

ISSN 1847-2001 (Print)

ISSN 1848-2295 (Online)

UDC 004:007

University of Zagreb
Faculty of Organization and Informatics Varaždin

Central European Conference on Information and Intelligent Systems

CECIIS



25th International Conference

September 17th - 19th, 2014
Varaždin, Croatia

Varaždin, 2014.

Publisher

Faculty of Organization and Informatics, University of Zagreb
Pavlinska 2, HR-42000 Varaždin, Croatia

Contact

e-mail: ceciis@foi.hr
phone: +385 42 390 851
fax: +385 42 213 413
web: www.ceciis.foi.hr
fb: www.facebook.com/ceciis.foi

For Publisher

Vjeran Strahonja (University of Zagreb, Faculty of Organization and Informatics)

Editors

Tihomir Hunjak (University of Zagreb, Faculty of Organization and Informatics)
Sandra Lovrenčić (University of Zagreb, Faculty of Organization and Informatics)
Igor Tomičić (University of Zagreb, Faculty of Organization and Informatics)

Editors In Cooperation with:

Albert-Ludwigs-Universität Freiburg, Institut für Informatik und Gesellschaft, Germany
Karl-Franzens Universität Graz, Institut für Informationswissenschaft, Austria
University of Zagreb, Faculty of Transport and Traffic Science, Croatia
University of Maribor, Faculty of Economics and Business, Slovenia
University of Maribor, Faculty of Electrical Engineering and Computer Science, Slovenia

Publishing Board

Igor Tomičić (University of Zagreb, Faculty of Organization and Informatics)
Bernarda Kos (University of Zagreb, Faculty of Organization and Informatics)

This publication is partially financed by:

Ministry of Science, Education and Sport, Republic of Croatia
University of Zagreb, Croatia
Varaždin County

All rights reserved. No parts of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without the prior permission of the copyright owner.

ISSN 1847-2001 (Print)
ISSN 1848-2295 (Online)

Contents

Index of Authors	V
Preface	VII

Data and Knowledge Bases

Goran Oreški, Stjepan Oreški An experimental comparison of classification algorithm performances for highly imbalanced datasets	4
Kornelije Rabuzin, Nikola Modrusan Business intelligence and column oriented databases	12
Danijela Subotić, Vladan Jovanović, Patrizia Pošćić Data Warehouse Schema Evolution: State of the Art	18
Josip Šaban, Toni Gržinić, Leo Mršić An event based framework for facilitating database activity tracking	26
Larisa Tipura, Denis Mušić Model for Discovering Students' Skills in Educational Institutions	32

Economics and Information Systems

Paula Bajdor, Tomasz Lis Cloud Computing In Polish SME Enterprises	40
Alenka Tot, Kristina Detelj Implementation of Cash Transaction Fiscalization Procedure in Businesses: Case of Croatia	48
Rebwar Kamal Gharib, Elly Philpott Towards understanding members' participation behaviour in B2B Virtual Communities: A socio-technical approach	56
Darko Lugonja Interoperability influence to network development through interoperability models	62
Kristina Maršić, Dijana Oreški Modelling the size of underground economy in Croatia: fuzzy logic approach	70
Slaven Smojver Complexity of Information Systems and Banks' Size: A Case Study of Croatian Banking System	78
Ksenija Vuković, Dina Korent, Irena Kedmenec Testing Gibrat's Law on Software Companies in Croatia	86

Education for Information Society

Dražena Gašpar, Jelena Zovko, Mirela Mabić	94
Education of Students of Economics for e-Society	
Kruno Golubić, Mihaela Banek Zorica	102
Presence and Activity of Croatian Higher Education Institutions on Social Networking Sites	
Tihomir Katulić, Marko Jurić	108
Creative Commons License Agreements in Croatian Law	
Mario Konecki, Marko Petrić	116
Main problems of programming novices and the right course of action	
Mladen Konecki	124
Learning to play musical instruments through dynamically generated lessons in real-time based on adaptive learning system	
Marjan Krašna, Tomaž Bratina	130
Video learning materials for better students' performance	
Darko Matotek, Dušan Mundar	138
An analysis of employment opportunities of graduated students in the field of information and computer sciences	
Radovan Vrana	144
Open access to information resources as support to academic achievement	

Information and Communication Technologies

Adel Alkhalil, Reza Sahandi, David John	154
Migration to Cloud Computing: A Decision Process Model	
Zoran Cosic, Jasmin Ćosić, Miroslav Bača	164
Biometric system reliability as a important factor of influence on Chain of Custody of Digital Evidence	
Melita Kozina, Tina Crnjak	170
IT Customer Relationship Management supported by ITIL	
Melita Kozina, Lucija Horvat	176
Measuring the level of quality of IT Service Management	
Sergej Lugovic, Vjeran Bušelić, Ida Tadej	182
Cloud Computing perception and organisational impact on large Croatian enterprises	
Goran Matošević	194
Towards a metric for on-page search engine optimization	
Jan Mittner, Alena Buchalcevova	200
Towards the IT Support of Processes in Small Software Companies	
Elisabeth Pergler, Isabel Anger, Thomas Rößler	208
V-PONI: A Framework for Value-in-use Predictions Based on Obtaining Non-precise Indicators	
Hrvoje Stancic, Adam Al-Hariri, Edvin Buršić	216
Archival Approach to IaaS Cloud Services	
Elmin Sudić, Jasmin Azemović	224
Comparative analysis of regular and cloud disaster and recovery systems	
Mario Zgela	230
Use of Outlier Detection in Database Availability Analysis	

Intelligent Information Systems

Marija Brkić, Maja Matetić, Sanja Seljan Pseudo-lemmatization in Croatian-English SMT	242
Igor Kaluđer, Goran Klepac Credit Risk Early Warning System using Fuzzy Expert Systems	250
Marko Maliković An Overview and Classification of Retrograde Chess Problems	256
Marko Maliković SAT-based Analysis of the Legality of Chess Endgame Positions	264
Alen Šimec, Magdalena Magličić Comparison of JSON and XML data formats	272
Ivo Ugrina, Mislav Žigo Searching for Semantically Correct Postal Addresses on the Croatian Web	276

