Reports of the Department of Mathematical Information Technology
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CM3

Computational Multi Physics, Multi Scales and Multi Big Data in Transport Modeling, Simulation and Optimization

New Challenges for the Greening of Transport

Book of Abstracts

Editors: Pedro Díez, Pekka Neittaanmäki, Jacques Periaux, Tero Tuovinen

ECCOMAS Thematic Conference
25–27 May 2015, Jyväskylä, Finland

UNIVERSITY OF JYVÄSKYLÄ

FEDERATION OF FINNISH LEARNED SOCIETIES
Delegation of the Finnish Academies of Science and Letters

LIMOWA

ECCOMAS Thematic Conference

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ECCOMAS Thematic Conference

CM3 – Computational Multi Physics, Multi Scales and Multi Big Data in Transport Modeling, Simulation and Optimization

New Challenges for the Greening of Transport

University of Jyväskylä
May 25-27, 2015

Editors
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FOREWORD

The CM3 event is the first ECCOMAS Thematic Conference organized by University of Jyväskylä, Finland in the context of activities proposed by the new Industrial Interest Group (IIG) of ECCOMAS.

Efficient European transport remains an important factor of economic growth to be considered in view of environmental and societal challenges. It is essential to develop scientific and technological mechanisms to encourage cooperation and competitiveness between transport systems in Europe and in the world. It is also crucial to answer a question how to conduct and apply research in transport in order to meet these challenges and provide mobility for people and goods at high level of energy efficiency, reliability and safety.

The CM3 Conference is a special event for researchers, industry representatives and policy-makers to meet and discuss green technologies that can drive a better transport system for Europe. The latest achievements of European research and technological developments are presented and discussed.

The scope of the CM3 Conference covers five modes of transport: Aviation and Airports, Automotive, Logistics, Maritime and Harbors and Rail. They are applied to both passenger and freight. The CM3 Conference include plenary sessions addressed by VIP speakers and senior technologists, Mini Symposia (MS) and Special Technological Session (STS), Round Tables with academic, governmental and industrial experts to discuss New Challenges for the greening of Transport, parallel scientific and technical sessions with reviewed papers presented by authors as oral presentations.

The CM3 organizers wish you fruitful discussions during the development of this event and a pleasant stay in Jyväskylä.

The Editors
P. Díez, P. Neittaanmäki, J. Periaux and T. Tuovinen
Co-chairmen of the CM3 Conference, Jyväskylä, May 12, 2015

CM3 CONFERENCE PROGRAMME - DAY 1

Monday May 25, 2015 **Location**

Jyväskylä Congress Centre, Paviljonki, Lutakonaukio 12, Jyväskylä

09:00 Registration — Paviljonki 3rd floor, in front of K305 Alvar

09:15 Coffee — 3rd floor, restaurant

Chair *Jacques Periaux, University of Jyväskylä, Finland* — 3rd floor, K305 Alvar
09:50 Welcome address
JYU: Vice Rector **Kaisa Miettinen** and **Jacques Periaux**, Finland
EC: **Michael Kyriakopoulos**, Belgium
ECCOMAS: Vice President **Pedro Díez**, Spain
10:10 Introductory Lecture
Multidisciplinary and Integrated Computational Aeronautics in H2020 and beyond
Michael Kyriakopoulos, EC DG Research & Innovation, Belgium

Chair *Adel Abbas, UPM, Spain* — 3rd floor, K305 Alvar
10:30 Plenary Lecture Aeronautics
Securing Further Gains in Aircraft Environmental Performance: Challenges and Opportunities for Multi-Fidelity and Multi-Scale Simulation
Stephen Rolston, Airbus, UK
11:00 Plenary Lecture Automotive
New trends in the automotive industry, transition from a mechanical industry to a software industry
Mårten Levenstam, Volvo Car Corporation, Sweden

11:40 Lunch — 3rd floor, restaurant

Chair *Mårten Levenstam, Volvo Car Corporation, Sweden* — 3rd floor, K305 Alvar
12:45 **Parallel Contributed Session 1: *Automotive***
- *Clustering driving destinations using a modified DBSCAN algorithm with locally-defined map-based thresholds*
  Ghazaleh Panahandeh, Volvo Car Corporation, Sweden
- *On Qualitative Properties of Cluster Model for Flows on Regular Networks — Composites*
  Marina Yashina, Moscow Tech. Univ. of Communications and Informatics, Russia
- *Generalized pendulums and transport logistic applications*
  Alexander Buslaev, Moscow Automobile and Road State Tech. Univ., Russia

Chair *Tero Tuovinen, University of Jyväskylä, Finland* — 3rd floor, K307 Elsi
12:45 **Parallel Contributed Session 2: *Simulation***
- *Investigating side-wind stability of high speed trains with CFD methods that resolve turbulent dynamics on decreasing scales*
  Moritz Fragner, German Aerospace Center, Germany

- *Numerical Simulation of the Thermal Comfort in a Double Decker Train Cabin*
  Mikhail Konstantinov, University of Ilmenau and Claus Wagner, Germany
- *Aircraft classification based on instantaneous Doppler curve extraction of VHF band*
  Piotr Ptak, Lappeenranta University of Technology, Finland

14:05 Break

Chair *Blas Galván, ULPGC, Spain* — 3rd floor, K305 Alvar

14:15 Semi Plenary Lecture Automotive
Challenges in Optimization of a Passenger Vehicle
Mikael Törmänen, Volvo Car Corporation, Sweden

14:45 Semi Plenary Lecture Maritime
Challenges to develop innovative multi-use offshore platforms servicing marine transportation and emerging coastal activities
Joaquin Brito, PLOCAN, Spain

15:15 Coffee — 3rd floor, restaurant

Chair *Jacques Periaux, University of Jyväskylä, Finland and Pedro Díez, CIMNE/UPC, Spain* — 3rd floor, K305 Alvar

15:45 **C-AERO2 STS Aeronautics**
Models and Tools for Greening Future Air Transport
- *Reduction of environmental effects of civil aircraft through multi objective flight plan optimization*
  Jordi Pons-Prats, CIMNE/UPC, Spain
- *A PGD computational vademecum for shape optimization: geometrical parameterization, fast and multiple queries*
  Pedro Díez, CIMNE/UPC, Spain
- *Basic versus applied research in transonic flows for aeronautics*
  Laurent Jacquin, Ecole Polytechnique and ONERA, France

17:15 Break

Chair *Joaquin Brito, PLOCAN and Blas Galván, ULPGC, Spain* — 3rd floor, K305 Alvar

17:30 **STS Maritime**
Sustainable and Innovative concepts to combine marine transport and emerging marine activities
- *Platea4D: A software platform for transnational maritime and coastal projects*
  Blas Galván, ULPGC, Spain
- *The Port of Houston and Gulf Coast Maritime Operations*
  William E. Fitzgibbon, College of Technology, University of Houston, USA

18:30 End of Day 1

19:00 Reception — Paviljonki 3rd floor, lounge

CM3 CONFERENCE PROGRAMME - DAY 2

Tuesday May 26, 2015 **Location**

Jyväskylä Congress Centre, Paviljonki, Lutakonaukio 12, Jyväskylä

08:45 Registration — Paviljonki 2nd floor, in front of Auditorium A2 Wivi

Chair *Pedro Díez, CIMNE/UPC, Spain* — 2nd floor, Auditorium A2 Wivi
09:00 Semi Plenary Lecture Railways
Large-scale wave propagation in ballasted railway tracks
Régis Cottereau, Ecole Centrale, France
09:30 Semi Plenary Lecture Aeronautics
Multidisciplinary Design Analysis/Optimisation System Needs and Development
Adel Abbas, UPM, Spain

10:00 Coffee — 3rd floor, restaurant

Chair *Jacques Periaux, University of Jyväskylä, Finland* — 2nd floor, Auditorium A2 Wivi
Moderator: William E. Fitzgibbon, University of Houston, USA
10:30 **Round Table 1:** ***New Challenges and Solutions for the Greening of Transport***
Panelists: **A. Abbas**, UPM, Spain, **O. Bräysy**, JYU, Finland, **R. Cottereau**, ECP, France, **B. Galván**, ULPGC, Spain, **M. Kyriakopoulos**, EC DG research, Belgium, and **M. Törmanen**, Volvo, Sweden

12:30 Lunch — 3rd floor, restaurant

Chair *Mikael Törmänen, Volvo Car Corporation, Sweden* — 2nd floor, Auditorium A2 Wivi
13:30 Plenary Lecture Logistics
Collaborative logistics – possibilities and challenges
Mikael Rönnqvist, Université Laval, Canada
14:00 Plenary Lecture Logistics
The key success factors in future logistics
Olli Bräysy, University of Jyväskylä, Finland
14:30 Semi Plenary Lecture Logistics
Extending the Scope of SCM Decision Making
Wout Dullaert, VU University Amsterdam, The Netherlands

15:00 Coffee — 3rd floor, restaurant

15:30 **Limowa Round Table 2:** — 2nd floor, Auditorium A2 Wivi
The Growing importance of Intra-logistics
Moderator: **Jorma Härkönen**, Limowa, Finland
Panelists: **W. Dullaert**, VU University Amsterdam, The Netherlands, **H. Fleuren**, Tilburg University, The Netherlands, **J. Särelä**, Fimatic Oy, Finland, and **J. Viinikainen**, Edicon Oy, Finland

16:30 Break

Chair *Wout Dullaert, VU University Amsterdam, The Netherlands* 3rd floor, K305 Alvar

16:45 **Parallel Contributed Session 3: *Logistics I***

- *Optimization of Large-Scale Waste Flow Management at HerAmbiente*
  Matteo Pozzi, OPTIT SRL, Italy
- *Dynamic and Real-time Management of Logistic Chain*
  Peter Grankulla, Oy Attracs Ab, Finland
- *Challenging Science for Innovations in Logistics*
  Ilkka Hämäläinen, Edicon Oy, Finland
- *Optimization in health care industry – Results and current practices from Finland and The Netherlands*
  Jarno Väisänen, Procomp Solutions Oy, Finland

Chair *Olli Bräysy, University of Jyväskylä, Finland* 3rd floor, K307 Elsi

16:45 **Parallel Contributed Session 4: *Logistics II***

- *Routing and scheduling of vessels to perform maintenance tasks at offshore wind farms*
  Lars Magnus Hvattum, NTNU, Norway
- *Managing and optimizing road transports and mobile work with LogiApps*
  Panu Silvasti, LogiApps, Finland
- *Approximating non-linear blending optimization in supply chain networks*
  Amir Salehipour, The University of Newcastle, Australia
- *Improving the Estimation of Arrival Times along a Vehicle Route*
  Alexander Kleff, PTV Group, Germany

Chair *Pekka Neittaanmäki, University of Jyväskylä, Finland* 3rd floor, K306 Anton

16:45 **Parallel Contributed Session 5: *Modelling and methods***

- *Design and Operation of Multiscale Modelling Platform*
  Vit Smilauer, Czech Technical University in Prague, Czech Republic
- *Computational Methods for the Stochastic Equilibrium Stable Dynamic Model*
  Yuriy Dorn, National Research University Higher School of Economics (HSE), KIAM RAS, Russia
- *Stochastic fracture analysis of a moving paper web*
  Maria Tirronen, University of Jyväskylä, Finland

18:05 End of Day 2

20:00 Conference dinner

CM3 CONFERENCE PROGRAMME - DAY 3

Wednesday May 27, 2015 **Location**

Jyväskylä Congress Centre, Paviljonki, Lutakonaukio 12, Jyväskylä

08:45 Registration — Paviljonki 2nd floor, in front of Auditorium A2 Wivi

Chair *Lars Magnus Hvattum, NTNU, Norway* — 2nd floor, Auditorium A2 Wivi

09:00 Plenary Lecture Logistics
How TNT Express saved more than 200 million in four years time by using Business Analyticsm
Hein Fleuren, Tilburg University, Bluerock Logistics, The Netherlands

09:30 Plenary Lecture Logistics
Changing Finnish Rail Market
Kimmo Rahkamo, Managing Director, Fennia Rail Oy, Finland

10:00 Semi Plenary Lecture Logistics
Digital Supply Chains
Kyösti Orre, General Industry Federation, Finland

10:30 Coffee — 3rd floor, restaurant

11:00 **Limowa Round Table 3:** — 2nd floor, Auditorium A2 Wivi
Role of Information and Big data
Moderator: **Heikki Lahtinen**, Limowa, Finland
Panelists: **O. Bräysy**, JYU, Finland, **V. Hara**, Rovio, Finland, **H. Kulmala**, Technology Industries, Finland, and **M. Rönnqvist**, Université Laval, Canada

12:00 **Logistics Software Demo session**
NFleet, Procomp Solutions, Silvasti Software, MultiAgent solutions

13:00 Lunch — 3rd floor, restaurant

Chair *Hein Fleuren, Tilburg University, The Netherlands* — 3rd floor, K305 Alvar

14:00 **Parallel Contributed Session 6: *Logistics III***

- *Digitalisation will democratise innovations in industry*
  Harri Kulmala, The Federation of Finnish Technology Industries, Finland
- *Challenges of the Order - Replenishment Process in Supply Chain a special case - picking without pick orders*
  Juha Särelä, Fimatic Oy, Finland
- *Towards more efficient logistics by using computational technology and intelligent information systems*
  Teemu Mustonen, Ecomond Ltd., Finland
- *Using a dynamic system model in ex-ante operational and profitability analysis of a metal mine through simulation*
  Mikael Collan, Lappeenranta University of Technology, Finland

Chair Mikael Collan, Lappeenranta University of Technology, Finland 3rd floor, K307 Elsi

14:00 **Parallel Contributed Session 7: *Logistics IV***

- *Automating the Vehicle Routing System Customization for Faster Deployment*
  Jussi Rasku, University of Jyväskylä, Finland
- *A Comparison of NSGA II and MOSA for Solving Multi-depots Time-dependent Vehicle Routing Problem with Heterogeneous Fleet*
  Arian Razmi Farooji, University of Oulu, Finland
- *Transport Equations in the Continuum Modelling and Analysis of Travelling Bodies*
  Juha Jeronen, University of Jyväskylä, Finland

15:20 Coffee 3rd floor, restaurant

Chair Pekka Neittaanmäki, University of Jyväskylä, Finland 2nd floor, Auditorium A2 Wivi

15:50 Semi Plenary Lecture Logistics
Competitive Green Vehicle Routing
Victor Zakharov, University of St. Petersburg, Russia

16:20 Concluding remarks
Pekka Neittaanmäki, University of Jyväskylä, Finland

16:30 End of Day 3

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Day 1 - Monday May 25, 2015

Multidisciplinary and Integrated Computational Aeronautics in H2020 and beyond

Michael Kyriakopoulos *

Computational Aeronautics is an enabler to innovations that we cannot imagine today. It is an enabler with a couple of orders of magnitude in return on investment. It is key to the European competitiveness and the European Commission aims to contribute towards a leap forward, compared to today's state of the art. In this CM3 ECCOMAS Thematic Conference on Transport, an overview of EU co-funded Research Framework Program activities will be presented with an eye towards identifying synergies and opportunities in the industrial transport research and development within H2020 and beyond.

Presentation CV

Michael Kyriakopoulos is Programme Officer in the Aeronautics Unit of DG Research and Innovation of the European Commission. Within the Aeronautics Unit, Michael is mainly responsible for Aerostructures, Manufacturing and Computational Methods as well as Clean Sky and Competitiveness issues (including SMEs, State-Aids). Michael is a Mechanical-Aeronautical Engineer - his PhD and most of his research work are in the area of computational mechanics applied to composites, impact dynamics, thermal barrier coatings, laser ultrasonics and manufacturing processes for aeronautics. Before joining the European Commission he served as senior design engineer in the Institute for Advanced Materials and the National Aerospace Laboratory (NLR) in the Netherlands as well as in Westinghouse Electric Company. Michael has been responsible for very interesting aerospace, defence and energy industrial projects.

Michael Kyriakopoulos,
Programme Officer in the Aeronautics Unit of DG Research and Innovation of the European Commission e-mail: Michael.Kyriakopoulos@ec.europa.eu

* Presenting author

Securing Further Gains in Aircraft Environmental Performance : Challenges and Opportunities for Multi-Fidelity and Multi-Scale Simulation

Stephen Rolston*

Significant steps have been made in addressing the environmental impact of Aircraft through reduced aircraft fuel burn and noise footprint. But the challenge grows more significant as greater gains in efficiency are required to mitigate trends in global warming and airport community noise. In addition the potential to achieve further gains through ongoing evolution are limited unless new technologies are integrated into the aircraft product with a clear understanding multidisciplinary interactions at the aircraft level. Examples are given from a range of 'Flight Physics relevant technologies that have a strong multi-disciplinary and/or multi-scale characteristic including Load Control, Laminar Flow Control, separation and turbulence control'.

Stephen Rolston
Airbus, UK, e-mail: Stephen.Rolston@eads.com

* Presenting author

New trends in the automotive industry, transition from a mechanical industry to a software industry.

Marten Levenstam *

Since the start of the industrial revolution in the late 19th century the modern industries emerged due to two key innovations, the limited liability company and the automation of production. The creation of the concept of a limited liability company model, i.e. the Ltd or public listed company, contained two key business model innovations; possibility to attract a large number of unknown investors (shareholders i.e. ”crowdfunding”), the concept of limited liability (you could run a company without jeopardizing your personal wealth).

The automation of production opened up for a tremendous technical growth and the possibility to efficiently produce large number of goods with increasing complexity at lower and lower prices.

Today we are facing another major change in the industrial world, the automation of mathematics. The advent of new cheap computer hardware have made it possible to put mathematics into production and products and this is currently transforming a large part of the industrial sector, including the automotive industry.

The automotive industry is a perfect example of a complex product sold in a free market with high degree of competition. This has led to a tremendous development in terms of technological advancement but at the same time new cars have in real terms become cheaper and cheaper.

In my talk I will give examples of how the new possibility of putting mathematics into products are rapidly changing the business landscape. I will cover both recent developments in product development, new possibilities for product offerings as well as the more fundamental issue of where the value creation occurs. One clear trend is that the value creation and the competitive advantage is shifting more towards software and algorithms. This is in sharp contrast to the situation in the past where the main asset for an automobile firm was hardware.

Marten Levenstam
Volvo Car Corporation, e-mail: marten.levenstam@volvocars.com

* Presenting author

Clustering driving destinations using a modified DBSCAN algorithm with locally-defined map-based thresholds

Ghazaleh Panahandeh* and Niklas Akerblom

1 Abstract

The aim of this paper is to propose a method to cluster GPS data corresponding to driving destinations. A new DBSCAN-based algorithm is proposed to group stationary GPS traces, collected prior to end of trips, into destination clusters. While the original DBSCAN clustering algorithm uses a global threshold as a closeness measure in data space, we develop a method to set local thresholds values for data points; this is important because the GPS data proximity strongly depends on the density of the street grid around each point. Specifically, the spread of GPS coordinates in parking lots can vary substantially between narrow (personal parking lot) and wide (parking lot of a shopping mall) depending on the destinations. To characterize the parking lot diversities at each destination, we introduce the concept of using a local threshold value for each data point. The local threshold values are inferred from road graph density using a map database. Moreover, we propose a mutual reachability constraint to preserve the insensitivity of DBSCAN with respect to the ordering of the points. The performance of the proposed clustering algorithm has been evaluated extensively using trips of actual cars in Sweden, and some of the results are presented here.

2 Introduction

Nowadays, huge amounts of location-based data are being shared through the cellular networks with GPS receivers in car navigation systems. The availability of such data opens up new research areas in pattern analysis and data mining. Analyzing individual driving/mobility-patterns from logged GPS data have found a wide range of applications, such as path or destination prediction, real time traffic volume estimation, city planning, energy consumption optimization, etc. In these systems, predictive models are constructed mainly based on statistical properties of data given that it follows some regularity patterns. The patterns can be inferred by analyzing driving history (routes from origins to destinations). Despite large similarities in trajectories when driving from an origin to a destination, diversity of parking locations can vary depending on vicinity of parking lots for different destinations. Therefore, grouping end-of-trip locations is an essential and primary step for driving data analysis, especially when constructing destination-dependent probabilistic models.

Ghazaleh Panahandeh, Niklas Akerblom
Volvo Car Corporation, Sweden, e-mail: gpanahan@volvocars.com, nakerblog@volvocars.com

* Presenting author

The focus of our study is to develop a destination clustering algorithm by analyzing the history of end-of-trip logged GPS data for individual drivers. That is, we are aiming to label the parking locations into physically meaningful clusters (destinations/origins). We propose a modified DBSCAN algorithm by introducing a new concept on using local density thresholds. The local threshold for each point is adapted according to the density of the street grid around that point, thereby capturing inherent differences between driver destinations in disparate areas, e.g. urban, residential or commercial zones.

Related works in this field attempt to cluster places into regions of interest for groups of people [1], i.e. identifying clusters with high densities. However in our application, the clustering is performed for individuals and it is independent of the data density at each destination. Other clustering methods use trajectory-similarity for grouping nearby locations [2, 3]. However, these methods have high computational complexity and result in clusters that are origin-dependent.

3 Proposed clustering algorithm

For our clustering application, data is recorded from cars equipped with portable GPS devices that are connected to a portal server. Data attributes are geographical information corresponding to stationary GPS traces collected prior to end of trip. A trip starts from an ignition-on event at a location corresponding to an origin cluster and ends by an ignition-off event at a location corresponding to a destination cluster. Assuming connectivity properties for each pair of origin-destination, we hereafter use the term *destination* when referring to both the origin and the destination.

A cluster is a group of data that share a set of similar properties. In our applications, data attributes are numeric (GPS locations) where the similarity between two data object can be judged based on a distance measure. Moreover in this problem, the number of clusters are not known in advance and data points are sequentially increasing over time. Given these requirements and the data type properties, we choose to use DBSCAN-based clustering algorithms because of their ability in discovering clusters with arbitrary shapes and processing large databases efficiently. The original DBSCAN [4] algorithm and its variations (OPTICS [5], LDBSCAN [6], PDBSCAN [7]) have been widely used for clustering spacial data. In these algorithms, the similarity measures are either defined globally in data space or determined locally based on density of data at different regions. In our application, finding appropriate threshold value as a closeness measure can be very challenging depending on the location of the parking lot, which is independent of density of previously collected data at each region. Therefore, the current density-based algorithms do not provide a complete solution in our application considering the region-based clusters specifications.

In this paper, we propose a modified DBSCAN clustering approach in which the local similarity measures are adapted according to the density of the road grid around each data point. Hence, the defined local similarities are independent of points density at each cluster. In the following, we briefly describe the original DBSCAN algorithm [4] and then present our proposed algorithm.

