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A road traffic simulation system with a microscopic model using a running line

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Abstract: Many road traffic simulation systems have been developed to analyze road traffic congestions in towns and city areas. However, most of them cannot typically be used for any other road traffic simulations, because they have been developed for analysis of such specified areas as intersections and roads, and because it is difficult to build the model which vehicle behaviors are described by their movement through two-dimensional space. Furthermore, simulations consume considerable execution time because of the complex vehicle models involved.

Therefore, these simulations are not remarkably effective. So, we propose a new type of road traffic simulation system to overcome these flaws. In this system, we adopt a traffic model where a vehicle has decision-making mechanism and runs along a running line. A vehicle usually describes a travel locus depending upon operations of a steering wheel. This locus is represented by the curve in proportion to angle and speed of a steering wheel. The curve is described by combining with straight lines, circles and clothoid curves.

A driver generally operates a steering wheel to aim at his image of its travel locus. Therefore, we adopt a vehicle model on the hypothesis that a vehicle runs along its travel locus.

Almost all travel loci are originally described based upon physical road conditions. If we find almost all travel loci of vehicles on road, they composite of a network on the roads like rail way. A network has originally points that traffic loci separate from or join to other traffic loci. A point is defined as a node and a unit of a traffic locus is done as an arc in the running line network. We call a unit of a traffic locus a running line. We can make the road database needed to carry out road traffic simulation in our system from the running line network by attaching physical and logical attributes of roads such as width, traffic signal and traffic regulation information to a running line.

We adopt a traffic model based on the database. As a result, our vehicle model can run only along running lines in running line network and be able to omit operations of steering wheel like railways. So, a vehicle runs reasonably on one-dimensional spaces but not on two-dimensional space. Therefore the simulation needs not to consume considerable execution time because of running line network. Moreover, we have developed a method to make a road database for our system from digital map through human interface. In addition to it, 3D view animation can be displayed in our system (Fig.1.). Therefore, simulation work is very effective.

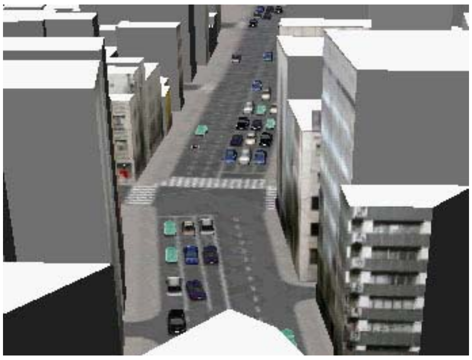


Figure 1. 3D view animation.

As our simulation system is able to build our traffic model easily, speedy and effectively on any areas because of our road database made easily of a digital map, we call it a general-purpose road traffic simulation system. Therefore, we are able to carry out more effective and better-quality road traffic simulations in real time.

In this paper, we describe a road traffic model, functions, its performance and validity in our system. Moreover we report verifications such subsystems as input, output and simulation.

Keywords: *Simulation model, road traffic, junction, clothoid curve, vehicle running line*

1. INTRODUCTION

Road traffic simulations are often carried out to analyze road traffic congestion in city areas. Most software created for them typically cannot be reused for any other road traffic simulations, because it has been developed only for analysis of such specified areas, and because it is difficult to build a model in which vehicle behaviors are described by their movement in two-dimensional space. In short, these simulations are not very effective.

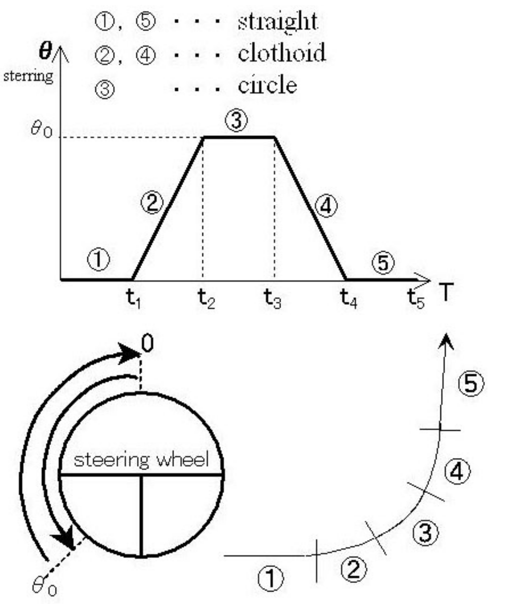


Figure 2. Relationship between steering wheel and locus (line, clothoid curve and circle).

