



Abstracts Booklet

Conference on Traffic and Granular Flow

2-5 July 2019

Universidad de Navarra
Pamplona, Spain



<https://www.unav.edu/web/traffic-and-granular-flow>
E-mail: tgf19@unav.es



Abstracts in this booklet are ordered alphabetically according to the name of the corresponding author.

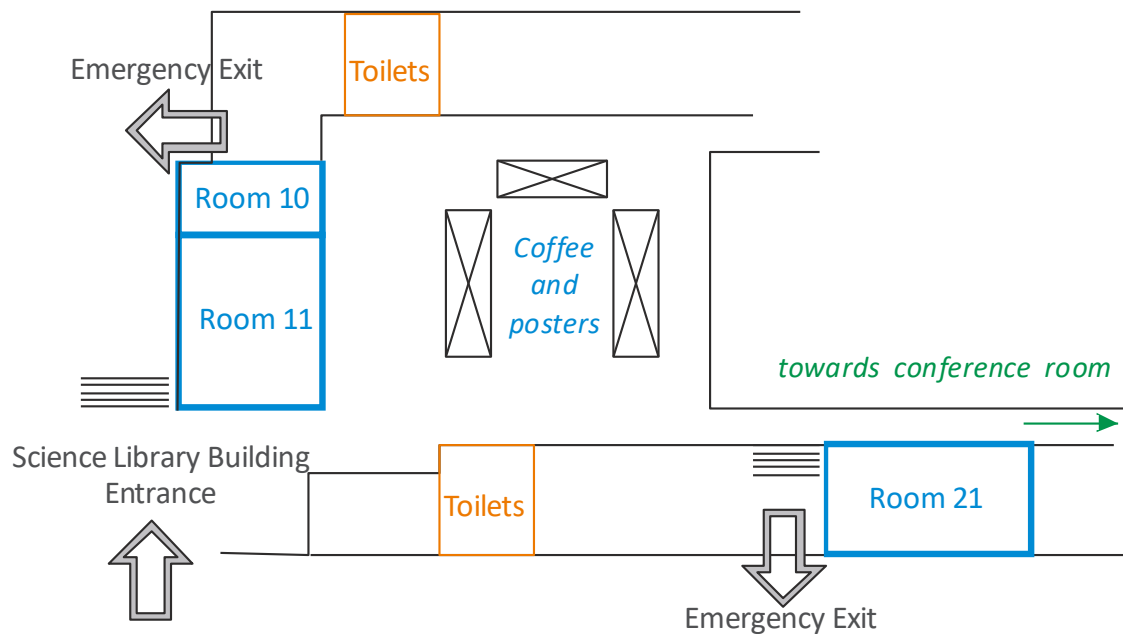
All posters will be displayed during the poster session

(Wednesday 3th, from 17:30 to 19:30).

Panels to hang posters will be available from the first day in the morning.

We suggest to leave all posters on display during the whole congress, there is no need to remove them.

The sessions will take place in the Science Library Building ("Edificio Biblioteca de Ciencias"). A sketch of the ground floor is shown below.



Preliminary programme

Wednesday 3

9:00	Presentation : Conference room	
9:15	Plenary session: conference room. Guy Theraulaz	
10:15	Coffee break	
	WA: room 11. PED orientation and avoiding	WB: room 21. Active granular and biology
10:45	1WA Nikolai Bode	1WB Hamid Kellay
11:05	2WA Alessandro Corbetta	2WB Thomas Barois
11:25	3WA Martijn Sparnaaij	3WB M. Reza Shaebani
11:45	4WA Weiguo Song	4WB Ralf Stannarius
12:05	5WA Tobias Schrödter	5WB Kenta Kaito
12:25	6WA Ernst Bosina	6WB Yuki Sugiyama
12:45	Lunch time	
	WA: room 11. PED social behaviour	WB: room 21. Suspensions
14:30	7WA. Invited: Mohcine Chraibi	7WB. Invited: Douglas Durian
15:00	8WA Francesco Zanlungo	8WB Alvaro Marín
15:20	9WA Long Liu	9WB Rubén Gómez González
15:40	10WA Benjamin S. Bergner	10WB Mathieu Souzy
16:00	Coffee break	
	WA: room 11. PED high density	WB: room 21. Network transportation (I)
16:30	11WA Maik Boltes	11WB Alonso Espinosa
16:50	12WA Daniel Lehmberg	12WB Jean-Patrick Lebacque
17:10	13WA Daniel Parisi	13WB Izabela Marqués de Oliveira
17:30	Beers and posters (17:30-19:30)	

Thursday 4

9:00	Plenary session: conference room. Karen Daniels	
10:00	Coffee break	
	TA: room 11. PED, bottlenecks	TB: room 21. Vehicular traffic
10:30	1TA Juliane Adrian	1TB Antoine Tordeux
10:50	2TA Marion Gödel	2TB Claudio Feliciani
11:10	3TA Pavel Hrabák	3TB Eduardo del Arco
11:30	4TA Ben Hein	4TB Akihito Nagahama
11:50	5TA Jun Zhang	5TB Hari Hara Sharan Nagalur Subraveti
12:10	6TA Yifan Zhuang	6TB Juan Guillermo Acosta
12:30	Lunch time	
	TA: room 11. Cyclists and the city	TB: room 21. Granular silos
14:30	7TA Invited: Winnie Daamen	7TB Invited: Tamás Börzsönyi
15:00	8TA Aleksandra Gavrilidou	8TB Pascale Aussillous
15:20	9TA Valentina Kurtc	9TB Diego Gella
15:40	Coffee break	
	TA: room 11. PED, evacuation	TB: room 21. Network transportation (II)
16:10	10TA Xiaolu Jia	10TB Andreas Schadschneider
16:30	11TA Ke Wang	11TB Marina V. Yashina
16:50	12TA Daichi Yanagisawa	12TB Kai Yuan
17:10	13TA Yuji Yoshimura	13TB Mattia Mazzoli
17:30	14TA Angel Garcimartín	14TB Maria Davidich
18:30	Depart - Dinner at Otazu Winery	

Friday 5

9:00	Plenary session: conference room. Marta González	
10:00	Invited talk: conference room. Alexandre Nicolas	
10:30	Coffee break	
	FA: room 11. PED, speed heterogeneity & others	FB: room 10. Granular, silos & others
11:00	1FA Dorine C. Duives	1FB Kiwing To
11:20	2FA Tobias Kretz	2FB Julian Talbot
11:40	3FA Ma Jian	3FB Luis A. Pugnaloni
12:00	4FA Cornelia von Krüchten	4FB Luke Fullard
12:20	5FA Akihiro Fujita	5FB Kerstin Nordstrom
12:40	6FA José Méndez Omaña	6FB Simeon Völkel
13:00	Lunch time : PAELLA	
15:30	Farewell & Sanfermín tips	

A cellular automaton model for the simulation of an articulated buses massive transportation system. ORAL 6TB

Juan Guillermo Acosta, José Daniel Muñoz.

Corresponding author: Juan Guillermo Acosta

e-mail: jugacostase@unal.edu.co

Affiliation(s): B.Sc.Physics, Transportation Engineering Master Student at the National University of Colombia.

This work tests the hypothesis that suggests giving priority to easy routes (buses that stop at every station along the road) over express routes, using as sandbox the 26th street lane, one of Bogota's main BRT lanes. For that purpose, a cellular automaton traffic model proposed by L. Olmos and J.D.Muñoz [1] was implemented, being modified in order to include bus drivers behaviours as they approach to stations and some physical properties of the buses. The simulation is run for two cases. In the first case the BRT system is assumed to have only easy routes, so commuters can only use this kind of service. In the second case, the system has both easy and express routes and commuters are forced to use easy routes in order to transfer to express routes stations. Results show that easy routes waiting times on each station become longer as the stations is farther from the departure station of the buses as a result of increasing interactions between the buses, the stations and people. This increased waiting time can be up to three times longer than waiting times in nearest stations. Introducing express routes in the system so commuters are forced to use easy routes to transfer express routes stations shows that total travel time increases in average.

[1] L.Olmos, J.D.Munoz. A CELLULAR AUTOMATON MODEL FOR THE TRAFFIC FLOW IN BOGOTA. International Journal of Modern Physics C, 15:1397-1411,2004.

Influence of Corridor Width and Motivation on Pedestrians in Bottlenecks ORAL 1TA

Juliane Adrian¹, Maik Boltes¹, Anna Sieben², Armin Seyfried¹

Corresponding author: Juliane Adrian

e-mail: j.adrian@fz.juelich.de

Affiliation(s): ¹Forschungszentrum Jülich GmbH, Jülich, Germany;

²Ruhr-University Bochum, Bochum, Germany

Understanding the behaviour of crowds is important in order to draw up or to adapt safety regulations for buildings and events. People confronted with spatial bottlenecks either follow the social norm of queuing or they start pushing. The latter leads to a high density of persons per square meter which can result in fatalities. A typical bottleneck situation, in which pushing might occur, is at the entrance gates to concert areas or events. We present bottleneck experiments investigating the influence of the width of a corridor leading straight to an entrance gate (see Figure 1-Left for the experimental setup) on the behaviour of the participants. Besides the corridor width, also the motivation of the participants was varied. The basic idea was that there might be a transition between a queuing and a pushing behaviour influenced by corridor width and motivation. Each group of participants performed two runs. The situation they had to imagine was that they want to enter the concert of their favourite band. In the first run, the motivation was high which was communicated as follows: Imagine that only the first persons who enter will have an undisturbed view of the stage. The others cannot see the stage directly. In the second run, the motivation was reduced by the announcement that everyone will be able to see the stage.

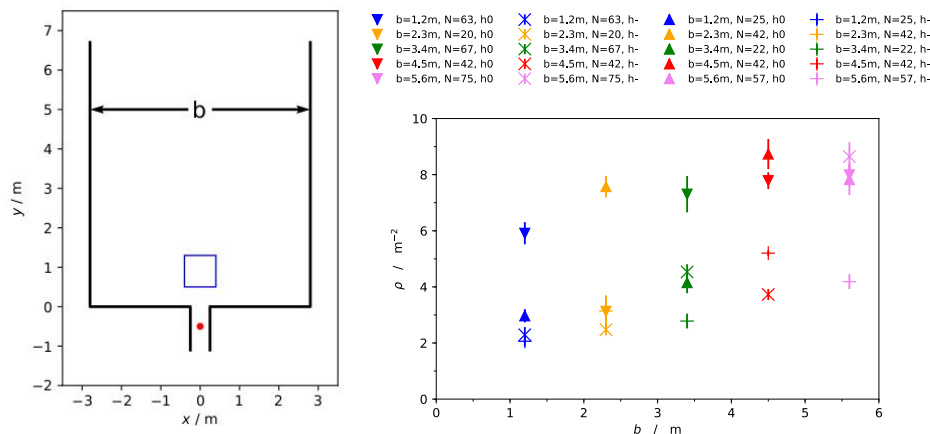


Figure 1: Left: Experimental setup. Direction of movement was from top to bottom. The corridor width b was varied between 1.2 m and 5.6 m. The entrance gate had a width of 0.5 m. The blue square indicates the measurement area; the red dot is the target at $x = 0$ m, $y = -0.5$ m. Right: Mean density (within time interval $t = 5$ s to $t = 10$ s) in the measurement area versus corridor width. N is the number of participants, h0 indicates high motivation and h- low motivation, respectively.

The presented results are based on individual trajectories that were extracted from overhead video recordings. Those results include, e.g., density and waiting time analysis. According to our findings, the density in front of the entrance gate as well as the area in which high densities are observed are generally increased by increasing the corridor width (see Figure 1-Right). For most groups, there is a density gap of ca. 3 – 4 people per square meter between the run with high motivation (h0) and the corresponding run with low motivation (h-). This does not hold for a small number of participants. However, this gap indicates the presence of two density stages. The low stage suggests that the social norm of queuing dominates whereas the high stage suggests that a pushing behaviour dominates and the social norm of queuing is broken. Further results are based on the ratio of active pushers to passive people and on analysis of the initial velocity, the preferred direction of movement and of the time-gap of persons reaching the target within the entrance gate.

Discharge Flow of a Granular Media from a Silo: Confinement Effect in a quasi 2D Silo.

ORAL 8TB

Pascale Aussillous¹, Zhenhai Zou^{1,2}, Yixian Zhou^{1,2}, Samira Laidaoui^{1,3}, Pierre-Yves Lagrée⁴, Pierre Ruyer², Blanche Dalloz¹.

Corresponding author: Pascale Aussillous

e-mail: pascale.aussillous@univ-amu.fr

Affiliation(s): ¹ Aix-Marseille Univ, CNRS, IUSTI, Marseille, France

² Institut de Radioprotection et de Sûreté Nucléaire (IRSN), PSN-RES, SEMIA, LIMAR, Cadarache, St Paul-Lez-Durance, 13115, France

³ Laboratoire FIMAS, Université de Béchar, B.P 417 Béchar 08000, Algérie

⁴ Sorbonne Universités, UPMC Univ Paris 06, CNRS UMR 7190, Institut Jean le Rond d'Alembert, F-75005 Paris, France

Silos are widely used in the industry. While empirical predictions of the flow rate, based on scaling law, exist for more than a century (Hagen 1852- Beverloo et al 1961), recently advances have been made on the understanding of the control parameters of the flow. In particular using continuous modeling together with a $\mu(I)$ granular rheology seem to be successful in predicting the flow rate for large number of beads in the aperture (Staron et al, 2012,2014). Moreover Janda et al (2012) have shown that the packing fraction at the outlet plays an important role when the number of beads in the aperture decreases.

However few studies concern the prediction of the mass flow rate of a granular media discharged from a silo with a lateral orifice, a situation which can have practical interest considering a tank of granular material with a leak on its side. This situation has some relevant similarity with the fuel particle ejection out of a rod within the core of a nuclear power plant during an hypothetical accident.

Based on these considerations, we have studied experimentally the effect of the position of the orifice on the discharge flow of a granular media from a thin rectangular silo, filled by spherical monodisperse beads. We have varied the size and the aspect ratio of the orifice, and we have considered three configurations for the orifice position: at the center of the base of the silo, at the lateral size of the silo, and at the corner of the base of the silo.

We have identified two regimes of discharge according to the aspect ratio (of width to height) of the rectangular orifice and its position. We propose a simple physical model to describe the effect of these parameters, considering a continuous granular media with a $\mu(I)$ -rheology and taking into account the role of the confinement. Using continuum Navier-Stokes simulations we showed that this model describes well the discharge flow of granular media from quasi 2D silos.

References:

- BEVERLOO, W. A., LENIGER, H. A. & VAN DE VELDE, J. 1961 The flow of granular solids through orifices. *Chem. Engng Sci.* 15, 260–269.
- JANDA, A., ZURIGUEL, I. & MAZA, D. 2012 Flow rate of particles through apertures obtained from self-similar density and velocity profiles. *Phys. Rev. Lett.* 108, 248001.
- STARON, L., LAGRÉE, P.-Y. & POPINET, S. 2012 The granular silo as a continuum plastic flow: The hour-glass versus the clepsydra. *Phys. Fluids* 24, 103301.
- STARON, L., LAGRÉE, P.-Y. & POPINET, S. 2014 Continuum simulation of the discharge of the granular silo, a validation test for the $\mu(I)$ visco-plastic flow law. *Eur. Phys. J. E* 37 (1), 5.
- TIGHE, B. P. & SPERL, M. 2007 Pressure and motion of dry sand: translation of Hagen's paper from 1852. *Granul. Matt.* 9, 141–144.

Transition to congestion for self-propelled particles confined in a looped-track with a bottleneck ORAL 2WB

Thomas Barois, Jean-François Boudet, Nicolas Lanchon, Juho Lintuvuori and Hamid Kellay

Corresponding author: Thomas Barois

e-mail: thomas.barois@u-bordeaux.fr

Affiliation(s): Univ. Bordeaux, CNRS, LOMA, UMR 5798, F-33405 Talence, France

In recent works, self-propelled granular particles have been used to explore either a free regime of traffic[1] or the congested regime obtained with a large number of particles in a hopper-like constriction[2]. The object of this work is to investigate the nature of the transition between a free regime to congestion as the number of particle in the track is increased. We use electromechanical robots similar to the one used in the works cited previously [1,2]. The robots are circulating in closed-circuit with a varying width presented in figure 1.

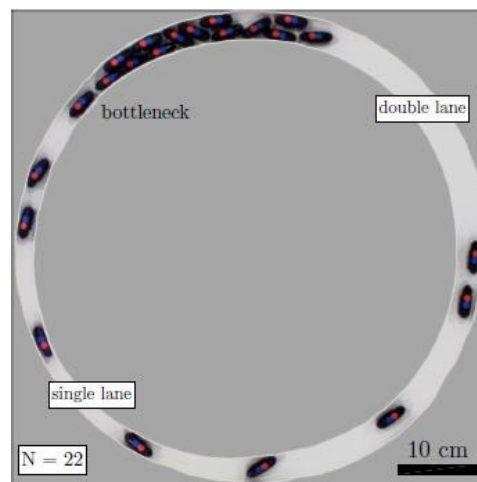


FIG. 1: Image of the traffic experiment with $N = 22$ self-propelled elements circulating anti-clockwise in a track of varying width. On half of the track, the track width is large enough to allow particle to overtake each other. A particle clogging is observed at the bottleneck.

The two results that we would like to present are:

The observation and the characterization of a transition from a free to a congested flow regime when the number of particles is increased.

The possibility to modify the flow relation, i.e. the dependence of the flux versus vehicle density, by velocity reduction strategy and beyond

For 1., we quantify the particle flux as the number of particle in the track is increased. A transitory state is uncovered for intermediate number of particles (typically 15), in which, for a fixed number of particles in the track, the flow regime switches back and forth between free and congested.

For 2., we test the “slower is faster” effect by imposing a velocity reduction of the particles on a short section of the track length. We show that the traffic performances close to congestion are improved. To go further, we test numerically additional strategies beyond the velocity reduction approach. We show that it is possible to modify significantly the traffic performances without modification of the average properties (such as mean velocity, mean escape time, ...) of the particles.

References:

- [1] Flow rate behavior and clustering of self-driven robots in a channel, Chinese Physics B 2017
- [2] Clogging transition of vibration-driven vehicles passing through constrictions, Phys Rev Lett 2017

The Measurement of Stress at Open Air Events: Monitoring Emotion and Motion Utilizing Wearable Sensor Technology ORAL 10WA

Benjamin S. Bergner

e-mail: benjamin.bergner@ru.uni-kl.de

Affiliation(s): Faculty of Urban and Environmental Planning, Urban Sociology, University of Kaiserslautern, Germany

Open air events like city festivals or concerts are regarded as essential for liveable communities. In terms of collective experience, events are characterised as social, non-routine, emotional and singular phenomena. They allow the experience of community, interaction and corporate identity for people with different backgrounds. Our research focuses on well-being and emotions of event attendees at open air events and primarily on situations, in which people feel stressed or unsafe. These types of feelings and accompanying emotions are important as they influence social behaviour. Especially in risky situations, stress can lead to avoidance behaviour or aggression and thus endanger the course of an event. Typically, unsafe areas are identified by means of classical empirical methods (quantitative and qualitative interviews). All these methods are based on cognitive self-perception, experiences and social desirability. To overcome these influences, nowadays it is possible to measure and track physiological vital data in real-time with the help of wearable devices combined with GPS sensors for spatial localisations. Social scientists are able to get objective information, which can be added to verbal statements on emotions and affections. With the rise of wearable sensor technologies the human being itself becomes an emotion sensor. It is questionable to what extent this data can be used for identification of spatial deficits, group processes or external effects. For decades, ambulatory assessment methods have been used to identify humans' emotions linked to distinctive stimuli in laboratories under controlled conditions. Knowledge transfer to real-world applications is still rare due to many uncontrollable environmental issues. Psychophysiological monitoring, however, shows high potential of transferability to real-world studies.

Methods: In order to identify stressful situations in our studies, classical methods like standardised questionnaires (n=746), observations and interviews (n=20) were conducted, but complemented by monitoring real-time stress experiences. Here, a sensor wristband was used, which allows to collect location-independent peripheral-physiological data as indicators for emotions/stress in real-time. The presented use cases are the city festival "Altstadtfest 2014" in Kaiserslautern and the "Back to the Woods Open Air 2014 & 2015" in Munich/Garching with a total number of 25 study participants equipped with sensor wristbands. The usage of user-generated emotion data in specific socio-spatial analyses still have to meet many challenges, concerning data acquisition, operability, validation and visualisation. In order to identify reasons for stress at this state of our research, further data sources were taken into account.

Standardised questionnaires conducted before and after visiting the event give insight in the study participants' personality, actual state of anxiety/fear, event affinity, perceived sense of safety and socio-demographic data. Our mixed-method approach combines classic empirical methods, psychophysiological monitoring, spatial analyses as well as GIS-based visualisation techniques for showing stress hot spots and motion patterns of the event attendees.

Results: There are significant differences between the three events and the standardised stress values of the participants. With the help of density and sectoral spatial maps of stress events, specific neuralgic areas were identified. They were validated by qualitative interviews with event organisers and security organisations, and by standardised questionnaires with event attendees.

Discussion: We want to discuss the transferability of the collected information from static events like open air festivals to dynamic gatherings like political demonstrations with high conflict potential. Dynamic gatherings are characterized by changing conditions of the emotional atmosphere, the behaviour and movement of the crowd, and constantly changing spatial surroundings. The application of stress monitoring requires adjustments concerning the analysis of stress eliciting situations and the sensitive handling of gathered data.

Numerical study of stress distribution in silos. POSTER P1

Rodolfo Blanco Rodríguez, Gabriel Pérez Ángel

Corresponding author: Rodolfo Blanco Rodríguez

e-mail: rodolfo.blanco@cinvestav.mx

Affiliation: Center for Research and Advanced Studies of the National Polytechnic Institute, Merida, Yucatan, Mexico.

Silos are fundamental structures in the industry; therefore, a depth analysis of stress distribution, both inside and at the boundaries of the silo, is necessary. In this work, simulations of a polydispersed two-dimensional silo were performed using molecular dynamics, with different numbers of grains reaching up to 64000, verifying numerically the model derived by Janssen and also the main assumption that the walls carry part of the weight due to the static friction between grains with themselves and those with the silo's walls. We vary the friction coefficient, the radii dispersity, the silo width, and the size of grains. We find that the Janssen's model becomes less relevant as the silo width increases since the behavior of the stresses becomes more hydrostatic. Likewise, we get the normal and tangential stress distribution on the walls evidencing the existence of points of maximum stress. We also obtained the stress matrix with which we observe zones of concentration of load, located always at a height around two thirds of the granular columns. Finally, we observe that the size of the grains affects the distribution of stresses, increasing the weight on the bottom and reducing the normal stress on the walls, as the grains are made smaller (for the same total mass of the granulate), giving again a more hydrostatic and therefore less Janssen-type behavior for the weight of the column.

References:

1. Spertl, M. (2006). Experiments on corn pressure in silo cells—translation and comment of Janssen's paper from 1895. *Granular Matter*, 8(2), 59-65.
2. Bertho, Y., Giorgiutti-Dauphiné, F., & Hulin, J. P. (2003). Dynamical Janssen effect on granular packing with moving walls. *Physical review letters*, 90(14), 144301.
3. Blanco-Rodríguez, R., & Pérez-Ángel, G., (2018). Stress distribution in two-dimensional silos. *Physical Review E*, 97(1), 012903.

Can we infer the directional movement intention of pedestrians from two of their steps?

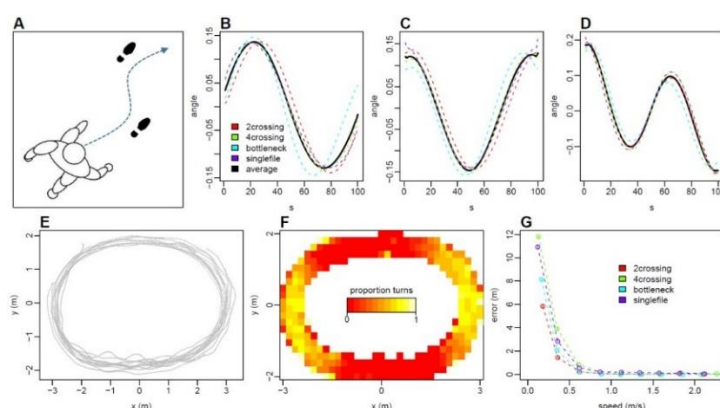
ORAL 1WA

Nikolai Bode

e-mail: nikolai.bode@bristol.ac.uk

Affiliation(s): Dept. of Engineering Mathematics, University of Bristol, Bristol, BS8 1UB, UK

The motion of pedestrians comprises predominantly of changes in speed and changes in movement direction. Previous work has observed that a natural discrete unit for individuals to adapt their movement arises from their bipedal motion: the step [1-4]. Thus, taking steps could be decision time points for pedestrians to select from options such as speeding up (extending step length/frequency), slowing down or changing movement direction (placement of next step relative to current position). To fully test this theory, it is necessary to infer from data when pedestrians take steps and what their movement intention is in these steps. Here, I present an approach designed to infer changes in movement direction from stepping patterns.



When walking, pedestrians shift their weight from one foot onto the other. This leads to a waveform in the movement path of their head (fig. 1A) which is typically tracked in pedestrian experiments. Using a measured relationship between speed and step-lengths [4], I extract trajectory segments consisting of approximately two pedestrian steps from published data (<http://ped.fz-juelich.de/db/>, 460,267 segments extracted). Using an established technique [5], similar to principal component analysis, I extract the waveforms responsible for most variation across all these trajectory segments. Three principal waveforms or stepping patterns explain between 66-88% of variability in the data and are very similar across experimental settings (fig. 1B-D, the figures represent patterns by angles measured along them, see [5]). Trajectory segments can be expressed as a linear combination of these principal stepping patterns and the weighting of each pattern indicates its amplitude in a given segment. The first two patterns (fig. 1B,C) relate to regular oscillations in straight-line walking, but the third pattern relates to turning behaviour [5]. For unimpeded walking (often associated with low densities), an amplitude >1 of the third pattern can be used to identify turning behaviour in individuals' steps, as illustrated by an analysis of a single-file experiment (trajectories in fig. 1E; proportion of identified turns in fig. 1F). For lower speeds (often occurring at higher densities), this approach does not work. My analysis shows why: the error in representing trajectories with only three principal stepping patterns increases with decreasing speeds (fig. 1G), suggesting that stepping locomotion becomes less regular and predictable. Therefore, with current data it may be difficult to infer directional intentions in stepping behaviour in all cases.

References: [1] Seitz, M. J., & Köster, G. (2012). *Physical Review E*, 86(4), 046108. [2] Seitz, M. J., Bode, N. W. F., & Köster, G. (2016). *Journal of the Royal Society Interface*, 13(121), 20160439. [3] Wang, J., Weng, W., Boltes, M., Zhang, J., Tordeux, A., & Ziemer, V. (2018). *Journal of Statistical Mechanics: Theory and Experiment*, 2018(2), 023406. [4] Wang, J., Boltes, M., Seyfried, A., Zhang, J., Ziemer, V., & Weng, W. (2018). *Physica A: Stat. Mech. and its Applications*, 500, 106-120. [5] Stephens, G. J., Johnson-Kerner, B., Bialek, W., & Ryu, W. S. (2008). *PLoS Computational Biology*, 4(4), e1000028.

Smoothing trajectories of peoples' heads POSTER P2

Maik Boltes, Jana Pick

Corresponding author: Maik Boltes

e-mail: m.boltes@fz-juelich.de

Affiliation(s): Institute for Advanced Simulation IAS-7: Civil Safety Research
Forschungszentrum Jülich GmbH 52428 Jülich Germany

Controlled experiments give the possibility to extract trajectories of the head of each individual person with high accuracy also in dense crowds. These trajectories allow a detailed analysis of the movement, provide a basis for quantifications in legal regulations, guidelines and manuals for the construction of pedestrian facilities and enable the design, calibration and verification of microscopic models.

Caused by the resulting swaying and bobbing the trajectories do not show directly the main movement direction. The movement of the head is influenced not only by the main movement direction but also by its bipedal gait and the associated relocation of the center of mass.

This leads for example to an overestimation of the velocity, if no preprocessing is performed. Also, lane formation is more difficult to identify.

This paper describes methods for smoothing trajectories of the head to determine the main movement direction and its implication to quantities in pedestrian dynamics, e.g., the fundamental diagram. Different methods are applied to existing data sets with varying velocity regimes and the results are compared (see Figure 1 right). An often-used method for smoothing data series is the moving average forming arithmetic averages over partial intervals of the original data. With an uniform step frequency, a good approximation to the desired line of the main direction of motion is already achieved. However, if the person walks at different speeds or stops, the size of the interval for averaging must be adapted.

The steps from one leg to the other results in periodic deflections. Thus, the second examined method choses the turning points between the maximum curvatures as knots for a spline interpolation.

A new third approach is a marching convex hull. This method particularly solves the problem at low velocities of the former methods. For this purpose, a convex hull is formed over a shifting interval along the original data. The resulting smoothed trajectory is located between the partial envelopes connected to a single tube around the trajectory (see Figure 1 left).

All methods can be improved by an adaptation to the velocity or a preceding step detection.

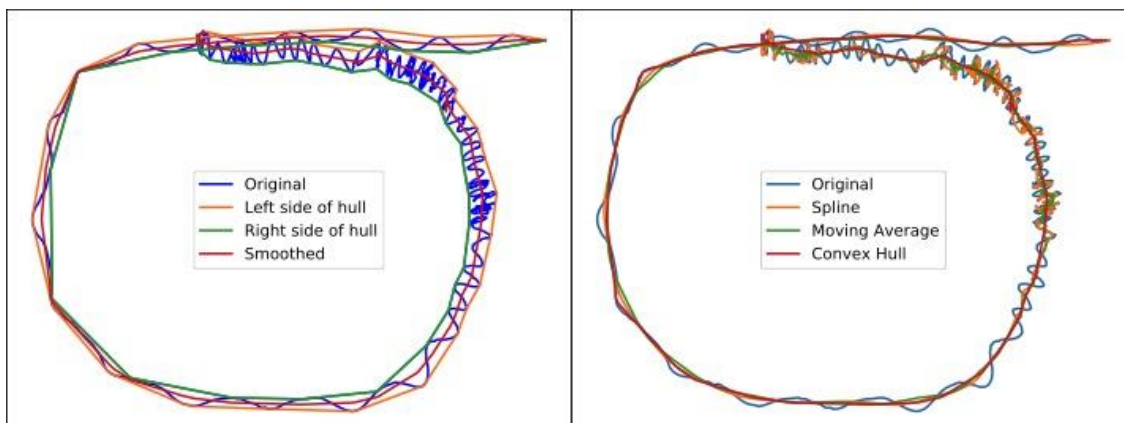


Figure 1: Left: Construction of a marching convex hull forming an envelope (yellow and green) around the resulting smoothed trajectory (red). Right: Smoothed trajectory from three examined methods (moving average, spline interpolation and marching convex hull).

Motion capturing in dense crowds by a combination of an inertial and optical system

ORAL 11WA

Maik Boltes, Juliane Adrian

Corresponding author: Maik Boltes

e-mail: m.boltes@fz-juelich.de

Affiliation(s): Institute for Advanced Simulation IAS-7: Civil Safety Research
Forschungszentrum Jülich GmbH 52428 Jülich Germany

Most controlled experiments to study pedestrian dynamics are equipped with a camera system making it possible to extract trajectories of each person's head even in dense crowds as long as the head is visible to the camera. These trajectories allow a detailed analysis of the movement, provide a basis for quantifications in legal regulations, guidelines and manuals for the construction of pedestrian facilities and enable the design, calibration and verification of microscopic models. Camera systems, most often used for extracting trajectories of the visible head of each individual, have in common that swaying and bobbing are included or have a negative influence respectively. Sometimes only the main moving directing is needed, but the more detailed the movement is recorded, the more accurate and meaningful the analysis can be.

The knowledge of the full body motion would enable the understanding of the physical part of pedestrian dynamics as a whole so that, e.g., a phenomenon like clogging could be examined in detail and general models could be developed taking the full body motion into account. Also, the bipedal movement of a general model could enclose stair climbing just like planar movement.

Typical full body motion capturing systems use an optical sensor system. Therefore, the performer has to wear optical markers near each joint to identify the motion by the positions of the markers or angles between the markers. Like for the mentioned camera systems, these markers have to be visible to the optical sensor system making these systems inapplicable for capturing the motion of a person inside a crowd.

Recently, new motion capturing systems came up using self-contained inertial measurement units (IMUs), biomechanical models and sensor fusion algorithms. IMUs contain a combination of gyroscope, magnetometer, and accelerometer, to measure rotational rates. These rotations are translated to a skeleton. No external cameras, emitters or markers are needed for calculating the relative motions meaning that also the movement of invisible parts of the body is trackable. The largest disadvantage of such a system is, however, the relative calculation of the motion. Thus, the absolute position is characterized by a drift.

In a bottleneck study in December 2018, we equipped the experiment with a combination of a camera system for the absolute positioning of all persons and an IMU system for the exact relative full body motion of one participant. By data fusion of both systems, the resulting trajectories have a correct and highly-precise absolute position in 3D space guiding a skeleton with the locomotion of that person (see Figure 1).

In the contribution, the hybrid tracking system will be described and first results of the experiment, such as the dependency of density and step length, step width and frequency will be presented.

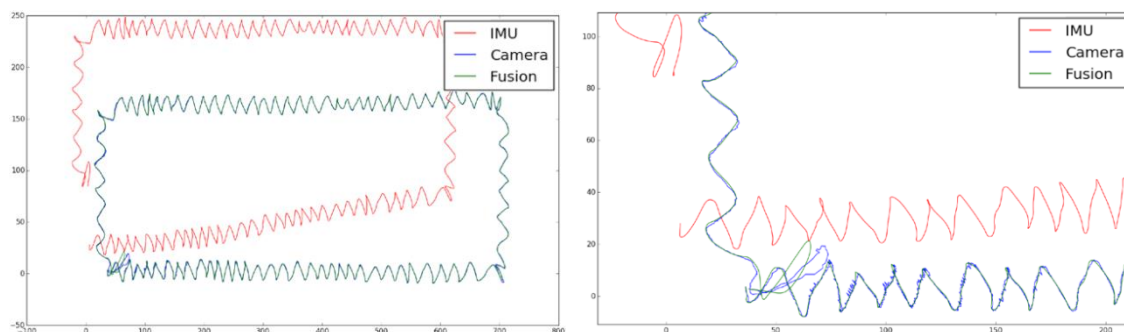


Figure 1: Left: Trajectory of a person walking very slowly along a closed rectangular path. The blue line shows the head trajectory extracted from a video sequence, the red line the path tracked by the IMU system and the green line the fused path, respectively; Right: Enlarged section of the bottom left corner of the left figure showing an absolute error of 50 cm of the IMU system between the equivalent start and end position.

Tamás Börzsönyi¹, Ellák Somfai¹, János Török², Dániel Nagy^{1,3}, Philippe Claudin³, Raul Cruz Hidalgo⁴ and Ralf Stannarius⁵

Corresponding author: Tamás Börzsönyi

e-mail: borzsonyi.tamas@wigner.mta.hu

Affiliation(s):

¹Wigner Research Centre for Physics, Hungarian Academy of Sciences, Budapest, Hungary

²Budapest University of Technology and Economics, Budapest, Hungary

³PMMH, ESPCI, Paris, France

⁴University of Navarra, Pamplona, Spain

⁵Otto von Guericke Universitaet Magdeburg, Germany

We report on experimental and numerical results on the flow of granular materials consisting of elongated particles. In a sheared system particles rotate with time dependent angular velocity and neighbors interact and often hinder each other's rotation. This complex dynamics leads to orientational ordering of the grains where the average alignment encloses a small angle with the flow lines (Fig.1a-b) [1,2]. We quantify numerically, how the effective friction of the system changes with particle aspect ratio. For large interparticle friction the effective friction of the system increases with aspect ratio [3], while for smaller interparticle friction an interesting non-monotonic behavior is detected [4]. We show experimentally, that the shear induced Reynolds dilation is only partially compensated by the compaction resulting from orientational ordering [5]. Analyzing the flow field in quasi 2D hoppers we find rather regular flow for spherical grains, while the flow of elongated grains is concentrated to the middle of the hopper, with a step like velocity profile and is characterized by large velocity fluctuations [6]. The grain orientations have been determined in a 3D cylindrical bin by X-ray computed tomography (CT). As the materials sinks in the silo, orientational order develops gradually in the sheared regions [7]. Similarly to simple shear flows, the average grain orientation is not parallel to the streamlines, but encloses a small angle with them (Fig.1c-d). We show, that the probability for clogging is increasing with increasing grain elongation [8].

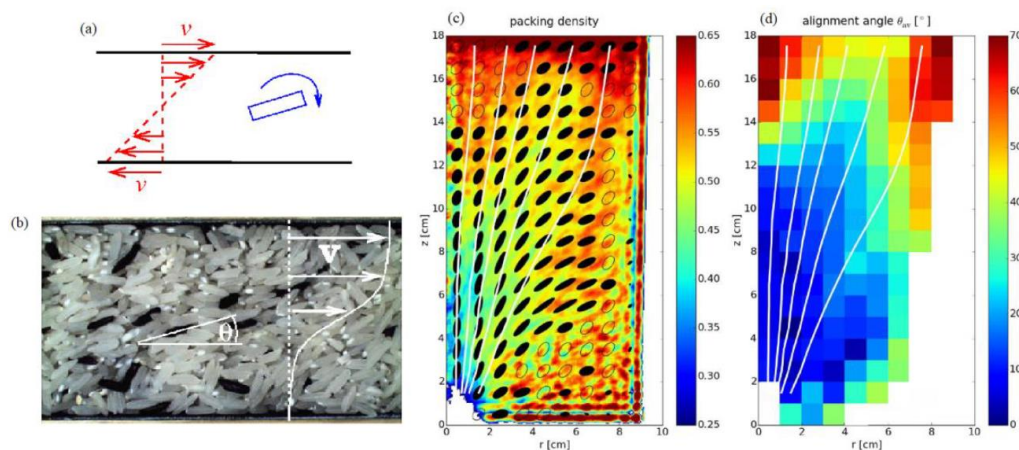


Figure 1. (a-b) Elongated objects rotate in shear flow, the average orientation encloses a small angle with the streamlines.. (c-d) Packing density and average grain orientation in a 3D cylindrical bin obtained by X-ray CT.

References:

- | | |
|---|---|
| [1] Börzsönyi et al., <i>Phys Rev. Lett.</i> 108 , 228302 (2012) | [5] Wegner et al., <i>Soft Matter</i> 10 , 5157 (2014) |
| [2] Börzsönyi & Stannarius, <i>Soft Matter</i> 9 , 7401 (2013) | [6] Szabó et al., <i>Phys. Rev. E</i> 97 , 062904 (2018) |
| [3] Hidalgo et al., <i>Phys Rev. Fluids</i> 3 , 074301 (2018) | [7] Börzsönyi et al., <i>New J. Phys.</i> 18 , 093017 (2016) |
| [4] Nagy et al., <i>Phys Rev. E</i> 96 , 062903 (2017) | [8] Ashour et al., <i>Soft Matter</i> 13 , 402 (2017) |

Influence of Small Scale Obstacles on Passenger Flows in Railway Stations ORAL 6WA

Ernst Bosina, Jasmin Thurau, Stephan Heule

Corresponding author: Ernst Bosina

e-mail: ernst.bosina@sbb.ch

Affiliation(s): SBB AG, Hilfikerstrasse 3; CH-3000 Bern 65; Switzerland

The railway network is the backbone of the well-known public transport system in Switzerland. To keep the system reliable and the planned connections on time, the railway stations and especially the pedestrian facilities therein need to be properly designed. Connection times have to be met, pedestrians have to be kept from getting close to the railway tracks and a comfortable walking and waiting situation has to be maintained. As in most other countries, railway stations in Switzerland are often within a dense city environment. In addition, the continuous improvement of the public transport system and the population rise lead to a significant increase in demand, which is expected to continue in the future. Therefore, several railway platforms and underpasses are close to capacity or experience severe crowding. Completely rebuilding stations, as it is planned for several big stations, is costly and time consuming. Hence, other interventions are needed to improve the passenger flows on platforms in a short-term perspective.

To better understand the pedestrian behaviour and to improve the passenger flows, the influence of obstacles on passenger flows and waiting locations are determined. By using currently available tracking techniques a quantitative assessment of the influences is performed. For this work, three different analyses were made.

At first, the influence of selected obstacles on railway platforms on the average number of pedestrians waiting in the surrounding was calculated and compared to sections without obstacles. This was done to determine whether the selected obstacle leads to lower space utilisation due to its physical extent or to higher utilisation, as pedestrians are observed to prefer waiting close to walls and obstacles.

In a second step, the effect of standing benches on the pedestrian waiting location is determined. In an effort to steer the chosen waiting location, standing benches were installed on one platform of the railway station Lenzburg. For this intervention, tracking data with and without the new standing benches is available. In addition, a survey was made on the perception of the standing benches. The data clearly showed an influence of the pedestrian distribution on the platform. Also, the preference between waiting at standing benches and at regular benches was observed.

As third, an intervention in the main underpass of the Bern railway station is presented. Here, advertisement monitors were installed in the middle part of the underpass. The monitors were installed in an 30° angle to the passenger flow, so that they face the desired walking direction. In the opposite direction, only the side wall of the monitor is visible. The goal of this adaption is to segregate pedestrians walking in the middle of the underpass as it is assumed that pedestrians do not like to walk towards the side walls of the monitors. To evaluate this scenario, pedestrian tracking sensors are installed in two sections of the underpass as well as eye-tracking measurements are planned.

The findings of this paper will provide quantitative data for all three analyses. Based on this the effect of the examined obstacles on the pedestrian flow and waiting locations will be described. It was revealed that it is possible to influence the pedestrian behaviour, but also limitations apply. Finally, recommendations on the use of the small-scale obstacles to guide the pedestrian behaviour in railway stations are given.

A simulation model for overtaking and platooning on two-lane roads POSTER P3

Frank Brooks-Tyreman, Prof R. Eddie Wilson

Corresponding author: Frank Brooks-Tyreman

e-mail: fb16610@bristol.ac.uk

Affiliation(s): University of Bristol

On two-lane single carriageway (known as S1) roads, the lack of safe overtaking opportunities results in faster vehicles becoming trapped behind slower ones. Our paper presents and analyses a new parsimonious model designed to investigate the resulting platoon formation and overtaking manoeuvres. The model is microscopic, capturing the key requirement of driver heterogeneity — both in terms of drivers' desired speeds and their propensities to overtake.

The main inputs in our model are: i) upstream demand modelled in the form of a Poisson process arrival rate; ii) a probability distribution for desired speeds that models a range of free-flow speeds across the vehicle / driver population; and iii) overtaking rules and associated parameters determined through empirical ANPR data obtained from Transport Scotland.

Our model consists of two parts: i) a longitudinal model — which can be thought of as a kind of first-order car-following model capturing the platoon dynamics; and ii) an overtaking model — capturing the decision making process, propensity to overtake and execution of the manoeuvre itself. Each vehicle i , is equipped with its own invertible speed-spacing function $V_i(s)$, where $v_i^{\max} := V_i(+\infty)$ is its desired speed.

We use three level of service (LOS) metrics for summarising the complex emergent dynamics in our simulations: i) the percentage time spent following (PTSF); and distributions across the vehicle population of ii) average speed and iii) overtaking rates. Roads with high PTSF and low overtaking rates are candidates for dualling. Other interventions in future might involve use of connected and autonomous vehicles (CAVs) to regulate platoon size or driver assist functions to coordinate overtaking opportunities.

The speed-spacing function in our model provides a modelling device for capturing overtaking measurements that are difficult to obtain empirically. Extending the heterogeneity of our model beyond the distribution of desired speeds we are able to capture: i) a good description of traffic patterns on S1 roads; ii) an accurate representation of platoon formation; and iii) realistic frequencies for overtaking.

Our simulation model is simple to use and can easily be applied in informing policy decisions. From our model we are able to advise, on both a population and an individual vehicle level, how best to improve the LOS for S1 roads.

