2014 ROBOCUP PROGRESS REPORT 1

DESIGN SELECTION PROCESS

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EXECUTIVE SUMMARY

This report provides an overview of the initial design process followed for the 2014 University of Canterbury Robocup. The 2014 Robocup involves two robots simultaneously competing to collect the greatest mass of packages within an arena for 5 minutes. First an outline of the general requirements to achieve this challenge is given in this report. The report then formalises a range of ideas associated with several elements identified as essential to fulfil these specifications. Based on these ideas three different concepts were then developed. Each of these concepts was then evaluated with respect to the concept's strengths and weaknesses. After evaluating and comparing each concept the final concept was recommended based on its superior driving speed and ability to pick up packages whilst moving.

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1.0 INTRODUCTION

The following report provides the basis of a preliminary design selection process for the 2014 University of Canterbury Robocup search and rescue challenge.

The 2014 Robocup takes the setting of a post zombie apocalypse where teams must design and build an autonomous robot to compete at collecting food packages about the 'city' or arena. Food packages (packages) take the exterior form of metal cylindrical weights and may be of 3 different masses of 0.5kg, 0.75kg and 1kg. The team with the winning robot is determined through a process of knockout rounds with each round involving two groups competing to collect packages scattered within an arena. The winner of each round is determined by the robot with greatest accumulative weight of packages including those either on-board the robot or within the robots color-coded headquarters (HQ).

Based on this scenario the following report outlines the range of different strategies and designs that were considered to build a competitive robot for this competition.

2.0 GENERAL REQUIREMENTS SPECIFICATION

These general requirement specifications outline the minimum requirements for the designed robot. Additional specification depending upon the final selected design and strategy are not elaborated upon in these requirements.

IDENTIFICATION

- R1.1 The robot shall be able to identify the food packages to be collected.
- R1.2 The robot shall be able to identify the HQ's as either its own or the other teams.

NAVIGATION

- R2.1 The robot shall be able to navigate towards the locations of identified packages.
- R2.2 The robot shall be able to navigate about obstacles including:
  - R2.2.1 Walls with a minimum gap separation of 0.5m.
  - R2.2.2 Rectangular profile speed bumps no greater than 25mm high.
  - R2.2.3 Up and down ramps.
  - R2.2.4 Another robot in the arena

PACKAGE INTERACTION

The robot's required interactions with food packages can be itemized to the following:

- R3.1 The robot shall be able to move with food packages.
- R3.2 The robot shall be able to collect food packages over 1kg.
- R3.3 The robot shall be able store food packages either on its own body or in the HQ.
- R3.4 The robot shall not pick up other food packages identified to be in a HQ.
- R3.5 The robot should be able to pick up packages that are positioned against a wall or a corner.

ROBOT

- R4.1 The robot shall be able to operate on the same battery for a minimum of 5 minutes.
- R4.2 The robot shall be autonomous with no external communication from other devices or human intervention.
- R4.3 The robot must be controlled by an Atmel ATmega 2560 8-bit microcontroller.

COSTS

- R5.1 The total cost of additional components must be no greater than $50. The following additional allowances which shall not be exceeded are available in excess of this.
  - R5.1.1 An allowance of $5 to accommodate for circuit board componentry.
  - R5.1.2 An allowance of $10 (200g of material) for 3D printed componentry.

SAFETY

- R6.1 The designed robot shall not cause deliberate damage to the other robot.
- R6.2 The robot shall adhere to the following relevant safety standards:
  - R6.2.1 Lasers onboard the robot must be below 5mW
  - R6.2.2 It is compulsory to use the power cut-off module

3.0 DESIGN SPACE AND CONCEPT GENERATION

The following section outlines the key considerations made when generating concepts for this project. In order to select designs for each of the three alternative concepts the task was broken into eight key elements including strategy, storage method, chassis design, package identification, collecting mechanism, wall detection, wheel design and search algorithm. Through a process of brainstorming different designs for each of these elements were generated.

4.10 EQUIPMENT PROVIDED

Before generating a range of concepts to fulfil the outlined specification the boundaries of hardware were first considered. In addition to the supplied equipment supplementary componentry can be bought in accordance with specification R5.1. The following list outlines the considered supplied equipment for this project.

