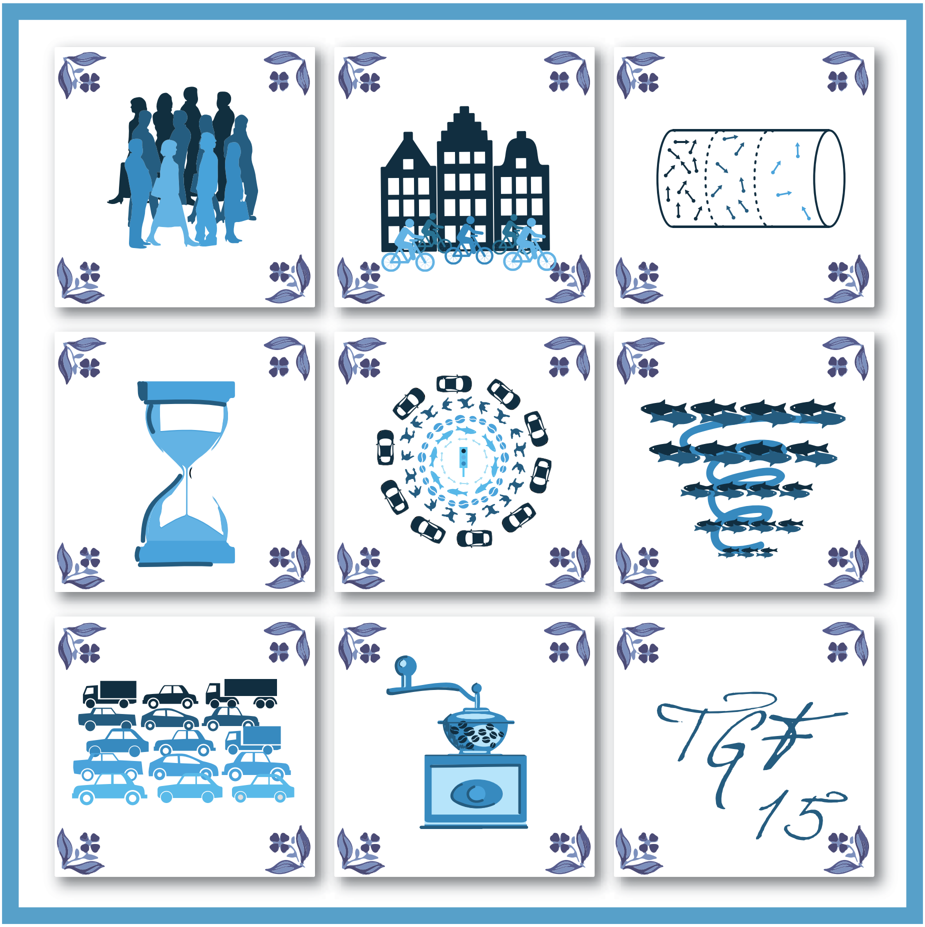
Traffic and Granular Flow '15

27 - 30 October 2015

Van der Valk hotel Nootdorp , the Netherlands



BOOK OF ABSTRACTS

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PREFACE

Welcome to the eleventh edition of Traffic and Granular Flow in the Netherlands. The 2015 edition of this worldwide biannual conference is organised by the Delft University of Technology, where it returns after 12 years. What started as a one-time event in 1995 has grown in 20 years to a conference series with a very good scientific reputation.

The conference is known for facilitating links between various disciplines. In this edition, we have amongst other things presentations on vehicular flow, pedestrian flow, granular flow, and biological flow. There are 90 high-quality papers, distributed over oral and poster presentations. Participants come from over 30 countries, spread over all continents.

We set up a program allowing maximum interaction between the participants. The conference is organised at a hotel which allows to have parallel sessions, poster sessions, all meals and overnight stay for most participants. We encourage the mix of junior researchers and PhD students with more senior researchers. The size of the conference allows for many interactions.

We are grateful for the financial support given by the Transport Institute of the Delft University of Technology. Moreover, organising this conference would not have been possible without the help of many colleagues, both in the preparation and during the conference. We would like to include a special acknowledgement for Nicole Fontein, Priscilla Hanselaar, Ilse Galama and Fieke Beemster.

We are looking forward to three days of fruitful presentations, discussions and initiations of future cooperation.

The tradition will go on. The next edition of the conference will be organised in 2017 by Samer Hamdar in Washington DC.

We hope that you enjoy the conference!

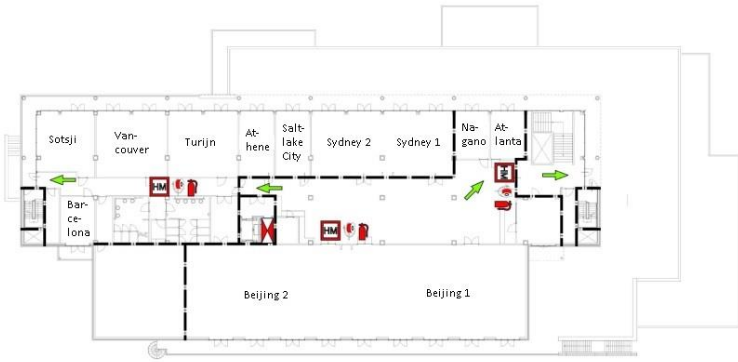
October 2015

Delft, the Netherlands

Victor L. Knoop

Winnie Daamen

GENERAL INFORMATION



First floor

27 October 2015

A welcome reception will be held in the van der Valk hotel in Nootdorp from 17.00 to 19.00.

28-30 October 2015

The conference will be held at the 1st floor of the van der Valk Hotel. Oral presentations are given in two parallel session, with distinct topics. Sessions will take place in the Beijing room and in the Sydney room.

29 October 2015

The social event is in Madurodam, transport to Madurodam will be by bus. At 16.15 the bus will leave from the parking place of the hotel. The bus will arrive in Madurodam around 17.00, George Maduroplein 1, 2584 RZ Den Haag.

30 October 2015

The event will be closed with a farewell lunch around 12.45.

ORGANIZING COMMITTEE

Victor L. Knoop

Winnie Daamen

Nicole Fontein

Priscilla Hanselaar

Delft University of Technology

Faculty of Engineering and Geoscienses

Department of Transport & Planning

TIMETABLE 27.10

	Tuesday , 27.10
	Conference room
17:00	Welcome drinks
19:00	End

TIMETABLE 28.10

	Wednesday, 28.10
	Room: Beijing
08:30	Registration
09.00	Opening by Rector Magnificus Delft University of Technology Karel Luyben
09:10	1st keynote by Prof. Ludovic Leclercq ☞15
10:00	An Unified Pedestrian Routing Model Coupling Multiple Graph Based Navigation Methods ☞16
10:20	Wayfinding and Cognitive Maps for Pedestrian Models ☞17
10:40	Adaptive Tactical Decisions in Pedestrian Simulation: a Hybrid Agents Approach ☞18
11:00	Coffee
11:20	Is Slowing Down Enough to Model Movement on Stairs? ☞19
11:40	Data-Driven Characterization of Multidirectional Pedestrian Traffic ☞20
12:00	Statistical Structures of Low Density Pedestrian Dynamics ☞21
12:20	On Collective Movement Characteristics of Four-directional Intersecting Flows ☞22
12:40	Lunch
13:40	A Queueing Model Based on Individual Social Attitudes ☞23
14:00	How do People Queue – A Study of Different Queuing Models ☞24
14:20	The Relationship Between a Waiting Crowd and the Average Service Time ☞25
14:40	"How Do We Wait?" – Fundamentals, Characteristics, and Modelling Implications ☞26
15:00	Coffee
15:20	Poster Session
16:10	Steady State of Pedestrian Flow in Bottleneck ☞27
16:30	Statistical Models for Pedestrian Behaviour In Front of Bottlenecks ☞28
16:50	Dynamic of Congestion in Pedestrian Traffic ☞29
17:10	Determining the Density Experienced by Pedestrians in Unstable Flow Situations ☞30
17:30	Make group picture
17:45	End
18:30	Dinner in Hotel van der Valk
21:00	End

THEMES: Pedestrian Vehicles

TIMETABLE 28.10

	Wednesday, 28.10
	Room: Sydney
08:30	
09.00	
09:10	
10:00	How to Get a Model in Pedestrian Dynamics to Produce Stop and Go Waves ☞31
10:20	A Force-based Model to Reproduce Stop-And-Go Waves in Pedestrian Dynamics ☞32
10:40	Impact of Impulse Stops on Pedestrian Flow ☞33
11:00	Coffee
11:20	A multi-class Vehicular Flow Model for Aggressive Drivers ☞34
11:40	Microscopic Simulations of Oversaturated City Traffic: Features of Synchronised Flow Patterns ☞35
12:00	Traffic Simulations With Empirical Data – How To Replace Missing Traffic Flows? ☞36
12:20	Dynamic Model for Assignment in "Sky-car" Transit System ☞37
12:40	Lunch
13:40	Impact of Synchronized Flow in Oversaturated City Traffic on Energy Efficiency ☞38
14:00	Evaluation of Transportation Network Resilience Using Adaptive Capacity ☞39
14:20	Network-Wide Mesoscopic Traffic State Estimation Based on a Variational Formulation ☞40
14:40	Route Choice Behaviour in a Three Roads Scenario ☞41
15:00	Coffee
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16:10	Calibrating the Local and Platoon Dynamics of Car-following Models on NGSIM data ☞42
16:30	Scaling from Circuit Experiment to Real Traffic based on Optimal Velocity Model ☞43
16:50	Traffic Flow Optimization at Sags by Controlling the Acceleration of Some Vehicles ☞44
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21:00	

Other

TIMETABLE 29.10

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10:30	Influence of Moore and von-Neumann Neighbourhood on Pedestrian Dynamics ☞50
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11:10	Methodology for Generating Individualized Trajectories from Experiments☞51
11:30	Measuring Pedestrians at Dutch Train Stations using Bluetooth, WiFi & infrared technology ☞52
11:50	Avoiding Walls – What Distance do Pedestrian Keep from Walls and other Obstacles?☞53
12:10	Measuring and Modelling Crowd Flows -Fusing Stationary and Tracking Data☞54
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13:30	Empirical Study of the Influence of Social Groups in Evacuation Scenarios☞55
13:50	Models and Analysis of Evacuation Dynamics of Asymmetrically Coupled Pedestrian Pairs☞56
14:10	Granulometric Distribution and Crowds of Groups: Focusing on Dyads☞57
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16:15	Departure for Social Event
17:00	Social Event
19:00	Conference dinner
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THEMES: Pedestrian Vehicles

TIMETABLE 29.10

	Thursday, 29.10
	Room: Sydney
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09:00	
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10:30	Granularity of Pre-Movement Time Distribution in Crowd Evacuation Simulations☞60
10:50	Coffee
11:10	When is a Bottleneck a Bottleneck?☞61
11:30	Jam Avoidance with Autonomous Systems☞62
11:50	Modelling of Backward Travelling Holes in Mixed Traffic Conditions☞63
12:10	Analysis in Kantorovich Geometric Space for Quasi-Stable Patterns in 2D-OV Model☞64
12:30	Lunch
13:30	A Pedestrian Dynamics Model in Discrete Time And Continuous Space☞65
13:50	Investigation on Cooperative Avoiding Behavior in Bidirectional Flow☞66
14:10	Pedestrian Dynamics at Transit Stations: A Hybrid Pedestrian Flow Modeling Approach☞67
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Other

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10:30	A Finite Element Simulation of High Density Pedestrian Flow☞72
10:50	Coffee
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11:30	Simulation-based Forecasts of Crowd Flows at Major Events using Real-time Measurements☞74
11:50	Level of Safety Concept for Major Events☞75
12:10	Brazilian Legislation and the Boate Kiss Tragedy- Computational Modeling of Evacuation☞76
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THEMES: Pedestrian Vehicles

TIMETABLE 30.10

	Friday, 30.10
	Room: Beijing
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10:30	Moving Without a Leader – The Benefits of Swarming☞79
10:50	Coffee
11:10	Fractal Analysis of Empirical and Simulated Traffic Time Series☞80
11:30	Physical Mechanism for the Occurrence of Wide-scattering in Traffic CA models ☞81
11:50	Effective Modelling of Traffic Dynamics: Classification and Unification☞82
12:10	Empirical Verification of Microscopic Traffic Models from the Detailed Acceleration Patterns☞83
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13.45	End

Other

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- Gao Zi-you - Beijing Jiaotong University, Beijing

WEDNESDAY, 28.10.

From Microscopic to Macroscopic Traffic Patterns : Different Applications of the Variational Theory

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This presentation tackles the question of the consistency between microscopic and macroscopic representations of traffic flow. To the authors best knowledge, the first attempt in this direction was in [3]: the fundamental diagrams related to different parameterization of General Motor (GM)s car following rule [1] were derived. This exhibits the corresponding macroscopic behavior corresponding to a given local car following process.In this presentation, we will discuss different applications of the variational theory [2] as a method to scale up local physical mechanisms to the corresponding global traffic patterns. The first application is related to the estimation of the capacity drop at freeway merges. Such a phenomenon occurs when vehicles from the on-ramp insert at low speed. The inserting process is first described on an individual basis using the moving bottleneck theory. Using the variational theory, we are able to integrate the local processes and to derive the mean capacity value [4,5,6,7]. The second application is the question of mean traffic states on urban corridor. Variational theory and the related cut theory [2] make it possible to easily determine the mean traffic states on a corridor while taking into account for local traffic dynamics including spillbacks. We will also show that this theory permit to derive the travel time distributions on a corridor and then to have a detailed description of the collective traffic flow motion.

References

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An Unified Pedestrian Routing Model Coupling Multiple Graph Based Navigation Methods

Peter M. Kielar*, Daniel H. Biedermann, Angelika Kneidl, and André Borrmann
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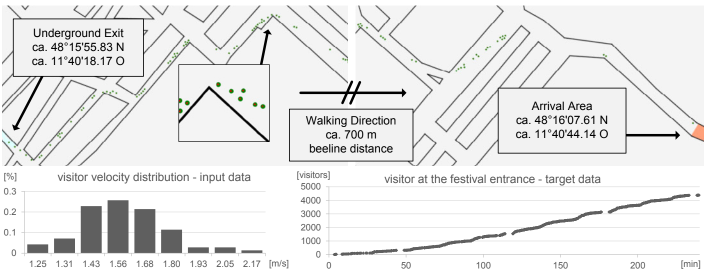
People navigate with ease in street networks and inside of complex buildings every day. Still, pedestrian never route perfectly and their navigation behaviour varies according to route network familiarity, spatial cognitive abilities, availability of landmarks, crowding, and many additional factors. In contemporary research, pedestrian routing models cover different and important aspects of pedestrian navigation. Some examples of these aspects include herding behaviour, walking alongside long and straight streets, and getting temporarily lost. However, the models cannot coherently cover multiple navigation aspects simultaneously. Here we show that a fusion of multiple graph-based navigation methods yields more sound and elaborate routing behaviour. The proposed navigation model is based on existing pedestrian routing methods [1, 2] and navigation-graph generation algorithms [3]. For model validation we made extensive use of data, which we collected at an annual local music festival. The festival audience is comprised of young adults starting their trip on foot at an underground station close to the festival venue. The comparison of the measured arrival times and the simulated arrival times revealed the correct routing methods mixture. Hence, the developed navigation model is able to predict the routing behaviour of pedestrians starting their trip at a joint starting location in order to travel to a common destination. Especially in the context of public events and festivals the forecast of the visitors' routing behaviour enables decision-makers to improve the people's safety by altering access routes.



References

[1] A. Kneidl, Methoden zur abbildung menschlichen navigationsverhaltens bei der modellierung von fußgängerströmen. Ph.D. thesis, Technische Universität München (2013)

[2] A. Kneidl, A. Borrmann, Proceedings of Emergency Evacuation of people from buildings (2011)

[3] A. Kneidl, A. Borrmann, D. Hartmann, Advanced Engineering Informatics **26**(4), 669 (2012)

Wayfinding and Cognitive Maps for Pedestrian Models

Erik Andresen*, David Haensel, Mohcine Chraibi, Armin Seyfried
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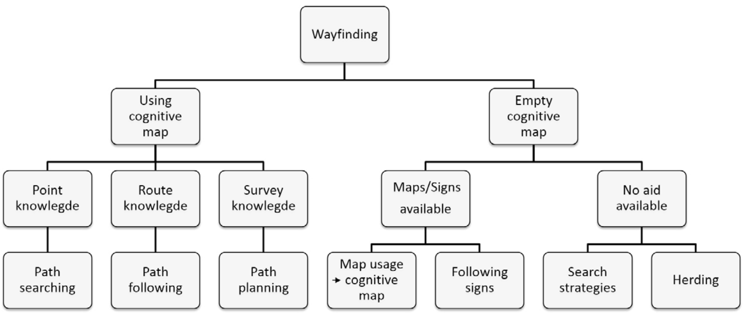
Regarding the question of exit and route choices wayfinding models in the field of pedestrian/evacuation dynamics assume agents to have a fullfilled and global knowlegde about the building's structure. Those models neglect the fact that real pedestrians posess no or only parts of information about their position relative to final exits and possible routes leading to those exits. We aim to close this gap by introducing the systematics of gathering and using spatial knowledge (cognitive map).

In this paper we propose a new wayfinding model created to use for pedestrian models inspired by modelling work by cognitive scientists and developers of artifical intelligence.

The model incorporates a graph-based topological network which allows simulated agents to learn routes and connections. This implies the pedestrians' possibility to gather and deduce parts of information about the network representing the building. The agents are moreover able to explore rooms or use search strategies if the cognitive map provides no or not enough information.

The model considers aspects, principles, taxonomies and constraints of wayfinding evaluated by psychologists and cognitive scientists. Particularly, for this purpose, we propose a new wayfinding taxonomy (Fig.) based on an approved taxonomy by [1]. Taking into account the taxonomies' statements the model i. a. incorporates the distinction and interconnection between different types of spatial information (point/route/survey knowledge) assembling the cognitive map (Fig.).

Finally, the model's limits and possibilities are discussed.



References

[1] J.M. Wiener, S.J. Büchner, C. Hölscher, Spatial Cognition & Computation **9**(2), 152 (2009)

10:40

Adaptive Tactical Decisions in Pedestrian Simulation: a Hybrid Agents Approach

Stefania Bandini, Luca Crociani, and Giuseppe Vizzari*
*CSAI - Complex Systems & Artificial Intelligence Research Center,
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Pedestrian research has growingly started approaching issues related to the modeling of tactical level decisions, either in the context of microscopic [3] or macroscopic approaches [2], both in normal or evacuation situations. The lack of empirical evidences on relevant aspects of human behavior, makes it difficult to evaluate and validate these approaches since the success criterion is not optimality but rather plausibility (optimal evacuation time can be useful only as a lower bound for the actual one). Moreover, in microscopic approaches to this kind of research, it is necessary to consider that tactical level decisions in general can and probably should employ information generally associated to the operational level, namely congestion of visible path alternatives.

This paper presents a hybrid agent architecture, extending a framework described in [1], for modeling different types of decisions in a pedestrian simulation system. In particular, we focus on *tactical level* decisions that are essentially related to the choice of a route to follow in an environment comprising several regions connected by gateways. These decisions are then enacted at the operational level by means of a floor-field based model in a discrete simulation approach. The described model allows the agents to take decisions based on a static a-priori knowledge of the environment, enriched with dynamic perceivable information on the current level of crowdedness of visible path alternatives. The a-priori knowledge is represented with a tree data-structure containing the costs of all *minimal* paths[1] from each region of the environment, towards one destination and for a certain category of agents, differentiated by their average speed but also other physical characteristics (e.g. difficulties in passing through special regions like stairs). The advantages of an off-line calculation and storage of paths in terms of computational complexity, respect to the usage of other well-known routing algorithms (e.g. the Dijkstra algorithm) will be discussed.

The paper presents the model formally, motivating the adopted choices with reference to the relevant state of the art. The model will be experimented in benchmark scenarios showing the adequacy in providing adaptive behaviors for the contextual situation. Finally, the paper presents requirements for observations or experiments to gather relevant empirical data for model calibration and validation.

References

[1] Luca Crociani, Alberto Invernizzi, and Giuseppe Vizzari. A hybrid agent architecture for enabling tactical level decisions in floor field approaches. *Transportation Research Procedia*, 2(0):618 – 623, 2014. PED 2014

[2] SP Hoogendoorn, Winnie Daamen, Dorine C Duives, Van Wageningen-Kessels, et al. Optimal crowd evacuation. In *93rd Annual Meeting Transportation Research Board*. TRB, 2013.

[3] Armel Ulrich Kemloh Wagoum, Armin Seyfried, and Stefan Holl. Modeling the dynamic route choice of pedestrians to assess the criticality of building evacuation. *Advances in Complex Systems*, 15(7), 2012.

[1] A fuzzy concept that will be discussed and clarified in the paper.

Is Slowing Down Enough to Model Movement on Stairs?