Double-deck Railcar Egress Experiment: The Influence of Heterogeneity, Exit Width and Exit Type on Pedestrian Time Headways POSTER P4

Marek Bukáček¹, Veronika Pešková², Hana Najmanová²

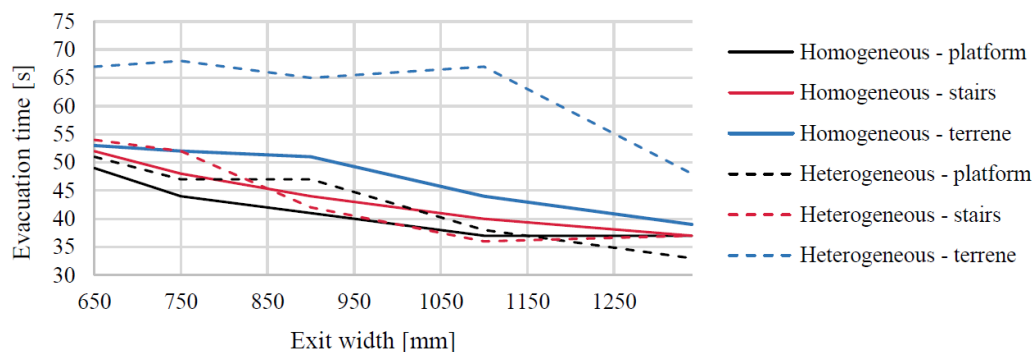
Corresponding author: Marek Bukáček

e-mail: marek.bukacek@fjfi.cvut.cz

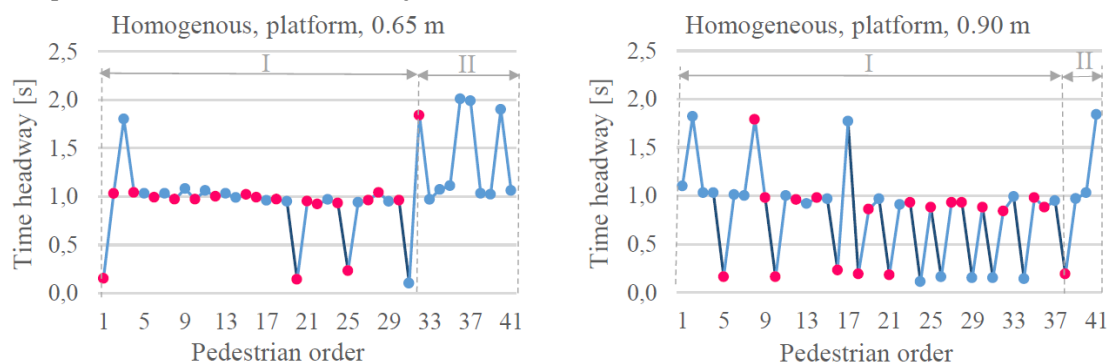
Affiliation(s): ¹ Faculty of Nuclear Sciences and Physical Engineering Czech Technical University in Prague

² Faculty of Civil Engineering, Czech Technical University in Prague

A double-deck railcar egress experiment aiming to estimate the effects of exit type, exit width and structure of passengers on evacuation time was organized. This project followed previous study realized in 2015 extending portfolio of observed parameters. In the egress experiment, almost 90 participants were divided into two groups: high school students created the homogeneous group, the heterogeneous group was mixed from young children, adults and elderly respecting the distribution observed in trains in the Czech Republic. The exit width varied from 0.65 m to 1.34 m and the exit type was changeable as well (a platform, stairs to the terrene, a ‘jump’ to the terrene). Since both groups egressed the train under all exit variations, in total 30 different scenarios were carried out. The experiment was monitored by 17 wide-range cameras covering the whole experimental area. Using manual detection, the passing time was recorded on the most important cross-sections. The time resolution is estimated to 0.1 s. Effect of the investigated parameters is visualized in the first figure: Evacuation time decreased with the increasing exit width (30% difference between 0.65 m and 1.34 m), the homogeneous group of students evacuated faster than the standardized passengers’ sample, and the egress to the platform is faster than using stairs to the terrain or jumping to the terrain.



The detailed insight how exit width affects evacuation time is provided by time headways (see the figure below). In case of the narrow exit, the default time headway between pedestrians was 1 s that corresponds to the flow 1 ped/s, i.e. 1.54 ped/s/m. With increasing the width, the mean value of flow increased, but the default headway stayed. Surprisingly the higher flow was caused by increasing the frequency of the situation when two participants passed the door simultaneously.



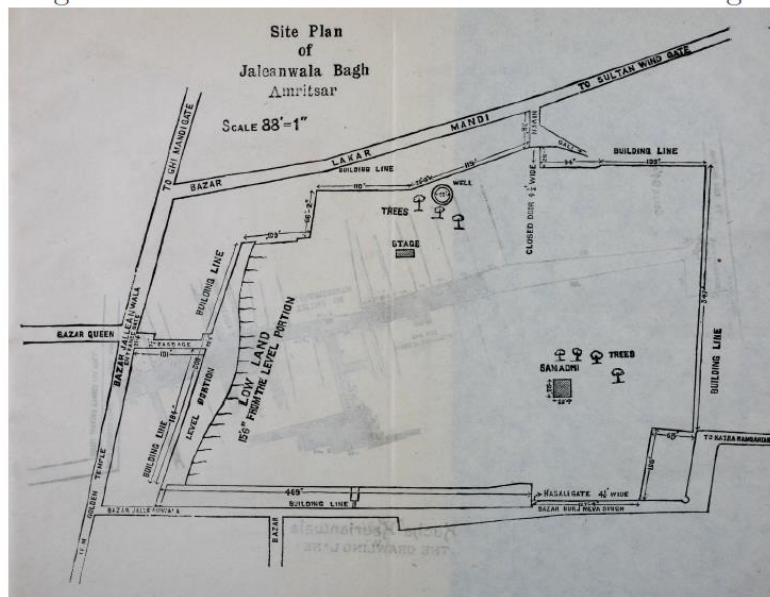
The standard zipper concept for bottleneck widths sufficient for a bit more than one line expects the decrease of time headways in comparison to strictly one-line geometry. This behavior would be detected by time headway values observed in the interval (0.3 s – 0.9 s) that is completely absent in the presented experiment. The article will deal with this conflict and moreover, the influence of the heterogeneity and the exit type on the time headways will be analyzed in detail.

INVITED 7WA

Corresponding author: Mohcine Chraïbi

Affiliation(s): Institute for Advanced Simulation – Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

Figure 1: The event site known as Jallianwala Bagh.



M. Chraibi¹, B. Steffen¹, A. Tordeux², Jun Zhang³

Corresponding author: Mohcine Chraibi

e-mail: m.chraibi@fz-juelich.de

Affiliation(s):

¹Institute for Advanced Simulation – Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

²School for Mechanical Engineering and Safety Engineering, University of Wuppertal, Wuppertal, Germany

³State Key Laboratory of Fire Science, University of Science and Technology of China, Hefei, China

Voronoi diagrams are an established method in the analysis of pedestrian motion for constructing a density from two-dimensional positions. It is in turn used to give pointwise values for speed, movement direction, flow etc. The method was firstly described for high-density situations inside a crowd moving in a simple geometry without considering the influence of walls. However, more complicated distance calculations are needed for more complicated geometries where there are several obstacles or corners. In addition, partially empty spaces also require some modifications and some limiting mechanisms to avoid excessively big cells. These problems are only sketched in the original Paper [1] but subsequently are not always handled correctly.

In this work, we now give details on how to modify the simple Voronoi diagrams to make it fit for the presence of walls and obstacles in complex geometries. Furthermore, we show how the size of a personal space can be reasonably restricted for persons at the edge of a group. Based on these modifications, having pointwise values for quantities of interest allows to give average values for arbitrary geometries, not just for lines or rectangles of measurements. To be useful, different quantities may need different kind of averages – arithmetic or harmonic, weighted with density etc. Finally, we will give some details and illustrating examples using real experimental data [2] to validate the effects of the generalized method..

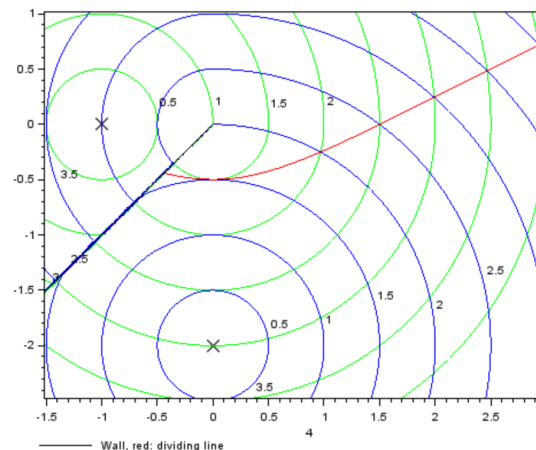


Fig.1 An example of the Voronoi diagram generation with modified algorithm when an obstacle separates two pedestrians (notated with x).

References

- [1] B. Steffen and A. Seyfried. Methods for measuring pedestrian density, flow, speed and direction with minimal scatter. *Phys. A*, 389(9):1902–1910, 2010.
- [2] ped.fz-juelich.de/database.

Measuring and modeling orientation in real-life pedestrian dynamics ORAL 2WA

J. Willems¹, A. Corbetta¹, F. Toschi^{1,2}

Corresponding author: Alessandro Corbetta

e-mail: a.corbetta@tue.nl

Affiliations: ¹Department of Applied Physics, Eindhoven University of Technology, Eindhoven, The Netherlands, ²CNR-IAC, Roma, Italy.

Shape and orientation of individual particles are known to have a significant effect on the properties of flowing matter [1]. In analogy with traditional fluid-dynamics of non-spherical particles, we expect the typical elongated shape of pedestrians in the plane of motion (i.e., as seen from a birds-eye view), and the individual orientation, to acquire a prominent role as the crowd density increases. This makes the orientation dynamics a crucial, but yet poorly investigated, aspect to study and also a key ingredient in order to accurately model dense crowds. In this contribution, we address a two-fold task: first, we develop a tool for estimating, with extremely high accuracy and with low computational effort, the orientation of pedestrians in depth-map based real-life measurements (see Fig. 1, and cf. [2]). Second, we model the orientation dynamics by including a rotation degree of freedom in our Langevin model for pedestrian motion [2]. We developed a tool for accurate orientation measurements from depth maps by leveraging on the excellent performance in image analysis of state-of-the-art convolutional neural networks (CNN). However, CNNs notoriously require extensive training by an exceeding amount of annotations, generally manually obtained. We avoid this labor-intensive process by exploiting physical properties of pedestrian dynamics in connection with shape. Training a CNN with such physically-educated annotation results in a tool that surpasses humans in estimating pedestrian orientation (see Fig. 1) with negligible human annotation labor. We employed this novel measurement tool on huge amounts of depth data to study the pedestrian orientation dynamics in statistical ensembles and, on this basis, formulated a Langevin-like model coupling motion and orientation dynamics. Depth sensors (Microsoft Kinects) cameras are mounted in the “measurement zone”.

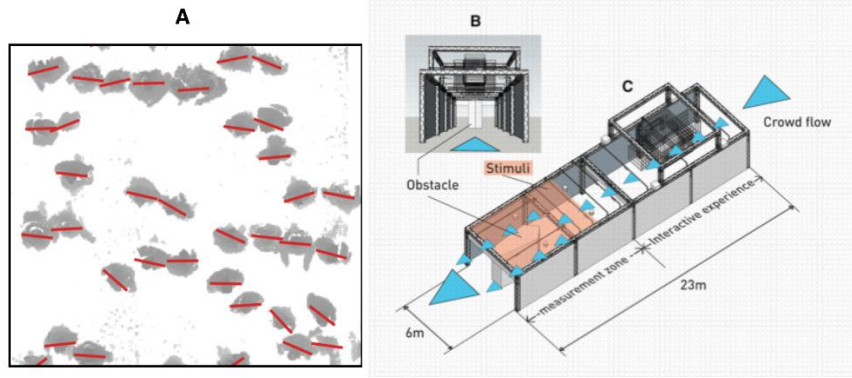


Figure 1: (A) Overhead depth map of pedestrians obtained in the setup in (B-C), cf. [3]. Grey shades represent the distance from each pixel and the camera plane. Hence bodies and heads (closer to the camera) come in darker color than the floor (white background). Individual orientation computed with our method are superimposed as a red bar to each pedestrian. (B-C) Pedestrian tracking setup described in [3]. (B) Sketch of the frontal view of the installation as seen by a pedestrian. (C) Aerial view. The blue triangles indicate the flow direction.

References: [1] D. Parisi, H. R. Cruz, and I. Zuriguel, “Active particles with desired orientation flowing through a bottleneck”, in *Scientific Reports*, vol. 8, no. 1, p. 9133, 2018.
[2] A. Corbetta, J. Meeusen, C. Lee, R. Benzi, F. Toschi. “Physics-based modeling and data representation of pairwise interactions among pedestrians”, in *Phys. Rev. E* 98, 062310, 2018
[3] A Corbetta, W Kroneman, M. Donners, A. Haans, P. Ross, M. Trouwborst, S. vd Wijdeven, M. Hultermans, D. Sekulowski, F. vd Heijden, S. Mentink, F. Toschi, “A large-scale real-life crowd steering experiment via arrow-like stimuli”, to appear: *Pedestrian and Evacuation Dynamics 2018*, arXiv:1806.09801, 2018

Moving Lights? Nudging pedestrian flows with illumination POSTER P6

Alessandro Corbetta¹, Werner Kroneman¹, Maurice Donners², Antal Haans³, Philip Ross⁴, Marius Trouwborst², Sander Van de Wijdeven², Martijn Hultermans², Dragan Sekulovski², Fedosja van der Heijden², Sjoerd Mentink², Federico Toschi¹

Corresponding author: Alessandro Corbetta

e-mail: a.corbetta@tue.nl

Affiliation(s): ¹Department of Applied Physics, Eindhoven University of Technology, NL | ²Philips Lighting, Eindhoven, NL | ³Human Technology Interaction, Eindhoven University of Technology, NL | ⁴Studio Philip Ross, Eindhoven, NL

Steering the route choice of pedestrians walking in crowds is a compelling issue in crowd management, and a necessity to ensure individual comfort and safety in crowded public spaces. Achieving such a steering non-invasively through nudging stimuli, such as via dynamic illumination, is not just suggestive, but comes with exceptional potential for scalability and automation, in comparison, e.g., with ad hoc displacement of barriers or stewards. Currently, little is known about the performance of nudging stimuli at steering, and almost no quantitative experiment performed in real-life exists (while Virtual Reality counterparts are growing). In this contribution we analyse the nudging effect of illumination when it comes to influence the binary choice of pedestrians between two identical exits at the end of a corridor. Our experiment is performed in real-life conditions as an exhibit, named “Moving Light”, along the city-wide route of the 2017 Eindhoven Glow Festival (see Figure 1 and introductory paper [2]).

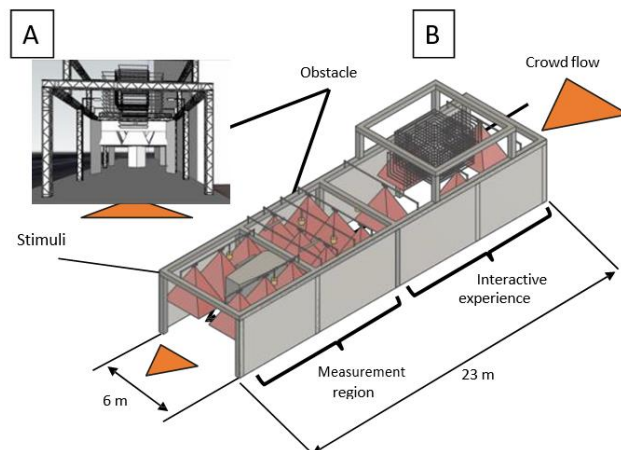


Figure 1. The “Moving Light” real life experiment. The triangle indicates the direction of the crowd flow. (A) Frontal view, as seen by an entering visitor. The central obstacle is visible at the end. (B) 3D sketch. The first half of the facility, with a timed interactive experience, ensures a regular scheduling in the crowd flow, that passes through the measurement zone in “batches” of 1 minute. In the measurement zone a stimulus (illumination-based or signage-like) changes at random every 3 minutes.

About 140.000 among the festival visitors walked through our installation as a unidirectional flow. While being individually tracked at extremely high resolution, visitors left our installation on the left or on the right side of a central obstacle. For the entire duration of the festival, we subjected the visitors stream to one among 18 different “stimuli” that encompassed, among others, uneven illumination of the paths left and right of the obstacle (e.g. an arrow pointing at either side). We discuss the nudging performance of illumination at “modulating” the decision of the flow to prefer either of the two exits in dependence on factor such as illumination intensity, local crowd density and entering location. We adopt the steering performance of traditional signage, also part of the measurements, as a benchmark.

References

- [1] A. Corbetta, W. Kroneman, M. Donners, A. Haans, P. Ross, M. Trouwborst, S. vd Wijdeven, M. Hultermans, D. Sekulowski, F. vd Heijden, S. Mentink, F. Toschi. *A large-scale real-life crowd steering experiment via arrow-like stimuli*. To appear: Pedestrian and Evacuation Dynamics 2018, 2018

Optimizing museums' experience via trajectory analysis of visitors POSTER P7

Alessandro Corbetta¹, Emiliano Cristiani², Marina Minozzi³, Federico Toschi^{2,4}

Corresponding author: Alessandro Corbetta

e-mail: a.corbetta@tue.nl

Affiliations: ¹ Department of Applied Physics, Eindhoven University of Technology, The Netherlands

²Istituto per le Applicazioni del Calcolo, CNR, Rome, Italy

³Galleria Borghese, Rome, Italy

⁴Department of Applied Physics and Department of Mathematics of Computer Science, Eindhoven University of Technology, The Netherlands;

In this work we discuss the results of an experiment that we recently carried out at the Galleria Borghese in Rome, Italy, aimed at enhancing the visiting experience by optimizing the museum floor usage.

Through IoT technologies developed in house, we traced the paths of thousands of guests across the museums. We employed 200 Bluetooth Low Emission (BLE) beacons, that were wearied anonymously by each visitor (see Fig.1 left), and 12 Bluetooth receivers, one per room (built with Raspberry Pi mini-computers), to follow the guests by measuring the beacon signal strength. This enabled us to collect a large database of trajectories, here intended as time sequences of visited rooms. Using this dataset, we extrapolated information about the museum visit and stay characteristic times for every room. On this basis, we could set up a first optimization procedure to compute the best visitors' entry rate aimed at maximizing the daily number of visitors under safety constraints of the museum.

Galleria Borghese is the perfect location to carry out such an optimization study since there is no suggested visiting path, the exhibition space is circular and it is distributed over two floors (see Fig. 1 right). As a consequence, guests generally visit each room multiple times and congestions often happen, frequently in the room hosting works of art by Caravaggio.

Our end goal is to compute optimal fine-time-scale entry schedules for the three museum entrances. This can only be achieved by modelling, understanding and forecasting the coupled and highly non-linear dynamics of the three sub-groups of visitors entering by the three doors and then “diffusing” within the museum rooms.

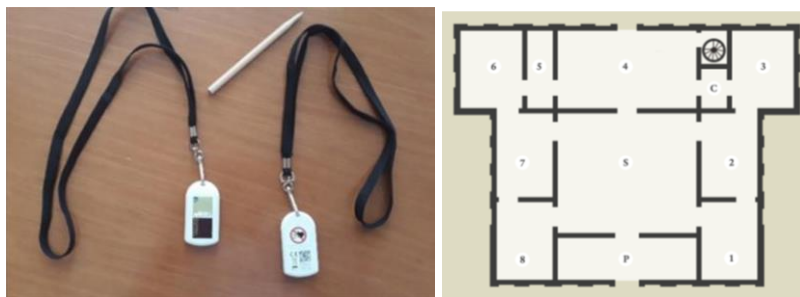


Figure 1. (left) Bluetooth Low Energy beacons provided to the museum guests. Tracking their signal across the rooms allows us to follow (anonymously) individual paths. (right) Floor plan of the first floor of Galleria Borghese: we placed one Bluetooth receiver, recording the signal strength from each beacon, in each room.

Universal scaling in bidirectional flows of self-avoiding agents POSTER P8

Javier Cristín, Vicenç Méndez and Daniel Campos

Corresponding author: Javier Cristín

e-mail: javier.cristin@uab.cat

Affiliation(s): Grup de Física Estadística, Departament de Física, Universitat Autònoma de Barcelona

Uncovering interaction rules between individuals out of collective movement patterns represents a major challenge. The analysis of the radial distribution function in the system provides a possible procedure for this, borrowed from statistical mechanics. This approach has revealed recently the existence of a universal scaling in pedestrian flows, provided the potential interaction $V(\tau)$ is conveniently defined in the space of the times-to-collision τ (*Karamouzas et. al. Phys. Rev. Lett. 113, 238701*). In our work we significantly extend this result by comparing numerically the performance of completely different rules of self-avoidance in bidirectional systems and proving that all of them collapse to a common scaling both in the disordered phase ($V(\tau) \sim \tau^{-2}$) and in the lane-formation regime ($V(\tau) \sim \tau^{-1}$), so suggesting that these scalings represent actually a universal feature of self-avoiding bidirectional flows. From that result we conclude that the same universal feature could emerge from very different actual pair interactions between the agents. Then using the spatial/structural properties of the system for uncovering the real rules of interaction between pairs is meaningless in this context.

A Distributed Virtual Reality System to Study Pedestrian Wayfinding: Motivations and First Experiments POSTER P9

Luca Crociani¹, Andrea Gorrini¹, Giuseppe Vizzari¹, Stefania Bandini^{1,2}

Corresponding author: Luca Crociani

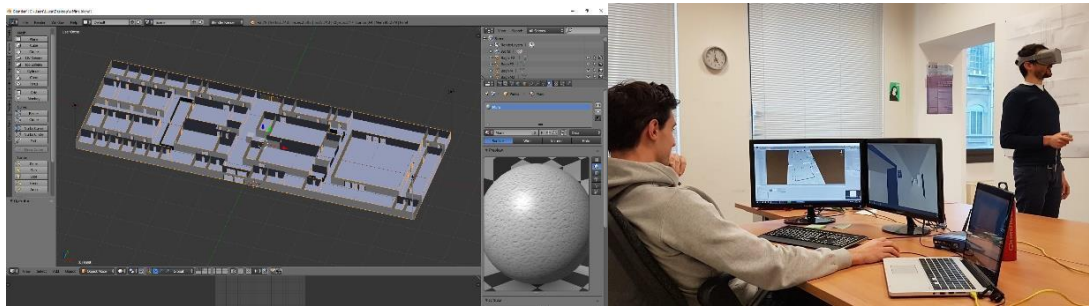
e-mail: luca.crociani@unimib.it

Affiliation(s):

¹ Complex System and Artificial Intelligence research center, University of Milano-Bicocca, Milan (Italy)

² Research Center for Advanced Science and Technology, University of Tokyo, Tokyo, Japan

Pedestrian dynamics have been thoroughly studied for almost three decades, and this has brought relevant insights and outcomes for public institutions and practitioners related to the management of the traffic in crowded facilities. In this context, the validity of simulation models is still growing with ongoing researches on the physics of the system, in order to disentangle the effects of the geometry of the environment and of the influence of social groups in the aggregated dynamics [1]. Such simulation models, calibrated through fundamental diagrams, already constitute a valid and consolidated tool for the analysis of pedestrian flows.



Nonetheless, the knowledge related to pedestrian wayfinding decisions at a higher level of behaviour (so-called *tactical level*, following the widely accepted model of three levels of behaviour [2]) is still rather poor, and simulations of complex scenarios and geometries are still based on coarse assumptions. This is mainly caused by the difficulties to perform naturalistic observations and controlled experiments on wayfinding [3], due to the need of larger settings and a higher number of sensors/cameras to allow a good tracking of people.

In this paper, we propose a novel Virtual Reality system which allows to design controlled experiments in virtual settings and to achieve new knowledge on pedestrian wayfinding. The system is designed and implemented through Unity™ engine and allows the simultaneous usage of multiple Head Mounted Displays (HMD) by different users (currently the Oculus Go™ is used). Their presence in the virtual environment is shared in all displays via the synchronization with a server. The centralised server does not represent a bottleneck for experiments with limited numbers of users, since the amount of information exchanged is limited (i.e. position and orientation), the update frequency not overwhelming, and easily managed by a single machine.

The experimental procedure consists in asking participants to accomplish a series of wayfinding tasks navigating through a 3D model of the main building of the campus of the University of Milano-Bicocca. The system allows collecting data about pedestrian wayfinding activity through trajectories and orientation tracking. The co-presence of multiple users in the system additionally allows to study the effects of their interaction on the resulting choice of route, so that group and following behaviours can be investigated. Other influences related to crowded environments can also be investigated with the introduction of simulated pedestrians in the scenario, whose behaviour is computed with simulation models running on the server side.

At this stage the system has been entirely developed and a preliminary experimental study is going to be executed with a sample of participants. The latter is aimed at achieving useful insights related to the impact of prior knowledge of the scenario and vertical/horizontal signages on wayfinding. Moreover, the study is aimed at evaluating the performance of the VR system in terms of user experience by means of two validated psychological measures focused on usability [4] and feeling of sickness due to the VR itself [5]

Urban transport systems are becoming increasingly complex. At the same time, transport technologies and services are developing rapidly, which changes travel behaviour. The Netherlands is one of the densest urbanized countries in the world, facing severe accessibility problems and environmental pressures from transport, while having a strong interdisciplinary and multi-stakeholder collaboration tradition. This combination demands new and integrated observation, analysis and modelling approaches. The Urban Mobility Observatory (UMO) will collect, integrate and store empirical and experimental multi-modal traffic and transport data and make these available for scientific research in order to better understand and facilitate multi-modal mobility in large urbanized regions.

The UMO facility will consist of five components:

- (1) sensor networks to support distributed data collection for real life and on-site controlled experiments. These sensor networks consist of instruments to permanently observe real-life situations in a broad range of urban conditions, and functionalities for flexible observations. It also includes a moving sensor network of instrumented vehicles and portable devices for additional observations. State-of-the-art sensor technologies include cameras, radars, LIDARs, BT/Wi-Fi trackers, PIR sensors, and cell phone apps.
- (2) crowd sensing and users panel data gathering abilities through a data collection platform. The panel data collection platform collects data from a representative sample of the Dutch population. It gathers self-reported behaviour and preferences of individuals, combining tested and validated questionnaires and app-based polling approaches. Traffic, travel and mobility data are gathered via crowd sourcing, social media and public fora data harvesting.
- (3) simulators including virtual reality, augmented reality, driving simulators aiming to closely observe human behaviour in situations that in reality would potentially be dangerous, not-yet existing, or rarely occurring.
- (4) links and interfaces with existing data sources including the National Data Warehouse, public transport data, data from private parties (TomTom, KPN, Google), and labs including Spatial Information Laboratory (SPINLab), Delft Integrated Traffic and Travel Laboratory (DiTTlab), and the Global Geo Health Data Centre (GGHDC).
- (5) module to store data in various formats and resolutions, including toolboxes for data retrieval, processing and visualisation.

UMO will offer the possibility to collect and combine data from a wide variety of data sources representing different time and geographic scales, transport modes, and different settings (real life, experimental, virtual). UMO will provide accurate, quantitative, real-time as well as off-line, large scale tracking opportunities of people and vehicles. The actual data will be acquired in research projects covering a range of research methodologies, including exploratory research, theory development, hypotheses testing, model identification, model calibration, and model validation. At the same time, the facility will provide enriched (real time) data, as the basis for insights and models to unveil possibilities for the development of new transport services, transport related product-market combinations, traffic management concepts, transport policy options, transport mode and infrastructure development options and even land-use strategies.

In this paper, we describe the conceptual framework of UMO as well as first examples of its possibilities, showing the need of such a platform.

The role of force networks in granular materials PLENARY SESSION

Karen Daniels

Corresponding author: Karen Daniels

e-mail: kdaniel@ncsu.edu

Affiliation: Department of Physics, North Carolina State University, Raleigh, USA

Granular materials are inherently heterogeneous, and continuum models of properties such as the shear modulus and sound speed often fail to quantitatively capture their dynamics. This lack of understanding has serious consequences for the engineering of both geotechnical applications, and the industrial storage and handling of granular materials. One likely reason for these difficulties is that boundary stresses are transmitted via a chain-like network of strong forces. In my talk, I will describe several experiments on two-dimensional photoelastic granular materials which bridge particle-scale, meso-scale, and continuum-scale approaches. These experiments allow us to both investigate the statistical ensembles from which force networks are drawn, as well as probe their effects on mechanical properties such as sound transmission and rheology.

Analysis of Train Delay Distributions: Root Causes and Implications ORAL 14TB

Tej Singh Chani, Michael Taylor, Maria Davidich

Corresponding author: Maria Davidich

e-mail:maria.davidich@siemens.com

Affiliation(s): Siemens Mobility GmbH, MO CS DS AS

Punctuality of a railway service is a crucial factor that influences transportation preferences: Who would choose a means of transportation that seems to always be late. In heavily used railway networks even a small delay of a single train easily propagates to other trains, dramatically reducing punctuality. Thus, understanding of key factors of train delays and their detailed analysis as well as an ability to predict future delays are very important for rail companies as they would enable to implement counter-measures: Switching to a more robust schedule, redirecting trains, provide better information to the customers, etc.

In this work we consider various factors which influence train delays such as weather, passenger traffic, accidents, towed vehicles etc. based on the data provided by Finnish Railways for the year 2017. We analyze the relation between individual disruption causes and the overall train delays happening per day: For each disruption cause we identify a statistical distribution with the best fit and represent the probability density function for the overall number of train delays per day as a regression function of these individual distributions. Finally, analyzing this regression function helps us predict the number of train delays.

A Geostatistical Approach to Traffic Flow Reconstruction from Sparse Floating-Car Data

ORAL 3TB

Eduardo del Arco-Fernández¹, Mihaela I. Chidean¹, Inmaculada Mora-Jiménez¹, Samer H. Hamdar², Antonio J. Caamaño¹

Corresponding author: Eduardo del Arco-Fernández.

e-mail: eduardo.delarco@urjc.es

Affiliation(s): ¹Dpt. of Signal Theory and Telecommunications. School of Telecommunications Engineering. Rey Juan Carlos University, Spain. ²Dpt. of Transportation Engineering. School of Engineering and Applied Science. The George Washington University, USA.

We present a new approach inspired on Geostatistics to determine the spatio-temporal features of road traffic flow from sparse data provided by vehicles (Floating-Car Data, FCD). Some authors¹ propose the interpolation of the Space-Time-Velocity (STV) field from static detectors. This is done to exploit the correlations between time series under the assumption that the propagation speed of perturbations in congested traffic is constant. Our approach takes advantage of geostatistical techniques such as semi-variography and Kriging to find relevant characteristics of traffic flow from highly scattered data. These features are: i) standard deviation of speed in free traffic, ii) transition from free traffic to congested traffic, iii) speed of propagation of compression and rarefaction waves in congested traffic, and iv) the wavelength of such perturbations. Once these characteristics are determined (captured by a directional semi-variogram), we can perform a realistic reconstruction for the spatio-temporal field of velocities. Recently, a geostatistical approach has been used to estimate traffic intensities in unmonitored junctions of urban networks². However, to the best of our knowledge, geostatistics havenot been used to determine the dynamical features of the traffic flow or STV field. We have applied our approach to both simulated data provided by the Intelligent Driver Model (IDM³), and real-world data from the I-80 highway (NGSIM⁴), in different traffic situations. Fig. 1 shows the spatio-temporal pattern for an IDM simulation with a fraction of sensor vehicles (FSV) of 12.5% of the total flow in a situation of slow oscillation traffic, and our reconstruction following a regular spatio-temporal mesh (Fig. 2). In real-world data (Fig. 3) our reconstruction overestimates velocity in the region with no FCD (see region about 750 seconds). Despite some sensor vehicles appearing and disappearing due to lane changes, the propagation speed of perturbations is correctly estimated (Fig. 4). A spherical directional semi-variogram model has been used, with geometric correction of the anisotropy, to determine the propagation speed of perturbations both in simulated and real-world data. Our approach is especially useful if the road infrastructure does not have static sensors or they are too far apart. Other potential applications are related to flows of pedestrians (some of them with location systems) or particle flows that lend themselves to Lagrangian measurements with instrumentalized particles

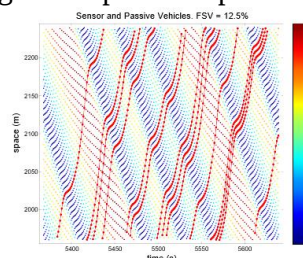


Fig. 1: IDM data and sampling points by FCD (red dots)

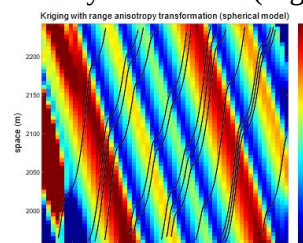


Fig. 2: Reconstructed field of velocities

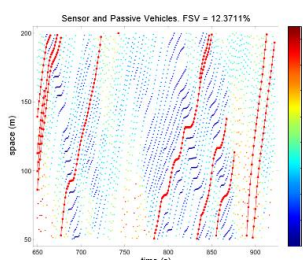


Fig. 3: I-80 data and sampling points by FCD (red dots)

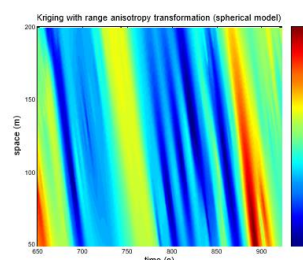


Fig. 4: Reconstructed field of velocities

References: 1 Martin Treiber, D Helbing. An adaptive smoothing method for traffic state identification from incomplete information. Interface and Transport Dynamics. Springer, Berlin, Heidelberg, 2003. Pages 343
2 B.Selby, K.M. Kockelman. Spatial prediction of traffic levels in unmeasured locations: applications of universal kriging and geographically weighted regression. Jour of Transport Geography, 29 (2013) P. 24-32.
3 Martin Treiber, Arne Kesting. The Intelligent Driver Model with stochasticity – New insights into traffic flow oscillations. Transportation Research Part B: Methodological, Volume 117, Part B, 2018, Pages 613-623.
4 Benjamin Coifman, Lizhe Li. A critical evaluation of the Next Generation Simulation (NGSIM) vehicle trajectory dataset. Transportation Research Part B: Methodological, Volume 105, 2017, Pages 362-377.

The impact of walking speed heterogeneity and the flow situation on pedestrian fundamental diagram ORAL 1FA

Dr. Dorine C. Duives, Martijn Sparnaaij, MSc. Prof. Serge P. Hoogendoorn

Corresponding author: Dorine C. Duives

e-mail: d.c.duives@gmail.com

Affiliation(s): Delft University of Technology Faculty of Civil Engineering and Geosciences Department of Transport & Planning

The capacity of pedestrian infrastructure is increasingly of interest. Research on the maximum demand that can flow through a cross-section, often dubbed capacity, has been presented. Most of these works have focussed on uni-directional movement base cases, studied relatively low density situations and instructed their participants to behave ‘normal’. However, during large crowd moments at train stations and event terrains, often far higher densities are encountered, the flow situations are more complex in nature, and pedestrians do not always behave ‘normal’. Therefore, more insights are needed with respect to the effect of heterogeneous pedestrian populations that are part of more complex flow situations. The objective of this study is to determine the impact of heterogeneity in walking speed and the flow situation of pedestrian interactions. More specifically, the capacity of the infrastructure and the shape of the fundamental diagram are determined. Here, we hypothesize that the capacity of the infrastructure is negatively influenced by increasing instabilities in the pedestrian flow which are created by the introduction of more complex flow situations and the introduction of local disturbances as a result of differences in walking speed.



Fig. 1. Illustration of CrowdLimit experimental setup

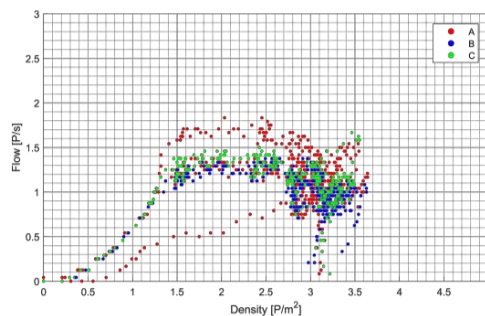


Fig. 2. Preliminary findings of the fundamental diagram for bi-directional flow situation, 50-50

On the 5th and 6th of June 2018 a large pedestrian experiment was performed by Delft University of Technology. This experiment mimics two specific flow situations, namely a bi-directional flow and intersecting flows under a 90 degree angle. In each run of the experiment the flow distribution over the entrances was varied (50/50 or 90/10). During each run the flow rate was increased every minute until the flow stagnated or the maximum run time was reached. Each of the participants received an assignment at registration, which they were asked to keep their assignment hidden from the other participants, namely: A) No assignment, B) Attempt to cross, C) walk at a fast pace. The participants with assignments B and C, both 10% of the total population, were asked only to perform their assignment at the moment the traffic sign indicated the letter of their assignment. In this research we have analysed the differences between series in which assignments A or C were active. A preliminary analysis of the data illustrates that especially the introduction of differences in walking speed and distribution between flows influence the shape fundamental diagram. That is, the capacity of a 90/10 distribution seems higher than a 50/50 distribution and the capacity decreases when flow instabilities are introduced in the experiment (i.e. assignments B and C). The full paper details a comprehensive description of the differences in the fundamental diagrams found for all three types of assignments and compare our findings to the work on the pedestrian fundamental diagram by other research groups.

The Dynamics of Granular Clogging INVITED 7WB

Douglas J. Durian

Corresponding author: Douglas J Durian

e-mail: djdurian@physics.upenn.edu

Affiliation(s): Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, USA

The gravity-driven flow of grains from a hole in a hopper is an iconic granular phenomenon. It's different from a fluid in that the rate is constant also in that it can suddenly and unexpectedly clog. How does the susceptibility to clogging decrease with increasing hole size, and is there a well-defined clogging transition above which the system never clogs? This problem is distinct from jamming due to the presence of boundaries and gradients. We show how the fraction F of flow configurations that cause a clog may be deduced from the average mass discharged between clogs. We construct a simple model to account for the observation that F decays exponentially in hole width to the power of dimensionality. Thus the clogging transition is not sharp but rather is defined by observation limits, similar to the glass transition. When the system is immersed in water, F barely changes. Therefore, grain momenta play only a secondary role in destabilizing weak incipient arches and the crucial microscopic variables are likely the grain positions. Work is now in progress to distinguish free-flowing versus clog-causing position microstates using machine learning.

Simulation of noncircular pedestrians dynamics with an obstacle POSTER P10

Iñaki Echeverría Huarte, Iker Zuriguel Ballaz, Raúl Cruz Hidalgo

Corresponding author: Iñaki Echeverría Huarte

e-mail: iecheverria.13@alumni.unav.es

Affiliation(s):

Departamento de Física y Matemática Aplicada, Facultad de Ciencias, Universidad de Navarra.

Nowadays, the study of evacuation processes on risk situations is really relevant. Its development will have a direct impact on society with the creation of safe infrastructures for citizens, in which we should try to prevent tragedies.

The investigation on this scope started with the pioneering work of Helbing et al.¹ (2000, Nature) based on simulations. There, they proposed that if an obstacle is placed on the upstream side of an exit, the flow rate would be enhanced.

However, recent experiments with pedestrians carried out by A. Garcimartín et al.² (2018, New Journal Physics) suggested that, working with high density and competitive configurations, the placement of an obstacle does not seem to improve the evacuation process. Instead of that, it only prevents the formation of movements transverse to the direction of the exit which would be originated if there was no obstacle.

In this context, it is reasonable to think that Helbing's model may not fully reproduce experimental results in such conditions of very high density and pressure among the individuals.

Therefore, our work tries to fill this gap implementing a model with noncircular pedestrians and an obstacle under high density and competitiveness conditions. We evaluate the most characteristic magnitudes of the evacuation process -i.e., the flow rate and the distributions of time lapses between two consecutive outgoing pedestrians. Once validated, it would be useful to measure other magnitudes not experimentally available such as pressure distributions near the exit or pedestrian orientations.

1 D. Helbing, I.J. Farkas, and T. Vicsek, Simulating dynamical features of escapes panic. Nature 407,487 (2000)

2 A.Garcimartín, D. Maza, J.M. Pastor, D.R. Parisi, C. Martín-Gómez and I. Zuriguel, Redefining the role of obstacles in pedestrian evacuation. New Journal of Physics (2018)

Investigating the role of network morphology on the emergence of a network fundamental diagram. ORAL 11WB

Alonso Espinosa Mireles de Villafranca, Eddie Wilson

Corresponding author: A. Espinosa Mireles de Villafranca e-mail: alonso.espinosa@bristol.ac.uk

Affiliation(s): University of Bristol

In this paper we solve variants of the *static traffic assignment problem* (in the *user equilibrium* or UE regime) on ensembles of randomly generated street networks in order to understand whether the *network fundamental diagram* (NFD) can be explained by a ground-up theory. Of special interest is how network morphology might play a role. The NFD (also known as the *macroscopic fundamental diagram*) is the empirically observed relationship between the mean traffic flow within a sub-region of a network and its average vehicle density (known as the *accumulation*) [1]. Empirical observations show that the performance of different sub-regions can be understood in terms of the traffic variables within them, independent of those elsewhere in the network. We generate

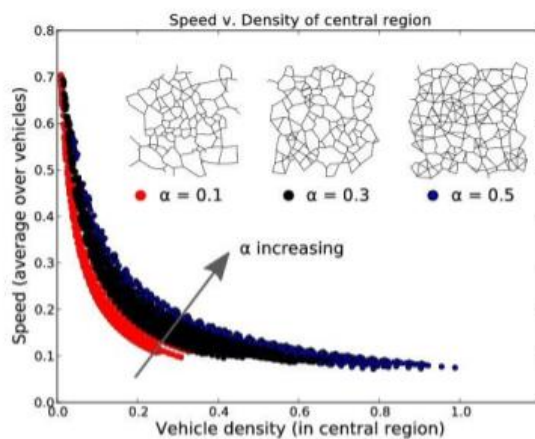


Figure 1 Vehicle mean-speed against vehicle density with different network morphologies parametrised by α .

synthetic test networks by constructing the beta-skeleton (a type of proximity graph) of a set of nodes representing intersections. The nodes' positions are obtained by homotoping a set of points from a regular square lattice to a uniform distribution of points. (This two-parameter family of random graphs [2] contains networks of strikingly different morphologies.) We then set the streets' capacities endogenously by a heuristic that captures fixed infrastructure supply, thus allowing a fair performance comparison between networks with different numbers of roads. Our computational experiments apply various origin-destination (OD) demand matrices to the synthetic networks and solve for the UE

assignment for a range of demand values. The OD matrices are built by selecting 10 random OD pairs with distinct origins and destinations. The range of demand values is chosen so that the network exhibits rich behaviour, ie, the most interesting situation is when the UE assignment and the System Optimal (SO) assignment are very different. For each network, we then extract a central area as a sub-region on which to compute statistics. For example, see Figure 1, which shows how uncongested sub-region statistics depend on network morphology; here the parameter α increases the irregularity of nodes' spacings.

The use of static assignment methods has two interconnected problems. 1. Firstly, since link-costs are typically increasing functions of flow, we obtain only the uncongested branch of the NFD; and 2. we are studying a phenomenon whose empirical observations are fundamentally dynamic. The resolutions to both problems are also related. 1. Firstly, we generalise to consider a quasi-dynamic setting that approximates dynamic user equilibrium, where the OD demand is time-dependent and we solve a static assignment problem for each time slice which is coupled to that preceding by loading the network with the preceding slice's solution flows. 2. Secondly, we consider model extensions in which there are finite capacity and spill-back (horizontal queuing) effects. These extensions allow us to replicate all empirically observed NFD features, including the congested branch, and to analyse how they depend on network morphology.

References ¹Geroliminis, Nikolas, and Carlos F. Daganzo. "Existence of urban-scale macroscopic fundamental diagrams: Some experimental findings." *Transportation Research Part B: Methodological* 42, (2008)

²Espinosa Mireles de Villafranca, Alonso and Richard D. Connors, and R. Eddie Wilson. "Static Traffic Assignment on Ensembles of Synthetic Road Networks." In *Traffic and Granular Flow '17: TGF17*, Washington D.C., July 2017. Springer.

Experiments and usability tests of a VR-based driving simulator to evaluate driving behavior in the presence of crossing pedestrians ORAL 2TB

C. Feliciani¹, L. Crociani², A. Gorrini², A. Nagahama³, K. Nishinari^{1,4}, S. Bandini^{1,2}

Corresponding author: Claudio Feliciani

e-mail: claudio.feliciani@gmail.com

¹Research Center for Advanced Science and Technology, The University of Tokyo. 4-6-1 Japan.

²Complex Systems and Artificial intelligence research center, University of Milano-Bicocca. Milan, Italy.

³Ritsumeikan Global Innovation Research Organization, Ritsumeikan University, Kusatsu, Japan.

⁴Department of Aeronautics and Astronautics, School of Engineering The University of Tokyo, Japan.

As highlighted by the WHO [1], road accidents represent the eighth leading cause of death in the world population: 1.2 million people are killed on roads every year, with most fatalities occurring in developing countries. In particular, pedestrians are some of the most vulnerable road users, with a percentage of fatalities corresponding to 22% of the overall victims. To contrast pedestrian-car accidents it is necessary to identify which factors influence traffic safety to support public institutions in the design of transportation infrastructures and traffic policies. Risky driving behavior is essentially caused by human factors and environmental factors. On one hand, traffic accidents are linked to the lack of coordination among motor, perceptive and attentional skills, and on individual psychological disposition towards hazardous situations [2]. All these elements affect the non-compliance of drivers to traffic norms (e.g., speed limit, right of way of pedestrian at zebra crosswalks...). This work presents a set of preliminary experimental results about driving behavior achieved through a Virtual Reality prototype developed by the authors. This is aimed at testing the possibility to more systematically employ VR tools to study the impact of *environmental* and *cognitive* factors on the behavior of drivers in the nearby of a unsignalized pedestrian crosswalk.



Fig. 1: scenario and system used for testing driving behavior in the presence of crosswalks in a VR environment. (a) VR system, (b) scenario screenshot and (c) selected car trajectory.

The VR system (see Fig. 1(a)) consists of a driving simulator in an *ad hoc* designed urban scenario (see Fig. 1(b)) representing an asymmetrical 8-shaped road intersecting multiple unsignalized pedestrian crosswalks as schematically presented in Fig. 1(c). A sample of 15 participants (composed by young adults and elderly drivers) were asked to wear the VR headset and to drive through the scenario for about 3-5 minutes. The preliminary analysis, which focused on driving behavior in the presence of crossing pedestrians, is in line with previous studies performed by the authors through naturalist observations [2], such as: driving compliance to pedestrian right-of-way, driving speed and driving accuracy. To more fruitfully evaluate the performance of the VR tool in terms of user experience, we administered to participants two validated psychological measures at the end of the experimental sessions, focusing on: usability [3] and feeling of sickness due VR by itself [4].

Driving analysis	Average d	Maximum speed	Minimum time ap	Driving accuracy
Adults (19-33)	46.86 km/h	76.12 km/s	0.351 s	0.814°
Elderlies (67-70)	20.78 km/h	59.09 km/h	0.528 s	1.358°
Questionnaire (0-	Nausea	Oculo-motors	mulation Fidelity	Overall System Usability
Adults (19-33)	0.412	.484	70	54
Elderlies (67-70)	0.500	.491	50	36

Tab. 1: Main results from the VR driving experiments. Aspects related to driving behavior and usability of the VR system are provided within the same table.