Information Systems Security

Bernard Vukelić, Miroslav Bača Comparison of RADIAL variance based and Maar-Hildreth operator perceptual image hash functions on biometric templates	286
--	-----

Intelligent Transport Systems

Martin Gregurić, Edouard Ivanjko, Ivana Galić, Sadko Mandžuka, Hrvoje Gold Urban Highways Level of Service Improvement Based on Intelligent Ramp Metering	296
---	-----

Software Engineering

Marko Jurišić, Dragutin Kermek Application Framework Development and Design Patterns: Current State and Prospects	306
Anton Kvesić, Danijel Radošević, Tihomir Orehovački Using SCT Generator and Unity in Automatic Generation of 3D Scenes and Applications	312
Martina Poljičak, Hrvoje Stančić, Sanja Seljan Interoperability of Standards and Models in Official Statistics	318
Zdravko Rosko Case Study: Refactoring of Software Product Line Architecture - Feature Smells Analysis	326
William Steingartner, Valerie Novitzká, Martina Benčková, Peter Prazňák Considerations and Ideas in Component Programming - Towards to Formal Specification	332
Author Guidelines	342

Index of Authors

- Al-Hariri, Adam 216
Alkhalil, Adel 154
Anger, Isabel 208
Azemović, Jasmin 224
Bača, Miroslav 164, 286
Bajdor, Paula 40
Banek Zorica, Mihaela 102
Benčková, Martina 332
Bratina, Tomaž 130
Brkić, Marija 242
Buchalcevova, Alena 200
Buršić, Edvin 216
Bušelić, Vjeran 182
Cosić, Zoran 164
Ćosić, Jasmin 164
Crnjak, Tina 170
Detelj, Kristina 48
Galić, Ivana 296
Gašpar, Dražena 94
Gharib, Rebwar 56
Gold, Hrvoje 296
Golubić, Kruno 102
Gregurić, Martin 296
Gržinić, Toni 26
Horvat, Lucija 176
Ivanjko, Edouard 296
John, David 154
Jovanović, Vladan 18
Jurić, Marko 108
Jurišić, Marko 306
Kaluđer, Igor 250
Katulić, Tihomir 108
Kedmenec, Irena 86
Kermek, Dragutin 306
Klepac, Goran 250
Konecki, Mario 116
Konecki, Mladen 124
Korent, Dina 86
Kozina, Melita 170, 176
Krašna, Marjan 130
Kvesić, Anton 312
Lis, Tomasz 40
Lugonja, Darko 62
Lugović, Sergej 182
Mabić, Mirela 94
Magličić, Magdalena 272
Maliković, Marko 256, 264
Mandžuka, Sadko 296
Maršić, Kristina 70
Matetić, Maja 242
Matošević, Goran 194
Matotek, Darko 138
Mittner, Jan 200
Modrusan, Nikola 12
Mršić, Leo 26
Mundar, Dušan 138
Mušić, Denis 32
Novitzká, Valerie 332
Orehovački, Tihomir 312
Oreški, Stjepan 4
Oreški, Dijana 70
Oreški, Goran 4
Pergler, Elisabeth 208
Petrlić, Marko 116
Philpott, Elly 56
Poljičak, Martina 318
Pošćić, Patrizia 18
Pražňák, Peter 332
Rabuzin, Kornelije 12
Radošević, Danijel 312
Rosko, Zdravko 326
Rößler, Thomas 208
Šaban, Josip 26
Sahandi, Reza 154
Seljan, Sanja 242, 318
Šimec, Alen 272
Smojver, Slaven 78
Stančić, Hrvoje 216, 318
Steingartner, William 332
Subotić, Danijela 18
Sudić, Elmin 224
Tadej, Ida 182
Tipura, Larisa 32
Tot, Alenka 48
Ugrina, Ivo 276
Vrana, Radovan 144
Vukelić, Bernard 286
Vuković, Ksenija 86
Zgela, Mario 230
Žigo, Mislav 276
Zovko, Jelena 94

PREFACE

The jubilee 25th Central European Conference on Information and Intelligent Systems (CECIIS 2014) was organized and hosted by the Faculty of Organization and Informatics, Varaždin, Croatia, from 17-19 September 2014. The most important aim of CECIIS is to strengthen the interface between researchers involved in the development and application of methods and techniques in the field of information and intelligent systems.

This Proceedings presents 44 scientific papers that were reviewed by the international Program Committee and divided into eight sections: Data and Knowledge Bases, Economics and Information Systems, Education for Information Society, Information and Communication Technologies, Information Systems Security, Intelligent Information Systems, Intelligent Transport Systems and Software Engineering. Selected papers will be further reviewed by two independent international reviewers with the possibility of being extended and included in the Journal of Organizational and Information Sciences (JIOS), the international scientific journal published by the Faculty of Organization and Informatics.

Within the jubilee 25th edition two invited lectures were presented and round table about use of modern educational technologies taking into account the protection of privacy was held. The Conference also offered several accompanying events. For the fourth time the Students poster and presentation section as well as the FOI Security Symposium (FSec) were held. Student poster abstracts and FSec presentations are published separately on-line. Also, for the third time FOI Mobile and Embedded Development Symposium (f-moed) was held with 48 hour Mobile App Challenge for students. Parallel events also included two workshops, one about software products for librarians and other about right to information access .

We would like to thank all the authors, presenters, reviewers, session chairs and attendees and, above all, our invited speakers. We acknowledge the help that the Faculty of Organization and Informatics provided, which was crucially important for the overall success of the Conference. We would like to extend our appreciation to the Program and Organizing Committee members.

Finally, we are most grateful to all our sponsors for their financial and material support.

We are confident that inside these covers you will find relevant and interesting papers in the field of information and intelligent systems. We also look forward to your participation in one of many CECIIS conferences to come.

