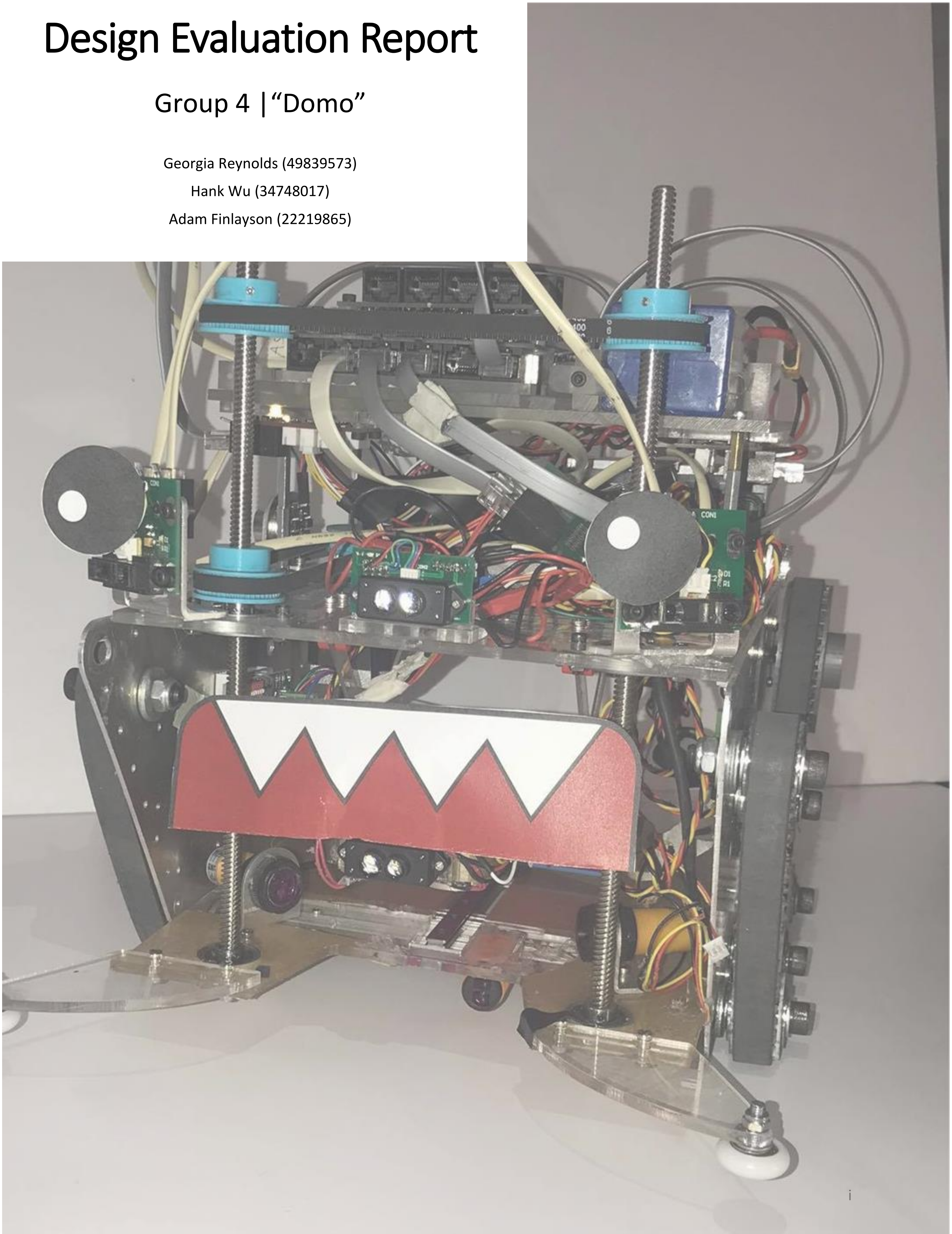
Design Evaluation Report

Group 4 |“Domo”

Georgia Reynolds (49839573)
Hank Wu (34748017)
Adam Finlayson (22219865)



1. Executive Summary

The Design Evaluation Report discusses group 4's performance in the 2020 Robocup Competition. This robot design was modified from the results of the Detailed Design Report. The changes made include changes to the track design, sensors used, and weight identification system. Each change was made to improve the robot's performance against the design specifications outlined in the Conceptual Design Report. Each of the subsystems of the robot have been fully detailed, the robot's performance evaluated and the performance of other robots analysed.

Two Time of Flight (ToF) mini sensors were used for weight identification and three infrared (IR) proximity sensors used to determine when a weight is ready to collect. The results from the two ToF mini sensors were compared based on intensity and distance to determine if an object was a weight or an obstacle. This was done while the robot spins and an IMU recorded the angle a weight was seen.

The collection mechanism used two electromagnets raised and lowered by stepper motor driven lead screws. The electromagnets were lowered until they touched the weight, turned on, then the weight was lifted to the dropping point. This was a point at which a tray was extended underneath the weights by two standard servos. The weight was then dropped and the tray tiled so the weight fell into the storage bay. The robot had no capability to collect plastic weights, so if one entered the collection bay the robot had to reverse away from it.

The robot lost both of its matches in the 2020 Robocup competition. However, its performance for both of those rounds was reliable collecting at least two weights. It lost both rounds on the tie breaker of most plastic weight. On average, in the competition, the weight collection speed was 9 seconds, metal weight collection accuracy was 100%, but false triggers were 37.5%. This meant weight collection was fairly slow but reliable for metal weights, with 100% accuracy collecting any metal weights that were in the collection bay. However, as the false trigger rate was 37.5%, it meant the collection mechanism triggered when there was no metal weight approximately once for every three weights actually collected.

This report also evaluated the performance of three other group's robots, groups 8, 25 and 27. Group 25 was the most successful of these robots gaining second place in the competition. Groups 8 and 25 were examples of the "ramp and scoop" system that was extremely popular in the 2020 competition. Overall, neither weight collection system design or speed seemed to impact success. A better metric would be the simplicity of the design.

Based on this analysis three changes would be suggested. First, the ability to identify and navigate away from plastic weights within five seconds would be beneficial in reducing false positives. Second, decreasing the false positive collection percent from 37.5% to below 15% would allow the clear measurement of success. Third, implementing wall following on start-up rather than random motion would decrease time taken to collect first weight when the first weight is along a wall. In addition, the high-level design strategy of simplicity should be implemented in any further design.

Domo succeeded in completing the base requirements outlined in the first Conceptual Design Report, to collect one weight. Domo collected at least two weights each round. For that group 4 is proud.

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2. Introduction

The report describes group 4's robot that competed in the 2020 Robocup competition. This is a competition that takes place between second professional year mechatronics students at the University of Canterbury. Group 4's robot "Domo" competed in two rounds of the competition, losing both rounds and being eliminated.

A Detailed Design Report was undertaken at an earlier stage of the design process. Most integral aspects from this design are still apparent in the this report. However, the main changes are listed as follows, alongside the reasons for each change.

- The drive wheel was changed to decrease stress on the motor and slip.
- Two Time of Flight (ToF) mini sensors were used for weight detection instead of IR sensors. This was done as the ToF mini sensors provided cleaner results without filtering.
- Passive obstacle avoidance bearings were added to aid Domo's obstacle avoidance.

These changes do not significantly change the overall design illustrated in the Detailed Design Report. Each of these changes were made to improve the robot's performance as measured by the design specifications. In addition, through the design process these design specification were altered to better reflect the competition strategy chosen by this group. These updated design specification are illustrated in Appendix A alongside how well Domo met them.

