Design and Implementation of Object Seeking Robot

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***Abstract*—This paper presents the design and implementation of an object seeking robot. The robot controller is first implemented using an FPGA for fast prototyping. All parts of the design have been simulated and implemented using Xilinx tools. The system controller is then implemented using PIC16F84A single chip microcontroller to achieve low power consumption, and quick movement, which is a basic requirement in environments where quick response is needed in continuously changing dynamic situations. The robot sensors are part of an object tracking program to determine the location of certain objects and act as actuators for the control system, which operates two DC motors. The speed and direction of the movements are based on the received information from the sensors. The robot was tested and found to meet the specification for reliable operation.**

***Index Terms*—Components, object seeking robot, microcontroller, Xillinx, FPGA.**

I. Introduction

A robot is an electro-mechanical device that can perform autonomous or preprogrammed tasks. A robot may act under the direct control of a human or autonomously under the control of a programmed computer. Robots may be used to perform tasks that are too dangerous, difficult or tedious for humans to implement directly or may be used to automate mindless repetitive tasks that should be performed with more precision by a robot than by a human. Robots are categorized into different types such as industrial, exploration, laboratory, medical and real world robots. Object seeking robot is kind of real world robots.

II. Object Seeking Robot

One of the applications that are used by robot is to seek or track an object. Object tracking is the key issue for autonomous mobile robot navigation.

Tracking a moving object is the process of establishing the spatial and temporal relationships between moving objects and the robot or between moving objects and stationary objects. It is believed that a solution to moving object tracking problem will expand the potential for robotic applications in proximity to human beings. Robots will be able to work not only for people but also with people. In the next section, we will illustrate the whole problem with an example application, Sumo robot.

III. Related Works

The detection and seeking of moving objects problem has been extensively studied for several decades [1], [2].

A mobile robot with various types of sensors via ubiquitous networks is introduced in [3]. The work suggests effective visual tracking system for moving objects with specified color and motion information. The work describe mainly the visual object tracking method in ubiquitous. The work in [4] introduces a method of mobile robot object tracking based on feedback of monocular - vision. It implements object tracking through identifying the special sign. The work in [5] is devoted to design and implement a non-holonomic wheeled mobile robot that possesses dynamic object-tracking capability using real-time image processing. Two motion control laws are proposed using Lyapunov's direct method and computed-torque method. Most of these methods are using camera and sophisticated algorithm which result in slow tracking in real time application

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IV. Objective of the Research

The objective of the research is to produce a high speed object tracking robot. The design uses infrared, ultrasonic sensors, fast DC motors and simple algorithm to track the object quickly. Following are the robot specifications:

1) The robot should have a lower power consumption, and speedier movement.
2) Can be easily operated and maintained for future use and upgrades.
3) Easy to diagnose.

In this work, in order to test the object tracking robot, a sumo robot is implemented. Sumo is a competition between robots based on Japanese wrestling [6], [7], [8]. "Sumo" is the Japanese word for wrestling. Similar to traditional sumo matches, two opponents (robots) face each other in a ring. The object is to stay in the ring while pushing the opposing robot out. The robot that stays in the ring the longest wins

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the match. Many sumo robot had been built by researchers at different universities such as the one developed at Ryerson University - Toronto, Ontario, Canada [9] and the Sumobot implemented at the University of New South Wales, Sydney, Australia [10], and many others [11], [12], [13], [16], [17], [18].

Some of these robots were built from scratch and others using robotic kits such as the one provided by Microsoft [14] or other kits [15] available in the market.

V. Operation Description

The object tracking robot should be able to do the following operations:

1) Search for other objects in the ring
2) Perform tasks such as following an object, avoiding the object, and pushing the object.
3) Find, follow and avoid white lines based upon some algorithm.

The implemented robot (as will be mentioned in section 2) has two infrared sensors (right and left) to detect the wrestling ring edge and ultrasonic sensor to detect the opponent. The robot also has two DC motors that can be moved forward and backward. The motors are controlled by Single Pole Double Throw relays.

The robot is turn on wirelessly. The robot begins to scan looking for inspected objects (cycle movement). If an ultrasonic sensor in the front of the robot is active high then the robot will go forward (attack the object), the robot will push the object out of the ring area. When the robot reach the white edge in the ring that mean the infrared sensor (left or right or both) active high, it returns back again to the ring.

