University of Canterbury

Robocup Progress Report 1

Group 10

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# 0.0 Executive Summary

Very brief summary of the main findings/recommendations of the report with some justification.

# 1.0 Introduction

Briefly describes the project (provides context for the report) and outlines what the reader can expect to find in the rest of the report.

# 2.0 Requirements Specification

## 2.1 General

1. The robot will be fully autonomous
2. The robot will be controlled be the Arduino Mega ATK supplied
3. The robot shall be able to move, identify and collect packages
4. The robot shall operate until all 11 packages are claimed or the time limit is reached

## 2.2 Identification

1. The robot shall be able to identify food packages
2. The robot shall be able to identify obstacles it cannot move over
3. The robot shall be able to distinguish home HQ and the opposition HQ
4. The navigation sensors should have redundancy

## 2.3 Movement

1. The robot shall be able to move over obstacles at least 25mm in height
2. The robot shall be able to fit through gaps of at least 500mm in width
3. The robot shall be able to manoeuvre around obstacles it cannot move over
4. The robot shall not leave the designated arena during the competition
5. The robot should not be phased by intimidating schemes of the opposing robot
6. The robot should not get stuck in any algorithmic loops for longer than 1 minute

## 2.4 Collection

1. The robot shall be able to pick up a package so that it is under the robots control
2. The robot shall have a way of carrying at least 3 packages
3. The robot shall not carry more than 3 packages simultaneously
4. The robot shall not collect any packages within the opposition’s HQ
5. The robot should be able to release any packages it has on-board to HQ
6. The robot should not be hindered by carrying three packages of mass 1kg
7. The robot should be able to pick up weights in any orientation and any part of the map

## 2.5 Construction

1. The cost of additional items shall not exceed $50 (except for R5.2)
2. Each member shall design their own PCB for use on the robot, not exceeding $5
3. The robot shall not be difficult to disassemble

## 2.6 Safety

1. The robot shall not cause any deliberate damage to anything or anyone
2. The robot shall have an accessible ‘off’ switch
3. The robot shall use the battery safety circuit provided

You’ll need to develop the system requirements from the vague description you have received (the rules etc.) – this isn’t simply copying them down, but converting them into formal requirements that your design can ultimately be measured against (tested). For example:

“The robot actuator arm shall be able to lift an object weighing greater than 1.0kg”

Note: These requirements are those that are general to the project. There will be additional requirements depending on the strategy you eventually decide to follow, which you will develop later. For example, a robot designed primarily to prevent the competition gathering weights will have some shared and some different requirements to a robot designed to gather as many weights as possible while ignoring the competition.

# 3.0 Design Space and Concept Generation

- Discuss how the systems fit together. Context diagram!

## 3.1 Navigation Sensors

A mechatronic system relies on interacting with the world around it, it uses sensors to see and give feedback to decide what the system should do. The robot we will design has a wide range of sensors we could use. In Table 1, a list of sensors are provided.

|  |
| --- |
| Ultrasonic Rangefinder |
| Infrared (IR) |
| Colour detector |
| IR Camera |
| Limit Switch |
| Weight Sensor |
| Sonar |

Table 1: sensors provided to use on our robot

To navigate around the arena sensor feedback will be needed to give distances to objects around the robot. Ultrasonic and IR sensors give distance feedback ranging from 40mm to 5m. IR gives close to medium range with a small beam angle and ultrasonic gives medium to long range with a large beam angle. Using both types of the sensors at the same time will give a good range in terms of distance and angle. The microcontroller will have good information for its navigational system. The downside of the ultrasonic is it has a 100ms measurement cycle compared to the IR 30ms measurement cycle. Both are analogue devices?

The colour sensor will be used for detecting whether the robot is in a base or not, and further to detect what base it is in. The robot can’t pick up weights from the other teams base so the robot will need to retract any mechanism for weight retrieval. Once three weights are on-board the robot will need to return to home base to drop them off. The colour sensor will confirm that it has moved from the arena to the home base before it starts to drop them off.

An IR camera is also supplied, this camera can see IR or fire sources. Because there is no fires in the arena to navigate the only source would be IR from the other robot, provided they have used IR sensors. Know where the other robot would be useful but the camera would only pick the robot up when it was pointing its IR sensors at our camera. This wouldn’t happen very often. This operates using I2C.

The limit switches supplied have a long arm to move to activate the switch. These could have a variety of different uses from detecting when the robot drove into a wall or a weight is picked up and bumps the switch.

