

Human-machine interfaces using fuzzification of facial movements to remotely control robots by means of XMPP internet protocol

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Abstract: - Currently there is a great development with respect to the creation of different types of human-machine interfaces that allow interacting people with electronic, mechanical or computational elements. Today, these interfaces are necessary due to the large number of technological aspects with which we find ourselves daily, being able to have control of technologies as diverse as remote control toys, industrial robots, and even fully automated houses. Classic interfaces present designs that require cumbersome or complex elements when they are used, resulting in rigid and unnatural communication with the devices we want to control, in addition, they may not be tools that can be easily usable by people who do not count with prior technical knowledge, or even by persons who have physical disabilities. Due to the aforementioned, it is necessary to generate human-machine interfaces that present natural interaction between the entities involved, as well as being easy to use by any type of person, without the need for prior specialized training or the need for physical manipulation to its use.

This work shows the development of an interface that can control a remote device by characterizing facial movements using fuzzy logic. Creating a natural interaction between the individual and the device to be controlled. This implementation is able to establish a remote communication with any electronic device through the Internet via XMPP protocol, which gives a dynamism of control over virtually any geographical position in the world where exist an Internet connection, in this way, it is possible to be able to integrate it into the Internet of things.

Key-Words: - Human-machine interfaces, Fuzzy controllers, XMPP, facial movements.

1 Introduction

Many human-machine interfaces (HMI) are developed and used every day to control various electronic and mechanical devices, such as smart TVs, drones and terrestrial, marine and even space reconnaissance robots. However, such kind of control needs of unnatural elements to work, for example: joysticks, radio frequency control (RF), teach pendants, and others.

This causes that a disabled or an untrained person can be confused and rigid when he tries to control any type of robot or technological device.

One of the biggest disadvantages of the classical interfaces is the fact that most of them are technological elements which can be manipulated by hands, this presents an adversity when people who have lost their hands, or don not have mobility on them, tries to manipulate such interfaces.

The generation and developing of human-machine interfaces which respond naturally and which can be controlled by different types of corporal behaviors, such as facial expressions, permits that any person can operate any device intuitively. In fact, almost any invalid person can

use this kind of devices because the interfaces do not require a body extremity to manipulate these controllers.

Human body, and in a general form any biological entity, possess unique traits and biological signals which can be used to manage a robotic system in a natural, e intuitive way. Many of these signals can be given by the facial movements of any person.

When common expressions or daily movements from a human face are used as controllers, a robot can be more easily handled, due to there is no necessity to learn commands or sequence of instructions.

Nowadays with the emergence of the *Internet of things* (IoT), and the connection of any technological device to the Internet, there is a great importance to be able to control robotic systems in big distances through a communication global network, for this reason a human-machine interface which can control and monitor any electronic device by the network of networks could has a great scientific and commercial impact. The advantages of this schema can increase with respect to the inclusion of population sectors with body disabilities, and population who cannot read or write. All of this, just because there is a more natural communication between the human and the device to control.

In the present paper, it is demonstrated that through the use of techniques of artificial vision it is possible to generate more ergonomic e intuitive controllers which can perform command actions in any kind of environments. The presented controller uses fuzzy logic to interpret the facial movements in order to convert them to control words.

It is necessary that the system be of low cost, and it needs to have the basic infrastructure to exchange information in order to have a penetration in population sectors of different social levels. Due to this situation, a project which uses the Internet communication protocol XMPP (*Extensible Messaging and Presence Protocol*) is proposed. XMPP was originally destined to send and to receive instant messaging. This protocol permits us, among other things, to transmit control signals between two separated identities, and to make easier their connection because anybody can use the free servers destined to this kind of tasks.

2 Preliminaries

2.1 Fuzzy logic

Fuzzy logic arises between the 60s and 70s, proposed by *Lofti A Zadeh* [1]. This logic permits to simulate the mechanisms of human reasoning in order to control the proposed system. It provides a mathematical model which can process the uncertainty from the human cognitive process, and in this way it can be possible to solve different kind of problems using mathematical and computational methods.

Basically, fuzzy logic is a manner to mathematically represent the uncertainty, and vagueness of a problem. When we are looking for a solution of a given problem, we have input and output variables, fuzzy logic allows the transformation of the input variables into its corresponding output, privileging the significance characteristics instead of the precision ones.

Fuzzy logic uses real values between 0 and 1 to indicate if a fact is completely false (0), or totally true (1), this is the membership degree corresponding to an input value in a fuzzy set. Being multivalued, an input can belong to more than one fuzzy set at the same moment, with a different membership value for each one. In this way, it provides a smooth transition between a pair of characteristics. All values which can take an input variable are called *universe of discourse*.

Once we have determined the different membership values of an entry to each of the sets in the universe of discourse we say that the variable has been *fuzzified*.

A standard control system based in fuzzy logic is showed in figure 1.

