THE SHOES SORTING ROBOT

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Contents

1 Introduction

1.1 Objective

Nowadays robots are becoming more and more important in our daily lives. During hurricane Katrina, robots like isensys UAV and precisionhawk can collect data needed by rescue team in 7 hours that usually take people 3 days to get any other ways. During the Japan Tsunami, by using the sonar of Sarbot Interface, engineers were able to reopen a fishing port in 4 hours, when the fishing port was told that it was going to be six months before they could get a manual team of divers in. During these six months fisherman in Japan will miss the fishing season, which is the major economy for them. There are many more examples like these two that shows the improvement robots bring to people's life. Robots go places people cannot go and do things that people don't want to spend time doing, robots even do things new by assist us in innovative ways.

Our goal is to bring a house-use robot that helps people organize shoes. Our group comes up with this idea because it is really annoying when people get tripped over a shoe in the doorway. Disorganized shoes can be a mess but sometimes people just don't get time to organize shoes after they take them off. A clear entrance in the doorway can not only make it easy for people to go through but it can make house look nice and clean in the first sight. Organizing shoes is the principal goal of our senior design, but after we successfully build the robot, this application can be extended into organizing all kinds of things like dishes, toys, and clothes.

Therefore, we aim to build a shoe sorting robot to free people from spending time organizing shoes. We will build a mobile robot with chasis and arm, the robot will load a camera for vision and a load cell for sensing the weight. Our robot will initially awaiting next to the shelf, after people take shoes off, robot will come to the shoe, pick it up and place one shoe next to the other on the shelf.

1.2 Background

Our robot is built based on the scenario that shoes are scattered on a 60*60cm entrance mat with a rectangular shoe organizer next to it. A camera will be held above a certain height to capture the whole mat. Our robot is constituted of a 6 degrees of freedom end effector and a mobile chassis. It sits quietly next to the organizer when no shoe appears on the mat, after the camera detects any object, the car moves to the mat and start working.

The robot moves to the shoe that is closest and distinguish each shoe by color filtering and weight filtering. The image captured by camera records the size and color of the object. If that object size lies in a certain range we assign it as a "shoe". Otherwise we just ignore it if the size of the object appears to be too large or too small. And the load cell on the robot records the weight of every object. In this way we can decide if two things are a pair depends on their color, size and weight.

So far there is no such robot on the market, therefore this project will be novel. The hit of mobile vacuum cleaner in the market is an inspiration for us and we believe our shoe sorting robot will be popular if we make it affordable and reliable.

1.3 High-Level Requirements Lists

- The robot must be able to locate a shoe and successfully pick it up in 3 times.
- The robot must be able to recognize two shoes in a pair and place them next to each other on the organizer with accuracy of 60% .
- The robot must be able to sort shoes(at least three pairs) effectively and return to its starting position upon completion within 8 minutes.

2 Design

2.1 Block Diagram

Our overall design contains three modules: the control module, the robotic platform and power supply.