A weight sensor supplied is able to measure a load its self. It uses a strain gauge to detect the load. If a weight is placed on the sensor it could register the load. The weights in the arena of three different types, 0.5kg, 0.75kg and 1.0kg. More points are awarded for the heavier weights. This means the heavier weights are more valuable when picking up weights. With the limitation of only having 3 weights on board having 3 light compared to 3 heavy could be a loss of half the points. Implementing the sensor mechanically to have the correct reading will be quite hard as the picking up or holding system will have to be suspended by the sensor. This sensor is digital, with serial output.

## 3.2 Locomotion

* Tracks
  + Environment
* Wheels – why they’re not very good
* Talk about chassis

## 3.3 Tactics and Navigation

Unlike previous years, our robot is required to return the food packages to base. This significantly increases the complexity of the problem, and leaves essentially two solutions (each with subsets). The robot must:

1. Have some way of reliably returning to base, or
2. Collect the heaviest packages it can find and hope for the best.

As such, two tactics have been formulated that can return to base, and one which relies of differentiating between light and heavier weights.

### Tactic 1 – Strategic Speed Runs

Figure 1.1: Strategic Speed Runs

The further into a round it gets, the more weights the opposition will have. That is why it’s important to collect the packages as quickly as possible. The fastest way to do both collect packages and return to base consistently is to have some kind of Simultaneous Localization and Mapping (SLAM) algorithm. Using the data that it has collected, it would then use the D\* pathfinding algorithm to navigate its way throughout the map. While this would create significant advantages in many areas, it would need to be able to differentiate between temporary obstacles (packages and opponents) and permanent ones. The complexity is such that it may not be able to function well enough in time for the tournaments.

### Tactic 2 – Perimeter Collection

Using a significantly simpler code, the robot could still exhibit a similar behaviour (as seen by comparing Figure 1.2 and 1.2). If it follows the edge of the arena, only deviating in order to pick up weights, it can turn and follow the edge in the opposite direction and get to its base. While this method could collect a large number of weights due to the layout of the map, there are multiple drawbacks. If the robot deviates from the outer wall, then it could find itself rotating about a loop or not able to return to base. There are many ways this could happen which include:

Figure 1.2: Perimeter Collection

* Moving to collect a package
* Avoiding the opponent’s base
* Avoiding the opposing robot.

### Tactic 3 – Weight Optimisation

Finally, it is a valid tactic to ignore the base completely. The robot would pick up three packages initially, and then each one after that would be weighed and compared with those on board. If heavier than any on board, the robot would replace the lightest package with the new one. Using this method, it could end with a maximum of three kilograms of food on board. Other non-weight discriminating tactics may have to pick up a total of twelve packages to get the same total mass. One simple addition to this tactic is to check to see if it’s in a base (It will need to anyway in order to comply with R4.4). If in its own HQ, the robot can drop the packages and continue.

Figure 1.3: Weight Optimization

You should describe the boundaries of your robot/solution in terms of hardware, different strategies to beat opponents, the competition environment, etc. You could mention/describe the equipment you have been provided. Very briefly describe how you came to these ideas – i.e. using methods that we spoke about in class (brainstorming, concept tables etc)

# 4.0 Proposed Concepts

Each of the three tactics discussed in Section 3.3 has been built on to become a full concept. The sensor used and propulsion methods will remain constant for reasons mentioned Sections 3.1 and 3.2, but each will have different package collection methods ( and ways of dealing with the opponent?). Table 2 shows the difference between concepts.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Concept 1 | Concept 2 | Concept 3 |
| Incorporated Tactic | Strategic Speed Runs | Perimeter Collection | Weight Optimization |
| Package Collection | Magnetic Arms | Electromagnetic Skirt | Scoop |
| [Opposition …?] | HQ Blocking | Sensor Interference | Speed |

Table : A list of the different aspects of each concept

-sketch each overall concept, plus any additional ones for picking up if required

## 4.1 Concept 1

Pathfinding will be used to navigate the robot around the arena. Once a weight is seen the robot will use a magnet to pick it up. The robot will drive up to a weight and it will attach to a magnet. A Hall-effect sensor will register when the weight is attached. The whole picking up assembly will rotate so the weights don’t get knocked off and to ensure the no weights are picked up in the others base. There are three magnets one for each weight, once three are on board the robot will drive back to base to drop the weights off by retracting the magnets and knocking off the weights. This process will be repeated until the end of the round. Figure 1 shows the state machine the robot will use to execute the task.

The magnets used will be strong enough to pick the weights up in any orientation. Because the magnets are strong, a powerful method of detaching the weights is necessary. All of the magnets will be linked and will retract together. A Perspex shield will allow the magnets to pass though and weights will now ###?. Two geared stepper motors will be used to drive the mechanism. This may take a while to complete but is worth it because of the power of the magnets.

Include results here?

