Designing of FPGA board for obstacle avoidance robotic vehicle

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Abstract- This paper presents a design and implementation of computational hardware and software of FPGA robot. In this paper; a prototype of robot for obstacle detection using IR proximity sensor has been designed using FPGA. The design includes the adaptation of the motor driven circuit with L293D to drive the motors of the robot. Using Verilog HDL coding the design is implemented on an ALTERA DE1 board. Co-Design of software and hardware which are used to design robotic systems that have improved reliability.

Keywords- DC Motor, IR proximity sensor, FPGA, ALTERA, GPIO’s.

I. INTRODUCTION

Obstacle avoidance is one of the most basic problems in mobile robotics. In those systems where there are no other moving objects other than the robot itself static obstacle avoidance is sufficient. The reason behind using FPGA is that the FPGA doesn’t have fixed hardware structure, on the contrary it is programmable according to user’s applications. The FPGA-bot is a low-cost moving robotics platform designed using DE1or DE2 board. The FPGA-bot is designed to be a small self-directed vehicle that is programmed to move in reaction to sensory input. A wide variety of sensors can be easily attached to the FPGA bot. Here we are using IR proximity sensors for the detection of the obstacle. Then 9V rechargeable battery pack is used to supply power. Two DC drive motors are used to move the robot. The robot can move forward, left, right and stop based on the detection of the obstacle. The FPGA is automated to act as the controller. The DC motors are controlled by timing pulses produced by the FPGA board. The appearance of reconfigurable Field Programmable Gate Arrays (FPGA) has given increased to a new platform of complete robot control system. With FPGA devices, we can design to fit the requirement of control system tasks for a robot. A FPGA-based control system is designed to solve the problem of parallel tasks attaining control which occurs on single processor machine. FPGA is as flexible as software and reliable as hardware. Timing analysis can be done easily and also the programs can be converted into hardware blocks which do not require any operating systems. Robots carry out many various tasks. During these tasks the robot moves and orients. While navigating, it uses signals from the environment and the contents of its own memory to make the correct decisions. This form of navigation may be many depending on the given task and problem. A robot with number of sensors and numbers of motors could be controlled concurrently with use of a single FPGA chip.

So that, this is a small attempt to implement a mobile robot which avoids obstacles with use of range sensors and wheeled motors. The algorithm is developed using combinational logic. This obstacle avoidance system can be implemented in medical assertive devices, industrial robots and outdoor/indoor navigation robots. Today’s FPGA are very different and have far greater capabilities. The ability to easily reconfigure Field Programmable Gate Array (FPGA) makes the design less expensive than predesigned hardware. FPGA provides suitable platform in realizing complex hardware system as well as implementing data intensive algorithm computation like sensing obstacle surrounding the environment of interest. These features bring convenience to incorporating an artificial intelligence-based program for mobile robot navigation and obstacle avoidance task or mission.
II. BACKGROUND AND LITERATURE REVIEW

A. FPGA

A Field Programmable Gate Array (FPGA) is an integrated circuit that can be programmed in the field after manufacture. FPGA is largely used for application specific design. FPGA contains an array of Configurable Logic Blocks (CLBs), Look-up Tables (LUTs) and programmable interconnects between them. By programming these interconnects, same CLBs can be used for several different functions. Power dissipation is reduced because out of all available paths the shortest path is chosen for the implementation. With the widespread of application of robot tracking system, it is necessary that the development of this robot tracking system that facilitate future enhancement. However, problem of detecting the object, planning path and avoiding obstacles during tracking the object is an important issue in mobile robot tracking system. Plentiful of sensors had been used to solve these problems and one of the FPGA platforms is chosen in this project. With FPGA, the designation can easily fit the requirements of application. This is because FPGA mainly design connection of logic block and parallelism can be achieved easily. We are interested in developing FPGA based robot to implement the shortest path algorithm since it has a reconfigurable feature. FPGA based robots are used for different applications due to its high performance on board processing unit with less power consumption and reconfigurable characteristics. The technical achievement in developing FPGA-based control system which utilizes the hardware/software re-configurable feature of the advanced fpga device. One of the main advantages of a FPGA-based processing core is creating a bridge between image processing algorithms and hardware in such a way that it can be used for realtime navigation and obstacle avoidance in mobile robots. The most salient feature of FPGA is the hardware reconfigurability, i.e., we can design and modify the hardware circuitry in FPGA fabric to meet the needs of specific applications. Resource-constrained miniature robots require small but high-performance onboard processing unit and reconfigurable electrical hardware to carry out different mission. The advances in Field Programmable Gate Array (FPGA) technology offer a system on programmable chip (Sops) solution to this demand. FPGA-based control system is utilizes the hardware/software re-configurable feature of the advanced FPGA device to achieve the goal. The ability to easily reconfigure Field Programmable Gate Array (FPGA) makes the design less expensive than predesigned hardware. FPGA provides suitable platform in realizing complex hardware system as well as implementing data intensive algorithm computation like sensing obstacle surrounding the environment of interest. These features bring convenience to incorporating an artificial intelligence-based program for mobile robot navigation and obstacle avoidance task or mission.
B. IR sensors

