INTELLIGENT TRANSPORT SYSTEMS - MASTER'S PROGRAM FOR UZBEKISTAN

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Chapter 1

ABOUT PROJECT

Introduction

In 2018 the Education, Audiovisual and Culture Executive Agency EACEA, acting under powers delegated by the European Commision awarded a grant to the consortium led by Gdansk University of Technology for a 3-year project entitled "Intelligent Transport Systems: New ICT- based Master's Curricula in Uzbekistan" nr 586292-EPP-1-2017-1-PL-EPPKA2-CBHE-JP. The project was given the acronym INTRAS. It was implemented by the consortium representing 9 universities: Gdansk University of Technology in Poland, University of Žilina in Slovakia, University of Klagenfurt in Austria, Andijan Mechine Building Institute in Uzbekistan, Jizzah Polytechnic Institute in Uzbekistan, Termez State University in Uzbekistan, Tashkent Institute of Design in Uzbekistan, Construction and Maintenance of Automotive Roads in Uzbekistan, Tashkent Institute of Railway Engineering in Uzbekistan, Tashkent University of Information Technology in Uzbekistan with support of ~~3~~ associated partners - Ministry of Higher and Secondary Specialized Education of the Republic of Uzbekistan, Passenger Transportation of Tashkent City, Via - Tashkent Company and Jizzakh Department of Uzbek Agency for automobile and river transport.

The project's objectives were to develop a new MSc curriculum in Intelligent Transport Systems, capacity building in Intelligent Transport Systems at 6 Uzbek universities and establishment of laboratories in ICT-based Intelligent Transport Systems, establishm the links between universities, public societies, institutions, organizations and enterprises in Uzbekistan creating an infrastructure and system for training new generation of engineers in ITS.

This objective was achieved by creating a new MSc program with tailored curriculas at all partner UZ universities. Main outcomes of the project were: Msc curriculum with 12 courses compatible with European standards in ECTS; fully functional and well equipped 6 Intelligent Transport Systems labs with all tools for analyses and experiments in the area; Uzbek professors and teachers with newly gained skills in ITS; growth of interest amongst specialists of industries, public administration institutions and the society in general in retraining and updating their skills.

Development of transportation in Uzbekistan is crucial for the growth of the national economy and social development as a whole. Uzbekistan is the most densely populated country in Central Asia. Its territory is 447.4 thousand sq. km, and population is ~~about 32~~ million. The high density of population, scattered clusters of industrial and agricultural production, as well as the remoteness from world markets make acquisition of developed transportation system vital for Uzbekistan. Uzbekistan is one of the very few double landlocked countries in the world. There is generally lack of waterways in the Central Asian region. Therefore it is very important to develop efficient road and railway transportation networks.

The development of transport communications is not possible without the use of modern technology, ICT and training of highly qualified engineers. With this in mind, the Government of Uzbekistan attaches great importance to the renewal of transport routes and development of transport infrastructure, as well as the training of highly qualified engineering personnel in the field of transport and road communications.

A number of government regulations have been adopted to improve transport infrastructure and the quality of training of engineers in the field of road transport and highways. For example, on October 9th, 2013 the President of the RUZ singed Decree № PP-2048 "On measures to further improve the system of passenger transportation in Tashkent". The purpose of this document was optimization of urban passenger transportation management, improvement of infrastructure and the efficiency of transport agencies. In particular, in 2016 a plan was devised to launch the intelligent transport system (ITS) for controlling traffic flow in the capital, the city of Tashkent. However, due to lack of qualified engineers on ITS, the program has yet to be realized.

On August 26th, 2016, the President of the Uzbekistan issued Decree № PP-2580, which aimed to further improve the training of highly qualified specialists in the field of Automobile transport and road communications. The document was necessary to organize a new modern profession in road transportation and road construction.

Today Uzbekistan is taking steps towards improvement of the whole mechanism for the efficient use of transport infrastructure. However, the pace of introduction of new methods and techniques, including the use of ICT in organization and management of traffic flow is very slow. Acute shortage of qualified engineering personnel in ITS is a major obstacle. So far there has been no an academic program in the country that trains engineering staff in the field of ITS. The need for such personnel has become ever so urgent in recent years.

INTRAS partner universities teach in the fields of road transport (Andijan Mechine Building Institute in Uzbekistan, Jizzah Polytechnic Institute in Uzbekistan, Termez State University in Uzbekistan), railway (Tashkent Institute of Railway Engineering in Uzbekistan) and IT (Tashkent University of Information Technology in Uzbekistan)). Therefore, the structure of the INTRAS program is based on a common program for 6 universities, the so-called common track courses and specialization courses at selected universities. Chapter 2 "Selected aspects for common track courses" contains articles prepared by partner universities from Europe directly related to the common track courses with the proposed literature necessary to conduct lectures. Chapter 3 "Uzbek partners' contribution to knowledge" contains articles prepared by academic teachers from Uzbekistan.

INTRAS project description

Table 1 List of courses

No	Name of the courses	Specialization*		
		1	2	3
		TICAR JizPI AndMI TerSU	TIRE	TUIT
Common track				
CT. 01/1	**Structured and Object Oriented Programming with MATLAB and PYTHON**	x	x	x
CT. 02/1	**Advanced Statistics and Data Analysis**	x	x	x
CT. 03/1	**Mathematical methods in transportation**	x	x	x
CT. 04/2	**Traffic modelling and simulation**	x	x	x
CT. 05/2	**Fundamentals of Transport Planning and Management**	x	x	x
CT. 06/1	**Geographic Information Systems**	x	x	x
CT. 07/2	**Fundamentals of ITS**	x	x	x
Specializations				
SC. 01/3	**Intelligent Vehicle Technologies & Smart Mobility**	x		x
SC. 02/2	**Transportation Economics and Demand**	x		
SC .03/3	**Road Traffic Engineering and Optimization**	x		
SC. 04/3	**In-Vehicle Information Systems**	x		
SC. 05/3	**Robotics, Autonomous Vehicles, and Smart Logistics**	x		
SC. 06/3	**Mobility Service Design-and-Management and Economics of Mobility**	x		x
SC. 07/3	**Communications and Information Systems in Smart Transportation**	x		x
SC. 08/2	**ITS and management of logistic systems**		x	
SC. 09/3	**Transportation Economics and Demand Analysis –**		x	
SC. 10/3	**Signalling, Command-Control, and Safety for Railways**		x	
SC. 11/3	**Communications and Localization Systems for Railways**		x	
SC. 12/3	**Traffic Management and Scheduling for Railways –**		x	
SC. 13/3	**Automation, Driver Assistance, and Digital Services in Railway System**		x	
SC. 14/2	**Machine Learning, Big Data, and Data Mining Fundamentals**			x
SC. 15/3	**Image Analysis, Computer Vision, and Video Surveillance Systems**			x
SC. 16/3	**Web Technologies, Recommender Systems, and Mobile Applications in Transportation**			x
MT. 01/4	**Master Thesis**			

1 Ground Transport, Logistics and Automotive
2 Railways
3 Intelligent Information-and-Communications Systems in Transportation

Table 2 *ECTS credits and hours*

No	Name of the course	ECTS	Hours	
			Theory	Practice
Common track				
CT.01/1	**Structured and Object Oriented Programming with MATLAB and PYTHON**	8	45	30
CT.02/1	**Advanced Statistics and Data Analysis**	6	45	30
CT.03/1	**Mathematical methods in transportation**	6	45	30
CT.04/2	**Traffic modelling and simulation**	6	45	30
CT.05/2	**Fundamentals of Transport Planning and Management**	6	45	30
CT.06/1	**Geographic Information Systems**	6	45	30
CT.07/2	**Fundamentals of ITS**	6	45	30
Specializations				
SC.01/3	**Intelligent Vehicle Technologies & Smart Mobility**	5	45	30
SC.02/2	**Transportation Economics and Demand**	5	45	30
SC.03/3	**Road Traffic Engineering and Optimization**	6	45	30
SC.04/3	**In-Vehicle Information Systems**	5	45	30
SC.05/3	**Robotics, Autonomous Vehicles, and Smart Logistics**	6	45	30
SC.06/3	**Mobility Service Design-and-Management and Economics of Mobility**	6	45	30
SC.07/3	**Communications and Information Systems in Smart Transportation**	6	45	30
SC.08/2	**ITS and management of logistic systems**	5	45	30
SC.09/3	**Transportation Economics and Demand Analysis –**	5	45	30
SC.10/3	**Signalling, Command-Control, and Safety for Railways**	6	45	30
SC.11/3	**Communications and Localization Systems for Railways**	5	45	30
SC.12/3	**Traffic Management and Scheduling for Railways –**	6	45	30
SC.13/3	**Automation, Driver Assistance, and Digital Services in Railway System**	6	45	30
SC.14/2	**Machine Learning, Big Data, and Data Mining Fundamentals**	6	45	30
SC.15/3	**Image Analysis, Computer Vision, and Video Surveillance Systems**	6	45	30
SC.16/3	**Web Technologies, Recommender Systems, and Mobile Applications in Transportation**	6	45	30
MT.01/4	**Master Thesis**			

