IMDL Formal Report

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Give & Go-bots

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1 Abstract

The purpose of my project is to design and develop a team of two robots that work together to complete a "find and retrieve" mission. My goal is to improve upon the speed and efficiency of a single-robot, find and retrieve system. I hope to exhibit a proof of concept that using multiple robots to carry out this kind of task is much more efficient, i.e., as more robots are added (to a "course" with a large enough size to handle more robots), the speed and efficiency of the process will increase.

The idea is to have one robot collecting an array of objects from the course while a second robot is constantly transporting these loads from the first robot to a depository. Each of the robots will have clearly defined behaviors and will be able to communicate the state of these behaviors to each other. This will allow the robots to know exactly what their next task should be after the current task is completed. My key is efficiency, so I will aim to minimize any time either robot spends waiting for the other to complete one of its tasks.

2 Executive Summary

3 Introduction

I have seen multiple projects that have to with some sort of find and retrieve mission. Most of these only consist of one robot, however. That robot will either find an object, return it to some depository, locate the next one, return it, and so on; or it will locate and collect as many objects as it can hold, then return them to the depository, etc. My goal is to improve upon the speed and efficiency of a single-robot, find and retrieve system, by using two robots. "Robot 1" will identify and locate a painted ball bearing, maneuver to it, pick it up with an arm by energizing an electromagnet, then deposit it in a bucket on its platform by de-energizing the electromagnet. Robot 1 will continue collecting these ball bearings until "Robot 2" is ready for a "hand-off". After Robot 2 is correctly positioned beside Robot 1, the contents will be dumped from one bucket to another (**The Give**). Robot 2 will then return the load to a depository (**The Go**) while Robot 1 collects more ball bearings. Finally, Robot 2 will return to Robot 1 and the process will repeat until all ball bearings have been cleared from the course.

This report will cover the details of the robots and their mission, including the construction of each robot, the individual roles of each robot, how they will carry out these roles, and how they will communicate with each other during the mission.

4 Integrated Systems

- Robot 1 (see Figure 1)

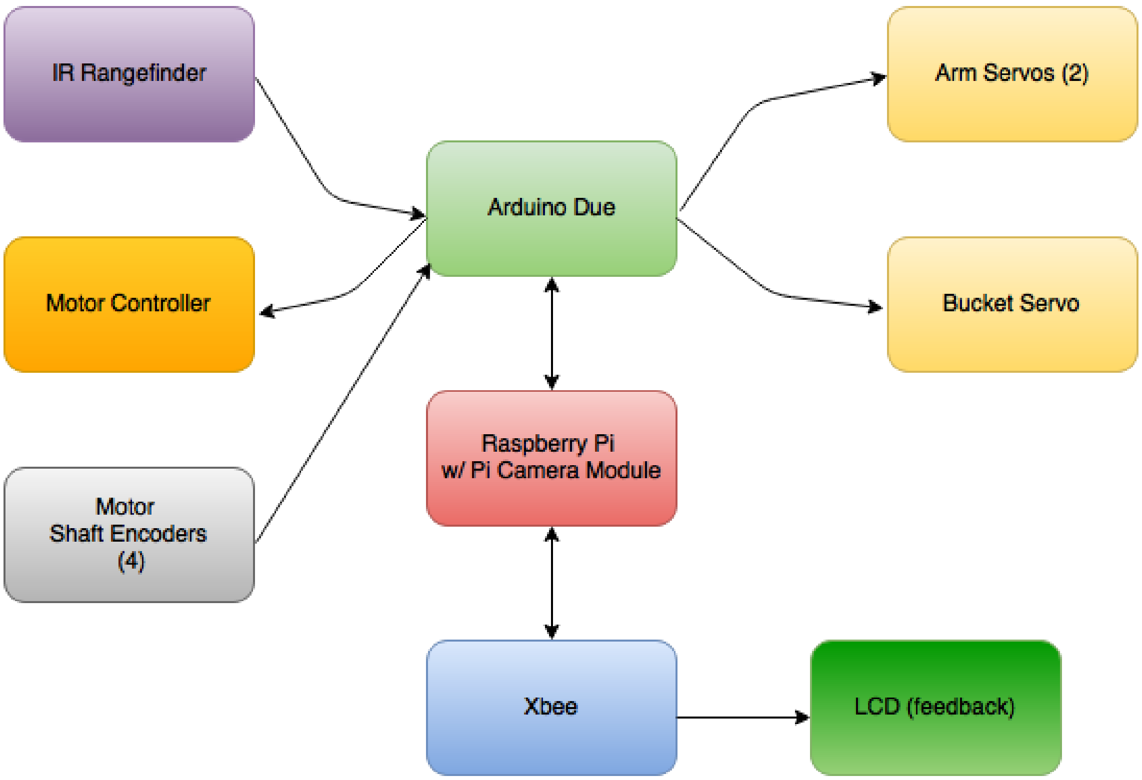

Figure 1: Preliminary Integrated System of Robot 1

- Robot 2 (see Figure 2)

