Lab 6: Bench-Top Testing of Gondola Hardware and Software (2019S)

Preparation

Reading

Lab Manual

Chapter 7 - Control Algorithms

RPILMS

Gondola Info

Objectives

General

- Port the heading (steering) and altitude (speed) control systems developed in Lab 4 to the *Blimp Gondola*. The *Blimp Gondola* mounted on the turntable in the classroom replicates all the flying and control characteristics of the actual blimp. The turntable has a fan mounted to simulate the tail fan of the *Blimp*. The gondola is mounted upside down in the studio just to allow variable ranger readings.

Hardware

1. Recognize the similarity between the thrust fans and tail fan on the *Gondola* to the car drive motor and steering servo, respectively.
2. Become familiar with the layout and design of the gondola and the sensors placed within it.
3. The wireless radio frequency (RF) link permits communication between the *Gondola* and your laptop. Use the LCD display and number pad or terminal to set 1) desired heading, 2) proportional and derivative gain for the heading control loop.

Software

1. Transfer the integrated code used on a *Smart Car* from Lab 4 and apply it to the gondola of the *Blimp*. As usual, the measurement from the compass with the desired heading controls the direction of rotation.
2. Implement proportional and derivative (PD) control based on the measurements from the compass. Note that you may change control gain constants by altering DIP switch states after the code had been downloaded using the keypad and LCD display.

Motivation (Historical)

Now that the integrated software has been tested on the *Smart Car*, we will make slight modifications to the code so that the code can be run on the *Gondola*. The simplest *Blimp* control is Hover Code, where the embedded controller causes the *Blimp* to maintain a constant altitude and a constant heading. The electronic compass is used to read the actual heading. This is compared it to a desired heading and the control algorithm sets a pulse width for the tail fan based on the error. The *Blimp* uses a speed control module to control the tail fan. That module uses PWM signals that are only slightly different than those for steering servo of the car. In addition, the *Blimp* requires proportional plus derivative feedback control, P&D. Therefore, with respect to the heading control, code developed to steer the car based on the compass reading can be ported to the gondola on a turntable with only two changes: the PWM range and the control algorithm. The desired heading and the gain constants are set using the number pad on the LCD display/keypad module or keyboard input on the terminal.

Normally, concurrent with the need to control the heading of the *Blimp*, is the need to control the altitude. The *Blimp* is propelled by two thrust fans. The thrust fans have two control values, the thrust angle setting and the thrust power setting. The fans are mounted on a shaft that can be rotated by a servo to change the thrust angle.

Traditionally for altitude control the thrust fan angle is adjusted so that the fans are horizontal (and left in that position) and the thrust is vertical. In this situation, the altitude can be controlled just by adjusting the pulse width to the fans. If the *Blimp* is near the floor, the fan power should be set to maximum. If the *Blimp* is at the desired distance from the floor, the power level should be set low (neutral pulse width). And if the *Blimp* is too far from the floor, the thrust should be reversed. To do this automatically, a PD controller for altitude is required for the *Blimp*, but it can't be fully tested using the gondola on the turntable. (Traditionally, a more complete test was possible in Lab 7 using the actual *Blimp*.)

The **enhanced control** instead rotates the thrust fans to be vertical – the same orientation as the tail fan. In this orientation they will triple the force available to rotate the gondola on the turntable and provide a much stronger and faster correction to heading errors indicated by the compass. The 3 fans will be driven equally, but remember that the left and right fans must spin in opposite directions to augment the tail fan. Code must be added that sets and fixes the angle of the thrust motors to vertical and implement a PD controller for the thrust power.

New objectives will be specified every semester that use the 3 fans in different ways or some not at all. Make sure you understand the current goals for your semester. For the Summer 2019 semester the 3 fans will be used for control to turn to the initial heading. Only the side fans will be used for control to a second heading. Only the tail fan will be used for control to turn to a final heading. When implemented, the side thrust fans will be vertical, spinning in opposite directions so as to not counteract each other.

In the debugging it is helpful to set the feedback gains (P & D) to 0 and then adjust them one at a time to verify correct operation.