CT.01/1	Structured and Object Oriented Programming with MATLAB and PYTHON

Learning outcomes

- Understanding of basics programming in Python/Matlab
- Acquiring basic knowledge in programs, functions, recursions, arrays, texts, strings, lists, and graphic in Python, and variables, matrices, vector and matrix data visualizing in MATLAB
- Mastering of the script creation, which can be used in other modelling programs (Aimsun API Programming)
- Mastering of base graphic in Tkinter and turtles

Contents

1. Introduction
2. Iterations
3. Graphic
4. Conditions
5. Functions
6. Strings
7. File Management
8. Lists
9. Lists and tuples
10. Tkinter events and binds
11. Turtle
12. Recursion
13. Two-dimensional array
14. Classes
15. Classes and methods
16. Classes and inheritance
17. Errors and Exceptions
18. Polymorphism
19. Matlab basic
20. Variables and expressions
21. Analyzing vectors and matrices
22. Automating commands with scripts
23. Working with data files
24. Working with data types
25. Writing programs with logic and flow control
26. Writing functions

CT.02/1	Advanced Statistics and Data Analysis

Learning outcomes

- Mastering of the tools/instruments to model stochastic phenomena
- Mastering of the tools for the simulation of stochastic dynamics/behavior
- Familiarizing students with the use of probability distribution functions (PDF) as well as cumulative distribution functions (CDF) in cases of univariate and multivariate distributions.

- Mastering of how to apply the background of modelling and simulation acquired in this lecture to real-world stochastic systems or scenarios selected in three different fields of transportation (Railway a Road transportation, Supply chain management and Logistics).
- Mastering the most relevant statistical methods to analyze stochastic data.
- Mastering of the statistical techniques to analyze experimental stochastic data.

Contents

1. **General introduction**
   - 1.1. Importance of statistics and data analysis in road and railway transportation as well as in supply chain management and Logistics.
   - 1.2. Definition of some important keywords and concepts in statistics: illustration through concrete practical examples selected in transportation
   - 1.3. Analytical techniques of modelling: Commonly used methods, concepts and algorithms for data analysis
   - 1.4. Time series forecasting: Classical estimation techniques
2. **Statistical analysis of stochastic phenomena**
   - 2.1. Deterministic systems versus stochastic systems
   - 2.2. Deterministic formalism versus stochastic formalism
   - 2.3. Importance and essence of the estimation process in data analysis
   - 2.4. Fundamental parameters of a stochastic process and measurements
   - 2.5. Importance of the metric Z-score in data analysis
   - 2.6. Importance of the metric confidence interval in data analysis
   - 2.7. Level of confidence and factors affecting the confidence interval range
   - 2.8. Z-score tables: Description, reading techniques, and importance in data analysis
   - 2.9. Elements of the confidence interval estimation
   - 2.10. The central limit theorem (CLT)
   - 2.11. Normal distribution versus standard normal distribution
   - 2.12. Factors affecting the confidence interval (CI) range
   - 2.13. Confidence interval estimates under some assumptions
   - 2.14. Application examples in railway and road transportation, Supply chain management and Logistics
3. **Basics of traffic theory: Fundamentals of queuing and simulation of queuing processes in stochastic scenarios/events selected in transportation**
   - 3.1. Overview of traffic processes/phenomena
   - 3.2. Methods used in traffic theory: Pros/Advantages and Cons/drawbacks
   - 3.3. Models used in stochastic theory: Pros/Advantages and Cons/drawbacks
   - 3.4. Probability distribution functions: Classical mathematical models
   - 3.5. Registration equipment
   - 3.6. Motivation and overview of queuing: Concrete application examples selected in transportation
   - 3.7. General queuing notation (Ref. Kendall 1951)
   - 3.8. Some queuing systems/models

3.9. State analysis of queue systems/models
3.10. Blocking queuing systems/models
3.11. General queuing notation (Kendall 1951)
3.12. Queuing models
3.13. State analysis of queue models/systems
3.14. Mathematical modeling of a single-server queuing system

4. Approximation and fitting
4.1. Norm approximation
4.2. Least-norm problems
4.3. Regularized approximation
4.4. Robust approximation
4.5. Function fitting and interpolation
4.6. Application exercises selected in transportation

5. Statistical estimation
5.1. Parametric distribution estimation
5.2. Nonparametric distribution estimation
5.3. Optimal detector design and hypothesis testing
5.4. Chebyshev and Chernoff bounds
5.5. Experiment design
5.6. Application exercises selected in transportation

6. Geometric problems
6.1. Projection on a set
6.2. Distance between sets
6.3. Euclidean distance and angle problems
6.4. Extremal volume ellipsoids
6.5. Centering
6.6. Classification
6.7. Placement and location
6.8. Floor planning

7. Selected real-world scenarios as application examples in transportation
7.1. Road transportation - Selected concrete scenarios are:
7.1.1 Stochastic modeling and simulation to vehicle system dynamics
7.1.2 Stochastic modeling and simulation of traffic flow
7.1.3 Chaotic behavior of traffic flow
7.2. Railway transportation - Selected concrete scenarios are:
7.2.1 Stochastic analysis of dynamic interaction between train and railway turnout
7.2.2 Simulation of train track interaction with stochastic track properties
7.2.3 Stochastic modeling of track irregularities using experimental data
7.3. Supply Chain Management - Selected concrete scenarios are:
7.3.1 Dynamic supply chains with stochastic policies
7.3.2 Dynamic supply chains with stochastic demands
7.3.3 Modelling of a supply chain network driven by stochastic fluctuations

CT.03/1	**Mathematical methods in transportation**

Learning outcomes

– Understanding of basic systems, scenarios and phenomena in transportation.

- Mastering of the basic concepts of systems' modeling in transportation
- Mastering of the modelling of transportation scenarios/phenomena in graphical forms
- Mastering of the modelling of transportation systems, scenarios and phenomena into mathematical forms.
- Mastering of the modelling of shortest path problems with applications in both road and railway transportation.
- Mastering of the modelling of traveling salesman problems with applications in both road and railway transportation.
- Mastering of the mathematical modeling of traffic flow at macroscopic level using Partial Differential Equations (PDEs); Applications in practice for the modelling of real traffic scenarios on arterial roads.
- Mastering of the mathematical modelling of traffic flow at microscopic level using Ordinary Differential Equations (ODEs); Applications in practice for the modelling of real traffic scenarios on arterial roads.
- Acquiring some basic knowledge in computational engineering. Specifically, the use of MATLAB/SIMULINK for scientific computing (e.g. numerical simulation of nonlinear Ordinary Differential Equations (ODEs) and Partial Differential Equations (PDEs)) of traffic flow on road networks
- Understanding of the functioning principle of supply chain networks (SCN) and their modelling principle.
- Acquiring some basic knowledge in logistics and scheduling.

Contents

1. General introduction

- 1.1. Mathematics as important instrument for improving traffic and transport
- 1.2. Definition of some keywords and concepts in transportation
- 1.3. Principles of modeling nonlinear dynamical systems/scenarios in transportation
- 1.4. Examples of systems' models and scenarios in transportation
- 1.5. Mathematical modeling in transportation: Pros, Cons and related challenges
- 1.6. Fundamentals of system theory
- 1.7. Evaluation of modeling techniques in Transportation
- 1.8. Selected examples of real-life systems/scenarios in transportation: Railway and Road transportation, Supply Chain Networks (SCN) and Logistics
- 1.9. Transportation systems/scenarios undergoing nonlinear & time varying dynamics

2. Basics of graph theory and applications in transportation

- 2.1. Selected applications of graph theory in transportation.
- 2.2. Basic concepts in graph theory
- 2.3. Description of SPP, SPST, MST, TSP, and Max Flow.
- 2.4. Dijkstra algorithm for SPST and MST detection problems in graph networks
- 2.5. Matrix- representation of graph networks (e.g., adjacency-, Incidence-, Circuit- matrices) with concrete examples in transportation

