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RUNNING MODEL OF VEHICLES AND ITS DATABASE IN ROAD-TRAFFIC SIMULATION

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ABSTRACT

Almost all road traffic simulations with a microscopic model have been carried out through a locally fixed road database system. However, these systems are not effective or useful. A general-purpose road database system is therefore desired to analyze traffic jams in all areas. Because such a general-purpose system is very large and complex, speedy input of road network attributes should be taken into consideration, as well as some effective error-correcting method. We propose a new concept whereby the running lines of vehicles on the various shapes of the road can be represented approximately by a combination of lines, circles and clothoid curves. We have developed a general-purpose road database based upon the concept of running lines. It is important to calculate, and to draw quickly and easily any running lines on the road network. This paper describes the running model of vehicles and the human interface for the database.

1 INTRODUCTION

Many road traffic simulation systems have been developed. But the road databases used in almost all of them were developed only for specific areas and purposes, and so cannot be reused in simulations for other areas.

The need exists for a general-purpose simulation system to analyze road traffic congestion of arbitrary wide areas accurately. Such a simulation requires a microscopic model for the vehicle's behavior. In simulating such a system, it is essential to have detailed and correct data on road conditions, including the road itself, as well as traffic signs and signals. In addition, it is important to reduce a simulation's execution time to the utmost. A road system is generally described as a network in which the road is an arc and each intersection is a node. It is represented approximately by a combination of lines, circles, and clothoid curves. We built a road network model based on this concept. Moreover, since road information is composed of lanes on which vehicles are running, we also built a running model of vehicles based on our concept of the road network model. Vehicles run approximately along center line on the lane. One lane is directly connected with the other lane on the other road through channels in an intersection. In addition to the lane, we employed the concept of a pseudo-lane set up temporarily in the road network model. The lanes on the various shapes of the road network can be represented approximately by a combination of lines, circles and clothoid curves. Thus vehicles could run freely as if under actual traffic conditions.

On the other hand, a road network has a number of attributes, such as width, form, traffic signs, and signals at intersections. These attributes can be divided into two classes: physical, pertaining to physical features of the road itself and its lanes; and logical, concerned with road traffic regulations. We built models for the former and developed a database system for them. This system includes all the information on physical attributes of the road necessary for road traffic simulation with a microscopic model. This road database system made it possible to simulate any road traffic system for any area. A database should be flexible enough to accommodate changes in road data. Because of the large amount of data, we also had to consider the addition of a graphic user interface for human interaction.

This paper describes the concept of our road network model in chapter 2, modeling for road information in chapter 3, a running model of vehicles in chapter 4, human interface in chapter 5, and concluding remarks in chapter 6.

2 CONCEPT OF ROAD NETWORK MODEL

The key point of doing a simulation with a microscopic model for congestion of a road traffic system is building a road network model. The following two points should be taken into account: one is how to reduce the execution time of road traffic simulation with a microscopic model; the other is a method for inputting data correctly, quickly and easily to the database.

The reduction of execution time is the most important requirement in the real time simulation of a road traffic simulation with a microscopic model. On the other hand, an effective human interaction system, using a two and/or three-dimensional graphic display, is another important requirement in the simulation of a large and complex system such as a road traffic system. Detailed and correct information concerning the conditions of the road itself, lanes and running lines, should also be used for the animation on the display screen during simulation.

2.1 Requirement for Road Network Model

An important element controlling the vehicle run in road traffic simulation is information concerning the road itself, as well as traffic signs and signals at intersections. A simulation for analyzing road traffic congestion requires that the two-dimensional behavior of the vehicles be described exactly as it occurs in the actual run. It may also be necessary to represent detailed two-dimensional behaviors of vehicles running on curves. The microscopic model should adjust for that effect. Thus the model must describe the detailed physical form of the road itself as well as the behavior of the vehicles, which have their own decision-making capability. The way in which the road network model and running model of vehicles are built is the most important point in the development of the road traffic simulation system.

The data for describing physical features, such as the roads form, width and lane configuration are voluminous. Related data should be correctly and quickly input, and easily modified. As a large amount is input through human interface, the data should be organized efficiently and its processing should involve minimal time.

2.2 Principal of Model-building

A road generally has a uniform width as measured from the center line. Also, a road network can be fundamentally defined by the center line using a combination of straight lines and circles. However, we adopt a clothoid curve for more precision in addition to these. The clothoid curve is a locus drawn by the run of vehicles, based on the movement of the steering wheel. Hence, we built our road network model using a combination of straight lines, circles, and clothoid curves. This is the principal concept of our road network model.

