Road Data Input System using Digital Map in Road-traffic Simulation

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Keywords: *traffic simulation, digital map, input system, database, car*

EXTENDED ABSTRACT

This paper describes a road data input system needed in road traffic simulation systems with a microscopic model. Widths, side lines, and center lines of road and lane information are included in the road data. These data are indispensable to carry out road simulations for all areas and purposes, and can be reused in simulations for other areas. 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 for particular purposes of the simulation, 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 vehicles' behaviour (Yikai *et al*. 2000). In simulating such a system, it is essential to have detailed and accurate data on road attributes, including the shapes of the roads themselves, as well as traffic signs and signals at intersections. Widths, side lines and center lines are included in the road attributes (Onodeara *et al*. 1996, Ueda *et al*. 2005). Moreover, lane information, a kind of traffic sign, is required in case of carrying out the simulation. There are essentially four types of attributes: widths, side lines, center lines of road, and lane information on the road, that are used fundamentally to carried out road traffic simulation with a microscopic model for vehicles' behavior. We call these the attributes a road information. Widths, side lines and center lines of road describe the physical features of a road. Lane information consists of signs, and gives the course of vehicles' running.

A vehicle runs approximately along the center of the lane. We call this course (the locus of a vehicle's running) the running line of the vehicle. One lane is directly connected with the other lane on the other road through channels in an intersection. On the other hand, vehicles may also be able to run by transferring from one lane to another when passing another moving or parked vehicle (Tanaka *et al*. 2006, Namekawa *et al*. 2007). In addition to the usual lane, we employed the concept of a pseudo-lane set up temporarily in the road. We call this a temporary lane.

In addition to vehicles running in the usual lane, some vehicles occupy and run in others areas on the road, including the parking and passing lanes. These are normally defined as pseudo-lanes, but we shall employ the terms "regular lane" for usual lanes, and "irregular lanes" for pseudo-lanes. Our road model has three kinds of lanes: regular, irregular and temporary. The combination of these three lanes can easily represent both normal running, and also passing and parking. The vehicle's free run in a two-dimensional area can be represented approximately using these lanes. On the other hand, we can say alternately that the vehicle's free run in a two-dimensional area can be represented approximately using their running lines, if vehicles run usually along the center of the lane. This concept is fundamental for our road model, in which the operation of the steering wheel is integral. In addition, it is important to reduce the simulation's execution time to the as far as possible (Ueda *et al*. 2004). The concept of running lines plays an important role in the reduction of a simulation's execution time.

For this purpose, we have developed a road database system. This system includes all information on the physical attributes of the road necessary for road traffic simulation with a microscopic model. This road database system makes it possible to simulate any road traffic system for any area. A database should be flexible enough to accommodate changes in road data. We propose a new method to input the data (road information) mentioned above using digital maps, and have successfully developed the input system used in this paper. Road information needed in road traffic simulation is read directly into the computer from a digital map, and is then transformed into running lines of vehicles through human interaction.

1. INTRODUCTION

Many road traffic simulation systems have been developed. However, the road databases used in most 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 accurately in arbitrarily wide areas (Namekawa *et al*. 2005). Such a simulation requires a microscopic model for vehicular behaviour. In simulating such a system, it is essential to have detailed and accurate data on road attributes, including the contours of the road itself, as well as traffic signs and signals. There are many attributes, such as widths, side lines and lanes, center lines, other traffic signs, signals at intersections and so on. 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. The physical attributes - that is, widths, side lines, lanes, center lines and lane information, are indispensable to carry out the road traffic simulation with a microscopic model.

On the other hand, vehicles run approximately within lanes. One lane is directly connected with other lanes on other roads through channels in intersections. In addition to the usual lane, we employed the concept of the pseudo-lane, set up temporarily in the road network model. Meanwhile, other lanes of varying shapes in the road network can be represented approximately by a combination of lines, circles and clothoid curves. We have built a vehicle model to run normally, along the center of its lane. We define "line" as the running line of a vehicles' model. Thus, the vehicles' model could run freely as if under actual traffic conditions by this concept. In addition, it is important to reduce a simulation's execution time as much as possible. The concept of the running line plays an important role in a simulation's execution time. We developed a database system for this. This system includes all information on the physical attributes of the road needed for road traffic simulation with a microscopic model. Widths, side lines, center lines and lane are included in the road information. 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.

