6CCE3SAC: Systems and Control

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This assignment is worth 30% of the module mark. It is designed to give you experience of designing a system model based on some modelling need and of applying methods from control theory to both passive and active dynamic systems. The assignment has two parts:

Part A – a dynamic model and design evaluation of vehicle handling
Part B – active controller enhancement of steering stability

Part A should be completed during the first half of the module and Part B in the second half of the module. Both parts should be submitted together with a deadline of Thursday 4pm Week 17. During the weekly tutorials you should bring questions and updates on your model progress.

Students must achieve a minimum mark of 30% on this assignment in order to pass the module overall.

Submission requirements:

You should submit a 9-page report covering the theory and development of your model including your approach to verification and validation. You should also submit your model files.

The structure of your report should include:

- Introduction and table of parameters for vehicle of interest
- Mathematical model of the vehicle and assumptions made – the model should comprise at least 2 degrees of freedom
- Design considerations of interest including customer and other requirements or performance targets
- Simulation requirements (list of tests that you will perform)
- Simulation results for open-loop model

- Control approaches considered including theoretical basis
- Verification and testing of the model and controller including use of international standard tests
- Final results
- Limitations and Conclusions and model improvements required

Parameters

Some example bicycle model parameters for two vehicles are given here. You can consider the impact of these parameters on the vehicle response. Other parameters can be found from literature.

Parameter	Car A	Car B
m (kg)	1,669	1,355
I_z (kg m^2)	3,144	1,912
l_f (m)	1.178	1.324
l_r (m)	1.567	1.052
$c_{\alpha f}$ (N rad^{-1})	59,410	45,336
$c_{\alpha r}$ (N rad^{-1})	50,730	56,492

Table 1: Vehicle System Parameters.

Modelling and design questions:

This is an open-ended modelling problem. The complexity of the model you create should be defined as part of your requirement setting. Some example model questions are below and you do not need to do all of these, you can also add your own questions.

- Steady state vs transient characteristics of the vehicle response at different speeds
- Steering Stability: You could explore the yaw and lateral movement of the vehicle in response to step or avoidance steering inputs for varying speed
- Influence of non-linear tyre model on the steering response
- Frequency response to sinusoidal steering input compared with theory
- The yaw mode of the vehicle
- Stability analysis: select whichever technique/s you deem most appropriate to analyse the closed-loop system's stability, and discuss how this analysis has in turn guided the control design process.
- Comfort/Human in the Loop: You could explore driver comfort or the impact of driver expertise on control design.

Marking Criteria:

The assignment is designed to allow you to demonstrate the learning outcomes and to enable you to achieve marks across the marking scale.

- **Excellent first:** these students will understand the motivation of the work and provided context for the discussion. They will expertly weave together mathematical and physical explanations of concepts including analytical solutions. They will present their model and data concisely and with helpful figures and diagrams. Their model may include a user interface and will be well tested and verified.
- **First**: Students will demonstrate excellent mathematical capability and theoretical understanding. The reports will show evidence of wider reading. These students will consider additional requirements such as ISO standards, driver experience and safety. Equations will be numbered, variables consistent and include units. Students will have a clear grasp of analytical as well as computational methods. Their model may include a user interface or will be well tested and verified.
- **2:1**: High quality work showing knowledge and understanding and analysis of the problem and solution. Improvements will be possible in synthesising the theory and context (mathematical and physical), use of software or other techniques or range of references or the problem solving process may not be clear.
- **2:2**: There may be formatting and presentation issues, references will be limited without reading beyond the lecture material, the theory, context or mathematical concepts will be missing or mis-understood and analysis will be limited.

Collaboration

We understand that students wish to work together on assignments. However, students submitting very similar simulations, reports or research will be referred for collusion interviews.