Design & Development of a Robotic System Using LEGO Mindstorm

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ABSTRACT

This research presents a design and development of robotic system based on LEGO Mindstorm kit. The system is capable in operating an off-line programming method, starting from its programming sequences until robotic implementation of the program. During early stages, the research is emphasis more towards designing a robotic system using RoboLab software and C++ programming language. A robotic hardware system has been developed using LEGO Mindstorm kit. The robotic model acts as a prototype or test-bed for programming execution. The model involves motorize movement, sensors detection and machine vision to be manipulated by the programmers inside their programs. Since the model is built using LEGO bricks, the model is fully customized, in term of its applications, to perform any relevant tasks. Ultimately, the algorithm development program designed earlier is linked up directly to the robotic model for program implementation and verification. For this research, several set of robots by using Lego has been developed and it uses LeJos and C programming techniques as a platform. A Java-based robot development tool has been set up as alternative programming methods incorporating LeJos and the controller. A prototype of a mobile robot based on Lego successfully implemented by using PIC and can be controlled through voice recognition.

KEYWORDS

Robotics, Lego, off-line programming, C/C++, PIC

1. INTRODUCTION

Lego's robot Mindstorms system is an excellent solution for learning robotics [1]. It is portable, easy to start with and relatively compatible. Lego Mindstorms sets combine Lego bricks with computers. It was developed by the LEGO Company after many years of research at the Media Laboratory at the Massachusetts Institute of Technology (MIT). The Robotics Invention System (RIS) was launches first in the United States and Europe in September 1998 [2]. Lego Mindstorms is a products combining programmable bricks with electric motors, sensors, Lego bricks, and Lego Technic pieces (such as gears, axles, beams, and pneumatic parts) to build robots and other automated or interactive systems. Lego Mindstorms is marketed commercially as the Robotics Invention System (RIS). It is also sold and used as an educational tool, originally through a partnership between Lego and the MIT Media Laboratory [2,3,4]. The educational version of the products is called Lego Mindstorms for Schools, and comes with the ROBOLAB GUI-based programming software.

Lego Mindstorms may be used to build a model of an embedded system with computer-controlled electromechanical parts. Almost all kinds of real-life embedded systems, from elevator controllers to industrial robots, may be modeled using Mindstorms. There is a strong community of professionals and hobbyists of all ages involved in the sharing of designs, programming techniques and other ideas associated with Lego Mindstorms [5,6].

For this research, there are several problems to be studied related to the Lego Mindstorm capability and limitations. It has shown that the RCX brick has very limited memory, which are 32 Kbytes and the user's program cannot be larger than 6 Kbytes. The user's program is restricted to no more than 32 variables. The robot's original operating system does not support recursion or arrays.

Normally, programs for the RCX are written on a computer, using software provided with the RCX, such as RoboLAB. The programs are then downloaded and executed on the RCX. It is also possible for users to use other language to program the RCX such as C or Java. In addition to the program/download paradigm, there are other ways to control the RCX, including direct-control programs for computers. The RCX normally connects to a PC via a null-modem RS232 cable and uses a custom communications format [4].

For this research, we have divided the project into two parts. The first part is to design and develop a robotic system by using Lego Mindstorm. Here, we have integrated the RCX with a different programming approach, such as by using Robolab, NQC, C and LeJos. Upon the success of this prototype, we have implemented a new model based on Lego robotic system by using a PIC in the second part. Through this stage, we have expanded the capabilities of the robotic system by introducing voice recognition to control the movement of the robot.

2. BACKGROUND

The LEGO Mindstorms robot has been chosen for this research because it is truly 'plug-and-play' and suitable to design a prototype model with a low cost [6]. The model does not required to design circuits or even solder components to build robots. Another reason why we chose the LEGO Mindstorms robot was that it is inexpensive: only about RM1,000 a kit for a larger components (bricks).

The first generation of Lego Mindstorms was built around a brick known as the RCX. It contains a Renesas H8/300 microcontroller as its internal CPU. The brick is programmed by downloading a program (written in one of several available programming languages) from a PC or Mac to the brick's RAM via a special infrared (IR) interface. After the users starts a program, an RCX-enabled Mindstorms creation may function totally on its own, acting on internal and external stimuli according to the programmed instructions. Also, two or more RCX bricks can communicate with each other through the IR interface, enabling inter-brick cooperation or competition. In addition to the IR port, there are three sensor input ports and three motor output ports (also usable for lamps, etc). There is also an LCD that can display the battery level, the status of the input/output ports, which program is selected or running, and other information.

