Wireless Control LEGO NXT robot using voice commands

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***Abstract*—This paper presents a wireless interface to control a LEGO NXT robot using voice commands through a computer. To perform speech recognition is used CSLU TOOLKIT with a corpus of Mexican Spanish voice, recognized commands are sent via Bluetooth from computer to robot, programming and motion routines to control the motors are done using Java and LeJOS NXJ. The interface consists of two main modules interconnected through the implementation of sockets: the voice recognition module and the wireless control module. The results indicate that the wireless control system of the LEGO NXT robot through voice commands successfully meets its objective.**

Keywords: Bluetooth; Speech Recognition; Robot LEGO NXT; Sockets.

I. INTRODUCTION

The great advances in technology have encouraged parallel development of disciplines such as robotics and voice recognition. The combination of both disciplines has allowed us to solve complex problems. In the field of robotic manipulation, there are very obvious benefits in several areas of application and research, for example in the exploration of unknown terrain and remote control of robots in hazardous environments.

The uses of multimodal systems that allow information from different sensory modes, such as voice or gesticulations, have increased levels of robustness and self-adaptability of such systems. Currently, the field of robotics provides several tools that allow the development of projects aimed at solving various problems of our environment. Some related work presented here is described below. In the ITESM Campus in Cuernavaca Mexico has been developed a robotic navigation system wirelessly controlled by gestures and vocal patterns [1].

Research at the Institute of Applied Mathematics Systems (IIMAS - UNAM) has developed a robot arm with 6 degrees of freedom that counts with the ability to assemble and collect sensory information obtained from speech recognition [2]. The Mexican Academy of Surgery has developed a robotic arm to hold and positionate the laparoscope, which has five degrees of freedom, three joints and three handling systems: head movements using infrared light, voice recognition and a physical manual system [3]. The Engineering and Research Institute of Aragon developed an intelligent voice-controlled robotic wheelchair [4]. Elsewhere consulted [5], we found a caterpillar explorer robot controlled by voice through a voice recognition chip (Voice Direct II). This robot is equipped with an array of sensors and a camera that lets you send information based on the explored environment. Voice commands are sent through a wireless microphone and the internal microcontroller interprets the instructions to give movement to the robot's motors.

Similar to the projects presented above, this work is to combine the area of robotics and speech recognition to solve the problem posed in the next section.

II. PROBLEM DESCRIPTION

Robotic manipulation through the voice provides a more natural way of establishing the man-machine interaction, which is why this paper presents a graphical interface wireless control of a robot through voice commands. Among the advantages possessed by the use of a voice navigation system, is the possibility to reach a greater number and type of users of these systems, taking into account that there are people who have a disability and are limited in handling manual systems.

With the implementation of this project it is pretended to wirelessly control a LEGO NXT robot [6], through voice commands delivered to a control terminal. To manipulate the robot through the spoken information, the following commands are implemented for voice recognition: forward, reverse, brake, right, left and stop, each representing one share for the robot motion control.

III. DESIGN AND DEVELOPMENT

In this section it is presented the general outline of the system, as well as a description of each of the modules that composes it, after that, it is described the design used for the LEGO NXT robot used in this work.

Later, the process of development of each module and the software tools used are described.

A. Software Architecture

The Figure 1 shows the architecture of the software system along with how they communicate the modules that are part of the wireless control system LEGO NXT via voice commands.

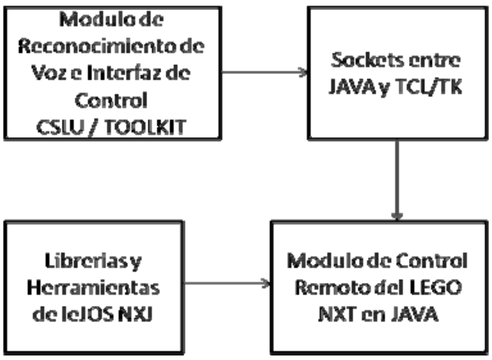

Figure 1. Software architecture.

1) Voice Recognition Module with Control Interface: This module performs the task of speech recognition, through CSLU TOOLKIT tools [7] the control commands are introduced for their recognition. This module supports the encoding based on the language TCL / TK [8], which achieves the performance of specific routines for each command recognized. The wireless control interface LEGO NXT robot is developed within the visual environment provided by the CSLU Toolkit, which includes a manual mode, which is used initially to test the Bluetooth connections and ensure that communication between the sockets are done satisfactorily, then it is possible to activate voice recognition.

