Introduction:

Our project aims to compare distance readings from the ultrasonic sensor with an infrared sensor. An ultrasonic sensor is a sensor that depends on the emission and receives sound waves. To measure distance, it works by emitting a frequency that humans cannot hear and begins to count the time it takes for that signal to reach back to the receiver. Unlike the ultrasound sensor, the infrared sensor works by emitting infrared waves and then measuring the intensity of the light it receives after it bounces back from the surface. This light intensity must then be converted to tell the distance between the sensor and the surface. Our null hypothesis is that the average distance measured from the ultrasonic sensor with the model car would be equal to the average distance measured from the infrared sensor. The alternative hypothesis is that the average distances would not be identical. Our significance level was set to 0.05.

Sensor Selection and Experiment Setup:

The model car we used was the 4WD model car from Freenove. Once the car was assembled, we attached the ultrasonic (HC SR-04) and infrared proximity sensor (SHARP GP2Y0A21YKOF). Figure 1 & 2 shows the ultrasonic & infrared sensors, respectively.

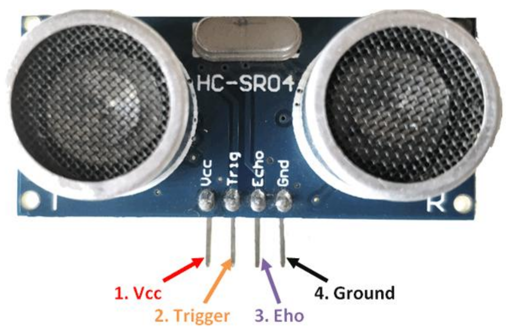
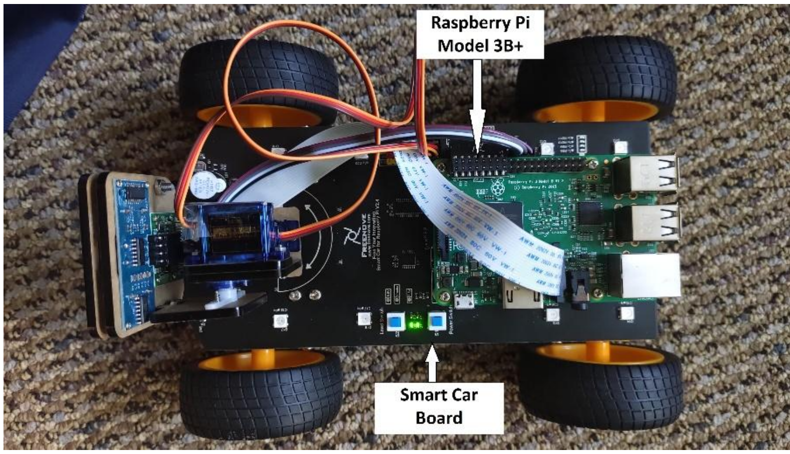


Figure 1: HC-SR04 Ultrasonic Sensor

Figure 2: SHARP GP2Y0A21YKOF Infrared Sensor

The car was powered by a Raspberry Pi, which we coded with Python. The setup had a set ultrasonic sensor code to stop and avoid any obstacles. We took this code and edited it instead to stop the motor once the sensor detected 15 centimetres (about 5.91 in) from the surface. Once it detected 15 centimetres, we used a ruler to take secondary measurements. This was done by measuring the closest and farthest distance from the surface and then taking the average of those two values. These values would become our raw data to be then calibrated. Figure 3 shows the assembled model car setup with the raspberry pi, and Figure 4 illustrates the front view of the setup consisting of the ultrasonic sensors mounted on the top & infrared sensors mounted at the bottom of the board.



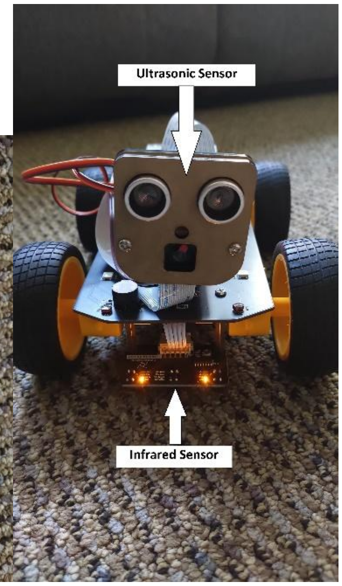


Figure 3: Assembled 4WD Smart Model Car setup

Figure 4: Sensors setup

Since the model car would stop at an angle, we had to take two measurements, one from the closest point and one from the farthest. Then we took the average of those two measurements as our sensor value. Table 1 indicates various parameters associated with the sensors for the experiment setup.

