IEEE Region 5 Competition

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April 16, 2024 Innovation Day UTA COLLEGE OF ENGINEERING

Executive Summary

- This year's IEEE robotics competition is centered around showcasing the capabilities of an autonomous robotic system operating within a confined area.
- The primary objective involves pushing a button at one end of the field and returning to the starting position autonomously. Subsequently, the robotic system engages in competitive maneuvers, navigating between charging stations and passing other robots until a singular system remains.
- Key robot requirements include construction by solely student comprised teams, autonomous operations, and compliance with size regulations to effectively avoid obstacles. Notably, a supercapacitor must replace the battery for final rounds, with wireless charging facilitated by 5V, 500mA transmitters.
- The presentation will primarily focus into two critical areas that demanded extensive experimentation and research: navigating power constraints and refining algorithms for mapping the robot's positioning within the field.

Background

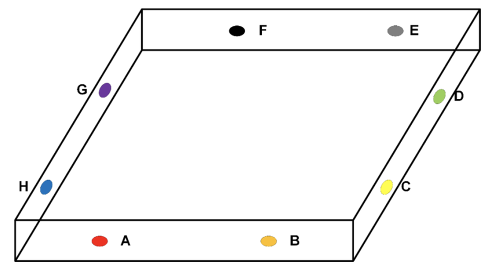

Figure 1: Game Field Layout for Elimination Rounds

Supercapacitors offer high power density and rapid charging capabilities; however, their limited capacity is a challenge to balance. This scenario also presented more unique constraints: a 5-minute charging window at the onset of each round, followed by only 10 seconds per visit to a charging station once the round commences. This resulted in a two-factor challenge—finding a supercapacitor that could charge sufficiently within 10 seconds while also having extended discharge times to cover substantial ground.

Navigating the field also proved challenging as we needed to be able to accurately map the field to ensure our robot could accurately discern its next coordinates amidst dynamic axis shifts. We approached this using an Inertial Measurement Unit (IMU) to establish system heading relative to a fixed point on the field, as well as Time of Flight (ToF) sensors for real-time distance measurements to calculate subsequent coordinates.

Experimental Setup

•Inertial Measurement Unit (IMU): readings from these sensors can be used to provide accurate orientation data using Euler angles.

•Time of Flight (ToF) Sensors: Provide distance measurements to identify the current location of the robot and strategically positioned on the top to detect distance from walls

•Servo Motor: enables precise control of the Time of Flight sensors based on IMU

• Two ToF sensors are mounted 90 degrees apart and adjusted by a servo motor.
  • Ensures at least one sensor is always optimally aligned to measure the nearest wall distance.

• Distances are recorded as x and y values transposed to the origin, corresponding to position relative to the walls.

• Starting each round, the IMU is calibrated to a new 0-degree point from the robot's facing direction.

• We first narrowed down the supercapacitor selection to avoid wasting time during testing.

• Chargers only supplied 5 Volts at 500 mA, so we used formulas such as the voltage across a capacitor at any given point in time for the charging and discharging periods as well as different voltage regulators to find prime candidates for usable supercapacitors.

Table 1. Theoretical Capacitor Discharging Times

	Charging	Discharging Utilizing Various Voltage Regulators			
C (F)	V(c) @ 5 mins	t (s) @ 4.5V	t (s) @ 3.3V	t (s) @ 2.7V	t (s) @ Vc-final
3	4.999772999	5.26575572	20.77350213	30.80703691	41.04675754
5	4.987606189	8.573223022	34.41946705	51.142025	68.20822606
7.5	4.908421559	10.85937733	49.62874337	74.7125803	100.3118819
10	4.751064156	9.048538164	60.74102621	94.18614212	128.3185442
12.5	4.546409501	2.137584182	66.75319424	108.5595891	151.2250918
15	4.323322673	-10.01328819	67.52544388	117.6931177	168.8917209
17.5	4.099537401	-27.18428372	63.27757037	121.8065232	181.5382269
20	**3.884348074**	**-49.04074435**	**54.34423175**	**121.2344636**	**189.4992678**
22.5	3.682013127	-75.23165576	41.07644235	116.3279532	193.1258579
25	3.494027725	-105.4259375	23.80528258	107.4180724	192.7490776
27.5	3.320443861	-139.3236761	2.830666069	94.80473482	188.6688406
30	3.160601557	-176.6575106	-21.58004645	78.75530128	181.1525076

• Based on the data, the 15F to 30F range would be optimal for testing.

