School of Electrical and Information Engineering
University of the Witwatersrand, Johannesburg
ELEN4016 Control II

Control Lab Exercise

Control of an Antilock Braking System

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1 Preamble

This project is computer-based and is to be conducted in groups of two in your own time. Laboratory time is to be used to consult laboratory assistants and the Course Coordinator if advice or direction is needed. The postgraduate students who are assigned to Control II as assistants/demonstrators are also available at reception by prior arrangement.

Any of the software MATLAB/SIMULINK, SCILAB or OCTAVE may be used for conducting numerical experiments. The final date for submission of project reports is as prescribed by the School of Electrical and Information Engineering. One report per group has to be submitted. Reports must comply with the school's guidelines as contained in the Blue Book. After submission of these reports it is up to the discretion of the laboratory assistants and the course lecturer to decide whether or not, in addition to marking these reports, specific individuals or groups need to be interviewed about the project.

2 Purpose

The purpose of this project is to expose the students to advanced modelling techniques applied to lumped, complex and interlinked subsystems, rapid prototyping, and discretisation effects as well as the design of state-feedback and MIMO controllers for such systems.

3 Objectives

On completion the student should be able to:

- Understand the derivation of a model for the given plant or system.
- List explicitly the assumptions needed to reduce the system to a linear system.
- Determine representations (e.g. state-space, transfer function etc.) for lumped parameter systems.
- Design and develop state-feedback and/or intelligent controllers to control the system.
- Implement the controller and plant combination in MATLAB/SIMULINK, SCILAB or OCTAVE or similar software.
- Interpret the results produced by the complete simulation.
- Critically analyse controller performance,
- Contrast digital control vs. analogue control for any given system.

4 References

4.1 Review topics

- System modelling
- MIMO system
- State-space modelling

4.2 Exploratory topics

- Modelling and interconnected subsystems.
- Plant nonlinearities and their impact on design.
- Effects of discrete controllers.

5 Overview

Various systems require the use of feedback control based on the concept of measuring certain variables of the plant and then adjusting actuators to bring about a desired state in the plant.

Figure 1, below, shows an Active Suspension System incorporating antilock braking system for a quarter car model. Here the objective of the control is to ensure that the driver experiences as smooth a ride as possible.