6X Micro-switches	1X Buck Boost Voltage Regulator
1X 4mm Sheet of Perspex 220mmX220mm	2X Variable Voltage regulators
2X 10mm Sheet of Perspex 220mmX110mm	1X Weight Sensor
1X Sonar HRLV Max Sonar	2X High Current Drivers ULN2003a
2X Stepper Motors ROB-10846	2X Wire breakout boards
2X Smart Servos	1X Battery Protection Circuit
2X Geared Stepper Motor	1X 4000mAH 3S Lipo
1X Arduino Mega ADK	2X Servo Mounts
1X Colour sensor	2X Stepper Mounts
4X Stepper Motor Drivers	2X Servo Mounts

LIST OF CONSIDERED SUPPLIED EQUIPMENT

4.20 OUTLINED STRATEGIES

4.21 OFFENSIVE HQ SWITCH

This strategy focuses on impeding the other robot from returning packages to its base. Such a method of impeding the opposing team's robot is achieved by confusing their robot of the locations of the two headquarters within the arena. This strategy assumes that the opposing robot is designed to identify each of the headquarters by colour and drop-off the packages to its own HQ.

With each of the headquarters color-coded the robot is required to swap the colours of the headquarters by placing a red piece of paper over the blue HQ and blue piece of paper over the red HQ. Once the colours of the two HQ's are switched the robot following this strategy may then adopt any search algorithm to find packages. The non-contact approach of this strategy ensures requirement R6.1 is satisfied.

4.22 RETRIEVE AND RETURN

This strategy focuses on monitoring the total mass of the packages so that the overall speed of the vehicle does not dramatically decrease. Such a method involves weighing each of the packages as they are collected, if the total mass of all the packages stored on the robot is above a specified amount the packages are returned to the HQ.

4.23 NO RETURN TO HQ

This strategy takes the opposite approach of the retrieve and return strategy and focuses on minimizing the number of return journeys made by the robot. The strategy involves having a high storage capability so the robot is not required to make return trips to the HQ. Such a strategy therefore eliminates the time required for return trips to the HQ from the time to collect packages.

5.0 PROPOSED CONCEPTS

Three concepts were developed on the basis of the three different strategies described in the section 4.0. The concepts were chosen to reflect the design space spanning the elements considered and mentioned in section 4.0. The following table summarises each of these alternative concepts.

Concept number	**One**	**Two**	**Three**
Strategy	Offensive HQ switch	Retrieve and return	No return to HQ
Storage	Tray	Bucket	Rail type system
Chassis	Circular design	Standard supplied chassis design	Modified supplied chassis design
Package Identification Method	IR array	Colour sensor	Multisensory system ArduCAM LIDAR
Collection mechanism	Magnetic Arm	Forklift	Auto-feed design
Movement	Wheels	Supplied tracks design	Custom track design
Search algorithm	Random search	Grid search	Wall follow
Wall detection	Micro switches	Ultra sonic sensors	IR sensor system

TABLE 5.0: ARRANGED CONCEPT TABLE SUMMARISING ALTERNATIVE CONCEPTS

5.1 CONCEPT 1 –THE PRINTER

DESCRIPTION: Concept one utilizes the offensive HQ switch strategy explained in section 4.21. The behavioural flow chart in Figure 5.0 shows how this strategy is carried out. A random search algorithm is used for this concept to collect packages once the HQ's have been switched. Upon detecting a wall the search algorithm rotates the robot by a random amount to select the new direction to drive in. Further details of the key features of this robot are outlined below.

PAPER ROLLER MECHANISM: Shown in Sketch 5.1 a continual rotation servo drives the centre roller. The desired coloured paper is selected depending on the rotational direction of the servo. This piece of paper is then feed through the cavity in the chassis and onto the floor behind the robot.