Analysis of the driving behavior in the VR environment show that results are in line with experimental observations [5]. In particular, young adults are more prone at showing a risky behavior by driving at higher speed and having a lower time gap compared to elderly. The lower driving accuracy by elderly (the closer to 0 the better) could be related to their difficulties in adapting with the VR system as shown in the results from the questionnaire. The results achieved through the usability and sickness measures show, from a qualitative point of view, the overall good usability of the VR system; the influence of participants' age, previous experience with VR and driving license will be also presented in the paper. Although a more complete analysis of the results indicates that there are also deficiencies in the developed VR system, it is also shown that it is possible to study aspects related to driving attitude. Considering the very low cost of such a solution (less than 500\$) it could represent an alternative to expensive driving simulators for developing countries which have the highest number of traffic accidents, but have limited financial resources.

Experimental investigation on information provision methods and guidance strategies for crowd control POSTER P11

Claudio Feliciani¹, Hisashi Murakami¹, Kenichiro Shimura¹, Katsuhiro Nishinari^{1,2}

Corresponding author:

Claudio Feliciani

email: claudio.feliciani@gmail.com

Affiliation(s):

¹Research Center for Advanced Science and Technology The University of Tokyo 4-6-1 Komaba, Meguro-ku, Tokyo 153-8904 Japan.

²Department of Aeronautics and Astronautics, School of Engineering The University of Tokyo. 7-3-1, Hongo, Bunkyo-ku, Tokyo 113-8656 Japan.

1. Introduction and background

Pedestrian guidance and crowd control are the key elements to ensure safe and smooth mass events, while also being an important aspect in the design of urban infrastructures dealing with large number of people. In the recent years, advances in people sensing technology and computational equipment are making it possible to simulate large crowds on real-time, thus increasing the volume and the type of information which can be used to guide people. However, there is only little experimental knowledge on which type of information can help efficiently guiding people and to which extent will people follow instructions given. In this study, different methods to instruct and inform crowds of people are considered in a real environment investigating both efficiency and perceived comfort for different solutions.

2. Experimental and technical setup

To study experimentally the above topics a course like the one schematically presented in Fig. 1 has been build. The course consisted of 2 lanes, clearly divided by a wall. People were allowed to move from the internal to the external lane (or vice-versa) only in 2 location, where an opening of 40 cm was provided. People were asked to avoid losing time and had therefore to choose the fastest lane when necessary. In addition, sensors were installed to allow measuring on real time walking speed in different locations and measurement results could be displayed on monitors provided along the course in various formats (numbers or arrows). Finally, we also tested the case in which people are guided by staff on-site and rely on their decision to change lane.

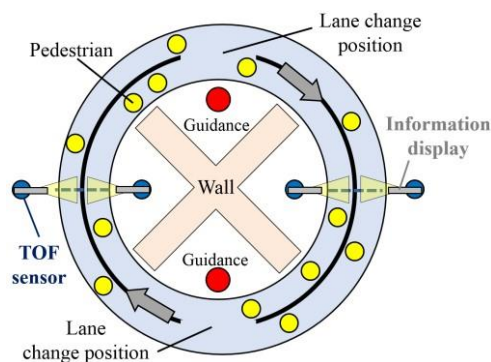


Fig. 1 Schematic representation of the experimental setup.

Each experiment started with 35 people in the inner loop and 5 in the outer one and lasted 3 minutes. Three conditions were varied to study crowd behaviour: type and timing of information provision (using the monitors along the course), strategy for human guidance (how guidance personnel steer people) and compliance (people could choose by their own or had to obey to the instructions/information given them).

3. Results

To evaluate the efficacy and suitability of different strategies for information provision and crowd control, two criteria have been used: the average flow of people transiting over a single lane during the experiment and the comfort perceived by the participants (through a questionnaire scaling from 1 to 7). Results for different experimental conditions are given in Tab. 1, while Fig. 2 provided the speed change in the inner and outer lanes for two selected cases.

Information provision	Guidance	Compliance	Flow [1/s]	Comfort [1-7]
N/A	N/A	Free choice	0.796	3.775
Present speed (numbers)	N/A	Free choice	0.857	3.875
	N/A	Must obey	0.775	3.375
Directed arrow (right/left)	N/A	Free choice	0.782	3.700
	N/A	Must obey	0.492	2.244
Predicted speed (simulation)	N/A	Free choice	0.785	4.049
	N/A	Must obey	0.501	2.829
N/A	Uniformed personnel	Free choice	0.801	4.436
N/A		Must obey	0.776	4.175
N/A	Real-time video provided	Free choice	0.810	4.100
N/A		Must obey	0.758	3.950

Tab. 1: Average pedestrian flow per lane and perceived comfort for different experimental conditions.

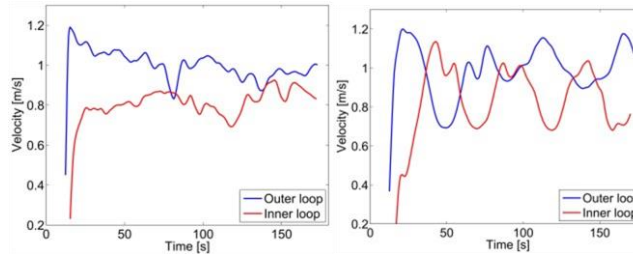


Fig. 2: Changes in average speed in the inner and outer lane depending on the experimental condition. Present speed is given as information in both; left is the free-choice condition, right the must-obey one.

Results clearly indicate that type of information provided, the strategy used to guide crowds of people and the degree of compliance among them clearly affect the overall dynamics of the group. On the overall, people move more efficiently when real-time speed is provided numerically. However, when comfort is considered, people prefer being guided by real people (guidance personnel) rather than relying on automated systems.

In this regard, it is quite surprising that the most efficient conditions in term of average speed and motion dynamics are different from what people identify as a comfortable situation, i.e. sub-optimal solutions in terms of flow seems to be more widely accepted by the participants.

4. Conclusion and future work

This study shows that type of information provision and crowd control strategy can influence the dynamics of crowd. While directly providing information to pedestrians is surely important, our results show that having an informed and trained security/guidance personnel is of central importance in crowd management. Building up a system able to provide them relevant information to perform an efficient work and possibly also predicting changes occurring in the near future would be an important task in the future research and more specific aspects will be investigated in the frame of this study.

Authors: Yan Feng, Dorine C. Duives, Serge P. Hoogendoorn

Corresponding author: Yan Feng

e-mail: y.feng@tudelft.nl

Affiliation: Transport & Planning department, Civil engineering and Geosciences Faculty, Delft University of Technology

This paper investigates Virtual Reality as a novel technique to study pedestrian exit choice behaviour during evacuations and in particular, the impact of different types of information on pedestrian's exit choice. Virtual Reality is a promising technique that can be used to study pedestrian evacuation behaviour. Yet, studies using virtual reality to study evacuation behaviour are still scarce. In a previous study, two experimental methods were compared, namely a field experiment of a real-life evacuation drill and a Virtual Reality experiment that covers the same situation. The results show that the pedestrians' exit choice behaviour during the evacuation are overall similar, which shows that the use of VR can be considered as a research tool for research on exit choice behaviour during evacuations.

Extending the experimental method, we used VR to investigate pedestrian exit choice behaviour in different scenarios to understand how different variables in the environment influence pedestrian exit choice behaviour during evacuations. With the same evacuation situation, we added different variables to create different scenarios to investigate and compare pedestrian exit choice during evacuations. The scenarios under the evacuation environment vary considerably, three variables were tested: no additional information, exit signs, direction signs (Figure 1).

The collected data was two-fold: (1) exit choice behaviour and (2) participants' experience regarding the VR experiment. The procedure of the VR experiment included the following parts: 1) participants were introduced to the purpose of the experiment; 2) got familiar with VR environment and the HMD device with the general scenario; 3) were presented with the scenario of the evacuation drill and chose one exit; 4) filled in the questionnaire.

Figure 1. Three scenarios under same evacuation situation, from left to right, no information, exit signs and direction signs.



With the collected data, we analysed pedestrian exit choice behaviour in three scenarios. Firstly, the statistics of the participants are described. Secondly, the exit choice from the different scenarios are compared. Based on the statistics data of pedestrian exit choice (Table 1), we formulated the hypothesis as follows: different information in the environment do influence pedestrian exit choice behaviour during evacuation. A comprehensive analysis of the this experiment will be presented in the full paper.

Table 1. Pedestrian exit choice in different scenarios in VR

Exit	A1	A2	B	C	D	E	F	G	Total
No additional information	5	2	0	2	8	0	2	0	19
Exit sign	5	5	0	4	5	5	1	1	26
Direction sign	2	0	0	4	9	3	0	0	18

Study of bottleneck in vehicular traffic using a cellular automaton model for Bogota traffic flow POSTER P12

Juan Sebastián Florez Jiménez, Jose Daniel Muñoz Castaño

Corresponding author: Juan Sebastián Florez Jiménez

e-mail: jsflorezj@unal.edu.co

Affiliation(s):

Physics student at National University of Colombia

A cellular automaton model for multiline traffic is implemented by augmenting the previously developed model for traffic flow in Bogota[1], this is done by creating rules to determine when a line change is safe, adding turning lights to the cars so they can ask for space in a neighbour line if is not safe to change lines, adding a parameter to quantize the likeliness of a car to give the way to a car in a neighbour line when is not safe for it to change lines, and adding a safe brake protocol so the cars would no crash due to over braking. The phase diagram for a two, three and four line system is studied when a bottleneck is created by a car who parks illegally in a lateral line, in the same system the mean travel time for a car is studied and its dependence on the likeliness of car to give the way to a neighbouring car. A way to enforce the density desired in the boundaries is created so the phase diagram and the mean travel time are analyzed using also the open boundaries instead of the periodic boundaries usually reported in the literature. The results for both boundaries are compared.

[1]L. Olmos, J.D. Muñoz. A CELLULAR AUTOMATON MODEL FOR THE TRAFFIC FLOW IN BOGOTA. International Journal of Modern Physics C, 15: 1397-1411,2004.

Stokesian and collisional responses of macroscopic suspensions flowing out a silo

POSTER P13

José Ilberto Fonceca Junior, Raúl Cruz Hidalgo, Diego Maza

Corresponding author: José Ilberto Fonceca Junior

e-mail: jfonceca@alumni.unav.es

Affiliation(s): Departamento de Física y Matemática Aplicada, Universidad de Navarra, Pamplona, Spain

Recently, researchers developed a well-founded description for the particle flow rate (Q) through the aperture of a silo. For dry granular materials, Q was shown to depend on two main observables: the particle density and velocity profiles at the aperture. Although this phenomenology is well-understood, the study of particle flows in the presence of an interstitial liquid has scarcely been investigated.

This work aims to experimentally study the flow of granular materials through hoppers, in a wide range of wet scenarios. We performed a systematic investigation, varying the intensity of the driving force (system's inclination angle θ), the viscosity of the interstitial fluid and aperture size. Our preliminary results (see Figure 1) suggest a linear dependence of the particle flow rate with $\sin \theta$ when the flow values are normalized by the ones obtained for the maximum inclination. These outcomes are in contrast, however, with the expected for the dry cases, i. e. a linear dependence with the $\sqrt{\sin \theta}$, which is explained by the existence of a “free fall arch”, produced by the particle collisions with the border of the aperture. At the particle's scale, our system seems to transit from a Stokesian behavior (high viscosity) to a collisional dependent response (low viscosity). Moreover, our findings also indicate that the lubrication interactions with both walls are also relevant.

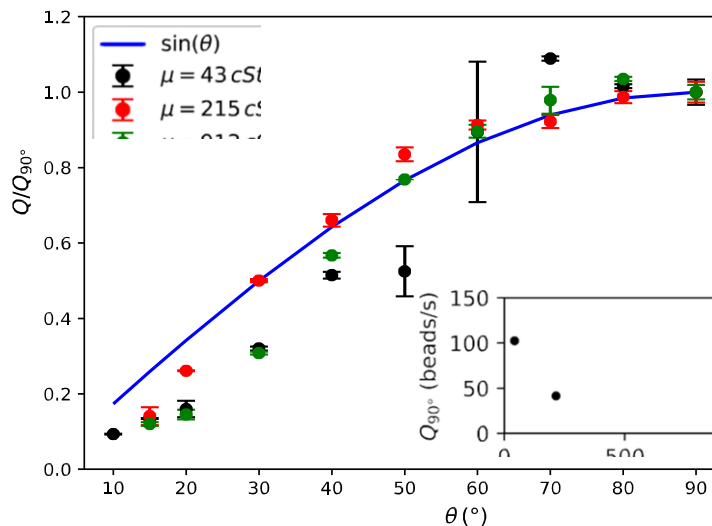


Figure 1. Particle flow rates obtained when varying the inclination angles. Results obtained for three liquid viscosities are shown.

An ultrasonic vehicular detector POSTER P49

M. Ebrahim Foulaadvand¹, Morteza Mohaqeqi², Masoud shakoorianfard², Mohammad Hadi² Namdar Ghalati², Hamed Ghafarirad²

Corresponding author: M. Ebrahim Foulaadvand

e-mail: foolad@znu.ac.ir

Affiliation(s): ¹Department of Physics, University of Zanjan, PC 45371-38791, Zanjan, Iran.

²Department of Mechanical Engineering, Amirkabir University of Technology (former Tehran Polytechnic), P.O. Box 15875-4413, Tehran, Iran.

We have designed and constructed a vehicular detector. The detector sensing mechanism is based on the ultrasonic waves at frequency 42 kHz. The detector counts and classifies the passing vehicles of the lane over which it is fixed and mounted. The ultrasonic sensor emits ultrasonic pulses and receives the scattered waves from the ceiling of moving vehicles. Classification is done according to the vehicle's height. Three classes are identified: normal vehicle, van and bus/trailer. Signals of the reflected waves are detected and then analysed by an electronic hardware. The output data are transmitted on a wireless basis to a neighbouring PC on the ground with the help of two radio modules.

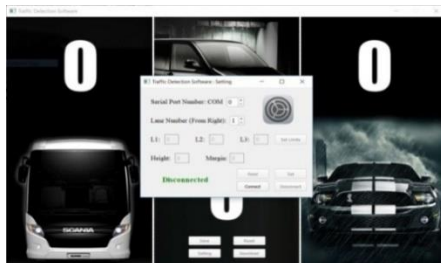


Ultrasonic vehicle counter and classifier



Electronic hardware which analyses the signals

The data transmitted to PC includes: passage time (day, hour, minute, second), vehicle class, number flow for each class. The data are shown in a GUI (Graphic User Interface) on the PC screen and can be filed in two formats of “txt” and “csv”.



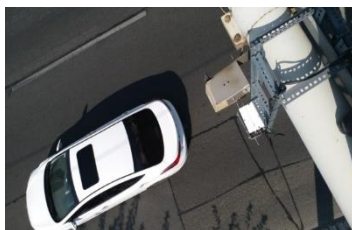
GUI to show the count/classification results

Type	Time	Class	Count
Type1: 0	10:00:00	Normal	1
Type1: 1	10:00:01	Van	1
Type1: 2	10:00:02	Bus/Trailer	1
Type1: 3	10:00:03	Normal	1
Type1: 4	10:00:04	Van	1
Type1: 5	10:00:05	Bus/Trailer	1
Type1: 6	10:00:06	Normal	1
Type1: 7	10:00:07	Van	1
Type1: 8	10:00:08	Bus/Trailer	1
Type1: 9	10:00:09	Normal	1
Type1: 10	10:00:10	Van	1
Type1: 11	10:00:11	Bus/Trailer	1
Type1: 12	10:00:12	Normal	1
Type1: 13	10:00:13	Van	1
Type1: 14	10:00:14	Bus/Trailer	1
Type1: 15	10:00:15	Normal	1
Type1: 16	10:00:16	Van	1
Type1: 17	10:00:17	Bus/Trailer	1
Type1: 18	10:00:18	Normal	1
Type1: 19	10:00:19	Van	1
Type1: 20	10:00:20	Bus/Trailer	1
Type1: 21	10:00:21	Normal	1
Type1: 22	10:00:22	Van	1
Type1: 23	10:00:23	Bus/Trailer	1
Type1: 24	10:00:24	Normal	1
Type1: 25	10:00:25	Van	1
Type1: 26	10:00:26	Bus/Trailer	1
Type1: 27	10:00:27	Normal	1
Type1: 28	10:00:28	Van	1

Data storage in txt format

A field measurement was done in Babaie highway in north of Tehran on November 24, 2018. The access to the video of this field measurement is provided by the following link:

https://mega.nz/#!5fxWBABa!_tYIVvHhDWi21sXqAjazHygHYtxHmNZ2FLbVX0kUMRg



Detector top views: mounted on a VMS (variable message signs) at height 5.5 m above the ground)

The system error is less than 5 percent. In addition, the price is cost-effective (less than 300 Euro).

Experimental study on crowds with different velocity composition ORAL 5FA

Akihiro Fujita¹, Claudio Feliciani², Daichi Yanagisawa^{1,2}, Katsuhiro Nishinari^{1,2}

Corresponding author: Akihiro Fujita

e-mail: f-akihiro@g.ecc.u-tokyo.ac.jp

Affiliation(s):

¹ Department of Aeronautics and Astronautics, School of Engineering, The University of Tokyo Japan.

² Research Center for Advanced Science and Technology, The University of Tokyo, Tokyo Japan.

This study focuses on the difference in walking speed among pedestrians, whereby experiments were conducted asking participants to walk at different speeds. We examined the various factors that affect a pedestrian's individual speed and the macroscopic difference between crowds with the same (homogeneous) velocity and crowds composed of people with different target velocities.

1. Experiment

The experiments were conducted on a circular course, as shown in Fig. 1. The crowd component was tested using three scenarios, including a group of pedestrians walking normally mixed with slow pedestrians (slow mix), a group of pedestrians walking normally mixed with fast pedestrians (fast mix), and the entire group of pedestrians walking normally (homogeneous).



Fig. 1 Overhead view of the experimental course

2. Fundamental diagram

Density-velocity diagrams are presented in Fig. 2. Note that all the plots represent the speed of normal pedestrians, wherein the color represents the composition. From Fig. 2(a), not only local density, but also the walking speed of other people can affect a pedestrian's speed. In Fig. 2(b), the average velocity for each crowd composition is plotted, where the shaded areas represent the one-sigma error.

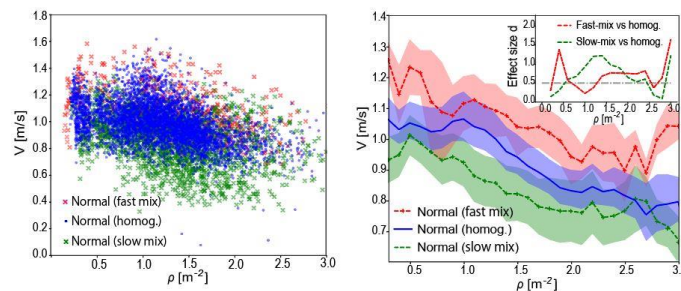


Fig. 2. Fundamental diagram for each crowd composition (a) Density and velocity (b) Density and ave. velocity

The average speed of pedestrians walking normally clearly differs according to the three different crowd compositions. Moreover, the inset of Fig. 2(b) is a plot Cohen's d of the t-test which was conducted to determine if the velocity for each crowd composition was different. The results indicated that the crowd composition had a significant effect on pedestrian velocity when the local density was between 1.2 to 2.3 m^{-2} .

Furthermore, in this density area, multiple regression analysis revealed that other people's velocity has a greater effect on a pedestrian's speed than the local density, in accordance with Eq. (1), where v_{sur} refers to the average speed of other pedestrians around a target pedestrian. All the explanatory variables in Eq. (1) (v , ρ , v_{sur}) were normalized.

$$v = -0.25\rho + 0.48 v_{\text{sur}} \quad (1)$$

3. Congestion level

To macroscopically analyze the difference between homogeneous flow and heterogeneous velocity flow, we considered the level of congestion reported in [2], which can be used to assess the degree of organization in pedestrian crowds and the relative smoothness of the crowd's motion. Its definition is generally based on the rotation of the velocity vector field. There are three steps to compute this value. First, the experimental field was divided into cells and the average velocity (v_x , v_y) for each cell was calculated over a defined time period (i.e. a cell size of 0.2m and an average velocity of 2.5 seconds). Second, for the rotation of this vector field $v(x,y)$, the velocity vector of eight neighbouring cells were used to compute the derivative ($\partial v_x / \partial y$ and $\partial v_y / \partial x$). From the abovementioned steps, the rotation of each cell ($r_{x,y}$) was calculated, and finally the congestion level can be estimated using Eq. (2).

$$Cl = \{\max(r_{x,y}) - \min(r_{x,y})\} / |v| \quad (2)$$

The absolute value of the maximum and minimum rotation over all the cells is divided by the average absolute velocity. Subtracting the minimum rotation from the maximum rotation can avoid obtaining high values for organized rotation. In addition, dividing the rotation by $|v|$ also indicated that when there big rotational gaps exist in a crowd, slower moving crowds are more likely to be congested than faster moving crowds. As Fig. 3 clearly shows, the congestion level was always higher in heterogeneous cases than in homogeneous cases. This indicates that heterogeneous flow includes more complex behaviours and interactions among pedestrians.

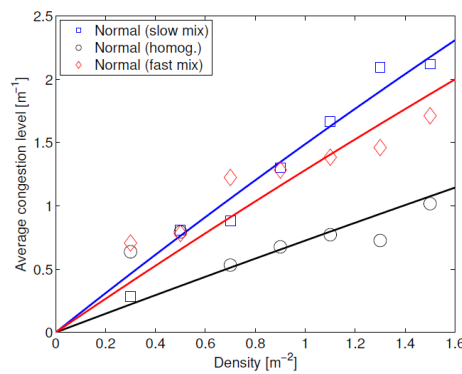


Fig. 3 Congestion level for each global density

4. Conclusion and future work

Through this experiment, we find both microscopic and macroscopic effects of velocity heterogeneity among pedestrians. As for the microscopic effect, based on the fundamental diagrams, both local density and crowd composition significantly affects each pedestrian's walking speed. As for macroscopic flow characteristics, our experiments also revealed that heterogeneous crowds are more likely to have intrinsic risk compared to homogeneous crowds of the same density.

Experimental and mathematical modelling study of 2D and 3D silo flows with single or dual exit orifices ORAL 4FB

Luke Fullard¹, Eric Breard², Clive Davies³, Daniel Holland⁴, Pierre-Yves Lagree⁵, Stephane Popinet⁵

Corresponding author: Luke Fullard

e-mail: L.Fullard@Massey.ac.nz

Affiliation(s):

¹School of Fundamental Sciences, Massey University, New Zealand.

²Department of Earth Sciences, University of Oregon, OR, USA

³School of Food and Advanced Technology, Massey University, New Zealand.

⁴Department of Chemical and Process Engineering, Canterbury University, New Zealand.

⁵Institut Jean le Rond d'Alembert, Université Pierre et Marie Curie, Paris, France.

For millenia granular materials have been kept in storage silos. The development of silo technology is more important today than at any previous time in history. Silos are used to store feed on farms, cement, food, and pharmaceutical powders, and many other bulk materials. Upon opening of the silo orifice the dynamics of discharge of the stored granular material from the silo is dependent upon both the type of particle contained within and the design of the silo itself. In this work we present results of experimental and mathematical modelling studies of granular flow in silos. The work is comprised of three main portions:

1. The generation of velocity fields of granular flow using Particle Image Velocimetry (PIV) and Magnetic Resonance Imaging (MRI) experiments.
2. A study of granular interference phenomena in silos with two exit orifices using PIV and dynamic mass flow rate measurements.
3. Mathematical modelling of dense granular flows using both continuum and discrete models.

In part a) we present results of PIV experiments in transparent planar silos with single and dual exit orifices, where the horizontal and vertical velocity components are measured at the silo wall. Additionally, we present MRI velocimetry experiments which allow us to measure granular velocities away from the silo walls in a variety of silos (of different half angles and wall frictions). Using the MRI technique we have captured the mass, funnel and core flow regimes and quantified the velocity field in each case.

In part b) the mass flow rate of grains is measured from silos with two symmetrically placed exit orifices as a function of the spacing between the orifices. Unlike in previous studies, where the flow rate in such a case was found to monotonically decrease as the openings are separated, we find a different dynamic. As the openings are separated the flow rate rapidly drops from its maximum (a separation of zero), reaches a minimum rate, before slowly rising to an equilibrium rate. An analogous behaviour has previously been observed in evacuation dynamics from a room with two exits.

In part c) we present results of mathematical modelling. Using DEM simulations and a coarse graining approach we reproduce the observed granular interference flow rate behaviour in silos with two orifices. Remarkably, we show that as the inter-granular friction is lowered we recover a monotonic decrease in the flow rate as the spacing between the openings increases.

We also present results of modelling using the $\mu(I)$ friction law which allows definition of an apparent viscosity to be used in fluid dynamics codes. We compare experimentally measured and modelled velocity fields and find encouraging agreement. We also discuss shortfalls of the model, and ongoing investigations to improve the continuum predictions.

Influence of the interaction potential in the acoustic behavior of a system of disks POSTER P14

Juan F. G. Saavedra, A. Rodríguez-Rivas, F. Vega Reyes

Corresponding author: Juan F. G. Saavedra

e-mail: juanfrangs@unex.es

Affiliation(s): Universidad de Extremadura, Spain

In this work, we consider a system composed of disks with the same size and different mass ratio. The disks are arranged in a hexagonal lattice and different boundary conditions in the x and y directions [1]. Using symbolic computation and molecular dynamics simulations, we can study the behaviour of the system for different expressions of the interaction potential. The spectrum of eigenfrequencies from the Hessian matrix can be obtained out of the mass-weighted dynamical matrix from a theoretical point of view [2] or using data from the evolution of the system. Moreover, it is possible to add a friction force to study how this changes the dynamical properties of the disks system.

Funding Acknowledgment:

This work has been supported by the Spanish Ministerio de Economía y Competitividad Grants No. FIS2016-76359-P and by the Junta de Extremadura Grants No. IB16087 and GRU18079 (partial support from the ERDF).

References:

- [1] Wu, Q., Cui, C., Bertrand, T., Shattuck, M. D. & O'Hern, C. S. (2019). Active acoustic switches using two-dimensional granular crystals. *Physical Review E*, 99, 062901.
<https://doi.org/10.1103/PhysRevE.99.062901>
- [2] Tanguy, A., Wittmer, J. P., Leonforte, F. & Barrat, J.-L. (2002) Continuum limit of amorphous elastic bodies: A finite-size study of low-frequency harmonic vibrations. *Physical Review B* 66, 174205
<https://doi.org/10.1103/PhysRevB.66.174205>

The effect of an obstacle before the exit: inert particles, sheep, persons ORAL 14TA

A. Garcimartín¹, J. M. Pastor², C. Martín-Gómez³, I. Zuriguel¹

Corresponding author: A. Garcimartín

e-mail:angel@unav.es

Affiliation(s):

¹ Dpto. de Física y Matemática Aplicada, Facultad de Ciencias, Universidad de Navarra, E-31080 Pamplona, Spain

² Focke Meler Gluing Solutions S.A., Pol. Los Agustinos c/Gnave D-43, 31160, Orkoien, Navarra, Spain

³ Dpto. de Construcción, Instalaciones y Estructuras, Escuela Técnica Superior de Arquitectura, Universidad de Navarra, E-31080 Pamplona, Spain

The placement of an obstacle before the exit has been put forward as a plausible mechanism to alleviate clogs. Whenever a dense flow of discrete particles goes through a bottleneck, arches can form at the constriction so that these mechanically stable structures halt or restrict the flow. The problem is that the driving force only tends to make the arches more stable, because the applied load increases their stability. An obstacle before the exit would reduce the load and therefore arches should be easier to break down by a perturbation.

We have tested this strategy in several different systems. I will present a comparative of these studies. In a two dimensional silo filled with grains, an obstacle can improve by two orders of magnitude the time between clogs. We have also demonstrated that an obstacle can ease the entrance of a sheep herd through a door. Surprisingly, this does not seem to work for people. We are still trying to understand the reasons behind this result.

Bicycle parking choice behaviour at train stations: a case study in Delft, the Netherlands

POSTER P15

Alexandra Gavriilidou, Laura Pardini Susacasa, Nagarjun Reddy, Theo Liu, Winnie Daamen

Corresponding author: Alexandra Gavriilidou

e-mail: a.gavriilidou@tudelft.nl

Affiliation(s): Delft University of Technology, Department of Transport and Planning

The interest in cycling is increasing in urban areas, also as access and egress mode for longer distance trips. The latter requires the provision of seamless connections to other modes. Bicycle parking facilities at train stations are, for example, of vital importance to guarantee this seamless connection. In order to provide appropriate bicycle parking infrastructure, it is important to understand and predict the bicycle flows in the facility. One of the main determinants of the underlying model is the parking spot choice behaviour of cyclists. The contribution of this paper is the development of such a choice behaviour model.

We hypothesise that the parking choice behaviour depends on three design attributes of the facility, namely the tier (upper/lower parking level), the distance to the platform entrance (far/close) and the use of dynamic information signs. Based on literature on cycling behaviour, personal characteristics are also believed to play a role in this choice. Finally, we assume that the occupancy of the facility matters. In an uncongested parking facility, cyclists are free to park in their desired spot, while in a congested state (i.e., when the majority of the parking places is occupied), the availability of spots constraints their choice. As we assume that the state of the parking facility affects the parking choice behaviour of cyclists, we develop two models, one for each state, using the random utility maximisation principle and discrete choice theory.

Revealed and stated preference data were collected at the central train station of Delft, the Netherlands, during peak hours. In this station, there is an underground bicycle parking facility that has 16 rows, two level racks and a capacity of 5000 spots. Each row has real-time information signs that display the number of available spots within that row. The revealed data consist of counts of the available spots and observations of the choices, while the stated preference data were collected with a survey, filled in by users of the parking facility. The observed choices are used to estimate the congested choice model, since during the data collection the number of available spots was limited. The estimation of the uncongested choice model is based on the stated choices. Both datasets cover aggregated choices, i.e., segments in the facility with similar characteristics, and not individual spots.

The uncongested model predicts the parking choice independent of the row and dependent on the distance, tier and gender. In the congested model, there are two processes in place, executed sequentially. First, a row is chosen and then, a spot area is selected within that row. The attributes that influence the row selection are the use of the information signs and the number they display. In the spot area choice within that row, the distance, tier and gender, as well as the spot area availability play a role.

An interesting finding is that women would rather park at the lower tier regardless of the distance to the platform entrance, while the preference of men depends on the state of the parking. In uncongested situations, men prefer to park closer to the entrance, whereas in a congested parking, they pick the first spot they find, even if it is far away from the entrance and on the top tier.

The specific model formulations and more insights will be discussed in the full paper. These behavioural insights can be used to further design guidelines.

Voronoi densities bicylists: adaptation for finite object size and speed ORAL 8TA

Victor L. Knoop, Flurin Hänseler, Marie-Jette Wierbos, Alexandra Gavriilidou, Winnie Daamen, Serge P. Hoogendoorn

Corresponding author: Alexandra Gavriilidou

e-mail: a.gavriilidou@tudelft.nl

Affiliation(s): Delft University of Technology, The Netherlands

To properly describe bicycle traffic in a macroscopic way, the macroscopic variables flow, density and speed need to be defined. We want to focus on local density, i.e. the density perceived by a cyclist since this is relevant for traffic operations: this explains how a bicyclist behave. As background: density for vehicular traffic is often simply taken as the number of vehicles on a road stretch of a particular length. Pedestrian traffic is two-dimensional, hence requires an other approach. One option is to allocate space to a pedestrian, which also limits the effect of counting one pedestrian just in or just out of an area. For this end Voronoi cells are often used. This means that space is allocated to the pedestrian closest to that amount of space. Or in computation, a boundary is created halfway one pedestrian and the other, leading to an area which belongs to the pedestrian. These areas, in turn, can be used to compute the local density to which a pedestrian adapts his/her behavior. For bicycle traffic this is different because cyclist have a larger physical size and have higher speeds, so they are less anisotropic and need to consider the space in front more than the space behind.

This paper introduces a new way of computing the space available for a bicyclist, accounting for speed and accounting for the non-zero size of a bicycle. The method proposed modifies the Voronoi densities, and assigns space to a bicycle, thereby changing local densities (and not overall, global density). We assign space to bicycles A if it is closer to any point of that bicycle A than any point of any other bicycle, accounting for speed. Note the two additions in *italics* which indicate the change compared to the Voronoi density. First of all, the bicycle is considered to be of non-zero size. If a point is close to the handlebar or any other part of the bicycle, it should be allocated to that bicycle, even if it is not close to the center of the bicycle. Moreover, we introduce anisotropy. Bicycles travel at a higher speed than pedestrians, hence take the space in front more into account than the space behind. If the path from the bicycle to a point in space is in line with the speed of the bicycle, the distance is discounted. This discount factor is gradually changing with angular direction and speed. The full paper provides the full description with equations.



Figure 1: Illustration of the spaces allocated to each of the cyclists. Note that the boundaries are not straight, but the areas are contiguous.

Applying this method leads to an allocation of space to each of the bicyclists. The separation boundaries are not straight anymore, but the areas of one cyclist are still one contiguous area. This will be mathematically proven in the full paper. The paper will show how variations in the parameters (cycle shape; speed and angle dependency) influence the space allocated to each cyclist. Overall, the method introduced in this paper can improve the description of perceived density and which in turn can be used in macroscopic models describing properties of streams of bicyclists.

Separation of geometrical and kinematic influences in the probability of clogging a granular silo. ORAL 9TB

Diego Gella, Diego Maza and Iker Zuriguel

Corresponding author: Diego Gella

e-mail: dgella@alumni.unav.es

Affiliation(s): Departamento de Física y Matemática Aplicada, Ed. Los Castaños, Facultad de Ciencias, Universidad de Navarra, Pamplona, Spain.

The granular flow in the discharge of silos may be interrupted by the formation of arches (in 2D) or domes (in 3D) if the orifice is few times greater than the typical particle size. Zuriguel et al.[1] showed that this probability is always constant in time, generating exponential avalanche (amount of grains discharged until the flow is arrested) distributions. Additionally, the dependence of the mean avalanche (and also of the clogging probability) on the orifices size is very strong [2]. To explain it some authors developed geometrical models over the years [3,4].

However, none of them have taken account of a possible influence of the particles velocity in clogging. In fact, when changing the outlet size, the number of arches that can form from one side of the orifice to the other is obviously altered. But what also happens is that the grains velocity will also be modified since its dependence on the square root of the outlet size is well known. Hence, a change in the orifice leads to the modification of two different properties that may affect the clogging probability in different degrees.

Aiming at separating both influences, we performed experiments in a quasi-two-dimensional silo with a conveyor belt placed just below the grains exit. By means of using that device, it is possible to change the grains velocity keeping the orifice size unaltered. Then, from avalanche statistics we obtained the clogging probability p_c that the silo gets clogged when a single particle cross the orifice for the set of parameters studied. In particular, we swept all the range of the conveyor belt velocities and three different outlet sizes in the region where the silo is prone to clog.

The dependence of p_c on the grains velocity resulted to be truly significant, changing up to almost two orders of magnitude in the whole range of belt velocities for the biggest orifice studied. In addition, we managed to decouple both influences (geometric and kinematic) by including a kinematic term in the geometrical model recently proposed by Thomas and Durian⁴.

References:

- [1] I. Zuriguel, L.A. Pugnaloni, A. Garcimartín and D. Maza, Phys. Rev. E **68**, 030301(R) (2003)
- [2] I. Zuriguel, A. Garcimartín, D. Maza, L.A. Pugnaloni and J.M. Pastor, Phys. Rev. E **71**, 051303 (2005)
- [3] K. To, P-K Lai and H.K.Pak, Phys.Rev. Lett. **86**, 71 (2001)
- [4] C.C. Thomas and D.J. Durian, Phys. Rev. Lett. **114**, 178001 (2015)

Inferring Input Parameters for Simulations from Measurements: Applying Bayesian Inversion to a Bottleneck Scenario ORAL 2TA

Marion Gödel,^{1,2} Rainer Fischer¹, Gerta Köster¹

Corresponding author: Marion Gödel

e-mail: marion.goedel@hm.edu

Affiliation(s):

¹Munich University of Applied Sciences, Munich, Germany

²Technical University of Munich, Munich, Germany.

Microscopic crowd simulations can enhance the safety of pedestrians if they correctly predict the crowd evolution in various environments. For this, it is necessary to investigate the role of input parameters and find proper choices for highly influential parameters. With the wrong parameter choice, even well tested and calibrated models may produce unrealistic results. The research field of uncertainty quantification investigates methods for systematic parameter studies. Objectives in this research field include determining the sensitivity of model parameters, investigating the impact of uncertain model parameters and deducing parameter values from data. While methods of uncertainty quantification have been widely applied to, e.g. hydrologic models, there are only a few applications to pedestrian dynamics. Von Sivers et al. use forward propagation to quantify the impact of parameters for a sub-model, which describes helping behaviour [1]. Similarly, Dietrich et al. investigate the impact of three uncertain parameters in a scenario of a train evacuation [2]. They construct and utilize a surrogate model to avoid computationally expensive evaluation of the model (here the simulator). Both applications focus on investigating the impact of uncertain input parameters to simulation results of interest. On the other hand, Bode as well as Corbetta et al., exploit methods of inverse uncertainty quantification to infer information about the input parameters from measurements [3, 4]. They aim for parameter calibration of models.

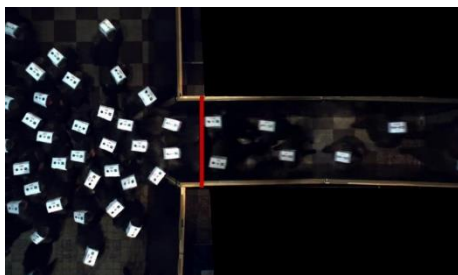


Figure 2 Still from bottleneck experiments from Liddle et al. [5].

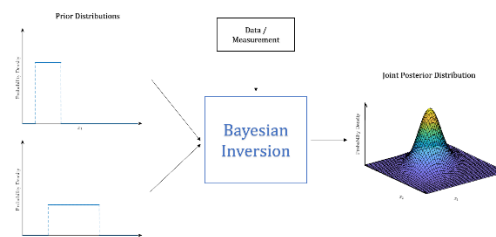


Figure 3 Concept of Bayesian inversion illustrated for two uncertain parameters.

In this work, we perform a first application of Bayesian inversion to our simulation framework Vadere. Bayesian inversion is a method that uses a prior belief in the distribution of uncertain input parameters combined with measurements of the quantities of interest, to obtain an informed distribution of the uncertain parameters. The concept of Bayesian inversion is illustrated in Figure 2. The results can provide insight into parameter choices as well as correlations between the parameters. We focus on a scenario that has been investigated in many experiments: a bottleneck as described in [5], shown in Figure 1. Based on the experimental results, we apply Bayesian inversion to infer two uncertain input parameters, the mean and variance of the free-flow speed of the pedestrian who took part in the experiments. By this example, we demonstrate the workings of Bayesian inversion and point out potential extensions such as active subspaces.

- [1] I. von Sivers, A. Templeton, F. Künzner, G. Köster, J. Drury, A. Philippides, T. Neckel, H.-J. Bungartz, Modelling social identification and helping in evacuation simulation, *Safety Science*, Volume 89, 2016.
- [2] F. Dietrich, F. Künzner, T. Neckel, G. Köster, H.-J. Bungartz, Fast and flexible Uncertainty Quantification through a data-driven surrogate model, *International Journal for Uncertainty Quantification*, Volume 8, 2018.
- [3] N. Bode, Parameter Calibration in Crowd Simulation Models using Approximate Bayesian Computation, *Pedestrian and Evacuation Dynamics Conference*, Lund, Sweden, 2018.
- [4] A. Corbetta, A. Muntean, K. Vafayi, Parameter Estimation of Social Forces in Pedestrian Dynamics Models via a Probabilistic Method, *Mathematical Biosciences and Engineering*, Volume 12, 2015.
- [5] J. Liddle, A. Seyfried, B. Steffen, W. Klingsch, T. Rupprecht, A. Winkens, M. Boltes, Microscopic insights into pedestrian motion through a bottleneck, resolving spatial and temporal variations, *arXiv*, 2011.
- [6] Vadere-Team (2016), www.vadere.org

The Enskog kinetic theory for moderately dense granular suspensions is considered as a model to determine the Navier-Stokes transport coefficients. The influence of the interstitial gas on solid particles is modeled by a viscous drag force term plus a stochastic Langevin-like term [1,2,3]. The suspension model is solved by means of the Chapman-Enskog method conveniently adapted to dissipative dynamics. As in previous studies on driven granular fluids [4], since the cooling terms (arising from collisional dissipation and viscous friction) cannot be compensated for by the energy gained by grains due to collisions with the interstitial gas, the reference distribution (zeroth-order approximation) depends on time through its dependence on temperature. On the other hand, to simplify the analysis and given that we are interested in computing transport in the first order of deviations from the reference state, the steady-state conditions are considered. This simplification allows us to get explicit expressions for the transport coefficients. As in the case of ordinary fluids, the transport coefficients are given in terms of the solutions of a set of coupled linear integral equations. Explicit forms for these coefficients are obtained by considering the leading terms in a Sonine polynomial expansion. The results show that the dependence of the transport coefficients on both inelasticity and density is clearly different from that found in its granular counterpart (no gas phase) [5]. Finally, a linear stability analysis of the hydrodynamic equations with respect to the homogeneous steady state is performed. In contrast to the granular case [6], no instabilities are found and hence, the homogeneous steady state is (linearly) stable. Comparison with Monte Carlo simulations shows a good agreement.

[1] V. Garzó, S. Tenneti, S. Subramaniam and C. M. Hrenya, *J. Fluid Mech.* **712**, 129 (2012).

[2] H. Hayakawa, S. Takada and V. Garzó, *Phys. Rev. E* **96**, 042903 (2017).

[3] R. G. González, V. Garzó, *J. Stat. Mech.* **2019**, 013206 (2019).

[4] V. Garzó, M. G. Chamorro and F. Vega Reyes, *Phys. Rev. E* **87**, 032201 (2013).

[5] V. Garzó and J. W. Dufty, *Phys. Rev. E* **59**, 5895 (1999).

[6] V. Garzó, *Phys. Rev. E* **72**, 021106 (2005).

Macroscopic Dynamics of Traffic to Plan Urban Systems PLENARY SESSION

Marta C. González

Corresponding Author: Marta C. González

e-mail: martag@berkeley.edu

Affiliation: College of Environmental Design, University of California, Berkeley and Lawrence Berkeley National Laboratory, Berkeley, California, USA

Stories of mega-jams that last tens of hours or even days appear not only in fiction but also in reality. In this context, it is important to characterize the collapse of the network, defined as the transition from a characteristic travel time to orders of magnitude longer for the same distance traveled. In this multicity study, we unravel this complex phenomenon under various conditions of demand and translate it to the travel time of the individual drivers. First, we start with the current conditions, showing that there is a characteristic time τ that takes a representative group of commuters to arrive at their destinations once their maximum density has been reached. While this time differs from city to city, it can be explained by Γ , defined as the ratio of the vehicle miles traveled to the total vehicle distance the road network can support per hour. Modifying Γ can improve τ and directly inform planning and infrastructure interventions.

Unclogging dynamics of long-lasting arches in a vibrated silo POSTER P16

Bruno V. Guerrero¹, Bulbul Chakraborty², Iker Zuriguel¹, Angel Garcimartín¹

Corresponding author: Bruno V. Guerrero

e-mail: bguerrero.3@alumni.unav.es

Affiliation(s):

¹ Departamento de Física y Matemática Aplicada, Facultad de Ciencias, Universidad de Navarra, 31080 Pamplona, Spain.

² Martin Fisher School of Physics, Brandeis University, Waltham, Massachusetts 02454, USA.

Arches can stop the flow from a silo during its discharge, but they may be destabilized by external perturbation to resume the outpouring. We present an experiment on the unclogging of a two-dimensional granular silo driven by a sustained gentle vibration. For a long enough vibration, the arches evolve until they may either collapse or get trapped in one fixed configuration. We focus on the long-lasting arches, both those arches that break and those that do not. They display a stick-slip like irregular motion, where large rearrangements are alternated with quiescent periods. This evolution is faithfully described in terms of a scalar variable related to the arch shape regularity, for which only the positions of the arch beads are needed. The observed behavior is modeled as a continuous time random walk, which is able to reproduce the experimental data. Our findings show that the unclogging phenomenon exhibits an aging dynamics like in glassy systems, regardless of whether arches break or not. Indeed, arches that do not break evolve in the same way as those arches that break.

Velocity-based modelling for crowding and queuing in front of bottlenecks ORAL 4TA

Ben Hein¹, Mohcine Chraibi², Armin Seyfried²

Corresponding author: Ben Hein

e-mail: ben.hein@uni-wuppertal.de

Affiliation(s):

¹School of Architecture and Civil Engineering, University of Wuppertal, Germany

²Institute for Advanced Simulation, Forschungszentrum Jülich GmbH, Germany

Experimental data shows that a guiding system in front of an entrance can reduce pushing of the waiting people. Furthermore, it has been shown that other factors like corridor width, number of participants and motivation have an impact on whether crowding or queuing behaviour and thus a high density occurs. In general, density in front of the bottleneck increases by widening the corridor and by intensifying the motivation of the participants, but the number of participants seems to influence the occurrence of pushing and the level of density as well.

Having these findings in mind, this contribution presents microscopic simulation results for bottleneck scenarios by making use of a velocity-based operational model. In a first step, corridor width, number of simulated agents and suitable model parameters, which are able to represent an agent's motivation, are varied through a number of simulation runs. In addition, simulations with two types of agents regarding their behaviour are carried out. Time-density series, width-density relations in a specific time interval as well as a comparison between individual distance to target and individual time to target are generated and analysed subsequently.

