
OBJECT-ORIENTED ROAD INFRASTRUCTURE FOR AGENT-BASED TRAFFIC SIMULATION

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Abstract

Agent-based modelling became very popular in many fields of science over last few years. Multi-agent systems (MAS) can simulate very closely behaviour of comprehensive, heterogeneous systems where another type of simulation fails. Traffic system is one of those complex systems. Microscopic traffic simulators based on MAS can model traffic system in realistic manner.

But realistic simulation cannot be performed without detailed representation of the road network. There is necessary to describe roads and crossroads up to the level of traffic lanes including lanes restrictions.

In this paper, an object-oriented road network environment for multi agent traffic simulation is present. The design of the environment based on the object structure was inspired by a standard for navigation data storage GDF. Additionally, road passport data from department of The Road and Motorway of the Czech Republic (Silniční databanka Ostrava) was used.

Keywords: ABS,MAS,GIS,traffic simulation

1. INTRODUCTION

Agent-based simulation (ABS) is a new paradigm that has been applied to simulation problems in biology, engineering, economics and sociology. Difference between classic simulation and ABS is in the point of view on simulating system. Classic simulation takes system as complex with the global rules and statistic description. In this case, model of system is characterized by global mathematic formulas and statistical functions. In contrast, ABS is focusing on system entities that form the system. The entities are described as autonomous units with its states and behaviors. In this case, simulation is based on interaction among entities (agents) and its environment.

One of the issues ABS is spatial context, spatial relations among agents and environment representation. These days, spatial ABS use regular grid environment model mostly. In these model is easy to define spatial relations, neighborhoods and movement definitions, but these model too much generalized real environment and can carries high spatial inaccuracy.

We designed object-oriented environment that represent real world at more realistic manner. The environment represent road network for traffic simulation. Road infrastructure and road furniture was generated from real road data.

2. ROAD NETWORK DATA MODEL

Present road network data representation is very simple. For instance, the GIS represent roads as line or polylines features connected by crossroads represented by point layer (Figure 1). In additionally, there are a few attributes of the road layer like number of lanes, road number, length, traffic directions. This information sufficient to common GIS analyses like finding optimal route,

service area definition and etc, but is deficient for precise simulation of individual car movement on traffic lanes.

More detailed information of road infrastructure has a data complying GDF international standard for transport telematics systems and car navigation. On the latest version of the standard GDF 4.0 concur NextMAP project, which extends description of the road. We used the ideas from this project to design object model of road infrastructure.

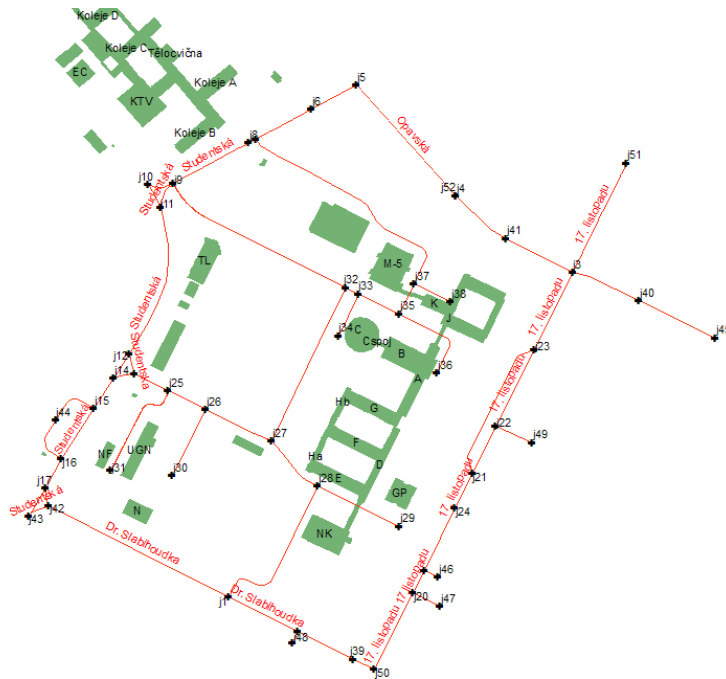


figure 1: Vector data model representation of road network(red lines)