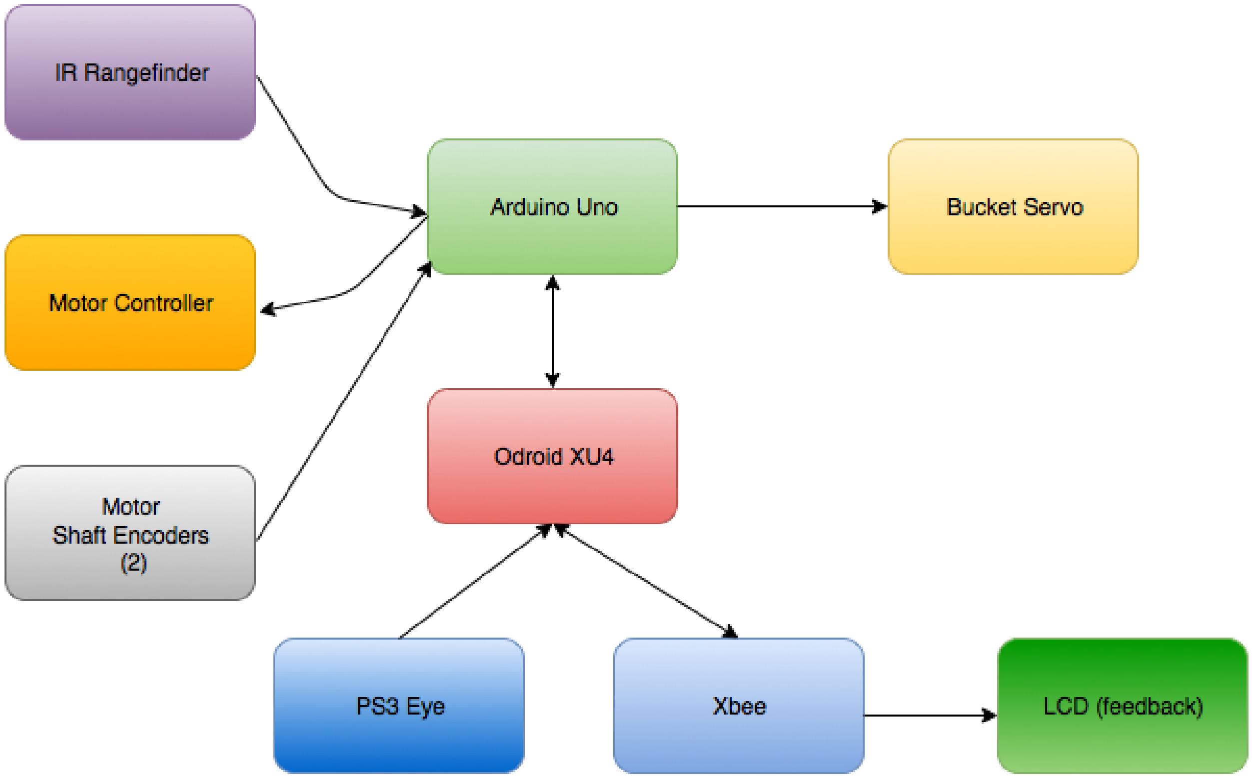

Figure 2: Preliminary Integrated System of Robot 2

5 Mobile Platforms

The platform design of each robot will differ significantly.
Robot 1 will have a two-layer, rectangular platform that accommodates 4 wheels. The lower platform will house most of the electronic components, including the battery, motor driver, and Arduino. The top layer will be taken up mostly by the arm and bucket, while the Raspberry Pi and remaining electronics will fill up any remaining room. The platform must be heavy and sturdy enough to handle an arm rotating out beyond the front edge.
Robot 2 will have a three-layer, circular platform that accommodates 2 wheels up front and a single castor wheel in the back-middle. The lowest layer will house the battery and motor driver, while the middle layer will house the Odroid and Arduino. The top layer will be devoted to supporting the bucket and its servo.
The key will be designing these platforms so their heights make for a smooth hand-off, when ball bearing are dumped from one bucket to another.

