Team Description Paper (socks)

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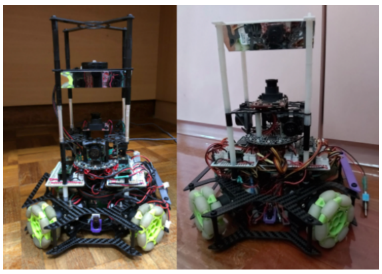
Abstract. This report documents our RCJ journey in the Lightweight category. In this paper, we discuss the hardware and software designs of the robot and the iterative process taken to reach our final product. Primarily, we investigated the use of a camera for aiming, as solely relying on localisation-based aiming is unreliable when there are many agents on the field.

1 Introduction

1.1 Team Background

Socks was formed in December 2019 in preparation for RoboCup 202021. When the event was called off last year, we took part in Virtual RoboCup Asia-Pacific, with Ashlee and Esther attaining 1st for TDP, and Cadence attaining 2nd for matches. Cadence also took part in RCJ Singapore Open, placing 4th. Our team won the Best Presentation, Logbook, Hardware and Software awards at RCJ Singapore Open 2021.

1.2 Team Photo



1.3 Current Year's Highlights

The biggest improvement from 2020 is the implementation of camera-based aiming to complement localisation-based aiming. Other changes include the switch from infrared-based to ultrasonic-based Time-of-Flight proximity sensors for rule compliance, as well as upgrades to our line detection sub-system.

2 Robots and Results

2.1 Team Background

Table 1. Mass of Robot, 2020 v.s. 2021.

Mass of Robot in 2020	Mass of Robot in 2021
1099g	1049g

Table 2. Bill of Materials.

Subsystem	Parts (for 1 robot)	Quantity	Price (USD)
Structural	Carbon fibre plates (CNC) *(prev. different designs)*	4	110.03
	Fasteners (e.g. Nylon Standoffs)	1	-
	V-Shaped Mirror Mount (3D printed)	1	-
	Mirror Sheet (Cut and Folded)	1	-
	Ultrasonic Mount (3D printed)	4	-
	TEMT6000 Mount (3D printed)	1	-
	Battery Gate (3D printed)	1	-
Locomotion	JoinMax JMP-BP-6059 Omniwheels	4	-
	JoinMax JMP-BE-3561 1700 RPM Motors	4	89.21
	JoinMax JMP-BE-3712 Motor Drivers	1	357.08
Power Systems	Mini Panel Mount SPDT Toggle Switch	1	200.00
	Turnigy HV SBEC 5A Switch Regulator / AEO 5V/5A X5 Pro UBEC Voltage Regulator *(prev. D36V50F7)*	1	0.95
	Turnigy Battery (11.1V 2200mAh)	1	19.77
Sensing	NeoPixel LED Rings (24 RGB LED w/ Drivers) *(prev. LED strips)*	1	16.95
	TEMT6000 sensors	18 *(p. 8)*	37.47
	OpenMV Cam M7	1	65.00
	LV-MaxSonar-EZ4 (MB1040) *(prev. VL53L1X)*	4	131.80
	JoinMax JMP-BE-1732 Compound Eyes *(prev. JMP-BE-1722)*	2	96.67
	JoinMax JMP-BE-2617 Compass / JoinMax JMP-BE-2613 Compass	1	118.98
Processing	Teensy 3.5s *(prev. 1 pro-micro)*	2 *(p.1)*	48.50
Electrical	Wires	-	-
	Adafruit Perma-Proto Half-sized Breadboard	2	11.60

Components highlighted in yellow have been changed from last year and those in green are new.

2.2 Software

The robots are able to track the ball, stay within bounds, and do localisation and aiming since 2020. The main functionalities added in 2021 are found within the vision system, including computing goal angle relative to the robot on the OpenMV using MicroPython, communicating this information to the main Teensy 3.5, having the Teensy receive this information, and re-writing the aiming function to prioritise the use this angle over the angle computed from ultrasonic-based localisation.

