Effect of Color on IR Light Sensor Distance Measurements

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Bots Who Say Ni

**Effect of Color on IR Light Sensor Distance Measurements**

1. Abstract:

*Making sure any possible deviations in a sensor's readings are compensated for is very important to building a reliable and competitive autonomous robot. This paper explores the effect of different colored objects on the accuracy of the Botball ET infrared proximity sensor. An experiment was conducted where the proximity sensor measured three different distances to different colored surfaces. Sensor readings were recorded using a Botball Wallaby controller for each color-distance combination. Although variations between colors of up to 1.256% from the control were observed, it was not enough to make a significant difference to compensate for different colored objects in Botball.*

2. Introduction

In Botball, many programmers use "dead-reckoning" movement methods, such as move() or turn(). This keeps the code simple, but is generally unreliable where accuracy of a robot's position is essential in an autonomous match. Inaccuracy may be due to: (1) changes in battery voltages driving wheel motors; (2) variances in the manufacturing of motors; (3) changes in a robot's weight or weight distribution; or (4) simply bumping into a displaced game piece on the playing field. During design and testing of our team's robot, I tried "dead-reckoning" to pick up a cube. That method proved to be inconsistent. Factors affecting positioning may have been the robot's center of gravity, differences in motor output, or the extent the battery was charged.

Another option for autonomous robots is to use a proximity sensor. The sensor tells the robot's controller the distance it is from an object. If the proximity sensor can overcome the shortcomings of "dead-reckoning", then it could be a viable alternative. To assess its viability, it must be tested. Understanding the weaknesses of the sensor can help the developer compensate in the design of the robot for those weaknesses.

An IR sensor measures distance by measuring the strength of its own light reflected off a distant object. Considering that IR is light and there is physical variability in the objects it measures, it makes sense to test and understand what might affect the light that returns to the sensor. With this information, the developer may be able to make adjustments in their robot's design or code.

3. Background:

A sensor widely used in Botball is the infrared (IR) proximity sensor known as the "ET" sensor. IR proximity sensors are used in every-day applications such as smartphones, home alarm systems, and hands-free paper towel dispensers. The ET sensor device has an LED IR emitter on one side and IR sensor on the other side. The LED emits IR light that reflects off a distant object, and is then received and measured by the sensor for light intensity. The intensity of the IR received varies depending on the distance of the object. The light intensity changes the voltage the sensor sends to the robot's controller. For this experiment, the controller is the Wallaby controller used in Botball. The Wallaby converts these voltages into numerical values for the coder to calculate distances. Figure 1 illustrates how an LED reflects IR light off an object for its own sensor to read the reflected light's intensity.

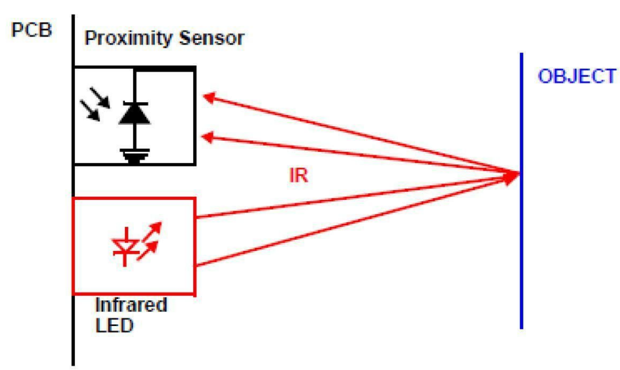


Figure 1: Diagram showing how a proximity sensor reflects light

off an object and receives the reflected light [2].

Proximity sensors can be found in robotics leagues such as Botball [5] and VEX [6]. As a key component of a robot, the ET sensor has been studied for Botball. A. Kealiher wrote a paper for the 2017 Global Conference on Educational Robotics about the need to write code to compensate for irregularities in a wall when using the ET sensor [4]. That paper brought my attention to considering other factors that might affect variability in distance measuring. After learning how the ET sensor uses IR, it occurred to me that color of an object may change the color or the intensity of the reflected light and therefore cause variation in distance readings.