The road itself is two-dimensional, but here we employ a modeling concept in which a locus drawn by the run of vehicle on a lane can be approximately replaced by a line centered along a lane. A vehicle runs along this line (Figure 1). This concept is fundamental for our running model of vehicles on the road network model. Therefore movements of vehicles on our model can be changed from two-dimensional space to one-dimensional space. Such a line is described more realistically and exactly by using a combination of straight lines, circles and clothoid curves. This permitted us to model the behavior of actual vehicles in a more natural way. In addition, it reduced remarkably the simulation's execution time.

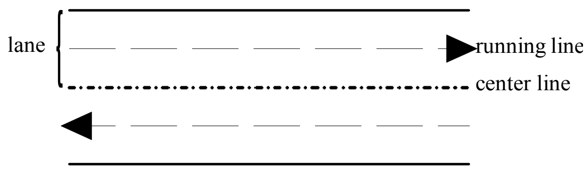


Figure 1: Lane and Running Line of Vehicle

According to this concept, it is possible to describe the behavior of a vehicle passing another moving or parked vehicles by temporarily establishing a pseudo-lane to connect from one lane to the other. The pseudo-lane is established only for representing non-regular vehicle behavior. This pseudo-lane is also used to describe the behavior of a vehicle parked and stopped on the side of the road.

This representation of lanes through a combination of straight lines, circles and clothoid curves makes it possible to organize a more effective road network model with running model of vehicles and road database system.

3 MODELING OF ROAD NETWOK

The important information needed for simulating the congestion of road traffic is the fundamental form of the road network model (Figure 2), the width of the road, and a set of lanes on which the vehicles will travel. In the following sections, we describe our road network model and running model of vehicles on it (Figure 3).

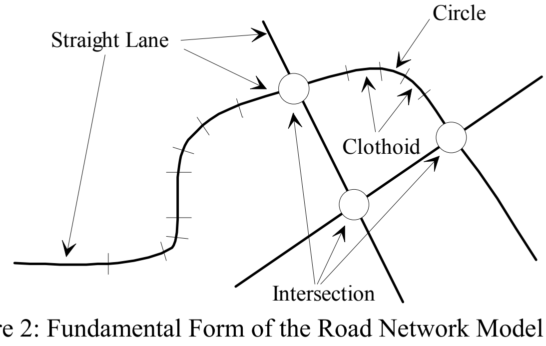


Figure 2: Fundamental Form of the Road Network Model

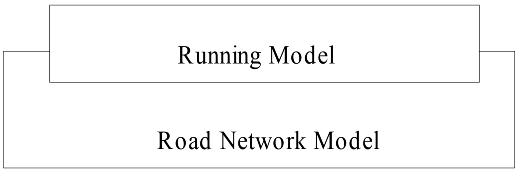


Figure 3: Architecture of Running Model on Road Network Model

3.1 Road Network Model

The fundamental form of the model is described by a combination of lines (straight and/or curved). The cross point of the fundamental form is the road intersection. A road system has basically uniform widths in relation to the line of the fundamental form. This line is usually called the center line of the road. This is shown in Figure 4 as a basic pattern with a consistent width. Some roads, however, have widths that vary in some places. The roads with such variable width portions are divided into three kinds of subroads as follows (2. - 4.):

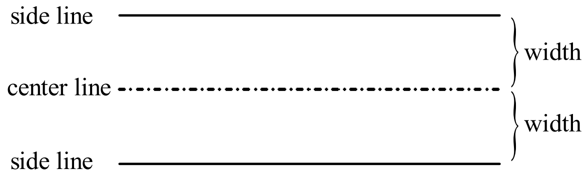


Figure 4: Road with Standard Width

1. Fixed and symmetrical in relation to the center line.
2. Partially varying and not symmetrical to the center line. Example: bus stop, vehicle rest station.
3. Partially varying and symmetrical to the center line.
4. Partially varying and not symmetrical to the center line.

3.2 Pattern of Subroad

A road generally includes various kinds of subroads. We built a road network model consisting of the four elements corresponding to the four subroads of road described before. Element 1 is a subroad corresponding to the usual road.

According to the modeling concept, the road network is represented by some combination of four basic patterns: element 1, element 2, element 3, and element 4, illustrated in Figure 5(a), 4(b), 4(c), and 4(d), respectively. These elements were built as a result of analysis for the road network constructed, and are described as follows.

