Modelling and Simulation of Mobility

Wolfram Ressel
Universität Stuttgart, Institut für Straßen- und Verkehrswesen
Pfaffenwaldring 7, 70569 Stuttgart, Germany
ressel@isvs.uni-stuttgart.de

Abstract: **The partial project „Modelling and Simulation of Mobility“ puts the main research ideas on time-discrete simulation of movement of single and several vehicles on road networks outside of built-up areas with microscopic models e.g. deterministic spacing models or psycho-physical spacing models. Also it is intended to simulate pedestrian movements on town places and in building complexes**.

Index term: **Microscopic simulation, Road Traffic Model, Pedestrian Movement Model, Augmented World Model**

I. Introduction

The neXus Center of Excellence comprises elementary methodical investigations into detailed describing of participants mobility in a considered spatial world model as well as concrete scenarios of traffic simulation. The achieved simulation results can be used on the one hand for the derivation of founded models on different system levels and on the other hand for further applications in a spatial world model. This makes possible to use directly the results in other partial projects, e.g. the input for modelling the local and chronological development of communication processes or adequate caching and hoarding strategies as well as the spreading of informations in dynamic systems.

II. Geometrical Basic Model

For road traffic or pedestrian simulations it is necessary to create a digital data basis of roads, squares or ways as the reflection of the real world. There are some data systems on the market which have to be changed into the neXus platform.

II.1 Architecture of neXus Platform

The neXus platform can be described as an open and distributed environment for local based informations. It consists of a federated architecture which manages services and information resources and provides a consistent view for the applications, named the Augmented World Model.

The Augmented World Model (AWM) is an object-oriented information model for local based applications [1]. It allows a unified view for the applications and enables the federation of spatial data from different providers. The object classes of AWM are defined in the Augmented World Schema (AWS). The AWS comprises the standard class scheme, a generatic set of all object classes, that might be relevant for location-based applications. To achieve a reasonable semantic, each standard class contains an extensive set of attributes. However, most of the attributes are declared optional. For example neXus service does not have to make the effort to provide all of the data, but if required, the name and type of the attributes are already defined. In case that an application still needs additional object classes that further specify the existing ones, they can be inherited from the class of the standard schema, forming a so called extended class schema (see Figure 1).

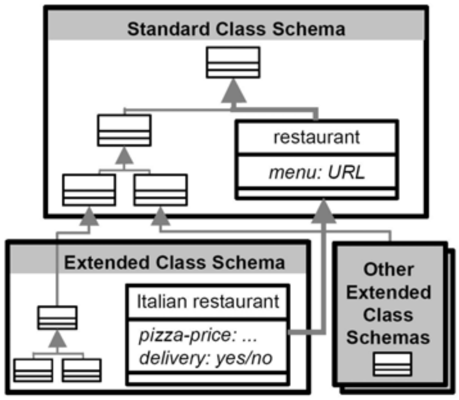

Figure 1: AWS standard class schema [2]

II.2 Existing Data Models for Road Data

Since the neXus platform was developed to provide an extensive and generic data basis for different kinds of location-based applications, it is the aim to integrate data sources from all possible application fields in the AWM. Therefore, existing data models has to be mapped onto the Augmented World Schema. In this way data from multiple sources can be federated since they are available in a common data format during the simultaneous use of already available data is guaranteed.

For road traffic models, e.g. on freeways, it is necessary to have a geometrical basic model for simulating different traffic conditions. In the recent years car navigation applications on the basis of digital road maps became very popular. The two most common road data models for Germany are the Geografic Data File (GDF) and ATKIS object catalogue.

The **GDF Data Model** [3] is an European standard that is used to describe and transfer road networks and road related data. It is much more than a common GIS data format. GDF regulates how data should be captured and how features and their relationships have to be defined. Features correspond to real world objects as roads and railways or administrative areas. The objects represented by point, line or area are called simple features, while comlex features are composed of a group of simple features. Features contain geometrical and topological informations, e.g. XYZ coordinates. In principle four feature classes are important for road traffic (see Figure 2):

1. *Junction* (point): feature bounding a Road Element
2. *Road Element* (line): smallest independent unit of the road network having a Junction at each end
3. *Road* (complex): contains different Road Elements
4. *Intersections* (complex): composed by Junctions and Road Elements

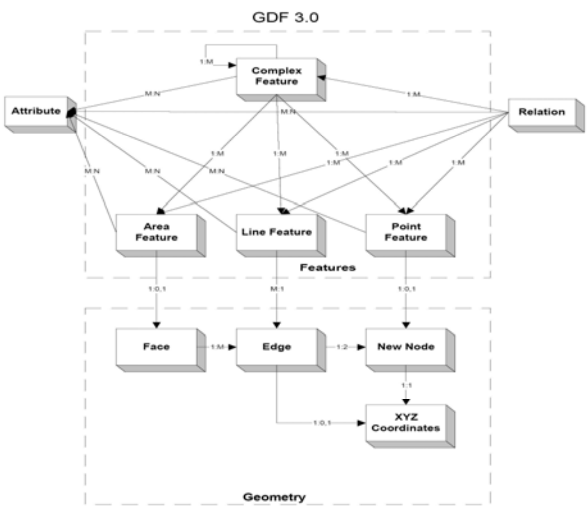

Figure 2: Simple and complex GDF features [2]

With the corresponding attributes to Road Elements it is possible to subdivide the lines into lanes and direction indicators with prohibited manoevres. This is an important fact for simulating lane changing and overtaking.