3. Design Description

Domo's resemblance to the initial Conceptual Design Report can be clearly seen. The robot's design has been broken into three subsystems the drive system, weight collection system and obstacle/weight detection systems. The hardware for each of these section is shown in Figure 1.

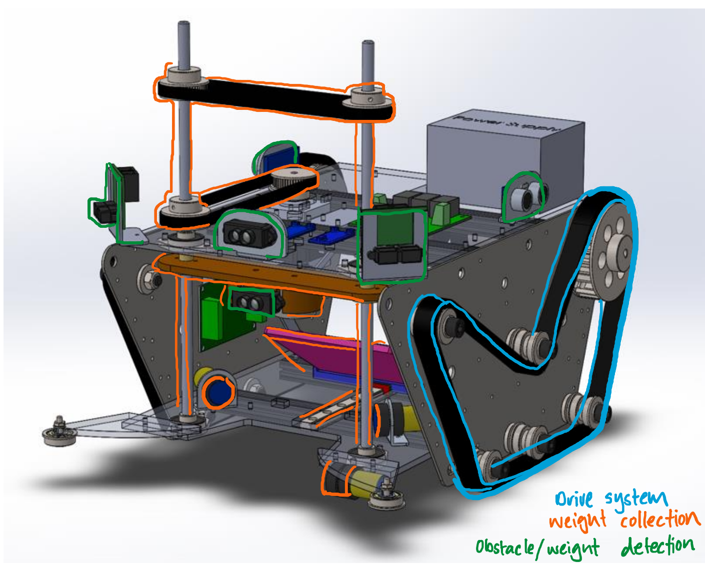


Figure 1: *Subsystems of Domo.*

3.1 Search Algorithm

The search algorithm Domo uses links the four states the robot would use in the competition. These four states are, the approaching state, scanning state, capture state and obstacle avoidance state. The relationship between these four high level subsystems is shown in Figure 2. Each of these states is further elaborated in the following discussion of the subsystems.

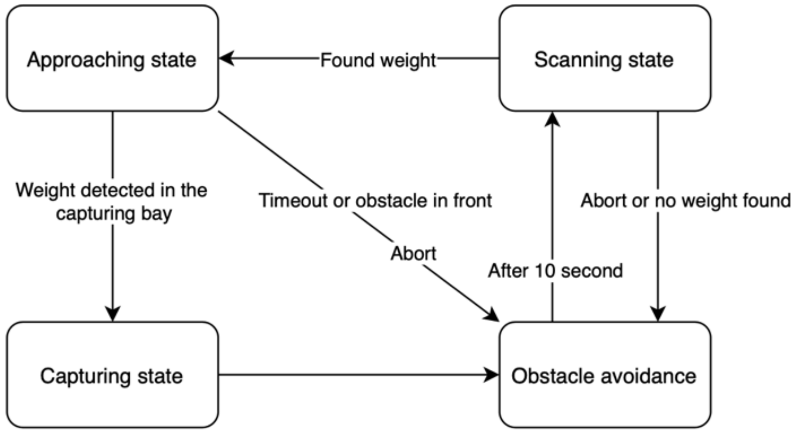


Figure 2: *Search algorithm flow chart.*

3.1 Weight Collection (Collection State)

The final weight collection system can be seen in Figure 3. The system can be broken into three subsystems, recognition, elevation and storage. A visual representation of this process can be seen in Figure 4.

The recognition stage identifies a weight needs to be collected. This is done by the two proximity sensors in the collection bay. In addition, these sensors allowed the robot to accurately detect the orientation of the weights. If the lower sensor activates the weight was classified as knocked over. If the upper sensor was activated the weight was classified as standing. This stage can be seen in Figure 3 a.

The elevation stage, shown in Figure 3 b involves activating the electromagnets and lifting the weight before storage. One key change that was made later in development was that that fallen weight collection occurs while the robot moves forward. The electromagnet is lowered and raised by a stepper motor driving two lead screws.

The storage stage drops the weight onto the collection tray, then retracts the tray. This deposits the weight into the storage bay. Figure 3 c depicts this process.

