Dynamic Traffic Flow Modeling and Control (TE-31)

COURSE OUTLINE

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. Optimization 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; Stability of a string of vehicles; Lane-changing models; Microscopic simulation tools)
   2.2. Macroscopic Models
       (Definitions; Speed-flow relationship and Fundamental Diagram; Conservation equation; Kinematic waves and shock waves; LWR model; Drivers’ anticipation; Second-order models; Model limitations; Modeling of on-ramp flow; Modeling 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 modeling; Qualitative and quantitative model features; Discretization; Comparative evaluation; Future research needs; Macroscopic versus microscopic modeling)

Exercises
3. MODELING OF TRAFFIC NETWORKS

3.1. Fixed-Routing Modeling
(Macroscopic node interfaces; Turning rates; Urban junction modeling; 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)

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

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; HERO; Limitations and impact on demand)

5.3. Link Control
(Variable speed limitation; Warning messages; Reversible flow; Impact on traffic flow; Implementation examples)

5.4. Route Information and Guidance
(General introduction and examples; Proposed 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
(Opportunities for integration; AMOC; Simulation examples)

5.7. Merging and Mainstream 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 optimization approach; Signal control and traffic assignment)
6.4. Coordinated Real-Time Strategies
   (SCOOT, OPAC; PRODYN, COP, CRONOS; Store-and-forward based approaches:
   Linear Programming, Quadratic Programming, LQ-regulation; TUC)

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)

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

Exercises

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
   (Linearization; 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