ENMT 301

Robocup: Progress Report 1

Group 5

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1 Executive Summary

This report concerns the initial concept generation of Group 5 for the Canterbury University Robocup competition. The first step was to define the problem scope – this was achieved by reading through the rules and regulations and constructing a context diagram. From this problem scope, a set of requirement specifications were outlined to give the limitations of the robot. This being done, a number of concepts were generated as to the strategy of the robot – this was achieved through brainstorming as a group. These strategies were the Knockover Method, the Garbage Truck Method and the Self-Aligning method. Within each of these strategies, a number of possible implementations were fleshed out to give both breadth and depth to the concepts. Finally, the different designs were entered into an evaluation matrix and it was found that the Knockover Method, using the Single Bar design, proves to be the most elegant solution.

2 Introduction

In a post-apocalyptic society it is desired that a food retrieving drone should be designed and built to retrieve food packages from a ruined city. The food packages take the shape of small steel weights with an annular groove cut around the top, with the ruined city being an arena with a number of obstacles placed around the course.

To find an effective solution, the problem was first defined in the form of a requirement specifications by reading the rules and regulations and constructing a context diagram. From this, a number of ideas were brainstormed that could solve the problem – with the main focus being aimed at the collection method. Each strategy had three different possible implementations discussed in order to ensure that the problem was well considered and that no possible solution was missed. Out of these concepts an evaluation matrix was used to determine the best design.

3 Requirements Specification

The majority of the problem scope was defined from the rules that were provided for the competition. Thus, to define the requirements a large amount of the time was spent determining which rules were defining the scope of the robot and which were simply providing information for the group. This, however, did not provide a comprehensive list of requirements and so a context diagram (Figure 1) was constructed in order to fully define the requirements for the system.

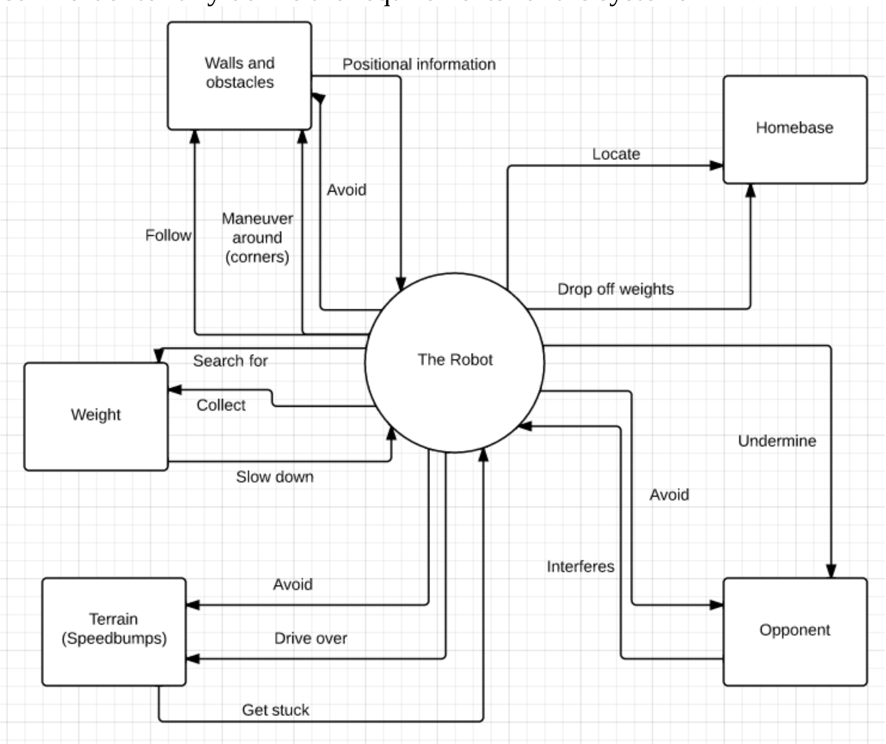

Figure 1: Context Diagram

3.1 General

3.1.1 The Robot will be controlled by an Arduino Mega ADK board.
3.1.2 The Robot will be fully autonomous
3.1.3 The Robot should be able to restart itself if a severe error occurs.
3.1.4 Any costs for extra equipment beyond that provided will be less than $50
3.1.5 The Robot shall have a clearly defined front end.
3.1.6 The Robot shall operate reliably for the full 5 minutes of the competition.
3.1.7 The Robot shall operate identically in both the NZi3 building and the mechatronics design lab.

3.2 Collection

3.2.1 The Robot shall be able to find actively search for, and find a weight.
3.2.2 The Robot shall be able to pick up a weight of maximum 1 kg in mass.
3.2.3 The Robot shall be able to determine the current number of weights it is carrying.
3.2.4 The Robot shall be able to carry at least 3 weights within its body.
3.2.5 The Robot should be able to "drop off" the weights at the home base.
3.2.6 The Robot should be able to pick an object from within 5mm of the wall
3.2.7 The Robot should be able to pick up a weight in under 15 seconds.

