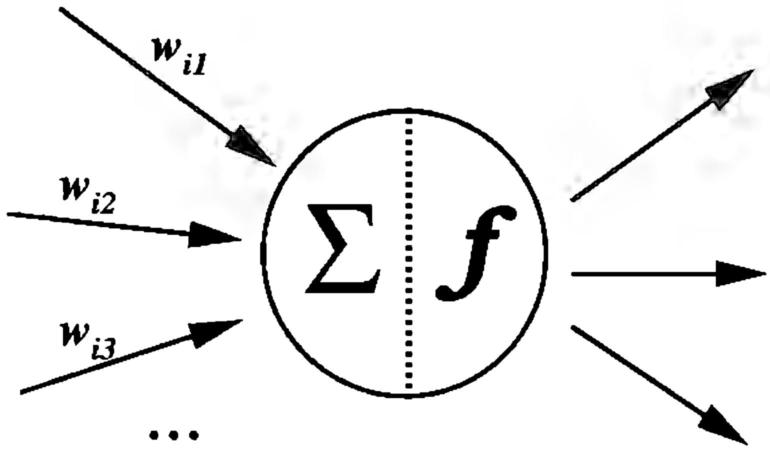


Fig. 5.1.1 A Biologic neuron

Looking at neurons means that research is trying to understand how the human brain can react in a generalized manner. Research is trying to comprehend how does the bran learn and react. why is it that when we have not really practiced throwing a ball and someone just shows us how to do it, we are capable of reproducing almost the same movement as our teacher? The answer isn't yet found. But research has shown that mimicking the brain learning and generalizing processes. could give us tools to perform incredible things.

Continuing with the artificial neural network model we can interpret the connection between axon and dendrites as weights. The connection grows stronger when the channel is used. and when the channel isn't being used or is used in very few occasions the connection grows weaker. The same happens in the model. The weight of the connection is increased or decreased depending on the necessities of the network. Once the weights have been adjusted all signals are summarized and compared to the core's activation function. Finally the result is transmitted through the axon to other neurons. Fig. 5.1.2 shows the diagram of the artificial neural network.



$$y_i = f(net_i)$$

Fig. 5.1.2 An artificial Neural Network diagram

The activation function of the artificial neuron can be any kind of function. But the more commonly used ones are the sigmoidal functions, linear functions and hyperbolic tangent functions.

For our project we used the Intelligent Control Toolkit for LabVIEW in which all of these are already included.

5.2 Classification

Classification of artificial neural networks is based primarily on the problem in hands. The five fields where these solutions are accepted are: Function approximation, linear and non-linear functions can be approximated; Classification, data classification or signal classification; Unsupervised clustering creates clusters of data in unknown classes; Forecasting, predict the next values of a time series; Control Systems; all the above applications are used in control systems, also neural networks are used for modeling and analyzing of control systems.

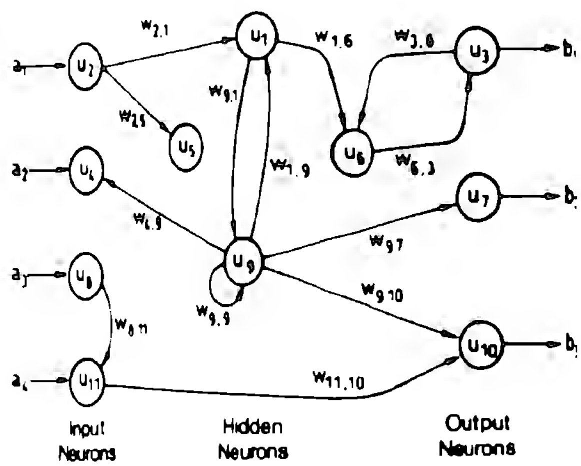


Fig. 5.2.1 Neural network and its weights

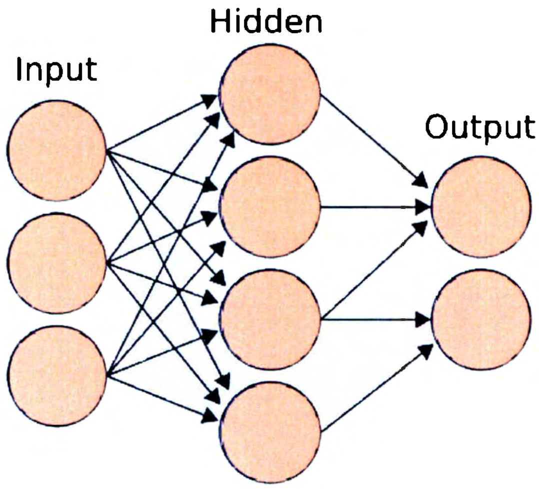


Fig. 5.2.2 Layers of the neural networks

The second way to classify artificial neural networks is the learning process: *Feed-forward networks* will only forward and process information in the direction of the output. The output signals are always consequence of the input signals and the weights associated to each of them. *Feed-back networks* structure resembles to the first one, but in this case some output signals are looped back to the same neuron or a previous group of neurons.

Neural networks are also classified based on their learning process:

1. Supervised Networks: The data for the training is very well known, in this case the input signals and output signals are defined and so the weights can be found.
2. Unsupervised Networks: For this kind of networks application are found where we don't have any information about the input. The network will find patterns in the input data for its own training. Examples of this are Hebbian Neural Networks which are used in our EOG process.

3. Competitive or self-organized networks: In this case each neuron will fight for a dedicated response to a specific input data. Kohonen maps are examples of this.

5.3 Controlling the wheelchair with the eye movements

Controlling the chair with the eyes was no easy task. Once we have read the theory explained in previous pages we can understand the whole EOG system.

The patient will place the electrodes in the right place, transmitting movement signals to the EOG circuit. Once the signals are amplified by the circuit a DAQ will receive them and transmit them forward to the computer. The first stage of programming is the filters for both channels, these are digital filters configured in LabVIEW, and we decided to program the filters instead of building analog ones, because digital filters can be reconfigured at any time.

The filtered signal must now be normalized. First it is split in windows of 400 samples, this is done to acquire only the useful sections of the signal and to have all the signals of the same length. The second normalization is done for amplitude; all signals will have 1 as peak.

The normalized signals are saved into arrays that will have the information point by point of the signals. These arrays are then connected to the Hebbian Neural Networks. Fig. 5.3.1 shows the amplitude normalization.

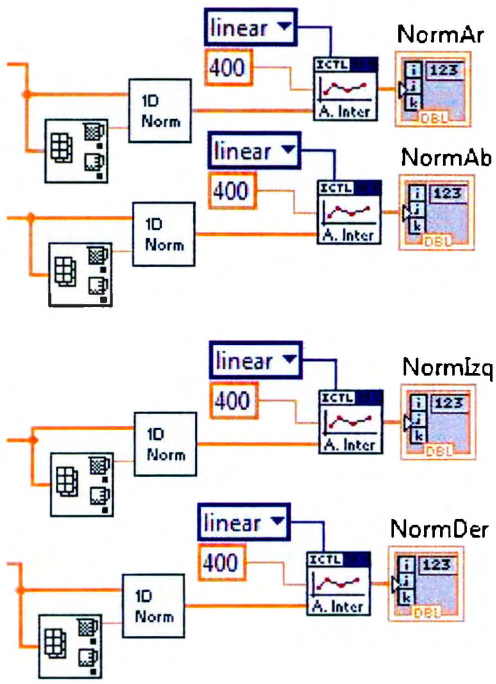


Fig. 5.3.1 Signal Normalization

Hebb`s rule for training states that whenever two units *j* and *k* are active at the same time, the connection between those units should be strengthened.

