WM9SF-15 Modelling and Control of Automotive Systems

27/28

Department
WMG
Level
Taught Postgraduate Level
Module leader
Kamyar Nikzadfar
Credit value
15
Module duration
4 weeks
Assessment
100% coursework
Study location
University of Warwick main campus, Coventry

Description

Introductory description

Modelling, simulation, and control are fundamental stages in engineering -particularly within modern intelligent and electrified vehicular systems- where key attributes and performance indicators arise from the synergistic integration of multiple sub-systems. These techniques enable engineers to evaluate various system configurations, predict their behaviour across a range of operating environments, and control system performance in the desired manner.

In this module, we will focus on the modelling and control of dynamical systems derived from various physical domains, exploring these aspects particularly within the context of electrified and intelligent automotive systems. This includes electric propulsion systems as well as autonomous driving technologies. Learners will develop an understanding of how to model such systems, evaluate their validity for different applications, and design controllers to regulate system outputs effectively.

Additionally, this module will equip students with the skills to adopt a model-based approach when designing controllers at different levels of automotive abstraction. Students will also gain hands-on experience using MATLAB/Simulink to model these systems and develop control strategies.

Module aims

This module aims to equip students with a comprehensive understanding and practical experience in the modelling, simulation, and control of physical systems within an automotive context, with a particular focus on electrified powertrains and autonomous vehicle systems. Using industry-relevant tools such as MATLAB/Simulink, students will develop the skills to derive ordinary differential equations from physical models, construct empirical models using data-driven techniques, and design controllers to meet predefined system characteristics.

Students will gain expertise in both time-domain and frequency-domain analysis, enabling them to develop and evaluate control strategies for complex automotive systems. This module provides a strong foundation in model-based control design, bridging theoretical concepts with practical applications in electrified vehicle technology, as well as vehicle dynamic control, with a particular focus on autonomous vehicles.

Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

- Lumped Multi-Physics Systems within electrical, mechanical, and hydraulic domains.
- Mathematical Modelling of Physical Systems using ordinary differential equations (ODEs), state-variable representation, and block diagram modelling for both linear and nonlinear systems.
- System Linearisation and Operating Points, including methods for linearising nonlinear systems around their operating points.
- Time-Domain and Frequency-Domain Representation and Analysis, utilising transfer functions and state-space methods to evaluate system behaviour and stability.
- Empirical Modelling Techniques for developing data-driven models of physical systems.
- Controller Design for Dynamical Systems, employing both classical and modern techniques for linear control system development.
- Modelling and Simulation for Performance and Energy Analysis of electrified powertrains as well as the vehicle dynamic performance.

Learning outcomes

By the end of the module, students should be able to:

- Demonstrate a comprehensive understanding of the practical application of mathematical modelling of one-dimensional physical systems, using ordinary differential equations and empirical models to develop lumped models of multi-physics systems. [AHEP:4; 7, M1, M3]
- Analyse the dynamic behaviour of linear systems using time-domain and frequency-domain techniques, assessing stability, performance, and system characteristics. [AHEP:4; 7, M1, M2, M3]
- Demonstrate an understanding of model linearization and validate linearized models, with specific applications in automotive systems. [AHEP:4; 7, M1, M3]

- Develop and implement control systems for dynamical systems in automotive applications, utilising classical techniques. [AHEP:4; 7, M1, M2, M5]
- Construct integrated models of automotive systems to gain practical insights into multi-physics simulation techniques. [AHEP:4; 7, M2, M5, M7]

Indicative reading list

Reading lists can be found in Talis

Specific reading list for the module

Subject specific skills

- Understand dynamical systems.
- How to model electrical, mechanical, thermal, fluid systems as analogous systems.
- Numerical/block diagram methods to solve ordinary differential dynamical systems.
- Implement data-driven and empirical modelling in automotive applications.
- Validating and verification of linearised dynamical models.
- Development of controllers for various sub-systems and components within electrified powertrains.
- How the automotive industry use such models and model based design methods.
- MATLAB programming/Simulink Modelling.

Transferable skills

- Technology literacy
- Dependability
- Communication
- Adaptability

Study

Study time

Type	Required
Lectures	10 sessions of 1 hour (7%)
Seminars	15 sessions of 1 hour (10%)
Tutorials	5 sessions of 1 hour (3%)
Online learning (independent)	10 sessions of 1 hour (7%)
Private study	50 hours (33%)
Assessment	60 hours (40%)
Total	150 hours

Private study description

Self-study time for revision of lectures after delivery, completion of independent study task and self-directed learning task including independent research, reviewing essential calculus concepts, and working through example exercises in calculus, MATLAB, and Simulink.

Costs

No further costs have been identified for this module.

Assessment

You must pass all assessment components to pass the module.

Assessment group A

	Weighting	Study time	Eligible for self-certification
Assessment component			
Modelling and Simulation of Automotive Systems- Group Assessment	40%	24 hours	No

Utilising a range of modelling approaches, including ordinary differential equations and empirical methods, to develop a model that accurately represents the performance and energy consumption characteristics of electric propulsion systems or handling of vehicles.

Groups of students will be required to simulate the performance of an electric propulsion system or vehicle dynamics through mathematical derivation and computer-based simulation, presenting both their written solutions and simulation outcomes.

This is a group-based task, with students working in teams of three to four, supported by a tutor. A peer review assessment methodology will be implemented as part of the evaluation process.

Reassessment component			
Modelling and Simulation of Automotive Systems- Individual Reassessment			No

Utilising a range of modelling approaches, including ordinary differential equations and empirical methods, to develop a model that accurately represents the performance, energy consumption or

	Weighting	Study time	Eligible for self-certification

vehicle dynamic characteristics of advanced automotive systems.

Students will be required to simulate automotive system through mathematical derivation and computer simulation, presenting both their written solutions and simulation results.

Assessment component

Development of Automotive Controllers - Individual Assessment	60%	36 hours	Yes (extension)

Development of a controller at the system or component level for an electrified or autonomous vehicle, using a model-based approach to fulfil the specified requirements.

This is an individual task and students will be required to solve problems using control design toolboxes and present both their written solutions and simulation results.

Reassessment component

Development of Automotive Controllers - Individual Assessment			No

Development of a controller at the system or component level for an electrified or autonomous vehicle, using a model-based approach to fulfil the specified requirements.

This is an individual task and students will be required to solve problems using control design toolboxes and present both their written solutions and simulation results.

Feedback on assessment

Written feedback and overall mark following on from WMG feedback sheet templates.

Availability

There is currently no information about the courses for which this module is core or optional.