In DBSCAN, clusters are formed by all points that are density-reachable from each other, i.e. connected through an unbroken chain of directly density-reachable points. In turn, a point p is directly density-reachable from a point q, if q has a minimum number of points (defined as $minPts$) including p within a distance threshold of ε. The $minPts$ and ε values are given as global parameters into DBSCAN. The set of all points that are directly density-reachable from q is called the ε-neighborhood of q. All points which are not density-reachable from any other point are classified as noise.

Fig. 1 and Fig. 2 show the results of DBSCAN clustering in a subset of GPS coordinates for one user centered in the town of Alingsås (vicinity of $5km^2$). The $minPts$ value was set to 3 for both of these examples. To depict the deficiency of DBSCAN with respect to our clustering application, we choose two distinct ε values for each experiment. Fig. 1 illustrates the resulting clusters with $\varepsilon = 100\ m$, where noises (depicted in black) and six distinct dense clusters (depicted with other colors) can be seen. The destination clusters correspond well to the self-identified activities of the user, except in the lower right corner, where two parking lots belonging to the same building are clustered as separate destinations. In an effort to correct that misclassification, the ε parameter is increased to 200 m, see Fig. 2. This results in merging the lower right clusters correctly, while it also has the side effect of clustering many of the noise points (corresponding to distinct destination) in town as one large cluster. As can be observed, resulting destinations are highly dependent on properties of parking lots areas (density of the street grid around these point), which cannot be captured using only one global ε value.

To adapt the ε value in DBSCAN according to density of the street grid around each GPS location, we propose a two-step solution. The first step is to modify the DBSCAN algorithm by defining an individual density threshold for each data point. The second step is to identify those thresholds using knowledge of the problem domain. To preserve symmetricity of the original DBSCAN algorithm when defining the individual density threshold for each data point, it is required to redefine the notion of ε-neighborhood from DBSCAN according to $N_\varepsilon(p) = \{q \in D | dist(p,q) < \varepsilon_p, dist(p,q) < \varepsilon_q\}$. That is p and q should be reachable from both directions to be considered members of the same neighborhood. It is worth mentioning that the run time efficiency of the DBSCAN is retained by performing the region query with ε_p and subsequently excluding results that do not fulfill the condition $dist(p,q) < \varepsilon_q$.

As has been previously stated, in densely-built areas, e.g. in town and city centers, the result of a high ε value could be that the entire area is clustered together, while the opposite applies for low values of ε in less dense areas, i.e., they should be clustered together. This observation implies that there is an inverse relationship between the density of the area in which a point p is situated and the density threshold ε_p. As a density measure, we use a map database to retrieve the number of road links within a constant *radius* of each point in the data set. These density values are then used in a linear interpolation between a lower ε-bound for dense areas and an upper ε-bound for less dense areas. The ε-bounds and their corresponding (two)-breakpoints for the density values are set intuitively according to the data. The density values below and above the breakpoints are set to the lower and upper ε-bounds respectively, resulting in the application of the original DBSCAN algorithm on those points. Fig. 3 shows resulting clusters when applying our proposed algorithm, referred to as the map-based local DBSCAN (ML-DBSCAN), to the same dataset. As can be seen, the previous issues with low and high ε values in Fig. 1 and Fig. 2 are resolved. For this implementation, the first and second breakpoints

Fig. 1 DBSCAN $\varepsilon = 100\ m$. Points with similar color are categorized into one cluster where noise points are depicted in black. The points in the lower right corner, which belong to one parking lot, are detected as two clusters.

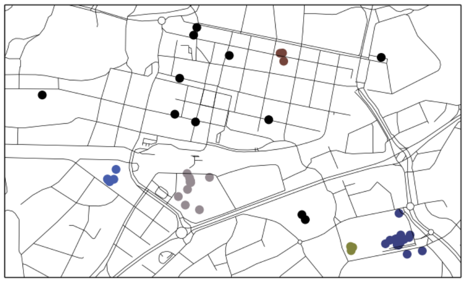


Fig. 2 DBSCAN $\varepsilon = 200\ m$. Points with similar color are categorized into one cluster where noise points are depicted in black. By increasing the ε value from 100 to 200, compared to Fig. 1, the points in the parking lot are clustered together, while many of the noise points (corresponding to distinct destination) in the city center are merged into one large cluster.

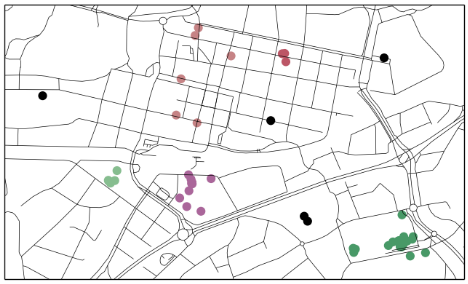
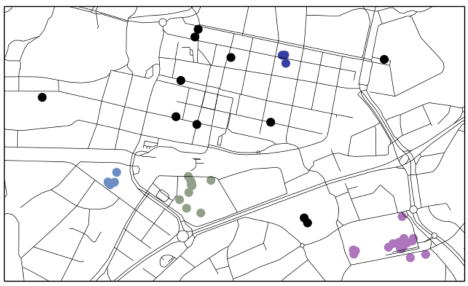


Fig. 3 The resulting clusters from our proposed algorithm, ML-DBSCAN. Points with similar color are categorized into one cluster where noise points are depicted in black. As can be seen, the previous issues with low and high ε values in Fig. 1 and Fig. 2 are resolved.



are set to 100 and 200, respectively, using the radius of 500 m, and the lower and upper bounds are set to 100 m and 200 m, respectively.

We have extensively evaluated the performance of our proposed clustering algorithm. Herein, some of the results are reported for five car users with 514, 366, 847, 599, and 754 detected parking events recorded during 4, 6, 6, 6, and 6 months, respectively. Table 1 shows the clustering results for three different radius settings, where interpolation parameters, including first and second breakpoints (1-BP, 2-BP), and upper and lower bounds are intuitively set to the given values. The experiments show that similar clustering results are obtained for all three radius values. These results were also visually confirmed on the map for individual users. To further study the sensitivity of the proposed algorithm to the parameter settings, the interpolation parameters (first and second breakpoints, and upper and lower bounds) were swept 10 percent around the values given in Table 1 at each radius, resulting to 81 different settings. The experiments show that

Table 1 Resulting clusters with different parameter settings for interpolation parameters, including first and second breakpoints (1-BP, 2-BP), upper and lower bounds.

					Number of clusters				
Radius	1-BP	2-BP	Upper bound	Lower bound	user 1	user 2	user 3	user 4	user 5
750	150	300	200	100	31	22	18	27	30
500	100	200	200	100	31	21	17	27	31
250	50	100	200	100	31	21	17	27	30

the proposed algorithm leads to stable and visually-meaningful results for a wide range of parameter values, and no major change in the clustering results were observed.

4 Conclusion and future work

In this paper, we propose a modified DBSCAN algorithm in which local density thresholds are adapted according to street grid-density around each data point. The results indicate the accuracy and reliability of our proposed map density-based clustering method compared to the original DBSCAN algorithm, specifically where data points are distributed in areas with different densities in the road grid. As a future work, we are investigating adaptive solutions in which street grid densities can be dynamically assigned to each point using the map database. For this purpose, we are analyzing road graph densities and statistical properties of points at different region.

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Keywords: Destination clustering, Driving history analysis, DBSCAN

On Qualitative Properties of Cluster Model for Flows on Regular Networks – Composites

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1. Discrete models of flows on networks based on finite automata and computer simulation were appeared in the works of Nagel and Schreckenberg at the nineties, [1], [2]. Mathematical formulation and exact statements connected with dynamical systems theory were developed by Blank, [3], [4]. It seems that interest to the study of flows on the regular networks was a long time, [5], [6]. But in concerning with the traffic megalopolis problems, the development of agent-based modeling and computer-integrated study of physical-mathematical approaches, we should mention the paper [7].

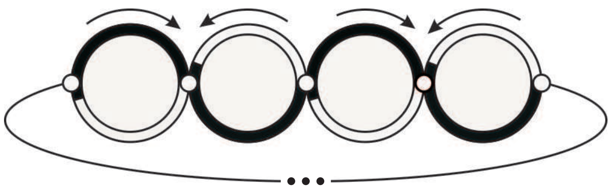

Fig. 1 Incompressible clusters on Necklace

2. Cluster flow model was introduced in the paper [8]. The model is a continual model and has middle position between the hydrodynamic analogy for traffic, beginning in [9], and numerical schemes and algorithms of this approach with the impressive progress of computer technology development since the 60s the twentieth century. As it was shown by experimental traffic data and results of intelligent monitoring of real traffic [11], [12], essentially the hydrodynamic approach is not suitable for simulate of saturated " not smooth " flows. Cluster model, on the one hand, greatly simplifies the approach, because it reduces the modeling problem to finite-parametric study of Ordinary Differential Equations (ODE) systems. On the other hand, the cluster approach reflects the known property of the real traffic flows behavior, i.e. *the existence of homogeneous packets of*

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moving cars. Important fact is that *cluster model is a natural limit of the discrete models of Nagel – Schreckenberg,* as it is proved in [13].

3. Some properties of the cluster chains on a circle as model support were found in [13]. However, the main purpose of creating the cluster model was a research of flows on the graphs. In the simplest case of graph it is *" necklace "*, i.e. closed chain of circles that denoting a highway in the composition with a local traffic network. In addition, *"Chainmail '* is right network of circles in a plane allowing to simulate the local and global traffic flows on a plane, Fig. 1, [14].

In order to reduce the number of problem parameters, at first it makes sense to consider the flows on a closed manifold as torus. As a result of computer experiments the hypothesis was developed on values of uniform load thresholds on regular necklaces and chainmail that lead to a collapse of movement. This problem has both practical and theoretical interest, and will be discussed in the presentation at the Conference, Fig. 1, 2.

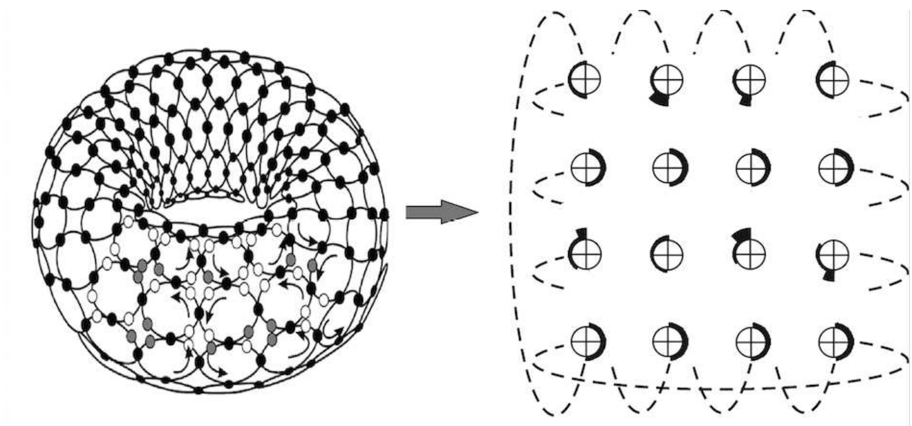

Fig. 2 Chainmail on a torus: elastic clusters on scan

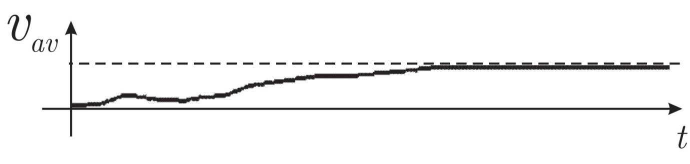

Fig. 3 Instantaneous average speed on Chainmail: access to the synergy

4. As next step of network research we consider *regular* mix of the right of networks, i.e. *composites* of the components of several types, Fig. 4.

In particular, a continuous mix of rectangular lattices and chainmail will be considered to discuss the optimization of network parameters at given flow characteristics.

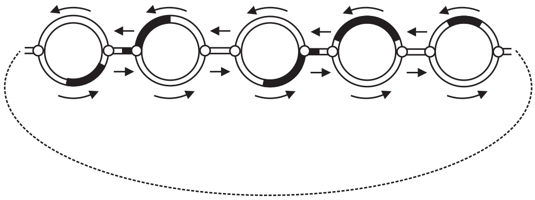

Fig. 4 Composite Necklace

Rules of the movement on the network, Fig. 4:

a) one-way movement on any ring (e.g., counterclockwise);

b) on a line the movement ”in order of queue” (FIFO);

c) if the interval length equals 0, then it is the case of the Necklace (Fig. 1), [14].

We will discuss the basic parameters for research of qualitative properties of systems of the class, and conditions of synergies and collapse.

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Keywords: transport-logistic problem, traffic flows, cluster model, regular networks

Generalized pendulums and transport logistic applications

Alexandex Buslaev* and Alexander Tatashev

1 Abstracts

Suppose there are N *vertices* $V_0, \dots, V_{N-1}$ and M *particles* $P_0, \dots, P_{M-1}$. Each particle is in one of N vertices at every time instant.

Definition 1. The $N-$ary representations of numbers $a_0, a_1, \dots, a_{M-1}$ are given:

$$a^{(j)} = 0.a_1^{(j)} a_2^{(j)} \dots a_k^{(j)} \dots, \; j = 0, 1, \dots, M-1.$$

The number $a^{(j)}$ is called *the plan of the particle* P_j. The plan $a^{(j)}$ is written on the tape of the particle P_j.

At each discrete time instant $T = 1, 2, \dots,$ the particle reads one of the digit on its tape. If the particle P_j reads the digit $a_i^{(j)}$ at time T, $i \leq T$, then this particle tries to come to the vertex $V_{a_i^{(j)}}$, and realizes its attempt if no competition takes place. The tape of this particle shifts a position and the particle reads the next digit of its plan at time $T+1$. A competitions takes place if $s_{ij} \geq 1$ particles try to move from the vertex V_i to the vertex V_j, and $s_{ji} \geq 1$ particles try to move from the vertex V_j to the particle V_i at time T. The particles which try to move from the vertex V_i to the vertex V_j wins the competition with probability $s_{ij}/(s_{ij} + s_{ji})$. Winning the competition particles realize its attempt, and losing the competition particles and its tapes do not move at current time.

The rational plan of the particle P_j can be represented as

$$a^{(j)} = 0.a_1^{(j)} a_2^{(j)} \dots a_{k_j}^{(j)} (a_{k_j+1}^{(j)} a_{k_j+2}^{(j)} \dots a_{k_{l_j}}^{(j)}) \dots,$$

where k_j is the length of the aperiodic part of the plan and l_i is the length of the repeating part, $j = 0, 1, \dots$.

Suppose the particle P_j loses $D_j(T)$ competitions on the time interval $(0, T)$.

Definition 2. The limit

$$w_j = \lim_{T \to \infty} \frac{T - D_j(T)}{T} \tag{1}$$

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is called *the particle P_j tape velocity* if this limit exists, $j = 0, 1, \dots, M-1$.

The system is in *the state of synergy* after an instant T_{syn} if no conflict takes place after the instant T_{syn}.

We also consider a stochastic version of the system. Suppose that each digit of the plan $a^{(j)}$ equals i with probability p_{ji}, independent of values of other digits $0 < p_{ji} < 1$, $0 \le i \le N-1, 0 \le j \le M-1, p_{j0} + p_{j1} + \cdots + p_{j,N-1} = 1$. This system is a generalization of the dynamical system, considered in the papers [1], [2].

The following problems are investigated.

(1). Suppose all plans are rational numbers. The problem is to find conditions of that the system comes to the state of synergy. If the system does not come to the state of synergy, the problem is to investigate the dependence of all tapes velocities on its plans.

(2). Suppose all plans are irrational numbers. The problem is to find conditions of existence of limit (1). For example, we have found that *for $M = N = 2$ there exist irrational plans such that limit (1) does not exist.*

(3). Suppose the plans are irrational numbers such that $\sqrt{2}(mod1)$, $\sqrt{3}(mod1)$, $\frac{\sqrt{5}-1}{2}$, $\pi(mod1)$. The problem is to investigate the connection this irrational pendulum with the stochastic pendulum.

(4). *If all plans are rational numbers then the limit (1) exists for any $j = 0, 1, \dots, M-1$. The sufficient conditions of synergy have been found.*

(5). It is interesting to find exact bounds of real valued pendulum tape velocity. We have proved that, *if $N = M = 2$, then the minimum possible tape velocity is equal to* $4/5$.

(6). Suppose $N = M = 2$. *We have proved that the stochastic pendulum tape velocity is equal to* $19/20$ *if*

$$p_{00} = p_{01} = p_{10} = p_{11} = \frac{1}{2}.$$

(7). *Suppose $N = M = 2$, and each plan is one of $\sqrt{2}(mod1)$, $\sqrt{3}(mod1)$, $\frac{\sqrt{5}-1}{2}$, $\pi(mod1)$, and $a^{(1)} \neq a^{(0)}$. Computer simulation shows that the velocity of particle tape is equal to* $19/20$ *by analogue to stochastic pendulum.*

(8). *Suppose the plan $a^{(0)}$ is one of the the numbers $\sqrt{2}(mod1)$, $\sqrt{3}(mod1)$, $\frac{\sqrt{5}-1}{2}$, $\pi(mod1)$, and we get the plan $a^{(1)}$, shifting the representation of the plan $a^{(0)}$.* In accordance with heuristic arguments and simulation results, we can suppose that *the system comes after a time interval to the state of synergy, and the expectation of this time interval is infinite.* The behavior of the system is similar to random walks of a particle on the one-dimensional lattice. In the random walks on the one-dimensional lattice, the particle comes to a given point, with probability, after a time interval with an infinite expectation, [3].

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Keywords: Dynamical systems, Markov processes, General transport-logistic problem, Logistics

Investigating side-wind stability of high speed trains with CFD methods that resolve turbulent dynamics on decreasing scales

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Modern high speed trains are of considerable risk of overturning or derailment when operating in the presence of strong cross winds. In order to assess the safety of such vehicles a detailed understanding of the aerodynamic forces is required. International documents regulating the verification of side wind stability of rolling stock are for instance the European norm 14067-7 or the standard RIL 807.0401-0449. These standards allow the determination of aerodynamic forces not only by scaled wind tunnel experiments but also by computational fluid dynamics simulations (CFD). Latter has the potential advantage of providing a cost-effective tool to gain a deep understanding of the aerodynamic flow around the vehicle for arbitrary operating and geometry conditions.

The numerical challenges are highly dependent on the wind impact angle of the flow. The key difficulties are associated with modeling and resolving turbulent dynamics on various multiple scales. For low wind impact angles ($\theta < 5^\circ$) the flow is dominated by stationary, attached boundary layer flow, which can be reasonably well simulated by applying moderately resolved Reynolds-averaged Navier-Stokes equations (RANS). Methods of this type are based on the assumption, that the flow variables are reaching an average steady state, whereby all fluctuations can be described by steady turbulent statistics. Since none of the turbulent scales are resolved in this case, the corresponding statistics need to be modeled, which limits the applicability to a restricted range of physical phenomena. Thanks to its simplicity and low resolution requirements RANS approaches have become industry standard for numerical simulations.

In the case of high speed trains operating in cross winds at large yaw angle, substantial unsteady vortex shedding on the roof and underfloor side of the train is expected as may be seen from Fig. 1. The complexity is even enhanced by the influence of the train nose, which renders the flow truly three-dimensional. Small scale unsteady effects are furthermore expected to result from the interaction of the flow with the bogie cavity and the wheels.

For flows dominated by such unsteady small scale flow features, stationary RANS techniques become inappropriate for simulation, because the RANS underlying turbulence models can not represent the unresolved scales in the problem. Consequently calculated forces on the train show sizeable discrepancies to experimental values. In order to estimate the minimal computational effort to properly simulate cross wind flows

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around high speed trains, we will present a case study comparing simulations with varying turbulence modelling assumptions, ranging from unsteady RANS to wall resolving large eddy simulations (LES).

Fig. 1 (left) shows simulation results of an unsteady RANS (URANS) simulation using the DLR's Next Generation Train 2 (NGT2) model train geometry from [1]. The NGT2 is a DLR in-house high-speed concept train specifically developed to foster train-related research. Particular emphasis is laid on simulating yaw angles of 30°, for which the vortex system on the leeward side of the train leads to sizeable uncertainies in predicted integral coefficients. We focus on a Reynolds number of 1,000,000 (based on the height of the train) for which experimental validation data from the DLR Cryogenic wind tunnel Cologne (KKK) is available.

The simulations have been conducted using the free open-source software OpenFoam. Because high speed trains are operating at rather low Mach numbers, we only considered incompressible methods, based on pressure-correction-type algorithms, in this work. The used implicit discretization is of second order accuracy in time and space. Here we use a conjugate gradient solver with incomplete Cholesky preconditioning when solving for the pressure equation and a simple Gauss-Seidel solver for the velocity. In addition we employ the k-ω-SST turbulence model to describe the effect of the unresolved turbulent scales. The shown URANS simulations employ ~ 52 million grid cells and have been terminated after running for ~ 50 convective timescales, which required 163 hours on 72 cores ($11,736$ h CPU) on a high-performance compute cluster consisting of compute nodes with 20-core Intel-Westmere processors.

It should be noted that although unsteady RANS simulations allow for resolved unsteadiness in the large scales of interest, the turbulent scales remain still unresolved, as can be seen by comparing left and right hand panels of Fig. 1, where the latter displays results from a DDES simulation, that partially resolves turbulent dynamics in the wakeflow. URANS simulations are therefore equally affected by modeling assumptions which will cause high levels of uncertainty for complicated flow features such as encountered here. It is therefore imperative to remove as many modeling assumptions as possible to correctly simulate side wind flows around high speed trains accurately.