1.1 Project NextMap

The NextMAP is research project to evaluate the technical and economical feasibility of enhanced map databases required for in-vehicle ITS applications[1]. The NextMAP project extend existing standard of data structure. There is three levels hierarchical structure of road infrastructure entities:

Level 0 - level 0 contain traffic lanes topology network described by Nodes and Edges, traffic lanes restriction

Level 1 - level 1 contain simple features road elements and junctions. At level 1 the features have attributes that are specific to the feature i.e. one way, width of road, number of lanes. Features also have relations like road element 1 has priority over road element 2.

Level 2 - the simple features are aggregate to a higher level feature. For instance, at level 1 all road element of an intersection should be presented. At level 2, the intersection is only represented with single point[1] depicted in figure 2.

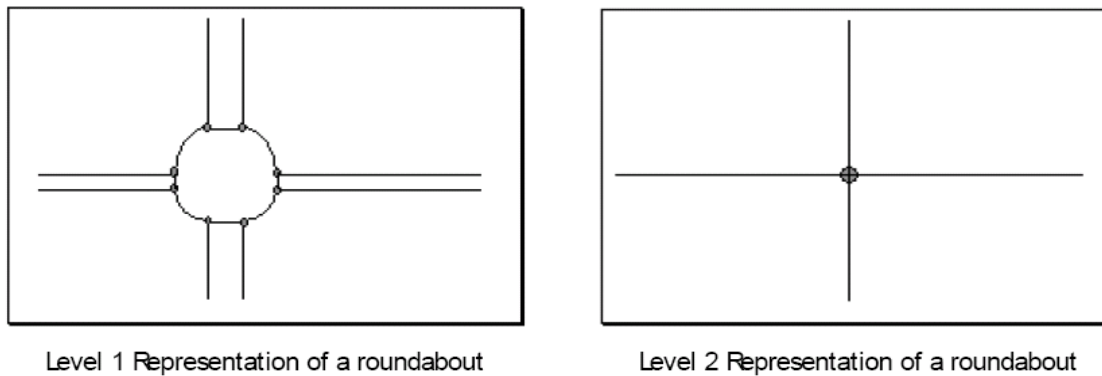


figure 2: Different representation of roundabout in level 1 and level 2 in NextMAP data model

1.2 Object-oriented data model

We have distinguished elementary road infrastructure entities from the NextMap model of infrastructure:

- level 2: roads, intersections
- level 1: road elements, junctions
- level 0: lanes

Relations of entities are depicted on figure 3. Road network entity (RNE) is abstract entity which defined the domain of entities.



figure 3: ER diagram of road infrastructure

The meaning of the levels is important for agent decision making conception. The intelligent mobile agent (described below) uses each level for a different task. The most abstract level 2 is intended for planning of the routes. The level 1 adds description of road like number of traffic lanes, traffic signs such as speed restrict, direction restriction, priority of the road. This level is important for driving decision process. The most detailed level 0 represent space by traffic lane set. In this level basic movement operation are simulated. The traffic lanes are identified by lane index and attributes such as width, turning restriction etc. These levels give awareness of spatial dislocation of all objects or agents on the road. Based on environment spatial information the mobile agent can for example analyse collision and adjust its speed or change movement direction.

The vector model commonly used for storage of GDF data is not suitable for ABS environment modeling, because relations and description of road entities are stored at relational databases approach. The better approach is object-oriented data model. The object encapsulates all

spatial and descriptive properties of entity. The objects can be easily connected to the graph structure which defines spatial relations. The mobile agents can perceive surroundings as collection of objects in certain distance and direction. Objects model is also convenient for the communication of agents. It is possible to build up ontology of objects that allow us to use logical deliberation and agents could exchange its knowledge of environment and use some kind of AI to making decisions. Class diagram of designed data model is depicted in figure 4.