There are five ways for robot motion, these ways give the robot ability to attack an adversary and push it outside the ring then return to the centre. Table I describes these ways where:

- A0 and A1 represent logic voltage that controls the input of relay1 which controls motor1
- A2 and A3 represent logic voltage that control the input of relay2 that controls motor2

A. System Design Flow

Fig. 1 shows the state diagram of a suggested robot. There are seven states S_0 to S_6. In each state, the letters in the arc (URL) represent the sensor inputs where U stands for ultrasonic sensor, R stands for the right infra red sensor and L stands for the left Infra red sensor. In each state the four digits represent the robot motor control switched (A_0 A_1 A_2 A_3). In S_0 (stop state) the robot is not moving nor is it sensing objects. The robot is waiting for the enable signal to make it work. The robot will remain in state S_0 as long as the enable signal (en) is not received. Once en signal is detected, the robot enters state S_1. This state mainly represents a time delay of almost 1.4 seconds (70M/50MHz). We had to insert this time delay since the FPGA's clock frequency is much faster than the enable circuit's frequency.

After the enable signal is received (in state S_0) and a time delay of 1.4 seconds has passed (in state S_1), the robot enters state S_2, the scan state. In the scan state the motor control switch is set to 1010 which cause the robot to rotate and scan any moving object. The robot stays in this state as long as no object is detected from the ultrasonic sensor. If the ultrasonic sensor detects any object, the robot enters state S_3, the attack state. In S_3, the robot motor control switches are set to 0110 causing the robot to attack the object. The robot will push the object until one of the infra red sensors (R or L) or both are active high. If the right infra red sensor is high it enter state S4 the right motor reverse state (RM_Rev). In this state the right motor direction is reversed so that the robot will stay inside the wrestling ring. If the left infra red sensor is high it will enter state S5 the left motor reverse state (LM_Rev). In this state the left motor reverse its direction and move the robot away from the ring edge and stay in the wrestling ring. If both the sensors (right and left) are one the robot will enter state S6. In S6 (the avoid state), the left and right motor will reverse their directions and thus the robot will avoid the ring edge immediately.

TABLE I: Robot Motion and Direction With Different Sensor Inputs

Ultrasonic Sensor	Infra red Left	Infra red right	Motion of the robot	Motor 1 control Switches A0	Motor 1 control Switches A1	Motor 2 control Switches A2	Motor 2 control Switches A3	Action
0	0	0	Rotation	1	0	1	0	Scan
1	0	0	Forward	0	1	1	0	Attack
0	1	0	Right Motor Reversed	1	0	0	0	Interrupt
0	0	1	left Motor Reversed	0	0	0	1	Interrupt
0	1	1	Right & left Motor Reversed	1	0	0	1	Avoid

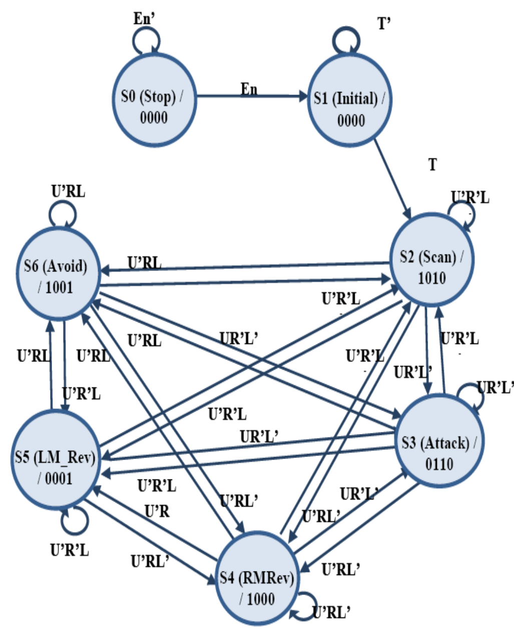

Fig. 1. State diagram of object tracking robot

VI. Robot Design

The design of object tracking robot is done according to the requirements mentioned in Section I and II. There are many components that can be used. The following four circuits are needed in order to build the proposed robot as shown in Fig. 2.