Gerta Köster*, Daniel Lehmberg, and Felix Dietrich
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There are many well validated models of pedestrian movement in the plane. This is not the case for movement on stairs. Experiments show that pedestrians slow down when climbing or descending stairs. It is tempting to model movement on stairs by simply slowing down by a factor. But this would imply that, other than being slower, motion on stairs mirrors motion in the plane. Is that assumption justified? Literature on the subject seems scarce and inconclusive [1,2]. Therefore, we conducted an experiment at the Munich University of Applied Sciences: Trajectories on stairs were captured and analyzed. Linear regression reveals a statistically significant dependency of speed on the crowd density, but with a very gentle slope (see Fig. 1, left). The correlation between density and speed is weak, with a coefficient of determination close to 0.

When we slow down agents in areas marked as stairs in a computer experiment with standard pedestrian models such as the Optimal Steps Model or the Social Force Model, we also observe a dependency on the density with a gentler slope and can achieve a good fit with the experiment. In that sense, the deceleration ansatz seems a good first shot. However, when looking closer, the stair's threads determine the stride length. Also, the participants avoided movement in the diagonal direction. Here, the deceleration model does not fit our observations. Thus, we derive a list of requirements from our experiment and propose a very simple extension of the Optimal Steps Model where the virtual pedestrians step from thread to thread. The results also show little dependency on the density (see Fig. 1, right).

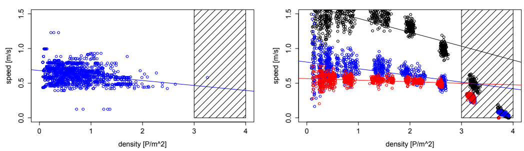

Figure 1: Left: Observed speed density dependency when walking downstairs (experiment in 2014). Right: Simulations with normally distributed free-flow velocities ($\mu = 1.52$, $\sigma = 0.13$ from controlled experiments). Model in the plane (black); using the plane model slowing down by factor 0.5 (blue); using the stair model (red).

References

[1] H. Frantzich, *Study of movement on stairs during evacuation using video analysing techniques*, (Tech. rep., Department of Fire Safety Engineering, Lund, Institute of Technology, Lund University, 1996).

Data-Driven Characterization of Multidirectional Pedestrian Traffic

Marija Nikolić * and Michel Bierlaire *

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Understanding and predicting of pedestrian flows are of the utmost importance for providing convenience and safety for pedestrians. Speed, density and flow are fundamental traffic variables used to observe and model pedestrian dynamics. The existing definitions of these variables mostly rely on an arbitrary chosen spatio-temporal discretization. This may generate noise in the data and the results may be highly sensitive to minor changes of discretization. Furthermore, the definitions are usually inspired by those from vehicular traffic hence lacking the ability to capture the multidirectional and heterogeneous nature of pedestrian flows. To address these issues we propose new definitions of traffic variables, derived by extending Edie's definitions [1] through a data-driven, spatio-temporal discretization and stream-based framework.

Discretization is performed with three-dimensional (3D) Voronoi diagrams [2] of pedestrian trajectories, such that each trajectory has a 3D Voronoi cell assigned to it. A cell defines a region in space belonging to a corresponding pedestrian for each point in time and a time interval occupied by a pedestrian for each point in space. The individual temporal and spatial units obtained in this way are adjusted to the reality of the flow thus resulting in the disaggregated pedestrian flow characterization that is independent from the arbitrary chosen discretization. The definitions are further adopted through a stream-based framework which assumes that pedestrian traffic is composed of different (exogenous) streams to which pedestrian trajectories contribute ([3]). The approach also allows for the aggregation of indicators at the stream level for any space-time domain of interest. In this study we specify the streams and corresponding individual contributions using principal component analysis and projection, respectively.

We show the consistency of the approach with the foundations of traffic flow theory in an analytical way and empirically illustrate its advantages. Using data from simulation and walking experiments ([4]) the approach is shown to: (i) reproduce the settings with uniform and non-uniform movement; (ii) reflect the self-organization phenomena typical for pedestrian traffic and pedestrian heterogeneity; (iii) lead to smooth transitions in measured traffic characteristics. Additionally, we consider a real case study for the analysis of the interaction among the characteristics from conflicting streams and subsequently for the specification of the multidirectional fundamental diagram.

References

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Statistical Structures of Low Density Pedestrian Dynamics

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The dynamics of pedestrian crowds is a relevant topic for the design and safety of civil infrastructures and furthermore a fascinating subject deeply connected with many scientific disciplines, including statistical physics and fluid dynamics. Walking pedestrians exhibit a large variety of different dynamical behaviours that may be influenced, amongst others, by many environmental factors (including geometry, temperature, illumination, etc.). Even in very simple geometries, individuals in crowds always display, in addition to average behaviours, small fluctuations as well as –more rarely– large "anomalous" deviations. Observations of crowds with very high statistics is thus expected to be able to display the statistical signature of both frequent and rare fluctuations.

Highly non-linear and chaotic phenomena are expected in dense crowds (e.g. [1]). Remarkably, extreme fluctuations with respect to average behaviours occur also when the pedestrians are in low-density situations. The present work focuses on the quantification of extreme fluctuations limiting to the cases of just one or two pedestrians walking in a corridor. Specifically, the cases of pedestrian pairs walking in the same direction (co-flow) and in opposite directions (counter-flow) are studied with high-statistics and compared with the case of a single pedestrian.

Our analysis is based on an unprecedented statistical database, obtained by a year-long high-precision measurement campaign [2, 3]. We recorded on a 24/7 basis the trajectories of pedestrians walking in a corridor inside a building at Eindhoven University of Technology. The recordings were performed by means of a Microsoft Kinect 3D-range sensor and an automatic head-tracking algorithm very similar to the one proposed by Seer et al. [4]. Our crowd tracking experiment resulted in the acquisition of a few hundreds of thousands of pedestrian trajectories in different (low) density conditions. By means of the large data volume collected, we extracted the fluctuations about the average pedestrian walking behaviours and completely characterized their statistics.

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On Collective Movement Characteristics of Four-directional Intersecting Flows

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Pedestrian movement in a crossing is complicated and easy to transform to critical situation under high densities. If there are three or more directional flows, the situation will become more complex because people will face unavoidable head-on conflicts and impede each other. Thus it is necessary to carry out the study on pedestrian collective movement in multi-directional intersecting flows, especially under the situation of high crowd density.

This paper presents an experimental study on four-directional intersecting pedestrian flows with the aim to give insight into collective movement characteristics of pedestrians in a crossing. The experiments were performed on the playground in a university and up to 364 male students took part in. Pedestrians trajectories are extracted by means of automatic image processing. From trajectories, we get positions of each person in every moment and find pedestrian gap at high densities, where pedestrians are easy to fall (Ma Jian et al, in Traffic and Granular Flow'13, p. 103), after significant interaction among pedestrians in the cross area. Velocity field and its corresponding stream lines are constructed and analyzed, as (Fig 1a,b) shown. An efficient rotary traffic pattern (Helbing et al, Transportation Science, 2005) which can minimize conflicts among pedestrians is found when people walk with right preference. Moreover, the stability of rotary traffic in the scenarios with and without an obstacle in the middle of cross area is compared and the results imply that putting an obstacle in the middle of cross area will improve the stability of rotary traffic, but at the same time it reduces flow rate. Furthermore, the contour lines of local velocity (Helbing et al, Physical Review E, 2007) field are also constructed in order to investigate the distribution of velocity in a crossing, as is shown in (Fig. 1c). These findings can be used to calibrate pedestrian simulation models and better understand the mechanism of collective movement.

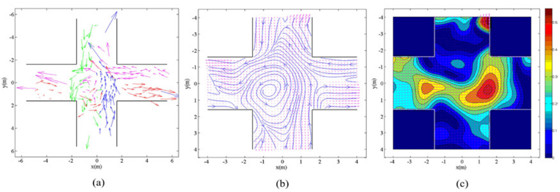

Figure 1: (a) velocity field (b) its corresponding stream lines (c) contour lines of local velocity in the density of 9.4 ped/m2 in the cross area

A Queueing Model Based on Individual Social Attitudes

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For realistic results, modern simulation models have to deal with queueing. Queues control the number of pedestrians entering or leaving a certain area and, through this, the number of pedestrians inside an area. Furthermore they impede passing pedestrians. Therefore it is important to study queueing behaviour and to model it appropriately. In this contribution we introduce a queueing model for different queueing conditions and individual social attitudes.

Getting in line or competing for the best position? How do humans decide on a queueing strategy? And how does this effect the form of the emerging queue? Based on dynamic floor fields for queueing [1] and heuristic decisions [2] we present a computer model that is able to capture different queueing patterns that we observe in every day life. We assume that there are two basic strategies: (a) aggressive competition for the spot closest to the service that is offered; (b) cooperative getting in line. We compare several combinations of heuristics and present the queue formations that emerge. The two extremes, fully cooperative lining-up and aggressive competition, can be produced by guiding all pedestrians on either one of two floor fields: one that makes the target most attractive and one that makes the queue itself attractive. Depending on their behavioral choice, pedestrians consider either floor field. We allow the behavioral choice to change over time depending, e.g., on the nature of the environment and the situation. We argue that this model is in accordance with social identity theory which predicts behavioral norms arising within an escaping group [3].

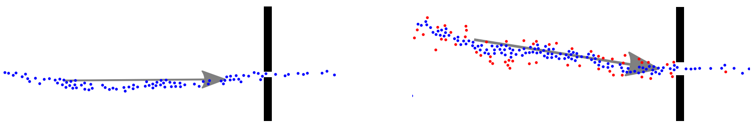

Figure 1: Snapshot of different queueing scenarios. The arrows (gray) indicate the walking direction of pedestrians. Left: Pedestrians queue up using a cooperative strategy during the entire time. Right: Pedestrians queue up in a more competitive way. Some are cooperative (blue) some are competitive (red) and head straight for the door.

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How do People Queue – A Study of Different Queuing Models

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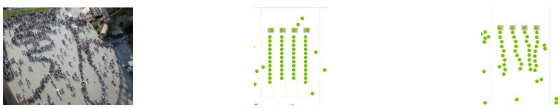
When observing crowds, an interesting aspect is the queuing behavior of people. Many different situations force people to queue: Waiting for a ticket counter, lining up for a train or bus, queuing in front of bottlenecks or simply waiting at a supermarket check-out. Such queues can be categorized into three main classes: (a) Organized queues: flexible demarcation tapes or barriers dictate the formation of a queue, (b) Queues in front of bottlenecks: Queues which naturally form in front of bottlenecks and (c) Un-organized queues: Queues which form without demarcation utilities (Fig. 1a)

For the first type of queues a lot of research has been done, inspired from classical queuing theory [1,2]. Here, the objective is to predict queue lengths and waiting times to make decisions about service provisions. Thus, a one-dimensional approach is sufficient, since the formation of the queue is given by the demarcation. The focus lies on waiting times and queue lengths.

The second type of queue was examined by Koester [3]. The authors state that people do not queue naturally in "mush-room"-shaped formations in front of bottlenecks. However, that is what most simulation models produce. In fact, the authors posit that pedestrian queue loosely in front of bottlenecks.

For the third type of queues we propose an agent-based model which allows approaching agents to line up at the end of the queue with a certain derivation from the queuing direction. This leads to a dynamic formation of queues. The update process is done individually: Each agent knows his predecessor, when the agent in front moves forward, he as well moves forward - with a certain relaxation time. The model produces livelike results for individuals as well as for groups and has been visually validated.

The full contribution covers a thorough investigation of existing queuing models, including the presentation and validation results of the newly proposed model.



(a) Queuing Eiffel Tower (b) Queuing Model Type 1 (c) Queuing Model Type 3

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The Relationship Between a Waiting Crowd and the Average Service Time

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This paper addresses the research question: What impact has the crowd in front of vendor stands on the average service time? In other words, the influence of the number of people and the shape of the crowd in front of vendor stands (e.g. food stands, concession stands or kiosks) on the average service time (the average time it takes for serving a single customer) is evaluated. The hypothesis, that a dense crowd in front of a vendor stand decreases the service time per person through increased pressure on the employees and therefore increased labor efficiency, is tested. The research question is examined for a music festival, where the queue shape in front of the vendor stand is often unorganized and densely packed and where furthermore batch arrivals occur [1].

For the analysis, three different approaches are used: qualitative reasoning, empirical observation and computer simulation. At first, a literature research, especially in the field of queuing theory [2, 3] is conducted to ground the paper in existing research. To the best knowledge of the authors, there exists no publication addressing the research question discussed above. In the first part of the paper, different effects that increase or decrease the average service time are proposed, discussed and grouped together. After that, video recordings are analyzed and data based on these recordings is presented. In the last part, a computer simulation is conducted with a pedestrian simulation software that has implemented the social force principles. Finally, a summary and a conclusion is provided.

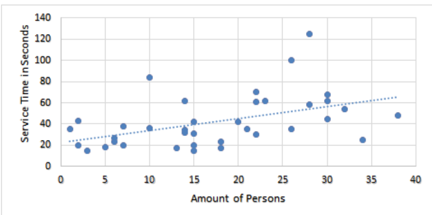

Figure 1: Empirical measurements of the service time and the amount of persons waiting in front of the vendor stand at the same moments in time. Data was collected at a music festival with over 5000 visitors in Garching, Germany.

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”How Do We Wait?” – Fundamentals, Characteristics, and Modelling Implications

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Pedestrian simulation models predominantly focus on the flow or motion of agents. However, in many real-world scenarios a large amount of pedestrians' time is spent waiting. We argue that this aspect of crowd behaviour should not be neglected in simulation studies. For instance, the initial spatial distribution of visitors of a mass event may contribute significantly to the overall evacuation time. In train stations, the unbalanced distribution of waiting passengers at platforms may affect the capacity utilisation of trains as well as boarding and alighting times [1].

In this paper, at the beginning we discuss social science concepts related to waiting, such as personal space requirements [2]. We do not focus only on the observable spatial behaviour, but take a broader perspective on the issue. For instance, the emotions and decision-making processes of pedestrians are typically not of direct interest to engineers, but research gives strong indications for their importance to modelling [3]. A broader understanding also leads to a more robust evaluation of model predictions and validity. For example, social norms for interpersonal distances when waiting can vary over cultures, even within Europe, and therefore empirical results might not be valid in another country [4].

We develop formal descriptions of waiting behaviours from underlying social concepts and observational perspectives. At first those are qualitative properties, which are subsequently complemented by quantitative measures. Both are important to assess pedestrian behaviour in real life, as well as in simulations. Only with a meaningful description of phenomena of interest can we calibrate and validate simulation models. We apply the defined measures to data from a field observation of passenger movement on a platform at a train station in Vienna. We specify several hypotheses for the mechanisms found for waiting passengers such as spatial distribution. Then we discuss their plausibility based on findings from the field observation. This leads us to the implications for modelling approaches to waiting, which have only recently been discussed as an important extension for the social force model [5].

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Steady State of Pedestrian Flow in Bottleneck Experiments

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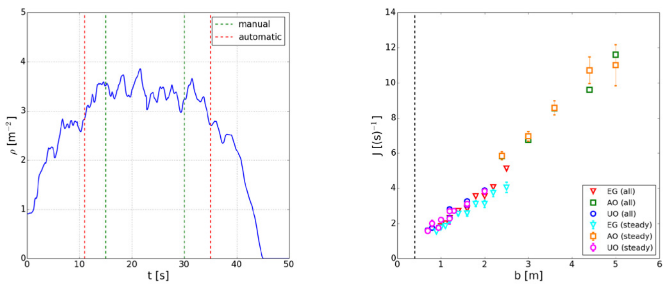
Steady state allows to draw conclusions from experiments which are independent from the initial conditions. However, most experiments in pedestrian dynamics are of short duration, which makes an automatic and robust identification of steady state difficult. In this work we propose a feasible CUSUM algorithm [1] to automatically detect steady state from density and speed time series (see Figure 1 (a)). For the improvement, a step function is introduced to enhance the sensitivity of the response to the fluctuations, a boundary is added, and an autoregressive model is used for the calibration. The modified CUSUM algorithm is applied to three groups of bottleneck experiments (see Figure 1 (b)). Previous study [2] shows that the flow using all data and using the data in steady state have different relationships with respect to the bottleneck width. Further on, we find that the difference mainly depends on the ratio of pedestrian number to bottleneck width. Compared with the manually selected steady state, our automatically detected one is accurate and reproducible.



(a) (b)

Figure 1: (a) Manual and automatic identification of steady state from time series of density. (b) Relationship between flow and bottleneck width.

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Statistical Models for Pedestrian Behaviour in Front of Bottlenecks

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Understanding the movement dynamics of human crowds passing through bottlenecks is important for our general understanding of group behaviour and for applications in building design and event planning. Here, we focus on narrow bottlenecks that only permit one pedestrian to pass at a time. We develop statistical models that describe pedestrian behaviour immediately in front of the bottleneck. With this approach we address two problems.

First, we seek to isolate the most important aspects of pedestrian behaviour from a number of candidate models. We fit our models to novel experimental data for pedestrian crowds passing through a 60cm wide bottleneck (fig. 1a). Model comparison suggests that at the time point when one pedestrian exits, the pedestrian who will exit next is already determined. This implies that for our data, pedestrian interactions immediately in front of the bottleneck are less important for the observed dynamics than interactions at larger distances upstream or downstream from the bottleneck.

Second, we demonstrate how our approach can be used to rigorously compare microscopic pedestrian behaviours across different contexts. Examples could include comparisons between non-competitive and competitive egress or between empirical data and simulated data. We fit the same statistical models for pedestrian behaviour to two additional data sets: another experimental data set (fig. 1b) and simulated pedestrian movement through a bottleneck (fig. 1c). There is good agreement in the findings from the two experimental data sets, suggesting that our approach robustly isolates important aspects of real pedestrian behaviour. In contrast to our analysis of experimental data, we find that in our simulations, the density of pedestrians immediately in front of the bottleneck is highly predictive of the observed dynamics. This shows that our approach is a promising tool to establish mechanistic similarities and differences between simulated and real pedestrian behaviour.

Figure 1: Datasets compared using our statistical model selection. (a), (b) experimental data. (c) simulated data. Our contribution is an illustration of principle and therefore we have deliberately not attempted to fit simulations to our experimental data.

Dynamic of Congestion in Pedestrian Traffic

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Understanding pedestrian dynamics is important for evacuation scenarios (forecast in real life and planning to support safety) and for optimisation pedestrian facilities in buildings and public areas like railway station, airport and shopping centre/mall. Thereby it is fundamental to know the conditions of the creation of a congestion and to describe the congestion itself.

This article considers executed one-dimensional laboratory experiments for pedestrians in a system with periodic boundary conditions, (Fig.1) left. The creation of congestions in pedestrian traffic (for diverse densities) is investigated. (Fig.1) on the right side shows the trajectories of pedestrians projected to the middle line of the given experiment ring.

At high densities pedestrian traffic separates into two distinct phases, standing pedestrians and accordingly moving pedestrians. The phase with standing pedestrians is called congestion. In our periodic system congestions can be described by the parameters number and length. We study those parameters depending on the density.

Furthermore, we investigate experiments with the same configuration as above. The participants are pupils of the lower grade and the upper school. Diverse body heights allow us to examine whether the degree of inhomogeneity influences the number and length.

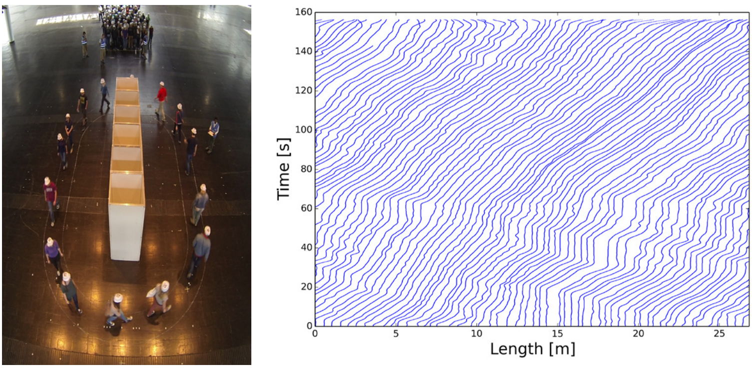

Figure 1: Left: Photo of the experiment, Right: Projected trajectories of pedestrians

Determining the Density Experienced by Pedestrians in Unstable Flow Situations

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In recent years several methods have been proposed to compute the density of a crowd. [1] and [2] both show that the fundamental diagrams produced by means of these methods differ greatly depending on the chosen density computation method. The lack of conformity between fundamental diagrams of distinct studies might indicate behavioural differences between the studies. However, the variation of the results might also be due to the use of different the computation methods or the parameter settings. As a consequence, it is currently difficult to compare research results.

The results of [1] and [2] suggest that two density computation methods (i.e. the Voronoi and XT method) are to be preferred over the others. [1] found that the Voronoi method is capable of visualizing discontinuous trends in the fundamental diagram. [2] shows that the XT-method, which is an adapted version of the method proposed by [3], provides good results for uni-directional flows through a bottleneck. These two studies show the applicability of the Voronoi and XT-method in fairly stable confined uni-directional situations.

In light of these results, the question rises whether these two computation methods also provide better results in more intricate flow situations that are unstable by nature. That is to say, can these two methods also be used to assess the density experienced by pedestrians in unstable flow situations. This paper aims at providing an assessment of the applicability of the Voronoi method and the XT-method in these more intricate flow situations.

In the assessment each computation method is tested by means of four distinct scenarios, namely the movement of pedestrians along a line, in a wide corridor, in a bottleneck situation and in a bi-directional flow situation. The input of the assessment is trajectory data resulting from simulations of the scenarios performed in Nomad. Accordingly, the distribution of the density over space and time and the fundamental diagram are estimated.