3.3 Navigation

3.3.1 The Robot shall be able to locate its home base
3.3.2 The Robot shall be able to traverse obstacles of at most 25 mm in height.
3.3.3 The Robot shall be able to navigate the entire arena within the time limit.
3.3.4 The Robot shall be able to fit through a gap of 0.5 m.
3.3.5 The Robot shall not exit the arena at any point.
3.3.6 The Robot should be able to detect when it is stuck, and as a result change its behaviour.
3.3.7 The Robot should be able to mount obstacles with a full load.
3.3.8 The Robot should be able to distinguish an obstacle from a wall.
3.3.9 The Robot should be able to manoeuvre around a corner.
3.3.10 The Robot should be able to return to its home base within 30 seconds.

3.4 Competitive

3.4.1 The Robot shall be able to distinguish an opponent's home base from its own.
3.4.2 The Robot shall not be able to pilfer an opponent's weights from their base.
3.4.3 The Robot should be in some way able to undermine the opponent's collection of weights.
3.4.4 The Robot should be in some way able to interfere with the opponent's navigation of the course.
3.4.5 The Robot should be able to identify and avoid an opponent.
3.4.6 The Robot should be designed to avoid interference with an opponent.

4 Design space and Concept Generation

4.1 Boundaries of the Robot

As can be seen from the Requirement Specification (Section 3), there are a number of constraints on the robot. The project has a limited budget - $50, but a large number of actuators and sensors are provided. It was thus desired that the final design should use these provided peripherals as much as possible in order to limit spending on the project. This will also limit the amount of sensor redundancy, and so consideration should be put into effective navigation methods.

Another limitation is the use of the Arduino ATMega, while this is excellent for interfacing to a large number of inputs and outputs it is only an 8-bit processor. This means that intensive image processing, or other expensive processing, are impractical. Instead weights will have to be identified through other means.

4.2 Concept Generation

There are two main aspects to the preliminary design; the strategy to be used and the physical shape of the robot. The strategy is the main design parameter that would define the collection method, importance of returning to the home base and many other requirements of the robot. This also defines the largest point of difference between opponents, and therefore choosing a strong design in this is likely to determine the success or failure of the robot. As a result of this, and the number of aspects that this will affect in the robot, it was the focus of the large bulk of the initial concept generation effort. The physical shape of the robot is closely tied to the strategy used, as each strategy will have different physical requirements of the robot. An important consideration in the design process was that each strategy may have had a number of different possible shapes for the robot to take.

The preferred concept generation tool was found to be group brainstorming. This technique was chosen because it is does not limit the creative process, and can very easily involve the whole team in the concept generation. It was desired that a large number of ideas should be found, as a simple, original, effective and, especially, unexpected idea is likely to give a large advantage against opponents.

From the brainstorming process the three ideas that were considered to be the best were selected and assigned to a single member of the team - these three ideas are outlined in Section 5. While working in a group is a great method for producing a large number of unique and diverse ideas, spending time going through a design in order to flesh out aspects was found to be best done individually.

Within each idea there were a number of different possible ways of carrying the design out. So, the goal of the individual work was to flesh out three different shapes that could be implemented from the assigned strategy. Most importantly considering, in broad terms, HOW the design would be achieved to meet the specifications. The advantages and disadvantages were considered for each design, as well as the advantages and disadvantages of the overall strategy. This gave a great breadth AND depth to the concept generation process.

Other aspects to the design were also considered, as can be seen in Section 5, namely that of navigation. These were not looked at with such depth, though, as there was a lot more ease in making changes to these preliminary design concepts much later in the design process - and a certain amount of trial and error may, in fact, be needed to determine the best method.

5 Proposed Concepts

5.1 The Knockover Method

The Knockover method proposes that the weights should be, as the name suggests, knocked over before effort is made to collect them.

Ideal strategy

The first portion of the 5 minutes will be spent quickly navigating the course, and very roughly knocking over as many weights as possible. After this portion is completed, the robot will then proceed to find these weights (favouring the edges of the course), and roll them into its body.
To drop the weights off at the base there will be a door at the other end of the robot where the weights should simply roll out and into the base area.

Advantages	Disadvantages
- Could undercut opponent's collection technique. - Likely to be fast. - Dropping off at base very simple. - Knocked over weights are easier to pick up. - If positioned well, easy to count. - Weights can be kept at a low level in the body.	- Will have to locate a single weight more than once. - Weight roll to walls - may be difficult to collect. - May be difficult to knock the weight over. - Ramp could provide issues, may need to be actuated so that it does not prevent the robot from mounting obstacles. - Weights may need to be positioned inside.

