ME 102B Mini Project

Gunn Lee

Department of Mechanical Engineering, University of California, Berkeley

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Simple Self Driving Vehicle

Ultrasonic sensors have applications as diverse as collision avoidance in autonomous vehicles and robots, detecting the presence of objects, and measuring the level of fluids in containers. These sensors function by emitting high-frequency (ultrasonic) sound waves and measuring the time taken for these waves to reflect and return to the sensor. As the speed of sound at room temperature is known, the distance between the sensor speaker and the object it is facing can be calculated. Thermocouples are used to measure temperature and function based on the thermoelectric effect. As a difference in temperature develops across the conductors of a thermocouple, a voltage is produced which is measured and used to determine temperature. Thermocouples are commonly found in thermostats and other consumer devices.

The HC-SR04 sensors included in the MicroKit do not compensate for the temperature of the surroundings. The speed of sound in air is not in fact constant, and varies with ambient temperature. As studied in my previous report for final project in ME103 course, my teammates and I concluded that incorporating the effect of temperature to the speed of sound when obtaining the distance using ultrasonic sensor has clear improvement when the temperature is not exactly 25 degrees Celsius, where the two results will be the same.

Following equations are the ones used to obtain the temperature from the thermocouple sensor and the corrected distance by incorporating the corrected speed of sound :

$$d\ [m] = \frac{1}{2} * high\ level\ time\ [s] * (331.3 \sqrt{1 + \frac{T}{273.15}})[m/s] \qquad (1)$$

$$T = \frac{(V_{out} - 1.25[V\})}{0.005\ [V]}\ [\mathrm{C}] \qquad (2)$$

The Table 1 in the Appendix shows our result from distance measured by default value from the HC-SR04 sensor and the corrected values and their uncertainties that show a clear improvement in performance by incorporating the temperature factor into calculation. And the Figure 1 in the Appendix shows the plots of the raw data points of the default and corrected distance values and their best-fit lines that shows a clear decrease in error when the distance value obtained is corrected by incorporating temperature from the distance measured by using caliper, which serves as a more reliable data.

I utilized the results I obtained from my past lab to implement a very simple self driving vehicle that can detect obstacle then stop when it is closer than the predefined critical distance of 20cm. I used L298N motor driver to control four DC motors in both forward and backward directions. Finally, IR remote controller and IR receiver were used to input the signal for the state transition of the vehicle.

Table 2 shows the complete parts lists and their descriptions. Figure 2 to 5 and 7 below show the images of the assembled car and the labels of the parts used. Table 3 shows the different modes available, their descriptions, and their corresponding buttons from the remote controller. Figure 8 below shows the circuit diagram and Figure 9 shows the FSD of this system.

Table 2. Parts list

Name	Description
HC-SR04 Ultrasonic Sensors	Ultrasonic Sensor used to determine the time interval between the high-frequency sound wave to be emitted then reflected back to the sensor.
K-type TES1310 Thermocouple	Thermocouple used to determine the temperature of the time when each measurement from the ultrasonic sensor is taken
AD8495 Thermocouple Amplifier	Thermocouple amplifier used along with TES1310 thermocouple to obtain a certain voltage value to later change it to temperature value using equation (2)
Arduino DUE	Microcontroller used instead of ESP32 due to the requirement of high number of pins
IR Receiver and IR Remote Controller	Receiver that gets inputted from the signals sent from the remote controller. It is used to control the modes the vehicle is currently in.
Wheels and Mounts	To mount the needed components and to mount the motor and the wheels to assemble a car like vehicle.
MG90S Servo Motor	Servo motor used for "SCAN mode" to scan the environment, when it is ordered by the remote controller, by rotating the two ultrasonic sensors to cover all 360 degrees.
9V batter and battery casing	9V batter used to run 4 DC motors and to power Arduino DUE