Hebbian Neural Networks in our case are used to let the system learn the five eye movements used to control the chair. Once the movement signal is received and filtered it is transmitted to the neural network. Given that one network can only learn one movement, we use five different networks. The Hebbian Neural Network will learn point by point the form of the received signal; once it is trained the network can start comparing incoming signals to the one learned. By subtracting the incoming value of a given point of the signal, to the same point in the learned signal we can calculate an error, this value will then be compared to an approval-threshold if the error is underneath the threshold value the incoming signal will be recognized as the learned signal. In our system we will be training the five networks to learn the eye movements; this means we will "save" the Blink, Up, Down, Left, Right movements each in one network. Once trained, the user will be able to move the eyes in any direction and the chair will be able to recognize the direction in which the user moved the eyes.

The comparison done in the Hebbian Neural Networks will return four Boolean variables, only the one movement corresponding to the one recognized will be set to true and the other three will return false. These Boolean variables are then transmitted to the general control of the chair which will make the chair move in the selected direction.

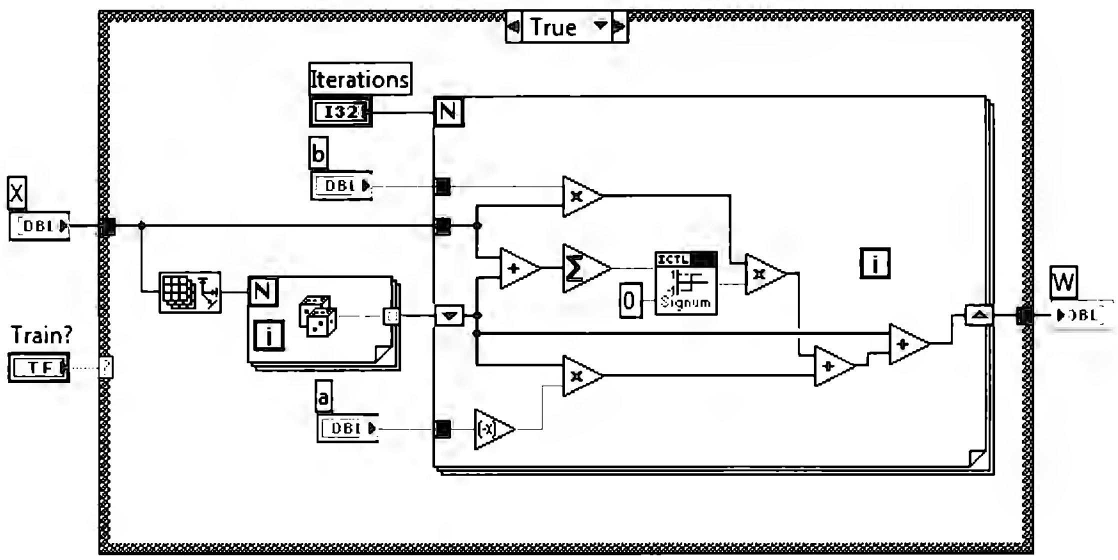


Fig. 5.3.2 Hebbian Neural Network

Fig. 5.3.2 shows the return of the four Boolean variables and the case structure built to respond to the selected movement.

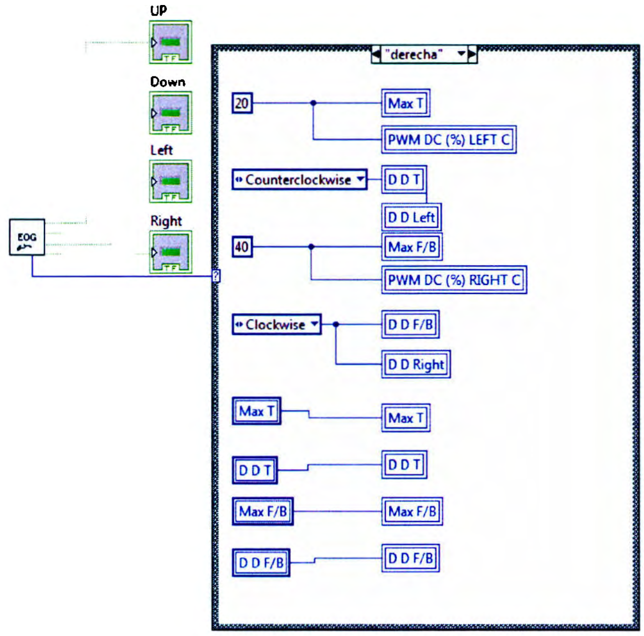


Fig. 5.3.3 Return of Boolean Variables

The software was programmed to disregard the natural eye movements. Blinking twice will set the chair into "Movement Mode", once in this mode the patient can move the eyes in any direction and the chair will respond by moving in the same way. By looking down the chair will stop, resetting the software to wait for the double blink code.

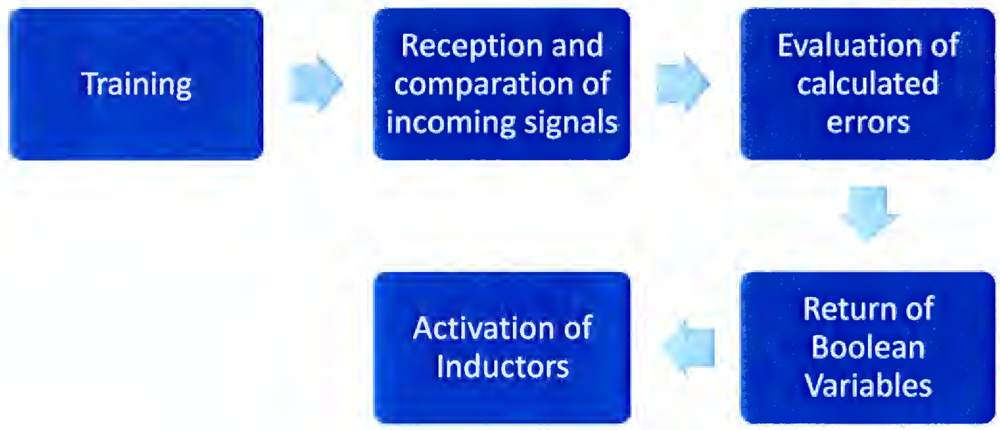


Fig. 5.3.4 Function Diagram of EOG Controller

5.4 Input signal amplification in the EOG circuit

Electro-oculography is based on the detection of the voltage created between the cornea and the retina while moving the eyes. This Voltage is of about 200μV, which means that any computing device will see it as noise and not an actual signal with a meaning. To be able to compute and analyze the signals, we use an amplification array. The circuit is designed with operational amplifiers. The first stage of amplification is made with an AD620, this stage will amplify the signal in a 1000 times basis, which gives us an output of around 0.1 V, the following stage is done with LF411, this will amplify the signal at about 10 times its incoming value. The output of the circuit will be in the range of Volts, this means that the amplitude of the signal will be, depending on the patient, of about 6V, having plus voltages of 2V-5V and the lower peak of about 1V of difference with the upper one.

The sampling of the incoming signals is done at 400 Hz; this is done so that the Nyquist theorem can be applied. This theorem states that the sampling frequency must be at least the double of the base frequency of the incoming signal. Our frequency is higher than that to reduce the lag time between the command done by moving the eyes and the reaction of the chair.