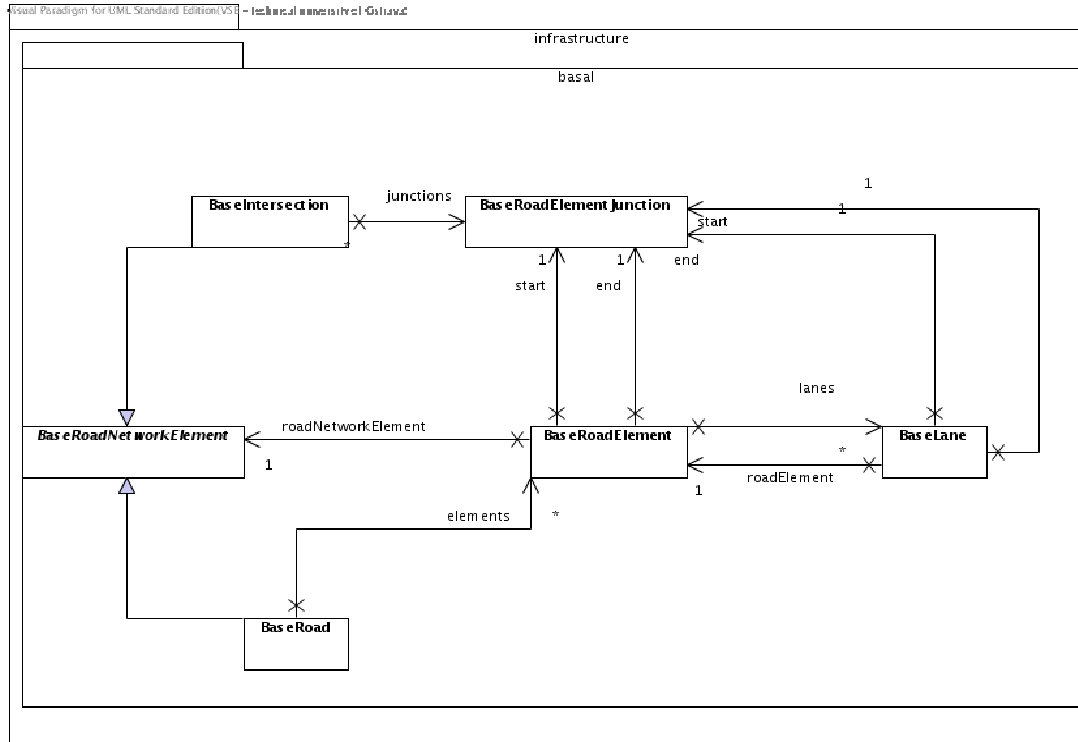


figure 4: Class diagram of road infrastructure

3. ROAD PASSPORT DATA FROM SILNIČNÍ DATABANKA OSTRAVA

Another problem of creating road network environment is getting real dataset to fulfill the road network objects. Data generally used in GIS doesn't cover all designed features. We have tested sample of TeleAtlas MultiNet road network data. These data theoretically satisfy our requirements but we don't have proper sample of dataset. At last, we used road inventory data of the Silniční Databanka of Ostrava (SDO). SDO administrate data of highways and road class 1,2 and 3 for Department of Road and Motorway Directorate of the Czech Republic in order to monitoring road layout condition, inventory of signs and other traffic furniture. These data have even more information that we need for creating intended infrastructure model. Unfortunately, the data model of road inventory is quite diverse from that we designed. There are several datasets:

- nodes localization system dataset
- constant parameters of road and crossroads
- non constant parameters of road and crossroads
- subsoil and construction layout of roads
- ecological information
- road constructions

Useful information for building agent environment contains dataset of constant parameters of roads and crossroads. These data are stored at two files in the ESRI Shapefiles format. One file (GIS layer) contains information about roads and the other contains information about crossroads. The road and crossroads geometry is represent only by points and polylines, but both files have additionally an attributes of the spatial representation. These attributes add missing spatial information of road objects

like width, length, spatial order and the other attributes enable to build the topology of road network. Here is the list of applied attributes [2]:

Road element layer

- road element id – composed id of start and end crossroad (important for building topology)
- section number– road element is composed of several sections. Every section holds constant values of attributes.
- traffic direction of road element
- total number of traffic lanes
- number of traffic lanes on the left side
- traffic restrictions
- length of section
- width of traffic lane

Crossroad layer

- crossroad id
- type of crossroad regulation
- number of connecting road elements
- description of road element connection (road element id, road id priority, number of lanes in/out the crossroad, connection angle)
- traffic lanes restrictions of connected road elements

Further, we have implemented parser for data of SDO that use JTS Topology Suite open-source library. The parser process raw SDO data and transform them to the object of road network.

4. INTELLIGENT TRAFFIC SIMULATION

The main goal of our project is to verify behaviour of intelligent agents in realistic environment. The ideas and implementation of realistic environment we described above. Further, we are going to describe the architecture of traffic simulator based on multi-agent system (MAS). As mention above, ABS perform simulation of complex systems with interaction of autonomous units - agents. The traffic system is such of complex system where interact many autonomous drivers. The developing simulator is trying to simulate behaviour of particular drivers in relation to designed object-oriented road network. The drivers behaviour is simulate by mobile agents with some degree of intelligent to deal basic drivers abilities such as accelerating, decelerating, overtaking, reading traffic signs and so on. The intelligence of agent is proceed by external application that we calling “agent brain”. Obviously, the simulation of many agents with own intelligent application is very computation consuming. Hence we have to design such simulator architecture that will be able to perform simulation in reasonably time. The solution of the problem is to distribute simulating agents and simulation environment on several computers connected in network (Internet) and define communication protocol (language). All this is handling by MAS, because multi-agent platform is inherently distributed and the communication of agent involving in MAS is based on sending and receiving multi platform messages. In fact, agents need to be able to communicate with users, with system resources, and with each other if they need to cooperate, collaborate, negotiate and so on. In particular, agents interact with each other by using some special communication languages, called agent communication languages, that rely on speech act theory and that provide a separation between the communicative acts and the content language[3].

So we build up entire simulator architecture on MAS. The architecture of simulator is depicted on figure 5.