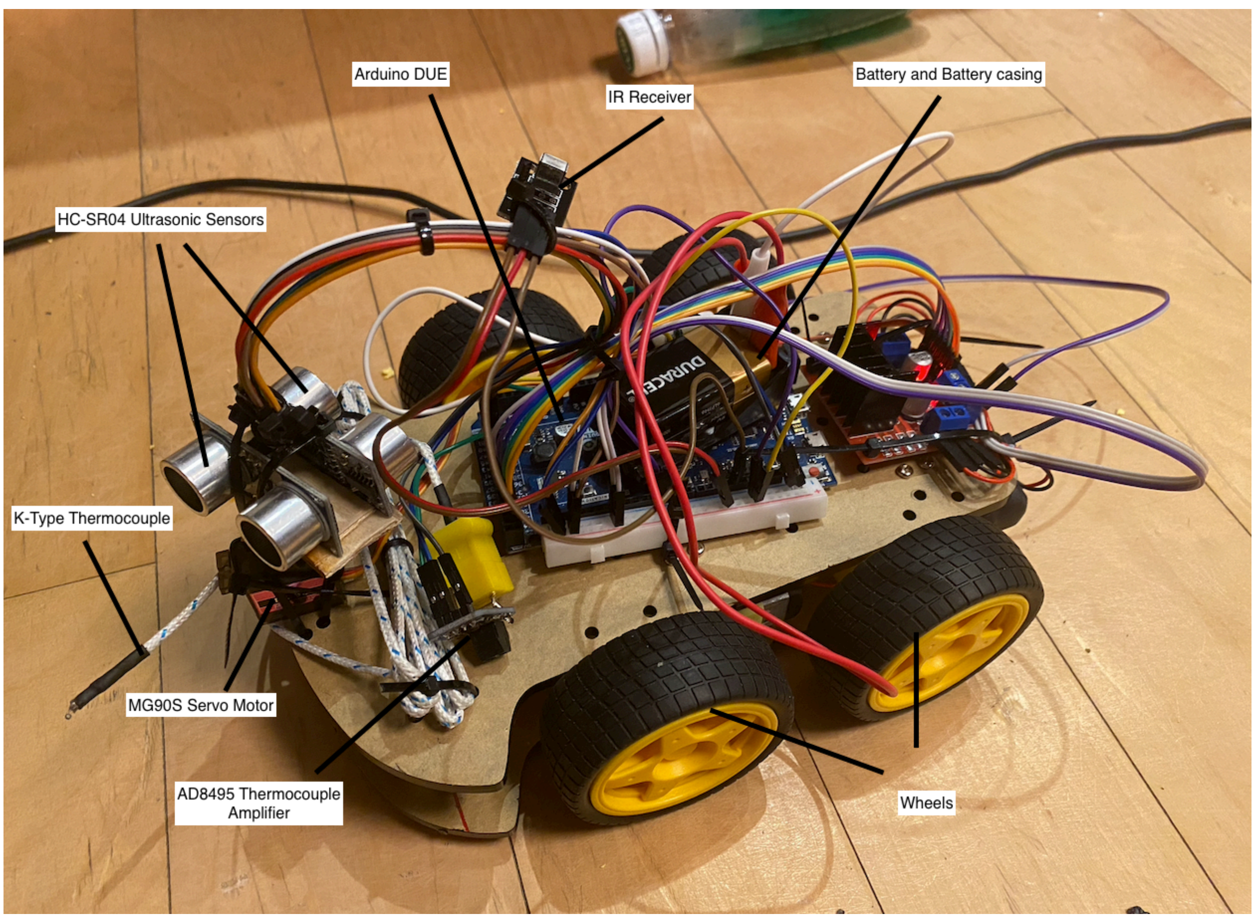

Figure 2. View from above of the assembled vehicle and the parts name

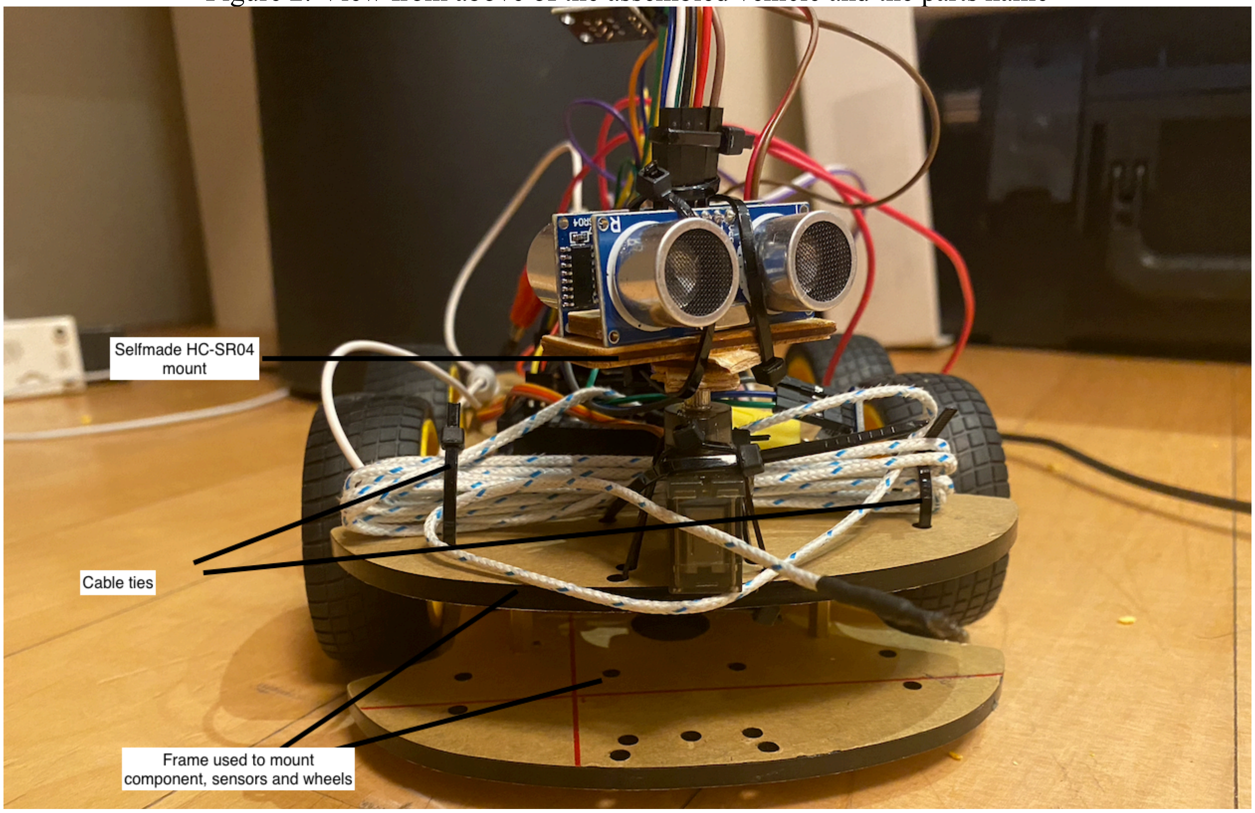

Figure 3. Front view of the assembled vehicle and the parts name

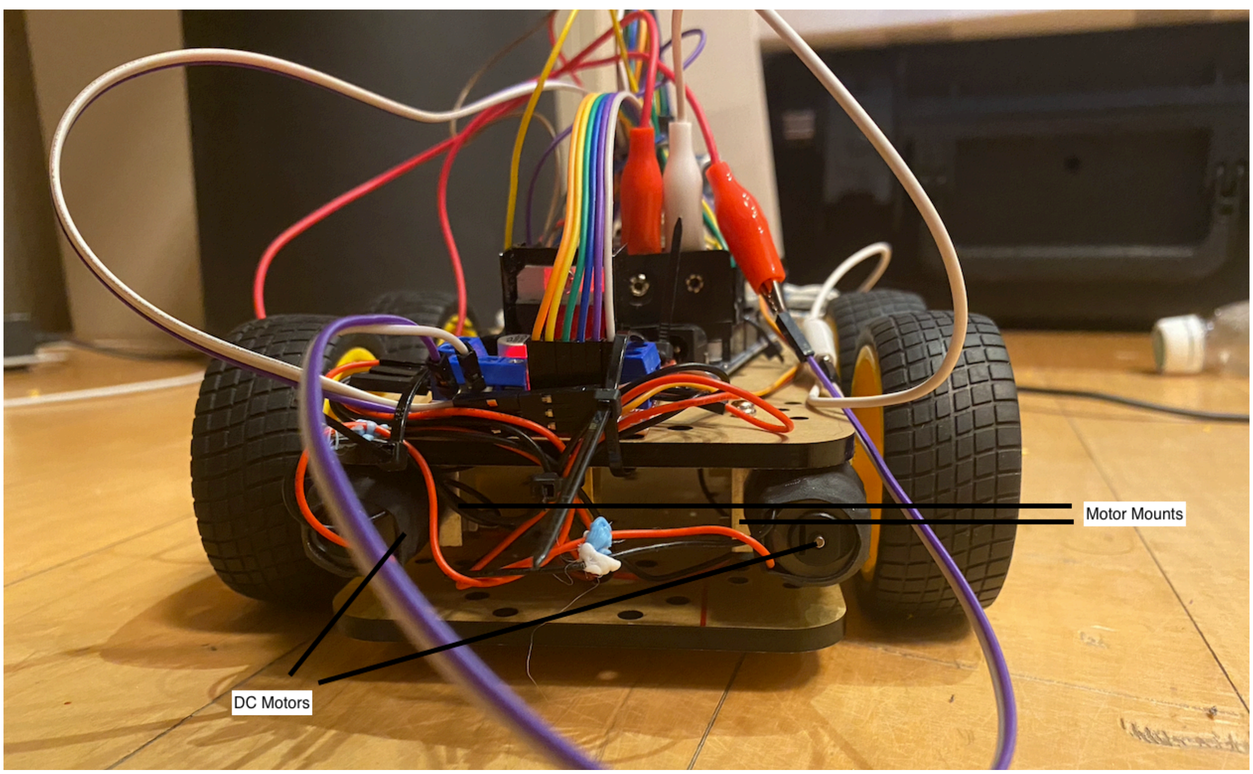

Figure 4. Rear view of the assembled vehicle and the parts name

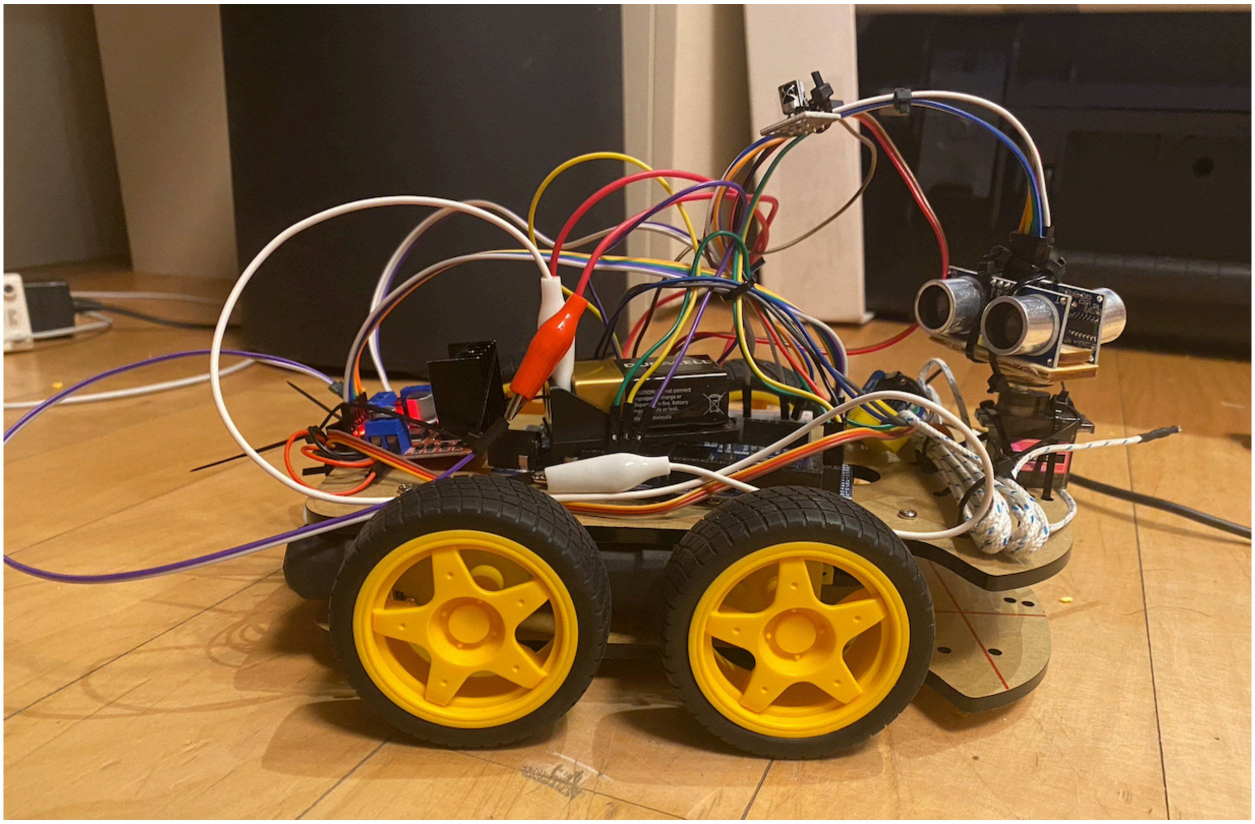

Figure 5. Side view of the assembled vehicle and the parts name

Figure 6. IR remote controller

Table 3. Available modes, its descriptions, and corresponding remote controller button

Mode Name	Description	Corresponding Button
