SENIOR DESIGN I

Fast Acquisition and Real-time Tracking Vehicle

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Table of Contents

List of Figures

List of Tables

Project Description

Motivation

The world of image processing is both vast and robust. Advancements in this field are steadily rising due to the high demand in both commercial and government industries. Image processing alone does not contain the complexity for many of these company's needs, for this reason, the field of computer vision blurs the line between human biology and robotics. A new generation of intelligent cameras has risen from this field, facilitating high-level analysis of both images and videos, the same way the human brain assigns information to imagery, using both visual and auditory acuity.

Our motivation for this project is to take a basic of-the-shelf RC vehicle and completely reconstruct it, equipping it with modern technology such as: autonomous track and detection, mid-range wireless communication and real-time video feedback.

Goals & Objectives

- The probe vehicle will have the ability to autonomously navigate an environment that is unfamiliar to the operator
- The probe vehicle will be able to autonomously seek out different color balls with the use of image processing
- Robust to noise and occlusion
- Multi-terrain operability
- The operator will have a ground control station which provides a live feed from the perspective of the probe vehicle
- The operator will have the capability of commandeering control of the probe vehicle at any point in time in order to navigate to and from the site or in case an object of interest is apparent to the operator but not the probe vehicle

- The probe vehicle will communicate with ground control via Wi-Fi (or other RF technology) on a dedicated wireless network

Function

When the system is turned on it will prompt the user to select the color of interest. After the target is defined in the system, it will first look around to find the target. If the target is detected, it will send a detection success command to the commander who is in charge of the system. It will then approach the target within a specified distance. This system is to continue tracking unless commanded otherwise. Once the vehicle is within a specified distance of the object, a low powered green laser will be activated from the robot to pop a balloon. The vehicle's' battery should be easily replaceable for immediate reuse, when the battery has drained. The batteries should be rechargeable, to alleviate reoccurring expenses for the consumer. The functionality of the system must be independent of the environment in which it is operating to some extent. When we say to some extent, we really mean that the system must be familiar to its surroundings for proper functionality, if it is not familiar to its surroundings, it may malfunction due to confusion. Our goal is to design a low cost off the shelf RC vehicle that is capable of being programmed to track and detect objects.

Project Milestones

This is a really challenging project which incorporates different fields of engineering disciplines. We decided to breakdown this project into 4 main parts as follows:

- **Research**
- **Development**
- **Implementation**
- **Prototype and Test**

Our goal is to finish the first three parts of our project by the end of this semester so that we have all the knowledge and tools to prototype our design and test every component/module in the design. Every part mentioned above is fully explained in the following numbered items:

1)Research

The first part of our project is the most valuable part of the design effort. This Research will help us prepare our final report paper by providing us the advance engineering theories behind different parts of our project. The research can be broken down into 5 main categories. The first category is the operation of the battery management system. We need to research and determine what type and size of battery we will need for optimal functionality. The battery charging station should be capable of docking multiple batteries at once.

The second part of the research deals with the development of the image processing and camera integration. The algorithm is used to detect the object of interest. We want to use python programming language to develop our detection, tracking, and command control. We will have to familiarize ourselves with python, especially opencv library and its functions. Image processing portion must be done carefully since our hardware is not as powerful as a general-purpose computer system that we have at home. The image processing must be simple enough to avoid latency issues and cause the vehicle to respond irradicably.

The third part of our design deals with controlling the robot. The control portion works based on the signals received by the main computer system of the robot. The control system will manipulate the movement of the robot. The robot is steered through voltage signals received from the GPIO; therefore, we will need to spend a significant portion of time developing a system that is capable of coordinated turns and precision movements.

The fourth part of the design is the PCB development. We will have to learn the fundamental rules for designing circuit boards on a development environment to make sure that our components operate smoothly and without any problem. The last part of the design is concerned with the communication system. We will have to learn ways to interface different processing hardware. Since this project is a modular type system, we must make sure that each module is following the same communication protocol.

2) Development

The development portion of the project is the part that we use our knowledge, attained from the research, to design a systematic approach of building different modules of the robot. In this portion, we will use mathematical theories to model our system. This modeling we'll be done using a processing programming language like MATLAB. Plots and charts will be collected and saved for the final report. After the model is simulated and perfected, we will start the development process of each module. From the ground up, development on the main module will involve coding in python using a combination of algorithms from the OpenCV library as well as hardware integration using other functions found on the web.

3) Implementation

After the development is done, we will have to think about how we will implement the design using the hardware that is available to us. We will have to deploy all our codes to the computer system(s) that we will be using for different modules. Our understanding is that we will have three modules that need programming. The main computer system will use Python programming language, and the other two will be in C/C++ to process information. The other important implementation is the hardware portion of the robot. We will have the carrier board on the robot and make sure proper connections are made between different modules.