2.2 Artificial vision and OpenCV

Artificial vision (AV) is a scientific discipline which consists in acquiring, processing, and mathematical modeling the processes of visual perception of living beings, capturing images from the real world in order to generate numerical or symbolic data that can be quantified and codified, and then using that information in algorithms and software. Collected data can be used in the decision-making needed to carry out a given process. A system which uses artificial vision recognizes figures and patterns, among other things.

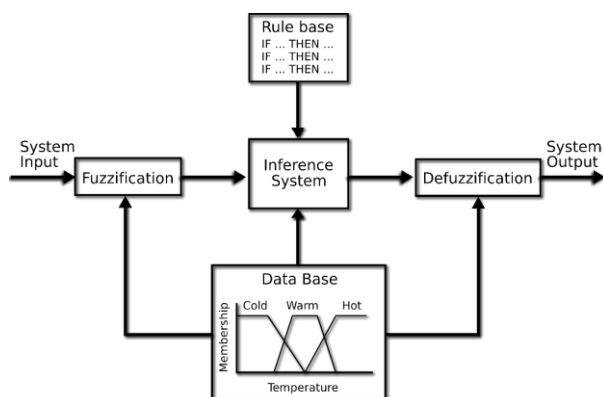


Fig. 1. Basic scheme of a fuzzy system.

Nowadays, artificial vision has great popularity over many technological, industrial, and services sectors due to the large amount of applications in which it can be directed. AV can solve problems of supervision in fruits and vegetables [2], obstacles detection systems in vehicles and smart transportation [3, 4], and even it is usefulness in the design, development, and generation of systems which can be helpful as prosthesis for blind people [5] [6].

Due to the big amount of uses that this kind of systems can have, there is many computing tools developed in order to facilitate the work of new researchers and developers in this knowledge area.

The number of software instruments to work with these schemes is in fact varied, ranging from the costly to the free, and from the private to the open access, however, for the development of this project we had used the Open CV (*Open Source Computer Vision*) library due to it is no restricted just to one operative system, it is compatible with *Linux*, *Windows* and *Mac OS X*, it has big dynamism, and additionally it has interfaces to work with Python¹, Ruby², Matlab³, and other languages.

Open CV is an open source library developed by *Intel* to be used in C language. It is oriented to work with real-time applications, for this reason it is a really good option to be used it in facial recognition [7], tracing movements and objects detecting tasks [8], and functionality on mobile devices [9]. The last of great importance and interest for the development of the proposed project.

¹ <https://www.python.org/>

² <https://www.ruby-lang.org/>

³ <https://www.mathworks.com/products/matlab.html>

2.3 XMPP, communication protocol

Extensible Messaging and Presence Protocol XMPP, is an open protocol based on XML (*eXtensible Markup Language*), designed to give solutions related to real-time communications. This protocol is daily used by many companies⁴.

Some of the most notable advantages of XMPP are:

1. *Decentralization*, XMPP works with decentralized client-server networks, due to this fact anyone can install their own XMPP server, and make a connection to the rest of the network using the Internet infrastructure or by a subscription to a public server.
2. *Safe*, the protocol core has SASL (*Simple Authentication and Security Layer*) and TSL (*Transport Layer Security*), which provides encryption and safe authentication algorithms.
3. *Extensible*, due to the XMPP core is based in XML, it is possible to obtain custom applications such as instant messaging services, voice over IP, communication between machines, notifications, and alerts. In order to maintain the interoperability of the XMPP applications, *software foundation* manages the most of the extensions.
4. *Open standard*, Internet Engineering Task Force (IETF)⁵ has formalized the XMPP protocol as an instant messaging standard [10].
5. XMPP protocols are free, public and easy to understand.

All the presented advantages of the XMPP protocol are useful in the development of human-machine interfaces which can control technological devices remotely.

2.3.1 Basics of XMPP

Each XMPP entity requires an identifier called a JID (*Jabber identifier*), which is composed of the user name, and the domain to which the resource is connected. The format of this identifier is like that of an email address "user @ domain / resource".

Using XML transmission technology, XML elements known as *stanzas* are exchanged between two entities in a network. A stanza can be understood as a basic unit of information. There are three types of stanzas in XMPP:

- a. The *message stanza*, transmits information from one user to another, contains information

⁴ <https://xmpp.org/uses/social.html>

⁵ <https://www.ietf.org/>

from the sender and recipient, as well as the content and subject of the message.

- b. The *Presence stanza* reports on the availability and status of a user on the network. Only those who have the contact of a user can see their status.
- c. The *IQ (Information / Query) stanza*, provides a request-response structure between network users.

2.3.2 Process of delivery of the messages.

Assuming two users with subscriptions in different domain, `quijote@lamancha.net` and `dulcinea@toboso.net`, when Quijote sends a message to Dulcinea the following events are triggered (see figure 2).

1. Quijote connects to `lamancha.net` server.
2. The server `lamancha.net` negotiates and opens a connection with `toboso.net`, in case that the connection is not achieved, the message is discarded.
3. The server `toboso.net` delivers the message to Dulcinea, if it is not online, the message will be delivered later.