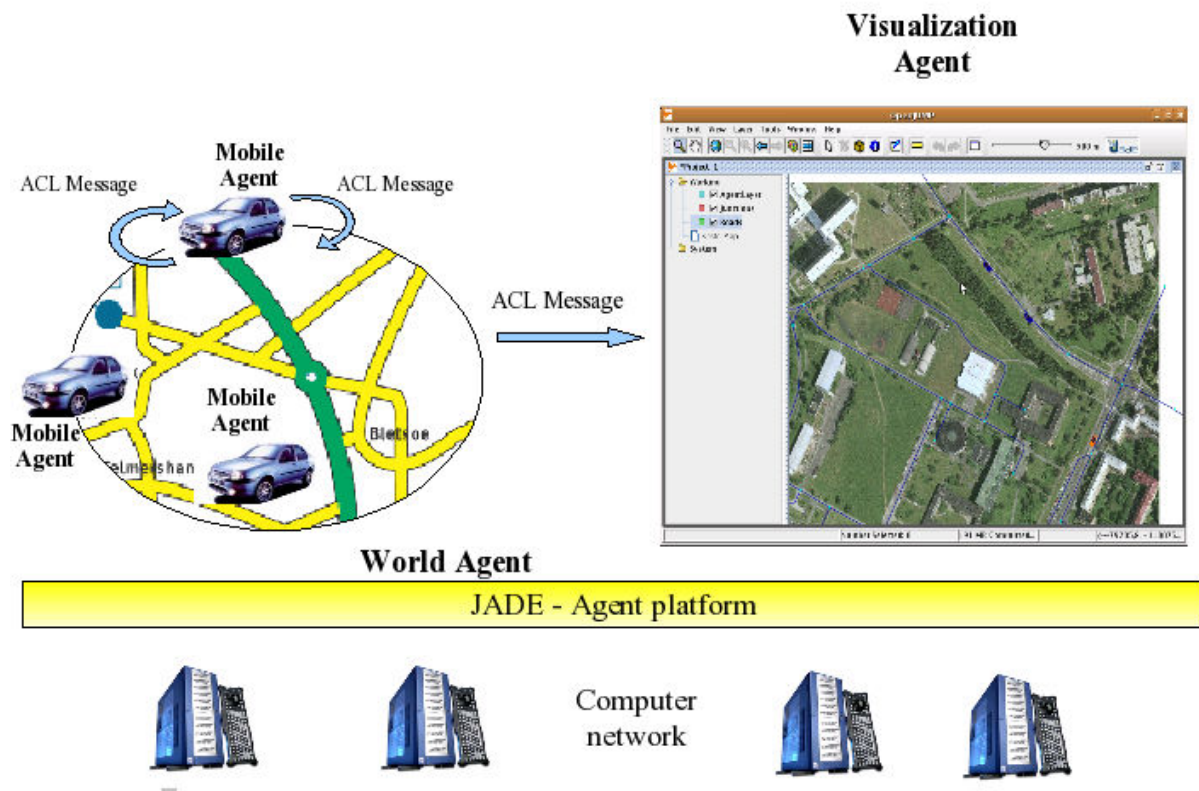


figure 5: Architecture of traffic simulator based on MAS

Here is short description of simulator agents:

World Agent - the world agent encapsulate road infrastructure and synchronized simulation time. The simulation time is divided to cyclic period. In the each cycle, world agent analyze mobile agent movement and send its coordinates to visualization agent. To announcement next time cycle world agent sending synchronizing messages to all mobile agents.

Mobile Agent – The mobile agents simulate drivers of cars on the infrastructure. Every mobile agent has defined basic collection of behavior for driving and planning routes. The position and description of surrounding infrastructure objects and mobile agents is getting from the world agent. The result of its deliberation process is sent back to world agent and then it waits to next time cycle. Each mobile agent can have a different set of parameters and driving habits. These parameters set user to control simulation.

Visualization Agent – The function of the visualization agent is to visualized simulation in some kind of application. We have implemented the visualization agent in open source GIS application OpenJump and we are working on visualization agent for leading GIS application ArcGIS. The GIS visualization was chosen because of used real geo-referenced data of road infrastructure. Moreover, GIS software is able to place the simulation on digital terrain model or aerial photography as is depicted at figure 6.