The lag time of the chair is presented in the following chart; it shows a comparison of the reaction time of the chair to the time that the chair has been working. Working with lap tops doesn't give the project a really good engine to perform all the computing in an efficient time. The following chart data was obtained experimentally using a lap top with 2 GB in RAM, a 2GHZ AMD Turion 64 processor and Windows Vista 32 bit OS.

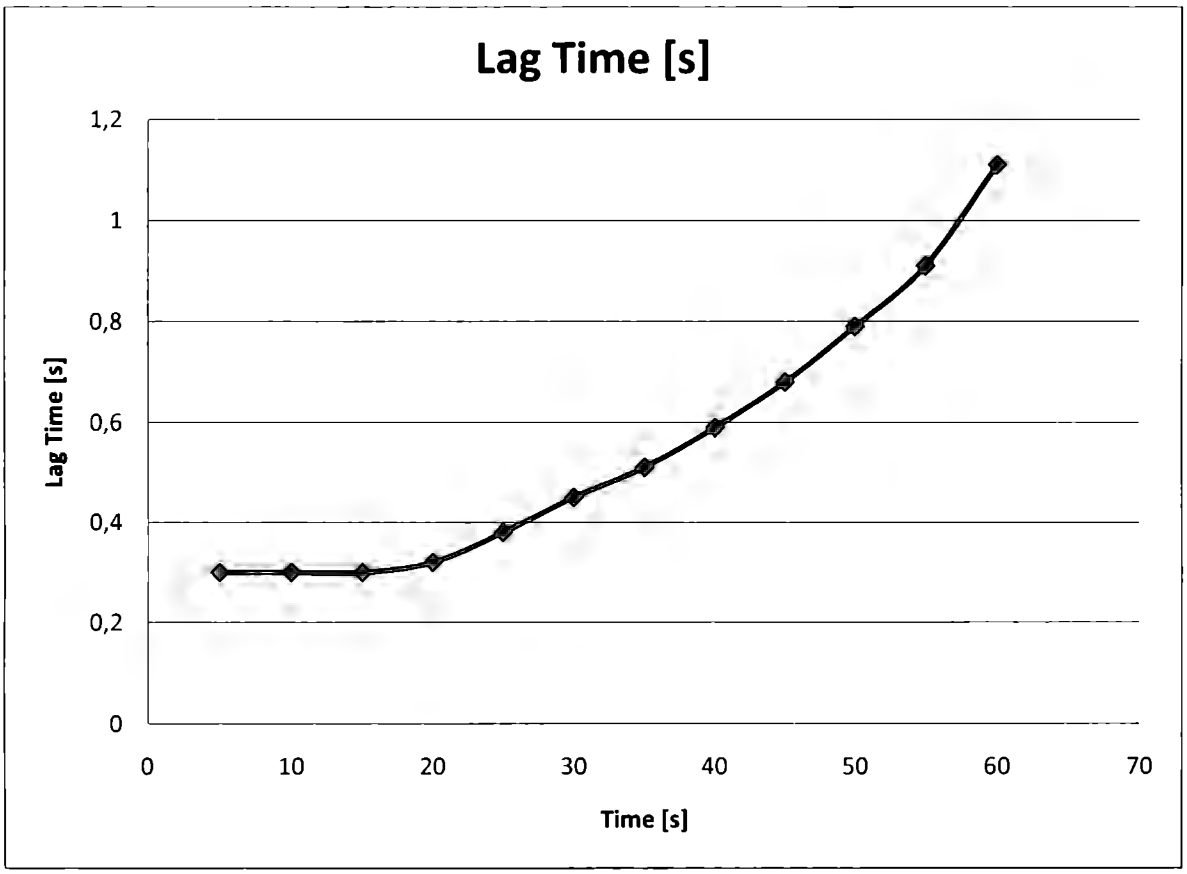


Fig. 5.4.1 Reaction time

As we see the performance of the computer decreases as the RAM gets filled and the core processor gets warmer.

5.5 Threshold manipulation in the EOG circuit

The acquisition is done through a threshold system. Taking the blink movement as an example, we know that the signal will resemble to a sinusoidal. Knowing so will help us to create our threshold constants. For this movement the upper threshold is 1V and the lower one is -0.6V, this means that unless the incoming signal goes through 1V in the first rising part of the signal and through -0.6V in the second part of the signal, the program will not record it and thus will not use it.

Using these thresholds allows us to differentiate two important things. The first one is the incoming ambience noise, which generally will not go through our threshold limits and thus will not be computed. The second one is the differentiation of all five signals. This is important since some signals are very alike, given this first differentiation and the training of the Hebbian Neural Networks, the system will recognize with no doubt each of the five eye movements used in the project.

5.6 Interference or noise in the EOG circuit

Our EOG circuit is a very sensitive device. Coming from the idea that it can detect signals that are generated with 200μV of amplitude, the circuit will be affected by almost any kind of noise. Working in a lab often has disadvantages and field tests must be performed. In our case we didn't plan a field test for the project. Instead having a presentation in another school and outdoors gave us the opportunity to analyze the accuracy of the circuit in every-day life conditions. This test's results were not really satisfying because we noticed that amplifying such little signals also amplifies incoming noise.

Normally the power of transmission of any kind of antenna or device must be normalized to ensure that this will not cause interference with other signals and devices. Law in Mexico in our times is not really applied, causing a globalized chaos in these kinds of fields. This means that not all devices and antennas are normalized and almost always transmit in higher power than they should be. With this in mind and understanding that our circuit is capable of amplifying very weak signals we conclude that this is a problem. The outdoors test in that school proves our theory. That day the circuit was performing awfully, we didn't understand why ambient noise could affect our circuit so badly; until one of the local teachers explained to us that the school's radio station was just behind us.

The result of the test was unrecognizable signals. This put us in a complicated situation, and so we modified the filters in LabVIEW. Before this test we only had low pass filters with a cut frequency of 12 Hz, this permitted the low frequency signals from the radio station to be amplified and included in our circuit. Changing the filter to a band pass filter with cut frequencies of 7 Hz and 12 Hz, allowed us to clear our signal of almost any incoming signal besides from those of the eyes.

Having had such a problem made us think about the security and certainty of receiving the true signal. Having a low cost detection device will always be a problem and a disadvantage in any kind of project. But another test outside of the lab allows us to say that our circuit is not the problem. In October 2009 the wheelchair was presented in a contest in the University of New Mexico in Albuquerque New Mexico. Regulations and law in the United States of America are stricter than in Mexico. By respecting the regulations all devices can co work in the same areas without affecting each other. Even though we were testing the chair outside the lab and in another country, the system worked perfectly even by being in the broadcast area of the UNM radio station, which proves that the EOG circuit can and should work with a high certainty.

5.7 Comfort given by the electrodes

One of the most asked questions in every presentation has always been if the electrodes are hard to place and if they are uncomfortable. The position of the electrodes is not really a problem. Placing the electrodes some millimeters away of the ideal position will not affect their performance.

The comfort of the electrodes is not really a discussion subject. They are not comfortable, but given the situation of the patients we consider that getting used to have them on the face is less painful, than getting used to be fully dependant of someone else.

Tied to the comfort comes the tiredness state of the patient. As the time flows during the day the patient will become tired not only of controlling the chair with the eyes but also from every-day life. To avoid miss directions we thought of a retraining system for the chair. This system isn't yet programmed on the chair's core, but could be a great addition to the control.