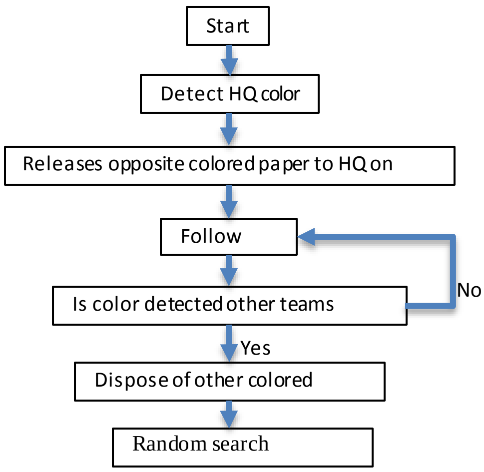


FIGURE 5.0: BEHAVIORAL FLOW CHART

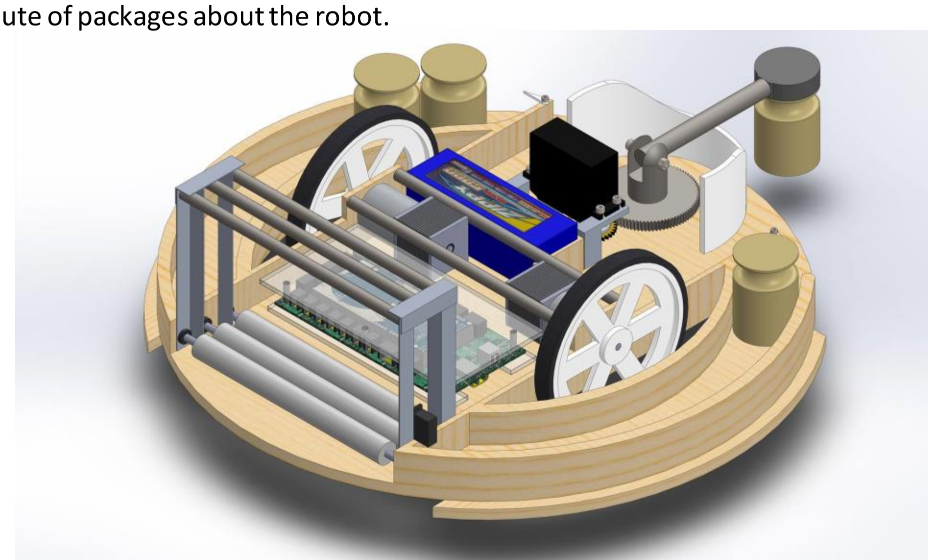
WHEELS: These 150mm diameter wheels will be 3D printed and positioned allowing for the full rotation of the robot about its centre. The wheels are driven by geared stepper motors.

CIRCULAR CHASSIS: This shall be constructed with plywood. Plywood can be easily built to shape at a low cost.

MICRO-SWITCHES: These were chosen as the method of wall detection where they are placed on the base of the robot and are triggered by bumpers on the robots edges.

IR ARRAY SENSOR SYSTEM: Used to detect packages such a system is configured with two sensors vertically positioned where one is at a height above the package and another at a height which can detect a package. The system distinguishes between packages and other objects when the two IR sensors give different distance readings.

MAGNETIC ARM: This shall be constructed from an aluminium and neodymium magnetics. A servo turns the arm along a guide constructed from PVC pipe lifting the packages into the storage bays. The chosen storage bay is alternated for each retrieved mass to evenly distribute of packages about the robot.



