ENME 501 (Fall 2020)

Individual Contribution Report

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Team number 2

**1. List and briefly describe your contributions of engineering design, project management**

**and communication to the capstone design project. You may also discuss any other types**

**of your contributions to the project.**

As the capstone design project group # 2, our team has worked on researching, designing and implementation of two comparable autonomous control systems utilizing conventional sensing techniques and artificial intelligence techniques. The project has been designed to simulate a smart factory setting to study the effectiveness of the two control systems.

Engineering Design

In terms of engineering design, I have been responsible for researching, implementing, and testing the logics and algorithms for ball detection and movement. Furthermore, I have worked on generating the computer aided designs to help manufacture the frame of our robot.

List below are the major design tasks that I have contributed to.

* Designing and implementation of PID controller.
  + To design a PID controller, it is necessary to determine the plant transfer function that describes the dynamics of our robot. The transfer function would depend on various factors such as armature resistance, back emf constant and friction coefficient. Unfortunately, these parameters were not provided by the manufacturers. As a result, I have obtained the motor response using the rotary encoder and generated an optimization routine that best agrees with the response of our system. The result was a second order transfer function that relates the input voltage from our controller to the speed of our motor.
  + As a background research, I have investigated various PID tuning methods used in the industry. From this work, I have discovered Ziegler Nichols’ step response method, Chien-Hrones-Reswick method, and Cohen-Coon methods being widely used. Based on discussions with Hari, Ziegler Nichols method was chosen as the tuning method due to its popularity and method generally being suitable for motored application like our project.
  + Before implementing the PID controller onto the real system, it is necessary to validate that it would behave adequately for our system. To do so, I have developed a Simulink simulation to model our system response. Based on this simulation result, our group has decided that the designed PID controller would be good to be used in the real system.
* Research and implementation of object detection routine.
  + For the robot to carry out its tasks, it must detect and identify the objects (i.e different colored balls). Based on literature research, I have found a combination of Color Filter, Canny Edge Detection and Hough Transformation will provide suitable detection algorithm for our problem.
  + I have implemented the algorithm into a standalone Python script to continuously detect and identify different colored balls. Figure 1 shows an instance of ball detection using the algorithm.

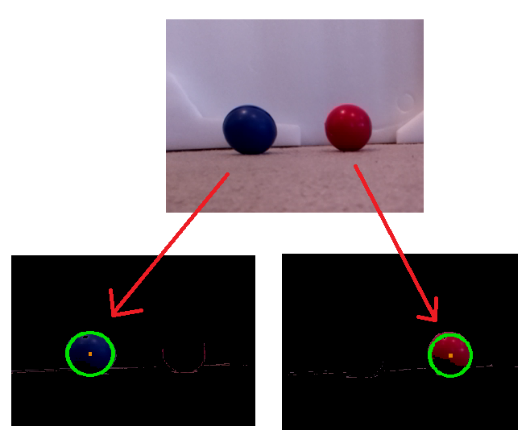


Figure 1: Detection of red and blue ball using the algorithm

* Implementation of robot position tracking algorithm.
  + For the robot to transfer the balls back to the respective inventories, it is necessary to keep track of real-time position of our robot. Since the rotating positions of the motors can be recorded using the encoders, kinematic equations were needed to calculate the robot position in 2D space. Syed has determined these kinematic equations based on geometry of the robot. Then, I have verified the calculations and implemented into a working algorithm.
* Designing the frame of the robot.
  + I have worked on determining geometry and positions of different components in the CAD design. This includes the location of claw mechanism, battery as well as the camera and lidar. Due to COVID restrictions, it was difficult to distribute the actual implementation of the work. As a result, it was most effective for me to determine the locations to allow minimal difficulties in program implementation. Once the preliminary design has been created using SolidWorks, Doowon validated the design and refined the geometry, assess for additional materials for connection such as bolts and nuts as well as conducting FEA to assess the integrity of the parts to be manufactured.

Project Management

In terms of project management, my major contributions include taking meeting minutes, managing/organizing project files and documents, as well as allocating budgets to the test setup.