This study concludes that particularly in the assessment of pedestrian movement dynamics in non-confined spaces both methods introduce significant noise. Moreover, this study shows that if computing the density of pedestrian movements in confined spaces, the differences in the results generated by the two methods are limited. This study, furthermore, ascertains that the XT-method provides more realistic results for non-confined spaces due to the limitations set by the space-time box.

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How to Get a Model in Pedestrian Dynamics to Produce Stop And Go Waves

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Stop and go waves are a prominent feature of flows of both pedestrians in corridors [1] and cars on highways [2]. Even in homogeneous (and thus artificial) conditions, these waves can occur "out of nowhere", meaning that a small error in the system can increase exponentially and change the flow from homogeneous to wavelike. This behaviour is well known in mathematics as hopf bifurcation of a dynamical system, where at a certain parameter setting, the system suddenly enters two or more different steady states, depending on the initial conditions.

We show that a certain class of microscopic models in crowd dynamics has such a hopf bifurcation, among them the recently proposed Gradient Navigation Model [3]. The exact parameter values of the bifurcation point are computed analytically. An interesting phenomena arises: the number of pedestrians in the system must be greater than or equal to ten for a bifurcation (and hence stop and go waves) to be possible at all. Below this number, no parameter setting will cause the system to exhibit a stable stop and go behaviour.

The result is also interesting for car traffic, where similar models to the one that is being examined exist. It is particularly important for automatic distance control mechanisms in cars: exactly this perfect alignment to the preceding car can cause the system to enter a stop and go state if the settings are tuned incorrectly.

Numerical experiments of several parameter settings and number of pedestrians are used to illustrate the mathematical results (see Fig. 1). Note that the given class of models does not suffer from overlapping of pedestrians.

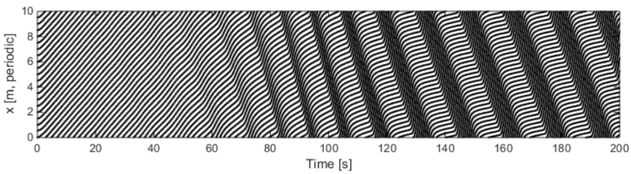

Figure 1: A 1D-scenario with 20 pedestrians and periodic boundary conditions.

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A Force-Based Model to Reproduce Stop-And-Go Waves in Pedestrian Dynamics

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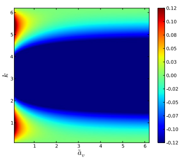
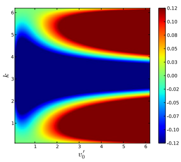
Stop-and-go waves in one-lane movement are a phenomenon that is observed empirically in pedestrian dynamics [1]. It manifests itself by the co-existence of two phases: Moving and stopping pedestrians. However, the properties of the phase separated state are different from those observed in vehicular traffic. The moving phase does not consists for pedestrians moving at desired (maximum) speed, in contrast to the situation in vehicular traffic. Therefore ideas from vehicular traffic can not easily be applied directly to pedestrian motion. We show analytically based on a simplified 1-D scenario that under some conditions the system can be described as a harmonic oscillator. Hence, oscillations in the trajectories and instabilities emerge during simulations. Yet, the dynamics has to remain collision-free.

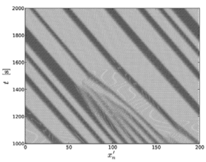
In this paper we develop a new force-based model for pedestrian dynamics able to reproduce qualitatively the phenomenon of phase separation. We investigate analytically the stability condition of the model and define regimes of parameter values where phase separation can be observed. We show by mean of simulations that the predefined conditions lead in fact to the expected behavior and validate our model with respect to empirical findings.



(a) Stability region with respect to the velocity dependency of pedestrian's shape.



(b) Stability region with respect to the desired speed of pedestrians.



(c) Simulation: Trajectories of pedestrians showing phased separation.

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Impact of Impulse Stops on Pedestrian Flow

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Walking is a fundamental activity of human life, not only for moving between places but also in interactions with surrounding environments. While walking to destinations, pedestrians may be influenced by attractive stimuli such as works of art and shop displays. Some pedestrians may shift their attention to such attractions, opting to stop walking and making an impulse stop to join an attraction [1].

By means of numerical simulations, we have investigated the impact of impulse stops on pedestrian flow for a straight corridor with multiple attractions. This study extends the switching behaviour model which postulates that the probability of pedestrians joining an attraction is associated with the number of pedestrians already staying near an attraction [2]. According to previous studies [3, 4, 5], it has been reported that a growing number of attendees around an attraction are likely to attract more passersby to the attraction, inferring that impulse stopping pedestrians can be affected by others' choice. While some pedestrians show impulse stops, other pedestrians are assumed to show non-impulse behaviour, meaning that they had determined which attractions they would visit before entering the corridor. Once pedestrians have joined an attraction, they are assumed to stay near it for a certain amount of time. For different proportions of impulse stopping pedestrians, we analyse the spatio-temporal dynamics of pedestrians such as flow, density, and speed over the simulation period. We believe that our study results can provide an insight into the optimal design and better management of pedestrian facilities where impulse stops may be expected to occur. By supplying an understanding of the impact of impulse stops on pedestrian flow, attractions can be more appropriately placed in pedestrian facilities such as airports, terminals, and shopping centres.

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A Multi-Class Vehicular Flow Model for Aggressive Drivers

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The kinetic theory approaches to vehicular traffic modeling have given very good results in the understanding of the dynamical phenomena involved [1, 2]. In this work we deal with the kinetic approach modeling of a traffic situation where there are many classes of aggressive drivers [3]. Their aggressivity is characterized through their relaxation times. The reduced Paveri-Fontana equation is taken as a starting point to set the model. It contains the usual drift terms as well as the interactions between drivers of the same class, as well as corresponding one between different classes of drivers. The traffic state used as a reference in the kinetic treatment is determined by a dimensionless parameter. Also, the kinetic equation is taken to write the balance equations for the density and the average speed in each drivers class. In this model we consider that each class of drivers preserve the corresponding aggressivity, in such a way that there will be no adaptation effects [4]. It means that the number of drivers in a class is conserved. As preliminary results, we obtain a closure relation to derive the Euler-like equations for two drivers classes. Some characteristics of the model are explored with the usual methods.

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Microscopic Simulations of Oversaturated City Traffic: Features of Synchronised Flow Patterns

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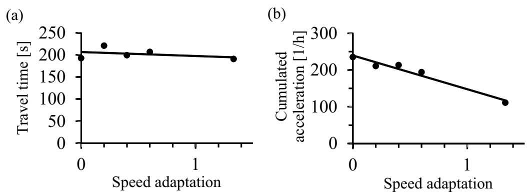
Understanding the physics of vehicular traffic and the emergence of traffic patterns in city traffic is important for the implementation of traffic management measures. Recently, the synchronised flow pattern has been found in empirical GPS probe vehicle data of oversaturated city traffic [1]. Traffic simulation models based on classical theories cannot reproduce this synchronised flow. We present simulation results of oversaturated city traffic with the stochastic microscopic Kerner-Klenov traffic flow model that is based on Kerner's three-phase traffic theory.

The main effect responsible for the emergence of synchronised flow patterns is the driver's speed adaptation. This effect describes how quick a driver adapts his or her speed to that of a slower moving vehicle in front, if he or she cannot change lanes. The effect is implemented into the model. The influence of the strength of the speed adaptation effect on the emergence of traffic patterns in oversaturated city traffic is analysed. Simulation results show that under strong speed adaptation, synchronised flow patterns can be produced in oversaturated city traffic. Under the influence of weak speed adaptation classical moving queue patterns emerge.

The strength of the speed adaptation effect influences the distance to the traffic signal (in upstream direction) at which moving queues dissolve into synchronised flow. We show and explain the emergence and subsequent dissolution of synchronised flow patterns in the simulations. The prevailing traffic pattern on a road affects vehicle parameters such as travel time or the recently developed cumulated vehicle acceleration [2] as shown in Fig. 1. The latter can be used as a measure for fuel consumption.



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Traffic Simulations with Empirical Data – How to Replace Missing Traffic Flows?

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For the real-time simulation of traffic on a real-world road network, a continuous input stream of empirical data from different locations is usually needed to achieve good results. Traffic flows for example are needed to properly simulate the influence of slip roads and motorway exits. However, quality and reliability of empirical traffic data is sometimes a problem, for example because of damaged detectors, transmission errors or simply lane diversions at road works.

In case of missing data, a decision has to be made how the simulation shall handle this issue. Here, different strategies are possible, from simply doing nothing in case of short-term gaps up to replacing the missing data using data from previous timestamps and/or neighbouring detectors.

In the work under preparation, we will compare a time-oriented approach with a space-oriented approach to replace missing traffic flows.

The time-oriented approach [1] is based on exponential smoothing a set $\mathbf{j}$ of historical traffic flows. $\mathbf{j}$ comprises previously collected traffic flows from up to 30 timestamps t, which are chosen by a clustering algorithm that distinguishes between different weekdays, school holidays and public holidays. The predicted flow j_t^* is then obtained by

$$j_t^* = 0.8 j_t + 0.8 \sum_{i=1}^{t-1} (1-0.8)^i j_{t-i} + (1-0.8)^t j_0 \ , \tag{1}$$

where j_t is the most recent historical traffic flow.

For the space-oriented gap filling [2], Poisson Dependency Networks (PDN) are used. Here, the set $\mathbf{j}$ comprises traffic flows from other detectors, but measured at the same time. The local model to obtain a traffic flow for detector a can be written as

$$p(j_a|\mathbf{j}_{\setminus a}) = \frac{\lambda_a^{j_a}(\mathbf{j}_{\setminus a})}{j_a!} e^{-\lambda_a(\mathbf{j}_{\setminus a})} \ , \tag{2}$$

where $\lambda_a(\mathbf{j}_{\setminus a})$ is a function modelled by Poisson regression trees, depending on all other detectors except for the faulty one, which is denoted as $\mathbf{j}_{\setminus_a} = \mathbf{j} \setminus \mathbf{j}_a$.

For the comparison, empirical traffic data from different areas of the motorway network of the German state North Rhine-Westphalia will be used. Additionally, road works data and police warning messages will be taken into account.

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Dynamic Model for Assignment in ”Sky-car” Transit System – Spatial Interactions with other Common Transport Modes

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In this paper, we provide Lagrangian dynamic fluid model for traffic of personal rapid maglev transporters. Maglev transporters denote the rapid vehicles using a system relying on magnetic levitation rather than wheels or conventional motors to propel cars, that we call sky-cars, along sky-railways lanes, resulting in nearly silent transportation. Assuming that sky-cars or pods are labelled according to a snapshot of line from downstream to upstream, the pod's labels $a \in \Lambda$ will increase with the position x. The dynamic of the pods along the sky transit network is governed naturally by the following proposed control laws [1, 2]: $\forall t \geq 0, \forall a \in \Lambda, \exists!(j) \in A_M$ such that:

$$\begin{cases} x_a^j(t+1) = x_a^j(t) + \Delta t u_a^j(t) \\ u_a^j(t) = \min\Big(U_e\big(x_{a-1}^j(t) - x_a^j(t)\big), u_{p_a}\big(x_a^j(t)\big)\Big) \end{cases} \tag{1}$$

where t is the time variable, x_a^j the position on the link (j) of the car labelled by a, Δt the time step, $u_a^j(t)$ the speed of the pod a at time t and on link (j). $U_e(.)$ denotes the speed equilibrium relationship, and $u_{p_a}(.)$ denotes the sky-car velocity profile that may depend on the pod a, the charge of the current link (j) and its mission. A_M is the set of all the links of the transit network. Λ is the set of all the pods of the system in the traffic, at rest or on the move. The pods are assumed equipped with an adaptive cruise control that increases the driving comfort, thereby reducing traffic incidents and increasing the traffic flow throughput. The proposed Lagrangian fluid model considers

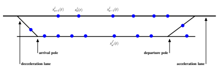

Figure 1: Notations of sky-car following model

the evolution of sky-car travelers' demand, and other context elements to obtain a more dynamic model, like the environment context [3], such as weather, or user context such as user preferences in term of transport mode [4] or user timetable.

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Impact of Synchronized Flow in Oversaturated City Traffic on Energy Efficiency of Conventional and Electrical Vehicles

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Navigation devices used in vehicles provide real field GPS data. In this study of city traffic, we relate these GPS data to empirical fuel consumption data of vehicles. We show that empirical synchronized flow patterns, which have been revealed recently in oversaturated city traffic [1], exhibit considerable impact on the energy efficiency of vehicles on urban road sections. In particular, we have found out that fuel consumption in oversaturated city traffic can decrease considerably when the oversaturated city traffic consists of synchronized flow patterns rather than consisting of moving queues of the classical traffic flow theory at traffic signals. With the use of empirical data from two different road sections in the city of Düsseldorf, Germany, we show that synchronized flow patterns and moving queues differ in their cumulated vehicle acceleration (a sum of positive speed differences along a vehicle trajectory) despite similar mean vehicle speeds. Fuel consumption in return is dependent on the cumulated vehicle acceleration because the accelerations of vehicles at lower speeds intensively influence the overall fuel consumption. This dependency of fuel consumption on the cumulated vehicle acceleration is obtained by means of a macroscopic consumption matrix which is based on empirical fuel consumption data as well as speed and acceleration profiles from traffic flow simulations [2].

In addition to the results for a vehicle with a conventional combustion engine, we use this approach for a purely electrical vehicle: differences and similarities of the macroscopic consumption matrix for these two kinds of vehicles are shown and discussed in the article.

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Evaluation of Transportation Network Resilience Using Adaptive Capacity

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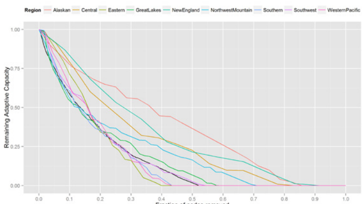
Securing network resilience in air transport system is essential to provide a stable level of service because it is one of major travel modes carrying international passengers and freights. In 2014, about 662 million passengers and 20,305 million pounds of freights are delivered by over 8.5 million flights in the United States. As seen in Iceland volcano eruption in 2010, a deficiency of hub airports can bring a huge impact on the whole transport system and even the world economy. So how the failure of individual node affects the overall network resilience is needed to be investigated.

Air transportation is one of representative scale-free networks, which has a few of hubs having high degree. It is known to be relatively robust against failure but vulnerable to targeted attack on hub. There are numerous studies devoted to measure node vulnerability and evaluate network robustness. A number of researchers analyzed topological properties of air transportation and resilience in terms of network structure. Other studies have proposed the network robustness index and the robustness coefficient, however, these studies could not consider the node capacity for evaluating overall network performance.

This paper focuses on the network-side resilience, where the nodes are located in a real space with a capacity to function. Using the data from Federal Aviation Administration, we demonstrate the network simulation and evaluate the US air transportation network resilience. In the study, we propose adaptation indices for quantifying network resilience in terms of adaptive capacity, the ability of a network to replace an attacked node by other adjacent nodes. The simulation has two parts to measure the adaptive capacity of networks under a single attack and the percolation model.

The results identify the susceptible nodes degrading the adaptive capacity of the network and evaluate each sub-networks resilience in case of cascading node failures. These findings are different from assessment of individual nodes, but have advantage of evaluating system-wide resilience. Therefore this study can help us to determine influential node and prioritize the plan for improvement of network resilience.



Network-Wide Mesoscopic Traffic State Estimation Based on a Variational Formulation of the LWR Model

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Traffic state estimation and short-term prediction are central components in dynamic traffic management. In essence, model-based traffic state estimators consist of a dynamic traffic flow model to predict the evolution of state variables; a set of observation equations relating sensor observations to system states; and data-assimilation techniques to combine the model predictions with the sensor observations.

This paper deploys a mesoscopic formulation of the LWR model in Lagrangian-space coordinates. The term mesoscopic is in response to its two other counterparts, since the Lagrangian-time coordinates can apply in a microscopic simulation framework and the Eulerian coordinates can accommodate in a macroscopic one. The current mesoscopic formulation combines a vehicular description with macroscopic behavioral rules. It relaxes the temporal coordinate, and this entitles a transformation of a temporal progressing approach to an event-progressing approach.

Specifically, a variational formulation of the LWR model is selected. Compared to the traditional conservation law approach, this formulation entitles a simplified expression and more accurate numerical results in the prediction step. Moreover, the related node model for network discontinuities in the Lagrangian-space framework is developed. Its corresponding observation models are also included to incorporate both spatial-fixed and moving observations. Both models can maintain the system linearity, thus a linear Kalman filter is applied.

Recent studies [1, 2] have shown that the Lagrangian-time formulated traffic flow model can deliver more accurate simulation and efficient data assimilation. The current formulation can incorporate the numerical benefits and modelling flexibility of Lagrangian-time models. Simultaneously, this formulation allows state distinction on both link class and vehicle class. More importantly, this scheme is particularly convenient for state estimation, because in reality, the flow characteristics are mostly observed at fixed point (spatial fixed) or along vehicle trajectories (vehicle number fixed). These observations are located on cell boundaries of the mesoscopic grid, which makes any traffic state estimation method convenient with this approach. Moreover, travel time can be directly derived from system estimates, and no state transformation is required compared to other estimation approaches. The proposed node model can further facilitate network-wide applications.

This framework is validated using synthetic data generated by a microscopic traffic simulation. Future work is needed to include empirical dataset to test the performance of the method in reality.

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Route Choice Behaviour in a Three Roads Scenario

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The project DiNav - Dynamics in Navigation [1] part of the EffizienzCluster Logistik Ruhr investigated the route choice behaviour in complex and dynamic systems. As part of our studies we simulated a system of three parallel roads with different lengths of 20 km, 22 km and 24 km. Each road has two lanes and the same bottleneck structure at their end. The simulation splits the traffic into two vehicle types, a car class (90% of vehicles) and a hgv class (10% of vehicles). A basic traffic load was assigned to each of the three roads. The base load is 75% of the specified value of the total traffic flow in the simulation. This basic setting is a stable undersaturated system.

The actual study examined the remaining 25% of traffic and the way of distributing it over the network. We assume that these vehicles choose their roads by given information for example by the advice of a personal navigation device (PND). We considered routing strategies based on the following observables:

- shortest path,
- equal distribution,
- travel times of the observed vehicles,
- travel times of all cars,
- traffic flow,
- mean traffic flow over a period of time.

We were especially interested in the routing strategies based on the traffic flow. For the algorithm we assumed a maximum road capacity of 40 vehicles per minute. Based on this value and the known traffic flow a remaining capacity for each road is calculated. This information is then used to distribute the routing advice.

The results show that the shortest path algorithm leads to an oversaturated and jammed system. An equal distribution of additional traffic gives better results than strategies based on the travel time. This is probably due to the fact that we studied very long road segments and that a car needs more than 10 minutes to pass through the route even in free flow. The best results were accomplished by measuring the traffic flow of each road and distribute the advices depending on this information.

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Calibrating the Local and Platoon Dynamics of Car-following Models on the Reconstructed NGSIM Data

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The NGSIM trajectory data [1] are used to calibrate two car-following models - the IDM and the FVDM. Both models contain five parameters and are therefore formally equivalent in their complexity. We used the I80 dataset which has been reconstructed to eliminate outliers, unphysical data, and internal and platoon inconsistencies contained in the original data [2]. This set contains 3366 vehicle trajectories through congested traffic allowing to obtain parameter value distributions. Data filtering algorithms are developed to eliminate short trajectories, lane-changes, and the beginnings and ends of the records.

Four error measures based on acceleration, speed and gap deviations are considered [3]. Furthermore, we apply three calibration methods: In local or direct calibration, the model's acceleration function is fitted directly to the observed accelerations without any simulation. In global calibration, the follower's trajectory is simulated for a data-driven leader and data-driven initial conditions. In "super-global" or platoon calibration, a platoon of several vehicles following a data-driven leader is simulated and compared to the observed dynamics. To our knowledge, the last approach is novel.

For both models and all error measures, we found average errors between 8.3 % and 12.5 % for the global calibration while the platoon calibration resulted in errors between 12.8 % and 32.4 %. Since global calibration pertains solely to intradriver variability while platoon calibration depends on both intradriver and interdriver variabilities [3], the different errors allow to estimate the relative contributions to these variabilities. Assuming orthogonality, we found that the variance ratios between interdriver and intradriver variations are 0.6-0.7 for the speeds, and 4.7-5.9 for the gaps, respectively. Since gaps, unlike speeds, can be chosen freely in congested traffic, we consider the latter ratios to be the relevant ones.