STOP	All DC motors, sensors except IR receiver are off.	0
GO	All DC motors are rotating forward. The vehicle starts accelerating forwards until there is another signal. The vehicle cannot recognize obstacle nor does it stop. All sensors except IR receiver are off.	1
REAR	All DC motors are rotating backward. The vehicle starts accelerating backward until there is another signal. The vehicle cannot recognize obstacle nor does it stop. All sensors except IR receiver are off.	2
AUTO	Initially before the ultrasonic sensor and the thermocouple start operating, all four DC motors are off, and the servomotor fixes the direction so that one of the two ultrasonic sensors is pointing forwards (0 degree). Only the ultrasonic sensor pointing forwards gets activated (the ultrasonic sensor pointing backwards isn't activated). Then, using the ultrasonic sensor and the thermocouple, we obtain the corrected distance value d every loop. If the corrected distance value is greater than the critical distance value 20cm, then the vehicle moves forward, if not then it moves backwards.	8
SCAN	The servo motor starts spinning for 180 degrees with a step of 5 degree. While it's spinning, the thermocouple and the two ultrasonic sensors act as a two-dimensional 360 degrees scanner of the space nearby then record the corrected distance value for each step. Then, for the largest corrected distance value, the vehicle turns towards that direction. Though, inaccuracy may occur while changing direction precisely, due to many factors such as slipping of the tires, resolution of PWM signals, low accuracy of the motors used etc. Thus, this process gets repeated until the smallest corrected distance value is obtained when the ultrasonic sensor is pointing forwards, at degree 0. The servo motor's angle is described with arrows in Figure 7.	9