2.3 Results

Hardware. We will be elaborating on the problems we faced with regards to hardware, and how we resolved these issues.

Problem 1: Our robot from 2020 was close to the weight limit, and would not have allowed us to add the components required for the vision subsystem needed to improve the success rate of the aiming function.

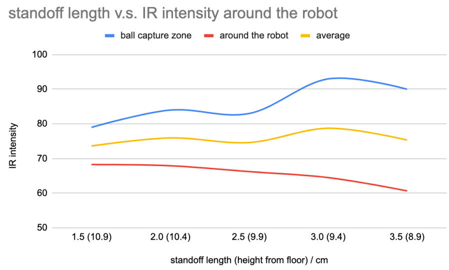
We found that the plates took up a large portion of unnecessary weight, Hence, we redesigned them to be more skeletal, as shown below.

The weight of our plates decreased from 111g to 62g, hence allowing us to add the vision subsystem, which weighed 26g and still make the 1.1kg weight limit.

Problem 2: The compound eye has to be able to detect the ball when it is in the ball capture zone and when it is close to the robot. As the compound eyes are mounted on the underside of the top plate, if they are placed too low, they would be obstructed by protruding JSTs, resulting in lower and inaccurate values being obtained. However, if placed too high, the compound eye would be unable to detect the ball in the ball capture zone.

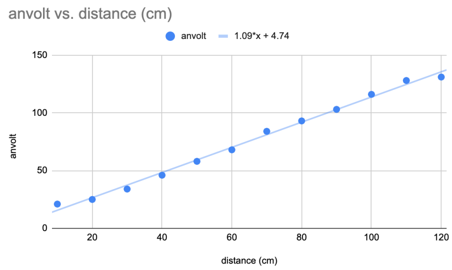
We conducted an experiment and plotted a graph of the distance of the compound eye from the top plate against the maximum IR intensity sensed to figure out the optimum distance the compound eyes should be placed at. We also reduced the maximum IR intensity in our code to 135.0 around the entire robot and 108.0 within the ball capture zone, as these were the maximum intensities obtained when the ball was placed as close as possible to the robot. In addition, we mounted a TEMT6000, facing outwards, at the ball capture zone, which detects the light emitted by the ball, and helps the robot determine if the ball is in the ball capture zone. The mount is constructed such that it ‘hangs’ over the plate. The tab below the mount itself is curved to fit against the curved nature of the plate.

From the graph below, it can be seen that the compound eyes sense a maximum average IR intensity of 78.8 when they are placed 3.0cm from the top plate, and hence this was the height that the compound eyes were placed. As for the TEMT6000 in the ball capture zone, the design of the TEMT6000 mount also prevents the TEMT6000 mount from shifting around, allowing it to sense the light intensity accurately. With all the solutions in place, the robot was able to accurately identify when it was in possession of the ball and when the ball was close to it.



Problem 3: The manufacturer suggested conversion from analog voltage to mm for the LV-MaxSonar-EZ4 (MB1040) was inaccurate.

We took the voltage readings of the ultrasonic sensors at 10cm intervals before plotting a linear best-fit line to obtain an accurate conversion which we use.



Problem 4: While aiming based on ultrasonic-based localisation was excellent when the robot was tested on its own, it performs erratically in the crowded conditions of a 2 vs 2 match. Due to the way we prioritise boundary control, the robot may not aim when the ultrasounds are blocked.

We used a camera and mirror to find and aim for the goal once the robot gains possession of the ball, by using colour blob tracking. The camera is mounted on the top plate, and is the highest component on the top plate so that it will not be obstructed by the other components on the robot. The mirror is V-shaped as the camera only needs to see the goal in order to aim. In the future, we also hope to use the mirror to localise the goalie since it is often blocked when opponents are scoring. It is also constructed such that the rays of the camera reflect off of it to form parallel rays, allowing the camera to see into infinity. To determine the angle of the mirror, we first had to determine the field of view of the camera. When we tried to find the field of view online, we realised that the manufacturing specification was incorrect. Hence, we mounted the camera and used a square piece of paper. After determining the distance at which the camera was able to fully see the paper, we could use trigonometry in order to determine the field of view of the camera, which is 55°. The remaining calculations to determine the angle of the mirror were done with the help of AutoCAD.

