Technical University of Crete
Dynamic Systems and Simulation Laboratory
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Chania 73100, Greece

14th Short Course 2021

DYNAMIC TRAFFIC FLOW MODELLING AND CONTROL

8 - 19 February 2021, online

Lecturer:	*Prof. Markos Papageorgiou*
Date:	*8 - 19 February 2021 (3 lecture hours per day)*
Location:	*online*
Fee:	• ***1.700 €*** • ***For graduate students: 1.300 €*** • ***20% reduction is granted in case of more than one participation from the same institution***

Scope

The design, analysis, implementation and evaluation of Intelligent Transportation Systems (ITS) requires good knowledge of traffic flow modelling and control techniques as well as of powerful methodologies from the areas of optimisation, automatic control, networks and dynamic systems. The purpose of this intensive course (10 half-days) is to cover the basic theory, methods and tools necessary for efficient design of ITS on road and freeway networks. After a basic introduction to dynamic systems and control, the course continues with traffic flow modelling and validation issues, the modelling of traffic networks, dynamic traffic assignment and simulation tools. Measurement devices and estimation problems in traffic networks, including automatic incident detection and OD estimation, are presented and discussed. The state-of-the-art techniques in freeway traffic control, road traffic control and integrated traffic control, employing ramp metering, signal control, variable speed limits and route guidance, along with several field-implemented case studies are presented. Emerging and future prospects and challenges related to vehicle automation and communication systems are discussed. Brief accounts of some optimisation, control and estimation techniques are provided. Some 50 exercises are delivered for consolidation of the provided knowledge. Written materials, including all utilized slides, are provided in electronic form.

Who Should Attend

Graduate students, faculty members, engineers, researchers, consultants, and government employees who are interested in improving their understanding of advanced traffic flow modelling and control tools and in becoming familiar with their application in ITS.

Please forward the information about the Short Course to any of your colleagues who may be interested.

Course Contents (provisional)

1. INTRODUCTION

1.1. Some Basic Notions
(Definitions; Control-loop elements; Mathematical models; Open-loop vs. closed-loop control)

1.2. The Regulation Problem
(Set values; Performance criteria; P, I, PI-type regulators; Regulator tuning rules)

1.3. Optimal Control Strategies
(Problem formulation; Solution alternatives; Hierarchical structures; Rolling horizon)

1.4. Optimisation Theory
(Classification of problems)

1.5. Heuristics
(Structural heuristics; Surveillance and emergency; Specifications)

1.6. Automatic Control Application Procedures
(Short history; System identification; Control design and implementation phases)

1.7. Overview of Comparable Domains
(Water, gas, sewer, electricity, communications, road traffic, air, maritime, rail networks: Common features and particularities)

Exercises

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2. TRAFFIC FLOW MODELING

2.1. Microscopic Models
(Car-following equations; Stimulus-response, Bando, IDM models; Stability of a string of vehicles; Lane-changing models; Microscopic simulation tools; Model validation)

2.2. Macroscopic Models
(Definitions; Speed-flow relationship and Fundamental Diagram; Conservation equation; Kinematic waves and shock waves; LWR model; CTM; Drivers' anticipation; Second-order models; Model limitations; Modelling of on-ramp flow; Modelling of incidents; Testing control strategies via simulation; Fuel consumption models)

2.3. Model Validation
(Basic validation procedure; Parameter sensitivity; Case studies)

2.4. Critical Discussion
(General remarks on modelling; Qualitative and quantitative model features; Discretisation; Comparative evaluation; Future research needs; Macroscopic versus microscopic modelling)

Exercises

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3. MODELING OF TRAFFIC NETWORKS

3.1 Fixed-Routing Modeling
(Macroscopic node interfaces; Turning rates; Urban junction modelling; Platoon dispersion; Saturation flow)

3.2 Traffic Assignment: Basic Notions
(User and system optimality; Braess paradox; Stochastic traffic assignment; Day-to-day dynamics; Limitations)