The **ATKIS Object Catalogue Data Model** has been developed by survey offices of the federal states of Germany [4]. ATKIS is ordered in seven functional classes (e.g. settlement or traffic), each functional class can be subdivided into object groups and these object groups include on the other hand several object types, which specify the geometrical representation and the attributes of the real world objects. The object groups are divided in object parts whenever the topology or attribute changes. Object parts contain the geometry of ATKIS objects as vector elements. ATKIS demands to build complex objects in case that a road has two or more physically seperated lanes.

For reaching an integration of these existing road data models in a extended class schema of the Augmented World Schema their original properties have to be mapped onto the corresponding object classes. So each object class of the GDF and ATKIS model has a precise relation to the classes of the Augmented World Schema. A more detailed insight is given in [2].

III. MODELLING AND SIMULATION

III.1 Road Traffic Model

A microscopic road traffic model is a computer simulation model of vehicle movements where every vehicle in the model is treated as individual to reproduce real traffic with longitudinal motion, turns, lane changing and overtaking based on physical kinematics. The main road traffic models for computer simulation are summarized below (according to [5]):

The **Deterministic Space Model** try to describe the spacing characteristics using kinematic variables (speed, deceleration, etc.). The model structure needs simplifications, particularly with respect to the relationship between the spacing and the driver observation-reaction process. An improved model proceeds from the safety requirement that the distance of two following vehicles is sufficiently large to avoid collission in any case.

In the reality, following drivers try to conform with the preceding vehicles´ behaviour. This process is called car following and is based on a cycle of stimulus and response, the so called **Car Following Model**. The nature of the response is an acceleration or a deceleration, delayed by an overall reaction time. This process therefore resembles a feedback control process in which oscillations may occur. In the past an entire family of car following models has been investigated based on the following general form:

$$\ddot{x}_{n+1}(t+T) = c\dot{x}_n^m(t+T)\frac{\left[\dot{x}_n(t)-\dot{x}_{n+1}(t)\right]}{\left[x_n(t)-x_{n+1}(t)\right]^l} \quad (1)$$

Psycho-Physical Spacing Models make it possible to combine car following models with psychological phenomena where drivers are subject to certain limits on stimuli to which they respond. The basis of such models is (see Figure 3):

1. at large spacings the driver of a following vehicle is not influenced by the size of the difference of velocity, and
2. at small spacings there are combinations of relative speeds and distance-headways for which there is, as in 1), no response of the driver of the following vehicle because of the too small relative motion.

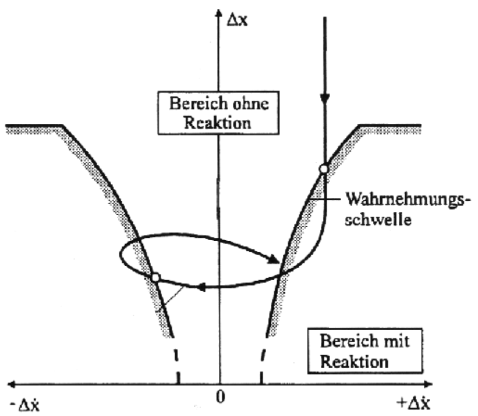

Figure 3: Psycho-Physical Spacing Model

In the **Cellular Automata Model** of Nagel and Schreckenberg [6] the road is thought to be subdivided into cells, each 7.5 m long, which corresponds to the mean frontbumper-frontbumper distance between two consecutive cars captured in a jam (see Figure 4). A cell is either empty or occupied by only one vehicle with a discrete velocity $v_i \in \{0; v_m\}$, when v_{max} is the maximum velocity. All speeds are measured in cells per time step. The motion of the vehicles is determined by rules for collision-free acceleration, randomisation and movement [7]. A time-step corresponds to Δt = 1sec (see Figure 4).

