BUTTER PASSING ROBOT

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Contents

1. Introduction

1.1 Objective

As the artificial intelligence being popular nowadays, more and more robots have been created in order to make people's lives more convenient. For example, floor mopping robot can automatically detect the room area and absorb dust on the floor; smart audio speaker can recognize voice commands and play the specified music, etc. For this project, we want to build a robot that can detect the "butter" and bring the "butter" back to a fixed position on the table. Specifically , the "butter" means the yellow cube object. Our project's main goal is to recognize the yellow cube object on the table. This task can be mainly divided into two subtasks: the first one would be to implement an autonomous vehicle which can move by itself on the table; the second subtask would be to implement certain sort of software to help the vehicle detect the target location and direct itself accordingly.

1.2 Background

This project idea was inspired by the famous sitcom Rick and Morty. In one of the episodes, Rick built a tiny robot which keeps asking "What's my purpose?". Rick then tells the robot to fetch the butter, and the robot successfully achieves that.

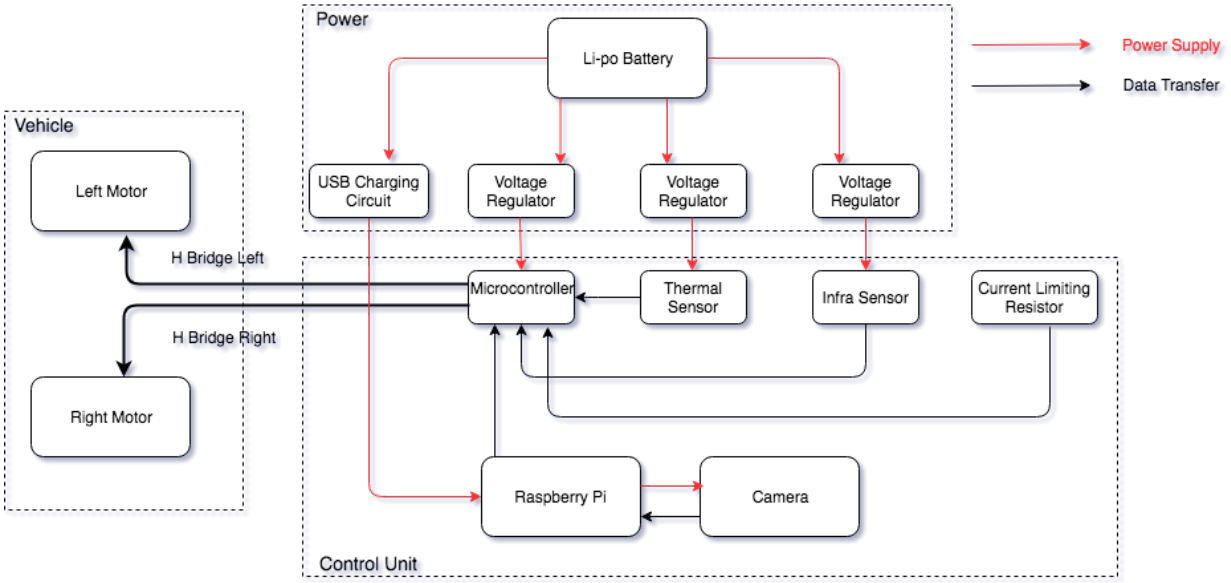
We plan to achieve the detection of "butter" by using Raspberry Pi and the cameras connected to it. There are several imaging processing code in openCV and we regard them as references for the software part.

1.3 High-level Requirement

- The vehicle can move by itself on a regular-sized(2m*1m) table.
- The vehicle can detect the edge of the table and it will stop in order to prevent itself from falling
- The object detection program can distinguish yellow, cubed butter from other common breakfast objects (juice, bread… etc) and direct the vehicle toward butter