2) Sockets between Java and TCL / TK: The sockets are responsible for establishing the connection between the voice recognition module and the wireless control module LEGO NXT. This is achieved by implementing client-server sockets to open a channel of communication between both programs; the control interface developed at CSLU TOOLKIT sends the command strings for each client through the socket. These channels are received by the socket server in Java [9] and interpreted for execution.

3) Wireless Control Module LEGO NXT robot in Java: In this module is performed the direct manipulation of the LEGO NXT robot motors, according to commands received through the channel of the socket, for this it is necessary to have libraries for LeJOS NXJ [10], which contain the essential functions for the control of the physical components of LEGO NXT robot, such as motors, sensors, screen, among others. Another important tool of LeJOS NXJ, is the firmware, which is installed on the NXT block and allows to work under the JAVA programming language and to establish communication using bluetooth libraries LeJOS NXJ package. Before running the wireless control module of the LEGO NXT robot in java, it is necessary to have configured the bluetooth device on your computer. Of course, both devices need to be visible to each other via Bluetooth.

4) Model of the LEGO NXT robot used in this work: To perform the system tests, it is used a LEGO NXT robot that features 2 motors that give movement to the wheels. The design of this model aims to be reduced in size and weight in order to navigate in tight spaces and be easy to handle. The LEGO NXT robot block is at the top to be easily manipulated or replaced.

Figure 2. LEGO NXT Robot.

B. System Development

The solution implemented consisted of a system that combined the following tools: the voice recognition engine CSLU TOOLKIT, the JAVA programming language in conjunction with libraries and tools LeJOS NXJ and the connection made through sockets.

1) Development of Speech Recognition Module and GUI in CSLU TOOLKIT: Once installed and configured the CSLU TOOLKIT for the Spanish language, it was proceed to develop the module for the recognition of voice commands defined above. These commands can be seen in the table below, together with their respective meanings.

TABLE I. COMMAND LIST OF MEMBERS AND THEIR MEANINGS NAVIGATION

Command	**Meaning**
Avanza	Indicates the robot to move continuously forward
Retro	Indicates the robot to move continuously backward
Izq	Indicates the robot to turn left
Der	Indicates the robot to turn right
Frena	Indicates the robot to pass into an idle state until another command is received.
Fin	Disable voice commands and returns to manual mode.

These commands are entered in CSLU TOOLKIT using the voice recognition tool, which has several output ports according to the number of commands to recognize.

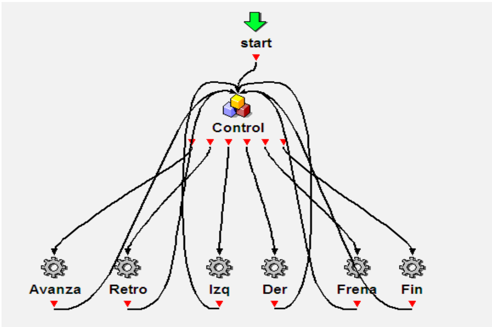

Figure 3. Schematic of vocal command recognizer CSLU TOOLKIT

Each of the commands should be spoken clearly through the microphone connected to the PC, it should be clear of the microphone must be calibrated at the start to get better results.

It is necessary to say that the commands defined to control the system must be phonetically different, because this factor is crucial to recognize a word correctly. Such is the case of the initially used commands: “izquierda” (left) and "derecha" (right), which caused a high number of errors in the recognition engine when was trying to distinguish the two words, because the phonetic similarities of several phonemes that exist in both words.

The solution to this problem is achieved by modifying the commands, so that their pronunciation is different, which is why it has decided to replace the words above ("izquierda" and "derecha") by their initial letters, respectively: "Izq" and "Der".

This achieves greater effectiveness in the recognition of movement instructions for the robot.

For the development of the wireless control interface of the Lego NXT robot it was used the tool MEDIA, provided by CSLU TOOLKIT, in which is inserted an image and are defined areas of action, each corresponding to a navigation command.

This tool has an output port for each defined area on the image.

