TraForSafe
Vehicular and pedestrian traffic models: From flow forecast to safety management

Politecnico di Torino and Compagnia di San Paolo Starting Grant
"Attracting Excellent Professors"

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The **TraForSafe** project, "Vehicular and pedestrian **TRA**ffic models: from flow **FOR**ecast to **SAFE**ty management", has received funding from the Compagnia di San Paolo (Torino, Italy) in the frame of the Politecnico di Torino Starting Grant "Attracting Excellent Professors".

Description of the research

Reference ERC panels

- `PE1` Mathematical foundations
  - `PE1_20` Application of mathematics in sciences

Research context

This research project deals with the modelling and simulation of traffic flows, whereof **vehicular traffic** on road networks has historically been one of the motivating applications [1]. Nevertheless, the methodological approach promoted in the project is suitable to tackle also similar systems, such as **pedestrian flows** and their interplay with the built environment, which are nowadays receiving a considerable attention from multidisciplinary scientific communities [2].

The project fits into the broad research line on **multiscale models**, which investigate the spontaneous emergence of macroscopic properties of the flows out of a detailed analysis of the microscopic interactions occurring among the "particles" of the system, either vehicles or pedestrians. Specifically, a hallmark of the project is that it focusses on the whole path from the stochastic microscopic phenomenology of human behaviour, which triggers most of the observable phenomena, up to the global macroscopic description of the flows, which ultimately meets the engineering need for bulk results. To accomplish this goal it is necessary to pursue new analytical and computational modelling methods, which are not yet fully developed in the existing literature.

Goals and expected results

This research project intends to push ahead with the study of two classes of equations, which have proved particularly promising for realising the multiscale bridge between the individual behaviour and the emergent collective dynamics mentioned above. One class is that of the **Boltzmann-type kinetic equations**, which provide a synthetic (aggregate) statistical description of the macroscopic effects out of the modelling of the microscopic, possibly random, behaviour of the single particles [3, 4, 5, 6, 7]. The other class is that of the **multiscale conservation laws** [8, 9, 10, 11], which incorporate the microscopic and macroscopic representations of a particle system into a single description, thereby letting the trajectories of the particles and their density evolve simultaneously and affect each other.

The goal is to use such mathematical formalisms to enrich the flow forecast with some aspects of **individual risk dynamics** and **collective safety**.

A non-negligible part of the risk in vehicular traffic is due to individual microscopic causes, such as the driving style or the level of attention, which have a strong impact on the resulting macroscopic flow. Likewise, the onset and the propagation of a disordered microscopic behaviour among walkers in a crowd, for instance in case of panic, may pose serious threats to the collective safety. In other words, it is necessary to consider that the microscopic particle interactions are influenced also by a non-mechanical behavioural component related to the psychology of the individuals. This motivates the introduction in the models of specific behavioural parameters or state variables translating the ability of the agents to express context-dependent functions and goals and thus able to modify the standard evolution of more classical variables such as position and velocity.

The predictions of the models conceived according to this conceptual paradigm are expected to help assess the average safety levels and to suggest countermeasures to keep the risk under control and hopefully minimise it. In the case of vehicular traffic a possible implementation may be the design of **controller road signs**, which change during the time to instruct drivers on the basis of suitable risk indicators deduced from the instantaneous average flow. In the case of pedestrian traffic the results of the models may indicate instead possible strategies for a **structural optimisation of the environment** [12], with the aim of shaping the macroscopic flow into more ordered, thus statistically less dangerous, configurations even under altered emotional states of the individuals.

Parallel to the design of these models, the project will also care of the validation of their mathematical foundations. This means studying the qualitative properties of the solutions, their asymptotic trends and the numerical schemes employed in the simulations, e.g. convergence and accuracy.

Methods

The multiscale models and the related numerical techniques for their approximate solution will be developed in the frame of the following mathematical approaches:

- the **Boltzmann-type kinetic theory** complemented with **Fokker-Planck asymptotic** and related simulation methods [13];
- the **multiscale conservation laws** in the context of the **measure and optimal transport theory** [14];
- the **uncertainty quantification** to treat the stochastic variability of some microscopic parameters and to investigate their impact on the collective response of the system [15].

Contacts

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