Modelling Circulation Behaviour of Vietnamese: Applying for Simulation of Hanoi Traffic Network

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Abstract. Recently, there are many simulation models proposed for traffic simulation. Although there are some models which are able to simulate with a big number of transports, they are not easy to apply to the traffic situation and the circulation culture of Vietnamese. In Vietnam, most of transports are motorbikes. Their drivers do not always respect the circulation laws: they could go to anywhere as long as there is enough place in ahead to go. Moreover, most of streets in Vietnam have no lanes and no one respect the rule of following only one lane on a street. This paper introduces a simulation model and tool typically for the traffic situation and the circulation culture of Vietnamese. The model is also based on multi-agent system and then, it is applied to the traffic network of Hanoi city.

Keywords: Traffic status aware · Traffic network · Intelligent transportation network · Multi-agents system · Simulation model

1 Introduction

Recently, there have been many researches interested in the field of transportation network simulation. Therefore, there have been many models and tools proposed. Most of them are agent-based models. In which, intelligent agent and multiagent system seem to be suitable for simulate transportation network at the micro level. Each transport is thus modelled as an intelligent agent. It could observe other transports and obstacles to change its own speed as well as direction to go to its destination as fast as possible. The transportation network therefore could be modelled as a multiagent system whose each agent has a personnel goal (its destination to go) and they have to coordinate and/or interact together in order to prevent accidents from happening.

There are many models proposed in this tendency. For instance, MATSim development team [3] is developing a framework and platform for a transportation network simulation, called MATSim. MATSim provides a toolbox to implement large-scale agent-based transport simulations. The toolbox consists of

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several modules which can be combined or used stand-alone: toolbox for demand-modeling, agent-based mobility-simulation (traffic flow simulation), re-planning, a controller to iteratively run simulations as well as methods to analyze the output generated by the modules. SUMO (Simulation of Urban MObility) [2,6] is a highly portable, microscopic road traffic simulation package designed to handle large road networks. It is mainly developed by employees of the Institute of Transportation Systems at the German Aerospace Center. SUMO allows to simulate how a given traffic demand which consists of single vehicles moves through a given road network. The simulation allows to address a large set of traffic management topics. It is purely microscopic: each vehicle is modelled explicitly, has an own route, and moves individually through the network. Al-Dmour [1] developed TarffSim, a Multiagent Traffic Simulation for micro-simulation and macro-simulation of traffic. Gokulan and Srinivasan [5] have been implemented two different types of multi-agent architectures on a simulated complex urban traffic network in Singapore for adaptive intelligent signal control. Piórkowski et al. [9] are developing TraNS, an open-source simulation environment, as a necessary tool for proper evaluation of newly developed protocols for Vehicular Ad Hoc Networks (VANETs). Mengistu et al. [8] provided a framework for development and execution of parallel applications such as multi-agent based simulation (MABS) in large scale. Lotzmann [7] presented an agent-based traffic simulation approach which sees agents as individual traffic participants moving in an artificial environment.

In spite of many advantages in modelling of individual's behaviors in circulation of agent-based models, they have a limitation in the number of agents in a simulation, especially in a large scale as a transportation network. Although there are some models which are able to simulate with a big number of transports, they are not easy to apply to the traffic situation and the circulation culture of Vietnamese. In Vietnam, most of transports are motorbikes. Their drivers do not always respect the circulation laws: they could go to anywhere as long as there is enough place in ahead to go. Moreover, most of streets in Vietnam have no lanes and no one respect the rule of following only one lane on a street.

Our objective thus is to develop a simulation model and tool typically for the traffic situation and the circulation culture of Vietnamese. The model is also based on multi-agent system. However, in order to get over the limitation of scale in agent-based models, we do not visualise all the agents in their instant circulations. We show only the instant status of streets to see the level of congestion in streets as well as the global status of the traffic network. All calculation of activities and attributes such as speed, travel path, time, plans of individual agent and the level of congestion on streets, etc. are done in background processes of the model.

This paper is organised as follows: Sect. 2 presents our agent-based model for simulation of traffic network status. Section 3 presents the modelling of the agents in the proposed agent-based model. Section 4 presents a case study in which we apply the proposed model to simulate the traffic network status of Hanoi. Finally, Sect. 5 discusses the presented work and draws some perspectives for future work.