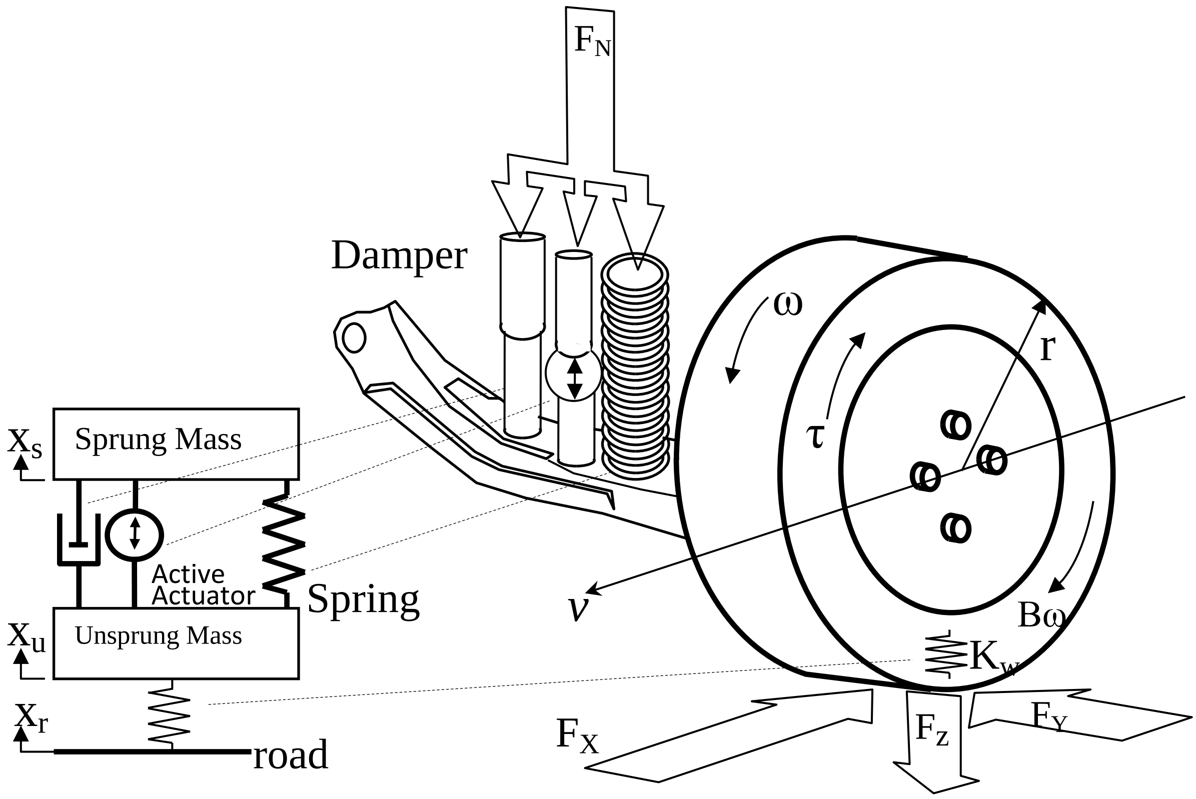

Figure 1: Quarter Car System Model

A black box model of the quarter car is provided on the course homepage along with limited model parameters. Additionally unique model parameters for each group are to be allocated to ensure unique results for each group's project.

6 Background

6.1 Modelling of the Active Suspension System

Groups will be expected to develop analytic models for suspension systems and from these solve the black box model solution. Literature review will be an expected part of this exercise. Students are further expected to use their black box solution to model driver comfort especially when going over a hump.

7 Project Task

7.1 Project Specification

The objective of the project assignment is to ensure driver comfort specifically when driving over a hump. Ideally the driver must feel no difference is her travel trajectory irrespective of the hump's presence or absence and also irrespective of the travelling speed of the car.

7.2 Optimal Specification

The suspension system is required to assist the braking system by adding to the normal reaction. Specifically before emergency braking the suspension continues in its normal mode of smooth ride comfort but during emergency braking up to 50% more normal reaction is obtained from the suspension system actuation. The 50% additional normal reaction is to be sustained for the full duration of the emergency braking which can take a time period of between 3 to 5 seconds. The rise time of the increase in normal reaction can be selected to have a minimum of 2s. x_s and x_u cannot be assumed to increase without limit and it is assumed that the control is unlimited in both maximum values and slew rate. The suspension system may be assumed to have a non linear spring factor (k_{nl}) for the active suspension system whose factor is any value of your choice but this non linear factor is to be in the range [0.1 … 0.25] of the linear spring factor. Further the nonlinear spring term appears only in the active suspension and takes the values $k_{nl}(x_s)^2$ where x_s is the extension of the active suspension spring.

7.3 Linearisation Specification

The analysis in 7.2 is to be repeated but this the nonlinear suspension system is to be analysed via linearization methods and subsequent pole placement or any other linear technique. Compare and contrast the benefits and drawbacks of the two approaches, i.e. non-linear optimisation versus linearization approach.

7.4 Simulation software

You need to develop your own models in MATLAB/SIMULINK, SCILAB or OCTAVE code to simulate the system. Use the parameter values stated earlier. All initial conditions and the required final - near rest conditions must be specified at runtime. Your code must be able to plot the complete response over any user defined time interval. Your code or models (e.g. Simulink block diagram) has to be included in the Appendix of your report and also on CD that is to be submitted as part of the project deliverables by the project deadline.

7.5 Further model refinements (optional for bonus marks!!)

The control input that actuates (active suspension force) is normally generated by a digital processor. Incorporate the basic sampling and holding effects that come with utilising a digital platform in your system model.

You may also consider disturbances input in the form of a random but limited noise and nonlinear effects.