There are three versions of the RCX, which were distributed with the appropriate version of Robotics Invention System: 1.0, 1.5, and 2.0. Version 1.0 RCX bricks feature a power adapter jack to allow continuous operation instead of the limited operation time when using batteries. Power adapter-equipped RCX bricks are popular for stationary robotics projects (such as robot arms) or for controlling Lego model trains [7]. The robot kit contains one light sensor, two touch sensors, two motors, several gears (including a differential), wheels, beams, bricks and assorted pieces, more than 700 components in all. Additional sensors and motors are available for purchase on-line and are relatively inexpensive. However, the LEGO Mindstorms robot has its drawbacks too. The RCX brick has very limited memory: 32K and the user's program cannot be larger than 6K. The user's program is restricted to no more than 32 variables. The robot's original operating system does not support recursion or arrays. But, we believe the ease of use and inexpensive nature of the robot outweighs these disadvantages.

The robot comes with a visual programming language, which does not permit nested control constructs. However, alternative languages and cross compilers are available for the robot, including NQC (Not Quite C), which is a subset of C. Other options available for use with the robot include C, Ada, SmallTalk, pbForth, Java and Scheme [4].

3. ROBOTIC DESIGN AND DEVELOPMENT

In order to ensure the success of this project, we have divided the project into two parts. The first part is to design and develop a robotic system by using Lego Mindstorm. Here, we integrate the RCX with a different programming approach, such as by using Robolab, NQC, C and LeJos. Upon the success of this prototype, we have implemented a new model based on Lego robotic system by using a PIC in the second part. Through this stage, we have expanded the capabilities of the robotic system by introducing voice recognition to control the movement of the robot.

3.1 Part I: Robotic Development by Using Lego Mindstorm

In order to develop a robot prototype, a mission has been proposed in order to specify the task for the robot. For this research, the robot developed by using Lego Mindstorms to collect a ball and reposition it to particular area. Java programming language is used to control the robot movement. This program downloaded or transferred to RCX. The testing process has been done to validate the functions for this robot.

The movement of the robot has been developed through the programming based on some simple algorithm. The program then transferred to the RCX via the IR communication. This process will take about 15 to 30 seconds, depending on program size. The movement of the robot will be executed once the RUN button is pushed. Basically, the prototype for this robot has three main tasks for its movements:

i) Move forward and turn when sensors detect black line
ii) Move forward and grab ball when touch sensor detect ball
iii) Line follower

3.2 Part II: Robotic Design and Development by Using PIC

For the second part, the project is consisted of three main sections. In the section I, the objective of this work is to familiarize with the radio frequency signal, the circuit, the numbers of data input and output and the signal transmit. In section II, the primary technical objective is to design the mobile robot and implement a microcontroller using the 16F84A PIC to control the motor system. For section III, the objective is to write the program using the Microsoft Visual Basic 6.0 as a programming tool in order to develop a speech recognition system to control the mobile robot system. Another objective is to develop a speech recognition tool that can respond to the certain fixed command by a different user.

In order to utilize the speech/voice recognition to control the robot, Microsoft Speech SDK has been used. Microsoft Speech SDK is a software development kit for building speech engines and applications for Microsoft Windows. Designed primarily for the desktop speech developer, the SDK contains the Microsoft Win32-compatible speech application programming interface (SAPI), the Microsoft continuous speech recognition engine and Microsoft concatenated speech synthesis (or text-to-speech) engine, a collection of speech-oriented development tools for compiling source code and executing commands, sample speech recognition and speech synthesis engines for testing with speech-enabled applications.

4. HARDWARE IMPLEMENTATION

There are two phases in this system design for hardware implementation by using PIC. The first one is to design the mobile robot with the used of the PIC microcontroller as the system brain to control the DC Motor. The purpose of PIC is to take inputs from the RF receiver to control the DC Motor. The second phase is to establish the RF remote control between the transmitter and receiver using ZD module. PIC16F84A is used to control the DC motor according to the input from the receiver. In this project, the microcontroller receives 4 inputs from the receiver. The input are Forward, Reverse, Left, Right and Stop. If the microcontroller received no input from the RF receiver (all inputs is zero), then the microcontroller will recognize it as Stop command. Fig. 1 shows the block diagram for the PIC16F84 operation. The microcontroller needs 4 inputs and 4 outputs. The mobile robot used two DC motor to drive the robot *forward, reverse, left* and *right.* Each DC motor has 2 inputs in order to rotate in two directions, forward and reverse.