1. Element 1: subroad width is fixed and is symmetrical in relation to the center line.
2. Element 2: subroad width is fixed and is not symmetrical to the center line.
3. Element 3: subroad width is not fixed and is symmetrical to center line.
4. Element 4: subroad width is not fixed and is not symmetrical to center line.

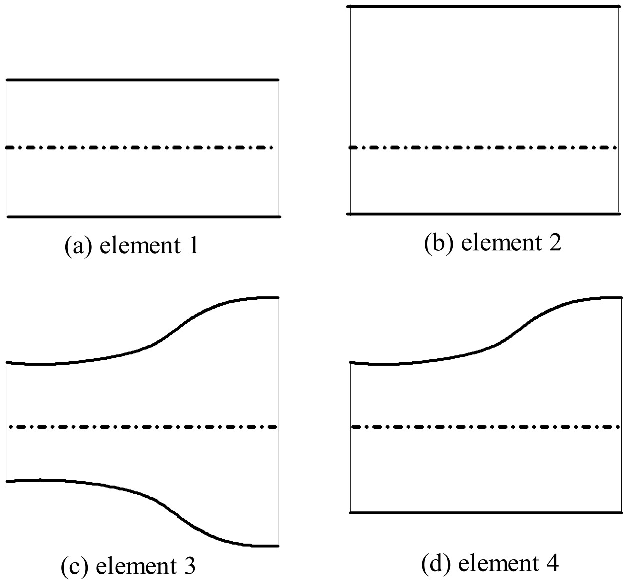


Figure 5: Four Kinds of Elements

Accordingly, the road network is represented approximately by a combination of elements 1, 2, 3, 4, and an intersection. Intersections are added at the stage when widths are input into the road network model. This is a road network model. It gives the fundamental line, widths, and construction of the subroads. Figure 6 shows an example of a road consisting of five elements of the subroads.

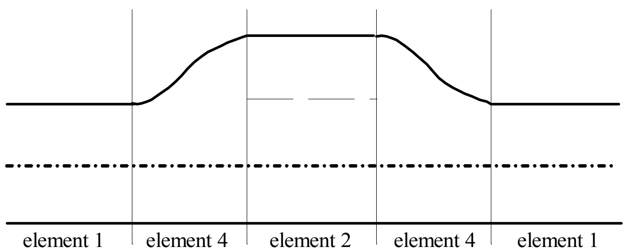


Figure 6: Example of a Road Model.

4 RUNNING MODEL OF VEHICLES

We describe relation of lane and running line in this chapter. The vehicle's free travels in a two-dimensional area can be represented approximately adopting the concept of running lines. We call a set of running lines the running model of vehicles.

4.1 Lane

The lanes can be described on the road network model. In general, vehicles travel in a regular manner along the lanes of the road system. We call this a regular lane (Fig.1). But vehicles may also be able to run non-regularly, e.g., by transferring from one lane to another when passing another moving or parked vehicle. This model is built to include the provision of a pseudo-lane (non-regular lane) and a temporary lane for transferring from one lane to another. The combination of these three lanes can easily represent such non-regular running as passing and parking.

Using their lanes, the vehicle's free run in a two-dimensional area can be represented approximately.

4.2 Running Line

In addition to this concept of lanes, we employ model-building in which the vehicles run along a center line of the lane (Figure 7). Vehicles must run along the center line of the lane. We call this a running line (Figure 1). This fundamental concept is our running model of vehicles. 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 (Figure 8 and Table 1). Of course, the running line of vehicles is represented using a combination of straight lines, circles and clothoid curves, and their application (Figure 9). It can represent approximately the behavior of vehicles. This model contributes considerably to the reduction of the execution time in the road traffic simulation with a microscopic model.