The results show that the current modelling approach is able to reproduce phenomena like queuing and crowding as well as width-density correlations observed in experimental setups. However, extensions to the original model like pushing behaviour are necessary in order to better describe the resulting dynamics.

Structural characterization of nonspherical particles flowing down an inclined plane

POSTER P17

Raúl C. Hidalgo, Dariel Hernandez-Delfín and Thomas Weinhart

Corresponding author: Raúl C. Hidalgo

e-mail:raulcruz@unav.es

Affiliation(s): Universidad de Navarra

We numerically study the steady-state granular flow of non-spherical particles down an inclined plane, using a hybrid CPU/GPU DEM implementation of nonspherical particles. Specifically, the structural dynamics of the flow is described in detail, by exploring the solid fraction fluctuations, particle-particle contact distributions, linear and angular velocity distributions, as well as, the particle-particle angular and velocity correlations. Our results, shed light on clarifying the difference in the individual particle movement, along and perpendicular to the advective flow, in the bulk region and in the surface region, where the system is notably diluted. We aim to determine the system's characteristic time and length scales, which help when developing a continuum mechanical description of granular flows composed of non-spherical particles.

Spatially dependent friction – a way of adjusting bottleneck flow in cellular models. ORAL 3TA

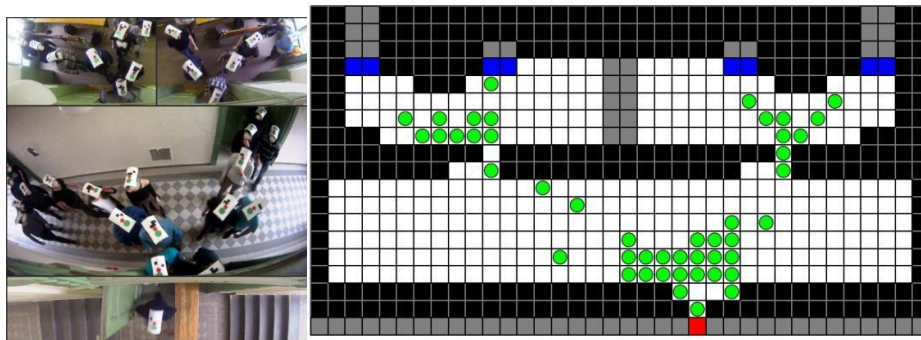
Pavel Hrabák¹ and František Gašpar²

Corresponding author: Pavel Hrabák

e-mail: pavel.hrabak@fit.cvut.cz

Affiliation(s): ¹Czech Technical University in Prague, Faculty of Information Technologies, Thákurova 9, 160 00 Prague 6, Czech Republic. ²Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Břehová 7, 115 19 Prague 1, Czech Republic.

We introduce the *spatially dependent friction* in cellular floor-field model of pedestrian flow as a possible way of proper adjustment of flow through individual bottlenecks/exits in a rather complex structure containing multiple consecutive bottlenecks. By the term spatially dependent friction we understand that the friction parameter is not global but is related to individual cells of the lattice, thus building friction-field. More specifically, we consider a bulk friction (rather low) responsible for the conflict-induced delay while walking within the crowd, and local friction defined individually for each exit-like bottleneck, which is responsible for the clogging in front of the exit. The idea then consists in calibrating the model in two steps: Firstly, the ‘bulk’ behaviour is considered (average speed, fundamental diagram in corridors etc.) and global parameters of the model (sensitivity to potential, time scale, bulk friction) are calibrated to fit this bulk behaviour. Secondly, the friction parameter is locally calibrated for each exit in order to adjust properly the maximal flow through the exit. The introduction of this local friction is motivated by the calibrating issues accompanying the multiple-bottleneck modelling by means of cellular automata (Hrabak et al 2016). The biggest problem was to calibrate the model to capture the flow through individual relatively narrow doors of different but similar width (70 cm, 85 cm), while simulating the egress from a lecture hall through several consecutive exits, as visualised in figure below.



For the purpose of this study a simple floor-field model with static field and friction-function mechanism of conflict-solving driven by parallel update is considered. The introduction of the spatially dependent friction to such simple model significantly improves the calibration flexibility. The model results are compared to the experimental study described in (Hrabak et al 2019).

The applicability of the introduced calibration method is successfully tested for various aspects of the model (Moore and von Neumann neighbourhood; Euclidean or Manhattan metric in static field definition; Homogeneous or Heterogeneous agents). Advantages and limitations of the method are discussed comparing the properties of important observables (maximal flow through the exit, time-headway distribution at the exit) measured by the simulation and the experiment.

The local friction calibration is very effective due to the Markov-chain based flow approximation of stationary flow presented at the conference Mathematics Applied in Transport and Traffic Systems (MATTS 2018).

References:

- P. Hrabák, M. Bukáček, P. M. Kielar, and A. Borrmann (2019) Pedestrian Flow through Complex Infrastructure, Experiments and Mass-Transport Processes. In: Hamdar, Samer H. (Ed.) Traffic and Granular Flow '17, Springer International Publishing (to be published).
- P. Hrabák, J. Porzycki., M. Bukáček, R. Lubaś, J. Wąs. (2016) Advanced CA Crowd Models of Multiple Consecutive Bottlenecks. In: El Yacoubi S., Wąs J., Bandini S. (eds) Cellular Automata. ACRI 2016. Lecture Notes in Computer Science, vol 9863, 396-404.

Analysis of group behavior of Boids using PCA POSTER P18

Yoshinari Inomata and Toshiya Takami

Corresponding author: Yoshinari Inomata

e-mail: yoshinarhi_i@yahoo.co.jp

Affiliation(s): Oita University, 700 Dannoharu, Oita-shi, Oita 870-1192, Japan

Swarm intelligence (SI), which is one of the artificial intelligence technologies, is a generic name of algorithms that emerge a group behavior of agents with simple functions. For the development of a system using SI, the purpose of this study is to analyze the group-behavior change by the difference of agent. We will analyze the Boid model which emerge various shapes of the flock depending on the parameter change.

In multi-agent simulations, the state of a group is represented by coordinate and velocity vector of all the agents. However, For the simulation of two-dimensional space with N boids, the data for each step has $4N$ dimensions, and it is very huge for the analysis. In order to solve this problem, the principal component analysis (PCA) is used to reduce the dimensions of data. Since the number of dimensions in each data must be the same due to the property of PCA, we numerically obtain different collections of data: (i) Interaction areas are changed various values, but number of agents is constant; (ii) Number of agents are changed various values, but interaction parameters are constant. In the case of (ii), we created 10-dimensional data calculated the variance and covariance of these data instead of using coordinate and vector data. In both collections, we analyzed whether low dimensional data visualized by PCA is used to classify dynamic states.

In the dataset (i), we observed three different states including the string-like torus. By the use of PCA up to the third principal component, the state of the string-like torus was distinguished from other states. In the dataset (ii), both states of parallel and torus motions were extracted from others, and transition from a random state to each state was observed. As the result, it is shown that several dynamic states are automatically classified by PCA.

In the presentation, we will also show other results and discuss the analysis for the function of a flock or the classification using methods other than PCA such as dynamic mode decomposition.

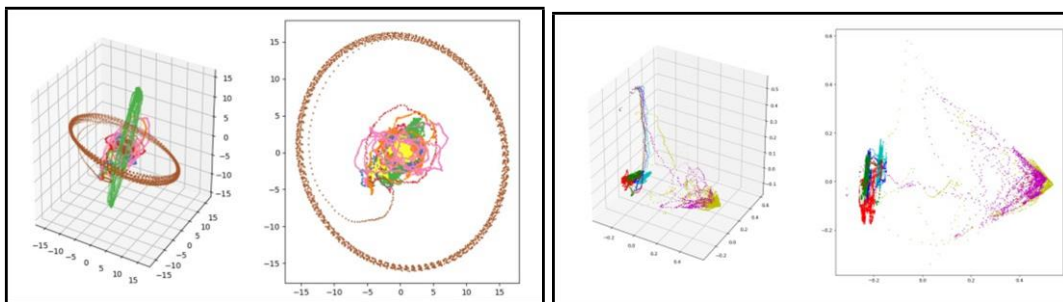


Fig 1. Result of PCA by (i). Fig 2. Result of PCA by (ii)

References

- [1] Craig W. Reynolds: Computer Graphics, Vol. 21, No. 4, pp.25-34 (1987).
- [2] D. Martens, B. Baesens, T. Fawcett: Machine Learning, Vol. 82, pp.1-42 (2011). [3] I. D. Couzin *et al.*: J. theor. Biol. 218, pp.1-11 (2002).
- [4] M Sakagami, K Terayama, R Sumiya: Kyoto Univ. RIMS Kôkyûroku No.1900, pp.110-117 (2014). [Japanese]
- [5] K Fujii, T Kawasaki, Y Inaba, Y Kawahara: PLoS Computational Biology 14(11): e1006545 (2018).

Experimental study on the influence of obstacle on pedestrian crowd egress under non-emergency conditions. ORAL 10TA

Xiaolu Jia¹, Claudio Feliciani², Daichi Yanagisawa^{2,3}, Katsuhiro Nishinari^{2,3}

Corresponding author: Xiaolu Jia

e-mail: xiaolujia@g.ecc.u-tokyo.ac.jp)

Affiliation(s):¹ Department of Advanced Interdisciplinary Studies, School of Engineering, The University of Tokyo. 4-6-1 Komaba, Meguro-ku, Tokyo 153-8904 Japan.

²Research Center for Advanced Science and Technology, The University of Tokyo. 4-6-1 Komaba, Meguro-ku, Tokyo 153-8904 Japan.

³ Department of Aeronautics and Astronautics, Graduate School of Engineering, The University of Tokyo. 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan

Many present studies have illustrated that the evacuation efficiency could be improved if an obstacle is placed properly before the exit. However, few have studied the influence of an obstacle away from the exit on pedestrian dynamics under non-emergency conditions, where pedestrians tend to walk in order. In this study, we have done experiments in a corridor with an obstacle in the middle. The congestion-sharing effect of the obstacle has also been observed and evaluated in this paper.

1. Experiment

As shown in Fig. 1, the corridor and the obstacle were built by cardboard boxes. We define the number of boxes used to build the obstacle as box , and the width of each box in y direction is 0.42 m. 30 males aged 20 to 24 have participated in our experiments on November 4th, 2017. Totally 20 tests have been conducted with pedestrian number N being 10, 15, 20, 25, 30 and box being 1, 2, 3 and 4. Before each test, N pedestrians are required to stand in a phalanx before the start line. During the experiments, pedestrians will walk from the start line to the exit and finally pass by the exit. We would detect the locations of pedestrians within the detection region using the coordinates system in Fig. 1.

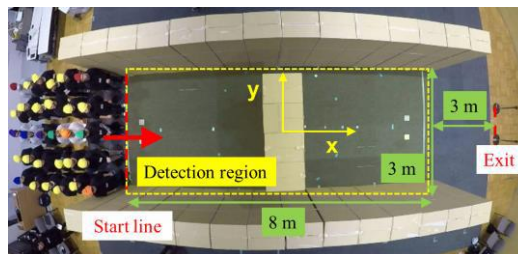


Fig. 1 Geometrical sizes of the experiment scenario.

2. Egress time

We define the time from the beginning to when the last pedestrian passes by the exit as egress time T . The variation of T can be seen in Fig. 2.

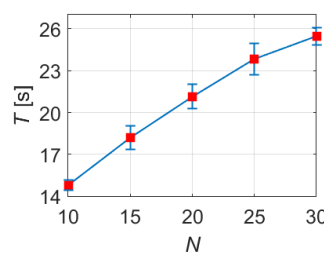


Fig. 2 Variation of average egress time and the error bars against pedestrian number N . Under a certain N , the error bar is the vertical capped line representing the one standard deviation range of the egress time corresponding to four obstacle widths. Fig. 2 shows the egress time increases with pedestrian number, while the obstacle width has little effect on the egress time considering the error range.

3. The congestion-sharing effect

Two examples of the trajectories and the velocities at each location can be seen in Fig. 3. When obstacle width is small ($box=1$), pedestrians will decelerate because of the congestion before the exit. When the obstacle is large ($box=4$), despite that pedestrians will get congested before the obstacle, they could walk at a higher speed between the obstacle and the exit. In this way, the congestion before the exit has been transferred by the obstacle, which we define as the congestion-sharing effect.

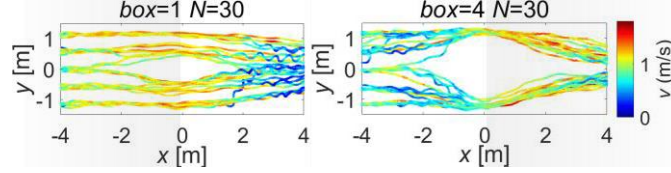


Fig. 3 Trajectories and the heat map of pedestrian velocity.

To validate the congestion-sharing effect, we propose the indicator in (1), where T_i^{total} represents the time period that pedestrian i is within the detection region and T_i^{after} is the time period after he has passed the obstacle. total i T after i T. The smaller α is, the less time that pedestrians will spend in the region between the obstacle and the exit, and the more that congestion will be shared from the exit to the region before the obstacle. The variation of α in different conditions can be seen in Fig. 4(a), which shows the congestion-sharing effect becomes apparent when $N \geq 20$ because the curves becomes more dispersed.

$$\alpha = \left(\sum_{i=1}^T T_i^{after} / T_i^{total} \right) / N \quad (1); \quad V = \sum_{i=1}^N \sum_{t=1}^M \delta_i |\vec{v}_i(t+1) - \vec{v}_i(t)| / N \quad (2)$$

We presume there is an optimal obstacle width that could minimize local congestion. The local congestion does not exist if pedestrians always keep constant speed, while is serious if pedestrians continuously change their speed. Therefore, we consider that the velocity variation could represent the level of local congestion and use the indicator V in (2) to evaluate it. Lower V represents less local congestion. In (2), δ_i equals to one when pedestrian i is in the detection region and zero when not. Velocity samples will be taken every $1/30$ s. M is the total sampling times and $v_i(t)$ is the velocity vector. The variation of V can be seen in Fig. 4(b), which shows that the local congestion is the minimum when $box=2$ and the maximum when $box=4$. The local congestion level is quite similar between $box=1$ and 3 (the p-value using t-test is $0.6 > 0.05$ while the p-value corresponding to any other two obstacle widths is lower than 0.05).

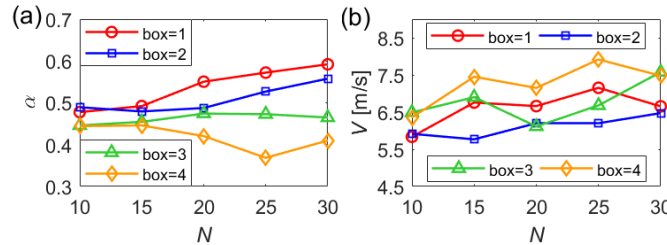


Fig. 4 Variation of (a) α and (b) V in different conditions.

4. Conclusion

The obstacle size will not apparently affect the egress time in our experiments. However, the increase of obstacle size could share the congestion before the exit. There exists an optimal obstacle size that could minimize local congestion. It is interesting that the optimal obstacle size is neither the smallest nor the largest.

Pedestrian fundamental diagram in between normal walk and crawling ORAL 3FA

Ma Jian, Shi Dongdong, Li Tao

Corresponding author: Ma Jian

e-mail: majian@mail.ustc.edu.cn

Affiliation(s):

¹School of Transportation and Logistics, National Engineering Laboratory of Integrated Transportation Big Data Application Technology, Southwest Jiaotong University, Chengdu, 610031, China

²Faculty of Geosciences and Environmental Engineering, Southwest Jiaotong University, Chengdu 610031, China

Due to the increase of the number and frequency of major events in the past decades, studies on pedestrian dynamics have attracted attentions of researchers of various disciplines [1-3]. The escape environment of the crowds, especially under special circumstances including fire, can be greatly affected by factors such as smoke, thus the pedestrian gait in emergency evacuation is usually different from normal walking. In this paper, an experimental study on fundamental diagram of single-file pedestrian movement at different available heights will be detailed.

We recruited 60 college students to participate in this experiment, and all of them are asked to wear a little red hat with a white dot in the middle of the head. This makes it easy to identify these participants and extract experimental data. All participants are required to walk in a single line, meaning that they were asked to stand evenly and face in the same direction, no overtaking is allowed. A translucent roof, which is made of protective screening as shown in Fig.1, was setup to control the available height for those pedestrians. It is noticed that for a height below 1.0m, it is difficult to walk thus pedestrians can only crawl, while for a height higher than 2.0m, pedestrian can use normal walking gait. As a consequence, in total five experimental scenarios with the available heights of 1.0m, 1.2m, 1.4m, 1.6m, 2.0m were investigated. To capture the locomotion features of these pedestrians, we placed a high-resolution camera on the top of the built single-file corridor. The trajectories were then extracted from the video. The relationship between velocity and density, density and flow, and head distance and instantaneous velocity were analyzed.



Fig.1 Snapshot of the experimental scene

Quantitative measurement of moving-light-modulated collective behaviour of soldier crabs, *Mictyris guinotae*. ORAL 5WB

Wataru Hasegawa, Kenji Kusumi, Naoyuki Uebayashi, Shusaku Nomura, Kenta Kaito, Yuta Nishiyama

Corresponding author: Kenta Kaito

e-mail: k.kaito0290@gmail.com

Affiliation(s): Nagaoka University of Technology

Animal collective behaviours, e.g. fish school, bird flock, ant foraging, are fascinating phenomena. Although they have been investigated as typical examples of autonomous distributed natural system for a long time, their mechanism remains unclear. It is crucial to find various methods to intervene such systems for experimental studies. Soldier crabs, *Mictyris guinotae*, form a group of huge numbers of individuals and wander en masse on tidal flats in the Ryukyu Islands, Japan, during the daytime low tide. Recently, it was reported that they make a taxis in response to light stimulus, so-called phototaxis. They approach a light source such as a flashlight. A previous study investigated a collective behaviour of 20 soldier crabs in a circular arena of 406 mm in diameter. 128 white light emitting diodes (LEDs) were arranged regularly at 10 mm intervals on the wall of the arena. A microcomputer sequentially lighted the LEDs one by one at any predetermined transition time and direction. Transition of the light causes a collective rotating behaviour of crabs. Main findings were that crabs move in the same direction as the light movement when the transition speed is slow (> 35 ms/cm), and move in the opposite direction when the transition speed is fast (< 15 ms/cm). In addition, their collective behaviour is unclear or takes more time to achieve when the light transition speed is middle (≈ 20 ms/cm). However, these findings were only analysed qualitatively based on video observations. To evaluate the previous findings quantitatively, we conducted experiments to reproduce them with equipment to acquire trajectories of individual crabs. The same experimental arena was used and enclosed with 120 cm high curtain in order to be dark. An infrared camera (HCW850M, Panasonic) and two infrared lights (HVL-LEIR1, Sony) were installed above the arena to record crabs' movements. A marker, white paper of 5 mm square, was attached on back of crabs for position tracking. Infrared light recording facilitated extracting a position of a marker even when light of LEDs on the wall changed brightness of markers. In an experiment, 20 crabs performed 8 trials of 3 minutes long each at different light transition speed: 1, 5, 10, 20, 30, 50, 100 ms/cm, and NO-Light (counter-balanced in clockwise and counter clockwise). Total of 12 experiments were carried out using different groups of crabs. Positions of crabs were extracted at a rate of 10 frames a second by semi-automatic tracking software (move-tr, Library). This paper shows results of two of experiments because tracking data acquisition is in progress. Our experiments reproduced collective rotation behaviours that the previous study showed (Fig. a and b for example). Rotation was quantitated with $rt(\theta_{t+1}-\theta_t)$, where rt is a radial position and θ_t is an angular position (origin at the centre of the arena) at a frame t (Fig. c). Positive and negative values represent the same and opposite direction as/to the light movement respectively. Moreover, crabs' activity was calculated as a mean velocity (Fig. d). These results are consistent with previous qualitative study. So far, we assume that individuals taking a shortcut in the arena lead collective behaviour. Further analysis of position data in all the experiments will reveal an interaction among crabs, individual behavioural change, and correlation with light movement.

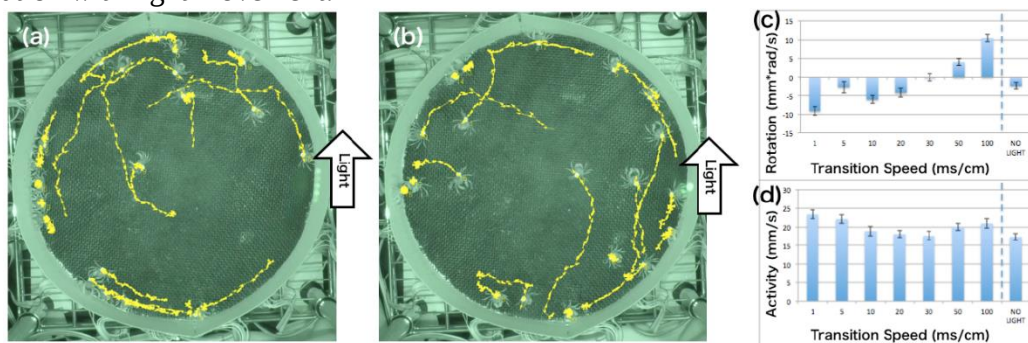


Figure. Twenty soldier crabs rotate collectively in a circular arena with a moving light. (a) Fast transition speed of the light (=1ms/cm) causes crabs' movements of an opposite direction to the light movement. In contrast, (b) slow speed of the light (=100ms/cm) causes crabs' movements of the same direction. Small arrows in the arena show trajectories of crabs for five seconds. (c) The critical speed for direction change is 30 ms/cm. At that speed, (d) crabs move slowly.

Numerical simulation of granular media flowing through vertical pipes POSTER P53

Authors: Daniel Hernández, Diego López, Iker Zuriguel, Diego Maza and Raúl C. Hidalgo.

Corresponding author: Daniel Hernández

e-mail: dhernandezd@alumni.unav.es

Affiliation: Depto. de Física y Matemática Aplicada, Facultad de Ciencias, Universidad de Navarra

In this contribution, we numerically study granular samples flowing through narrow vertical pipes. We aim to compare the numerical results with those already obtained experimentally, which evidence the presence of clogging due to the spontaneous development of hanging arches. We examine monodisperse and bidisperse systems, and we report the probability of clogging as a function of the pipe size in terms of the particle diameter $\xi = D/d$. The outcomes reveal a nonmonotonous behavior of the probability of clogging, which contrasts to the silo case. Indeed, in the case of the monodisperse samples, there are isolated zones of the ξ values where the development of arches is prevented by the formation of well-ordered geometrical structure, whereas others are likely to clog. Additionally, we obtain the polar distributions of contact force directions, relative to the vertical direction. These distributions show sharp peaks for pipe sizes, where there is no clogging. In contrast, more broadened distributions are found for cases where clogging is frequent. From these results, we can correlate the existence of clogging with the amount of disorder within the sample.

Authors: Qing Ma¹, Yu Kang^{1,2}, Weiguo Song¹, Yang Cao², Jun Zhang¹

Corresponding author: Yu Kang

e-mail: kangduyu@ustc.edu.cn

Affiliations: ¹. State Key Laboratory of Fire Science, University of Science and Technology of China, Hefei, China ². Department of Automation, University of Science and Technology of China, Hefei, China

The fundamental diagram of pedestrian flow, which describes a relation between pedestrian velocity and crowd density, is an important means for pedestrian dynamics analysis. Some recent work calculate the fundamental diagram of pedestrian flow by tracking each pedestrian in the crowd from video recordings. However, such methods are limited in representation of crowd density and hard to achieve a real-time analysis. To address this problem, this work proposes a novel convolutional neural network based framework, called deep fundamental diagram network(fig. 1), for real-time pedestrian dynamics analysis. Our proposed framework is consisted of two sub-networks, the multi-scale recursive convolutional neural network (MSR-Net) and a convolutional neural network for optical flow (OF-Net), accounting for density distribution estimation and pedestrian motion prediction, respectively. Specifically, MSR-Net is presented to learn the direct mapping from the input image of pedestrian flow to the output map of crowd density. OF-Net is introduced to predict the velocity and direction of pedestrian in real-time. In this way, by aligning the position of pedestrian density map we are able to obtain the fundamental diagram, which shows good agreement with the ones from classical methods(fig. 2, Table 1) but higher computational efficiency. Simultaneously, deep fundamental diagram network can carry out pedestrian anomaly detection (Fig. 3 In this work, the anomaly is defined as sudden stop and acceleration, reverse walk.), which is meaningful for crowd analysis.

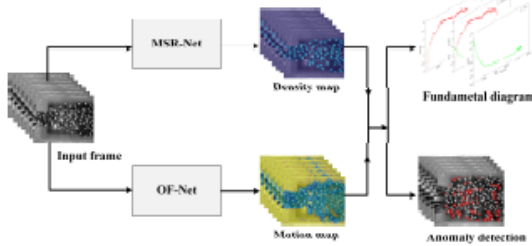


Fig. 1 The structure of our proposed deep fundamental diagram network.



Fig. 3 Anomaly pedestrian (marked by red point) who stopped.

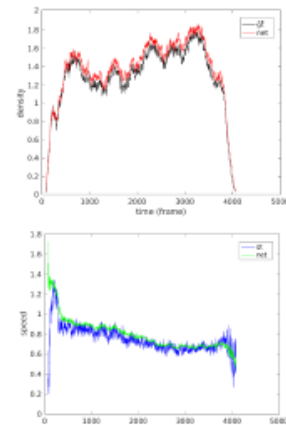


Fig. 2 The video from¹, we choose the third to seventh video verify that the fundamental diagram obtained by our method is consistency with the classical methods. Because of the space limit, we only show the fundamental diagram of the third video. Time evolution of density(top) and time evolution of velocity(bottom). Black and blue line represent the evolution calculate from classical method, network output evolution represent by the red and green lines.

Table 1. Quantitative result for pedestrian density($1/m^2$) and velocity(m/s). Calculated from classical method as ground truth. MAE indicates the accuracy of the estimates. MSE is a metric complementary to MAE and indicates the robustness of the estimates.

UNI_CORR_500		03	04	05	06	07	average
MAE	density	0.0794	0.1116	0.0818	0.0862	0.0784	0.08748
	speed	0.0618	0.0404	0.0503	0.0312	0.0318	0.0431
MSE	density	0.0084	0.0162	0.0094	0.0099	0.0101	0.0108
	speed	0.0149	1.5164	0.0086	1.1659	0.0065	0.54246

¹ <http://ped.fz-juelich.de/db/doku.php?id=corridor5>

How to force an army of self-propelled mindless robots to act collectively? ORAL 1WB

A. Deblais, T. Guerin, T. Barois, J. Lintuvuori, J. F. Boudet, J. C. Baret, and H. Kellay

Corresponding author: H. Kellay,

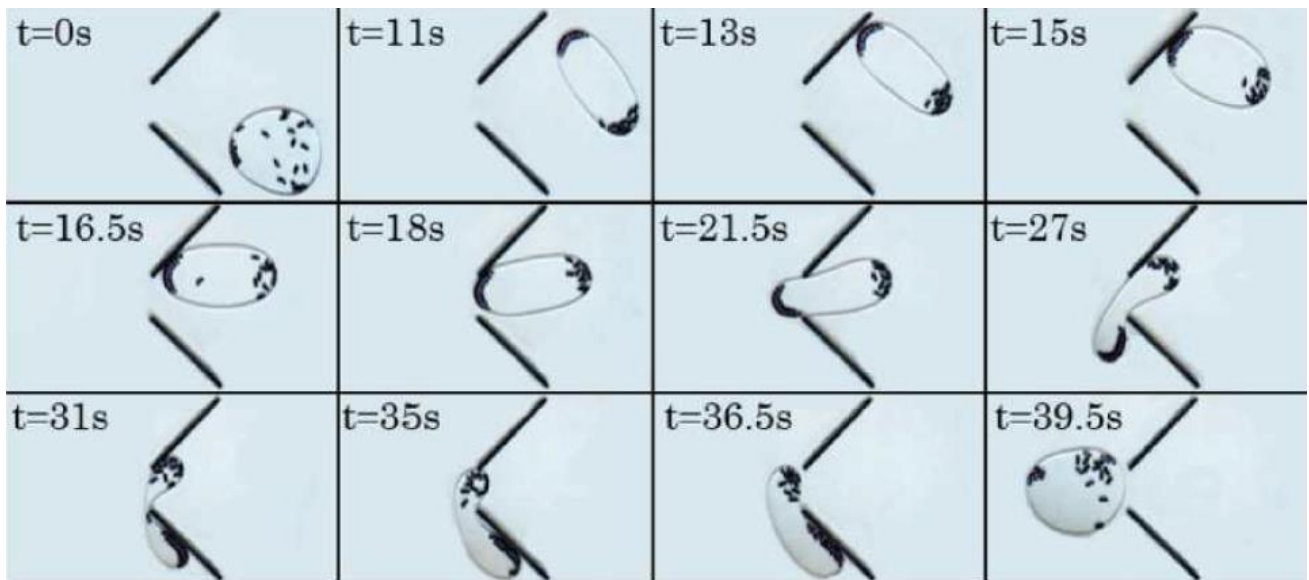
e-mail:hamid.kellay@u-bordeaux.fr

Affiliation(s):

Laboratoire Ondes et Matière d'Aquitaine, CNRS/Université de Bordeaux, France

Centre de Physique Paul Pascal, CNRS/Université de Bordeaux, France

We study assemblies of rodlike robots made motile through self-vibration. When confined in circular arenas, dilute assemblies of these rods act as a 2D gas of particles. But above a critical surface fraction, some fraction of the bots line up in one or more tight clusters along the corral boundary while, in the bulk, gaslike behavior is retained. We find that the unified pushing of the clustered bots on the boundary can drive collective motion: by selecting corrals that are deformable but free to move, we take advantage of surface cluster formation to force the robot army to work together. The deformability of the arena allows the assembly to go through narrow slits or to circumvent obstacles.



Extended longitudinal motion planning for autonomous vehicle including lane changing prediction of the target vehicle. POSTER P19

Basma Khelfa, Antoine Tordeux

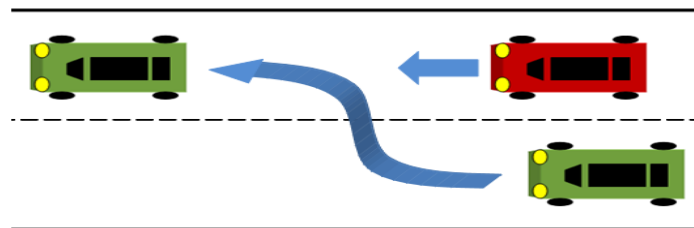
Corresponding author: Basma Khelfa

e-mail: khelfa@uni-wuppertal.de

Affiliation(s): Division for traffic safety and reliability, School of mechanical engineering and safety engineering, University of Wuppertal, Wuppertal, Germany

More than 90% of the road accidents are due to human errors [1]. The main factor of accident is lane changes [2]. Predicting the trajectories and the lane changing intention of other drivers is one of the crucial issues for the safety of an autonomous vehicle. Although planning trajectories is not a determinist task, it is possible to specify the most probable trajectory and lane changing events [3]. It has been observed that drivers smoothly regulate their speed and spacing in case of cutting or overtaking events [4]. Basic Adaptive Cruise Control (ACC) systems can provide unadapted responses, for instance unsafe over-breaking in case of cut-in [5].

We propose an extended algorithm for the longitudinal motion planning of autonomous vehicles including the detection of cut-in/cut-out of the target vehicle. The extended longitudinal model is based on a Hidden Markov Model (HMM) to detect the lane-changing intention of the target vehicle coupled to the adaptive time gap (ATG) car-following [6] for the pursuit behavior. The HMM algorithm consists in the estimation of the probability that the target vehicle lane changes (cut-out), or the insertion of a new vehicle (cut-in).



Specific pursuit regulations in the ATG are provided in case of cutting, in order to smooth the behaviors as observed in real situations. We train the HMM and calibrate statistically the ATG car-following model thanks to trajectory database of the NGSIM American Project [7]. The reliability, robustness and safety level of the extended longitudinal planner are evaluated through simulations of different cut-in and cut-out driving situations observed in the data.

References

- [1] S. Singh. Critical reasons for crashes investigated in the national motors. Technical report No. DOT HS 812 115, NHTSA, 2014.
- [2] U.S. Department of Transportation, _Lane change/merge crashes: Problems size assessment and statistical description, U.S. DOT, Washington, DC, USA, Rep. DOT HS 808 075, 1994 / H. Lum and J. A. Reagan, “Interactive highway safety design model: accident predictive module,” Public Roads, vol. 58, no. 3, 1995.
- [3] I. Dagli, G. Breuel, H. Schittenhelm and A. Schanz, "Cutting-in vehicle recognition for ACC systems - towards feasible situation analysis methodologies," *IEEE Intelligent Vehicles Symposium*, 2004, Parma, Italy, 2004, pp. 925-930.
- [4] A. Carvalho, A. Williams, S. Lefèvre and F. Borrelli Autonomous cruise control with cut-in target vehicle detection: 13th International Symposium on Advanced Vehicle Control, 2016.
- [5] Y. Zhang, Q. Lin, J. Wang, S. Verwer and J. M. Dolan, Lane-Change Intention Estimation for Car-Following Control in Autonomous Driving, in *IEEE Transactions on Intelligent Vehicles*, vol. 3, no. 3, pp. 276-286, 2018.
- [6] A Tordeux, S Lassarre, M Roussignol. An adaptive time gap car-following model. *Transportation Research B: Methodological* 44(8-9):1115–1131, 2010.
- [7] US Department of Transportation, “NGSIM – Next Generation Simulation”, 2007, <https://ops.fhwa.dot.gov/trafficanalysisistools/ngsim.htm>. Access date: December 17, 2018

Network-based model for activity choice behaviour in pedestrian simulations POSTER P20

Christopher J. King¹, Nikolai W.F. Bode², Oksana Koltsova³, R. Eddie Wilson⁴

Corresponding author: Christopher J. King

e-mail: chris.king@bristol.ac.uk

Affiliation(s):

¹Department of Engineering Mathematics, University of Bristol, BS8 1UB, Bristol, United Kingdom.

²Bentley Systems Ltd

The problem of route choice and wayfinding in pedestrian simulations has been the subject of extensive research in the last few years, particularly when modelling evacuation behaviour (Liao, Kemloh Wagoum, & Bode, 2017), (Heliövaara, Kuusinen, Rinne, Korhonen, & Ehtamo, 2012). However, less work has been done on modelling how a person chooses and schedules their activities and where they will perform said activities – a process that will have a substantial impact on the routes used. For example, at a train station, a person may want to collect their tickets first, then buy a coffee from one of several coffee shops, before going to the platform. The schedule of desired activities and/or the locations to perform these activities is often input manually into pedestrian simulations, but is there a way of modelling the activity choice behaviour of individuals generally?

We present an individual-level, network-based approach to this problem, where nodes are locations of interest and edges represent the possibility to perform an activity (Figure 1). As entities move over the network, they perform the activity associated with each node. We present a logit model where the probability of moving along an edge depends on various factors, such as the next activity in the schedule and the number of entities currently at neighbouring nodes. One of the statistics that this model can predict is the number of people engaging in an activity at a given location. We demonstrate how such a model can be calibrated on data by using simulations of pedestrian movements in a shopping mall. By comparing several models, including a Markov-based and a random walk model, using a maximum likelihood model selection approach we illustrate how the explanatory power of different behavioural mechanisms for activity location choice can be established. We find that while simple models can capture trends aggregated over time, they fail to describe the temporal dynamics.

Our work aims to establish general mechanisms by which people choose activities and will be useful for studying the dynamics of facility-wide movements and across a range of scenarios.

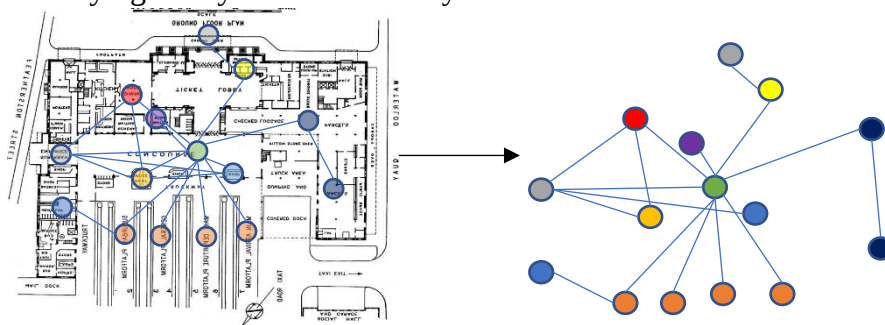


Figure 4: Converting complex environmental geometry, e.g. a railway station, into an activity-location network. Colours indicate activity types, e.g. train platforms are shown in orange, ticket machine is yellow etc.. Floorplan redrawn from <https://www.pinterest.com/pin/554294666615500014/?lp=true>.

References: Heliövaara, S., Kuusinen, J.-M., Rinne, T., Korhonen, T., & Ehtamo, H. (2012). Pedestrian behavior and exit selection in evacuation of a corridor – An experimental study. *Safety Science*, 50(2), 221–227. <https://doi.org/10.1016/j.ssci.2011.08.020>

Liao, W., Kemloh Wagoum, A. U., & Bode, N. W. F. (2017). Route choice in pedestrians: determinants for initial choices and revising decisions. *Journal of the Royal Society, Interface*, 14(127), 12. <https://doi.org/10.1098/rsif.2016.0684>

Evasion manoeuvres: One behaviour fits all? POSTER P21

Benedikt Kleinmeier, Gerta Köster

Corresponding author: Benedikt Kleinmeier

e-mail: benedikt.kleinmeier@hm.edu

Affiliation(s): Munich University of Applied Sciences, Munich, Germany

We present two new controlled experiments to observe evasion manoeuvres among pedestrians:

- (a) Participants evading collision with a dyad of pedestrians standing apart.
- (b) Participants who squeeze through a dense crowd to reach their destination.

We present the observed behaviour qualitatively and, as far as possible, quantitatively. We then re-enact the experiments with a standard locomotion model, the Optimal Steps Model (OSM) (Seitz and Köster, 2012, von Sivers and Köster 2015). The OSM resembles many other well-known locomotion models such as the Social Force Model or the Gradient Navigation Model (Helbing and Mólmar, 1995, Dietrich & Köster, 2014) in the way it models collision avoidance: A “potential” – or decreased utility – around a pedestrian is coded in a floor field and makes other pedestrians evade. In the case of the OSM, this is best interpreted as personal space (Sivers and Köster, 2015). In the case of the SFM the potential’s gradient results in a repulsive “force” similar to forces in Newtonian mechanics (Helbing and Mólmar, 1995). The computer experiments reveal that, for the OSM, personal space parameters can be adjusted to fit the evasion of dyads as they can be adjusted to queuing at a bottleneck (Liddle et al, Sivers and Köster, 2015), but not with the same parameter. In the squeezing experiment virtual pedestrians get stuck, no matter what personal space parameters are chosen. We think this plausible, because the two scenarios show a different human behaviour: evasion and squeezing through.

Thus, the first outcome of this work is experimental evidence, showcasing the need to model behavioural changes. The second outcome is data for model validation that will be made available to the scientific community, pending anonymization.

References

1. Seitz, Michael and Köster, Gerta, Natural discretization of movement in continuous space, *Physical Review E*, 2012
2. Von Sivers, Isabella and Köster, Gerta, Dynamic Stride Length Adaptation According to Utility And Personal Space, *Transportation Research Part B: Methodological*, 2015
3. Dietrich, Felix and Köster Gerta, Gradient navigation model for pedestrian dynamics, *Physical Review E*, 2014
4. Helbing, Dirk and Mólmar, Péter, Social Force Model for pedestrian dynamics, *Physical Review E*, 1995
5. Liddle, Jack and Seyfried, Arnim and Steffen, Bernd and Klingsch, Wolfram and Rupperecht, Tobias and Winkens, Andreas and Boltes, Maik, Microscopic insights into pedestrian motion through a bottleneck, resolving spatial and temporal variations, *arXiv*, 2011

How to change the value of Social Force Model's parameter tau with desired speed such that bottleneck flow remains unchanged. POSTER P22

Tobias Kretz

Corresponding author: Tobias Kretz

e-mail: Tobias.Kretz@ptvgroup.com

Affiliation(s): PTV Group, Haid-und-Neu-Straße 15, D-76131 Karlsruhe, Germany

When simulating pedestrian dynamics with the Social Force Model or one of its variants one may commonly be faced with the situation to have calibrated the model such that the model reproduces capacity flow values at bottlenecks which have been observed or which are required by a guideline or regulation, but that then the need arises to change desired speeds. The question is then how the values of the other model parameters need to be adjusted to recover the original flow value. In this contribution it is shown that to achieve this it often suffices to adjust the value of tau [1] and leave all other parameters unchanged. An equation is derived which allows to compute the new value of tau. Where this new value of tau produces flow values which match the original flow only approximately the method at least limits the search space for tau. Furthermore, the method allows to see in advance in which cases (of modifications of the desired speed) it is not enough to adjust only the value of tau, but where other parameter values need to be modified as well.

Reference:

[1] Johansson, F., Duives, D., Daamen, W., and Hoogendoorn, S. "The many roles of the relaxation time parameter in force based models of pedestrian dynamics." *Transportation Research Procedia* 2 (2014): 300-308.

An analytical solution of the Social Force Model for uni-directional flow ORAL 2FA

Tobias Kretz

Corresponding author: Tobias Kretz

e-mail: Tobias.Kretz@ptvgroup.com

Affiliation(s): PTV Group, Haid-und-Neu-Straße 15, D-76131 Karlsruhe, Germany

Second order microscopic models of vehicular or pedestrian dynamics have the advantage that it is principally easy to consider all motivations and restrictions of the dynamics. It is, however, in general not known in advance how entities move in consequence including the shape of the fundamental diagram and the speed-density relation. The latter are an important part for deciding how realistic a micro model is. Therefore, and to understand the role of parameters of a micro model and to have an indication how to set their value to produce realistic simulation results it is desirable to derive a speed- or flow-density relation analytically from the original microscopic model using simplifying assumptions and scope limitations where required. As for the Social Force Model of pedestrian dynamics and the case of for single-file movement this has been presented at TGF 2015 [1]. Following up on this in this contribution the 2d case with uni-directional flow will be investigated and as result a speed-density relation will be derived. Different to the speed-density relation previously derived for single-file movement the new relation for the 2d case allows – depending on the choice of parameters – more complex functional forms including a minimum as well as non-vanishing values up to very high densities as it has been found empirically before [2, 3, 4] but rarely been treated in theory.

References:

- [1] Kretz, T., Lohmiller, J. and Schlaich, J. "The Inflection Point of the Speed–Density Relation and the Social Force Model." *Traffic and Granular Flow'15*. Springer, 2016. 145-152
- [2] Predtechenskii, W. M., and A. Milinski. "Planning of foot traffic flow in buildings. National Bureau of Standards." (1978).
- [3] Helbing, D., Johansson, A., and Al-Abideen, H.Z., "Dynamics of crowd disasters: An empirical study." *Physical review E* 75.4 (2007): 046109.
- [4] Lohner, R., Muhamad, B., Dambalmath, P., and Haug, E. "Fundamental Diagrams for Specific Very High Density Crowds" *Collective Dynamics* 2 (2017)

Single-file dynamics of cyclists: two experiments and two microscopic models. ORAL 9TA

Valentina Kurtc¹ and Martin Treiber²

Corresponding author: Valentina Kurtc

e-mail: kurtsvv@gmail.com

Affiliation(s): ¹Peter the Great St. Petersburg Polytechnic University (SPbPU), St. Petersburg Russia, 195220,

²Institute for Transport & Economics, TU Dresden, Germany.

Bicycle traffic operations become increasingly important and yet are largely ignored in the traffic flow community, until recently. We hypothesize that there is no qualitative difference between vehicular and bicycle traffic flow dynamics in the single-file case, so the latter can be described by reparameterized car-following models. To test this proposition, we reproduce German (Andresen et. al., [1]) and Chinese (Jiang et. al., [2]) bicycle experiments on a ring with the Intelligent-Driver Model (IDM) and compare its fit quality (calibration) and predictive power (validation) with that of the Necessary-Deceleration-Model (NDM) [1], which is specifically designed for bike traffic. We find similar quality metrics for both models, so the above hypothesis of a qualitative equivalence cannot be rejected. Moreover, for the Chinese experiments, calibration errors of the IDM turn out to be slightly smaller compared to that of the NDM (Table 1). The NDM represents significant calibration errors for high flow densities, which correspond to flow states, when stop-and-go wave emerge (Table 1, $N = 63$). The application of several objective functions (absolute error measure and relative error measure) indicates that the IDM calibration is also more robust in comparison to the NDM.

Table 1 Calibration and holdout validation errors (%) and averaged ratios for IDM and NDM, Jiang et al experiments

	$N = 39$	$N = 48$	$N = 63$
IDM			
Calibration error	18.27	15.43	32.15
Validation error	26.71	22.18	34.13
Ratio	1.5	1.4	1.1
NDM			
Calibration error	23.83	18.75	62.95
Validation error	28.11	21.77	58.35
Ratio	1.2	1.2	0.9

Since lengths of the trajectories cover less than 20 m in the German experiment and often there are no significant accelerations during this time, it is very easy to calibrate leading to unrealistically low errors of a few percent, only. In contrast, the Chinese trajectory pairs include several stop-and-go phases [2], which makes them harder to calibrate. As a result, calibration errors of Chinese experiments are more than 10 times higher than those of the German experiments. We conclude that the short trajectory data of the German experiments are not really useful for calibration and validation.

According to validation tests, the IDM and the NDM performances are nearly the same. Applying two types of validation techniques, we discover that inter-driver variation is higher than the intra-driver variation for bicycle traffic. This is consistent with the results obtained from vehicular traffic experiments [3].

We conclude that the dynamics of bicycle traffic differs only quantitatively from vehicular traffic and properly parameterized car-following models such as the IDM work at least as well as dedicated “bike-following” models.

