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FPGA based Navigation Approach for Visually Impaired Individuals

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Abstract: This manuscript describes design and implementation of a navigation-based-guidance robot for the visually impaired individuals. These types of systems play vital role in assisting their day-to-day navigation. Our work is incorporated with various cutting-edge technologies such as sensor-fusion systems to interpret and use all the input data from various sensors, fuzzy logic for accurate true-parallel processing, state-of-the-art navigation algorithm and wireless systems to overcome various challenges, human error and provide solid user-centred system. Many researchers have identified that optimised and system specific navigation algorithms are more efficient than traditional and generic algorithms like bug algorithm, dijkstra algorithm, greedy algorithm, etc. Our Robot comprises of ultrasonic sensors, compass sensor, Wi-Fi module and wheels (including stepper motor, motor driver for the propulsion of the robot). Ultrasonic sensors and compass sensors provide necessary and key data for the navigation algorithm resided in the FPGA which interprets in the input data, analyses the environment and calculates the shortest and efficient path towards the destination before navigation process takes place. Navigation process also includes consistent active obstacle detection and avoidance. The directional and path data is also shared through Wi-Fi module to visually impaired subject's cared persons, this helps to continuously monitor and support the subject. The proposed work has been implemented through simulation in our laboratory on the platform of FGPA board (Xilinx Zynq – 7000 ZedBoard) and the results are very satisfactory.
Keywords: Obstacle avoidance, FPGA, Verilog, Navigation, Wireless, Compass

I. INTRODUCTION

Visually Impaired Individuals are the people who has vision impairment and decreased ability to see. And they are unable to see their surrounding environments and face many challenges in their daily life. These individuals need human assistance, especially in outdoor environments and their cared individuals need constant monitoring of the subject. So here in our project, we are using sensor-based navigation robot to aid the impaired individuals in their day-to-day navigation and also incorporated wireless technology to share and monitor the location of the individual. In this era, robots are used in many ways to help and assist in various applications and domains and thus human aiding robots have become a popular research area over the last few years, there are also some challenges, past work, open problems discussed in [8] which are diligently studied. In recent years, significant amount of research has been focused on path planning in robotics and it plays an important role in robotics for navigation process. When a navigation task is assigned to the robot it is necessary to find a shortest feasible path with no obstacles to move towards the destination. Initially, a task is assigned to robot to travel between two points and by using shortest path algorithms the robot travels through the shortest path. This process is repeated for every time to assign each task which leads to increase in time, to avoid this a set of tasks which has to be done is given in a sequence to the robot at a time so that the robot can perform multi task and also the time is reduced including reliability and continuously high quality of work. Robots can also be effective in areas where there are skill shortages. Significant application opportunities exist in the emerging service robotics sectors, whose products will impact on our everyday lives by contributing high-value-added services and providing safer working conditions. Robotic technologies, such as navigation, motion control and sensing and cognition, will enable a broad range of innovations in today's products resulting, for example, in more flexible, environmentally friendly transport systems and intelligent household appliances.

In future, robots will autonomously assist with the protection of offices and homes, and will help secure borders or monitor the environment in both routine and emergency operations. In space, the use of robots has become almost obligatory. Both unmanned and manned missions, be it in earth orbit or interplanetary, will be preceded or augmented by robots. In addition, the technologies applicable to space robotics will enable a wide range of earth-based exploration and material-processing activities from automated undersea inspection to mining and mineral extraction under hazardous conditions. This no denying that Robotic technologies are all set to change the way things are done in the industries in which they are being implemented. All the entrepreneurs are clearly optimistic about the use of Robotics in various industrial segments and its future in India. Resource-constrained miniature robots

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require small but high-performance onboard processing unit and reconfigurable electrical hardware to carry out different missions. The advances in Field Programmable Gate Array (FPGA) technology offer a system on programmable chip (SoPC) solution to this demand as stated in [1]. As it turns out, low-power optimized FPGAs are able to enhance the computation of several types of algorithms in terms of speed and power consumption in comparison to microcontrollers of commercial sensor nodes. We show that architectures based on the combination of microcontrollers and FPGA can play a key role in the future of sensor networks, in fields where processing capabilities such as strong cryptography, self-testing and data compression, among others, are paramount as stated in [7]. Use of FPGAs in robotics gives us lots of option to solve the complex operations and real time applications as well. The speed and reconfigure ability of FPGA make that possible. Wireless communication which is having tremendous applications, we are making the use of wireless communication along with FPGA to have industrial security as well as application as stated in [4]. Various path planning algorithms are studied in [2] and [3] which helped in designing our short path planning algorithm.