3. **Mathematical modeling of traffic flow**
    3.1. Fundamental parameters of traffic flow: Speed-Flow-Density & related challenges
    3.2. Mathematical modeling of the fundamental parameters of traffic flow
    3.3. Mathematical modeling of the car-following theory of traffic flow and analysis of the dynamics of headways (both space- and time- headways)
    3.4. Mathematical modeling of traffic flow on a single lane road segment
    3.5. Mathematical modeling of traffic flow on a double lane road segment
    3.6. Generalization: Mathematical modelling of traffic flow on a multilane segment (with both overtaking and ramps)
    3.7. Mathematical modeling of wheel pairs movement of a rail vehicles
    3.8. Mathematical modeling of Railway Rescheduling Problem
4. **Basics of traffic signals control at isolated junction**
    4.1. Performance criteria of a traffic junction
    4.2. Mathematical model of a traffic junction
    4.3. Identification of a traffic junction and classification of traffic into streams
    4.4. Protected- and Unprotected- turns; Critical lane concept
    4.5. Traffic signal phasing and timing plan
    4.6. Cycle length; Green time; All-red interval; Delays; Dilemma zones; Pedestrian crossing time; Level of service (LOS); Some illustrative examples from practice.
    4.7. Graphs for traffic lanes and lane- groups
    4.8. Graph representation for road network
5. **Mathematical modelling of scenarios/events in Railway transportation**
    5.1. Graphical models of specific examples in Railway transportation
    5.2. Mathematical models of specific examples in Railway transportation
6. **Basics of supply chain networks (SCN) and modelling principles**
    6.1. Integration and management of business processes
    6.2. Structure of a SCN
    6.3. Framework for SCM
    6.4. Different types of intercompany business process links
    6.5. Different types of intercompany business process links background
    6.6. Fundamental management components in a supply chain network
    6.7. General design principle of a SCN
    6.8. Graphical modeling of a SCN
    6.9. Mathematical modelling of a SCN.
7. **MATLAB-CODING: Numerical simulation of Microscopic, Macroscopic and Mesoscopic traffic dynamics**
    7.1. Case 1. Microscopic traffic dynamics modelled by ordinary differential equations
    7.2. Case 2. Macroscopic traffic dynamics modelled by partial differential equations
    7.3. Case 3. Mesoscopic traffic dynamics modelled by the coupling between ODE&PDE
8. LAB: SYNCHRO 7 & 9: Design of traffic junctions with different control strategies using SYNCHRO and measurement of the performance criteria (e.g. Green signal splitting, Cycle time/length, Throughput of junctions,

Delay at junctions, Number of stops at junctions, quality of service of junctions, etc.) of various traffic junctions

CT.04/1	**Traffic modelling and simulation**

Learning outcomes

- Mastering of the basic concepts of systems' modeling in transportation
- Mastering of the basic concepts of systems' simulation in transportation
- Mastering of the traffic models presented by the literature and their use to analyze and understand the related (or corresponding) scenarios/ events/phenomena
- Mastering of the traffic simulation tools presented by the literature and their use to analyze and understand the scenarios/events/phenomena in transportation.
- Mastering the basic concepts of optimization and the application to some case studies
- Mastering the basic concepts of Neural Networks
- Learning how to model some specific scenarios in road transportation
- Learning how to model some specific scenarios in railway transportation
- Learning how to model some specific scenarios in supply chain networks
- Acquiring some basic knowledge in logistics and scheduling.
- Mastering the application of the concept of optimization in road transportation
- Mastering the application of the concept of optimization in railway transportation
- Mastering the application of the concept of optimization in supply chain networks
- Mastering the application of the concept of optimization in graph networks
- Acquiring some basic knowledge in computational engineering. Specifically, the use of MATLAB/SIMULINK for scientific computing (e.g. numerical simulation of nonlinear Ordinary Differential Equations (ODEs) and Partial Differential Equations (PDEs))

Contents

1. **Introduction to traffic modeling, simulation, management and control**
   1.1. Some illustrative examples: Road-, Rail-, Air, Boat- traffic, and traffic of Goods.
   1.2. Pros/Advantages and Cons/Drawbacks of modeling and simulation
   1.3. Traffic stakeholders and traffic problems: Case studies in Road and Rail traffic.
   1.4. Methods for solving traffic problems: Challenges of traffic modeling & simulation
   1.5. Traffic models classification: Static models; Dynamic models; Continuous model; Discrete model; Deterministic model; Stochastic model; Event-based model;
   1.6. Physical Interpretation of the modeling procedure: White-box modeling; Black-box modeling; Grey-box modeling;
   1.7. Presentation of traffic models: Macro-, Micro-, Meso-,

and Nanoscopic models;
   1.8. Cons/Advantages and Cons/Drawbacks of using traffic simulation models/tools
   1.9. Sample examples of traffic models: Macro, Micro, Meso, & Nanoscopic models

2. **Overview of traffic models and traffic simulation tools**
   2.1. Models of specific road/rail traffic scenarios
   2.2. Three phase traffic theory
   2.3. Some basic terminologies in road and/or rail traffic
   2.4. Presentation of selected traffic simulation tools (commercial and/or open source)
3. **Basics of neural networks and application in transportation**
   3.1. Introduction to neural networks
   3.2. Neural networks structures
   3.3. Learning/Training phase of artificial neural networks (ANNs)
   3.4. Usage phase of artificial neural networks (ANNs)
   3.5. Neuron model and network architecture
   3.6. Convergence of neural network architecture (or platform)
   3.7. Sample application examples of how to solve problems using neural networks
   3.8. Some exercises to check the knowledge acquired in the chapter
4. **Basics of optimization and simulation algorithms/tools for optimization**
   4.1. Linear programming (LP)
   4.2. Quadratic programming (QP)
   4.3. Case studies: Some illustrative application examples
   4.4. Neural networks for optimization
   4.5. Case studies: Some illustrative application examples
5. **Optimization in graph networks with applications in transportation**
   5.1. Modelling of the Shortest path problem in graphs: Applications in transportation
   5.2. Modelling of the Minimum spanning tree (MST): Applications in transportation
   5.3. Modelling of the Traveling Salesman Problem (TSP) in graphs: Applications in transportation. Extension to various Vehicle Routing Problem scenarios (VRP).
   5.4. Mathematical modeling of the Maximum Flow Problem (MFP) in graph networks with application examples in transportation
6. **Optimization in road transportation**
   6.1. Mathematical modeling of the traffic signal control principle at isolated (local) traffic junction: Traffic signals splitting, Green signal sharing, etc.
   6.2. Mathematical modeling of the traffic signal control principle in a network of coupled traffic junctions: Traffic signals splitting, Green signal sharing, etc.
7. **Optimization in railway transportation**
   7.1. Modelling of the train dynamics and optimization of the Energy consumption
   7.2. Mathematical modeling and optimization of the railway

blocking problem
7.3. Optimization of the train trajectory: Modelling concept and simulation method
7.4. Extension of the study in section 7.3 to the derivation of the "Optimization model" for two-train trajectory
7.5. Trains on time. Optimization and Scheduling of railway time tables

8. Supply chain networks (SCN) – Modelling and Analysis of the Dynamics of SCN
8.1. Overview of supply chain networks
8.2. Modelling principle of supply chain networks
8.3. Modelling and optimization of the assignment problem in a SCN
8.4. Supply Chain Management Optimization Problem

9. Scheduling – Fundamentals of Scheduling and Applications in Transportation
9.1. Overview of scheduling
9.2. Principles of scheduling
9.3. Modelling job-shop scheduling problems
9.4. Railway scheduling by network optimization problem
9.5. Modeling of the railway scheduling problem and time-tables optimization
9.6. Modeling and optimization of the Crew scheduling problem in Railway traffic

CT.05/1	Fundamentals of Transport Planning and Management

Learning outcomes
- To realize transport system components and processes
- To understand transport problems on site level and to define these problems
- To understand the context between transport planning and land-use, social and economic conditions
- To realize transport planning actors, institutions, methods and procedures
- To realize role and activities of transport management
- To set up an analysis and implementation programs
- To realize fields for its applications.