In the following charts we will present the accumulated error from the signal comparison to the saved signal to the time, this will show that the error will increase significantly as the use of the chair goes by. The charts are done by tracking the error from the UP movement.

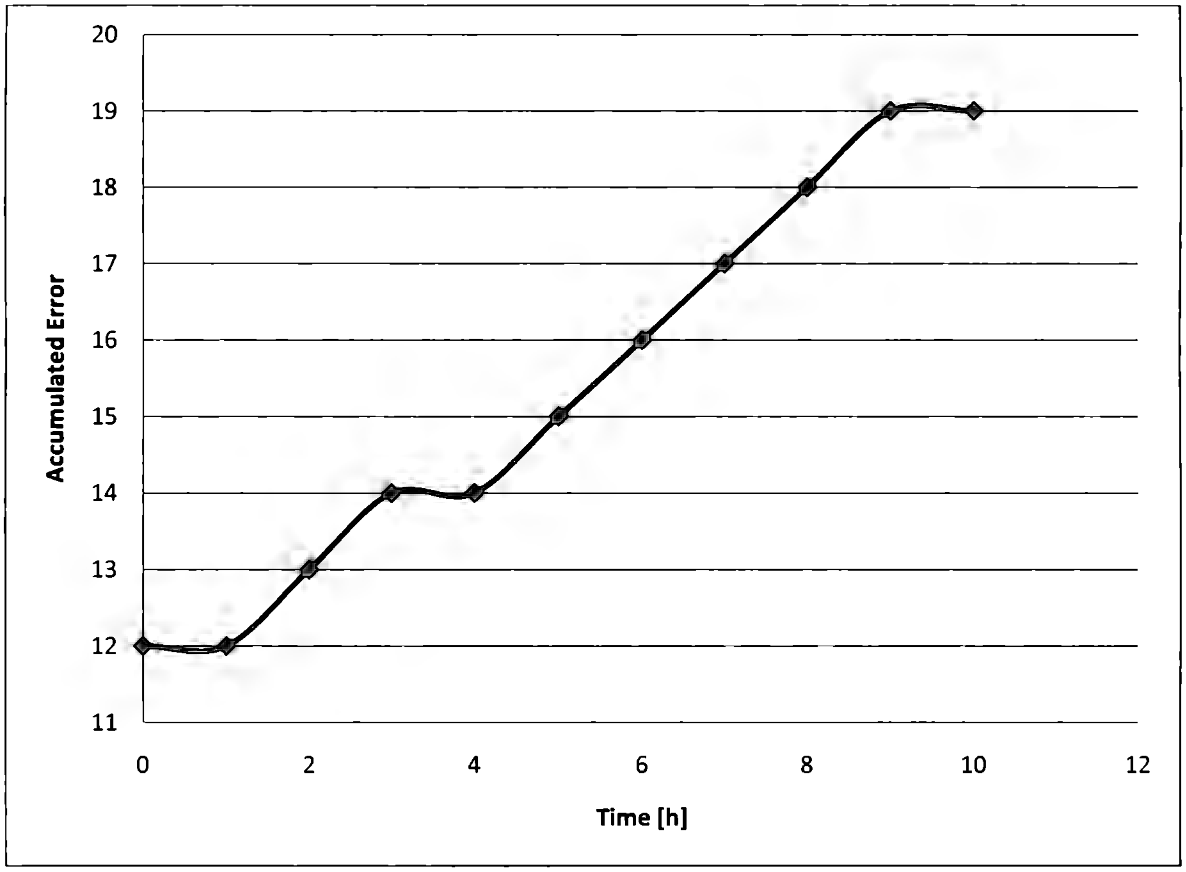


Fig. 5.7.1 Un-retrained test

In the following scenario we present what could happen if the Hebbian Neural Networks would be retrained as the day goes by.

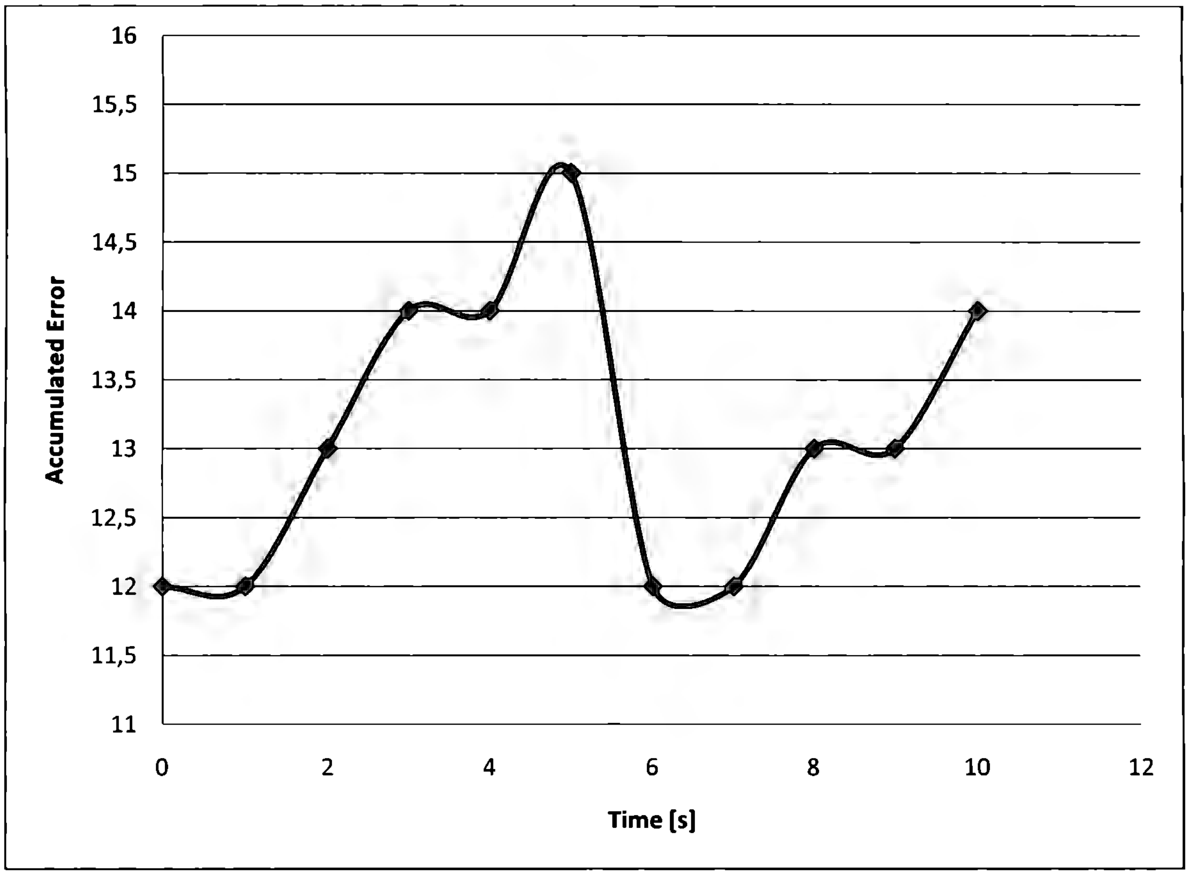


Fig. 5.7.2 Retraining test

Comparing both scenarios we conclude that the retraining of the system is necessary, because of time we couldn't add this to our project, but we would like to suggest our following coworkers to include this.

6. Voice Messages System

Analyzing the problems that quadriplegic people have in everyday life the idea of adding prerecorded voice messages to the chair's system was brought to the table. Using the EOG system as control to select the prerecorded message the voice message system was added.