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Scaling from Circuit Experiment to Real Traffic based on Optimal Velocity Model

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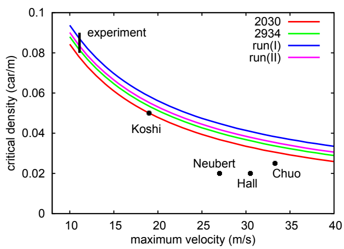
The critical density of the transition between free flow and jammed flow was estimated by a indoor circuit experiment[1]. In this paper, we investigate the relation between the critical density obtained in the experiment and that observed in real traffic based on the optimal velocity (OV) model. First, parameters of the OV model are determined by the data of the experiment. The occurrence and non-ocurrence of jammed flow in the experiment agree with the prediction of the model with the determined parameters. Next, we investigate a scaling rule of the parameters in the model. In our scaling method, it is supposed that so-called sensitivity parameter is unchanged and only the OV function is scaled.

$$V(h) = \alpha \tanh[\beta(h - h_0)] + \gamma \, , \tag{1}$$

$$(\alpha, \beta, h_0, \gamma) \to (\alpha', \beta', h_0', \gamma') \, , \tag{2}$$

where h is headway and $\alpha,\ \beta,\ h_0,\ \gamma$ are parameters. When the stop-and-go flow is realised, the OV model indicates that the backward velocity of jam clusters is decided by minimum and maximum values of headway and velocity, and also the inflection point (h_0, γ) of Eq.(1). We propose a scaling rule using a fact that the backward velocity of jam clusters are common for the circuit experiment and real traffic. When (h_0', γ') for real traffic is given, parameters (α', β') for real traffic is calculated from parameters for the experiment. By use of this scaling rule, we can calculate the critical density for arbitrary scales. Figure shows relations between the critical density and maximum velocity obtained for four cases of experiments. Critical densities estimated for real traffic are also shown.



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Traffic Flow Optimization at Sags by Controlling the Acceleration of Some Vehicles

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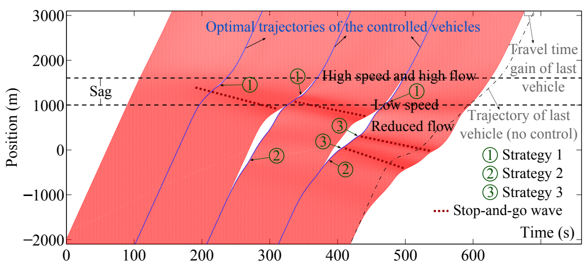
Sags (or sag vertical curves) are bottlenecks in freeway networks. The main cause is the acceleration behavior of drivers along this type of freeway sections. Various specific traffic management measures for sags have been proposed in the last years. We argue that, before designing new measures, it is crucial to determine how vehicles should ideally behave at sags in order to minimize total delay.

This paper presents an optimal control framework aimed to identify the ideal longitudinal driving behavior of selected vehicles along sags and its impacts on traffic flow dynamics. We formulate a control problem in which a centralized controller regulates the acceleration of a number of vehicles in a traffic stream that goes through a single-lane sag. The control objective is to minimize total travel time. The problem is solved for various scenarios with different initial traffic conditions, number of controlled vehicles and positions in the stream. The results show that the optimal longitudinal driving behavior of controlled vehicles is generally defined by a mixture of three strategies: 1) quick deceleration-acceleration maneuver in the sag; 2) slowing down upstream of the sag; and 3) quick deceleration-acceleration maneuver upstream of the sag.

Strategy 1 is used to create a low-speed region at the beginning of the sag, which induces drivers to accelerate faster along the vertical curve. Strategy 2 is used to (partially) dissolve a stop-and-go wave. Strategy 3 is used to trigger a new stop-and-go wave or to amplify an existing one. By adequately combining strategies 2 and 3, the controller is able to manage congestion upstream of the sag in such a way that the inflow to the bottleneck is regulated in an optimal manner. In most scenarios, the combined effect of the three strategies is the substitution of congested traffic by high-flow uncongested traffic at the end of the sag (bottleneck). New traffic management measures can be designed based on the strategies identified in this paper.



Multimodal Traffic on Networks with Information

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V2V and V2S communication is developping very fast; for instance the use of VANETs for traffic management has been the object of intensive study: refer to [1], [2], [3]. The flow of information is instantaneous, non directional, and it is liable to induce adverse effects (Braess-like paradoxes) at a local level and also, in the case of routing, at a global level. In order to study such effects, we propose in this paper to analyze macroscopic and mesoscopic traffic modeling in conjunction with information flow. The difficulty is that classical macroscopic traffic modeling is based on a finite information speed propagation (wave speed/car following) in contrast to V2X communication.

The setting of the problem is multi-modal: all modes sharing the road infrastructure will be considered (private cars, taxis, demand responsive transportation, electrical cars, ...). All these modes are affected by the information flow. The starting point of our model will be constituted by the GSOM model ([4], [5], [6]), which combines a LWR-like kinematical representation of traffic, with dynamics of driver attributes. The driver attributes include modal and OD descriptors and thus enable the description of a multimodal system with assignment. They also include the impact of information on users and enable the modeling of this impact, particularly at the mesoscopic level. Information has an instantaneous long range impact. The study of routing issues will be addressed based on ideas of [7] concerning reactive dynamic assignment, and [8] for behavioral and modeling aspects. The emphasis in this part of the paper will be on the prevention of adverse effects of the interplay between instantaneous information flow, traffic flow and assignment.

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THURSDAY, 29.10.

Distributed Information Systems to Assist Pedestrians, Traffic and Logistics

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Traffic systems are highly complex multi-component systems suffering from instabilities and non-linear dynamics, including chaos. This is caused by the non-linearity of interactions, delays, and fluctuations, which can trigger phenomena such as stop-and-go waves, noise-induced breakdowns, or slower-is-faster effects.

Recent information and communication technologies (ICT), promise new solutions for congestion avoidance. For example, adaptive cruise control systems (ACC) now enhance traffic performance by increasing the stability of traffic flows and the capacity of the road. Vehicles become automatic traffic state detectors, data management, and communication centers when forming adhoc networks through intervehicle communication (IVC) concepts.

These concepts lead from the classical, centralized control to decentralized approaches in the sense of collective (swarm) intelligence and ad-hoc networks. Such concepts reach more adaptiveness, flexibility, resilience and robustness with respect to local requirements and temporary failures.

Another interesting problem is adaptive traffic control in urban road networks. Synchronization is only one approach to reach coordination among neighboring traffic lights, including green waves. We propose an adaptive strategy of traffic light control which can considerably improve throughputs and travel times, using self-organization principles based on local interactions between vehicles and traffic lights.

Finally, I introduce the Nervousnet project, a real-time measurement platform to jointly produce a data commons, which will create many new application opportunities.

Modeling Stride Length and Stepping Frequency

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A pedestrian motion model must be calibrated to measured data and validated against observations to achieve predictive power for the simulations.

The relationship between the speed of pedestrians and the density of a crowd is widely accepted as an important characteristic of pedestrian movement. The fundamental diagrams that have been determined in controlled experiments or in field observations are often used to validate or calibrate models for pedestrian dynamics. However, other crucial characteristics of pedestrian movement have been discovered in recent studies.

In several experiments, the correlations between stride length and speed as well as stride length and density have been investigated. The stride length of walking pedestrians in a free area depends linearly on their speed [1]. In denser situations, when pedestrians reduce their speed, they also reduce their stride length [2]. Another important observable is the stepping frequency. It rises slowly with the speed [3,4].

These correlations between stride length, frequency, density, and speed can only be reproduced by a pedestrian locomotion model that captures stepping behavior. We show that, with the Optimal Steps Model (OSM), one can reproduce the dependencies as measured in the experiments in [2,3,4].

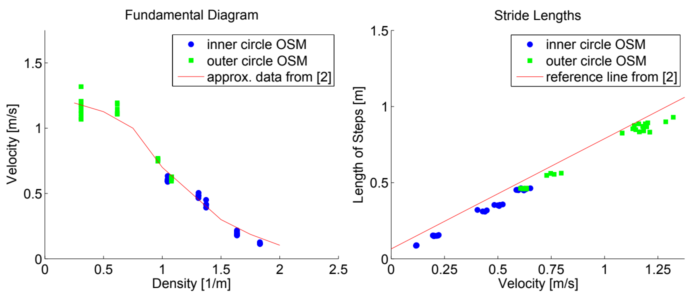

Figure 1: Results of a reproduction of the ring experiment from [2] with the OSM.

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Experimental Study on the Influence of Step Phase in Pedestrian Movement

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Abstract
The relationship between the required length and velocity is very fundamental in pedestrian dynamics, and it is also of great importance in building pedestrian movement model. However, it is found that even the experiment conditions are strictly controlled, the velocity of one pedestrian varies significantly with the same headway. It implies that the micro-level states of pedestrians should be considered thoroughly and its influence to macroscopic parameters need to be quantified.

A single-file pedestrian movement experiment is carried out to analyze the microscopic moving characteristics of pedestrians. The trajectories of participants in a straight passageway are extracted through an image processing method based on mean-shift algorithm. The transverse swing of trajectories is correlated with the phase of pedestrians' step period. The stride length and frequency of pedestrians are collected from the trajectories. We mainly focus on the lock-step effect in the experiment. It implies that the pedestrian moves forward with the front neighbour in a same time-step in the high density and low velocity[1]. Some researchers have found lock-step effect has a significant impact on pedestrian microscopic behaviors under high density. Here we further analyze the influence of step phase differences and headway on the stride length and micro-level movement process[2]. Results of high-density experiment show that pedestrians can still move with a low velocity when the step phase difference between neighbours is small, but pedestrians will stop when the phase difference increases. It is also found that the synchronization of lock-step group varies during the movement. The findings can give the stop-and-go phenomenon a new microcosmic explanation. It is hoped that this study would be useful for the evaluation of pedestrian microscopic movement and the development of evacuation models.

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The Influence of Moore and von-Neumann Neighbourhood on the Dynamics of Pedestrian Movement

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Developing models for pedestrian and evacuation dynamics using a cellular automata is based on the fundamental question of the neighbourhood pedestrians should use to move from one point to another point in a selected geometry. If a rectangular lattice is used for pedestrian movement and geometry representation, there are two possible types of neighbourhouds, which can be chosen:

- the Moore-Neighbourhood or
- the von-Neumann-Neighbourhood

Both neighbourhoods (see Figure 1) are used in different kind of models, e.g. the PedGo-Model [2] uses a Moore-Neighbourhood, the Dynamic Floor Field Model [1] uses a von-Neumann-Neighbourhood.

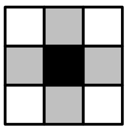

Figure 1: von-Neumann-Neighbourhood: pedestrian (black cell in the center) can only move to gray cells by moving over edge, by using a Moore-Neighbourhood the pedestrian can additionally move to the white cells by moving over corner

To show the effect the chosen neighbourhood has on the dynamics of pedestrian movement, different scenarios are investigated using both neighbourhoods by using the same evacuation model. Additionally to that it will be discussed how to deal with the fact that pedestrians moving in a Moore-Neighbourhood can move a larger distance by moving from cell to cell ($\sqrt{2}$ longer distance when moving over corner) contrary to moving in a von-Neumann-Neighbourhood, where pedestrians only move over edge from cell to cell.

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Methodology for Generating Individualized Trajectories from Experiments

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Traffic research reached a point where trajectories are available for microscopic analysis [1, 2]. The next step would be trajectories which are connected to human factors, i.e information about the agent. The first step in pedestrian dynamics has been done by [3] and others, who use video recordings to generate precise trajectories. We go one step further and present two experiments for which ID-markers are used to produce individualized trajectories. (1) A large scale experiment on pedestrian dynamics. (2) An experiment on 1D bike traffic.

The camera set-up has to be carefully chosen when using ID-markers. It has to read out the markers, while at the same time being able to capture the whole experiment. This leads to contradicting requirements when using only one camera, since a single camera will not offer a high enough resolution to do both. In this paper we propose two set-ups to address these problems. We outline the design decisions during the planning of these experiments. We show how detailed but local observations can be transferred to trajectories collected from the entire set-up.

One option is to only read out the markers in part of the scene, using one of the cameras. Trajectories can still be generated for other cameras, but might not have IDs attached to them. Then the IDs can be transferred to these anonymous trajectories, using overlapping cameras and a minimum of geometry information.

Alternatively, the ID markers themselves can be used to connect the generated trajectories across the views of different cameras. They can also be utilized to connect the trajectories to further knowledge which is needed to produce meaningful and precise 3D trajectories. For example, monocular cameras are not able to generate 3D positions if the heights of persons are not known. If their heights are known from another source, they can be connected to the trajectories using the marker IDs.

Data from these two experiments has already been used in pedestrian dynamics and traffic research [4, 5].

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Advances in Measuring Pedestrians at Dutch Train Stations using Bluetooth, WiFi and Infrared Technology

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Due to technological developments, decreasing sensor costs and an increasing demand for traffic data, automated pedestrian sensor technologies are being deployed in an increasing number of pedestrian facilities. Examples are airports, inner cities and festivals. The data from these sensors are used for various applications, such as scientific research and practical facility design and operations.

Depending on sensor and data processing configuration, automated measurements generate local or global data. Local data describe pedestrian movements at a specific location inside a facility, for example trajectory data of flows near entries and exits. Global data describe pedestrian movements in a larger area, for example flows between entry A and point-of-interest B.

Since 2012, three Dutch train stations have been equipped with automated pedestrian traffic sensors, as result of the SMART Station initiative of Netherlands Railways. The concept consists of hybrid Bluetooth/WiFi sensors of BLIP Systems and infrared sensors of IRISYS. The Bluetooth/WiFi sensors track global movements and dwell times of mobile radio devices (ie. smart phones, tablets and laptops) in the facility . The sensor configuration and the data processes are tailor-made to make sure that the privacy of the person who carries the mobile devices is respected. The infrared sensors count local passenger traffic at strategic points inside the station. Combining global and local data results in a detailed picture of pedestrian dynamics in the facilities. Currently, there are over one hundred sensors installed at three of the largest stations in the country: Utrecht Central Station, Amsterdam Airport Schiphol station and Leiden Central station, with respectively 250.000, 83.000 and 85.000 train passengers per day.

SMART Station data has been used in previous research on route choice behaviour in train stations, in particular with respect to vertical circulation infrastructure. However, many other kinds of pedestrian dynamics occur at train stations. In this paper we will present new, preliminary results of our on-going research at Dutch train stations. Firstly, an estimation of escalator capacity will be presented, based on several months of data collection. Secondly, we will show the temporal and spatial flow characteristics between a station and two bike parking facilities in the station area. Thirdly, the use of train stations by non-train passengers will be explored. These flows are mostly the result of train stations connecting two sides of the city which are separated by the railway tracks. Fourthly and finally, station occupancy will be explored, which describes the number of passengers inside the building at any moment of time. This topic is extremely relevant for estimating the size of station halls and platforms, which both combine the function of walking (flow) and waiting (dwell).

Avoiding Walls – What Distance do Pedestrian Keep from Walls and Other Obstacles?

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An important aspect of pedestrian movement is the avoidance of obstacles. When moving around, pedestrians actively avoid colliding with walls and obstacles and aim to keep a certain distance to them. In pedestrian simulations [1] as well as in analytical approaches to pedestrian flow characteristics this behaviour has to be respected. When using analytical calculations to estimate the level-of-service for a flow cross-section, a separation distance is usually subtracted from the actual width of the walkway to reflect the influence of walls and obstacles on the capacity of the walkway. The obtained effective width can then be used to calculate the density and thus the level-of-service using the fundamental diagram. Depending on the characteristics of the wall or obstacle, different values can be used for the separation distance. In literature, only few values for these distances were found, which are sometimes even contradictory [2, 3]. Knowledge about the precise mechanisms of this separation distance does not exist. This is corroborated by the lack of data in the field.

This work aims at contributing to the knowledge about the pedestrian-wall distance by applying observations techniques with high spatial resolutions. For the determination of the distances kept from walls, small ultrasonic sound sensors were used which were attached to the wall. They measure the distance to the nearest obstacle in front of the sensor. In another experiment, the distances and trajectories of pedestrians passing an obstacle were obtained using a laser scanner. Compared to video recordings and other observation techniques this enables a much more accurate measurement of the separation distance. Using this data the distribution of pedestrian-wall distances can be studied and a suitable method to determine the minimum separation distance can be found.

The results confirm the previous observations that pedestrians keep a certain minimum distance from walls and obstacles. As was expected, the effect of obstacles on pedestrian flows is not limited to the cross section in which the obstacle occurs and can also be observed upstream. Furthermore, it was found that the distance kept to obstacles is dependent on the pedestrian density. Additionally, this paper suggests a method for determining the effective width of walkways that can be used in pedestrian facility design.

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Measuring and Modelling Crowd Flows - Fusing Stationary and Tracking Data

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While vehicular traffic data analysis and flow modeling is a mature research field [1], only few scientific investigations exist for the dynamics of unidirectional crowd flow, particularly in mass-sports events [2, 3]. Nevertheless, the problems for the organizers of such events are similar to that of road transportation managers: Optimize the infrastructure or the operations (e.g., introduce a wave start instead of a mass start) to minimize traffic jams occurring regularly at nearly any popular Marathon, cross-country-ski, or inline-skating event.

In order to assess the options, one needs dynamic crowd flow models that are calibrated and validated against data. Interestingly, the main vehicular data categories are also available for many mass-sports events: Loop detectors and other stationary vehicular data sources find their counterpart in the RFID tags of the athletes recording the split times at several stations during the race. Moreover, more and more athletes carry smartphones during the race generating track data points that are the equivalent of floating-car data. These two data sources complement each other: Split-time data are available for all the athletes but only at a few positions. In contrast, "floating-athlete data" cover the whole track but only have a limited, generally unknown, pentration rate (percentage of athletes with activated smartphones).

In this contribution, we present a methodology to reconstruct the spatio-temporal speed distribution of the athlete's crowd flow by fusing these two data sources using the macroscopic crowd flow model presented at the last TGF conference [3] to resolve ambiguities or fill the data gaps.

We apply this method to several Marathons including the Vasaloppet crosscountry ski race 2014 and the Tel-Aviv Marathon 2014 and use the results to validate the macroscopic model.

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Empirical Study of the Influence of Social Groups in Evacuation Scenarios

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The effects of social groups on pedestrian dynamics, especially in evacuation scenarios, have attracted some interest recently. However, due to the lack of reliable empirical data, most of the studies focussed on modelling aspects, see e.g. [1] and references therein. It was shown that social groups can have a considerable effect, e.g. on evacuation times.

In order to test the model predictions we have performed laboratory experiments of evacuations with different types and sizes of the social groups. The experiments have been performed with pupils of different ages. Parameters that have been considered are (1) group size, (2) strength of intra-group interactions, and (3) composition of the groups (young adults, children, and mixtures). For all experiments high-quality trajectories for all participants have been obtained using the `PeTrack` software, see e.g. [2]. This allows for a detailed analysis of the group effects. One surprising observation is a decrease of the evacuation time with increasing group size.

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Models and Analysis of Evacuation Dynamics of Asymmetrically Coupled Pedestrian Pairs

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We recently proposed floor field cellular automaton models which introduce different types of social group attractions to evacuation dynamics [1]. In the present paper we focus on evacuation dynamics of crowds with inhomogeneous pedestrian pairs which are coupled by asymmetric group interactions. Such pairs consist of a leader, who mainly determines the couples motion and a follower, who has a defined tendency to follow his leader. Examples for such pairs are mother and child or two siblings of different age. Using extended floor field cellular automaton models for computer simulations we examine the system properties and compare them to the case of a homogeneous crowd. We find a strong dependency on evacuation times for the regime of strong pair coupling due to the occurrence of a clogging phenomenon which does not appear in homogeneous crowds. In addition we obtain a non-trivial dependence of evacuation times on the follower's coupling to the static floor field, which carries the information of the exit location. In particular we find that systems with fully passive followers, who are solely coupled to their leaders show lower evacuation times than homogeneous systems where all pedestrians have an equal tendency to move towards the exit.

We compare the results of computer simulations with recently performed experiments [2].

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Granulometric Distribution and Crowds of Groups: Focusing on Dyads

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Several empirical contributions [1] have clearly showed that pedestrian flows in crowded scenarios are characterised by the preponderant presence of groups: social units featured by common goals and variable strength of membership. This aspect was found to negatively impact flow rate and speed, due to the difficulty in movement coordination among group members and the need to maintain spatial cohesion to communicate and/or to evacuate together in case of emergency. In particular, early studies performed by the authors [2] highlighted that the granulometric distribution of crowds is strongly affected by two-members groups (i.e. *dyads*), which represent the most frequent and basic interacting elements that compose a crowd.

In this framework, the paper presents a research based on *in vivo* empirical surveys focused on group locomotion behaviour, and *in silico* pedestrian simulations aimed at evaluating the impact of grouping and testing the spatial efficiency of alternative architectural layouts and courses of action. The present study is particularly aimed at measuring the combined effect of grouping, age and density on pedestrians' speed, trajectories and spatial behaviour (e.g., spatial distance and degree of alignment between dyad members). Data collection was focused on an urban commercial-touristic walkway. Data analysis was performed by using an open source tracker tool for video analysis, relying on a sample of pedestrians composed of adult singles and dyads, elderly singles and dyads (aged from about 65 years old).

Results confirmed that in situation of irregular flows (LOS B) adult dyads walked much slower than singles. Age significantly reduced the pedestrians' speed, due to the decline of locomotion skills related to ageing. Elderly dyads walked less aligned than adults, maintaining a diagonal shape to face the contextual situation of density (to the detriment of social interaction). The achieved results have been used towards the validation of the agent-based simulation platform ELIAS 38, with reference to the representation of the granulometric distribution of groups and heterogenous speed profiles [3], but also for developing automated analysis tools employing computer vision techniques. The proposed approach is finally aimed at improving the walkability of congested urban areas and the security of large gathering-transit facilities in the light of specific needs (e.g., impaired mobility, elderly), in an attempt to fulfil the prescriptions of the European Chart of Pedestrian Rights (1988) (i.e. *Age-friendly Cities*).