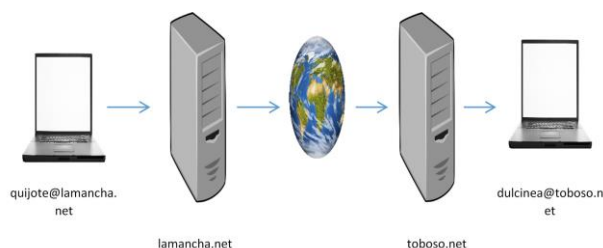


Fig. 2. Basic scheme of sending and receiving data through XMPP.

2.4 Internet of things

The *Internet of Things* (IoT) is a paradigm that quickly gains ground in the world of modern wireless telecommunications. The main idea of this paradigm is that many elements such as sensors, TV devices, appliances, telephones, among others, are able to interact between each of them through the Internet [11].

In this area, XMPP can not only be used as a protocol to send instant messages between two humans, but can be used to send commands between humans to objects, sensors or actuators and in this way, an automated remote control.

2.5 Raspberry Pi

*Raspberry Pi*⁶ is a reduced-board computer, meaning that all its components, including processor, memory, and input and output ports, are integrated into a single board. The processor that has the board is an ARM⁷ that runs at about 700 MHz, its RAM is 1 GB, and both in addition to the graphics processor are encapsulated in a single chip. Raspberry has user-configurable input and output pins that are programmable by the user, allowing you to interact with sensors and actuators. System storage is done on a micro SD card in which the operating system is also installed, this allows to change the functionalities of the card only by changing micro SD card. Raspberry can connect to the Internet through an Ethernet port or in some models using WiFi, allowing you to interact with remote applications too.

The software that can be installed in Raspberry Pi as an operating system is commonly based on Linux distributions for ARM, such as *Android*⁸, *Firefox OS*, *Pidora*⁹, but the most common and also officially supported is *Raspbian*¹⁰, based on *Debian*¹¹, which has preinstalled features destined to the development of applications, like Python and Mathematica among others.

Raspberry Pi was developed by the *Raspberry Pi Foundation* in the UK, intended to bring young people to the development of skills in computer science, but the low cost, small size, ease of connection to the Internet and interaction with sensors and actuators have expanded the uses that can be given to this computer. In this sense the applications can go from a personal computer, an entertainment center or a system dedicated to specific tasks in the scientific, academic or industrial sphere [12].

An important fact to use Raspberry Pi is that it has been analyzed as an element that can be linked quickly within the IoT network [13].

3 State of the art

As already mentioned, fuzzy logic was proposed in 1965 [1], but this development was only the beginning of all the possibilities that this concept

⁶ <https://www.raspberrypi.org/>

⁷ <https://www.arm.com/>

⁸ <https://www.android.com/>

⁹ <http://pidora.ca/>

¹⁰ <https://www.raspbian.org/>

¹¹ <https://www.debian.org/index.es.html>

could generate. From that moment, an endless number of applications have been proposed and developed.

Bose described in 1994 [14] that artificial intelligence will open the way to a new era in electronics and motion control in the decades to come. In his work he defined concepts such as neural networks and fuzzy logic, and how these concepts can be applied to areas of electronics and movement control, showing the wide range of applications that can be developed and explored.

Although *Bose's* claim was correct, in the absence of a logical demonstration proving such an assertion, there was no way of corroborating that such applications could actually be carried out, however, *Castro* proved in 1995 [15] that control systems based in fuzzy logics and membership functions were able to approximate any real continuous function within a compact set of arbitrary accuracy. With this thinking, he tried to answer the question "Why does fuzzy control have such a good performance for a wide variety of practical problems?" This point is important because it generalizes the operation of a fuzzy logic and its relations of belonging, for the solution of particular cases by means of this concept, giving an explanation of why many applications could be elaborated by means of this logic.

Zadeh in 1996 [16] presented a methodology where daily used words, instead of numbers and abstract elements, are used to perform computational calculations, he mentions that computing with words (CW) is a necessity when the available information is too imprecise to justify the use of numbers. This methodology can also be used when there is a tolerance to imprecision that can be exploited to achieve malleability, robustness, low cost of solution and better relation with reality, exploitation of tolerance to imprecision is a vitally important issue. In his work, the premises are assumed to be expressed as prepositions in a natural language. The inference rules of fuzzy logic are used to propagate constraints from premises to conclusions.

According to *Zadeh*, in a traditional sense, computers require the manipulation of numbers and symbols to process information. In contrast, humans mostly use words in calculus and reasoning, arriving at conclusions expressed as words from premises expressed in natural language. Words have fuzzy

denotations when used by humans, giving an analogy to the fuzzy treatment of information.

According to *Isermann* [17], fuzzy control at a basic level must be attractive in processes where only qualitative knowledge is available and there are nonlinear properties or where human control is limited. In his work, he shows how fuzzy logic approaches can be applied to process monitoring, and to fault diagnosis with approximate reasoning about observed symptoms.