2. Design

2.1 Block Diagram

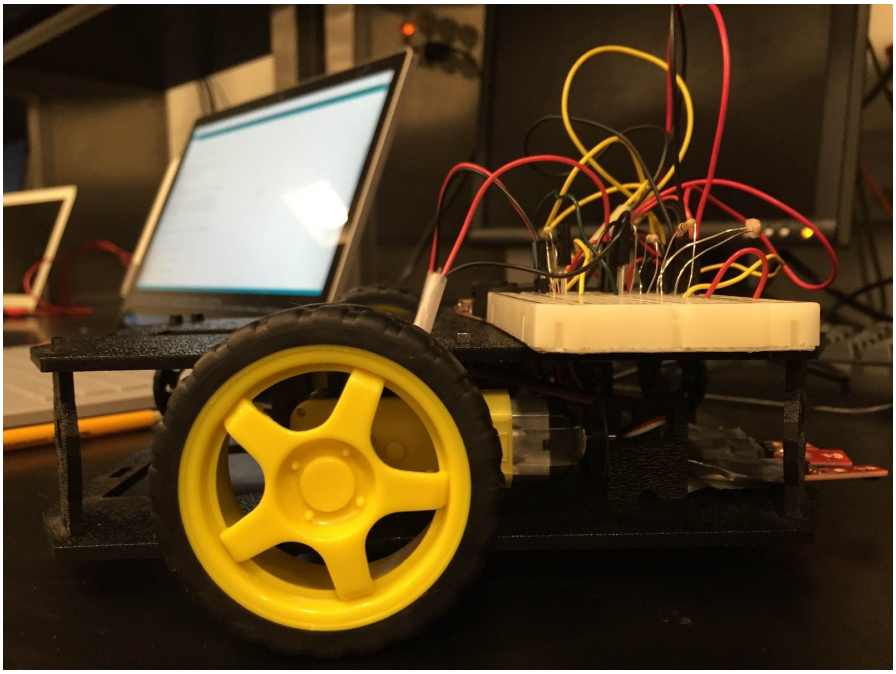


2.1.1 [Subcomponent or subblock]

To create a subsection head, go to the Styles gallery under the Home tab and pick Heading 3. It automatically formats as above and creates a table of contents entry (after you click the Update tab). Even lower level section heads can be created the same way, but they are likely unnecessary.

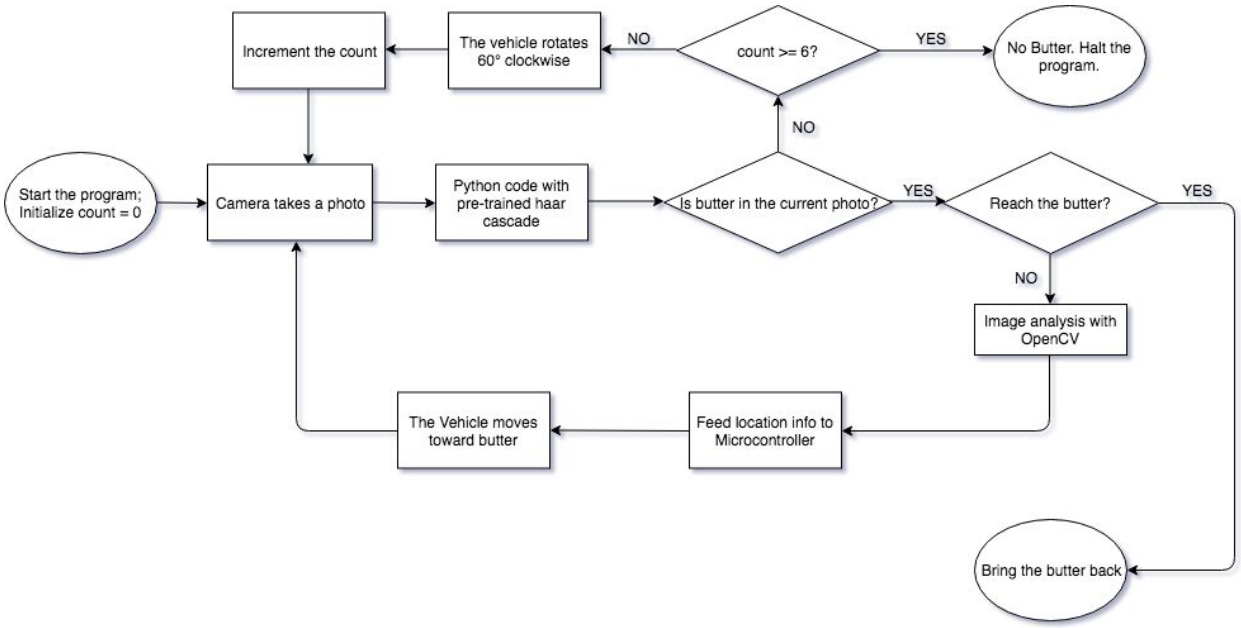
2.2 Physical Design

The physical design of our project is mainly based on the sparkfun vehicle. We will place, a Raspberry Pi with a camera and a PCB board (with sensors and a microcontroller) on the vehicle. To enable the vehicle to bring the butter back, we plan to add a small magnet extending out of the front of the vehicle and another magnet sticking on the container of the butter.