We propose a new method to input the data using a digital map, and have successfully developed this input system. Digital maps may be read directly into the computer, while road characteristics in the digital maps are transformed into the running lines of vehicles.

This paper describes the requirements of the road network model in chapter 2. The road network model may be found in chapter 3, the running model of vehicles in chapter 4, road data input system in chapter 5, and concluding remarks in chapter 6.

2. MODEL-BUILDING FOR ROAD NETWORK

The key point of performing a simulation with a microscopic model for congestion of a road traffic system is to build a road network model. The following two points should be taken into account: one is to build an exact model for the behaviours of vehicles' running which is able to reflect the circumstances of road traffic congestion. For this purpose, a precise road network model based upon a real road network is required. It is also necessary to develop a method for putting data into the database for the model quickly, easily, and accurately. It is also necessary, however, to reduce the execution time of simulations. The reduction of execution time is the most important requirement in the real time simulation of a road traffic simulation with a microscopic model.

2.1. Requirements of Road Network Model

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

The data required for describing physical features, such as a given road's form, width and lane configuration, are voluminous. The data needs to be quickly and accurately input, and easily modified. As a large amount is input, the data should be organized efficiently and its processing should involve minimal time. For this purpose, we have developed a new method to input data using a digital (electronic) map.

2.2. Principal Concepts 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 have adopted, in addition to these, a clothoid curve for a more precise vehicular model. 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.

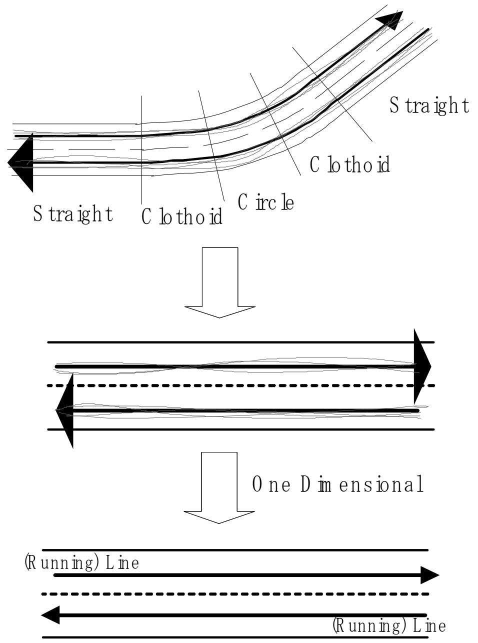

Figure 1. Definition of a running line.

The road itself is three-dimensional, but we approximate it using a two-dimensional space. In addition to this, we employ a modeling method 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 (Fig.1). This concept is fundamental for our model of vehicles on the road network model. Therefore movements of vehicles using our model can be changed from on the two-dimensional space to on the one-dimensional space (Satoh *et al.* 1991). 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.

3. ROAD NETWORK MODEL

The important information needed for simulating the congestion of road traffic includes the fundamental form of the road network model (Fig. 2), the width of the road, and a set of lanes on which the vehicles will run. The fundamental form is delegated by the center line on roads.

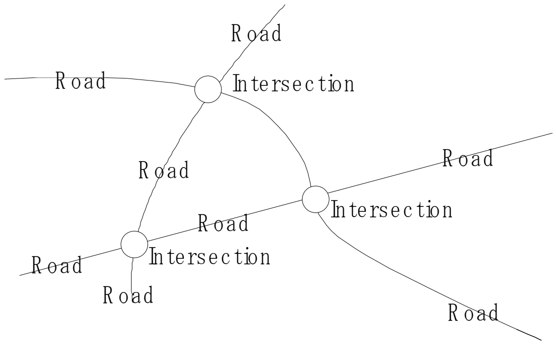

Figure 2. Fundamental form of the road network model.