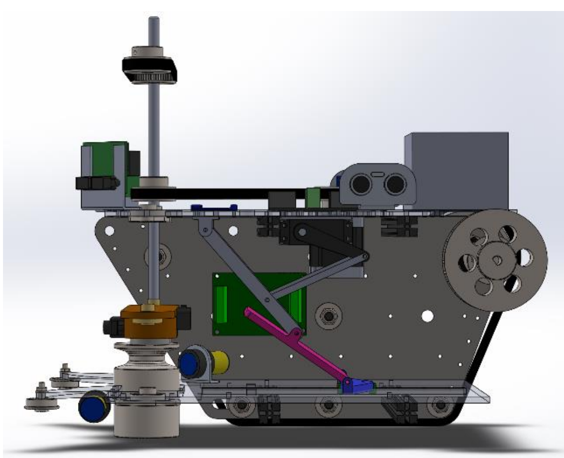


Figure 3 a: *Recognition stage of collection mechanism.*

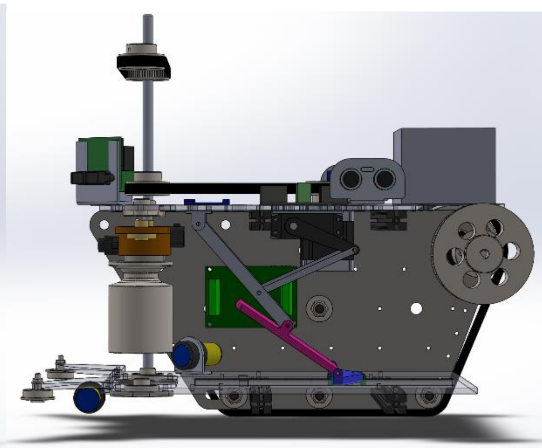


Figure 3 b: *Elevation stage of collection mechanism.*

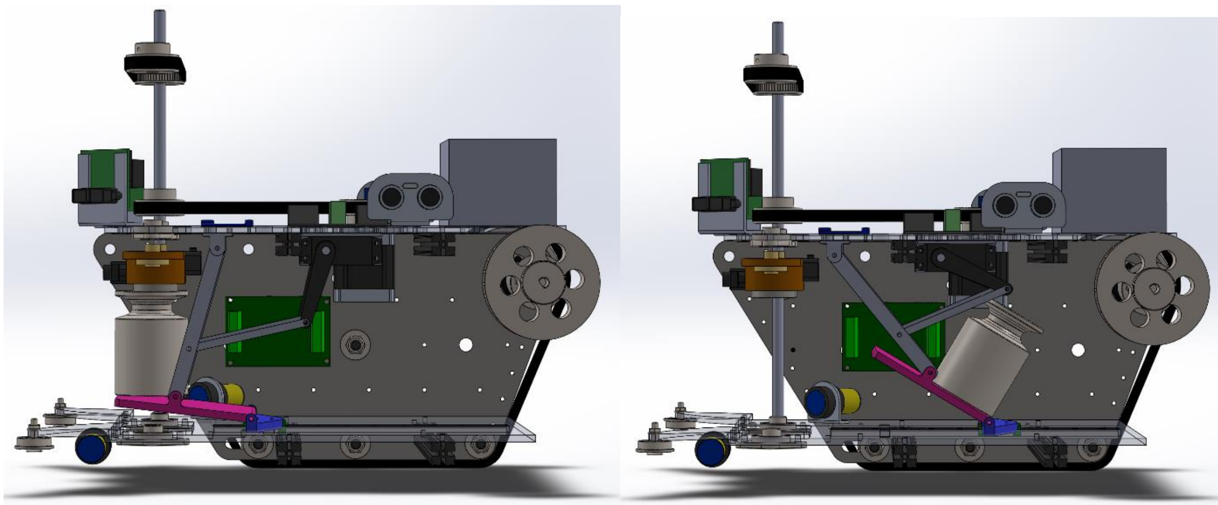


Figure 3 c: *Storage stage of collection mechanism.*

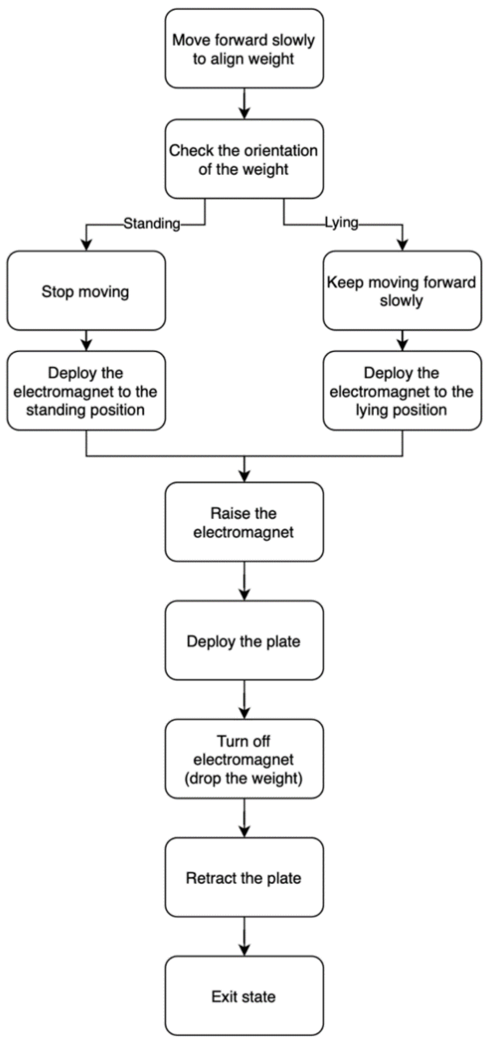
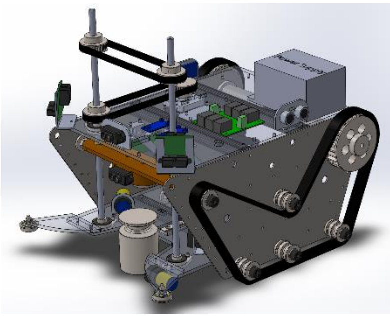
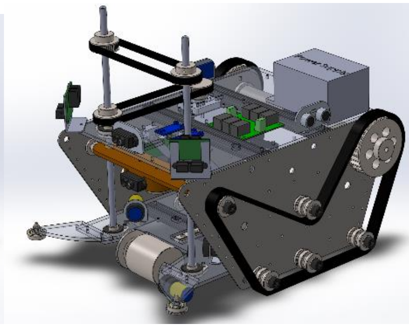


Figure 4: *Collection mechanism flow chart.*

3.1.1 Collection Orientation

It was important in group 4's competition strategy to be able to collect weight at any of the three orientations weights could be during the competition. These were, standing, fallen parallel or fallen perpendicular. Figure 5 a, b and c show these orientations. The electromagnet holder was designed so that each of these orientations could be collected.





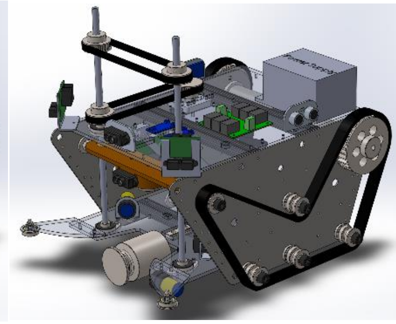


Figure 5 a: *Standing orientation* ***Figure 5 b:*** *Parallel orientation* ***Figure 5 c:*** *Perpendicular orientation*

3.1.2 Approaching State

The approaching state refers to the state the robot is in as it approaches weights before collection. It causes the robot to move forward until the proximity sensor activates or an abort is triggered. Aborting conditions include a timeout, the watch dog activating or a tilt being detected. The length of time needed to cause a timeout in the approaching state is adjusted dynamically based on the distance to the weight. This time varies from three to six seconds. Figure 6 shows the flow chart demonstrating this logic.

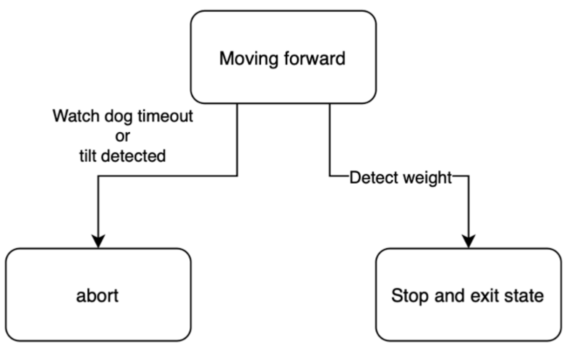


Figure 6: *Approaching state flowchart.*

3.2 Weight Detection (Scanning State)

Domo used two methods to detect weights, both of these needed to identify a weight for the object to be designated a weight. Both of the methods rely on two ToF mini sensors and a spinning scanning technique. The sensors need to be carefully placed to ensure accurate results. The two detection methods are:

- Comparing the results of the two sensors. If the bottom sensor sees an obstacle that the top sensors doesn't, the obstacle is a weight. This is done by checking if the difference between the sensors is greater than a threshold.
- Recording the angle a sensor is triggered using the Inertial Measurement Unit (IMU). If this angle is greater than 8 degrees, the object is deemed a weight.

Figure 7 shows the signals compared between the two ToF mini sensors. Its shows the distance and intensity graphs for the two sensors. When there is nothing in front, the red (bottom intensity) line is lower than the blue (upper intensity) line. This occurs because the bottom sensor is picking up some light reflected from the floor. The algorithm looks for a spike in the intensity, if only the bottom sensor detects a spike it is probably a weight. This occurs in Figure 7 each time a weight was placed in front. Additionally, this figure shows the difference in distance typically seen between the lower and upper sensors for weights or obstacles which is used to detect weights.

Both systems were implemented as errors from each one individually caused significant inconstancy. For example, as the bottom sensors pick up reflected light from the floor they consistently read lower than the top sensors.

An IMU was implemented to allow the robot to accurately detect and measure its yaw. This allows the robot to record the angle at which it 'sees' a weight. Additionally, a scan watchdog timer was implemented to ensure the robot does not get stuck in scanning mode. If the robot were to not move for 200 ms this watchdog would be triggered. This would cause the robot to abort out of scanning mode and move to extract itself.