Even if the robot or goal is being blocked by another robot, there is still a high chance that the robot would be able to detect the colour of the goal and attempt to score.

Problem 5: There is not much ambient light under the plate, resulting in a poor dynamic range and signal to noise ratio. When readings from the TEMT6000s fluctuate, discriminating between the green field and white boundary lines is difficult, resulting in the robot going out of bounds if the ultrasounds are blocked.

Initially, we used LED strips to provide active illumination to increase dynamic range. However, we were unable to find good adhesives. Eventually, we switched them out for an LED ring which could be mounted securely.

This allowed the robot to obtain consistent values, detecting boundary lines more accurately, and ensuring that it would not go out of bounds.

Problem 6: Given a constant loop time and line width, the blind spots of the robot would increase with speed. In order to maximise the speed that we can travel at and still have the line sensors function as an effective failsafe, we will need them more densely packed.

In 2020, we used 8 TEMT6000s placed on the 4 sides (front, back, left, right) of the robot to detect the boundary lines. This year, we used 17 TEMT6000s arranged in circles inside and outside the LED ring.

The new denser setup is able to reduce blindspots, allowing us to increase the base speed at which the robot runs.

Other considerations. In addition to the aforementioned problems, we also made other considerations.

Ultrasonic sensors: We decided to use 2 ultrasonic sensors on each axis in order for the robot to do localisation. This is because the reading from 1 ultrasonic (on each axis) is insufficient to pinpoint its location as the robot is unable to tell if it is being blocked by another robot, and the location that is found might not be accurate. Using 2 ultrasonics on each axis (i.e. one ultrasonic facing the front, back, left and right) allows the robot to take into account the total distance sensed by the ultrasonics on each axis (total distance sensed by left and right, or front and back ultrasonics). As a result, the robot is able to determine if it is being blocked. If it is, instead of pinpointing its exact location, the robot is able to determine the possible area in the field in which it could be located.

Software

Problem 1: In 2020, two strikers were used. When attacking, the robots clash in some cases, reducing goal-scoring efficiency. Additionally, with both robots at the attacking end of the field, we lose ground over the opponent robots when situations such as when the ball is placed at a neutral point behind our offensive robots.

Hence, we decided to designate one robot as a goalie. This involved increasing its IR intensity threshold so it would only move from its home position if the ball was very close to it. The robot also returns to its home, set directly in front of the goalpost at the goal line if the ball is not detected.

The result was a better block rate when the ball was rolled from neutral point to goal as a simulation of the opponent attacking when the ball is brought back into play. Additionally, collisions up front were also reduced.

Problem 2: Movement is not smooth when the robot heads in the direction of the compound eye port with the maximum IR value due to the limited and discrete positioning of the bulbs.

By taking into account the IR intensity of the compound eye ports to the left and right of the maximum port, we can find the ratio of the difference between left and middle IR values and the difference between the middle and right IR values. This allows us to accurately interpolate the angle of the ball, resolving the angle to a greater resolution.

The robot has smoother movement with less sudden changes in its acceleration, making the overall movement more efficient.

Problem 3: If the robot moves directly towards the ball while tracking the ball, it might touch the ball with its body, causing the ball to move away instead of allowing the robot to gain possession of the ball.

We implemented a function to orbit around the ball, allowing the robot to move at an angle in order to get behind the ball. This angle can be calculated by combining the IR intensity from the compound eyes, which is a proxy for the distance between the ball and robot, and the angle of the ball.

The robot consistently receives the ball in the ball capture zone and has better ball handling, hence the chances of the ball accidentally sliding out of the ball capture zone are reduced.

Problem 4: Previously, the robot was unreliable in using localisation to determine its location when it was being blocked by other agents in the field. This caused it to go out of bounds often and in a game situation, the robot would need to be removed for 1 minute which would be undesirable.