* Taking meeting minutes.
  + The responsibilities of taking meeting minutes were divided evenly amongst the team members. This was necessary to always take note of important action items and follow up with sponsors, vendors as well as other team members.
  + The meeting minutes were taken using a templated created by Hari to maintain consistency and accuracy.
* Managing/organizing project files and documents.
  + To effectively work towards the project objectives, it is necessary to effectively manage and organize project files and documents. To do so, I have utilized the Google Drive to keep track of writings, presentations, meeting notes and videos. In contrast to other project files, the source codes and program algorithms were difficult to manage using Google Drive. Therefore, I have created a GitHub repository to manage source codes and program algorithms. Using the repository, our team members were able efficiently access their files and commit their changes.
* Budget allocation for test setup.
  + Due to the COVID-19 restrictions, University of Calgary campus could not be used to conduct our test runs. Therefore, the test setup was stationed at my house. Thus, it was most effective that I figure out the cost, size, and material required for the setup. In the end, our group was able to produce adequate setup for less than $50 from our total budget.

Communication

In terms of communication, my major contributions include formulating emails/calls with our stakeholder (Dr. Lee) and vendors, as well as communicating in the report, update meetings and presentation to the course instructor as well as Dr. Lee.

* Formulating emails/calls with stakeholder and vendors
  + The responsibility of reaching out to vendors, providing updates through emails and phone calls were split amongst the team members based on their expertise and tasks. Large portion of my tasks involved designing and implementation of the control system. Therefore, I have reached out to industrial automation companies and Dr. Lee to gain insights of program implementation.
* Project report and progress update presentations.
  + In the project report, I have written the design development (control systems and logics), background research on PID based control system and engineering analysis (PID tuning) sections. The materials covered in these sections mainly outlines the tasks that I have done. Furthermore, in terms of program implementation, I have periodically updated progress and difficulties as well as communicated any suggestions for different techniques and resources that may be utilized to our project sponsor Dr. Lee.

1. **Identify and explain two contributions that you are most proud of.**
2. In this project, I had the pleasure of researching and implementing the ball detection algorithm. There were various mathematical formulations and implementation routines that I had to familiarize myself with. Furthermore, I had to learn Python program to deliver the object detection algorithm as standalone script to be integrated with other functionalities of the robot. In the end, with a combination of color filter, edge detection and Hough Transformation techniques, the ball was able to be reliably detected using our camera as seen in Figure 1. I am very proud of it.
3. In this project, I also had the pleasure of designing the PID controller for the robot. Designing the PID controller required interesting tasks such as creating optimization routine to obtain the system transfer function, studying different tuning methods, and applying Ziegler Nichols tuning method for our system. Then, I have verified the use of controller on our model by creating a Simulink simulation. The designed PID controller allowed the robot to move in smooth and accurate manner. I am very proud of it.
4. **Identify and explain one contribution that you would plan to do differently if there is a second chance.**

In designing the frame of the robot, I have focussed too much effort into designing it from scratch. This was mainly because our group wanted the frame of the robot to be robust to potential design changes and improvements that could be made later. In many cases, this would not be an issue. However, given the timeline and budgets provided for this project, extra designing process can be impractical. Instead, more time and effort could have been spent on investigating and refining the control system as this is the main objective of the project.

I believe this was mainly because the project objectives were not clearly defined in the earlier stage of the project. Without a clear objective, our group had no choice to create the robot that is robust to changes. Once the project goal was clearly defined, it became easier to identify our needs.

If there is a second chance, I would try to define a very clear project objectives earlier in the project. Then, I would attempt to purchase frames that are available in the market based on the project goal. I believe certain components will be required to make from scratch. However, major part of the frame could be replaced with the components available in the market.

1. **Describe a scenario where you find the importance of teamwork collaboration toward the quality of your project delivery.**

There was an instance when teamwork was necessary to complete the requirements for our project deliverable. The final tuning of the control logics and algorithm is highly depended on the robot after it has been assembled. Therefore, it was necessary to finish assembling the robot few weeks prior to the project due date. Our group has recognized the need and postponed their own individual tasks to complete the assembly of the robot within 10 days in total. As a result, the timeline for the control system development was more flexible and our group was ultimately able to complete the required project deliverables on time. This would not have been possible without teamwork collaboration. The group recognized the necessary needs to complete the objectives, prioritized it, and we were successful in completing the project goals on time.