Table 1: Advantages and Disadvantages of the Knockover Method

The main advantage for the Knockover Method is that it can undercut other team's collection methods. If a group assumes that the weight will be standing up, their robot may be unable to pick up a knocked over weight. If a group must pick it up from standing, then even if they have considered that they may be knocked over, it will take much more time to right them and therefore still providing a competitive advantage.

Knocking over weights also has a flow-on effect. Because the weights are very circular, they tend to roll to one of the walls of the arena. This means that the walls of the arena can be focused on when searching for weights - which is likely to increase the speed.

Conversely, the greatest disadvantage to the Knockover Method is that it involves a lot of double handling, i.e, many weights will have to be located twice before being picked up. If the advantage gained by hitting over the weights is not large enough, this could be very detrimental to the robot's performance. The three main designs considered were:

5.1.1 Single Bar

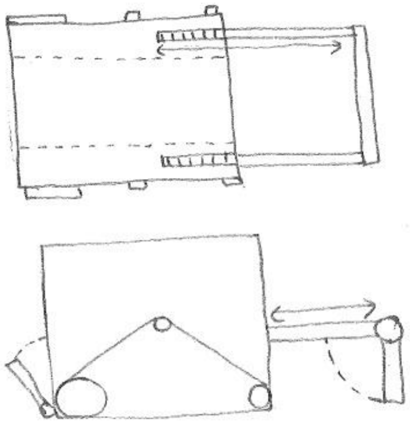

Figure 2: Sketch of Single Bar Design

Description
A single bar, the width of the robot. Actuated forwards and backwards by motors located inside the body of the robot.

Collection
Hits weights over with the bar by actuating the arm forward quickly. When the weight is horizontal the bar can pass over and then be retracted to roll the package into the main body of the robot.

Equipment needed
1 Stepper motor, 1 rotary to linear linkage, 1 servo

Advantages	Disadvantages
- Knocking over and collection can occur at different times. - Likely to be fast. - Can be assisted by the ramp. - Orientation of the weight not crucial. - Can pick up from walls.	- Needs to convert between rotary and linear motion. - Needs a ramp. - May not be able to pick weights up immediately. - May be difficult to knock weight over.

Table 2: Advantages and Disadvantages of the Single Bar design

5.1.2 Wings and Ramp

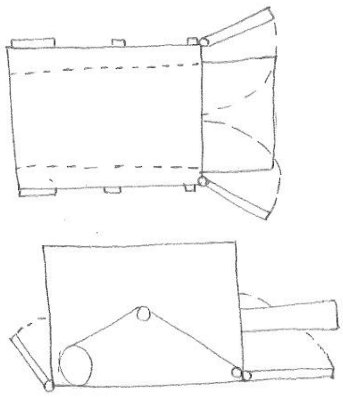

Figure 3: Sketch of Wings and Ramp Design

Description

Has two arms at a high level which can swing out from the body. Has a "collector", which is a ramp that can be actuated up and down.

Collection

Arms arm horizontal out from the body and then swing in sharply. The weight is knocked into the collector which then rotates up so that the weights roll into its body.

Equipment needed

2 Servos, 1 Stepper motor (possibly 2)

Advantages	Disadvantages
- Picks the weights up immediately. - Use only rotation. - Collector acts as the ramp. - Easier to knock the weight over as the collector "trips" the weight.	- Lose advantage of undermining the opponent. - May be difficult to lift up the ramp. - May be slow. - Weights need to be positioned well before they can be knocked over. - Can't pick up from a wall.

Table 3: Advantages and Disadvantages of the Wings and Ramp Design

5.1.3 Wings and Sweepers

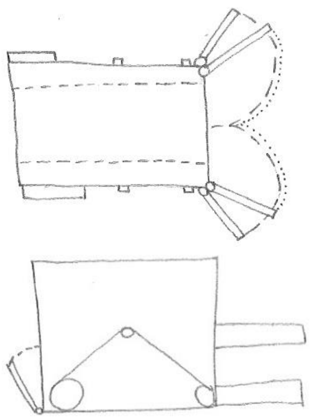

Figure 4: Sketch of Wings and Sweepers Design

Description

Has two arms at a high level which can swing out from the body. Has two arms at a low level which can also swing out from the body.

Collection

Arms swing in quickly to knock over weights. Bottom arms then rotate around to push the weights up a ramp, into the main body.

Equipment Needed

2 servos, 2 stepper motors

Advantages	Disadvantages
- Easy to choose between different tactics, i.e. can choose to pick up immediately or wait until later. - Uses only rotation. - More compact. - Simple to assemble. - Easier to knock the weight over as the lower arms "trip" the weight.	- Orientation of the weight may be important. - Weight needs to be positioned well. - Needs a ramp. - Bottom arms may struggle to push it up the ramp.