3.3 Dynamic Traffic Assignment
(Time-dependent travel times; Microscopic, mesoscopic, and macroscopic dynamic traffic assignment; Splitting rates; Instantaneous and experienced travel time; Feedback and iterative algorithms for user and system optimum)

3.4 Dynamic Network Models
(METANET/METACOR, CONTRAM/MCONTRM, INTEGRATION, DYNAMIT, DYNAMEQ)

Exercises

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4. MEASUREMENTS AND ESTIMATION

4.1 Measurement Devices and Data Processing
(Loop detectors; Traffic occupancy; Edie's traffic variable definitions; Space mean speed and time mean speed; Data processing for single and multiple loops; Magnetic sensors; Ultrasonic detectors; Video sensors; Video image processing; Average travel time; Floating car surveys)

4.2 Estimation of Traffic Variables
(State estimation for freeway links and networks; RENAISSANCE; Extended Kalman Filter application; Estimation of vehicle count in signalized links)

4.3 Automatic Incident Detection
(Definitions, context, and impact; Performance criteria; e-Call; Loop-based AID; Classification of methods; California algorithm; Exponential Smoothing; Neural Networks; Optimal calibration; The DAISI tool for AID; Video sensor based AID)

4.4 Origin-Destination Matrix Estimation
(Problem statement; Static O-D estimation; Dynamic O-D estimation; Kalman Filter application)

Exercises

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5. FREEWAY TRAFFIC CONTROL

5.1 Introduction
(Control measures; Bottlenecks; Congestion impact)

5.2 Ramp Metering
(Why ramp metering; Implementation issues; Fixed-time ramp metering using Linear and Quadratic Programming; Local ramp metering strategies; ALINEA; Coordinated feedback ramp metering using LQ-control; Field results from Paris, Amsterdam, Glasgow; Corridor impact of ramp metering; Nonlinear optimal ramp metering and applications; AMOC; Feedback coordination via HERO; Field results from Melbourne; Limitations and impact on demand)

5.3 Link Control
(Variable speed limits (VSL); Impact on traffic flow; Implementation examples; Optimal VSL control; Mainstream traffic flow control; SPECIALIST; Reversible flow)

About the Lecturer

Professor Markos Papageorgiou's general area of scientific interest is in modelling, optimisation and automatic control, and their applications to traffic and transportation systems, water networks, and further areas. Over the past 45 years, Prof. Papageorgiou has been involved with the development and validation of traffic flow models, and with the design, testing, and implementation of traffic control strategies for a variety of traffic control problems. He has taught regular and intensive courses on *Traffic Flow Modelling and Control* at renowned universities and institutions in many countries. He has been actively involved in national and international R&D projects and programs in different capacities and he has served as a consultant to industrial, research, and governmental institutions in various countries. He is the author of "*Applications of Automatic Control Concepts to Traffic Flow Modelling and Control*" (Springer, 1983) and "*Optimierung*" (Oldenbourg, 1991; 1996; Springer, 2012; 2015), the Editor of "*Concise Encyclopedia of Traffic and Transportation Systems*" (Pergamon, 1991), and the author of numerous technical papers. He was the Editor-in-Chief of *Transportation Research - Part C* (2005-2012); Prof. Papageorgiou is a Life Fellow of the IEEE and a Fellow of IFAC. He was a recipient of the IEEE Intelligent Transportation Systems Society *Outstanding Research Award* (2007) and of the IEEE Control Systems Society *Transition to Practice Award* (2010). He is the recipient of the *Highest Cited Author Award* by the Committee of Traffic Flow Theory and Characteristics of the TRB (2014); and of many other distinctions and awards. He was presented the title of honorary Visiting Professor by the University of Belgrade, Serbia (2010). He is the recipient of the 2020 *IEEE Transportation Technologies Award.* The Dynamic Systems and Simulation Laboratory he has been heading since 1994, received the IEEE Intelligent Transportation Systems Society *ITS Institutional Lead Award* (2011). Prof Papageorgiou received two ERC Advanced Investigator Grants for the projects TRAMAN21 (Traffic Management for the 21st Century) (2013-2018) and TrafficFluid (Lane-Free Artificial-Fluid Environment for CAV Traffic).

