AUTONOMOUS ROBOT PROTOTYPE DESIGN PROPOSALS

RE: RFP-QC120-12345

ENGR120-A08

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Greetings,

The enclosed report outlines two candidate designs for small-scale autonomous hazardous waste removal robots. The designs described in the report are in response to RFP-QC120-12345 published by Innovation Canada.

In the report, background on the project is provided, along with objectives the project aims to satisfy. Two candidate robot designs are described in detail; their features, potential shortcomings, and testing data are included. The designs are then compared using weighted objectives and a recommendation is made as to which design would be best to further develop. Finite state machine diagrams are included in the appendix to give some indication of code complexity for each design.

Thank you for taking the time to read the report and considering the designs contained herein.

Sincerely,

Trek Wars Engineering LLC

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Executive Summary

In order to address the issue of hazardous material cleanup, two small scale prototype robots were designed to perform simulated nuclear waste disposal. The two robots chosen, SpockBot and ForkBot, completed a series of tasks to assess their efficacy and feasibility. Both robots excelled during testing, however Spockbot was chosen as the recommended robot as it performed marginally better based on a set of chosen metrics.

Glossary

Term	Description
IR	Infrared - Electromagnetic radiation with wavelengths that are just longer than the red side of the visible light spectrum
Phototransistor	A sensor that detects infrared signals and has a variable resistance depending on the strength of the input IR signal
Potentiometer	A variable resistor usually controlled by a mechanical interface that has rotary or linear motion
SLOC	Source Lines of Code - An industry standard in measuring the complexity of code within a program
VEX kit	Major source of materials from which most of the robots are made. The kit is provided and manufactured by VEX Robotics, Inc.

1 Project Background

After the nuclear disaster at Fukushima Daiichi it has become glaringly obvious that a solution for hazardous material disposal is needed. As radioactive waste poses a severe hazard to human life, it is necessary to employ robots in the cleanup of such waste. To meet this need, Innovation Canada has published a request for proposals outlining designs for small-scale autonomous robots that can neutralize and dispose of hazardous waste.

2 Project Objectives

To simulate successful disposal of radioactive waste, several objectives must be met by a robot during testing. An arena measuring 2.29m by 2.29m with 5cm high walls serves as the setting for testing. Since radioactive materials pose such a health hazard to humans, a radioactive source is simulated by an IR source. A target designed to be used in conjunction with each robot must be removed from atop the source and placed outside the arena.

Several testing objectives have been considered during the design of each prototype. The proposed prototype robot designs must

- be able to locate and remove simulated radioactive material from the arena
- move itself and its target without damaging the surroundings
- function without human assistance, and
- not contact the IR source.

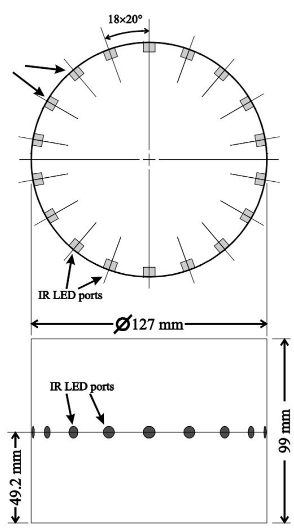


Figure 2.1 - Beacon

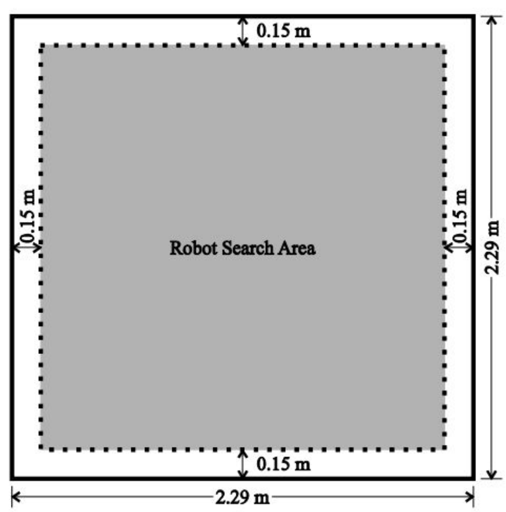


Figure 2.2 - Search Area

3 Comparison Criteria

The designs outlined in this document will be compared based on a number of metrics. The metrics upon which the designs will be judged are

- efficiency
- straight-line speed
- costs external to the VEX kit
- code complexity
- turning radius
- number of failsafes, and
- maximum carry weight.