Experimental Test Plan

•Static calibration of the IMU and ToF sensors was performed to ensure accuracy through stationary tests and adjustments to sensor parameters to eliminate biases.

•Testing Conditions: The system was tested on the 8'x8' field to mimic the competition's conditions of following the predetermined path and was programmed to go to a specific location on the field, where its final position was tested for accuracy.

•The critical "Jiggle" function determined the robot's current angle relative to the four walls of the playing field, enabling the robot's exact position to be calculated and transposed to the origin, located at the bottom left corner of the playing field.

•The system then calculated the angle of attack, which was

•derived from the robot's current position and the target location

•The current 8'x8' field was transposed into four quadrants. We subtracted our goal x and y coordinates with the current x and y coordinates. The result gave us a positive or negative integer. Since the ToF sensors faced precisely 90 degrees to their corresponding walls, we could use simple trigonometry and our orientation for the next angle.

Table 2. Formulas for Angle Orientation

$$\theta = tan^{-1}((Goal\,Y - Current\,Y)/(Goal\,X - Goal\,Y))$$

$$\theta_{relative} = \theta + sum$$

Sign of X	Sign of Y	Sum
+	+	270
+	-	270
-	+	90
-	-	90

• To test our optimal range of supercapacitors, we used 15F, 20F, and 25F ones

• To simulate the load our system would use, a 300 mA load was applied, which consisted of one esp32-s3 microcontroller and two TT DC motors at full speed.

•To achieve 20F,5.5V, we put two 10F 5.5V supercapacitors - actually two 20F 2.7V caps in series - in parallel, which adds up the capacitance and brings the total to 20F, 5.5V.