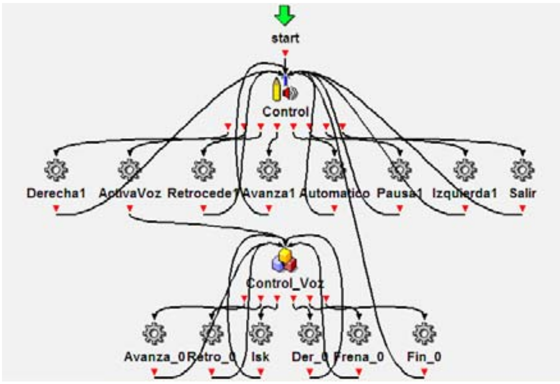

Figure 4. Schematic of the wireless control interface developed at CSLU TOOLKIT

The control interface allows you to manipulate the LEGO NXT robot manually by clicking on some of the arrows in the image, also provides the option to enable the automatic speech recognition.

Figure 5. GUI Wireless control LEGO NXT

The process of recognizing voice commands is based on the following pseudo code.

BEGIN
Input commands through the microphone
The system recognizes the command and creates a client socket, making a request to the Java socket server
IF the connection is accepted
The system sends a corresponding string to the command through the client socket
The system waits for the entry of a new command
END

Regarding the operation of client socket defines the following steps:

BEGIN
Client socket is created by specifying the server port number
The client socket sends a connection request
IF the server is awaiting
The request is accepted and the connection is established

ELSE
The connection cannot be established
The socket client sends the recognized commands to the server
The connection is terminated
END

2) Development of the LEGO NXT Wireless Control Module in JAVA: Prior to the codification of the LEGO NXT Wireless Control Module in JAVA language, it is necessary to install and configure the libraries LeJOS NXJ, as well as the USB driver for the LEGO NXT robot. These libraries must also be included in the programming IDE (JCreator, NetBeans, Eclipse, etc), in our case it was used JCreator 5.0 [11]. To achieve successful communication between the LEGO NXT robot and the computer it was used a Bluetooth adapter compatible with standard Class II v 2.0 [12]. This technology was used because the advantages of wireless communication by Bluetooth.

Wireless Control Module performs directly the manipulation of the LEGO NXT robot motors, for that it is necessary to include the bookstore LeJOS NXJ as well as the libraries necessary to establish communication through the Bluetooth device, this is achieved through the instructions: "*import lejos.nxt.**", "*import lejos.nxt.remote.NXTCommand*", and "*import lejos.pc.comm.**".

This module requires the implementation of a socket server, which opens a channel of communication with the voice recognition module. This requires import the library "*java.net*".

The socket server implemented in this module behaves according to the following pseudo code:

BEGIN
Server socket is created indicating a port number for communication
The socket is blocked waiting for a connection request from the client process
It checks the number of port and accepts the client connection
The socket receives the recognized commands
The connection is terminated when the client program send the command "Fin"
END

As for the overall operation of this module is presented in the following pseudo code:

BEGIN
Bluetooth connection is made with LEGO NXT block.
Server socket is set in standby mode.
DO WHILE
Receive commands through the client socket
CASE
Commands: = forward
Turn motor A and B forward
Command = backward
Turn motor A and B back
Command = left
Turn motor A back and motor B forward
Command = right
Turn motor A forward and motor B and backward
Command = stop
Stop motor A and B
END CASE
END DO WHILE
STOP

In Figure 6 it is showing the location of the motors A, B and the NXT programming block used in the design of the robot employed in this job.

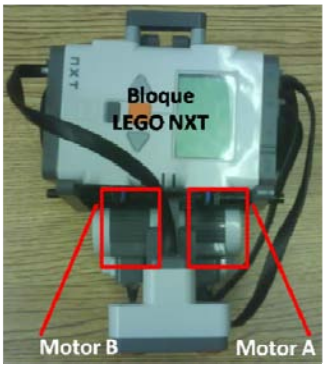

Figure 6. Location of the motors A, B, ultrasonic sensor and NXT block

IV. TESTS AND RESULTS

This section presents the tests and the results obtained by testing the performance of wireless control interface LEGO NXT robot using voice commands. The evidence presented below was carried out both for recognizing voice commands as to the robot's wireless manipulation through these commands.

The tests were conducted in a setting with moderate noise, good lighting and a flat surface for the evaluation of the robot's movements.

A. Testing Recognition Voice Commands

The evaluation criteria for the performance of the interface with voice recognition are based on the percentage of correct recognition. This percentage is determined from the error rate performance of the recognizer and can be handled as the percentage of correct recognition at the level of words used as commands of robotic navigation.