A promising development in this direction are large eddy simulations (LES). Within the framework of LES, most of the turbulent energy containing scales (i.e. eddies) are resolved and therefore do not require modeling assumptions. LES is based on the concept of scale separation, in which the unresolved sub-grid scales can be separated from the larger resolved scales. The separation of scales is achieved theoretically by applying a filtering operation to the Navier-Stokes equations. This yields for the filtered momentum equation

$$\hat{u}_t + \nabla(\hat{u}\hat{u}) = -\nabla\hat{p} + \nu\Delta\hat{u} + \tau_{\mathrm{SGS}}, \tag{1}$$

where the hat denotes filtered (resolved) quantities and τ_{SGS} is the effect of the unresolved turbulent scales on the dynamics of the resolved scales. It is exactly this term which needs to be modeled. It should be noted that although RANS and LES are conceptually different approaches, Eq. (1) is formally identical to the unsteady RANS momentum equation, the difference being that all turbulent dynamics are hidden in the stress

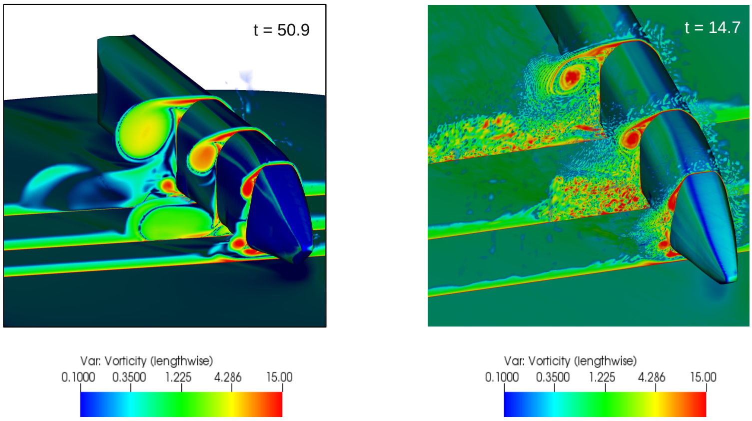

Fig. 1 Instantaneous vorticity (in train length direction) for three different slices of the incompressible URANS (left) and DDES (right) simulation. Also shown is the stream-wise component of wall shear stress on the train surface. Time is expressed in units of convective timescales.

tensor τ_{SGS} in URANS, while in LES the largest part of turbulent motion is resolved and τ_{SGS} carries only the remaining portion.

The resolution requirements for LES are normally orders of magnitude larger than for simple RANS or URANS simulations. LES has been popular for strongly separated flows, where scales containing most of the turbulent energy are in the wake and are relatively large, therefore limiting the additional computational overhead. For attached boundary layer flows on the other hand, the need to resolve small streak-like structures in the buffer layer demands considerably larger resources at technically relevant Reynolds numbers.

A compromise between high resolution LES and relatively cheap RANS simulations are hybrid methods, such as (delayed) detached eddy simulations (DES / DDES). In a DES computation, the wall near regions are being simulated using a RANS approach, therefore removing the need to resolve the boundary layer. Further away from the wall the model switches to LES mode, which resolves large turbulent eddies as they form in the wake flow. DES methods employ RANS models for τ_{SGS} near the wall and transition into LES mode by manipulating the destruction terms of these models, such that modeled turbulence is substantially reduced away from the wall where eddies are large enough to be resolved.

An example of a DDES simulation is shown in the right hand panel of Fig. 1. It is clear that such simulations are much more capable than URANS in capturing the large turbulent eddies that form in the wake after the flow has interacted with the wheels and bogie section of the train. However, the spatial and temporal resolution requirements are significantly higher, increasing the run times easily by a factor of ~ 20 compared to URANS. To model the effect of sub-grid scale turbulence we used here the Spalart-Allmaras DDES model. Since DES/DDES is nevertheless utilizing RANS modeling in the boundary layer, it also cannot be expected to deliver high fidelity results for a variety of flow conditions and geometries, such as considered in this investigation.

For example, the front nose of the train introduces significant streamline curvature, which may have a sizable influence on boundary layer formation and separation on the roof of the train. Further, complicated interaction of the flow with the bogie details and wheels of the train may introduce turbulent dynamics that cannot be determined a priori.

Hence, in order to obtain high fidelity numerical results for this problem, it is unavoidable to resort to wall resolving LES simulations. Due to its large computational overhead however, simulations of this type are typically not performed in train industry. In this contribution we will present wall resolving LES reference results for the NGT2 model train geometry. These are extremely highly resolved simulations involving up to ~ 100 million cells.

The high resolution LES calculation serves as a reference point to fully understand all physical phenomena of the flow. This is compared against the simulations involving turbulence modeling on increasing scales, i.e. DDES and URANS. For the high-resolution LES simulations we will employ a simple Smagorinsky model to describe the sub grid scale stress tensor τ_{SGS}. This is supplemented with van Driest damping functions to ensure modeled turbulence disappears on the train surface.

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Keywords: detached eddy simulation, CFD, Railways aerodynamics, large eddy simulation

Numerical Simulation of the Thermal Comfort in a Double Decker Train Cabin

Mikhail Konstantinov* and Claus Wagner

1 Introduction

The project "Next Generation Train" (NGT), initiated by the German Aerospace Center (DLR), faces the question of how to reduce travel times of future trains, while also improving the safety, passenger comfort and environmental aspects [1]. Part of this project is the prediction of thermal comfort in the NGT passenger cabin consisting of an upper and a lower deck. The geometry of the middle car cabin is presented in Fig. 1. For the prediction of the thermal comfort numerous thermal sources have to be taken into account in the flow simulations, one of which is the passenger itself. In our former work [2] we studied the air flow and the thermal comfort in the upper level of train cabin. The present paper focuses on numerical simulations of the air flow including heat transport, thermal radiation and the thermal comfort of passengers in both levels of the NGT cabin. The computations have been performed by coupling solutions of the Reynolds-averaged Navier-Stokes (RANS) equations, obtained with the Computational Fluid Dynamics (CFD) code OpenFOAM, with the heat transport within the passengers' predicted with the finite-element code THESEUS-FE, developed by P+Z Engineering GmbH. With the latter one, the bodies of passengers were modelled based on various layers with different heat transport characteristics, taking into account effects like blood flow, heat transfer through skin and clothing as well as activity levels and ambient humidity. Based on these computations the thermal comfort of passengers in the cabin was simulated and analysed. In particular the thermal comfort depends on the air flow, the temperature distribution and the thermal radiation in a specific cabin configuration.

2 Thermal Comfort Model

To exchange data between the CFD simulations and the thermal comfort computation, an interface realizing the communication between the two codes was developed [3]. Within THESEUS the heat transport simulation is performed for a thermal manikin, a so-called FIALA-Manikin Model. The body of this manikin consists of 14 segments. These are the head, torso, upper and lower arms, hands, upper and lower legs and feet. Each of these body segments consists of several material layers. Additionally, it is possible to

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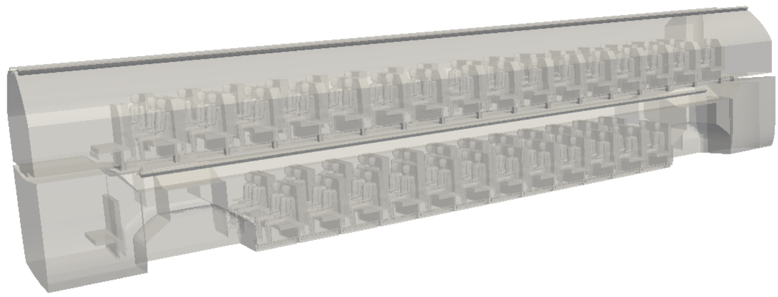

Fig. 1 Whole middle car of NGT II.

define an individual layer of clothing for any of the segments mentioned above. Finally, it must be noted that the core of each segment has its own attributes. Gender effects as well as differences in the human thermal regulation are not considered. For each body segment the thermal energy conservation equation is solved to describe the temperature changes in each material element. The clothing is defined through its thickness, clothing resistance, evaporation resistance, non-structural mass and specific heat. To analyse the thermal comfort, a number of indices are used. First, an equivalent temperature is determined which is influenced by radiation, convection and evaporation. The equivalent temperature is the so called "feeling" temperature. The equivalent temperature and any other comfort indices are calculated with THESEUS-FE. These are the Zhang local sensation index (zhangSI), estimating a thermal feeling of passengers from "very cold" to "very warm" and the Zhang local thermal comfort index (zhangLc), determining a well-being from "very uncomfortable" to "very comfortable". At the beginning of the simulations, the initial temperature on the surfaces of all body segments of the passengers is prescribed. The heat flux densities, resulting from heat radiation and convection, are computed on these surfaces and written to an output file. The code for the thermal comfort simulation receives the heat flux densities and calculates a new set of boundary conditions for the surface temperature. The results can be interpreted as an estimate of the response of a typical human body to the specified thermal loading. Then new surface temperatures are passed on to the RANS simulations by updating the surface temperature boundary condition through an intermediate output file. The whole procedure is repeated every 10 iterations of the RANS computations.

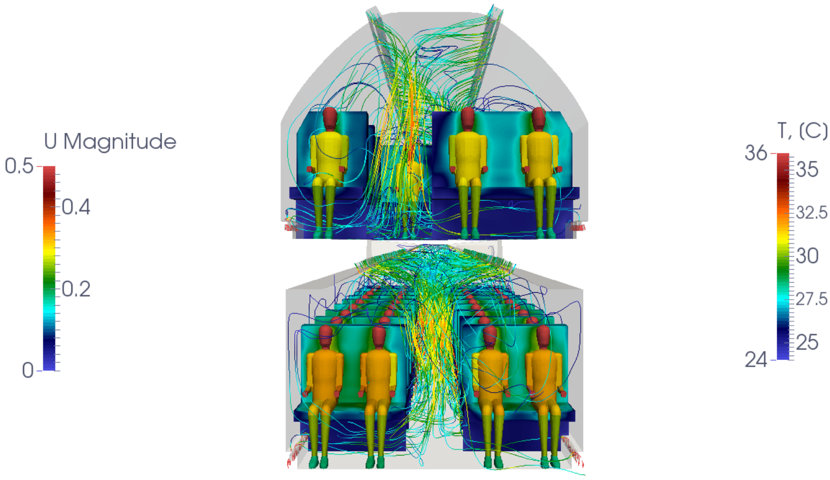

Fig. 2 Streamlines emerging from inlet surfaces colored with the velocity magnitude and temperature distribution on passenger bodies.

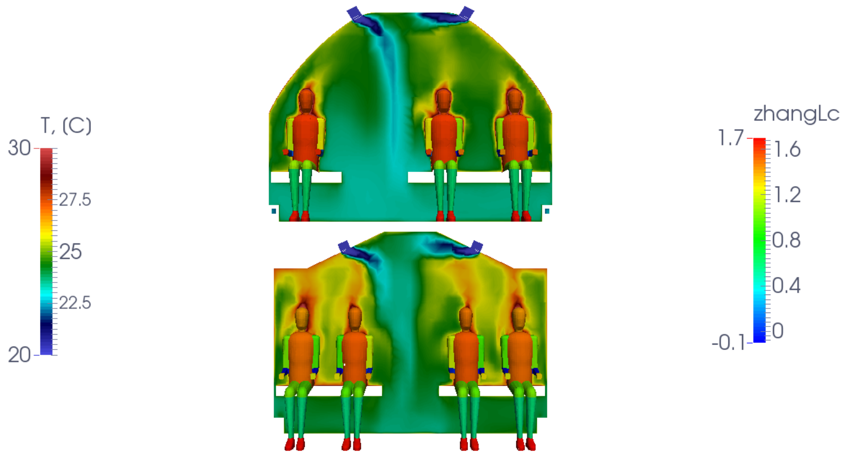

Fig. 3 Temperature distribution in a cross-section in the middle of the cabin and zhangLc indices on passenger bodies.

3 Comfort Predictions

In OpenFOAM the Reynolds-averaged Navier-Stokes equations together with the Boussinesq approximation are discretized and integrated on a hybrid structured/unstructured mesh, consisting of approximately of 29 million cells in the upper and 22 million cells in the lower cabin. The numerical mesh has been generated with the mesher of the commercial program StarCCM+. There are a total of 95 passengers in both decks. The upper deck belongs to first class (three passengers sit in each row with a larger legroom

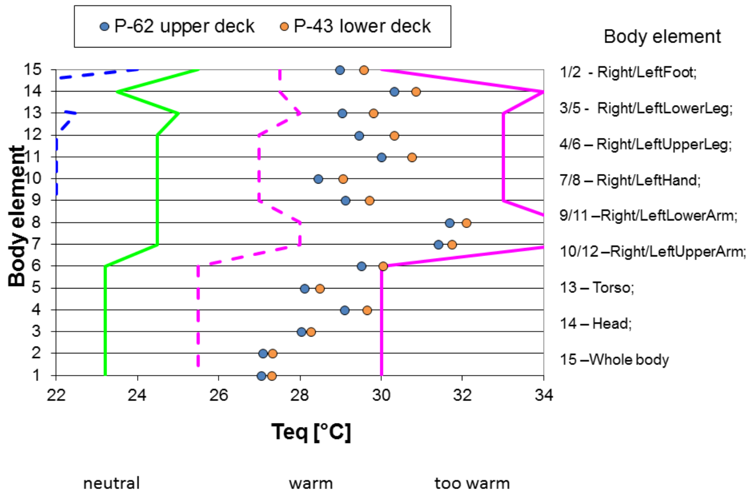

Fig. 4 Comparison of the equivalent temperatures for a passenger in the upper and lower deck.

compared to the lower deck). The lower deck consists of four passengers per row. For both cabin decks the overall inlet volume flux of 0.66 m^3/s and an inlet temperature of 20° C are prescribed. The conducted turbulent flow simulations include heat radiation effects which were computed with the Discrete Ordinates Model (DOM) using 40 rays. The RANS simulations were carried out with the “buoyantBoussinesq” solver of OpenFOAM together with the k-ω/SST Menter model. The predicted temperature distributions and streamlines emerging from inlet surfaces are presented in Fig. 2. The temperature distribution in the cabin is inhomogeneous with considerably larger temperature values in the centre than at the sides. Due to the asymmetric seating arrangement in the cabin, the flow is highly three-dimensional. Thus, the topology of the developing large scale flow structures depends on the shape of the aisle and the seating order in the cabin. An example of a cross-section temperature distribution with Zhang well-being indices (zhangLc) is presented in Fig. 3.

In Fig. 3 it is shown that at the lower deck higher air temperatures occur over the human bodies compared to the upper deck and thus, the well-being indices are reduced. In the Fig. 4, distributions of equivalent temperatures for one passenger seated in the upper (P-62) and one passenger in the lower (P-43) deck are presented. P-62 means, that the passenger is seated in row 6, seat 2. P-43 correspondingly means row 4, seat 3. Both passengers have the aisle seat and are located in the same vertical segment. Better comfort values are obtained for a passenger in upper deck at P-62. Nevertheless, the values for a passenger in lower deck at P-43 also remain in a warm but still comfortable range. We need to reduce the initial inlet temperature in the lower deck to get comparable temperatures for both levels. This action increases the costs of energy, but is not necessary for the simulated case, because the equivalent temperatures for a passenger in the lower deck do not exceed the warm zone. The boundaries of ISO comfort zones are reflected in Fig. 4 as lines.

4 Conclusions

The developed coupled simulation approach allows the prediction of passenger thermal comfort as well as the velocity and temperature distribution within the cabin. Although better comfort values are obtained at the beginning and at the end of the considered NGT-cabin, all measured parameters are located in a warm but comfortable area.

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Keywords: CFD, Train, Thermal Comfort

Aircraft classification based on instantaneous Doppler curve extraction of VHF band

Piotr Ptak*, Juha Hartikka, Mauno Ritola, and Tuomo Kauranne

The paper demonstrates performance of a mathematical model of instantaneous Doppler signature extraction from within VHF band spectrogram image [2] when the type of an observed aircraft is addressed. The method proposed in [3] calculates Radar Cross Section (RCS) profiles and the correlation between them for seven types of aircraft. The analysis is based on data represented by Automatic Dependent Surveillance – Broadcast (ADS-B) trajectory collection and Passive Bistatic Radar with TV station as an illuminator of opportunity, broadly demonstrated in [1]. Throughout the analysis ADS-B data on location of an aircraft is adjusted with the use of extracted Doppler shift information. This ground truth information on location is then used for proper evaluation of RCS profiles and finally validating the extraction method. The method was able to classify common inter-continental aircraft by size class with 70 per cent accuracy from a hundred kilometer distance using an illuminator of opportunity located 300 km away.

1 A Doppler curve detection method

The method presented in detail in [2] for estimation of the Doppler signature based on VHF frequency Doppler effect is derived from the probability density function (pdf) of the First Order Derivative of Doppler Shift (FODDS). This pdf is used to define an expected value and therefore an expected frequency shift. It is assumed that the system is incapable of tracing Doppler curves that emerge from isorange contour trajectories, or baseline's trajectory. The main blocks of the method consists of the following blocks:

- Constant false alarm rate (CFAR) model. It is responsible for detection of amplitude-wise outlying cells;
- Cells detected with CFAR are analyzed to find separated peaks, defined as a group of neighboring points corresponding to the same peak, which could represent different signal sources. This step is achieved through analysis of first and second derivatives.
- The center of mass formula is applied to find the frequency that corresponds to the true maximum amplitude of each peak which further called as the *pretenders*.
- Classification block in which the system classifies the pretenders into separated groups which form a logically consistent time series in a sense of Doppler shift curvature. This block is based on a continuation of the energy concentration parameter,

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the distance in frequency between two consecutive steps and probability of frequency difference.

- Signal intersection block is responsible for finding cases in which two or more signals are intersecting for some period of time. These cases are resolved basing on the history of the signal's shape and amplitude.
- Rejection block consists of the set of rules needed to reject or accept the pretenders' group.
- Prediction block is based on a first or second order polynomial fit of the groups of the pretenders found, depending on the class of the signal, and on an extrapolation one step (one scan line) forth.
- Linking block is responsible for joining two signals separated by a time gap once certain conditions are fulfilled. The missing link is then created by extrapolating with a second order polynomial based on the number of points from the proper ends of both signals.

2 Data

Radio signal data (RSD) used for the analysis was retrieved using a 4-element horizontal dipole array at about 14 m above ground and a gain of 4 to 5 dBd. The transmitter located in Saint Petersburg had frequency of $f_t = 49.75\,\text{MHz}$ and effective radiated power of 149 kW. The receiver was located a distance of 301 km away from the transmitter. The receiving aerial is connected to a FT-100D receiver used in CW/USB mode with 500 Hz filter. Coaxial feed line loss between aerial and receiver was about 3 dB. Audio from the receiver was connected to computer's sound card for numerical analysis. The required audio width for aircraft scatter doppler observations was less than $\pm 100\,\text{Hz}$ from the 600 Hz center audio frequency.

Such preprocessed signal was then sent via internet with use of Ventrilo$^{\text{TM}}$ software with sampling frequency of 8 kHz to a location in Oslo, Norway. Average signal delay varied around 79 ms. The signal was then transformed using Short Time Fourier Transform (STFT) with adjusted width of symmetrically positioned Hann window of 1 s and calculation time step of 0.5 s.

In the same time another type of data (FR24) were collected from flightradar24.com website. The FR24 data consists of tracks of aircraft in proximity to the the transmitter and the receiver. During recordings of FR24 ninety nine different trajectories created by eleven different types of aircraft have been collected from which seven most frequent types were used for the analysis: Airbus A330-300 (A333), A340-300 (A343) and A340-600 (A346), Boeing 747-400 (B744), 777-200 (B772), 777-300 (B777W) and 787-8 (B788). The remaining group of aircraft is categorized by their size into three groups: **G1**:mid-size (B788, A333, A343), **G2**:large-size(B772, B77W, A346) and the largest aircraft **G3**:(B744).

After the synchronous recordings of RSD and FR24 has been finished, the analysis of RSD for tracing of Doppler and carrier signatures is started. The tracing of Doppler signature and carrier is conducted using the technique briefly presented in [2]. For each extracted signature the associated FR24 signature is found by calculating the proximity between the extracted Doppler and the FR24-resulted Doppler on time-frequency plane.

Table 1 An average correlation with respect to the type of an aircraft.

ICAO	B788	A333	A343	B772	B77W	A346	B744
B788	0.57	0.65	0.56	0.28	0.20	0.28	0.20
A333	0.65	0.74	0.65	0.31	0.35	0.41	0.24
A343	0.56	0.65	0.70	0.36	0.42	0.34	0.29
B772	0.28	0.31	0.36	0.75	0.73	0.69	0.35
B77W	0.20	0.35	0.42	0.73	0.76	0.71	0.36
A346	0.28	0.41	0.34	0.69	0.71	0.80	0.38
B744	0.20	0.24	0.29	0.35	0.36	0.38	0.75

The FR24-related Doppler signature is calculated based on spherical coordinates and altitude with respect to the location of the transmitter and the receiver by the Vincenty inverse formulae. It is worth noting that since the trajectory based on FR24's latitude and longitude information was distorted, the resulting Doppler frequency was distorted too. Moreover, it was observed that the synthetic Doppler based on FR24 projected onto the spectrogram do not overlap with the extracted Doppler.

To overcome this difference the whole trajectory was shifted by latitude and longitude factors defined with the minimum cost function. By this process RSD data was now also accompanied by FR24-based information like trajectory, type of an aircraft *ICAO* and FR24-based Doppler signature.

3 Aircraft type detection

The radar cross section σ_B (RCS) of the extracted signatures was calculated using the following formulae [4].

$$\sigma_B = \frac{A_d}{A_c} \frac{(4\pi)^3 d_{\mathrm{TA}}^2 d_{\mathrm{AR}}^2}{d_{\mathrm{TR}}^2} \tag{1}$$

where A_d and A_c are the amplitudes as a function of time t of Doppler and carrier respectively, d_{TA}, d_{AR} and d_{TR} are distances between the transmitter (T), aircraft (A) and the receiver (R) as the functions of time t.

The performance of the technique is tested by checking the correlation between calculated RCS's for different types of aircraft. This is achieved by calculating the correlation between RCS for every pair of trajectories available, then classifying them by the aircraft type and finally calculating an average correlation factor. The result of this analysis is presented in Table 1.

We can notice the relatively higher correlation factors of the three groups on the diagonal of the matrix. In the next analysis we have found an optimal correlation threshold for which the number of aircraft-pairs from the same class is maximized and the pairs from different classes is minimized. The threshold has been found to be equal 0.58. The result for this is shown in Fig. 1.

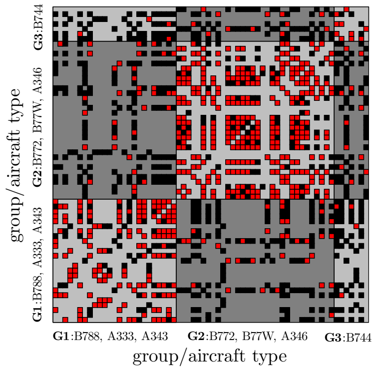

Fig. 1 Result of optimal correlation-threshold estimation. Red squares denotes values over the threshold, black ones values below the threshold.

Table 2 Probability of classification/misclassification between the groups G1, G2 and G3.

