EE CprE 491 – May 1718
MicroCART Senior Design Team
Week 9 Report

October 31 – November 6
Faculty Advisors: Phillip Jones, Nicola Elia

Team Members:

Brendan Bartels — *Controls Software Key Concept Holder*
Kris Burney — *Ground Station Key Concept Holder*
Joe Bush — *Quadcopter Software Key Concept Holder*
Jake Drahos — *Team Webmaster*
Eric Middleton — *Hardware Maintainer*
Tara Mina — *Team Communications Leader*
Andy Snawerdt — *Control Systems Key Concept Holder*
David Wehr — *Team Leader*

Summary for Progress this Week

This week we had to work a lot on the Design Document, which had to be finished, or at least almost finished, by the end of this week. We met to discuss the general structure that was created for the Design Document template and why this structure made sense and was a good one to follow in general. This was the main focus of our work this week, since this document is such a large one, with lots of details needed to be figured out in terms of our design plan and ideas for the system as a whole, as well as each of its sub-systems in more detail. Additionally, we continued working on the quadcopter model in Simulink, and we did some restructuring of this model so that it is not only more organized, understandable, and easy to follow by future team members, but also so that it works in Simulink.

Past Week Accomplishments

- Continued working on the Design Document – All team members
    - Followed a general template created based on the course requirements and the Design Document of last year's team
    - Used Project Plan that we created as a reference for some of the sections, such as the Deliverables section
    - Included some of the testing data, including:
        - Motor speed prediction testing based off of its percent duty cycle
        - WiFi communication latency times
    - Met together to discuss what we needed to do for the document and how it is different from the Project Plan
        - Needs to include more details about preliminary testing we have done the past several weeks
        - Needs some brief analysis of our testing results to determine why our current design approach is a good one for
- Re-structured Actuation Block for Simulink Model – Andy

    - Had to change the actuation block since structs could not be passed in as inputs to other functions in Simulink
        - Originally were saving all model parameters of the quadcopter as a struct
        - Had a function block that would generate this in the model
        - Changed this setup so that a MATLAB function should be run before running the Simulink model, which would put all relevant quadcopter data in the workspace
    - Created masks for each of the function blocks to make it more simple to follow for future MicroCART teams
        - Used LaTeX notation to make it easier to read
        - Could represent almost all of the parameters exactly, except could not use dot-notation for representing the derivative of a parameter
    - Debugged the block when each of these changes were made
- Debugged the Actuation block to get outputs that made general sense – Tara and Andy
    - Only a general check, not checking for precision of outputs, mostly just checking that the quadcopter is rotating and moving in the right direction, and not in the opposite one
    - Originally, when testing the output of each of the Actuation block in Simulink, were getting results that would not make sense, for example:
        - At first, when changing the motor speeds for motors 0 and 2 (at the back of the quadcopter) to be greater than the motor speeds for motors 1 and 3 (at the front of the quadcopter)
            - Expected to see the quadcopter pitch (rotate about the y-axis) in the positive direction
            - But the quadcopter did not rotate whatsoever - 0 rotation in pitch
        - When speed for motors 0 and 1 (on right side of quadcopter) were greater than the speed for motors 2 and 3 (on left side of the quadcopter):
            - Expected to see the quadcopter roll (rotate about the x-axis) in the negative direction
            - But the quadcopter instead rolled in the positive direction
    - Reviewed the signs of each of the rotation matrices
        - These matrices convert the rotation speeds of each of the four motors to a change in angular rotation of the quadcopter
        - Found some sign errors with the elements of these matrices
        - Made changes to make the sign errors accurate
    - Reviewed the signs of the gamma vectors of each of the motors
        - These vectors give the rotation of each of the motors a sign that gives them a thrust that is in the correct direction of the z-axis (which is positive downward)
        - When reviewing these signs, they seemed correct
        - However, we tried switching the signs anyways, and this also gave us results that made more sense
- Continued working on documentation tutorials - Tara
    - Finished the data collection description section of the Measuring Motor Resistance documentation
    - Measuring Motor Resistance documentation is basically completed

        - All important points are included
        - Includes all relevant directions and instructions for doing the setup and taking measurements
        - Need to just add some photos to mirror what is being described in the text for a more insightful understanding of the process
- Investigated WiFi high latencies - David, Kris
    - 921600 baud rate between the WiFi module and Zybo board may be unreliable. We occasionally ran into issues with corrupted data when using it, and switching to 115200 seemed to help. We're not certain that the issue is the baud rate, but it's something to watch out for.
    - Unable to find a solution to the high TCP latency, but seem to have pinpointed where the issue is.