2 Propose Model

Our model is depicted in the Fig. 1. The main idea is to separate the visual level (presentation level) and the calculation level (Modeling and simulation level). This makes our model more flexible: it is easy to change the input data to display. The input data thus could be either that from simulation, or the realistic data captured from on site cameras. Moreover, this separation also limits the effects of processing speed on the visualisation: we could simulate the traffic network with a huge number of transports with a bit slow speed, but the results are then displayed as those of fast speed because the display is now independent from the calculation in simulation. This section presents the mains steps in our model. The module of *Agent Modeling* will be presented in Sec. 3.

– *Step 1: Load GIS files.* This step loads the GIS (Geographic Information System) files to create the roads network. The use of GIS files enables us to work with the realistic data from the real transportation network.
– *Step 2: Initiate agent position.* The second step initiates the agent's position. The position of agents is determined by a zone.
– *Step 3: Generate agent plans.* This step generate plans for each individual agent. The plans are generated based on the population distribution, the structure of jobs in society, and the distribution of offices, commercial centres, schools, hospitals, etc... in the city.
– *Step 4: Simulation.* Each individual is represented by an agent with its daily plans. At any moment, we can detect the position of agent on the road by considering two factors:

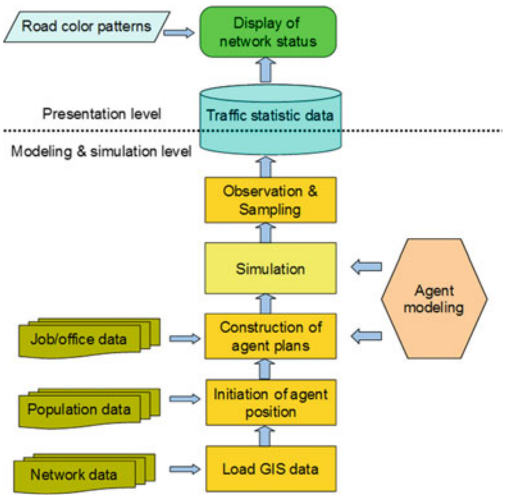


Fig. 1. Steps and processing data in the propose model

  - Its circulation path: this is either statically determined by the Dijkstra's algorithm (Dijkstra [4]), or dynamically optimum algorithm (modelled in Sect. 3.1).
  - Its speed: the real speed of agent.
- *Step 5: Observation and sampling.* The actual status of road is determined by the observation of the current through put of road a pre-planned time, this through put could be represented by the average speed of circulation on the road.
- *Step 6: Display road/network status.* The displayed color of road (intersection) depends on the circulation status of the road (intersection resp.):
  - Red: the road (intersection) is blocked
  - Orange: the road almost full, the vehicles movement is very slow
  - Yellow: the road contains many transports, the movement is slow
  - Gray: the road has a normal traffic, the movement is normal

3 Agent Modelling

In this section, we model all types of agent in the system. Section 3.1 will model the transport agent. Section 3.2 will model the traffic light agent.

3.1 Transport Agent

A transport could be a trunk, a bus, a car (including taxi), a motor. It has some attributes, behaviors and ability to move. So we need to model it as an agent in the system. Because a driver is assigned to his transport so we consider the whole of a driver and his transport as an unique transport agent.

Attributes. A transport has these attributes:

- *name*: name of a transport.
- *length (denoted as l)*: real length of a transport.
- *width (denoted as d)*: real width of the transport.
- *max speed (denoted as v_{max})*: the maximal allowed speed, for the transport, by law.
- *current speed (denoted as v)*: the current speed of the transport.
- *max technical speed (denoted as v_{tech})*: the maximal technical speed of a transport, limited by the engine of the transport.
- *safe front distance (denoted as d_f)*: the minimum distance to the nearest transport in front that keep safe for circulation. This distance is estimated by following formula:

$$d_f = \frac{l * v}{v_{max}} + \theta \tag{1}$$

  where θ is the minimum distance allowed among transports when stopping.