In [18], *Pires* and *Nunes* described a reactive shared control system that allows semi-autonomous navigation of a wheelchair in unknown environments. The authors generated a fuzzy controller and showed three types of behavior: Intelligent obstacle prevention (combining commands by voice or joystick), collision detection, and contour tracking.

According to the authors, their work is focused on helping people who are unable to run their own wheelchairs because of severe disadvantages such as tetraplegia or general muscle degeneration. Through a human-machine interface it is possible to contribute to the social independence of this group of wheelchair users.

The paper [18], is a sample of how the fuzzy controllers allow generating projects not only of scientific nature, but also of social nature. From the fuzzy processing it was possible to generate a technological device capable of helping a disadvantaged population sector.

When we talk about natural HMI, one of the possibilities of interaction with enough potential is the recognition of facial behaviors or emotional reactions.

According to *Wo*, the affective computer, is a computation that tries to approach or influence emotions, obtaining that it can have many applications in the future implementations of human machine interfaces, in [19] was proposed a system of affective computation that included recognition of emotions, the modeling of emotions and control of them. The author found that different people have different perceptions and different expressions of the same emotion, this is an important challenge to model within the proposed system.

According to *Ilbeygi* and *Shah-Hosseini* [20], the recognition of emotions plays an important and

effective role in human-computer interactions (HCI). Under this scheme, the authors propose a new method for recognition of emotions from facial expressions using fuzzy inference systems. Method that according to the authors, is able to recognize emotions of images with the face partially hidden. Reporting in their experimental results an average accuracy range of 93.96% for the recognition of 6 emotions.

Ilbeygi and Shah-Hosseini [20] divided the facial characteristics into two categories: 1. The primary categories; Opening of the eyes, opening of the lips, constriction of the eyebrows and displacement of the corners of the mouth. 2. The secondary characteristics: length of the mouth, wrinkles in the nose, existence of the tooth, slope of the eyebrows and thickness of the lips.

Not only the recognition of facial reactions is important and used in HMIs, any part of the body can be used as a control element. According to Chaudhary, Raheja, Das, and Raheja [21], hand gesture recognition (HGR) is one of the major areas of research for engineers, HGR can be applied from game control, virtual reality, to intelligent home systems. HGR is a natural way of interacting with computers and other machines.

There is a great amount of work related to the detection of manual movements as gestures of control. In [22], Rautaray and Agrawal, present a fairly complete survey related to this topic.

Within the applications of fuzzy controllers we have the project proposed by Ye, Yung and Wang [23]. They developed a fuzzy controller with supervised learning that could learn to avoid obstacles.

On the other, there is a control system that increases the speed of metal removal, while maintaining a constant shear force. It was developed by means of a fuzzy controller, this work was presented by Kim and Jeon in [24].

Shamir showed an application of a diffusion-based color segmentation method in [25].

There are a lot of applications in which fuzzy logic has worked properly. It is difficult to mention all the existing applications using fuzzy logic, however, in [26] a survey of some of them is presented.

4 Development

A remote control system was developed by means of Internet protocol XMPP, the control commands are obtained by means of an artificial vision system, and fuzzy logic that identifies the facial movements of a person.

The prototype is composed of two entities, one whose function is to generate the control words for the mobile robot through artificial vision and a fuzzy inference process, this will be called « console ».

The second entity is responsible for receiving control words from the console and activating the actuators in the mobile robot. This entity will be called “mobile receptor”.

Communication is done using the Internet as a transmission channel, using the XMPP protocol for sending data. This protocol is used in order to save resources by avoiding installing an own server, and making development faster by taking advantage of existing infrastructure and Internet services, the basic scheme of this system can be seen in figure 3.



Fig. 3. Basic scheme of the developed prototype.

4.1 Console

The console is the part of the prototype from where the mobile receiver is controlled. This entity is executed on a computing system complemented with an image receiving and capturing element such as a webcam.

The first step that the console performs is the acquisition of data through the camera, when recognizing that there is a face in its field of vision, the position of the center of the face is calculated, a value that is used as a reference point to determine the commands that control the mobile receiver.

One of the main features of the application is that once it has detected the face that will give the orders, the software follows the movement of the face within its particular field of vision, and this

situation allows the operation to be performed in real time.

Once the system has defined that a particular facial movement has been a command and not a sporadic movement, the facial position is calculated and the control word is obtained, it is at this time when the control word is sent as a text message through the Internet to the robot or element to be controlled, as can be seen in figure 4.

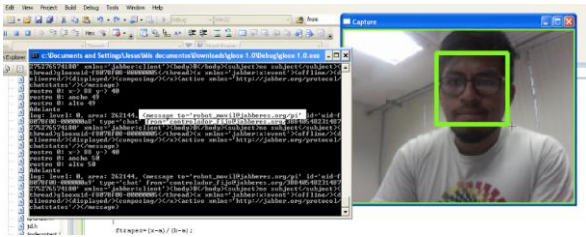


Fig. 4. Detection and sending of messages through XMPP to a remote robot.