References:

1. Andresen, E., Chraibi, M., Seyfried, A., et al., 2014. Basic Driving Dynamics of Cyclists. In: Simulation of Urban Mobility, Berlin, 2014.
2. Jiang, R., Hu, M.B., Wu, Q.S., et al., 2016. Traffic dynamics of bicycle flow: Experiment and modeling. Transportation Science 51(3), 791–1029.
3. Kurtc, V., Treiber, M., 2016. Calibrating the Local and Platoon Dynamics of Car-following Models on the Reconstructed NGSIM Data. In: Traffic and Granular Flow'15.

The highD Dataset: is this dataset suitable for calibration and validation of vehicular traffic models?

POSTER P23

Valentina Kurtc^{1,2}

Corresponding author: Valentina Kurtc^{1,2}

e-mail: kurtsvv@gmail.com

Affiliation(s): ¹Peter the Great St. Petersburg Polytechnic University (SPbPU), St. Petersburg, Russia

²A+S Transproekt, St. Petersburg, Russia,

To date, the NGSIM is well-known naturalistic highway trajectory dataset. It was extensively used for calibration and validation of microscopic car-following models. Relating to the traffic-state variety, the NGSIM is superior, since rarely (if at all) any congestions are recorded. The highway Drone Dataset (highd-dataset.com) [1] is a new dataset of naturalistic vehicle trajectories recorded on German highways. Using a drone, typical limitations of established traffic data collection methods such as occlusions are overcome by the aerial perspective. Authors processed the 4K videos recorded by the drone using their own algorithms and accuracy of about 10 cm was achieved. The created dataset contains measurements from six different locations and includes more than 110000 vehicles driving 44500 km. Recording time duration was about 10 times more than those of NGSIM dataset. In case of highD, the recorded area was 400-420 meters, whereas American experiments (NGSIM) captured 500-640 meters. It results in longer NGSIM trajectories, what is a significant factor, when calibrating and/or validating traffic models. The average duration of highD trajectory is approximately 14 seconds (Fig. 1, left) and mean track speed distribution demonstrates two peaks at 80 km/h (trucks) and 120 km/h (cars) [1]. Our descriptive speed analysis of some of the highD data reveals, indeed, that there is mostly free traffic. Such trajectories are not valuable in terms of calibration of car-following models. However, there are other data sets with less speed, down to 25 km/h, about 8 m/s and even standing traffic can be observed (Fig. 1, bottom-right). The trajectory durations exceed 80 seconds. Stop-and-go waves were detected for some data sets as well (Fig. 1, upper-right). These trajectories are of interest in terms of representing the following regime of drivers and calibrating car-following models as well.

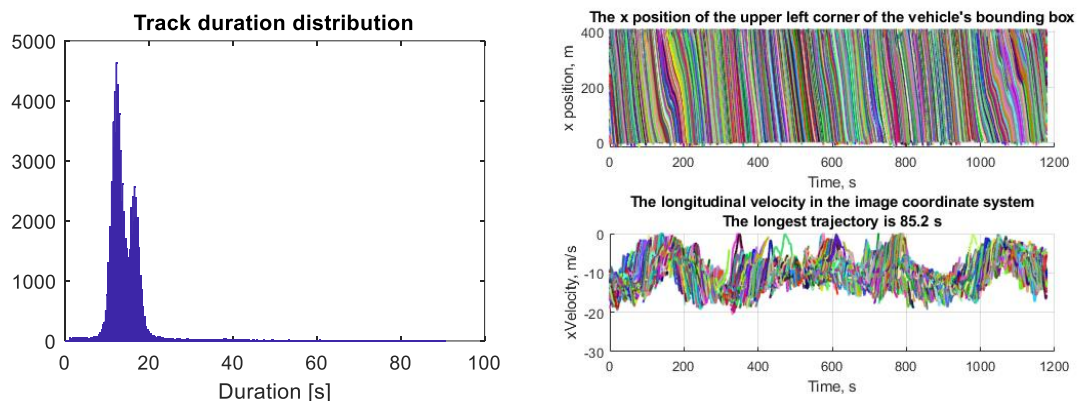


Fig. 1. Histogram of track durations (left). The longitudinal position time series (upper-right) and the longitudinal velocity time series (bottom-right)

It is worth to mention that the original NGSIM dataset contains numerous errors. This dataset was reconstructed and refined afterwards to use it for calibration and validation analysis. If the highD dataset needs such type of pre-processing procedure is an open question, which should be studied as well.

References

1. Krajewski, R., Bock, J., Kloecker, L., and Eckstein, L. The highD Dataset: A Drone Dataset of Naturalistic Vehicle Trajectories on German Highways for Validation of Highly Automated Driving Systems. IEEE 21st International Conference on Intelligent Transportation Systems, USA, November 2018.

Continuum traffic flow modelling: network approximation, flow approximation ORAL 12WB

Megan M. Khoshyaran¹ and Jean-Patrick Lebacque²

Corresponding author: Jean-Patrick Lebacque

e-mail: jean-patrick.lebacque@ifsttar.fr

Affiliation(s): ¹ETC Economics Traffic Clinic, France. ²GRETTIA, COSYS, IFSTTAR, France

In order to model traffic over very large areas, typically region sized, and to solve such problems as DTA (dynamic traffic assignment, reactive or predictive) or global management problems, a new approach is emerging, based on the idea of continuum approach.

The continuum approach relies on a double approximation process: the approximation of the underlying network as a bi-dimensional continuous medium, and the approximation of traffic flow in the network by the flow of a bi-dimensional fluid. It has been applied both to vehicular and pedestrian traffic (for instance the Hughes model is well-known). Taguchi and Iri initiated these ideas by proposing a description of the network as a medium with anisotropic capacity and velocity constraints. Further research (Ho and Wong 2006, Huang et al 2009, Jiang et al 2011, Mollier et al 2018) centred on a isotropic model of the underlying network and a single density for describing a many to one (or one to many) flow. Aghamohammadi and Laval consider applying the concept of MFD (macroscopic fundamental diagram) to dynamic continuum modelling of traffic on large networks.

Saumtally et al 2011, Sossoe 2017 approximate the network as an anisotropic medium with privileged directions of propagation, and traffic flow is disaggregated per direction or mode, thus allowing for many to many dynamic flows. For applications, the first fundamental problem to be solved is to recover the physical characteristics of the medium representing the network, from the geometric and regulatory properties of the network, as well as from the properties of intersections. The second problem to be solved is to approximate correctly the traffic dynamics in this setting. The paper addresses these two problems, and proposes a methodology based on ideas from homogeneization as well as on the use of the supply-demand approach to traffic and to intersection modelling in the GSOM framework (Lebacque and Khoshyaran 2013).

References:

1. Taguchi, A., & Iri, M. (1982). Continuum approximation to dense networks and its application to the analysis of urban road networks. In *Applications* (pp. 178-217). Springer, Berlin, Heidelberg.
2. Ho, H. W., & Wong, S. C. (2006). Two-dimensional continuum modeling approach to transportation problems. *Journal of Transportation Systems Engineering and Information Technology*, 6(6), 53-68.
3. Huang, L., Wong, S. C., Zhang, M., Shu, C. W., & Lam, W. H. (2009). Revisiting Hughes' dynamic continuum model for pedestrian flow and the development of an efficient solution algorithm. *Transportation Research Part B: Methodological*, 43(1), 127-141.
4. Jiang, Y., Wong, S. C., Ho, H. W., Zhang, P., Liu, R., & Sumalee, A. (2011). A dynamic traffic assignment model for a continuum transportation system. *Transportation Research Part B: Methodological*, 45(2), 343-363.
5. Aghamohammadi, R., & Laval, J. A. (2018). Dynamic Traffic Assignment using the Macroscopic Fundamental Diagram: A Review of Vehicular and Pedestrian Flow Models. *arXiv preprint arXiv:1801.02130*.
6. Mollier, S., Delle Monache, M. L., Canudas-De-Wit, C., & Seibold, B. (2018). Two-dimensional macroscopic model for large scale traffic networks.
7. Saumtally, T., Lebacque, J. P., & Haj-Salem, H. (2011). Static traffic assignment with side constraints in a dense orthotropic network. *Procedia-Social and Behavioral Sciences*, 20, 465- 474.
8. Sossoe, K. (2017). Modeling of multimodal transportation systems of large networks (Doctoral dissertation, Université Paris-Est).
9. J.P. Lebacque and M.M. Khoshyaran. (2013) A variational formulation for higher order macroscopic traffic flow models of the GSOM family. *Transportation Research Part B*, 57:245– 265

Exploring Koopman Operator Based Surrogate Models to Accelerate Analysis of Critical Pedestrian Densities ORAL 12WA

Daniel Lehmborg^{1,2}, Felix Dietrich^{3,4}, Ioannis G. Kevrekidis^{3,4}, Hans-Joachim Bungartz², Gerta Köster¹

Corresponding author: Daniel Lehmborg

e-mail: daniel.lehmborg@hm.edu

Affiliation(s):

¹University of Applied Sciences Munich, Munich, Germany

²Technical University of Munich, Munich, Germany

³Princeton University, Princeton, USA

⁴Johns Hopkins University, Baltimore, USA

We explore the application of the Koopman operator framework to pedestrian dynamics through a concrete example. In general the Koopman operator provides an alternative view on a dynamical system (here: pedestrian simulation), which is equivalent to the original definition. Instead of acting on the original system's state (e.g. a snapshot of a pedestrian simulation), the operator composes observation functions with the flow map of the system. The Koopman operator has the favourable property of being a linear operator that – nevertheless – captures the nonlinear dynamics of the system. Spectral decomposition of the operator yields valuable insight into qualitative properties of the system. Moreover, an accurate approximation can be used for forecasting. For the numerical approximation of the operator in matrix form, we use the *Extended Dynamic Mode Decomposition* algorithm with a dictionary from the nonlinear machine learning method *Diffusion Maps* [2, 3].

We then treat the approximated operator as a surrogate model for the original system (here: the simulation software). In pedestrian dynamics analysis, it is becoming increasingly important to compute a large number of simulation runs of the same scenario with different parameter settings. For example, quantifying parameter uncertainty of a simulation can require millions of simulation runs. Usually, the quantity of interest (QoI) relevant for the concrete analysis is macroscopic (e.g., pedestrian density in a critical area). An accurate – but slow to simulate – microscopic locomotion model then becomes a computational burden for such repeated simulation runs. With the surrogate model we can reproduce the dynamics of the pedestrian model and can generate new data through interpolation (Figure, right part). This allows approximate trajectories of the QoI to be obtained by evaluating a numerical model which is orders of magnitude faster than the original microscopic model. In our example, we use a typical scenario at a public transport station: Several pedestrians leave a bus (Figure, left part), and after a short walk exit the scenario through a door of the station. The microscopic simulations are performed through the software Vadere (<http://www.vadere.org/>), obtaining data for the surrogate (the QoI). We measure the density at three observation areas: (1) the interior of the bus, (2) the door of the bus, and (3) an exit door of the station. The Koopman operator framework has great potential for pedestrian safety, because it allows analysing time- dependent QoI, such as expected time durations of higher densities in the observed measurement areas.

Characteristic Analysis and Safety Management of Mixed Non-motorized Vehicle Traffic Flow
POSTER P24

Tao Chen, Meng Li, Hezi Liu

Corresponding author: Meng Li

e-mail: meng-li18@mails.tsinghua.edu.cn

Affiliation(s): Institute of Public Safety, Tsinghua University, Beijing

The mixed traffic flow which is composed of conventional bicycles and electric bicycles has complex operational characteristics. Moreover, there is a lack of planning, design, monitoring and management methods for non-vehicle lanes currently, leading to a continuous increase in the number of non-motorized traffic accidents and casualties. Based on the present situation, this paper intends to use the videos captured by existing surveillance cameras to foster the traffic data set, and train the faster region convolution neural network and 3d convolutional neural network to extract non-motor vehicle traffic flow parameters and to locate anomaly events. Afterwards, this paper aims to find the inherent law of traffic flow parameters through in-depth statistical analysis and realize the algorithm of monitoring non-motor vehicle illegal behaviours.

Applications of quasi-particle methods to segregation in granular mixture flows POSTER P25

Dan Liu, Muller Gerhard

Corresponding author: Dan Liu

e-mail: dliu@hartford.edu

Affiliation(s):

University of Hartford

University of Rhode Island

The method of quasi-particles, which is based on a generalized Pauli exclusion principle, can analytically solve systems with neighbour interactions. We apply the method to one dimensional jamming disk models to explore how the systems change along external effects such as vibration, gravity, rotational rates and friction. Our current research progress on jamming models with different size disks is promising to explain segregation in granular mixture flows.

Modelling Complex Pedestrian Social Group Behaviour with Expression-Matrix and Social Force

ORAL 9WA

Xiaolei Zou, Long Liu, Xiaoyi Qu

Corresponding author: Long Liu

e-mail: liul0121@tongji.edu.cn

Affiliation(s): Tongji University, Shanghai, China

Our experiments and studies in recent years^[1,2] have shown that the complex pedestrian social group has a hierarchical structure. Small pedestrian groups of 2-3 people are simple groups with simple and stable formations^[1]. The simple groups are also cellular units which act as subgroups and constitute a larger complex social pedestrian group. Complex social pedestrian group has multiple patterns^[2] in movement and form change. We measured the form and size of complex groups of 4-5 members and developed symbol expressions and relationship matrixes^[3] to describe the common forms of complex pedestrian groups.

Through experiments and analysis^[4], we also studied the formation variation strategies of complex pedestrian social groups when encountering spatial limits and crowd conflicts. The variation strategies of complex pedestrian groups can be basically divided into global strategy and local strategy. In the global strategy, the relative position between subgroups keeps synergy and stability, and the internal formation of subgroups changes greatly. In the local strategy, the internal formation of subgroups remains relatively stable, and the positions between the subgroups change greatly.

Social force model is widely used in pedestrian dynamics research and simulation analysis. In recent years, some scholars have tried to use social force model to describe the behaviour of simple groups(Moussaïd,2010,) and also behaviour of complex pedestrian groups in counter flows (Lin Huang,2018).

In this paper, on the basis of our previous experimental study of multi-pattern and formation variation strategies of complex pedestrian social groups, we use Expression-Matrix method and social force model to model the formation change strategy and behaviour of complex pedestrian groups in complex space environment and crowd conflict. In the model, Expression-Matrix is used to coordinate the hierarchical relations of the complex group and the social relations among subgroup members, and to generate global and local strategies for formation changes of complex pedestrian groups (see Figure 1). The social force model controls the dynamics of group members and forms a stable group formation according to the relationship between members and the strategy of formation change. In order to achieve the process, a set of inter subgroup relationship force is added to the social force model to maintain relatively stable position between subgroups. The model also adds a set of inner subgroup relationship force between group members to maintain the relatively stable position relationship among the members in the same subgroup.

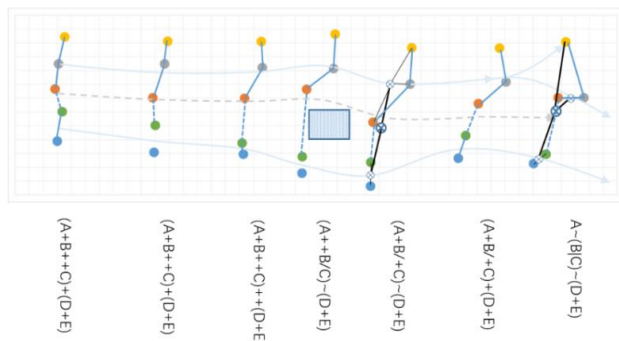


Figure 1. the coordination of Expression-Matrix on complex group formation change

The model is used to simulate the behaviour and movement of multiple complex pedestrian groups in the experimental scenes of walking through narrowing passage and in counter flow in different passage widths. The model is validated by comparing the simulation results of pedestrian trajectories and probability of adopting different formation change strategies with the data in the experiment.

Statistical properties of a granular gas fluidized by turbulent air wakes POSTER P26

Miguel Ángel López-Castaño, Álvaro Rodríguez-Rivas & Francisco Vega Reyes

Corresponding author: Miguel Ángel López-Castaño

e-mail: malopez00@unex.es

Affiliation(s): Universidad de Extremadura, Spain

In this work, we study a system composed of multiple identical spheres of ~ 40 mm diameter. These particles are subject to a uniform air stream that causes turbulent wakes past the spheres, thus producing stochastic dynamics. [1]. In particular, we analyze the case of not large average packing fractions; i.e., the system can be regarded as a granular gas under a white noise since particles contacts are short and only between two spheres (thermality in the system is driven only through binary collisions). We track particles positions at short time intervals, by means of a computer vision algorithm. We then perform a detailed analysis on single-particle trajectories [2], studying properties such as the ensembled mean squared displacement, velocity autocorrelations, distribution functions [3] and diffusive properties. We compare these results with theoretical predictions for Brownian motion.

Funding Acknowledgment:

This work has been supported by the Spanish Ministerio de Economía y Competitividad Grants No. FIS2016-76359-P and by the Junta de Extremadura Grants No. IB16087 and GRU18079 (partial support from the ERDF).

References:

- [1] Ojha, R. P., Lemieux, P. A., Dixon, P. K., Liu, A. J., & Durian, D. J. (2004). Statistical mechanics of a gas-fluidized particle. *Nature*, 427(6974), 521–523. <https://doi.org/10.1038/nature02294>
- [2] Lanoiselée, Y., Briand, G., Dauchot, O., & Grebenkov, D. S. (2018). Statistical analysis of random trajectories of vibrated disks: Towards a macroscopic realization of Brownian motion. *Physical Review E*, 98(6), 062112. <https://doi.org/10.1103/PhysRevE.98.062112>
- [3] Scholz, C., & Pöschel, T. (2017). Velocity Distribution of a Homogeneously Driven Two-Dimensional Granular Gas. *Physical Review Letters*. <https://doi.org/10.1103/PhysRevLett.118.198003>

Tuning suspension-based hourglass by ear ORAL 9WB

Alvaro Marin¹, Tamy Guimaraes², Rune Barnkob³

Corresponding author: Alvaro Marin

e-mail: a.marin@utwente.nl

Affiliation(s): ¹Physics of Fluids, University of Twente, The Netherlands

²Bundeswehr University Munich, Neubiberg, Germany.

³Heinz-Nixdorf-Chair of Biomedical Electronics, Technical University of Munich, Germany.

Fluidic systems filled with particle suspensions are prone to get clogged, often due to particle agglomeration induced by particle-particle and/or wall-particle adhesion [1]. However, even in the absence of adhesion or aggregation clogs may occur when stable archs of particles form at the constriction. This is typically the case in granular hoppers with non-cohesive particles, but also with pedestrians and animals passing through constrictions [3]. In a recent paper, Marin et al. [2] showed that clogging in suspensions passing through constrictions can also be described as an stochastic Poisson process. Several strategies are often suggested to reduce the clogging probabilities and increase the performance of a constricted system, i.e. to increase the number of material/individuals passing through the constriction. Granular hoppers can improve significantly its performance by vibrating the system at high accelerations, which reduces the stability of the particle archs [4]. On the other hand, pedestrian escape simulations have suggested that an organized crowd can substantially increase its escape rate (number of people escaping per unit time) than a randomly distributed crowd [5].

Motivated by both mechanisms of improving the performance of in suspensions passing constricted channels, we acoustically actuate a microchannel to investigate its influence on the clogging probability when suspended non-Brownian particles are injected through the channel. In this study, we experimentally confirm that a performance enhancement indeed exists and using discrete element-based numerical simulations we study the mechanism behind the increased performance.

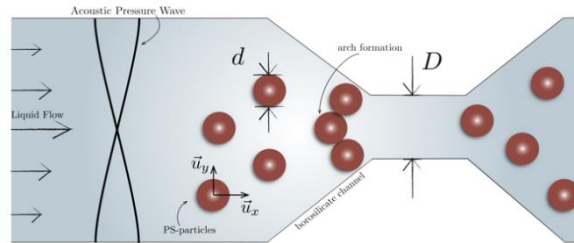


Figure 1.- Sketch of the microfluidic channel employed for the experiments: the main channel has a cross-section of $4D \times D$ which shrinks to a neck of cross-section $D \times D$. Particles of diameters d in the range $D > d > D/3$ are delivered towards the neck at packing fractions $\phi = 0.2 \pm 0.05$. The channel is connected to a piezoelectric actuator that induces a standing pressure wave with a half-wavelength of the same size of the main channel width $4D$. Particles with positive acoustic contrast will experience a force towards the node of the acoustic pressure wave, i.e. the channel's centerline.

References:

- [1] Wyss et al., Physical Review E 74 (2006).
- [2] Marin et al., Physical Review E 97 (2018).
- [3] Zuriguel et al., Scientific Reports 4:7324 (2014).
- [4] Mankoc et al., Physical Review E 80, 011309 (2009).
- [5] Helbing, Farkas, and Vicsek, Nature 407, 487 (2000).
- [6] Muller et al., Physical Review E 88, 023006 (2013).
- [7] Karlsen and Bruus, Physical Review E 92, 043010 (2015).

The bicycle is a major and popular mode of transport in Japan, as well as in some European countries such as the Netherlands, Denmark, and Germany, in terms of the modal share and the number of bicycles per population. However, the bicycle traffic environment has remained less developed in Japan, where the transport policy has traditionally put importance on the car traffic. Now the policy is changing toward the coexistence of various modes of transport, where the arrangement of the bicycle environment is to play a key role. In this work, we aim to verify, on site, the effectiveness of the on-road “bicycle lane”, which is visually separated from the car lane by painting in blue and can be installed more easily and at less cost in comparison with the separate “bicycle path”, which is physically separated from the roadway, *e.g.* by means of curbs or hedges.

We record the bicycle-passing behaviors of cars by a video camera, on two types of straight roads; one with bicycle lanes, and the other without bicycle lanes but with side strips, which are just separated from the car lanes by white lines (see Figure). Both roads are one lane each way and of similar lane widths, and the essential difference between the two is if the lane for bicycles is painted in blue or not. Then we extract some quantities to compare the traffic behaviors on both roads by image processing. The following are some preliminary results so far obtained after the Wilcoxon–Mann–Whitney test:

- (i) Distance between the road edge and bicycle: $D_{eb}' > D_{eb}$
- (ii) Distance between the road edge and car in normal condition: $D_{ec0}' \approx D_{ec0}$
- (iii) Distance between the road edge and car while passing bicycle: $D_{ec}' < D_{ec}$

Bicycles tend to travel closer to the car lane on the road with the bicycle lane (i), which implies that the bicycle lane provides a sense of ease to cyclists. As to cars, although the bicycle lane does not affect the car trajectory position in normal condition (ii), it causes cars to pass bicycles with a smaller gap (iii), which suggests some psychological effects on drivers.

These results show that even only painting the lane for bicycles can affect the traffic behaviors of bicycles and cars, which will contribute to safer and smoother urban traffic at low cost. Now we are

collecting more data to make the results statistically conclusive, and the details will be presented in the conference.

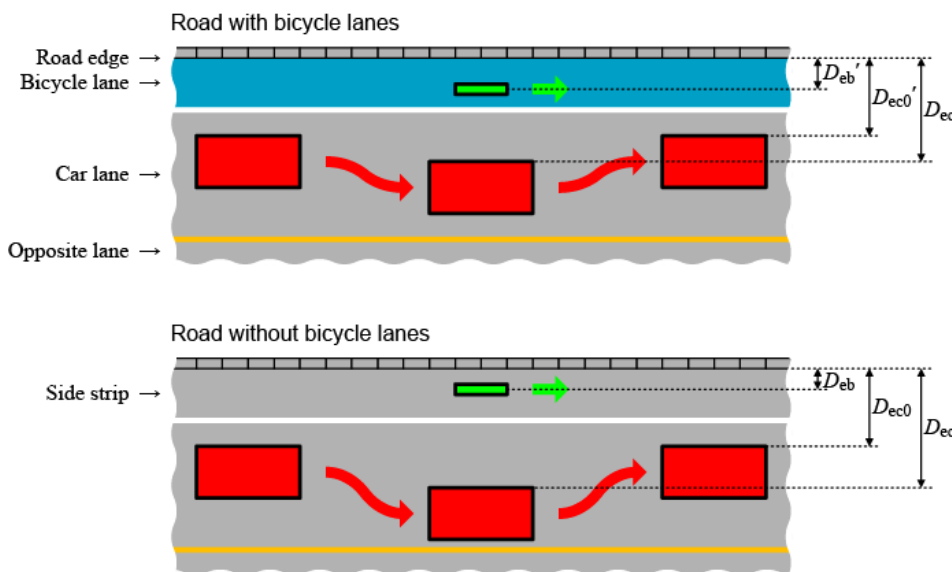


Figure: Bicycle-car traffic on roads with and without bicycle lanes

Field theory for recurrent mobility ORAL 13TB

Mattia Mazzoli, Alex Molas, Aleix Bassolas, Maxime Lenormand, Pere Colet and Jose J. Ramasco

Corresponding author: Mattia Mazzoli

e-mail: mattia@ifisc.uib-csic.es

Affiliation(s): IFISC (CSIC-UIB), Palma de Mallorca, Spain

Mobility flows are mathematically encoded using the so-called Origin-Destination (OD) matrices. Given a set of geographical areas, such matrices can be seen as weighted networks in which the nodes are the unit areas and the links point from the origin to the destination of the flow (see [1] for a recent review). Several models have been proposed to obtain the flows from basic variables as the population. The bet is high since determining transport demand is fundamental for infrastructure building and urban planning. In this work, we introduce a new approach based on the observation that the flows can be represented as vectors pointing from the origin to the destination, and that these elementary vectors can be summed to produce an average field in every unit area. This mechanism is illustrated for London in Figure 1b with ODs from Twitter data. Furthermore, we found that this vector field fulfills the Gauss (divergence) theorem and also that its rotational is nearly zero in all the space. The first feature allows us to study the flux around different closed perimeters, we used essentially circles of different radius around the center of the cities. The classical models to reproduce OD matrices are then employed to generate fields and their results are tested against the empirical fields. The flux produced by a gravity model with an exponentially decaying deterrence function with the distance fits much better than the radiation model. Additionally, it is possible to define a potential in the space. The maximum of the potential is located in the center of the cities, and then it decays as one gets further. The extrema of the potential can be used to find mobility attraction areas and to delimit the areas of influence of different cities as it can be seen in the case of the Manchester-Liverpool conurbation (Figure 1c). The results of this work will appear soon in a coming paper [2].

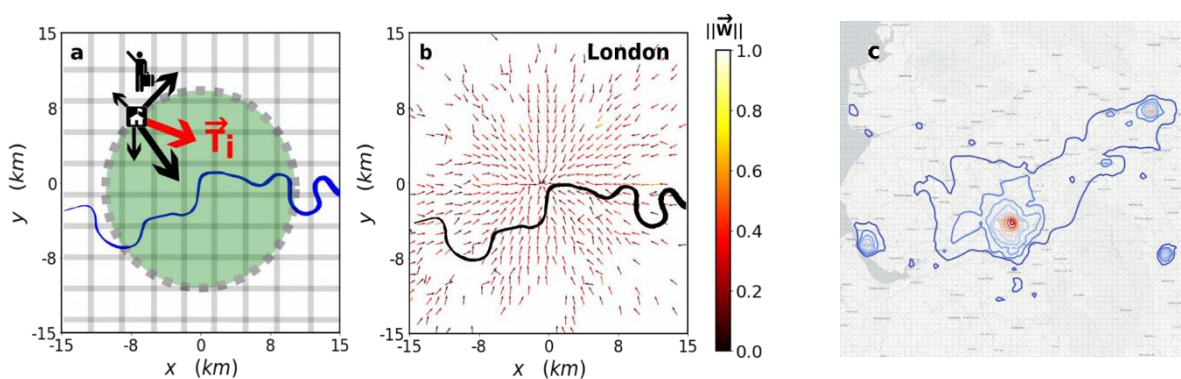


Figure 1: a) Example of the definition of the average vector in every cell (red vector). b) The vector field in an area comprehending London. c) The potential field calculated using empirical vectors in the area of Manchester and Liverpool.

References

- [1] H. Barbosa-Filho et al., Human mobility: Models and applications, arXiv: 1710.00004, Physics Reports (2018).
- [2] M. Mazzoli et al., Field theory for recurrent mobility, to appear soon.

Méndez Omaña, José

Corresponding author: Méndez Omaña, José

e-mail: mendez@beuth-hochschule.de

Affiliation(s): Beuth-Hochschule für Technik Berlin, Berlin, Germany

The aim of this paper is to develop a path or trajectory designing tool for pedestrian dynamics based on the one hand on Shannon's concept of entropy [11] and on the other hand on Lewin's concept of psychological field [6],[7],[8]. Applying Shannon's concept of entropy as a measure of uncertainty leads to the idea of considering a social event or an event in pedestrian dynamics as a source of information, this means, we may define time series [9] and apply the theory of stochastic processes. For the necessary interplay with psychological variables we apply a diagnostic test as implementation of Lewin's Field Theory [9]. The tool development includes a discussion of the entropy concept developed by von Förster [1] and a some matters concerning self-organizing systems [1],[13]. From the point of view of cybernetics, developing a model of human behaviour should include a discussion of the developing process itself. We present a short discussion based on some topics pointed out by von Förster [2].

When designing path's for pedestrian dynamics we eventually apply the solution of boundary problems, including some stochastic ordinary differential equations, and shall apply already existent environments: CA-based software PedGo [5] and the framework JuPedSim [4]. Concerning other aspects as social forces and forming groups we apply some ideas of Helbing and Molnar [3] and some other found in von Sievers et. al.[12].

One case study will illustrate the method. Evacuation models should provide predicted times [10]. As the time variable suggests the analysis in two directions, we do it: prediction and forensics are both a subject of our interest and path design.

References

- [1] H. von Förster, "On Self-Organizing Systems and their Environments", in *Understanding Understanding. Essays on Cybernetics and Cognition*, Springer Verlag, N.Y. 2003 pp. 1-19.
- [2] H. von Förster, "Cybernetics of Cybernetics", in *Understanding Understanding. Essays on Cybernetics and Cognition*, Springer Verlag, N.Y. 2003 pp. 283-286.
- [3] D. Helbing, P. Molnar, "Social Force Model for Pedestrian Dynamics", in *Physical Review E*, vol. 51(5), pp. 4282-4286, 1995.
- [4] W. Kemloh, U. Arnel, M. Chraibi, J. Zhang, G. Lämmel "JuPedSim an open framework for simulating and analyzing the dynamics of pedestrians", in *Proceedings of the 3. Conference of Transportation Research Group of India*, 2015.
- [5] H. Klüpfel, T. Meyer-König and M. Schreckenberger "Models for crowd movement and egress simulation", in *Proceedings of Traffic and Granular Flow '03*, Berlin, 2004a, pp 357-372.
- [6] K. Lewin, "Principles of Topological Psychology", New York: Mac Graw-Hill, 1936.
- [7] K. Lewin, "Field Theory in Social Sciences", New York: Harper & Brothers, 1951.
- [8] J. Méndez Omaña, "Field Theory and Quantitative Models for Pedestrian Dynamics", in *Transportation Research Procedia*, vol.2 pp. 442-445, 2014.
- [9] J. Méndez Omaña, "Field Theory in Practice", in *Proceedings of the 9th International Conference on Pedestrian and Evacuation Dynamics (PED2018)*, Lund, Sweden, 2018, Paper No. 111.
- [10] A. Schadschneider, A., Seyfried, "Validation of CA Models for Pedestrian Dynamics with Fundamental Diagrams", in *Cybernetics and Systems: An International Journal*, vol.40 5, pp. 367-389, 2009.
- [11] C.E. Shannon, "A Mathematical Theory of Communication", in *The Bell System Technical Journal* , vol. 27, pp. 379-423, 623-656, 1948.

The impact of social groups on collective decision-making in evacuations: a simulation study

POSTER P28

Hisashi Murakami¹, Claudio Feliciani¹, Kenichiro Shimura¹, Katsuhiro Nishinari^{1,2}

Corresponding author: Hisashi Murakami

e-mail:hssh415@gmail.com

Affiliation(s): ¹Research Center for Advanced Science and Technology, University of Tokyo, Tokyo Japan.

²Dept. of Aeronautics and Astronautics, School of Engineering, University of Tokyo, Tokyo, Japan.

The study of pedestrian dynamics has attracted the attention in various research fields because of its potential impact on the design of infrastructures and crowd safety. Recent studies have emphasised that the presence of social groups such as families and friends would impact on pedestrian dynamics. However, how social groups affect collective decision-making on the move is largely unknown. Here, we construct a simple simulation model of collective decision-making in evacuation situations, and show that the presence of social groups can result in a robust collective sensing in response to uncertain exit information.

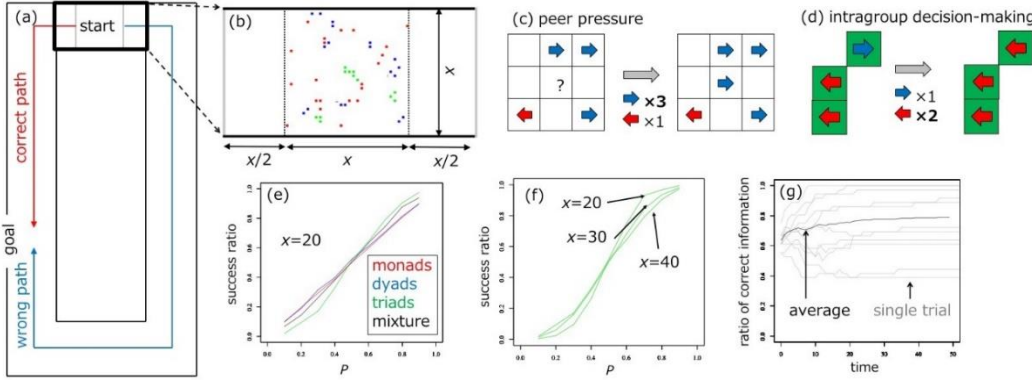


Fig. 1: considered scenario, simulation dynamics and principal results.

We considered a simple evacuation scenario where there are two routes towards the final goal: correct (shorter) path and wrong (longer) path (Fig. 1a). Pedestrians in the starting area initially

cannot know which route is correct. They may try to get information to escape as soon as possible, but such information would not be always correct, especially in the case of emergency. We supposed that people are given information about which route they should use: each individual is given information of the correct path with probability P (the one relative to the wrong path is $1-P$). We will call this probability as “certainty of information”. Therefore, there are two kinds of informed individuals that hold conflicting preferred directions of motion. Note that we focused on the behaviour of individuals around the starting area because the issue that matters here is from which path (direction) they leave that area (Fig. 1b). We propose an extended Floor Field cellular automaton (CA) model incorporated with social group behavior, which is based on the leader-follower behavior rule that is evident in group dynamics, similar to previous models. In short, individuals intend to move through the shortest path to egress (with their preferred directions), and followers in a group intend to stay close to the leader. In our model, at each time-step, individuals change the preferred directions by two rules. (1) peer pressure: each individual determines its preferred direction by the majority of directions of its neighbours in the neighbourhood (Fig. 1c). (2) intragroup decision-making: in each group, group members unify their preferred directions by the majority of directions of the group (Fig. 1d). With the above setting, we calculated the average success ratio defined by a proportion of individuals ($n=54$) getting out from the starting area with correct path, changing size of the start area (20, 30, and 40; x in Fig. 1b), P (from 0 to 1), and group composition (a group of monads (i.e., individuals), a group of dyads (i.e., pairs), a group of triads (i.e., trios), and a mixture of them), with 100 trials. As a result, we found that although success ratio of singles linearly increased as P became larger, that of groups (particularly, triads and mixture) showed sigmoid-like curves against P . This result implies that when there are social group, the sensitivity to “the probability of giving good correct information” rises compared to when there is no group (Fig. 1e). When $P > 0.5$, more individuals selected correct path than initially expected, suggesting a positive effect of the presence of social group. On the other hand, when $P < 0.5$, the reverse was true, suggesting a negative effect. These effects became stronger when the density increased (i.e., x decreased) (Fig. 1f). Fig. 1g presents the time development of the ratio of individuals with correct information, showing that information individuals have can be dynamically changed through their movement dynamics. Although, the negative effect of social groups in evacuation situation has been stressed by previous works, our results suggest that there can be the positive effect of social groups in collective decision-making on the move. In this regard, our findings show that information provision is an important aspect in crowd management and that social roles may contribute in creating unexpected dynamics when incorrect or misleading information are provided.

Response time and deceleration affected by lateral shift of leaders in vehicular traffic with weak lane discipline ORAL 4TB

Akihito Nagahama¹, Takahiro Wada²

Corresponding author: Akihito Nagahama

e-mail: naga0862@fc.ritsumei.ac.jp

Affiliation(s):

¹Ritsumeikan Global Innovation Research Organization, Ritsumeikan University, Kusatsu, Japan

²College of Information Science and Engineering, Ritsumeikan University, Kusatsu, Japan

In this study, in order to accurately simulate traffic with weak lane discipline, we focus on the effect of the lateral shift of leading vehicles (leaders) and the steering operation of following vehicles (followers) on the response time and deceleration of followers.

A physical investigation on heterogeneous traffic with weak lane-discipline is required because it has recently started causing heavy congestion in some developing countries. It has been already reported that combinations of vehicle types in mixed traffic without lateral shift affect traffic stability. On the other hand, two-dimensional microscopic traffic models enabled researchers to simulate vehicles' acceleration in traffic with weak-lane discipline.

However, to the best of our knowledge, although response time is one of the main factors affecting traffic stability, there is a lack of research that discusses the acceleration considering the variation of response time caused by the lateral shift. In this study, we conducted experiments with a driving simulator and observed the followers' behaviours when the leaders suddenly commenced deceleration. We compared the deceleration and response time of the follower a) when the leader was located just in front of the follower and the follower could not steer, b) when the leader that was located just in front of the follower shifted lateral position and the follower could not steer, and c) when the leader shifted lateral position and the follower could steer. The distributions of the deceleration and response time depending on leaders' position were different in respective cases.

Multi-lane traffic flow model: speed vs density difference as lane change motivation and effect of lateral flow transfer on traffic flow variables ORAL 5TB

Hari Hara Sharan Nagalur Subraveti, Victor L Knoop, Bart van Arem

Corresponding author: Hari Hara Sharan Nagalur Subraveti

e-mail: h.h.s.nagalursubraveti@tudelft.nl

Affiliation(s): Dept. of Transport and Planning, Faculty of Civil Engineering and Geosciences, Delft University of Technology

For better and more efficient motorway traffic control strategies on a lane level, accurate modelling and prediction of traffic conditions is essential. Existing real-time traffic state estimation methods aggregate traffic across lanes. But it has been observed that on multi-lane motorways, lanes operate differently. Hence, there is a need for lane-specific traffic flow models. Majority of the existing macroscopic lane change models use one of the two traffic flow variables - speed or density in order to explain the lane change decisions with speed difference among lanes being the more popular choice. One of the major disadvantages of using speed difference as motivation for lane changing is the different speeds at which the lanes operate. On multi-lane motorways, the difference in the operating speeds of the outer and median lane can be anywhere in the range of 10-20 km/h. Speed difference can be an option if a single fundamental diagram (FD) is used for the entire road section. But if the objective of the model is to predict conditions on a lane level, then using a single FD would not yield accurate results. Density difference offers more opportunities for the computation of lane change rates even in free-flow conditions with an added advantage being the fact that density is the state variable of these models.

Most of these macroscopic models use the well-known Cell Transmission Model (CTM) as the starting point (based on the discretization of the LWR model using the Godunov scheme) which is extended to include lane change dynamics. A limitation in most these models is the way in which lateral flows are transferred among cell segments in the discrete scheme. In most of these models, the lateral flow leaving a cell is dependent only upon the receiving capacity of the downstream cell in the adjacent lane. While this works in free-flow state, this may not work in congested conditions where the lateral demand is dependent on the receiving capacity of both the adjacent cell and downstream cell in the target lane. Considering a diagonal transfer of flow among cell segments can lead to the under-estimation of the distance over which the congestion propagates as well as the strength of congestion. In order to overcome these limitations, we propose a model using density difference as an incentive to calculate the lane change rates along with a two-step transfer of lateral flow among cell segments where the lateral demand of a cell is dependent upon the receiving capacity of the adjacent and downstream cells in the target lane. A framework for the multi-lane traffic flow model is proposed which includes how this method of lateral flow transfer relates to the computation of longitudinal flows. The advantages of this approach is shown by then comparing the proposed model with a model using speed difference as explanatory variable for lane change and diagonal transfer of flow.

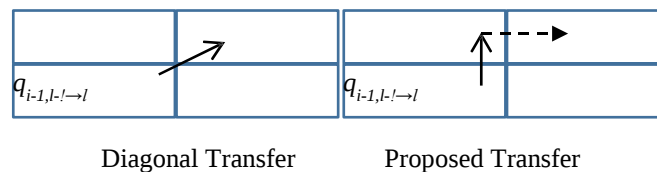


Fig 1 : Transfer of lateral flow among cell segments

Synthetic data generated from a microscopic simulation package for a lane drop location is used to validate the proposed model and compare it with existing models. Preliminary results show that, indeed the distance over which the congestion propagates is under-estimated by around 100m on every lane along with the strength of congestion in the vicinity of the bottleneck though further validation is required. Although the results are promising, some of the limitations of this study include use of simulation data, using a simple definition for the lane change motivation and applicability to isolated bottlenecks. The proposed model will be a step in the development of more accurate lane-specific traffic flow models validated against real-world data considering not just isolated bottlenecks but multiple bottlenecks along with their interactions.

Dense pedestrian crowds *versus* granular packings: An analogy of sorts INVITED

Alexandre Nicolas, Cécile Appert-Rolland, Sebastián Bouzat, Angel Garcimartín, Santiago Ibáñez, Marcelo Kuperman, Ioannis Toloupas, Iker Zuriguel.

Corresponding author: Alexandre Nicolas

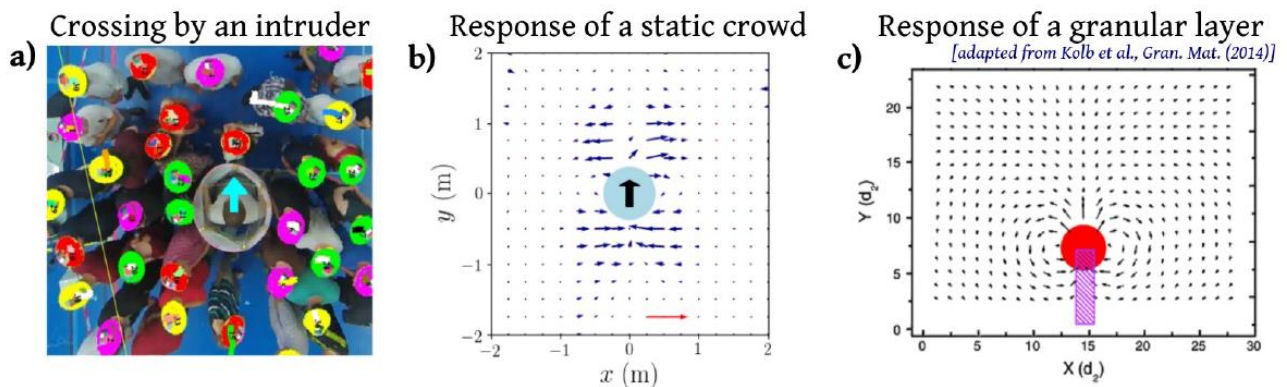
e-mail: alexandre.nicolas@polytechnique.edu

Affiliation: Explain consultancy, Lyon (France). *Formerly at:* LPTMS, Univ. Paris-Sud & CNRS, Orsay, France

The mechanical behaviour of dense pedestrian crowds has often been compared to that of a granular packing. The underlying idea is that strong excluded-volume constraints (common to both systems) suppress the manifestation of the *specificities* of pedestrians or grains. In my presentation I will put this idea to the test in diverse settings. First in line, flow through a constriction (whether it be a doorway or a silo) is an experimental setting in which one would expect excluded-volume hindrance to play the prominent part. And, indeed, striking analogies have been brought to light between competitive pedestrian evacuations and granular flows through a silo. These analogies are linked with the intermittency of the escape dynamics, in particular the distribution of time intervals between escapes, their correlations, and the size of bursts. I will inquire into the origins of these features in both systems in order to determine how generic they really are and precisely what characteristics are at the root of the similarity.

Secondly, we will consider the response of a dense assembly to its crossing by a cylindrical intruder (see Fig. 1). Regardless of whether the assembly consists of grains or pedestrians, some common points can be spotted in the response. Nonetheless, I will show that, notwithstanding the mechanical constraints induced by high densities, crowds also exhibit robust features that dramatically depart from the granular response and whose origins can be ascribed to the anticipation capabilities of pedestrians, combined with self-propulsion. The delineation of these characteristics is important not only on account of the practical relevance of the scenarios under study, but also from a fundamental perspective, for the prospective development of an empirically rooted physics of crowds.

Figure 1: Crossing of a dense assembly by a cylindrical intruder. **(a)** Snapshot of our experiment. **(b)** Velocity field induced by the crossing in a pedestrian crowd. **(c)** Velocity field induced by the crossing in a granular layer.



Gravity-Driven Flow and Clogging in the Presence of Intruders POSTER 5FB

Anna Belle Harada, Kerstin Nordstrom

Corresponding author: Prof. Kerstin Nordstrom

e-mail: knordstr@mtholyoke.edu

Affiliation(s): Department of Physics Mount Holyoke College, South Hadley, Massachusetts, USA

We present experimental results of 2D gravity-driven flows of $>10,000$ monodisperse hard spheres (diameter = D) through varying aperture widths (width = W). We introduce into the system intruders of various types: 1) A fixed obstacle of varying size (diameter = D_0) and distance above the aperture (L), 2) an unfixed obstacle (“intruder”) of varying size, and 3) numerous randomly placed intruders (number density = n). We use a force sensor to measure the bulk flow rate, and high-speed, high-resolution video to track individual grains. We observe that obstacles tend to decrease the flow rate, but also decrease the clogging probability, and specifically measure the flow rate and clogging probability as a function of D_0 , L , (and n where applicable) for different aperture widths. As our initial packing is crystalline, we can correlate these phenomena with structural measurements in the material such as dislocations and the bond order parameter. We also present dynamical measurements such as nonaffine rearrangements and cooperative motion.