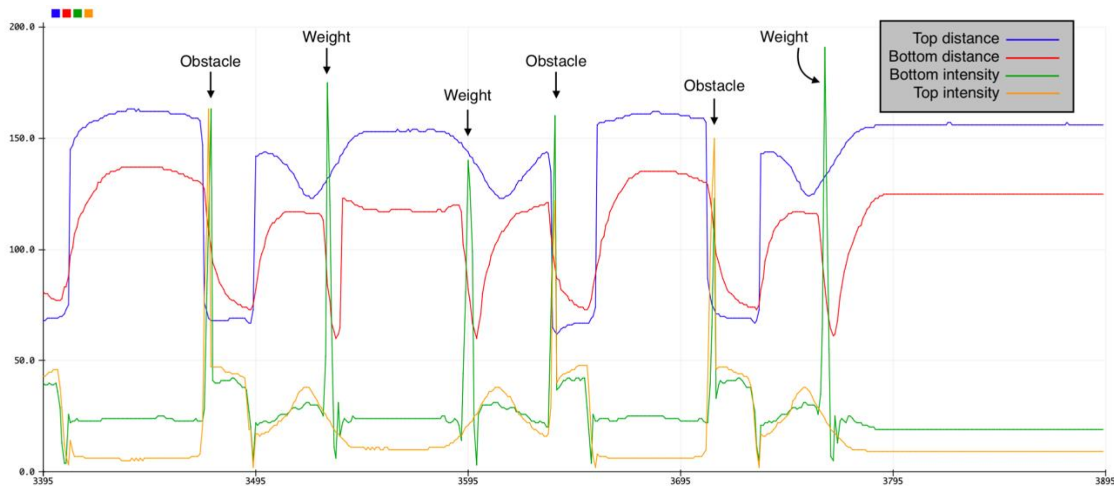


Figure 7: *Example of ToF mini sensor values for weights and obstacles.*

3.3 Obstacle Avoidance

Obstacle avoidance was done using predominately the forward angled IR sensors shown alongside the other sensors in Figure 8. The sensor types used are shown in Table 1. When either of these IR sensors trigger the robot adjusts the opposite way (if the left sensor triggers, the robot steers right). In addition, the ToF mini sensors were used in parallel with the side facing ultrasonic sensors to assist in obstacle avoidance. If the ToF mini sensors detect an object less than 30cm away it checks the ultrasonic sensors for which has the most space and turns towards that direction. This secondary system was designed specifically to deal with corners. A flow chart of this process is shown in Figure 9.

Table 1: *Sensors used on Domo and their purpose.*

Number	Sensor Type	Purpose
1	Medium Range IR	Wall detection
2	Ultrasonic	Deciding which direction to turn when "head on" against a wall
3	Proximity Sensor	Determining when a weight is in the collection bay
4	ToF mini	Upper sensor to see over weights (also used for obstacle avoidance)
5		Lower sensor to see both weights and obstacles
6	Proximity sensor	Determining if a weight is standing or knocked over.

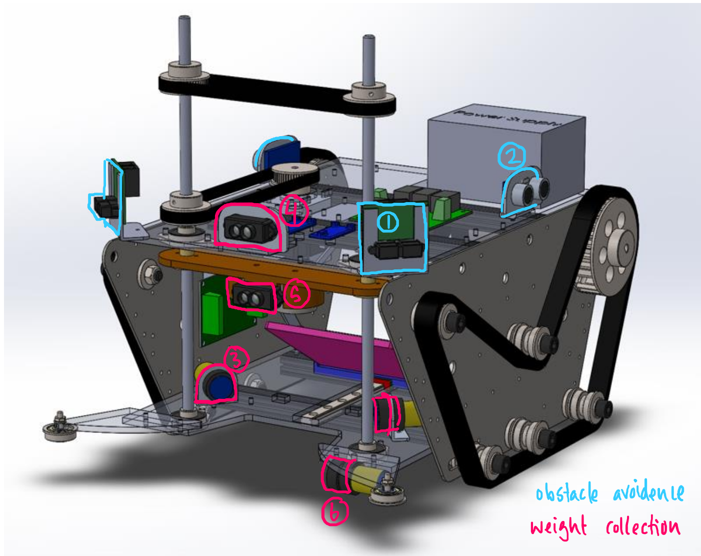


Figure 8: *Placement of the sensors used on Domo.*

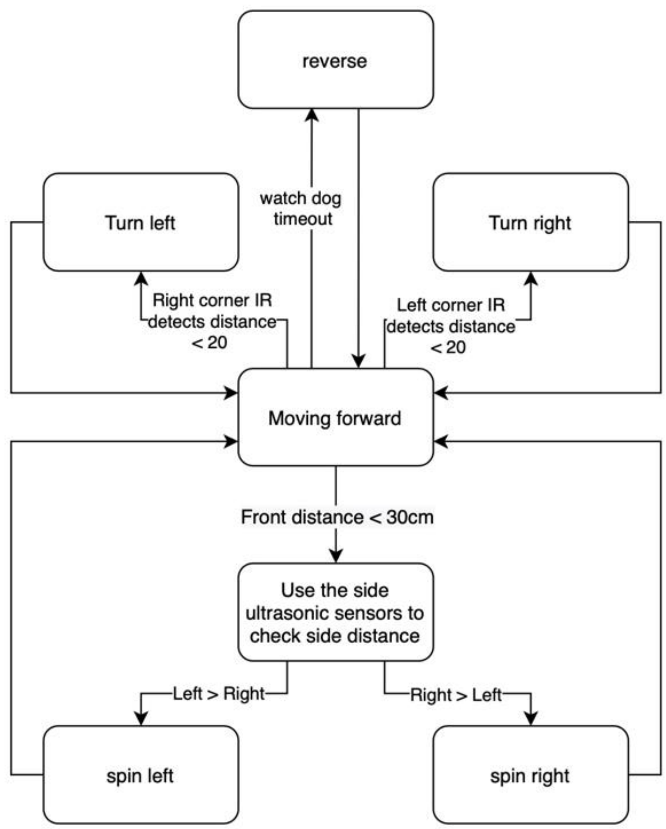


Figure 9 *Obstacle avoidance flowchart.*

Two other aspects were added to improve performance increasing randomness and implementing a watch dog timer. A random component was added to each turn made. This was done to decrease the likelihood to getting stuck in loops larger than could be recognised by the robot. The watch dog timer checks if the front ToF-mini value doesn't change for two seconds while in obstacle avoidance mode. This would mean the robot is stuck. In this situation the robot would reverse at full speed, a manoeuvre that was typically successful at dislodging the robot.

3.4 Motion

Decreasing track slippage was incredibly important for optimum functionality. Figure 10 shows the layout chosen to minimise slip. In addition to this layout, two pieces were constructed to aid in reducing the slip a toothed drive wheel (Figure 11) and timing pulleys for the bearings (Figure 12). This meant that not only was slip reduced but also the tension on the belt could be reduced without fear of losing a track. This put less strain on the motors which struggled to move when tensions were too high.

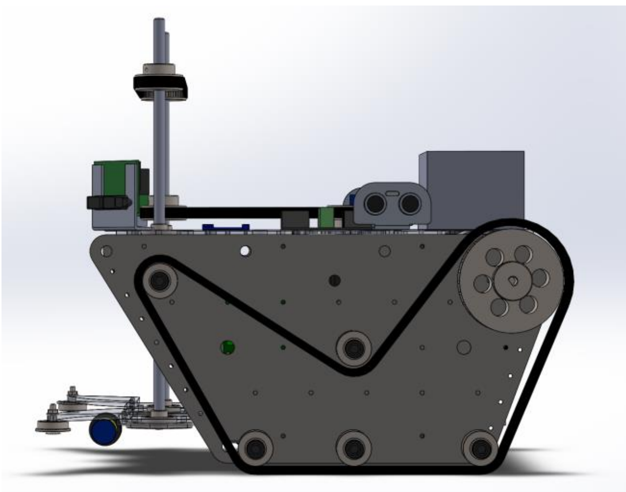


Figure 10 *Track Layout.*

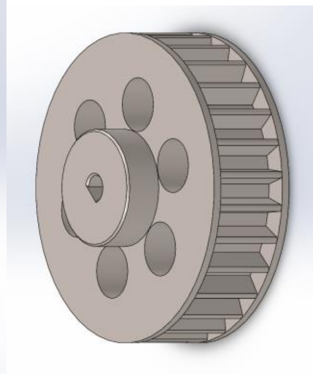


Figure 11 *New drive wheel with teeth.*

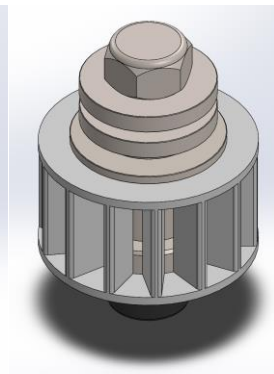


Figure 12 *Bearing attachment with teeth*

4. Results and Evaluation

4.1 Domo Evaluation

4.1.1 Robocup Performance

Domo did not win either of its rounds in the Robocup competition. Both rounds were decided on a dummy weights tie breaker. Domo's competition results can be seen in Table 2. In total Domo collected five metal weights with a total weight of 4.5 kg over the two rounds it competed. Domo collected the most weight per round of any robot collecting on average 2.25 kg per round.

