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A Microscopic Traffic Simulation Web Toolkit

Kirill Pupynin*
Department of Information Systems and Technologies
Samara University
Samara, Russia
kir730@yandex.ru

Oleg Golovnin
Department of Information Systems and Technologies
Samara University
Samara, Russia
golovnin@ssau.ru

***Abstract*—There is presented a software toolkit for urban traffic simulation. The advantages of the toolkit are defined by using software implementation based on a web-oriented approach that does not require the installation of any programs as well as high-performance hardware. In order to increase the modeling efficiency, the toolkit uses layers: road network elements are placed on the first unchanged static layer; vehicles are placed on the second dynamic layer. Vehicles are redrawn at each modeling step; the road network is redrawn on demand. The software toolkit is based on SUMO traffic flow simulator by TraCI protocol for data transfer. The paper describes a component and structural diagrams of toolkit architecture and contains developed data processing algorithms. The technique of hardware optimization required for traffic modeling is implemented through the use of design patterns. The graphical user interface of the toolkit for changing modeling parameters during the simulation is presented. Modeling on a section of the road network of Samara, Russia was carried out. Based on the results of this modeling, restrictions are imposed on the size of the simulated road network and on the number of vehicles: total area of road network should not exceed 3 square km, while the number of road network elements should not exceed 10000, the total number of vehicles should not exceed 5000.**

Keywords—microscopic simulation, traffic flow, mobility, web-oriented approach, SUMO

I. Introduction

With the increase in cars, traffic jams also increase and road safety decreases. To rid cities of traffic jams and improve traffic management, there are many effective ways [1]. For example, intelligent transport systems (ITS), which provide end-users with greater information and security through the use of innovative developments in the regulation of traffic flows and modeling of transport systems [2]. Such systems can significantly increase the level of interaction between participants [3]. One of the ways of interaction is the modeling of the traffic of the road network sections [4]. A key part of intelligent transport systems is VANET, which uses wireless technology to helps road users join in groups [5]. In addition, modern systems use electronic terrain maps and geographic information systems [6]. However, before the introduction of ITS and VANET networks on the roads, realistic computer simulations using a combination of urban traffic simulation and network modeling are necessary [7].

At the moment, there are quite a number of powerful modeling systems that support the modeling of large-sized road networks: MATSim [8], VisSim [9], MOTUS [10]. Each of these products during the simulation is based on one of the groups of simulation models. As a rule, three groups of simulation models are distinguished, which differ in the degree of detail of the analysis performed: macroscopic, microscopic, and mesoscopic. All types of models are well described [11].

The main purpose of the work is to simplify access and end-user work with modeling software. In this regard, it was decided to implement a web-based toolkit for modeling, so the user can immediately get rid of such problems as the need to install any programs and dependence on the operating system. However, the most important thing is that the user doesn't need more powerful and expensive hardware since the simulation itself takes place on a remote server with which the client part of the toolkit will communicate. Thus, the user simulates traffic directly in the browser, adjusting the modeling parameters before it begins and directly during the process.

A microscopic simulation model was chosen for developing the toolkit because it achieves the greatest detail in the simulation due to the fact that each vehicle in the traffic flow is considered separately and modeled by its own equation, a function of its position, speed and acceleration [12]. As a modeling tool, the open-source microscopic simulator SUMO was chosen, which simulates various modes of transport, as well as pedestrian traffic, in addition, it supports the simulation of large road networks [13]. The toolkit is implemented using the approach described in [14].

II. Microscopic traffic flow model

The toolkit uses a microscopic model of a traffic flow that moves along various traffic lanes $\tilde{l}_i \in \tilde{L}$. Within the microscopic approach, each participant in the movement $\tilde{v}_i \in \tilde{V}$ is considered separately.

Objects of the class **Vehicle** $\tilde{v}^{\tilde{l}_i} = \left\{V_j{}^{\tilde{l}_i}\right\}$ are characterized by the following attributes: identifying number $id^V \in N = \{1,2, \dots, n\}$, vehicle type $vType^V \in VType^V$, route $route^V \in$ Lanes $= \{l_1, l_2, \dots, l_n\}$, $l_i \in$ Lane, Speed $speed^V \in R^+$, current lane $lane^V \in$ Lane, lane index $laneIndex^V \in N = \{1,2, \dots, n\}$, current position $position^V = \{x: double, y: double\}$, distance $distance^V \in R^+$.

