OBSTACLE & STAIR DETECTION SYSTEM FOR MAGIC2BOTS

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***Abstract*: A MagicBot is a versatile robot that is capable of a multitude of tasks. While these robots are fairly good at detecting and navigating around obstacles, they are less effective at accounting for negative obstacles. Failing to account for these can cause irreparable damage to the robot and its systems. Existing solutions to this problem usually involve elaborate LIDAR and camera systems, which are invariably expensive and slow. This project explores an easy and inexpensive solution to this problem using a set of infrared proximity sensors to form a detection system.**

1. Introduction

Robots used for commercial and other purposes can be very expensive; a robot containing expensive equipment such as a variety of sensors and motors may be resilient to many environmental factors but are prone to accidents and damage. Robots from the Magic2 series are an example of this; they are otherwise resilient, but very vulnerable to falls.

The STOP (Stairs, Trouble and Obstacle Prevention) sensor, as shown in Figure 1, is an inexpensive and efficient solution designed to prevent fall related accidents that may occur during training or navigation. The STOP sensor is an array of five inexpensive infrared proximity sensors that successfully detect fall-offs and stairs.

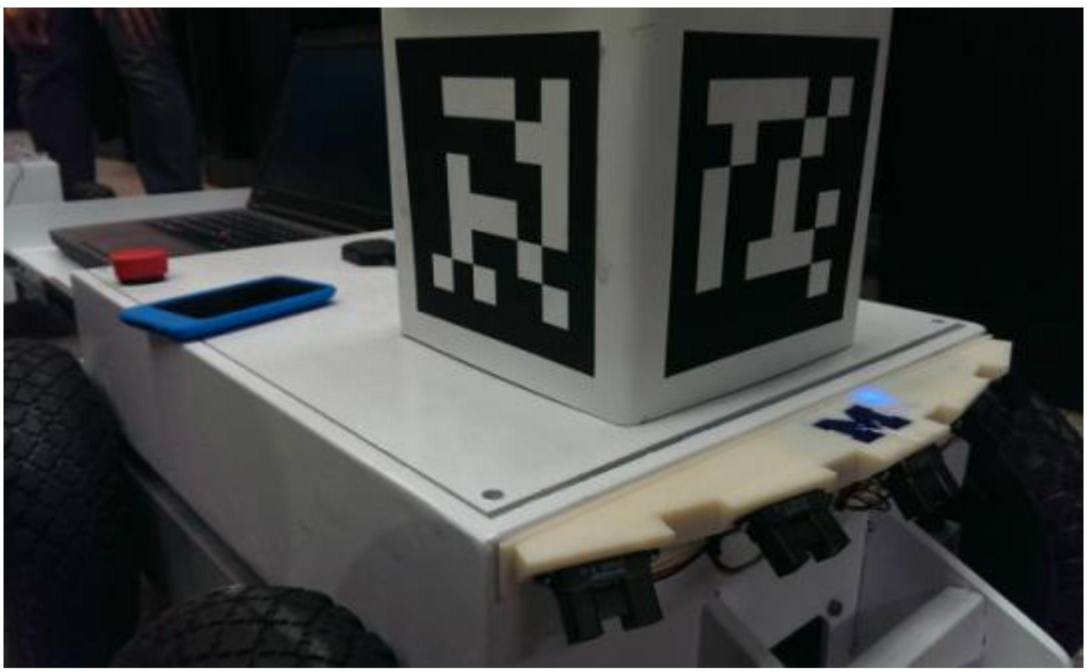

Figure 1. STOP Obstacle sensor mounted on the robot.

This paper describes the design and implementation of the STOP sensor for the Magic2 Bot. This project focuses on Team Michigan's revision of the Magic Bots from the MAGIC 2010 Competition (Multi Autonomous Ground-robotic International Challenge). This revision built upon the software and hardware from the Magic Bots and improved upon many aspects such as maximum speed, software, motors, wheels, PCBs, robot chassis design and radios. The STOP sensor is a novel addition to this robot that aims to prevent crashes.

2. Related Work

The problem of obstacle detection in robots has been investigated by many other researchers. This section summarizes some of their works.