To make the interface, the OpenCV library was used to generate facial recognition, and Gloop as an XMPP client.

The program follows the steps showed in Figure 5.

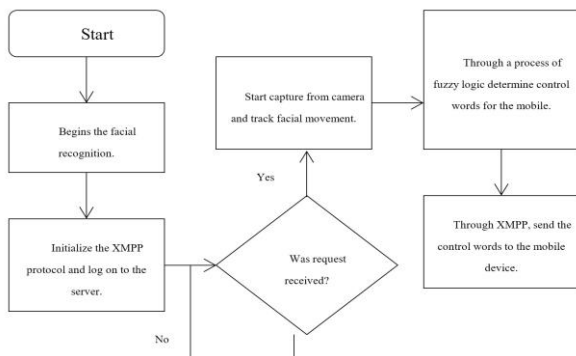


Fig. 5. Flow diagram corresponding to the behavior of the face detection system and sending control signals to a robot positioned in a different geographical area.

4.1.1 Creation of the instant messaging session

When the console is run, it connects to the messaging server and creates a remote session in which it reports its availability online, waiting to receive a message to open a chat session with the mobile receiver. Once session is opened, it starts facial detection and the process of generating and transmitting control words to any remotely connected device.

4.1.2 Detection and facial tracking

The description of the process completed by the console to make the facial recognizing and tracing is listed below.

- 1) Capture the image from the camera.
- 2) Convert the image to grayscale.
- 3) Equalize the histogram of the grayscale image to standardize the brightness and contrast of the image, so that in different lighting conditions the image content is not affected.
- 4) Once the image is processed, the classifier to be processed is loaded.
- 5) When the face has been identified, a pair of X, Y coordinates are generated for the upper left and lower right corners, these coordinates are used to generate a recognition frame in the area where the face is located, and therefore, to calculate the center coordinates will be used as inputs for the fuzzy inference system.

4.2 Inference system

It was decided by fuzzy inputs as they allow a gradual transition between variables, also if the user is into the camera’s viewing and he makes a subtle facial movement but without the intention of generating a change in the state in which the robot is, the fuzzy input allows a tolerance range to avoid fake commands.

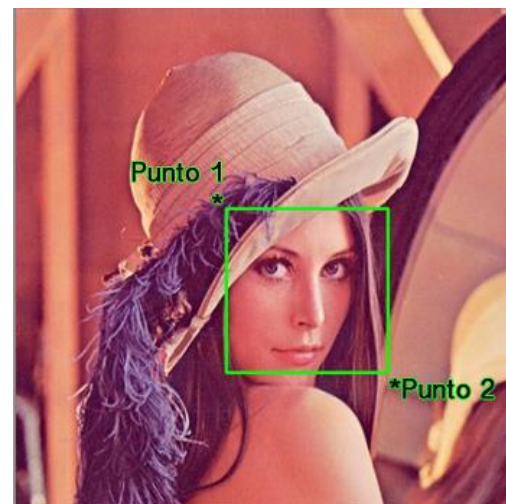


Fig. 6. Face identification by coordinates XY.

The camera's viewing area is divided into two axes, X, and Y, being the origin the upper left corner so that the values of the X axis grow to the right and those of the Y axis to the left, both in a positive way.

Each axis as output universe of discourse is divided into three membership functions which can be observed in figure 7.

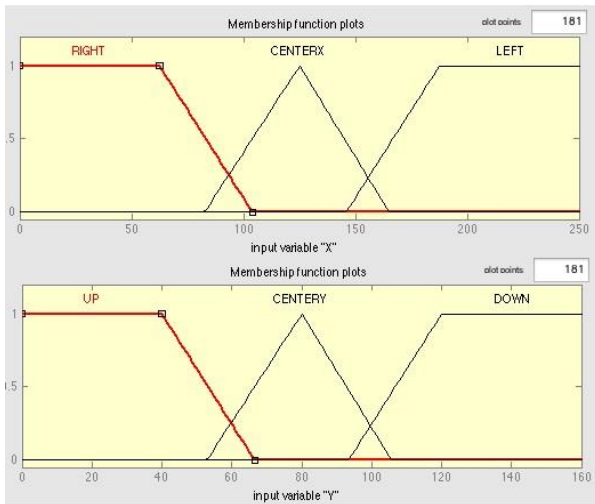


Fig. 7. Membership functions used for the identification of facial movements.

For the inference system was developed a *sugeno-type* with just one output variable, the variable has nine sets with constant value. With the inputs, and outputs sets were generated the rules showed in the figure 8.

With the rules (IF X=Left AND Y=Forward THEN Forward Left) showed in figure 8, it has been generated 9 different control words which will be sent to the mobile receptor. These words indicate to the robot the movement to do. There is a rule classifier with the velocities and directions programmed from the beginning in the mobile receptor.

		Left	Center X	Right
Forward	Forward Left	Forward	Forward Right	
Center Y	Left	Stop	Right	
Backward	Backward Left	Backward	Backward Right	

Fig. 8. Used rules in the inference system.