Contents

1. Fundamentals of transport systems
1.1. Transport system components
1.2. Transport modes and terminals
1.3. System key issues for all transport modes
1.4. Role of ITS in transport system

2. Transport planning processes
2.1. Formal transport planning procedures on national, regional and local level (planning acts)
2.2. Integration of transport and land use planning

- 2.3. Planning steps (diagnosis and evaluation, goals and concepts, decision making, implementation and monitoring)

3. Transport policy and multi-modal transport studies
- 3.1. Transport policy and strategic planning for ITS
- 3.2. Transport strategies (top-down approach)
- 3.3. Transport plans (bottom-up approach)

4. Surveying and modelling in transport planning
- 4.1. Data availability and travel surveys
- 4.2. Transport models for planning
- 4.3. 4 step travel-demand forecasting model
- 4.4. Scheduled service model
- 4.5. Software availability and specialist modelling knowledge

5. Urban transport planning
- 5.1. Public transport system planning (lines, networks, stations, terminals)
- 5.2. Walking and cycling system planning
- 5.3. Parking system planning
- 5.4. Information system planning
- 5.5. Planning case studies of ITS implementation

6. Intermodal integration planning
- 6.1. Principles of transport integration
- 6.2. Barriers to intermodal integration
- 6.3. Passenger interchange supplies and quality
- 6.4. Freight interchange supplies and quality

7. Accessibility and mobility planning
- 7.1. Accessibility versus mobility
- 7.2. Travel demand management
- 7.3. Mobility management

8. Transportation impacts
- 8.1. Transport safety and security planning
- 8.2. Sustainability in transport planning
- 8.3. Territorial development evaluation
- 8.4. Economic analysis

9. Transport Safety
- 9.1. Transport accidents
- 9.2. Safety evaluation
- 9.3. Safety countermeasures
- 9.4. CBA

CT.06/1	Structured and Object Oriented Programming with MATLAB and PYTHON

Learning outcomes
- independent analytical work in the field of geographic data processing for the purpose of their cartographic visualization in both electronic and analogue form, with the ability to automate their work;
- solving more complicated geographic and cartographic problems in practice;
- work with geographic information systems to solve specific problems

of application character;
- creation and use of digital and analogue topographic and thematic maps;
- creative use of the GIS, GNSS and other ICT techniques.

Contents

5. Input data in GIS
- 5.1 Introduction
- 5.2 Primary data sources
  - 5.2.1 Geodetic measurement
  - 5.2.2 Photogrammetry and photointerpretation
- 5.3 Secondary data sources
  - 5.3.1 Digitalization of map background

6. Analysis in raster and vector format
- 6.1 Spatial and database queries
- 6.2 Grid analyzes
- 6.3 Overlay map layers
- 6.4 Distance analysis
- 6.5 Terrain model analysis
- 6.6 Network analysis
- 6.7 Image analysis

7. Navigation systems
- 7.1 Introduction
- 7.2 Navigation needs
- 7.3 Principle of satellite navigation - trilateration
- 7.4 GPS satellite navigation
- 7.5 Differential correction

8. Excercises
- 8.1. Getting acquainted with GRASS - basic operations, listing map layers, monitors, layer display, imaging region settings, distance measurements. Selection of selected parts of the layers.
- 8.2. Data input - georeferencing of the specified image, vectoring of selected image partitions, acquisition of attribute data, management of the GRASS database part.
- 8.3. Grass analysis - as a background, demonstration datasets from GRASS (spearfish, leics) are used. Due to the fatal lack of vector data, vector-based analyses are not undertaken.
- 8.4. The basics of working with ArcGIS (in preparation) - introduction to ArcEditor from ESRI, including all basic GIS operations.
- 8.5. Generating map output in ArcGIS - processing the result of analyzes in the form of publishable map delta.

CT.07/1	Fundamentals of ITS

Learning outcomes
- To explain the need for intelligent techniques in transport systems
- To identify the basic design problems of Intelligent Transport Systems
- Mastering the tools/instruments for planning the ITS architecture, taking into account the needs of transport process users and the services that can be provided to them (Tutorials/exercises - ITS architecture creating with the FRAME Architecture tools)
- To familiarise students with the basic principles of using ICT technology and the possibilities of using technology in ITS services.

- To familiarize students with the possibilities and methods of acquisition and processing data from sensors.
- To familiarize students with the structures of databases in Traffic Management Centres/Train Operation Management Centres and for what purpose are used data from sensors on the road and data from connected vehicle positioning and vehicle identification systems.

Contents

1. General introduction
  - 1.1. Importance of Intelligent Transportation Systems in road and railway transportation as well as in supply chain networks
  - 1.2. Definition of some important keywords and their illustration through concrete examples: Intelligent Transportation Systems, Traffic Sensors Technologies, Data Acquisition and Processing, ITS Architectures & Services, Information and Communication Technologies, V2V, V2I, V2X
  - 1.3. The historical context of ITS from both public policy and market economic perspectives
  - 1.4. Benefits of ITS

2. Sensors technologies and Data Requirements for ITS
  - 2.1. Applications of Sensor Data to Traffic Management – examples of strategies, algorithms and requirements
    - 2.1.1. Traffic signal parameters
    - 2.1.2. Incident detection
    - 2.1.3. Ramp metering
    - 2.1.4. Speed management
    - 2.1.5. Coordinated operation of motorways and alternative roads (including Advanced Traveller Information Systems)
    - 2.1.6. Traffic data collection
    - 2.1.7. Using sensor data to characterize, detect, and analyze sensor failure modes
    - 2.1.8. Detection of priority vehicles
    - 2.1.9. Overheight and Weigh-in-Motion sensors
    - 2.1.10. Weather and surface condition sensors
    - 2.1.11. Vehicle-Mounted Sensors that Enhance Safe Operation
    - 2.1.12. Measures of data uniformity
    - 2.1.13. Statistical Measures of Data
    - 2.1.14. Use of data to supply transport models
  - 2.2. Traffic Flow Sensor Technologies
  - 2.2. Traffic Flow Sensor Technologies
    - 2.2.1. Video Image Processor
    - 2.2.2. Microwave Radar
    - 2.2.3. Laser Radar Sensors
    - 2.2.4. Infrared Sensors
    - 2.2.5. Ultrasonic Sensors
    - 2.2.6. Passive Acoustic Array Sensors
    - 2.2.7. Inductive Loop Detectors
    - 2.2.8. Magnetic Sensors

- 2.2.9. Traffic Flow Data from Automatic Vehicle Identification Transponders
- 2.2.10. Traffic Flow Data from Mobile Devices
- 2.2.11. Sensor Combinations

2.3. Sensors in railway transportation
- 2.3.1. Signal Sensing Technologies of Traction System Sensors
- 2.3.2. Sensor Data Acquisition and Processing
- 2.3.3. Sensor Fault Diagnosis
- 2.3.4. Intelligent Sensor Technology

3. Information and Communication Technologies in ITS and system fundamentals

3.1. Importance of communication and computer technology in the ITS
3.2. Transponders and Communication systems
3.3. Information Management, Traffic Management Centers (TMC), Train Operation Management Centres
3.4. IT networks: transmitters, receivers, transmission media. Data transmission protocols.
3.5. Local and Wide Area Networks, LAN, WAN. Rules of network connection.
3.6. Brief overview of wireless systems, e.g. GSM, GSM-R, VSAT, WiFi, GPRS. Wireless sensor networks WSN. Standardization.
3.7. Elements of Positioning, Vehicle Location and Route Navigation and Guidance concepts
- 3.7.1. GPS
- 3.7.2. Automatic Vehicle Location (AVL)
- 3.7.3. Automatic Vehicle Identification (AVI)

3.8. Geographic Information Systems fundamentals and applications
3.9. Data collection, data storage, data bases in ITS, big data
3.10. Video data collection and analysis
3.11. Connected Vehicle Technology
3.12. Data Fusion at the Traffic Management Centres
- 3.12.1. Definition of Data Fusion
- 3.12.2. Processing levels and methods
- 3.12.3. Data Fusion Architectures
- 3.12.4. Intelligent systems overview
  - Expert systems,
  - Bayesian Inference
  - Dempster-Shafer Inference
  - Voting Fusion
  - fuzzy logic systems,
  - artificial neural networks,
  - evolutionary computations,
  - multi-agent system

4. ITS Architectures & Services

4.1. ITS user services and applications
- 4.1.1. Travel and traffic management
- 4.1.2. Public transportation operations
- 4.1.3. Electronic payment

4.1.4. Commercial Vehicle operations and ITS services in supply chain networks
4.1.5. Advanced vehicle control and safety systems
4.1.6. Emergency management
4.1.7. Information management
4.1.8. Automatic Train Control (ATC)
4.1.9. Rail Traffic Management Systems and Train Control Systems (e.g. ERTMS, ETCS)
4.1.10. Maintenance and construction management

4.2. ITS Architecture
4.2.1. National ITS architecture
4.2.2. User services and their requirements
4.2.3. Logical architecture
4.2.4. Physical architecture
4.2.5. Market packages

4.3. Railway Intelligent Transportation System architecture

4.4. ITS Planning
4.4.1. Planning integrated ITS using ITS Architecture
4.4.2. Transportation planning and ITS
4.4.3. Integrating ITS into Transportation planning

SCA.01/3	**Intelligent Vehicle Technologies & Smart Mobility**

Learning outcomes

Contents

MODULE 1: INTELLIGENT VEHICLE TECHNOLOGIES

1.1 General Introduction

a) ITS (intelligent transport systems) overview
b) Intelligent vehicles initiatives in various countries (USA, EUROPE, JAPAN)
c) Core ITS services, a brief overview
d) General architecture(s) / frameworks for intelligent vehicles
e) Five key stages to the processing aspects of a self-driving vehicle