Table 2: Domo's Robocup performance statistics.

Robot weight(kg)	# rounds contested	Total target weight collected (kg)	Total target weight collected (#)	Total dummy weight collected (#)	Total weights collected (#)	Place
6.75	2	4.5	5	0	5	9

From the two rounds Domo competed in some positives and negatives were identified.

- + Target weights could be collected at any orientation consistently.
- + Weights were identified accurately and precisely.
- – The system could not collect plastic weights. In addition, the process for moving away from them was slow and did not work every time.
- – The system could not collect the snitch.
- – The system could not collect weights against the wall.

- The scanning cycle took too long when there were lots of weights in the arena.

None of these faults were identified in the Detailed Design Report's Fault Tree Analysis (FTA). This was because the FTA focused on "The Robot Failed to Collect a Weight", which was not a problem in the competition as shown by the 100% weight collection accuracy in Table 4. Further analysis should have been done into failing to move away from plastic weights in order to better address that situation.

Table 3 shows the competition weight collection statistics collected for every robot assessed. The time before the first collection varied greatly between the first two rounds. This was because Domo got stuck on a plastic weight in its second round greatly increasing the time taken to collect its first weight. Domo's collection speed was consistent and moderately fast. The approximate arena speed was rarely achieved due to slower speeds being used during the collection process.

Table 3: *Robocup performance statistics for Domo's two rounds.*

	Time before first weight collection (s)	Time to collect weight (s)	Approximate arena speed (m/s)
Round 1	25	9	0.25
Round 2	78		
Average	51.5		

Throughout the competition, Domo was extremely successful at identifying weights and collecting metal weights. Additionally, Domo collected weights in both orientations during the competition. This proved the importance of multi-orientation collection mechanisms. Domo's success rate in an empty arena was 90% but in the competition, this increased to 100% of metal weights. Table 4 shows this comparison. Domo did not fail to collect a metal weight that was in it's collection bay during the competition. However, the issue came in finding metal weights to collect. Due to Domo's inability to collect plastic weights if a plastic weight was in the collection bay "misfiring" and falsely attempting to collect the plastic weight costs valuable time. Table 5 shows the percentage of false positive collection attempts for each round. A trigger event was defined as the collection mechanism running, whether there was a weight present or not.

Table 4: *Metal weight collection accuracy, tested versus observed.*

Tested Weight Collection accuracy	**Observed Weight Collection Accuracy of Metal Target Weights**				
	Round 1		Round 2		**Total Percentage**
	Attempted	Successful	Attempted	Successful	
90.1%	3	3	2	2	100%

Table 5: *Table of false positive collection triggers – calculated by counting successful collections and all weight collection attempts no matter if there was a weight to collect.*

	Number of collection trigger events	Number of Collections	Percentage false positive
Round 1	4	3	25%
Round 2	4	2	50%
Average	4	2.5	37.5%

Domo had two tuning cases that were used for each round. In the first round Domo used the "conservative" tuning case and in the second round Domo used it's "hard and fast" tuning case. The first round had longer reverse times when the weight collection system was falsely triggered. This allowed Domo to get further away from a plastic weight before searching again. Whereas the "hard and fast" tuning focused on maximising efficiency and not wasting time reversing. Looking as Tables 3 and 5, it is clear the first "conservative" tuning was more effective.

4.1.2 Design Specification Evaluation

A full breakdown of the Design Specifications is available in Appendix A. Domo fulfilled all but three of the original hard constraints from the design specifications. These were:

- 2.a The robot should not become stuck by obstacles including but not limited to: "Ramps"
- 10. The robot should be able to climb a gradient of 30%
- 16. The robot should be able to pick up weights in a corner or against an obstacle.

Being able to collect weights against obstacles was originally prioritised in the design process, however was eventually overlooked. In the competition rounds, weights were often placed close to the walls in positions Domo could not collect. This was clearly an oversight that should be adjusted in future development.

Ramps were not an issue in Domo's run of the competition. In the first arena configuration, the ramp was not in the arena, so the fact Domo could not climb the ramp did not affect its performance. However, when Domo was tested in later arena configurations the ramp proved difficult to detect. Not being able to detect the ramp is a problem, but climbing the ramp was not necessary to win at all. Therefore, these two design specifications are not necessary and should be replaced with the ability to "detect and navigate around the ramp".

Another design specification was met with inconsistent results:

- 14. The robot should not repeat the same task, or sequence of tasks, for more than 15 seconds.

In order to meet this criteria watchdog timers were added. These typically ensured the robot did not get stuck on things like ramps or the speed bumps. However, longer loops, like repeatedly going for the same plastic weight were not avoided by the watchdog timers. This was an issue in the competition.

Finally, there were some design criteria that were deemed to negatively affected Domo's performance, these included:

- 7. The robot should actively seek weights or the snitch.
- 9. The robot should distinguish between weights and obstacles.

These ratified the goal to have Domo actively search for weights and distinguish them from obstacles. As is elaborated in the Opponent Evaluation section, other robots were very successful through random motion and having a short range triggers rather than long range detection. Therefore, if this project were to be redone, removing these two criteria might be beneficial. These two design constraints significantly increased the complexity of the search algorithm. Were this to be simpler, more time could have been spent on testing and improving Domo's reaction to the ramp.

4.2 Opponent Evaluation

4.2.1 Winston (Group 8)

Winston is an excellent example of a "ramp and scoop" combination robot that competed against Domo in its second round. These were very popular style of collection method in the 2020 Robocup competition. Winston can be seen in Figure 13. Overall, Winston scored highly gaining 5th place and collecting a total of 8.25 kg. Winston was eventually knocked out in the final arena configuration, when weights were sparse.

Winston has been analysed based on its performance against group 4's design specifications. This is shown in Appendix A. The main points of difference are:

- 7. The robot should actively seek weights or the snitch.
- 9. The robot should distinguish between weights and obstacles.

For both these criteria, Winston had a system, but it did not behave reliably. In terms of actively seeking weights, Winston could see weights up to a range of 500 mm and utilized some rudimentary rotation (approx. 20 degrees) to increase range. However, in practice this range was significantly smaller, dramatically decreasing the effective range when searching for weights. In addition, Winston used sensors at two heights to distinguish weights from obstacles, yet the success of this was also varied. Winston meets most of the design specifications illustrated by group 4. By examining these differences, it becomes clear that group 8 had slightly different goals than group 4.