	G1: B788, A333, A343	**G2**: B772, B77W, A346	**G3**: B744
G1	$\frac{74}{101} = \mathbf{0.73}$	$\frac{34}{171} = 0.19$	$\frac{4}{59} = 0.06$
G2	$\frac{34}{171} = 0.19$	$\frac{162}{205} = \mathbf{0.79}$	$\frac{12}{75} = 0.16$
G3	$\frac{4}{59} = 0.06$	$\frac{12}{75} = 0.16$	$\frac{5}{7} = \mathbf{0.71}$

The number of correctly classified pairs within groups on the diagonal significantly exceed the number of misclassified pairs. With this condition in mind the probability of misdetection/detection was calculated and presented in Table 2. The values on the diagonal reflect the probability of correct classification, whereas the upper and lower triangles the probability of misclassification.

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Keywords: Doppler signature, Passive Bistatic Radar, Radar Cross Section, aircraft classification

Challenges in Optimization of a Passenger Vehicle

Mikael Törmänen*

Optimization has become every engineers everyday tool for balancing the product design to meet the demanding customer and legislation requirements. The capability of modern CAE tools have also been developed at an ever faster pace pushing the analytical performance up to new levels. These two together gives huge possibilities when analyzing the product performance from the different attributes points of view as well as finding cost effective solutions to provide business cases of interest. This presentation will give insights into some examples of success stories at Volvo Car Corporation as well as address some challenges to be solved.

Keywords: Optimization, CAE tools

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Challenges to develop innovative multi-use offshore platforms servicing marine transportation and emerging coastal activities

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The global population is growing, and space and resources along the coast are limited. Therefore, the development of novel offshore technologies allowing for the exploitation of oceanic resources becomes more and more important. The recently finished FP7 TROPOS project (`http://www.troposplatform.eu/`), which came to an end in January 2015, aimed at developing a floating modular multi-use platform system for use in deep waters, with an initial geographic focus on the Mediterranean, Tropical and Sub-Tropical regions, but designed to be flexible enough so as not to be limited in geographic scope.

In order to provide efficient marine transportation, a floating design facilitates access to deep sea areas and resources where deployment of conventional platform types is not possible. The modular multi-use approach allows integrating a range of functions from four different sectors: Transport, Energy, Aquaculture, and Leisure (in short: TEAL). Marine Transport (T) provides critical services to the society ranging from building commercial and leisure ships, shipping of goods and fuel around the world, passenger transfer, to servicing offshore structures. The development of renewable Energies (E) is essential to address the dramatic depletion of fossil fuel reserves and to mitigate climate change which has become one of the most critical issues in recent years. Natural marine living resources are already heavily exploited, while the demand for these resources is steadily increasing. To reduce the fishing pressure on wild stocks, the demand needs to be increasingly met additionally by Aquaculture (A). Finally, the tourism industry represents the third largest socio-economic activity in the EU and space is needed for the development of new Leisure (L) activities. Not only in Europe, but all over the world there is an increasing demand for innovative, eco-friendly solutions in the tourism sector.

Three different concepts (shown in Figure 1) were developed in the scope of TROPOS with various combinations of TEAL functions. Appropriate locations for the different concepts were identified and final TROPOS scenarios were defined with the help of a specifically developed GIS support tool: (1) Green & Blue scenario north of Crete, integrating wind energy exploitation and fish and algae aquaculture, (2) Leisure Island off the coast of Gran Canaria, combining leisure facilities with the use of solar energy, and (3) the Sustainable Service Hub on the Dogger Bank (North Sea, UK), focusing on transport and energy related needs of the offshore renewable energy sector, i.e. it provides service for offshore wind farms.

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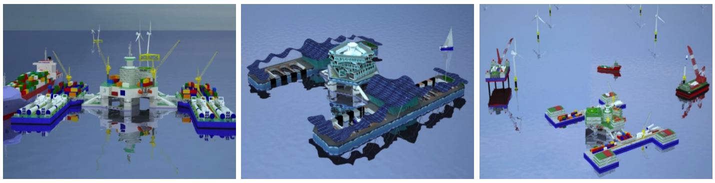

Fig. 1 Engineering design of TROPOS platform concepts. UPM-AID design for the TROPOS project. From left to right: Green & Blue, Leisure Island and Sustainable Service Hub

The different scenarios developed in the scope of the project are feasible in terms of technology and logistics, and acceptable in terms of their environmental impact, provided that mitigation strategies are pursued and strict monitoring is applied. All scenarios have the potential to be built at least at pilot scale in the near future. However, the Sustainable Service Hub concept has currently the highest potential for near-term development. Considering all different aspects examined in the scope of the TROPOS project, the Sustainable Service Hub turned out to be the most economically viable and ecologically sustainable concept. The analysis revealed that an Offshore Wind Service Hub is already cost effective for wind farms of >200 MW. The Sustainable Service Hub will significantly contribute to a reduction of the impact of offshore wind farms on ecosystems as the amount of traffic will be significantly reduced through the presence of the Service Hub, and most of the traffic will occur in a limited area within the wind farm site.

The next essential step, which is urgently required now, is to move from the theoretical approach and modelled designs towards ”real world” deployments. Even if financial support is possibly required at the beginning, pilot scale deployments are essential to proceed in the field of multi-use offshore installations, to work on and solve problems (e.g. in legislation or standards, as raised above), to test and improve the developed installations in reality and to monitor (positive and negative) effects of multi-use offshore platforms on the society, regional economy and environment.

Reduction of environmental effects of civil aircraft through multi objective flight plan optimization

Felipe Gonzalez, Dong Seop Lee, Jacques Periaux, Jordi Pons-Prats*, and Gabriel Bugeda

Aircraft emission targets worldwide and their climatic effects have put pressure in government agencies, aircraft manufacturers and airlines to reduce water vapor, carbon dioxide (CO2) and oxides of nitrogen (NOx) resulting from aircraft emissions . The difficulty of reducing emissions including water vapor, carbon dioxide (CO2) and oxides of nitrogen (NOx) is mainly due to the fact that a commercial aircraft is usually designed for a particular optimal cruise altitude but may be requested or required to operate and deviate at different altitudes and speeds to archive a desired or commanded flight plan, resulting in increased emissions. This is a multi- disciplinary problem with multiple trade-offs such as optimizing engine efficiency , minimizing fuel burnt and emissions while maintaining prescribed aircraft trajectories and air safety. There are possible attempts to solve such problems by designing new wing/aircraft shape, new efficient engine, ATM technology, or modifying the aircraft flight plan.

This paper will present the coupling of an advanced optimization technique with mathematical models and algorithms for aircraft emission, and fuel burnt reduction through flight plan optimization.

To different approaches are presented; the first one describes two multi-objective design optimizations which are conducted to find the best set of flight plans for current aircraft considering a discretized altitude and Mach number without modifying aircraft shape or engine type. The objective of the first optimization is to maximize range of aircraft while minimizing NOx with constant mission fuel weight. The second optimization considers minimization of mission fuel weight and NOx with fixed aircraft range. The second approach presents the robust optimization of the flight plan and profile in order to reduce the fuel consumption while reducing distance and time.

Numerical results will show that the methods are able to capture a set of useful trade-offs solutions between aircraft range and NOx, mission fuel consumption and NOx. In addition, alternative cruise operating conditions including Mach and altitude and flight profile that produce minimum NOx, CO2 (minimum mission fuel weight) and fuel consumption will be discussed.

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Keywords: Multi-objective Optimization, Aircraft Emissions, Games strategies, Evolutionary Algorithm

A PGD computational vademecum for shape optimization: geometrical parameterization, fast and multiple queries

Pedro Díez*, Sergio Zlotnik and Antonio Huerta

In the general framework of shape optimization for aerodynamics, the flow around an obstacle is analysed for a variety of geometries. This requires introducing a number of geometrical parameters (taken as design variables in a shape optimization setup) and evaluating the objective function for many points in the multidimensional parametric space. To improve the efficiency of the optimization algorithm, also the sensitivities (derivatives of the objective function with respect to the parameters) are required. The computational complexity explodes with the number of dimensions, as it is stated in the so-called curse of dimensionality.

The Proper Generalised Decomposition (PGD) is devised as a computational strategy allowing to circumvent the difficulties associated with the multidimensional framework. The PGD is based on three ideas: (1) seeking a separable approximation (a sum of terms, each of them being the product of functions depending on only one of the parameters), (2) using a greedy algorithm approach to compute sequentially the different terms and (3) iterating with a fixed point method, using an alternate directions approach to resolve each term. The resulting PGD solution is seen as a computational vademecum allowing the user to evaluate the multi-parametric solution (instead of solving a new CFD problem for each value of the set of parameters) with a very small computational cost. Moreover, the parametric dependence is explicitly described in the PGD approximation and therefore parameter sensitivities are readily evaluated by differentiating the solution with respect to the parameters.

Keywords: optimization, logistics, information systems

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Basic versus applied research in transonic flows for aeronautics

Prof. Laurent Jacquin*

As an example of research in-between ”academic” style research and more applied research relevant in aeronautics, we present recent research on transonic flows conducted by the Fundamental and Experimental Aerodynamics Dept of ONERA which operates the world class wind tunnel S3Ch located at Meudon. The main focus is the flow field associated with transonic airfoil buffet. This mechanism limits the load capacity of cruising civil aircrafts and its control could enlarge aircraft's flight envelopes and should lead to energy saving. Whereas conventional aircraft operate with turbulent boundary layers, laminar flow conditions must be also considered for advanced and greener transport aircraft. In the case of an ”academic” 2D airfoil in turbulent conditions, buffet onset observed in experimental results can be explained by the global hydrodynamic stability theory. This has been proved by using a combination of the stability theory based on perturbing a steady flow field obtained from the Reynolds averaged Navier- Stokes equations. The theory and experiment show good agreement for the buffet onset conditions, including the critical angle of attack and the buffet-onset frequency. In the case of realistic 3D airfoils, experiments shows that the buffet develops in a restricted region on the wing. Global stability of these 3D flows are envisaged but are not yet feasible due to computing capacity. However, experiments show that 3D buffet can be delayed using mechanical or fluidic actuators. As for laminar wing designs, the buffet flow on a laminar airfoil has been considered recently in the framework of a European-Russian project called Buterfli*, coordinated by Onera. Experiments reveal that the buffet is strongly sensitive to the incoming boundary layer state: in the case where the boundary layer is laminar, buffet is weaker and the onset frequencies are moved to larger values. Global stability analysis of this flow is underway. Its full simulation by DNS (Direct Numerical Simulation) now becomes tractable, due to the laminar nature of the boundary layer upstream of the shock, but this will still require the use of the largest available computing capacities. A PRACE (**) project on this subject will be submitted soon. Understanding and controlling the buffet physics, by combining theory, experiments and high power computing is of primary importance for future developments of transonic ”greener aircraft”.

(*) BUffet and Transition delay control investigated with European-Russian cooperation for improved FLIght performance)

(**) Partnership for Advanced Computing in Europe

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Platea4D: A software platform for transnational maritime and coastal projects

Blas J. Galván*

Platea4D is a software platform capable to store and analyse in real time georeferenced information and to follow events evolution along the time. 4D means that every data piece have properties associated to its spatial coordinates (x, y, z) and the time (t) and every process module can consider such four variables anytime.

The main features are: Interactive, customizable and user-friendly interface, Optimized information organization for screen display, High performance core allowing integration and connection of high complexity processing modules with different functions (Optimized Processing Engine), Cataloguing of a big amount of heterogeneous kinds of information which can be simultaneously analysed due to an efficient memory management optimization. The easy integration of real time information and process modules form different remote sources have been a key characteristic along the development process of the platform.

As examples the platform can be used to help the decision-making process necessary for optimal response planning in emergencies such us sea or coastal sovereign violation (Smart surveillance through UAVs,...), contaminant events in the environment (Oil spills, Toxic Clouds,...), accidents were hazardous substances are involved (Explosions, ...), adverse meteorological phenomena (Storms, Waves, ...), forest fires, earthquakes, etc.

Platea4D started in 2001 and have kept a continuous growth in both code size and experience in real applications. Several regional, national and European projects have been developed using the platform. At the present time the total amount invested is near 2M Euros. The platform and its team are open to new project proposals.

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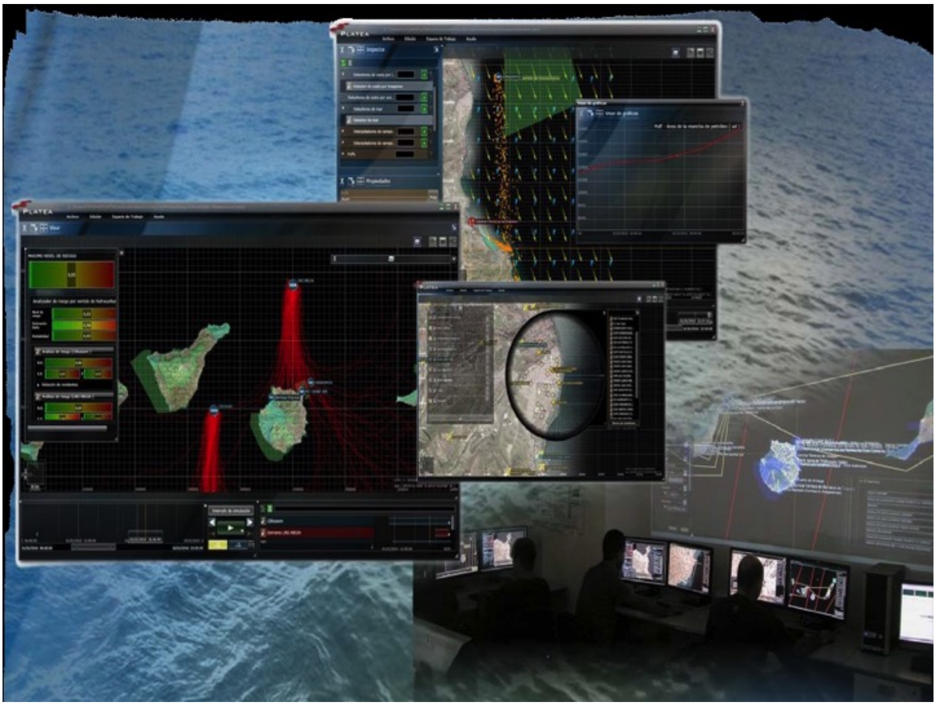

The Port of Houston and Gulf Coast Maritime Operations

W. Fitzgibbon*, Maria Burns, and Neils Aalund

The speaker will overview Port of Houston and Western Gulf of Mexico Maritime operations and assess their economic impact. Particular attention will be paid to environment issues and security concerns.

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Day 2 - Tuesday May 26, 2015

Large-scale wave propagation in ballasted railway tracks

R. Cottereau*, L. de Abreu Correa, J. C. Quezada, S. Costa d'Aguiar, and C. Voivret

We consider in this work the dynamical modeling of ballasted railway track. The dynamical loads caused by the passage of high-speed trains accelerate track deterioration and may damage neighbour buildings [1]. Two classes of numerical models are used to (try to) predict the behaviour of these dynamical systems: (1) discrete approaches, in which each grain of the ballast is represented by a rigid body and interacts with its neighbours through nonlinear contact forces (with non-smooth contact dynamics and software LMGC90 [2]); and (2) continuum approaches, in which the ballast is replaced by a homogenized continuum and the classical Finite Element Method (FEM, or similar) is used. On the one hand, discrete approaches are today capable of solving a few meters-length of ballast, and the coupling with the underlying layers of soil remains an open problem. On the other hand, homogenized approaches are not capable of representing the heterogeneity of the strains and stresses within the ballast. We investigate in this work an alternative approach using a heterogeneous continuum model, that can be solved with a FE-like method while retaining some degree of heterogeneity. The present work is divided into two parts: (1) the statistical identification of the parameters of the continuum material; (2) large-scale wave propagation in a ballasted railway track. The first part identifies the parameters of our continuum model (average, correlation length, and variance of a random field of Young's parameter) on small cylindrical samples of discrete ballast (solved using LMGC90), with confinement pressure, gravity and a top pressure. The second part of the presentation concentrates on the solution of the dynamical equations on a large model of a ballasted railway track with the Spectral Element Method [3]. The generation of the elastic linear heterogeneous material was made using the stochastic spectral representation. Different trains velocities are analysed, in subsonic and supersonic regime.

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https://subver.lmgc.univ-montp2.fr/trac_LMGC90v2/
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Multidisciplinary Design Analysis/Optimisation System Needs and Development

Adel Abbas*

The development of an integrated, efficient and multidisciplinary design chain in industry is a prime objective for successful products. In this design chain numerical optimization is important to support design of improved shapes to speed up design cycles and to explore new shape concepts.

Although, the past few decades have seen an increased interest in general-purpose ”black-box” optimisation algorithms that exploit limited knowledge concerning the optimisation problem on which they are run. Those however, demonstrate the danger of comparing algorithms by their performance on a small sample of problems. These same results also indicate the importance of incorporating problem-specific knowledge into the behaviour of the algorithm.

Therefore, the automatic modelling and exploration of a design space requires the identification of parameters and constraints defining the design space, identification of objectives cost function defining the optimisation problem, choosing an ”optimal” optimisation approach and an optimal value of the parameters (shape) that answers to the optimisation problem.

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Round Table: New Challenges and Solutions for the Greening of Transport

W. Fitzgibbon *

Generalities

The logic Smart, Green and Integrated Transport is an approach that recognizes modal specificities, that is focused on the societal challenges, caters for users' needs, and takes into account the imperatives of competitiveness. It encompasses the different dimensions of the transport system: the transport means, the modes (road and rail: optimisation of network and traffic management), waterborne (integrated planning and management, port operations, airport transport systems: traffic management, passenger and freight handling) the infrastructure and the services.

- sustainable transport : resource efficient transport that respect the environment
- seamless transport : better mobility , less congestion, more safety and security
- competitive transport : global leadership for the European transport industry (next generation of transport means, on board smart control systems, advanced production processes , new transport concepts (automated vehicles)

Which and how Green Key Technologies will master these Transport issues ?

- Moderator: W. Fitzgibbon (Univ. of Houston, Texas , USA)
- Chairman: J. Periaux (Univ. of Jyvaskyla , Finland)

Panelists:

- Adel Abbas (UPM, Spain) (Aviation)
- Regis Cottereau (ECP, France) (Rail)
- Michael Tormanen, (VOLVO, Sweden) (Automotive)
- Blas Galvan (ULPGC, Spain) (Maritime)
- Michael Kyriakopoulos (EC DG Research and Innovation)
- Olli Bräysy (JYU, Finland) (Logistics)

Format:

Part 1: (6x10 mns) Speakers' contributions setting the scene for the Round Table.

W. Fitzgibbon
Univ. of Houston, Texas , USA

* Moderator

Part 2: (60 mns) Round Table Discussion: Questions-answers moderated with the audience.

Collaborative logistics – possibilities and challenges

Mikael Rönnqvist*

Collaboration is one important approach to develop sustainable logistic sectors. In different studies it has been shown that such collaboration in for example collaborative transportation can save 10-15 percent of the overall cost. In addition, negative environmental impact of emissions can be reduced by the same number or even more. With such convincing numbers all companies should be involved in such collaboration. However, this is not the case and the question is why? There are several reasons. One is the need to build the coalition but who should lead, who should take first initiative and who should be invited to participate? A second is the need to establish a sharing mechanism such that all partners are treated fair and with respect to their effort, level of data uncertainty and specific requirements. In logistics, the evaluation of quantitative collaboration benefits is mainly conducted using Operations Research (OR) models. Game theoretic models and procedures to establish collaborative coalitions, mechanisms and sharing principles have recently gained a lot of attention in the scientific community. A third is the need to keep sensitive information classified and to have trust among all participants. This may be a problem unless the coordination is done by a third party. A number of industrial applications will be described and discussed. These arise as various transportation and logistics problems in forest and petroleum industries.

Keywords: optimization, logistics, collaboration, coordination

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* Presenting author

The key success factors in future logistics

Prof. Olli Bräysy*

New technologies, increasing competition and customer demands as well as changing operation environment create hard challenges to logistics industry. To maintain competiveness and efficiency, one not only needs optimal planning, but also for example the best service and operational concepts, correct focus, collaboration and the most suitable technology and tools. We shall discuss these topics and try to provide new insights via carefully chosen real-life example cases.

Keywords: Logistics, Optimal planning, Real-life examples

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* Presenting author

Extending the scope of SCM decision-making

Wout Dullaert*

The scope of supply chain decision-making is expanding rapidly, both in business and in academia. By using several examples of ongoing industrial research projects we will illustrate how both traditional supply chain decision problems and novel research challenges triggered by ecommerce and sustainability concerns continue to offer significant potential for improvement and model development.

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* Presenting author

Round Table: The Growing Importance of Intra-Logistics

Jorma Härkönen*

Intra-logistics has been developed as a new scientific discipline and managerial area under the already multidisciplinary logistics field, and it has developed remarkably from traditional materials handling and warehousing operations. Although intra-logistics costs are often as high as transportation costs, public discussion has been limited mainly to the latter. There are significant needs and enormous opportunities for productivity improvements as well as for new value creation.

- How to define intra-logistics?
- Intelligent machines, processes, and/or people?
- What are the similarities and differences in intra-logistics between distribution center and production facilities?
- In which way digitalization will effect and enhance our intra-logistics?
- How to link intra-logistics for the whole supply chain?

Panelist

- W. Dullaert
- H. Fleuren
- J. Särelä
- J. Viinikainen

Jorma Härkönen
Limowa

* Chairman

Optimization of Large-Scale Waste Flow Management at HerAmbiente

Matteo Pozzi *, Daniele Vigo, Angelo Gordini, Fabio Lombardi, Tiziano Parriani, Claudio Gambella, Adriano Guarnieri, Fabrizio Salieri, and Lorenzo Ravaglia

During the last decades, solid waste management has constantly increased its influence on a variety of factors impacting on the entire society, especially for what concerns economical and environmental issues. Waste logistic networks became articulated and challenging because the traditional source-to-landfill situation switched to multi-echelon networks in which waste flows generally go through more than one preliminary treatment before reaching their final destinations (see Fig.1). Complex optimization problems arises in this context, with the objective of maximizing the overall profit of the service.