![IR Sensor](image)

Fig. 2. IR Sensor

An IR sensor is a device which detects IR radiation falling on it. An IR sensor is basically a device which consists of a pair of an IR LED and a photodiode which are collectively called a photo-coupler or an opto-coupler. The IR LED emits IR radiation, reception and/or intensity of reception of which by the photodiode dictates the output of the sensor. For primarily making an IR sensor the components which we used are IR Led, OP-AMP, Photodiode, 2 x 150 Ω Resistance, 1 x 10 KΩ Resistance, 1 x 10 KΩ Variable Resistance (Potentiometer), 5 Volt power source, wires, breadboard.

C. Motor Driver

![Motor Driver](image)

Fig 3. Motor Driver

The processing unit drives the wheel’s control circuits with four groups of programmable input and outputs (GPIOs), controlling whether the auto goes forward/backward or turns left or right. Where H-Bridge (L293D) motor driver circuit is used to realise the above controls. An H bridge is built with four switches (solid-state or mechanical). In a single L293D chip there are two h-Bridge circuit inside the IC which can rotate two dc motor independently. Due its size it is very much used in robotic application for controlling DC motors. There are two Enable pins on l293d. Pin 1 and pin 9, for being able to drive the motor, the pin 1 and 9 need to be high. For driving the motor with left H-bridge you need to enable pin 1 to high. And for right H-Bridge you need to make the pin 9 to high. If anyone of the either pin1 or pin9 goes low then the motor in the corresponding section will suspend working. It’s like a switch. Given below is the pin diagram of a L293D motor controller.
III. PROPOSED SYSTEM

A. BLOCK DIAGRAM

The system architecture is shown in Fig.3. It consists of different blocks includes IR proximity sensors (IR1 and IR2), DC motors with the driver circuit and these are interfaced using GPIO’s to EL-BERT V2 board using Verilog HDL code in Xilinx. Where DE1board is a "brain" of the bot which will drive the motors in reaction to the sensor readings. It shows the block diagram of FPGA board interfacing with peripherals required in the work. In this work, FPGA hardware is designed and VHDL code for application required is dumped into the target FPGA hardware. In this way, this application will be example of Embedded Systems i.e. software embedded into the hardware. It concludes that this work is related to interdisciplinary approach.
B. FLOW CHART

![Flowchart of system architecture](image)

Fig 6. Flowchart of system architecture

IV. WORKING

Software Tools

a. Implementation of Motor Module:
After analysis of functional stimulation report we interfaced the module to EL-BERT V2 board and checked the functionality by assigning the pins so that LED's should glow for the inputs given. We successfully verified the operation by varying the switch inputs to all the four cases. Then we implemented the module by using the hardware.
b. Implementation of IR Sensor Module:
After analysis of functional stimulation report we interfaced the module to EL-BERT V2 board and checked the functionality by assigning the pins so that LED’s should glow for the IR inputs given. We successfully verified the operation by varying the switch inputs to all the four cases. Then we implemented the module by using the hardware.

Fig 8. RTL Schematic of IR Sensor Module

V. EXPERIMENTAL RESULTS

Fig. 9. DC motor driven circuit
To test the working of the dc motor driven IC circuit we prepared the circuit using the bread board IC L293D to drive motor having inputs and outputs, voltage regulator to have 5V dc supply, interconnecting wires, 12V dc power supply to drive motors. These are connected as per the circuit shown in the fig:5

![Fig 10. Circuit for IR proximity sensor](image)

To test the working of the IR proximity sensor circuit, we prepared the circuit using the bread board, IC LM358, transmitter and receiver LED's, resistors each across transmitter and receiver, LED to check working, voltage regulator to have 5V dc supply and interconnecting wires. These are connected as per the circuit shown in the fig 6.

VI. CONCLUSION

We implemented the complete system of FPGA-bot using Xilinx and we successfully generated the necessary architecture required for the detection of obstacle using IR proximity sensors. We performed the hardware of the system for each and every module and successfully designed the FPGA based robot for the detection of the obstacle using IR proximity sensor. By working on this project we came to know how to implement the software designed code to real time applications. We faced a lot of problems with regard to drive the FPGA-bot to all conditions but our continued efforts paid result of working drive the robot to all conditions.

VII. FUTURE WORK

1. Adding a camera: If the current project is interfaced with a camera (eg. a webcam) robot can be driven beyond limit itself Line-of-sight and range become practically unlimited as network have a very large range.
2. Using a fire fighting robot: By adding temperature sensor, water tank and making some changes in programming we can use this robot as fire fighting robot

REFERENCES