Table 4: Advantages and Disadvantages of the Wings and Sweepers Design

5.2 The Garbage Truck Method

Heavily influenced by common garbage truck design a robotic arm utilised to pick up weights and store these within the body of the robot.

Ideal Strategy

The robot finds the weight and positions the weight to be directly in front of the robot. The robot then secures the weight using forks to slide into the circular groove cut around the top and grips the weight. The robot arm then actuates back to store the weight.

Advantages	Disadvantages
- Able to pick up weights on a different level than the robot. - Allows easy stacking of weights within robot. - Allows individual weights to be weighed.	- Collection of weights comparably slow. - Highly reliant on positioning of robot and weight. - Bulky component of robot. - Large moments created when lifting weights therefore increased complexity in design.

Table 5: Advantages and Disadvantages of the Garbage Truck Method

The Garbage Truck Method allows for some tactical advantages such as; weighing individual weights on collection - which can be achieved through using the strain gauge attached to one of the forks, and the possibility of picking up weights from different heights – which could eliminate the need to mount any speed bumps.

Its biggest disadvantage is the positioning requirements of the robot; because the forks provide such a small collection area the weight must be positioned almost perfectly in front of the robot so that the forks can slide into the grooves. There is also the large issue of the large moments created from picking up a weight at a distance. Both of these factors are likely to increase design complexity which may make the robot less maintainable.

5.2.1 Set Forks

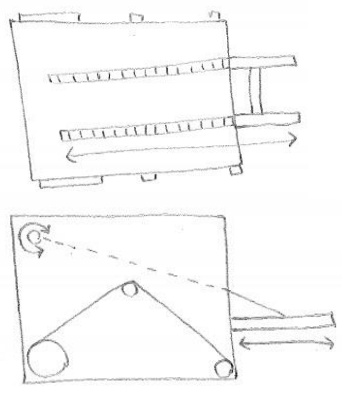

Figure 5: Sketch of Set Forks Design

Description

Two set forks sit at the front of the robot – much like a fork lift. However, the forks can extend back and forth. The forks can be tilted by a wire attached to a motor.

Collection

The robot positions its body so that the weight is directly in front of it. It then extends the forks forwards into the grooves and uses the wire to tilt the weight backwards. The forks are then brought back into the body to store the weight.

Equipment Needed

2 Servos

Advantages	Disadvantages
- Simplest implementation of the method. - Height of pick up can easily be adjusted. - Weight only needs to be lifted slightly off the ground, thereby decreasing the required force.	- Robot controls must be sensitive and accurate enough to position correctly. - Needs to convert rotational to linear movement. - Will still require large forces to tilt weight. - Cannot drop of weights.

Table 6: Advantages and Disadvantages of the Set Forks Design

5.2.2 Positioning Forks

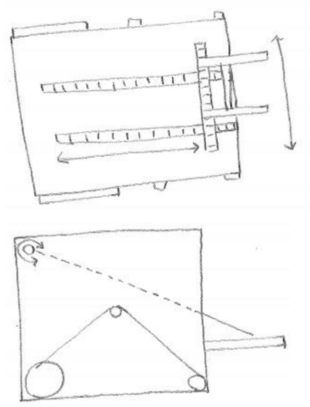

Figure 6: Sketch of Position Forks Design

Description

The positioning forks elaborates on the set forks method by allowing the forks to move horizontally.

Collection

Same collection method as set forks, except that it reduces reliance on the robot to position itself as the forks can move in both x and y

Equipment needed

2 Servos, 1 Smart Servo

Advantages	Disadvantages
- Lower requirements for positioning. - Quicker collection than Set Forks. - Large pickup area. - Weight only needs to be lifted slightly off the ground, thereby decreasing the required force.	- Increased mechanical complexity. - Increased number of sensors and therefore increased software and hardware complexity. - Need 2 linear to rotary converters. - Cannot drop off weights.

Table 7: Advantages and Disadvantages of the Positioning Forks Design

5.2.3 Side Arm

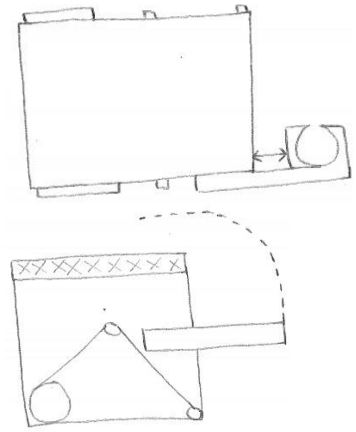

Figure 7: Sketch of Side Arm Design

Description

The side arm is connected on one side only with the forks at 90 degrees to the arm. One fork can move back and forth along the arm.

Collection

The arm rotates down so that the forks are in line with the weight. The forks then clamp down on the weight and rotate back up to drop the weight in a bucket.