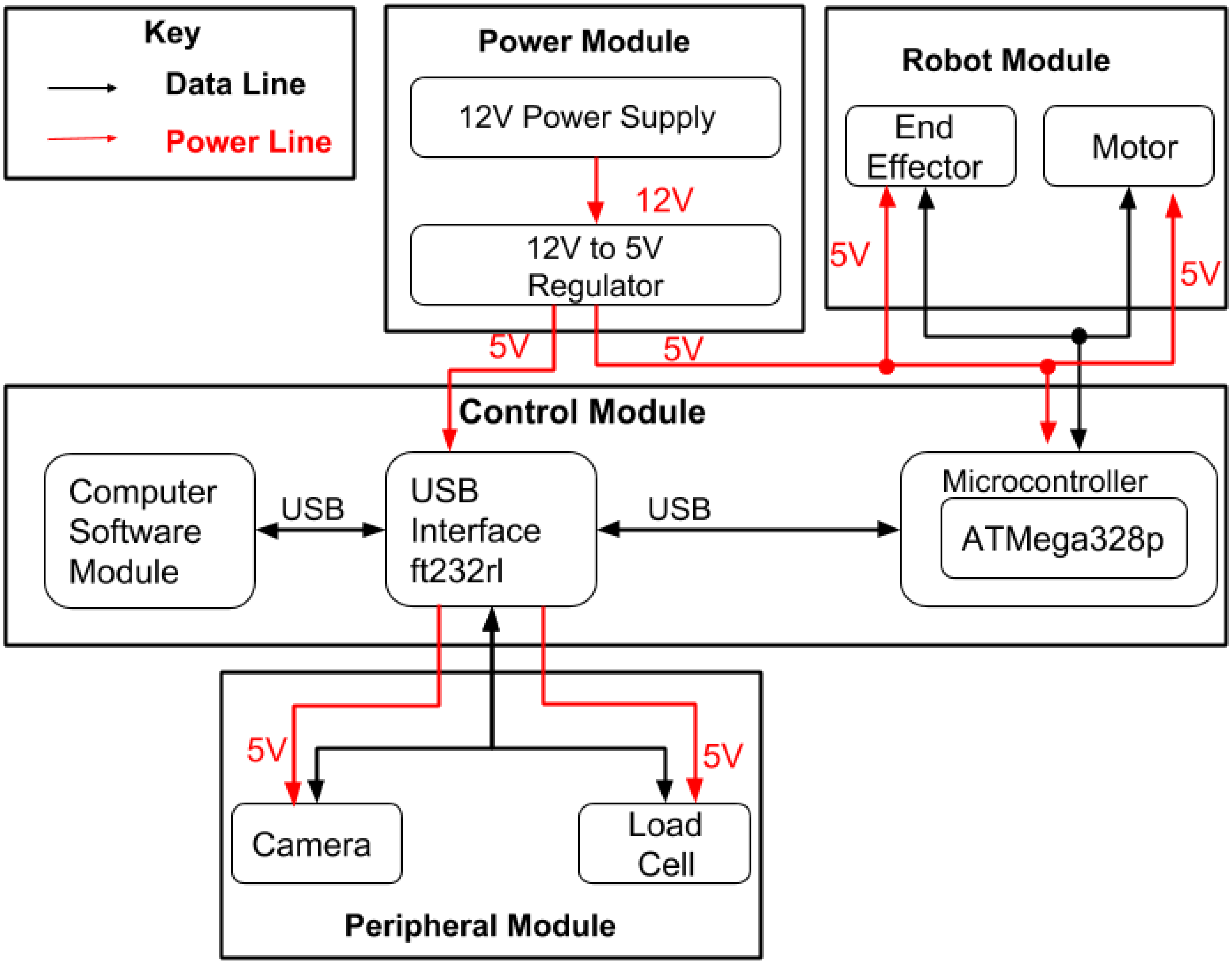

Figure 1.

2.2 Functional Overview and Block Level Requirement

2.2.1 Control Module

The control module collects all the data from camera, sensor, motor and end effector and sends and uses these information to lead the robot to pick up shoes and put them on shelf. It is powered by the power supply module. We test control module by giving a input signal 1 indicating object detection, if the output from microcontroller signals motor and end effector to start working, we think the control module can work successfully independent of other modules.

2.2.1.1 ATMega328p Microcontroller

We will use ATmega328p as our main control unit to accept data from USB Interface with USB ft332rl and send signals back to the USB Interface and robot module. This control unit also analyzes data with given code and figures out what the robot arm should do in the next step.

Requirement: Be able to communicate with the USB ft332rl and robot modules efficiently.

Requirement: Support 5V and 1MHz.

2.2.1.2 USB Interface

The USB Interface is used to transfer data between computer, Peripheral Module(camera and load cell) and the microcontroller Atmega328p. In addition, the 12V to 5V regulator inside the Power Module powered this interface so that it can then provide power to the Peripheral Module.

Requirement: Be able to provide 5V to Peripheral Module at 3A +/-5 %.

Requirement: Must have 4 ports and can be powered by the voltage regulator.

2.2.1.3 Computer

The computer receives image, applies filters to the image, vectorizes the image, converts the final vector image into machine code, and sends command to the ATMega328p over the USB interface. The computer will interface, through our USB hub, with microcontroller and peripheral module.

Requirement: Must have at least one port to communicate with USB ft332rl.

Requirement: Must be able to do image filtering and processing with up to 5s delay.

2.2.2 Robot Module

The robot module receives demands and data from the microcontroller and then controls the robot's movement through the end effector and two motors. We will test robot module by giving input signals to motor and end effector. If the end effector can start grabbing objects and motor starts moving when input signal is high, and end effector can let object go and motor stops when input is low, we think the motor module works fine independent of other modules.

2.2.2.1 End Effector

We will use a gripper that is able to pick up an object at around 500g. Although each shoe is around 300g, we plan to allow some discrepancies between shoes that might occur. The gripper has a maximum stretch up to 14 cm and can catch the object smoothly.

Requirement: Be able to catch the object at around 500g steadily. In our previous experiment, the average weight of 10 shoes is 376g.