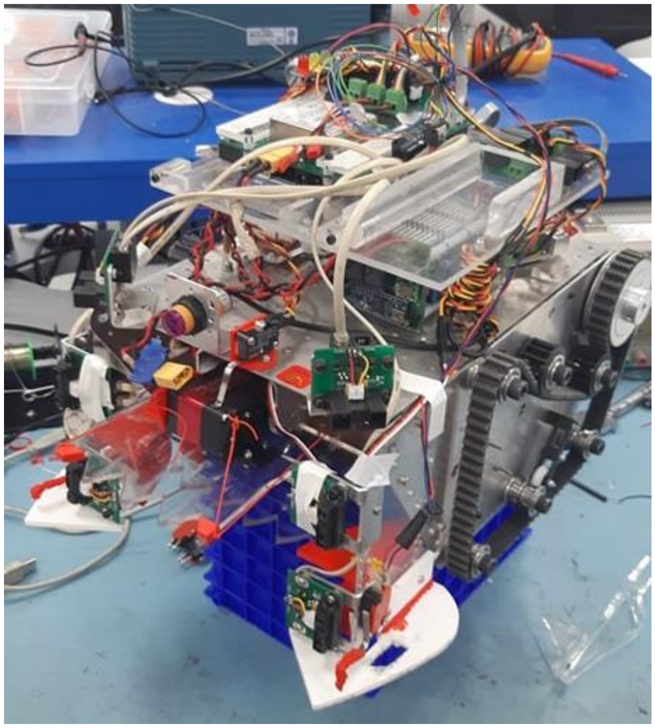


Figure 13: *Winston, Group 8's robot.*

Winston gained notoriety and become a crowd favourite after catching the snitch in its 5th round. It managed to place 5th overall and collect a total of 16 weights. Table 6 shows it's final results.

Table 6 *Competition results of Winston.*

Robot weight(kg)	# rounds contested	Total target weight collected (kg)	Total target weight collected (#)	Total dummy weight collected (#)	Total weights collected (#)	Place
6.344	7	8.25	12	4	16	5

Winston had trouble collecting its first weight in round 1. This is similar to what happened to Domo in its second round. Winston avoided the weight placed directly in front of the robot costing it valuable time in the early stages of the competition. Winston lost that round but managed to fight its way through the "loser bracket". Winston's weight collection time average three times faster than Domo's. However, both robots had to stop while collecting, increasing the real collection time. Table 7 shows these statistics.

Table 7: *Round statistics for Winston's first two rounds.*

	Time before first weight collection (s)	Time to collect weight (s)	Approximate arena speed (m/s)
Round 1	74	3	0.35
Round 2	13		
Average	43.5		

4.2.2 Hot Glue (Group 27)

Hot Glue versed Domo in the first round of the competition. It ranked 8th beating only Domo in the competition. Much like Winston, it utilised a scoop like "sweeper" that lifted weights over a barrier into storage as shown in Figure 14. Like many of the other robots, Hot Glue had a tiered sensor system to distinguish between weights and obstacles. Hot glue was knocked out in round 4, and collected a total of 12 weights. Specific competition details can be found in Table 8.

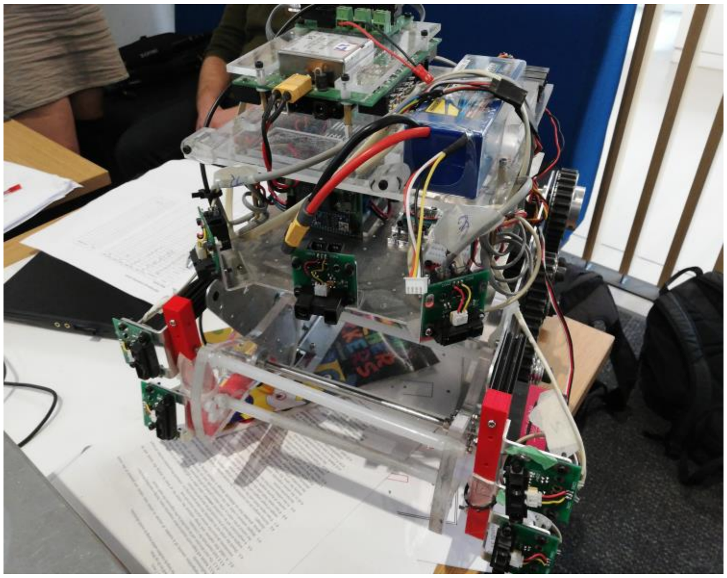


Figure 14: *Hot Glue, group 27's robot.*

Hot glue was analysed with respect to Domo's design specifications in order to gain an understanding of where Hot Glue performed better or worse than Domo. The areas were Hot Glue performed better than Domo are:

- 14. The robot should not repeat the same task, or sequence of tasks, for more than 15 seconds.

Hot Glue did not get stuck in a loop and covered much of the arena, giving it many opportunities to run into a weight.

The areas where Hot Glue performed worse than Domo are:

- 7. The robot should actively seek weights or the snitch.
- 9. The robot should distinguish between weights and obstacles.

Hot Glue relied on the tiered sensor system to find weight and distinguish between obstacles and weights. This system was relatively unreliable as Hot Glue would often drive past weights that were right in front of it. However, this was mitigated by the systems discussed above.

Table 9 shows information on how quickly Hot Glue could pick up a weight, and how long it took Hot Glue to get to its first weight. Hot Glue had a very fast weight collection time at three seconds and was able to continue to move while collecting a weight. This increased the amount of ground Hot Glue could cover per round. Hot glue had a variety of ways it could win a round. It is lighter than Domo, Winston, and The Garbage truck. It could pick up plastic weights and the snitch. Hot Glue's ability to pick up plastic weights is the reason it beat Domo in round two.

Table 8: *Competition results of Hot Glue.*

Robot weight(kg)	# rounds contested	Total target weight collected (kg)	Total target weight collected (#)	Total dummy weight collected (#)	Total weights collected (#)	Place
6.541	4	6.5	8	4	12	8

Table 9: Round statistics for Hot Glue's first two rounds.

	Time before first weight collection (s)	Time to collect weight (s)	Approximate arena speed (m/s)
Round 1	9	4	0.2
Round 2	13		
Average	11		

Hot Glue utilised a well optimised navigation system, along with a quick weight collection, to achieve success in the Robocup competition.

4.2.3 The Garbage Truck (Group 25)

The Garbage truck was the second place robot in the competition, showing its strength. Much like Domo it utilised magnets in its collection method, yet conversely it used only permanent magnets.

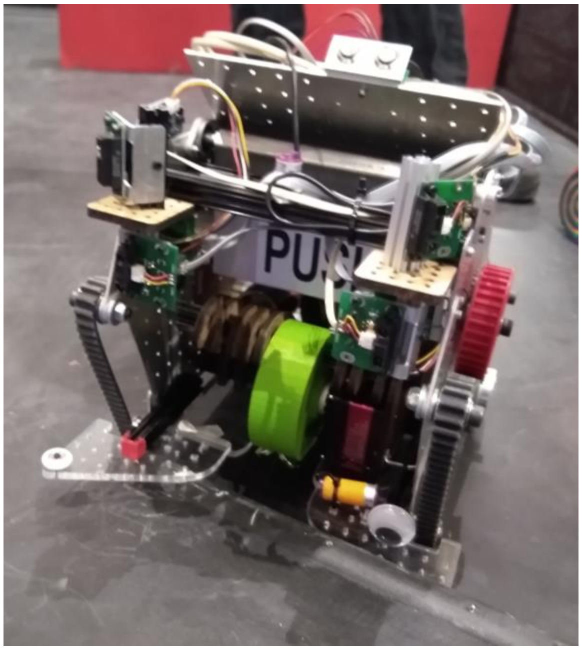


Figure 15: *The Garbage Truck, group 25's robot.*

The Garbage truck has been analysed based on its performance against group 4's design specifications. This is shown in Appendix A. The main points of difference are:

- 7. The robot should actively seek weights or the snitch.
- 9. The robot should distinguish between weights and obstacles.