This program works in the same way as the EOG. the patient will select the prerecorded message by moving the eyes in a direction.

Fig. 6.0.1 shows the connection diagram of the EOG to the message selector and the message playback connection, taken and simplified from a given example in lab view. The Boolean variable set to true will select the message by locating the path in the computer and playing it.

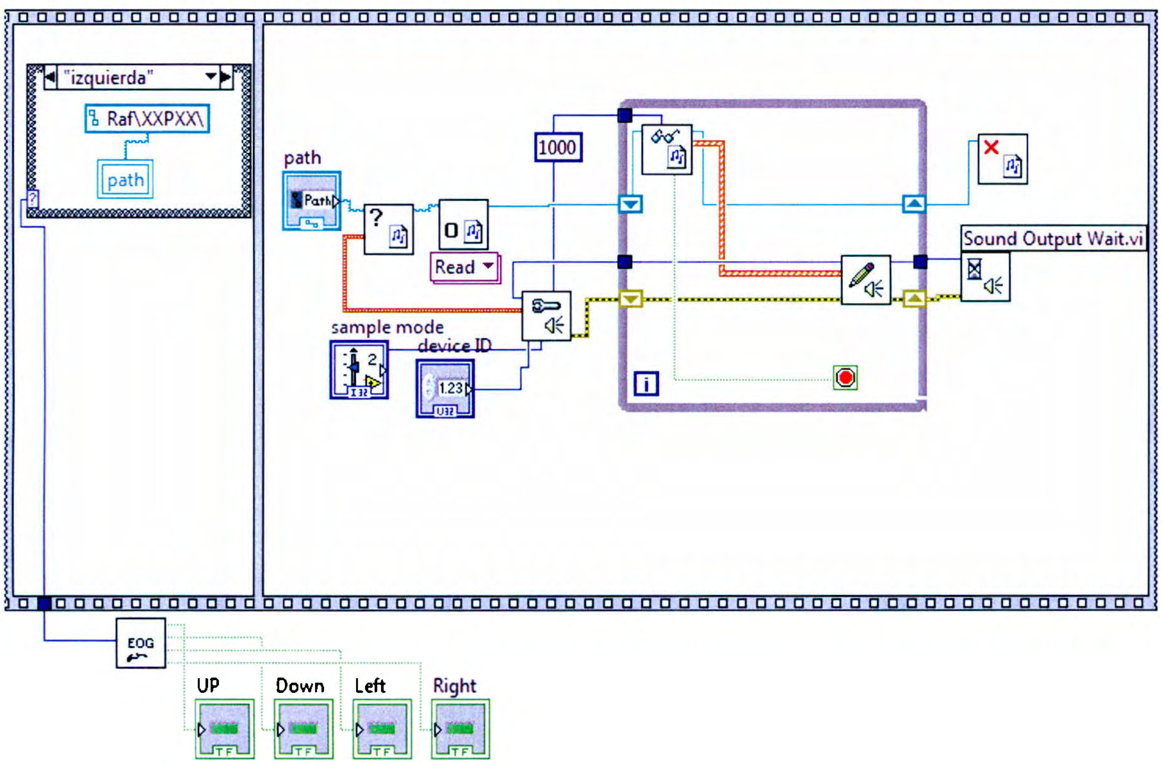


Fig. 6.0.1 EOG system used on the message selector and the message playback

The sound output programming consists in 3 basic steps, opening file, reading file and closing file the whole sequence is described below.

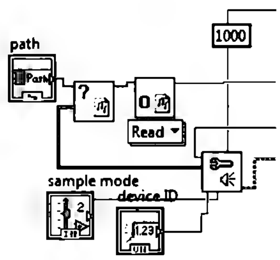


Fig. 6.0.2 SubVi that let us choose the wav file to reproduce a pre-recorded sound

Fig. 6.0.2 shows how the file path is read by the information retrieve vi, after it has been checked for errors the file is opened, meanwhile the configuration vi sets ready the output device in a continuous samples mode with a 1000 samples limit.

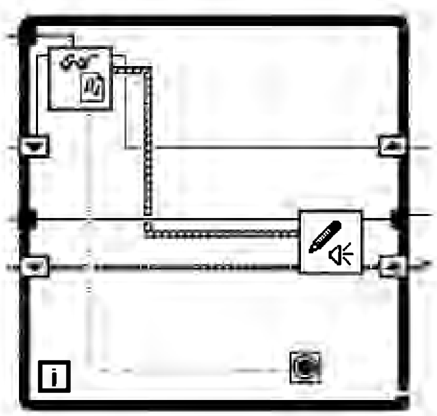


Fig 6.0.3 SubVi that enables the reproduction of the message

Fig. 6.0.3 is the while structure that will play the whole file sample by sample. The upper left vi reads the file and sends the information to the output write vi. When the file reading reaches the end of the file generates a signal to stop the while. Once the while is finished the file is closed with the red cross vi in fig Xx and there is a small delay in order to let the speakers sound, the delay is shown in the lower side of fig.

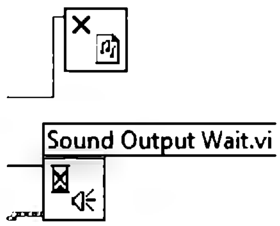


Fig 6.0.4 Vi that delays the time of the next reproduced sound

The next diagram shows the whole picture of how audio message displaying works in synergy with the eog recognition methods.

Fig. 6.0.5 Sound diagram

6.1 Voice control system accuracy test

The system was tested under different circumstances to prove it's accuracy in various ambiences, see Fig. 6.1.1

140 dB	Umbral del dolor
130 dB	Avión despegando
120 dB	Motor de avión en marcha
110 dB	Concierto
100 dB	Perforadora eléctrica
90 dB	Tráfico
80 dB	Tren
70 dB	Aspiradora
50/60 dB	Aglomeración de Gente
40 dB	Conversación
20 dB	Biblioteca
10 dB	Ruido del campo
0 dB	Umbral de la audición

Fig. 6.1.1 Levels of noise

The test was performed using the computer's integrated microphone. Using the information on Fig 6.1.1 about sound levels in different ambiences we could use the voice commands to check the recognition's accuracy. The results are presented in Fig 6.1.2