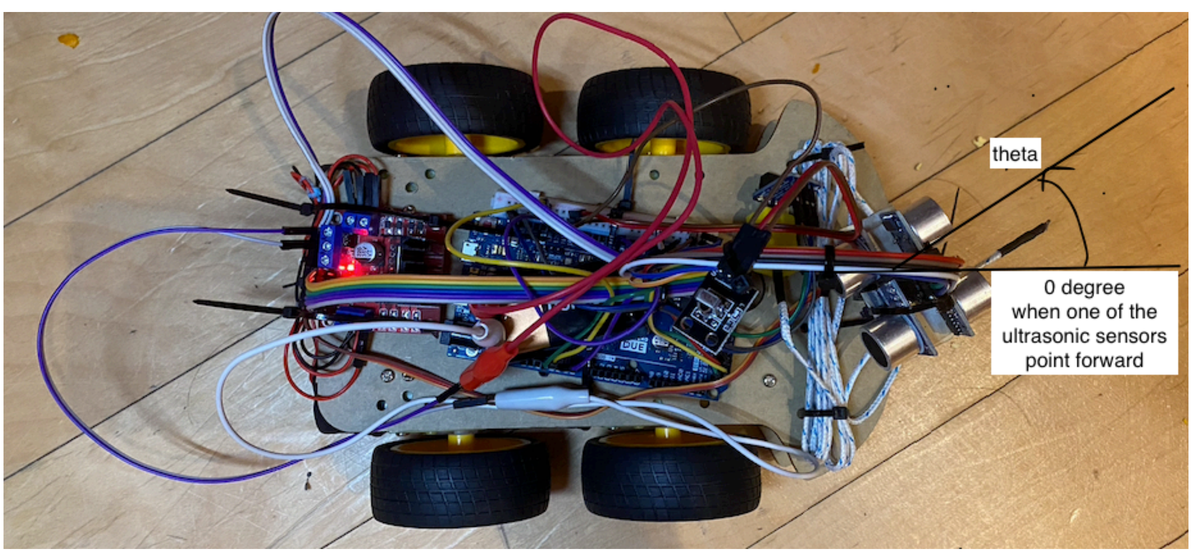

Figure 7. Description of the servo motor's movement

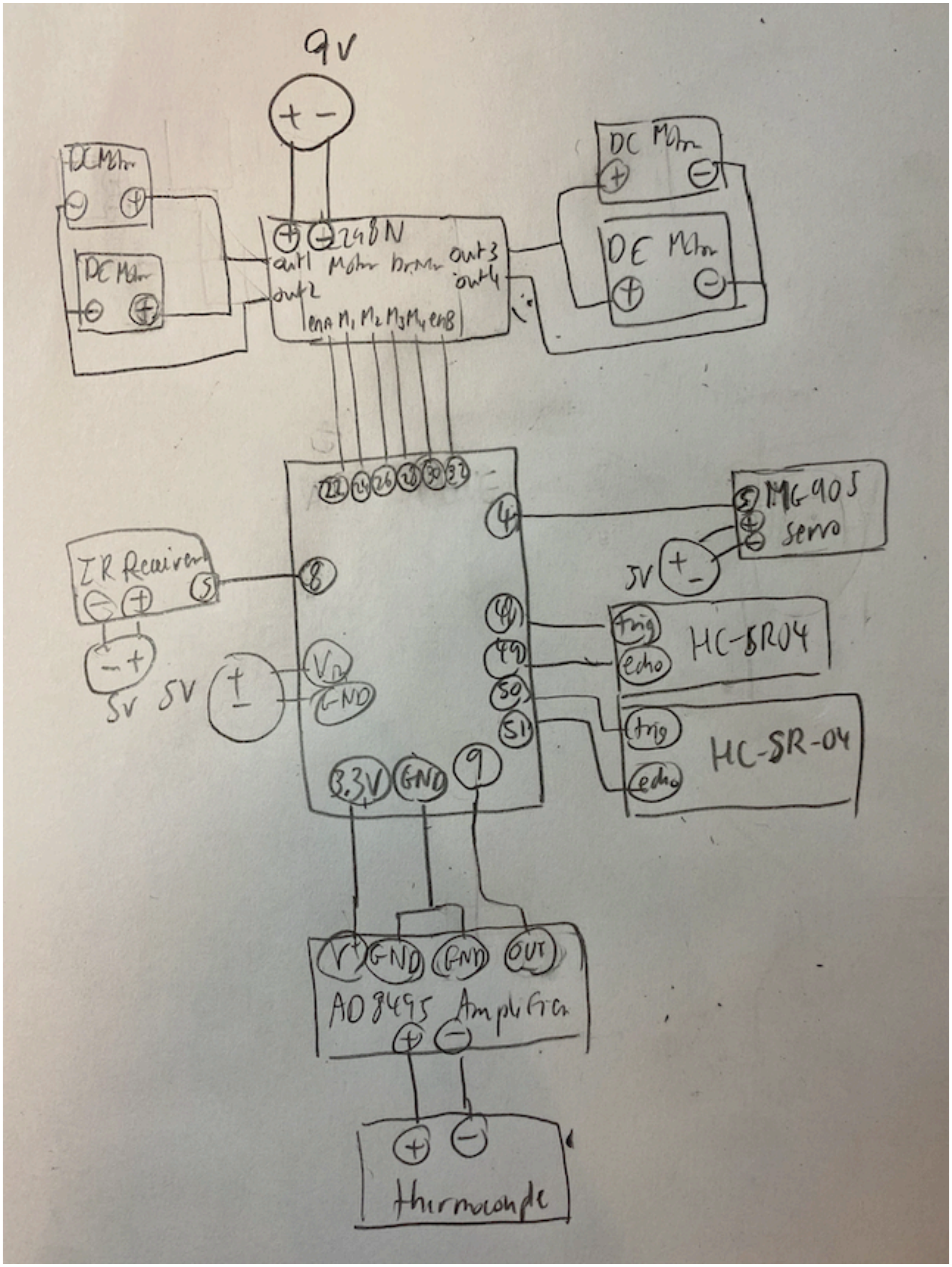

Figure 8. Circuit Diagram of the Simple Self Driving Car