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On the Use of Sheep to Model of Pedestrian Evacuation through Narrow Doors

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In this presentation we will compare extensive experimental results on the flow through bottlenecks of pedestrians and sheep. Given the highly competitive behavior of this animal when looking for food, the appropriateness of its usage in controlled experiments will be discussed to understand pedestrian room evacuation in very competitive situations. Despite the obvious differences among sheep and humans (the former are quadruped and move along their major axis, the later are biped and move along their short axis) interesting analogies are evidenced in several scenarios. In particular, we will analyze the effect of enlarging the door size, altering the motivation (which is related to the 'Faster is Slower' effect) and placing an obstacle in front of the door. Finally, we will discuss why the average evacuation time is not enough to evaluate the potentially danger of a given situation, evidencing the need of performing a careful statistical analysis of the time lapse among consecutive beings.

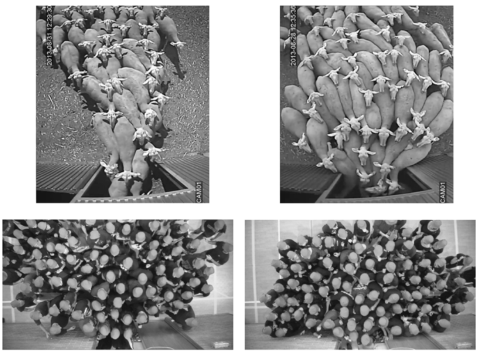

Figure 1: Snapshots of the evacuation drills for sheep and pedestrians. The charts on the left column correspond to a scenario with low competitiveness, whereas the ones on the right display highly competitive situations.

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Boarding of Finite-Size Passengers to an Airplane

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An airplane-boarding model, introduced earlier by Hemmer and Frette, is considered. In this model, N passengers have reserved seats, but enter the airplane in arbitrary order. Besides, there is only a single isle of rows and only one seat in each row. Each passenger occupies a place equal to the distance between rows. In this model, a passenger requires one time step to place carry-on luggage and get seated, the time for walking along the isle being neglected. However, a passenger must wait for a possibility to move forwards to his/her seat if the motion is blocked by other passengers. Here we focus on the blocking relations between passengers. The total boarding time is equal to the longest blocking sequence, represented by a line, connecting points of the two–dimensional q vs r scatter plot. Here $q = i/N$ and $r = j/N$, i and j being sequential numbers of passengers in the queue and their seat numbers, respectively. Such blocking sequences have been studied theoretically by Bachmat. We have developed an algorithm for numerical simulation of the longest blocking sequences, and have compared the results with analytical predictions for $N \to \infty$, i. e.,

$$r(q) = 0 \quad : \quad 0 \le q \le q_0(k)\ , \tag{1}$$

$$r(q) = -4e^{k(q-1)} + 4e^{2k(q-1)} + 1 \quad : \quad q_0(k) \le q \le 1\ , \tag{2}$$

where $q_0(k) = 1 - \ln 2/k$. Here $k = bu/w$, where u is the passenger width, w is the distance between successive rows and b is the number of passengers per row. We have $k = 1$ in the actual model of Hemmer and Frette. The theoretical curve is shown in Fig. 1 by solid line. The simulated longest blocking sequences for $N = 10^7$ passengers are shown here for comparison.

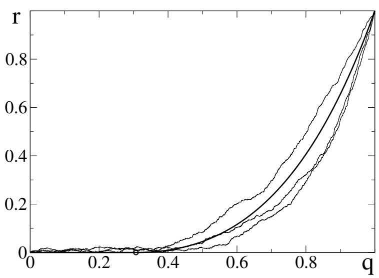

Figure 1: The analytical curve, representing the longest blocking sequences in the asymptotic limit $N \to \infty$, as well as the longest blocking sequences (fluctuating curves), extracted from 3 different simulation runs with $N = 10^7$ passengers.

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Granularity of Pre-Movement Time Distribution in Crowd Evacuation Simulations

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The paper focuses on influence of groups on pre-movement time distribution in pedestrian evacuation simulations. In most simulation models, as well as, verification and validation guidelines the only requirement that refers to pre-movement time is that it should fulfill a given distribution (in most cases normal distribution). Simultaneously, no attention is paid to spatial granularity of pre-movement time distribution.

Experimental data shows that pre-movement time distribution is coarse grained in terms of spatial relations. In general, pedestrians in a group have a tendency to wait for each other, until they start movement. Contrary to this, typical simulation approach uses fine granularity (uniform spatial distribution) - not taking into account "group effect" in pre-movement time distribution.

In this paper we analyse the influence of pre-movement time distribution granularity on evacuation process. Existence of groups of nearly located pedestrian with similar pre-movement time can lead to creation of local clogs and affect the route choice of other pedestrians (both in positive and negative way - depending on situation). We show an illustrative case study, where granularity of pre-movement time distribution have an influence on the qualitative and quantitative characteristics of evacuation process.

In general, fine granularity is an optimistic assumption. In some cases evacuation results can be similar in both cases (fine and coarse granularity of pre-movement time distribution), but in other cases such an approach can omit some possible threats.

Figure 1: Normal condition egress from East Tribune of Wisla Krakow stadium. Example of coarse granularity of pre-movement time distribution.

When is a Bottleneck a Bottleneck?

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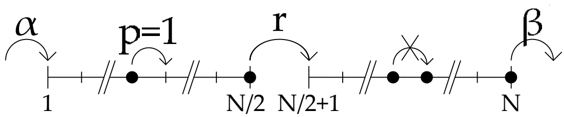
A simple way to model the effects of bottlenecks in traffic and other transport models, especially cellular automata and lattice gas models, is to introduce a local reduction of the hopping probability (or rate), usually called *slow bond*, *defect* or *blockage*. Although this is used frequently some very basic issues have only been clarified recently, especially the question "What is the critical strength of the defect that is required to create global effects, i.e. traffic jams localized at the defect position". Even for the simplest and best studied traffic-like system, the asymmetric simple exclusion process (ASEP), a longstanding debate on the answer has only been settled recently.

For an ASEP containing a slow bond with hopping rate r in the center, i.e. with defect strength $1 - r$ (see figure below), computer simulations [1] indicated that global effects (jamming, queuing) only occured for $r < r_c \approx 0.80(2)$. This is in contrast to the predictions of mean-field theory which predicts $r_c = 1$, i.e. jams occur at arbitrarily small defect strength.



Here we improve the numerics to show that $r_c > 0.99$ and give strong evidence that indeed $r_c = 1$ as predicted by mean-field theory. Recently this has also been shown rigorously [3], but these mathematical results do not give any *quantitative* information beyond $r_c = 1$, e.g. how the current is reduced as a function of r. Using extensive Monte Carlo simulations [4] we are also able to explain the problems in previous numerical studies that have indicated $r_c < 1$. This has important implications for the analysis of results from computer simulations also for more complex and realistic traffic models.

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Jam Avoidance with Autonomous Systems

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Recently, many car-following models have been developed for jam avoidance in highways [1]. Autonomous systems are models solely based on the predecessor (next-neighbor interaction). Feedback mechanisms through speed and spacing differences allow to improve the stability of the homogeneous solution and to avoid jam formation [2, 3]. Several vehicles in the neighborhood are taken in the interaction for cooperative systems. Many studies show improvements of homogeneous solution stability for a model class if the number of neighbors in interaction increases [4, 5].

Oppositely to autonomous models for which the variables can be directly measured, cooperative systems require that the vehicles are connected to communicate their states. This makes difficult their implementation. Moreover, recent results show that increasing the number of neighbors in interaction does not systematically yield to stability improvement [6, 7]. They suggest that next-neighbor interactions may be sufficient to control the jamming phenomena. Yet, classical autonomous models are not stable for any values of the parameters, and stable parameter sets give in general unacceptable acceleration rates.

In this paper, we propose a minimal autonomous model for which the uniform solutions are stable for any values of the parameters. It allows to avoid the jam formation with acceptable acceleration rates. The model is a second-order linear differential system based on the optimal velocity function (OV) and feedback control on the speed difference. We rigorously show exact homogenization properties [8], ensuring collision-free convergence to the uniform solution for any initial condition. The feedback control is approximated by spacing time-difference to make the model operational (i.e. simply based on spacing variables that can easily be measured). The model becomes a second-order delayed linear differential system. It can be exactly solved. Simulation results in a ring conclude the paper. They show how penetrations of the new model suppress jamming phenomena.

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Modelling of Backward Travelling Holes in Mixed Traffic Conditions

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A variety of vehicles, differentiated based on their static and dynamic characteristic, is prevalent in most of the developing economies. Concurrently, simulation time for large scale scenario is another emerging concern due to rapid increase in sizes of the cities. Thus, the present study investigates the complex heterogeneous traffic modelling with the help of a computationally efficient framework to model such traffic conditions more realistically.

An multi agent based simulator, MATSim, is chosen in which daily plans of all agents are loaded simultaneously on the network using a so-called "queue model" which is computationally more efficient than other simulators. In an iterative process, agents learn and adapts to the system. In a previous study, the traditional queue model's *first-in-first-out* sorting approach was replaced by *earliest-link-exit-time* to allow passing of smaller vehicles by faster vehicles in free flow regime. The present study, continues with the above approach by introducing the more realistic behaviour, *backward travelling holes*, in the queue simulation which resembles with the Newell's simplified kinematic wave model (KWM) [1].

The idea behind the backward travelling holes approach is that during jammed regime, if a vehicle leaves the downstream end of link, space will not available instantly on upstream end of link. Instead, it will take some time for the free space to reach the upstream end of link [2, 3]. This space is termed as 'hole' which has the same passenger car unit that of the leaving vehicle. Thus holes differ in their sizes but a constant speed is assigned for all holes by which they travel towards upstream end of the link. This speed corresponds to the speed of the backward travelling kinematic wave in the KWM. The holes implicitly introduce an inflow link capacity, in addition to the existing outflow link capacity.

The queue model with holes eliminates the unclear dynamics of the queue model in jammed regime. To validate the model, fundamental diagrams for homogeneous and heterogeneous traffic conditions and bike passing rates are presented with the help of a triangular test network. Furthermore, the sensitivity of the model is tested for different modal splits and number of lanes combinations. Since, the queue model model accounts only for the vehicles behaviour during link entry and exit, the computational efficiencies are maintained which is suitable to simulate large scale scenario in realistic time domain.

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Analysis in Kantorovich Geometric Space for Quasi-Stable Patterns in 2D-OV Model

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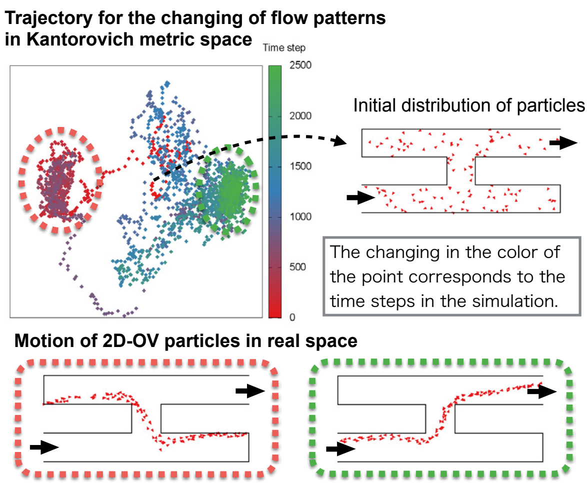
The two-dimensional optimal velocity (2D-OV) model, which consists of self-driven particles, reproduces a big variety of dynamical patterns as seen in biological collective motions [1]. When we perform simulations of 2D-OV model in a simple maze, dynamically stable patterns are observed from the simulation results. The stability of the patterns seems to be related to a kind of degeneracy of a state. In order to look for some physical quantity, which can indicate the relation between the stability and the degeneracy, we construct a geometric space based on the Kantorovich distance among patterns and represent the changing of flow pattern as the trajectory in the geometric space. As a result, a point corresponding to distributions of particles for the quasi-stable pattern converges to the localized region in the space.



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A Pedestrian Dynamics Model in Discrete Time and Continuous Space

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An increasing number of mass events and challenges in the design of large public buildings require realistic and efficient methods for the simulation of pedestrian flows. Two main types of models have been used in the last years. Cellular automata (CA) models which are discrete in space and time, and social-force (SF) models that are continuous in both space and time. Both classes of models are able to reproduce the main features of pedestrian streams in many scenarios. On the other hand, both also have important drawbacks. The spatial discreteness of CA models makes it impossible to reliably reproduce empirical trajectories of pedestrians. Also geometrical structures which are incommensurate with the size of the cells can not properly be modelled. The dynamics of SF models is usually given in terms of differential equations that have to be solved numerically. Therefore numerical accuracy becomes an issue since the equations have to be discretized. Furthermore, it is not clear whether the description of human behaviour by forces works for all situations and densities. Especially the normal behaviour at smaller densities is dominated by rules and decisions and a force-based approach becomes rather unintuitive.

Based on these observations we aim at combining the advantages of both model classes using discrete time as in the CA models and the continuous space of SF models. The discrete time allows for an intuitive implementation of rule-based dynamics and the continuous space provides a sufficient spatial resolution to determine accurate trajectories and model any geometry without restrictions. In one dimension, such a model has successfully been used for the prediction of phase separation [1].

In two dimensions, many new problems and challenges arise. The transition function is based not only on the distance and on the velocity of the nearest neighbour in front, but on the whole situation in the field of view of a pedestrian. All objects (walls, barriers, signs, other pedestrians) and their properties have to be considered in the determination of motion. On this basis, the transfer function computes length and direction of the next step. The size of the field of view depends on the environment, state variables (e.g. densities) or properties of the pedestrians itself.

One of the first goals is the reproduction of trajectories in single person experiments, e.g. the motion around corners [2]. Next, more complex situations with interacting pedestrians are considered, e.g. lane formation in counterflow. Finally, the model will improved to reproduce quantitatively fundamental diagrams and density-profiles determined in large-scale laboratory experiments.

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Investigation on Cooperative Avoiding Behavior in Bidirectional Flow

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We have combined a one-dimensional cellular-automaton and a evolutionary game model to investigate evolution and maintenance of cooperative avoiding behavior in bidirectional flow of self-driven particles.

In our model, there are two kinds of particles, which are right-going (black) particles and left-going (white) particles as in (Fig. 1a). Since the model is one dimension, they often face opponent particles. In order to avoid conflicts, particles try to avoid their opponents by swerving to right or left stochastically. If their swerving directions agree, the two particles avoid conflicts and exchange their position with each other. Particles in our model have a memory parameter of swerving direction. It is enforced and weakened when the particles succeed or fail to avoid opponent particles, respectively. The memory is also weakened by memory-loss effect, which represents spontaneous oblivion.

Results of our simulation indicate that cooperative avoiding behavior is achieved, i.e., swerving directions of the particles are unified, when the density of particles is close to 0.5 and the memory-loss rate is small as in (Fig. 1b). This result implies that particles need to interact with their opponent particles in order to maintain their swerving direction and achieve smooth flow. Few interaction diminishes the memory of the particles, and swerving direction of each particle becomes random. Furthermore, in the case that right-going particles occupy the majority of the system, we observe that their flux increases when the number of left-going particles, which prevent the smooth movement of right-going particles, becomes large. This is because the opportunity of reinforcement learning is increased by the increase of left-going particles.

Application of our research will be useful to study evolution and maintenance of cooperative avoiding behavior in pedestrian dynamics.

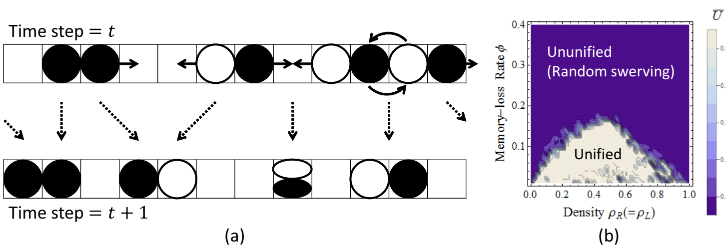

Figure 1: (a) Schematic view of the model. (b) Contour plot of average unified ratio.

Pedestrian Dynamics at Transit Stations: A Hybrid Pedestrian Flow Modeling Approach

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The objective of this paper is to accurately and efficiently model pedestrian behavior observed at transit stations. To realize this objective, a hybrid modeling framework is tested using concepts from 1) the Social Force model [2], 2) behavioral heuristics [3], and 3) materials science [1]. The basic one-to-one interaction between bodies (i.e. pedestrians or obstacles) is adapted from the Social Force model. Physiological and cognitive processing constraints (example: eyesight and angle of vision) are incorporated based on literature related to behavioral and information processing heuristics. Finally, the multi-body potential concept from materials science is incorporated; this concept implies that accurately modeling pedestrian behavior requires social force calculations not only between the two closest bodies but rather between multiple bodies (i.e. multi-body potential interactions) within the corresponding field of vision.

Using the aforementioned modeling framework, the closest N other pedestrians and obstacles are taken into account when determining a specific pedestrians course of action. The corresponding rules are programmed in a JAVA simulation platform built by the authors. Two experimental scenario types are considered: 1) interrupted scenarios (i.e. movement at bottlenecks represented by train doors, escalators, elevators and entrance/exit gates) and 2) uninterrupted scenarios (i.e. diverging/merging/weaving movement on transit platforms). As an illustration, the pedestrian movement at the Foggy Bottom Metro Station in Washington DC is modeled. Realistic trajectory patterns are observed (Figure 1). An elaborate sensitivity analysis evaluating the impact of each simulation parameter on the transit infrastructure performance measures (i.e. waiting time and critical density locations) will be conducted.

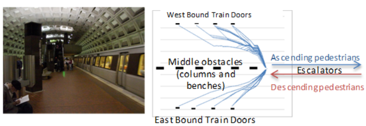

Figure 1: Image of Foggy Bottom Metro Station (photographed by Ben Schumin on January 3, 2004) and corresponding simulation layout.

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The Self-Organised Dynamics of Shape and Internal Structure of Flocks of Starlings

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Coordination of birds, such as starlings, in large, travelling flocks of thousands of individuals is amazing, especially, since individual birds adjust their movement only to a few neighbors close by. To explain what processes may underlie the many characteristics of flocks, computational models are needed. Models of self-organization have proven increasingly useful. Here we use such a model (called StarDisplay)[1]. In this talk we examine what causes the dynamics of flock shape and internal structure in huge flocks of starlings in the absence of predatory attacks[2] and during a wave of agitation evoked by an attack [3].

Using this model, we show in three subsequent steps:

- The local rules that suffice to generate the variation in flock shape and spatial positions of flock members,
- The processes that may underlie the emergence of variation of shape and internal structure of flocks,
- What is needed to generate the internal structure in flocks, during waves of agitation,

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A Macroscopic Loading Model for Dynamic, Multi-Directional and Congested Pedestrian Flows

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Modeling and prediction of pedestrian flows is an important challenge, particularly in the context of densely populated urban environments. Dynamic traffic assignment models represent an established pathway in that endeavor. To contribute towards their development, we present a dynamic network loading model applicable to anisotropic, time-varying and congested pedestrian flows.

The model is formulated at the aggregate level with respect to time, space and pedestrians. Space is partitioned into cells, each associated with a set of prevalent walking directions. These uni-directional pedestrian streams are represented by links that interact unless pedestrian density is very low.

The mathematical formulation of the model is based on a generalization of the cell-transmission model and the underlying LWR theory for traffic flow [1]. It makes use of a recently proposed stream-based pedestrian fundamental diagram that empirically relates density and walking speed for multi-directional pedestrian flows [2].

Besides presenting and motivating the proposed loading model, several test cases are discussed that illustrate the behavior of the model under various conditions. Particular emphasis is thereby given to the study of test cases involving multi-directional flow. For example, in counter flow problems, the speed of the major stream has been shown to be larger than that of the minor one [3]. A comparison to a related isotropic loading model [4] allows to assess the advantages of the multi-directional formulation in terms of accuracy and realism. Moreover, a real test case is considered to calibrate the model and to assess its ability to reproduce empirical results.

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Collision-Free First Order Model for Pedestrian Dynamics

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Operational microscopic pedestrian models in two dimensions are investigated. Classical force-based approaches allow to describe a large variety of pedestrian dynamics [1]. Yet, these models describe particle with inertia and are not strictly collision-free. In particular crowded situation unrealistic behavior could occur. Beside the limited analogy between pedestrian movement and particles with inertia, the solution of differential equations cause numerical difficulties resulting in small time steps and high computational complexity. In this paper, a new first order model is elaborated and analyzed by simulation. Oppositely to force-based Ansatz, the model is intrinsically collision-free. It belongs to Maury and Venel mathematical framework [2].

The speed model is an optimal velocity function (OV) depending on the minimal spacing in front. The approach is borrowed from traffic models [3]. The model parameters are well connected with measurable quantities such that the fundamental diagram. E.g. basic OV functions depend on three parameters: the agent length, time gap in following situations, and free speed. The direction model is a simplified version of the model proposed by Dietrich and Köster with additive neighbor repulsion [4]. The repulsion exponentially decreases with the distance spacing. It is calibrated by the repulsion rate and repulsion distance.