September 2014

On the behalf of

Program and Organizing Committees

Tihomir Hunjak & Sandra Lovrenčić

Intelligent Transport Systems

Martin Gregurić, Edouard Ivanjko, Ivana Galić, Sadko Mandžuka, Hrvoje Gold
Urban Highways Level of Service Improvement Based on Intelligent Ramp Metering

Urban Highways Level of Service Improvement Based on Intelligent Ramp Metering

Martin Gregurić, Edouard Ivanjko, Ivana Galić, Sadko Mandžuka, Hrvoje Gold

Faculty of Transport and Traffic Sciences, University of Zagreb

Department of Intelligent Transportation Systems

Vukelićeva 4, HR-10000 Zagreb, Croatia

`martin.gregurich@gmail.com`, `edouard.ivanjko@fpz.hr`, `ivana.galic.7@hotmail.com`

`{sadko.mandzuka, hrvoje.gold}@fpz.hr`

Abstract. *Urban highways have undergone a transformation in the recent years due to increased traffic demand. Optimal usage of the existing road transport infrastructure has become a priority. To ensure efficient usage of the existing traffic system capacity, intelligence needs to be added to its control systems. Such control solutions are from the domain of intelligent transportation systems (ITS). Mostly used solutions are ramp metering and variable speed limit control (VSLC). This paper presents a new learning based cooperative ramp metering strategy in which several well-known ramp metering strategies (ALIENA, SWARM, HELPER) are used to create a learning set and then create an ANFIS based cooperative ramp metering controller. Proposed urban highway control approach is tested in simulations using an augmented version of the CTMSIM simulator, traffic data for a typical working day and city of Zagreb bypass as case study. Obtained results are compared to standard ramp metering approaches and VSLC using travel time, Delay, and maximum vehicle queue length as quality measures.*

Keywords. Ramp Metering, Speed Limit Control, ANFIS, Level of Service, ITS, Cooperative Control

1 Introduction

In the second half of the last century traffic slowdowns and congestions are the most prominent problems in urban road networks. Traffic congestion appears when too many vehicles attempt to use a common road infrastructure with limited capacity, [1]. Limited capacity of today's urban road networks is consequence of the inability to expand its capacity due to limited economic and physical resources. One among the last build-only solutions applied in order to mitigate congestions on urban road networks is the construction of urban highways. Urban highways are planned to provide a bypass to the urban road network by absorbing part of its traffic. Over the years urban highways were progressively integrated into the road network and urban en-

vironment. Nowadays urban highways have the same problem as the urban road network regarding limitation in capacity extension. Generally high Level of Service (LoS) projected for urban highways is significantly reduced due to negative differences between traffic supply and traffic demand.

LoS can be defined as a group of qualitative measures which characterize operational conditions within traffic flow and their perception by motorists and drivers, [2]. Mentioned group of qualitative measures are used to analyze highways by categorizing traffic flow and assigning quality levels of traffic based on performance measure like speed, density, etc. Six LoS are defined for each type of facility that has analysed procedure available. Letters designate each LoS level ranging from A to F, with LoS A representing the best and LoS F the worst operating conditions, [3]. LoS takes into account only mean density or/and speed of the mainstream so it is necessary to use several additional measures for highway service quality assessment especially when ramp metering is applied, [1]. Travel Time (TT) and Delay (D) are the two most used service quality measures. TT gives the information how much time one vehicle needs to travel through observed highway segment. It is measured in minutes. Delay is defined as the difference between the actual time spent by all vehicles on a congested highway and the time spent in case they have travelled at free flow speed. Delay also considers vehicles which are waiting in on-ramp queues or in mainstream queues caused by the bottlenecks. It is measured in vehicle-hours. In order to increase urban highway LoS, the imperative is to use optimal utilization of the available infrastructure via adequate application of a variety of traffic control measures, [1]. Nowadays most of the mentioned traffic control measures are known under domain of intelligent transportation systems (ITS).

Most prominent traffic problem on urban highways is known under the term downstream bottleneck which location can be seen in Fig. 1. Downstream bottleneck has impact on the area where on-ramp and mainstream flow are actually coming in interaction. Mentioned

highway problem can be mitigated by use of a special ITS control measure which is known under the term - ramp metering. Ramp metering controls queues at on-ramps in order to maintain maximal capacity flow on a highway. This is achieved by restricting access of on-ramp traffic to mainstream traffic with special traffic lights and appropriate signalization, [4].

This paper describes and test a new learning based ramp metering strategy in which several ramp metering algorithms are used to create a learning dataset for ANFIS (Adaptive Neural Fuzzy Inference System) with emphasis of on-ramp queue length as continuation of the authors previous work. Another important control method is known under the term Variable Speed Limit Control (VSLC). Main purpose of VSLC as standalone application is to homogenize vehicle speeds and suppress shockwaves. This paper also describes cooperation between ramp metering and VSLC including analysis of their influence on on-ramp queue length. In order to enable and test mentioned type of cooperative control, macroscopic highway traffic simulator Cell Transmission Model SIMulator (CTMSIM) is adequately augmented, [8].

This paper is organized as follows. Second section briefly describes ramp metering in general. Description of cooperative control approaches on urban highways is presented in third section. Concept of learning based cooperative ramp metering is explained in the fourth section. Simulation results of the comparative analysis of implemented urban highway control approaches is given in the fifth chapter. Paper ends with conclusion and future work description.

2 Ramp Metering

Main goal of ramp metering is to reduce the impact of downstream bottleneck on the mainstream highway traffic, [7]. In order to accomplish that ramp metering uses special road signals at on-ramps to control the rate or size of vehicles platoons entering mainstream traffic according to current traffic conditions, [6]. While reducing the downstream bottleneck, ramp metering may cause the traffic to spill over into feeder arterial roads as the on-ramp queue length increases. Especially when highway traffic flow is high, [5]. Location of the downstream bottleneck close to the on-ramp and the spillback effect on the adjacent local urban road network is given in Fig. 1.

Furthermore, Fig. 1 presents general local ramp metering system installation on a highway. Most important part of the ramp metering system is the algorithm which determines the "access rate reduction" for every on-ramp flow, [8]. Generally it is possible to divide ramp metering algorithms in two major categories: local (or isolated) and coordinated, [5].