Vehicle Type is represented by attributes: identifying number $id^{vType} \in N = \{1,2, \dots, n\}$, vehicle class $vClass^{vType} \in VClass^{VType}$ = {passenger, vehicle, truck, bus, ebus, etc}, color $color^{vType} \in Color\ [R, G, B]$, shape $shape^{vType} \in Polygon = \{p_1, p_2, \dots, p_n\}$, where pi = $\{x: double, y: double\}$, length $length^{vType}$, lane change model $laneChangeModel^{vType} \in\ string$, car follow model $carFollowModel^{vType} \in\ string$.

Car following model attributes are: $sigma^{vType} \in\ R^+ = [0,1]$, $tau^{vType} \in\ R^+$.

Lane is described as a set of the following attributes: identifying number $id^l \in N = \{1,2, \dots, n\}$, lane index $index^l \in N = \{1,2, \dots, n\}$, max speed $speed^l \in R^+$, length $length^l \in R^+$, shape $shape^l \in Polygon$ = {p1, p2, …, pn}, where pi = $\{x: double, y: double\}$.

III. Toolkit Architecture

"Fig. 1" shows the architecture of the toolkit. The end-user can download sections of road networks from open sources, such as the Open Street Map, or choose from the proposed ones. After the map is transferred and processed by SUMO, and the user clicks the "Start" button, the simulation will be launched, the application server will use TraCI protocol to obtain the necessary simulation data for processing and displaying it to the user in the browser. The user can pause the simulation or change the simulation parameters in real-time, then the application server will send the user commands SUMO, so that, in turn, change the simulation parameters. Thus, the user will not need to install any software on his computer, as well as worry about its performance.

When implementing the toolkit, we were faced with the problem of spending overhead on storing a huge number of objects in the program memory. Moreover, the application does not depend heavily on the identity of the object, and most of the internal state of some objects can be replaced by an external state. In this way, to reduce the load on the computer's RAM, it was decided to use the Flyweight design pattern. The essence of the pattern is to select a repeating state from the object and replace it with a link to the object that stores the external state, which can be the same for a large number of objects.

Consider the Vehicle class, take parameters such as vClass, color, sprite, length as an external state. We transfer these parameters from the Vehicle class to another class that will store the external state and call it VehicleType ("Fig. 2").

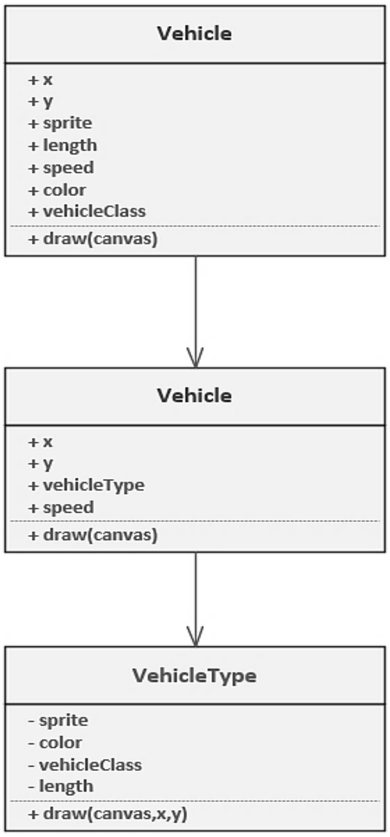

Fig. 2. Transferring the external state of the Vehicle class.

