Submission Title: Integration of a microscopic force-based 2D pedestrian simulation into a framework for large-scale transport systems simulation

Keywords: force-based 2D pedestrian simulation, large-scale transport systems simulation, multi-modal simulation

Conference Topics:

* Large-scale and transport modeling
* Model development and modeling methods

Transport simulation is an important research topic for many years. In general there are two different areas of transport simulations. On one hand, models have been developed for the simulation of large-scale scenarios with hundreds of thousands or even several million entities. On the other hand, there are models for smaller scenarios with some hundred or a few thousand entities. The former class of models usually deals with vehicular traffic, where a microscopic modeling of the physics is not needed an one, instead, can draw on simpler models known from the field of dynamic traffic assignment. The latter class of models usually deals with pedestrians, where the scenarios are often related to evacuation situations. In those scenarios a microscopic modeling of the underlying physics seems to be necessary.

In recent years, the interest in multi-modal simulation models has increased significantly. In such models, various transport modes are simulated simultaneously, including the interactions between agents using different modes. Typical fields of application are, for example, studies on car sharing and public transport.

However, attempts to implement a multi-modal simulation have to solve the problem that the computational effort to simulate large-scale scenarios with a microscopic model is enormously. To overcome this problem, we present an approach, where the level of detail within a model can vary. By doing so, it is, for example, possible to model interactions between cars and pedestrians only at selected areas.
To simulate the interaction between the transport participants, a microscopic modeling is needed. This calls for a multi-agent simulation, where every transport participant is represented by a software agent. In the simulation, agents make independent decisions. This can for example be route and destination choice (e.g. where to go shopping and which route to take to the shopping mall). The use of agents in a transport simulation gives the opportunity to model the human behavior in a realistic manner.

This paper introduces a combination of both—macroscopic and microscopic—approaches, where the vehicular traffic is simulated with a so-called queue model while the pedestrian movement is simulated by a force-based model. The obvious scenarios for such an approach are situations where the agents are arriving at a location by one mode of transport and then switching to another mode of transport.

The main advantage of the queue model is its computational efficiency, which is a basal requirement for large-scale simulations. In this model, the transport system is transformed into a network of links and nodes. Each link (street segment) is represented as a FIFO (first0-in first-out) queue. Every agent has to remain on the link for a certain time (free flow travel time). Each link has a specific outflow capacity, which corresponds to the flow capacity of the associated street segment. If at any time the outflow capacity is used up, no more agents can leave the link. Furthermore, each link has a specific storage capacity. If it is used up no more agents can enter the link.
In the force-based 2D simulation, the agents' high-level planning (i.e. route and destination choice) is performed on a graph representing the transport system, while the low level behavior (i.e. physical interaction between the participants) is simulated with a force-based model. In the force-based model the simulation entities are emitting repelling (other agents and obstacles) and attracting forces (goal locations). The force-based model itself is based on existing well established approaches.

A challenging task is to model the switch from one mode to another. This is particular complicated when the involved modes are simulated with different simulation models—i.e. switch from the queue model to the force-based model or vice versa. An example is an agent who arrives by car in a parking lot, simulated by the queue model, and then switches to a true 2D simulation model. The reason is that different models are simulating on different physical resolutions but nevertheless influencing each other.

The proposed approach is developed as an extension—which is based on [1] —to the MATSim framework. MATSim stands for Multi-Agent Transport Simulation and is widely used in the transport simulation community. The main field of application is the simulation of large-scale vehicular traffic. Balmer [2] gives a detailed description of the framework, its capabilities and its structure. MATSim's application to a large-scale Switzerland scenario (over 6 million agents simulated on a high resolution network with 1 million links) is presented by Meister et al. [3]. MATSim is also applied to other scenarios like large-scale pedestrian evacuation simulations or the simulation of air transport. However, so far all applications are based on the queue model.

The introduced multi-modal model is tested on a hypothetical scenario. In the scenario, the agents arrive at a metro station or parking area next to a shopping mall. After leaving the metro station, the agents have to cross a street before they enter the mall, go shopping and return back to the metro station. Once the agents are again at the metro station, they get on the next train. Agents arriving at the parking area can walk directly to the mall. However, the access road to the parking area crosses the footpath between the metro station and the shopping mall.

In this scenario there are three different modes of transport. First, there are trains serving the metro station. Second, there are pedestrians moving from the metro station to the shopping mall. The pedestrians are simulated by the force-based 2D model. And third there is traffic on the access road to the parking area next to the shopping mall.

The novelty in this paper is the combination of simulation models of different scales. The proposed approach gives the opportunity to simulate large-scale scenarios, while staying highly resolved where needed and being more aggregated where possible.

[1] G. Lämmel (2011) Coupling force-based and graph-based models for multi-agent wayfinding in complex environments, Working Paper, 11-20, VSP, TU Berlin, Berlin.

[2] Balmer, M. (2007) Travel demand modeling for multi-agent traffic simulations: Algorithms and systems, Ph.D. Thesis, ETH Zurich, Zurich, May 2007.

[3] Meister, K., M. Balmer, F. Ciari, A. Horni, M. Rieser, R. A. Waraich and K. W. Axhausen (2010) Large-scale agent-based travel demand optimization applied to Switzerland, including mode choice, paper presented at the 12th World Conference on Transportation Research, Lisbon, July 2010.