Even if the model is minimal with only five parameters, it allows to capture many observed phenomena of pedestrian dynamics [5]. First, unidirectional flows in a corridor are studied to evaluate the fundamental diagram and parameter values. Then, maximal flow through bottlenecks are explored. We show that the zipper effect occurs and the flow linearly increases with the bottleneck width [6]. In bidirectional simulations, we observe formations of lanes by direction in steady state, even at high density levels. Yet the phenomenon disappear if a noise is introduced with a variability sufficiently high (freezing by heating effect [7]). Bottlenecks with bidirectional flows lead to intermittent flows [8].

The modeling framework facilitates the description of pedestrian flows characteristics. Statistical estimations and further model validations are necessary. Yet, the large range of collision-free dynamics reproduced, the few and measurable parameters, and the low computational cost of the model make the approach promising for microscopic simulation of pedestrian flows.

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A Finite Element Simulation of High Density Pedestrian Flow

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We analyse the results of a finite element simulation of a macroscopic model, which describes the movement of high density crowds, where the crowd is considered as a continuum. The development of the time-dependent density distribution ϱ of pedestrians is described by the model introduced by Hughes [1]. This model is based on two coupled, non-linear partial differential equations: the eikonal and the continuity equation. The solution of the eikonal equation determines the direction of the flow field. We achieve a minimization of the travel time, while areas of high density are avoided because of the density-dependent external force. The continuity equation ensures the required mass conservation of the crowd. In total we have

$$\varrho_t - \nabla \cdot \left(\varrho\, f(\varrho)\, \frac{\nabla \Phi}{|\nabla \Phi|} \right) = 0\,, \quad \text{where} \quad |\nabla \Phi| = \frac{1}{f(\varrho)} \tag{1}$$

together with suitable boundary conditions which account for the conservation of mass and possible existing obstacles. The function f is given by the fundamental diagram, which provides the density-dependent velocity.

The solution of each equation is approximated by a viscosity solution to obtain a numerically stable algorithm after the finite element discretisation. The regularised eikonal equation is reformulated as a Helmholtz equation, which is a linear second-order differential equation.

We validate our simulation results with real measurement data and we compare them with the results of a commercial simulation tool, which is based on a microscopic modelling approach.

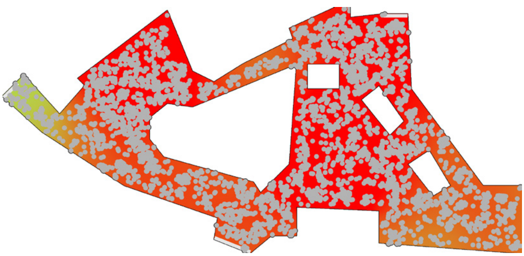

Figure 1: Simulation of the Münsterplatz in Zurich, Festival 2014

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Oppilatio – The Forecast of Crowd Congestions on Street Networks during Public Events

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At many events, the arrival of visitors depends mainly on public transport services or shuttle bus systems. On such occasions, people have to walk from the station to the event site. This can lead to crowd congestions since the visitors arrive in large numbers according to the schedules of the public transport services. Unfortunately, organizers of such events have very limited information about the routing behaviour of these pedestrians. The organizers normally know the number of visitors only after their arrival at the event. It is difficult to realize crowd management successfully with so little data. The ”Oppilatio”-method only needs information about the number of tickets sold and the schedule of the transport service along the time line of the event in order to manage successful crowd control. The developed algorithms can use this limited data to calculate important parameters like the most likely routing paths of incoming visitors. It allows an early recognition of potential crowd congestions and the initiation of countermeasures (e.g. signposting of detours to reduce the burden on main routes). The method detects peaks in the flow of arriving visitors. Afterwards, the probability of possible route choices can be calculated based on the distributions of incoming pedestrians. The algorithms consider navigation behaviour of pedestrians like the preferability of routes with long, straight streets [1] or the preference of beelines [2]. The developed method was validated by field data from a large annual music festival close to Munich over two consecutive years. Based on these scientific findings, a toolbox was developed to support organizers of public events. This was done in close cooperation with experienced event organizers, professional crowd managers and the Strategic Innovation Center of the Bavarian police department to achieve an useful and intuitive tool for crowd management. Figure 1 shows an example input scenario with the incoming visitors and a network of possible paths.

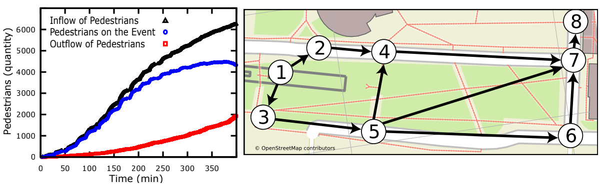

Figure 1: Pedestrian flows during a music festival and example routes as input data

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Simulation-based Forecasts of Crowd Flows at Major Events using Real-time Measurements

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Despite extensive pre-event planning and well-developed security concepts, the complexity and dynamic nature of large events can lead to unforeseen, tragic incidents. While real-time sensor measurements on human motion may deliver essential quantitative data, complete coverage of an entire large outdoor event area with counting sensors to provide all required data is prohibitively expensive. Here, the combination of fast crowd simulation tools with various types of real-time pedestrian flow measurement technologies can achieve the required spatial and temporal resolution for estimating the distribution, densities and walking speed of pedestrians. In [1] an evacuation assistant has been developed which allows forecasting the emergency egress of large crowds in complex buildings by using data of video-based person counting as input for a real-time simulation core. Extending this concept to a monitoring and decision support system of large outdoor events rises the need for the ability to handle dynamic origin-destination-relations (OD-relations). Whereas the OD-relations during an evacuation are pre-defined and nearly static pedestrian flows between multiple stages of a venue are highly dynamic. These dynamic OD-relations can be determined, example given, by Bluetooth sensors.

In this work we present a pedestrian simulation model based on a Mesoscopic Cellular Automaton which simulates crowd flows at major events faster than real-time and incorporates measurements from counting and Bluetooth sensors. This enables decision makers to assess the current situation and to derive multi-temporal forecasts in order to identify critical situations in a timely manner and to initiate appropriate countermeasures. From the measured motion data, the following input for the simulation model is derived: 1) pedestrian generation rate at each starting point, 2) exit rates and 3) the OD-relations which are updated every 15 minutes. The first two are provided by counting sensors which have to be deployed at neuralgic points such as entrances and exists. The third input data is obtained by Bluetooth sensors. Depending on the number and locations of Bluetooth sensors, in general, the resulting data reveals the relations between origin and final destination points as well as the relations between intermediate targets. Thus, the model is required to deal with dynamic OD-matrices which are extended by intermediate targets.

For the model verification, we investigated case studies from two music festivals in Austria in 2012 and 2013 where extensive measurements on human motion data were obtained to estimate both, the errors of modeling the walking times and the errors of reproducing the dynamic OD-relations over time. For instance, the mean error of the simulated data compared to the data measured by a counting sensor is smaller than the error of the data calculated with an estimated counting rate.

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Level of Safety Concept for Major Events

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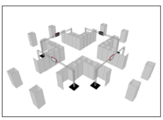
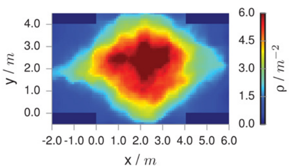
As part of the project 'BaSiGo – Safety and Security Modules for Large Public Events'[1], funded by the German Federal Ministry for Education and Research, large-scale laboratory experiments with about 2,000 pedestrians were conducted in 2013 [1]. In about 200 runs, the uni-, bi- and multidirectional pedestrian flow at intersections, corners and corridors was studied. The density was increased up to about six persons per square meter. Thus the emergence of critical states could be investigated. Thanks to the individual marking of all persons and questionnaires handed out to the participants we can also analyse the influence of individual characteristics, such as group affiliation, age, or the "experience" with major events.

In this paper, the results for intersections and bidirectional flow in corridors are presented. The figures below show one of the experiments with a crossing of 90°. Each of the entrances is four meters wide. Two and four streams with a total of up to about 600 people passed the intersection. The right figure [2] shows the crowd densities as mean values over time and space during the stationary state.

The aim of our work is to convert the 'level of *service* concept' [3] used for the planning of transport facilities into a 'level of *safety* concept' based on a traffic light system (green, yellow, red). We developed indicators for major events, allowing operators and approval authorities to assess the safety of a major event in terms of pedestrian traffic.





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Brazilian Legislation and the Boate Kiss Tragedy- Computational Modeling of Evacuation

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In 2013, Brazil was the scene of a great tragedy in the nightclub Boate Kiss in the city of Santa Maria - state of Rio Grande do Sul, where 242 people were killed, most of them young university students. The investigations conducted after the tragedy pointed out several primary causes for the beginning of fire and to the amount of the damages and human losses. Also, they emphasized the necessity to discuss some crucial technical details in the applicable Brazilian legislation. Historically, accidents in environments such as nightclubs (even in small ones) can be considered critical in terms of safety.

In this work, the computational modeling of evacuation in midsize environments, for example nightclubs or discothques, is performed using the software FUGA (a discrete fuzzy automata model). In all cases studied here, the environments (and its specifications) are strictly according to the Brazilian legislation. The rooms simulated are square (1:1) and rectangular (1:3). The emergency exits have been placed in different positions, from contiguous to each other to opposites in the environment. The dynamics of people flow is evaluated by checking the flow capacity of the exits, the time and flow profile and the possibility of the occurrence of internal collisions. It has been demonstrated that even if all the requirements of Brazilian codes are thoroughly followed, serious accidents can still potentially occur in certain situations, demonstrating the need for a greater discussion of the codes applied to these types of environments in Brazil. Additionally, an environment similar to the nightclub Boate Kiss is simulate and the previously conclusion for simpler environment are again confirmed. At the end, some considerations are made in order improve the Brazilian codes.

Two-Channel Partially Coupled Exclusion Process with Mutually Interactive Langmuir Kinetics

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Driven diffusive systems show surprisingly rich and complex behavior even in one-dimension and play an important role for understanding many non-equilibrium phenomenon like kinetics of biopolymerization, protein synthesis, vehicular traffic, transport of motor proteins etc. Totally asymmetric simple exclusion process (TASEP) being the simplest paradigmatic model to study such systems can well describe some of the complex non-equilibrium phenomenon such as boundary-induced phase transitions, phase separations, spontaneous symmetry breaking and shock formation etc. To describe the above mentioned phenomenon more realistically, TASEP has also been extended to include the possibility of transport on multiple parallel lanes with Langmuir Kinetics (LK).

In this work, we investigate an open system comprised of two-parallel TASEP, A and B each having L sites with mutually interactive LK under partially asymmetric coupling conditions. Motivated by the recent finding on clustering of motor proteins on microtubules, the attachment and detachment rates are assumed to be dependent on the state of the neighboring site. The schematic diagram of the proposed model is shown in fig. 1.

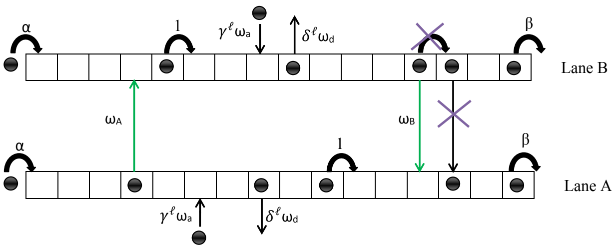

Figure 1: Here, α and β are entrance and exit rates, respectively. $\gamma^\ell \omega_a$ ($\delta^\ell \omega_d$) is attachment (detachment) rate, where ℓ depends upon the occupancy of the next nearest neighbor and $\omega_{A(B)}$ is the lane-changing rate from lane A(B) to B(A).

Under the mean field assumption the hydrodynamic equations representing the evolution of particle density is studied and the phase diagrams are obtained using boundary layer analysis. The effects of mutual interaction on the phase boundaries are discussed in detail. We have also investigated the effect of lane changing rate on the phase diagram. Monte-Carlo simulations are performed to validate the theoretical results.

Transcription on Crowded DNA

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The molecular machine RNA polymerase (RNAP) performs the first step in gene expression by sliding along DNA and transcribing the genetic information into an RNA molecule. RNAP must maintain robust functioning even though the interior of the cell is thermal and densely crowded with proteins. Although DNA is covered with proteins, and single-molecule experiments have shown that these proteins affect RNAP dynamics, this has so far been largely ignored when modeling transcription.

To better understand the effect of crowding on transcription, we study transcription in the context of a traffic model known as the Bus Route Model. Using heuristic arguments we calculate relevant quantities like the RNAP flux and protein occupancy as a function of experimentally controllable parameters.

We show that even moderate transcription levels can deplete the DNA of roadblocks, effectively mitigating roadblock effects above a critical RNAP flux. Further, we show that the presence of roadblocks induces moving traffic jams, so-called transcriptional bursts. Interestingly, transcriptional bursts have been seen in experiments, but their origins are not well understood. Our work suggests that molecular crowding on DNA can be a source of bursty transcription.

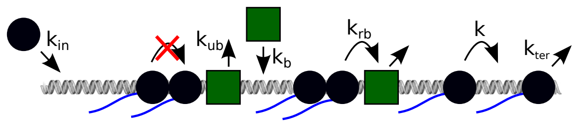

Figure 1: Schematic of transcription. Several RNA Polymerases (circles) transcribe a gene while proteins (squares) can bind from solution and form obstacles.

Moving Without a Leader – The Benefits of Swarming

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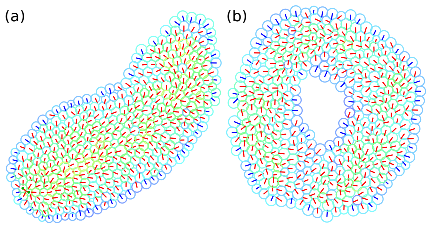
Swarming behaviour occurs on many levels, from herds of mammals and flocks of birds to unicellular organisms. We present a model for swarming behaviour in dense biological environments, using nearest-neighbour interactions only. Our model captures a rich array of behaviour also found in swarms of bacteria and other unicellular organisms. We combine Viscek type interactions with granular soft matter to simulate cells as self-propelled particles. Similar to the Viscek model our particles propel themselves in the direction of their orientation. A particles orientation is subject to noise and to a term that turns it towards the average orientation of its neighbours. Moreover, just as in granular matter, the particles have a finite size. Particles will repel each other using a simple spring-like repulsive potential. The particles are held together by a boundary term that makes particles on the boundary turn and push inwards. A particle determines whether or not it is on the boundary by considering the positions of its neighbours. We find that swarming behaviour can result from these local interactions only, without the need for either a (long range) attraction force or confinement.



The collective of particles exhibits various types of behaviours, depending on the relative strength of the interaction terms. For low self-propulsion strength our model reduces to soft granular matter, and the cluster is in a jammed state. When particles strongly align with each other, the cluster is in an ordered state and performs a random walk on the infinite plain (figure a). On the other hand, when particles weakly align, the cluster forms a rotating state (figure b). On the boundaries between the jammed state and the migrating state, and between the migrating and rotating state, clusters will display both types of behaviours. The cluster changes its behaviour in time, resulting in a run-and-tumble motion. Finally, we find that the diffusion constant for the migrating clusters can be up to three orders of magnitude larger than for a single diffusing particle. This suggests that the formation of clusters (swarming) is an advantageous strategy when, for example, searching for food [1].

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Fractal Analysis of Empirical and Simulated Traffic Time Series

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Fractal geometry has been a tool in timeseries analysis for quite some time. Not only statistical self-similarity but also roughness of timeseries is quantified by signatures of fractal behavior like box counting dimension [1]. Some studies indicate that time series of traffic data also show fractal and especially multifractal behavior. In this context traffic timeseries from Paris and Bejing were analysed [2] [3]. We will present an analysis of emipirical and simulated timeseries of german motorway traffic in the context of fractal geometry. As there are quite distinct differences in traffic regulations and behavior between countries and different kinds of roads, it is interesting if this relates to the fractal features of the corresponding time series.

The traffic data for the study is gathered from the motorway network of the German State of North Rhine-Westphalia. We use detector data from the vicinity of Cologne. Based on emipirical traffic data, synthetic traffic time series are gathered from simulations with a cellular automaton approach and a Nagel-Schreckenberg-alike model.

We obtain different estimates for signatures of fractal behavior in these traffic timeseries, e.g. estimators of fractal dimension, and multifractal dimensions. On the one hand fractal features of empirical and simulated traffic data are compared. We try to explain the slight differences found in this comparison and how this can help to improve traffic modelling and traffic predictions. On the other hand our analysis focuses on estimates of fractals in the separate flow and velocity timeseries of heavy vehicles, i.e. trucks and buses on the same motorways and how this relates to the general (i.e. of all passenger cars, buses, and trucks) traffic time series. We also analyse if and how signatures of fractals in time series change for different traffic states, time of the day, and day of the week.

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Physical Mechanism for the Occurrence of Wide-scattering in Traffic Cellular Automata (TCA) Models

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Based on current traffic flow theories, there are controversial views on the nature and formation of traffic congestions. One of these controversy lies in the occurrence of wide scattering of flow-density states in congested traffic[1]. In this study, we investigated a possible physical mechanism which could lead to wide-scattering in fundamental diagrams of Traffic Cellular Automata (TCA) models.

By simulating road bottlenecks on highways using the Nagel-Schreckenberg (NaSch) model, varying degrees of wide-scattering is observed. Numerical analysis of the simulation shows a strong correlation between the variance in the number of clusters and the width of scattering in the flow-density data. By studying the microscopic dynamics of the NaSch model, we proposed the physical mechansim of wide-scattering in TCA models to be the heterogeneity of cluster formation in congested traffic flow.

In relation to existing theories of wide-scattering, numerical studies were done in comparison with the existing TCA models proposed by J.F. Tian(2010)[2]and J.P.L Neto et. al.(2011)[3] that were claimed to produce wide-scattering as well. In addition, conceptual consistency is discussed via heuristic arguments on the current theories of wide-scattering put forth by Kerner(2009)[4], Treiber(2006)[5], Helbing(1999)[6].

Lastly, flow intervention techniques based on our proposed mechanism of wide-scattering is explored. Specifically, we discussed how algorithmic driving - which can be performed by autonomous vehicles (AV) - could maximise the flow rate during congested traffic flow, thereby reducing the impacts of congestion.

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Effective Modelling of Traffic Dynamics: Classification and Unification

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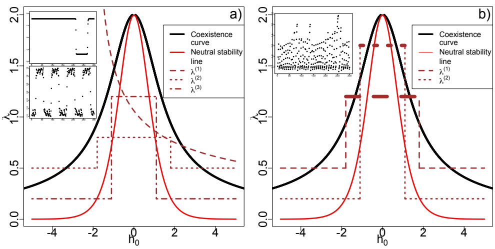
We propose a framework for the construction of microscopic traffic models that can in principle be empirically verified. All existing deterministic microscopic traffic models with identical drivers (including both two-phase and three-phase models) can be understood as special cases of a master model, expanded around a set of well-defined "ground states". This allows any two traffic models to be properly compared, therefore potentially resolving the controversy between the two-phase and three-phase traffic theories.

The emergent behaviors of the non-linear dynamics of the generalized OV models are also explored. The qualitative features of such behaviors are classified by the way the model parameters intersect with the coexistence curve and the neutral stability line(see figure), when they are plotted as functions of the traffic density (previous work and more details in [1]). Understanding the emergent properties of various solution types can be useful for realistic modelling of the traffic dynamics, as well as optimizing algorithms for adaptive cruise control and driverless vehicles.



The general framework is further illustrated by a simple algorithm in tuning traffic models based on statistically well-defined quantities extracted from the flow-density plot, which extends from the work in [2]. While the three-phase traffic models and the IDM are known to capture the complex spatiotemporal patterns of the highway traffic, we show that contrary to popular beliefs, with proper tuning even a simple OV model can capture most (if not all) well-defined empirical observations of the highway traffic.

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Empirical Verification of Microscopic Traffic Models from the Detailed Acceleration Patterns

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Collection of microscopic traffic data of the highway traffic flow is indispensible both for studying the phase transitions of the highway traffic, as well as for the construction of realistic traffic models for numerical simulation and optimization. Conventionally the traffic flow is measured by double loop sensors, which do not give the detailed acceleration patterns of individual drivers in response to their immediate environment. Such microscopic data is important for the construction and tuning of realistic traffic models, and understanding which of the factors (non-linear interactions, stochasticity, diverse vehicle types, lane changing, etc.) are fundamental to the characteristic empirical observations of the highway traffic.

We use commercially available high-speed video camera to record the traffic flows of Queensway, one of the major expressways in Singapore. Advanced video-processing techniques are employed to extract velocity, acceleration, headway and approach velocity of each passing vehicle. Our algorithm combines machine learning, edge detection and adaptive averaging to give accurate measurement of velocities and accerelations(see figure), with errors close to the systematic limit.

The acceleration patterns of a large number of individual drivers allow us to empirically measure the master microscopic model given below (also see [1] and [2]).

$$a \sim \sum_{\{n\}} \mathcal{F}_{\{n\}}\left(h, v, \Delta v\right) = \bar{f}\left(h, v, \Delta v\right) \tag{1}$$

where a is acceleration, h is headway, v is velocity and Δv is the approach velocity, and $\{n\}$ is the set of unimportant factors that are averaged over. We will show such master model can be used to validate various approximations of the traffic models in the literature, especially focusing on the deterministic microscopic models with identical drivers.