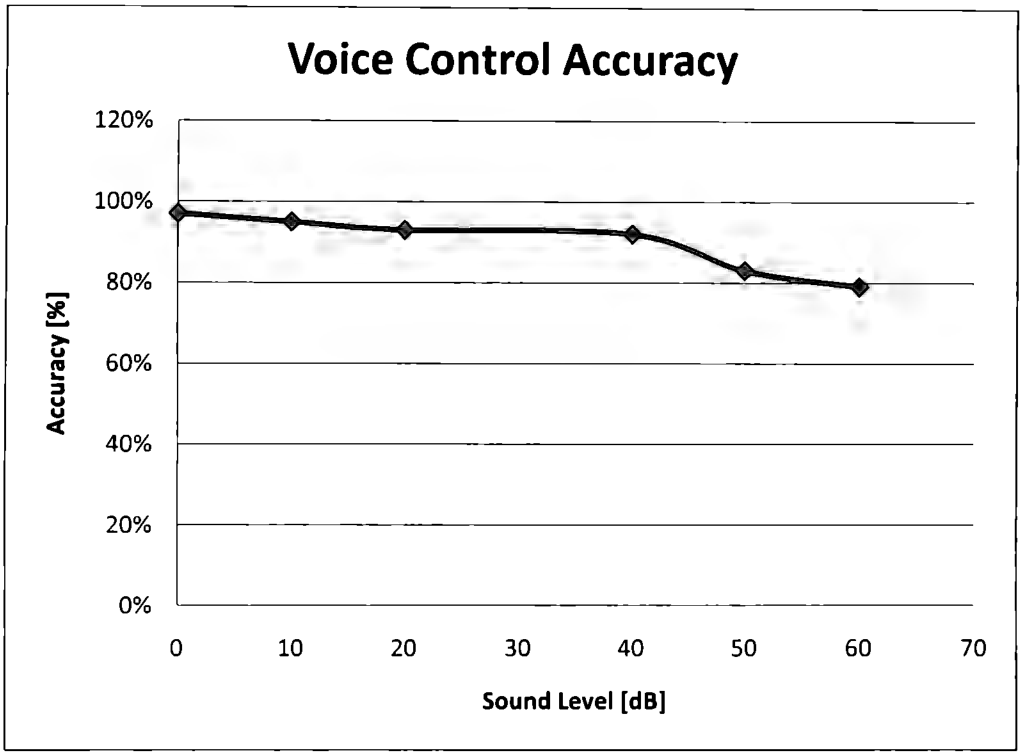


Fig. 6.1.2 voice control accuracy

Results show clearly that the use of the Voice Command System has no problems indoors. While using the wheelchair in the laboratory or the library even when the surrounding people are having a conversation we encountered accuracy greater than 90%. When the test was performed outdoors and near big people's gatherings the accuracy fell to an average of 80%. This test shows that the system is working as it should be and the use of the Voice Command System indoors would encounter no problems at all.

6.2 EOG training test

As soon as the training program for the Electro-oculography was ready we started acquiring data about the accuracy of the recognition system. Our test subject was Rafael Mendoza and data was collected from day one until the last week of October 2009, testing the accuracy of the system while in use. The results are presented in figure 6.2.1

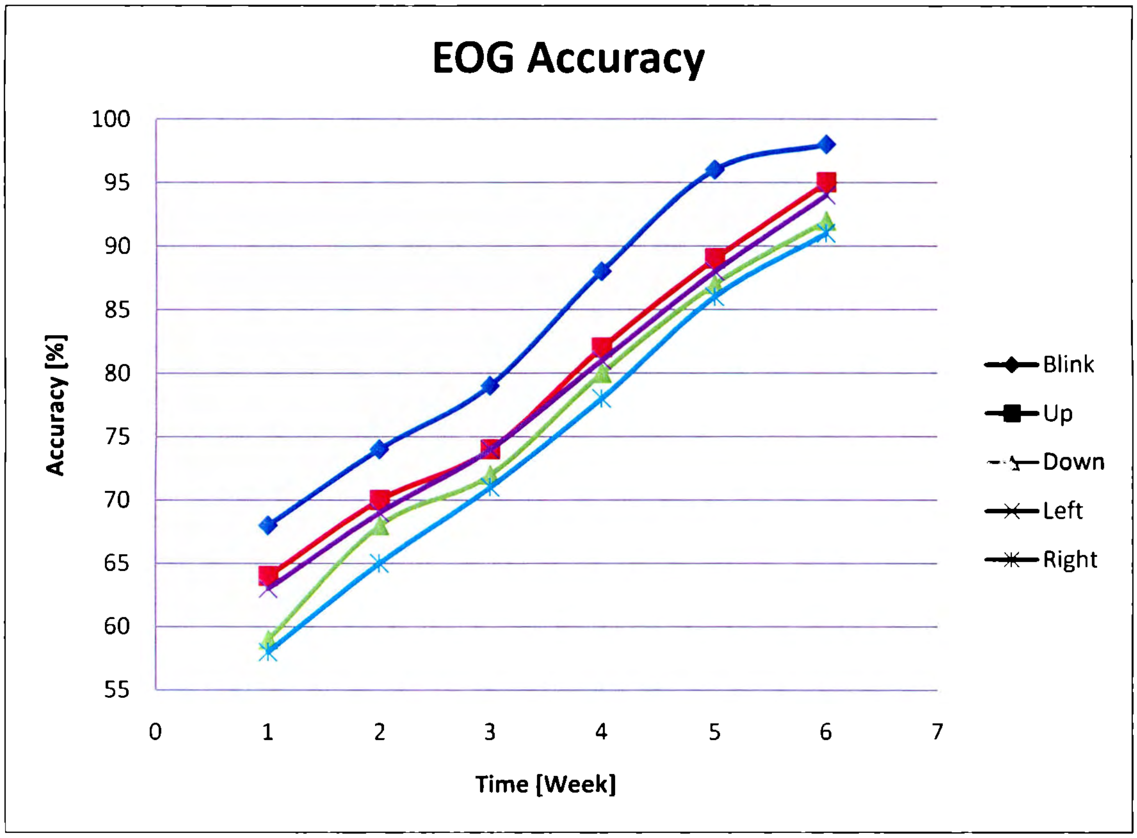


Fig. 6.1.3 EOG Accuracy test

The graph clearly shows how the accuracy of the system improves as the patient uses the wheelchair. In week one the accuracy of every eye movement is around 60% and as the patient gets used to performing the same movements the accuracy increases almost linearly through time. By the end of week six the precision of the system is of about 95% for every eye movement. Even if the system should adapt itself to the patient it requires that the patient learns to do approximately the same movements each time.

7. Results

7.1 Test and visual analysis

Once the EOG (electro-oculography) circuit was working we began to work with the different kind of signals generated by the eyes. The first obtained signal was the blink, this is as following:

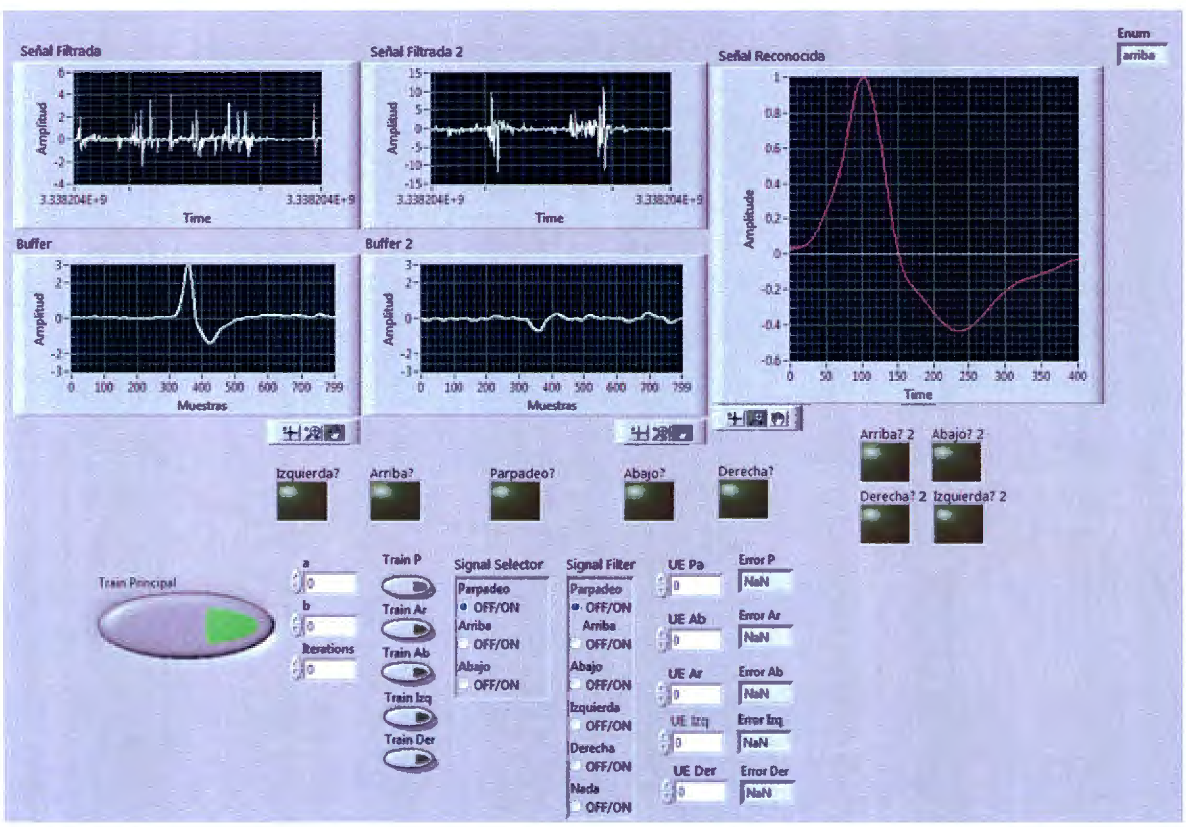


Fig. 7.1.1 Blink that represents "to look up"

If we delete the high frequency noise there will be a signal very close to a sinusoidal signal. the period has duration in the range of 100ms depending on the blink speed having as central value of 400ms and a period in about 250ms. Another important characteristic is the generated amplitude; we can see in the image how it reaches a top level in the range of 5 V and a low in about 4V. This amplitude is variable depending on the person.

Over this channel we took movement samples that indicates the up and down movement. By this way we could obtain the following data:

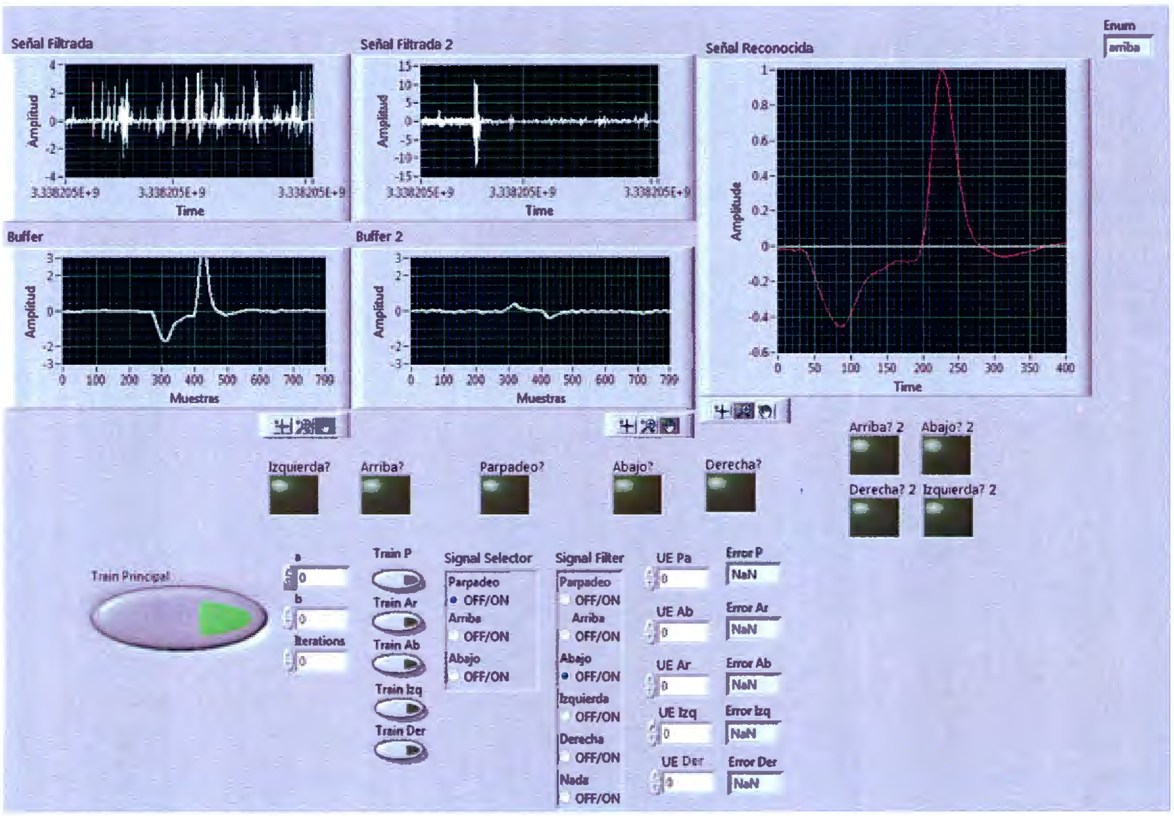


Fig. 7.1.2 Signal that represent the "look down"

For up and down movements we can appreciate almost the same characteristics than in the blink signal with the difference of a null section in which no movement is detected.

This is due to the creation of the voltage between the retina and the cornea during the movement. When the eye moves up a voltage is generated, if it stays up no movement and therefore no voltage is registered; when the eye moves back to its original position an inverse voltage is detected.

Analysis on the horizontal channel is performed in the same way, it is important to know that the blink, up and down movements will not be detected in this channel and vice versa. In the following figures the different oscilograms will be presented.