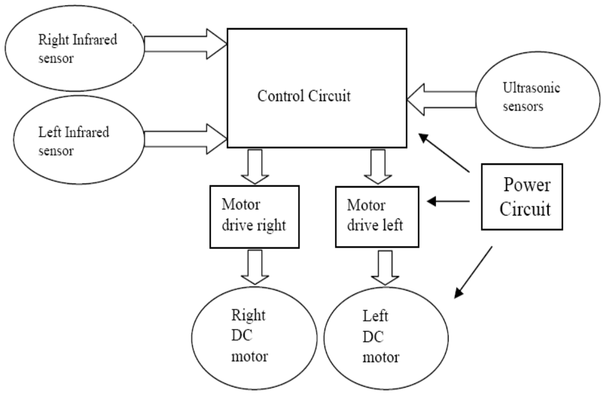

Fig. 2. The robot components

1) Power Circuit (feeding all components with suitable power).
2) Sensors circuits
   - Ultrasonic sensor used to detect objects
   - Infrared sensor used to detect the ring border
3) Circuit to drive the motors.
4) Control circuit to control the robot and give the robot the intelligence needed to track the object.

A. The Power Circuit

One of the work objectives is to design a robot with low power consumption so that it can be operated with small available battery for reasonable time. Two R9V/6F22 9.0 VOLT batteries are used as a power source. A regulator circuit based on LM7805 voltage regulator is designed to derive the suitable operating voltages for control circuit, sensor circuits and the two DC motors from the batteries.

B. The Sensor Circuit

Following sensors are used:

1) Ultrasonic sensor sender MA40B8S
2) Ultrasonic sensor receiver MA40B8R.
3) Infrared sensor sender IR LZD.
4) Infrared sensor receiver IR RZCIZR.

The ultrasonic receiver and the infrared sensors circuits use an operational amplifier (TL074) to amplify the signal received when the robot detects an enemy or when the robot reaches the edge of the ring.

C. Motors

Two bidirectional DC motors (MSYS-1717 [19]) are chosen because of their bidirectional and high speed features. This is the most important feature for the victory. The bidirectional nature helps to attack the opponent form both sides. In other words, even if the opponent attacks from the back the robot will be able to defend. Another appealing feature is its plastic body, which will help to maintain the maximum weight of the robot. The MSYS-1717 propulsion set consists of the Micro DC 1717 motor with a molded plastic, center output gear head and an output drive shaft having a 2 mm diameter. The propulsion is optimized for a default carbon props but the gear ratio can be easily change for other prop dimensions by simply changing the gear head.

In order to decrease the power consumption the AT5550 2-Ch H-Bridge low voltage Motor driver is used. The AT5550 has the following features:

- Independent 2-Channel H-Bridge
- Low Voltage Operation (VCC = 2.0V)
- Low on-resistance (<1.25 Ohm).
- Low Operating Current.
- Built-in Thermal Shutdown Protection
- MSOP-10/DFN-10 Package

D. The Control Circuit

The main part of the object seeking robot is the controller. Two implementations of the control circuit are investigated: FPGA and Microcontroller. The FPGA approach was used first to achieve fast prototyping. After testing the prototype, the FPGA was replaced by off-the – shelf cheap microcontroller.

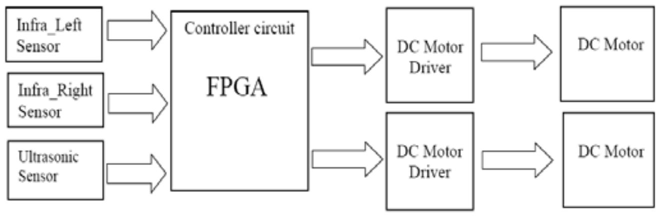

Fig. 3. FPGA based control circuit

E. FPGA Implementation

A prototype of the control circuit is first implemented using VHDL and Xilinx Spartan 3 FPGA as shown in Fig. 3 The main function of the controller is to get signals from the sensor circuit and acts accordingly by sending output signals to the motor circuits. The controller has four input signals and two output signals as shown in the VHDL top level model of Fig. 4 The input signals are clock, and Infra_*L*_Sen, Infra_*R*_sen and Ultra_sen sensors; the output signals are Motor_1 and Motor_2. The RTL schematic of the controller is shown in figure (5). The ISE simulation screen is shown in Fig. 6.