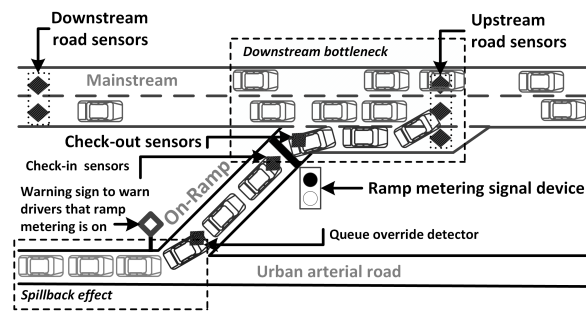


Figure 1: Local ramp metering installation with downstream bottleneck and spillback effect

2.1 Local ramp metering

Local ramp metering algorithms take into account only the traffic condition on particular on-ramp and nearby highway segment where they are applied. Main drawback of local ramp metering algorithms is unawareness of overall highway traffic situation.

The ALINEA algorithm is the most often used standard local ramp metering algorithm. Core concept of ALINEA is to keep the downstream occupancy of the on-ramp at a specified level by adjusting the metering rate, [1]. Specified level of downstream occupancy is usually called occupancy set-point. Value of occupancy set-point is slightly lower or equal to occupancy at maximum downstream capacity. Main disadvantages of ALINEA are its inability to resolve upstream congestions of the particular ramp and to locate optimal detector mounting zone.

2.2 Coordinated ramp metering

Coordinated algorithms are taking into account the traffic situation on the overall highway transportation system. In the literature these algorithms are further divided on: cooperative, competitive and integrated algorithms, [9].

Ramp metering algorithms based on cooperation work in two phases. In the first phase the metering rate for each on-ramp is computed by local ramp metering algorithms. Furthermore, in the second phase additional adjustment of each local on-ramp metering rate is done based on system-wide information about the traffic situation on the whole highway segment, [10]. HELPER algorithm is one among the first algorithms which have used mentioned cooperative ramp metering working principle. It includes several local traffic responsive metering algorithms which are communicating with a centralized operational unit with override possibility. HELPER algorithm creates virtual queues in upstream on-ramps to reduce queue length on the congested one, [6].

Competitive algorithms execute local and global control ramp metering logics, both of them compute appropriate solution for current traffic situation.

System-Wide Adaptive Ramp Metering (SWARM) is the most efficient algorithm in this group. SWARM contain two types of control algorithms: SWARM1 and SWARM2B. SWARM1 algorithm conducts global coordination by taking into account traffic state on each on-ramp. SWARM2B is a local algorithm and defines metering rate according to the difference between current and critical traffic density for a particular on-ramp. Metering rates obtained by local and global algorithm are compared and smaller value is selected, [7].

Integrated algorithms are based on optimization of a specific LoS value while considering constraints such as maximum allowable on-ramp queue, bottleneck capacity, etc. Most sophisticated algorithms in that group are algorithms based on fuzzy logic. Fuzzy logic based algorithm can be described as one type of expert systems applied for ramp metering, [8].

3 Cooperative control of urban highways

In general, a cooperative system can be defined as a system which involves multiple dynamic entities that share information or tasks in order to accomplish a common, though perhaps not singular objective, [11]. Main task of cooperative traffic control is to find the combination of control measures that results in the best traffic performance, [12]. At urban highways with dense traffic and complex interactions between traffic flows, cooperative control methods under the domain of the ITS are especially interesting. Cooperative highway control systems, according to results published in [8] and [12] are more effective in contrast to standalone control methods at highways.

Originally, cooperative control on urban highways implied only to exploitation of adjacent on-ramps queue, [8]. Nowadays, concept of cooperative control on highways is expanded to cooperation between ramp metering, VSLC, prohibiting lane changes system, various driver information systems and vehicle on-board-unit (OBU). Higher number of management strategies included into cooperation with ramp metering contributes to a more comprehensive control over highway section. Cooperative ramp metering architecture with all mentioned highway management strategies can be seen in Fig. 2.

3.1 Cooperation between on-ramps

Main problem with local or isolated ramp metering is a risk of fast upstream congestion propagation known as a "shock wave", [8]. Mainstream "shock wave" travels backward or upstream. Upstream on-ramps with local ramp metering applied cannot provide appropriate solution to stop the upcoming "shock wave" due unawareness of current traffic situation on the upstream

on-ramps. In order to suppress such "shock waves" cooperation between on-ramps has to be applied, [9].

Cooperation between on-ramps demands that several local traffic responsive metering algorithms communicate with a centralized operational unit with override possibility. Cooperative algorithm in the centralized operational unit uses a control logic which exploits queue capacity of upstream on-ramps to reduce queue length on the congested one. In order to compute and adjust values of metering rates computed by local ramp metering algorithms, cooperative algorithm uses overall highway traffic information and mentioned control logic.

3.2 Cooperation between VSLC and ramp metering

Ramp metering is ineffective in two cases: (i) traffic demand is too low and (ii) traffic demand is extremely high, in which case traffic breakdown will happen anyway, [1]. The main goal of VSLC in cooperation with ramp metering is to prevent a traffic breakdown by limiting the inflow into the area where the traffic breakdown starts, [8]. Decreased mainstream speed induced by VSLC consequently increases the value of critical density in the highway segment where the traffic breakdown starts. Since the inflow is lower than the highway segment capacity where breakdown starts there will be some space left to accommodate the traffic from the on-ramp and traffic breakdown can be prevented, [12]. Due to higher value of critical density there is also possibility for ramp metering to increase metering rate in critical segment. This action consequently can have positive impact on overall highway throughput.

4 Learning based cooperative ramp metering

Extreme fluctuation in traffic demand is one of the most prominent traffic problems on urban highways. For example, at the peak hour traffic demand is extremely high, while at night traffic demand for highway transportation capacity is extremely low. It is possible to conclude that one ramp metering strategy cannot equally efficiently respond on every traffic situation on urban highway. This is the reason for development of a learning framework which will summarize knowledge from several different ramp metering strategies into one control structure.