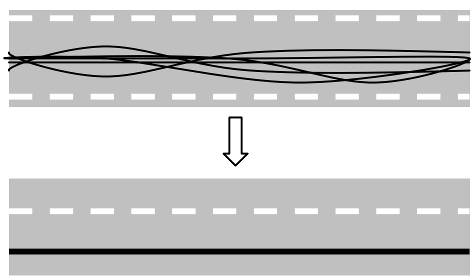


Figure 7: Locus of Vehicle's Run and Running Line

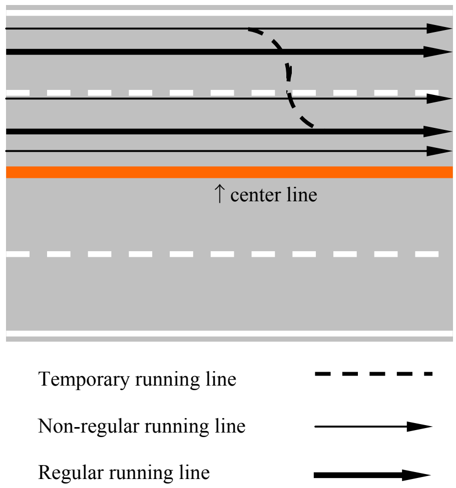
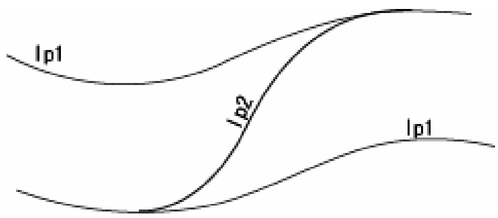


Figure 8: Running Line and its Locus of Vehicle



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

Figure 9: Temporary Line to Transfer from One Running Line to the Other

Table 1: Architecture of Running Line

<table>
<tr><td colspan="3">running line</td></tr>
<tr><td>non-regular running line</td><td>regular running line</td><td>temporary running line</td></tr>
<tr><td colspan="3">locus of vehicle's run</td></tr>
</table>

5 HUMAN INTERFACE

The input data for a road database system is, first, information on the road itself, namely the fundamental lines and widths. We used a road map for input, as shown in Figure 10. This map can be read directly into the computer using an image scanner, but we were not able to obtain digital information at the required level of precision. Here we employed a new method of inputting it approximately through human interaction based on analog data read by the image scanner. This method contributes toward reducing the input processing time because it eliminates the need for inputting the coordinates (x_i, y_i) of the road information. This coordinate is a relative point on the road map. Moreover, this method contributes remarkably toward prevention of input errors because the user can consult the image of road network through the road map on the display screen.

The data is input in the following stages : Stages (1), (2) and (3) are input using the image of the road map on the display screen; stage(4) is generated automatically based on the lanes.

1. General lines of road-network
2. Widths and intersections
3. Lanes
4. Running lines of vehicles

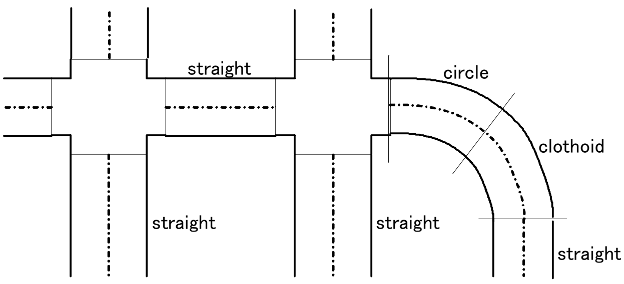


Figure 10: Road Map

5.1 Input of Fundamental Line

The center lines of the road network were approximately represented by a combination of straight lines, circles and clothoid curves. Therefore the road network can be described by inputting fundamental lines on the basis of segments. At this stage, the segments can be determined by the user. In order to gain obtain a good approximation of the road map, however, the user must divide the road network into smaller segments when necessary.

A segment is drawn automatically by specifying two pairs of data on the display screen: a starting and an ending point, and their directions. These data are determined by looking up the form of the road map on the display screen. Fundamental lines are set up by connecting the input portions, one after another (Fig. 11). At this stage, fundamental information needed for road traffic simulation, e.g., the length, the form of the road network, and its locations (x- y coordinates), are input. These data are recorded in the database as digitalized information.

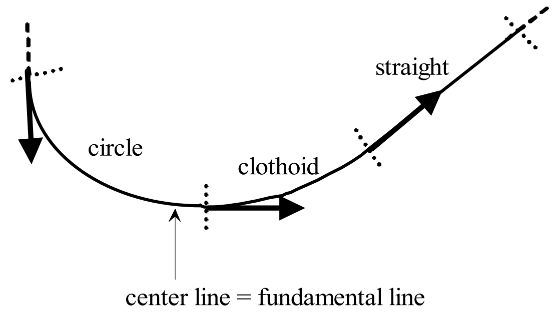


Figure 11: Input of Fundamental Line

5.2 Input of Width and Intersection

The width data is input by specifying the width at every segment and assigning one of the road elements described before (Fig. 5). If the width is set up along a fundamental line, the road network becomes a two-dimensional geometrical form as shown in Fig. 12. A subroad is built based on the fundamental line at each segment. Intersections are established at this stage. If the boundary line between a road and an intersection is designated, the form of the intersection is defined automatically. The width and form of the intersection can be modified later if necessary.