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LIST OF POSTERS

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PedVis – Pedestrian Flow Visualizations

Arne Scheuermann, Jimmy Schmid*, Nicolo Bernasconi, Judith Buehling, and Michael Flueckiger
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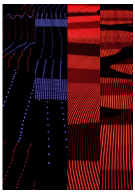
More and more people are using public transport. The Swiss Federal Railways (SBB) is expanding its railway stations and redesigning them so that all passengers will in future still reach their destinations safely and quickly. In this context, the depiction, planning and simulation of people flows (customer flows, movement patterns) are of increasing importance. This project will open up new access points in this field. Starting with seven topic clusters, different aspects of people flows will be analysed and depicted anew, based on a comprehensive collection of images. The protoypes for new visualizations developed from this will be validated using a Delphi survey of expert opinions and tested for their future potential. The SBB will then be presented with a catalogue of recommendations with all the visualization models and a practice manual.



Distributed Computing in Crowd Dynamics Simulation Systems

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In recent years one can notice a growing demands on the crowd dynamics simulation for mass events: concerts, sport events or religious pilgrimages. The most computationally challenging tasks are related with crowd management, on-line or data driven simulation - that often are expected to be significantly faster than real time.

Distributed computing is a powerful methodology, that enables for efficient execution of simulation. Whole simulation area can be divided into smaller regions, that can be handled separately by different nodes (computers). Such an approach brings speed up which is crucial in terms of on-line crowd analysis. However, distributed computing leads to complex problems with calculation cohesion preservation.

In this paper we analyse the problem of dividing the simulation area for distributed computing purposes. On the basis of the authors experiences the guides for distributed computing of simulations are proposed and discussed on the illustrative examples. The aspect of synchronization between nodes is also discussed.

On the other hand, we propose a synchronization protocol between computational nodes. The protocol defines the universal input/output interface for microscopic crowd dynamics simulations. This makes it possible to easily exchange information between different simulation methods as well as acquire data from sensors in similar way.

This paper is intended to be a voice in discussion about efficiency and optimization of practical applications of crowd dynamics models for mass events. We believe that solutions based on distributed computing and simulations methods "black boxing" are the most effective approach to response on such demands.

Facing Needs and Requirements of Crowd Modeling: Towards a Dedicated Computer Vision Toolset

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The modeling and simulation of pedestrians and crowd dynamics requires empirical evidences and quantitative data describing the relevant phenomena that models must be able to reproduce. This need is both for sake of model definition and calibration (whenever it includes parameters whose values determine the overall quality of achieved results) as well as validation. The symbiotic relationship between activities of synthesis and analysis has recently led researchers to argue that integrated research programs should be defined and carried out [4]. To face this need the community has developed valuable research efforts, often in the context of dedicated projects with relevant fundings dedicated to ad-hoc experiments granting proper control of the relevant involved variables (see, e.g., [1]). Automated analysis tools adopted in these cases exploit state of the art computer vision models and technologies that, however, are not necessarily actually tailored to the specific goals and desired outputs from the perspective of the pedestrian modeler. Moreover, data from experimental observations are extremely valuable, but field data from naturalistic observations represents a complementary necessity posing challenges not yet solved by state of the art computer vision techniques. This paper presents, first of all, an attempt to systematically organize the different needs and requirements of crowd modeling activities to automated analysis tools based on computer vision techniques. Based on these considerations, we then present the blueprint of a computer vision toolset comprising instruments and technologies that directly provide a solution to some of the above identified needs. For instance, modelers need information about the pedestrian demand, determining crowding conditions, pedestrian arrival and destination points and traveled paths in the environment to be simulated. Some recent results by the authors actually present solutions supporting the identification and characterization of the main pedestrian flows in video scenes (e.g. through flow segmentation and people counting techniques) [2], and also the identification of points of entrance and exit of pedestrian flows [3], which represent a first step towards the automatic generation of origin-destination matrices.

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Simulation of Crowd in the Corridor of Ziara in Masjid-e-Nabwi, Madinah

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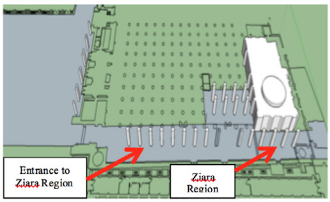
Visitors to Saudi Arabia for Hajj and Umrah from around the globe are constantly increasing with each passing year and hence visitors to the Prophet Muhammad (S.A.W)'s mosque, in Madina Munawara are also increasing. During Eid days, in the month of Ramadan, and during Friday Prayers, thousands of visitors flock to the Prophet (S.A.W)'s mosque It is a common desire of visitors to spend as much time as possible near the Ziarah Place. However, this usually creates bottlenecks around both the entrance and at the ziara place.

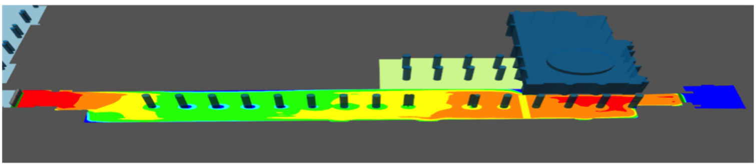
This paper investigates numerically the corridor of Ziarah Place which is the most congestion place in the mosque. In order to improve crowd management and minimize the occurrence of emergency situations or hazardous conditions necessary arrangements e.g. decreasing the waiting time, avoiding barriers, controlling the crowd size and optimizing the queuing process, are suggested.

Certain simulation scenarios are studied in helping to reduce the risk of people colliding into each other, as well as helping to reduce long waiting times in this particular area. Visitor's behavior, crowd density, and crowd flow around the Prophet (S.A.W)'s grave is analyzed for varying crowd densities.

(a) Crowded view of Ziara place



(b) 3D sketch of the investigated area



(c) Average Density Map

Simulation of People Flow by a Fuzzy Discrete Automata Model and an Ergonomic Approach

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This work presents the computer program FUGA (v. 1.0), developed to simulate the movement of people in constructed environments in normal situations and also during an evacuation in emergency situations. There are a lot of evacuation models in the literature, but FUGA introduces two paradigms still little used, but promisingly valuable. This program is based on a discrete automata model and uses an ergonomic approach associated with human movement and fuzzy logic as a computer intelligence tool to emulate the human decision-making process.

The nuances involved in human movement are multidisciplinary, involving physical, environmental, organizational, physiological and mental aspects, and an ergonomic approach allows for the incorporation of these different quantities in the model. Additionally, on top of those, there are several humans mental factors concurrently involved. Thus, the modeling needs to incorporate all the mechanical and mental aspects, as well as their quantitative and qualitative nature. Fuzzy logic can encompass these features.

This work shows how selected ergonomic quantities are incorporated into a human decision-taking process emulated by a fuzzy logic system. FUGA is capable of simulating environments with any internal or external geometry; with one or more floors; with or without stairs or ramps; with different kinds of floors; with uni or multi directional flows; with or without the formation of internal groups; and, incorporating people with different anthropometrics and behaviors (physical and cognitive). Besides, it can include situations of organized or competitive evacuation. The program was implemented in the Python computer language.

Finally, the process of verification and validation of the model was undertaken using the NIST Technical Note 1822 as base where pertinent, as well as some simulations, illustrating how the software can be used in the design of safer environments, in a way that could hardly be achieved through by simply applying the existing regulations.

The Inflection Point of the Speed-Density Relation and the Social Force Model

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It has been argued that the speed-density digram of pedestrian movement has an inflection point [1] (p. 3, *"Domain I: ... At low densities there is a small and increasing decline of the velocity ... Domain III: ... For growing density the velocity remains nearly constant."*). This inflection point was found empirically in investigations of closed-loop single-file pedestrian movement. See for example figure 5 of [2].

The reduced complexity of single-file movement does not only allow a higher precision for the evaluation of empirical data, but it occasionally also leads to a reduced complexity when models of pedestrian dynamics are applied for this situation such that analytical considerations become possible. This is especially true if one neglects temporal variations (consider time averages, neglect stop-and-go waves), individual differences of pedestrians (all simulated pedestrians have identical parameters) and investigates only steady-state (not the intitial phase).

With these simplifications for the Social Force Model (SFM; circular specification and elliptical specification II, not elliptical specification I) [3] one can show that there is no inflection point in the speed-density diagram if – assuming periodic boundary conditions – infinitely many pedestrians contribute to the force computed for one pedestrian and that – if one considers only the closest N pedestrians to contribute to the force – the inflection point moves to ever higher densities with rising N.

One could conclude that the original idea of the SFM that infinitely many pedestrians contribute to the force on one particular pedestrian was not realistic anyway and needs as modifcation a cut-off at some number, which anyway appears to be wise in terms of computation time. Still, particularly since such a cut-off number would be arbitrary, one may ask if there are other modifications of the SFM which a) yield an inflection point for the speed-density diagram, b) allow to sum up infinitely many pedestrians and ideally c) makes intuitively sense.

In the contribution we will show that multiplying the force from a pedestrian by a factor k^{n-1} where $0 < k < 1$ is some constant and n denotes the nth closest pedestrian to the pedestrian on whom the force acts fulfills all three requirements. We point out that this modification breaks with the idea that forces from various pedestrians are mutually independent.

If presentation time and paper length allow, we will furthermore discuss the issue of the inflection point for a car-following model (Wiedemann/Vissim).

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Sensitivity of the Continuum Model Regarding Pedestrian Movement Phenomena

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Numerous pedestrian simulation models have been proposed in the last decade, many of which simulate the movement behaviour of pedestrians microscopically. Given the high amount of detail of the simulation environment and the pedestrian movement behaviour, the computation speed of many microscopic simulation models leaves much to be desired. Moreover, the numerous degrees of freedom of microscopic models complicate the calibration process severely. Especially in cases where computation speed is essential and no microscopic data is available to calibrate the model, macroscopic models outperform microscopic models.

[1] presents an extension of the multi-class continuum model proposed by [2]. This model captures two key features which have proven difficult to simulate macroscopically, namely self-organizing movements and phase transitions. These two studies detail a class-specific equilibrium direction relation of the pedestrians consisting of a global route choice and a local route choice based on prevailing flow conditions. In [2] the local route choice is only dependent on the aptitude of pedestrians towards the density gradient of their own and the other groups. [1] determines the local route choice based on the combination of the density gradient and the predicted delay.

While both studies show that crowd movement phenomena can be captured by both versions of the model, it is currently undetermined which of the two versions predicts these phenomena most realistically. This study provides a detailed assessment of the impact of the combination of delay and crowdedness within the formulation of the local route choice behaviour on the predicted movement dynamics of the crowd.

This study aims to understand how the parameters of the respective versions of the continuum model influence the development crowd movement phenomena. The impact of the parameter sets of the continuum model is assessed for several distinct flow situations, namely uni-directional bottleneck, uni-directional corner rounding, bi-directional straight and intersecting movements.

This paper shows that the density gradient and the delay impact the walking behaviour in a similar manner. That is to say, both formulations force pedestrians to deviate from their globally optimal path. Furthermore, this paper shows that the combination of delay and density leads to either entirely similar (uni-directional flows) or undesirable behaviour (bi-directional and intersecting flows). Therefore, this study concludes that the continuum model described in [2] provides the most realistic prediction of crowd movement phenomena.

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POSTER

Method for Simulating the Evacuation Behaviors of People in Dynamically Changing Situations

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Multi-agent simulations (MAS) have been used to study the dynamics of social systems [1]. Disaster-related simulation is one of the applications of MAS; it allows examining out-of-the-box scenarios that are difficult to emulate in the real world. MAS express the microscopic behaviors of humans and simulate the evacuation behaviors of a crowd. People decide and alter their actions during emergencies based on the guidance instructions from public announcement (PA) systems in dynamically changing situations. Examples of announcements are "Please follow the warning lights leading to the emergency exit" or "The fire shutter closes automatically, so please use caution."

However, it is reported in past disasters that neither did PA systems help people effectively begin evacuations nor did they sufficiently guide people to safe refuges [2][3]. The installation of fire shutters in buildings is a mandatory requirement by law. Fire shutters are designed to close automatically in case of a fire. The PA announcements and the closing of the shutter affect the evacuation behaviors and evacuation indexes, such as safe egress time calculated based on simulations. We believe that evacuation simulation systems should account for all factors that have been reported to affect evacuation behaviors in past emergencies, such as pedestrian dynamics, information exchange among agents, and changes in the disaster environment.

The typical architecture of an agent-based system consists of two elements: environment and agents. Consider the following time events: a fire breaks out at t_1, guidance instructions are announced to start evacuation at t_2, and fire shutters are closed at t_3. The shutter closing forces evacuees to change evacuation routes that avoid the location of the shutter after t_3. A map module for the environment changes the accessible network of the floor at t_3. After t_3, a path-planning module for the agent outputs other paths away from the fire in a manner similar to how people would typically change directions in that situation.

This paper proposes a method for simulating the changing path of agents when fire shutters close and the method is implemented in TENDENKO [4]. The evacuation behaviors of 1,000 people from a building are simulated for various scenarios. The differences in evacuation simulations and the evacuation indexes are useful to improve prevention plans for emergency situations and to mitigate damage from disasters.

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Efficacy of Evacuation Time Estimation Framework for Total Pedestrian Evacuation Derived From Agent Based Model on Queuing Network and Volunteered Geographic Information of UK Cities

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An essential component of proactive evacuation planning for cities where there is an increased risk or a higher stake due to combination of rising instances of extreme events [1] and growing urban settlements [2] is determining an Evacuation Time Estimate (ETE) [3]. Full city evacuation could be one of the most stressing mobility use case for a city. A common approach at present to understand the interaction between large numbers of autonomous agents and establish an ETE for a region is by running an Agent Based Model (ABM) simulation [4, 5].

In a previous work, 50 regions in the UK were investigated $235.82 \pm 25\%\ \mathrm{km}^2$ which is the area of polygon for 'City of Bristol' on OpenStreetMap (OSM) database [6] and established a link between parameters that describe a city (spatial size, population, exit width) and its ETE. In this work, we compare the efficacy of the predictions made by that model with 53 new cities within a new scope of $235.82 \pm 50\%\ \mathrm{km}^2$.

The use of population data crudely estimated from GRUMPv1 year 2000 dataset [7] is maintained chosen for its granularity of 1 km scaled up by a factor of 9.37% in order to take into account rise in UK population to the year 2015 [8].

The model is expected to help back up the efficacy of previously established evacuation time estimation framework and increase confidence for emergency planners using it who need to make snap decisions in the run up to an impending disaster.

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POSTER

Modeling Pedestrian Evacuation Movement in a Swaying Ship

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With the advance in living standard, cruise travel has been a rapid expanding field around the world in recent years. A worldwide annual growth rate of 6.55% for passage by sea from 1990 to 2019 has been recorded which is expected to grow continuously. The transportation of passengers in water has also made a rapid development. It is expected that ships will be more and more widely used in transporting passengers. Unfortunately, several ship disasters occurred in these years which caused serious losses to people's lives and properties. It raised the concern on the effectiveness of large crowd passenger evacuation on ships.

Basically, the design layout of the cruise ships is same as that of hotels on the ground, which includes separated accommodation cabins, restaurants, sports facilities, etc., so that cruise ships can be regarded as mobile hotels. However, one of the important differences between them is that cruise ship attitude may get inclining as a result of periodical water movement. Thus pedestrian movement characteristic is different from when walking on a horizontal floor because the friction force from the ground keeps changing. Taking into consideration of this special feature, an agent-based pedestrian model is formulized based on our former model CityFlow [1], and the effect of ship swaying on pedestrian evacuation efficiency is investigated. Results of the simulations are compared with the standards for ship design and guidelines developed by the International Maritime Organization (IMO) for regulating passenger ships evacuation analysis. From the comparison we can find that the model can well represent the pedestrian movement features in a swaying ship and can be used to analyze the evacuation process in a inclining ship.

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Estimation of Density Levels in the Holy Mosque from a Network of Cameras

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Al-Masjid Al-Haram is the prayer direction for all Muslims around the world and Muslims travel to this mosque annually for Hajj and Umrah rituals. The current expansion of mosque will be the largest expansion seen throughout its history thus indoor navigation and route planning technique will be highly in need. Usually people tends to sit close to the gate they entered from which makes congestion at the gates and give a false indication of the mosque being fully occupied while some places in side remain vacant [1].

In this work we developed a system for estimating the density levels in the holy mosque of Makkah using video cameras installed in the mosque. This setup relies on dividing the image into smaller segments and counting the number of people in each segment to infer the density. For counting we adopted a method form [2] that fuses texture, frequencies and head detection in multiple scales to calculate accurate counts for the crowd using support vector regression. However this algorithm did not consider the perspective distortion of cameras and thus all blocks are assumed to have equal sizes. Since the cameras in the mosque can be accurately calibrated, we have improved the accuracy of the counting method and the retained densities are based on correct block sizes. We have evaluated this methodology with two cameras in King Fahd Expansion and we managed to achieve accurate counting and density estimation as presented in Figure 1. Once the development of this project is completed, the density maps will be presented in large screen at the main gates of the mosque to help visitors to plan their routes and avoid congested areas. Moreover, the authorities in the mosque will be able to take correct decision on when and where to redirect crowds in the mosque.

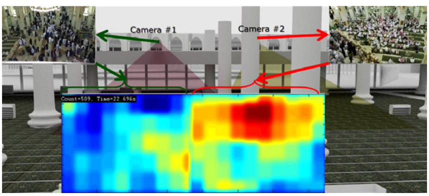

Figure 1: Illustration for destiny estimation in from two cameras

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POSTER

Method for Measuring Pedestrian Density with Low Computational Costs and High Resolution

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The progress of sensors capable for human detection and localization allows measuring the microscopic-scale pedestrian characteristics such as local densities. Standard methods for measuring pedestrian density average over large areas or long time periods and do not provide accurate information on a current situation within the examined area. Newly developed methods such as methods based on Voronoi diagram are accurate, but incur high computational costs. We propose a new method for automatic recognition of densities based on pedestrian trajectory data requiring relatively low computational costs. The method is not related to any grid and escapes the typical border-grid-relevant problem when high pedestrian density reached on cell border gets ignored due to averaging. Rather, densities on circular areas around each pedestrian and its neighbors are averaged to estimate density. We test the proposed method on two examples: video data from real life scenario and a simulation of a complex crowded scenario. Finally we discuss the problem of simulation validation based on comparison of density evolutions.

Individual Microscopic Results of Bottleneck Experiments

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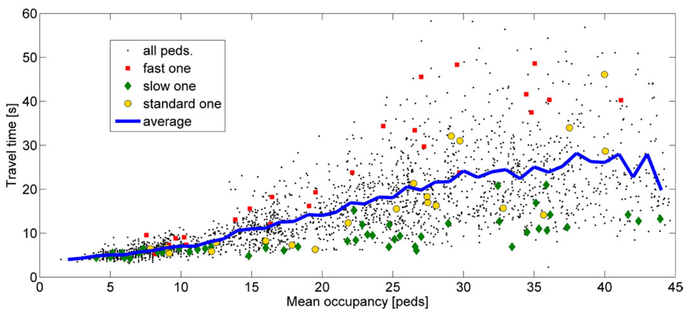
Various experiments have been conducted in order to verify crowd behaviour models and to enable fundamental research of various phenomena. Advanced processing of video records provides microscopic analysis of individual behaviour. During critical situation, the individual behaviour plays important role – less aggressive pedestrians spend more time in affected area, which may cause unexpected complications.

This article is based on passing through scenario [1], entrances were controlled by traffic lights to get demanded traffic mode inside the experimental room. Participants were instructed to pass the room as fast as possible without strong physical contact. By means of unique codes on the hats of participant, the travel time (covering the period from entrance to exit) and trajectory of pedestrians for each transit has been extracted and assigned to specific participant.

As mentioned in [1], recorded travel time significantly depends on the occupancy, but the trend is individual and more complex, see Figure below. While some participants reached similar travel time in free flow and congested mode, the others were not able to pass through the dense crowd and spent incomparable more time in the room.

This contribution provides deeper study of microscopic motion, explains the deviations of individual travel time by the statistical analysis of trajectory. To describe participant's properties, the term velocity is generalized to capture the effective velocity inside the dense crowd. It is shown that the "aggressivenes" and the desired velocity is less correlated than expected.



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POSTER

Understanding the Pedestrian Group Behaviour in Normal Conditions

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Significant research has been carried out on the walking speeds of individual pedestrians in a variety of environments such as sidewalks, crosswalks, bottlenecks etc. both empirically and experimentally. However, most of the times pedestrians move as groups, the application of individual walking speeds of pedestrians underestimates the capacity of pedestrian infrastructure facilities. Furthermore, the walking speed behaviour of pedestrians while moving in groups has yet to be fully understood. To fill this research gap, similar observations were performed with the primary focus on group behaviour of pedestrians. This study is believed to be first to focus on walking speed variations of pedestrian groups in university campus.