II. IMPLEMENTATION

The implementation is carried out in Verilog HDL using Xilinx Vivado Software tools. The control logic describes the required action at every instant of time. The control logic and navigation algorithm is resided in FPGA which is connected to Ultrasonic sensor (HC-SR04), Wi-Fi module (ESP8266-01), Compass sensor (Pmod CMPS2) and Stepper motors. The design of each individual modules is illustrated in the RTL shown below.

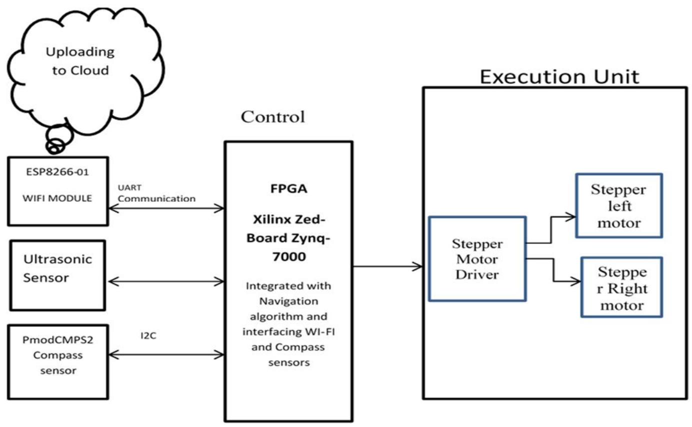

Fig 1. Block Diagram of Proposed System

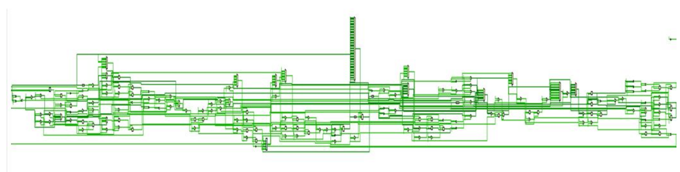

Fig 2. RTL Design – Wi-Fi module interface

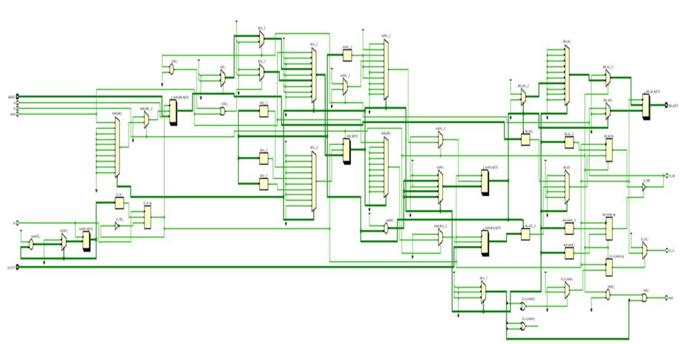

Fig 3. RTL Design – Compass sensor interface

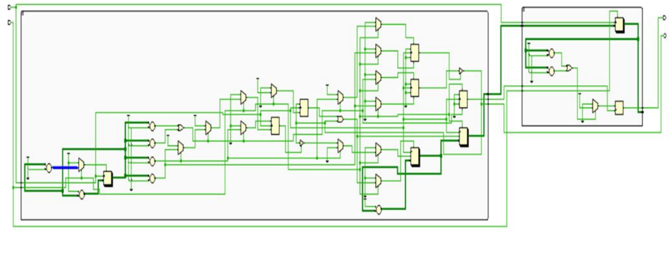

Fig 4. RTL Design – Navigation algorithm

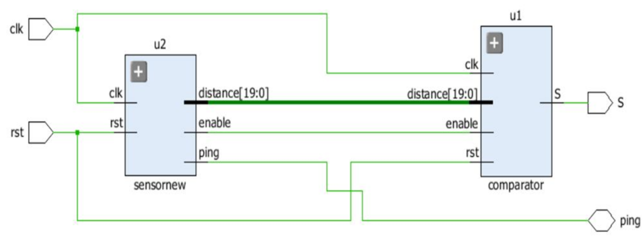

Fig 5. RTL Design – Wi-Fi module interface

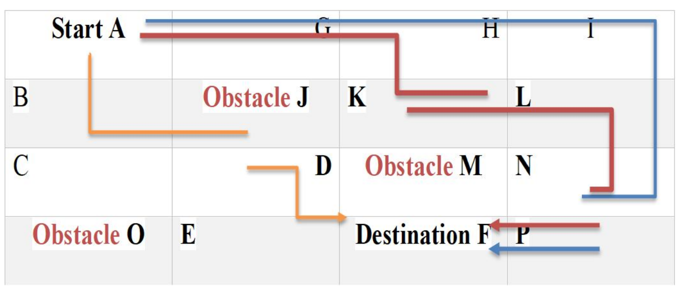

Fig 6. Navigation path environment

As soon as the system i.e. robot starts, Wi-Fi module is connected to a Wi-Fi network and a TCP/IP protocol has been established to a preferred cloud service, compass and ultrasonic sensors provide constant data stream to the navigation algorithm. The robot with the impaired individual uses the sensors data and moves accordingly, it calculates the shortest path between final destination point to its initial position and plans its movement. If any obstacle is detected, the robot finds a way around it and moves accordingly until final destination point is reached. Wi-Fi module shares data like current direction and distance travelled to cloud continuously so that cared ones of the impaired individual can monitor and support the subject which can also be implemented in [9]. The Wi-Fi module works by interpreting AT commands it receives from the FPGA through UART protocol. Compass sensor provides the direction continuously to the FPGA through a standard I2C communication protocol. FPGA controls the compass sensor and takes the data from sensor continuously. Compass sensor's I2C address is 0110000. Similarly, ultrasonic sensor works simultaneously with other modules to provide continuous stream of the data for the navigation.

