Challenge name	*Crowdflow*
Challenge owner	*TU/e*
	□ *Company* π *Research* □ *Student team*
Brief summary	Pedestrians walking in crowds show complex dynamics and stunning collective motions. This challenge focuses on the development of quantitative models and fundamental understanding of the dynamics of human crowds, including the possibility to nudge crowd behaviors (e.g. via visual or audio stimuli). In this way we plan to achieve more efficient, safer and enjoyable commuting experience in dense urban environments.

About the challenge owner

Prof. dr. F. Toschi is responsible for the USE Learning Line “Physics of Social Systems”. Stakeholders include but are not limited to: ProRail, Signify (previously Philips Lighting), the TU/e Intelligent Lighting Institute (ILI). The USE LL has connections within several departments and research groups at TU/e who can support students during this project: Centre for Analysis, Scientific Computing and Applications; Fluids and Flows group; Scientific Computing group; Data mining; Philosophy & Ethics; Signal Processing Systems group; Security W&I group Human Technology Interaction group; Innovation, Technology Entrepreneurship & Marketing group, Building Lighting group and the Future Everyday group.

Challenge description

The quantitative modelling of social systems naturally lies at the crossroad between physics, mathematics, psychology and ethics. The topic of this challenge is the modelling and nudging of human crowds in dense urban settings. ProRail is the main stakeholder, offering guest lecturers and facilitating access to data and train stations for simple measurements and experiments. Eindhoven train station has been equipped with sensors in order to allow quantitative studies and experiments involving the nudging of human crowds. Other stakeholders involve the Intelligent Lighting Institute (ILI), Signify, Amsterdam municipality, Eindhoven municipality and several others.

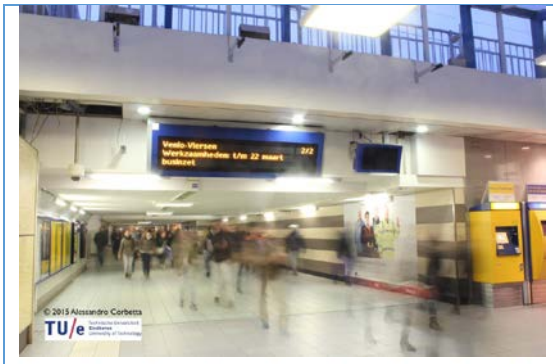
Only recently the quality and quantity of data about social systems could allow considerable progress. Today, thanks to the recent enormous advances in technology and communications, we have potential access to enormous databases that quantify -with very high accuracy- the way humans interact in crowds both virtually (e.g. on social media, in investment strategies, in spending patterns, reading material, etc.) as well as in real-life (e.g. tracking of individuals' location via GPS or via electric travel documents, etc.).

This unprecedented availability of data has already led to a vast number of applications while many more are still beyond our imagination. For such applications to be successful knowledge of physics alone no longer suffices. Instead, interdisciplinary approaches are needed.

In this challenge students are expected to bring together mathematical, physics (model driven) and machine learning (data driven) modelling approaches with ethics and psychology on a concrete and challenging real-case problem.

For this challenge students will develop a way to quantify, model and nudge the dynamics of human crowds. They will also realize a concept that can be tested in a real environment such as on the train platform in Eindhoven Central Station, at a festival (such as GLOW), in a living lab (such as Markthal or 3D virtual environment if COVID-19 restrictions still apply). For this purpose several elements will need consideration: the physical model with its mathematical description (possibly including algorithms or machine learning approaches), the system design, the sensors to monitor people and crowds and the lighting scenarios to influence the behavior of people.

Challenge Picture



Input and involvement of challenge owner

Concretely a large number of resources will be made available to students, these include:
Inspiration and coaching from Stakeholders (including ProRail, Signify, municipalities, TU/e Intelligent Lighting Institute,...)
Coaching from a highly multidisciplinary team with expertise in Physics, Mathematics, Computer Science, Ethics, Psychology
Access to experts of TU/e Intelligent Lighting Institute
Access to lighting armatures, state-of-the-art sensor networks and control software for testing in the real world
Access to the sensors network of the partners for additional hardware, interviews and test locations

Resources

What resources do you offer to students?

π Expertise; in physics modelling, mathematics and machine learning, ethics and psychology
π Materials; student will have access to the network of sensors deployed at Eindhoven train station and to the nudging equipment. We can also make data from other train station available to student
π Workplace; the lectures and meeting are normally happening in the Innovation Space
□ Other; ...

Roles of different disciplines (only for ISBEP)

Please describe possible contributions you expect to see from as many disciplines as you see fit for this project.

Automotive Technology	
Biomedical Engineering	
Architecture, Urbanism and Building Sciences	Considering how space (but also explicitly light) around humans shapes the way it is used and influences the behaviour of the people. Influence the usage of an environment through design elements. Providing insight in the requirements from multiple locations, thereby contributing to the scalability of the design.
Computer Science and Engineering	Development of the system architecture and data analytics in internet of things and smart spaces context, privacy issues, software, algorithms for intelligent lighting systems, control systems, real-time systems and system architecture.
Data Science	Design of data-handling, data-processing, deep-learning and control. Analysing the data that concerns crowds, to eventually design an optimal intelligent lighting application.
Electrical Engineering	Designing complex systems, electronical design and sensor technology. Working on algorithms for intelligent lighting systems, signal processing, wireless communication networks (incl. Lifi), data analytics, architectures and systems for lighting applications and security with noisy data.
Industrial Design	
Medical Sciences and Technology	
Psychology and Technology	
Chemical Engineering and Chemistry	
Sustainable Innovation	Considering the environmental impact of the intelligent lighting application and whether the design of the system could enable circularity (e.g. with 'lighting as a service' business models).
Industrial Engineering	Developing a business case and business model that makes the concept economically viable for multiple

	stakeholders, conducting a market analysis or designing the supply chain.
Applied Physics	Designing the system, e.g. including data-handling and sensor technology. For example, automatically localizing pedestrians in real-life conditions through overhead depth imaging using neural networks, data augmentation and custom data annotation strategies. Work on a robust and scalable machine learning-based localization algorithm, which delivers near-human localization performance in real-time. Crowd dynamics has similarities with fluid flow, and is therefore also interesting to look at.
Applied Mathematics	The skills of mathematics students in data-handling, complex systems analysis and modelling are relevant in the realisation of the project. Crowd modelling describes the 'flow' of a large group of people, typically in a major train station or entering a football stadium. The dynamics is often modelled in terms of attractive/repulsive forces between members in the crowd. It would be interesting to develop and evaluate mathematical models describing the impact of several lighting scenarios on the movement of crowds. It is anticipated that numerical analysis and stochastics are relevant for this project.
Mechanical Engineering	Structural/mechanical design, modelling, programming, and especially control/sensor technology.