Latest approaches in learning based cooperative ramp metering include use of hybrid intelligent systems such as fuzzy-neural control systems. They are used in order to perform adaptive mitigation of congestion which is varying in strength and in time. In [13] a conceptual design of the Fuzzy Neural Network Control Method for Ramp Metering is described. Mentioned design is used on a single on-ramp and on eight

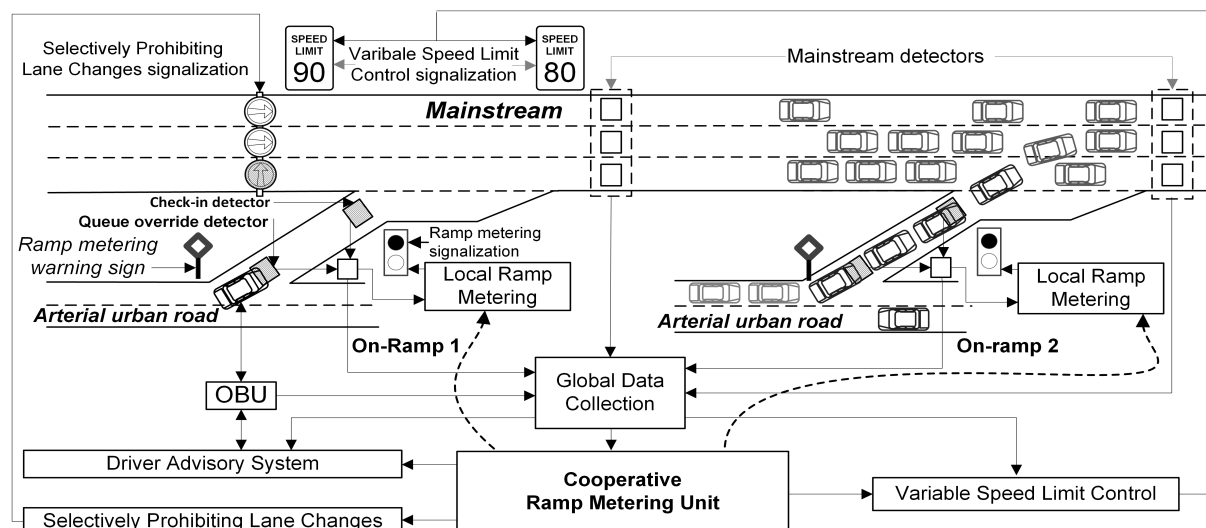


Figure 2: Cooperative ramp metering architecture

on-ramps which from two different directions converge at common mainstream. Between the eight on-ramps a coordinated control has been implemented, [13]. Recent work described in, [14] and [7] includes use of ANFIS algorithm. In [14] cooperative control between several on-ramps is achieved by the integration of several traffic inputs into all ramp controllers upstream of a bottleneck and a periodical update of the fuzzy control system every 25 minutes, by a hybrid learning procedure. To assess the impacts of the ANFIS cooperative ramp metering algorithm a section of 25 kilometers of the A9 highway was simulated with the FREQ model and compared with two other control scenarios (no control and linear programming control approach), [14]. In this paper ANFIS is trained by a hybrid learning algorithm, [13]. Proposed ANFIS based control architecture for cooperation between on-ramps is shown in Fig. 3. In order to acquire knowledge from different ramp metering algorithms it is necessary to define the ANFIS structure and select appropriate learning procedures. Firstly it is imperative to select teaching ramp metering algorithms with distinctively different control logic in order to cover wide range of traffic scenarios on particular urban highway, [7]. Following teaching ramp metering approaches have been chosen: ALINEA algorithm as local algorithm, HELPER as cooperative and SWARM as competitive ramp metering algorithm. ANFIS ramp metering learning scheme is shown in Fig. 4.

Next step is to create a learning dataset according to simulation results of all mentioned chosen teaching algorithms, [7]. It is imperative to select the best solutions provided by all the teaching ramp metering algorithms in a learning dataset for actual learning process. This is done according to the following criterion function:

$$f(r) = 0.5 \cdot TT + 0.5 \cdot D, \quad (1)$$

where $f(r)$ is metering rate function. According to the adjusted learning data set it is necessary to select suitable inputs and outputs among traffic variables relevant for ramp metering. This procedure is achieved by brute force optimization and appropriate fuzzification and defuzzification methods, [10].

Model used in this paper has 2 inputs variables and one output in form of ramp metering rate value. Fuzzification is achieved using Gaussian fuzzifiers. The middle of maximum method is used for defuzzification. Upon completion of the learning process, ANFIS output results are compared with output training data. Based on the difference between these two values, degree of matching is derived in form of Root Mean Square Error (RMSE), [14]. Learning dataset is created by the use of simulation results derived from Zagreb bypass (section between the nodes Jankomir and Lučko) as use case model. Traffic dataset of the use case model is reconstructed according to the traffic data of Ljubljana bypass.

During the learning process higher error values are reported due several reason. One of the reasons is lack of real use case traffic data so only a set of 24 hours traffic data is used. Another problem which cause higher error rate is sudden increase in traffic in-flow during afternoon peak hour. This scenario enables adequate test scenario for cooperative control strategies but requires sudden maximal increase in metering rates after the peak hour ends. This control behaviour is harder to learn. Potential solution which has to be tested in future work is in customization of the criteria function and fine tuning of ANFIS algorithm parameters. Graph of the relationship between learning/testing data and various combination of the two traffic inputs is shown in Fig. 5.

5 Simulation results

Urban highway section between the nodes Jankomir and Lučko on the Zagreb bypass is selected to be the simulation use case model. Traffic demand data for each on-ramp at the use case model is reconstructed by use of interpolated traffic data from Ljubljana bypass. Additionally, original CTMSIM environment is augmented in order to support simulation and verification of cooperative ramp metering algorithm HELPER and standalone VSLC, [8]. Furthermore, this section provide comparative analysis which involves following highway control strategies: commonly used ramp metering algorithms (ALINEA, SWARM, HELPER), standalone VSLC, cooperation between VSLC and HELPER, and proposed ANFIS based learning approach.

5.1 Simulator CTMSIM and its augmentations

CTMSIM is an interactive simulator based on macroscopic traffic models specifically designed for simulations of interactions between highway traffic flows, [15]. Macroscopic traffic model used by CTMSIM is based on the Asymmetric Cell Transmission Model (ACTM) [15]. ACTM model divides the highway model into I cells. CTMSIM simulation time is divided into K intervals with length Δt (equal to 5 minutes in this paper). The possibility of using various MATLAB toolboxes makes this simulator suitable for development of advanced ramp metering algorithms.