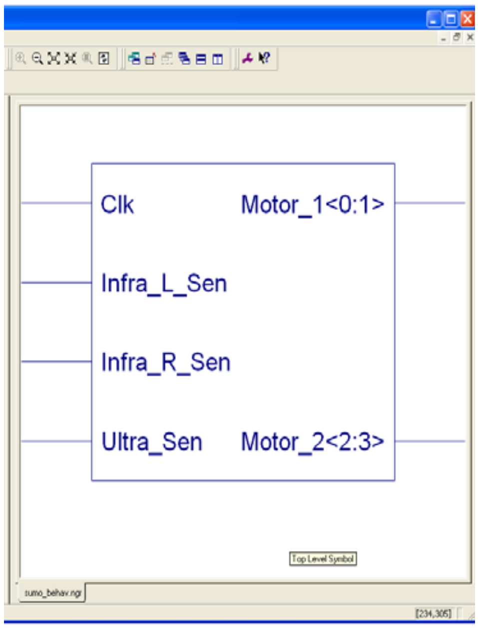

Fig. 4. VHDL top level model

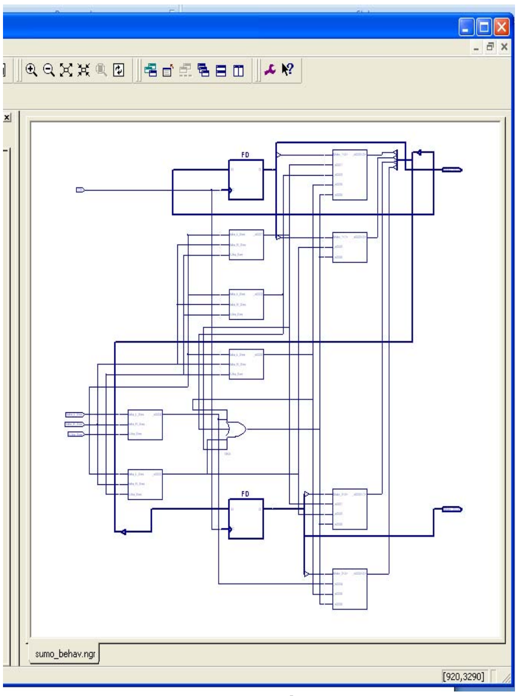

Fig. 5. RTL schematic

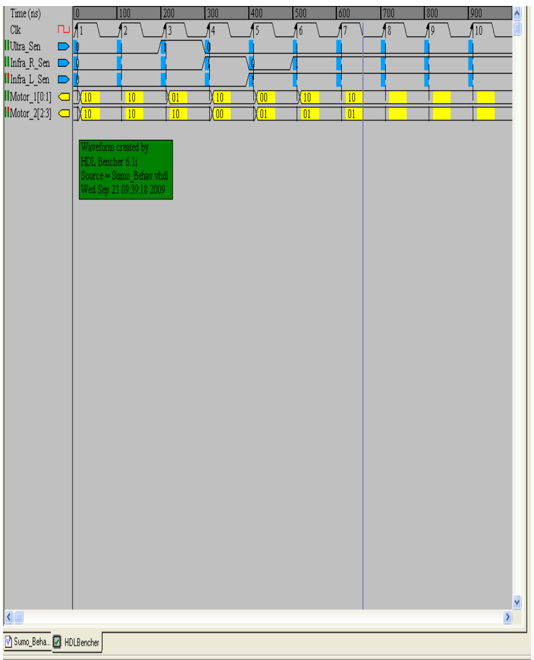

Fig. 6. ISE Simulation for the controller

After finishing the design using FPGA, the control unit we have two choices: The design can be loaded into CPLD chip or using off-the-shelf microcontroller. The first method of design can eliminate the FPGA but it has the limitation of code complexity as well as the interfacing complexity as the driving circuits assumed to be signaled with TTL levels which are mostly used in the controllers I/O such as microcontroller's, FPGA's, Parallel ports….etc. because of these limitations, the second method (using off-the shelf microcontroller) can be better choice in implementing the tracking object robot than using CPLD chip approach as will be discussed next.