– *safe beside distance (denoted as d_b)*: the minimum distance to the nearest beside transport that keep safe for circulation. This distance is estimated by following formula:

$$d_b = \frac{d * v}{v_{max}} + \theta \tag{2}$$

– *accelerate factor (denoted as α)*: the ability to speed up in an unit of time.
– *decelerate factor (denoted as β)*: the ability to slow down in an unit of time.
– A set of *circulation plans* as depicted in Sect. 2.

Behavior. Behavior of obedient transport agents:

– *find a path*: this will find a path to go. A transport agent finds a path when: either it starts a new plan; or it want to change the path when it is blocked somewhere on the way.
– *observation*: this is an action of the driver of a transport, including of observation of the traffic light, observation of obstacles.
– *stop*: a transport agent stops at an intersection when the traffic light is in red.
– *accelerate*: a transport agent will accelerate when: (1) there is no obstacles in *safe front distance* and *safe beside distance* of it; and (2) its speed does not reach the *max speed* yet. The new speed will accelerate to:

$$v_{t+1} = min\{v_t + \alpha, v_{max}\} \tag{3}$$

where v_t, v_{t+1} are the speed of the transport agent at the simulation step $t, t+1$, respectively.
– *decelerate*: a transport agent has to decelerate when: (1) there is some obstacles in *safe front distance* or *safe beside distance* of it; or (2) it intends to stop. The new speed will decelerate to:

$$v_{t+1} = max\{v_t - \beta, 0\} \tag{4}$$

Behavior of disobedient transport agents who break the law has some differences in these actions:

– *accelerate*: a disobedient transport agent will accelerate when there is no obstacles in *safe front distance* and *safe beside distance* of it. The new speed will accelerate to:

$$v_{t+1} = min\{v_t + \alpha, v_{tech}\} \tag{5}$$

where v_t, v_{t+1} are the speed of the transport at the simulation step $t, t+1$, respectively.
– *decelerate*: a disobedient transport agent has to decelerate when: (1) there is some obstacles in *safe front distance* or *safe beside distance* of it; or (2) it intends to stop. The new speed will decelerate to:

$$v_{t+1} = max\{v_t - \beta, 0\} \tag{6}$$

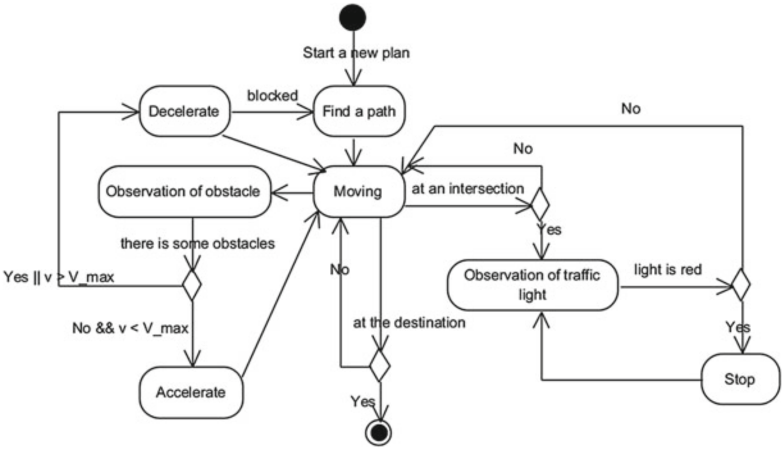


Fig. 2. Behaviors of transport agent

The transition among behaviors of a transport agent is depicted in the Fig. 2: A transport agent starts his movement by starting a plan on time. Firstly, it finds a path to go. During moving, it observes three kinds of objects: the traffic light, the destination, and the obstacle. In observing the traffic light at an intersection: if the light is red, it will *stop*; otherwise, it will continue to move. In observing the obstacle, it will *accelerate* if there is no obstacle and its current speed v is still lower than the allowed speed v_{max}. It will *decelerate* if there are some obstacles or its speed v is already higher than the allowed speed v_{max} (for the case of obey transport). It could re-find the path if it is blocked somewhere. Otherwise, it continues to move with the current speed. In observing the destination, if it is at the destination, it finishes the circulation. Otherwise, it continues to move.

3.2 Traffic Light

A traffic light plays the role of a traffic controller at an intersection. Although a traffic light can not move, it still has some attributes and behaviors as an agent. We thus need to model a traffic light as an agent in the system.