The weighting for these metrics can be found in §A.1.

4 Designs

Two candidate robot designs were conceived in order to obtain the best possible robot. Due to the critical nature of radioactive waste removal, it is necessary to evaluate multiple options.

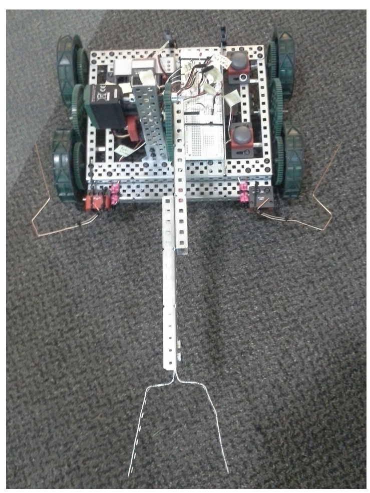


Figure 4.1.1 - SpockBot Overview

4.1 SpockBot

SpockBot employs a simple design having four wheels and a long grabbing arm for target acquisition and removal. As illustrated in figure 4.1.1, it has a frame that is wider than it is long with multiple sensors mounted to the front to detect the target beacon.

4.1.1 Materials

SpockBot is built on a rectangular chassis that promotes lateral stability. A subframe is used to mount the two encoded VEX motors for the drive wheels, the VEX controller, and the battery pack. A superstructure supporting the grabbing arm protrudes vertically from the front of the subframe and braces against the outer frame to enhance rigidity.

4.1.2 Sensors

SpockBot uses an array of 3 IR Phototransistors to track and detect the target beacon (see figure 4.1.2). During the search state (see §A.2), the robot rotates until the middle sensor detects IR above a specified threshold. If no IR source is detected during a rotation, the threshold is lowered for the subsequent rotation. During the approach state, it locks onto the beacon's location by comparing the difference between the left and right sensor values and adjusts wheel speed accordingly.

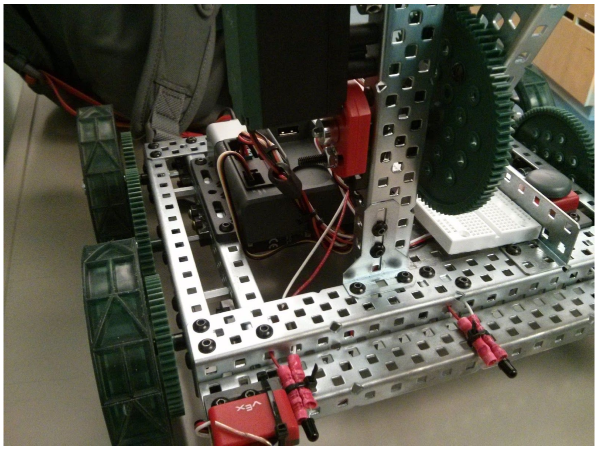


Figure 4.1.2 - SpockBot's Front IR Sensors, Wall Bumper, and Arm Potentiometer

Bumper sensors mounted on the left and right of the front of the chassis provide physical detection of walls and objects. Wall detection is bolstered by extending wire attached to each bumper sensor. When either sensor is triggered, it backs up, maneuvers and corrects its course towards the target.

4.1.3 Motion

Two encoded motors drive each pair of left and right side wheels. Motor encoders provide a ratio of rotation speeds and the robot's wheel speeds are adjusted based on the values returned from the encoders to ensure straight movement. By using two separate drive motors, SpockBot is able to make very small radius turns and minute corrections in each side's wheel speed.