SKETCH 5.1: CONCEPT 1 DESIGN

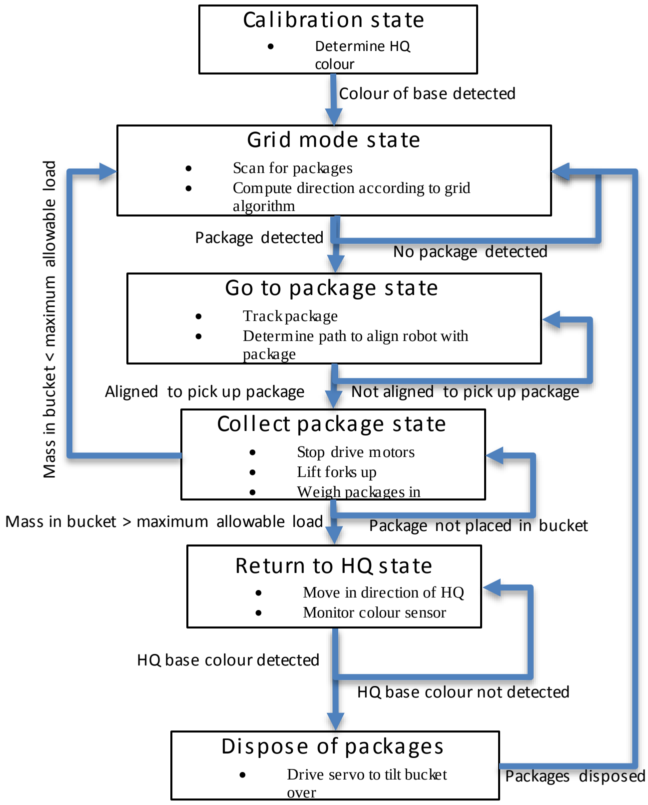


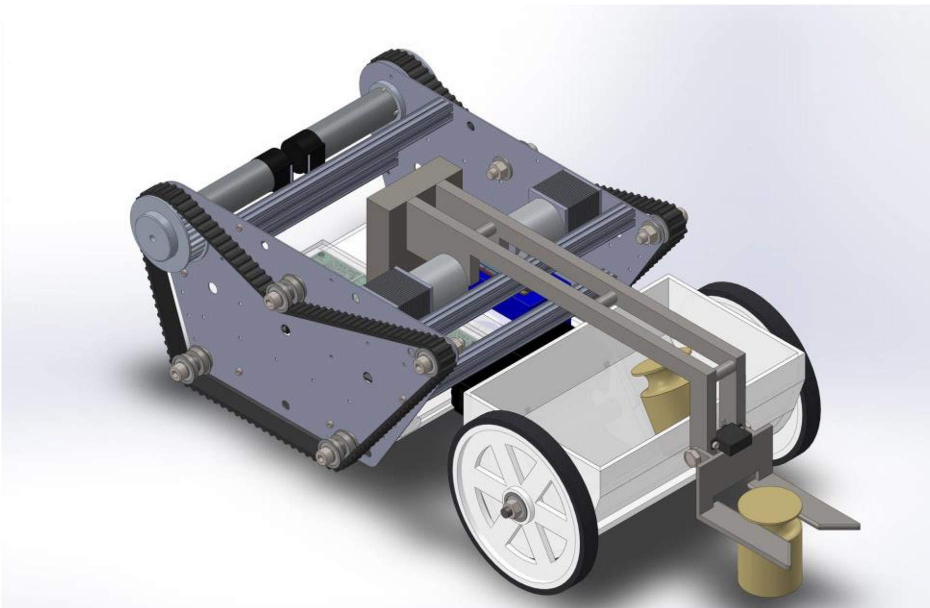
FIGURE 5.2: FINITE STATE MACHINE DIAGRAM

DESCRIPTION: This concept employs the retrieve and return strategy explained in section 4.22. Further explanation of this strategy is illustrated in the finite state machine diagram in Figure 5.2. The concept uses a grid search algorithm to search for packages. Such an algorithm divides the arena into sections, where each area is then searched by the robot systematically. Further details of the key features of this robot are outlined below.

FORKLIFT: This mechanism, constructed from aluminium tube and plate, lifts the packages up with two stepper motors. The package then slide down through the forks and into the bucket. A counterweight is at the rear of the forklift arm to reduce torque required by the stepper motors to lift heavy packages.

BUCKET: Constructed from Perspex the bucket has a weight sensor at its base to measure the total mass of the packages. The bucket is tilted to dispose of the packages using two servos mounted to the chassis frame. The wheels attached to the bucket are 3D printed.

SENSORS: For package detection a colour sensor is positioned at the front of the bucket and searches for the bronze coloured packages. For wall detection an ultra-sonic sensor is scanned 180˚ using a servo at the top of the chassis.



SKETCH 5.2: CONCEPT 2 DESIGN

5.3 CONCEPT 3 –THE HARVESTER

DESCRIPTION: Concept 3 employs the no return strategy described in section 4.23. A wall following algorithm is used to navigate about the arena with continuous scanning of the surroundings. An outline of the structural interfaces of this concepts design is illustrated in Figure 5.3. Further details of the key features of this robot are outlined below.

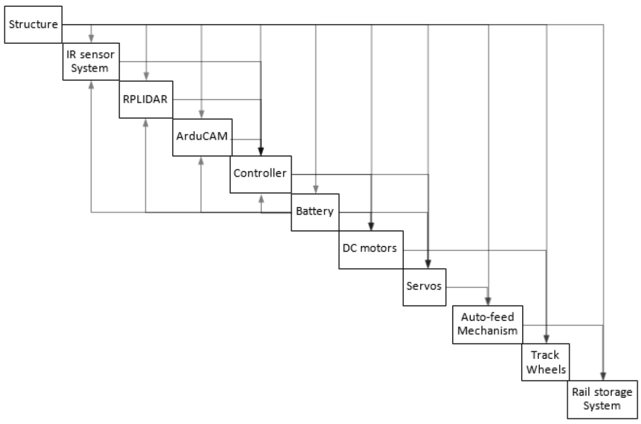


FIGURE 5.3: N2 STRUCTURAL INTERFACE DIAGRAM

CHASSIS DESIGN: This concept utilizes the existing componentry to construct the modified chassis in Sketch 5.3. The chassis has been modularised into three respective layers, (from top to bottom) electronic componentry, sensors and storage.