1.2 Enabling Technologies overview

a) Environment perception for intelligent vehicles
- Road detection and tracking (lane detection, lane tracking, road recognition)
- Vehicle detection and tracking
- Multiple-sensor based multiple-object tracking
- Dynamic environment modeling

b) Vehicular communication
c) Positioning technologies/concepts and digital maps
- GPS based localization fundamentals
- Integrated DGPS/IMU (differential global positioning system / inertial measurement unit) positioning approach
- Vehicle navigation using global views
- Framework(s) for vehicle localization and map building

d) Big data in road transport and mobility research
e) Prediction and routing
f) Path planning and decision making
g) Control of intelligent vehicles
   – Lateral motion control
   – Longitudinal motion control

1.3 Applications

a) Driver assistance systems and safety systems
b) Cooperative systems
c) Automated driving
d) Use cases for autonomous driving

1.4 Further Aspects (incl. social, economic, simulation, and research)

a) Overview of human factors (human driver behaviors, user interface(s), impact of automated cars/vehicles on society and mobilities)
b) Law, ethics and liability issues (special legal questions, product liability, regulation, risks assessment (technical, legal, and economic))
c) Acceptance issues
d) Simulation tools (driving simulators, traffic simulation, data for training models, domain adaptation)
e) The socio-economic impact of the intelligent vehicles: implementation strategies
f) Future perspectives and hot research areas/issues

1.5 Simulation exercises of intelligent vehicles using open source software tools

Software Tools (open source):

- Apollo
- Autoware

MODULE 2: SMART MOBILITY

2.1 General Introduction

a) Urban mobility trends and challenges (traffic congestion, parking problems, traffic accidents, energy consumption, environmental impacts)[1]

2.2 Fundamentals[2]

a) Urban mobility systems & infrastructures
   – Urban transport systems (UTS) definitions
   – Examples of the need for UTS engineers
   – Example of a simulation tool to simulate UTS: MATSim
b) Monitoring mobility in smart cities (introduction to big data, monitoring mobility, time geography, travel momentum fields (TMF), TMF – transport route projections, TMF – before-after analysis)
c) Modeling and simulation of mobility systems – a brief introduction

d) Learning from public information / inverse transportation problems (machine learning applications in urban transport, inverse transportation problems, multiagent inverse transportation problems, network learning)

2.3 Systems

a) The 5 smart digital layers[3] (urban layer (smart buildings, smart grid, smart mobility, smart waste management); sensor layer (this layer includes smart devices that measure and monitor different parameters of the city and its environment); connectivity layer (this layer involves the transport of data and information from the sensor level to storage and to data aggregators for further analysis); data analytics layer (this layer involves the analysis of data collected by different smart infrastructure systems, to help predict some events (such as traffic congestion); automation layer (the digital enabling interface layer that enables automation and scalability for a large number of devices across multiple domains and verticals)).
b) Technologies and data transmission in ITS and smart mobility
c) Smart cities, smart communities: definitions of the concepts
d) Smart mobility in urban/metropolitan areas + case studies[4]
   – People mobility (walking and cycling, sharing mobility systems (bike sharing, car sharing, ride-sharing and ride hailing), local public transport, integrated multi-modal transport and smarter mobility services)
   – Transport demand management (real-time traffic management, smart parking)
   – Urban freight and city logistics
   – Green mobility and low emission zones (clean and energy efficient vehicles, congestion charges and low emission zones)
   – Other mobility solutions of the future
e) Building blocks of intelligent mobility[5]
   – Smart mobility program management
   – Smart services (mobility platforms for route optimization and intermodal ticketing in transportation, smart parking solutions, automated logistics, new flexibility in public transport)
   – Smart data
   – Smart products
   – Smart spaces
f) Automation and autonomous driving in mobility systems
g) Mobility as a Service (MAAS) – a brief overview
h) Human factors

2.4 Mini-Project

a) A mini-project or a study-seminar in groups (2-3 students per group)
b) An open source simulation software should be used.

c) Simulations of interesting scenarios of urban mobility.
   Tool: Polaris

2.5 Field visit

- Visit one infrastructure/facility, a project, a manufacturer or a relevant service provider in the region

[1] *Source, see Chapter 2 of the Book:*
https://www.amazon.com/dp/B01IFBO5ZQ/ref=rdr_kindle_ext_tmb

[2] *Source, see Chapter 1 and 2 of the Book:*
https://www.amazon.com/dp/0128136138/ref=rdr_ext_tmb

[3] *Source (s. page 7):*
https://unctad.org/meetings/en/SessionalDocuments/ecn162016d2_en.pdf

[4] *Source, see Chapter 3 of the Book:*
https://www.amazon.com/dp/B01IFBO5ZQ/ref=rdr_kindle_ext_tmb

[5] *Source, see Parts II and III of the book:*
https://www.amazon.com/Smart-Mobility-Connecting-Everyone-Practices/dp/365815621X/ref=sr_1_3?keywords=Smart+mobility&qid=1552572735&s=gateway&sr=8-3

SCA.02/2	**Transportation Economics and Demand**

Learning outcomes

- to analyze fixed and variable costs;
- to use the dynamic calculation;
- to use the elasticity of demand to dynamic calculation
- to design the organizational structure of the enterprise.

Contents

1. Impact of Transport Policy on Economy of Road Transportation Enterprise

2. Own Costs and Their Division

2.1. Classification by Elements of Costs
2.2. Classification of Costs According to Purpose
2.3. Classification of Costs According to Place of Occurrence and Responsibility for their Occurrence
2.4. Calculating Classification of Costs
2.5. Classification of Costs according to Dependency on Volume of Performed Performances
2.5.1. Fixed Costs
2.5.2. Variable Costs (Flexible, Variable)

3. Calculations of Own Costs

3.1. Calculation System
3.2. The Method of Calculation with Classification of Costs to Variable and Fixed
3.2.1. Methods of Fixed Costs Calculation
3.3. Dynamic Calculation of Own Costs
3.4. Comparison of the "Current Practice" in Calculation and Dynamic Calculation

3.5. Some Possibilities of Utilization of Dynamic Calculation Computer Model

4. Determination of Prices in the Road Transport

4.1. Costs Principle
4.2. Utility Principle
4.3. Price Limits in Transport
4.4. Price Regulation
4.5. Tariff Systems
4.5.1. Price Policy
4.5.2. Tariff in Regular National Bus Transport
4.5.3. Tariff System of Integrated Transport System
4.5.4. Tariff Types
4.5.5. Tariff Arrangement for Zone Tariff
4.6. Price Policy
4.7. Possibilities of Discounts Use

5. Human Resources and Wages

5.1. Legislative Requirements on Human Sources in the Companies of the Road and Urban Transport
5.1.1. Management of Road and Public Transportation Companies
5.1.2. Drivers of the Road Freight Transport and Bus Transport
5.2. Wages and Labour Market
5.2.1. General Level of Wages
5.2.2. Labour Offer
5.3. Wage Systems
5.4. Motivation of the Employees
5.5. Work Productivity in the Road and Urban Transport

6 Firm Organizational Structures

6.1 Types of Organizational Structures
6.1.1 Line Organizational Structures
6.1.2 Functional Organizational Structures
6.1.3 Divisional Organizational Structures
6.1.4 Line-and-Staff Organizational Structures

7. Analysis of production factors in road transport company

7.1. Transformation process and corporate production factors
7.2. Production factors of road transport company
7.3. Regularities of the transformation process of turning inputs into outputs in form of transport services.
7.3.1. Transport service as a product
7.3.2. Secondary character of the demand for road transport services
7.3.3. Irregularity of the demand for road transport services
7.3.4. Dependency of customers on road transport industry
7.3.5. Changes in the number, structure and distribution of population

SCA.03/3	Road Traffic Engineering and Optimization

Learning outcomes

- To explain the need for traffic engineering application in transport systems
- To identify the human and vehicle dynamics factors in traffic engineering design as well as relationships among human-vehicle-road
- To use an appropriate traffic flow theory for traffic characteristics
- To familiarise students with the traffic count methods
- To familiarize students with the the capacity and signalized intersection analysis as well as signal optimization at intersection and within traffic control system
- To familiarize students with the basic knowledge on traffic control systems as ITS service.