The gondola has a radio frequency link to allow 2-way communication for data between the *Gondola* and your laptop. These RF modules **are different** than the ones used in Labs 4 and 5, with one half of unit mounted on the gondola hardware. Make sure you are using the matching module for the blimp (again, not one you used in the previous laboratories). **The black transceiver box on the table with the gondola should always be left on the table.**

Lab Description and Activities

It is your responsibility to find a division of labor in this laboratory. Note, watching your partner(s) code is not considered a division of labor.

Summary - Compass

1. **For the Summer 2019** Implement a 3-stage control algorithm: 1) Using the keypad, enter a desired heading and use a PD algorithm to turn to that direction using all three fans 2) After 20 seconds, the desired heading should change by +/- 120^o and a PD algorithm should be used to turn to that direction using only the side fans 3) After another 20 seconds, the desired heading should change by +/- 120^o (in the same direction as stage 2) and a PD algorithm should be used to turn to that direction using only the tail fan. The direction of change should depend on a slideswitch connected to P3.7, +120^o if HI and -120^o if LO.
2. Test on turntable with different values of gain constants and rotation speeds that determine the switching point between fast rotation and the slower rotation for correcting the heading error.
3. Include code to adjust the tilt angle of the side fans. Since every gondola will have a different thrust angle when the controller is in the neutral position, your code should include a routine that allows you to manually adjust the angle so the fans are vertical when initializing everything. Code from Lab 3-1 should be considered here.
4. Use the LCD display and number pad or RF link to set initial desired heading, heading proportional gain constant, and heading derivative gain constant.
5. Use one combined printf() statement that includes desired heading, actual heading, ranger reading, heading angle adjustment, thrust pulse width, and battery voltage. The modified desired heading may be printed less frequently to save time and reduce clutter. This should be printed in columns (separated by commas) to allow later processing and plotting using Excel or MATLAB

Hardware

Gondolas placed on turntables are located in the LITEC studio. These will be used to emulate actual *Blimps*. A ranger sensor, a compass sensor, C8051, LCD display/keypad, and all the necessary wiring is already installed within the gondola. Familiarize yourself with the placement of the hardware components inside the gondola. One of the major differences between the *Blimp* and this mock-up is that the ranger is still facing upwards while on the *Blimp* it would face downwards. You will be downloading your code onto the C8051 inside the gondola.

Software

Although teams were allowed to choose a capture compare module (CCM) in Labs 3 and 4, the CCMs used by the ranger and compass are preset. They will be specified by the instructor in class. Modify your functions so that the pulse-width modulated signals based on the ranger and compass readings are output to the appropriate CCM.

Since the hardware in the gondola has already been implemented, the Port pin connections are fixed. Check the **Gondola_info** file on LMS for the latest up-to-date configuration data. If the gondola uses 4 Capture/Compare Modules with CEX outputs on Port pins P0.4, P0.5, P0.6 and P0.7. then the crossbar setting is (2019 Summer):

```
XBR0 = 0x25;
```

Make sure to use the selected feedback control statement from Worksheet 11 (worksheet_11.c) in your code. For the compass, allow the user to set a desired heading at the start of your program. The code uses that desired heading and the measurements from the compass to implement a proportional plus derivative control algorithm. At first, set the derivative gain to zero, so that it is purely proportional control. The control algorithm should modify the duty cycle of a PWM signal sent to the tail (and vertically oriented thrust fans in some semesters

Thereafter implement a proportional and derivative control algorithm. Test different values for the proportional and derivative gains. Print the values of desired and actual heading that will be plotted later using Microsoft Excel or MATLAB.

Data Acquisition (Worksheet 11)

As a final check of your control calculations you must set a fixed desired heading and manually rotate the gondola a full 360° turn, observing the values of the compass reading, the error calculation, the feedback control and the fan motor PW calculated by your control value. For this you should switch off the fan motors using the 3 switches on the side of the gondola since you will only be observing the values. For simplicity set the derivative gain kd to zero. This exercise will validate two items: the accuracy of the electronic compass (you may want to compare values with a mechanical compass) and the correctness of your control calculations. With improper use of long integer calculations in C it is possible that the control values will be incorrectly calculated for certain angles and this exercise will allow you to detect and fix those errors much more quickly. Starting at the desired heading angle, the control should be 0 and increase (or decrease, depending on the rotation direction) until the error reaches 180°. Passing this angle should flip the error and the control value as you continue on back to the desired heading. If any anomalies occur in any values the way the program calculates the results should be checked. If the electronic must be calibrated, do so and then repeat this exercise.

