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FPGA Implementation of Data Fusion Technique for Mobile Robot Obstacle Detection and Avoidance in Indoor Environment

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Abstract: ***Data fusion techniques has an important role in today's life, especially in the modern world where devices are now more of intelligent devices. This intelligent devices requires to sense data and then fused them to obtain better result with respect to their objectives. Two sensors are often fused to acquire information which cannot be acquired by a single sensor alone. Sensor fusion is extremely use for mobile robots for obstacle detection, avoidance and navigation. So a technique is propose which can detect an obstacle, judge its distance and avoid obstacles using the two ultrasonic sensor with the help of an FPGA and a rear ultrasonic sensor is also employ to protect the robot from obstacle at the back side of the robot. Here the propose data fusion technique is Extended Kalman Filter type of estimation method which is use as the fusion algorithm. A motor controller is also employ to control the four wheel robot during navigation. The proposed technique aims to ease robot control methods, make cost effective, faster processing and less complex system for sensor fusion.***

Keywords: FPGA, Robot Model, Ultrasonic sensor, EKF, Motor controller

1. Introduction

Sensor data fusion technichque play an important role in the processing of information and control of mobile robot technololgy. The data can be collected using different type of sensors and then processed for optimal performances. Sensor fusion means information integrated from several types of sensor and then arrive at unified result, sensor fusion technique help robot to know its location, its path, and where its need to follow. So the fused data provided by morethan one sensor gives an improve information than a single sensor.

Hall and Linas [1] define data fusion as a techniques which combine data from multiple sensors and related information from associated database to achieve improved accuracy and more specific inferences than could be achieved by the use of a single sensor alone. Sensor data fusion technique have been employed by multiple sensor environments in order to fuse the data from different sensors. The purpose of using data fusion techniques in multiple sensor environment is to minimize error and arrive at high reliability.

The two ultrasonic sensor at the front side in this research will sweep through the front side to collect data with respect to the availability or non-availability of obstacles. The data obtain from this two sensors are then fused to obtained the aggregate information for implementation of the obstacle detection, avoidance and navigation.

This paper is organizes as follows. In section II, i will briefly explain the indoor environment where the robot will navigate. In section III, i will explain about the structure of the complete model which comprises the robot itself, the sensor, and the FPGA (Field Programmable Gate Array). In section IV, i will discuss about the data fusion techniques and how to navigate the robot based on the proposed algorithm.

2. The Indoor Environment

The indoor environment is the types in which all is known about the building itself but most of the internal objects are not stationed, which means their location may change from time to time. Indoor environment in most of the cases look horizontally flat, having no bumps. The fercilities of indoor environment mostly are solid blocks, glasses, fabrics, and soft objects etc., some of this objects are easily breakable which means the robot need not to collide with them especially when moving at a high speed. This indoor environment can be an office, home, or even a factory where various machines are kept for operations

3. Structure of the Complete Model

3.1 Robot Model

The robot model is a four wheel differentially drive platform, it has a rectangular frame work, it also has a motor controller that control the left and right wheels motors. The Phidgets Stepper Unipolar 4-Motor Stepper Motor Controller allows you to control the position, velocity, and acceleration of up to 4 unipolar stepper motors. It can be used in applications that require precise positioning and continuous rotation, at low cost. The stepper motor controller is compatible with almost all operating systems and can be programmed in a wide variety of different languages [6]. The motor cotroller drives the dc motors by selecting the forward or reverse motion of the robot depending on th obstacles around the robot itself. The control board is the FPGA board which have been loaded with the fusion algorithm and the obstacle detection and avoidance program in the indoor environment. The complete structure of the robot model is shown below:

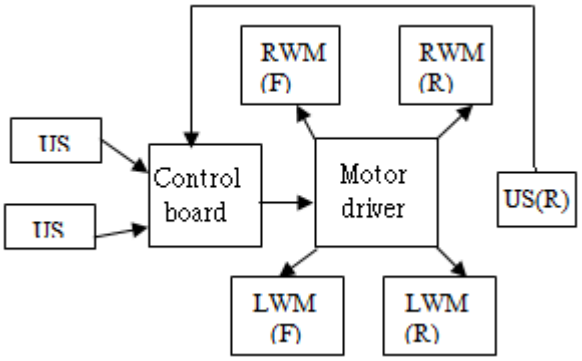

Figure 1: Complete Mobile Robot Structure

- US= Ultrasonic sensor
- RWS= Right wheel Motor
- LWM= Left Wheel Motor
- (F) = Front
- (R) = Rear

3.2 Ultrasonic Sensor

Sensors can be employ to find distance between itself or robot position and an obstacle(s), and the robot take decision base on the presence or non presence of obstacle around it, this is called range finding. Ultrasonic sensor is one of the range finding sensor, and it is the sensor i employ for this research.