4) Prototype and Test:

At this point, all the modules are designed and implemented on the robot. Our goal is to set up an environment that is familiar to the design environment and can be used to test our robot. We will develop a testing criteria document to make sure that our robot performs as it is designed to do so.

Requirement Specifications and Constraints

Specifications

- 1GB LPDDR2 SDRAM
- 64-bit ARM Cortex A53 1.2 GHz Quad-Core Processor
- Sufficient internal memory (expandable via SD card)
- RF connectivity *Bluetooth,WIFI etc.
- Camera interface capability
- UART
- SPI
- I2C
- 500mW laser for popping balloons

Constraints

- The autonomous robot may have difficulty locating a target behind obstructions without manual input.
- RF signal degradation will have major impacts on communication signal strength between ground control station and probe vehicle
- Extremely rugged terrain may pose difficulty for navigation.
- Targets that are heavily covered in debris (e.g. dust or snow) may cause detection errors.
- Vehicle may not be able to perform in inclement weather such as rain, snow, fog, etc.

House of Quality

The house quality in *Figure 1* shows some of the customer and engineering requirements and expectations.

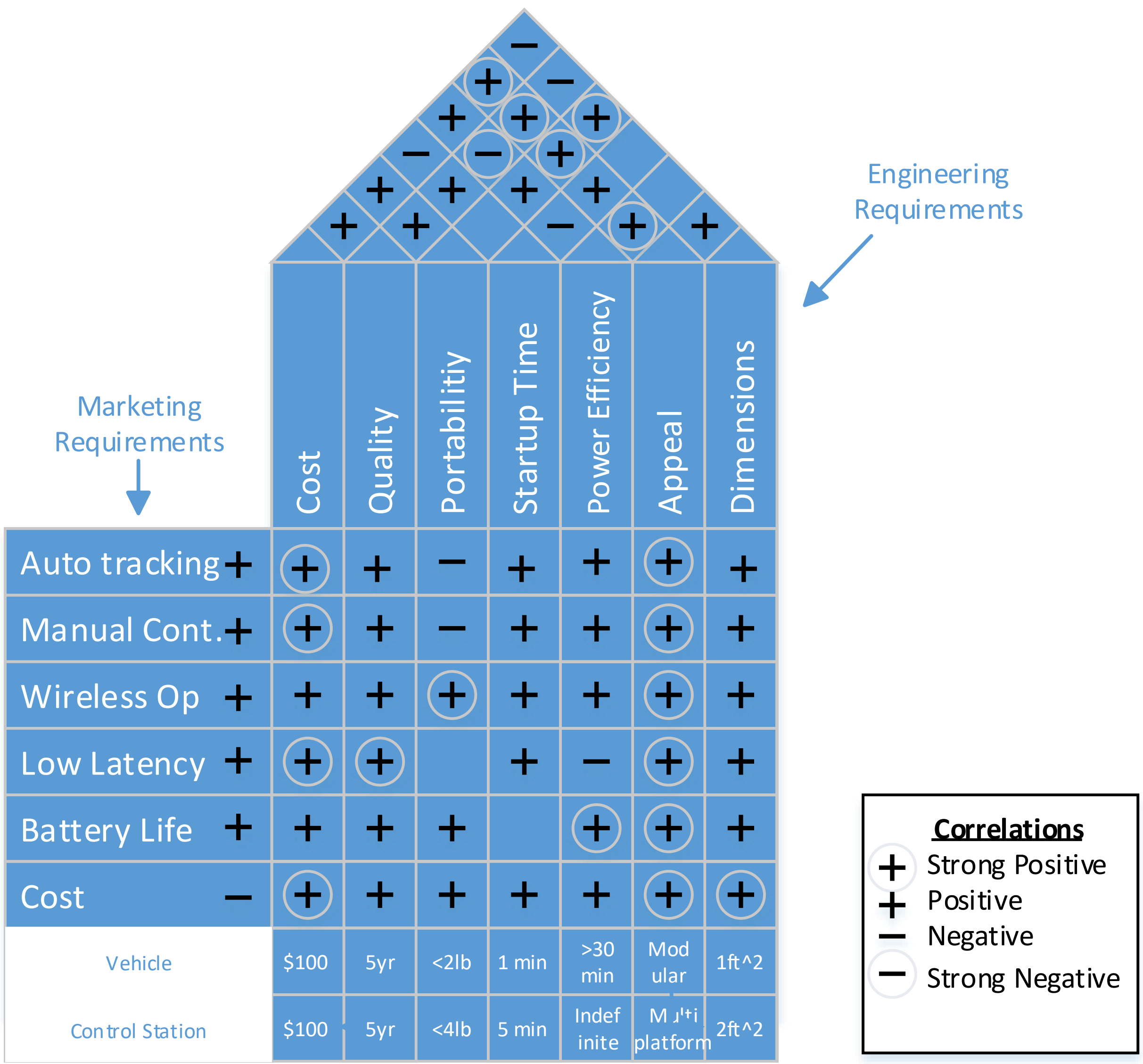

Figure 1 - House of Quality

Hardware Block Diagram

A rough concept design of the planned hardware control for our senior design project is shown in *figure 2*.