4.1.4 Disposal Mechanism

The target object for SpockBot is an hourglass shape manufactured using 3D printing (see figure 4.1.3). A long arm mounted to SpockBot's superstructure picks up the target object after reaching the correct distance from the target beacon. The arm's movement is controlled by a VEX motor and regulated by a potentiometer so that an exact lifting and dropping height can be consistently achieved. The arm employs a specific gear ratio so the arm does not move too quickly and possibly disrupt the target object during the removal process. After picking up the object, SpockBot turns toward a wall, and drops the target when a wall is detected by a bumper switch.

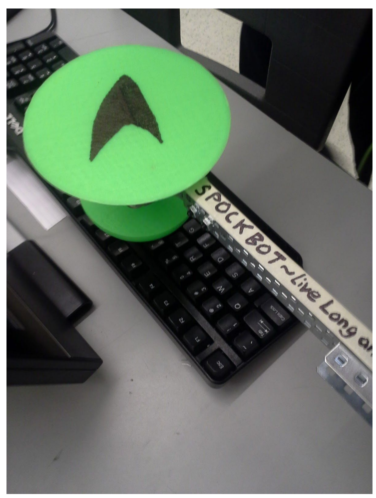


Figure 4.1.3 - SpockBot's Target Object and Lifting Arm

4.2 ForkBot

ForkBot is centered around a simple 4-wheeled rectangular design, utilizing a long range forklift arm for object retrieval (see figure 4.2.1). A dropping arm is located under the lifting arm, and a sensor array is mounted at the front.

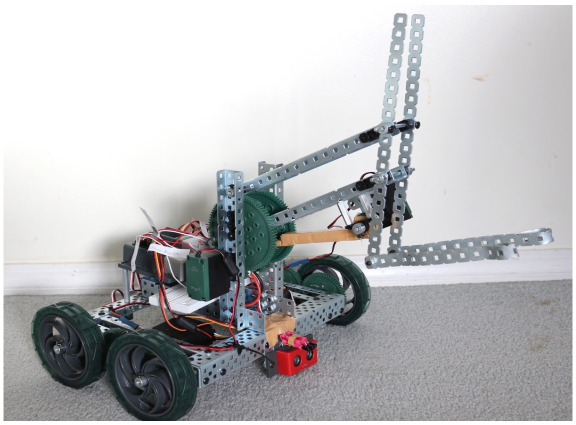


Figure 4.2.1 - Robot Overview

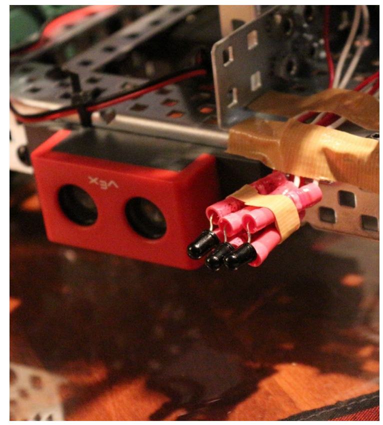


Figure 4.2.2 - Sensor Layout

4.2.1 Materials

The robot is constructed from a VEX robotics kit, which consists mostly of metal parts. Areas that require an increased support structure use duct tape and metal rods. Wooden pieces taped together make up the object dropping arm; small heavy screws and small metal objects are used as counterweights.

4.2.2 Sensors

Three infrared sensors are located on the front of the robot as seen in figure 4.2.2. Each sensor uses a different resistance, resulting in varying sensor sensitivities. Differing sensitivities allows for accurate readings at multiple ranges. As the robot rotates and the IR sensors pass the light emitting object, maximum and minimum readings are stored within the system. After an initial scan of the search area to find these values, a second scan is initiated to find the previously set maximum infrared readings with a small margin of error. When this maximum is sensed, the robot stops rotating. This results in pinpointing the beacon's location with accuracy and consistency.

An ultrasonic range finder mounted at the front locates objects using sound waves. Readings from this sensor allow for distance calculation and object avoidance.

4.2.3 Motion

There are two wheels on each side of the body. Each pair of wheels is powered by an individual motor with a motor encoder. The exact number of rotations done by the wheels is tracked by the motor encoders and allows for accurate turns to be made. For turning, each motor rotates in opposite directions, and forward and backward motion is achieved by the motors rotating in the same direction.