The garbage truck did not search for weights at all. It moved forward "blindly" and turned if encountered obstacles. This was very different to the strategy group 4's design specifications were written for.

The navigation algorithm of the garbage truck was also very different from Domo. The garbage truck used the side ultrasonic sensor to follow the wall. This navigation strategy allowed it to get around the entire arena very quickly.

Although the Garbage Truck did not search for weights, there were ample weights in the arena for it to capture by random motion. Although it could only capture metal weights, the capture mechanism was so fast that it could compensate for this problem. This speed can be seen in Table 11, twice as fast as Domo.

The Garbage Truck was able to contest seven rounds to place second. Table 10 shows it's competition statistics. It collected a total of 18 metal weights and averaged 2.6 weights a round. This is similar to Domo.

Table 10: Competition results of the Garbage Truck.

Robot weight(kg)	# rounds contested	Total target weight collected (kg)	Total target weight collected (#)	Total dummy weight collected (#)	Total weights collected (#)	Place
6.885	7	11.75	18	1	19	2

Table 11: *Round statistics for the Garbage Truck's first two rounds.*

	Time before first weight collection (s)	Time to collect weight (s)	Approximate arena speed (m/s)
Round 1	18	4	0.3
Round 2	9		
Average	13.5		

4.2.4 Overall Opponent Evaluation

Having evaluated a variety of robot's performances in the competition one thing is prominently clear, simplicity is key. Each of the robots evaluated exemplified keeping at least one aspect simple, to allow another to be perfected. Table 12 compares the competition results of the four robots addressed in this report.

Winston and Hot Glue used similar and simple collection methods. Therefore, it is clear why their time to collect a weight is the same, a very quick, three seconds. The two systems had their differences, but were both three times faster than Domo.

Hot Glue and Garbage Truck had efficient obstacle avoidance algorithms for the first arena layout. They both successfully collected weights in the first 15 seconds of their first two rounds. These two robots were "blind" and didn't actively search for weights which benefited them in the first two rounds where a weight was placed directly in front of the robots. Domo, on the other hand, had a search algorithm that was too complicated and sent it away from the weight initially due to random motion. This meant it took Domo far longer to collect its first weight on average.

Arena speed was something Domo struggled with. As the approaching speed was slower than maximum speed it greatly increased the total collection time when the approach was accounted for. Robots like the Garbage Truck could collect weights almost at full speed. This meant it could continue searching the arena as it was collecting.

Table 12: *Comparison of three robots against Domo based on competition results.*

	Time before first weight collection (s)	Time to collect weight (s)	Approximate arena speed (m/s)	Average weight collected (#)	Place
Domo	51.5	9	0.25	2.5	9
Winston	43.5	3	0.35	1.7	5
Hot Glue	11	3	0.2	2	8
Garbage Truck	13.5	4	0.3	2.6	2

4.2.4.1 Design Specification

The two most successful groups, 8 and 25, both met less of group 4's design specifications than group 4. This would indicate that group 4's design specifications were not a very good indicator of success. Perhaps, these design constraints hemmed in group 4's thinking. By restricting the design to have to search for weights, group 4 did not examine the variety of simpler and potentially more effective options.

The Garbage Truck still did well, despite not being able to collect plastic weights. However, as Domo lost both its rounds on plastic weights, this would be something group 4 would prioritise were the design process to be started again. Winston and

Hot Glue's "Ramp and Scoop" systems were incredibly efficient and were able to collect the snitch were it to come near. This put them at an advantage were the snitch to approach, as it did for Winston. In Domo's first round the snitch entered the collection bay, so had there have been a mechanism able to collect the snitch it would have won the round. The probability of snitch capture was underestimated by group 4 when they decided not to attempt snitch capture.

Based on this analysis, the design specifications that should be changed to better reflect group 4's new understanding of the competition would be:

- Remove 7. The robot should actively seek weights or the snitch.
- Replace 9. The robot should distinguish between weights and obstacles.
  - With "The robot should detect a weight when in its collection bay."
- Add. "The robot should be able to collect plastic weights."
- Add. "The robot should be able to collect a weight (from approach to storage) in less than 10 seconds. "

4.2.4.2 Competition Strategy

The best competition strategies were the robot's that were simple and consistent. The best example of this is Winston and the Garbage Truck. Both of these robots had very different collection mechanisms, yet their simplistic search algorithms and reliability helped them score well in the competition.

4.3 Post Mortem

Domo was not very successful overall, yet had strong potential were some adjustments made. These can be broken down into three points:

- If the robot could identify and navigate away from plastic weights within 5 seconds.
- Decrease false positive collection percent from 37.5% to below 15%.
- If wall following was implemented on start-up rather than random motion.

The change that would have the most obvious effect on the competition performance is to better deal with dummy weights. This is done by better identifying, navigating away from and not attempting to collect plastics weights. In competition false positives cost Domo

Based on opponent evaluation it is clear the weight collection strategy had little effect on competition success. The main factor that affected success was the search algorithm and overall simplicity of the design. Reliable and simple behaviour was what set Winston and especially the Garbage Truck apart from Domo. This high level concept cannot be added to Domo after the fact. Therefore, it should be considered from the initial design process at the start. Group 4 did not place enough emphasis on ensuring simplicity in its design.

6. Conclusion

In Robocup simplicity is king. Unfortunately, Domo was perhaps too complicated to succeed. Domo ranked in 9th place in the 2020 Robocup competition, losing both its matches. The report illustrated the final design of the robot as well as evaluated its run in the competition compared with three of its opponents.

Domo focused on actively seeking out weights. This was done using a scan, where Domo spun around in a circle and compared two ToF mini sensors to find weights. The angle at which Domo "saw" a weight was recorded and aimed for. Once a weight was detected in the collection bay it was collected using the electromagnets if it was metal. Plastic weights could not be collected, and this was a major flaw in the competition as both rounds were lost on plastic weights.

In the competition it became clear that the weight detection group 4 implemented was unnecessary. This was confirmed after analysing the three other robots. All of the other robots, groups 8, 25 and 27, outperformed Domo. Yet, they did not have the level of weight detection Domo did. Winston had some rudimentary weight identification and scanning, but The Garbage Truck especially was "blind" and did not attempt weight detection. Group 25 was able to gain 2nd place with this strategy. Therefore, the weight detection system may have been more of a hindrance than help due to its complexity. This is only true for the first arena layout and may have changed in different arena configurations.

Domo performed strongly compared to other groups when metrics were compared. In terms of metal weight collection, Domo scored highly collecting on average 2.5 weights per round. This was second only to the Garbage Truck who collected 2.6 weights on average. Where Domo lagged behind was collection time. Domo took approximately 9 seconds to collect a weight from when the IR proximity sensors were triggered. This was three times slower than Winston and Hot Glue. Speed of weight collection wasn't necessarily an indicator of success, but it means more time could be used to search the arena. The area where Domo lagged the most was in time before first weight collection. Domo took 51.5 seconds on average to collect its first weight. This is significantly slower thank Hot Glue or the Garbage Truck, who both collected weights in less than 15 seconds. This fast collection time is likely due to their basic navigation code that meant they would easily collect the first weight located directly in front of the robot on start, unlike Domo who scanned the arena and went away from that first weight.