Equipment Needed

2 Servos

Advantages	Disadvantages
- Smaller footprint. - Less mechanical parts than both other garbage truck concepts. - Allows unimpeded front sensor mounting. - Allows weights to be stored in a bucket on top.	- Single arm causes double the moment and therefore increased size of arm. - Reliant on the positioning of robot relative to weights. - Needs to convert rotational to linear. - Lifting the weight through a greater height.

Table 8: Advantages and Disadvantages of the Side Arm Design

5.3 The Self-Aligning Method

The Self-Aligning Method uses a large “V” at the front of the robot to naturally direct any weights into the centre of the robot, once they have entered the collection area. Designs using this method are intended to be simple, with minimal moving components and large catchment area.

Ideal Strategy

Locate the nearest weight and move towards it. The weight should be aimed to fall within the large catchment area – the catchment area is defined by the edges of the “V”. When the maximum number of weights is reached, drive to the base and simply reverse to release the weights.

Advantages	Disadvantages
- Fast. - Low software requirements. - Low hardware requirements. - Very large collection area. - Less need to accurately locate weights. - Simple drop off method.	- Dragging weights around will slow the robot down. - The large “V” will make the robot less manoeuvrable. - Lip around home base may provide difficulties. - Weights must be dropped off or they won’t count towards total.

Table 9: Advantages and Disadvantages of the Self-Aligning Method

This method of collection is most suited to a design focused on speed, giving a large advantage over designs with a much slower collection method. The weights simply need to be driven into to be collected, thereby making this, by far, the simplest collection technique. Because of this, there are reduced software and hardware requirements, meaning the collection can be developed quickly and therefore tested thoroughly before implementation.

The greatest disadvantage to this method is the reduced manoeuvrability caused by dragging the weights around with the robot. The large “V” at the front will also make it more difficult to navigate the course as there are some gaps as small as 0.5 m (requirement 2.3.4)

5.3.1 Trawling

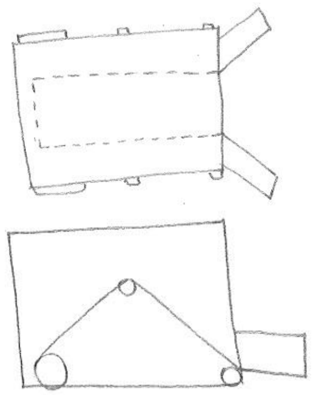

Figure 8: Sketch of the Trawling Design

Description

Two bars form a large V out the front of the robot. There is a large holding area which is a cut-out of the ground floor.

Collection

The weights are collected by simply driving into them, the will naturally be funnelled underneath the main chassis. To drop the weights off, the robot drives into the HQ and simply reverses.

Equipment Needed

No extra equipment needed

Advantages	Disadvantages
- High speed collection possible. - Very simple drop off method. - No moving mechanisms needed to collect or store weights. - Weights may be collected in any orientation.	- Cannot reverse, the robot must turn on a point. - Potential difficulty collecting weights against an obstacle or in a corner - Large area required for weight storage under robot. - Robot will not be able to traverse obstacles (requirement 2.3.2). - Cannot measure number of weights collected. - Weights higher than the robot can climb are inaccessible. - The Robot will be slow with a full load.

Table 10: Advantages and Disadvantages of the Trawling Design

5.3.2 Dropping bar

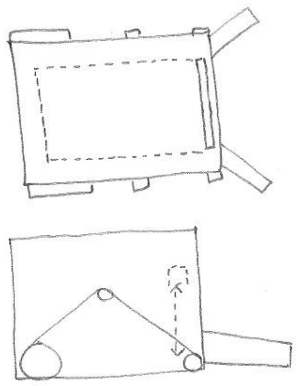

Figure 9: Sketch of the Dropping Bar Design

Description

Identical to trawling method described in 5.3.1, with the addition of a bar that can drop down to close off holding area.

Collection

The weights are collected in the same way as the trawling method, except after the weights have been collected the bar will drop to close off the holding area.

Equipment Needed

1 Servo

Advantages	Disadvantages
- Robot can reverse. - Higher security for the weights. - High speed collection still possible.	- Would need to recognise when a weight is entering to open bar. - The motor would likely would reduce storage area under the robot. - The bar would be redundant if an excess of weights was collected, since it would likely be jammed open. - Need rotary to linear converter.

Table 11: Advantages and Disadvantages of the Dropping Bar Design

5.3.3 Floored

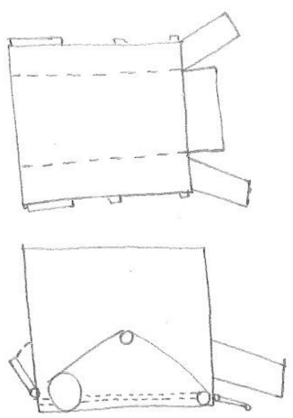

Figure 10: Sketch of the Floored Design

Description

Identical to the trawling method described in 5.3.1, with the addition of a floor, and an actuated ramp

Collection

Collection method is mostly identical to the trawling method. The ramp will be actuated downwards when a weight is being picked up, and lifted up to get over obstacles. A door at the back allows weights to be dropped off at the home base.