- Replaceable battery
- Microcomputer PCB is the master of this design, performs the calculations and provides control signal
- Some of the DATA lines are to provide a way for all the peripherals to relay information to the master.
- All the peripherals that have the same color are to be assembled as one single module
- GREEN: Battery Management System; YELLOW : Micro processing/detection ; BLUE : BMS subcomponents; Grey: Vehicle Platform Purple: Control

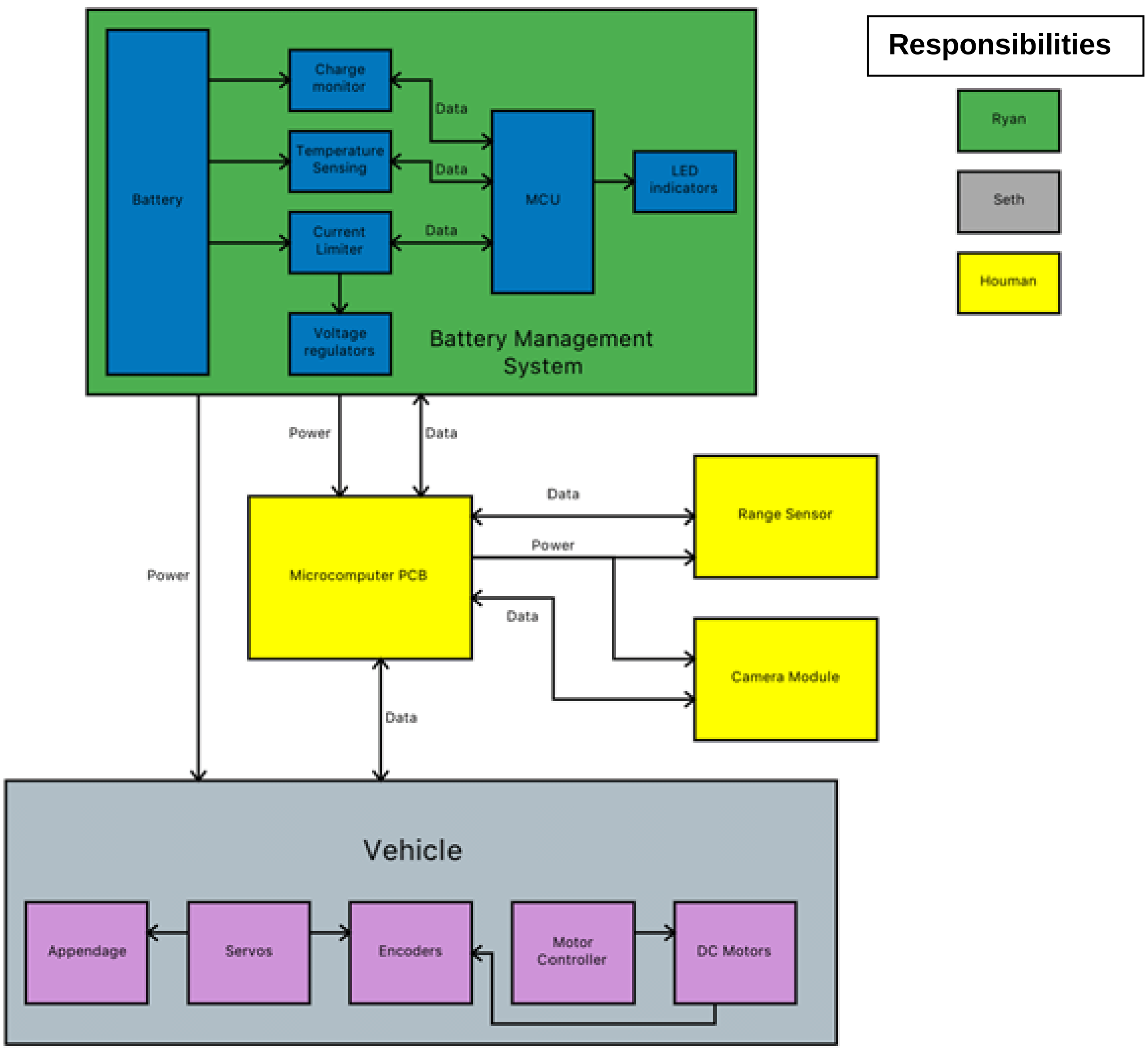

Figure 2 - Hardware block Diagram

Software Flow Chart

A high-level flow diagram (*figure 3)* shows how the robot will operate. The simplistic logic flow allows for low latency and high effieciency.