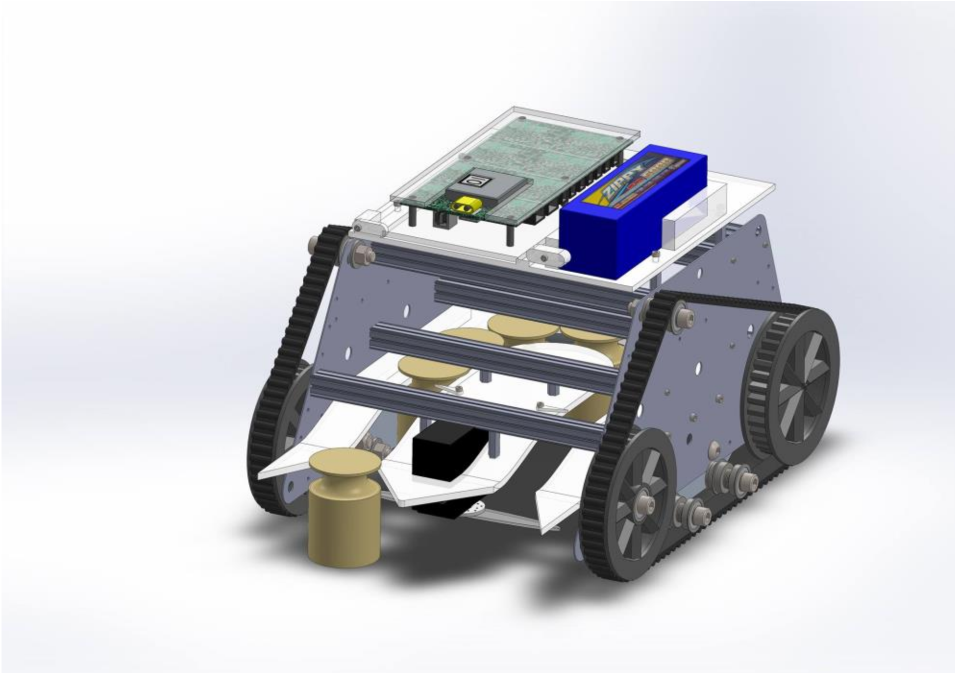
AUTO-FEED MECHANISM: Packages are feed into the rail system. Packages are positioned via the V-guide to the left or right inlets of the rail system. These are then pushed up the rails with the use of a large servo rotating a mechanical arm as illustrated in Sketch 5.3. This mechanism was based on how a grain harvester operates.

IR SENSORS: These are positioned in the middle layer of the robot and are used to detect the distance from a wall or obstructing object. Three sensors are used to give a 220˚ detection angle. One of these sensors is dynamically scanned to reduce blind spots. A moving average filter is required to reduce interference and noise.

WHEELS: The custom rollers (wheels) are 3D printed with a diameter of 100mm. This diameter was chosen to accommodate the provided tracks and chassis wall plates. The bearings at the top of the wall plate may be moved horizontally to adjust the tension of the tracks.

RAIL STORAGE SYSTEM: The packages are stored on a U-shaped rail system constructed from Perspex. This system allows for the total storage capacity to be independent of the side with which packages enter. Spring loaded one-way latches are positioned at the entrances of the rail system to contain the packages.

LIDAR (LIGHT DETECTION AND RANGING): This constructed module consists of a 5mW 980nm IR laser, IR position camera and the ArduCAM. The IR laser is scanned horizontally and the IR positioning camera detects the relative angle of the packages with respect to the robot as the beam is reflected back. As this occurs the ArduCAM detects the relative distance from the robot to the package by tracking the laser dot and processing the image. The combination of these two cameras creates a full 2D scanned map of the surroundings. The module is positioned at the bottom of the chassis in line with the packages.



SKETCH 5.3: CONCEPT 3 DESIGN

6.0 CONCEPT EVALUATION

6.1 CONCEPT 1 EVALUATION –THE PRINTER

ROBUSTNESS: The micro-switch wall detection system is impervious to interference from external sources as it requires physical contact with the wall. This makes this method of wall detection the most robust method out of the three concepts. As the design is relatively simple the potential for failure is reduced.