The inference system can be modified in order to have two continues output sets, a set by each actuator. Each set has to transmit to the actuators, or CD motors, the gradualness in the velocities and directions of the controlled robot.

The proposed system has an output with nine control commands, resulting from the 9 rules that can be applied, the output commands can be seen in table 1:

Outputs: command.		
Parameter	Transmitted command	Output function
1	A	RIGHTFWD
2	B	FORWARD
3	C	LEFTFWD
4	D	RIGHT
5	E	STOP
6	F	LEFT
7	G	RIGHTBWD
8	H	BACKWARD
9	I	LEFTBWD

Table1. List of sent commands to the robot.

The data transmitted to the robot is one of the commands shown in table 1. The robot will execute an action according to the received command, if it has received the "A" command, executes the RIGHTFWD function.

This inference method facilitates the transmission of the commands to be executed by the robot, so the robot should only classify the command it receives and executes according to the match with a list.

In figures 9 to 10, we can see a simulated example of the system.

When the inference process has generated the output command, this is passed as argument to the method which sends it through the messaging session that has been created previously. When it is ended the sending of the command, the program continues in a loop generating new commands until the session is finalized.

The session ends when the robot sends a message indicating to the console "terminate the connection".

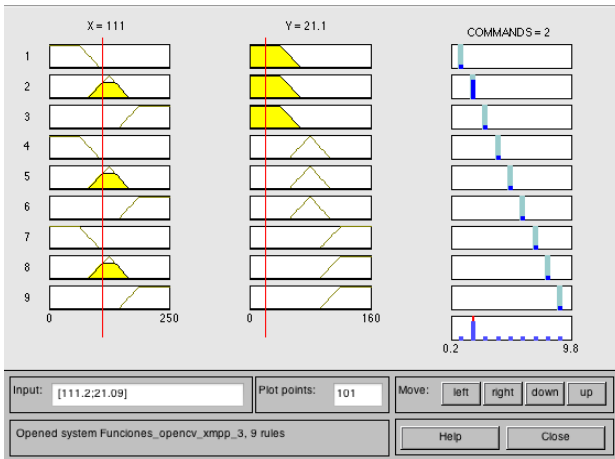


Fig.9. Simulated example with X=111, Y=21.1, and the transmitted command is 2.

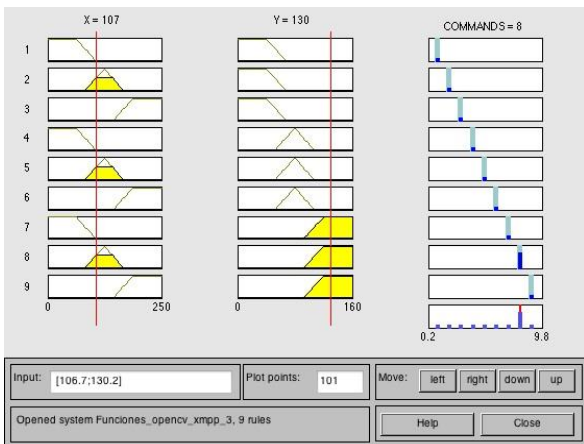


Fig.10. Simulated example with X=101, Y=130, and the transmitted command is 8.

4.3 Alternative method to lead a remote-controlled vehicle

There is another method to control the car in which two outputs are used, the inference is made of the Mamdani type.

The inference system would have two outputs with three sets. Each output corresponds to each of the motors, left and right. The data obtained from this system are the speeds at which the engines will be activated.

The behavior of such system can be seen in table 2.

The robot must be able to understand the speeds that must be assigned to each engine. The data

received would be used to modify the motor speeds using a pulse width modulator (PWM).

The advantage of this method is a lower processing load for the robot, and as disadvantage is that the speeds are fixed according to the values assigned in the list.

	Set 1	Set 2	Set 3
MotorL	BACKWARDL	STOPL	FORWARDL
MotorR	BACKWARDR	STOPR	FORWARDL
	If this set is activated, the speed value will be negative, indicating that the motor is turning backwards.	If this set is activated, the speed value will be zero, indicating that the motor is not activated.	If this set is activated, the speed value will be positive, indicating that the motor will rotate forward.

Table2. Behavior of the system's outputs, where MotorL is the output 1, and MotorR is the output 2.

We have simulated the method as can be seen in figures 11 to 14. Figures 11 and 12 show the inference system, and figures 13 and 14 show simulated examples.

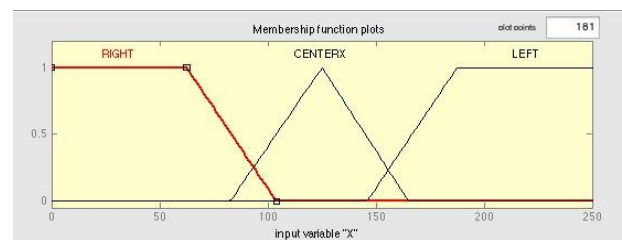


Fig. 11. Inputs membership functions, simulation.