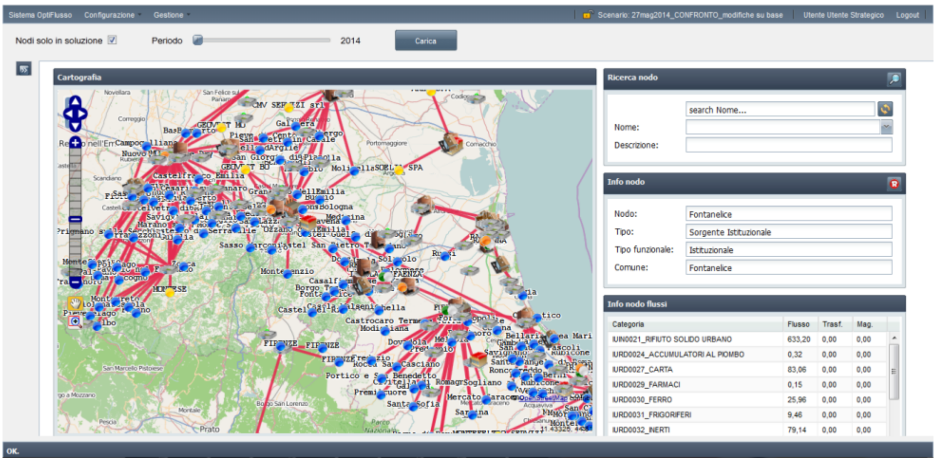

Fig. 1 A diagram representing the typical waste facilities network. SMW is for Sorted Municipal Waste, ND is for Non-Dangerous, MBT is for Mechanical Biological Treatment, PBT is for Phisiochemical Biological Treatment, WtE is for Waste to Energy, T&EE is for Termal and Electrical Energy, Env. Eng. is for Environmental Engineering, Pre.Tr. is for preliminary treatments

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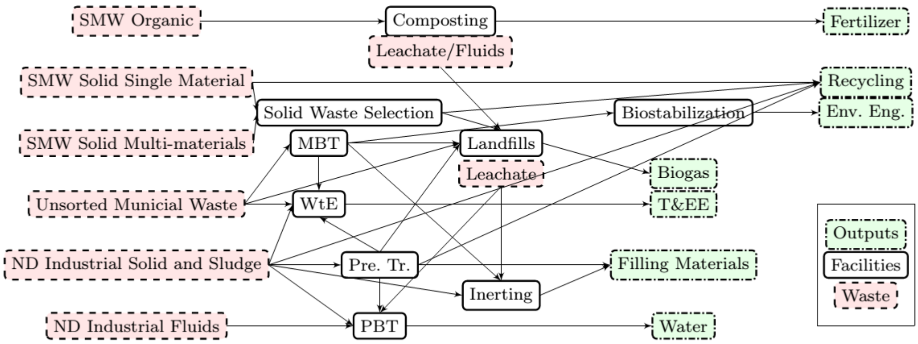


Fig. 2 Picture exemplifying the web-based software solution developed.

We describe the business case of the leading Italian Waste Management Company, and how their issue was tackled to develop an innovative solution to support strategic, tactical and operations planning using mixed integer linear formulations.

The model, formulated and solved using state-of-the-art of commercial software, aims at maximizing the overall margin of the system (logistics costs + treatment costs/revenues) under a set of constraints defined considering several different aspects of the problem (e.g. treatment plants capacities, limits of the law, waste composition in and out the facilities, etc.).

The actual challenge, though, is more on the actual capability to manage all network configurations and resolution strategies in a way that could be useful for the business' purposes, provided that:

- the complete value chain counts almost a hundred types of waste;
- several hundreds of waste sources are used, with more than 4000 constraints on output flows;
- several millions of tons of waste are transported each years (counting hundreds of thousands of trips, with several logistics constraints);
- a few hundreds of treatment plants (80 of which are owned by HerAmbiente) are subject to several hundreds flow and mix constraints;
- the sheer granularity of the scenario time horizon, that ranges from 4 years for an industrial plan down to 54 weeks used for a tactical planning (budget execution).

This was achieved through an enterprise web-based solution (see Fig. 1) that allows central planners manage the strategic module, while over 40 peripheral users (i.e. plant and logistic coordinators) manage short term planning (i.e. week-ahead) through a tactical module, achieving significant return on the project's investment.

Keywords: optimization, waste, logistics

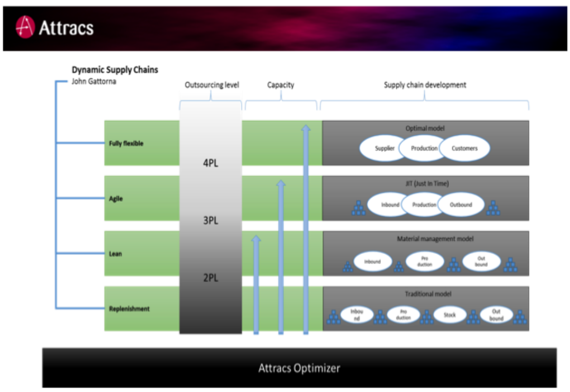
Dynamic and Real-time Management of Logistic Chains

Peter Grankulla *

We are moving from supply chains to supply chain network. The future is already here, but how do we design supply chain services across networks for optimal performance. The solution can’t be found in traditional logistic models where key focus is on specific goods flows, coasts and capacity.

Case study:

Attracs Dynamics – Combining and optimizing several supply chain types in one single SCE suite, using John Gattornas general supply chains; Continuos replenishment, Lean, Agile and Fully flexible as a base reference.



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Challenging science for innovations in logistics

Ph.D. Ilkka Hämäläinen*

Economist's point of view

The traditional point of view of economist is to see the society as a market place for two agents: business firms and households. In this context the logistics would be the flow of information, knowledge and physical goods between these two agents. Classical economics suggest that the maximum of welfare of the society can been achieved, when the households maximize their utility, and business firms maximize their earnings or profits. This basic setting - the core of capitalism - should give guidelines for the firms to the continuous development, as well as incentives to cannibalize both own business and competitors' business, following the ideas of Schumpeterian creative destruction (Capitalism, Socialism, and Democracy (1942)). The markets should be the meeting place for the firms and the household to find these maximum functions in socially accepted and proper way. The only value adding aspect in logistics in this context is delivering the goods to marketplace to give end users easier access for search and choice to purchase the goods.

Science and Universities

The idea of science has since the early pre-stages been announced as observing the nature or environment for acquiring knowledge to understand the world and ourselves better. The institutionalization of science to the universities has been given the structure of systematic scientific knowledge growth. On the other hand, universities have reserved the scientific knowledge production and global scientific knowledge legitimation as their own monopoly. Universities have always seen themselves independent and somehow isolated from the society (Humboldian autonomy): universities create their own agendas. The development of science has generated more and more new independent disciplines. The body of scientific knowledge is more and more fragmented, and scientists are more and more focused to more and more specific and narrower agendas about the phenomena in the nature and society.

The world is getting more and more complex for people to live in as well as the firms to serve the people to satisfy their needs. In the spirit of market economy the best decisions by the management are considered to be achieved by using latest knowledge from markets and science, the challenge for the management is huge: one should on the other

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hand have complete understanding which disciplines of science might have something to give for this problem or open challenge, and then try to get an access to those knowledge sources. Complexity means that the problem setting is multidisciplinary, and the solution (the knowledge) should be developed by interdisciplinary methods. In most of universities there are not yet developed and structured anything such as interdisciplinary research teams to meet these challenges. There is a major gap between the business needs of interdisciplinary knowledge and the capabilities of the universities to produce interdisciplinary knowledge. This is one of the key questions in developing the process ”Science-to-Business” or S2B.

Innovation

The linguistic term ”Innovation” has been widely used for the last 20-30 years for various purposes: in building competitive edge for business or for the country, generating wealth to both business and states, for delivering better life to the people etc. Innovation theories have developed through the last decades from science push and market pull to the holistic and systemic view of the innovation process. The challenges for the business is to combine all factors which might lead to new ideas and further on to something which might be called on the business firm’s side as an innovation - without forgetting, that after all, innovation is always more or less an emerging phenomena, you cannot ex post exactly explain the birth story of the innovation. The concept of innovation has been defined usually as ”new and beneficial”. In context of cognitive management, however, this does not create a proper concept for a thinking society (people who should share the thoughts for mutual gain), for instance inside a company or inside an R&D team. In the model of cognitive management (as described by the author) the thinking society will choice for themselves the best definition suitable for the focused issue. The general concept might be defined as ”innovation is smaller or larger betterment in the feature of the product that enables the end user to achieve a (personal) social change”. For more specific focusing of thoughts the society might admit commonly used definitions like frugal innovation, jugaad innovation, DIY innovation, innovation for sustainability, price deductive innovation, reverse innovation etc. These different approaches should help the team/society to achieve new ideas for creating new offerings with new products and services.

Logistics

Logistics has been traditionally considered as an independent function of business activities: there are given goods to be transported from the given place (location of manufacturing) to the given place (customers or resale location). Innovation efforts in business of the logistic operations have focused to cut the cost of these transportations.

These, mainly incremental innovations in context of the whole process of creating utility for the end users, have been such as optimizing the transportation roads, cutting the consumption of petrol/diesel, cutting the costs of tires, cutting the working hours, delivering information to the agents involved during the transportation, etc. The question

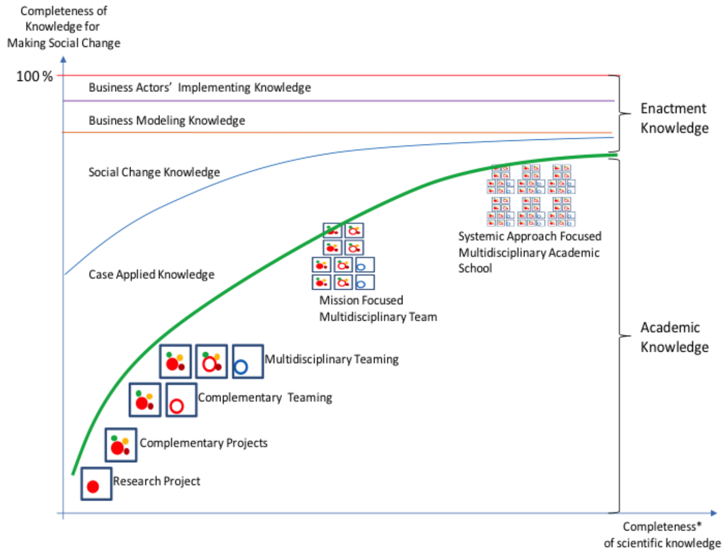

Fig. 1 Enactment knowledge for capitalizing academic findings.

might rise about the holistic view: are we sure that the logistics in focus of innovation process is actually a solution for the best conceptual model of the product itself or for the business model for the product. Could it be possible that competitors will come to the markets with totally new concepts, where logistic solution would be totally in a new context?

Would you see here the greatest innovations in logistics for example in following innovative models in last decades: Amazon changed the rules of the game in delivering books by leaving local bookshops out of the whole logistic chain? How about IKEA: understanding the development in the society (for ex. increasing number of cars in households in 1950/60's which made it possible to the end users to take care of transportation of goods to their homes from the store, if the products are packed to suitable box sizes), and possibilities through the product design to outsource the furniture assembling to the end users. Internet has changed the rules of traditional logistic chain dramatically. The digitalization has and will have in the future a huge impact of the need of transportation of physical goods as well as information. Where is the next major game changing innovation in the logistic operations? Or are the consumer behavior changes dictating new rules for the whole society and the models of satisfying consumer needs: what shall be the role of logistics in this new world view? Who will be the game changers: business or universities? Will there be new ecosystems for business and people? Will this development lead to differentiation on consuming, meaning larger varieties in the demand of products and services, in the supply side to the economies of scope instead of economies of scale? These developments will not just happen, somebody will orchestrate the process, and somebody will create and own this new ecosystem business. Have you thought where to be, when these disruptive innovations will start changing the world?

A new approach for co-thinking with universities and business

Governments (at least in Finland) are pushing universities to produce scientific knowledge which should be more usable for the society, particularly in economical way. On the other hand business is meeting a more and more complex world to find growth and options to increase the use of local labor markets. For both parties, business and academia, the key concept is interdisciplinary knowledge. There is, however, a clear dilemma: universities are not structured for interdisciplinary research, although they might be institutionally multidisciplinary. Or you cannot find in business too many mangers with interdisciplinary skills. It is most important to understand that multidisciplinary team as such does not mean that it will be capable of producing interdisciplinary knowledge. Skilled managers with interdisciplinary education and talent (and will) will be needed in both universities as wellas in the R&D teams of business firms.

In business this kind of integrating interdisciplinary skills have been used to acquire from management consultants. However, in most of the cases management consultants have not been so much linked to science, and almost never to academics. On the academia's side - due to academic commitments to Humboldian principles - consultants in this context have never been a resource for new way of enactment of scientific knowledge.

For understanding the gap between academic knowledge and business knowledge the author has developed the following model in which I compare the completeness of scientific knowledge in context of completeness of the knowledge for making social change (innovation impact). In this model the knowledge creators inside the university might be:

- A single researcher (with just a single disciplinary stand) and additionally enriched with complementary knowledge from other researcher or a complementary research team
- Multidisciplinary team with agenda specified internally in academia
- Multidisciplinary team with agenda specified co-creatively with academia and business
- Multidisciplinary school of Logistics with interdisciplinary research

The gap - here called as enactment knowledge - between the knowledge produced by universities and the business context where the knowledge will be used for successful operations, have been defined in this model as follows:

- Case applied knowledge
- Social change knowledge
- Business modelling knowledge
- Business actor's implementing knowledge

By this modelling and conceptualization one might see an option for a new kind of approach to tackle the existing obstacles between the business and academia: high interdisciplinary skilled independent teams for co-creating continuous think-tank processes and mutually specified agendas for industry specific analyzes and problems

Would you like to be a member of this progress?

Optimization in health care industry – Results and current practices from Finland and The Netherlands

Jarno Väisänen*

Cultural loans are common-place. We copy and mimic all the time. There is no way we should or could stop this. Sometimes loaning something from one place or time, a thing, an expression or an idea, seems like a stroke of genius. Sometimes, and I'm afraid more often than not, even the most good-willed introduction of a new tool or an organization leads to unwanted, even devastating result. The problem of course is, that there are no natural outlines ”out there” and that the whole context cannot be transferred.

A classic example of introduction gone wrong is the case of the Yir Yoront Aboriginals. Missionaries brought steel axes, which were of course much more efficient than those, handmade axes. As it was, making axes was a central tradition in maintaining the cultural structure. When the new and superior steel axes became available for everyone, meaning also to women and children, the cultural structure collapsed within weeks.

Another example, closer to home, is the introduction of team organizations to Finnish work places. Finland was (self-)titled as ”The Japan of the North” in the 1980's. It was deduced that because the idea of teams was the key to success in Japan, it should boost Finland's economy as well. What happened was that occupational wellbeing and workplace satisfaction dropped dramatically. Japanese culture is often described as collectivist whereas Finnish culture was in a strong individualization phase. Workplaces became the venues where the individuality was fought for and showcased.

Home care is, or so they claim in the Finnish media, in crisis. Not that long ago, it was the most desirable and politically viable solution for the problems of elderly care. What happened?

To meet the expansive demand, to increase efficiency, a model was loaned from industrial processes. Process means that events and performers are both so standardized that they are interchangeable. The idea behind this was the economy of scale. The bigger the unit is, the less there are underworked carers. The local home care areas and units would do work force planning based on the lowest demand of carers. The extra carers, when needed would be, ordered from a specific centralized resource pool. The underlying assumption was that any carer could tend any customer. Whatever information the carers needed was to be transmitted via mobile systems.

This model did not work. Or, more precisely, it will not work, even if many municipalities are stilling trying to implement this idea. The problem was not the single visits, but the combination of many visits when the service times, time windows and skill requirements had to be breached. With most of the current planning tool this was

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the situation all the time. The routes assigned to the carers were mathematically impossible to follow right from the start. The carers who were permanently assigned to specific team could handle these situations. They were not happy, but they knew the clients so they knew where and when to speed up, so they could handle all the visits without seriously dangerous situations or causing clients to suffer. The temps ordered from resource pool were just lost. They did not possess the local knowledge required to apply the planned routes. In both cases, however, the carers on the field were left alone to prioritize who gets service when and for how long time. Hence the sudden drop in occupational wellbeing.

The industrial process model and economy of scale do not work in home care. The good news is that they do not have to. Efficiency can be improved dramatically without them. The required increase in client time and number of clients can be achieved in surprisingly small units and team. I will show some case studies in my presentation. In fact, more amazingly, we have achieved all three; high efficiency, better client satisfaction and improved occupational wellbeing.

The results come both directly and indirectly. The direct results come from the R2-optimizing tool. The routes that it creates are realistic in all the relevant ways. They are based on care plans, the service times, time windows and skill requirements are the just as care managers see them fit. There is enough time reserved for preparation, break and task after the route, in the home base. There is plenty of time for transportation. Most importantly of all, the number of routes is calculated directly from the care plans, with optimal team structures, working hours and skill requirements.

The indirect results come from our maxim: ”the desired efficiency in the smallest possible unit.” When the carers really know the customers, the customers’ family, the colleagues and the area, the quality of the service improved. When there is no need for unfamiliar temps, the care quality is improved. When something unexpected and unplanned happens, all the carers know how the deal with the situation.

Mathematical, heuristic optimization has a key position in the home care. However, the tool needs to be very good and it must to be used in the correct way to fit the context. I will present case studies from Finland and The Netherlands.

Keywords: optimization, home care, resistance for change

Routing and scheduling of vessels to perform maintenance tasks at offshore wind farms

Lars Magnus Hvattum*, Nora Raknes, Katrine Odeskaug, and Magnus Staalhane

1 Introduction

Wind energy is among the fastest growing electricity generation systems in the world. The industry is driven offshore due to factors such as space limitations onshore. Operation and maintenance (O&M) costs accounts for up to a third of the total lifetime costs of an offshore wind turbine. A reduction of these costs is therefore crucial to achieve a competitive price in the market. Hence, the demand for effective scheduling of the maintenance activities increases.

This work considers a tactical multi-period problem, addressing the scheduling of maintenance tasks and routing of maintenance vessels for offshore wind farms. The problem is deterministic, with a planning period of a specified length, split into shorter time periods called shifts. There is one shift each day, i.e. no night shifts. Given a vessel fleet and a set of maintenance tasks, the tasks are assigned to different vessels in different shifts in the planning period. The schedules are generated to minimize the combined costs of transportation, downtime costs, and a penalty costs for tasks that are not performed.

The problem is based on the situation where two or more wind farms have a joint vessel fleet, but can also be used in the case of only one wind farm. All turbines within the same wind farm are assumed to be identical. Vessels operate from one depot, but can service all the associated wind farms. Travel times and travel costs within a wind farm are assumed to be negligible relative to the travel times and costs from the depot to the wind farms and between different wind farms.

The vessel fleet is given and heterogeneous, and consists of three different categories of vessels: AVs (accommodation vessels), and two types of CTVs (crew transfer vessels): SESes (surface effect ships) and regular CTVs. Within each category the vessels are assumed identical, but vessels of different categories may vary in speed, fuel consumption, capacities, onboard equipment, wave limits, and how often they need to return to the depot. Therefore all vessels may not be compatible with all maintenance tasks. Both AVs and CTVs can leave the depot at most one time during a shift. CTVs are required to return to the depot at the end of the shift, and they are not allowed to travel between wind farms. AVs travel between shifts (during the night), and can only travel once between each shift, either from the depot to a wind farm, from a wind farm to the depot or between two wind farms. They are required to return to the depot within a given

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number of shifts. They cannot leave the depot the same shift they return to the depot due to the time needed for preparations and loading of equipment and spare parts.

The problem is based on a periodic maintenance strategy. Both preventive and corrective maintenance tasks to be performed within the planning period are assumed known at the beginning of the period. The vessel that starts a maintenance task must complete the entire task, and it is not possible to pause the performing of a maintenance task before it is completed. It is assumed that all tasks require less time than the length of a shift, and it is not allowed to start a task that cannot be finished during the same shift. The different types of failures that can occur demand different vessels and equipment, and the time needed to perform the maintenance varies with the type of failure.

The weather has a significant impact on the scheduling of maintenance. The weather forecast for the current time period is known when planning the schedules. It is assumed that the weather does not deviate from the forecast. The energy production, and therefore also the downtime costs, varies with the wind speed. Additionally, the vessels have limitations on wave height, making the availability of the wind turbines and which vessels to use dependent on the weather. The periods when wave heights are low enough for a vessel to transfer technicians to the turbine and perform maintenance are defined as weather windows. A vessel can only leave the depot in a shift if its weather window during the shift is longer than a specified length. This weather window must be continuous, otherwise the weather is assumed to be too unstable.

2 Related literature

An overview of decision support models for O&M strategies for offshore wind farms is given by Hofmann in [6]. A majority of these models use simulation tools to analyze O&M related costs, and the use of optimization models for analyzing O&M costs are limited. Halvorsen-Weare et al. [5] and Gundergjerde et al. [4] use optimization models to investigate vessel fleets and determine the optimal fleet size and mix for an offshore wind farm. These models can be used as support in the decision-making of when and how many vessels to purchase or rent. They address decisions on a strategic level for O&M in offshore wind farms. Maintenance tasks are also scheduled to the accumulated number of vessels of the same type. This is used to decide the number of vessels of each type to acquire within an investment budget.

Dai et al. [2] present an optimization model for the routing and scheduling problem of a given vessel fleet of CTVs for O&M in an offshore wind farm. The model minimizes costs related to travelling to the respective turbines and delaying tasks. The time aspect of the model is a finite, short planning horizon discretized in shorter time steps (days). It allows for tasks being performed in parallel and include pick-up and delivery of personnel. A genetic algorithm to schedule maintenance tasks for both onshore and offshore wind farms is presented by Fonseca et al. [3]. Besnard et al. [1] present an opportunistic optimization model for offshore wind farms for scheduling of corrective and preventive maintenance tasks. Their model takes advantage of the possibility to perform preventive tasks when power production, hence downtime costs, are low, or when a turbine is shut down due to corrective maintenance. The objective of the model is an optimal planning of preventive and corrective maintenance tasks in regard to production forecasts and required corrective maintenance. The output of the model are daily schedules of corrective and preventive tasks for a short finite time period, divided in shorter time steps.

3 Method and results

We have formulated a mixed integer programming model for the problem described in the introduction. The model is implemented in Mosel and solved using the Xpress Optimizer. To reduce running times, symmetry-breaking constraints are added to the model and pre-processing of variables is performed before running Xpress. An instance generator producing realistic test instances has been implemented and used.

The results from a computational study conducted shows that the presented optimization model can provide optimal solutions to problems with as much as 160 turbines and seven shifts within a time limit of two hours computational time. This corresponds to a problem where more than 50 maintenance tasks must be scheduled and assigned to specific vessels. It was found that increasing the size of the wind farms, the number of maintenance tasks and the number of shifts in the planning period all increase the time required to solve the problem. The solution time is however not affected by increasing the number of wind farms, given that the number of turbines is kept constant.

