Wireless security system implemented in a mobile robot

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Abstract

This paper presents the design and implementation of a security system in which a mobile robot Lego NXT continuously monitors its surroundings while traveling in search of moving objects or people, considered unauthorized elements. An ultrasonic sensor is used for the monitoring. On suspicious movement detection, a warning signal is sent to a computer via Bluetooth technology. The mobile robot motion is observed with a camera that sends images to the computer controlling the robot remotely. The results indicate that the security system is reliable in 85% of cases.

Keywords: *Robot, Lego NXT, Bluetooth, security system, communication.*

1. Introduction

Today, the growing insecurity makes us live with much distrust and the incidents of robbery have been devising new ways to preserve public safety. In Mexico, according to the ICESI [1], the number of preliminary inquiries in 2010 was registered 608 cases, an increase of 266% over 2007.

So, there are much effort in implementing new security systems like security alarms, surveillance cameras, IP recording systems, and more. In order to give people certainty about what happens in their homes or businesses, however many of these systems prove to be inefficient for lack of mobility. Because of this situation various types of technologies have been designed and implemented in search of greater security.

Considering that a security system must be the least suspect and as mobile as possible, wireless technologies have been categorized as one of the best alternatives for this area of work, as these avoid the use of wiring, allowing an efficient mobility in the security system as well as a good presentation.

Mobile robots and wireless communication join to make their presence felt in a satisfactory manner in the situations described before and in situations unrelated to a security system. The wireless communication more used for these types of jobs is given by means of Bluetooth technology, since different jobs and projects in different areas have been performed with the help of a mobile robot and communication via Bluetooth, with efficient results.
For example, Moutaouakkil et. al. [2] describes several articles related to the use of robotics in security contribution.

Abad et. al. [3] describe a robotic vision application in MatLab, which created a mobile robot able to move and display a given area using a camera integrated into LEGOs. All this is developed using MATLAB elaborate programming where you create a graphical interface that enables communication between two devices using the Bluetooth protocol. The detection of different obstacles or objects that are wished to perceive with the equipment is made through a wireless camera installed on the robot's top, that camera sends the information to the wireless router connected to the computer, and this in turn communicates via intranet with the Control Center from which is monitored all perceived by the robot, using Fixed Public IP.

As above, other papers relating to the use of robotics in various projects as [5], where a robot arm is used in assembly and [6] where techniques of computer vision are used in a system for locating a mobile robot. In [7], is showed a wireless control system of a robot using LPT interface in conjunction with Arduino + X-bee, wich providing autonomy to the robot.

2. Current Issues

Many companies invest resources and deploy a small army to protect themselves from the many security threats that are found these days. However, these resources results inefficient in many cases in terms of mobility, warning signs, etc.

Most security systems that are deployed today in many homes and businesses are static, i.e. they cannot look beyond their initial limitations, which open the door to insecurity. Also worth mentioning is that many security systems do not send alarm signals but leave this job to the person in charge, which is closely watching what the security system displays, i.e. involving a double job.

3. Proposed Solution

The main objective to be achieved by this research is to create a security system that allows monitoring every so often a given space and send warning signals to the PC if it detects any moving object.

It is therefore necessary to design and implement a mobile robot, such as the Lego NXT, to be in constant movement and to monitor the surrounding environment, and is controlled remotely by a user or in an autonomous way.

All movements of the mobile robot Lego NXT will be seen from the computer that controls it through a chamber which is connected directly to the computer.

3.1 Implementation of Lego NXT

There is a wide range of robotic platforms with which it is possible to develop security systems. These are all valid to a greater or lesser extent, although it is advisable to choose the most versatile.

One of the robots more accessible by its low cost and ease of programming is the LEGO NXT MINDSTROMS since it offers a multitude of design possibilities in regard to software and hardware, a good rate quality/price and also there is a large number of sensors and actuators as well as different environments and programming languages with high quality [4]. That is why, according to the features offered, the implementation of the Lego NXT would be well suited for this research.

3.2 Bluetooth technology

Bluetooth technology is basically a standard for wireless communications to connect various devices remotely. This technology eliminates the need for numerous and cumbersome cables that usually connect to PCs, mobile phones, Laptop and all types of handheld computer to exchange information between them.

Connections are instantaneous and are retained even when the devices are not within its range, i.e. even when the devices are separated by objects or walls. This is perhaps one of the most important characteristics that have Bluetooth.

3.3 NXJ LeJOS Implementation

We also want to implement Bluetooth technology to establish wireless communication between the PC and the Lego NXT. This is feasible, since the robot Lego NXT supports Bluetooth on its Programmable Brick, allowing the computer to download programs or information from the Lego NXT, or vice versa, wirelessly, and thus give a good presentation to the design of the Lego NXT, leaving aside the use of wires [8].