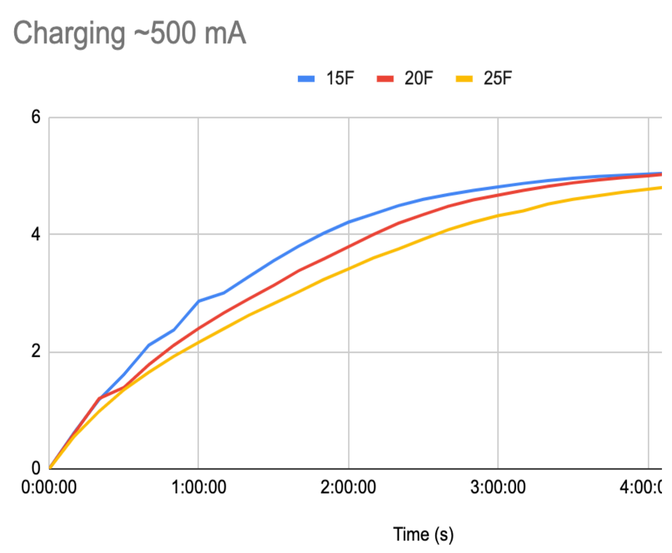

Figure 2: Supercapacitor Charge Rates

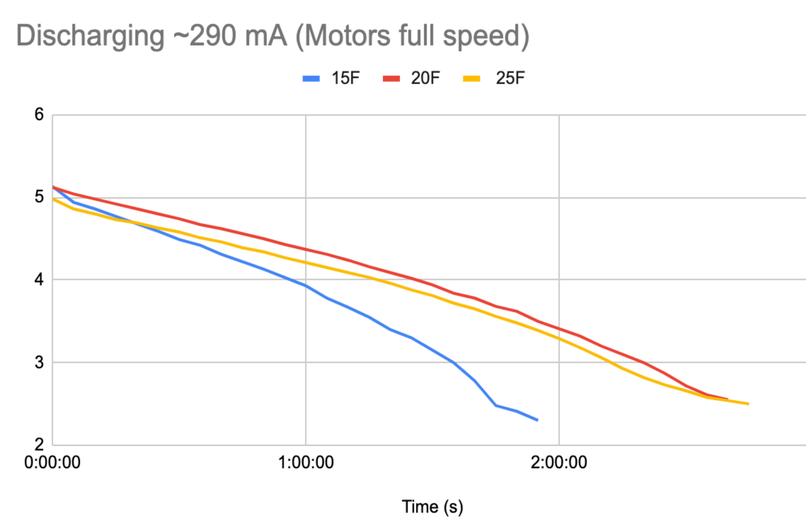

Figure 3: Supercapacitor Discharge Rates

Experimental Results

Through the created functions, the system consistently demonstrated the capability to navigate to specified coordinates accurately. The precision of the initial positioning, coupled with the dynamic adjustments made during motion, resulted in successful navigation with minimal deviation from the intended path. The process from calibration to destination had a high degree of accuracy, showcasing the effectiveness of the navigational strategy and the reliability of the robotic system in a competitive environment.

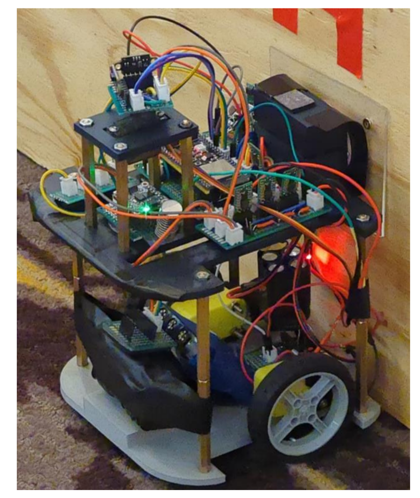

Figure 4: Final Robot Sensors in Action

For the supercapacitor testing, the results proved similar to theory. Although the 20 and 25 farad capacitors were close, the 20 Farad was chosen. We would not have gotten the full 500 mA from the chargers with the 25F, so the 20F had a longer discharge time better suited to the system's needs.

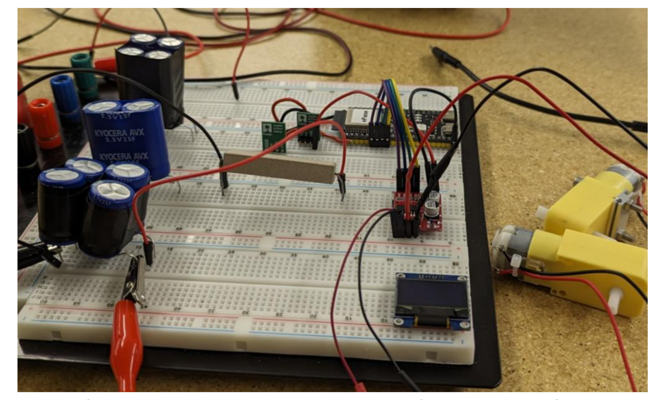

Figure 5: Supercapacitor Testing

Conclusions

Overall, the rigorous testing over the two main hurdles in the timeline to the system's completion was successful. The chosen components and designs fit well within the competition's height, weight, and power criteria, while still allowing for a unique, low-power solution. While we may have not completed all criteria in the allotted time frame, such as accurate object detection, focusing on these critical aspects allowed our team to take home first place in the competition.

We could not have achieved this result without the help of a lot of our mentors, as well as extra funding provided to be able to test out as many variations and iterations of components as we did!

References

1. Urone, P. P., & Hinrichs, R. (2022, July 13). *19.6 capacitors in series and parallel - college physics 2E*. OpenStax. https://openstax.org/books/college-physics-2e/pages/19-6-capacitors-in-series-and-parallel
2. Urone, P. P., & Hinrichs, R. (2022b, July 13). *21.6 DC circuits containing resistors and capacitors - college physics 2E*. OpenStax. https://openstax.org/books/college-physics-2e/pages/21-6-dc-circuits-containing-resistors-and-capacitors