In the present study the influence of group size on walking speeds and time headways were examined. Two dedicated definitions, exact following behaviour and Follow-Up headway were introduced to explain the behaviour of groups more effectively. For analysing the group dynamics, the video data was collected at the annual science and technology festival TRYST- of the Indian Institute of Technology Delhi, held in February 2015 to capture the crowd movement. The selection of study area was done such that there is no interaction of vehicular traffic with pedestrians. Data was collected with the help of video graphic technique. The vantage point was kept on the top of the building which is of 10 m height selected adjacent to the data collection site so that exact time headways, group identification and gender composition of group can be captured easily. Video data extraction was done manually.

Initial results based on data collected in this study revealed that there is a significant difference between speeds as well as headways maintained by individuals with respect to groups. Also the mean walking speeds of groups are reducing with increase in group size. In addition when comparing with the individual pedestrian speeds the mean walking speeds of groups are reduced by 15%. It is empirically observed that mean time headways increases with increase in group size. Further, the groups consisting of only females present a larger time headways than mixed or groups consisting of only males. This study endeavours to gain a better understanding of how pedestrians behave while they are part of a group in academic environment. In order to understand the complete nature of group behaviour, this research work would be extended to various pedestrian environments which involve large crowd gathering.

Traffic Phase Dependent Fuel Consumption

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Fuel consumption is one of the key cost factors relevant for the movement of vehicles. In this paper is shown that when congested traffic states are defined based on Kerner's three-phase traffic theory, then a more precise *empirical analysis* of fuel consumption is possible. In the three-phase theory, in addition to free traffic there are two traffic phases in congested traffic: (i) the synchronized flow traffic phase and (ii) the wide moving jam traffic phase. In the three-phase theory, the synchronized flow phase exhibits a great importance for both highway traffic and city traffic. In particular, at undersaturated city traffic a moving synchronized flow pattern (MSP) effects considerably on traffic breakdown at traffic signal, i.e., on traffic breakdown at the signal that leads to transition from under- to oversaturated city traffic. Recent empirical inverstigations of microscopic data from navigation devices in vehicles show that in oversaturated city traffic in addition with classical moving queues, there are synchronized flow patterns [1] as predicted in the three-phase theory.

In this paper, we present empirical probability functions for traffic breakdowns for both highway bottlnecks and traffic signals in city traffic. We show that the prediction of traffic breakdown and the determination of the emerging traffic phase in congested traffic is crucial for the prediction of additional fuel consumption. The fuel consumption prediction with regard to congested traffic is probabilistic as the nature of traffic breakdown itself. By investigating of empirical field data from vehicles driving on a specific freeway section, a statistical analysis of this empirical data made in the paper reveals fuel consumption factors for two different phases in congested traffic in comparison to free flow. It is shown that up to 2.3 times more fuel consumption for wide moving jams on freeways compared to free flow and on average up to 1.4 times more fuel is needed in case of synchronized flow. For typical wide moving jams with a length of about 1km the average additional fuel consumption is 120ml compared to free flow. A microscopic fuel consumption matrix [2] is developed for usage in a method for fuel-dependent eco-routing: Depending on the additional fuel consumption due to congested traffic a vehicle can choose a different route minimizing the fuel consumption which is a different criterion and results in a different route than using travel times.

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Examining Perimeter Gating of Urban Traffic Networks with Locally Adaptive Traffic Signals

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Recent findings regarding macroscopic relationships of urban traffic measures—such as the Macroscopic Fundamental Diagram (MFD) [1]—has lead to the development of novel traffic control strategies that can be applied at a network-wide level [2]. One pertinent example is perimeter flow control (also known as gating or metering), which limits the rate at which vehicles are allowed to enter an urban region [3]. In general, these gating strategies seek to prevent a network from becoming congested and maximize network efficiency/productivity by maintaining an optimal accumulation of vehicles within the network. This optimal accumulation is based on the existence of a well-defined MFD with very little scatter, although full MFD information is not required for the design of an efficient gating strategy [4]. Several studies have found that MFDs are more well-defined (i.e., have less scatter and show better overall network performance) when adaptive traffic signals are installed that dynamically respond to local traffic conditions [5, 6]. The reason for this is that adaptive traffic signals help to provide more homogeneous vehicle distributions in a network. Thus, a combined gating and adaptive traffic control scheme can leverage the more reproducible macroscopic traffic patterns achieved with adaptive signals to provide more robust and efficient gating control.

The purpose of this paper is to explore the benefits of combining perimeter gating with locally adaptive traffic signals through micro-simulation of the Chania, Greece traffic network. Two adaptive traffic signal strategies are considered with the feedback-based gating strategy adopted in [3]: a simple density-based strategy and a modified version of the Syndey Coordinated Adaptive Traffic System (SCATS) algorithm. The results of the combined gating/adaptive signal control scheme are compared to gating under fixed traffic signals and the implementation of adaptive signals only. Overall, the study finds that travel delays and congestion can be significantly improved with the combined strategy—the adaptive traffic signals allow the network to achieve higher network productivity while the gating control allows the network to maintain this higher efficiency for a longer period of time than if left uncontrolled. The results are promising for the implementation of perimeter gating strategies in practice.

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A Comparison of Tram Priority at Signalized Intersections in Melbourne

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We study tram priority at signalized intersections using a stochastic cellular automaton model for multimodal traffc flow. We simulate realistic traffc signal systems, which include signal linking and adaptive cycle lengths and split plans, with different levels of tram priority. We find that tram priority can improve service performance in terms of both average travel time and travel time variability. We consider two main types of tram priority, which we refer to as full and partial priority. Full tram priority is able to guarantee service quality even when traffic is saturated, however, it results in significant costs to other road users. Partial tram priority significantly reduces tram delays while having limited impact on other traffic, and therefore achieves a better result in terms of the overall network performance. We also study variations in which the tram priority is only enforced when trams are running behind schedule, and we find that those variations retain almost all of the benefit for tram operations but with reduced negative impact on the network.

Macroscopic Modelling of Heterogeneous Traffic Flow Using Area Occupancy

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Heterogeneous traffic is characterized by diverse physical and dynamical characteristics of vehicles and the same right of way for motorized and non-motorized traffic with no-lane discipline. The problems associated with this kind of traffic are intrinsic and thus makes the modelling more complex. As the existing macroscopic continuum models are considering homogeneous traffic with only one or two type of vehicles, this do not cater the need for heterogeneous environment. Even though some first order macroscopic models are extended to fill this gap, they have their inherent shortcomings. The objective of the present study is to explore the appropriateness of Speed Gradient (SG) type higher order macroscopic models in describing heterogeneous traffic flow conditions with the new density metric area occupancy.

Mallikarjuna & Rao (2006)[1] have introduced new density metric called, 'Area Occupancy' to replace linear density parameter (veh/km). This was desirable as the conventional linear density parameter may be unrealistic in heterogeneous traffic conditions. The research presented here attempts to gain a better understanding of how area occupancy can represent the heterogeneous behaviour of macroscopic traffic flow paradigm. Speed Gradient (SG) model[2] was chosen to represent vehicle dynamics on the road, as it is successful in producing non-equilibrium vehicle dynamics. Each vehicle mass and momentum is conserved separately and interaction between the vehicles will be maintained using density ratio.

For data collection two study locations were selected such that one consists of free flow traffic (off-peak period) and the other consists of flow at the capacity The observations were taken for one hour at both the locations at various sections such as entry, exit and middle section. The data related to speed and flow were extracted manually from the video records for every 5 seconds. Equilibrium speed-density relationships were derived based on the field data. Parameters for the steady state equation and the model are estimated from the field data. Four widely used numerical schema such as, Upwind, Lax-Friedrichs, Lax-Wendroff and MacCormack were chosen as solution methods for SG model. The analysis shows that modified density parameter alone is not sufficient and it needs further adjustments to the macroscopic model.

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Influence of Various Densities of Traffic on 1/f Noise.

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Traffic noise is one of the most important sources of noise polution. It is well known that this is a health hazard. In this study we wish to check the frequency distribution of the noise. Empirical observations of traffic flux and velocities, show that at high enough densities the behaviour of traffic becomes quite complex. Therefore, Cellular automata is one of the most used methods for evaluating traffic and that is because of their speed and complex dynamic behaviour.

Previously we examined 1/f noise for a simple cellular automata model[1]. For illustrative purposes we considered a specific case of approaching a city. The case involves a traffic light where one continues on the main road, into which additional cars are entering at the light. At this intersection an alternative route begins, which is longer but into which no additional cars are entering.

In this paper we have one modification, which is quite significant. Previously the model enabled a car to move if there was an empty space in front of it. In this sudy we assume that a certain part of the cars do not follow into the empty space in front of them. This is equivalent to having some cars which are slow to start. This is a more realistic model than the one we used in our previous study. This is called *slow to start rule*[2] and we can expect that it will give more realistic results. We calculated the Fourier transform of the average velocity for each traffic light cycle. We consider different average 'slow to start' and obtain different results for the different cases. All the cases can be written as $1/f^{\alpha}$. When $\alpha = 0$, we say that we have white noise. If $\alpha = 1$, we say we have pink noise and if $\alpha = 2$, we say we have brown noise. We check by least squares the value of α for different densities and for different percentage of 'slow to start' cars. We compare qualitatively our results to experiments[3]. When we do not assume cars which are 'slow to start', the results differ from experiment for densities at the jammed region. We obtain $\alpha = 2$, but when we introduce 'slow to start' cars, the results are similar to the experimental values, which give $\alpha = 1$. We show that there are different characteristics for low densities mid range and high densities.

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Bifurcation Analysis of Experimentally Accessible Car-Following Model

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In the last few decades, a lot of mathematical models for the traffic flow have been proposed and have made a valuable contribution toward understanding the mechanism of various traffic phenomena, e.g., spontaneous traffic jams on a highway. In particular, "Car-Following" model, in which the behavior of a driver-vehicle unit is described as nonlinear system of ordinary differential equations, is useful for simulating and analyzing theoretically the traffic state from the viewpoint of microscopic dynamics.

Recently, Shamoto *et al.* [1] proposed a new car-following model including effects of relative velocity, which has the following form :

$$\frac{d}{dt}v_j = a - b\frac{v_j}{(h_j-d)^2}\exp\Big(-c\Delta v_j\Big) - \gamma v_j, \tag{1}$$

where a, b, c, d and γ are positive parameters. One of the advantages of their model is the experimental accessibility, that is, all the parameters in (1) are measurable from experimental or observed data. Shamoto *et al.* [1] have shown by linear stability analysis that the stability of the homogeneous traffic flow for (1) changes depending on parameters. However, they did not analyze the global bifurcation structure.

In this paper, we numerically investigate the bifurcation structure of (1) in detail. One of the results is shown in fig. 1; we have found a supercritical Hopf bifurcation of the homogeneous traffic flow. When L decreases, the Stable Equilibrium (SE) loses the stability at some $L = L_c$ and a Stable limit Cycle (SC) bifurcates for $L < L_c$. It is interesting to note that the limit cycle undergoes two saddle-node bifurcations and the bistability of the homogeneous flow and jamming flow occurs. In addition to the one-parameter bifurcation analysis, we will investigate the dependency of bifurcation points on the parameters in order to explore the possibility of alleviating spontaneous traffic jams.

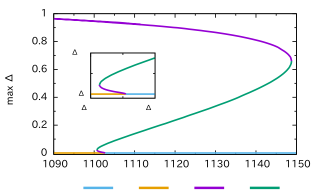

Figure 1: Enlarged view of bifurcation diagram around a bifucation point for (1).

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POSTER

Lane Changing and Speed Interaction on Freeways: An Analytical Microscopic Study

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It is crucial to understand the impact of lane-changing manoeuvres, as initial perturbations, on the capacity, stability, and breakdown of traffic flows. Knoop et al. [1] revealed that there are different strategies related to lane-changing behaviour among various drivers. Four distinct strategies have been empirically found; (1) *Speed Leading*: drivers adapt lanes such that they can drive their with desired speed; (2) *Speed Leading with Overtaking*: this strategy is similar to the previous one, only, the drivers increase speed when they are in the left lane; (3) *Lane Leading*: drivers choose a lane and adapt their speed to the speed of the vehicles on that lane; (4) *Traffic Leading*: drivers try to have a behaviour in line with the traffic stream. Note that in the last-mentioned strategy, speed choice and desired lane changes cannot be separated from a behavioral point of view.

The principal aim of this paper is to investigate the impact of the forenamed driving strategies on freeway traffic operations. To the best of our knowledge, combining speed choice and lane preference is not currently considered in most driving behavior models. The developed lane-change model is tested on a three-lane freeway stretch including a bottleneck in the microscopic simulation environment MOTUS [2]. Several scenarios based on various combinations of lane-change model parameters and different fractions of drivers per strategy have been simulated. A sensitivity analysis on the model parameters according to their effect on the traffic flow patterns has been conducted. More specifically, a thorough study on the simulation results (e.g. lane flow distribution, number of lane-changes, frequency of instability occurrence, impact on the capacity of the freeway and the speed distribution) has been carried out. In particular, the capacity drop and stop-and-go waves phenomena for the simulated scenarios are scrutinized. The findings, resulted from the simulation appraisal, potentially lead to significant changes in traffic operations. Moreover, it might be beneficial for modelling of multi-lane traffic control, especially if control measures are being applied. Other further research directions include calibrating the lane-change model and testing it on more complex road layouts.

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Granular Flow to a Blast Iron Ore Furnace - Influence of the Particle Size Distribution on Segregation of the Mixture

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For an optimum performance of a blast furnace the homogeneity of the infeed material is important. This means that segregation is an unwanted effect. The feed to a blast furnace for iron ore production consists of a mixture of sinter, pellets and cokes. They are of different sizes and each have different particle size distributions (PSD) and densities; all ingredients for segregation [1].

For modelling the heat exchange and chemical processes in a blast furnace Discrete Element Modeling becomes popular. However, one of the aspects that requires more attention is the realistic modelling of material behavior. Because of the computational costs often small particles and particle size distributions are left out of consideration. This might be acceptable for modeling some macroscopic characteristics such as angle of repose or bulk density, but it can severely affect the quality of the simulations when segregation plays a crucial role like as in blast furnaces.

The aim of this research is to analyze the influence the presence of the particle size distribution for three materials (sinter, pellets and cokes) on segregation of the mixture fed to a blast iron ore furnace. This has been done by modelling each of the three materials with DEM software. An acceptable degree of accuracy of the model was obtained by calibration and verification with lab experiments; both for individual material characteristics as well as for the mixture as a whole.

A pile formation setup was created (Fig.1) that is known to cause segregation. Simulations with and without PSD for each material were performed and the results were analyzed to find the degree of segregation in the mixture. The final conclusion is that for the given setup the effect of taking the particle size distribution of the individual materials into account, is limited.

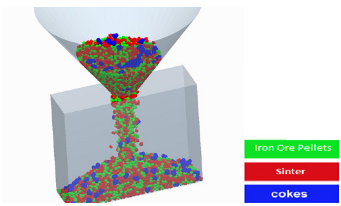

Figure 1: Setup to assess segregation of a mixture of iron ore pellets, sinter and cokes

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Estimation of Discretized Motion of Pedestrians by the Decision-Making Model

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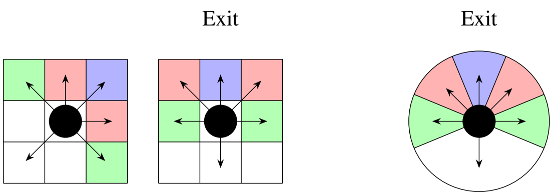
The contribution introduces a micro-structural insight into the pedestrian decision process during an egress situation. The study can be used as an auxiliary calibration tool for microscopic models of pedestrian flow with spatially discretized motion of agents, as e.g. Floor-Field or Optimal-Steps Model.

The conception assumes that pedestrians choose the direction of their motion in each step stochastically. This decision is highly influenced by the state of their close neighbourhood, i.e., by the occupancy of surrounding space. This can be described by the probabilistic dependence $f(\text{decision} \mid \text{state})$ denoting the probability that a pedestrian makes the decision from the set of **decisions** given the state from the set of all possible **states of the neighbourhood**. By the decision we understand the choice of the direction of the next step, e.g. **decisions** $=$ $\{$to stay, to move forwards, backwards, to the left, to the right, diagonally to the left, diagonally to the right$\}$. Here, the direction is not meant in the absolute orientation of the grid, but it is related to the straight direction towards the exit (or in the preferred direction for given area), as indicated by following Figure. The state of the neighbourhood is represented by the occupancy of the sectors in given directions.



We introduce a method how to extract the decisions of pedestrians from the trajectories recorded during the experiments. It has been applied to the data from experiments described in [1]. Furthermore, we discuss several methods for estimation of the decision making process represented by the probability density f from these data. The focus is given on methods which deal with the problem of high cardinality of the set of neighbourhood states, e.g. the approximation by finite mixtures [2]. The introduced concept can be easily modified to more complex decision process, e.g. by including the influence of the previous state and decision, which leads to the model $f(\text{decision}_t \mid \text{state}_t, \text{state}_{t-1}, \text{decision}_{t-1})$.

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Discrete Phenomena-Based Multi-Scale Traffic Flow Modelling

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Traffic is a highly complex system in a sense that it is made up of multiple interconnected elements (vehicles). One of the features of traffic as a complex system is that it may exhibit emergent phenomena that is different from average behaviour of its individual elements. For example propagation of shockwave to the upstream sections is an emergent phenomenon that is resulted from individual vehicles' deceleration. On the other hand, behaviour of elements in the complex system can be adapted with respect to the emergent phenomena. One example of this adaptation is drivers' rerouting to avoid traffic jams.

The behaviour of a complex system can be best modelled in a multi-scale manner. Such multi-scale model dynamically switch modelling paradigms depending on traffic condition.One important question in this approach, relates to the criteria that activates the switching mechanism. The time and position of shifting the modelling paradigms should be chosen wisely to avoid inconsistency between integrated models. Furthermore, finding the appropriate modelling scale that can accurately reproduce and predict the phenomena of interest is not a trivial task.

To answer the above-mentioned questions, we propose a discrete simulation algorithm to switch from one modelling representation to the next. This approach enables the switching paradigm based on discrete sequence of traffic phenomena that are occurring in various spatial and temporal scales. The switching criteria on this basis relates to the probability of occurring the phenomenon s in the set of Phenomena S. When $P(s) \geq \alpha$ - with α an arbitrary threshold between $[0, 1]$- the multi-scale simulation switches to the model that can best reproduce and predict the phenomenon s.

To find the a modelling scale that can 'best' represent the phenomena of interest, a systematic modelling selection method is required. The selected modelling scale should provide sufficient amount of information to reproduce the phenomena of interest. On one hand, we need to quantify the level of detail (complexity) that is needed to explain/describe the traffic phenomena. On the other hand, the traffic model that is selected to be integrated in multi-scale modelling framework, should provides the information that matches the phenomena's complexity. In this paper, the power of models to reproduce and predict the traffic phenomena is evaluated and the relation between phenomena's complexity and predictive power of traffic models is extracted.

In the full paper we first evaluate the existing traffic flow multi-scale simulation algorithms and analyse their switching criteria. Next, we present the proposed phenomena-based multi-scale modelling approach. To find a systematic modelling selection method, we will asses the phenomena's degree of detail and the power of traffic models to reproduce and predict the phenomena. We conclude the paper with an illustrative example that shows the applicability of our proposed methods.

Traffic Capacity Estimation Method of a Waterway Intersection

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Maritime transportation is growing and waterways have to handle larger ships and larger traffic flows. Thus, waterway intersections become busier and more dangerous for navigation. Although extensive research to assess risks in ports and waterways has been already performed, there is no existing method to estimate traffic capacity of waterway intersections.

The objective of this research is to develop a method to estimate this capacity. The Automatic Identification System (AIS), which is an automatic tracking system obligatory installed on large vessels, allows to record and view marine traffic in an area. Based on an exhaustive AIS data analysis of a busy waterway intersection in the Port of Rotterdam (Hartelkanaal – Oude Maas), the influence of infrastructure geometry, such as waterway width, on vessel navigation is identified for different vessel types and shares. The effects of traffic and priority rules at that intersection need to be also investigated. An exploration of fundamental relationships between traffic variables is proposed. The analysis of trends and relations between traffic variables and real AIS data help to develop the method. Due to the diversity in vessel types, factors have to be defined in order to make the capacity estimation method applicable for any vessel type and share, as well as, any infrastructure geometry.

Since the capacity is linked to the risks allowed, the method has to consider likely risk measures, such as the ship domain concept [1], that should highlight the relation between different levels of traffic and different risk thresholds to be taken. Road intersection traffic performance methods, such as [2] and [3], are the reference point to find analogies with the proposed method and prove its validity. The optimal method developed is applied at the intersection of two real wateways, Hartelkanaal – Oude Maas (Port of Rotterdam). The results show which is the estimated capacity based on infrastructure geometry, vessel types and share.

This research should help to assess and improve current traffic management strategies or traffic rules, looking always for an optimization of safety and capacity of any intersection.

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This book contains abstracts of the papers presented at the Traffic and Granular Flow'15 conference, organised in Nootdorp, the Netherlands, by the Delft University of Technology. The biannual TGF conference gives the newest insights in granular and traffic flow patterns, and addresses important scientific topics with many urgent applications for practice. Twenty years after its first edition, the conference has established a firm reputation in science.

This conference brings together scientists with different backgrounds to make interdisciplinary links. It is known for its interactions between the participants, coming from all over the world. The location of the conference moves globally; the 2017 edition will be organized by George Washington University in Washington D.C., United States.