There is great diversity of high level programming languages as Bricx [9], LeJOS NXJ [10], NXC [11], among others, that allow programs to build LEGO MINDSTORMS NXT robots.

The chosen language for this work is LeJOS NXJ since it is a textual programming software, with free distribution, that allows programming the NXT using Java and provides, among others, the following components:

- An enhanced firmware for the NXT brick that includes a Java virtual machine (JVM).
- A Java API to use the NXT bricks.
- Communications with the PC.
- Tools to change the firmware, downloading software, debugging programs and other functions.

NXJ LeJOS interface consists of a set of classes where there are defined methods that directly access the functions of each of the devices in the robotics kit [12].

Because of these extensive features offered, it turns out to be a good alternative to implement in the programming of the Lego NXT, precisely because we want to communicate with the PC wirelessly.

As for programming environments, could be used either to allow to create Java programs such as Netbeans, JCreator, Eclipse, etc. In this particular case of carried work, JCreator was used because it has a free edition and turned out to be a development environment very easy to use.

4. Development

Communicate with a Lego NXT using a PC turns out to be a more complex task than establish a similar connection between NXT themselves. However, the communication between PC and NXT Lego opens a wider range of communication possibilities with this type of robots.

A Bluetooth adapter is necessary in order to communicate any Bluetooth device with the computer, that adapter can be integrated into the motherboard of the PC, or if not embedded, can be purchased separately.

After installing the Bluetooth adapter on your computer, it is necessary to add the NXT robot as a new Bluetooth device, which requires turn it on and activate the Bluetooth communication in the robot. Once ready the NXT is necessary to go to Control Panel, Bluetooth devices in the Devices tab and go to Add, which opens the window of the Bluetooth Device Wizard, while been there activate My device is set up and ready to be found. Once the NXT is detected it is necessary to select it, press the next option and choose a proper key (1234). At this step the communication between the PC and the NXT is ready.

One of the most advantageous aspects in this type of communication implemented is that does not need to run any programs in the NXT robot, but that all processing is done from the PC, which facilitates many things, from the possibility of wireless communication to the speed to perform complex calculations.

4.1 Configuration

To establish a successful communication between a PC and the Lego NXT using LeJOS NXJ, is necessary to have the right hardware as well as the correct installation and configuration of software in order to obtain good performance.

Considering that LeJOS NXJ allows to program Lego NXT robots using the Java programming language, the JCreator software is used to allow creating Java applications in an efficient way, therefore it is of utmost importance setting JCreator to program the Lego NXT. The LeJOS communication protocol between PC and NXT uses the libraries *pccomm.jar* and *bluecove.jar*, instead of *classes.jar*.

Now the environment is ready to write and compile, from the computer, the application for the Lego NXT. It is important that within the project code the libraries are imported: *lejos.nxt.**, *lejos.pc.comm.** and *lejos.nxt.remote.NXTCommand*.

4.2 Security System Application

When running the implementation of the security system the first thing done is the connection between the Lego NXT and the computer. In the absence of any connection is sent a connection failed message and the application ends. These connection failures could occur for several reasons, among which are: not having enabled the Lego Bluetooth, because the Lego robot is off, not having added the Lego robot as a Bluetooth device in the PC, Bluetooth failures in the Lego or the computer, among others.

If the connection is successful, the application continues to open a menu which shows the instruction sheet or the options so that a user takes responsibility for handling the movement of the Lego NXT from the keyboard, for its navigation. The menu screen shown in Figure 1.

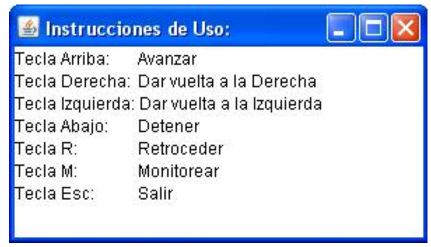

Fig 1. Main menu.

When a valid character of the system is pressed, the associated action is performed immediately and then continues with the previous action that was running before the character was pressed, i.e. if the robot was moving backward when the ‘M’ key was pressed, then the robot monitors and after that continues moving backward.

To utilize the keyboard the function “keyPressed (KeyEvent event)” is used, that function returns a different value for each character of the keyboard, so the pressed key can be compared with those indicated in the menu, in order to perform some action on the Lego NXT. It is important to note that even pressing the key once the keyPressed function takes its corresponding value immediately, i.e., if a character is left pressed for a given time Keypress takes the same value repeatedly, which causes that the Lego NXT robot gets confused and not do some action, that it does not accept any other option until the number of times the same value was taken finalize, or that the program cycles and therefore be required to be canceled and re-run the application from the start.