The model developed can also be used to analyze the synergy effects of having a joint vessel fleet for two wind farms, and in this way can be used not only for tactical decisions, but also for strategic decisions. Further work includes extensions of the model, allowing maintenance tasks to be performed in parallel, allowing task durations larger than a shift, and allowing vessels to move between wind farms with less restrictions. We also intend to evaluate the model as a decision tool by embedding it in a simulation framework.

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Keywords: Routing, Maintenance, Scheduling, Wind energy

Managing and optimizing road transports and mobile work with LogiApps

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LogiApps is a cloud-based software system for managing and optimizing road transports and mobile work. It is especially well-suited for small and mid-sized transportation companies and mobile home care services. It has features for route optimization, dispatching and invoicing transportation tasks as well as a mobile application for the drivers or mobile workers and vehicle telematics for tracking and analysis.

This talk will cover key features of the system and our experiences in route optimization. By optimizing the routes we have achieved savings of 5-30 percent in the mileage and in some cases also reduction in number of required vehicles.

Keywords: route optimization, transport management systems

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Approximating non-linear blending optimization in supply chain networks

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Dynamic blend optimization is about making blending decisions in a time dependent environment where supply of raw materials (coal components here) and demand for end products (blended coals) arrive at known points in time. Furthermore, the quality (grade) of raw materials changes over time as materials are extracted from the mines. We propose a mixed-integer linear programming formulation (MILP) for this non-linear dynamic blend optimization (grade control) problem. The objectives are to minimize the deviation from target end product qualities and vessels arrival delay. An important goal of our study is to accurately model the changing quality of inventories using linear approximations. In addition we will use these approximate models to investigate the benefits that can be obtained by moving vessel arrival times, that is the times when material is removed from the stockpiles. The study is motivated by a real-life industry setting.

Keywords: Blending, Grade control, Shipment arrival, Coal shipping

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Improving the Estimation of Arrival Times along a Vehicle Route

Alexander Kleff*

Planning routes for vehicles is a key aspect in transport logistics. The underlying combinatorial optimization problem is widely studied, and yet there is one real-life issue that has attracted only little attention: break and rest rules of truck drivers.

The European Union as well as other countries impose restrictions on the maximum driving and working times before a minor break or a major rest is due. Furthermore, there may be additional agreements with the driver or even vehicle-related restrictions (e.g., for electric vehicles). We implemented an algorithm for finding the shortest possible schedule for a given vehicle route that inserts breaks and rests to comply with all of the constraints mentioned above. This sub-problem of the vehicle routing problem can get surprisingly involved as the number of potential schedules grows exponentially with the number of visited customers.

After route planning comes route execution, and both are becoming more and more entangled. While a route is being executed, new information on the driver's current status, traffic conditions, or even cancelled/added orders may come in and make a re-planning desirable or even necessary. But every re-planning is likely to change the computed arrival times. Services like the recently launched PTV Drive&Arrive inform all members of the supply chain about the newly estimated times of arrival (ETA).

State-of-the-art arrival time estimation uses all the data that is available on the market like historical time-of-day dependent speed patterns and information on road closures, road blocks, and traffic congestion. While all this leads to good ETAs for cars, we can do better when it comes to trucks. This is especially true when the truck drivers are obliged to maximum driving and working hours, as we have enhanced our break scheduling algorithm to cope with time-dependent driving times derived from the data at hand.

There are multiple ways to further improve the ETA. The app Truck Parking Europe has thousands of parking spaces across Europe in its growing data base. Without this data we can already compute the beginnings and ends of breaks. With this data we can also find optimal parking spaces and incorporate the necessary detour in the ETA.

This will further improve the ETA unless the parking space is fully occupied. Such uncertainties could ruin our estimation. So besides trying to consider more and more real-life aspects to make the ETA as precise as possible, it is important to make the estimation more robust. One possible mid-term goal is to calculate ETAs with the corresponding probabilities. Luckily, the app could help here as it collects data on occupancy of parking spaces. Furthermore, with the help of data available to PTV Drive&Arrive

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we could also tune parameters for calculating service times at customers, driving times and even actual break times.

Keywords: time-dependent, truck driver scheduling, arrival time estimation

Design and Operation of Multiscale Modelling Platform

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The reliable multiscale/multiphysics numerical modeling requires including all relevant physical phenomena along the process chain and across multiple scales, requiring the combination of knowledge from multiple fields. The development of a new multiphysics tool for a particular problem would be extremely time and resource consuming. A more viable approach lies in combining existing, usually single-physics tools, to build a customized multiphysics simulation chain for a particular problem. The most important advantage of this modular approach stays in reusing of existing tools. In order to achieve a full potential of such a modular approach, an integration framework is needed to provide underlying infrastructure that enables to facilitate data exchange and integrate/steer individual applications.

The approach followed in this contribution is based on a application of object-oriented approach, consisting in designing a system of interacting objects for the purpose of solving given software problem. The proposed abstract classes are designed to represent the entities in a model space, including, for example, simulation tools, fields, discretizations, properties, etc. The purpose of these abstract classes is to define a common interface that needs to be implemented by any derived class. Such interface concept allows using any derived class on a very abstract level, using common interface for services, without being concerned with the implementation details of an individual components. The main feature is that individual applications as well as simulation data are represented by abstract classes. Therefore, the focus is on services provided by objects (object interfaces) and not on underlying data itself, leading to independence on particular data format(s).

Complex simulations are extremely resource and time demanding. Distributed and parallel computing environments provide needed resources and computational power. Common feature of these environments is a distributed data structure and concurrent processing on distributed processing nodes. This brings in an additional level of complexity that needs to be addressed in a platform design. The important role of the presented framework is providing a communication mechanism that will take care of the network communication between the objects.

The communication layer is based on transparent distributed object system fully integrated into Python. It takes care of the network communication between the objects when they are distributed over different machines on the network, hiding all socket programming details. One just calls a method on a remote object as if it were a local object

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– the use of remote objects is (almost) transparent. This is achieved by the introduction of so-called proxies, a special kind of object that acts as if it were the actual object, forwarding the calls to the remote objects, and pass the results back to the calling code. An important feature, particularly for the end user, is transparency, hiding the details of remote communication to the user and allowing to manage local and remote objects using the same interface.

The application of developed tool will be illustrated on practical engineering problem. The adopted approach will be compared to other existing solutions. The performance of the platform will be evaluated.

Keywords: operation, multiscale, platform, multiphysics

Computational Methods for the Stochastic Equilibrium Stable Dynamic Model

Yuriy Dorn*, Alexander Gasnikov, Yuriy Maximov, and Yuriy Nesterov

Abstract In this work we propose a new stochastic version of the Stable Dynamic model. The problem of finding the equilibrium in this model leads to huge-scale convex optimization problem with a specific structure. We prove that the coordinate descent algorithm is very efficient for solving this problem.

1 Stochastic Stable Dynamic model

1.1 Stable Dynamic model

Let $\Gamma(V,E)$ be a weighted oriented graph. Here V is the set of nodes, E is the set of arcs. The $\{d_{ij}\}$ is known origin-destination matrix (OD-matrix). The pair $(\Gamma(V,E),\{d_{ij}\})$ is called an instance. Each arc e is decribed by two parameters: free flow travel time $\bar{\tau}_e$ and arc capacity $\bar{f}_e$. Denote by P_{st} the set of all paths from node s to node t. Let $C_q(\tau) := \sum_{e\in E} \tau_e \delta_{eq}$ be the cost of a path q if the vector of costs on arcs is τ. Here δ_{eq} is equal to 1 if $e \in q$ and 0 otherwise.

At any equilibrium (f^*,τ^*) the Wardrop's equilibrium condition holds and the following conditions are satisfied:

- $\tau_e^* = \bar{\tau}_e$, if $f_e^* < \bar{f}_e$,
- $\tau_e^* \geq \bar{\tau}_e$, if $f_e^* = \bar{f}_e$.

Denote by $T_{ij}(\tau) = \min_{q\in P_{st}} C_q(\tau)$ the cost on the shortest path for the OD-pair (i,j). The standard way to analyse any instance is to compute equilibrium flow [5]. A standard way to solve this problem is to reduce equilibrium computing to optimization problem of potential function (see, for example, [1]). Then the equilibrium in the Stable Dynamic model can be computed as a solution of the following optimization problem:

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$$\sum_{(i,j)} d_{ij} T_{ij}(\tau) - - \sum_{e \in E} \bar{f}_e(\tau_e - - \bar{\tau}_e) \to \max_{\tau} \tag{1}$$
$$s.t. \quad \tau \geq \bar{\tau}$$

But the pure equilibrium approach is based on the assumption of full rationality of all agents (drivers). This assumption means that any economic agent (driver) have full knowledge of the payoff function (costs on every path). This assumption is quite tough. Usually the full rationality assumption is replaced by the bounded rationality assumption. The bounded rationality assumption implies that the agents estimate their payoffs with errors.

1.2 Stochastic version of the Stable Dynamic model

From the mathematical programming point of view the bounded rationality assumption often leads to the smoothing of the potential function.

We can model the errors into two ways. First, agents estimate shortest path cost with stochastic error. Second, agents estimate costs of arcs with errors.

First approach leads to the following optimization problem [3]:

$$\sum_{i \in S,} \sum_{j \in V} \mu \cdot d_{ij} \cdot \ln\left(\frac{1}{|P_{ij}|} \sum_{q \in P_{ij}} \exp\left(\frac{-C_q(\tau)}{\mu}\right)\right) + \sum_{e \in E} \bar{f}_e(\tau_e - \bar{\tau}_e) \to \min_{\tau} \tag{2}$$
$$s.t. \quad \tau \geq \bar{\tau}$$

In this work we show, that the second approach leads to the smoothed version of the Stable Dynamic model:

$$\Psi(T) = \sum_{(i,j) \in E} \bar{f}_{ij} \cdot \mu \ln\left(\frac{1}{|S|+1}\left(\sum_s \exp(\frac{T_{sj} - T_{si} - \bar{\tau}_{ij}}{\mu}) + 1\right)\right)$$
$$- - \sum_{\substack{s \in S, \\ i \in V}} d_{si} \cdot (T_{si} - - T_{ss}) \to \min_{T} \tag{3}$$

Here S is the set of the origin nodes for an inctance $(\Gamma(V,E), \{d_{ij}\})$, and T_{si}, where $s \in S$ and $i \in V$ are new variables, which represent shortest path cost for OD-pair (s,i).

In both models parameter μ determines how rational the agents are [6]. From the optimization point of view μ is the smoothing parameter (see, for example, [2]).

Problem (2) and problem (3) both are convex with smooth objective function. These problems have nice structure and allow to use optimization technique for huge-scale convex optimization problems.

2 Computational techniques for the stochastic equilibrium problems

2.1 Coodinate descent method for huge-scale convex optimization problems

Problem (3) has $|V| \cdot |S|$ variables as an argument. In real life problems $|V| \cdot |S| \sim 10^8$. In [4] it is shown that the coordinate descent algorithm is effective for huge-scale convex optimization problems with the structure similar to (2) and (3).

Denote by L_{si} the Lipschitz constant for $\Psi_{si}(T)$ and denote by U_{si} the vector from R^m with all components exept *si* equal to zero, and *si* component is equal to 1.

The following algorithm is proposed to solve this problem.

1. Take $T^0 := 0$.
2. For $k \geq 0$ do
   a. Compute $\nabla\Psi(T^k)$;
   b. Check stopping criteria, return if it is satisfied;
   c. Choose $(s,i) := \arg\max|\nabla\Psi_{si}(T^k)|$;
   d. Compute T^{k+1}

$$T^{k+1} = T^k - -U_{si}\frac{|\nabla\Psi_{si}(T^k)|}{L_{si}}. \tag{4}$$

We show that due to the special structure of the problem (3) we can compute $\Psi(T)$ in effectively, so that each iteration of this method is extreamly cheap.

To achieve the solution of the problem with absolute accuracy *e* the algorithm requires

$$O\left(\frac{R^2 \cdot P}{\varepsilon}\right)$$

iterations. Here $R = \|T^0 - -T^*\|_1$ and $P = \max_{si} L_{si}$. From [2] we know that $P \sim O(\frac{1}{\mu})$.

Note, that

$$\nabla\Psi_{si}(T) = \sum_{(ji)\in E}\frac{\bar{f}_{ji}\sum_s e^{\frac{1}{\mu}(T_{si}-\bar{\tau}_{ji}-T_{sj})}}{1+\sum_s e^{\frac{1}{\mu}(T_{si}+\bar{\tau}_{ji}-T_{sj})}} - -\sum_{(ij)\in E}\frac{\bar{f}_{ij}\sum_s e^{\frac{1}{\mu}(T_{sj}-\bar{\tau}_{ij}-T_{si})}}{1+\sum_s e^{\frac{1}{\mu}(T_{sj}-\bar{\tau}_{ij}-T_{si})}} + W_{si}(d)$$

Here $W_{si}(d)$ is a linear function from demands.

Hence a change in one component of T, say T_{si}, changes no more then $|S| \cdot C_i$ components of $\nabla\Psi(T)$. Here $C_i = \{\sharp j : (i,j) \in E \text{ or } (j,i) \in E\}$. Let $C := \max_i C_i$. But then we can rearrange components of the gradient $\nabla\Psi(T^{k+1})$ in $O(C \cdot |S| \cdot \ln(n \cdot |S|))$.

The overall complexity of the method is

$$O\left(\frac{R^2 \cdot C \cdot |S| \cdot P \cdot \ln(n \cdot |S|)}{\varepsilon}\right)$$

2.2 Computation of the dual solution

The dual solution of the problem (1) corresponds to the equilibrium flow. On the other hand, the dual solution of the problem (3) corresponds to the gap between incoming and outcoming flow for every node (at the equilibrium the gap equals to zero) and represents violation from balance constraint.

In our work we show that one can compute the stochastic equilibrium flow corresponds to the solution of (3) explicitly:

$$f_{ij}(T^*) = \frac{\bar{f}_{ij} \sum_{s \in S} e^{\frac{1}{\mu}(T^*_{sj} - \bar{\tau}_{ij} - T^*_{si})}}{1 + \sum_{s \in S} e^{\frac{1}{\mu}(T^*_{sj} - \bar{\tau}_{ij} - T^*_{si})}},$$

where f_{ji} is a flow from j to i, and T^* is the solution of (3).

Same holds for arc cost:

$$\tau_{ij}(T^*) = \max_{s \in S}(T^*_{sj} - -T^*_{si}, \bar{\tau}_{ij})$$

3 Conclusion

In this work we propose a new stochastic version of the Stable Dynamic model (3).

We propose to use the coordinate descent method and proof that in our setup this method has very cheap iterations.

Finally we provide a method to restore the equilibrium flow and cost from the solution of optimization problem (3).

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Keywords: Optimization methods, Equilibrium modeling

Stochastic fracture analysis of a moving paper web

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There are many systems in industry in which material moves unsupportedly between two rollers under a longitudinal edge tension. Such an open draw can be found, e.g., in band saws, power transmission belts, printing presses and manufacturing of different kinds of materials, e.g. textiles, plastic films, aluminium foils and paper. Such systems are sensitive to runnability problems in open draws. Runnability problems lead to unnecessary use of resources and thus, the behaviour of a material travelling in an open draw has gained interest in research.

In printing presses, the major runnability problems include register errors, wrinkling and the instability of the paper web, and web breaks [1]. Especially, reducing the number of web breaks is a major concern in the print industry. Consequently, many studies have focused on finding what causes web breaks. In printing presses, the tensile loading varies temporally, and also material properties have random fluctuations. The concept that has begun to be accepted in the industry is that a web break is a combined probabilistic event of high tension and low strength [2]. The lowest values of tensile strength may be caused by defects. Even though paper is seemingly flawless, it can still fail at very low tensions due to stress concentrations caused by discontinuities in structure, such as cuts and shives [3].

This study considers the probability of fracture when a cracked paper web travels in an open draw. The paper web is modelled as a moving elastic and isotropic plate, subjected to homogeneous tension acting in the travelling direction. Temporal variations of tension are described by the Langevin (Ornstein-Uhlenbeck) equation. Cracks are assumed to occur in the longitudinal direction of the paper web according to a stochastic counting process. Considering the probability of fracture leads to first passage time problems. In solving them, explicit representations of the first passage time density of an Ornstein-Uhlenbeck process to a constant boundary [4] as well as Monte Carlo simulation can be exploited.

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Keywords: Fracture, random fluctuations, moving paper web

Day 3 - Wednesday May 27, 2015

How TNT Express saved more than 200 million in four years time by using Business Analytics

Hein Fleuren*

TNT is one of the world's leading express delivery companies. The introduction of operations research (O.R.) at TNT during the past ten years has significantly improved decision-making quality and resulted in millions of Euros in cost savings. The Global Optimization Program (GO) initiative has led to the development of an entire suite of optimization solutions and the GO Academy, TNT's management development program for teaching the optimization principles. The tools and available knowledge allow operating units to analyze performance, identify optimization opportunities and overcome operational challenges. To date, the most significant savings originate from the network routing and scheduling solution (TRANS) and the supply chain solution (DELTA Supply Chain). As a result of all these initiatives, O.R. is now an effective part of TNT Express' DNA, and over the period 2008-2011, more than 207 million in savings were realized and 283 million kg of CO_2 were saved.

Keywords: supply chain optimisation, operations research, Application

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Changing Finnish Rail Market

Kimmo Rahkamo*

The Finnish rail market has been dominated by the Finnish State Railways (VR) for the existence of the rail network since 1862. Some steps have been implemented to enable competition, such as the incorporation of VR and separating the regulator and infra management roles from VR. Also from legislative point of view the rail freight market has been opened to competition already in 2007.

Despite the market being open for competition, no competing companies have started their operations yet. At the same time in most other European countries new rail companies have emerged to complement the commercial offering of the incumbent operators. Why Finland is lagging behind?

The Finnish rail system differs from all other rail systems due to its rail gauge and other technical requirements. Therefore acquiring rolling stock to Finland is much more complicated, more costly and more time consuming than to other markets. Also market being smaller than many other markets does not really help newcomers to start their operations.

Fennia Rail will be the first commercial contender in the Finnish rail freight market. It will start its operations in the second half of 2015 using three diesel-electric locomotives. How will that reshape the market?

Being a privately held company Fennia Rail needs to focus on competitiveness and profitability in its operations. The only way to achieve these targets is to add value in its customers' processes. In practice, Fennia Rail's offering needs to be different from the incumbent's offering.

With a lean corporate structure Fennia Rail can profitably operate routes, which are no longer interesting to VR. This in turn will increase the total volumes transported by rail. As a consequence congestion on roads, road accidents and air pollution will be reduced.

Most importantly, the logistic costs of Fennia Rail's customers will be reduced and their ability to meet their competition will be improved. This will have a positive impact on the Finnish heavy industry, which bears a significant portion of the Finnish national economy.

Although the domestic rail freight market has been deregulated, the cross-border freight market to and from Russia still remains VR's exclusivity. Also, VR will continue to enjoy a monopoly status on passenger market until at least 2024.

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Digital Supply Chains

Kyösti Orre*

The aim of the project is to develop a digital and mobile cloud service tool for SMEs supply chain management. The service will provide companies with a tool to digitalise their order handling, delivery, labelling, dispatch advice and customer invoicing. The service will also serve as a traceability tool and an industrial internet platform. It offers different parts of the supply chain with up to date quality data and increased advance planning and tracking capabilities. This will improve resource efficiency by reducing material waste along the way, in addition to increasing supply chain efficiency. The service aims to reduce material and product waste as well as minimise energy consumption.

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Round Table: Role of Information and Big Data

Heikki Lahtinen*

There is an immense – and explosively increasing – amount of information available for managerial decision making. Punctual logistics activities have been based on accurate information, but now we have a wide range of additional opportunities to create new innovative solutions and more value for our customers. However, there are a number of barriers to utilize Big Data in decision making, and we have to clarify the effectiveness and efficiency of collecting and analyzing data, and how to link new solutions into daily business practices.

- How do we assess the cost of usability?
- Who controls and owns the flow of data?
- Will the value creation shift away from logistics companies to ICT service providers?
- What are the limits of the digitalization of logistics?
- Is this trend for or against SMEs?
- How to start to utilize Big Data?

Panelists:

- H. Kulmala
- O. Bräysy
- M. Rönnqvist
- V. Hara

Heikki Lahtinen
Limowa

* Chairman

Digitalisation will democratise innovations in industry

Harri Kulmala*

The democratisation of innovations due to the new digital tools is strongly related to the lowered barrier of participation. The more and easier participation tools we have available e.g. via Internet, the more we have people, who can and are willing to participate. This brain power will be used, it is the technology imperative. Open innovation, crowd sourcing, and big data analysis tools outperform already in some cases the traditional corporate R&D. Democratisation means more possibilities to more people than before. It does not mean equal share of outcomes or money, but it means less privileged minorities, who can limit the participation opportunities of others.

Keywords: Digitalization

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Challenges of the Order - Replenishment Process in Supply Chain a special case - picking without pick orders

Juha Särelä *

How to improve the effectiveness in the supply chain?

- Pick System in the key role:
  - sensors and scales integrated to Pick to Light (PTL) and combined with WMS software
  - correct real time information through the chain
- Delivery terminals integrated to the same system (PTL)
  - Effective material flow possible also for small volumes

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Towards more efficient logistics by using computational technology and intelligent information systems

Teemu Mustonen*

Logistic processes have become more and more complex and challenging during the past few years. Modern logistic operators are facing many challenges trying to find more efficient and cost effective ways for managing logistic operations with always higher customer demands in service level. Although it has been clearly proved that by using modern information systems and optimization methods the operators can achieve many advantages, it is not without a doubt that all information system implementation projects will end happily.

Since 2000 Ecomond Ltd. has been developing and successfully implementing intelligent information systems in many different logistic fields from Services to Logistics. Although computational technology and optimization methods have played a very important role in the Ecomond products there are also many challenges that have to be overcome in order to have success in the implementation project. In this paper we introduce these challenges by case study of logistic systems in forest biomass supply chain.

Keywords: optimization, logistics, information systems

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Using a dynamic system model in ex-ante operational and profitability analysis of a metal mine through simulation

Jyrki Savolainen, Mikael Collan*, and Pasi Luukka

Abstract

This paper presents a general system dynamic (SD) model of a metal mine that is usable in ex-ante operational and profitability analysis. We show how the model can be used to analyse mutually dependent operational flexibilities (real options) and the effect of leverage on the profitability and the operational strategy of a mining investment under different market scenarios. The model is able to capture the dynamic interaction between real options, a topic whose importance is acknowledged, but seldom adequately considered in analyses. A numerical simulation example is used to illustrate the usability of the model and to show how under different states of the world the profitability and the optimal operational strategy of a Nickel mine project change. The results are presented as histogram pay-off distributions for the project.