Table 1. Technical Specification of Sensors

Parameters	IR Sensor (SHARP GP2Y0A21YKOF)	Ultra Sonic Sensor (HC SR-04)
Range	10cm-80cm	2cm-10m
Beam-width	75 Deg.	30 Deg.
Beam Pattern	Narrow (line)	Conical
Frequency	353 THz	40 KHz
Unit Cost	~ 750 INR.	~ 130 INR.

Results:

Table 2 provides the raw data we measured for ultrasonic & infrared sensors at a 15 cm fixed distance. We observed an average offset of 2.54 cm for the ultrasonic sensor and an average of 2.61 cm for the infrared sensor.

Ultrasonic Sensor data (cm)	13.49	13.65	13.34	14.21	13.02	12.70	13.65	13.18	13.10	12.38	12.86	12.38	12.86	12.38	13.73
Infrared sensor data (cm)	16.64	16.90	17.73	17.23	15.80	12.98	14.42	13.52	16.91	19.20	18.92	17.65	17.83	18.06	17.40

Ultrasonic Sensor data (cm)	15.00	13.02	13.34	13.02	13.49	12.86	13.02	13.49	13.26	13.18	13.34	14.92	13.10	14.92	13.49
Infrared sensor data (cm)	17.22	15.84	17.77	19.37	20.19	17.83	18.92	19.48	20.90	19.43	20.57	17.86	18.06	16.63	17.23

Table 2: Raw Sensor Data Measured at 15 cm fixed distance

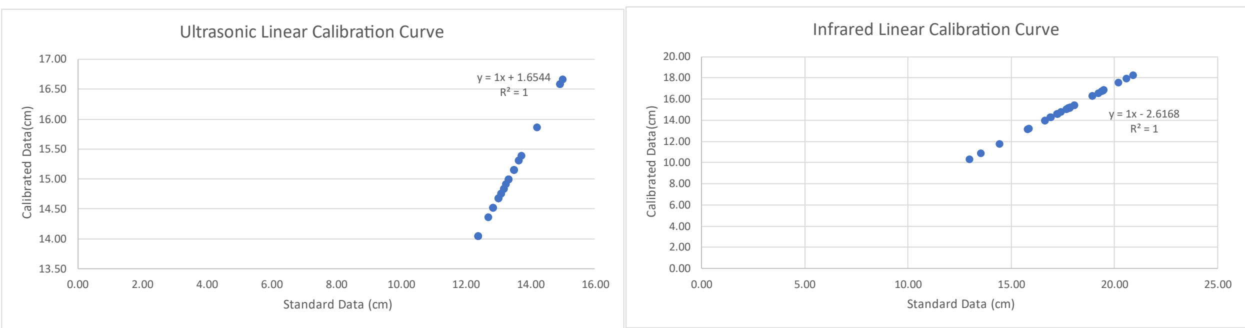


Figure 5: (i) Ultrasonic Sensor Calibration Curve (ii) Infrared Sensor Calibration Curve

Also, figure 5 provides the calibration curve of the two sensors observed vs standard data. We do see that the calibration offers a linear curve for both sensors.

Figure 6 provides the deviation plot from the standard 15 cm with a trend line. We find that the ultrasonic sensor data portrays a less detrend than the standard data, but infrared sensor data shows a more detrend than the ultrasonic sensor.

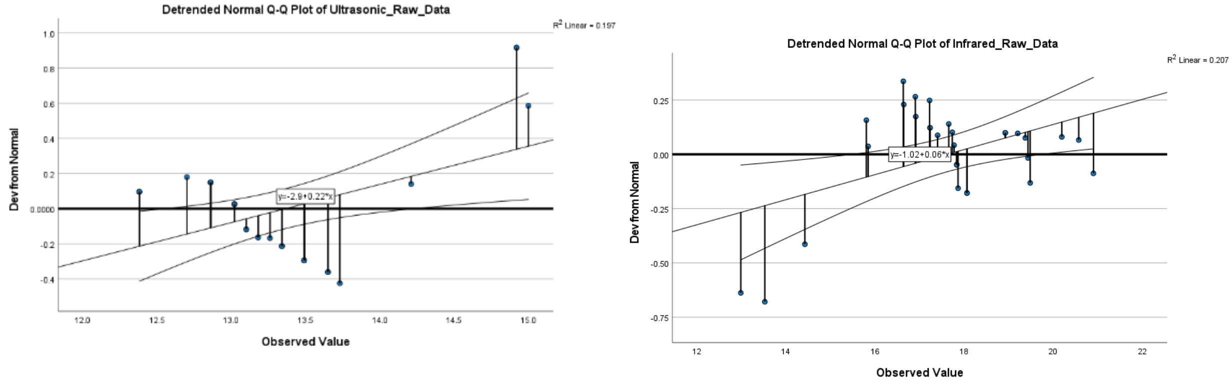


Figure 6: (i) Ultrasonic Sensor Deviation Plot (ii) Infrared Sensor Deviation Plot