Diversities in Brazilian air network ORAL 13WB

Izabela M. Oliveira¹, Laura C. Carpi², Allbens P. F. Atman

Corresponding author: Izabela M. Oliveira

e-mail: izabelamarques@cefetmg.br

Affiliation(s):

¹Departamento de Matemática, Centro Federal de Educação Tecnológica de Minas Gerais - CEFET-MG, Av. Amazonas 7675, 30510-000, Belo Horizonte-MG, Brazil

² Programa de Pós-Graduação em Modelagem Matemática e Computacional, Centro Federal de Educação Tecnológica de Minas Gerais - CEFET-MG, Brazil

³ Departamento de Física, Centro Federal de Educação Tecnológica de Minas Gerais - CEFETMG, Av. Amazonas 7675, 30510-000, Belo Horizonte-MG, Brazil

Worldwide and domestic air transportation systems have been studied from the point of view of complex networks over the last decade. Several measures have been taken to characterize the networks, identify hubs, measure the impact caused by interruptions, delay's propagation and other characteristics. In this work, we assume that the Brazilian air transport network is a complex system with multiplex structure, whose nodes are the airports and the routes between them, the links that connect them. The layers are defined according to the different airlines that operated in Brazil over the period considered. The objective this work is to analyze the effect of two factors that possibly provoked changes in the network, that are the policy of airport privatization started in 2011 and the World Cup in Brazil in 2014. We consider the dynamics of the network in the period between 2011 and 2018 to study the impact of these changes and to infer possible alterations due to the process of airport privatizations, scheduled to continue in 2019. We will present the diversity of the multiplex network considered, opening the possibility of identifying the structural modifications able to broaden or reduce the global diversity of the system, analyzing the efficiency of air transport coverage. Through the diversity measure it is also possible to predict most efficient merging of airlines to cover the absence of others. The systematic study of Brazilian air transport is essential to verify hypotheses about the spread of epidemics in the country, as the recent difusion of arbovirus causing the epidemics of Zika Virus Disease, Dengue and Chikungunya Fever in Brazilian territory.

Competitive egress simulation with non-spherical particles

Daniel R. Parisi¹, Raúl C. Hidalgo², Iker Zurigue^{1,2}

Corresponding author: Daniel R. Parisi

e-mail: dparisi@itba.edu.ar

Affiliation(s): ¹Instituto Tecnológico de Buenos Aires, CONICET, Lavardén 315, C.A.B.A., Argentina. ²Departamento de Física y Matemática Aplicada, Universidad de Navarra, Pamplona, Spain.

We present a numerical framework to simulate pedestrian dynamics using a force-based model that considers non-spherical particles, instead of traditional symmetric disks. This modification increases the degrees of freedom and allows a more realistic description of the room evacuation process in highly competitive conditions. In particular, the modification of the shape of the simulated individuals allows to naturally reproduce recent experimental findings of the process of evacuation of a room through a narrow door. For instance, we obtain a power-law distribution for the time intervals between the passage of two consecutive individuals. Moreover, the distribution of normalized burst size displays an exponential tendency, which is also in agreement with the experimental results. Complementary, we study the significance of the desired orientation in the flow rate. Surprisingly, we obtain that particles moving with their long axis aligned to the moving direction (sheep-like) present a lower flow rate than particles which desired orientation is perpendicular to the motion (human-like). Our outcomes indicate the strong significance of considering torques among the individuals, being a step forward in counting on validated models for this kind of situation.

Set-up of a method for people counting using images from a U.A.V. POSTER P30

Daniel R. Parisi¹, J.I. Giribet², Claudio Pose³ and Ignacio A. Mas⁴

Corresponding author: Daniel R. Parisi

e-mail: dparisi@itba.edu.ar

Affiliation(s):

¹Instituto Tecnológico de Buenos Aires, CONICET, Lavardén 315, C.A.B.A., Argentina

²Departamento de Ingeniería Electrónica and Departamento de Matemática, Facultad de Ingeniería, Universidad de Buenos Aires, Av. Paseo Colón 850, C.A.B.A., Argentina and Instituto Argentino de Matemática "Alberto Calderón" – CONICET.

³Departamento de Ingeniería Electrónica, Facultad de Ingeniería, Universidad de Buenos Aires, Av. Paseo Colón 850, C.A.B.A., Argentina.

⁴Departamento de Matemática, Instituto Tecnológico de Buenos Aires, CONICET, Av. E. Madero 399, C.A.B.A., Argentina.

We present a new method for obtaining the positions of all people attending and outdoor gathering, such as: street demonstrations, music festivals, parades, religious processions, etc.

Once the positions of pedestrians are determined, we can calculate the density field. Integrating this field in the area of interest we can count the total number of people.

The method is based in the following pillars:

- Taking images of the event using an unmanned aerial vehicle (UAV, also known as multirotor drone).
- The images comprise both visible and infra red (IR) information from the surface. The IR component allows to discriminate people from non-animated objects and highly improves the correct identification of individuals.
- Image processing in order to obtain the (x,y) positions of each pedestrian.
- Post processing for obtaining density fields and counting.

In this work we present the initial set-up and calibration of the system composed of: the UAV, cameras and other sensors. And the first characterization of experimental (small) crowds.

In future works more complex gathering will be presented. The possible applications of this method are, first, quantifying with small error the number of people attending a certain event. Second, measure and study the evolution of the density field. And third, consider the dynamic of the crowd "on-line" which can be used for preventing safety issues.

Elongated self-propelled particles roaming a closed arena present financial stylized facts

POSTER P31

German A Patterson and Daniel R Parisi

Corresponding author: Daniel R. Parisi

e-mail: dparisi@itba.edu.ar

Affiliation(s): Instituto Tecnológico de Buenos Aires, CONICET, Buenos Aires, Argentina

Financial stylized facts are the common statistical properties that can be found in different studies of markets and instruments. Although they are qualitative properties, stylized facts are difficult to find in synthetic stochastic processes generated by financial models [1]. Interestingly, it has been shown that the counterflow of simulated pedestrians with decision-making capacity through a door presents several of the stylized facts observed in financial markets [2].

In this work, we present results of experiments carried out with vehicles driven by vibration. The system under study comprises two closed regions linked by a narrow opening and a set of elongated self-propelled agents that are internally excited by an unsynchronized stochastic force (Fig. 1). We study the temporal evolution of the density of particles around the opening and make a statistical comparison with the price evolution of bitcoin. We report several analogies and differences between these systems by measuring various statistical properties of the return of the market price and its correspondence of the mechanical system. Interestingly, for the chosen experimental conditions, we find that the time series of density shares several of the stylized facts found in financial series, such as the bitcoin price, even for particles that do not have the possibility of making decisions.



Figure 1: Experimental setup. Two regions are linked by a narrow opening. This particular geometry design allows to generate a continuous flow of agents between both regions.

References:

- [1] Cont, R., 2001. Empirical properties of asset returns: stylized facts and statistical issues, *Quantitative Finance*, 1:2, 223-236
- [2] Parisi, D.R., Sornette, D. and Helbing, D., 2013. Financial price dynamics and pedestrian

Rafael F. Martin¹ and Daniel R. Parisi^{1,2}

Corresponding author: Daniel R. Parisi

e-mail: dparisi@itba.edu.ar

Affiliation(s): ¹Instituto Tecnológico de Buenos Aires (ITBA), Lavardén 315, C. A. de Buenos Aires, Argentina. ²Comisión Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina.

The problem of navigation and collision avoidance is a central issue when developing realistic pedestrian simulation models. Traditionally, models are first proposed and, then calibrated with experimental data. But recently a new approach of data driven models have arose. The idea is avoid proposing an explicit model, but instead use available experimental data to decide the movement of simulated particles. A natural tool for doing this are artificial intelligence methods, in particular the use of neural networks. In general multi-layer neural networks are used [1]. Instead, we propose to work with a radial basis neural network (General Regression NN: GRNN) which only has one intrinsic parameter: the spread. [2]

This approach can be fitted into the general framework proposed in [3] and thus the data is used to dynamically adjust the desired velocity of the simulated pedestrian moving by a first order model.

The data of the trajectories used were extracted from controlled experiments in a the Motion Capture Laboratory at ITBA and then a low-pass Fourier filter was used to eliminate the natural oscillation of the walking mechanism.

To adjust the spread of the GRNN, a cross-validation process was carried out, which consisted in eliminating an experimental trajectory of our train data set and then use it to test the error made by simulating a trajectory with the same initial conditions as the eliminated one. The error function used when the trajectory j was eliminated was

$$E_j = |D_j^e - D^S|$$

Where D_j^e is the minimum distance between the obstacle and the pedestrian in the experimental trajectory j and D^S the corresponding considering the simulated particle. Then we use the spread that minimizes the average of all the E_j . In Fig 1 we can see this average as a function of the spread.

Using this optimal spread and adding some trivial trajectories that do not evade any obstacle we manage to reproduce all the cases of a pedestrian evading a fixed obstacle as indicated in Fig 2.

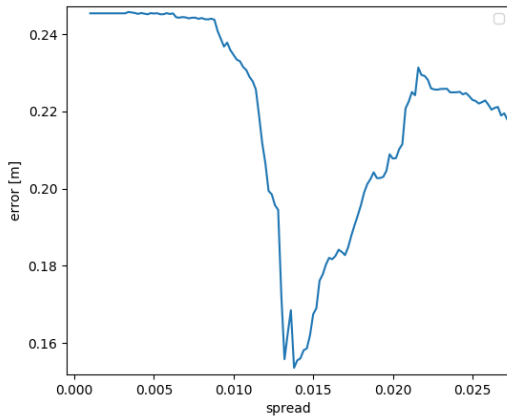


Fig 1: Average error vs. spread

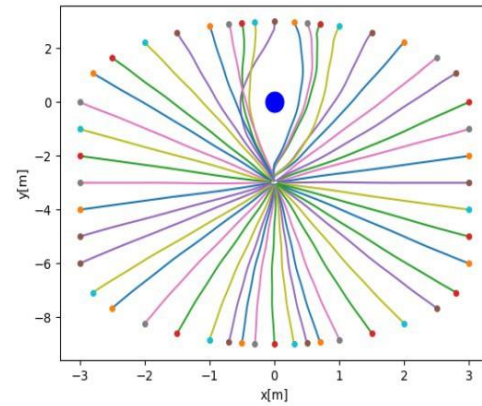


Fig 2: Simulated trajectories from several initial positions and final target at (0,-3)

References

- [1] Wei, X., Lu, W., Zhu, L., & Xing, W. (2018). Learning motion rules from real data: Neural network for crowd simulation. *Neurocomputing*, 310, 125-134
- [2] Specht, D. F. (1991). A general regression neural network. *IEEE transactions on neural networks*, 2(6), 568-576.
- [3] Martin, Rafael F., Parisi, Daniel R. (2018). Pedestrian collision avoidance with a local dynamic goal. *Proceedings of the PED2018 Conference*. In Progress.

Flow and clogging of polygonal grains POSTER P33

Ezequiel Goldberg¹, C. Manuel Carlevaro^{2,3}, Luis A. Pagnaloni⁴

Corresponding author: Luis A. Pagnaloni

e-mail: luis.pagnaloni@gmail.com

Affiliation(s):

¹Sección Códigos y Modelos, Gerencia Ciclo del Combustible Nuclear, Comisión Nacional de Energía, San Martín, Buenos Aires, Argentina

²Instituto de Física de Líquidos y Sistemas Biológicos (CONICET La Plata, UNLP), La Plata, Argentina

³Dpto. Ingeniería Mecánica, Facultad Regional La Plata, Universidad Tecnológica Nacional, La Plata, Argentina

⁴Dpto. Física, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de La Pampa, CONICET, Santa Rosa, Argentina

We study, using discrete element method (DEM) simulations, the discharge of polygonal grains through an aperture at the bottom of a two-dimensional silo. We consider the effect of the grain shape on the flow rate (for large apertures) and the clogging of the flow (for small apertures). We found that the mass flow rate is lower for polygons than it is for disks due to a combination of a smaller packing fraction and reduced average vertical velocity. On the other hand, the probability of clogging presents a non-linear behavior as a function of the number of vertexes. We discuss the critical role played by the criteria used to decide when two particles of different shape are considered to be of equal size.

Energy dissipation in forced silo discharges ORAL 3FB

Marcos A. Madrid¹, J. R. Darias², Luis. A. Pugnaloni³

Corresponding author: Luis. A. Pugnaloni

e-mail: luis.pugnaloni@gmail.com

Affiliation(s):

¹ Dpto. Ingeniería Mecánica, Facultad Regional La Plata, Universidad Tecnológica Nacional, La Plata, Argentina

² Laboratorio de Óptica y Fluidos, Universidad Simón Bolívar, Caracas, Venezuela

³ Dpto. Física, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de La Pampa, Santa Rosa, Argentina

We consider the discharge of grains from a silo. It is well known that, during the discharge, the flow rate is independent of the height of the granular column. Less well-known is the fact that the flow rate is fairly insensitive to the material properties of the grains (density, Young's modulus, friction coefficient, etc.). In this work we show, experimentally and numerically, that these two features are lost if the discharge is forced using a piston. In contrast to viscous fluids, the flow rate increases during discharge if a constant pressure is applied to the free surface of a granular column. Moreover, the flow rate becomes sensitive to the material properties. Interestingly, we have found that the dissipated power scaled by the mean pressure and the flow rate follows a master curve for forced and unforced conditions and for all material properties studied.

Simulation of Emergency Evacuation of Passengers with and without Disability at Different Types of Metro Stations POSTER P34

Tarapada Mandal¹, K. Ramachandra Rao², Geetam Tiwari²

Corresponding author: K. Ramachandra Rao

e-mail: rkalaga@civil.iitd.ac.in

Affiliation(s): Department of Civil Engineering, Indian Institute of Technology Delhi, New Delhi, India, ²Department of Civil Engineering, Indian Institute of Technology Delhi, New Delhi, India

Metro authorities around the world take multiple initiatives for safe emergency evacuation of commuters. Incidents of fire and fire induced smoke require evacuation within specific time limit to ensure commuters' safety. In order to evaluate the efficiency of the evacuation process, evacuation simulation of three different types (different geometric features: underground island type platform, underground side platform and elevated) of Delhi metro stations are done in this study. This study performed both platform and train evacuation for those stations. Different fire locations for various stations are also considered. Computational Fluid Dynamics (CFD) models are not used in this study for fire simulation. However, NFPA 130 standards are used for Available Safe Evacuation Time (ASET) determination for all simulation cases. Assisted evacuation simulation that incorporates disabled commuters in the simulation of emergency evacuation from different types of stations, is done in this study. This study used Design of Experiment (DOE) method for different combinations of parameter inputs in the simulations and conducted statistical tests for analysing the significant parameters. The parameter inputs are obtained from survey conducted in this study. The simulation models are calibrated using pre-evacuation time obtained from a survey conducted in this study as well as an unannounced drill data obtained in from a dataset in this context (1). Passenger load at stations and trains are obtained from Delhi Metro authorities and train load surveys. The speed of normal and disabled evacuees are obtained from Delhi Metro and some other experimental studies (2). Ceiling values (maximum number that can be accommodated) for the assisted and non-assisted evacuees in three different types of platforms during evacuation is calculated. This study compared the different evacuation strategies for assisted evacuation. Results of the study suggest that presence of even minimum number of disabled evacuees increases the total evacuation time for all three types of stations. Results also show that different crowd management techniques can have a significant effect on the jam time (the time during which a disabled evacuee is stopped due to high crowd level and waiting for an elevator) faced by the disabled evacuees.

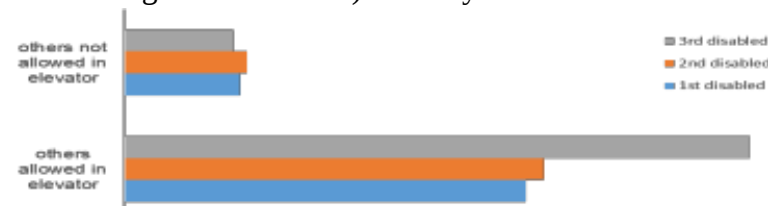


Figure 1: Jam time of three disabled evacuees with control in elevator use

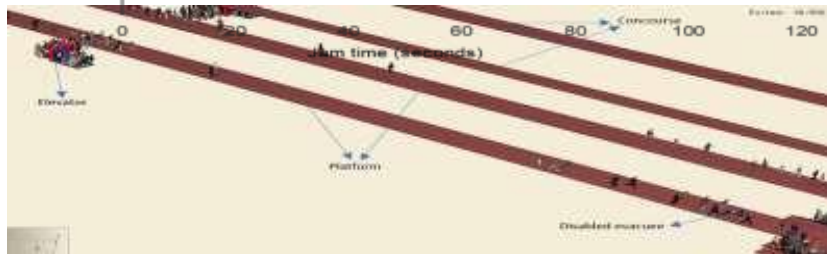


Figure 2: Snapshot of the disabled evacuation from underground side type platform

References:

- 1.Lovreglio, R., E. Kuligowski, S. Gwynne, and K. Boyce. A Pre-Evacuation Database for Use in Egress Simulations. *Fire Safety Journal*, 2019. <https://doi.org/10.1016/J.FIRESAF.2018.12.009>.
- 2.Georg, P., R. Polzin, J. Schumann, S. Holl, and A. Hofmann. Small-Scale Studies on Evacuation Characteristics of Pedestrians with Physical, Mental or Age-Related Disabilities. 2018.

Selection of boundary conditions in Cellular Automata Simulation Models for Vehicular Traffic

POSTER P35

Mohit Kumar Singh^a, K. Ramachandra Rao^b

Corresponding author: K. Ramachandra Rao

e-mail: rrrkalaga@civil.iitd.ac.in

Affiliation(s): ¹Dept of Civil Engineering, Indian institute of Technology Delhi Hauz Khas, New Delhi, India

²Department of Civil Engineering, Indian Institute of Technology Delhi, New Delhi, India

Many of the cellular automata (CA) simulation models developed for traffic simulation have either closed or open boundaries. However, the choice among these is not clearly understood. It is known that the inputs of the simulation changes with boundary conditions, for instance in case of closed boundary, densities/occupancies is given as an input. While in open boundary vehicle flow/arrival rate is given as input. Hence the number of vehicles in closed boundaries remain conserved (Fig. 1a and 1c) whereas, in open boundaries vehicles are deleted at the end of the link (approach) (Fig. 1b and 1d). Further, it is evident from other studies, that boundaries affect the simulation results (Marzoug et al. 2014; Zhang and Zhang 2009). The advantages and limitations in simulating with closed and open boundaries were studied. It was found that the modelling of open boundaries simulation can be better in most of the situations. While simulating the facilities such as bus stops, metro stations and intersections it is better to use open boundaries. If closed boundaries are chosen at these places then the gap between all the consecutive facilities becomes the same, which may be unrealistic. Further, closed boundaries require warm-up time to settle the vehicles initially, if at the end of that approach, vehicles on one approach need to go to another (Fig. 1c). In this case warmup time will be needed but other vehicles on same leg will be moving normally at this time, hence two separate phenomena would result at the same time (warmup and normal movement). This can affect the fundamental diagram's properties. Closed boundaries simulations are helpful to simulate an infinite length of the road mid-block section (Fig. 1a). One of the problems while simulating intersections using closed boundaries occurs while sending vehicles to the origin approach from the rest of the three approaches. In the present study, 36x4 (36 feasible combinations of mode shares, (2+2) open and closed boundaries for mid-block and intersections) were simulated and results were observed and compared in terms of fundamental diagrams. It was found that the flows observed in closed boundaries are underestimates, compared to open boundaries. Further, the shape of fundamental diagram is different in both the cases.

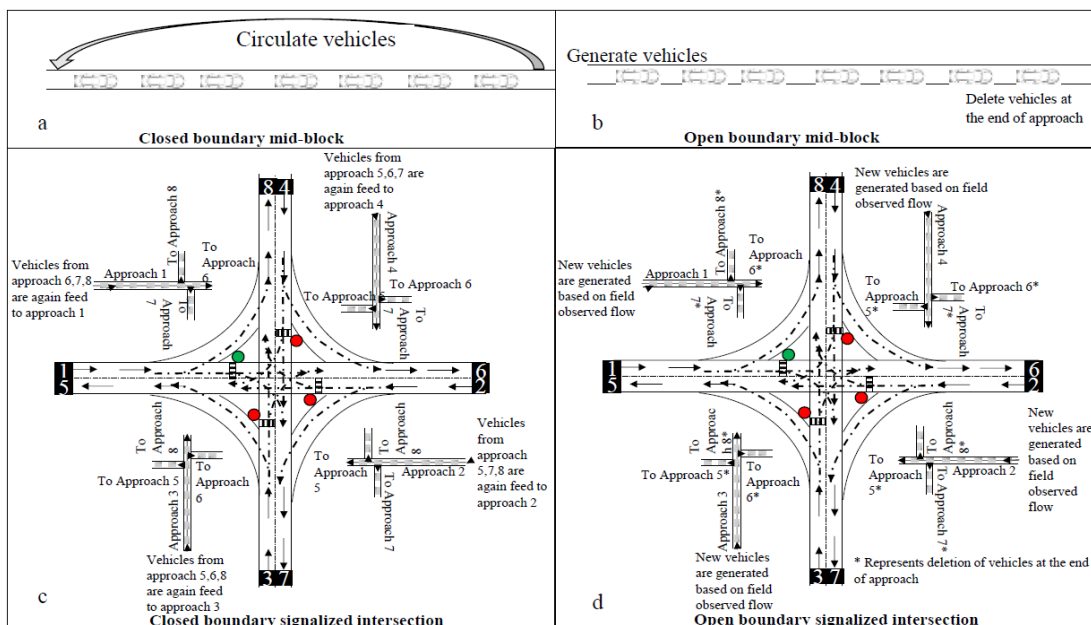


Fig. 1 (a) Closed boundaries mid-block. (b) Open boundaries mid-block, (c) Closed boundaries signalized intersection. (d) Open boundaries signalized intersection

References:

- Marzoug, R., Ez-Zahraouy, H., and Benyoussef, A. (2014). "Cellular automata traffic flow behavior at the intersection of two roads." *Physica Scripta*, IOP Publishing, 89(6), 065002.
- Zhang, W., and Zhang, W. (2009). "Vehicular traffic flow at a intersection controlled by signal light with a new probability." *Science*, (10447111), 3–6.

Neural Network based approach to recover downstream inductive loop sensor errors for bicycle counts: An explorative study POSTER P36

Giulia Reggiani, Azita Dabri, Winnie Daamen, Serge Hoogendoorn

Corresponding author: Giulia Reggiani

e-mail: g.reggiani@tudelft.nl

Affiliation(s): Technical University of Delft

Loop sensor technology is often deployed over cycle paths, of large cities in the Netherlands, mostly in a configuration shown in Figure 1. Two sensors are installed at the upstream of the traffic light and one downstream at the stop-line. Currently this technology is simply used to detect bicycles, and if the car traffic conditions allow, it triggers (or extends) a green light for cyclists. Our research is driven by the interest of using this same technology to infer more information about bicycle traffic. We are interested in recovering the downstream detector signal in order to estimate the number of cyclists on a link. In this work, we explore how to recover the downstream detector signal by estimating individual total travel times of cyclists.

To identify the number of cyclists between two loop sensors, on a signalized link, one could use the conservation law of bicycles. However, we have observed that using this conservation law based on bicycle loop sensor signals leads to a cumulative error due to inaccuracies in the downstream loop counts. Whilst cyclists predominantly pass over the upstream sensor one at a time, they tend to cycle over the stop-line sensor (when the traffic light turns green) very close to each other, with a slight sidewise shift. As a result, as Figure 1 shows, the upstream detector delivers precise signals for each passing of a bicycle, while the downstream sensor provides many long signals, due to continuous loop occupancy, that do not give explicit information on the number of bikes that have passed. In order to reconstruct the passing moment of each cyclist over the downstream sensor one approach is to add the total travel time (consisting of the cycling time plus the waiting time in case the signal is red) to the upstream passing moment. While the latter can be extracted from the upstream sensors easily, the estimation of the former is more demanding. The methodology proposed in this work is to use a Feedforward Neural Network (NN) to estimate total travel times of cyclists. NN models have shown to be extremely versatile and perform incredibly well even without a priori assumption on the variable distribution. Their generalization properties make NNs a good model for our purpose. As a fact, once it is trained on reliable data, it can be applied to never seen before signalised links. In order to explore the accuracy of the proposed model, we train different NNs with simulated data. First, we simulate simple arrival-departure processes of cyclists at a traffic light, then gradually add complexity to the process to observe how estimation accuracy of NNs changes. Data is simulated based on four scenarios which vary depending on the cycling time and queueing model of cyclists.

1. Deterministic scenario: cycling time is the same for all individuals and cyclists depart from the stop line as soon as the traffic light turns green.
2. Discharge Rate scenario: similar to the deterministic scenario with the added complexity that cyclists may not depart from the downstream sensor all at the same time; hence the discharge rate comes to matter.
3. Stand over queues scenario: road capacity constraints are taken into account and arrival rate is modelled appropriately so as to create a scenario where cyclists may stay in the queue for more than one red light cycle.
4. Stochastic scenario: cycling time is not fixed but modelled according to a normal distribution.

This study shows how accurately a NN can estimate the individual total travel time of cyclists approaching an intersection in all four scenarios. The NN model revealed to be suitable for this specific estimation task, reaching a RMSE of 0.36 s in scenario 1, where the arrival-departure process of cyclists does not include stochasticity. Error values slightly increase in the more complex scenarios (i.e. RMSE = 4.32 s in the stochastic scenario) but can be compensated by including more information on accumulated cyclists. Once the NN is accurate enough to estimate the total travel time, we can use this estimation to reconstruct the downstream loop signal. This will enable us, in future works, to use the conservation of bicycle equation to count number of bikes on a link at any given time.

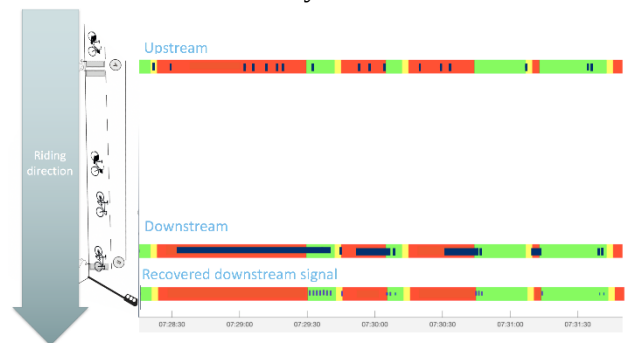


Figure 1: configuration of loop sensors in proximity of a traffic light and graphical representation of their signals (in blue): upstream, downstream and recovered downstream signal. The red, green and yellow stripes behind the blue signals indicate the traffic

The trouble with 2nd order models or how to generate stop-and-go traffic in a 1st order model

POSTER P37

Andreas Schadschneider^{1,2}, Antoine Tordeux³

Corresponding author: Andreas Schadschneider

e-mail: as@thp.uni-koeln.de

Affiliation(s): ¹ Institut für Theoretische Physik, Universität zu Köln, Germany

² Institut für Physikdidaktik, Universität zu Köln, Germany

³ Institut für Sicherheitstechnik, University of Wuppertal, Germany

Stop-and-go dynamics are commonly observed in vehicular, bicycle or pedestrian flows both in reality and experiments [1]. Theoretically, they are reproduced by discrete stochastic models, like cellular automata, see e.g. [2], and microscopic models based on nonlinear differential equation systems, see e.g. [3]. In the latter this is achieved by means of instability of perturbed systems and periodic stationary solutions (limit-cycles) [4] describing the propagation of self-sustained traffic waves (solitons) [5]. For vehicular traffic there is strong empirical evidence (e.g. hysteresis, capacity drop) for phase transitions that have been observed both in real data and experiments. In contrast, for pedestrian dynamics the situation is less clear. To our knowledge, convincing empirical evidence for phase transitions and metastability has yet to be found for pedestrian flows.

Classical 2nd order models of pedestrian dynamics, like the social-force model, suffer from various unrealistic behaviors in the dynamics, e.g. backward motion, oscillations and overlapping of pedestrians [6]. These effects are not related to the discretization of the equations of motion, but intrinsic to the dynamics. They are, at least in part, related to the strong inertia effects that usually appear in 2nd order models. However, it is often argued that pedestrian dynamics shows no pronounced inertia effects since human capacity nearly allows any speed variation at any time. Furthermore, pedestrian motion does not show mechanical delays. Nevertheless, stop-and-go behaviour is observed at congested density levels.

Here we propose a novel explanation of stop-and-go phenomena in pedestrian flows as a consequence of noise effects in an alternative linear stochastic modeling approach [7]. The model is based on a minimal deterministic dynamics of first order (i.e. without inertia) and an additive *correlated* noise described by the Ornstein-Uhlenbeck process at the second order. The relaxation is driven by the noise, making the dynamics, in contrast to classical approaches, stable in the deterministic case. The system is linear and ergodic, i.e. non-chaotic, and has a unique invariant measure. It is therefore different from classical non-linear systems and provides a simpler and more natural way to describe and understand stop-and-go dynamics in pedestrian flows. We have analysed the model on a ring analytically and by simulation, and interpreted the results according to the parameter values. Statistical estimations of the relaxation time in the ergodic system vary from approximately 5 to 20 seconds, corroborating the different role of the parameter compared to classical approaches, for which the relaxation is related to the reaction time of the pedestrian or driver and is estimated by around 0.5–1 seconds. We also present statistical evidence for the existence of Brownian noise in empirical pedestrian speed time-series which adds further support to the assumptions made.

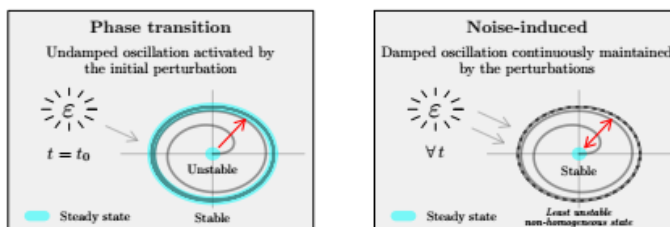


Fig. 1: Illustrative scheme for the modelling of stop-and-go dynamics with phase transition in the periodic solution (left) and the noise-induced oscillating behaviour (right).

References:

- [1] J. Zhang, W. Mehner, S. Holl, M. Boltes, E. Andresen, A. Schadschneider, A. Seyfried, *Phys. Lett. A* 378(44), 3274 (2014)
- [2] K. Nagel, M. Schreckenberg, *Journal de Physique I* 2 (12): 2221 (1992)
- [3] M. Bando, K. Hasebe, A. Nakayama, A. Shibata, Y. Sugiyama, *Phys. Rev. E* 51(2), 1035 (1995)
- [4] G. Orosz, R. Wilson, G. Stepan, *Proc. R. Soc. A* 368, 4455 (2010)
- [5] M. Muramatsu, T. Nagatani, *Phys. Rev. E* 60, 180 (1999)
- [6] M. Chraïbi, T. Ezaki, A. Tordeux, K. Nishinari, A. Schadschneider, A. Seyfried: *Phys. Rev. E* 92, 042809 (2015)
- [7] A. Tordeux, A. Schadschneider, *J. Phys. A* 49, 185101 (2016)

Braess paradox in networks with microscopic stochastic dynamics and traffic information

ORAL 10TB

Andreas Schadschneider^{1,2}, Stefan Bittihn¹

Corresponding author: Andreas Schadschneider

e-mail: as@thp.uni-koeln.de

Affiliation(s): ¹ Institut für Theoretische Physik, Universität zu Köln, Germany

² Institut für Physikdidaktik, Universität zu Köln, Germany

The Braess paradox describes a counterintuitive situation in which the addition of a new road to a road network leads to higher travel times for all network users. The paradox can occur for the case of drivers who want to minimize their own travel times. The origin of this paradox lies in the fact that for such situations the user optimum and the system optimum are not identical. This can drive the network into a state, the user optimum, in which no driver can improve his/her travel time by choosing an alternative route. For certain network types the user optimum with an additional road may have higher travel times than that of the same network without the new road.

Braess presented a mathematical model [1,2] based on simple networks with 4 and 5 links (where links represent roads), respectively. He showed that for adequately chosen travel time functions for the roads and selfish drivers, the paradoxical situation described above can occur. The paradox was since observed in several real world situations where newly built roads led to a worse traffic situation or inversely where the closing of heavily used roads led to an improvement of the traffic situation.

We have generalized Braess' simple model which is based on a macroscopic and deterministic traffic model to more realistic microscopic stochastic dynamics [3,4]. The traffic on the network is modeled by the paradigmatic totally asymmetric exclusion process (TASEP) which models the motion of each vehicle. The TASEP is based on stochastic dynamics which allows including fluctuations and provides a mechanism for random formation of jams. We consider two different cases in which 1) routes are chosen stochastically by each driver and 2) drivers use fixed strategies for their route choices. Both models show a rich phase diagram that includes an extended region where the Braess paradox occurs.

Furthermore we have studied the effects of traffic information systems on the occurrence of the paradox. Modern traffic information systems provide driver with up-to-date information either about the traffic state on different routes or even predictions of travel times. We have introduced such information into the model and find that Braess paradox can still occur.

References:

- [8] D. Braess, Unternehmensforschung 12, 258 (1968)
- [9] D. Braess, A. Nagurny, T. Wakolbinger, Transp. Sc. 39, 446 (2005). (english translation of [1])
- [10] S. Bittihn, A. Schadschneider: Phys. Rev. E 94, 062312 (2016)
- [11] S. Bittihn, A. Schadschneider: Physica A 507, 133 (2018)

Modelling the waiting behaviour of pedestrians in public places ORAL 5WA

Tobias Schrödter, Mohcine Chraibi, Armin Seyfried

Corresponding author: Tobias Schrödter

e-mail: t.schroedter@fz-juelich.de

Affiliation(s): Institute for Advanced Simulation, Forschungszentrum Jülich GmbH, Jülich, Germany

In general, pedestrian models describe the movement of pedestrians with varying level of detail. Often complex processes like wayfinding in buildings or navigation through a crowd are solved in a simplified way by collision avoidance algorithms or social forces. For some applications, like the evacuation of a building the moving of pedestrians towards a goal is the substantial contribution determining the dynamic of the process. This changes in more general context, like pedestrians on platforms or airport gates, where waiting people restrict the space for the movement of the others. After reaching their waiting position, pedestrians don't have any need to keep moving unless the event they are waiting for occurs, e.g. arrival of a train or boarding of the plane starts. In this regard, as opposed to “moving dynamics” resulting from pedestrians evacuating a specific place, we focus on “waiting dynamics” where pedestrians visit some temporary areas and wait for a certain amount of time.

In the last years the investigations of inflow processes gained importance in research of pedestrian dynamics. In Lui et al. (2016) different hypotheses of the inflow process are compared with experimental data. Ezaki et al. (2016) conducted experiments on the inflow to a confined space and derived a theoretical description of the process. A stochastic model to describe the redistribution of pedestrians inside a small room is discussed in Dolfen et al. (2018). When investigating inflow processes always a confined space with a dedicated entrance/exit is considered. Although, multiple models to describe the inflow to a waiting area exist, little attention was paid to “the waiting” of pedestrians for a specific event and the resulting dynamics.

In this paper, we develop a mathematical model to describe the waiting behaviour of pedestrians. We define “waiting” as the time, when a pedestrian enters a certain region, called waiting area, e.g. platform, until an event is triggered, e.g. the arrival of the train. Between both times the pedestrian distributes within the waiting area in a certain way. After finding a preferred spot the person comes to a halt or moves around in a reduced manner.

We consider different factors which influence the waiting behaviour of pedestrians. First, the geometry of the waiting area, including the size and the position of entrances and exits is of importance. Depending on the available space and waiting situation the pedestrians can either move freely within the waiting area, e.g. platforms, or they line up in queues, e.g. airport gates. Second, the positioning inside the waiting area, or how pedestrians distribute in a confined space is to be investigated. Here the location of physical points of interests as information sources as well as the position of the exits and hence the next goal of the pedestrian has an influence on their distribution inside the waiting area. Last, psychological influences as the need of personal space and a comfortable distance to the neighbours, are considered. As we assume a dynamically change of the density, a push effect needs to be considered. To maintain their personal space pedestrians may get pushed in the middle of the room without any physical contact.

After developing our mathematical model, we verify it with multiple simulations. The results are compared with data from former experiments. With the resulting data the model and input parameters are adjusted accordingly.

Exploring the effect of crowd management measures on passengers' behaviour at metro stations

POSTER P38

Sebastian Seriani¹, Taku Fujiyama²

Corresponding author: Sebastian Seriani

e-mail: sseriani@miuandes.cl

Affiliation(s):¹ Universidad de los Andes, Santiago, Chile.

²University College London, United Kingdom.

To reduce problems of interaction at the platform train interface (PTI) crowd management measures have been implemented in different urban railway systems worldwide. As an example, platform edge doors (PEDs) and markings on the platform are used as door positions indicators at the PTI. The common methods to study the effect of these measures are based on average values of density using Fruin's Level of Service (LOS), however identification cannot be made of which part of the PTI is more congested.

To solve this problem, a new method is proposed. A mock-up represented an urban railway vehicle and its adjacent platform at University College London's Pedestrian Accessibility Movement Environment Laboratory (PAMELA). The method included a conceptual model in which the PTI was discretised into 40 cm square cells to identify which part of the platform is more congested. In addition, the PTI was divided into semi-circular layers of 0.50 m each, equivalent to the body depth of passengers. The use of layers in the PTI enables the identification of how far passengers waiting to board are located from the doors. The tracking tool PETRACK was used to identify the movement and dynamic of passengers at the laboratory. Passengers' behaviour was recorded considering two situations before the train arrives: i) passengers waiting in front of the doors; ii) passengers waiting beside the doors. The laboratory experiments were compared to existing stations (e.g. Ñuble station in Metro de Santiago), in which PEDs are installed.

Results from the experiments at PAMELA show that PEDs changed the behaviour of passengers as they were located beside the doors rather than in front of them. In addition, when markings (e.g. narrow lines or waiting areas) were used on the platform, then this behaviour was reinforced. This behaviour was also observed in existing urban railway stations. As an example, Figure 1, shows the conceptual model in which the PTI is discretised into square cells. In the figure, squares beside the doors are in red, which mean that more passengers are using this space compared to those who are in front of the doors (less used squares or green cells).

360	2	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1
320	1	2	1	1	1	1	3	1	1	1	2	1	1	1	1	1
280	0	2	0	0	0	0	1	0	1	0	0	0	0	0	0	0
240	1	0	2	2	0	0	0	1	1	0	0	1	0	1	0	0
200	0	0	0	2	1	1	1	1	0	2	1	0	0	0	0	0
160	1	0	0	0	1	1	0	0	0	1	1	0	0	0	0	0
120	0	0	2	2	1	2	0	1	1	1	2	0	1	0	0	0
80	1	1	2	2	4	2	0	0	1	1	3	1	1	0	0	0
40	1	3	2	3	7	1	0	0	1	4	6	2	3	1	0	0
	DOOR															
Distance	-280	-240	-200	-160	-120	-80	-40	0	40	80	120	160	200	240	280	

Figure 1. Average time each square cell was used at the PTI in Ñuble station.

The discretised PTI helps to identify which part of the platform is more congested and therefore where a high interaction occurs. Therefore, it is recommended to use this method to better design the PTI rather than the LOS which is used to design the whole platform. Further research is needed to explore the use of tracking tools in existing stations. In addition, new experiments are needed to study the effect of PEDs on passengers with reduced mobility.

Nonaffine Deformations in Sheared Wet Granular Materials POSTER P39

Mostafa Taheri¹, S. Mehdi Vaez Allaei¹, M. Reza Shaebani²

Corresponding author: M. Reza Shaebani

e-mail: shaebani@lusi.uni-sb.de

Affiliation(s): ¹Department of Physics, University of Tehran, Tehran 14395-547, Iran

²Department of Theoretical Physics & Center for Biophysics, Saarland University, Saarbrücken, Germany

The mechanical response of granular materials considerably differs from that of an ordinary elastic solid. Understanding the behavior of these systems, besides the scientific interest, has important practical applications. The emerging nonlinear relation between stress and strain can be attributed e.g. to the presence of disorder, nonlinearity of the contact force law, Coulomb friction threshold, and unilateral interactions. However, experimental and numerical measurements reveal deviations from the expected elastic response when all these elements are taken into account in the nature of the interactions and the environment. The deviations are attributed to the contribution of nonaffine motions during the deformation process, since opening of a contact terminates the local transmission of restoring or frictional forces, while formation of a contact provides new possibilities for it. Less is known so far about the nonaffine motions in wet granular packings and the resulting impact on the elastic behavior of these systems. Using a minimal model in the capillary bridge regime, we report numerical simulations of wet granular materials under shear deformation. We clarify how nonaffine displacements depend on the liquid content, applied shear strain, and surface tension in the capillary bridge regime. Moreover, the deviation of the evolution of the probability distributions of contact forces from the affine assumption during isotropic compression or shear deformation processes is investigated. The results provide the opportunity to develop stochastic models of stress transmission in wet granular media by including the effects of non-affine motions.

First-Passage Times of Intermittent Random Walkers on Treelike Networks POSTER P40

M. Reza Shaebani, Robin Jose, Ludger Santen

Corresponding author: M. Reza Shaebani

e-mail: shaebani@lusi.uni-sb.de

Affiliation(s): Department of Theoretical Physics & Center for Biophysics, Saarland University, Saarbrücken, Germany

The problem of random search in finite tree-like networks is investigated analytically and by means of Monte Carlo simulations. The first-passage time distribution decays exponentially in finite networks with a tree topology, with a slope which scales as a power law or exponentially as a function of the extent of the tree (depending on the tendency to jump toward the target node). The slope is, however, independent of the initial conditions of entering the tree. In order to uniquely determine the extent of the tree and the tendency to jump toward the target node from the transport properties of tracer particles entering the tree at the boundaries and performing stochastic jumps until arriving at the target node, one should evaluate higher moments of the first-passage time distribution. However, it is considerably more difficult to evaluate variance or higher moments of the first-passage time distribution in experiments. Here we introduce intermittent random walkers that take steps with a given probability when jumping on the nodes and return with an independent probability from the leaves. By deriving an exact analytical expression for the mean first-passage time of the intermittent random walk, we show that the structural information of the tree can be uniquely extracted by measuring the mean first-passage times for two randomly chosen types of tracer particles with distinct jumping probabilities at nodes and leaves. The applicability of our approach in the presence of disorder in the structure of the tree is also addressed.

Active Motion in One-Dimensional Geometries in the Presence of Drift and Absorption

ORAL 3WB

M. Reza Shaebani

Corresponding author: M. Reza Shaebani

e-mail: shaebani@lusi.uni-sb.de

Affiliation(s): Department of Theoretical Physics & Center for Biophysics, Saarland University, Saarbrücken, Germany

The stochastic dynamics of active particles with direction-dependent persistency and random immobile periods are studied analytically in one-dimensional geometries. An analytical solution is found for the stationary probability distribution of the particle in the general case of asymmetric transition probabilities between the mobile and immobile states. The problem can be also mapped onto an isotropic persistent motion in the presence of drift and absorption. An exact expression is derived for the time evolution of the mean-squared displacement, from which an effective asymptotic velocity is deduced. The interplay between absorption frequency and activity anisotropy leads to a variety of different regimes, including anomalous, diffusive, and ballistic behaviors, on varying time scales. A generic phase diagram describing the evolution from continuous isotropic to intermittent anisotropic active motion in the presence of traps is presented. Our study provides new insight into the behavior of active systems characterized by direction-dependent activity on sticky substrates.

Qiao Wang^{1,2}; Weiguo Song¹; Jun Zhang¹; Siuming Lo²Corresponding author: Weiguo Song

e-mail:wgsong@ustc.edu.cn

Affiliation(s): ¹State Key Laboratory of Fire Science, University of Science and Technology of China²Department of Civil and Architectural Engineering, City University of Hong Kong

The motion postures of pedestrian influence the evacuation efficiency and health in fire and smoke filling buildings. In building fire, the smoke would fill the space from the roof to the ground and harm to people's health. Thus, people should leave the fire and smoke environment as soon as possible and avoid contacting with smoke. The effective method is to lower the height of the body, especially the mouth and nose. In that way, it is necessary to investigate the movement efficiency with different motion postures, such as stoop walking, knee and hand crawling and low crawling.

A one-dimensional pedestrian movement experiment is conducted to study the movement characteristics with different motion postures. The subjects are elementary and middle school students. The experimental scene is a 12 m long narrow channel. One half is for upright walking, and the other part is for stoop walking, knee and hand crawling and low crawling. To restrict the motion posture, the fishnet is used to fix the height of the channel. Before entering the narrow channel, all participants are demanded to pass through the channel quickly. The trajectories are extracted by using the software *PeTrack* that can output the real coordinates. Firstly, it is observed that the speed of upright walking is the largest, and the smallest one is low crawling. However, there is no significant difference in speed between upright walking and stoop walking, as shown in Fig. 1(a). According to the trajectories of participants, it is found that the amplitude of lateral oscillation is related to the motion postures. The participants moving with low crawling have bigger oscillation amplitude and the body sway is periodic (see Fig. 1(b)). In upright walking, the lateral amplitude increases with the speed decreasing (Liu et al, Physica A, 2009). On the other hand, the lateral amplitude increases with low crawling is due to the need for a body sway to move forward in present work. Through this experiment, the basic speeds of upright walking, stoop walking, knee and hand crawling and low crawling can be obtained, which can be used to provide basic data for evacuation simulation in fire and smoke buildings. Meanwhile, for different motion postures, it influences the evacuation directly. These findings can provide insight to evacuation strategy when building fire occurred.