Contents

1. General introduction

1.1. Traffic engineering discipline

1.2. Introduction to traffic engineering: Road user characteristics, human and vehicle characteristics (Vehicle motion and human factors)

1.3. Road dependent factors, climatic and meteorological factors.

2. Traffic stream characteristics

2.1. Fundamental parameters and relations of traffic flow (speed, density, volume, travel time, headway, spacing, time-space diagram, time mean speed, space mean speed and their relation, relation between speeds, flow, density, fundamental diagrams)

2.2. Traffic stream models (e.g. Greenshield's model, Greenberg's logarithmic model, Underwood's exponential model, pipe's generalized model, multi-regime models, basic statistical concepts; traffic volume studies; speed, travel time & delay studies, queuing theory and traffic flow analysis, traffic analysis at motorway bottlenecks)

2.3. Advanced Microscopic traffic flow modelling

2.3.1. Car-following models: Concept of stimulus-response, safety distance, pscho-physical, optimal velocity, fuzzy logic models, and applications;

2.3.2. Lane changing models: Conceptual framework, lane selection model, gap acceptance models;

2.3.3. Vehicle arrival models: Poisson distribution, headway modeling, random vehicle generation,

2.3.4. Microscopic traffic simulation: Vehicle generation, design, calibration, validation, applications, operational models.

2.4. Macroscopic and mesoscopic traffic flow modelling

2.4.1. Traffic flow modeling analogies: Fluid flow analogy, heat flow analogy, granular flow, Lighthill-Withams theory, shock waves;

2.4.2. Cell transmission models: Flow conservation, flow transmission;

2.4.3. Traffic progression models: Robertson progression model,

platoon movement, dispersion index, applications;
- 2.4.4. Discrete simulation models: Cellular automata concepts, discretization of time and space, rules for acceleration, deceleration, randomization, and vehicle updation.

3. Traffic measurement procedures and methods

- 3.1. Measurement at a point: Traffic volume and speed measurement, equipment for flow measurements, data analysis, concepts of ADT, AADT;
- 3.2. Measurement over a short section: Speed measurements, 15th and 85th percentile speeds, design speed, speed distributions;
- 3.3. Measurement along a length of road: Density measurement, travel time measurement;
- 3.4. Automated traffic measurement: GPS devices, loop detectors, video analysis, and other technologies

4. Road geometry basics

5. Capacity and level of service analysis. Measures of traffic effectiveness.

- 5.1. Capacity and Level of service LOS: Definitions, highway capacity, factors affecting LOS, HCM methods;
- 5.2. Urban Streets: Classification, operational performance measures, congestion management; MOEs
- 5.3. Multilane highways: Characteristics, capacity and level of service;
- 5.4. Freeway operations: Operational considerations, capacity and level of service of a basic freeway segment, weaving and merging operations;
- 5.5. Ramp metering: Merging and diverging areas; gap acceptance, speed at ramps; fixed, reactive, and predictive systems;
- 5.6. Corridor analysis: Segment capacity, free flow travel time, queue delay, transit corridor.

6. Traffic control and management

- 6.1. Principles of traffic control: Requirements, basic driving rules, priority movements, principles of traffic control, intersections conflicts;
- 6.2. Traffic signs and road markings: Regulatory, warning, and information signs; longitudinal, transverse, and object marking;
- 6.3. Uncontrolled intersection: Level of service, priority streams, conflicting traffic, critical gap and follow-up time, capacity, queue length, delays;
- 6.4. Assessment of the reasonableness of traffic signals introducing (choice of intersection type) and links between geometrical solutions and traffic organisation in terms of signs and marking and signalling parameters
- 6.5. Traffic signal design
  - 6.5.1. Elements of traffic signal: Definitions, basic parameters, analysis of saturation headway, saturation flow, lost time, critical flows, derivation of cycle length;
  - 6.5.2. Design principles of a traffic signal: Phase design, cycle time determination, green splitting, pedestrian phases

and performance measures;
- 6.5.3. Evaluation of a traffic signal: Definitions and measurement of stopped and control delay, Webster's delay model, oversaturated conditions;
- 6.5.4. Capacity and LOS analysis of a signalized intersections: HCM 2010 method of analysis of a signalized intersection and determination of the level of service;
- 6.5.5. Coordinated traffic signal: Concepts of offset, common cycle length bandwidth, offset for one-way and two way streets ;
- 6.5.6. Vehicle actuated signals and area traffic control: Basic principles of vehicle actuation, collection of data, system architecture and algorithms
- 6.5.7. Methods to optimise signals at intersection, along the streets and in the area.

SCA.04/3	In-Vehicle Information Systems

Learning outcomes

Contents

1. **Introduction and motivation**
2. **Definition of vehicle information systems**
3. **Scope and examples of vehicle information systems**
4. **Vehicle Information System Architecture**
   - 4.1. Running controlling machine (communication, monitoring, auxiliary driving, environmental awareness, help)
   - 4.2. Information management machine (communication, monitoring, environmental awareness, help, information querying, auxiliary driving, position navigation)
   - 4.3. Security network communication machine (communication, help, monitoring, environmental awareness, position navigation, cooperative engagement, remote operations)
   - 4.4. Public network communication machine (internet searching, internet data querying, communication with other vehicles in the Internet)
5. **In-vehicle bus systems**
   - 5.1. CAN bus
   - 5.2. Flexray
   - 5.3. Others in-vehicle communication networks
   - 5.4. Internet of vehicles
6. **In-vehicle information databases**
7. **On-board vehicle cloud center information system**
8. **Human factors and driver behavior**
   - 8.1. Human factors
   - 8.2. Driver behavior
   - 8.3. Effect of human factors on driver behaviour
9. **Usability evaluation framework for in-vehicle information systems**

9.2. Preparing a usability evaluation
9.3. Selecting usability evaluation methods
9.4. Usability evaluation methods (analytic evaluation methods, empirical evaluation methods)

10. Vehicle control systems and information systems

10.1. Introduction
10.2. Vehicle dynamics control systems
10.3. On-board environmental recognition sensors
10.4. Links between vehicle dynamics and information systems

11. Vehicle services

11.1. Definition of vehicle services
11.2. From vehicles to vehicle services
11.3. Mobile services for vehicles
11.4. Conceptual Framework for remote vehicle diagnostics services
11.5. Vehicle ecosystem
11.5.1. What is a vehicle ecosystem
11.5.2. Traditional vehicle ecosystem
11.5.3. Electric vehicles ecosystem
11.5.4. Towards safe and secure autonomous and cooperative Vehicle Ecosystems

12. Selected Topics for Students Research Seminars (2-3 students per group)

12.1. Data analytics and artificial intelligence for vehicle data processing
12.2. Wearables for vehicle information systems
12.3. Privacy, trust, security, safety, legal, moral and ethical aspects in vehicle data processing and usage
12.4 Standardization of vehicle interfaces and information
12.5. Business models and platform ecosystems in the context of Vehicle IS
12.6. Decision support systems (DSS) in the context of Vehicle IS

13. Practical simulation experiments using the simulation tool VSimRTI

14. Field visit - Visit one infrastructure/facility, a project, a manufacturer or a relevant service provider in the region

SCA.05/3	**Robotics, Autonomous Vehicles and Smart Logistics**
Learning outcomes	

Contents

MODULE A: INTRODUCTION TO ROBOTICS

1. Introduction

1.1. What is robotics
1.2. Robot mechanical structures (robot manipulators, mobile robots)
1.3. Industrial robotics
1.4. Advanced robotics (field robots, service robots)
1.5. Robot modelling, planning and control

2. Selected challenges

2.1. Intelligence and embodiment

2.2. A roboticist's problem
2.3. Ratslife
2.4. Challenges of mobile autonomous robots
2.5. Challenges of autonomous manipulation

3. Locomotion and manipulation
3.1. Locomotion and manipulation examples
3.2. Static and dynamic stability
3.3. Degrees-of-freedom

4. Forward and inverse kinematics
4.1. Coordinate systems and frames of reference
4.2. Forward kinematics of selected mechanisms
4.3. Forward kinematics using the Denavit-Hartenberg scheme
4.4. Inverse kinematics of selected mechanisms
4.5. Inverse kinematics using Feedback-Control

5. Path planning

6. Trajectory planning

7. Actuators and internal sensors for robots

8. External environment perception sensors

9. Control architectures

10. Artificial intelligence reasoning and learning for robots
10.1. Artificial intelligence reasoning
10.2. Robot learning

MODULE B: Autonomous Vehicles overview

1. Benefits of autonomous driving

2. General architecture and autonomous driving technology overview

3. Selected technologies enabling autonomous vehicles
3.1. Sensors (cameras, lidar, ultrasonic sensors)
3.2. Electronic control systems (throttle system, brake-by-wire, steer-by-wire, shift-by-wire)
3.3. Computer processing
3.4. Software (software architecture, sensor fusion, simultaneous localization and mapping, simulation, machine learning)
3.5. HD mapping (localization)
3.6. Vehicle-to-X Communications
3.7. 5G communications
3.8. Electric vs. Hybrid Vehicles