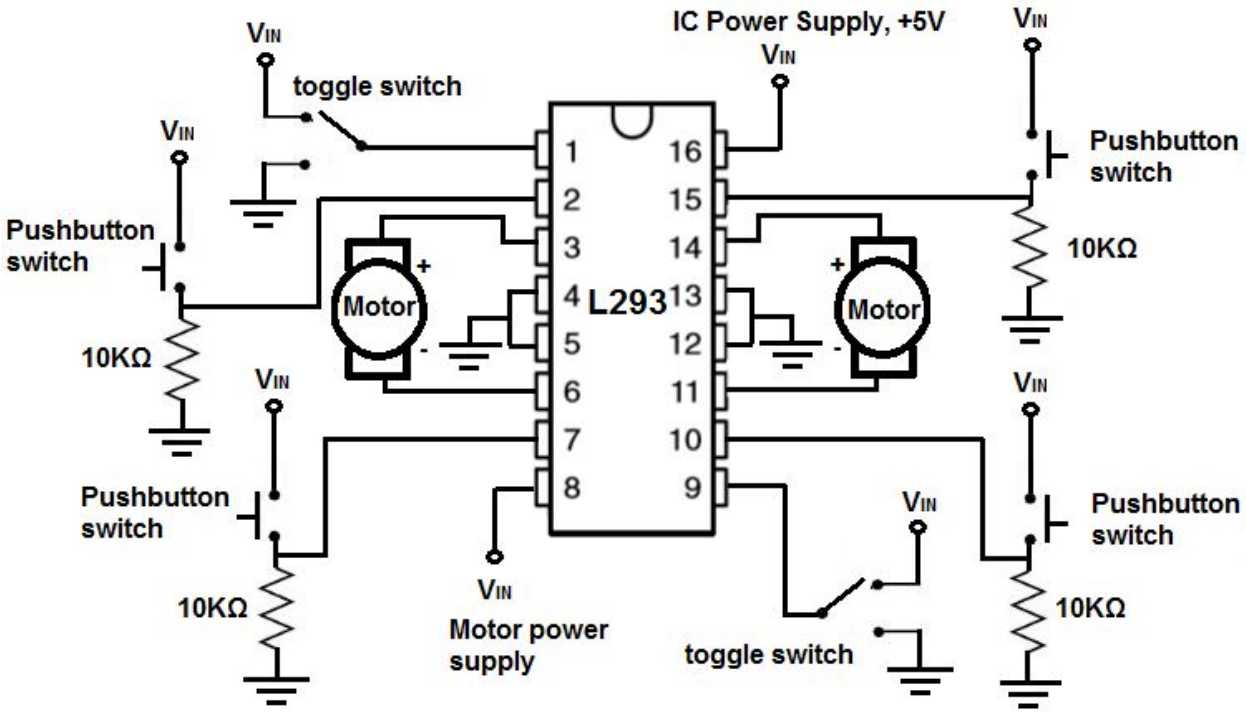
2.3 Block Design

2.3.1 Object Detection Program



Requirement	Verification
The program can finish processing an image in 0.5 s, so that the motor can always react in time	We will try different object detection approaches as well sa platforms: Cascade Classifier, CNN... If the raspberry pi does not have enough computing power for our purposes, we will consider using a wireless module and run the program either in cloud or on a remote desktop [cascade vs cnn]
The program can distinguish butter from other kitchen objects of similar color: orange juice, honey mustard	When training the classifier, we will feed in and test with images of similar-color kitchen objects
The program can detect yellow, cubed butter in the size smaller than 12cm * 3cm * 3cm[butter size]	When training the classifier, we will feed in and test with images of cubed butter at different sizes, different angles
The program can derive location information of the butter from the image	When running the classifier, we will loop the search window through the whole image, taking notes of the leftmost, rightmost positions with butter present. Since we know the field of view of v2 camera[field of view], we can calculate the angle to turn. [classifier]