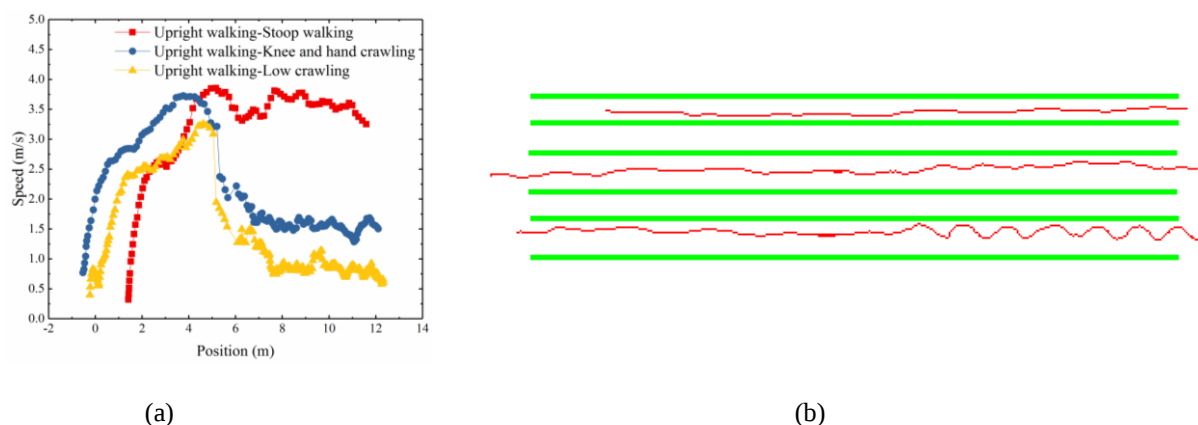


Fig. 1 (a) Instantaneous speed varies with the position and (b) trajectories (up: upright-stoop walking, middle: upright-knee and hand crawling, down: upright-low crawling) in the narrow channel for different motion postures.

Bidirectional Flow on Stairs with Different Directional Split Ratios ORAL 4WA

Rui Ye¹, Jun Zhang¹, Mohcine Chraïbi², Weiguo Song¹

Corresponding author: Weiguo Song

e-mail: wgsong@ustc.edu.cn

Affiliation(s):

¹*State Key Laboratory of Fire Science, University of Science and Technology of China, Hefei 230027, People's Republic of China.*

²*Institute for Advanced Simulation, Forschungszentrum Jülich, Jülich 52425, Germany.*

As a typical building structure, stairs can be found everywhere. Pedestrian's walking characteristics on stairs are crucial in the field of pedestrian dynamics. So far, most studies concerning stairs focus on the unidirectional descending process when pedestrians evacuate downstairs in high rise buildings. However, for stairs outside the buildings or in some public transportation facilities, the bidirectional scenario where ascending and descending pedestrians exist at the same time is a more common case. The bidirectional flow on stairs can be dangerous especially at high densities. For example, a stampede that happened in Shanghai in the New Year's Eve of 2015 is due to the high density bidirectional flow on stairs, leading to 36 deaths and 49 injuries. As far as the authors are concerned, empirical study about bidirectional flow on stairs is particularly rare. Therefore, to close this gap, experiment should be conducted to thoroughly investigate bidirectional flow on stairs.

Considering the fact that in our daily life the bidirectional flow on stairs could be unbalanced, we conduct bidirectional experiment on stairs under different directional split ratios r ($r = N_{\text{ascending}}/N_{\text{total}}$) with up to 100 participants. Unlike planar motion, the ascending flow and descending flow could be different even when r equals to 0.5 as pedestrians in the ascending flow have to overcome the gravity. Thus, totally 11 runs will be conducted with r varying from 0 to 1 at a step of 0.1. The detailed data analysis will be based on the precise trajectories extracted from video recordings rather than manual count like in most current studies concerning stairs. The relationship between directional split ratio r and the capacity on stairs will be investigated, which again may be distinguished from that in planar motion where a "U" or "W" shape is reported [1,2]. Since the ascending flow is the more constrained one and this constraint will be reduced with the increase of r , the directional split ratio above which the constraint of the ascending flow can be eliminated (maybe when $r > 0.5$) will be explored through variables like average walking speed of each flow or the distribution of time lapse between two successive pedestrians in the same walking direction across certain line. Then the fundamental diagrams will be compared for different directional split ratios. Besides, the fundamental diagrams on stairs will also be compared with those obtained from planar motion, to reveal the differences and similarities. Moreover, a more microscopic variable, time to collision [3], will be introduced to quantify the conflicts between the ascending and descending flow for different directional split ratios. Our results will provide new insights into the influence of directional split ratio on the capacity of stairs in bidirectional flow. Besides, data obtained in our experiment are helpful for model validation and calibration in this scenario [4].

References

- [1] J. Zhang, Q. Wang, Y. Hu, S. Cao, L. Xia, and W. Song, *Journal of Statistical Mechanics: Theory and Experiment* **2018**, 073408 (2018).
- [2] C. Feliciani, H. Murakami, and K. Nishinari, *PLoS one* **13**, e0208496 (2018).
- [3] I. Karamouzas, P. Heil, P. Van Beek, and M. H. Overmars, in *International Workshop on Motion in Games* (Springer, 2009), pp. 41.
- [4] M. Liu, S. Wang, Y. Oeda, and T. Sumi, *Accident Analysis & Prevention* **122**, 350 (2019).

Intermittent flow in constricted particulate suspension ORAL 10WB

Mathieu Souzy, Alvaro Marin

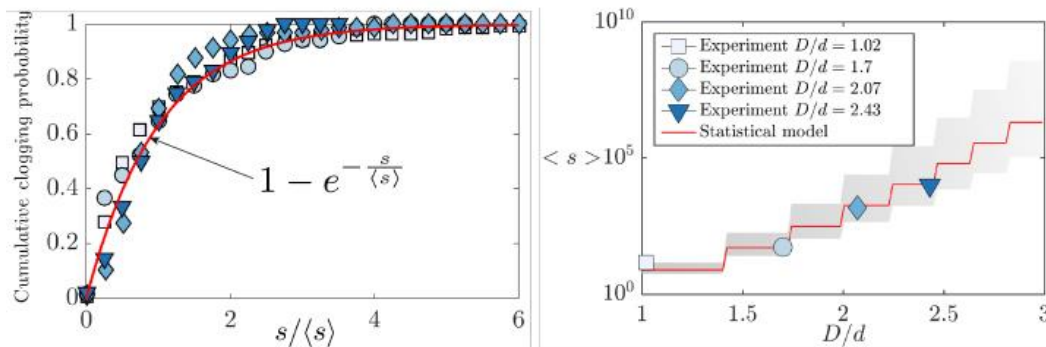
Corresponding author: Mathieu Souzy

e-mail: mathieu.souzy@gmail.com

Affiliation(s): Physics of Fluids, University of Twente, The Netherlands

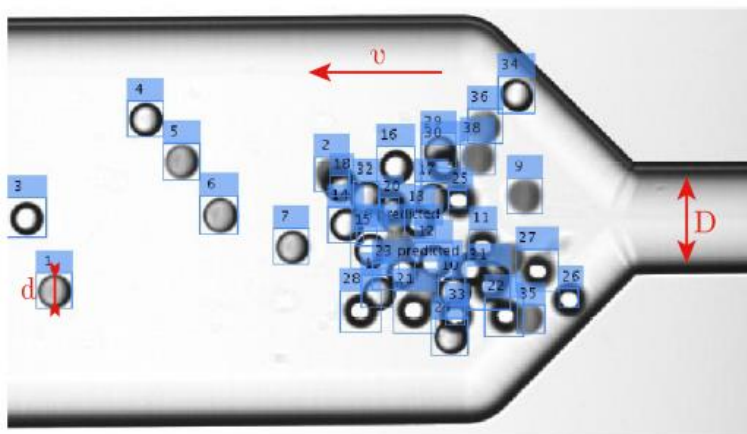
When people, animals, or particles are forced through a constriction, they either flow continuously, intermittently, or even not at all when a clogging arch is formed. Although there are some qualitative and quantitative understanding of how the flow behaves for dry granular material, in our work we focus on non-adhesive colloidal particles in suspension flowing through a constriction. Herein, the neck-to-particles size ratio D/d determines the flow regime: for low aspect ratio $D/d < 3$, the flow is interrupted by the formation of a clogging arch, while for larger $D/d > 3$, the flow seems to be uninterrupted, even at large particle volume fraction.

Noticeably, for $D/d=3$ the particles flow following intermittent bursts, in a strikingly similar way as dry non-cohesive granular systems do. A unified description was proposed by Zuriguel *et al.* (2014), which quantitatively capture the statistics of this intermittent burst regime for a wide variety of scenarios (sheep herds, assembling of grains, pedestrian crowds). Here, we explore if this unified description is still valid for a flow of particulate suspension, by experimentally investigating the time distribution of the intermittent bursts and the distribution of escaped particles per burst, using image analysis particle tracking. We also address the question of the physics behind clogging arches break out.



Left : Cumulative clogging probability of the relative number of escapees $s/\langle s \rangle$ for various aspect ratios D/d . The solid line is the curved expected for an exponential distribution.

Right : Average number of escapees $s/\langle s \rangle$ observed experimentally and predicted using a stochastic model. (Marin *et al.*, 2017)



Particle tracking to count the number of escapees particles per burst, and the time lapse between successive intermittent bursts.

Rotation behaviour of pedestrians in bidirectional and crossing flows ORAL 3WA

Martijn Sparnaaij, Dorine C. Duives, Serge P. Hoogendoorn

Corresponding author: Martijn Sparnaaij

e-mail: m.sparnaaij@tudelft.nl

Affiliation(s):

Delft University of Technology, Department of Transport & Planning

One of the most popular ways to represent pedestrians in microscopic models is by using a circle. Though this is more computationally efficient than more accurate representations such as ellipses or complex polygons, circles have the limitation that they cannot represent the rotation behaviour seen in pedestrians whereby a pedestrian temporarily turns his/her upper body to solve a conflict. As rotation behaviour of pedestrians is seldomly studied empirically, and as the available studies focus on exiting through a doorway, to what extent this circular representation presents limitations to the accuracy of model predictions in other flow situations is unclear. This study aims at providing first insights into the rotation behaviour of pedestrians in bidirectional and two-way crossing streams.

The rotation behaviour of pedestrians is studied based on data obtained in the CrowdLimits experiments. The experiments were performed at Delft University of Technology and encompassed experiments of high density bidirectional and crossing flows using a heterogeneous population of approximately 140 participants in the age range of 18 to 70. For nine datasets the shoulders of all pedestrians were manually annotated (see Figure 1) to obtain the rotation of the upper body of the pedestrians relative to their effective travel direction. Due to time limits and to limit autocorrelation, one frame per 2 seconds was annotated. This resulted in approximately 150 annotated frames per dataset containing roughly 2000 annotated pedestrians per dataset.

Based on this data the rotation behaviour relative to the density has been studied. It was hypothesized that as density increases the amount of pedestrians that rotate their upper body increases as more conflicts are solved by rotation, and, that as density increases even more the rotation decreases again as the crowd is so dense that rotation cannot be effectively used as a strategy to avoid conflicts.

Analysis of the data shows that, as Figure 2 illustrates, in all nine cases the likelihood that, in a single frame, one or more pedestrians have an upper body rotation larger than 20 degrees generally increases with density. However, the rate of large rotations (i.e. the percentage of pedestrians that have a rotation larger than 20 degrees) remains fairly stable as density increases. Furthermore, it can be observed that both the rotation rate and how the likelihood of observing large rotations increases with density depends on the scenario (e.g. the movement base case or flow ratio). Overall the data does not support the hypothesis stated above.

So, it does seem that the density does affect the amount of large rotations in a crowd but not the rate at which pedestrians rotate and, furthermore, that the effects differ between the different flow scenarios. Therefore, more research is necessary to determine exactly what the effect is, how factors such as movement base case, flow ratios and population heterogeneity affect rotation behaviour and to what extent the choice to rotate is related to another conflict avoidance strategy, namely adapting ones speed to wait for a gap in the flow.

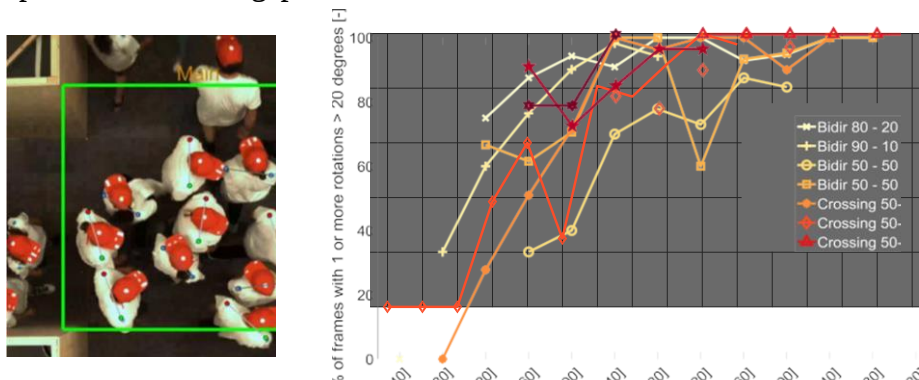


Figure 1: Illustration of method to annotate the shoulders

Figure 2: Frequency of large rotations in the crowd in relation to the global density

Passage of active granular particles through narrow bottlenecks ORAL 4WB

Tina Hanselka, Torsten Trittel, Ralf Stannarius

Corresponding author: Ralf Stannarius

e-mail: ralf.stannarius@ovgu.de

Affiliation(s): Otto von Guericke University Magdeburg Institute of Physics, Magdeburg, Germany

Active granular particles can be used to mimic the dynamics of biological systems, bacteria, algae, animals or even humans. The behaviour of individuals can be studied as well as their interactions in large ensembles. One interesting problem is the passage through bottlenecks.

We have prepared screws that propagate, when excited on a vibration table, in a well-defined axial direction. The velocity in propagation direction is Gaussian, accompanied by rotational diffusion. The average velocity can be controlled by the excitation parameters. By tilting the vibration table by very small angles, we can simulate a preferential direction of motion. Special insets on the vibration table allow the study of passage through narrow gaps, sedimentation in a closed container, and other characteristics. The focus of our study is the statistical characterization of the passage times and non-permanent clogs.



Figure 1: The figure shows an ensemble of screws passing a narrow gap of a funnel-shaped enclosure. The vibrating ground plate is tilted by about 1 deg towards the bottom-right corner. By video analysis, positions and orientations of all objects are detected and evaluated.

Analysis of dynamically stable patterns in maze-like corridor using the Wasserstein metric

ORAL 6WB

Ryosuke Ishiwata, Ryota Kinukawa, Yuki Sugiyama

Corresponding author: Yuki Sugiyama

e-mail: sugiyama@phys.cs.is.nagoya-u.ac.jp

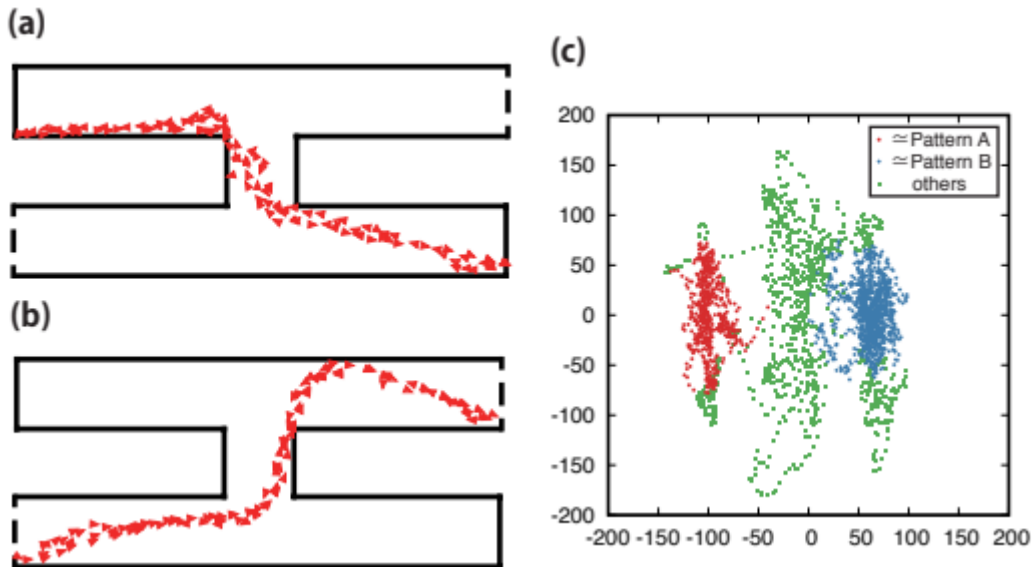
Affiliation(s): Department of Complex Systems Science, Graduate School of Information Science, Nagoya University, Furo-chou, Chikusa-ku, Nagoya, Aichi, Japan.

The two-dimensional optimal velocity (2d-OV) model represents a dissipative system with asymmetric interactions, thus being suitable to reproduce behaviours such as pedestrian dynamics and the collective motion of living organisms. In this study, we found that particles in the 2d-OV model spontaneously form optimal flow patterns like strings in a maze-like corridor.

We mapped these patterns into the Wasserstein metric space and represented them as points in the space, in which the similarity of patterns can be distinguished by a distance. We verified the existence of two macroscopic patterns which were cohesive, stable, and appeared regularly over the time evolution of the model. Furthermore, we estimated the stability of such patterns using the Wasserstein metric technique. As a result, we discovered that the stability of the dynamical patterns is strongly affected by the model sensitivity, which controls the reaction of each particle.

A maze-like corridor is set as figure (a) or (b): The bold lines denote elastic walls, and dashed lines denote the gates connected between the upper-right and the bottom-left corners.

Particle distributions of emerged optimal patterns within a maze-like corridor are described as Figs. (a) and (b). These two patterns are mapped into the Wasserstein metric space as Fig.(c).



(a) Particles move back and forth between the upper-left and bottom-right dead ends. (b) Particles pass through the gates with motion in two directions. (c) Macroscopic pattern evolution over time for sensitivity $\alpha=20$ in the two-dimensional Wasserstein metric space. Pattern classification. Red and blue points represent patterns (a) and (b), respectively, whereas green points do not exhibit any string-like pattern.

Strategy to Control Swarms: Self-organization of Controlled Dynamics POSTER P42

Toshiya Takami

Corresponding author: Toshiya Takami

e-mail: takami-toshiya@oita-u.ac.jp

Affiliation(s): Oita University, Oita, Japan

Various kinds of organisms, e.g. animals, insects, bacteria, etc., often group together to exhibit highly-developed functions even if each one is simple. Swarms of insects configure intelligent social systems, flocks of birds perform large-scale dynamic dances without any conductor, and many multicellular organisms develop complex structures to ensure their survival. In order to study self-organization of swarms and their functions, our approach in this study is to apply the optimal control theory (OCT) [1] to swarm dynamics. The OCT is one of the prominent methods to obtain control signals, which can be utilized for various kinds of classical and quantum systems [1]. We analyse the controlled dynamics by a time-dependent optimal field that is numerically obtained by optimizing an objective function. The swarm is created numerically by the use of a boid model [2], which is a well-known simulation method that creates large-scale swarms in various research fields from computer graphics to complex systems [3].

Our interest here is what kinds of control strategies are found under the numerical approach:

(1) a continuous control signal to all particles; (2) a train of spike-like signals to a specific agent, etc. We are also interested in the difference between controlled and free dynamics of swarms. We will present numerical results on the formation of swarms under obtained control fields. An iterative computation under the OCT has been used as a standard numerical method to obtain those optimal signals. In addition to this, we introduce the reinforcement learning as an effective computational strategy, where it is recently revived with deep learning technologies to solve complex tasks without any supervisor. The relation between these two strategies, the reinforcement learning and the optimal control, is discussed in the field of neuro-dynamic programming [4]. We analyse effectiveness of the reinforcement learning as a numerical method for complex control problems. Thus, in this presentation, we show our recent numerical results of the controlled swarm dynamics. We also give related discussions from numerical and theoretical points of view.

References:

- [1] T. Takami and H. Fujisaki, *Analytic approach for controlling quantum states in complex systems*, Physical Review E **75**, 036219 (2007).
- [2] C. W. Reynolds, *Flocks, birds, and schools: A distributed behavioral model*, Computer Graphics, Vol.21, No.4, pp.25-34 (1987).
- [3] T. Ikegami, Y. Mototake, S. Kobori, M. Oka and Y. Hashimoto, *Life as an emergent phenomenon: studies from a large-scale boid simulation and web data*, Phil. Trans. R. Soc. A **375**, 20160351 (2016).
- [4] D. P. Bertsekas, *Reinforcement Learning and Optimal Control* (Draft Textbook, 2019).

Stochastic Models of Blockage in Channels and Channel Networks ORAL 2FB

Chloé Barré, Gregory Page, Julian Talbot, Pascal Viot

Corresponding Author: Julian Talbot

e-mail: talbot@lptmc.jussieu.fr

Affiliation(s): Laboratoire de Physique Théorique de la Matière Condensée (LPTMC) Sorbonne Université, CNRS, Paris, France.

A channel conveying particles may be vulnerable to blockages if the carrying capacity of the individual channels is limited. Examples include filtration, vehicular and pedestrian traffic and the flow of macromolecules through micro- and nano-channels. We model a particulate flow of constant entering intensity through confined geometries, ranging from a single channel to a bundle of N_c identical coupled channels, under conditions of reversible blockage. Quantities of interest include the exiting particle flux (or throughput) and the probability that the bundle is open. For a constant entering flux, the bundle evolves through a transient regime to a steady state. We present analytic solutions for the stationary properties of a single channel with capacity $N \leq 3$ and for a bundle of channels each of capacity $N = 1$. For larger values of N and N_c , the system's steady state behaviour is explored by numerical simulation. Depending on the deblocking time, the exiting flux either increases monotonically with intensity or displays a maximum at a finite intensity. We also compare the relative efficiency of coupled and uncoupled bundles. For $N = 1$ the coupled system is always more efficient, but for $N > 1$ the behaviour is more complex.

Collective motion and propagation of information in fish schools PLENARY SESSION

Guy Theraulaz

Corresponding author: Guy Theraulaz

e-mail: guy.theraulaz@univ-tlse3.fr

Affiliation(s): Centre de Recherches sur la Cognition Animale, CNRS, UMR 5169, Université Paul Sabatier, Toulouse, France

Swarms of insects, schools of fish and flocks of birds display an impressive variety of collective patterns that emerge from local interactions among group members. These puzzling phenomena raise a variety of questions about the interactions rules that govern the coordination of individuals' motions and the emergence of large-scale patterns. While numerous models have been proposed, there is still a strong need for detailed experimental studies to foster the biological understanding of such collective motion. I will describe the methods that we used to characterize interactions among individuals and build models for animal group motion from data gathered at the individual scale. Using video tracks of fish shoal in a tank, we first determined the stimulus/response functions governing an individual's moving decisions from an incremental analysis at the local scale. We found that both attraction and alignment interactions are present and act upon the fish turning speed, yielding schooling models whose parameters are all estimated from data. We also found that fish mainly react to one or two neighbors at a time. Moreover the magnitude of these interactions changes as a function of the swimming speed of fish. The consequence being that schools of fish adopt different shapes and motions: group polarization increases with swimming speed while it decreases as group size increases. The phase diagrams of the models revealed that the relative intensities of attraction and alignment play a key role in the emergent collective states at the school level. Of particular interest is the existence of a region close to the critical lines between two states in which the school exhibits multi-stability and intermittence between schooling and milling for the same combination of individual parameters. In this region the school becomes highly sensitive to any kind of perturbations that can affect the behavior of just a single fish. This phenomenon, which seems to occur in numerous animal species that move in groups (starlings, midges, etc.) enables the school to adapt their collective behavior more effectively to changes occurring in their environment: presence of food, prey, or predators.

Granular flow from silos with rotating exit ORAL 1FB

Kiwing To¹, Yi-Kai Mo¹, Jung-Ren Huang¹, Yun Yen²

Corresponding author: Kiwing To

e-mail: ericto@gate.sinica.edu.tw

Affiliation(s):

¹Institute of Physics, Academia Sinica, Taipei, Taiwan R.O.C.

²Department of Physics, National Taiwan University, Taipei, Taiwan R.O.C.

For granular materials falling through a circular exit at the bottom of a silo, no continuous flow can be sustained when the diameter D of the exit is about 5 times the characteristic size of the grains. If the bottom of the silo rotates horizontally with respect to the wall of the silo, finite flow rate can be sustained even at small exit diameter. We investigate the effect of bottom rotation to the flow rate of a cylindrical silo filled with mono-disperse plastic beads of $d = 6$ mm diameter. We find that the flow rate W follows Beverloo Law down to $D = 1.2d$ and that W increases with the rotation rate in the small exit regime. If the exit is at a distance from the axis of the silo, flow rate increases with the rate of the area swept by the exit. On the other hand, when the exit diameter is large, flow rate decreases with rotation rate ω at small ω but increases with ω at large ω . Such non-monotonic behaviour of flow rate on rotation speed is found to be related to a change in the flow pattern from funnel flow to mass flow in the silo due to shear at the bottom.

Antoine Tordeux¹, Sylvain Lassarre² and Jean-Patrick Lebacque²

Corresponding author: Antoine Tordeux

e-mail: tordeux@uni-wuppertal.de

Affiliation(s): ¹Division for traffic safety and reliability, University of Wuppertal, Germany

²GRETTIA, COSYS, IFSTTAR, France

Adaptive cruise control (ACC) systems are fundamental in the automation of the driving. They specify the speed of a vehicle in normal pursuit situations. ACC and Full Speed Range ACC systems are based on car-following models determining the acceleration rate of a vehicle according to the distance spacing to the next vehicle in front and the speed difference. The models have to provide safe, comfortable and robust speed behaviors for various longitudinal driving situations.

Speed planners allow to keep a constant time gap with the predecessor. Such a pursuit strategy is the one recommended by the ISO norm for ACC systems¹ (with targeted time gaps varying from 0.8 to 2.2 s). Classical planners are linear feedback and relaxation processes,² or non linear models such as the intelligent driver model.^{3,4} Their active safety is tackled thanks to local (over-damped) and global (string) stability analysis.^{5,6} Generally speaking, the stability occurs if the relaxation is sufficiently strong. The stability conditions constraint the viable domain of the parameters and limit the use of the models.

We propose a novel minimal non-linear speed planner for ACC systems based on the adaptive time gap (ATG) car-following model⁷. The model simply assumes relaxation of the time gap to the targeted time gap recommended by the ISO norm. It describes safe and comfortable speed regulations for many longitudinal driving situations. Reasons are stability properties of the new planner, that hold locally and globally for any value of the relaxation time and targeted time gap. We extend and test the model and demonstrate, notably by means of simulation, its robustness to mechanical and computational latency, or noise, interference and measurement errors.

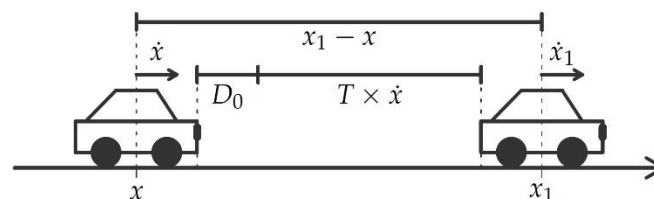


Figure -- Scheme for a pursuit situation. T is the targeted time gap while D_0 is the minimal distance gap for topped vehicles.

References

1. ISO 15622 Intelligent transport systems – Adaptive cruise control systems, 2018.
2. B. Paden *et al.* A survey of motion planning and control techniques for self-driving urban vehicles. *IEEE Transac. Intell. Veh.*, 1(1):33, 2016.
3. A. Kesting, M. Treiber, M. Schönhof and D. Helbing Extending Adaptive Cruise Control to Adaptive Driving Strategies. *Transport Res Rec* 2000(1):16, 2007.
4. O. Derbel *et al.* Modified Intelligent Driver Model for driver safety and traffic stability improvement. In *IFAC Proceedings Volumes* 46(21):744, 2013.
5. S. Darbha, K. Rajagopal. Intelligent cruise control systems and traffic flow stability. *Transp Res C: Emerg* 7(6):329352, 1999.
6. G. Orosz, R.E. Wilson, G. Stépán. Traffic jams: Dynamics and control. *Proc. Roy. Soc. London Ser. A* 368(1928):4455, 2010.
7. A. Tordeux, S. Lassarre and M. Roussignol. An adaptive time gap car-following model. *Transport Res B: Meth* 44(8-9):1115, 2010.

Multi-anticipative car-following model with explicit reaction-time delay POSTER P43

Danila Trufanov¹, Valentina Kurtc² and Igor Anufriev²

Corresponding author: Danila Trufanov

e-mail: danila.trufanov@gmail.com

Affiliation(s): ¹Aquaright Ltd, St. Petersburg, Russia

²Peter the Great St. Petersburg Polytechnic University (SPbPU), Russia, St. Petersburg, Russia.

We propose new microscopic car-following model of vehicular traffic. This model is an extension of well-known optimal velocity model and incorporates driver's reaction time explicitly. This fact results in delay differential equations. Acceleration function incorporates several predecessors (leaders) in interaction

$$\ddot{x}_n(t) = \sum_{k=1}^K a_k \left(V \left(\frac{d_{n,k}(t - \tau)}{k} \right) - \dot{x}_n(t) \right), n = 1, \dots, N,$$

where K is a number of leaders, τ is driver's reaction time, N is a number of vehicles, x_n is the position of the n th vehicle, a_k is a sensitivity of k th leader, $V(x)$ is the Optimal velocity function and $d_{n,k}(t) = x_{n+k}(t) - x_n(t)$. The idea to incorporate reaction time of a driver and several leaders in interaction comes from the desire to reproduce microscopic car-following dynamics in more accurate and plausible way. We perform linear stability analysis of the uniform solutions considering a ring-type geometry. Linear stability conditions of uniform solutions are obtained in analytical form. It was found out that the increase in the number of leaders makes traffic flow more stable (Fig. 1). This result is in agreement with earlier studies [**Error! No se encuentra el origen de la referencia.**]. The critical reaction time τ_{crit} , which is an upper bound for τ (stability condition is $\tau < \tau_{crit}$), is not monotone with respect to distance (to the nearest leader) $d_{n,1}$ (Fig. 1). For the distances close to the free flow τ_{crit} slightly depends on the K . For $K \geq 3$ the critical reaction time τ_{crit} is close to realistic values, while for $K = 1$ and $K = 2$ an upper bound for τ is extremely small.

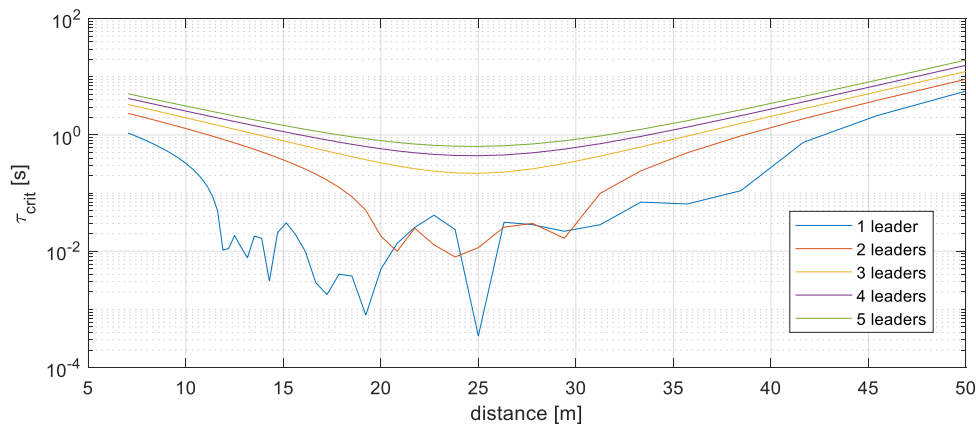


Fig. 2. The critical reaction time τ_{crit} as a function of headway $d_{n,1}$

The evolution of stop-and-go waves was studied by means of the proposed model. Results of computer simulations demonstrate that stop-and-go waves dissipate faster with increasing the number of predecessors in interaction. This confirms the fact, that the increase of the model parameter K stabilizes the traffic flow from a macroscopic point of view.

Reference:

1. Tordeux A., Chraïbi M., Seyfried A. Influence of the interaction range on the stability of following models – Proceeding of the Eighth International Workshop on Agents in Traffic and Transportation. — 2014. — 10 p.

Laboratory experiments and DEM simulations of dense granular flows driven by vertical vibration POSTER P44

Daisuke Tsuji¹, Michio Otsuki², and Hiroaki Katsuragi¹

Corresponding author: Daisuke Tsuji

e-mail: tsuji.daisuke@d.mbox.nagoya-u.ac.jp

Affiliation(s):

¹ Department of Earth and Environmental Sciences, Nagoya University, Japan

² Graduate School of Engineering Science, Osaka University, Japan

This study investigates dense granular flows in a vibrating system by means of both laboratory experiments and particle-scale simulations using the discrete element method (DEM). In the experiment, a conical granular pile is subjected to vertical vibration. Depending on its strength, granular media are fluidized, and the shape of the pile is gradually relaxed. During the vibration, the relaxing pile is continuously measured by a high-speed laser profiler.

Based on the obtained data, we propose a granular transport model which can predict the depth-averaged velocity of flowing granular layers. This model introduces the fitting parameter that means the conversion efficiency from inputted vibration energy into granular transport energy. By comparing the experimental data taken under various conditions, this parameter turned out to be a universal constant.

In order to consolidate this universality and explore the flow property inside the pile, a series of DEM simulations have also been conducted. As a result, we have confirmed that the proposed transport model holds in DEM simulations as well as experiments, and the conversion efficiency does not change. The DEM simulations have also revealed that the flow velocity of granular particles decreases exponentially from the surface of a pile, which suggests the presence of shear-band structure. Finally, this study shows that the depth-averaged velocity predicted by the transport model can be consistently deduced by integrating this velocity function throughout the fluidized layer.

Two-dimensional Set-Voronoi tessellation for particulate systems ORAL 6FB

Simeon Völkel, Kai Huang

Corresponding author: Simeon Völkel

e-mail: simeon.voelkel@uni-bayreuth.de

Affiliation(s): Experimentalphysik V, Universität Bayreuth, D-95440 Bayreuth, Germany

Investigations of granular systems often rely on accurate measurements of properties such as neighborhood, local volume fraction, etc. For mono-disperse spherical particles, the well known Voronoi tessellation is an appropriate and widely available tool. However, particles in reality are typically poly-disperse or have significant deviations from spherical shape, which prohibits the standard Voronoi tessellation from giving reliable results (cf. the right side of Figure 1), especially for systems close to jamming.

To overcome this limitation, an accurate method for dense systems of irregularly shaped particles is introduced. Instead of just relying on each particle's center, all points belonging to each particle's circumference are considered. Using the collective behavior of discs of different shapes under vertical vibrations, we demonstrate the application and advantages of Set-Voronoi tessellations in two dimensions.

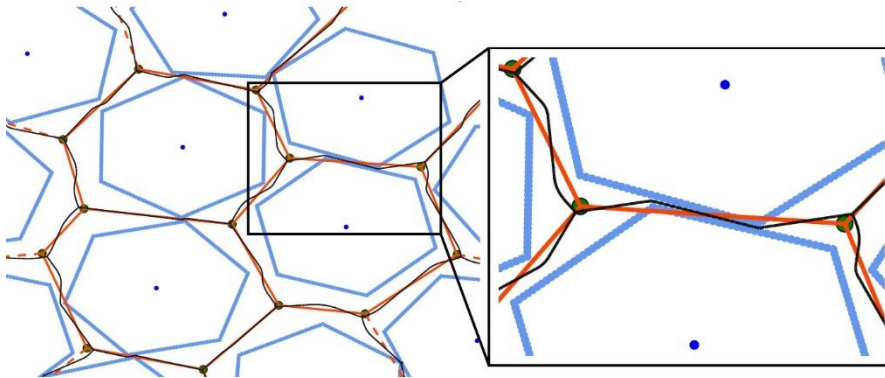


Figure 1: Comparison of standard Voronoi tessellation (red) and Set-Voronoi tessellation (black) for monodisperse hexagonal discs (blue). The dark blue points mark the center of the hexagons, while the green points show the vertices of the standard Voronoi cells.

A cognitive, decision-based model for pedestrian dynamics ORAL 4FA

Cornelia von Krüchten¹, Andreas Schadschneider^{1,2}

Corresponding author: Cornelia von Krüchten

e-mail: cvk@thp.uni-koeln.de

Affiliation(s):¹ Institut für Theoretische Physik, Universität zu Köln, Germany

² Institut für Physikdidaktik, Universität zu Köln, Germany

Model development and simulations are essential parts of investigating and understanding pedestrian dynamics. Reproducing the emergence of macroscopic collective phenomena by modelling microscopic behaviours can help at understanding basic mechanisms of pedestrian movement.

In this contribution we want to present a modelling approach that combines several aspects of different model classes. As a basis, we use discrete time but continuous space to maintain the simple rule-based structure of cellular automaton models without coping with spatial artefacts. Principal idea of the model is to reproduce a pedestrian's decision about the direction of motion and the velocity for the next time step.

The choice of the direction of motion relies on the personal goals and information provided by visual perception of the environment. While reacting to the current situation, the pedestrian estimates the distance-to-collision to the elements of the infrastructure and to other pedestrians. This provides the basis for the decision process which is modelled by a stochastic process to represent inaccuracies in the pedestrian's perception and decision process. Subsequently, the velocity is calculated which depends linearly on the agent's headway.

As a first test, we consider low density scenarios. The results show that the collision avoidance behaviour described by the model dynamics leads to realistic trajectories. For calibration, simulation results are compared to empirical data qualitatively and quantitatively for different scenarios. The fundamental diagram for single-file motion fits well to the empirical data [1] (Fig.1). Furthermore, the approach is one of the few models to reproduce the experimentally observed phase separation at high densities [2]. This shows that this two-dimensional approach can also describe (quasi-) one-dimensional movement in a realistic way. In evacuation scenarios, the model reproduces egress times found in experiments [3]. In addition, we considered further basic situations in pedestrian dynamics like bidirectional flow in a corridor. In this case, lane formation as observed in experiments [4] can be reproduced.

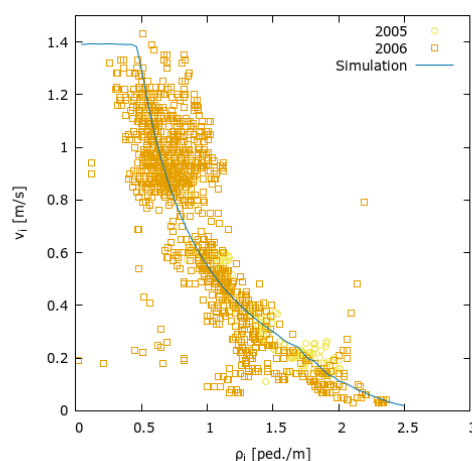


Figure 5:
Fundamental diagram for
single-file motion. The
simulation result (blue line)
fits well to the experimental
data sets [1].

References:

- [1] <http://ped.fz-juelich.de/da/2006singleFile>; <http://ped.fz-juelich.de/da/2005singleFile>
- [2] Seyfried, A., Portz, A. and Schadschneider, A., *Phase coexistence in congested states of pedestrian dynamics*, *Cellular Automata*. ACRI 2010, vol 6350, 2010
- [3] <http://ped.fz-juelich.de/da/2014socialGroups>
- [4] Zhang, J. et al., *Ordering in bidirectional pedestrian flows and its influence on the fundamental diagram*, *J. Stat. Mech.*, P02002, 2012

Ke Wang¹, Shunzhi Qian¹, Zhijian Fu²

Corresponding author: Ke Wang

e-mail: KWANG012@e.ntu.edu.sg

Affiliation(s): ¹School of Civil and Environmental Engineering, Nanyang Technological University, 639798 Singapore, ²School of Transportation and Logistics, Southwest Jiaotong University, Chengdu, PR China

Efficient evacuation is crucial for reducing deaths and injuries caused by disastrous events such as earthquakes. Notably, pre-evacuation time constitutes a large proportion of the total evacuation time; whether and when to initiate the evacuation largely determines the outcome of the evacuation in an emergency. Despite considerable efforts made to elaborate the pre-evacuation process, the evacuees' vague and imprecise cognitive evaluation on the environment in pre-evacuation decision-making process is underrepresented in these studies. This study aims to enrich behavioral knowledge in the evacuation process during earthquakes and to explore modeling methods for characterization of the pre-evacuation process.

As such, we conducted detailed analysis of real earthquake evacuation records to gain some insight into evacuees' behavioral features. Influencing factors of evacuating decisions were identified and individual heterogeneity was observed. These extracted information from the records, together with empirical knowledge formed the basis of a fuzzy-logic based decision-making model shown in **Fig. 1**. Some outside cues can affect one's risk perception, such as physical signals, instructions, and others' behaviors. The level of perceived risk is calculated through Fuzzy Inference System (FIS) as shown in **Fig. 2**. The proposed model allowed the prediction of investigating/ evacuating decision time with the consideration of individual heterogeneity and change of cues.

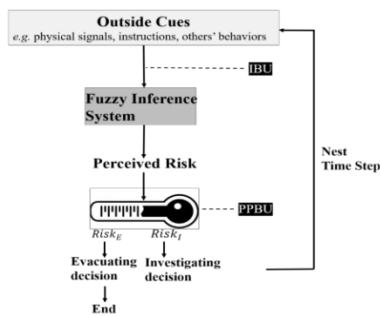


Fig. 1 Pre-evacuation decision-making model.

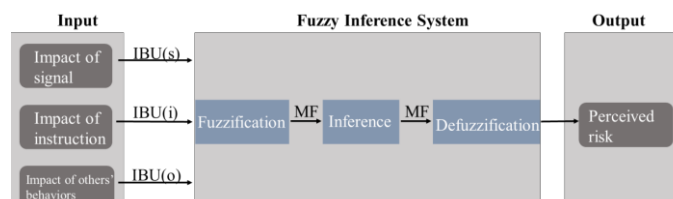


Fig. 2 Fuzzy inference process of the proposed model (Main FIS). The IBU(s), IBU(i), and IBU(o) are distributions of personal traits in perceiving the physical signal cues, instruction cues, and others' behaviors respectively.

Calibrated with one of the earthquake videos, the proposed model was then validated against another earthquake video with reasonable agreement. A further parametric study was conducted to investigate the influence of the features of physical signals and those of instructions on the investigating/ evacuating decisions (**Fig. 3**). We further conclude from simulation results that investigating decision time is mainly determined by physical signals, while the evacuating decision is influenced by both physical signals and instructions. Moreover, evacuees are more sensitive to the onset of physical abnormality than the magnitude of abnormality.

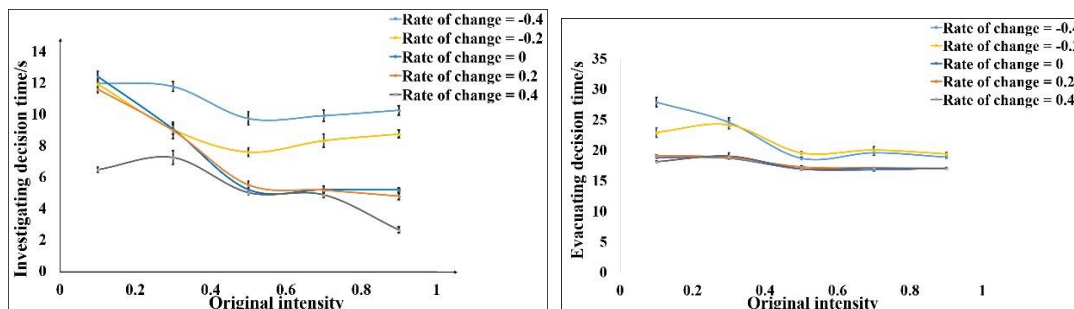


Fig. 3 Plot of investigating decision time (left) and evacuating decision time (right) against the original intensity of the signal under different rate of change of intensity

Simulation of evacuation process in a supermarket with the consideration of its operational characteristics POSTER P45

Ke Wang¹, Jarron Jun Hui Lee¹, Shunzhi Qian¹, Zhijian Fu²

Corresponding author: Ke Wan

e-mail: KWANG012@e.ntu.edu.sg

Affiliation(s):¹ School of Civil and Environmental Engineering, Nanyang Technological University, Singapore

² School of Transportation and Logistics, Southwest Jiaotong University, Chengdu, 610031, PR China

Supermarkets are usually packed with high density of people during peak hours, posing high risk of safety in case of emergency. Moreover, supermarkets are usually divided into multiple functional zones such as fresh product zone, beauty product zone *etc.* These functional zones are accompanied with unique operational features, such as demographic distribution, layout of obstacles (shelves), peak hour *etc.*, adding to the complexity of emergency evacuation dynamics. This study intends to investigate the influence of these operational characteristics on evacuation efficiency.

Field observation was conducted to characterize demographic features and layout of obstacles within each of the functional zones in a typical Singapore supermarket. The evacuation process was then simulated via a social force model based software, Massmotion. By varying the distribution of these functional zones and layout of shelves, the optimal layout was selected with the consideration of total evacuation time, level of service of each evacuee *etc.* (**Fig.1**).

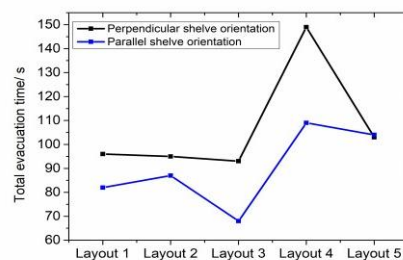
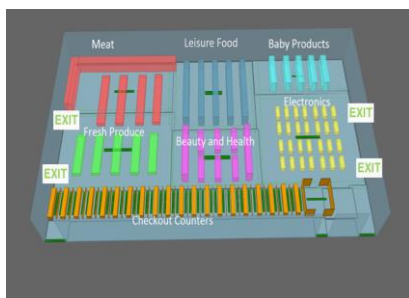


Fig. 1. Graphic representation of one of the layouts (left) and the evacuation time for five different layouts of with perpendicular shelf orientation and parallel shelf orientation (right).