To enable simulation of cooperative ramp metering approaches two modifications have been made to CTMSIM, [8]. First modification involves implementation of VSLC for every cell in the simulation model. Original equation for mean speed in i -th cell is changed into eq. 2 in order to implement VSLC into CTMSIM environment:

$$v_i^c = \min(v_i^{ff}, \frac{f_{i[k]}/(1 - \beta_{i[k]})}{n_{i[k]} + \gamma r_{i[k]}} (\frac{L_i}{\Delta t}), v_i^{SLC}), \quad (2)$$

where parameter $r_{i[k]}$ denotes number of vehicle entering cell i , from its associated on-ramp at time step k , while $\beta_{i[k]}$ denotes split ratio for off-ramp flow. Parameter γ represents on-ramp flow blending coefficient, both from interval $[0, 1]$. Free flow speed value is denoted by v_i^{ff} for cell i , and $L_{i[k]}$ represents length of cell i . Mainstream flow during interval k in cell i is represented by $f_{i[k]}$. Speed limit value for i -th cell is represented by v_i^{SLC} must be lower than free flow speed value of the current cell.

5.2 Zagreb bypass and traffic flow data

Physical use case model of Zagreb bypass between nodes Lučko and Jankomir is designed according to its real constructional parameters. ACTM model of section between nodes Lučko and Jankomir is shown in Fig. 6. This section has an expressed traffic load at peak hours at nodes Lučko and Jankomir. Additionally, this section contains 70 % of traffic generated by the nearby town Zagreb, [16]. On-ramps traffic demand characteristics and in-flow of the Zagreb bypass simulation model are reconstructed according to interpolated Ljubljana bypass traffic data. Traffic behaviour patterns of Ljubljana bypass are similar to Zagreb's since city of Ljubljana has also a bypass and in the summer season many tourists are using its bypass when travelling to the Croatian seaside. This action is taken due unavailability of accurate hourly traffic flow data for the Zagreb bypass.

Created use case model combines constructional parameters of Zagreb bypass and traffic dataset from Ljubljana bypass characterized by increased traffic load during the peak hours. Additionally, created model contains many close on- and off-ramps making

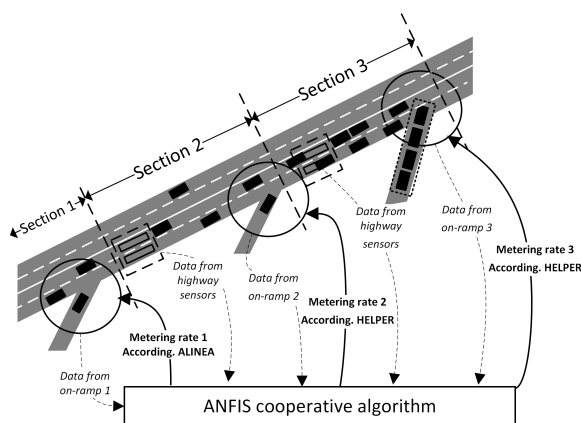


Figure 3: ANFIS based control architecture for cooperation between on-ramps

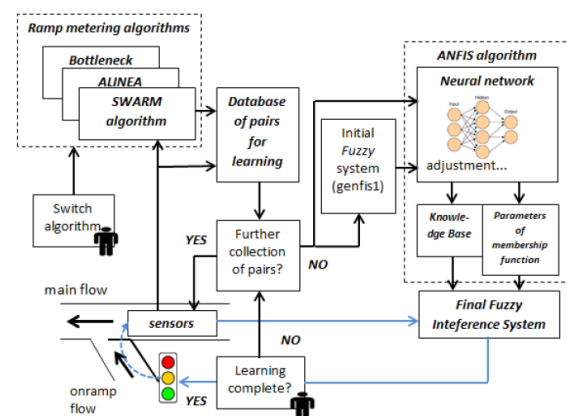


Figure 4: ANFIS algorithm scheme for ramp metering learning, [10]

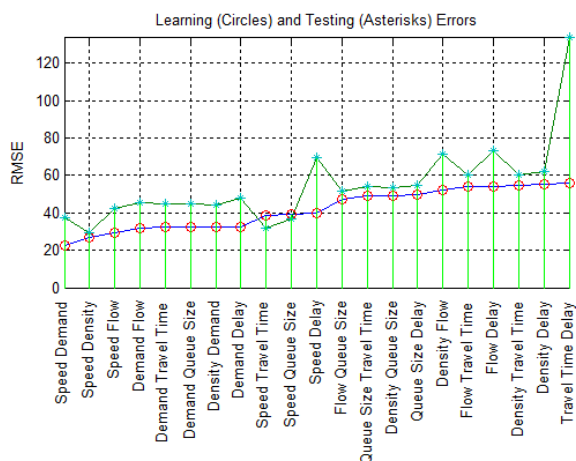


Figure 5: Relationship between learning/testing data and various combination of the two traffic inputs

it suitable for analysis of cooperative ramp metering algorithms such as HELPER.

In Fig. 7 it is possible to see characteristics of use case model traffic in-flow curve which is reconstructed and interpolated according to the city of Ljubljana traffic data. Main feature of the in-flow curve is expressed traffic load in the afternoon peak hour. Average LoS of all cells in described use case model (section between Lučko and Jankomir) is E according to [3] and [16].

5.3 Cooperation between on-ramps

In this section HELPER algorithm is considered under the domain of cooperative ramp metering algorithms. HELPER ramp metering algorithm is developed using the mentioned CTMSIM augmentation for cooperative ramp metering. HELPER is compared with local (ALINEA), competitive (SWARM) and learning based (ANFIS) ramp metering algorithms in order to verify its operational work. All mentioned ramp metering algorithms are simulated under the same simulation model using settings for a typical working day (24 hours).