2.3.2 Motor Module



Enable	Logic Pin 1	Logic Pin 2	Result
High	Low	High	Forward
High	High	Low	Reverse
High	Low	Low	Stop
High	High	High	Stop
Low	/	/	Off

The enable pins control the motors. If they are connected to ground, then neither of the motors can be operated. Through the H-bridge circuit, if the logic pin 2 of either motor is high, then the corresponding motor will spin in a forward direction. Similarly, if the logic pin 1 of either motor is high, then the corresponding motor will spin in a reverse direction. Once two logic pins are both low or high, then the motor will shut off. This is how we control the forward and reverse movement of motors.

2.3.3 Supporting Material

3. Cost and Schedule

3.1 Cost Analysis

The total cost of this project would be the sum of our labor cost and the cost to purchase hardware parts.

3.1.1 Labor

According to Engineering Career Services at UIUC[salary], the average starting salary for Engineering graduates from UIUC is $71,856. Dividing this number by working hours per year: 40*52 = 2080, we get the average hourly rate: $35. However, since we all haven't graduated yet, it would be more realistic to estimate our hourly rate to $30. Given the design of our project, we assume each of us will work 10 hours per week for 13 weeks. Thus, the total labor cost of this project would be:

$$\$30/hr/person * 3\ persons * 10\ hrs/week * 13\ weeks = \$11700$$

3.1.2 Parts

To successfully implement this project, we need to purchase some hardware parts. The following table gives detailed information about the cost of each component.

Table X Parts Costs

Part	Manufacturer	Retail Cost ($)	Bulk Purchase Cost ($)	Actual Cost ($)
Raspberry Pi 3B Motherboard	Raspberry Pi Foundation	35.91		35.91
Raspberry Pi Camera Module V2	Raspberry Pi Foundation	26.45		26.45
Total				

3.1.3 Grand Total

3.2 Schedule

Week	Objectives	Yuchen	Yuxiang	Yu Jie
02/19	Prepare for Mock Design Review; Finish Design Document	1.) Write the cost, schedule and block diagram section 2.) Requirement and Verification	1.) Write the objective, background and high-level requirement	1.) Write the functional overview and ethics section

			2.) Requirement and Verification	2.) Requirement and Verification
02/26	Research different platforms for object detection; Prepare for Design Review	Train a classifier for butter detection and test the computing speed	Research the H-bridge circuit	Research different hardware parts, design the circuit protection scheme
03/05	Finalize PCB design; Test the parts on breadboard; Get familiar with soldering	Train another object detection scheme using CNN, time the processing	Finalize PCB design. Test different parts on breadboard.	Finalize PCB design. Experiment with different sensors output range.
03/12	Finalize on the object detection method; Transfer the desired one onto Raspberry Pi; Test the first PCB board	Compare different software and transfer the most suitable	Test the circuit on the PCB board, check against schematic and simulation	Test the functionality of different sensors on board
03/19	Integrate the Raspberry Pi with microcontroller	Test software program output with manually fed images simulating the demo environment	Test signals going into microcontroller and adjust the input to H-bridge circuit	Test the functionality of the vehicle: rotation, movement
03/26	Check the functionality of the vehicle	Improvise on software;	Find issues with prototype, revise and may resubmit for final PCB design	Test all power supply, revise and may resubmit for final PCB design
04/02	Assemble all different parts together	Finish software code. Debug code to control prototype precisely	Work on physical installment of the project	Work on assembling final PCB and ensuring that power is delivered to PCB while it operates and spins
04/09	Debug	Final debugging and ensure that everything is	Final debugging and ensure	Final debugging and ensure that everything is

		operating correctly	that everything is operating correctly	operating correctly
04/16	Prepare for Mock Presentation	Mock demo preparation. Optimize code to run quicker.	Prepare for mock demo and help with communicatio ns issues from the motors	Prepare for mock demo and help with communications issues with the controller
04/23	Finish up on final report and summarize the work	Work on presentation and paper	Work on presentation and paper	Work on presentation and paper
04/30	Prepare for Final Presentation	Finish up final papers	Finish up final papers	Finish up final papers