4. Categories and levels of automation
4.1. Categories of autonomous driving (semi-, sufficiently-, fully-)
4.2. SAE levels of autonomous driving
4.3. Basic driver assistance functions
4.4. Semi-autonomous driving functions
4.5. Sufficiently-autonomous driving
4.6.. Special situations
4.7. How an autonomous system sees the world
4.8. Interior of autonomous vehicles

5. Autonomous driving algorithms
5.1. Sensing

5.2. Perception
5.3. Object recognition and tracking
5.4. Action

6. Autonomous driving client system
6.1. Robot operating system (ROS)
6.2. Hardware platforms

7. Autonomous driving cloud platform
7.1. Simulation
7.2. HD map production
7.3. Deep learning model training

8. Prediction and routing
8.1. Planning and control overview
8.2. Traffic prediction
8.3. Lane level routing

9. Trucks, Delivery Vehicles, and Buses
9.1. Ridesharing systems
9.2. Autonomous trucking
9.3. Autonomous package delivery
9.4. Autonomous food delivery
9.5. Autonomous shuttle services
9.6. Autonomous bus transportation
9.7. Military autonomous vehicles

MODULE C: SMART LOGISTICS OVERVIEW

1. A brief introduction to logistics and supply chains
1.1. Definitions of the core concepts: logistics, supply chain, E-logistics
1.2. Supply chain, a brief survey
1.3. Logistics, a brief survey
1.4. Inventory management in supply chains, a brief survey
1.5. E-logistics – historic development

2. Supporting ICT infrastructure for future logistics
2.1. ICT and logistics
2.2. Intelligent transportation systems
2.3. Smart grids
2.4. The convergence infrastructure for ITS and the smart grid
2.5. Applications of a convergence infrastructure for ITS and the smart grid

3. ICT for airfreight management
3.1. Introduction
3.2. Airfreight – the challenges
3.3. The airfreight supply chain
3.4. Customer interfaces
3.5. Issues

4. ICT for rail freight management
4.1. Introduction
4.2. Basic principles of ICT for rail freight operations
4.3. What do rail freight customers want?
4.4. Tracking and tracing information for customers
4.5. Other ICT applications that help rail freight to play to its strengths

4.6. The role of ICT for rail freight in European railways

5. ICT for efficient road freight transport

5.1. Introduction
5.2. Skylark cargo services
5.3. Cloud computing
5.4. Telematic data
5.5. Data sources
5.6. IT system development
5.7. Big data

6. Port-centric ICT system

6.1. Introduction
6.2. The importance of ICT to port systems
6.3. The port-centric ICT
6.4. Information matrix of port-centric ICT
6.5. ICT investment
6.6. Port community systems
6.7. Policy implications

SCA.06/3	Mobility Service Design-and-Management and Economics of Mobility

Learning outcomes

- Mastering of mobility plans creation and implementation
- Mastering of infrastructure designing for mobility services
- Mastering of mobility services designing and linking
- Acquiring knowledge of shared mobility
- Acquiring knowledge of information systems and technologies used in mobility services
- Understanding problems and advantages of electro mobility
- Understanding environmental impact of the transportation systems and mobility services
- Acquiring basic knowledge of mobility services in low emission zones
- Mastering of mobility services assessment and calculations of services' costs and benefits

Contents

1. Mobility plans and their importance

1.1. Definition and content
1.2. Citizens and stakeholders participation
1.3. How to design and develop a mobility plan
1.4. Objectives, targets, goals
1.5. Mobility survey
1.6. Planning and implementing measures
1.7. Monitoring
1.8. Best practices from abroad

2. Planning infrastructure and services for people

2.1. Pedestrians
2.2. Public transport

2.3. Cyclists
2.4. Cars
2.5. Parking
2.6. Mobility of disabled people

3. Transportation terminals and multimodal travelling

3.1. Analysis
3.2. Design

4. Electro-mobility and impact on transport system

4.1. Infrastructure needed
4.2. E - buses - technologies and route planning
4.3. E - bicycles
4.4. E - scooters
4.5. E - cars
4.6. Influence of electro – mobility on peoples´ transport behaviour

5. Shared mobility

5.1. Car sharing
5.2. Carpooling
5.3. Taxi services sharing (UBER, TAXIFY, WETAXI)
5.4. Bike sharing
5.5. Business model
5.6. Mobility as a service (MaaS)

6. Information and communication systems and technologies

6.1. Infrastructure
6.2. Public transport
6.3. Sharing systems

7. Energy consumption and environmental impacts

7.1. Calculation of transport impacts
7.1.1. Consumption
7.1.2. Emissions
7.1.3. Voice, vibration
7.2. Various transport mode comparison

8. Designing services in low emission zones

8.1. Access policy
8.2. Mobility inside low emission zones
8.3. Parking policy
8.4. City logistics

9. CBA of investments

SCA.07/3	Communications and Information Systems in Smart Transportation

Learning outcomes

- independent analytical work in the field of intelligent transport systems;
- provide qualified look at solutions of transport issues using communication and information systems;
- applications of ITS to improve quality and permeability of transport and reduce a number of traffic accidents and their consequences;
- using communication and information systems to provide real time

information to all users of road network;
- Familiarize with information systems in vehicles and systems affecting traffic flow.
- Familiarize with support software PTV Map and Guide Internet uses in freight transport management.

Contents

10.1. Legislative requirements of information systems in companies
10.2. Software support for freight transport planning as a part of information system

11. Excercises

11.1. Getting acquainted with PTV Map and Guide Internet - basic operations.
11.2. Data input – defining a transport from origin to destination, vehicle parameters, type of goods (loading/unloading), defining restrictions (legislative, real time traffic conditions, and weight limitations).
11.3. Calculation results – route from origin to destination, environment impacts of transportation, emissions and energy consumption.
11.4. Project elaboration – every student will elaborate own project with defining an origin and destination of transportation by lecturer. Students will make this project with lecturer assistance for better understanding of each part of modelling specified transportation relation in PTV Map and Guide Internet.

INTELLIGENT TRANSPORT SYSTEMS – MASTER'S PROGRAM FOR UZBEKISTAN

Chapter 2
GOOD PRACTICE

Mathematical modeling and numerical simulation of traffic behavior at a macroscopic level of detail

J. C. Chedjou[1], and K. Kyamakya[2]

Abstract: *This work investigates the dynamics of traffic flow on a road network. The investigation is restricted to the scenario of the traffic flow on a single road segment without overtaking maneuvers and without differentiating between vehicle types (macroscopic level of detail). The mathematical modeling of the scenario is performed and the resulting mathematical model is obtained in the form of a partial differential equation (PDE). The equation obtained corresponds to the LWR model (Lighthill-Whitham-Richards model). The numerical simulation of the PDE is carried out and the numerical results/solutions lead to the discovery of various striking (conspicuous) traffic flow phenomena. In particular, some interesting phenomena such as shock waves, rarefaction waves, and synchronized waves are observed through the numerical simulation of the PDE. Based on the numerical solutions of the PDE, the fundamental diagram of traffic flow (i.e., the 3D representation of the relationship between speed, flow and density) is analyzed. The analysis reveals/shows various critical states of traffic, namely the state under saturation, the state at saturation and the state oversaturation. In order to validate the mathematical model (PDE) obtained for the traffic scenario envisaged in this work, the numerical solutions of the PDE are used to draw the fundamental diagram of the traffic flow and the results obtained are compared with the results of the fundamental diagram of the classic Greenshields model. The comparison shows a very good agreement between the methods (i.e., "PDE-based model" versus "Greenshields model"). Finally, we explain how the preliminary results obtained in this work can be extended to the analysis of more complex traffic scenarios that include overtaking maneuvers, ramps and a distinction between vehicle types. Such complex scenarios could lead to the discovery of very complex states of the traffic flow, which could range from periodic states to quasi-periodic states and even up-to chaotic states.*

Index Terms - *Mathematical modeling of traffic, Numerical simulation of PDE, Traffic phenomena, Shock waves, Rarefaction waves, Synchronized waves, Complex traffic states, Under-saturated traffic, Saturated- traffic, Over-saturated traffic, Fundamental diagram of traffic flow, Benchmarking.*

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Introduction

In the last few decades, great attention has been paid to the development of innovative techniques, concepts and algorithms for traffic analysis and forecasting. This tremendous attention has resulted in interesting papers proposing new analytical and numerical methods for traffic analysis and forecasting. Some selected contributions that have attracted the attention of scientists are the mathematical methods for microscopic traffic analysis [1-21], the mathematical methods for macroscopic traffic analysis [22-39], the mathematical methods for mesoscopic traffic analysis [19 -20] and the cellular automata for traffic analysis [19-20], neural networks for traffic analysis and calibration [43-44], to name just a few.