The evaluation of opposing robots shed some light onto potential faults with group 4's design specification. Four key changes should be made.

- Remove 7. The robot should actively seek weights or the snitch.
- Replace 9. The robot should distinguish between weights and obstacles.
    - With "The robot should detect a weight is in its collection bay."
- Add. The robot should be able to collect plastic weights.
- Add. The robot should be able to collect a weight (from approach to storage) in less than 10 seconds.

Changing these would have affected group 4's high level strategy. In addition to these high level changes, future improvements to Domo that could be undertaken include:

- The ability to identify and navigate away from plastic weights within 5 seconds.
- Decreasing the false positive collection percent from 37.5% to below 15%.
- Implementing wall following on start-up rather than random motion.

Overall, group 4 was proud of Domo for the weights it collected. It was a successful robot for what was defined and did fulfil the goal, both rounds, of collecting at least one weight. Hopefully, after reading this report other students will have a better idea of how to succeed in Robocup and will not make the same mistakes group 4 did. Good luck.

7. Appendix

7.1 Contribution Statement

7.1.1 Georgia Reynolds

Georgia took the lead role in four areas, report formation, CAD modelling different wheel variations, weight storage fabrication and aesthetic additions.

Georgia was responsible for ensuring a complete and cohesive report. This started in the planning phases, drafting a working skeleton plan and determining which images would be the most useful in the communication of ideas. She delegated the creation of these images to Adam and Hank. Georgia then proceeded to draft, write and polish the main body of the report. This was done to ensure clear voice and flow.

Changing the drive wheel was something that was highlighted in the previous report. Georgia was responsible for modelling and printing a variety to test.

The weight storage bay was Georgia's work also. It involved designing a suitable piece and fabricating it on the laser cutter. She then bent the piece using a heat gun. Due to a few mishaps some quick thinking was done by Hank to make the design workable.

Perhaps Georgia's most valuable contribution was her craft skills in attaching the "Domo" features to group 4's robot. This gave it real character and greatly improved morale.

7.1.2 Hank Wu

Hank finalised the weight collection mechanism, as well as the software.

Hank optimised the stepper motor by adding acceleration to it. This improved the speed of the stepper motor from 1600 steps per second to 5000 steps per second. This speed up the capture time significantly.

Hank designed the Finite State Machine for the system. He wrote the algorithm for the scanning state to identify weights precisely and accurately. He also worked out a way to pick up knocked over weights. Previously, the robot was not able to pick up knocked over weights because they would roll away when the robot approached. Additionally, the weight would get stuck on the collection plate from time to time. Hank programmed the robot to reverse jerkily to shake the weight to the storage chamber. Finally, Hank wrote the code for the obstacle avoidance.

Hank has been working with the i2c devices on the robot and found a circuit bug on the provided I2C breakout board. Additionally, Hank found out that the electrical noise induced by the motor would cause the i2c sensors to stop working randomly. Therefore, he made the decision to ditch the i2c sensors and go for the UART sensors.

For the report, Hank has created the flow charts and contributed to the sections that related to the collection mechanism and software. Hank also contributed to the evaluation of the Garbage Truck.

7.1.3 Adam Finlayson

Adam (along with Hank) was responsible for the testing and optimisation of Domo prior to the competition, in order to ensure that domo would be working as well as possible for the competition.

Adam was responsible for finalising the CAD model of Domo, and producing the figures that represent Domo's key parts, systems and design. Adam was also responsible for finding, recording, and tabulating the data for Domo, Winston, Hot Glue, and The Garbage Truck. Adam also wrote the evaluation of Hot Glue and provided discussion on the evaluation of Domo and comparison between the other robots.

7.2 Appendix A – Design Specifications

	Design Specifications	Domo	Winston	Garbage Truck	Group 27
General Specifications					
1	The robot must be autonomous and controlled by the supplied Arduino Mega ADK microcontroller.				
2	The robot should not become stuck by obstacles including but not limited to:				
a	25 mm high rectangular speed bumps				
b	10 mm high rim to base				
c	Vertical cylinders				
d	Vertical cuboids				
e	Opposing robot				
f	Ramps				
3	All materials used to build the robot must be either supplied in the provided kits or fall within the $50 budget.				
Movement and Navigation					
4	The robot should move.				
5	The robot should be able to turn.				
6	The robot should use sensors to navigate.				
7	The robot should actively seek weights or the snitch.				
8	The robot should be able to detect and navigate obstacles.				
9	The robot should distinguish between weights and obstacles.				
10	The robot should be able to climb a gradient of 30%				
11	The robot should not leave the arena.				
Performance					
12	The robot should be able to lift at least one weight of 1kg.				
13	The robot should be able to store at least one weight of 1kg. (Store defined as held off the ground)				
14	The robot should not repeat the same task, or sequence of tasks, for more than 15 seconds.				
15	The battery should last over 2 minutes.				
16	The robot should be able to pick up weights in a corner or against an obstacle.				
Safety					
17	Any lasers on the robot must have a power rating below 5mW.				
18	All spinning devices on the robot must travel at under 200RPM.				
19	The robot must use a compulsory power cut off module must be used between the battery and electronics.				
20	The robot may not utilize naked flames, chemical explosives or EMPs.				
21	The robot's voltage must never exceed 100V DC.				
Soft Constraints					
22	The robot should be sturdy enough such that damage taken in one round takes less than 5 minutes to fix.				
23	The robot's weight should be minimized.				
Additional Features					
24	The robot should collect standing and knocked over weights.				
25	The robot should be able to collect plastic weights.				
26	The robot should be able to collect the snitch				

7.3 Appendix B - Bill of materials

Part	Part Number	Cost per unit	Quantity
DC Motor 143RPM	28PA51G	$70.00	2
Standard Servo	HX12K	$14.00	2
Stepper Motor NEMA17	42BYGHM809	$32.00	1
Electromagnet	JK-P30/22	$6.60	2
IR Distance Sensor 10-80cm	GP2Y0A21YK0F	$8.00	2
ToF Mini Sensor	-	$50.0	2
Digital Ultrasonic Sensor	HC-SR04	$1.80	4
IR Proximity Sensor	SEN0019	$6.00	3
Flanged Pillow Block Bearing	KFL08	$4.50	4
Drive Track Support Hardware	-	$3.00	8
Linear Rail	MGN9 C	$17.00	1
Main Drive Wheel	-	-	2
Drive Track	880-8M	-	2
Timing Belt	320 XL	-	2
Lead Screw 300mm	-	-	2
Main Body – Side Plate	-	-	2
Perspex laser cut Top	-	$6.00	1
Perspex laser cut base	-	$6.00	1
3D Print Lead Screw Pulley	-	$0.36	3
3D Print Motor Pulley	-	$0.36	1
3D Print Electromagnet holder	-	$1.14	1
Open beam Aluminium profile	-	-	6
3D Print Servo Mount	-	$0.31	2
3D Print Linear Bearing Mount	-	$0.45	1
3D Print Tray	-	$0.88	1
Perspex laser cut Connector	-	$2.00	2
IR Sensor Mount	-	$2.50	6
Ultrasonic Sensor Mount	-	$2.50	5
Arduino Mega ADK	A000067	$40.00	1
Servo Distribution Board 12 Channel	-	$4.00	1
Stepper Motor Drive Board	-	$8.00	1
Power Protection and Distribution	-	$25.00	1
DC Motor Driver Board	-	$125.00	1
DC Motor Cable	-	-	2
Standard Servo Cable	-	-	2