4. Ethics and Safety

The major safety concern within our project is the use of a lithium battery. Failure in performance can be caused by poor execution of a design, or an unanticipated use or abuse of a project. Risks include the thermal stability of active materials within the battery at high temperatures. Lithium-ion battery fires and explosions come down to a problem of short circuiting. We need to check our circuit design in order to prevent it. Also, we should always place our battery in a safe position in order to prevent it from violent collisions, since the violent collisions will damage the separator and cause the electrodes to touch. If the battery be pierced(either by accident or deliberately), then short circuit will happen. Another safety concern of our project is current overflow. This can be caused by motor overheat or getting stuck. Current overflow can do damage to all the devices we have on the board and can also potentially damage our Raspberry Pi. In order to prevent this from happening, we will add some current limiting resistor to limit the current. [IEEE Code]

References

[1] *Motorola Semiconductor Data Manual,* Motorola Semiconductor Products, Inc., Phoenix, AZ, 2007.

[2] *Double Data Rate (DDR) SDRAM,* datasheet, Micron Technology, Inc., 2000. Available at: http://download.micron.com/pdf/datasheets/dram/ddr/512MBDDRx4x8x16.pdf

[3] Linx Technologies LT Series, web page. Available at: http://www.linxtechnologies.com/products/rf-modules/lt-series-transceiver-modules/. Accessed January 2012.

[4] J. A. Prufrock, *Lasers and Their Applications in Surface Science and Technology,* 2nd ed. New York, NY: McGraw-Hill, 2009.

[5] W. P. Mondragon, "Principles of coherent light sources: Coherent lasers and pulsed lasers," in *Lasers and Their Applications in Surface Science and Technology,* 2nd ed., J. A. Prufrock, Ed. New York, NY: McGraw-Hill, 2009, pp. 117-132.

[6] G. Liu, "TDM and TWDM de Bruijn nets and shufflenets for optical communications," *IEEE Transactions on Computers*, vol. 59, no. 1, pp. 695-701, June 2011.

[7] S. Al Kuran, "The prospects for GaAs MESFET technology in dc–ac voltage conversion," in *Proceedings of the Fourteenth Annual Portable Design Conference*, 2010, pp. 137-142.

[8] K. E. Elliott and C. M. Greene, "A local adaptive protocol," Argonne National Laboratory, Argonne, IL, Tech. Rep. 916-1010-BB, 2006.

[9] J. Groeppelhaus, "Java 5.7 tutorial: Design of a full adder," class notes for ECE 290, Department of Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, 2011.

[salary] Engineering Career Services, "Student Success". Available at: http://ecs.engineering.illinois.edu/outcomes/

[cascade vs cnn] Convolutional Neural Networks vs. Cascade Classifiers for Object Detection. Available at: https://dzone.com/articles/cnn-vs-cascade-classifiers-for-object-detection

[butter size] Size and Shape of Packaging, Butter, Wikipedia. Available at: https://en.wikipedia.org/wiki/Butter

[classifier]OpenCV Classifier Documentation. Available at: https://docs.opencv.org/2.4.13.5/modules/objdetect/doc/cascade_classification.html#cascadeclassifier-cascadeclassifier

[field of view] Field of View of Raspberry Pi V2 Camera, Raspberry Pi Forum. Available at: https://www.raspberrypi.org/forums/viewtopic.php?f=43&t=154155

[IEEE Code] IEEE Code of Ethics. Available at: https://www.ieee.org/about/corporate/governance/p7-8.html

Appendix A Requirement and Verification Table

An appendix is a good place for the Requirement and Verification Table from your design review. Below is a starter table. Including these details here will help to avoid lengthy and tedious narrative descriptions in the main text, which may not be of immediate interest to your imagined audience of company managers and professionals. Any requirement that is not verified should be explained either in the main text or the appendix. Note that both the pagination and the numbering of figures, tables, and equations continues from main text to appendices.

Table X System Requirements and Verifications

Requirement	Verification	Verification status (Y or N)
1. Requirement a. Subrequirement b. Subrequirement c. Subrequirement	1. Verification a. Subverification b. Subverification c. Subverification	
2. Requirement a. Subrequirement b. Subrequirement c. Subrequirement	2. Verification a. Subverification b. Subverification c. Subverification	
3.	3.	
4.	4.	