6 Actuation

Aside from the motors controlling the wheels, four servos will be used for the three different actuations.

The first actuation will be moving the arm in order to pick up and drop the ball bearings (with the help of an electromagnet). The arm will have two degrees of freedom, and thus two servos. The shoulder joint at the base of the arm, on the platform, will lower the arm down towards the ball bearing to pick it up, and then back up, past 90 degrees, so the elbow joint can then rotate back towards the bucket to drop the ball bearing.
The second and third actuations will be rotating each of the buckets to dump the ball bearings either in another bucket or in the depository. A single servo attached to the base of each bucket will be used for these movements.

7 Sensors

Robot 1 will be equipped with a Raspberry Pi and Pi Camera Module (special sensor) that, with the help of computer vision, will identify the shape and color of the ball bearing. The position and size of the object will then determine how the motors that control the wheels will behave, in order to correctly maneuver and position the robot near the object. The scope of computer vision on this robot will be limited to finding the the orange spheres.
Robot 2 will also be equipped with an Odroid XU4 and PS3 Eye (special sensor). As Robot 2 leaves the depository in search of Robot 1, its camera will look for specific symbols/colors, each of which represent one of the fours sides of Robot 1. Once Robot 2 is in close range of the symbol/color it is looking for, it will tell Robot 1 to stop moving (via Xbee communication) so it can initiate its docking maneuver. It will then continue using computer vision to position itself on the correct side of Robot 1 for the hand-off. Computer vision will finally be used to locate another specific symbol/color attached to the depository.
Aside from cameras, each robot will be equipped with IR rangefinders to help with their positioning and obstacle avoidance. Robot 2 will additionally have a bump switch that will help ensure it is docked correctly next to Robot 1 for the hand-off.
Finally, both robots will have shaft encoders on their wheel motors to help specify steering controls and possibly assist in dead-reckoning maneuvers if obstacles are eventually added to the course.

8 Behaviors

Robot 1's behaviors are limited to identifying a ball bearing with its camera, moving itself "in front of" the ball bearing, picking up and dropping off the ball bearing with the arm and electromagnet, and finally dumping the ball bearing(s) into Robot 2's bucket. When Robot 1 receives information via the Xbees that Robot 2 is in close range and ready for a hand-off, it will stop moving or finish dropping the ball bearing it is currently holding into its bucket, then wait for confirmation that Robot 2 is in position for the hand-off. If Robot 1 hasn't collected any more ball bearings since the last time Robot 2 left for the depository, it will continue on until it has collected one ball, while Robot 2 follows.
Accordingly, Robot 2's behaviors are limited to locating the depository with its camera, docking at the depository, dumping its bucket of ball bearings into the depository, locating and moving within close range of Robot 1 with its camera, docking beside Robot 1 for the

hand-off with help from its IR and bump sensors, and following Robot 1 with its camera.
Again, Xbee communication will be necessary when Robot 2 is within some close range of Robot 1 so the next hand-off can take place. At this point, Robot 1 may tell Robot 2 that it hasn't collected any new ball bearings yet. Robot 2 would then follow Robot 1 to the next ball bearing. Otherwise, Robot 2 will tell Robot 1 when it has successfully docked and is ready for the next hand-off.
Each robot will also have an LCD screen to serve as a feedback device and output messages from the Xbees. This will tell me what action each robot is currently trying to perform and when they start communicating.

9 Experimental Layout and Results

Initial experimentation will involve detecting ball bearings with Robot 1's camera and recognizing the depository and different sides of Robot 1's platform with Robot 2's camera.
As time goes on, I will test more functionality such as motor control, arm and bucket control, and Xbee communication.
When it's time for full experimentation, I will need to test the robots under numerous course conditions. Different starting positions for the robots, ball bearings, and depository could cause unexpected behavior.

10 Conclusion

Thus far, I have ordered almost all of my electronics and have begun testing some basic vision algorithms for detecting spheres on the Raspberry Pi and its camera. As I order more parts and finalize the remaining designs, work will pick up significantly and this project will begin to take form.

11 Documentation

12 Appendices