Ultrasonic sensors are use to detect location or movement of targets and at the same time measure the distance to the targets. Ultrasonic sensor is base on sound wave propagation which is unaffected by glass or mirror base obstacles, they are also useful under conditions of poor light and transperent obstacles. Ultrasonic sensors are also called transceivers becouse they send and receive signal inform of waves, and they work base on the principles similar to radar or sonar [3]. In this project, i use three ultrasonic sensors, two at the front which are fused to provide an information with respect to front obstacle distances, and the single rear sensor which help the robot to avoid obstacle at the back of the robot when it is moving backward i.e. when reversing.Usually the ultrasonic sensors are design to measures distances from 1cm to 255cm.

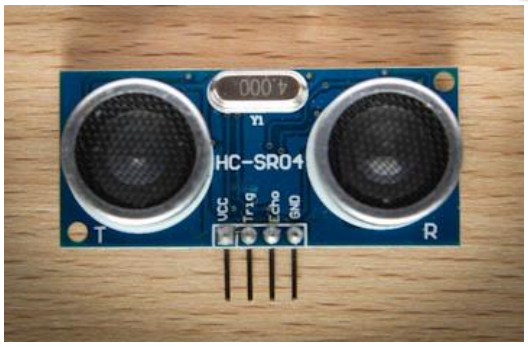

Figure 2: Ultrasonic sensor

3.3 FPGA

The use of FPGA has been given much consideration for solving computational problems. FPGAs are semiconductor devices base on configurable logic blocks (CLBs) connected via programmable interconnects. FPGA algorithm provide a programmable features which have great potential for implementation of sensor fusion. An efficient data fusion algorithm for the two ultrasonic sensors using FPGA which tackle many problems related to complexity and good performance and low power consumption is employ in this project for better result. Xilinx Spartan 3E FPGA is the processor use, as it support clock frequency up to 32MHz.

4. Data Fusion Techniques

In data fusion technique, complementary relation between the data source is employ, because it represents different parts of the scene and could be used to obtain more complete global information. But for the data fusion algorithm, State estimation technique is employ because it involves finding the values of the vector state such as position, velocity, and size that really fits as much as possible with the observe data. Some of the most common state estimation methods are maximum likelihood and maximum posterior, Kalman filter, particle filter, distributed Kalman filter, and covariance consistency methods [4]. Among this state estimation techniques kalman filter is the most popular estimation technique which is originally propose by R.E. Kalman in 1960s, but in this project, the data fusion is based on Extended Kalman Filter (EKF) which is a modified technique of Kalman filter.

EKF has two core steps, the prediction step and the update step. In predictive step, the robot predict its position one step in advance by utilizing the information about the control actions which are being taken, it formulate the predicted pose under the influence of noise which might exist in control actions information, therefore due to noise existence in the predictive step, one cannot be assure that the predicted pose is accurate [5]. But the update step is required to bring back robot predicted pose close to its real position.

The two front ultrasonic sensors provide the data from the front view which is digital in nature, and then send to the FPGA. The interfacing code for the sensors are written in Arduino IDE and then loaded to the FPGA, after interfacing all the three sensors with the FPGA board then the two front sensors fusion will be carried out using EKF as fusion algorithm in MATLAB.

The robot is design to navigate in both direction, that is forward and reverse, and it can also turn itself in a limited space area. When writing the programs, the distances at which the robot is to avoid the obstacle will be specified so that a control action will be applied when the robot is at specific distance from the obstacle(s) it detect.

5. Conclusion

The research is design for Data Fusion Technique for Mobile Robot obstacle detection and Avoidance in Indoor Environment, all the component required for the hardware implementation where listed and explained, the research aims to ease robot control methods, reduce production cost, and lessen complexity of sensor data fusion. The future research work will be on developing the programs and the hardware.

References

[1] D. L. Hall and J. Llinas, "An introduction to multi-sensor datafusion," Proceedings of the IEEE, vol. 85, no. 1, pp. 6–23, 1997.
[2] B. Salina, and P. Malachi, "FPGA implementation of data fusion algorithm for object localization" IEEE International Conference on Recent Advances and Innovations in Engineering, 2014. ICRAIE-2014, 09-11 May, 2014.
[3] http://en.wikipedia.org/wiki/Ultrasonic_sensor
[4] Review Article, "A review of data fusion techniques," the scientific world journal, volume 2013, article ID 704504, Hindawi publishing corporation, 2013.http://dx.doi.org/10.1155/2013/704504.
[5] H.Chae, Christiand, S. Choi, W. Yu, J. Cho (2010). "Autonomous navigation of mobile robot based on GPS/INS sensor fusion by EKF in semi-outdoor environment", IEEE/RSJ International Conference on Intelligent Robots and Systems, October 18-22, Taipei, Taiwan.
[6] http://www.robotshop.com/en/phidgetstepper-unipolar-4-motor.html.

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