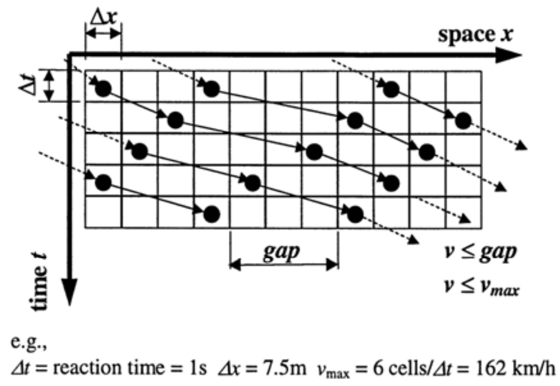

Figure 4: Cellular Automata Model

The objectives in the partial project „Modelling and Simulation of Mobility“ in neXus Center of Exellence are to find in

1. fast algorithms with cluster processes and parallel computing
2. GeoRef-Tool for vehicle movements in the third dimension
3. fundamental diagramms for the relation between traffic volume, speed and density (see Figure 5)

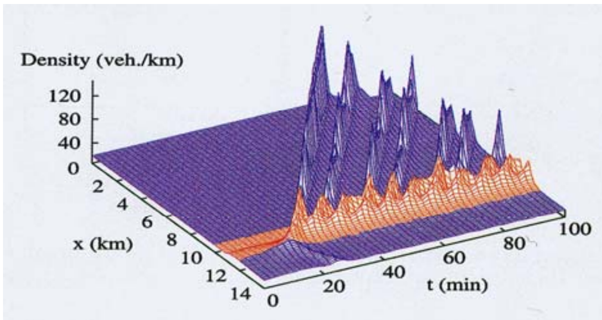

Figure 5: Examle of fundamental diagram

III.2 Pedestrian Traffic Model

A microscopic pedestrian simulation model is a computer simulation model of pedestrian movement where every pedestrian in the model is treated as individual. Most of pedestrian researches have been done on macroscopic level which does not consider the interaction between pedestrians and does not well suite for prediction of pedestrian flow performance in pedestrian areas or buildings. On the other hand, microscopic level has a more general usage and considers details of the design. The numerical solution of the analytical model for microscopic pedestrian models is difficult and simulation is favorable. The model has practical applications in evacuation from buildings, design of pedestrian areas and experimental and optimization design tools. There are several microscopic pedestrian simulation models:

The **Benefit Cost Cellular Model** [8] simulates the pedestrian as particle in a cell. Each cell can be occupied by at most one pedestrian and a score assigned to each cell on the basis of proximity to pedestrians. The score represents the gain made by the pedestrian when moving toward his destination. Where the field of two pedestrians overlap, the score in each cell is the sum of the score generated by pedestrian individually. The score is calculated in the nine-cell neighbour of the pedestrian (including the location of the pedestrian). Pedestrian will move to the next cell that has maximum net benefit:

The **Magnetic Force Model** [9]: The application of magnetic models and equations of motion in the magnetic field cause pedestrian movement. Each pedestrian and obstacle have positive pole. Negative pole is assumed to be located at the goal of pedestrians. Pedestrian moves to their goals and avoids collisions. Two forces act on each pedestrian. First, magnetic forces as formulated by Coulomb's law, which depends on the intensity of magnetic load of a pedestrian and distance between pedestrians. The exerted acceleration *a* is calculated as (see Figure 6):

$$a = V \times \cos(alpha) \times \tan(beta) \qquad (2)$$

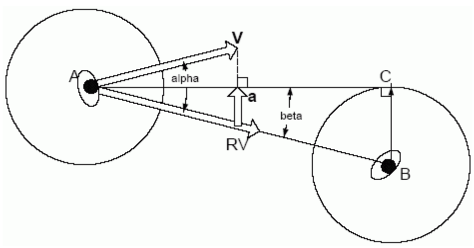

Figure 6: Magnetic Force Model [9]

The **Social Force Model** [10], [11] has similar principles of both, Benefit Cost Cellular Model and Magnetic Force Model. A pedestrian is subjected to social forces that motivate the pedestrian. The summation of these forces act upon a pedestrian create acceleration dv/dt as:

$$m\frac{d\vec{v}(t)}{dt} = m\frac{v_0\vec{e} - \vec{v}_i(t) + \vec{\xi}_i(t)}{\tau} + \sum_{j(\neq i)} \vec{f}_{ij}(\vec{x}_i(t), \vec{x}_j(t)) + \vec{f}_b(\vec{x}_i(t)) \qquad (3)$$

The first term on the right hand of equation (3) represents the motivation to reach the goal. The model based on the assumption that every pedestrian has intention to reach a certain destination at a certain target time. The direction is a unit vector from a particular location to the destination point.

The ideal speed is equal to the remaining distance per remaining time. The remaining distance is the difference between the destination point and the location at that time, while the remaining time is the difference between the target time and the simulation time. The second and last term on the right hand side of equation (3) designates for interaction between pedestrians and pedestrian to obstacles and interaction pedestrian with the boundaries.

IV. Conclusion

After one year of financing by the Deutsche Forschungsgemeinschaft (German Research Foundation) the convertation of optimal microscopic simulation models for road traffic and pedestrian movement onto the Augmented World Model is in the beginning and still in work.

The next steps in the research project are to construct the scaling of large road network systems in hierarchical geometrical models using data transmission into and from the Augmented World Model, the microscopic time-discrete simulation of vehicles and pedestrian movements, processing aggregated mobility data in movement profiles and the computer aided visualisation of spatial mobility.

V. References

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