Weight (kg)

* On flat: 15.4, 15.7, 16.1
* On curve: 12.5, 12.4, 13.4
* On edge: 8.6, 7.8, 8.8

IR, ultrasonic and colour sensors will be used to aid the pathfinding. IR and ultrasonic will give the position to the walls, these will be placed on top of the robot to make sure it doesn’t register the other opposition into the map. They will be placed to face all four directions. There will also be a IR sensor mid-way up the robot on the front to see where the robot is going. Low mounted IR sensors will find the weights. Colour will be used to detect what area the robot is in, this will be placed under the robot.

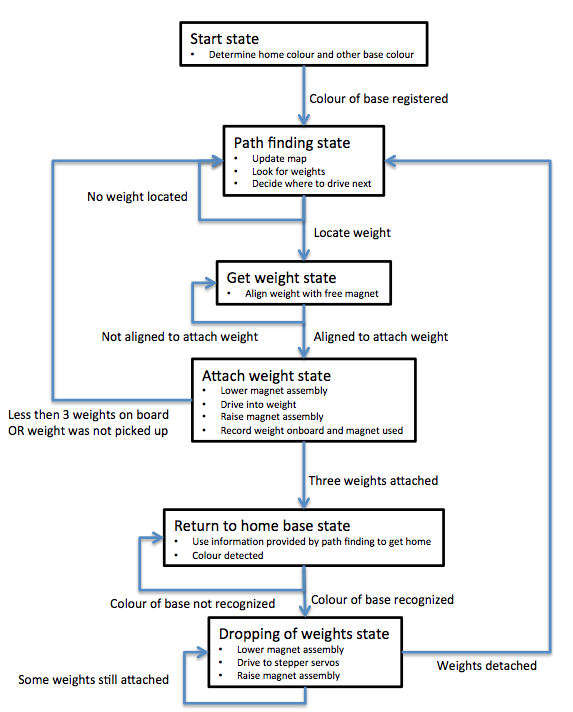


Figure : Finite state machine for concept 1

## 4.2 Concept 2

Since this concept would ideally continually follow the outer wall, it would be useful in many cases if it had the ability to collect packages from not only the front but also the sides. This robot will have an electromagnet along all four sides so that it only needs to drive past the package to attract it. This has many advantages including:

* It will collect packages in obscure corners as well as ones in the open
* The robot does not need to stop to coordinate any mechanism on the front
* There is no limit to the number of weights it drags behind it, as they are not on board (R4.3)

To avoid collecting from the opposition’s HQ, it will simply turn around and return to HQ again, following the wall. Since the weights are not technically on-board (a violation of R4.1), returning to HQ is crucial for this concept to work. Once it has returned to base, it will de-activate the electromagnet until out of the HQ and continue in the same direction. Using this algorithm, the robot would collect all the weights around the perimeter up to the opponent’s HQ on each side.

The robot must also be able to detect if it has collided with the other robot so that it can temporarily turn off the electromagnet. The one major downside of this concept is that it would require a very high current draw on the batteries to achieve enough force to keep the packages.

The electromagnets considered for this concept were 12V, 3W magnets with a holding force of 25N. This force is sufficient to hold the packages, but will only attract the heaviest packages from just over 1mm away. The current draw is discussed further in Section 5.2.

## 4.3 Concept 3

Ignore base, pick up heaviest weights (random) - Jack

* No return
* Scoop
* Speed

Present initial sketches, models, and descriptions etc of your 3 options. You need to show that you have thought through high-level system design of these concepts, using some techniques such as – Context diagrams, functional architecture diagrams, N2 charts, behavioural flow chart, FSM graphs. (Not all of these, but choose a couple that you think are appropriate to indicate how your concepts would work and be put together).

# 5.0 Concept Evaluation

The following section contains an evaluation of each section separately. Calculations have been done only in the case that some aspect of the concept may not work under the restrictions we have, such as power consumption.

## 5.1 Evaluation of Concept 1

### Robustness

With the Perspex frame at the front of the robot a solid barrier is the first point of contact. This is good because small parts won’t break off when in contact with things. The magnets out the front might come into contact with the other robot and attach to the robot. If this happens there will be no way to detach without dropping our weights. The robot may be more prone to front weight distribution. If the other robot is very high our sensors on top of our robot will give us wrong readings because of the obstruction.

### Reliability

The magnets will be industrial grade and not be prone to chipping or lose of magnetism. This concept heavily relies on the pathfinding algorithm to work. If it map is incorrect the robot will not know where it has been or has to go. If the map works but the sensors don’t give reliable information the algorithm won’t know where to go and will get confused. Gears slipping in the pickup mechanism could also be a problem.