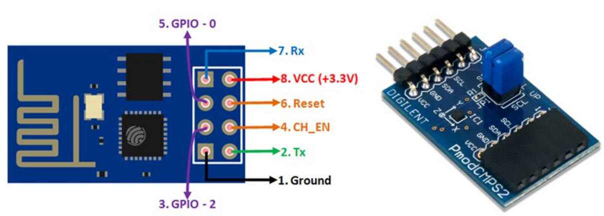

Fig 7. ESP8266-01 Wi-Fi module and Pmod CMPS2 Compass sensor

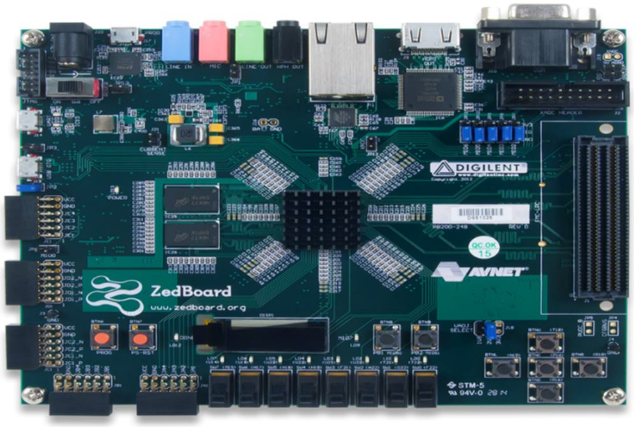

Fig 8. Xilinx Zynq – 7000 ZedBoard

The navigation approach we used in our project is shortest Path Algorithm. Our static environment comprises of 4 x 4 grid, where each individual block is a node i.e. there are 16 nodes namely A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P as shown in the figure above. Our algorithm finds the shortest path between two given nodes. Here in our environment, there is a source node and a destination node and some obstacles in the path, the robot finds the shortest path and starts navigating towards destination. If any obstacles are detected, the robot avoid them and continue to be directed towards the destination. In the grid for given source node, the algorithm finds the shortest path between that node and destination node. For example, if the nodes of the grid represent cities and edge path costs represent driving distances between pairs of cities connected by a direct road (for simplicity, ignore red lights, stop signs, toll roads and other obstructions), this algorithm can be used to find the shortest route between one city and all other cities. A widely used application of shortest path algorithm is network routing protocols, most notably IS-IS (Intermediate System to Intermediate System) and Open Shortest Path First (OSPF). It is also employed as a subroutine in other algorithms such as Johnson's. Looking at the path planning, there are three paths which can be considered from the source to destination. The first path (Blue) is from the A-G-H-I-L-N-P path and second path is A-G-H-K-L-N-P (Red) and the third path (Yellow) is A-B-C-D-E-F these are considered with the obstacle avoidance. In these three paths, the shortest path is A-B-C-D-E-F using 6 nodes with the obstacles avoidance. This explains about our navigation in the desired environment.