One method for obstacle detection in robots employs IR Sensors, LIDAR, camera and image processing. In [2], Hyunwoong Park, Sungjin Baek and Sooyong Lee experiment with robots that utilize multiple rotating range sensors with a sensor system for improving the accuracy of the range information; a total of 12 sensors were placed around the body of the robot so as to cover all the sides. Information from the overlapping sensor rays was then analyzed using an iterative algorithm to construct a map of the obstacles.

Meha Sharma, Rewa Sharma, Kamna Ahuja and Swati Jhain implement an obstacle detection system for a robot in [1] based on a multi-sensor integration technique using IR proximity sensors; IR sensors were selected over ultrasonic sensors due to their narrow beam width and their resistance to sound absorbing materials.

The LIDAR/camera system in the Magic2Bots handles positive obstacle detection efficiently but fails to recognize every negative obstacle; the STOP obstacle sensor fixes this blind spot using a simple array of infrared proximity sensors that detect stairs and drop-offs.

3. Methodology & Results

While the Magic2Bot's LIDAR/camera system can efficiently create 3D maps of its surroundings, the LIDAR system takes a very long time to accurately scan its environment. This is often a problem, especially when the robot needs to react in time to avoid negative obstacles, such as drops or cliffs. Failing to accurately account for negative obstacles can cause serious harm to the robot, or any equipment that may be onboard.

Instead of building on LIDAR based systems, we decided to implement our solution using individual sensors; such a solution, when implemented correctly, would be inherently faster and lighter weight than existing solutions. For our design, we decided to explore infrared proximity sensors that would detect positive and negative obstacles to supplement the data from our current sensors.

We decided to use GP2Y0A02YK, which is a Sharp IR Distance Sensor with a proximity sensor with a range of 20-150 cm. The voltage read by the analog sensors was plotted against the distance between the sensor and the point on the ground. The different colors with Columns D through J depict different angles from the vertical starting with 15 degrees up to 75 degrees. Sensor data was taken with five sensors in different environments and light conditions to check for accuracy and consistency. The following graphs (Figure 2) were obtained for two different conditions: wet concrete and grass on a sunlit day.

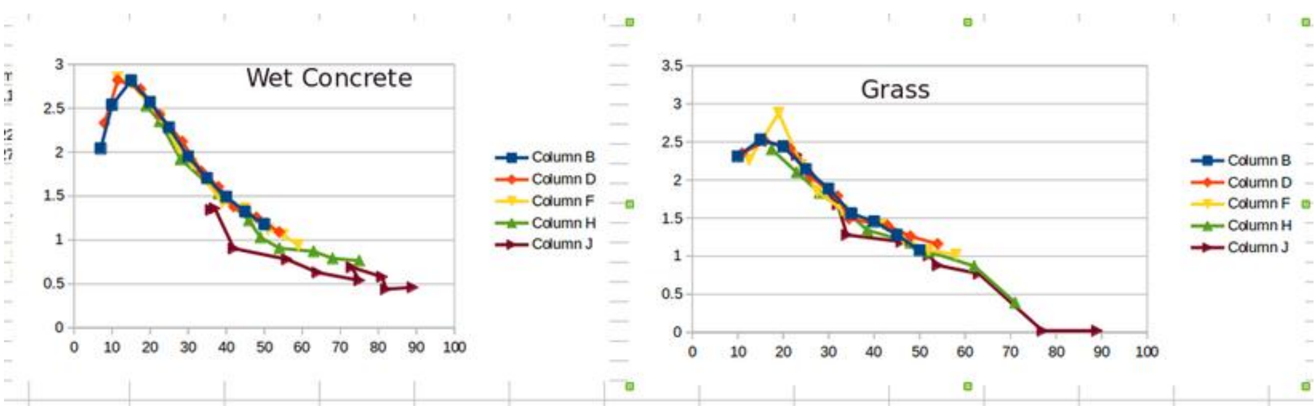

Figure 2. STOP Graph for sensor data.

Sensor data was collected with four sensors with different values of incidence, angle and height from the ground and graphs obtained suggested consistency up to 45 degrees; the angles were fixed for varying distance and points on the ground and this data was plotted; 60 degrees lead to high distortion in data values in comparison to angles lower than 60 degrees. This data is shown in Figure 3.