With regard to traffic analysis at a microscopic level of detail, several microscopic models for car-following behavior have been developed. The non-linear effect in the car-following behavior was first described by Newell [1]. Bando et al. [2] later developed a simple but innovative and popular OV (Optimal Velocity) model for car- following behavior [3–7]. The OV model was improved by Jiang et al. [5] by developing an FVD (Full Velocity Difference) model that takes the positive speed difference factor into account. The Jiang's FVD model is better (compared to the OV model and the GF (Generalized Force) models [8]) when it comes to characterizing the real behavior of vehicle tracking [9–11]. The FVD model was further significantly improved by Zhou [12], who developed an expanded version of the FVD that takes driver behavior into account. Another improvement on the FVD model was made by Peng et al. [13]. The authors developed a new car-following model taking into account the anticipation effect. Based on the FVD model, Yu et al. [14] developed an advanced adaptive cruise control strategy that integrates the relative speed change. Other notable/remarkable dynamic models have been proposed (see Pengcheng et al. [15], Nagatani [16], Ge et al. [17] and Sun et al. [18]) to address the stability/robustness problem of the OV, GF, FVD models. Let us mention that models based on cellular automata [19], [20] have also been developed for car-following behavior. Despite the proven efficiency (characterized by high computing speed) of the CA models, their accuracy is questionable (not good). Finally, a group of so-called microscopic traffic simulators with discrete events, e.g. B. VISSIM (see [21] and the references therein), were used to simulate car-following behavior. The microscopic traffic simulators with discrete events offer the best precision of all previous alternatives, but their main limitation is the enormous computation time and the enormous memory requirements.

The pioneering/seminal model for traffic flow was proposed by Lighthill-Whitham (1955) [22] and Richards (1956) [23] under the acronym of the LWR model. This model is first order and is based on the continuity equation from the theory of compressible dynamics. The LWR model expresses the conservation of a flowing quantity from one point to another. It is known (from literature) that the LWR model can efficiently handle the development of shock waves [23]. The LWR model is subject to limitations, however, as it requires both a "constant speed" and "infinite acceleration of vehicles". To address the disadvantages of the LWR model mentioned above, the Payne [24], Ross [25] and Del Castillo [26] models were developed. However, it was further shown that the Payne, Ross and Del Castillo models do not integrate/respect the anisotropic principle. This disadvantage can lead to negative speed values when using the models. This latter specific disadvantage was addressed by the development of a class of models such as Zhang [27], Jiang et al. [28] and Gupta and Katiyar [29], to name just a few. Although the above PDE models for macroscopic traffic can efficiently capture the spatio-temporal behavior of traffic flow on a road segment, they appear to be less accurate and very time consuming (i.e. computationally intensive). Therefore, they do not meet the tough requirements for online traffic simulation. Overall, several analysis methods/concepts have been developed to efficiently detect some specific key insights/features of traffic flow such as oscillatory waves [30], stop-and-go-waves [31], rarefaction waves [32], bottlenecks caused by onramps, offramps, road works, accidents [31], etc. More information on the mathematical models for traffic flow (ODEs & PDEs) can be found in [31– 39].

In order to make the aforementioned mathematical traffic models (e.g. microscopic models (ODEs) and macroscopic models (PDEs)) more realistic, calibration is essential. Indeed, the ability / potential of ODEs and PDEs models to efficiently estimate the correct insight/knowledge of traffic flow depends essentially on calibration. Here the calibration consists in using the real traffic data (e.g. sensor data) to estimate the parameters (or coefficients) of the ODEs and PDEs models to make them more realistic. Various techniques for calibrating macroscopic and microscopic models have been developed. The more interesting techniques are based on optimization processes (e.g. data mining [40], genetic and memetic algorithms [41] and bisection analysis [42], to name just a few). Let's mention that traffic models are generally calibrated offline while using appropriate math or soft computing tools. Further details on the calibration of traffic models can be found in [40 - 42]. Further information on the calibration-based neural network can be found in [43 - 44].

This work mainly focuses on the mathematical modeling and numerical simulation of the traffic flow on a road segment. The macroscopic level of detail is taken into account since no distinction is made between the vehicle types. Furthermore, the scenario under study does not take into account overtaking maneuvers and the ramps (i.e., entering and exiting) are not taken into account. The work is organized as follows. Section 2 deals with the mathematical modeling of the traffic scenario. The resulting mathematical model is expressed in the form of a partial differential equation (PDE). Section 3 focuses on numerical simulation. The discretization scheme LAX [45] is used to determine the optimal conditions under which convergent solutions can be obtained when performing the numerical solving of the PDE. The boundary conditions corresponding to the LAX scheme of the PDE are derived analytically. Various numerical results are obtained from which some specific traffic phenomena are expressed (e.g. shock waves, rarefaction waves, bottlenecks, etc.). These phenomena are further commented on with regard to the real (or concrete) traffic dynamics on the road. The fundamental diagram expressing the 3D representation of speed, flow and density is obtained by numerically solving the PDE. The PDE-based fundamental diagram is further compared with the fundamental diagram of the Greenshields model [46]. Section 4 is devoted to the concluding remarks. We offer a brief summary of the results obtained. Finally, we discuss a possible extension of the preliminary results to more complex traffic scenarios that include overtaking maneuvers, ramps and mixed mode traffic (e.g. different vehicle types).

II. Mathematical Modeling

Figure 1 shows the traffic flow on a road segment located between two stations of length ΔX. The traffic states are characterized by the fundamental parameters flow, speed, and density. The traffic states estimation (TSE) is very important for traffic management. The TSE is based on the analysis of interactions between flow, speed, and density. The outcome of the analysis leads to the depiction of potential traffic states (e.g., under-saturated states, saturation states, oversaturated states, chaotic states) and also the depiction or observation of some traffic phenomena characterized by shockwaves, rarefaction waves, synchronized states, bottlenecks, to name just a few.

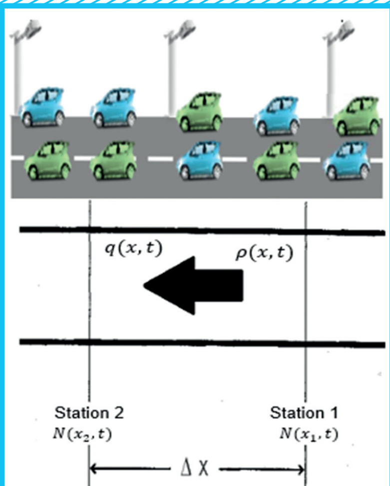

Figure 1.
General representation of the traffic flow on a road segment of finite length. The road segment is located between two stations 1 and 2.

II.1. Traffic volume on roadway

Figure 2 is the representation of a cross section of the road segment as a dynamical system with inputs q_{in} and outputs q_{out}. This representation is considered for the sake of facilitating the modeling procedure. The aim of the analysis in this section is to establish the mathematical model expressing the traffic volume $N(x,t)$ on roadway. The mathematical modeling is carried out by expressing the cumulative number of vehicles both in space and time by the spatiotemporal function $N(x,t)$. Taking into account the definition of the flow $q(x,t)$, which corresponds to the

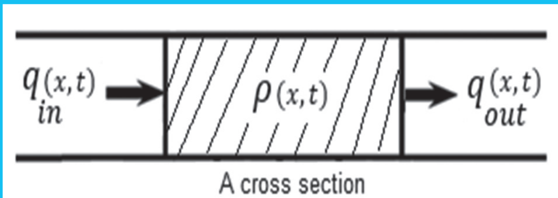

Figure 2.
Representation of the traffic flow in a cross section of the road segment in figure 1.

number of vehicles passing a given section of the road within a time period Δt, this definition can be expressed mathematically as follows (where, $\Delta N(x,t)$ is always positive in the time dimension):

$$q(x,t) = \frac{\Delta N(x,t)}{\Delta t} \tag{1}$$

The expression (1) can be approximated by (2) if we consider the infinitesimal variation of the cumulative number of cars in a very small time interval ($\Delta t \ll 1$).

$$q(x,t) \approx \frac{\partial N(x,t)}{\partial t} \tag{2}$$

If we also consider the definition of the density, which corresponds to the number of vehicles that can be found in a road segment of length Δx, this definition can be expressed mathematically as follows (where, $\Delta N(x,t)$ is always negative in the space dimension):

$$\rho(x,t) = -\frac{\Delta N(x,t)}{\Delta x} \tag{3}$$

The expression (3) can be approximated by (4) if we consider the infinitesimal variation of the cumulative number of cars in a very small space interval ($\Delta x \ll 1$).

$$\rho(x,t) = -\frac{\partial N(x,t)}{\partial x} \tag{4}$$

Given that there is a relationship between flow and density, equations (2) and (4) can be written as:

$$\frac{\partial N(x,t)}{\partial t} = \mathcal{F}\left(-\frac{\partial N(x,t)}{\partial x}\right) \tag{5}$$