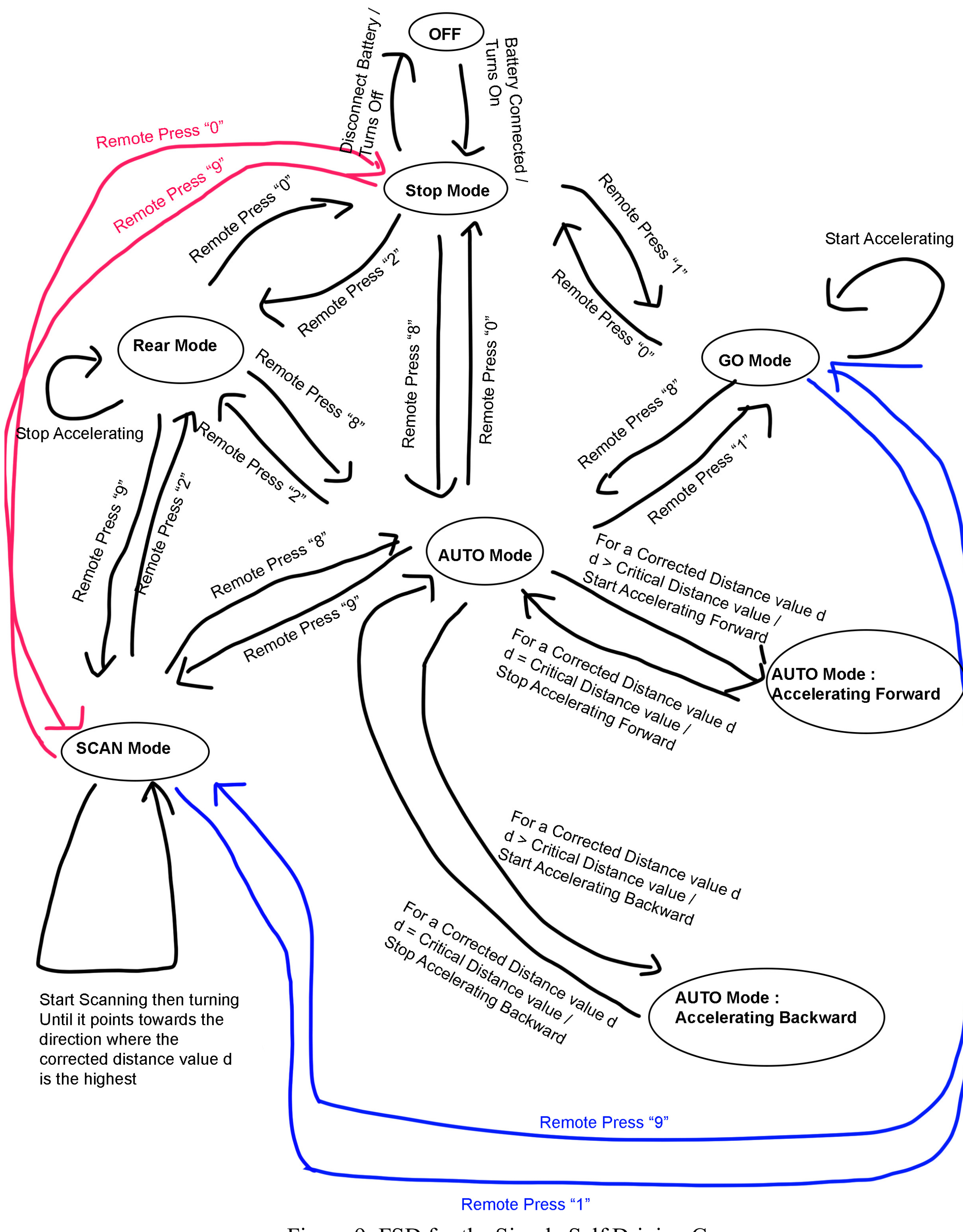

Figure 9. FSD for the Simple Self Driving Car
Each mode in this FSD is described and explained in detail in Table 3
Some arrows are colored for readability