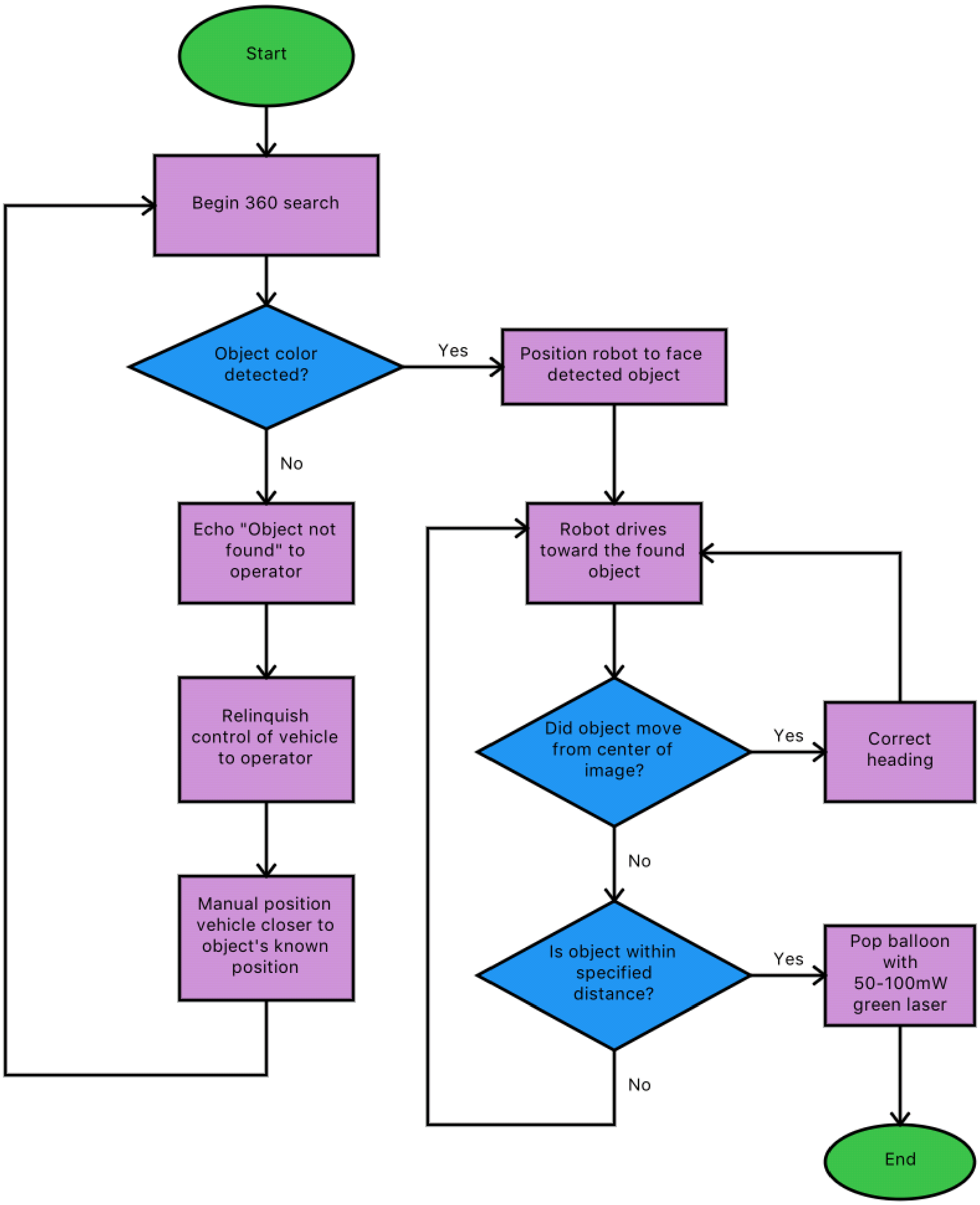

Figure 3 - Software Flow Chart

Estimated Budget and Financing

Many of the expenses have been forecasted in *Table 1*. We plan on reducing costs while delivering optimal performance. For this reason, the microprocessor will be the largest expense and has a wide range, due to the increased cost in computational power. The specific hardware will be determined after further research.

Table 1 - Projected Budget

Item Description	Price / Unit	Amount	Estimated Price
Microprocessor (Probe Vehicle)	$50-$300	1	<$300
Microcontroller (Ground Control Station)	$20	1	$40
Video Camera	$30	3	$90
RC Vehicle	$40	2	$80
Wireless Router	$100	1	$100
Rechargeable Battery	$20	2	$40
3D Printed Vehicle Enclosure	$20	2	$40
Printed Circuit Board	$100	3	$300
Depth Sensor	$150	1	$150
Green laser (50-100mW)	$15	2	$30