Requirement: Must be able to reach every spot within our 60x60cm mat.

2.2.2.2 Motor

The robot chassis has two motors that are wired to the microcontroller and receives signals from microcontroller. The motors run in different speed according to the input values. The motor robot we build will have a rotational speed of 152 revolutions per minute.

Requirement: Be able to accelerate and decelerate smoothly within 5 seconds.

Requirement: The robot chassis must be steady and must guarantee not to turn over when a shoe(around 300g) is picked up by the gripper.

2.2.3 Power Module

2.2.3.1 Power Supply

The 12V voltage source will be the input of the regulator.

Requirements: Convert the 12V voltage to 5V DC +/- 5%

2.2.3.2 Regulator

The 12V to 5V regulator is wired to the USB interface**,** which supplies power to microcontroller and other peripheral components such as load cell and camera.

Requirements: Must supply steady 5V at 3A +/-5 %

2.2.4 Peripheral Module

2.2.4.1 Camera

The camera takes image upon instruction from computer and sends the image back to computer through the USB interface. We will test two elements individually in peripheral module. If the image captured by camera matches what shows on the mat, the camera is working properly; if weight we get from load cell is approximately the same as the weight we get from my digital body weight, we consider the load cell works fine as well.

Requirements: Must allow capture over USB ft332rl

Requirements: Must be able to capture the image of the 60x60cm mat

2.2.4.2 Load Cell

The load cell receives signal from microcontroller and send the weight of the object back to the computer through USB interface.

Requirements: Must have a load wearing of at least 300 grams

2.3 Physical Design

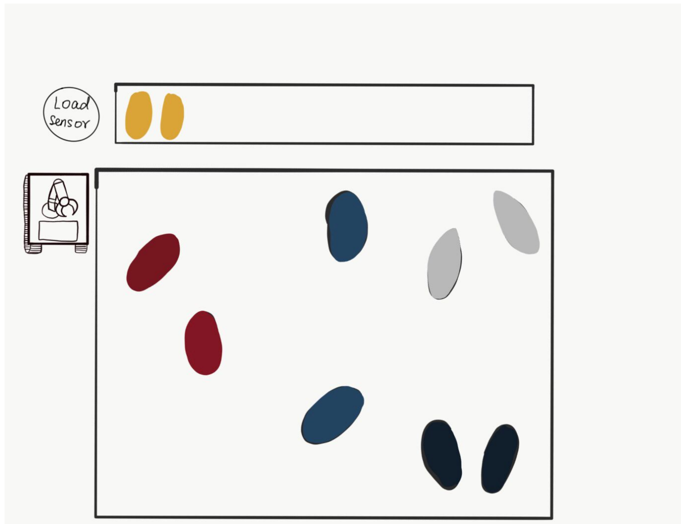

Figure 2.1

The physical design of our project includes a moving chassis with a robotic arm and load sensor on it, as indicated in figure 2.1 . The picture above shows the circumstance when the robot gets the signal of working. The big square in the middle is the shoe mat with four pairs of shoes with different colors. The rectangle above the mat represents the shoe organizer and robot sits on the side will move to the closest shoe when start working.

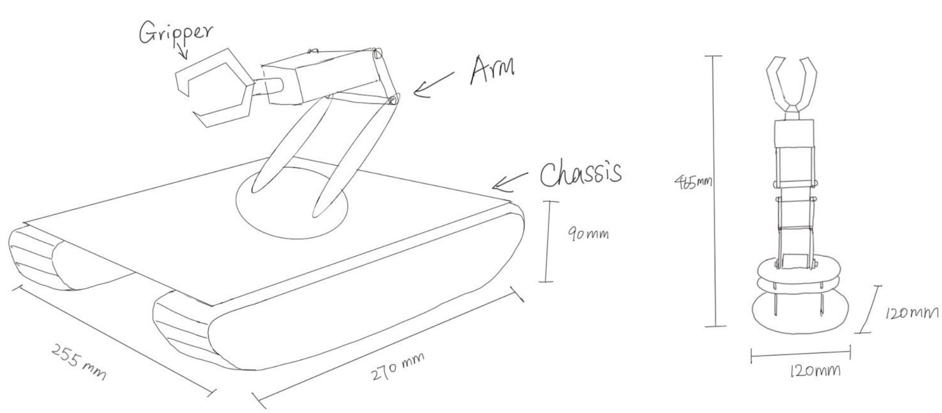

Figure 2.2

Figure 2.2 is the physical form of our robotic arm and it shows the dimension of the arm is 465*120*120mm. The picture on the left is the chassis of our robot and the dimension is 270*255*90mm(L*W*H).