Infrared is a type of radiation belonging to the electromagnetic spectrum. IR waves are longer than the waves of visible light meaning they're invisible to the human eye [7]. In sensors using light, it is possible to use other types of light such as a laser mouse which uses visible light. However, the reason why many proximity sensors use IR light as the way to sense is because the chance of interference from ambient IR is less. This is because there is usually less ambient IR light than ambient visible light [8].

The amount of IR light reflected varies based on color because of the fundamentals of how colors work. Colors are visible because they reflect and absorb light. For example, an apple is red because it absorbs all colors and reflects only red light [1]. Since IR is a type of light, different colors absorb and reflect different amounts of it [7].

4. Hypothesis:

Knowing colors absorb and reflect light differently, it's conceivable that the ET sensor's distance measurements could vary. For example, white reflects all light, black absorbs all light, and a red apple absorbs all light except red. It is conceivable that since IR is light, some objects may reflect or absorb IR light at different intensities and would therefore affect the amount of IR reflected back to the sensor.

*The hypothesis of this paper and experiment is that*

*different colored objects will cause enough variability in the IR sensor's measurements to require adjustments be made in a robot's design.*

5. The Experiment:

In my experiment, I wanted to test the accuracy of the IR sensor in measuring constant distances to different colors of foam sheets. Following are the parts, procedures and results of the experiment.

5.1 Parts list for the experiment:

- Eight foam pieces in the colors of white, red, orange, yellow, green, blue, purple, and black.
- A flat, vertical surface to paste the foam pieces against.
- One ET sensor, Figure 2.

- One Wallaby controller with battery.
- Two sheets of 8 ½ x 11 white copier paper.
- One pencil.
- One ruler.
- One carpenter's square.

The exact model number of the ET sensor could not be identified because Botball does not publish that information on their website. However, based on appearance and specifications of the sensor and searching the internet, the sensor is believed to be the Sharp model GP2Y0A21YK0F with a range of 10 – 80 cm.

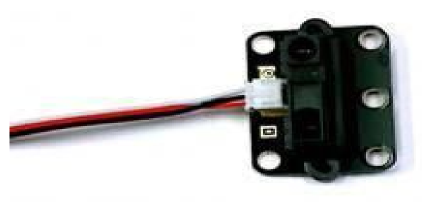

Figure 2: Photo of the Botball sensor used in this experiment [5].

5.2 Setup:

1. Use the two sheets of paper and tape their widths end-to-end.
2. Use the ruler to make marks at 10 cm, 20 cm, and 30 cm from the short edge of the paper.
3. Fix the two sheets of paper to a horizontal surface with the 10 cm mark closest to the vertical surface where the colored foam will be attached.
4. Fasten and connect the ET sensor on top of the Wallaby controller.

Figure 3 shows the setup of the experiment. The experiment used the ET sensor, a Wallaby controller from Botball, different colored foam sheets, and a carpenter's square to ensure the sensor was vertical to the marked distance lines.

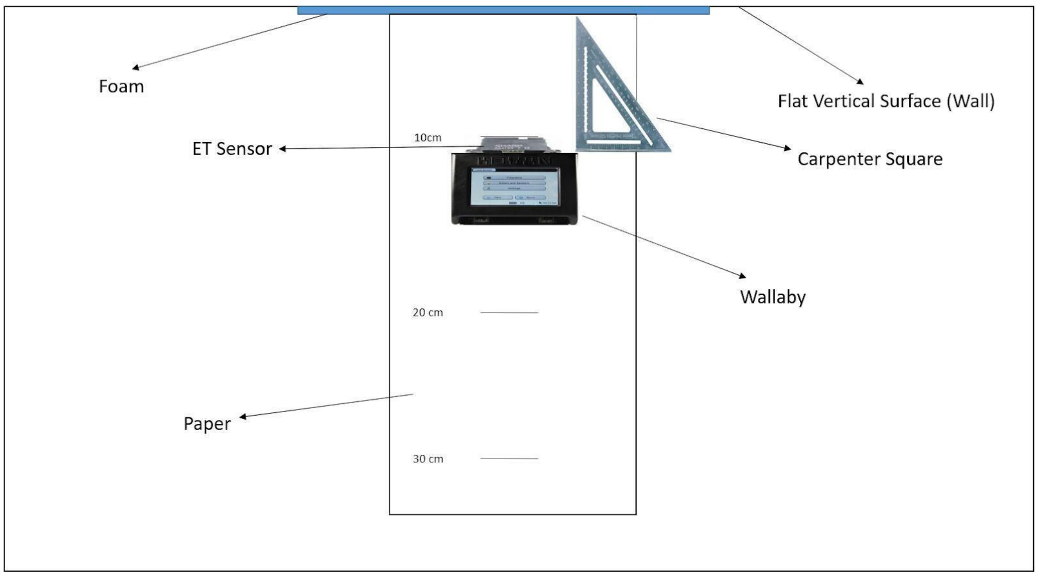


Figure 3: Top-down view of the experiment's setup.