Results of comparative analysis are shown in Table 1. According to Table 1, among the standalone ramp metering algorithms cooperative algorithm HELPER has achieved second best TT value due to its restrictive nature. HELPER restrictive nature is a result of the decreased metering rates on several upstream on-ramps regarding the congested on-ramp. Mentioned upstream so-called "slave" on-ramps are af-

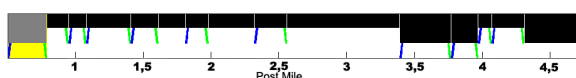


Figure 6: ACTM model of section between nodes Lučko and Jankomir

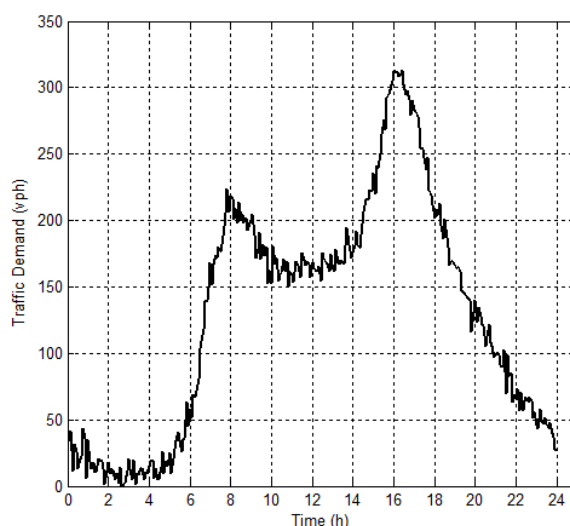


Figure 7: Highway mainstream traffic in-flow characteristic

ected by creation of virtual queues. This behaviour causes longer queues at "slave" on-ramps increasing the average Delay, respectively. Such control logic reduces impact of congestion back-propagation on the mainstream throughput which consequently decreases TT. HELPER algorithm has achieved LoS categorization C.

SWARM algorithm has achieved best TT, because SWARM control logic completely stops traffic flow at the on-ramps affected by congestion. Consequence of mentioned behaviour is highest value of average Delay achieved by SWARM ramp metering algorithm. Best A categorization of LoS is achieved by the SWARM algorithm what is expected since this algorithm has lowest TT value.

As a conclusion, HELPER algorithm achieves slightly higher values of TT compared to the SWARM algorithm, but significantly smaller average Delay values compared to the same algorithm. Smallest Delay was achieved in the simulation scenario without ramp metering. This result can be explained by used simulation settings enabling immediately merging of on-ramp flows with mainstream under the condition that in a current cell maximal mainstream capacity is not exceeded. Such behaviour induces absence of on-ramps queues but significantly increases traffic density of mainstream which increases average TT also. These specific behaviours can be seen in Figs. 8 and 9.

5.4 Variable speed limit control

It is possible to notice that standalone VSLC only effects TT, since it is applied to mainstream flow. VSLC produces vehicle platoons which are traveling at lower speeds in comparison to the free flow speed. This impacts the process of mainstream congestion back-propagation. In Table 1, it is possible to observe

Table 1: Results of cooperative analysis between different ramp metering algorithms

	No Control	ALINEA	SWARM	HELPER	VSLC	HELPER + VSLC	ANFIS
LoS (HCM2010)	E	D	A	C	E	C	B
Average TT [min]	14,32	5,61	3,99	4,41	11,01	4,63	6,42
Average Delay [vh]	5,42	20,53	24,18	10,94	4,51	7,62	6,75
Maximum queue [veh]	0	79	89	58	13	57	38

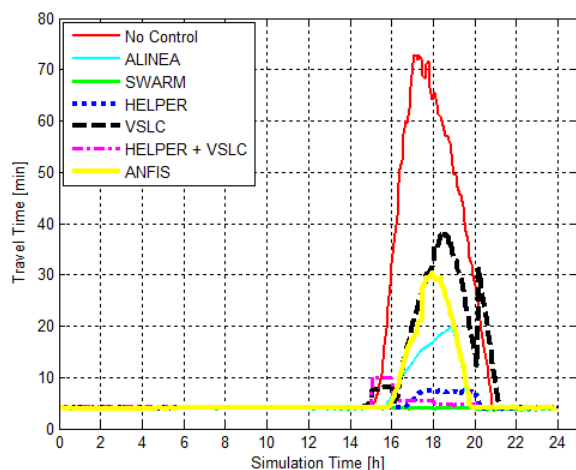


Figure 8: Comparative analysis according to TT

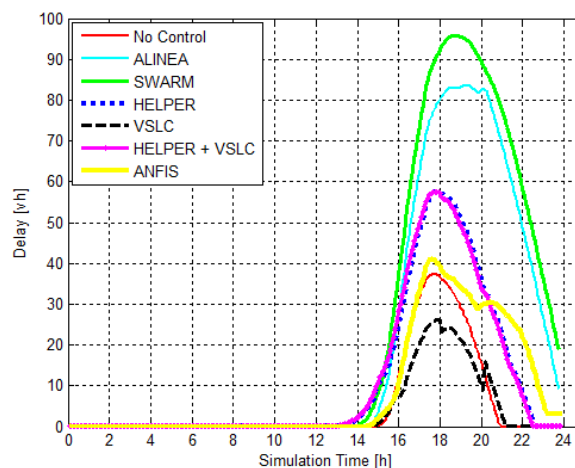


Figure 9: Comparative analysis according to Delay

that application of standalone VSLC produces smaller value of TT compared to the situation without any traffic control. Additionally, application of standalone VSLC has achieved best average Delay regarding all other traffic control methods. Lowest value of Delay is consequence of vehicle platoons which are traveling with lower speeds. Mentioned scenario enables more space at mainstream traffic lines due to slower arrival of vehicle platoons to the congested area. VSLC standalone application has achieved same LoS as the situation without any control what is expected since the both case have highest TT value.

5.5 ANFIS ramp metering approach

Proposed ANFIS based approach has produced highest average TT values compared to the other ramp metering algorithms involved into analysis except for VSLC. In the other hand, ANFIS has produced lowest Delay values compared to the other ramp metering algorithms except VSLC what is consequence of the generally higher TT values. According to eq. 1, it is possible to conclude that ANFIS learning process of finding the best combination of inputs and outputs within the learning dataset which will achieve results with desired ratio between TT and Delay can be tuned.