When your code is functioning correctly, gather data to plot response curves for your steering control. You should plot actual heading (y-coordinate) vs. time (x-coordinate). In order to save the data, you will need to print the heading to the terminal screen that is set to copy what is printed to a log file. Then import the file to a plotting utility, such as Excel or MATLAB. Read the **Terminal Emulator Program** section in the **Installing_SiLabs-SDCC-Drivers** manual on LMS for more details. You need to obtain curves for different gain combinations. The following settings are to be tried to help you gain a feel for how the system responds, however you also must also find an “optimal” setting. You should also look at other combinations to verify trends. Testing and discussing the following represents a typical effort and that will be considered when the report is graded.

2019 Summer: Include one plot of an “optimized” best response. Three other plots must be in the report. The other plots should clearly demonstrate an overdamped response, an underdamped response and any other response characteristics you think are interesting.

Lab Check-Off: Demonstration and Verification

1. Complete the entries in your lab notebook and present it to your TA.
2. Explain to the TA how P&D control works on the gondola.
3. Explain how the control to stop the gondola spinning works.
4. Show the TA the heading vs. time graphs for the eight required cases and your optimal settings. Good performance is indicated by a short rise time, low over shoot and short settling time.
5. For the graphs in 4. show responses to both forced changes in the gondola's position as the desired heading remains fixed.
6. (Optional if used in an enhancement) Demonstrate how the orientation of thrust motors' axis changes with changes in pulse width of the PWM signal to thrust angle servo.
7. Your TA may ask you to explain how sections of the C code you developed for this exercise works. To do this, you will need to understand the entire system.
9. Print the output to the terminal screen in the following format similar to

```
Des. Heading   Heading      Error     PW
      xxxx,      xxxx,       xxxx,    xxxx
      xxxx,      xxxx,       xxxx,    xxxx
      ....,      ....,       ....,    ....
      xxxx,      xxxx,       xxxx,    xxxx.
```

Enter the full schematic of the circuitry. You must show the pins (and hence which CCM) that are connected to the components on the gondola. You know enough to create the schematics even though you don't do the wiring. The inputs use the SMBus, the outputs use the PCA. The power modules and the thrust angle servo are black boxes with three wires; input, power and ground. The DIP switch is connected to Port 3.

Describe any modifications you made to the code from Lab 4 to allow it to function on the gondola. Make comments about the performance (heading and ranger values) with both high gains and low gains.

For each set of gains, print the actual and desired headings. Use the capture command within the terminal emulator to save these values in a file. Open the file as an Excel or MATLAB CSV file and graph the pulse-width modulated as signals over an interval of 15 seconds. Title these graphs.

Writing Assignment - Gondola Report

You will be submitting a single design report detailing the operation of your *Gondola* (except Lab 7, if applicable). The report covers the development of the Lab 6 controller. Some of this report may be written while working on the lab. Once Lab 6 is functioning, the report can effectively be completed with the response plots. This should include a brief discussion of response curves. Detailed information about writing the final report can be found in the sections *Embedded Control Design Report format* and Grading *Gondola Report Guidelines*. A rubric for the report follows.

Lab 6 Gondola Report

Group names: ______________________________ ______________________________ ______________________________

The following list is a suggestion of material that would logically be included in the report. It is not intended as a direct guide. You have done the experiments, so you have the best idea of what you needed to complete those projects and what you learned during the process. This means that the following information may be incomplete based on your experience with the project. If you feel part of what you did during the laboratory is pertinent, include that information.