4.3 Implemented Algorithm

Pressing the ‘M’ key the action of monitoring is performed in which the robot is ordered to take measurements from its ultrasonic sensor and make comparisons between those measurements to determine whether there is or not any movement in its environment.

Pseudo code for the monitoring action:
Activate the ultrasonic sensor
DO

Capturing distancia1
DO
Capturing distancia2
If distancia1 ≠ distancia2
Send alarm to the PC
WHILE time <5 sec
WHILE spin < 360º
Deactivate the ultrasonic sensor

The ultrasonic sensor of the robot is activated only when it is wanted to monitor and is deactivated on completing the task.

Monitoring starts at the point where the robot is when the monitoring order is received, the first distance measurement is keep and compared with the following distance measurements. The comparison of measurements is made for five seconds and if exists inconsistency in the distance measurements, a warning signal is sent to the computer, indicating that there are suspicions of insecurity.

If five seconds has elapsed and the distance measurements obtained are the same, the security system assumes that everything is in order, rotates 45 degrees, resets its measurement of distances and takes its new values according to the current position, in order to continue with the comparison. The monitoring ends when 360 degrees are accomplished, i.e., until returning to the place where the process started.

LeJOS Ultrasonic Sensor class has several methods that help to take distance measurements accurately. The method used in this research is "*int GetDistance ()*", which calculates and returns the distance in centimeters to the nearest object. The maximum value is 255 cm, but often returns this value as error.

The Lego NXT ultrasonic sensor has a delay, it means, the first actual distance in which it is currently takes a certain time to be captured by the sensor and sent to the computer, until it has captured the actual distance, the value taken as distance is 255. To give a solution to this error in this project a timeout has been included in the algorithm to skip the first values until a certain time has passed, in this case wait one second, and then take the first real distance. For several tests it was found that for measurements in the range of one second, there are wrong values, that is the reason why we chose to take as the first distance the one that is found after one second. After one second the measured distances are reliable.

To send an alarm signal to the computer, the implemented algorithm performs comparisons between the taken distances, which must meet:

1. The current distance is different from the first distance.
2. The difference between the actual distance and the first distance is greater than 3 centimeters.

It was chosen a difference greater than 3 centimeters because of the precision limitations of the Lego NXT ultrasonic sensor.

4.4 Autonomous navigation

The autonomous navigation sets aside the manual manipulation of the Lego NXT robot, consists of executing a routine to allow the robot to navigate its environment randomly according to the requirements of the surrounding environment. In circumstances such as obstacles the robot avoids them performing a rotation to another place to continue navigating.

The monitoring action is also randomly activated, that means it is never known when the robot will monitor the environment, since can be done consecutively as well as to wait a certain time to do it again, this was decided so for greater security.

4.5 Lego NXT design

The Lego NXT robot design has been made taking into account two important points that make a good security system such as agility and discretion. Built design is shown in Figure 5.

Fig 5. Lego NXT robot design.

It was opted for a design whose movement is achieved with 3 wheels as this allows greater ease and agility to navigate their environment, streamlining the mobility and speed of the Lego NXT robot.

The size of the Lego NXT robot is designed as small as possible in order to make a security system at least suspect and should be mentioned that the size is a contributing factor in the success of a good security system.

For a good introduction to the Lego NXT robot design is to avoid excessive unnecessary parts such as sensors and motors which may contribute to the design class but also affect the size of the robot.

4.6 Using the webcam

It has been designed a foundation on which sits the webcam, which consists in accommodate the camera on an engine that will be rotating constantly to see the place where the Lego NXT robot is in order to control it with the computer, considering the characteristics of its surrounding. This is very useful when the Lego NXT is going to places where users can no longer observe the surroundings of the Lego robot, if the camera is installed in that place, which the user cannot see, this will allow seeing the current position of the Lego NXT and thus make a good handling on the Lego NXT robot.

5. Tests and Results

After having completed the development stage of the Lego NXT robot, for the security system, various tests were made in order to get reliable statistics and see how this project turns out to be as a security system. The tests performed were the following:

5.1 Manual handling of the Lego NXT robot.

The first phase of this test was performed within the same room, i.e. the room where the computer was installed, for handling the security system, was the same place on which it was wanted the robot to surfs. As a result of this first phase it was obtained proof that all instructions told to the robot from the computer such as rotate clockwise, move backwards, monitoring, etc. were performed instantly and satisfactorily, therefore we can deduce that the manual handling of the security system is 100% reliable when the robot is controlled remotely in the same place where is navigating.