To overcome these flaws, we are proposing a new type of road traffic simulation system. It is a general-purpose road traffic simulation system, which is able to carry out easy, fast and effective road traffic simulations on any road in any area. Within this system, we will adopt a traffic model in which a vehicle has a decision-making mechanism and runs along running lines. A vehicle usually describes a travel locus depending upon the operation of a steering wheel. This locus is represented by the curve in proportion to angle and speed of steering wheel as shown in Fig.2. The curve is described by combining with straight line, a circle and a clothoid curve.

A driver generally operates a steering wheel while visualizing his image of its traffic locus. Therefore, we will adopt a vehicle model based on the hypothesis that a vehicle runs along its traffic locus.

Almost all travel loci are typically defined based upon physical road conditions as well as a driver's intended destination. Almost all travel loci of vehicles in a given location compose of a network on the roads like railway. This network has points where traffic loci either separate from or join with other traffic loci. A point is defined as a node and a unit of a traffic locus is expressed as an arc in the running line network. We call a unit of a traffic locus a running line. A running line contains the physical and logical attributes of roads such as width, traffic signals traffic regulation information. This running line network makes up the road database needed to carry out road traffic simulation in our system.

We will adopt a traffic model based on such a road database. As a result, our vehicle model should be able to run without a steering wheel using only the running line network for guidance. Therefore, such a vehicle would run reasonably well in one-dimensional spaces, but not in two-dimensional ones.

In addition, our traffic model is designed so as to avoid the flaws found in traditional simulation systems. It has the following characteristics:

(a) It can make a fast and effective road database based on a digital map
(b) It can analyze simulation results very quickly due to its 3 D animation capability
(c) It can build an effective traffic model through the use of a road traffic database.
(d) It can carry out real time simulations because of both the running line network and the road database
(e) Simulation work is very effective because of simple model building, speedy execution time and quick analysis.

Therefore, we are able to carry out better-quality, efficient and accurate road traffic simulations in real time.

In this paper, we describe a general-purpose system and features of our system in chapter 2. In chapter 3 the configuration of our system, including functions of the subsystem and its data flow, are explained. The definition and general concept of a running line network is outlined in chapter 4, and input subsystems from digital maps to running line networks are touched upon in chapter 5. Chapter 6 explains our simulation subsystem, which displays the results of a given simulation. Chapter 7 contains our final analysis and conclusions.

2. GENERAL-PURPOSE ROAD TRAFFIC SIMULATION SYSTEM

Recently, many road traffic simulation systems have been developed, and they are useful in many fields. However, their software cannot typically be utilized for any other road traffic simulations because it has been developed only for the analysis of such specified areas, and because it is difficult to build a model where vehicle behaviors are described their movement through two-dimensional space. Therefore, a general-purpose road traffic simulation system is needed. The term “general-purpose” means that a simulation system can be used in any area and for any type of problem. This is in contrast to the former system, which cannot be adapted for multiple purposes.

2.1. System requirements

The following functions and performances may be required in a general-purpose road traffic simulation system:

(i) To build a model in any area and for wide range of problems in traffic congestion

(ii) To reuse in other road traffic simulations

(iii) To accomplish a given simulation task easily and speedily

2.2. Functions and performances

We would like to introduce the concept of a running line in model-building for use with such things as train tracks on a railway or an orbit for rocket in space. Such a system might principally have the following features and functions:

(a) The vehicle model runs only along a running line, which is described by a curve combined with straight line, a circle and a crothoid curve.

(b) The running line network is made up of running lines.

(c) The vehicle model runs along a given running line in one-dimensional space, thus eliminating the need for a steering wheel.