Equipment Needed

2 Servos

Advantages	Disadvantages
- Higher security for the weights. - Higher manoeuvrability over obstacles. - Weights can now be counted before returning to home base. - No longer drags weights, so will be faster.	- Increased difficulty to drop off weights. - Reduced storage space under robot. - Weights may be pushed around by the ramp. - Ramp may need to be actuated. - Lose simplicity of the original method.

Table 12: Advantages and Disadvantages of the Floored Design

5.4 Navigation

The two main kinds of navigation discussed were locating weights, and finding home base. Obstacle avoidance and arena navigation will be dominated by the numerous distance sensors provided. These sensors will be highly changeable and, as such, decisions about their positioning and implementation will be finalised later in the design process.

5.4.1 Locating Weights

One of the most important functions for the robot navigation is to be able to locate the weights within the arena. A clear competitive advantage lies in a robot that can quickly locate and move towards the weights in the arena. The possibilities considered were:

5.4.2 Colour Sensor

It is known that the weights are a yellow tint in colour, and that the majority of the arena will be black. A colour sensor could be employed so that when it detects a strong yellow colour that it will move towards the object - which will likely be a weight. The colour sensor has a very short range, and is highly dependent on the light conditions in the room – hindering the accuracy.

5.4.3 Scanning Distance Sensor

The weights are a known height. If a distance sensor is set at around the height of a weight and scans, it can detect if there is a small section of the sweep that is much closer than the others. This section is likely to be the weight. This would be a software heavy solution, and would need an intelligent algorithm for it to work effectively. It may also take a long time to locate the object. It would, however, have a very long range.

5.4.4 Magnetic Field Sensor

The weights are made out of ferrous iron, this can be detected by a magnetic field sensor. The opponents rig is made out of aluminium which will appear differently to the magnetic field sensor. Thus, this sensor can scan until it detects a ferrous metal object. This object is likely to be the weight. The effectiveness of this option is highly dependent on the range of the sensor, and it may eventuate that it has difficulty distinguishing between a weight and an opponent.

5.5 Home Base

While not essential to success - since weights are counted once on board the robot, it is important to be able to quickly locate the home base for the robot. The robot has a limited capacity, therefore the unloading weights may be a necessary task within the competition. Unloading weights also provides a tactical advantage in the sense of reducing weight of the robot. This will allow for increased speeds and easier movement within the arena.

5.5.1 Infra-red

There will be an infra-red tower located in the centre of the course, if the robot is equipped with the proper equipment this can be used to give a relative position reading from anywhere in the course. The position of the home base can be stored so that it can easily be navigated to when required. This is a very accurate way of locating the home base, but could be interfered with by opponents.

5.5.2 Optical Encoders

The wheels are equipped with optical encoders that can be used to measure the total distance travelled. This can be used to backtrack in order to find the home base again. This is likely to be extremely inaccurate as the encoders have no measure of slip, which occurs often with the treads.

5.5.3 Searching

Since the home base is in the corner, it is possible to simply follow walls to this corner. This would require some calibration at the start in order to determine which corner the robot was in. The main advantage to this is its simplicity, as it doesn't rely on any sensors to operate correctly. The presence of obstacles could mean that it has high software requirements.

5.6 Summary

To easily visualise these possible solutions a concept table was constructed (Table 13). This also allowed combinations of solutions to be theorised, as the concept table provides a great way of viewing all of the possible options.

Collection			**Navigation**	
Knockover	**Garbage Truck**	**Self-Aligning**	**Weight**	**Homebase**
Single Bar	Set Forks	Trawler	Colour	Infra-red
Wings and Ramp	Positioning Forks	Dropping Bar	Scanning Distance	Optical Encoders
Wings and Sweepers	Side Arm	Floored	Inductive	Searching

Table 13: Concept Table for Robocup designs

6 Concept Evaluation

As explained in Section 5, there are two main aspects to the design process; the overall strategy employed by the robot and the final shape of the robot. The best way to evaluate the merit of different options is by drawing an evaluation matrix. This allows you to measure different concepts based on desired aspects – these aspects can be determined from the Requirements Specification and can be weight dependant on their relative importance.

An evaluation matrix was used to determine the best strategy to employ for the competition, the results are shown in Table 14.