4.2.4 Disposal Mechanism

As illustrated in figure 4.2.3, a two column beam houses a motor and gear assembly that is connected to the lifting arm. With a gear ratio of 1:10, torque is maximized and allows for a wide range of heavy objects to be lifted. The arm consists of two metal rods that are parallel to each other, and a metal arm base to which the rods connect. This use of parallel arms allows for the lifted object remain perpendicular to the ground at all times and ensures a stable and reliable lifting mechanism.

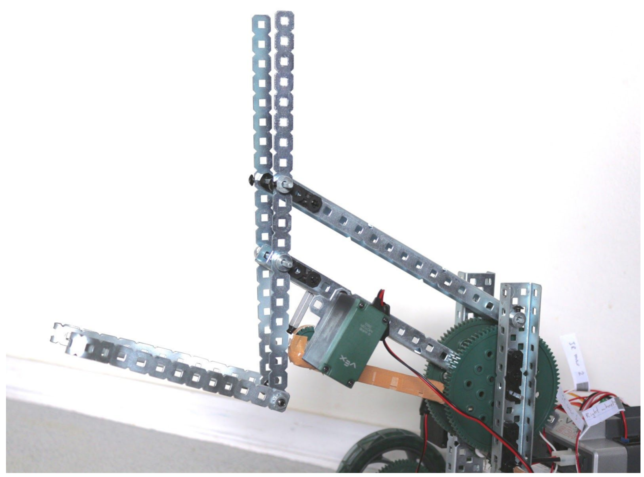


Figure 4.2.3 - Lifting Arm

The dropping arm, as seen in Figure 4.2.4, is located to actuate between the two carrier arms at the end of the lifting arm. The dropping arm is powered by a VEX motor and spins vertically. This motion knocks the object resting on the two carrier arms away from the robot.

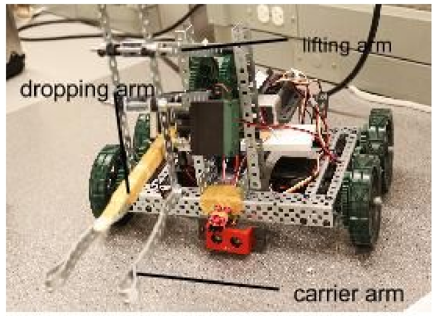


Figure 4.2.4 - Dropping arm Actuated

5 Comparative Evaluation

Both the SpockBot and the ForkBot performed well in all aspects, with the possible exception of overall efficiency. The robots scored similar values for each objective, with failsafes and maximum carry weight being exceptions. As seen in Table 1 below, SpockBot utilized more failsafes, whereas ForkBot could carry more weight.

Table 1 - Weighted Objectives Chart

Objective (criteria)	Weight	Measurement Parameter	SpockBot			ForkBot		
			Magnitude	**Score**	**Value**	**Magnitude**	**Score**	**Value**
Efficiency	0.4	Completion Time (s)	<30s	2	0.8	<30s	2	0.8
Robot Speed	0.15	m/s	1.10	4	0.6	1.15	4	0.6
Additional Part Cost	0.1	Dollars (CAD)	0$	5	0.5	0$	5	0.5
Code Complexity	0.1	SLOC	482 lines	3	0.3	441 lines	3	0.3
Turning Radius	0.1	cm	0cm	5	0.5	0cm	5	0.5
Failsafes	0.1	# of Failsafes in code	5	4	0.5	2	2	0.2
Maximum Carry Weight	0.05	g	300g	3	0.15	591g	5	0.25
				Overall Utility Values:	3.35			3.15

6 Conclusion

SpockBot outperformed ForkBot with a score of 3.35 compared to ForkBot's 3.15. Though the robots completed each of the objectives effectively, the implementations of failsafes within the SpockBot gave it an 0.3 point edge over ForkBot.

7 Recommendations

Based on the comparative evaluation, the robot that best fits implementation for waste cleanup is the SpockBot.