### Ease of build

The pickup mechanism will be the hardest part to build as the it has a few tricky gear process. This will take planning and will have small tolerances. Because the build is only a few moving parts it won’t take very long to get things fabricated. The difficult part of this design is getting the code and algorithms working, and the RAM in the ADK will become an issue. The map must be split into a grid, and if split into 4cm square segments with 1 byte per node, will have the following memory usage:

The Arduino Mega ADK has 8kB of SRAM, so that would be cutting it very fine. Implementing pathfinding could easily double the requirements, meaning there would have to be some work-around, such as external storage.

### Maintenance

With the front of the robot having a Perspex sheet, access from the top of the robot will be easy and preferred. The main controller and battery will be able to be removed via a quick release mechanism. The pickup assembly will be able to be fully detached easily for maintenance inside the chassis or to work on the pickup assembly.

### Modularity

This concept is very modular, as the pickup mechanism will work for a variety of tactics. Conversely, the tactic could use any range of collection methods without impeding its functionality. If anything needed to be changed later on in the process, it could be done.

### Cost

## 5.2 Concept 2

### Robustness

Since this robot has no moving parts (besides the tracks), this design is about as robust as it gets. It will be important to ensure that the sensors are well attached and not prone to being knocked off. Another major consideration of this robot compared to the other two is its power consumption – it must be able to last the whole round (R1.4). Assuming ten electromagnets each at 12V, 3W:

If the battery has a capacity of 4Ahrs, lasting the whole round wouldn’t be a problem.

### Reliability

While being very robust, this concept is not very reliable. It is possible for the robot to get lost in the map and unable to find HQ, and it’s also possible for the packages to get removed by obstacles. These are both crippling problems with this concept.

### Ease of build

Again, due to the lack of moving parts, this robot would be very simple to create, unless an extra power management circuit board is required. Even in this case, the only complexity would be in designing the board rather than physical assembly.

### Maintenance

As with Concept 1, there is a quick release mechanism for the controller and battery. There are almost no other parts inside, so there will be lots of space to work in, and the other functional parts are all external. As long as the brackets are designed decently, maintenance would be trivial.

### Modularity

While the tactic employed is not restrained to the chosen method of package collection, this concept is not very modular. If we found that the electromagnets would not work, for example, the robot would have to undergo a massive overhaul and redesign costing many hours of work.

### Cost

<http://www.aliexpress.com/item/5PCS-of-DC-12V-3W-Holding-Electromagnet-Lift-Solenoid-2-5Kg-5-6lbs-25N-20mm-New/1742033663.html>

## 5.3 Concept 3

### Robustness

### Reliability

### Ease of build

### Maintenance

### Modularity

### Cost

## 5.4 Final Comparison

- ‘Merit table’ score chart

Need some basic/approximate calculations or estimates of costs, forces, power requirements, available computation and memory. Evaluate/compare the concepts – FOM table. This doesn’t need to be exquisitely detailed or accurate at this stage – just provide enough to be able to evaluate and compare the concepts in a relatively objective manner. Briefly discuss/comment on these 3 concepts in the context of the competition and specs – factors such as robustness, reliability, ease of build and maintenance between rounds, modularity, and cost.

# 6.0 Conclusions and Recommendations

Based on your evaluations, make a recommendation for one of the concepts to be developed – back this up by summarising its benefits or why you chose it. While we won’t hold you to this design, we would expect that your final form be based on what you present in this report.

# Contribution Statements

## Jack Hendrikz

## Peter Nicholls

* Concept 2 description and evaluation
* Description of tactics
* Requirements specification
* Document Formatting

## Ryan Taylor

* Concept 1 description and evaluation
* Sensor concept development

Briefly describe the specific contributions of the team members in the project up to this point. For example:

Howard Wolowitz:

 Requirements specification

 FOM calculations for concept 1 and 2

Leonard Hofstadter:

 Sketching concepts

 FOM calculations for concept 3

 Report writing

Sheldon Cooper:

 Room-mate agreement

 Making tea

Parts List:

* DC Motor x2
* DC Motor driver x2
* High current driver ?
* IMU ?
* IR PhotoInterrupter x1
* IR Camera ?
* IR LED ?
* IR MR \ 1 of these ?
* IR SR /
* IR Variable distance x1 (or 3)
* LED ?
* Power Protection Circuit x1
* Relay x2
* Standard Servo x4
* Micro Servo x4
* Smart Servo x4
* Sonar x1
* Stepper Motor x2
* Stepper Motor Geared x2
* Toggle Switch x1
* Variable Resistor 10k
* Weight Sensor x1

Diagrams:

* State diagrams
* Flow diagrams
* Functional diagrams
* Context diagrams
* N2 charts
* Data flow diagrams