Attributes. A traffic light has attributes:

– A set of *control directions*: the directions that is controlled by a traffic light agent. An intersection could have several control directions (e.g. in the Fig. 3, there are four control direction for the intersection).
– Each control direction has:
  – *duration for green light (denoted d_g)*: during this interval (in seconds), the light is green for a control direction, and the transports could pass the intersection via the control direction of the traffic light agent.

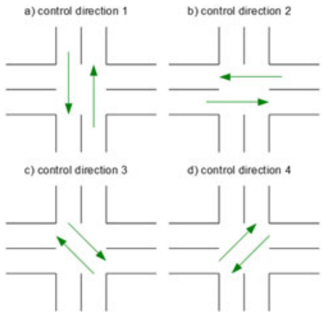


Fig. 3. An intersection with four control directions

- *duration for red light (denoted d_r)*: during this interval (in seconds), the light is red for a control direction, and the transports have no right to pass the intersection via the control direction of the traffic light agent.
- *minimum time for green light (denoted MIN_TIME)*: the minimum green light duration to avoid the case that the light color changes too fast.
- *maximum time for green light (denoted MAX_TIME)*: the maximum green light duration to avoid the case that the other control directions are blocked too long.
- *timer counting (denoted counter)*: the time counting variable to change the color of the light.

Behavior. A traffic light has three behaviors:

- *change to green*: when the light is in red and the *counter* value equals to d_r, the light will change to green, and the *counter* value is re-initiated by zero.
- *change to red*: when the light is in green and the *counter* value equals to d_g, the light will change to red, and the *counter* value is re-initiated by zero.
- *optimisation of green/red time*: the traffic light is able to dynamically update the d_g and d_r to optimise the traffic routing at the intersection. The algorithm will be presented in the next section.

The transition among behaviors of a traffic light agent is depicted in the Fig. 4: Firstly, it initiates the green/red time for each control direction. Then there is a loop of transition between *change to red* and *change to green*. This transition is controlled by the value of *counter*, in comparing with that of d_r and d_g. This loop works in parallel with the function of *Optimisation of green/red time*.

4 A Case Study: Simulation of Hanoi Traffic Network Status

This section applies the proposed model to simulate the circulation in the traffic network of Hanoi (the capital of Vietnam). Section 4.1 presents the modelling

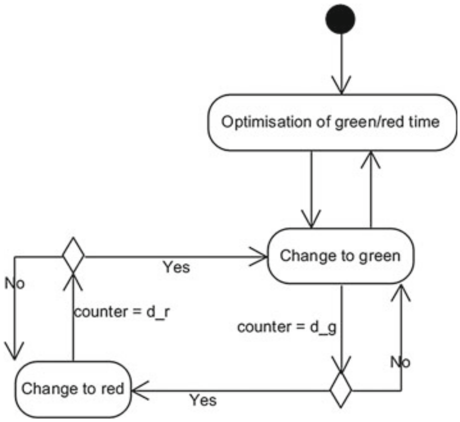


Fig. 4. Behaviors of traffic light agent

and simulation of the traffic network status. Section 4.2 presents the results in several points of view.

4.1 Simulation Setup

This section presents the applying of mains steps in the proposed model to model and simulate the traffic network of Hanoi.

Initiation of agents population.
The initial position of agents is created with the same rate of realistic population distribution of Hanoi, by districts. The destination of agents is determined based on its jobs and family situation. For instance, a student will go to his university. An officer may go directly to his office or pass over his or her son's school. The data about the distribution of offices, hospitals, schools, universities, tourist sites, commercial centres, manufactures, etc. is stocked in a GIS file. This enables us to capture the realistic position of an individual's destination, and then the real travel distance for each agent on its plans.

Construction of agent plans.
An agent's plan is created based on many information about the agent: its home position, its jobs will determine an office or a school. This will then determine the time and destination to move.

Once all agents' plans are planned for each day, we launch the simulation for the day and calculate the intensity of transportation on each street as the proposed model.

4.2 Results

This section presents some beginning results of the simulation at several levels: displaying, analysing, and validation of the dynamic optimum path finding.