1 Introduction

Mining investments are large industrial investments that require large investments that operate in uncertain markets. The profitability of metal mining investments is closely linked to the price-development of the metals produced during the economic-life of the mine [10], metal prices are cyclical and there may be large differences in mine profitability between the different stages of cycles. Dependence of mine profitability to market prices is accentuated for "high cost" projects with low grade ore. Efficient use of operational flexibilities (real options) within the projects and the proper selection of the capital structure are important in profitably managing high cost mines.

In this paper we present a general dynamic system model for metal mining projects that consists of four sub-models. The type of uncertainty we face is assumed to be parametric [5],[2]. Dynamic system models are a way to capture the requisite variety [6] of industrial investments and to consider how the profitability of these investments is generated as a result of the interactions of a complex system. Previously system models have been used in framing mining investments in, e.g., [7],[8],[4]. To the best of our knowledge, there are only very few instances of using systemic models in the analysis of mining investment profitability, e.g., see [3]. We use the systemic model to analyse the profitability of the investment by running simulations with altogether 28 configura-

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tions that compose of seven different real option combinations, two capital structures (debt-levels), and two states-of-the-world (high and low metal price states). Each real option combination is in essence an operation strategy for the mining investment, each simulation will "run" the dynamic systemic model and exercise (use) the available real options according to the "firing rules" and also capture the interaction between the real options.

As the outcome of the simulations we will obtain information about the profitability of each configuration in the form of a histogram of the simulation outputs (NPV) and will be able to draw conclusions about which operation strategies may be useful in different market situations. Furthermore, we gain information about the effect of leverage on the profitability of the investment in the different states of the world.

This paper continues with a short presentation of the systemic model. Section three goes through the numerical example by first presenting the case, then presents the simulation procedure, and then presents and discusses the results. The paper is closed with a discussion and some conclusions.

2 Systemic model

The presented model is a techno-economic system model, built with the Matlab^{TM} software. The model is based on a real world metal mining investment and it composes of four sub-models. The sub-models are interconnected and their mutual parameters are inputted into a common Matlab^{TM} workspace, allowing the formation of feedback loops between input variables and the resulting calculated values. This allows the treatment and the analysis of various decision-making aspects in a single dynamic environment. The model reduces the need of separate spreadsheet calculations for different aspects of capital budgeting and there is no additional work needed in putting together a comprehensive view of the overall feasibility of an investment. A blueprint of the overall model structure is visible in Figure 1.

The four sub-models describe the technical mining or ”production calculation” system, the ”cash-flow calculation” and management system, the financing side or ”balance sheet” system of the investment, and the investment ”valuation” or analysis system (names of the sub-models in quotation marks). The ”production calculation” model includes modules that calculate the fixed and variable costs of operating the investment, the operation status of the investment (on / off), the revenue generation from running operations as a function of world market prices of metals mined (MR-models) and foreign exchange rates (assumed to be fixed). The ”cash-flow calculation” model houses modules that feed into the liquidity position calculation of the investment, including the cash-flow coming from sales revenues, the cost-side out payments, the costs of financing that are connected to the prevalent interest rates, loan pay-back schedules, and the initial investments & working capital. The ”balance sheet” model keeps check of the overall balance of the investment project financing and includes the loan balances, the credit limits, the total debt-level, and the burn-rate. The ”valuation” model keeps track of the mining investment ”market value” as a function of time and includes, in addition to the inputs from ”production calculation” and ”cash-flow calculation”, modules for considering the balance of the remaining reserves and for handling the discount rate used in

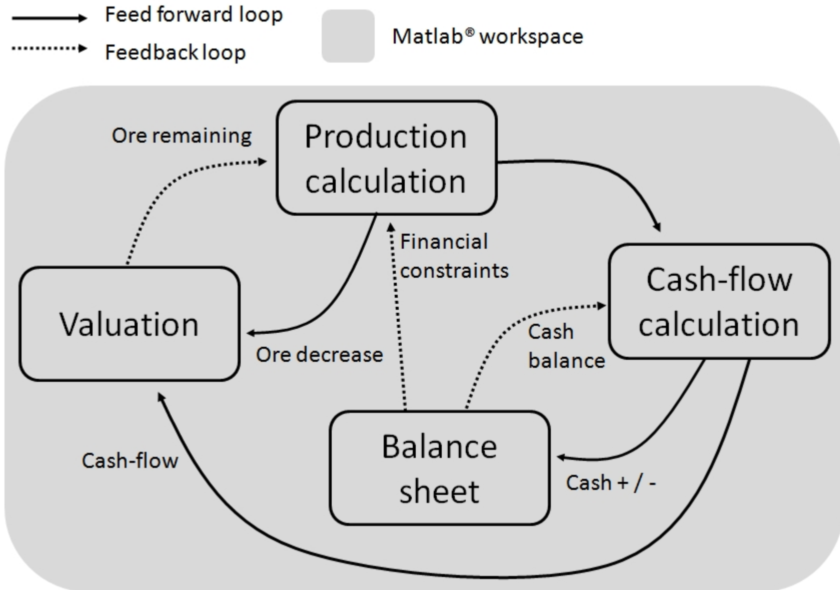

Fig. 1 Blueprint of system model

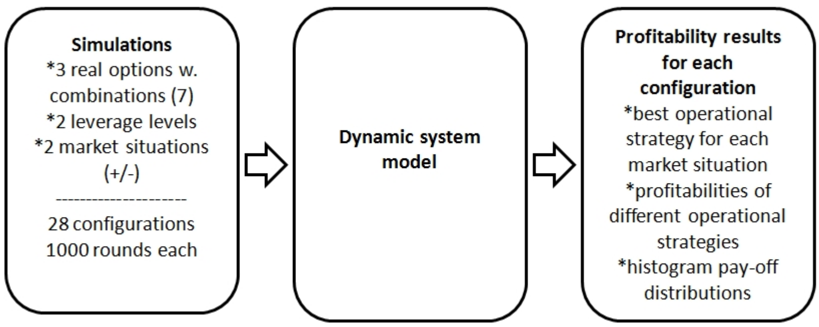

Fig. 2 Design of the simulation example

the profitability analysis. The financial conditions related to real options are given in the valuation model. The valuation of the investment in the base model set-up is done by using a typical net present value (NPV) calculation. The model operates in discrete time with a one month time-step. Monetary units are in millions (*euro*). In the analysis case, the production rate is either fixed or variable, according to the decision making rules connected to the available real options.

3 Case: simulation analysis of a high-cost metal mine

This section will describe the simulation and the obtained results. The simulation "agenda" is illustrated in Figure 2.

4 Discussion and Conclusions

This section will discuss the findings, draw some conclusions, and discuss possible avenues for future research.

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Keywords: metal mining, system modeling, system dynamics, profitability analysis, real options, production optimization

Automating the Vehicle Routing System Customization for Faster Deployment

Jussi Rasku*, Tuukka Puranen, Antoine Kalmbach, and Tommi Kärkkäinen

1 Introduction

Savings up to 30 percent in operational costs, reduced planning time, and exclusion of human error, are often listed as advantages of Vehicle Routing Systems (VRS) [13]. It is therefore unsurprising that logistics operators, who struggle under high demands for efficiency, customer service expectations, timeliness, reactivity, and cost savings [5], are showing interest to deploy such systems.

Although academic Vehicle Routing Problem (VRP) research has provided efficient algorithms for these problems, they typically use idealized models. [5] This has led to the research field having a somewhat questionable reputation of overpromising, yet under-delivering. Partyka and Hall [10] hint that the same might be true also with commercial providers.

In addition to challenges due to idealized models, different operators have differing requirements. It is not commercially viable to build a new VRS each time [13]. Instead, VRSs are designed to be customizable. The customization of commercial VRSs is done manually [10, 7], which forms practical obstacles that prevents the recent innovative advances from being disseminated to wide use.

In this paper, we address the issue of laborious manual customization by providing an deployment automation framework, and a do review on the suitable automation methods for different phases of the routing process. The framework should be of interest not only to VRP researchers, but also to providers and users of VRSs.

2 Trends in Vehicle Routing Problem Research

Over 50 years of academic interest in VRPs has experienced many shifts of research focus. The trends of VRP research, as illustrated in Figure 1, were recently described, e.g. by Puranen [11].

The research has progressed from the **idealized** to **"rich"** models that try to capture complex decisions, constraints, and objectives of the problem. Recently, there have been efforts to develop **unified** modeling approaches that can capture the aspects of different VRP variants.

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models: idealized ⟶ rich ⟶ unified ⟶ inferred

methods: simple ⟶ refined ⟶ adaptive ⟶ learning

Fig. 1 Trends in vehicle routing research.

The solution methodologies have followed a similar trend. The first methods relied on **simple** heuristics or on mathematical programming. The growing problem size and model complexity led to interest in more **refined** methods. However, due to scale of the real-life problems, exact solution methods cannot usually be used. Thus, a number of metaheuristics have been proposed. Recently, there has been interest in **adaptive** and self-adjusting methods. This continues as a trend of applying **learning** hyperheuristic systems that are capable of enabling and disabling different algorithms depending on the observed search space.

3 Design of a Vehicle Routing System

The main responsibilities of a VRS is to obtain data from necessary sources, construct and visualize the routing scenario, and algorithmically provide a plan that conforms to the operational rules such as product loading order, compatibilities and work time regulations.

Of particular interest is the *data flow* through such system, that is, in which form the problem instance is passed from system module to another. The flow of information is one of the main aspects affecting the deployment, integration, and utilization of the system in practice.

The data flow can be divided into phases as illustrated in Figure 2. First, the data is read from a data storage and then written into a domain model (1). The domain model is then translated into optimization model (2). This involves describing the decision variables, the objective function, and the necessary constraints. The result is the mathematical model of the problem, which can be then fed to the algorithms residing in the solver module (3). It is also needed to derive a set of parameter values for algorithms (4). After the optimization (5), the results can be transformed to the primitives of the domain model (6) which in turn is translated into an actionable plan (7).

Each of the aforementioned phases exposes a potential point of customization. We suggest the usage of machine-learning based adaptive mass customization techniques for automating the customization task, and argue that these represent one of the keys for achieving cost-effective routing system deployment.

4 Vision of an Automated Routing System

Our main contribution is an outline, or a vision, of how a highly automated VRS could be constructed. We concentrate on the high level techniques we have either successfully applied, or see as pragmatic solutions to the presented opportunities for automation.

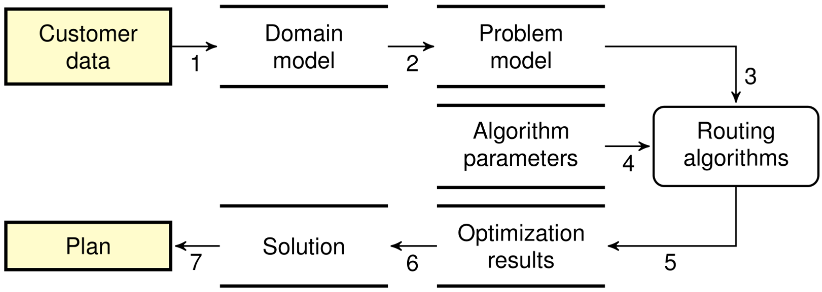

Fig. 2 Data flow trough a VRS.

Interpreting the customer data (1) and transforming it into routing problem starts with the creation of a domain model, which offers primitives for concepts such as truck, driver, and request. The transformation task consists of taking the problem data as input and then extracting the data into the domain model.

A likely scenario for data integration input is a relational dataset, such as relational database, but in general, any kind of flat dataset with interconnected files, or relations, can be used. Finding semantic links between the relations in these datasets is what we call *join inference*, which in turn is based on previous work in foreign key discovery [12]. After join inference we propose the use of schema mapping [2] to extract the required information from the data and find pairings between two schemas. Having to find these attribute pairings makes the problem a kind of *data exchange problem* [8], where the goal is to take data from different sources and assimilate it, in this context, to the domain model of a VRS.

The domain model then has to be **translated into a format understood by the VRP solver (2)** This includes selection of an optimization model. We propose experimenting with four different approaches in implementing such an automated transformation: *Separate models*, *Coupled models*, *Model composition*, and *Model reduction*. The result is a optimization model that matches the domain model and the customer data, thereby capable of expressing the relevant vehicle routing problem. We note that the feasibility of applying automation to this phase is uncertain, mostly because of the lack of (even loosely related) prior art.

A known way to improve solver performance on a large set of benchmark problems is the utilization of *hyperheuristics*, which is a high level learning “supervisor” algorithm that ***selects and combines*** **lower level algorithms from a portfolio (3)**. Similar ideas have been tried in VRP e.g. by Walker et al. [14] and Garrido and Riff [4]. This scheme could be especially useful when adapting an industrial VRS to a new set of customer provided sample problem instances.

The settings of the algorithm parameters have a substantial effect on the performance of the algorithm. [6] Doing this automatically is known as the problem of ***automated algorithm configuration*** **(4).** It can be divided into *parameter tuning* that involves finding good parameters values before the deployment of the algorithm and *parameter control* where the values of parameters are reactively changed during the optimization run.

In practice, parameter tuning can be used to automatically adapt the a routing solver specifically for each VRS deployment. In fact, Becker et al. [1] have reported tuning of the parameters of a commercial VRP solver with real-world routing problem instances.

The **solver module is responsible of performing the optimization (5)**, which comprises of the tasks of coordinating the mapping of tasks to vehicles as well as routing the vehicles as efficiently as possible according to the objective function.

In our solution the optimization services are available through cloud services. This opens a new dimension in the customization, namely the allocated computing time and priority based on the customer requirements, service level agreements, and instance characteristics.

The interpretation of the optimization results (6) has a direct connection to the construction of the optimization model, as in this phase the values of the decision variables need to be interpreted in the relations and values of the entities in the domain model. In practice, we can use the inverse of the domain model to optimization model transformation to decode the solution.

Finally, an automated VRS could **adapt its own output to the format most convenient to the end user (7)**. If the database of the system includes example plans, a possible method is to reverse the schema mapping procedure. This method would compose a output format that looks like the example plans. Another option is to infer the structure of a source document using methods such as table extraction, visual object and information extraction, and entity identification [9]. The product of the document object recognition would be a template with the customer company letterhead that can be then filled with the relevant data of a new plan produced by the VRS.

5 Conclusions and Outlook

Vehicle routing systems provide several advantages over manual transportation planning, but the deployment of these systems is in many cases prohibitively costly. In this paper, we outlined a framework of the strategies for the automation of the customization and deployment process.

Concurrently, logistics operators have begun to see the information as a vital asset that can be used in decision making. This opens new possibilities for machine learning where accuracy is often dependent of the amount and availability of data that can be used to train the models.

Taken together, we argue that in order to bring the latest academic routing knowledge to the hands of logistics operators in a massive scale, techniques such as those presented in this paper are needed. Further experimental work is required to establish whether the proposed techniques are fully applicable to practice. However, the preliminary results are promising. We have recently experimented with parameter tuning and automated data integration and will next concentrate our research efforts on developing a algorithm selection for rich VRPs. In general, this area requires extensive further studies in several disciplines, but should provide a promising area of research with a potential for a very wide array of practical benefits.

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Keywords: data exchange, software mass customization, vehicle routing, automatic algorithm configuration

A Comparison of NSGA II and MOSA for Solving Multi-depots Time-dependent Vehicle Routing Problem with Heterogeneous Fleet

Arian Razmi Farooji*

Time-dependent Vehicle Routing Problem is one of the most applicable but least-studied variants of routing and scheduling problems. In this paper, a novel mathematical formulation of time-dependent vehicle routing problems with heterogeneous fleet, hard time widows and multiple depots, is proposed. To deal with the traffic congestions, we also considered that the vehicles are not forced to come back to the depots, from which they were departed. In order to solve our bi-objective formulation, we presented two well-known Meta-heuristic algorithms, namely NSGA II and MOSA and compared their performance based on a set of randomly generated test problems. The results confirm that our MILP model is valid and both NSGA II and MOSA work properly. While NSGA II finds closer solutions to the true Pareto front, MOSA finds evenly- distributed solutions which allows the algorithm to search the space more diversely.

Keywords: Bi-objective optimization, Time-dependent Vehicle Routing Problem, Meta-heuristics

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Transport Equations in the Continuum Modelling and Analysis of Travelling Bodies

Juha Jeronen*, Nikolay Banichuk, and Tero Tuovinen

1 Introduction

Solid materials experiencing high-speed axial motion are often encountered in process industry applications. Modelling their physical behaviour leads to transport equations, which are principally the same as those for the behaviour of the track under a train, as the observer sits on the train and considers how the track (which is undergoing axial motion relative to the train) vibrates. A theoretical concept shared by these application areas is the *axially moving material*. Whether it is the track under a train (observed with respect to the train) or a paper web travelling through the machine at a paper factory (observed with respect to the factory floor), the material of interest (respectively the train track, or the paper web) is in relative motion with respect to the boundaries of the domain of interest (respectively the train, or a free span in a paper machine).

Let us consider a solid moving in the $+x$ direction and undergoing some deformation such as torsional, longitudinal and/or transverse vibrations. Let us also consider that the object can be modelled as a one-dimensional continuum travelling at a constant transport velocity V_0, and take a state variable $U = U(x,t)$ as a measure of deformations. Let $\tilde{x}$ denote the material coordinate. We will set up the problem for the moving continuum using the Euler (laboratory, stationary) coordinate system (x,t) and the material derivative (also known as the Lagrange derivative or the total derivative). Note that between the material and laboratory coordinate systems there is a relation $x = x(\tilde{x},t)$. We have

$$x = \tilde{x} + V_0 t \;, \qquad \frac{\partial U\,(x(\tilde{x},t))}{\partial \tilde{x}} = \frac{\partial U}{\partial x} \;, \qquad \frac{\mathrm{d}U}{\mathrm{d}t} \equiv \left(\frac{\partial U}{\partial t}\right)_{x=\text{const.}} + V_0 \frac{\partial U}{\partial x} \;, \tag{1}$$

$$\frac{\mathrm{d}^2 U}{\mathrm{d}t^2} \equiv \left(\frac{\partial}{\partial t} + V_0 \frac{\partial}{\partial x}\right)\left(\frac{\partial U}{\partial t} + V_0 \frac{\partial U}{\partial x}\right) = \frac{\partial^2 U}{\partial t^2} + 2V_0 \frac{\partial^2 U}{\partial x \partial t} + V_0^2 \frac{\partial^2 U}{\partial x^2} \;. \tag{2}$$

Using Newton's second law (or d'Alembert's principle) and the relations (1)–(2), we model the movements of an axially travelling elastic continuum as

$$\frac{\partial^2 U}{\partial t^2} + 2V_0 \frac{\partial^2 U}{\partial x \partial t} + V_0^2 \frac{\partial^2 U}{\partial x^2} + \mathscr{L} U = 0 \,, \tag{3}$$

where $\mathscr{L}(\cdot)$ is a problem-specific differential or integro-differential operator.

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2 Continuum equations with transport operator

Using the identification presented in Table 1 for torsional vibrations (Mode I), longitudinal vibrations (Mode II) and transverse vibrations (Mode III), we write the equation of small elastic vibrations of the one-dimensional continuum, moving at transport velocity V_0 in the x-direction, in the following form:

$$a\frac{\partial^2 U}{\partial t^2} + 2b\frac{\partial^2 U}{\partial x \partial t} + c\frac{\partial^2 U}{\partial x^2} = 0 \, . \tag{4}$$

Mode	I	II	III
U	θ	u	w
a	ρI_0	ρS	m
b	$\rho I_0 V_0$	$\rho S V_0$	$m V_0$
c	$\rho I_0 V_0^2 - GI_k$	$\rho S V_0^2 - ES$	$m V_0^2 - T$
D	$\rho I_0 G I_k$	$\rho S^2 E$	mT

Table 1 Definitions for torsional (I), longitudinal (II) and transverse (III) vibrations.

In the table, ϑ is the angle of torsion, u and w are the longitudinal and transverse displacements, ρ is the material density, I_0 the moment of inertia, GI_k the torsional rigidity, G the shear modulus, E Young's modulus of the material, S the cross sectional area of the body, $m = \rho S$ the mass per unit length, and T a tensile load.

Observe that equation (4) is written in the laboratory frame (x,t). In the case of longitudinal vibrations of an axially moving material, following the idea first presented by [Koivurova & Salonen, 1999], the quantity $U(x,t)$ must be understood as a *mixed Lagrangean–Eulerian* longitudinal displacement. It is a snapshot of the instantaneous displacement, at the laboratory coordinate x at each fixed point of time t, with respect to a reference state that only travels axially at the constant velocity V_0 (without vibrating).

In the case of transverse vibrations, equation (4) describes strings, but not beams or panels; these would require also a fourth-order term representing the effect of bending rigidity. For small bending rigidities (such as is the case with paper materials), it is possible to neglect this term, and still obtain a good result for e.g. the critical velocity. For a singular perturbation analysis of the natural frequencies and critical velocities of beams with small bending rigidity, we refer the reader to [Kong & Parker, 2004]. Here we consider only second-order models.

For all three modes considered in Table 1, the discriminant D of this second-order linear partial differential equation, $D = D_j(j = \{\theta, u, w\}) = b^2 - ac$, is positive, and consequently equation (4) is always hyperbolic, regardless of the value of the axial transport velocity V_0. At certain special values of the transport velocity, $V_0 = C_j$ for $j = \{\theta, u, w\}$, the coefficient c in (4) vanishes, and the equation simplifies into

$$\frac{\partial^2 U}{\partial t^2} + 2c_j \frac{\partial^2 U}{\partial x \partial t} = 0 \, , \qquad j = \{\theta, u, w\} \, , \tag{5}$$

where $c_j = b/a$ (for each case separately). These values are as follows:

$$V_0 = \left(\frac{GI_k}{\rho I_0}\right)^{1/2} \equiv C_\theta \, , \qquad V_0 = \left(\frac{E}{\rho}\right)^{1/2} \equiv C_u \, , \qquad V_0 = \left(\frac{T}{m}\right)^{1/2} \equiv C_w \, , \tag{6}$$

These special values for the axial transport velocity V_0 are known as the critical velocities or divergence velocities. In the following, it is assumed that $V_0 \neq C_j, (j = \{\theta, u, w\})$, and the dimensionless values $\tilde{x} = x/\ell$, $\tilde{t} = t/\tau$, $\tilde{U} = U/U_0$ are used. Here ℓ indicates a characteristic length, τ is a characteristic time and U_0 is a characteristic value of the state variable U. In the following, we will omit the tilde from the notation.