(d) Running lines are directly extracted and created from digital map through human interface.

(e) A road database is made with running lines by adding such road information as logical and physical regulations.

(f) As a result of matching physical road data and running line length, which is outputed from simulation subsystem in real time, the simulation can quickly display animation

On one hand, our road traffic simulation system could serve as a general-purpose one. On the other hand, it can be called a ‘special-purpose’ system due to having functions and performance capabilities as mentioned above.

Requirement (i) is fulfilled by function (a) and (b), (ii) is done by (d), (e) and (f), (iii) is also done by (c), (d), (e) and (f). Moreover this system can carry out a real time simulation with high-speed execution time.

3. CONCEPT OF RUNNING LINE NETWORK MODEL

We will describe the concept of a running line in this chapter. A vehicle's free travel in a two-dimensional space can be represented approximately by adopting the concept of running lines. We call a set of running lines a running line network for vehicles.

3.1. Relation between a lane and a running line

A lane is described on the road network. In general, a vehicle travels in a regular manner along a lane described on the road. A vehicle runs in the center of the lane, which we call a regular running line. But vehicles run temporarily, e.g., by transferring from a regular line to another place when passing another moving or parked vehicle. We call another location a non-regular running line, and a

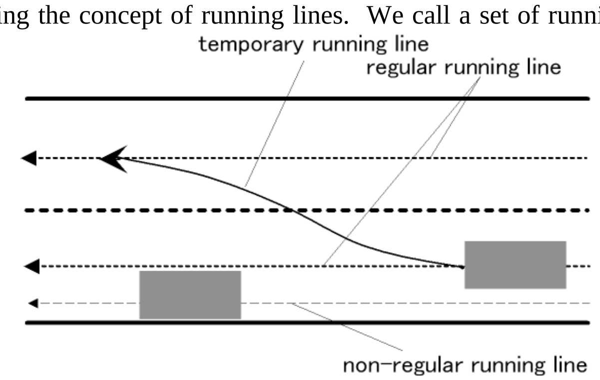
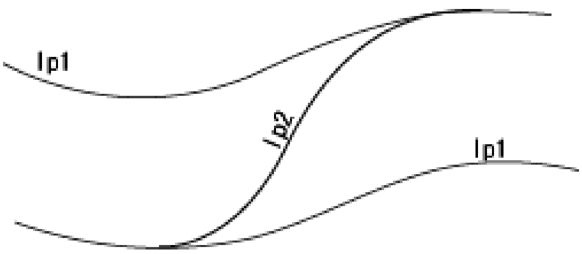


Figure 3. The kinds of the running lines.



lp1 : Regular or non-regular running line
lp2 : Temporary running line

Figure 4. Temporary line to be able to transfer from one running line to the other.

running line which is set up to transfer from a regular one to non-regular one a temporary running line. This model is built to include the provision of a pseudo-line (non-regular running line) and a temporary running line. The relation between a running line, non-running line and temporary running line are shown as Fig.3. Fig.4 shows a temporary running line to transfer from one regular (non-regular) running line to non-regular (regular) running line. The combination of these three lines can easily represent such non-regular running of vehicles as passing and parking. Using their running lines, the vehicle's free runs in a two-dimensional space can be represented approximately.

3.2. Running line network

Based upon the concept of running line, we employ model-building in which vehicles generally run along a center line of a lane on roads. This model is built to include the provision of pseudo-lines (non-regular lines) and a temporary line for transferring from one line to another. That is to say that three kinds of running lines can be identified: regular, non-rsegular and temporary running line. Of course, the running lines are represented by using a combination of straight lines, circles and clothoid curves.

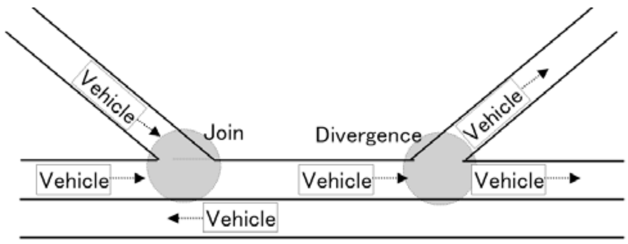


Figure 5. Vehicle travels the point of join and divergence.