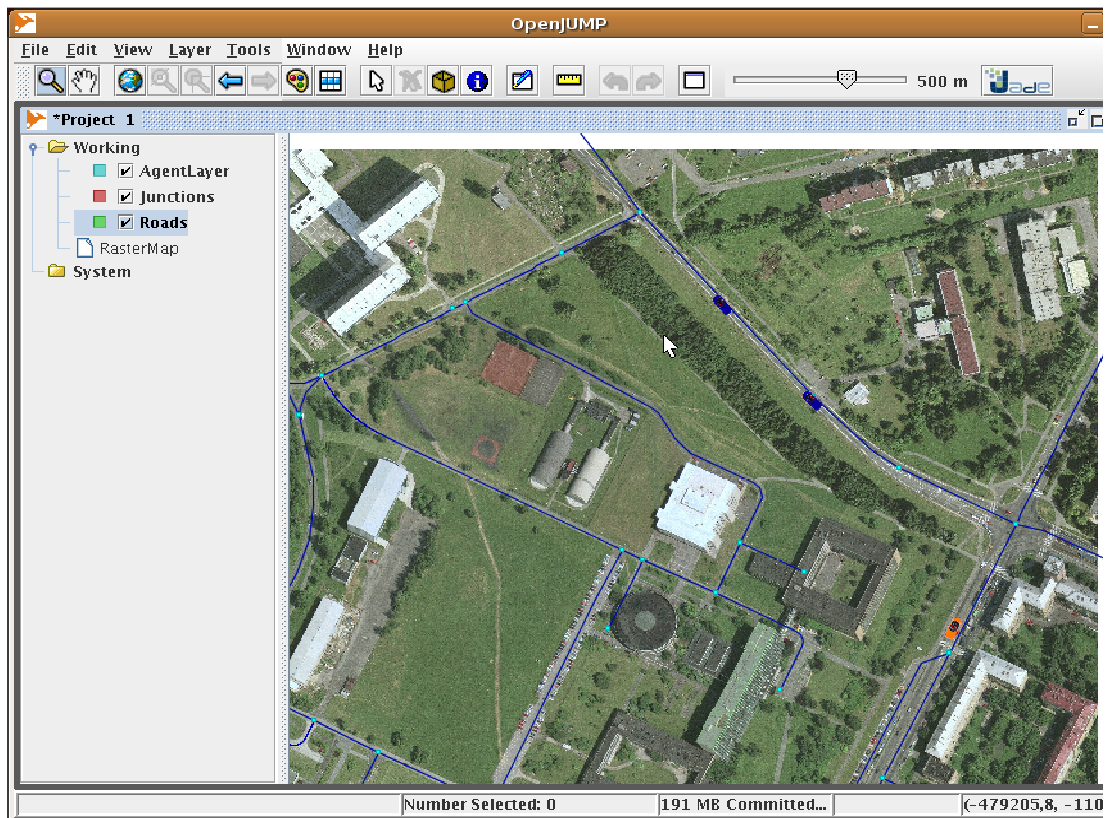


figure 6: Simulation visualization in OpenJUMP software

5. PRACTICAL APPLICATIONS

The traffic simulator based on MAS serves as case study for project Logic and Artificial Intelligence for Multi-Agent Systems. The project is concentrate on the development of a platform that affords a fine-grained natural-language analysis, specified in a formal language, which enables us to adequately represent knowledge in the multi-agent world. The external representation of particular pieces of knowledge will make it possible to design intelligent and relatively autonomous systems that can and must communicate with each other in a (pseudo-) natural language. Last but not least, the analysis and synthesis of intelligent systems that can derive useful conclusions under incomplete or imprecise knowledge is also studied[5].

Traffic simulation is appropriate environment for testing of agent's artificial intelligence and communication. There are autonomous entities (cars) with defined group of elementary driving behaviours and the traffic system defining rules and restriction that must be obey. All this can be easily represent by ontology and logical rules. The result of this research project can be useful in area of transport infrastructure development and the transport telematics applications. Here is a list of eventual applications:

- Rescue systems - advanced navigation through the road network which will be able to avoid congestions and dynamically find the optimal route which can minimize the time needed to get to the place of an accident and help to save human lives.
- Transportation of goods - goods transportation and delivery in urban areas represents a significant problem for the majority of cities. The key to success for the delivery companies is to transport goods at the right time, as fast as possible and for the lowest possible price. Wrong timing and coordination results in increased expenses, higher traffic intensity etc. Intelligent navigation systems can help to improve this situation.
- Security systems - Preventive safety applications help drivers to avoid or mitigate an accident through the use of in-vehicle systems which sense the nature and significance of the danger, while taking the driver's state into account. Preventive safety makes use of information, communications and positioning technologies to provide solutions for improving road safety. With such technology, which can operate either autonomously on-board the vehicle or co-

operatively based on vehicle-to-vehicle or vehicle-to-infrastructure communication, the number of accidents and their severity can be reduced, leading to a decrease in the number of accidents.

6. CONCLUSION

We have a designed and implemented object-oriented model of road infrastructure for traffic simulator based MAS. The road infrastructure model is built on ideas of international standard for intelligent transport systems GDF and project NextMap. The mayor benefits are complex description of real road network and usage of object-oriented approach. The complexity of road network model was achieved using data of road inventory from Silniční databanka Ostrava. Created model was used in traffic simulation that serve as testing platform for project Logic and Artificial Intelligence for Multi-Agent Systems.

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