Displaying level
The results of traffic network status are presented in the Fig. 5. These visual representations of traffic network status enable us to track and to compare the overall status of traffic network at many daily moments. These also show whether a moment is a rush hour or not. In order to represent more detail on the traffic network, our tool also enables to see in detail on any point on the network by clicking on it, there will be a small window with the detail information appears.

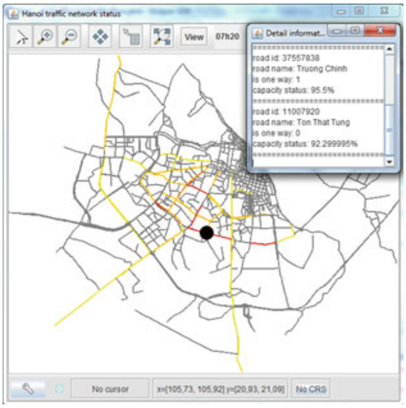
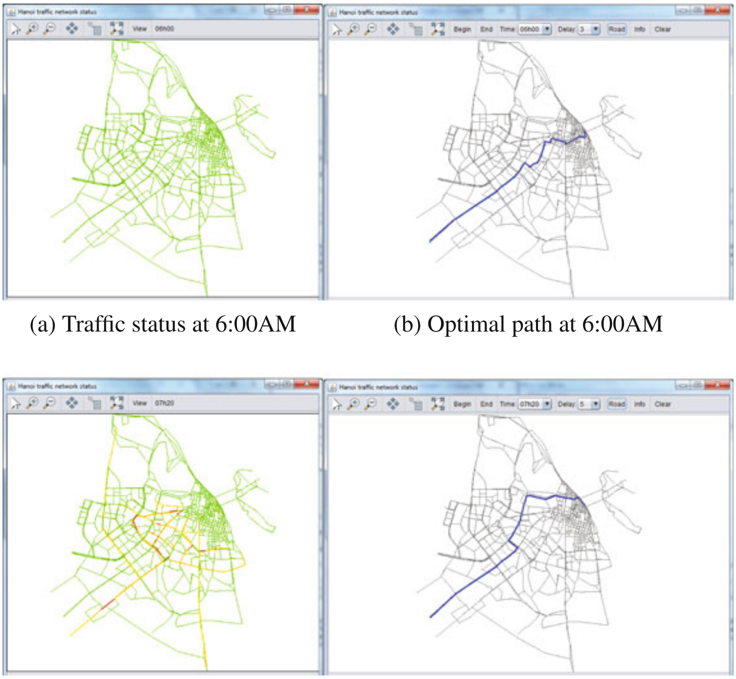


Fig. 5. Traffic network status and detail view on a point

Dynamic path finding.
The results are presented in Fig. 6. We compare the results from two different traffic conditions: low traffic condition and that in rush hour.

In the case of low traffic condition (all roads are in green status - normal speed, Fig. 6a), the found fastest path is very similar to the physical shortest path (Fig. 6b). This is reasonable: in a low traffic condition, drivers could drive with normal speed, this is the case to estimate the *static fastest path* which is identical with the physical shortest path.

In the case of high traffic condition (many roads are in red, orange, yellow - Fig. 6c), the found fastest path is different from that from the low traffic condition (Fig. 6d vs Fig. 6b). This difference indicates the dynamic in optimisation as well as the effects of taking into account the user preferences: If we choose the preference k different, the found fastest path will be different.



(a) Traffic status at 6:00AM (b) Optimal path at 6:00AM

(c) Traffic status at 7:20AM (d) Optimal path at 7:20AM

Fig. 6. The variations of optimal path depending on the traffic status

5 Conclusion

This paper proposed an agent-based model for simulation the traffic network status. The model is then applied to simulate the traffic network status of Hanoi. This model enables to show the instant traffic network status at any daily moment. This also helps us to analyse the statistic on some particular street as well as those of all streets in the network. Another advantage of this model is that it could simulate the traffic network status for any city as long as we have data about the real traffic network, the population distribution, and the jobs/age distribution of the city.

Testing some real scenarios in the traffic network to find out the best scenario, simulating to optimise some routing strategies, or evaluate some new propose policies on the urban circulation are our works in the near future.

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