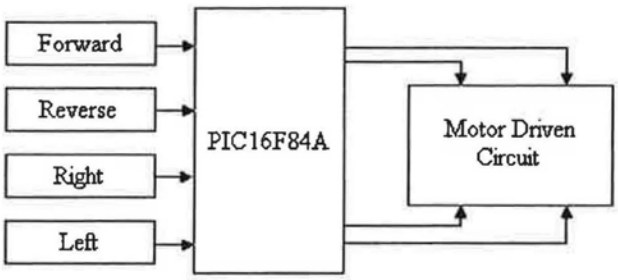

Fig. 1. Block Diagram of PIC16F84A Operation

For the second stage, the RF remote control, there are two significant elements; transmitter and receiver. The transmitter commonly uses to transmit data via antenna through transmission medium (air, copper wire and optical cable). The receiver then will receive the signal that is transmitting from transmitter and decode it to useful information. In this part, it is important that the transmitter deal with 4 inputs and outputs.The transmitter will receive inputs from personal computer and transmit it to the receiver using the Radio Frequency. The ZD transmitter with 330 MHz signal frequency is applied in this project. The Fig. 2 show that the transmitter use AX5326P-4 Encoder IC for 4 Bits RF remote control systems.

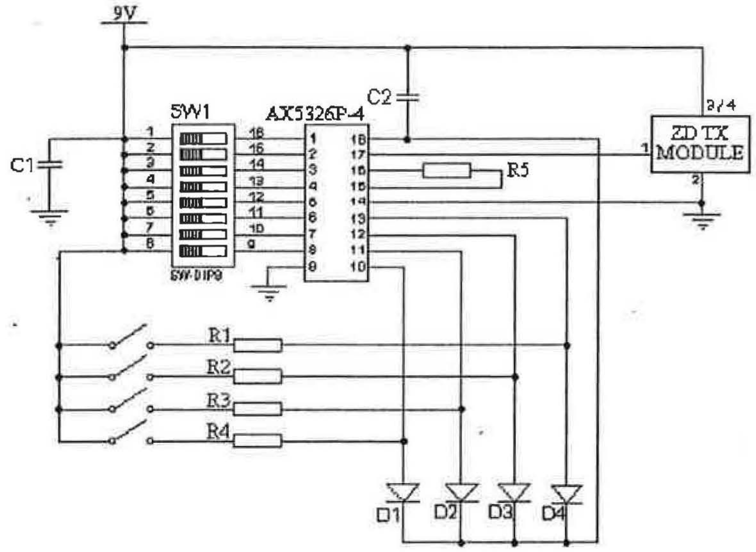

Fig. 2. Transmitter Schematic

The receiver also operates at 330 MHz, and has 4 inputs. The ZD RX Module receiver operates from 4.5 to 5.5 volts-DC, and has both linear and digital outputs. For maximum range, the recommended antenna should be approximately 35cm long. The Fig. 3 show that the receiver use SMC6527.3P Decoder IC for 4 Bits RF remote control systems.