Hence, we decided to implement a function to determine the confidence of the robot regarding its position in the field, before scaling the speed of the motors based on its confidence, hence reducing the chance of it going out of bounds and prioritising boundary control over scoring aggression. In addition, we use the TEMT6000 sensors to detect the boundary line, and if they do, the robot will move in the direction of the nearest neutral point until it is off the line.

The result was the robot being able to stay within bounds reliably even when blocked.

Problem 5: Previously, ultrasonic-based localisation was used for aiming, which was not ideal as when the robot has possession of the ball, it should attack instead of being more defensive due to it being unconfident of its position. Furthermore, if the robot was being blocked, it would be unable to pinpoint its exact location on the field and hence the calculated angle of travel might not be accurate. The robot is also unable to tell if the goal is blocked and is unable to aim towards open space.

Hence, we decided to use camera-based aiming by implementing colour blob tracking, which allows the robot to aim even if the goal is blocked. Once the robot gains possession of the ball, it would find and aim towards the largest blob of colour detected, which is the largest unblocked area of the goal.

The result was that the robot was able to aim and score even when it was completely blocked on both sides. The robot would still be able to detect the colour of the goal and attempt to score, even if part of the goal is being blocked as the camera has a wider view. The camera is also able to aim towards open space, and since this method does not rely on the robot's location, the robot is able to head towards the goal even if it is blocked.

3 Conclusions and Future Work

3.1 Summary of Learning Experience

During this competition, we not only learnt how to make use of software like AutoCAD to facilitate the preparation of the hardware aspect of our robot, but also were exposed to coding platforms like OpenMV, Arduino and Teensyduino. Besides that, we also learnt how to code in C++ and MicroPython. All of these new technical skills that we obtained will come in especially useful for future projects, proving this competition experience a fruitful one.

Besides that, we have learnt the importance of adaptability, especially with the changing COVID-19 situation. We were unable to meet in person to work on the robots together, due to full home based learning. We adapted by shifting our meetings online to ensure that everyone is aware of the current state of the robot and the code.

We realised that the process is more important than the result. While it is satisfying to see your robot finally work after spending months on end building it, we realised that the process we had taken to achieve that was more meaningful. Throughout this entire RoboCup journey, we have learnt new skills and knowledge in terms of both hardware and software, and this competition has indeed been an enriching experience for us.

3.2 Future Work

We would like to implement a goalie-to-striker or striker-to-goalie transition in future to be able to score more goals and prevent the opponent from scoring. The goalie-to-striker transition ideally occurs when the goalie is in possession of the ball. The goalie can then take the opportunity to attempt to score instead of only hitting it away from the goal. The striker-to-goalie transition will be implemented when the goalie is attempting to score or out of play. This ensures constant defence in front of the goal. Implementing these strategies requires Bluetooth communication between the robots, but our robots currently do not have sufficient hardware.

4 References

4.1 Past Year Resources

Team Raffles [ng mh]. (2019, April 12). RCJ Soccer Lightweight - RI v/s HCI [2nd Half] [Video]. YouTube. https://www.youtube.com/watch?v=00oocWPDm4M

Storming FC [Jasper Tan]. (2020, June 23). Robocup Junior Soccer Video Presentation [Video]. YouTube. https://www.youtube.com/watch?v=i5F3fuh59lw

Team Transcendence [bozotics]. (2020, June 26). Team Transcendence - RoboCupJunior Soccer Open “Poster” Video [Video]. YouTube. https://www.youtube.com/watch?v=s2tOrOdC2fA

RoboCupJuniorTC. (n.d.). RoboCupJuniorTC/awesome-rcj-soccer. GitHub. https://github.com/RoboCupJuniorTC/awesome-rcj-soccer.

4.2 Datasheets and Documentation

Overview — MicroPython 1.15 documentation. (2021, May 23). Overview — MicroPython 1.15 Documentation. https://docs.openmv.io/