Pending Issues

- Unable to get desired TCP latencies - David, Kris
    - Round trip latency between quadcopter and ground station
    - Wanted it to be below 50 milliseconds
    - Problem is likely occurring because of delayed acknowledgement, need to investigate more

Individual Contributions

Team Member	Contribution	Weekly Hours	Total Hours
Brendan Bartels	Design document, software diagram	6	62
Kris Burney	Design document, WiFi latency	6	83
Joe Bush	Design document, quad software	8	64
Jake Drahos	Design document, client software	4	43
Eric Middleton	Design document	4	80
Tara Mina	Design document, Actuation block debugging of model, continued updating documentation	10	89
Andy Snawerdt	Design document, rotor speed error calculations, duty cycle operating range calculations, model	13	92
David Wehr	Design document, WiFi latency	10	78

Comments and Extended Discussion

A decent amount of work has been done on the Design Document this week, which has helped us gain a better sense of where our progress on the project has been so far, in comparison to the progress we want to achieve by the end of this semester and the end of the year. Although it initially feels like the Design Document can be a drain on our time spent on actually doing work on the project, once we get started working on it and making updates to our design ideas and methods, and consider from a step back our progress so far and our end goals for the project, it helps us gain a better perspective on the project as a whole. Furthermore, it helps us gain a better understanding of what we need to achieve and by when, and understand the long-term milestones we need to maintain for our project to be

successful, instead of fixating on the work we are doing each week on a particular aspect of our respective sub-system, without reflecting on how this fits into the objective of the project as a whole.

Plans for Coming Week

- Work on Project Plan version 2 – All team members
    - Need to meet to address some changes we need to make in the current document:
        - Changes wanted by Dr. Jones, such as including more figures
        - Changes wanted by the senior design course including:
            - Deliverables section organization
            - Reference section
            - Citations
        - Changes we as a team want to make to the document
        - General revisions to make document better, more organized, and more clean
    - Need to meet with sub-teams to discuss general updates we need to make to the current project plan
        - Add anything new to the plan, including more detail, now that we have done more and have a better sense of our respective subsystems
        - Update the preliminary design approach to be more detailed now that we have thought about it more, especially after doing the Design Document
    - Due on Sunday, November 14th it seems? (not very clear due date on Blackboard)
- Work on Sensor Block in Simulink – Tara and Andy
    - Now that Actuation block is done and seems to be working well, need to begin the next functional block, which will represent the sensors on the quadcopter including:
        - IMU
        - Gyroscope
    - Not something that is represented in Matt's thesis
    - More complicated than we originally were thinking, will need to schedule a time to meet with Matt and/or Ian to discuss how to approach this
        - Possibly need to do more testing on these sensors
        - Will discuss our tasks for modeling this block with them
    - Also need to discuss with Brendan about the code setup currently for doing the calculations on the data received from the sensors
- Continue improving communication on quad side - Eric
    - Finish implementing real-time logging
    - Convert any human-readable messages to binary packets
    - Work with ground station team to identify any more packets that would be useful to implement
- Hardware improvements - Eric
    - Try to find last year's WiFi module cable, or make new one
    - Find and order a LiPo-safe charging sack
    - Research better storage system for batteries
    - Organize with Lee and FP&M to have bloated LiPos disposed of
- Quad software analysis - Joe
    - Removing memory leaks
- Figure out TCP latency - David, Kris

- May involve switching to UDP, or implementing a packet parser on the WiFi bridge to prevent premature sending

Summary of Weekly Advisor Meeting

This week during our weekly meeting, Dr. Jones gave us certain recommendations for things we should be doing for keeping up-to-date with our documentation which will be used for future years' teams. He also explained the purpose of each location where documentation is included. Furthermore, Dr. Jones also made some recommendations to follow when describing things in our documentation. With this, he gave us pointers on key phrases that we should avoid in our documentation because it could be misleading, and more generally, simply incorrect, such as saying we are developing an "optimal" control system. He also explained what statements in our documentation would require additional information, by the nature of the statement, since without such information, the statement would be essentially meaningless.