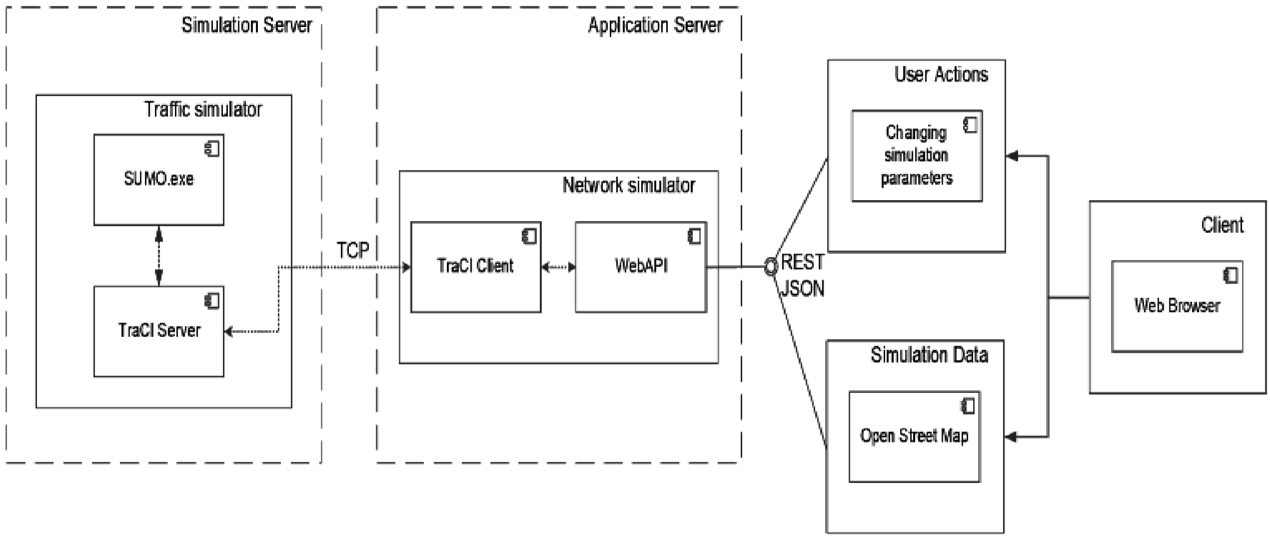

Fig. 1. Toolkit architecture.

The scheme for creating a new instance of the Vehicle class is shown in “Fig. 3”.

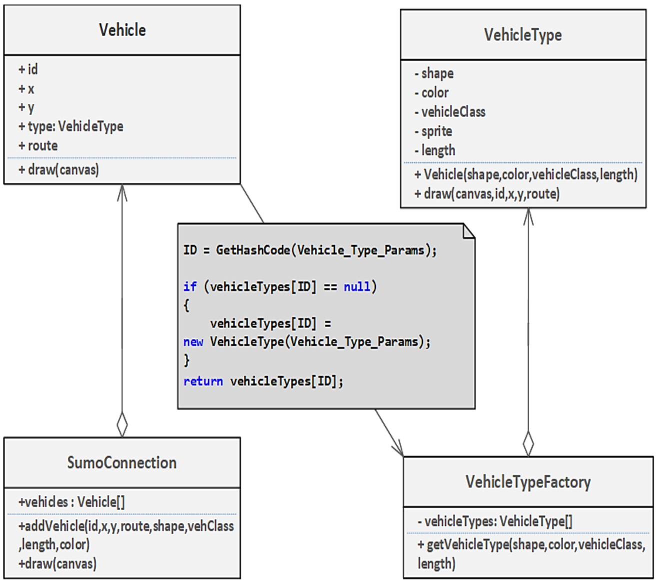

Fig. 3. Flyweight pattern implementation scheme.

IV. Results

We developed the web-based toolkit for road network modeling in the browser. The toolkit user interface is shown in “Fig. 4”.

“Fig. 5” demonstrates the operation of the tool in the process of modeling traffic flow. Simulation modeling is controlled by the user through the browser in the online mode.

The toolkit provides the following functions:

- open a simulation;
- open a network;
- start the loaded simulation;
- stop the running simulation;
- perform a single simulation step;
- locate any map objects such as edges, polygons, vehicles, junctions, etc.;
- edit visualization and viewport.

With the developed toolkit we carried out the modeling on a section of the road network of Samara, Russia. The modeling results show that to use the developed toolkit it is necessary that the total area of road network should not exceed 3 square km, while the number of road network elements should not exceed 10000, the total number of vehicles should not exceed 5000.