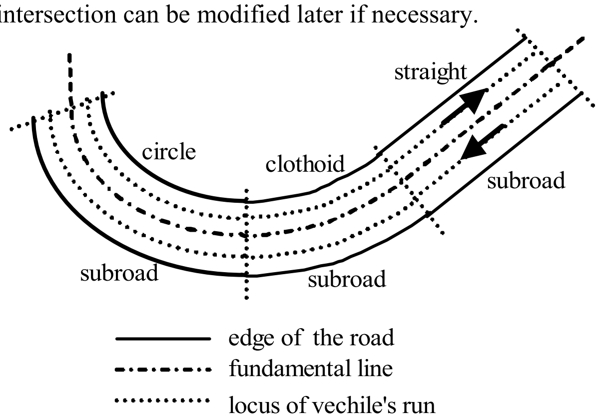


Figure 12: Subroads with Widths

5.3 Input of Lanes and Running Lines of Vehicles

The entrance and the exit points of the subroads are designated in order to input the lanes. These points can be decided automatically by specifying the number of lanes for the subroads. All lanes (regular and non-regular) and running lines of vehicles are defined in every subroad as shown in Figure 13. If lanes merge or diverge, or right-turn lanes exist, a subroad is divided further into smaller subroads. All the running lines are generated automatically based on the lanes except for temporary running lines.

A temporary lane is generated depending upon the decision of vehicle's model with decision-making mechanism during road traffic simulation. Finally the lanes and running lines of vehicles in all the intersections are input automatically (Figure 14). As a result, once the process is completed, lane network, that is, a set of running lines (Figure 15), is organized in the road network.

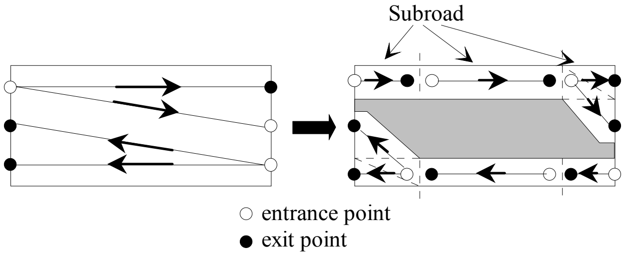


Figure 13: Example of Lanes and Running Lines in road

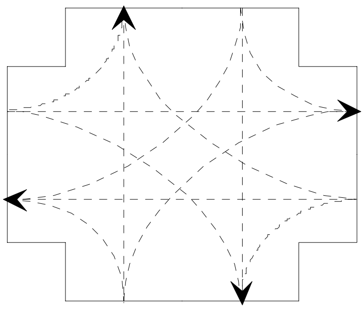


Figure 14: Running Line at an Intersection

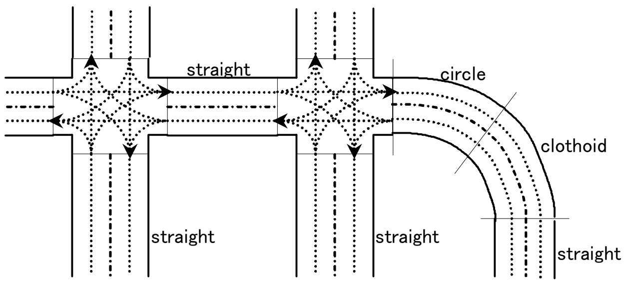


Figure 15: Running Lines on the Road Network

6 CONCLUDING REMARKS

A simulation for analyzing road traffic congestion requires a microscopic vehicle model that has its own decision-making mechanism. Further, it requires a road network model capable of describing the microscopic behavior of vehicles. We have succeeded in building a model that represents the conditions of a road network with greater detail, precision, and faithfulness to the actual road. We achieved this by using clothoid curves, and the development of a more rapid means of calculation. Our model is composed of a road network model and a running model of vehicles, and includes all the information on the road itself for road traffic simulation, except for traffic regulation information such as traffic signals and signs. These models enabled us to develop a general-purpose road database for road traffic simulation. This system has a human interface that allows quick, easy, and precise input of road information.

An issue to be addressed in the near future is the improvement of the running model of vehicles and the addition of a function to input traffic regulation information, e.g., traffic signals and signs, to this system. Other items include enhancing the human interface, and developing animation for increased realism of the road traffic representation to include three-dimensional features.

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