RELIABILITY: The random search algorithm ensures the robot will not get stuck or trapped in a loop when navigating about the arena. Due to the shape of the chassis one of the hindering aspects of this concept is its potential inability to manoeuvre over objects such as speed bumps as per requirement R2.2.

CONSTRUCTION AND MAINTAINENCE: The construction of the robots chassis is the most difficult of the three concepts with its unique design. The open chassis however enables easy access to any of the componentry, allowing for convenient maintenance between rounds if required.

SPEED OF COLLECTION MECHANISM: This collection mechanism is the slowest of the three designs as the robot must stop to retrieve the weights. The gearing system between the servo and the arm is designed to provide high torque to lift the packages up the PVC guide. A compromise of this high torque is the speed at which the arm rotates.

STORAGE CAPABILITIES: This concept is capable of storing all 11 packages within the arena, distributing the mass of these objects evenly about its centre

PACKAGE IDENTIFICATION: This system provides medium range detection of the packages (up to 800mm). As this method of detection is simple it requires minimal use of the micro-controller's CPU.

STRATEGY: One of the disadvantages of this strategy is that it is heavily based on the assumption that the other robot returns to its base and uses a colour sensor to detect the location of its base. It is likely due to the variation in the designs that these assumptions will not be meet. Another disadvantage of this robots strategy is that whilst the searching algorithm employed is the most reliable of the three searching methods it is also the slowest.

OTHER APSECTS: The steppers motors driving the wheels of this design ensure high precision and torque. These motors do not require optical encoders to track the position of the robot further increasing the simplicity of this design.

6.2 CONCEPT 2 EVALUATION –THE FORKLIFT

ROBUSTNESS: The ultrasonic wall detection system is resistant but not impervious to interference. The supplied chassis design provides a solid frame to house and protect the components from other robots.

RELIABILITY: The output from the colour sensor can vary depending on the lighting sources in the room. Therefore there is potential possibility that packages are not detected within the expected range of wavelengths. This flaw significantly decreases the reliability of this concept. The particularly large rectangular design greatly restricts the mobility of the robot in tight spaces. This coupled with the grid search algorithm could result in the robot becoming immobile in confined areas in the arena.

CONSTRUCTION AND MAINTAINENCE: The construction of this concept is the most simple to implement of the three designs as it is built from the supplied equipment and uses the pre-existing chassis and track system. Disassembly of the robot is required to access the components, including programming of the micro-controller, enclosed within the chassis increasing the difficulty of maintenance.

SPEED OF COLLECTION MECHANISM: The collection mechanism is relatively fast compared to concept one as the robot must only stop momentarily to raise the package into the bucket. Once the package is raised the robot can continue to search for packages about the arena.

STORAGE CAPABILITIES: This concept is capable of storing a maximum of 6 packages. The storage capabilities of this robot are inferior to the other two concepts which can both store all 11 packages. As the packages are returned to the HQ such a large storage capacity is not required.

STRATEGY: The retrieve and return strategy optimises the robot's speed and manoeuvrability over obstacles by restricting the total allowable mass which can be carried. The cost in time returning to the HQ may however outweigh any potential advantages from this restriction in load.

PACKAGE IDENTIFICATION: The colour sensor is the most ineffective means of detecting packages due to its short range and dependence on the lighting of the room. However it is slightly less prone to interference compared to the IR sensors which operate on a narrower range of wavelengths.

OTHER ASPECTS: Using the pre-existing chassis there will be no mechanical advantage over the other team's robots. This is the major flaw of this concept.

6.3 CONCEPT 3 EVALUATION –THE HARVESTER

ROBUSTNESS: This collection mechanism is simple in design and has few moving mechanical parts decreasing the likelihood of failure of this component. Such a collection mechanism is therefore the most robust of the three designs. A disadvantage of this collection mechanism however is that it requires objects to be positioned upright and away from tight corners of the arena.

RELIABILITY: The wall detection method incorporates multiple sensors to increase the reliability of readings. These readings are then passed through a moving average filter to ensure accuracy in the data, reducing the effects of noise. The IR sensors are however susceptible to interference from outside sources. Two cameras are also used in the detection of the packages to ensure consistent acquired relative positions of the packages. Cameras can operate independently giving the package's general location if required.