Fee and Registration

Registration is limited to **40** participants on a **first-come-first-serve** basis. The fee is 1.700 € (for graduate students 1.300 €). A fee reduction of 20% is granted in cases of more than one participations from the same institution.

Method of Payment

Payment may be effectuated via:

- **check** (indication: "Short Course Prof. M. Papageorgiou") or
- **bank transfer** (please ask for details) or
- **credit card**.

Location

The course will take place online. Related instructions for participants will be provided in due time. All course materials (lecture slides, exercises and solutions) will be provided electronically prior to the course.

Program

The Short Course duration is from Monday 8 February through Friday 19 February 2021. The daily schedule is as following (EET time):

14:00 - 15:30 (Lecture)	
15:30 - 16:00 (Coffee break)	
16:00 - 17:30 (Lecture)	

Evaluation of the previous Short Courses

The thirteen previous Short Courses (3-7 May 1999, 29 May - 2 June 2000, 28 May - 1 June 2001, 27-31 May 2002, 9-13 June 2003, 20-25 September 2004, 17-21 July 2006, 21-25 July 2008, 19-23 July 2010, 8-12 October 2012, 3-7 November 2014, 14-18 November 2016, 19-23 November 2018) were attended by a total of 283 participants from 28 countries (from Greece 56, Germany 44, The Netherlands 38, Italy 31, Sweden 25, Switzerland 17, Belgium 11, UK 9, Spain 5, Republic of Korea 5, France 4, Australia 4, Israel 4, Portugal 3, Hungary 3, Austria 3, Czech Republic 3, Finland 3, Canada 3, USA 2, UAE 2, Luxemburg 2, Ireland 1, Japan 1, Yugoslavia 1, Tanzania 1, Russia 1, Iran 1). Participants were active in Universities and Research Centres (80%), Consultants and Industrial Companies (17%), and Authorities (3%). At the end of each course the participants completed an anonymous **Evaluation Form**, the average results of which are summarized in the following table:

Course Aspect	Oral Presentation	Reading Materials	Lecture Transparencies	Organisation	Theoretical Aspects	Practical Aspects
Average evaluation*	4.9	4.3	4.4	4.8	4.5	4.6

* **5**: excellent, **4**: very good, **3**: good, **2**: fair, **1**: poor

Here are citations of some participants' overall impressions:

- *"I found this an extremely interesting course, very much what I was looking for. I learned a lot and I am very happy to have participated. Next time my company will send someone again".*
- *"It is a very good course giving an excellent overview. I would really recommend it to my colleagues".*
- *"I was impressed by the presenter's knowledge and technical depth as well as breadth. The introduction to Automatic Control was very useful and it definitely gave ideas that I'll try to explore in my own research".*
- *"I overcame my best expectations for the quality of the presentation and the great interest of the arguments. A really stimulating experience".*
- *"Excellent course, essential for any PhD student entering the realm of traffic control".*

The Short Course was also delivered in the past in different forms in various countries, including its teaching as a graduate course at MIT, Cambridge, Massachusetts in 1997 and 2001. More recently, it was delivered at the Institute of Automation, Chinese Academy of Sciences, Beijing, China, 9-13 August 2010; at the University of California at Berkeley, California, June 6-10, 2011; at the Technical University of Braunschweig, Germany, 25-27 November 2015 and 7-9 March 2018; and at the Delhi Technological University, Delhi, India, 4-8 December 2017.

To register
please complete and send (via mail, or e-mail) the
registration form