With respect to the dimensionless quantities, equation (4) can be rewritten as

$$\frac{\partial^2 U}{\partial t^2} + 2V_0 \frac{\tau}{\ell} \frac{\partial^2 U}{\partial x \partial t} + \left(V_0^2 - C_j^2\right) \frac{\tau^2}{\ell^2} \frac{\partial^2 U}{\partial x^2} = 0\,, \tag{7}$$

where $j = \{\theta, u, w\}$. It can be shown that with the pinhole boundary conditions $U(0,t) = U(1,t) = 0$, the kth vibration mode of the complex-valued free vibration solution

$$U(x,t) = \exp(s\,t)\,\hat{U}(x) \tag{8}$$

(with s the complex-valued eigenfrequency) of equation (7) is ([Swope & Ames, 1963]; see also [Banichuk et al., 2014] or [Jeronen, 2011])

$$U(x,t) = \gamma \exp\left(\pm i \frac{k\pi\ell}{c_j} \left[\left(V_0^2 - C_j^2\right) \frac{\tau^2}{\ell^2} t - V_0 \frac{\tau}{\ell} x\right]\right) \sin(k\pi x)\ , \tag{9}$$

where the $\pm$ corresponds to the $\pm$ in $s = \pm i\omega$, $i = \sqrt{-1}$ (i.e. both positive and negative frequencies are admissible), and γ is a free coefficient for the amplitude. Taking the real or imaginary part of (9) gives the real-valued solutions.

Note that in problems of axially moving materials, the space part $\hat{U}(x)$ is irreducibly complex-valued. Its real and imaginary parts are not real-valued solutions of the pseudo-steady-state problem that is obtained by inserting (8) into (7) and ignoring the common factor $\exp(s\,t)$. This is because the pseudo-steady-state problem has complex-valued coefficients, even though the coefficients of the full problem (7) are purely real.

3 Some criteria estimated in frame of transport equations

The continuum modelling of travelling mechanical systems using the transport operator, as was considered above, can be directly generalized for two-dimensional continuum models, described by partial differential equations of the second or the fourth order (membranes, panels, plates, etc.), and applied for estimation of different functionals. Below we present some of the most important functionals considered in the studies in the frame of continuum models (see for example [Banichuk et al., 2014]). The first one is the critical velocity

$$J_V = V_0^{\mathrm{cr}}\,, \qquad 0 < V_0 < V_0^{\mathrm{cr}}\,, \tag{10}$$

characterizing the loss of stability, with the safety interval shown in (10). The functional

$$J_\omega = \omega_0\,, \tag{11}$$

expresses the fundamental frequency of the free vibrations, characterizing the rigidity (integral stiffness or compliance) of the moving body.

The functional

$$J_c = \kappa_i T V_0 \,, \qquad (\kappa_i > 0 \,, \text{ coefficient}) \tag{12}$$

estimates energy consumption in process industry applications of moving materials, such as paper making. The critical number of cycles N^{cr}, or the critical period of time t^{cr}, before fracture can be considered as a safety criterion

$$J_N = N^{\text{cr}} \sim t^{\text{cr}} \,, \tag{13}$$

which is closely related to web breaks in industrial processes. The efficiency of many processes with transport operators (e.g. the amount of produced paper between web breaks) can be estimated as

$$J_\varepsilon = \kappa_\varepsilon t^{\text{cr}} V_0^{\text{cr}} \,, \qquad (\kappa_\varepsilon > 0 \,, \text{ coefficient}) \,. \tag{14}$$

Some of the presented criteria such as (10) and (11) have been considered in previous publications, such as [Banichuk et al., 2014], for both one-dimensional (panels, beams) and two-dimensional continua (orthotropic membranes and plates). Other criteria (12) and (13) are more sophisticated and require more deep investigations in the frame of modern fatigue theory and fracture mechanics. The efficiency criterion (14) is new.

The functionals (10)–(14) can be optimized in a vectorial (Pareto) sense. It is possible to consider a multi-objective optimization problem, for example, for

$$J = \{-J_v, J_\omega, J_c, -J_N, -J_\varepsilon\}^{\text{T}} \to \min \,. \tag{15}$$

Some multi-objective optimization problems in structural mechanics have been studied earlier in [Banichuk & Neittaanmäki, 2010]. Note also that many transport problems with travelling bodies, modelled as a continuum, have incomplete information (uncertain data) concerning applied forces, material parameters and internal defects. See [Banichuk et al., 2014], which contains an effective approach to such problems, using guaranteed (minimax) and probabilistic (stochastic) approaches.

The talk concentrates on a simple example on vectorial optimization in the application of moving materials. The optimization is performed using the classical weighting method, which is surprisingly useful for this class of models. This is because the model is simple enough to allow for an analytical solution.

Simple models, where applicable, are extremely useful in a modern setting, because they easily lend themselves to highly efficient and extremely fast (realtime) solvers. Realtime solvers, in turn, have applications such as optimal control, parametric studies of complex physical situations, modelling-based measurements, statistical quantification of uncertainty, agile modelling, and indeed as considered here, industrial optimization.

In this application, there is no need to choose the component weights a priori (which is typically the principal shortcoming of the classical weighting method); the whole Pareto surface is obtained analytically as a function of the weighting parameters.

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Competitive Green Vehicle Routing

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1 Introduction

Transportation sectors of modern worldwide cities consume a large portion of fossil fuel and significantly contribute to greenhouse gas (GHG) emissions. According to Federal State Statistics Service of Russian Federation since 2000 in this country emission of road transportation were 41,9 percent of all greenhouse gas [1]. In particular, the use of passenger cars contributes to 15 percent of the overall carbon dioxide emissions. In Europe passenger cars emitted 12 percent of air contaminants and there exist increasing dynamic of this indicator [2]. In 2011, 27 percent of total GHG emissions in the U.S. comes from transportation end-user sector and passenger vehicles are responsible for 43 percent of this total share [3]. Developing countries of South America demonstrate the same state. While industrial sector of Brazil emitted in 2010 29 percent of air pollution, road transport contributed 43 percent [4]. Certainly, such situation influence on quality of life directly and authorities are interested in decisions that could change situation in the direction of pollution decreasing.

The authority is interested in increasing of green vehicles fleet on the transportation network to resist greenhouse gas emission. To motivate drivers for using green vehicles decision maker could define special green subnetwork consisted of routs for green vehicle transit only. The point is how green vehicles could be provided with sufficiently attractive alternative. Since the government possess' information about current quantity of green vehicles the question could be reformulated quantitatively. How many transportation routes should be offered for green vehicles transit only (let us call such routes as green routes as opposed to non-green routes). Indeed, on the one hand, if green routes are partially loaded but non-green routes are overloaded then transportation network will be unbalanced [5]. On the other hand, if green routes could be overloaded by fleet of green vehicles then it will be not so attractive for drivers to use green vehicles. In this context, special attention should be paid to the mutual influence of different competitive groups of users that act on transportation networks of modern cities. Taking into consideration these groups it is necessary to find conditions that could guarantee well-balanced using of green and non-green routes of the network. In this study we are going to define such conditions.

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2 Several groups of users on transportation network

Consider transportation network presented by digraph consisted of one origin-destination pair and n parallel links. We believe that there are green and non-green routes on the network. Green routes could be used only by green vehicles while non-green routes could be used by both green and non-green vehicles. We use following notations: $N = \{1,\dots,n\}$ – set of numbers of routes, $i \in N$; $N_1 = \{1,\dots,n_1\}$ – set of numbers of green routes, $N_1 \subset N$; $N_2 = \{n_1+1,\dots,n_2\}$ – set of numbers of non-green routes, $N_2 \subset N$; $M = \{1,\dots,m\}$ – set of numbers of users' groups (UG), $j,q \in M$; F^{j1} – quantity of green vehicles of UG j, $F^1 = \sum_{j=1}^m F^{j1}$; F^{j2} – quantity of non-green vehicles of UG j, $F^2 = \sum_{j=1}^m F^{j2}$; f_i^j for $i = \overline{1,n_1}$ – traffic flow of green vehicles of UG j through route i; f_i^j for $i = \overline{n_1+1,n_2}$ – traffic flow of green and non-green vehicles of UG j through route i; $f^j = (f_1^j,\dots,f_n^j)$, $f^{j1} = (f_1^j,\dots,f_{n_1}^j)$ and $f^{j2} = (f_{n_1+1}^j,\dots,f_{n_2}^j)$; t_i^0 – free travel time through route i; c_i – capacity of i-th route; F_i – traffic flow through route i; $t_i(F_i) = t_i^0\left(1+\frac{F_i}{c_i}\right)$ – travel time through congested route i. We are modeling travel time as linear BPR-delay function [6].

Each group of users tries to minimize its own travel time:

$$\min_{f^j} z^j(f^j) = \min_{f^j} \sum_{i=1}^{n_1} t_i(F_i) f_i^j + \sum_{i=n_1+1}^{n_2} t_i(F_i) f_i^j \quad \forall j \in M, \tag{1}$$

subject to

$$\sum_{i=1}^{n_1} f_i^j \le F^{j1} \quad \forall j \in M, \tag{2}$$

$$\sum_{i=n_1+1}^{n_2} f_i^j \ge F^{j2} \quad \forall j \in M, \tag{3}$$

$$\sum_{i=1}^{n_1} f_i^j + \sum_{i=n_1+1}^{n_2} f_i^j = F^{j1} + F^{j2} \quad \forall j \in M, \tag{4}$$

$$f_i^j \ge 0 \quad \forall i \in N, j \in M. \tag{5}$$

Competitive relationship between different groups of users leads to their mutual influence and this point addresses us to find Nash equilibrium. It should be mentioned immediately that the process of finding Nash equilibrium when behavior of each UG is modeled by optimization program (1)-(5) seems to be sorely complex problem. However boundary value of n_1 could be estimated directly. Indeed, boundary value of n_1 corresponds to the situation when all green vehicles are assigned only to green routes and their travel time is less or equal to travel time of non-green vehicles assigned to non-green routes. In such a case program (1)-(5) could be reformulated as two independent problems:
1) for green vehicles

$$\min_{f^{j1}} z^{j1}(f^j) = \min_{f^j} \sum_{i=1}^{n_1} t_i(F_i) f_i^j \quad \forall j \in M, \tag{6}$$

subject to

$$\sum_{i=1}^{n_1} f_i^j = F^{j1} \quad \forall j \in M, \tag{7}$$

$$f_i^j \geq 0 \quad \forall i \in N_1, j \in M, \tag{8}$$

2) for non-green vehicles

$$\min_{f^{j2}} z^{j2}(f^j) = \sum_{i=n_1+1}^{n_2} t_i(F_i) f_i^j \quad \forall j \in M, \tag{9}$$

subject to

$$\sum_{i=n_1+1}^{n_2} f_i^j = F^{j2} \quad \forall j \in M, \tag{10}$$

$$f_i^j \geq 0 \quad \forall i \in N_2, j \in M. \tag{11}$$

Definition 1. Some value of n_1 is called *optimal* if:

- travel time of the flow of green vehicles through green routes is less or equal to travel time of the flow of non-green vehicles;
- there are no unused green routes.

For any fixed n_1 problems (6)-(8) and (9)-(11) are solved explicitly in [7]. If we employ results obtained in [7] and assume, without loss of generality, that

$$t_1^0 \leq \ldots \leq t_{n_1}^0 \text{ and } t_{n_1+1}^0 \leq \ldots \leq t_{n_2}^0, \tag{12}$$

the following theorem will be held.

Theorem 1. *The fixed value of n_1 is optimal if and only if*

$$\sum_{i=1}^{n_1} \left(\frac{t_i^0}{m+1} + \frac{F^1 + \frac{m}{m+1} \sum_{r=1}^{n_1} c_r}{\sum_{r=1}^{n_1} \frac{c_r}{t_r^0}} \right) \left(\frac{c_i}{t_i^0} \frac{F^{j1} + \frac{1}{m+1} \sum_{r=1}^{n_1} c_r}{\sum_{r=1}^{n_1} \frac{c_r}{t_r^0}} - - \frac{c_i}{m+1} \right) \leq$$
$$\leq \sum_{i=n_1+1}^{n_2} \left(\frac{t_i^0}{m+1} + \frac{F^2 + \frac{m}{m+1} \sum_{r=n_1+1}^{n_2} c_r}{\sum_{r=n_1+1}^{n_2} \frac{c_r}{t_r^0}} \right) \left(\frac{c_i}{t_i^0} \frac{F^{j2} + \frac{1}{m+1} \sum_{r=n_1+1}^{n_2} c_r}{\sum_{r=n_1+1}^{n_2} \frac{c_r}{t_r^0}} - - \frac{c_i}{m+1} \right) \tag{13}$$

$\forall j \in M$ and

- $$F^{j1} > \frac{1}{m+1} \sum_{i=1}^{n_1} c_i \left(\frac{t_{n_1}^0}{t_i^0} - -1 \right) \quad \forall j \in M, \tag{14}$$
-

$$F^{j2} > \frac{1}{m+1} \sum_{i=n_1+1}^{n_2} c_i \left(\frac{t_{n_2}^0}{t_i^0} - -1 \right) \quad \forall j \in M. \tag{15}$$

Proof. According to [7] inequalities (14), (15) state that all green routes N_1 are used by green fleet F^1 and all non-green routes N_2 are used by fleet F^2 when condition (12) holds.

Due to results obtained in [7] we can get in explicit form total travel time of green and non-green fleets through green and non-green routes respectively. Taking advantage of this opportunity one could check that left part of (13) corresponds to the travel time of green fleet through green routes while right part of (13) corresponds to the travel time of non-green fleet through non-green routes. □

Above theorem gives the rule of defining optimal n_1. Really, if authority provides such amount of green routes that condition (13) holds then for any group of users it would be preferable to assign green vehicles through green routes. In this situation non-green vehicels recognize that green vehicles are provided with less travel time assignment. This could be the best motivation for drivers to use environment friendly vehicles. Inequalities (14), (15) guarantee that the network is fully loaded: no one route is unused.

3 Conclusion

We considered the problem of green routes allocation on the transportation network of non-general topology with several competitive groups of users. The approach for optimal green subnetwork construction is developed. In further work it is expected to expand this approach on the transportation network of general topology.

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Keywords: competitive routing, Nash equilibrium, green vehicle routing

VENUE

Jyväskylä - Human Technology City in the heart of Finland

Jyväskylä is a dynamic, youthful and lively city, which on the basis of its specializations promotes itself as the Human Technology City. The City of Jyväskylä is the seventh largest city in Finland with 131 000 residents, which is famous for achievements in science and technology, high-quality cultural activity, and beautiful nature. Jyväskylä is situated 270 km from Helsinki at the northern end of Päijänne, Finland´s second largest lake. A third of Lake Päijänne lies within the boundaries of Jyväskylä.

Jyväskylä was established in 1837. From the very beginning the city has been closely associated with education. Teacher training in particular has long traditions here. Nowadays Jyväskylä is home to students in many different fields. Almost thirty per cent of the population consists of school-goers and students.

Local educational establishments are located close to one another and engage in various forms of cooperation - for this reason the city is like one large campus.

The traditionally strong industrial branches, machinery and automation, printing and communication and wood processing are flourishing fields of industry in the Jyväskylä Region. Special expertise is also to be found in the fields of paper making, energy and environmental and information technologies. These are complemented by growing new sectors such as wellness and nanotechnology. A number of international companies, including Metso, UPM-Kymmene, M-Real and Vapo are located in Jyväskylä. Collaboration between higher education and business is the foundation for new entrepreneurial activity.

Jyväskylä is a university city. It hosts one of the largest Finnish multidisciplinary universities with a total of seven faculties. University of Jyväskylä is a well-known international scientific center where students and scientists from all parts of the world work in a friendly and thoughts supporting atmosphere.

The Faculty of Information Technology is the first and largest IT faculty in Finland. Information Systems Science has been taught at the University of Jyväskylä since 1967. At the Department of Mathematical Information Technology, information technology is studied from the perspective of natural sciences. Here, studies are based upon strong knowledge in modern applied mathematics and participation in industrial projects. Special attention is also being given to research training in addition to both international and national co-operation.

Jyväskylä is a great city for those on foot, since key services in the city centre are located within walking distance of each other. The real gem is the pedestrian precinct, the lively heart of the city, which serves as a venue for events and as a general rendezvous for residents and visitors alike. The region's inhabitants are friendly and possess an excellent service attitude. Price levels in Jyväskylä are clearly more favourable than in and around Helsinki, the state capital.

Culture lovers can enjoy a voyage into the creations of world-famous architect Alvar Aalto, as Jyväskylä is his home city. The region boasts more buildings designed by Aalto than any other city in the world. The Alvar Aalto museum, the only museum in the world dedicated to life and work of Aalto is among of the top tourist attractions of the city. Other tourist attractions are Nyrölä rock planetarium, and Oravivuori triangulation tower, a UNESCO world heritage site.

Photos:
University of Jyväskylä, City of Jyväskylä and Jyväskylä Convention Bureau

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A 1/2011	SERGEY REPIN, TIMO TIIHONEN, TERO TUOVINEN, Proceedings of CAO2011 - ECCOMAS Thematic Conference on Computational Analysis and Optimization, University of Jyväskylä, June 9-11, 2011
A 1/2014	PEKKA NEITTAANMÄKI, SERGEY REPIN, TERO TUOVINEN, Book of abstracts, International Conference for Mathematical Modeling and Optimization in Mechanics (MMOM 2014), honor of the 70th anniversary of Prof. Nikolay Banichuk, University of Jyväskylä, March 6-7, 2014

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Monday May 25

09:00–09:50	3rd flr	Registration
09:15–09:50	*3rd flr, restaurant*	*Coffee*
09:50–10:10	3rd flr, K305 Alvar	Welcome address: JYU: Vice Rector **Kaisa Miettinen**, and **Jacques Periaux**, Finland; EC: **Michael Kyriakopoulos**, Belgium; ECCOMAS: Vice President **Pedro Díez**, Spain
10:10–10:30	3rd flr, K305 Alvar	Multidisciplinary and Integrated Computational Aeronautics in H2020 and beyond, **Michael Kyriakopoulos**, EC DG Research & Innovation, Belgium
10:30–11:00	3rd flr, K305 Alvar	Securing Further Gains in Aircraft Environmental Performance: Challenges and Opportunities for Multi-Fidelity and Multi-Scale Simulation, **Stephen Rolston**, Airbus, UK
11:00–11:40	3rd flr, K305 Alvar	New trends in the automotive industry, transition from a mechanical industry to a software industry, **Mårten Levenstam**, Volvo, Sweden
11:40–12:45	*3rd flr, restaurant*	*Lunch*
12:45–14:05	3rd flr, K305 Alvar	Parallel Contributed Session 1: Automotive
12:45–14:05	3rd flr, K307 Elsi	Parallel Contributed Session 2: Simulation
14:15–14:45	3rd flr, K305 Alvar	Challenges in Optimization of a Passenger Vehicle, **Mikael Törmänen**, Volvo, Sweden
14:45–15:15	3rd flr, K305 Alvar	Challenges to develop innovative multi-use offshore platforms servicing marine transportation and emerging coastal activities, **Joaquin Brito**, PLOCAN, Spain
15:15–15:45	*3rd flr, restaurant*	*Coffee*
15:45–17:15	3rd flr, K305 Alvar	C-AERO2 STS Aeronautics: Models and Tools for Greening Future Air Transport
17:30–18:30	3rd flr, K305 Alvar	STS Maritime: Sustainable and Innovative concepts to combine marine transport and emerging marine activities
19:00	*3rd flr, lounge*	*Reception*

Tuesday May 26

08:45–09:00	2nd flr	Registration
09:00–09:30	2nd flr, Aud A2 Wivi	Large-scale wave propagation in ballasted railway tracks, **Régis Cottereau**, Ecole Centrale, France
09:30–10:00	2nd flr, Aud A2 Wivi	Multidisciplinary Design Analysis/Optimisation System Needs and Development, **Adel Abbas**, UPM, Spain
10:00–10:30	*3rd flr, restaurant*	*Coffee*
10:30–12:30	2nd flr, Aud A2 Wivi	Round Table 1: New Challenges and Solutions for the Greening of Transport
12:30–13:30	*3rd flr, restaurant*	*Lunch*
13:30–14:00	2nd flr, Aud A2 Wivi	Collaborative logistics – possibilities and challenges, **Mikael Rönnqvist**, Université Laval, Canada
14:00–14:30	2nd flr, Aud A2 Wivi	The key success factors in future logistics, **Olli Bräysy**, University of Jyväskylä, Finland
14:30–15:00	2nd flr, Aud A2 Wivi	Extending the Scope of SCM Decision Making, **Wout Dullaert**, VU University Amsterdam, The Netherlands
15:00–15:30	*3rd flr, restaurant*	*Coffee*
15:30–16:30	2nd flr, Aud A2 Wivi	Limowa Round Table 2: The Growing importance of Intra-logistics
16:45–18:05	3rd flr, K305 Alvar	Parallel Contributed Session 3: Logistics I
16:45–18:05	3rd flr, K307 Elsi	Parallel Contributed Session 4: Logistics II
16:45–18:05	3rd flr, K306 Anton	Parallel Contributed Session 5: Modelling and methods
20:00	*Conference dinner*	

Wednesday May 27

08:45–09:00	2nd flr	Registration
09:00–09:30	2nd flr, Aud A2 Wivi	How TNT Express saved more than 200 million in four years time by using Business Analyticsm, **Hein Fleuren**, Tilburg University, Bluerock Logistics, The Netherlands
09:30–10:00	2nd flr, Aud A2 Wivi	Changing Finnish Rail Market, **Kimmo Rahkamo**, Managing Director, Fennia Rail Oy, Finland
10:00–10:30	2nd flr, Aud A2 Wivi	Digital Supply Chains, **Kyösti Orre**, General Industry Federation, Finland
10:30–11:00	*3rd flr, restaurant*	*Coffee*
11:00–12:00	2nd flr, Aud A2 Wivi	Limowa Round Table 3: Role of Information and Big data
12:00–13:00	2nd flr, Aud A2 Wivi	Logistics Software Demo session
13:00–14:00	*3rd flr, restaurant*	*Lunch*
14:00–15:20	3rd flr, K305 Alvar	Parallel Contributed Session 6: Logistics III
14:00–15:20	3rd flr, K307 Elsi	Parallel Contributed Session 7: Logistics IV
15:20–15:50	*3rd flr, restaurant*	*Coffee*
15:50–16:20	2nd flr, Aud A2 Wivi	Competitive Green Vehicle Routing, **Victor Zakharov**, University of St. Petersburg, Russia
16:20–16:30	2nd flr, Aud A2 Wivi	Concluding remarks, **Pekka Neittaanmäki**, University of Jyväskylä, Finland

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