In addition to this concept, we define a running line network as lanes either joined with another lane and/or diverging from multiple lanes as shown as Fig.5 (Namekawa 2007). Vehicle travel is represented by movement within a running line network, which can represent practically all of the vehicles traveling in the area (Tanaka 2004).

This model contributes considerably to the reduction of execution time in road traffic simulations using microscopic models.

4. SYSTEM CONFIGURATION

We show a system configuration in Fig.6. Our road database (II) is made from input sub-system(I). Simulation (III) is carried out by using the road database, and 3D view-animation (IV) is created by using the results of a given simulation.

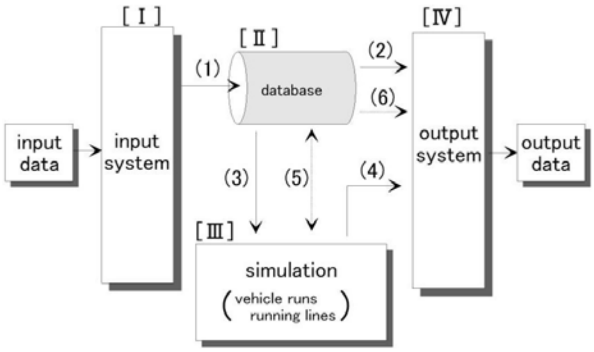


Figure 6. System configuration.

4.1. Input sub-systems (I)

The running line network is made by reading physical road data from digital maps and inputting some traffic regulation data through human-interface. Vehicle generation data and signal information are read and kept in road database with running line network.

4.2. Road data base (II)

The following data are kept in road database.

(a) running line network
(b) vehicle generation data
(c) signal information
(d) 3D view data on road

4.3. Simulation (III)

Partial running line network, signal information, and vehicle generation data are read in proportion to the simulation clock. The vehicle model runs along the running line and the simulation sub-system output positions data of the running line, strictly the length of the running line as the data of output sub-system. This sub-system outputs a temporary running line (refer to Fig.3) made by the vehicle model if necessary. The temporary running line is sent via database subsystem from the simulation subsystem.

Input and output data are shown in the following;

Input data:

(a) running line network
(b) signal information
(c) vehicle generation data

Output data:

(d) position data of running line
(e) temporary running line

4.4. Output sub-system (IV)

Data for animation as the simulation result are made of road database and simulation results, 3D view-animation is displayed (refer to Fig.4).

5. INPUT AND OUTPUT SYSTEMS

We have already illustrated the concept of the running line model in chapter 4 and Fig.4. In this chapter, we will describe the input and output systems that utilize the theory of the running line network model that is the most important point of road traffic simulation systems. Furthermore, we will explain the relationship between input system and output system (Maeda 2004).

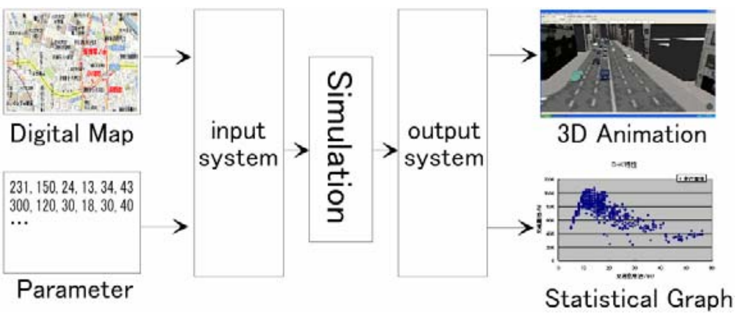


Figure 7. Concept of the input and output systems.

Fig.7 shows a whole simulation system which illustrates the relationship between the input system and the output system.

The use of digital maps is an important point. Recently, digital maps such as web-based Google or Yahoo versions have been developed and have popularized rapidly. It is very easy to carry out simulations accurately and quickly using such digital maps. Their most notable feature is that they are easy to apply to simulations in any region. Generally speaking, paper maps (e.g. road maps or survey maps) have been most typically used in the building of simulation systems up to this point. However, if we use an electronic map (e.g. "Zenrin digital map [1/2,500]") for input, it is much easier to build a model for simulation data.