In the second and final phase of this test was wanted to get the results of the security system reactions when receives the orders given from the computer while it is located in another area in order to draw conclusions on how to intervene obstacles such as walls, windows, crystals, etc. about communication between the computer and the robot. For this, the computer, which controls the robot, was installed in a room disconnected of those wanted to be navigated. On the start of the test satisfactory results were obtained, i.e. the security system performed the given instructions instantly even when the communication between it and the computer was interrupted by concrete walls, however as the robot was introduced into other rooms, which means greater distance and more obstacles for the communication, the instructions were carried out after a short period after these were given by the user. Thus as a result of this final test phase it was concluded that the success of manual handling is shrinking as the robot is going away and being interrupted by obstacles which affect the communication established between the system and the computer.

5.2 Autonomous mode of the Security System.

In order to test the autonomous operation of the security system it was necessary to position the robot at any point of a room. Once positioned the program was executed so that it can start its work. The results were as follows: the robot randomly monitored and when an obstacle was detected it was avoided by rotating to other direction, i.e. all the tasks to be undertaken by the security system were met but were not satisfactory because the robot was instructed to if it detects an obstacle at 15 cm it should rotate the other direction to avoid colliding with the obstacle, but was found that only 10% of times the obstacles detected at 15 cm were avoided and the other 90% remaining it collided with the obstacle and after a certain time, being over the obstacle, the robot rotates in another direction. It is therefore concluded that the security system in autonomous mode does not result to be effective because it collides with other objects resulting in a bad navigation.

5.3 Monitoring of the Security System.

For monitoring tests a person was posing as a thief who enters the room, where is the robot, and performs various movements in order to avoid detection by the security system. Three scenes were simulated:

1. The thief enters the room when you are just monitoring the robot. The results were satisfactory, because 95% identified the person and sent an alarm signal to the computer.
2. Being the thief in the room, he moves slowly to avoid detection by the security system. The results were 100% satisfactory, i.e. every time the test was conducted the security system sent a warning signal to the computer.
3. Being the thief in the room, he moves quickly to avoid detection by the security system. The results were the following: 75% of the times the faster thief was spotted by the security system by sending the alarm signal to the computer and the remaining 25% was not detected.

Taking a general result of these 3 scenes was obtained that the monitoring of the safety system responds successfully as long as the movements are not too fast, are in the direction in which the system is monitoring, and are in range of the ultrasonic sensor of the Lego NXT, in this case at most 255 cm.

6. Conclusions

Has been described the design and implementation of robotic platforms as an alternative to a security system in our homes or businesses in order to put a stop to the insecurity of today.

A limited set of resources for the project in this paper has allowed to demonstrate in a short time that the implementation of robotic platforms in security systems can be a good choice because in spite of their few chances, against other platforms that can offer more possibilities, was demonstrated that it is 85% reliable, according to the cases that were performed in the tests, which means that if this work were carried out with higher technology resources it could reach 98%.

All non-favorable cases obtained in tests of this project were due to limitations of the technology used such as the limitations of Bluetooth causing communication being lost as the distances grow far.

The project results allow us to conclude that the implementation of a good algorithm for robotic platforms is to be a major contributing factor in the success of these. Also worth mentioning that alternative programming languages which allow high-level coding to develop such robots are quite users friendly making it save time and effort when designing, implementing and program an algorithm. It follows that the cost of learning a programming language for robotic platforms is very low and with high efficiency.
As a final point, this article supports the conclusion that the use of wireless communication technologies along with the robotic platforms and high level programming languages are positioned a place above the security systems that in many places are still implemented with the use of static cameras, recording systems, etc. because they offer mobility from one place to another allowing to observe what happens even in the most hidden places which are difficult to observe by other security systems.

7. Future Work

Currently this project has been implemented in a Lego NXT robot due to its low cost and ease of programming as described in Section III.A. One aspiration is that this project be conducted on a robotic platform to provide greater opportunities in a security system. For example, some possible factors of quality that other platforms can offer would be:

1. The size. The size of the robot can be decreased. There are hardware platforms, which can be used on a Lego NXT, which can perform the functions of the brick. The Arduino board is one of these platforms that besides offering compatibility with the Lego NXT offer a smaller size thus contributing to minimize the size of the security system.
2. Sensors. To use sensors that are capable of making measurements on very long distances and with high precision on real measures contribute to greater system reliability.

Currently, most people have a cell phone, which is considered the implementation of mobile devices to send alerts, i.e. the signs of insecurity will be sent an alert to a wireless device in the form of this message and may perform another instruction that contributes to safety. This would save the trouble of having to be behind a computer to know when there is a warning. This implementation would contribute to greater efficiency in the security system by permitting knowing of what happens in our home or business from where we are so that we can give a good solution without having to be at the scene.

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