Aspect	**Scale**	**Knock over**		**Garbage Truck**		**Self-Aligning**	
		Score	**Scaled**	**Score**	**Scaled**	**Score**	**Scaled**
Robustness	**3**	7	21	6	18	9	27
Reliability	**5**	9	45	5	25	3	15
Competitiveness	**4**	10	40	3	12	2	8
Ease of build	**2**	7	14	5	10	9	18
Maintenance	**3**	4	12	3	9	7	21
Total			**132**		**74**		**87**

Table 14: Evaluation Matrix for Robocup Strategies

Table 14 shows that the best strategy is the Knockover Method. This strategy has three different possible implementations which can be developed using this method. These different implementations were compared using another evaluation matrix to give the final overall design, shown in Table 15.

Note that Table 15 has more aspects to consider because of the increase specificity of the designs.

Aspect	Scale	Single Bar		Wings and Ramp		Wings and Sweeper	
		Score	Scaled	Score	Scaled	Score	Scaled
Robustness	**3**	8	24	6	18	5	15
Reliability	**5**	7	35	9	45	7	35
Speed	**4**	9	36	5	20	5	20
Competitiveness	**4**	8	32	6	24	9	36
Ease of Build	**2**	5	10	4	8	7	14
Maintenance	**3**	5	15	6	18	6	18
Cost	**1**	8	8	7	7	7	7
Power Consumption	**3**	7	21	4	12	7	21
Software Requirements	**2**	9	18	5	10	4	8
Total			**199**		**162**		**174**

Table 15: Evaluation Matrix for different Knockover Method Designs

This shows that, while each of the concepts is a strong option, that the Single Bar is the best design for the final shape of the robot.

7 Conclusions and Recommendations

As can be seen from Table 14 the best strategy to take is the Knockover Method. The greatest advantage that this provides is the ability to knock all of the weights over before collecting them. This is liable to undermine a large number of opponent design, and at the very least will require opponents to increase the complexity of their designs to facilitate this. The greatest disadvantage to the Knockover method is the double handling of weights - this would be especially detrimental if knocking the weights over did not impair the opponent too largely. This disadvantage can be minimised by ensuring that navigation and locating of weights is robust, so that it is made easier for the weights to be located twice in one round. The strategy is also somewhat versatile as it can be decided at the start of the round - depending on the opponent, whether it should have the period of time where it is focused on knocking weights over or if it should start collecting them immediately. This allows for opponents who are adept at picking up knocked over weights - where no advantage would be gained from the original strategy.

Within the Knockover Method three designs were brainstormed. As Table 15 shows, out of these, the Single Bar proves to be the simplest and most robust design. The simplicity of the design comes in the single motion of the collector. The arm will be quickly actuated forwards in order to knock over a weight. When a weight is knocked over it is at a lower height, so the arm will be able to pass over it.

The arm will employ a flap which has a limited range of rotation, this flap will pass over the weight before dropping down – allowing the arm to draw the weight back into the body of the robot.

Figure 11 on the next page gives preliminary sketch of the proposed final concept.

A quantitative analysis was not performed on the different navigation concepts, as some of the options require more research before selection. Judging simply by the advantages and disadvantages talked about in Section 5.4 it seems that the magnetic field sensor would be the best option for locating weights in the arena. This should give the greatest surety that a weight will be accurately detected while also requiring less software development. However, more research needs to be done into the effective range of these sensors.

Using the concept table (Table 13), it was deemed that the most elegant solution for finding the home base would be a combination of wall-following and infra-red. The optical encoders were discarded as any slip in the tracks - a common occurrence, would cause inaccuracies in the measurement. Using the two methods together means that efficiency and speed can be used from the infrared sensor, but if the infrared is interfered with the home-base should still be locatable.

8 Contribution Statement

Michael McAdam

- Requirements Specification
- Description of Knockover Method
- Description of navigation options
- Report tweaking

Sarah Howe

- Sketching concepts
- Description of Self-Aligning Method
- Figure of Merit for design

