CHAPTER 1

Introduction

1.1 Purpose

The intent of this thesis is as follows:

1. Select a well-established control problem as a focal point. [*Inverted Pendulum: Two-wheeled Robot*]
2. Develop a modular test platform, such that differing control methods could be independently applied to the selected control problem, in real-time and in simulation.

   [*MinSeg Two-Wheeled Robot* and *Mathworks Software Suite*]
3. Select or derive the dynamic equations for the physical model, and populate it. [*Yamamoto [1]*]
4. Select the first controller design to address the selected control problem on the test platform, and implement it in simulation. [*Optimal Controller*]
5. Time permitting, implement the same controller design on the hardware.

1.2 Statement of the Problem

The two-wheeled robot is a well-established control problem. The robot is topheavy and must continually work to balance itself. The robot is able to move freely on a two-dimensional plane; however, any movements performed by the robot create additional disturbances against its ability to balance itself.

Numerous command regulator approaches (PID, pole-placement, optimal) have been developed to control such a device; however, no one approach has been determined as a clear choice. Additional functionalities other than command regulators which significantly improve performance may also be implemented in a controller.

This study therefore intends to comparatively study multiple control approaches involving optimal-control-focused command regulators and to study the effects of additional functionalities which may be beneficial in general control cases. As a prerequisite to this work, a test platform must be developed for which to design the controllers. This study intends to design the test platform such that:

- Studies could be performed on actual hardware.
- Studies could be performed in simulation *(using a hardware-equivalent model)*.
- Similar work involving alternate control methods could easily be incorporated.

The intent of the latter is to significantly diminish several barriers to entry to perform a control study relating to hardware *(initial implementation, interfacing/communication, and theoretical/simulation modeling)*. This would ideally encourage future studies as well as draw them to a common platform, which would allow for effective comparisons between those studies.

1.3 Methodology

The methodology of this thesis is as follows:

1. Select a well-established control problem as a focal point. [*Inverted Pendulum: Two-wheeled Robot*]
    - Select compatible hardware and software. [HW: *MinSeg (Two-Wheeled Robot)*; SW: *Mathworks Matlab & Simulink*]
    - Implement basic hardware-software interfaces. [*Datatype conversion*; *Unit conversion*; *Derivation/Integration*; *Filtration*]
        - Process signals input to hardware drivers.
        - Process raw signals output from hardware sensors.
2. Develop a modular test platform.
    - Establish infrastructure.
        - Develop a unified, modular Simulink model which is capable of representing any desired system configuration. [*Variant subsystems used.*]
        - Create a Matlab script hierarchy which is able to:
            - Configure the Simulink model to any desired system configuration.
            - Configure the Simulink model to any desired build/run state.
            - Organize the relatively large number of parameters involved in such a system.
            - Minimize the effort required for the user to incorporate additional system configurations.
            - Minimize the effort required for the user to transition between any system configurations.
    - Establish robust methods of signal routing.
        - Implement bus structures.
        - Implement serial communication between hardware and development computer.
            - Minimimize sampling interval within the limits of the board hardware.
            - Process transmitted signals prior to sending and reconstruct after receiving.

- Calibrate hardware sensors.
    - Mitigate gyroscope bias.
- Develop theoretical plant model.
    - Research (non-linear) physical equations.
    - Linearize the physical equations.
        - Develop a state-space model.
    - Acquire linear plant model parameters.
    - Implement linear plant model into unified test platform.

3. Design and develop and optimal controller for the test platform.
    - TBD.

1.4 References

[1] Y. Yamamoto. (May 1, 2009). Nxtway-gs (self-balancing two-wheeled robot) controller design, [Online]. Available: https://www.mathworks.com/matlabcentral/fileexchange/19147-nxtway-gs--self-balancing-two-wheeled-robot--controller-design (visited on 07/03/2017).