5.3 Procedures

1. Paste one of the colored foam pieces on the vertical surface at a height the ET sensor will see.

2. Use the carpenter's square to line up the ET sensor vertically above the 10 cm mark to ensure the sensor is as near as possible to 10 cm from the colored foam.

3. Turn on the Wallaby and record the measurement.

4. Move the ET sensor back to the 20 cm mark.

5. Record the measurement.

6. Move the ET sensor back to the 30 cm mark.

7. Record the measurement.

8. Remove the current foam piece and replace it with a different colored piece.

9. Repeat steps 2-8 until all colors are measured.

5.4 Results:

Figure 4 shows the Wallaby's readings at 10 cm, 20 cm, and 30 cm using different colors of foam. The readings are directly from the Wallaby's sensor list. White is the control color because first, it's a combination of all colors and second, Sharp uses white for its testing [3].

| | Real Distances | Color | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | White | Red | Orange | Yellow | Green | Blue | Purple | Black |
| ET Distance Measurements | 10 cm | 2600 | 2600 | 2615 | 2620 | 2640 | 2620 | 2645 | 2620 |
| | 20 cm | 1515 | 1520 | 1515 | 1530 | 1520 | 1515 | 1520 | 1550 |
| | 30 cm | 1095 | 1095 | 1090 | 1090 | 1100 | 1090 | 1095 | 1210 |

Figure 4: The table of data collected from the experiment.

There was a 0.769% average percent deviation of all colors from white at 10 cm, a 0.536% average percent deviation for all colors at 20 cm, and a 1.256% average percent deviation for all colors at 30 cm. The average percentage deviation at 30 cm becomes 0.0006523% without black.

Some variation to the accuracy of the recordings may be due to the fluctuations in the readout of the Wallaby. The readings were not constant, but moved up and down within a range of readings. The readings recorded in Figure 4 are the mode and based on my best guess as I was observing the Wallaby readouts. Therefore, these numbers are not precise but based on observation of a fluctuating readout. The fluctuations appeared to be ranging +/- 5 – 10 units from the number shown in the table; a very small percentage compared to the reading.

Although a carpenter's square was used to make sure the sensor was vertically above the distance line, one could consider that deviations from the line might make a difference in the readings. This experiment did not examine the impact of the sensor not being square, since the margin of error in the distance measurement would be close to the thickness of the distance line; not a significant amount in the context of Botball.

6. Analysis:

The average percentage deviation at 30 cm would be 0.0006523% if black is removed from the average. Black would be expected to show the largest deviation since it absorbs all colors of light. At 30 centimeters, black exaggerates the loss of IR intensity. Interestingly, the percent deviation was opposite of expectations at the 20cm distance than it was at the 10 cm distance. Regardless, at 30 cm, a 1.256 percent deviation from white is less than a millimeter

(0.377 mm). Not much in deciding if distance measuring should be adjusted for color in Botball.

Green and Purple also showed some deviation, but again not significant for Botball. Green and purple at 10 cm measured 2,640 and 2,645 respectively compared to 2,600 for white or about 1.7% deviation on 10 cm. Green and purple were either very close or the same as white at 20 cm and 30 cm. Again, not significant for Botball.

The remaining colors at the three distances were all very close to the control and therefore not significant for Botball.

7. Conclusion:

In conclusion, my hypothesis was wrong. An object's color has an insignificant effect on measuring distances of up to 30 cm with the Botball ET sensor. Even with the margins of error in positioning the ET sensor at the three distances from the wall and the margin of error in reading the mode from the Wallaby display, color still had little effect in distance variation. There is no need in Botball to adjust distance measurements due to the color of an object.

8. Bibliography:


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