F. The Microcontroller Implementation

Using microcontroller to implement the robot controller has the following advantages that serve the objectives of this work:

1) It achieve low power consumption,
2) It works on higher frequencies so it results in robot quick tracking and movement.
3) It has low cost

The PIC16F84A microcontroller [20], [21], [22], [23] was chosen to implement the circuit that controls the robot due to the following:

1) Have fewer I/O 13 pins and are therefore fabricated in smaller packages.
2) The device is a very basic but useful device. It's the most popular of all the Microcontroller devices.
3) FLASH memories are excellent for us because it can be erased and reprogrammed.
4) Only 35 single word instructions to learn

The microcontroller design is divided into following:

1) Interfacing all the hardware mentioned in the previous sections (sensors, motors) and providing the pushing clock and power supply. Fig. 7 shows the PIC16F84A interfacing.
2) Programming the PIC16F84A to do the job needed by the robot using a suitable program [24]. There are several ways of programming the PIC - using BASIC, C, or Assembly Language. The BASIC language is used because it is the easiest way to program the PIC [25]. The MLAB Editor (Programmer's editor to write and edit source files) is used. First, the program in the PIC BASIC EDITOR was wrote and saved as a source file (*.bas). After that, the .bas file was compiled to convert it in to assembly language (*.asm). Then by using PIC Shell it was converted to Hexadecimal (*.Hex) which is the actual machine language understood by the PIC.
3) Testing the robot to ensure that it is working correctly.

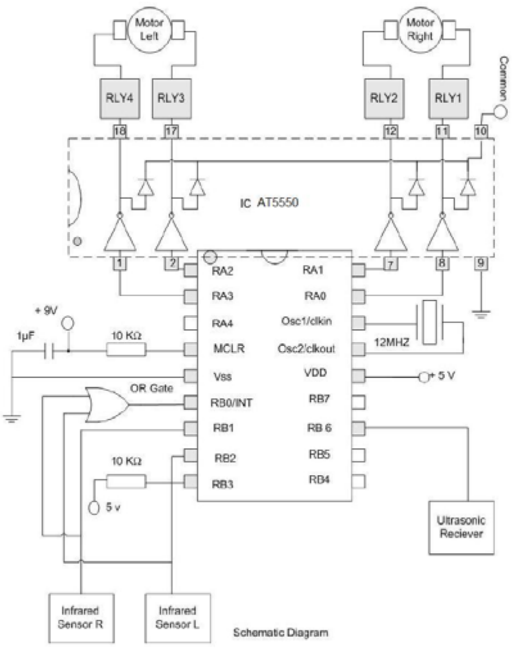

Fig. 7. Interfacing the PIC microcontroller

VII. CONCLUSION

The project objective to design an autonomous object seeking robot was fulfilled. The robot is double sided wedge shaped. The inner design has a microcontroller, reflective object sensors, and motor. The major difficulty was in the software/hardware integration where software and hardware work together. Two robot controllers were implemented using the FPGA Spartan3 and then PIC microcontroller. The FPGA implementation was used first to provide fast prototyping The FPGA based controller was replaced by microcontroller based controller. The final version of the robot has lower power consumption, and speedier movement. The lower power consumption achieved using low voltage motor driver that has low voltage operation (VCC = 2.0V), low on-resistance (<1.25 Ohm) and low operating current. The speed comes from using a bidirectional high speed DC motor. The designed robot is able to search for inspected objects in the ring and perform tasks such as attacking, following and avoiding. However, the proposed robot has some limitations:

1- It is used only in flat floor with dull black ring.

2- The robot need to be charged completely before it used (the work time for the robot = 20 minute only).

3- It is also need to be discharged completely before the robot is put away for storage.

4- The robot need to calibrate the range of sensors: ultrasonic sensor, and two infrared sensors.

VIII. RECOMMENDATION AND FUTURE WORK

There are still many improvements that can be made such as the use of the many unused outputs of the microcontroller to make the robot respond at faster rate, and give more speed to it. Higher intelligence can also be implemented to the robot via extra unused ports in the future.

The designed robot is targeted for tracking objects, but the technology developed in this design can easily be adopted for use in almost any applications.

There are some functions that can be added:

1) Use of laser instead of infrared to improve tracking precision
2) Add a remote camera for scanning and recording the objects.
3) Use arrays of solar cells to charge rechargeable cells and batteries.
4) Add additional sensors for more intelligent activities.

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