CONSTRUCTION AND MAINTAINENCE: The construction complexity is between that of the other two considered. The majority of the chassis is constructed using materials from the standard supplied chassis with some parts fabricated to meet the design. The modular layer design allows for individual sections to be removed from the robot for maintenance.

SPEED OF COLLECTION MECHANISM: This concept has the fastest collection mechanism as it has been designed with the intention to pick up packages without having to stop. This is the major advantage of this design over the other concepts.

STORAGE CAPABILITIES: The rail system holds all 11 packages independent of the side at which they are feed into the storage system.

PACKAGE IDENTIFICATION: As explained the multisensory package identification system is the most reliable of the three identification systems. A single scan is able to detect and map multiple packages allowing for their relative locations to determine the optimum path of collection. With the image processing required on the output from the ArduCAM it is expected that this design will require the greatest amount of computational power.

STRATEGY: The time taken to collect the packages is expected to be greatly reduced by not returning to the HQ. One disadvantage of this strategy is that at high package loads the robot may find it difficult to manoeuvre over objects. By following the outside wall of the arena it is expected that the robot will eventually navigate about the entire arena, therefore acquiring a full map of the relative placement of packages.

OTHER ASPECTS: The larger rollers and modified track layout increase the overall speed and efficiency compared to the standard supplied chassis.

6.4 CONCEPT COMPARISON

6.41 COST

When considering the cost of each of the concepts only the additional costs were considered. The costs of the supplied equipment were therefore excluded from this analysis. Such an analysis provided a means of evaluating if the cost specification requirements under R5.1 were met. Table 6.1 summarises this analysis where the full analysis can be found in the appendices.

Concept	**Concept 1**	**Concept 2**	**Concept 3**
3D printing Costs	NZ$10	NZ$10	NZ$10
Additional componentry costs	NZ$26.81	NZ$8.40	NZ$36.08
Total cost	**NZ$36.81**	**NZ$18.40**	**NZ$46.08**

TABLE 6.1: SUMMARY OF COST ESTIMATES

The cost analysis shows that it is expected that all three concepts will meet the cost requirements. This factor was therefore considered to be equally meet by all three concepts and therefore not considered in the factors of merit (FOM) Table 6.3.

6.42 POWER CONSUMPTION

Battery Capacity (I): 4 Ahr
Battery Voltage (V): 11.1 V
Max depth of discharge (D): 80%

$$Energy\ capacity\ of\ battery = I * V * D$$

$$= 128kJ$$

$$Maximum\ power\ dissipation\ of\ element = Current * Working\ voltage$$

$$Battery\ life = \frac{Energy\ capacity\ of\ battery}{Maximum\ power\ dissipation\ of\ concept}(s) * 60\left(\frac{min}{s}\right)$$

Component	Concept 1	Concept 2	Concept 3
Stepper motor	8.88W	0W	0W
DC motor	0W	86.4W	86.4W
Microcontroller	25W	25W	25W
IR sensors	0.363W	0W	0.726W
Sonar sensors	0W	0.155W	0W
Servo	12W	9W	12W
LIDAR sensor	0W	0W	0.225
Maximum power draw (W)	46.2W	120.6W	124.4W
Design Battery life (Minutes)	**46.1 minutes**	**17.7 minutes**	**17.1 minutes**

TABLE 6.2: SUMMARY OF POWER CONSUMPTION OF COMPONENTS IN DESIGN*

Table 6.2 highlights that in any worst case scenario the chosen concept will be able to operate for the full 5 minutes of each round of the competition in accordance with specification requirement R4.1. With this specification equally met by all the concepts the battery life factor was not considered in the FOM Table 6.3.

*A detailed analysis of the power values for each component is found in the appendices

6.43 RELEVANT DYNAMICS ESTIMATIONS

RELATIVE TORQUE AND VELOCITY CALCULATIONS OF DIFFERENT SIZED WHEELS

Relevant concept information:
Concept 1 wheel diameter: 150mm
Concept 2 wheel diameter: 60mm (standard supplied wheel size)
Concept 3 wheel diameter: 100mm

Note: Assume constant angular velocity of wheel;

$$\boldsymbol{v} = \boldsymbol{\omega} \cdot \boldsymbol{r}$$

$$\mathrm{v}_1 = 0.150\omega; \qquad v_2 = 0.060\omega; \qquad v_3 = 0.100\omega;$$

Compared to the standard wheel design

$$v_1 = 2.5v_2 \qquad v_3 = 1.7v_2$$

VELOCITY ESTIMATIONS RELATIVE TO STANDARD WHEEL DESIGN

These rough calculations illustrate the potential gain in speed of the robot which can be achieved with larger wheels.