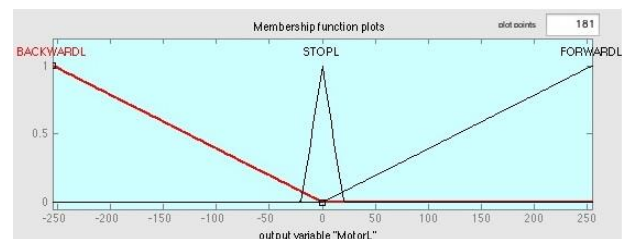


Fig. 12. Output set, simulation.

4.4 Mobile receptor

The mobile receptor is formed by the unit of control, power stage, and actuators.

Unit of control is formed by the Raspberry Pi board which receives, processes, and manages the commands that have been sent through the Internet. Raspberry uses the processed data to activate the actuators, cameras or any device connected to the robot, and control them according to the received instructions.

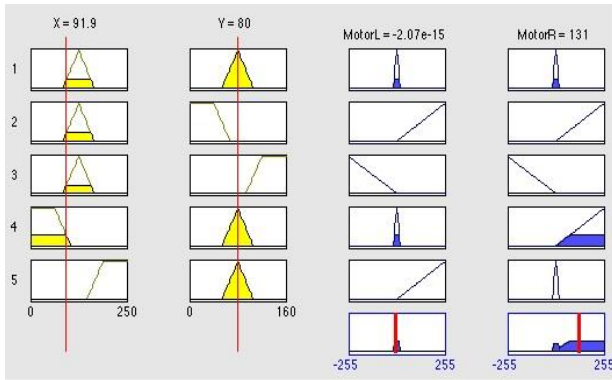


Fig. 13. Simulated example, different behaviors in the motors.

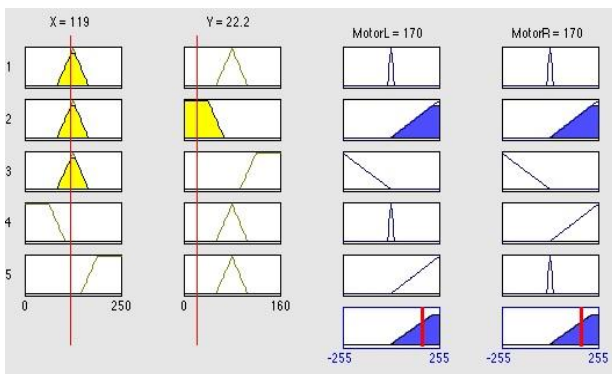


Fig. 14. Simulated example, equal behaviors in the motors.

It is very important to say that the Raspberry PI's GPIO pines are unbuffered and it has the level voltage of 0 volts for the logic zero, and 3.3 volts for the logic one, limited to 500mA. These levels are good enough to connect LED's (Light Emitting Diode), but they can destroy the board if a motor is directly connected, for that reason it is necessary to have a power stage between the board and the actuators. The power stage in this prototype is made with a simple electronic device: the H bride¹² which generates the necessary energy to turn on the actuators.

¹² An H bride is an electronic circuit which allows that a DC electric motor can rotate in both ways forward and backward.

In the proposed model, Raspberry was loaded with Raspbian¹³ as operating system, because it has development tools such as a Python¹⁴ interpreter.

The mobile receptor is ready to start a chat session and information exchange with the console when it has been successfully connected to the jabberes.org server, these steps can be seen in the figures 15, and 16.

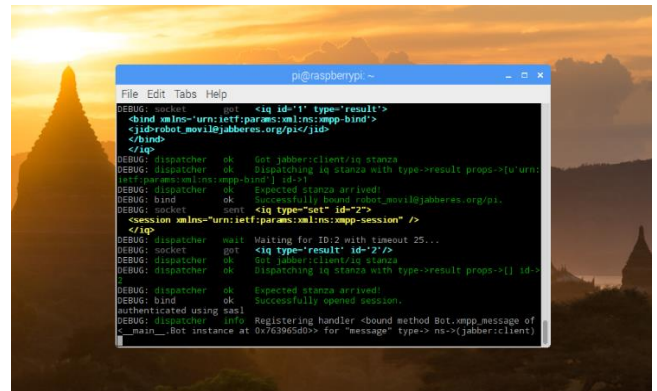


Fig. 15. Connection between the console and the Raspberry Pi installed in the remote robot to control.

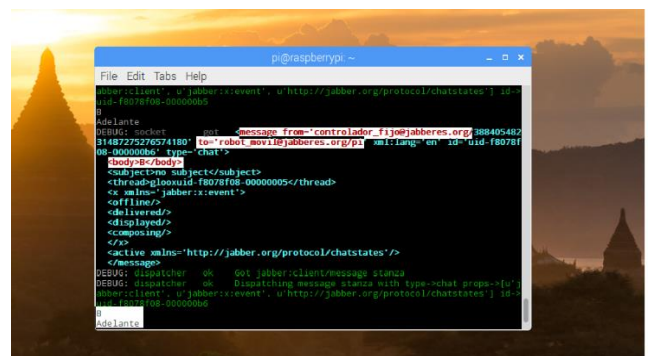


Fig. 16. Reception and interpretation of control commands, execution made by the remote Raspberry Pi.