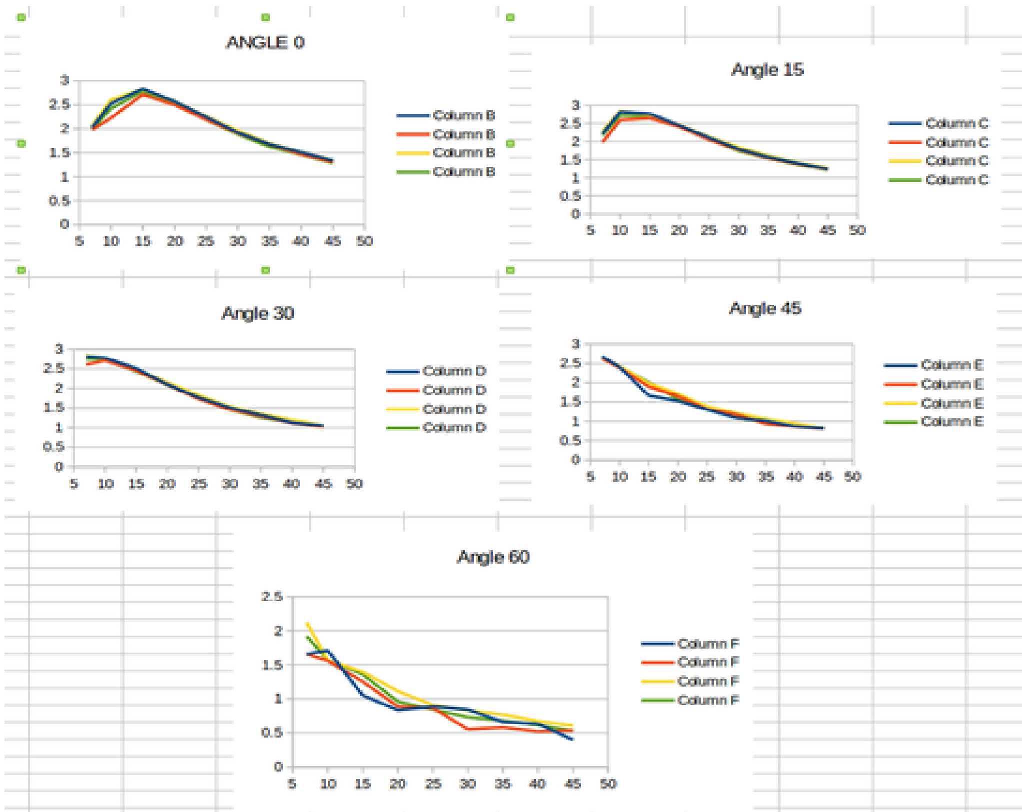

Figure 3. Graph for sensor data .

However, lower angles implied a lower range for the sensor which would mean less reaction time in case of a warning. The angle had to be maximized in order to maximize range of operation and reaction time for the robot to stop in time.

The robots have rectangular chassis and so a linear mount was designed to hold five sensors was 3-D printed using SolidWorks and the UPrint printer. The sensors were positioned so as to fan out and cover maximum area in the direction of motion of the robot as shown in Figure 3.

Two sensors positioned at extreme ends of the mount were angled at 45° downward and 20° outward while the pair on either side of the center one was angled at 54° downward and 10° outward. The height for the linear mount was fixed at 25cm off the ground after considering all the sensor data and the robot's physical constraints to ensure maximum range for the sensor. This configuration is illustrated in Figure 4.