III. RESULTS

The simulation results illustrated below.

Fig 9. Wi-Fi module interface with FPGA

The above simulation result provides a clear overview of the AT commands sent to the ESP8266-01 Wi-Fi module from the FPGA controller.

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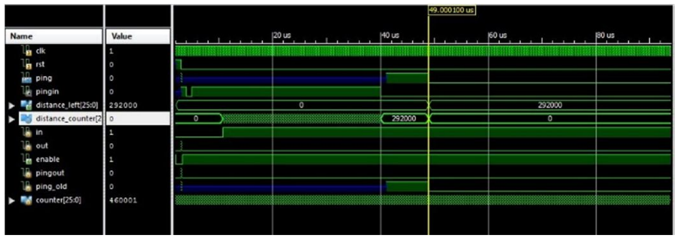

Fig 10. Ultrasonic sensor interface with FPGA

The above simulation ultrasonic sensor is interfaced with FPGA and trigger, echo signals can be observed clearly.

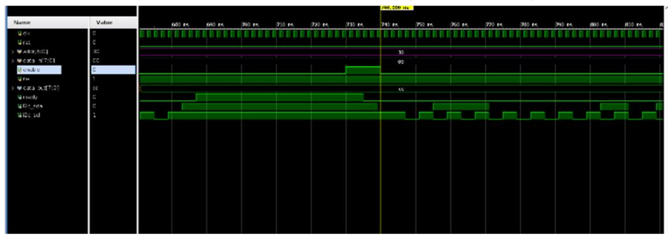

Fig 11. Compass sensor interface with FPGA

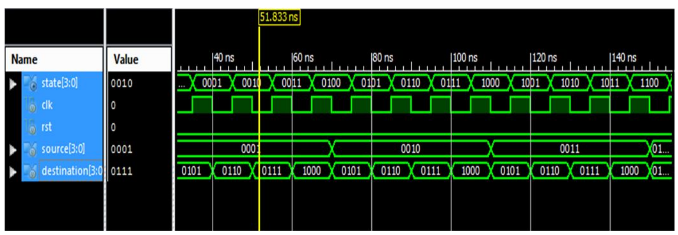

Fig 12. Path probability of navigation algorithm

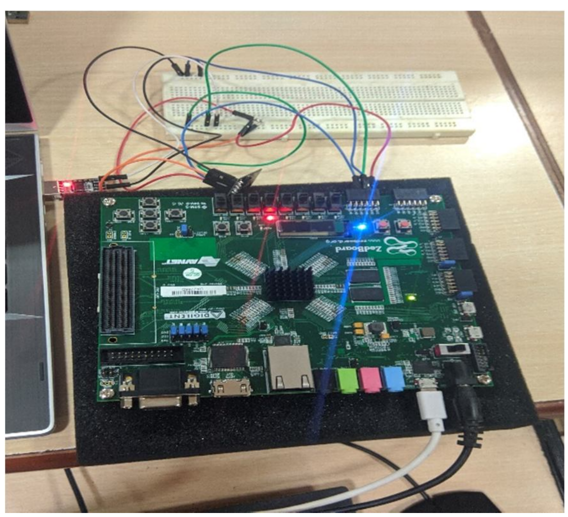

Fig 13. Hardware verification of Wi-Fi module

Working of Wi-Fi module i.e. ESP8266-01 is verified successfully and the data packets are successfully being transmitted from the FPGA to another TCP/IP host. Wi-Fi module has more advanced protocols, features and security than in [5].

IV. CONCLUSION

The work done through this project is environment specific. This project can be further extended to multiple robots as in [6]. Thus, it can be satisfactorily concluded that our design can be implemented to be used as real time guidance system for the visually impaired individuals and sharing critical information of subject wirelessly for constant monitoring and support.

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