2.4 Risk Analysis

The movement of robot will pose the greatest risk to this project. By using Inverse Kinematics, (we attach the formula below as figure 2.3), we can solve a path for robot to get to its destination. However, due to variables such as friction force, there are still many uncertainties that robot may not stop right next to each shoe. Our solution is to derive with a relationship between calculated distance and voltage So later on, after we get calculated distance between the robot and the shoe, we can know approximately how much voltage it will take the robot to get there. We are planning on testing the time it takes the robot to get to 30 locations on the mat with different distance given a power of 5 Watt and 1 second for time. In this way, we can know how much voltage it takes the robot to travel 20cm for example.Throughout the time, the camera will always track the current location of the robot. If the robot misses the designated position during first time, we will compute again and instruct the robot with a new path. If the distance is within the reachable distance of end effector, even if the robot misses destination it can stay still, we will adjust the end effector so it can reach the object by rotation. Ideally the robot will get to destination within three tries.

In the process of picking up shoes, there are two possible risks. The first one is how to control the angle of the gripper to line up with the shoe's angle so it is easier for gripper to pick. To solve this problem, we will try to find out the coordinates of two points that are near the toe and tail of each shoe and connect them to form a line. Then gripper will line up with that line and move to the midpoint to pick the shoe up.

The second risk is that the weight of the shoe, the load cell, and end effector combined together might be the too heavy. After the robot picks up the shoe, chassis might get turned over. If that happens, we are thinking about taking the load cell from the chassis and place it by the shelf. The robot will weigh the shoe every time before put it down. But if that is the case, the robot will take longer time to organize so we may need to increase the robot's speed to make up for that loss of time.

We will divide the test in several parts. For robot section, we will have three tests - picking up (to test if the gripper can successfully pick up a shoe in proper angle and position), robot moving while carrying a shoe(to test if the shoe will fall down), placing shoe on shelf(to test if the shoes can all be placed on shelf in one direction). For camera recognition, we will also have three tests - detecting the coordinate of each object, detecting the toe and tail coordinates of each shoe, detecting the current position of the robot.

$$T(\theta) = e^{[\mathcal{S}_1]\theta_1} e^{[\mathcal{S}_2]\theta_2} e^{[\mathcal{S}_3]\theta_3} e^{[\mathcal{S}_4]\theta_4} e^{[\mathcal{S}_5]\theta_5} e^{[\mathcal{S}_6]\theta_6} M.$$

Figure 2.3

3. Ethics and Safety

3.1 Ethics

After reading the IEEE Code of Ethics[1] and the ACM Code of Ethics and Professional Conduct[2], I think our project is compliance with all the Ethics requirements mentioned above. In our design, the shoes sorting robot is small and does not take much space. The maximum height of the robot is about 55.5cm but usually it only takes around 30cm. In addition, the robot will only pick shoes and will not harm people. The speed of the car chassis is slow and the voltage that needed for this robot is only 5 Volts, which is acceptable for human body and will not hurt others. The IEEE Code of Ethics #9, "to avoid injuring others, their property, reputation, or employment by false or malicious action", also support this idea. In addition, we will try our best to reduce any possible risk when using this robot, as according to IEEE Code of Ethics #1, "to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment"[1].

3.2 Safety

There are two underlying safety issues that we will face. The first one is that in our robot design, we need to convert 12V power to 5V 3A by a regulator. The 3A current might be relatively high with respect to human being and people will get hurt easily by improper touching. The maximum current an average man can grasp and let go is 16 mA and 2A current can cause cardiac standstill and internal organ damage.[3] In addition, the Lithium Battery with a poor wiring and bad connection will lead to safety issues as well. Therefore, we must make sure that the connections between elements are stable and are in good conditions.

The second issue is the risk of soldering. Soldering can be dangerous if we inappropriately manipulate the soldering tools. Also we need to be careful of the high temperature during soldering and remember to turn the tools off when we are done.

4. References

[1] “IEEE Code of Ethics”, Ieee.org. (2019).[online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html [Accessed 5 Feb. 2019].

[2]Acm.org. (2019). *The Code affirms an obligation of computing professionals to use their skills for the benefit of society*. [online] Available: https://www.acm.org/code-of-ethics [Accessed 5 Feb. 2019].

[3] Raymond M. Fish, L. (2019). *Conduction of Electrical Current to and Through the Human Body: A Review*. [online] PubMed Central (PMC). Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2763825/ [Accessed 7 Feb. 2019].