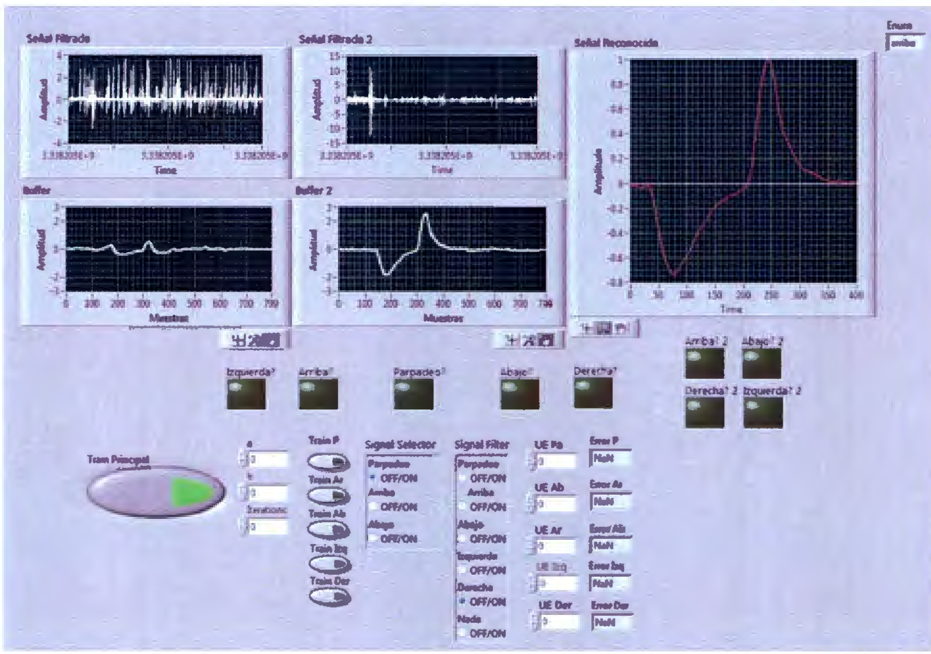


Fig. 7.1.3 Oscilogram that represents to look right

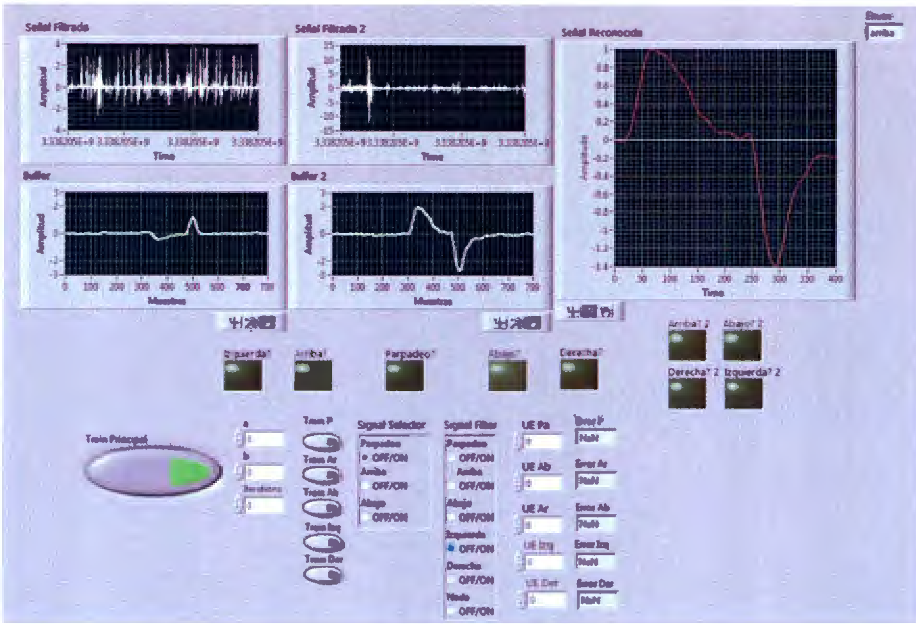


Fig. 7.1.4 Diagram that represents to look left

As shown in the figures we can notice that the signals in the horizontal channel are like the vertical signals, this allows us to analyze and compute them in the same way as the blink, up and down signals. Once we obtain the signals we notice that they are very logical. Signals of an up movement will start by presenting a positive voltage and then a negative section, so we infer that the directions of the movements are directly related to the properties of the signal.

Knowing the five different signals permits us to start programming the system to learn and understand the incoming signals and to perform a comparison to execute a command.

Having developed and performed tests on all the systems described above, we can prove that creating a wheelchair that can be controlled by eye movements or voice commands has been a success to improve the mobility not only in quadriplegic patients, also to help other kind of patients that have other kind of injuries.

In resume we integrated four systems on the chair. The first one is the EOG system, this system comprehends the EOG circuit, Artificial Neural Networks, and PWM generation. We believe that this system works in a right way, and that's why this test was a success. The second system refers to the Voice Commands, this system was created by modifying Speech Test 8.5 and using Windows Speech Recognizer, the system responds to four commands: *Derecho, Derecha, Izquierda and Atras*. The chair does move in the indicated direction, which allows us to conclude that this test was successful.

The third system is the Voice Message feature, the chair can reproduce prerecorded voice messages, this is done using the EOG system, by moving the eyes the user is able to play the messages and have a spoken interaction with the people around him. The test for this feature was playing four different messages, the chair can now reproduce four messages by moving the eyes up, down, left or right, the test was then considered completed and successful.

The fourth system is the Avoidance feature. This system is intended to be integrated in the first two, for the moment we could only complete tests with the chair navigating alone, t his due to the low computing capacity (RAM memory) of our equipment. Inspite the computing difficulties, the test performed was considered a success when the chair was able to avoid six non moving obstacles and two students walking in the chair's way.

Having concluded all the above proposed tests with success we can conclude that we have completed the proposed problematic for the wheelchair.

8. Interview with experts.

Because this Project is made to help people with some type of disability specially quadriplegic patients, we needed to go to an expert looking for its opinion and indicate us what happens in real life with patients that have this disability, we were looking for the actual solutions for moving or simply stay motionless. It was determined that because of the type of disability and patients problems the motion of the chair should be very carefully controlled based on the velocity indications for each type of disability. The damage of the person should determine a maximum velocity since it is not the same to be only damaged from the neck than having a problem involving the whole column.

The specialist we interviewed was Jorge Letechipia, director of rehabilitation engineering and technology center of the national rehabilitation institute who has a wide experience in wheel chairs and orthopedic apparatuses. The fist issue to talk about was about velocity depending on disability type, the answer was immediate "in Mexico it doesn't exist", the reality of our country is that the doctors sometimes specify wheelchairs that don't fit the patients need because of the lack of money. Because of the poverty in our country 90% of the people who need wheelchairs actually can't afford them. Some of these protocols are being worked on in the United States in a very effective way, but in Mexico this information is not available because the doctors have not studies about this.

In the other hand it was also mentioned the technology used by our system, the ocular movement one, would create eye movement instructions to generate a previously programmed response. This technology was compared to others in which voice commands are used, this system was added lately to our prototype, even though it was mentioned to be bad because of the environmental noises. The use of electrodes was a good idea but there was a main concern in this, the patient's side of the story, using electrodes attached to the face could generate self esteem problems to the patient. Another issue was brought to light when talked about the economical problems when manufacturing the chair, the assembly in the country is usually to expensive when batch manufacturing is taken into account.

As main observation the first thing to do is to look for ways in how to reduce the cost in order to get a significant competition market price, mainly focusing on making it feasible to people with disabilities in the country. Also there is a good thing about this type of project because it can generate technological employment which doesn't exist in the country.

9. Conclusions

The complete system works well in a laboratory environment. The signals from eye movement and voice commands are translated into actual movement of the chair allowing people who are disabled and cannot move hands or even head to move freely through spaces. There is still not a full version that can run avoidance system at the same time as the chair is been controlled with eye movement. This should be the next step for further work.

As it was intended we successfully completed the four main control systems which give the wheel chair more compatibility and adaptability to patients with different disorders. This allowing the chair to move with the eyes for those who cannot speak, speech recognition for people that cannot move and directional buttons (joystick) for any other users.

Many problems were presented at the time of trying to interfere between the system already built by the manufacturer, the use of magnetic inductors is one of the temporal solutions that should be eliminated even though the emulation of the joystick is good and works well. The use of these inductors produces lots of power loses reducing the in-use time of the batteries considerably. Also generates a small retardation to the

The use of windows vista speech recognition software also enters some faults to our system since it is well known this user interface is not well developed and sometimes doesn't recognize what we are saying, which is not that good for a system as ours that requires a quick response to the commands.

With this project we demonstrate how intelligent control systems can be applied to improve already existing products. When using intelligent algorithms we widen the possibilities of interpretation and manipulation.

Many things had to be studied carefully in order to understand how the chair works; finally we got a true understanding on some of the systems that were already implemented in the chair so we were able to work with and apply new knowledge to the actual building of the prototype. Many improvements we made, some big changes were done to what was before. The circuits for EOG control were rebuilt, the programming was done from bare nothing, adaptation of other systems to motion control were added, and a redesign of the chair adding space for our devices, these and other hard work leaded to the successful building of the prototype, now we can say we have a complete adaptable wheel chair system.

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