Appendix

Table 1: Processed Distance Data

Distance measured with calipers (cm) [d_1]	Measured distance (assuming room temperature) (cm) [d_2]	Calculated distance for $T_{avg} = 8°C$ (cm) [d_3]	Magnitude Δ between d_1 and d_2 (cm)	Magnitude Δ between d_1 and d_3 (cm)
5.00 ± 0.01	5.39 ± 0.30	5.30 ± 0.43	0.39 ± 0.31	0.30 ± 0.44
10.00 ± 0.01	10.69 ± 0.30	10.56 ± 0.44	0.69 ± 0.31	0.56 ± 0.45
15.00 ± 0.01	15.66 ± 0.30	15.46 ± 0.45	0.66 ± 0.31	0.46 ± 0.46
20.00 ± 0.01	20.81 ± 0.30	20.51 ± 0.47	0.81 ± 0.31	0.51 ± 0.48
25.00 ± 0.01	25.60 ± 0.30	25.31 ± 0.49	0.60 ± 0.31	0.31 ± 0.50
30.00 ± 0.01	30.99 ± 0.30	30.58 ± 0.51	0.99 ± 0.31	0.58 ± 0.52

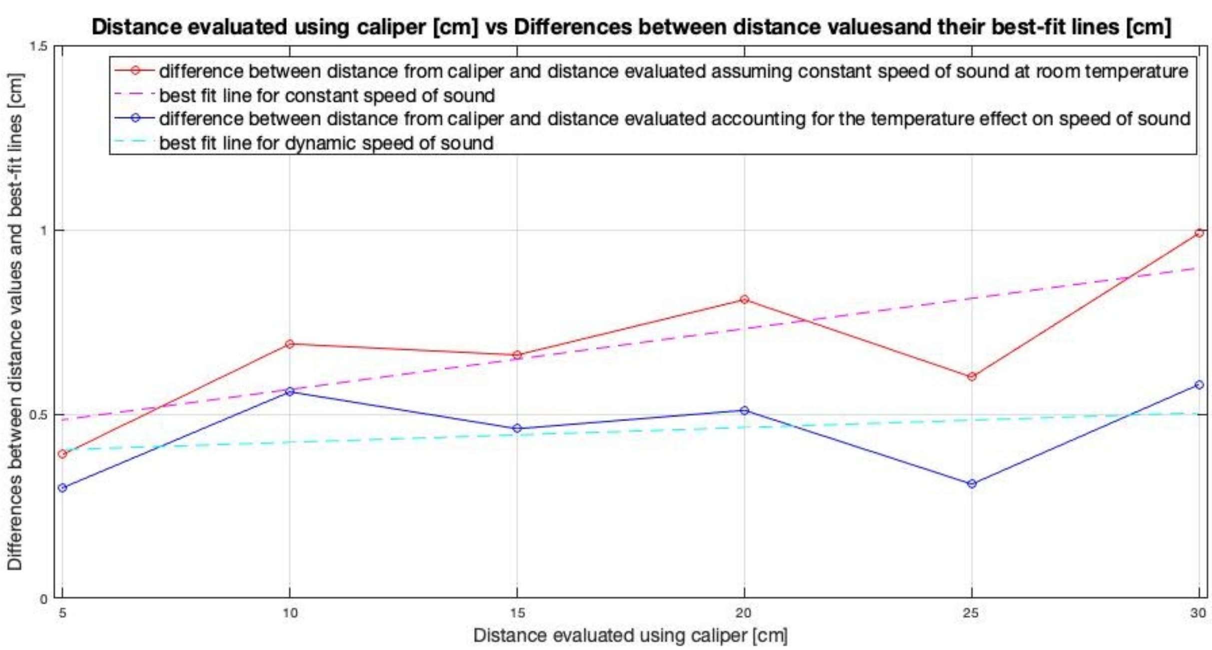

Figure 1: Distance measured using calipers alongside adjusted and non-adjusted sensor measurements