Using digital maps also makes cooperation between the input system and the output system much easier. Usually we have to make additional data, such as input data for simulation and display data for 2D or 3D animation. But, digital maps of unify the format and make a smooth data stream from left to right as shown in Fig.7.

5.1. Input system

In this input system, we used multi-purpose digital maps. However, since these maps were not made for simulation, we had to model our road information data from them. These digital maps are made the road information data line by line, and we approximated the data as groups of straight lines, clothoid curves and circles.

The algorithm is as follows.

[Step 1] recognize the map (To extract the road information from digital map)
[Step 2] make the running line network
[Step 3] check accuracy of the map
[Step 4] make the road-information database

Now, we describe the algorithm of these steps.

[Step 1] recognize the map (To extract the road information from digital map)

In this process, we extracted the road shape information by recognizing a map with many kinds of information. On most digital maps, road shape information is approximated by line data. So, we cannot use the map's road data. We need road information that is constructed from curves combined with straight lines, clothiod curves and circles. So, we reconstruct the road information from the line map data, turning it into road data which uses such shapes as a base.

[Step 2] make the running line network

We first make rough shape of the road in [Step 1]. Then, we make the running line network from those data. We illustrate the running line network model in chap 2. We make the regular running line and non-regular running line. Fig.8 shows a sample of this method.

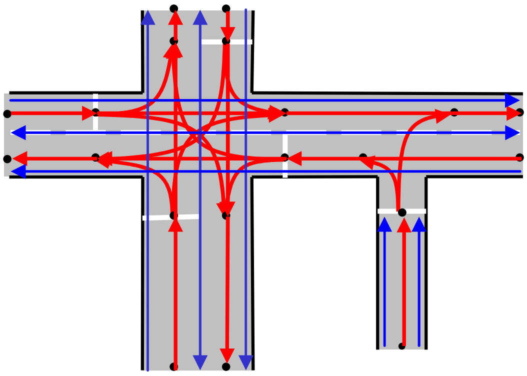


Figure 8. Making the running line data.

[Step 3] check the accuracy of the map

The running line network/road information data is checked in Step 2. One method is to use a survey map. But, as it is very time-consuming job, we propose using aerial photographs instead. Aerial photographs are easily taken from the web. In this process, we can rough check of the road map or missing to input the road data.

[Step 4] make the road-information database

In this step, we construct the road-information database. This database system is made up of running lines, consisting of a combination of straight lines, circles and clothoid curves. These curves are defined by digital information. Therefore, our road database is made up of digital data. And, we add other data such as road traffic laws (e.g. one way and give way). In this way, the simulation uses the principles of car driving (Onodera 1996).

Moreover, this digital road database has animation data which will serve as output during the simulation.

5.2. Output system

5.2.1 Graphical output (Animation)

Our models and the process of simulation were verified by way of a three-dimensional animated imagery. We were also able to verify our results by observing traffic flow characteristics on a macrocosmic level (Satoh 1992).

In our animated imagery, the process of traffic simulation was actually visualized, and we were able to confirm that there were no anomalies in our simulated runs (Fig.1).

5.2.2 Statistics output

We then evaluate the simulation by using such results as the numerical data and its animation. It checks the simulation with calculated data from many features of road traffic (e.g. running speed, distance between two cars, etc.)

6. CONCLUDING REMARKS

We have proposed a general-purpose road traffic simulation system to analyze road congestion in towns and city areas. The use of a digital map will allow us to build easy, efficient and quick traffic models which can be used for multiple purposes in many areas. We call this system a general-purpose road traffic simulation system.

We have verified the functions and performances of sub-systems within the larger system. However, we have not verified total system performance which includes all sub-systems. Moreover, the temporary running lines with clothoid curves are made of default data by referring specified table. This method is not good in terms of the exactness of vehicle model. Thus we are currently developing a more exact method.

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