(suggested # of pages, but you may go higher)

Introduction		(<1pg)	**5**	
Purpose/Objectives	______	______		
Overview of gondola feedback control		______	______	*Sum:* ______
Results, Analysis & Conclusions		(1-2pg)	**40**	
Description of gondola performance		______	______	
Verification of performance to specifications		______	______	
Analysis of plots from data		______	______	
What was Learned		______	______	
Problems Encountered & Solution		______	______	*Sum:* ______
Performance Plots		(?pg)	**40**	
Logical layout of data		______	______	
Labeled axes with units		______	______	
Presentation of plots		______	______	*Sum:* ______
Formatting & Neatness		(1pg)	**15**	
Consistent Page Numbering thru report		______	______	
Cover Sheet (section # & side, grading TA)		______	______	
Spelling & Grammar		______	______	
Required: Academic Integrity and Division of Labor page - **signed** (See the provided template form)		______	______	*Sum:* ______
Lateness (unexcused)				
-20% per School Day	-20% x ______		______	*Sum:* ______
Total			**100**	***Total Points:*____________

NOTE: No report grades will be given without uploading softcopies of the .c file to LMS for archival purposes in addition to the <u>signed</u> hardcopy of the report. Use last initial of members in the .c file name (ex. 2B_HLR_lab6.c. for a team in section 2, side B with last names Hamlet, Lear, and Romeo). Only one team member should upload the file but it must contain all 3 member's name in the header comments. Everyone on the team must sign the hardcopy of the report using the Academic Integrity form given below.

Be sure to read "(Bad) LITEC_Report_examp_graphs" under this rubric on LMS to avoid common mistakes when plotting data. Axes must be scaled and units specified. These plots are being used to show bad plotting formats (independent of the actual data).

LITEC Gondola Report Guidelines (revised, 2016 Spring)

The gondola lab report for LITEC covers only the material in Lab 6. This rubric (GradingGondolaRpt-student), provided on the previous page, lists most of the items to be included, but the list is not necessarily exhaustive.

The report should include detailed descriptions of the final goal: the feedback systems on the gondola involving the compass. The discussion should explain how the PWM pulse-width calculations are made based on the errors and feedback gains (proportional, derivative, and integral, if appropriate). With respect to response plots (described below), analyze the various plots and justify their characteristics for the sets of gains used. It is up to you to decide how to document and justify your results through carefully chosen plots and clear narrative in your report.

2019 Summer: Four plots are required showing a range of responses (overdamped, underdamped, oscillating, etc.) and at least one that demonstrates an "optimized" response.

Report submission includes:

1) Program listings (.c file) for gondola (Lab 6) program is only uploaded on LMS
   Program listings **must be formatted as follows**:
   Make sure proper indenting is used consistently throughout
   Include an appropriate prolog (programmer names, section & side, date, brief description, etc.)
   Line comments and block comments should be used liberally with detailed description of what the code is doing or how it works
2) Clearly labeled and captioned plots for data acquired during lab, with scaled axes & units
   Time plots from gondola showing heading angle as it corrects itself for several different values of P and D heading gains (Follow the cases given in the lab procedure). Use appropriate scaling or axes.
   If further investigations were made of the heading control with the addition of the vertically oriented side thrust fans to assist the tail fan in correcting heading errors, those response plots should also be included.

†Diagrams should be generated using appropriate drafting software.

Academic Integrity Certification *(this part is required exactly as stated)*

All the undersigned hereby acknowledge that all parts of this laboratory exercise and report, other than what was supplied by the course through handouts, code templates and web-based media, have been developed, written, drawn, etc. by the team. The guidelines in the Embedded Control Lab Manual regarding plagiarism and academic integrity have been read, understood, and followed. This applies to all pseudo-code, actual C code, data acquired by the software submitted as part of this report, all plots and tables generated from the data, and any descriptions documenting the work required by the lab procedure. It is understood that any misrepresentations of this policy will result in a failing grade for the course.

Participation *(this is only a template; make changes as appropriate or necessary)*

The following individual members of the team were responsible for (give percentages of involvement)

Hardware implementation: ________________________________
(wiring & pin-out sheet) ________________________________
____

Software implementation: ________________________________
(pseudo-code & code) ________________________________
____

Data analysis (if relevant): ________________________________
____
____

Report development & editing*: ________________________________
(schematic, diagrams & plots) ________________________________
____

The following signatures indicate awareness that the above statements are understood and accurate.

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*Note, notebook keeping and report development/formatting do not constitute an engineering contribution toward successful laboratory completion.