Note: Assume torque provided by motor to wheel is constant;

$$F = \frac{\tau}{r}$$

$$F_1 = 6.7\tau; \qquad F_2 = 16.7\tau; \qquad F_3 = 10\tau;$$

$$F_1 = 0.4F_2 \qquad F_3 = 0.6F_2$$

DRIVING FORCE ESTIMATIONS RELATIVE TO STANDARD WHEEL DESIGN

These calculations indicate that the larger wheels may have difficulty moving under heavy package loads or over objects such a speed bumps or ramps, with a driving force of only 40% of that of the standard chassis. Where an increase in load may significantly decrease the speed of the robot with the motor unable to provide enough torque. It should be noted however that the stepper motors are capable of providing 80% more torque ($18kgcm^{-1}$) than the DC motor $(10kgcm^{-1})$ this has been be taken into account for concept one when analysing its relative torque capabilities in the factors of merit table.

MOTOR DRIVING TESTS

Testing was carried to verify if the motors would be sufficient to carry large loads. This testing revealed that the two DC motors on the standard chassis setup were sufficient at carrying up to 6kg of packages on board the robot without significantly compromising the speed. From this it was estimated that therefore larger loads will not significantly reduce the speed to justify a return trip to the HQ.

6.44 OVERALL CONCEPT EVALUATION

The following factors of merit table is based upon the comparisons and evaluations made in this section of the report.

Factor	Weighting /10	Concept 1 Scores		Concept 2 Scores		Concept 3 Scores	
		Real	Weighted	Real	Weighted	Real	Weighted
Robustness (strength)	6	5	30	9	54	7	42
Reliability	8	6	48	5	40	7	56
Ease of build	2	4	8	9	18	6	12
Ease of maintenance	3	10	30	6	18	7	21
Speed of collector mechanism	10	5	50	7	70	10	100
Driving speed capabilities	10	7	70	6	60	9	90
Driving torque capabilities	5	7	35	7	35	6	30
Storage capabilities	8	10	80	5	40	10	80
Package identification method	8	7	56	3	24	9	72
Strategy	7	2	14	4	28	8	56
Overall score:			**421**		**387**		**559**

TABLE 6.3: FACTORS OF MERIT TABLE OF DESIGN CONCEPTS

7.0 CONCLUSIONS AND RECOMMENDATIONS

Overall after evaluating and comparing the three different concepts, it is shown in Table 6.3 that concept 3 would be the recommended choice for a preliminary design. Concept three's major advantages over the other concepts are its driving and collecting speeds which were deemed critical to success in the Robocup competition. As this design is only a preliminary design it is expected that various changes may be made to improve the weaker factors of the design if they are later deemed an issue. One such issue which may require further consideration in this design is the inability of this concept to retrieve packages from the corners of the arena. Other than this issue concept 3 meets all of the general requirement specifications outlined in section 3.0.

COST ESTIMATIONS OF CONCEPTS

Concept 1	cost/unit	unit	number of units	cost
3D printing	0.05	$/g	268	$ 13.40
Plywood	4.18	$/m^2	0.36	$ 1.50
Miscellaneous parts	5	$/parts	1	$ 5.00
PVC pipe 150mm diameter	26.67	$/m	0.05	$ 1.33
Gears 54 tooth cnc spur gear	11.25	$/gear	1	$ 11.25
kds700 motor pinion 14teeth	4.32	$/pinion	1	$ 4.32
Total cost				**$ 36.81**
Concept 2				
3D printing	0.05	$/g	268	$ 13.40
Miscellaneous parts	5	$/parts	1	$ 5.00
Total cost				**$ 18.40**
Concept 3				
3D printing	0.05	$/g	484	$ 24.20
Miscellaneous parts	5	$/parts	1	$ 5.00
Magnets	4.66	$/magnet	1	$ 4.66
IR laser	11.99	$/laser	1	$ 11.99
Red laser	0.2	$/laser	1	$ 0.20
Scrap Aluminium	1.21	$/kg	0.024	$ 0.03
Total cost				**$ 46.08**

All price in $NZ