13th Short Course 2018

Dynamic Traffic Flow Modelling and Control

19-23 November 2018, Chania, Greece

Lecturer: Prof. Markos Papageorgiou
Date: 19-23 November 2018
Location: Chania (Crete), Greece
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, 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, control, networks and dynamic systems. The purpose of the intensive 5-day course is to cover the basic theory, methods and tools necessary for efficient design and evaluation 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. Future prospects and challenges related to emerging vehicle automation and communication systems are discussed. Brief accounts of some optimisation, control and estimation techniques are provided. Some 50 exercises are used for consolidation of the provided knowledge. Extensive written materials, including all transparency copies, are handed out.

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.
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 regulators)
   1.3. Optimal Control Strategies
        (Problem formulation; Solution alternatives; Hierarchical structures; Rolling horizon)
   1.4. Optimisation Theory
        (Classification of problems; Application areas)
   1.5. Heuristics
        (Structural heuristics; Surveillance and emergency; Specifications)
   1.6. Automatic Control Application Procedures
        (Short history; 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

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

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

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; 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

5. FREEWAY TRAFFIC CONTROL
   5.1 Introduction
        (Control measures; Basic problems)
   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; SPECIALIST; Reversible flow)
   5.4 Route Information and Guidance
        (General introduction and examples; Travel times: experienced, instantaneous, predictive; Travel-time
versus congestion-length information; Route guidance approaches; Iterative, optimal control, and feedback (P, PI, LQI) approaches; Simulation examples)

5.5 **Case Studies**
(The Aalborg VMS information and guidance system; The interurban Scottish highway network system of VMS for driver information and guidance; Goals, characteristics, control strategy design, simulation tests, implementation and impact for both systems)

5.6 **Integrated Freeway Network Traffic Control**
(Optimal integrated freeway network control; AMOC; Simulation examples)

5.7 **Bottleneck Traffic Control**
(Basic concept; Control algorithms; Applications to freeway work zones and toll plazas; Microscopic simulations testing; Mainstream traffic flow control)

Exercises

6. **ROAD TRAFFIC CONTROL**

6.1 **Introduction**
(Basic definitions; Stages, split, cycle, and offset; Classification of control strategies)

6.2 **Isolated Intersection Control**
(Fixed-time strategies; Webster signal settings; SIGSET and SIGCAP; Phase-based approach; Application examples; Real-time strategies; Vehicle-interval method; Volume-density method; MOVA)

6.3 **Fixed-Time Coordinated Control**
(MAXBAND: Details of problem formulation and solution, extension to networks, examples, recent extensions; MULTIBAND; TRANSYT: Problem description, model, and optimisation approach; Signal control and traffic assignment; Network design problem)

6.4 **Coordinated Real-Time Strategies**
(SCOOT, OPAC; PRODYN, COP, CRONOS; Store-and-forward based approaches; Linear Programming, Quadratic Programming, LQ-regulation; TUC; SURTRAC; Max-Pressure; Feedback gating and perimeter control)

6.5 **Public Transport Priority**
(Aims, trade-offs and methods)

6.6 **Parking Control Systems**
(Design principles and examples)

6.7 **Integrated Urban-Freeway Traffic Control**
(Aims; Basic methodological approaches; IN-TUC)

6.8 **A Case Study**
(Glasgow implementation and field evaluation of IN-TUC)

Exercises

7. **EMERGING CHALLENGES WITH VACS (Vehicle Automation and Communication Systems)**

7.1 **Emerging VACS**
(Emerging technology changes; Taxonomy of VACS; Traffic management needs and challenges)

7.2 **Modelling**
(Modelling needs; Microscopic models; Macroscopic models; Model usage results)

7.3 **Estimation**
(Estimation possibilities; Estimation scheme for motorway traffic using connected vehicle data; Results)

7.4 **Traffic Control**
(Urban intersection control; Vehicle level control; Automated merging; Bottleneck feedback control; Link and network level tasks)

7.5 **Functional/Physical Architecture**
(Conventional, decentralised and hierarchical architecture)

APPENDIX A: **KALMAN FILTER**

A1. **The Kalman Filter for Linear Systems**
(Problem formulation; Filtering and one-step prediction; Recursive solution)

A2. **Extended Kalman Filter**
(Nonlinear problem and suboptimal solution)

Exercises

APPENDIX B: **LINEAR-QUADRATIC OPTIMAL CONTROL**

B1. **Problem Formulation**
(Linearisation; Problem formulation)

B2. **LQ and LQI Regulators**
(LQ-regulator; Problem augmentation for LQI control)

B3. **The Impact of Constant Disturbances**
(Constant disturbances; Steady-state error)

Exercises

APPENDIX C: **NONLINEAR OPTIMAL CONTROL**

C1. **Problem Formulation and Necessary Conditions**

C2. **Feasible-Direction Algorithm**
(Reduced and constrained gradients; Algorithmic steps; Descent directions)

Exercises
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 40 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 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 was presented the title of Visiting Professor by the University of Belgrade, Serbia (2010). 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 an ERC Advanced Investigator Grant for the project TRAMAN21 (Traffic Management for the 21st Century) (2013-2018). He is the recipient of the Highest Cited Author Award by the Committee of Traffic Flow Theory and Characteristics of the TRB (2014).

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. This fee includes:
- Handout materials (transparency copies, exercises and solutions – hardcopies and pdf files)
- Refreshments
- Daily lunch
- One course dinner.

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 at the hotel Akali (http://www.akali-hotel.gr), Kissamou St. 55, 73100 Chania, Crete, Greece, Tel. +30 28210 92872-5, email: akalihotel@otenet.gr

Accommodation

Specially priced rooms (single 65 €/day, double 80 €/day, incl. breakfast) will be reserved for the participants at hotel Akali, the Short Course venue. Participants will have to arrange their reservations themselves. Detailed information on how to reach Chania, the city attractions, and more will be provided upon receipt of the registration.
Evaluation of the previous Short Courses

The twelve 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) were attended by a total of 252 participants from 28 countries (from Greece 51, Germany 40, The Netherlands 38, Italy 27, Sweden 22, Belgium 11, Switzerland 11, UK 9, Israel 4, Spain 4, Canada 3, France 3, Portugal 3, Hungary 3, Austria 3, Australia 3, Czech Republic 2, Finland 2, USA 2, South Korea 2, UAE 2, Ireland 1, Japan 1, Yugoslavia 1, Denmark 1, Luxemburg 1, Russia 1, Iran 1). Participants were active in Universities and Research Centres (78%), Consultants and Industrial Companies (19%), 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:

<table>
<thead>
<tr>
<th>Course Aspect</th>
<th>Oral Presentation</th>
<th>Reading Materials</th>
<th>Lecture Transparencies</th>
<th>Organisation</th>
<th>Theoretical Aspects</th>
<th>Practical Aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average evaluation*</td>
<td>4.8</td>
<td>4.1</td>
<td>3.9</td>
<td>4.4</td>
<td>4.5</td>
<td>4.3</td>
</tr>
</tbody>
</table>

* 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”.

✍️ “Excellent organisation, excellent food, perfect hospitality. Thanks for this great experience”.

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