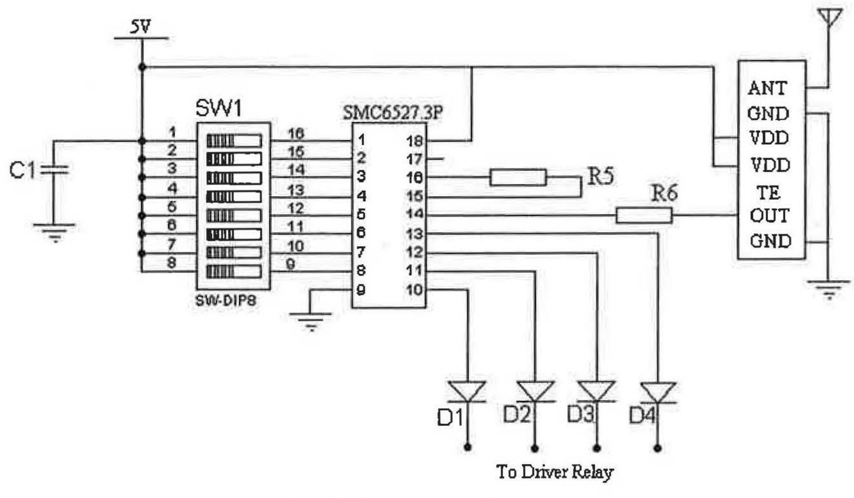

Fig. 3. Receiver Schematic

5. RESULT

This project has successfully produced two significant outputs: a robotic system designed with a Lego Mindstorm (Fig. 4) and the other one implemented by using PIC (Fig. 5). The first system will enables user to develop programming codes to be executed by the prototype robots available. Programmers can exploit various sensors, camera and movement that are already accessible through the Lego Mindstorm robotics model.

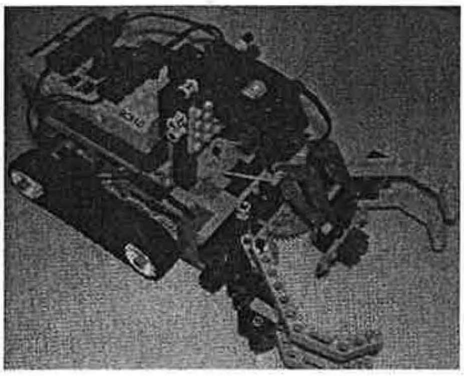

Fig. 4. Robotic system by using Lego Mindstorm

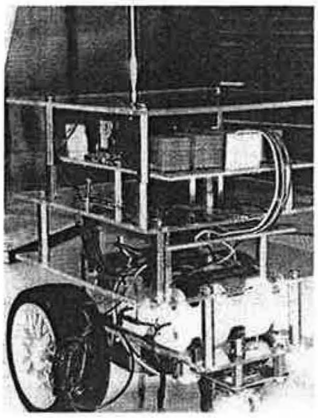

Fig. 5. Robotic prototype implemented by using PIC

The outcome of the second part of this research project is a voice-controlled robotic system. The robotic system will be able to perform as the user would expect. The robot will act through the voice commands from the user. There are no features of the final design that will be user-controlled. The user will only be able to use the voice control over the robotic system only for the commands that have been encoded. At the beginning, the outcome obtained was not as predictable. Some errors have been occurred to this system. The worst part is the software development where the program is not corresponding with voice of the user. After several test and debugging, this project is finally has attained its objective. The final result in this project is this system is capable to let user to control and navigate a robotic system using voice command via personal computer. The microphone attach to the personal computer will be used as input from user. The software that has been developed was successfully corresponding with the hardware.

The voice-controlled robotic system software that is develops using the Microsoft Visual Basic 6.0 and Microsoft Speech Recognition SDK. The mobile robot movement is fixed to five commands; *forward, reverse, left, right* and *stop*. The user will only be able to use the voice control over the robotic system only for the commands that have been encoded. Each time the correct command is given, the software will give the result on the text box. Refer to the Table 1, the words *FORWARD, REVERSE, LEFT* and *RIGHT* at the main page indicates the command that is still executed by the software. If there is any, the software will recognize it as in red color. If all the command text is in black color, the software is executed stop command for the mobile robot. The program waits until the next command is given or the stop button is pressed to stop the voice dictation. For the debugging and testing process for the software developed. The manual control is used to recognize the signal sent to the parallel port from the software.

Table 1: Voice Command

Voice command	Signal send to Parallel port
Forward	b'00000001'
Reverse	b'00000010'
Left	b'00000100'
Right	b'00001000'
Stop	b'00000000'

6. CONCLUSION

This project has successfully implemented by using Lego Mindstorm. It gave a new approach to the application of programming and robotics design. At the final stage of research, a fully-functioned robotic system has been designed and implemented successfully. The system will enables user to develop programming codes to be executed by the prototype robots available. Programmers can exploit various sensors, camera and movement that are already accessible through the robotics model.

The robotic system controller, which is RCX controller manufactured by LEGO, can be replaced and re-constructed using PIC or other microcontroller. This approach will produce more independent and versatile robotic system. For this research, several set of robots by using Lego has been developed and it uses LeJos and C programming techniques as a platform. A Java-based robot development tool has been set up as alternative programming methods incorporating LeJos and the controller. A prototype of a mobile robot based on Lego successfully implemented by using PIC. The mobile robot controlled by using voice recognition.

7. ACKNOWLEDGEMENT

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