Taylor Howatson

- FOM calculations
- Description of Garbage Truck Method
- SolidWorks sketch

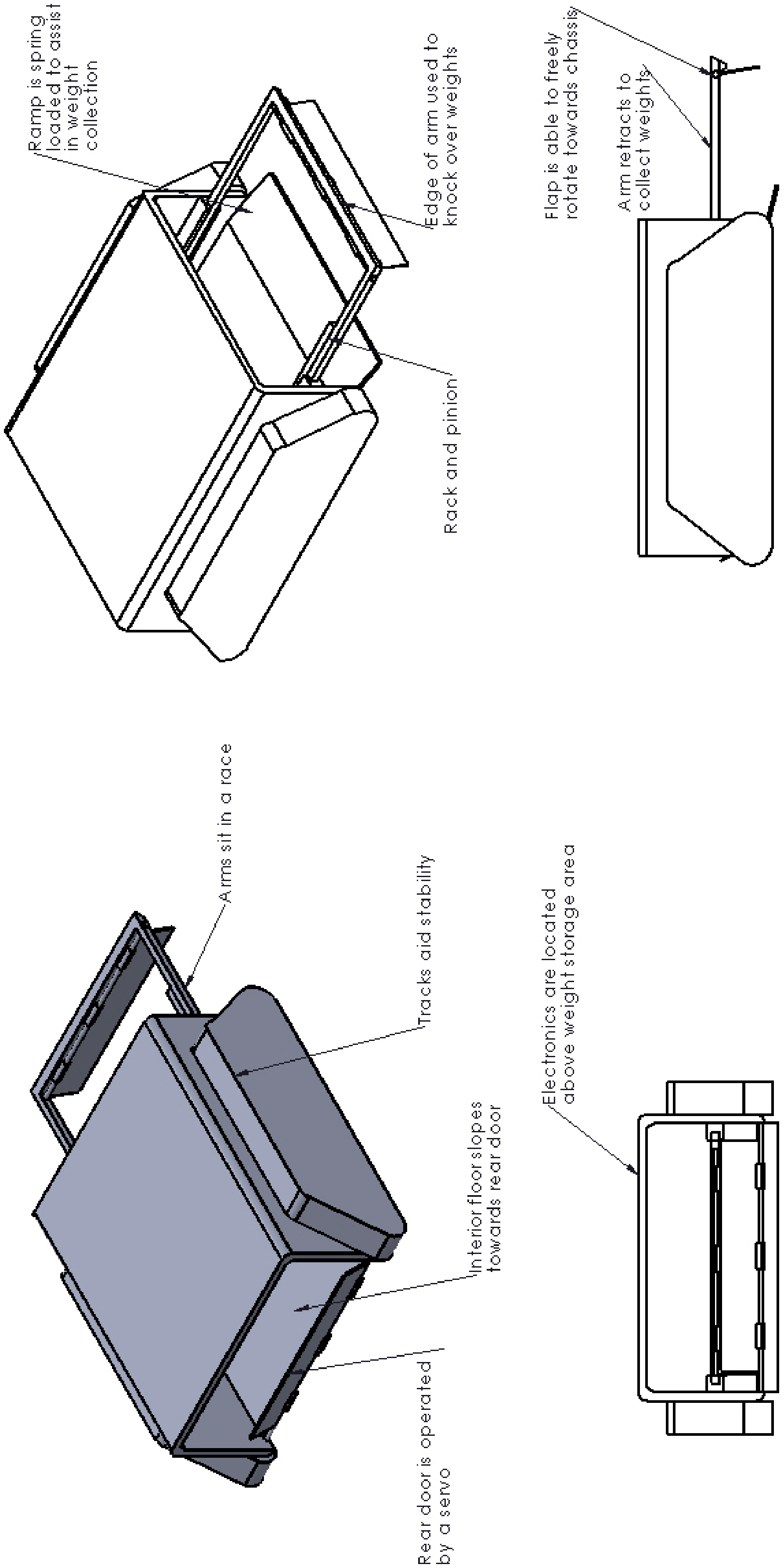

Figure 11: Preliminary Sketch of the Single Arm Design

9 Appendix

Power Consumption

IF Camera
Power consumption requirements: 5V/48mA

$$P = IV$$
$$P = 5x0.048 = 0.24W$$

IF Long-range Sensor
Power consumption requirements: 5.5V/33mA

$$P = 5.5x0.033 = 0.19W$$

Servo
Power consumption requirements:
Idle: 6V/9.1mA
Under load: 6V/450mA

$$P_i = 0.0091x6 = 0.06W$$
$$P_l = 0.450x6 = 2.70W$$

Stepper Motor
Power consumption requirements: 3V/(1.7A/Phase), 2-Phase

$$P = IVX$$
$$P = 1.7x3x2 = 10.20W$$

Comparing pick up methods power consumption
Single Bar Method:
Pickup and storing phase duration of single bar design: 15 sec
For the single bar knockover design 1 stepper motor and 1 servo is used continuously over the pickup phase.
For every weight picked up the robot will use $\frac{15}{3600}\ x\ (2.7 + 10.2) = 0.11Whr^{-1}$
Wings and Ramp Method:
Pickup and storing phase duration of wings and ramp: 30sec
For the wings and ramp knockover design 1 stepper motor and 2 servo is used continuously over the pickup phase.
For every weight picked up the robot will use $\frac{30}{3600}\ x\ (2x2.7 + 10.2) = 0.13Whr^{-1}$
Wings and Sweeper Method:
Pickup and storing phase duration of wing and sweeper: 15sec
For the wings and ramp knockover design 2 stepper motor and 2 servo is used continuously over the pickup phase.
For every weight picked up the robot will use $\frac{15}{3600}\ x\ (2x10.2 + 2x2.7) = 0.1075Whr^{-1}$