Regarding the approach with the Flyweight design pattern, the loading on memory was significantly reduced. Estimating the amount of engaged memory with the classic approach for 1 vehicle: ID – 4B, length – 4B, color – 4B, speed – 4B, vClass – 4B, position – 8B, sprite – 30KB. To simulate the movements of 10,000 vehicles, about 310 MB will be needed. Estimating the amount of engaged memory with the Flyweight approach for 1 vehicle: ID – 4B, position – 8B, speed – 4B, vehicleTypeID – 4B. Vehicle Type is estimated as following: vehicleTypeID – 4B, color – 4B, length – 4B, vClass – 4B, sprite – 30 KB. To simulate the movements of 10,000 vehicles, about 0.2 MB will be needed. Thus, the loading of computer memory was reduced by more than 1000 times.

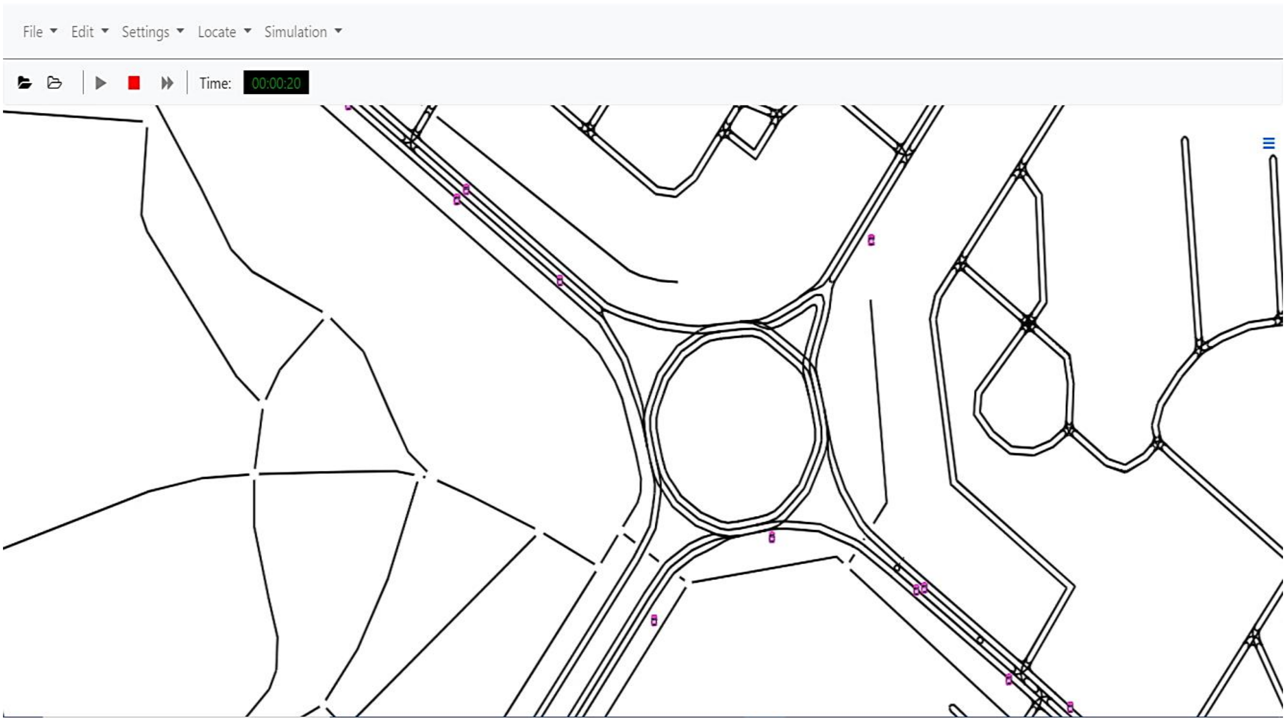

Fig. 4. Toolkit interface.

Fig. 5. Traffic modeling.

V. CONCLUSION

In order to increase the efficiency of traffic simulation, we developed the toolkit for modeling traffic flows based on a microscopic simulation model and multimodal modeling system SUMO. The created toolkit simulates road networks with a high degree of detail without powerful equipment and special software – the simulation in the toolkit is controlled from the browser.

The results achieved showed the ability to simulate a section of the road network consisting of several intersections. Further work will be aimed at increasing the size of the simulated street-road network and improving the quality of visualization.

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