Thus the command recognition rate is defined as:

$$\%Commands = 100 - (\%S + \%O) \tag{1}$$

Where %S is the percentage of errors by substitution of words, and %O the percentage of errors by omission of words. The test consists of 30 iterations for each command: "*avanza*", "*retro*", "*izq*", "*der*", "*frena*", "*fin*". The obtained results are shown in the table below. The first column shows the command, in the second and third column it is showing the percentages of word substitution error (%S) and omission of words (%O) respectively. The last column shows the percentage of correct recognition of the commands (%Commands).

TABLE 2 RESULTS OBTAINED IN EVALUATING THE VOICE COMMAND RECOGNITION WITH 30 ITERATIONS

Command	%S	%O	%Commands
"avanza" (forward)	**5**	**7**	**88**
"retro" (backward)	**4**	**3**	**93**
"izq" (left)	**6**	**8**	**86**
"der" (right)	**5**	**8**	**87**
"stop" (brake)	**3**	**5**	**92**
"fin" (end)	**4**	**3**	**93**

Error rates could be caused by the tone of some phonemes that caused the non-recognition or the replace of the original words. For example the command "fin" provides better recognition results when pronounced with the sound of "m" at the end instead of "n", i.e. "fim".

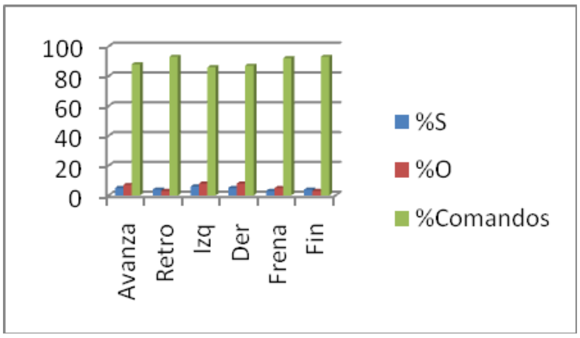

Figure 7. Graph of the levels of recognition of voice commands

In general the results of the recognizer were satisfactory for this work, because the correct recognition rates were maintained between 80 and 100 percent.

B. Handling tests through voice commands

To evaluate the performance of the wireless control interface of the robot through voice commands, manipulation tests were conducted which consisted on guiding the robot through an outline drawn on the floor.

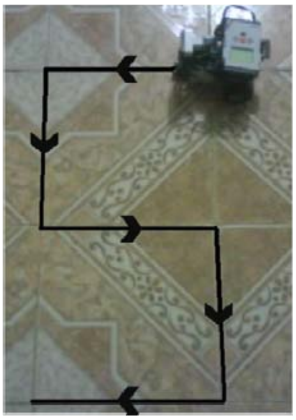

Figure 8. Line tour guide for the robot forward

These tests were performed with 30 iterations manipulating the robot forward and 30 backward.

Figure 9. Line tour guide for the robot in reverse.

In the first case when the robot was manipulated forward successfully completed the course 28 of the 30 iterations performed, thus obtaining a shooting percentage of 86.7%. In the second case when the robot was manipulated in reverse successfully completed the course 26 times in the 30 attempts made.

While performing the tests could be observed that the design of the robot directly affects its proper functioning, for this work, the robot was equipped with two rear wheels and a front wheel support, which allows for left turns and right properly.

It is noteworthy that in iterations in which the robot could not complete the course with minimal movement was due to increased noise levels in the external environment, which caused interference in the recognition of commands delivered.

In general the results obtained during testing of wirelessly controlled robot navigation via voice commands have been satisfactory for this work, taking into account that the percentages of functionality are found in a range of 80 to 100 percent.

V. CONCLUSION

Throughout this paper were presented modules developed to achieve the main objective of this project: to allow wireless control of a LEGO NXT robot through voice commands, these required the design and coding of a graphical interface combined with speech recognition and the use of Bluetooth wireless communication technology.

Later it was presented the performed tests, as well as the results obtained on the evaluation of the system performance in general.

Currently, the area of speech recognition is in development and is used in a large number of projects, however, there are still many improvements that could be done later, as in the case of the speech corpus used in this work, which can be improved to recognize complete commands with less ambiguity.

Future work for this project is to equip the robot with a camera to monitor and extend voice commands to have more and better control over the wirelessly operated actions of the robot.

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