4.5 Trial

We made many experiments with the proposed system, the longer distance we proved was about 4.8 km (2.98 miles). We made the control of the robot placed in UNAM Ciudad Universitaria, from UNAM FESC. It can be seen in figure 17 (Image taken from google maps) the distance between the terminal and the receptor of commands.

The control of the robotic vehicle was made completely by face. The hands were not used in any way to make the experiment.

¹³ <https://www.raspbian.org/>

¹⁴ <https://www.python.org/>

5 Results

From integrating techniques and methods described through the paper was achieved:

1. It was established a control system using a fuzzy controller, and artificial vision. In this, fuzzy logic allows generating command words through the interpretation of facial movements.
2. It was made a connection between two identities using a free real-time communication protocol through the Internet, sending and receiving command words.
3. It was made a remote control of a robot using a computing reduced system as interface to generate access to the Internet.
4. We could control a robot in a different geographical position by just making face movements, the robot started, moved to different directions, and turned off. It could be possible to monitoring the environment in which it was moving.
5. It was developed a control system easy and intuitive for final users. It can be used for people with corporal disabilities, untrained, and even can be used by people who cannot read and write. This is a very important fact due to this system is easily incorporated in any population sector.
6. It was developed a low cost system, and for that, accessible to population sectors with low economic resources.

6 Conclusions

Artificial vision as means of capture of the input variables in a control system gives to users a different experience in which there is no necessity to use only fingers or hands as control elements, but they involve a different mobility for its execution.

Fuzzy logic permitted processing efficiently the information obtained by the camera, mainly because this logic is more tolerant to errors than classical logic, it allows an adequate and flexible control in reference with the image capture, and so a better recognition of command words. By means of fuzzy logic, it is possible to avoid mistakes when the control words are generated because the proposed system can distinguish between movements that indicate a command and those movements that just are generated by a reaction not related to the control of the mobile receptor.

The XMPP instant messaging protocol as means to send commands through Internet allowed to facilitate the process. The fact that it is possible to use the free servers represents a considerable saving

in the economic and in the temporal. It is not necessary to have an own server, and it is not necessary to waste time in develop an information exchange protocol.

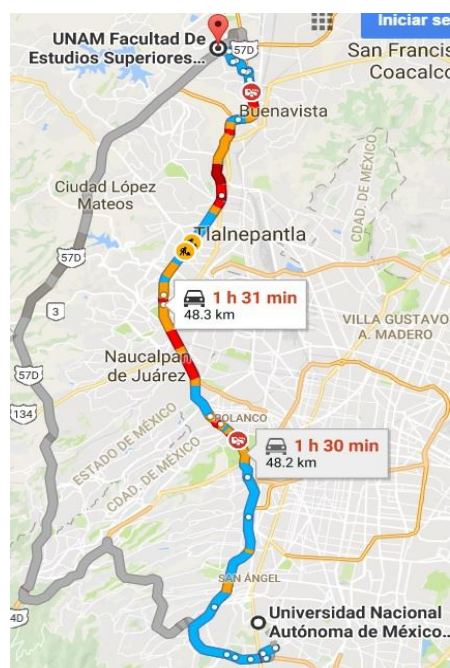


Fig. 16. Distance between two points in where the control of the robot was made.

The use of a reduced computer such as Raspberry Pi facilitates the development of prototypes which requires of more complex functionalities in comparison with a microcontroller which has not many resources. Its multiple forms of connection, and its integration with standard peripherals via USB or low-level hardware make it ideal to interact with the real world through sensors and actuators. The easy form to connect it to Internet, positions it as a suitable device to control different technological, electronic, and mechanical systems remotely.

One of the most interesting advantages of the proposed system is the fact that it allows an easy, and fast interaction with the Internet of things, due to it can make hardware-hardware communications in a manual or autonomous way.

The most important advantage of the proposed model with respect to classical human-machine interfaces is that it can be easily used by people with corporal disabilities, even it can be used by illiterate people because this system does not need complex instructions or previous technical knowledge, it is not necessary to include hands, fingers, feet or any corporal extremity to control it, the system is

entirely controlled just by natural facial expressions. All of this allows that almost anyone can use it. By means of the inputs data fuzzification, it is possible to particularize the gestures that can be used as control words for anyone.

Indeed, there is a necessity to improve the transmission velocity, under this scheme, we are working in an algorithm to transmit video in full duplex. This algorithm will permit us to see the environment of the controlled robot in real time, increasing the quantity of applications of the system.

It is important to say that the development of this project was made by using free use hardware and software.

Acknowledgment

The authors thank PAPIIT IN113316 and the program PI-API1634 of the FESC-UNAM.

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