Furthermore, according to Table 1, it is possible to conclude that ANFIS average TT value is similar to the value of HELPER teaching ramp metering algorithm. ANFIS TT characteristic (Fig. 8) has higher values compared to the other teaching ramp metering algo-

gorithms. This fact enables ANFIS algorithm to provide lowest Delay values in contrast to the other teaching ramp metering algorithms what can be seen in Fig. 9. It is possible to assume that ANFIS algorithm has learned that increasing the value of TT simultaneously lowers the value of Delay. At this point it is possible to conclude that ANFIS based ramp metering algorithm has achieved balance between TT and Delay values due to similar average values of TT and Delay. It is important to notice that ANFIS algorithm has achieved LoS categorization B which is the second best LoS result.

6 Conclusion and future work

In this paper an intelligent ramp metering algorithm realized through an ANFIS structure is described and analysed by means of LoS, TT, Delay and queue length. It presents a foundation of a learning based framework in which several standard ramp metering strategies (local ALINEA, competitive SWARM and cooperative HELPER) are used as a learning dataset to create a cooperative ramp metering strategy.

Simulation results obtained by proposed ANFIS algorithm are compared with results obtained by its teaching ramp metering algorithms. Additionally, ANFIS algorithm is compared with approaches based on cooperation between VSLC and HELPER, and standalone VSLC. The Zagreb bypass between nodes Lučko and Jankomir is used as highway simulation model for evaluation of implemented ramp metering algorithms. According to the simulation results it is pos-

sible to conclude that ANFIS algorithms has achieved smallest Delay values compared to the other ramp metering algorithms. Overall smallest average Delay value is achieved by VSLC standalone application. Smallest TT values are achieved by SWARM, and cooperation between HELPER and VSLC but with longer queue lengths.

Proposed ANFIS algorithm shows promising results in achieving an effective balance between values of TT and Delay. Its LoS categorization value is B with small on-ramp queue lengths. These results are promising for future development of this algorithm. Relevance of this research is also in the fact that the proposed ANFIS learning framework can be used for learning ramp metering algorithms with various criteria functions. So a learning platform for other cooperative highway control strategies is established. Future work will include augmentation of ANFIS learning framework to enable cooperation between ramp metering and VSLC.

7 Acknowledgments

The research reported in this paper is partially funded by the FP7 - Collaborative Project: Intelligent Cooperative Sensing for Improved traffic efficiency - ICSI (FP7-317671), University of Zagreb Faculty of Transport and Traffic Science and EU COST action: TU1102 Towards Autonomic Road Transport Support Systems.

References

- [1] Papageorgiou, M; Diakaki, C; Dinopoulou, V; Kotsialos A; Wang, Y. *Review of road traffic control strategies*, Proceedings of the IEEE, 91(12):2043-2067, 2003.
- [2] Treiber, M; Kesting, A. *Traffic flow dynamics - Data, Models and Simulations*, Springer-Verlag, Berlin, Heidelberg, 2013.
- [3] Ryus, P. *Highway Capacity Manual 2010.*, Transportation Research Board. Retrieved 15, January, 2012.
- [4] Lee, C; Hellinga, B; Ozbayc, K. *Quantifying effects of ramp metering on freeway safety*, Proceedings of 38th Conference on Accident Analysis and Prevention, Ontario, pp. 279-288, 2006.
- [5] Esposito, M. C; Polak, J. W; Krishnan, R; Pleydell, M. *A Global Comparison of Ramp-Metering Algorithms Optimizing Traffic Distribution on Motorways and Arterials*, Road Transport Information and Control Conference and the ITS United Kingdom Members' Conference - RITC 2010, pp. 1-6, London, UK, 2010.
- [6] Papageorgiou, M; Kotsialos, A. *Freeway ramp metering: An overview*, Proceedings of IEEE 5th Intelligent Transportation Systems Conference, pp. 271-281, Oakland, California, USA, 2002.
- [7] Gregurić, M; Ivanjko, E; Mandžuka, S. *New concepts for urban highways control*, REAL CORP 2014. - Clever plans for smart cities, pp. 423-432, Vienna, Austria, 2014.
- [8] Gregurić, M; Ivanjko, E; Mandžuka, S. *Cooperative ramp metering simulation*, International convention on Information and Communication Technology, Electronics and Microelectronics - MIPRO 2014., pp. 1204-1209, Opatija, Croatia, 2014.
- [9] Papamichail, I; Kotsialos, A; Margonis, I; Papageorgiou, M. *Coordinated ramp metering for freeway networks - A model - predictive hierarchical control approach*, Transportation Research Part C, 18(3):311-331, 2010.
- [10] Gregurić, M; Buntić, M; Ivanjko, E; Mandžuka, S. *Improvement of highway level of service using ramp metering*, Proceedings of the 21th International symposium on electronics in transport - ISEP 2013, Ljubljana, Slovenia, 2013.
- [11] Murphey, R; Pardalos, P. *Cooperative Control and Optimization, Series: Applied Optimization*, Springer, 2002.
- [12] Hegyi, A; De Schutter, B; Hellendoorn, H. *Model predictive control for optimal coordination of ramp metering and variable speed limits*, Transportation Research Part C, 13(3):185-209, 2005.
- [13] Feng, C; Yuanhua, J; Jian, L; Huixin, Y; Zhonghai, N. *Design of Fuzzy Neural Network Control Method for Ramp Metering*, Proceedings of Third International Conference on Measuring Technology and Mechatronics Automation 2011, Vol. 1., pp. 966-969, 2011.
- [14] Bogenberger, K; Keller, M; Vukanovic, S. *A Neuro-Fuzzy Algorithm for Coordinated Traffic Responsive Ramp Metering*, 2001 IEEE Intelligent Transportation Systems Conference Proceedings, Oakland (CA), USA - August 25-29, pp. 94-99, 2001
- [15] Kurzhanskiy, A; Varaiya, P. *CTMSIM Traffic Macro - Simulator for MATLAB*, User Guide, TOPL Group, UC Berkeley, 2008.
- [16] Štefančić, G; Marijan, D; Kljajić, S. *Capacity and Level of Service on the Zagreb Bypass*, Promet - Traffic and Transportation, Zagreb, Croatia, 24(3):261-267, 2012.