Both ForkBot and SpockBot performed considerably well, but SpockBot's implementation of extra failsafes while also remaining competitive with ForkBot in every other aspect showed its potential for adaptability. Though ForkBot has a greater maximum carry weight, the number of failsafes were unsatisfactorily low. The exceptionally high number of failsafes within SpockBot's code make it ideal for real world situations. All obstacles in the testing arena remained static, but this is unlikely in a real-world scenario. It is difficult to predict the multitude of scenarios the autonomous robots will encounter, but the objectives in §5 suggest that SpockBot is the most suitable robot for waste disposal.

8 References

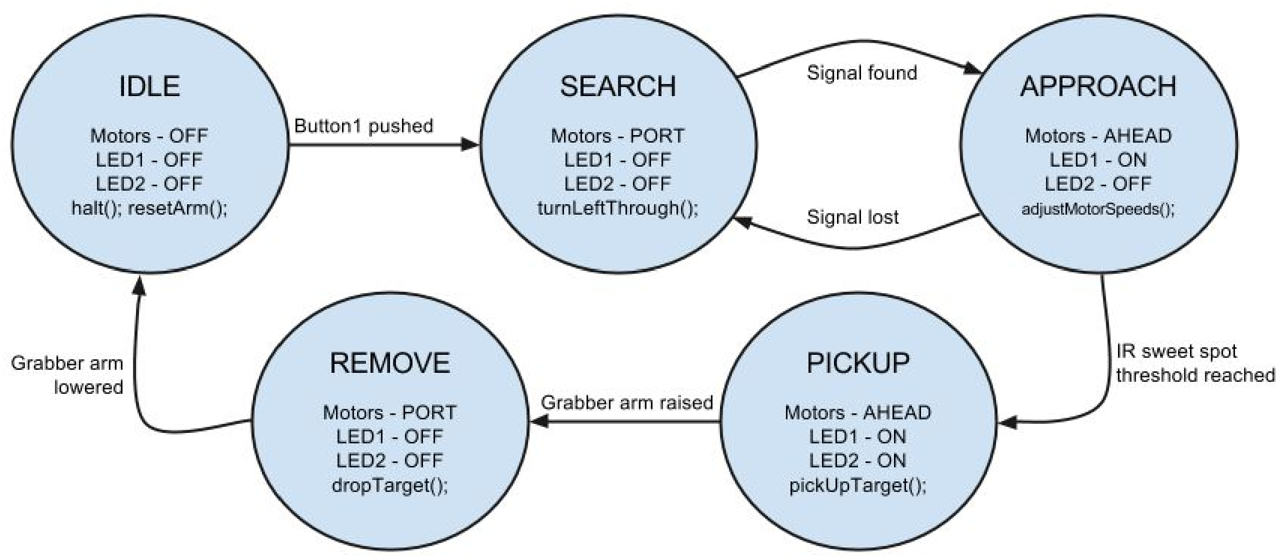
[1] Canada Foundation For Innovation , "Autonomous Robot Prototype Design", RFP-QC120-12345, 7 Apr. 2014.

Appendix A

A.1 Evaluation Parameters

	0	1	2	3	4	5
Efficiency (avg. task time)	> 40s	< 40s	< 35s	< 30s	< 25s	< 20s
Robot Speed	> 0.10m/s	> 0.25m/s	> 0.50m/s	> 0.75m/s	> 1.0m/s	> 1.25m/s
Additional Part(s) Cost	Over $30	Under $30	Under $25	Under $20	Under $15	Under $10
Code Complexity	> 1000 SLOC	< 850 SLOC	< 700 SLOC	< 550 SLOC	< 400 SLOC	< 250 SLOC
Turning Radius	> 5cm	< 5cm	< 4cm	< 3cm	< 2cm	< 1cm
Failsafes	0	1	2	3-4	5-6	7+
Maximum Carry Weight	<50g	100g	200g	300g	400g	450g+

A.2 Spockbot Finite State Machine



A.3 Forkbot Finite State Machine