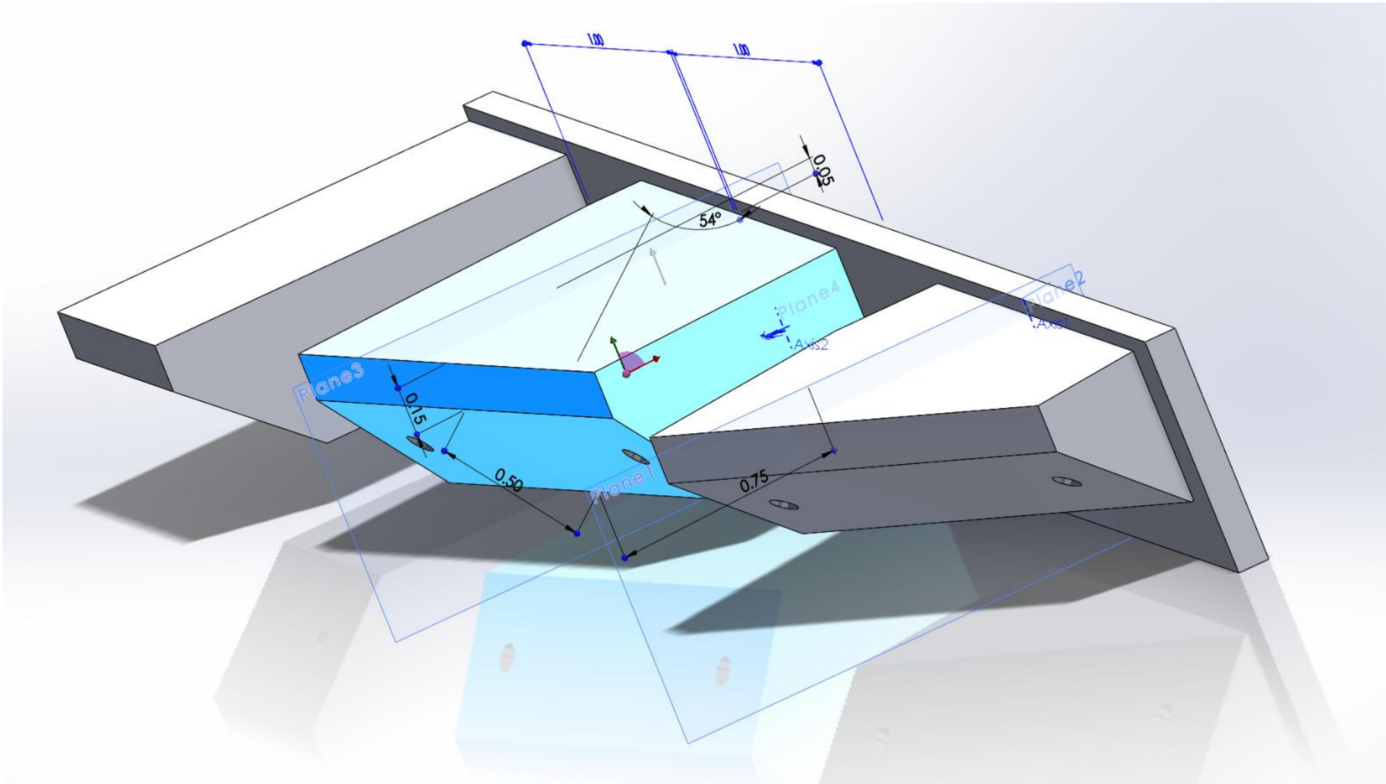

Figure 4. SolidWords model for STOP sensor.

After analysing physical design considerations, we moved on to the circuit design for the STOP sensor. The schematic was designed using Eagle CAD and consisted of different components such as voltage regulators, ferrous beads, 7.2MHz crystal clock, Atmel Xmega32A4 micro-controller. Figure 5 shows a portion of the schematic of the STOP PCB:

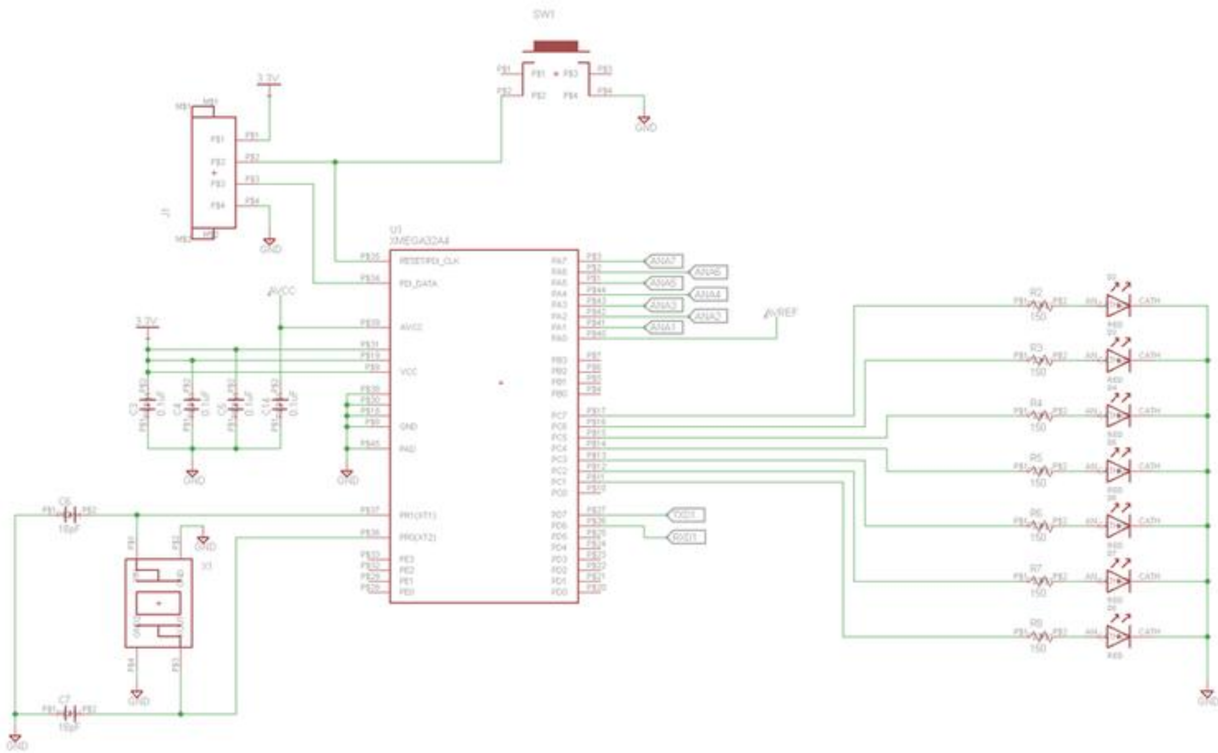

Figure 5. Schematic for STOP sensor PCB

The sensor inputs were read as analog values by the microcontroller, which were converted by the analog-to-digital convertor into digital values; these values were checked against each sensor’s specified range of acceptable input values. Values outside the accepted threshold were classified as either errors or danger zones and an 8 bit character was sent through the USART on the STOP PCB to the Magic2 robot’s laptop. The messages were relayed through a 8 bit character; ‘D’ was sent for drive, ‘E’ was sent for error and ‘S’ was sent for stop.

Lightweight Communications and Marshalling (LCM) was used extensively to relay messages between the motor and sensor control for the robots. LCM is a set of libraries and tools for message passing and data marshaling that was applied extensively in the Magic2Bots. It provides a publish/subscribe message passing model and automatic marshaling/un-marshalling code generation with bindings for applications in a variety of programming languages [3].

A channel was created for the STOP sensor that published messages at the rate of 110 Hz;

The motor controller program subscribed to the 'channel' for the 'STOP SENSOR' to receive information about the sensors. The robot controller file was modified to include instructions to 'kill' the motor if the motor channel read a 'S' character for stop.

The sensor was tested on the robot with different speeds starting with about 1 mph and gradually increasing it to the maximum speed of 4.5 mph. The normal operational speed for the robot (roughly walking speed) was only 50% of the maximum speed. The sensor successfully stopped the robot up to 85% of the maximum speed which is roughly 3.8 mph.

4. Conclusion & Future Research

While the STOP sensor could effectively identify negative obstacles, there is a lot of scope for future work. The system could be modified to extract and retain more information. This information could be used to construct a 3 dimensional map of all detected obstacles in an area. This map could be shared between all robots in the area, thus allowing for safer navigation even for robots that are not equipped with the STOP sensor. The sensors could also report more informative messages, thus allowing the robot to correctly react to the obstacle, as opposed to always coming to a complete stop.

5. References

[1] Meha Sharma, Rewa Sharma, Kamna Ahuja, Swati Jha, "Design Of An Intelligent Security Robot For Collision Free Navigation Applications", *2014 International Conference on Reliability, Optimization and Information Technology - ICROIT 2014*, India, Feb 6-8 2014.

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[3] Albert S. Huang, Edwin Olson, David C. Moore, "LCM: Lightweight Communications and Marshalling", *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2010.