We also discussed some problems that each sub-team has been having with the entire group, and discussing our approaches for fixing the problems, as well as helping figure out what the best plan of attack would be to do next. The controls sub-team discussed issues they were having representing the motor speed given the percent duty cycle of the PWM signal to the ESC, but after discussing this issue, the entire team decided that the error (about 15%) was not significant enough to be concerned about at this current moment, and that the sub-team should simply continue developing the Simulink model and only be concerned if it creates issues with our controller design.

- Dr. Jones's recommendations for the website and Wiki:
  - Wants us to be updating the Wiki
  - Wants us to give a link to the website
  - If we are uncertain as to what to put on the website or the Wiki, here is a good rule of thumb to follow:
    - On the Wiki, we can put our "how-to" documents for future MicroCART teams
    - On the website, we can put our general information for MicroCART project
  - Also, don't be worried if there is some overlap between what is on the website and what is on the Wiki page
- Select Problems:
  - Issues have been figured out - mostly have not been using Select correctly
  - Dr. Jones's suggestion: if the mistakes were something common, like a common "pitfall", then it may be useful to write some documentation on it for future MicroCART teams
- Dr. Jones's note on our descriptions in our weekly report
  - When we write "accurate" or "carefully" in our weekly report, we have to make sure we have some quantitative value associated with those statements
  - In other words, we have to indicate how accurate something is or is not
- Problems with Controls Team and representing the motor speed:
  - Taking the PWM signal, and using its duty cycle is the only thing we are changing
  - We are using this percent duty cycle to predict the motor speed of the motors on the quadcopter, using some of the expressions in Matt's thesis
  - Graphed the predicted motor speed and compared it to actually measured data from each of the four motors

    - Sometimes we would be 10 or 15 percent off in parts of the graph
    - According to Paul, some error is fine, and this 10 or 15 percent error may not be an issue, and may be somewhat negligeable compared to the variation between different motors themselves
    - However, the motors themselves were significantly closer in their variation than the expected motor speed curve
    - Another issue: do not know how the ESCs are working, since we do not have any documentation on them
    - Paul believes we should not be too worried about this error
- Another documentation thing to be careful about: Saying "optimal" control system
    - This means something very specific and very different from what we are doing
    - In fact, this means a mathematically optimal solution that gives us minimal error
    - Definitely not that rigorous of an approach, for what we are doing
- Dr. Jones's recommendation:
    - When putting the control system we design on the quadcopter, he agrees that we have to make sure it is stable in simulation
    - However, we have to recognize that our model is uncertain, as well, so we have to still be very careful when putting it on the quadcopter
- Software diagram updates:
    - Added some loop indications to the software diagram
    - Understanding the code base should be done very soon
- Note for this week:
    - The design document is due by the end of the week
    - Should take a lot of time
- To-dos for this week:
    - Eric:
        - Update logging and convert all ascii messages to binary
        - Suggestion from David: Could maybe help out the WiFi connections to the quadcopter, because it is just hanging on right now
    - Brendan:
        - Continue working on the software flow diagram
        - Add to the website
    - David:
        - Working on the WiFi latency and trying to decrease the latency time
        - Looking over the software code flow as well
    - Jake:
        - Finishing the front end applications of the ground station
        - The backend is currently stable
    - Controls Team:
        - Work on the design document, for sure
        - Not worrying about the doing the testing of the ESCs
        - Model is on Git currently if anyone wants to look at it
        - Looking at the sensor side of things next
        - Working with Brendan to learn how the data from the sensor will work with the model, since we have to model this in Simulink

- Joe:
  - Will be gone for interviews this week
  - Plan to finish code analysis
  - Plan to look for more memory leaks
  - Work on the design document