It is found that by placing the leisure food adjacent to the emergency exits, the evacuation efficiency improved than when the leisure food are placed at the center of the store, which is usually the case for most supermarkets in an attempt to maximize sales. However, the leisure food should not be placed next to the emergency exits adjacent to another zone that also has high occupant density as this may cause congestion and cause delay in the evacuation time. The simulation results also show that when the shelves are orientated parallel to the emergency exits, the evacuation time significantly improved from when they are perpendicular to the emergency exits (**Fig.2**). The observations and results obtained from this study will hopefully be useful to help retailers make operational decisions with consideration to evacuation safety.

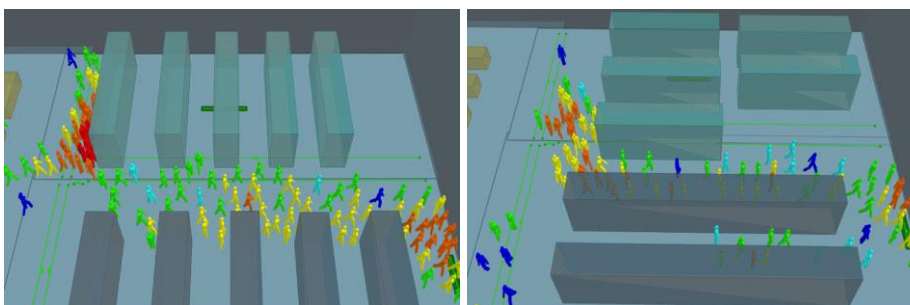


Fig.2. Pedestrian flow with perpendicular shelf orientation (left) and parallel shelf orientation (right). Congestion is eased in the second scenario.

Clogging in collision-free velocity models for pedestrian dynamics POSTER P46

Qiancheng Xu, Mohcine Chraïbi, Armin Seyfried

Corresponding author: Qiancheng Xu

e-mail: q.xu@fz-juelich.de

Affiliation(s): Institute for Advanced Simulation, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

Clogging caused by pedestrians in narrow spatial structures e.g. bottlenecks is a very common phenomenon especially in high density situations. It can arise in our daily life, e.g. when a large number of passengers at the train station enter carriages from narrow train doors, or after a large concert, the audiences exit the concert hall with a higher flow than the capacity.

In real situations under normal movement conditions these kind of clogging are avoided by a complex but transient communication process of pedestrians. This process begins with perceiving and releasing information via body language, eye contact, etc. and eventually results in the adaption of the movement strategies, like rotating the shoulder, adjusting the speed, changing the moving direction or a combination of these actions to avoid collisions that may develop into clogging.

However, models based on physical principles, merely concerned by guaranteeing a volume exclusion, lack this kind of communication, which could lead to stable clogging. These are identified as two or more pedestrians blocking each other and not moving further.

Zuriguel et al. have done several experiments to explore the property of clogging in granular materials. Besides, Kirchner et al. investigated this phenomenon with a cellular automaton model for pedestrian dynamics, they introduced a friction parameter as conditional probability to solve the problem of clogging. However, in pedestrian dynamics little research has been done in investigating under which conditions these clogging situations occur and how to solve them in a systematic way.

In this paper, we focus on the clogging that occurs in collision-free velocity models for pedestrian dynamics and quantify this phenomenon by exploring decisive factors which favor its occurrence.

The factors that we considered can be divided into three categories. The first one includes environmental factors, which are width of the exit and the flow of pedestrians at the entrance. The second one consists of technical factors, including the size of simulation time-step and the update scheme for agents e.g. sequential or parallel update. And the third one is comprised of model related factors. In this study we use several collision-free velocity models with increasing complexity.

We perform several simulations in a simple bottleneck scenario i.e. a rectangular room with one narrow exit. In these simulations, pedestrians are generated with a constant flow rate. These simulations last long enough to ensure that we can observe sufficient clogging. When clogging occurs, we record it and randomly remove one of the pedestrians involved in the clogging. Then the simulation results are used to figure out relationships between the probability of clogging and the factors mentioned above. Based on the relationships obtained, the decisive factors are identified and the corresponding solutions are implemented.

Exit-choice behaviour in evacuation through an L-shaped corridor ORAL 12TA

Daichi Yanagisawa¹, Milad Haghani², and Majid Sarvi³

Corresponding author: Daichi Yanagisawa

e-mail: tDaichi@mail.ecc.u-tokyo.ac.jp

Affiliation(s): ¹Research Center for Advanced Science and Technology, The University of Tokyo, Japan

²Institute of Transport and Logistics Studies | Business School, University of Sydney, Darlington, Australia

³Department of Infrastructure Engineering, The University of Melbourne, Parkville, Australia

In this study, the exit-choice behaviour of evacuees has been investigated in an L-shaped corridor. Recently, the influence of various factors, such as the exit distance, visibility, width, familiarity, exit crowding, and herding (imitating other evacuees), on the exit-choice behaviour was quantitatively investigated [1–3]. The evacuations considered in these studies were either simple rectangular rooms or realistic complex venues. By considering an L-shaped corridor, we investigated the factors that affect the exit-choice behaviour when the evacuees turn at a corner. We analysed the experimental data in [1]. The half part of the experimental area as in Fig. (a) was focused in this study. Depending on the scenario, approximately forty participants entered the corridor from the entrance at the bottom left and exited through either Exit A or Exit B at the top right. A total of ten scenarios were selected for performing the analysis. The evacuees walked in four of those scenarios and ran in the remaining six scenarios.

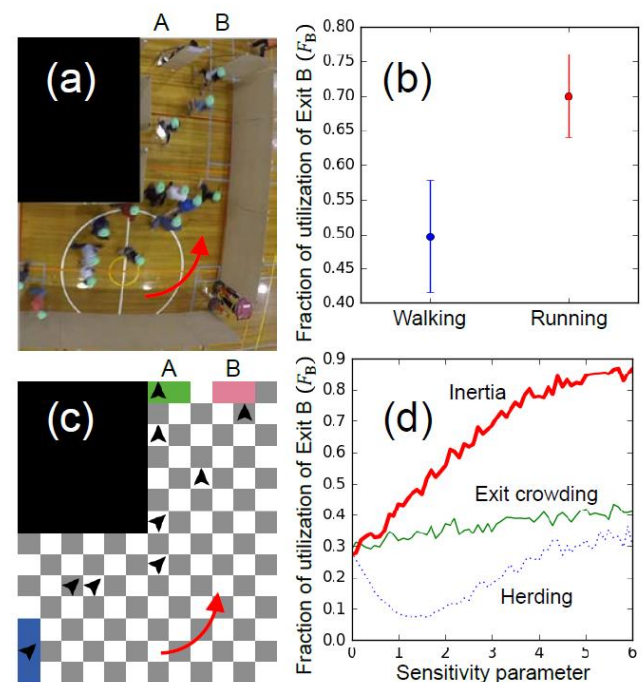
Figure (b) depicts the fraction of utilisation of Exit B (FFB) and its 95% confidence interval in the walking and running scenarios. We can observe that $FFB=0.5$ in the walking scenarios and that it is considerably larger than 0.5 in the running scenarios. The result of the Z-test was $pp = 5 \times 10^{-4}$; hence, the null hypothesis was rejected. The effect size (Cohen's h) was $h = 0.42$, therefore, there was small-to-medium effect size between two values of FFB .

As can be observed from Fig. (a), Exit B was farther than Exit A. Distance is considered to be one of the most important factors influencing the exit choice. However, it seems that more significant factors determined the exit choice in the running scenarios.

To investigate the significant factors influencing the exit choice through the L-shaped corridor in the running scenarios, we conducted an evacuation simulation using the floor field cellular automata model [4, 5] as depicted in Fig. (c). The direction of movement of the agents was determined by the following four factors: the distances to the exits; herding behaviour; exit crowding; and inertia effect. By considering exit crowding, the evacuees were observed to avoid the crowded exit and move to the other exit [4]. Further, when the inertia effect was increased, the evacuees moved in the same direction as that of their previous movement [5]. The four aforementioned factors were weighted using four sensitivity parameters.

Figure (d) depicts the results of the simulation (FFB) as a function of the sensitivity parameters. We fixed the sensitivity parameter of the distance effect and controlled one among the remaining three parameters (two parameters were set to zero) in each plot. Neither herding behaviour nor avoidance of exit crowding overcomes the distance effect and achieves $FFB > 0.5$. In contrast, when the inertia effect increases, FFB increases, exceeds 0.5 and becomes 0.7, which can be observed in the running scenarios in real-time experiments. The inertia effect depends on the speed of the evacuees. Therefore, the results of the experiment and simulation correspond well if the relation between the speed and inertia effect is considered. Thus, our results indicate that the inertia effect was the main cause for the occurrence of large FFB in the running scenarios.

In the conference and full paper, we present our analyses of the evacuation times and trajectories of the evacuees. Furthermore, the calibration and validation of the model will be discussed.



Estimation of laminar vehicular flow perturbation caused by component of dangerous drivers
POSTER P47

Vladimir Tishkin, Vladimir Yashin

Corresponding author: Vladimir Yashin

e-mail: hekkoki@gmail.com

Affiliation(s):

Keldysh Institute of Applied Mathematics of Russian Academy of Sciences, Moscow, Russia
Moscow Technical University of Communications and Informatics (MTUCI), Moscow, Russia

One of the serious aspects of modern traffic flow is driver's dangerous behavior and risky driving. Such driving manner causes interference to the regular automotive traffic and increase the probability of car accidents. The scientific community discusses this problem not only from technical point of view, but also as a social-psychological phenomenon, since society (social problems) and ecology (pollution, poor health and unstable psyche) are influencing the driver's behavior. At the same time, increasing of comfort level and technical progress, affordability of vehicles lead to the expansion of members of society who can drive a vehicle. These factors are comprehensively studied in the following works (Daganzo C. 1999; Dula C., Geller E. 2003; Hamdar S., Treiber D., Ionescu C., 2009) and so on. It should also be noted, that modern road construction is also one of the factors, confounding the problem. Indeed, it's hard to enjoy all the technical advantages of modern vehicles on a narrow road with bad pavement, while broad multi-lane highways produce lots of opportunities for reckless driving.

Improving the technical capabilities of modern vehicles allows a driver to create a fast acceleration, use flexible maneuverability, provides stability and control, allows driver to change lane cutting into a small gap between consequently moving vehicles in one lane in close to zero time relative to the driver's response. The problem is to estimate the total perturbation of the traffic flow depending on the proportion of dangerous drivers in it.

Laminar solutions of the classical hydrodynamic model are studied here. The new additional parameters that mimic dangerous driving are introduced. A method for evaluation of the impact of this dangerous component, depending on the proportion of number of risky drivers in the flow and the number of lanes, is proposed.

Uniform cluster traffic model on closed two-contours system with two non-symmetrical common nodes

ORAL 11TB

Alexander G. Tatashev, Marina V. Yashina

Corresponding author: Marina V. Yashina

e-mail: yash-marina@yandex.ru

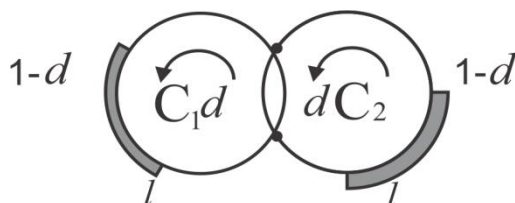
Affiliation(s): Moscow Automobile and Road Construction State Technical University, Moscow, Russia

Well-known traffic model (Nagel, Schreckenberg, 1992) is a cellular automaton on a one-dimensional infinite lattice with given rules and connected with elementary cellular automata (CA) introduced by Wolfram, 1982. More generally in models of this class, particles move on a multi-lane road or on the graph, (Maerivot S., De Moor B., 2005), (Tordeux, Roussignol, Lassare, 2009). Models of this class describe the individual motion of particles and were studied using computer simulations, and analytical results are obtained for only simple cases, such as line and circle.

Particles movements are connected with probabilistic values for changing their sites and many parameters. It is very difficult to generalize such models types to complex networks. The main problem of traffic network system is time movement delays caused by traffic jams. Fundamental approach leads to question what description is more effective: dynamical systems (deterministic) or Markov process (probabilistic)?

For the aim to clear the questions, the concept of a contour network (**contour network of Buslaev**) was introduced in (V.V.Kozlov, A.P.Buslaev, A.G.Tatashev, 2013). In systems of this class, particles (clusters) move in the given direction in accordance with the rules along closed contours having common points (nodes) through which located on adjacent contours particles can't pass at the same time, that causes the delays at the nodes. In the series of works there were studied the regular networks. To describe the connected motion of particles, which is more typical for saturated flows of the current traffic state, the concept of **cluster motion** is introduced in (Bugaev, Buslaev, Kozlov, Yashina, 2011). In the model of cluster motion, particles occupying neighboring cells of the supporter of systems, form a cluster and move simultaneously.

The research of discrete dynamical systems on chain in the research group under leadership of prof. Buslaev created the method of analysis of flow on regular networks. The basic concept is **spectrum of the dynamical system** as set of limit average velocities and **corresponding spectral cycles** in state space, Buslaev et al 2015, 2017, 2018.



In this paper we are developing the approach. We study the spectrum of a continuous system containing two identical contours. The length of each contour equals 1. There are two nodes common to contours that divide each contour into two arcs whose lengths are equal to d and $1-d$ ($d \leq 1/2$), fig.1. On each contour there is a cluster represented by a moving segment of length $l < 1$. A cluster stops if it comes to the node when the other clusters crosses the

node. If the clusters come to the node simultaneously, then one of the clusters (*priority cluster*) passes through the node first. If there is no delay, the cluster moves at a speed taken as a unit. The direction of movement of the clusters is such that, passing one of the nodes, the two clusters go to a smaller arc, and passing another node both clusters go to a larger arc. We denote by v the average cluster velocity on the spectral cycle with regard to delays. In the symmetrical case ($d=1/2$), this system was considered in (Buslaev, Tatashev, Yashina, 2018). In this case, if $l \leq 1/2$, from any initial state, the system results in a states of free movement, and if $l > 1/2$, from any initial state the system results in a state of collapse. Thus in the symmetrical case the spectrum of velocities contains only one point for every fixed value l .

It is proved the following. On any spectral cycle, clusters move with the same average velocity. If the condition $l \leq d$, and $l \leq (1-2d)/2$ or $1-2d \leq l$ is not fulfilled, then the **self-organization** takes place, i.e. starting from some moment the system is in **free movement state** (both clusters move without delay), $v = 1$ (spectrum of velocities contains one point for any fixed d and l). If $l \leq d$ and $(1-2d)/2 < l < 1-2d$, then for each spectral cycle the velocity $v=1$ or $v=1/(2(l+d))$ depending on the initial state (the spectrum of velocities contains two points).

If $l > 1-d$, or $l > d$ and $1-2d \leq l$, then at some moment the system results to the **collapse state** (clusters do not move), $v = 0$. If $l > d$ and $(1-2d)/2 < l < 1-2d$, then there are two spectral cycles. One of them contains only a state corresponding to collapse. On the other spectral cycle, each cluster moves with the velocity $v = 1 / (2 (l + d))$. If $d < l \leq (1-2d)/2$, then depending on the initial state the system enters either a state of free movement or a state of collapse. Thus the **spectrum of velocities contains one or two points** for any fixed d and l .

Sequence Alignment Methods for analyzing passenger movement behavior through Wi-Fi access points ORAL 13TA

Yuji Yoshimura¹, Stefan Seer², Carlo Ratti¹

Corresponding author: Yuji Yoshimura

e-mail:yyyoshimura@gmail.com

Affiliation(s): ¹MIT senseable city lab

²AIT Austrian Institute of Technology

This paper proposes a novel analytical framework for investigating passengers' spatio-temporal behaviors in a large-scale train station located in Paris, France. We focus on extracting passengers' behavioral patterns considering their sequential movement between key locations, the length of stay, and the relationship between them based on Wi-Fi access points dataset (see Figure 1). The exponential growth of Wi-Fi access point data provides great opportunities to address novel research questions. However, the increase of data quantity raises the significant issue of how to process large-scale Wi-Fi datasets and which analytical methodology to apply for extracting meaningful knowledge from them. We answer this question using Sequence Alignment Methods, which were first introduced to analyze DNA or RNA strings of information in molecular biology. One of the significant advantages of our approach is the ability to consider the order (or sequence) of events, thus it is well-suited for the analysis of passengers' behaviors in spatio-temporal aspects.

Our results show that the spatial usage by passengers is unevenly distributed among the walkable area inside the train station. In addition, we discovered that the shorter stay type passengers (less than 30min) tend to explore a wider spatial dimension actively than the longer stay type (more than 70min). Conversely, longer stay type passengers are more likely to remain in the confined area during their duration of stay. However, the paths for shorter stay type passengers are more selective than the longer stay type, resulting in a stronger emerging pattern for the former than the latter. Although the methodology presented herein was applied to a selected station, it could easily be generalized and applied to other stations or other types of buildings or public spaces.

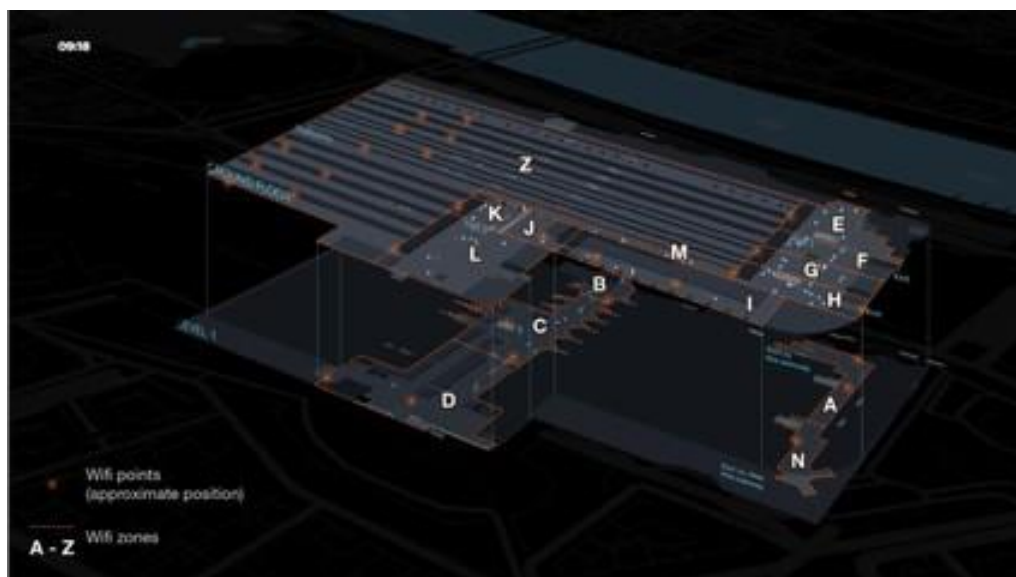


Figure 1. Location of 15 Wi-Fi access points indicating their approximate sensing range

Departure rates optimization and perimeter control: comparison and cooperation in a multi-region urban network ORAL 12TB

Kai Yuan, Victor L. Knoop, Boudewijn Zwaal and Hans van Lint

Corresponding author: Kai Yuan

e-mail: K.Yuan@tudelft.nl

Affiliation(s): Delft University of Technology, Department of Transport and Planning, Delft, The Netherlands

With the renewed interest in the Macroscopic Fundamental Diagram (MFD) in the last decade, studies on network-level urban traffic control have increased in popularity. One popular urban traffic control approach is perimeter control, in which vehicle accumulation is kept below some critical accumulation value. An alternative control strategy is to optimize the dynamic departure rates as a means to limit inflows into the (sub)network. In this paper we test how these approaches compare in terms of minimizing total time spent (TTS), and whether network performance can be improved by combining these two approaches. To the best of the authors' knowledge, answers to these two questions are still missing.

We formulate the research question as a comparison among four study cases: (a) Without any control measure: The aggregated departure rate in every time window is the same. The perimeter control is off; (b) Perimeter control: The aggregated departure rate in every time window is the same. The perimeter control is on; (c) Departure rates optimization: The time series of departure rates is optimized through the genetic algorithm. The perimeter control is off; (d) Combining perimeter control and the departure rates optimization: The time series of departure rates is optimized through the genetic algorithm. The perimeter control is on. The results are shown in Figure 1, which presents the cumulative curves of departure rates, entering rates and arrival rates in four study cases. The TTS cost in each figure is associated with the area between the departure (solid line) and arrival (dashed line) cumulative curve. The area between the cumulative curve of entering and arrival rates indicates the total time spent in the monitored network, excluding the waiting time out of the network.

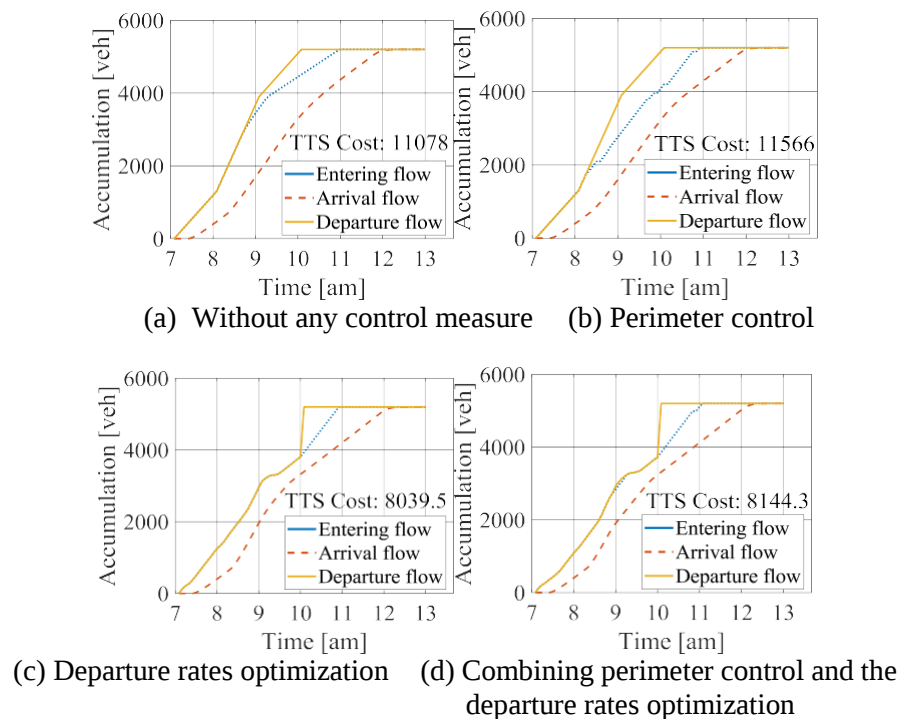


Figure 1. Cumulative curve of departure, entering and arrival flow in four study cases. The cost in each case is put in each sub-figure.

This research offers two main findings: (i) departure rates optimization outperforms perimeter control in minimizing TTS in a multi-region urban network; (ii) perimeter control may even have adverse effects on the performance of departure rates optimization when combining the two measures. The second finding also indicates that partial over-saturation could result in less TTS than fully under-saturation under the application of perimeter control. We believe our work contributes to the research of applying departure time control (by whatever means) in combination with perimeter control in more complex (multi-region) networks.

*Zeynep Yucel¹, Francesco Zanlungo², Takayuki Kanda^{2,3}*Corresponding author: Zeynep Yucel

e-mail: zeynep@okayama-u.ac.jp

Affiliations:¹Department of Computer Science, Okayama University, Japan ²Intelligent Robotics Laboratory, ATR, Kyoto, Japan ³Department of Social Informatics, Kyoto University, Japan

Within the crowd dynamics and safety community, behavioral differences between genders have been attracting considerable attention in recent decades. Various empirical studies have proven that gender has a significant relation to pedestrians' decision making, route choice, rule compliance, as well as risk taking/perception [1, 2]. However, most studies examine behavior of individuals, and only few consider (pedestrian) groups with different gender profiles [3].

Therefore, this study investigates the effect of gender composition of pedestrian dyads on the tangible dynamics of the dyad, which may potentially help in automatically understanding and interpreting the higher level behaviors such as decision making and the like.

To that end, we first propose a set of variables to represent the dyads' physical/dynamical state and relation. In doing that, we use only depth information, which poses no concern on privacy issues. By observing the empirical distribution of these variables, we comment on the effect of gender interplay on locomotion preferences. Subsequently, adapting the algorithm of [4] so as to recognize gender composition, we demonstrate that it is possible to identify the gender profile of dyads with considerable accuracy.

Gender profile, which can be either all-males **M**, all-females **F** or mixed gender **X**, is suggested to have a close relation to the following variables: inter-personal distance δ , group velocity v , velocity difference of peers ω , average height η and height difference of peers $\Delta\eta$.

A qualitative analysis based on empirical distributions of these variables indicates that **M** has significantly larger inter-personal distance and velocity, in addition to being taller. Interestingly, in **X** males move in a way similar to females (i.e. slower and in closer distance). In addition, **X** is distinguished by its peculiar height difference.

By using the proposed Bayesian algorithm to detect a dyad's gender composition, we achieve an overall recognition accuracy of 70%, where **M**, **F** and **X** are recognized with 83%, 76% and 47%, respectively. Removing one variable at a time from the recognition algorithm, we rate the contribution of each variable in recognition of gender composition. Namely, average height η is shown to contribute the most, followed by height difference of peers $\Delta\eta$, group velocity v , and inter-personal distance δ , in that order. Though velocity difference of peers, ω , contributes the least, its removal causes a decline in performance.

The contributions and interesting conclusions of this study are as follows:

4. To the best of our knowledge, this is the first study on gender profiling of pedestrian groups.
5. Gender composition can be identified with satisfactory accuracy from trajectory and height.
6. The distinguishing properties of male locomotion are diminished as they pair with females.
7. In relation to the previous statement, average height emerges as the most influential variable in recognition of gender, since it is not affected by the gender of the partner. Anyway, even after removing this information, we are still able to correctly assign the highest rate to the true category for each of the three gender profiles.

References

- [1] Papadimitriou, E., Lassarre, S., Yannis, G.: Introducing human factors in pedestrian crossing behaviour models. *Transp Res Part F Traffic Psychol Behav* 36, 69–82 (2016)
- [2] Tom, A., Granié, M.: Gender differences in pedestrian rule compliance and visual search at signalized and unsignalized crossroads. *Accident Analysis & Prevention* 43(5), 1794–1801 (2011)
- [3] Willis, A., Gjersoe, N., Havard, C., Kerridge, J., Kukla, R.: Human movement behaviour in urban spaces: Implications for the design and modelling of effective pedestrian environments. *Environment and Planning B: Planning and Design* 31(6), 805–828 (2004)
- [4] Yucel, Z., Zanlungo, F., Feliciani, C., Gregorj, A., Kanda, T.: Estimating social relation from trajectories. to appear in *Pedestrian and Evacuation Dynamics* (2018)

The effect of social groups on the dynamics of bi-directional pedestrian flow: a numerical study

ORAL 8WA

Francesco Zanlungo¹, Luca Crociani, Zeynep² Yücel³, Takayuki Kanda^{1,4}

Corresponding author: Francesco Zanlungo

e-mail: zanlungo@atr.jp

Affiliation(s): ¹Intelligent Robotics Laboratory, ATR, Kyoto, Japan

²CSAI Research centre – University of Milano – Bicocca, Milan, Italy

³Department of Computer Science, Okayama University, Okayama, Japan

⁴Department of Social Informatics, Kyoto University, Kyoto, Japan

Pedestrian social groups represent a large portion of urban crowds and are expected to have a considerable effect on their dynamics. In this paper we investigate the effect of groups on a bidirectional flow, by using novel computational methods. Our focus is on self-organisation phenomena, and more specifically on the time needed for the occurrence of pedestrian lanes, their stability and their effect on the velocity-density relation. Moreover, we are interested in understanding the amount of physical contact and of turbulence in the crowd. To this end, we use a novel model considering the asymmetrical shape of the human body and describing its rotation during collision avoidance. The model is based on the one introduced in [1] and it describes a system of second order differential equations with three degrees of freedom for pedestrians: x , y for position and θ for the body orientation. The behaviour of pedestrian groups is modelled by using forces introduced and discussed in [2, 3].

The collision avoidance model, one of the novel steps of this work, is modelled by exerting a force and torque on pedestrian body in case a collision is predicted in the next τ steps. The introduction of τ is motivated by the assumption that if a collision is going to happen in such short time the person will most likely avoid it by rotating the torso, while, in a farther future, collisions are avoided with adjustments of the trajectory. Due to the current lack of datasets describing the detailed body rotation of pedestrians in real world settings, the novel parameters related to collision avoidance have been optimized using a genetic algorithm. The proposed fitness function considers four components describing: (i) kinetic energy exchanged in physical collisions; (ii) the angle between body orientation and the pedestrian velocity; (iii) the value of the group potential ([2]); (iv) the difference between the pedestrian velocity and preferred velocity. The calibrated model is used to study the dynamics of different bi-directional flows of pedestrians in corridor settings with periodic boundary conditions. The aim is to investigate the influence of social groups in the aggregated dynamics and in the emergence of the lane formation phenomenon. Hence, we configure several scenarios by fixing: the width W of the corridor; the global density ρ of pedestrians; the ratio r_g describing the percentage of grouped pedestrians in the simulation. The chosen observables are the average ratio v between actual and preferred speed over time, the number and stability of lanes (analysed using the algorithm [4]) and the amount of physical collisions. Figure 1 shows $v(t)$ for four simulated values of $\rho = 1, 2, 3, 4$ ped/m² respectively shown by circles, squares, up and down triangles; blue points relate to $r_g = 0$, red to $r_g = 0.5$). The effect of groups on v appears to be stronger at low ρ . Nevertheless, a deeper analysis shows that groups influence dynamics also at high ρ ; i.e. the amount of physical collisions between pedestrians is at least one order of magnitude higher for any ρ in presence of groups. This is related to the instability of lane separation when groups are present, an effect due to their larger occupation of space while walking abreast (Figure 2). Although based on strong simplifications, we believe that these preliminary results show great theoretical and practical implication of the consideration of realistic group behaviour in pedestrian models.

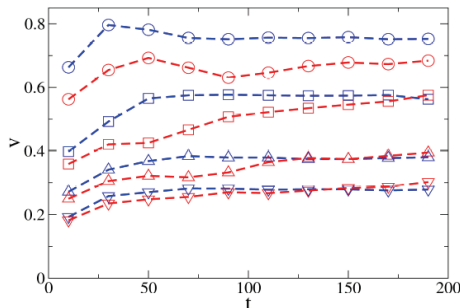


Figure 1: speed ratio over time for the simulated scenarios.

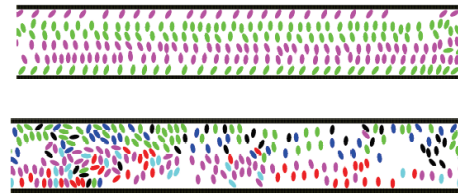


Figure 2: screenshots of two simulation runs with $r_g = 0$ (top) and $r_g = 0.5$ (bottom). Pedestrians in green, black and blue move left.

Experimental study on pedestrian flow under different age groups and movement motivations POSTER P48

Jun Zhang, Xiangxia Ren, Hongliu Li, Weiguo Song

Corresponding author: Jun Zhang

e-mail: junz@ustc.edu.cn

Affiliation(s): State Key Laboratory of Fire Science, University of Science and Technology of China, Hefei, China

The worldwide population is aging and countries are facing ongoing challenges in meeting the transportation demand of the elderly. Meanwhile, children under 9 years represents about 17.9% of the world's population. Among them the ones between 3 to 5 years are a special group, since most of them stay in kindergarten for a long time according to National Center for Education Statistics (NCES, 2017) but with weaker self-care ability compared to the pupils. These people are vulnerable groups in the society but their movement characteristics are less investigated up to now. How to guarantee their safety under emergency and improve their comfort during daily life are really necessary to be considered. The movement dynamics of pedestrian crowds may show great different due to several internal and external factors. Controlled laboratory experiments have been recently employed as a reliable approach to obtain empirical data in this field to have a deep understanding on pedestrian movement by considering certain factors.

Based on these consideration, in this work we performed series of laboratory experiments with preschool students, university students and the elderly older than 60 years old. From these experiments, different movement behaviors among these groups are observed. For example, the preschool children are the most active ones and like competition but easy to be fell, while the elderly move always very carefully. It is found that the relations between flow and bottleneck width for adults and children can be unified when the body size and movement motivation are considered in certain way. The fundamental diagram of the elderly shows a similar trend compared with that of young pedestrians. However, at the same densities the speeds of the elderly are always lower than those of the young pedestrians in the observed density range. Besides, high movement motivation leads to competition among pedestrians, which results in different spatial-temporal distribution of the density and speed compared to normal movement of adult. Based on Voronoi method, an arch-like distribution is observed for the children movement with competition, whereas it is teardrop-shaped for the adults without competition (see Fig. 1). These findings can be useful for the improvement of pedestrian modelling and design of pedestrian facilities that are much friendlier to the elderly.

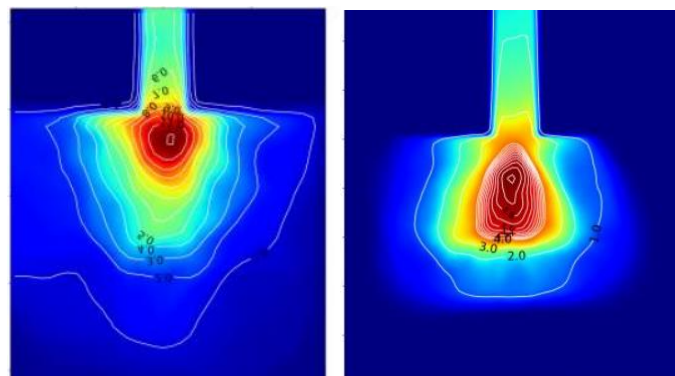


Fig.1 Density profiles for pedestrian flow through bottleneck under different motivations. (Left:With competition, Right: movement in normal speed)

Evacuation Characteristics of Pedestrian through Bottlenecks ORAL 5TA

Hongliu Li^{1,2}, Jun Zhang¹, Weiguo Song¹, YUEN Kwok Kit Richard²

Corresponding author: Jun Zhang

e-mail: junz@ustc.edu.cn

Affiliation(s): ¹State Key Laboratory of Fire Science, University of Science and Technology of China, Hefei, China. ²Department of Architecture and Civil Engineering, City University of Hong Kong, Hong Kong

Bottlenecks restrict the pedestrian flow since the narrowings reduce the passing capacity. The reasonable size of bottleneck like emergency exits is of great importance to improve the safety of occupants in buildings. During the past few decades, several studies have been performed focusing on the movement characteristics of pedestrian flow through bottlenecks, both in empirical experiments and in simulations [1, 2]. The geometry of bottleneck, like width, shape, length and position have been widely investigated [1]. Lane formation and zipper effect have been also observed from pedestrians flow through bottlenecks [3, 4]. However, most of findings in the past empirical studies are obtained by taking adults in normal situation. Less attention were paid to the movement characteristics of running adults especially in case of emergency.

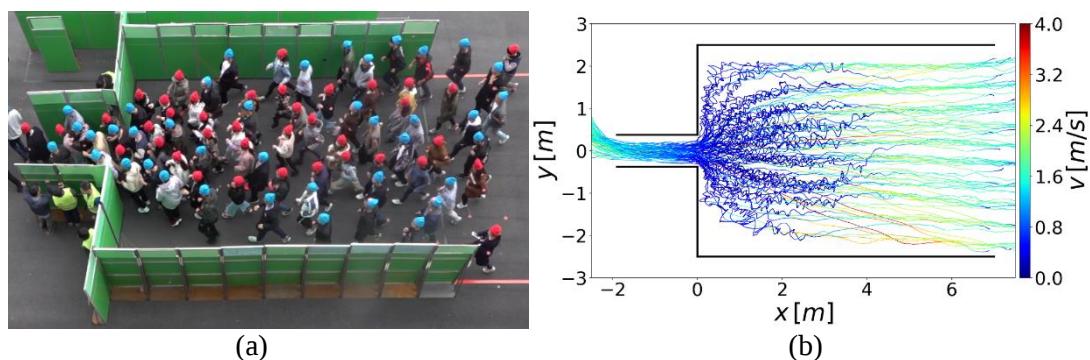


Fig. 1 (a) A snapshot of experiment for students evacuating through a bottleneck. Bottleneck width (b) ranges from 0.6 m to 1.65 m at 0.15 m intervals. Totally 86 students participated in the experiment. (b) Trajectories of the students in the run for the bottleneck width of $b = 0.75$ m.

In this work, we mainly focus on evacuation characteristics of running adults through a bottleneck with varying widths (from 0.60 m to 1.65 m at 0.15 m intervals) experimentally. A total of 86 students (41 females and 45 males) aged about 22 years old in a university participated in the experiment as shown in Fig. 1(a). The participants were asked to run out of the bottleneck carefully. The trajectories of each student were extracted semi-automatically through the recorded videos by using the software PeTrack [5]. During the experiment, students were highly motivated and tried to leave the bottleneck quickly. Twisting behaviors were observed at the bottleneck which improved the flow. Fig. 1(b) shows the trajectories for the run with bottleneck width of 0.75 m. The speeds of frontal pedestrians are nearly 4 m/s observed from the velocity information in Fig. 1(b). Pedestrians at the back of the queue are eager to leave the bottleneck and swing their heads to find a way as the oscillating trajectories shows. The influence of bottleneck width on the flow is analyzed and compared with that of adults walking in normal conditions. The distributions of density before the bottleneck entrance are analyzed by constructing the contour lines of local density field. These findings can help design buildings and help understand the movement characteristics of crowds.

References

- [1] A. Seyfried, O. Passon, B. Steffen, M. Boltes, T. Rupprecht, and W. Klingsch, "New Insights into Pedestrian Flow Through Bottlenecks," (in English), *Transportation Science*, vol. 43, no. 3, pp. 395-406, Aug 2009.
- [2] D. Helbing, I. Farkas, and T. Vicsek, "Simulating dynamical features of escape panic," *Nature*, vol. 407, no. 6803, pp. 487-90, Sep 28 2000.
- [3] X. D. Liu, W. G. Song, and W. Lv, "Empirical data for pedestrian counterflow through bottlenecks in the channel," (in English), *Conference on Pedestrian and Evacuation Dynamics 2014 (Ped 2014)*, vol. 2, pp. 34-42, 2014.
- [4] S. P. Hoogendoorn and W. Daamen, "Pedestrian behavior at bottlenecks," *Transportation science*, vol. 39, no. 2, pp. 147-159, 2005.
- [5] M. Boltes, A. Seyfried, B. Steffen, and A. Schadschneider, "Automatic extraction of pedestrian trajectories from video recordings," in *Pedestrian and Evacuation Dynamics 2008*: Springer, 2010, pp. 43-54.

ORAL 6TA

Corresponding author: Yifan Zhuang

Affiliation(s): ¹College of Urban Railway Transportation, Shanghai University of Engineering Science, Shanghai, P. R. China. ²Institut fuer Theoretische Physik, Universitaet zu Koeln, D-50937 Koeln, Germany

⁴State Key Laboratory of Fire Science, University of Science and Technology of China, Collaborative Innovation Center for Urban Public Safety, Hefei 230026, P. R. China

In this study, pedestrians from entrances in different directions were arranged to pass through a room with one exit (Fig.1). The real-time pedestrians' trajectories are extracted through a high accuracy indoor positioning technology — Ultra-wideband (UWB). With four base stations located at four outside corners, the pedestrians' motion animation can be displayed at all times by tracking their electronic tags (Fig. 2). The pedestrians were required to walk normally or queue through the exit successively. Macroscopic pedestrian's behaviour is evaluated by actual outflow, local density and passing velocity against time. By comparing several fundamental diagrams, **the experiment results are consistent with the observational findings with the entry restriction at the traffic bottleneck.** Besides, the crowd phase and area show different patterns when pedestrians enter the room with a mixture of different entering directions. The achieved results represent useful empirical data for the calibration and validation of models to simulate **the inner order regulation behaviour of crowd dynamics** when there are restriction measures at bottleneck, but also for the development of automated positioning techniques for data collection and analysis.

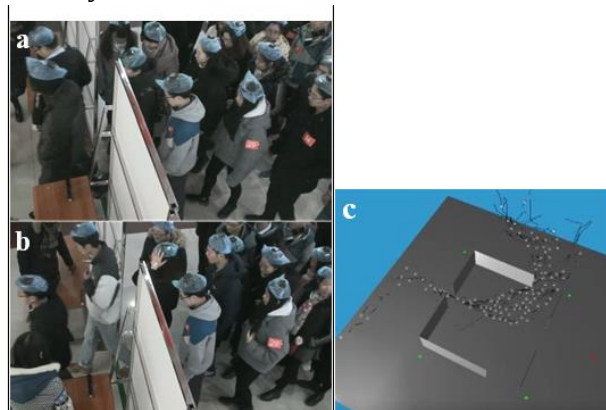
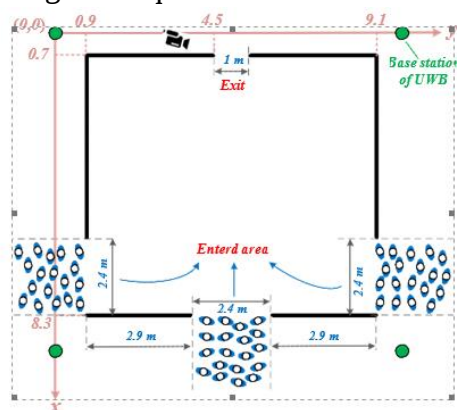


Fig.2 (right) Screenshots of pedestrians through the exit. (a) Normal condition; (b) Queuing condition; (c) Queuing condition of the trajectory animation.

Vadere – A simulation framework to compare locomotion models POSTER P52

Authors: *Benedikt Zönnchen, Benedikt Kleinmeier, Gerta Köster*

Corresponding author: Benedikt Zönnchen

e-mail: zoennchen.benedikt@hm.edu

Affiliations: Benedikt Zönnchen & Benedikt Kleinmeier: University of Applied Sciences Munich, Technical University of Munich; Gerta Köster: University of Applied Sciences Munich

Georg Box once said, “All models are wrong, but some are useful”. This is certainly true for pedestrian dynamics. On top of that, the usefulness of a model depends on the real-world scenarios it is applied to. For example, the situation at a Christmas market is very different from the evacuation of a building and one set of equations modelling both situations might not be available. We present Vadere, a platform-independent simulation framework for pedestrian dynamics to help distinguish between and assess the many different locomotion models. Vadere is designed to enable researchers from our interdisciplinary community to compare existing and new locomotion models. On the one hand, Vadere already contains a range of different locomotion models like the Optimal Steps Model [1], the Social Force Model [2] and the Gradient Navigation Model [3]. On the other hand, additional models can be implemented quickly because developers can focus on the model code. The common code base offers the rest. This includes the scenario geometry, modern algorithms and data structures, and many more tools like a graphical user interface, Python scripts to compare simulation outputs and a command line interface to run multiple simulations in a systematic manner. All these features facilitate comparison of different locomotion models and open this analysis technique to an interdisciplinary community. We show a real-world example of how to compare different microscopic locomotion models with our framework. Similarity of outcomes is measured using established microscopic as well as macroscopic metrics. Aside from quantitative aspects, we will also discuss the visual result of simulations, i.e. which parameters or model characteristics cause a specific movement pattern. In [4] a comparison of the Optimal Steps Model and the Social Force Model was presented. Since then, the Optimal Steps Model has been extended by the personal space theory [5]. To evaluate the effect of the model adaptation, we include the Social Force Model as well as the Optimal Steps Model in its current state into the comparison. Finally, we give further insight into the Vadere software, its purpose, software design, and discuss strengths and weaknesses.

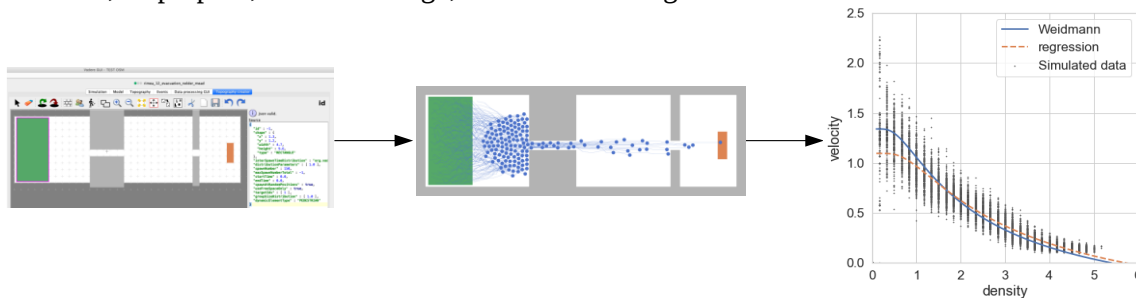


Figure 1: From left to right: Set up, run and analyze a pedestrian dynamic simulation with Vadere and its shipped Python scripts.

References

- [1] Seitz, Michael and Köster, Gerta, Natural discretization of movement in continuous space, *Physical Review E*, 2012
- [2] Helbing, Dirk and Molnar, Péter, Social Force Model for pedestrian dynamics, *Physical Review E*, 1995
- [3] Dietrich, Felix and Köster, Gerta, Gradient navigation model for pedestrian dynamics, *Physical Review E*, 2014
- [4] Stefan Seer, A unified framework for evaluating microscopic pedestrian simulation models, *Doctoral Dissertation*, Vienna University of Technology, 2015
- [5] Von Sivers, Isabella and Köster, Gerta, Dynamic Stride Length Adaptation According to Utility and Personal Space, *Transportation Research Part B: Methodological*, 2015

From the conference room to the university canteen: a 15 minute walk