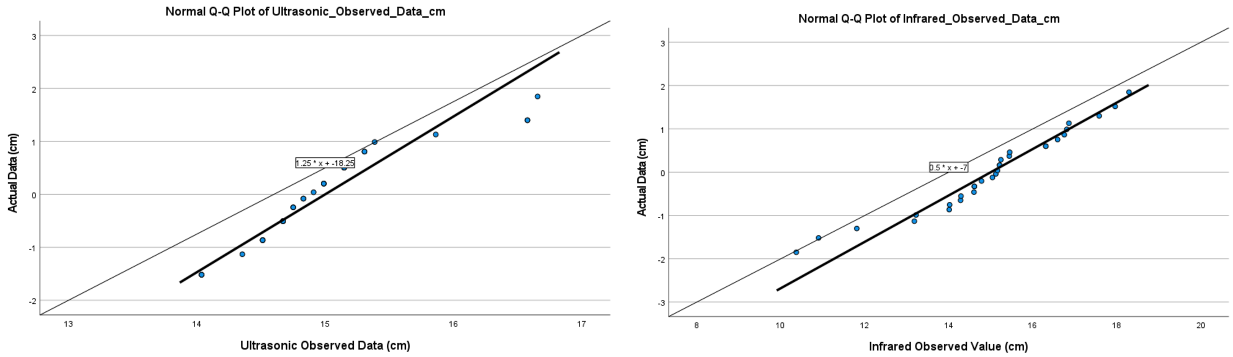


Figure 7: (i) Ultrasonic Sensor Q-Q Plot (ii) Infrared Sensor Q-Q Plot

We also did the Q-Q plot for both sensors, as mentioned in figure 7. We found the ultrasonic sensor's R^2 = 0.975 & infrared sensor's R^2 = 0.945

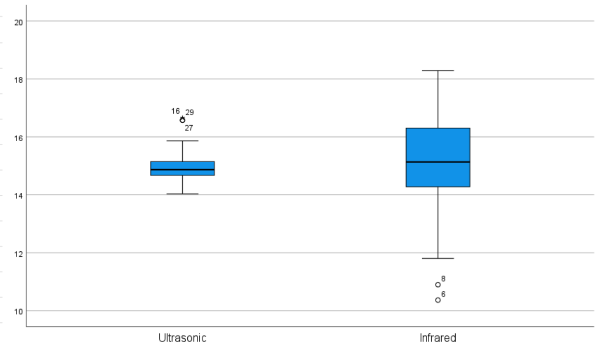
We performed a paired t-test since the sample size was small. We analyzed the data in excel as well as IBM SPSS Statistics software. The results are provided below,

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Ultrasonic - Infrared	.00000	2.02933	.37050	-.75777	.75777	.000	29	1.000

t-Test: Paired Two Sample for Means

	Ultrasonic	*Infrared*
Mean	15	15
Variance	0.462636959	3.480698
Observations	30	30
Pearson Correlation	-0.068898691	
Hypothesized Mean Difference	0	
df	29	
t Stat	6.39258E-16	
P(T<=t) one-tail	0.5	
t Critical one-tail	1.699127027	
P(T<=t) two-tail	1	
t Critical two-tail	2.045229642	



Also, we performed manual calculations to find the $t_{critical}$ value per below,

$$t = \frac{x_{difference}}{\frac{s_{difference}}{\sqrt{n}}} = \frac{0}{\frac{2.03}{\sqrt{30}}} = 0$$

$\alpha = 0.05$, $df = 30 - 1 = 29$

$from\ t - distribution\ table: t_{critical} = 2.045$, which is greater than t.

Discussion:

We observe that the $P = 1$, which is greater than $\alpha = 0.05$. So, we should reject the alternative hypothesis. There is strong evidence for Null hypothesis & we retain the Null hypothesis. ANOVA test was not performed since we did not have multiple levels. Factorial designs can be performed considering multiple levels, i.e. we can measure the sensor data in different surfaces. Ultrasonic sensor's standard deviation, 0.68 was found far less than Infrared sensor, 1.866

Reference:

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2. https://www.coderdojotc.org/micropython/sensors/08-ir-distance-sensor/
3. https://www.electronicshub.org/interfacing-ir-sensor-with-raspberry-pi/
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