3.1. Type of Road

The fundamental form of the model is based on the center line on the road, delineated by a combination of lines (straight, curved and clothoid lines). The cross point of the fundamental form is the road intersection. A road has a basically uniform width in relation to the line of the fundamental form.

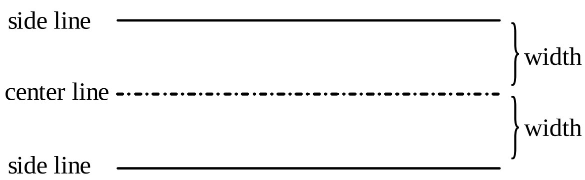

Figure 3. Basic pattern with a consistent width.

This is shown in Fig. 3 as a basic pattern with a consistent width. Some roads, however, have widths that vary in some places. Roads, especially roadways, usually have lanes on them. And vehicles run on the lanes. Roads with such variable widths are classified into three kinds of roads, as follows ((a) – (d)):

(a) Fixed and symmetrical in relation to the center line;

(b) Partially varying and not symmetrical to the center line. Example: bus stop, vehicle rest station;

(c) Partially varying and symmetrical to the center line;

(d) Partially varying and not symmetrical to the center line.

3.2. Pattern of Roads

A road generally includes various kinds of patterns. We built a road network model consisting of the four elements corresponding to the four kinds of roads described above.

According to our modelling concept, the road network is represented by some combination of the four basic patterns: element 1, element 2, element 3, and element 4, illustrated respectively in Fig. 4. These elements were built as a result of analysis for the road network constructed, and are described as follows.

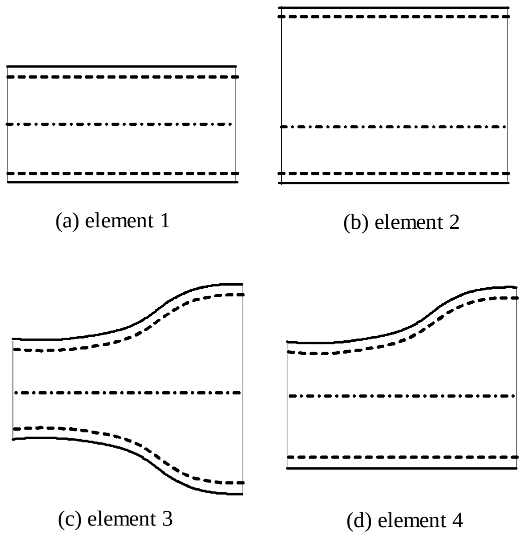

Figure 5. Basic patterns of road elements.

Accordingly, the road network is represented approximately by a combination of elements 1, 2, 3, 4, and an intersection with lanes. This is our road network model. It gives the fundamental line, widths, and construction of the roads. Fig. 6 shows an example of a road consisting of five elements of the road.

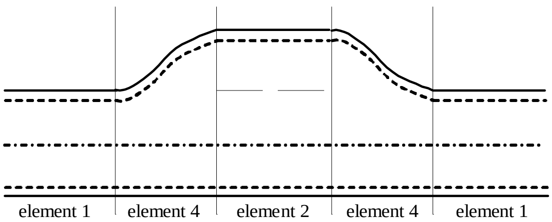

Figure 6. Example of a road consisting of five elements.

4. RUNNING MODEL OF VEHICLES

We describe the relation of lanes and running lines in this chapter. The movement of vehicles in a two-dimensional space can be replaced approximately by one in a one-dimensional space by adopting the concept of running lines. Steering wheel operation of vehicles can be abbreviated using the concept of running lines. Movement of vehicles in a two-dimensional space is accomplished by selecting running lines according to a given road. We call a set of running lines the running model of vehicles.

4.1. Lanes

The lanes can be described on the road network model. In general, vehicles run in a regular manner on a given lane of the road. We call this a regular lane (Fig.1). But vehicles sometimes run in a non-regular manner, e.g., by transferring from one lane to another when bypassing another running or parked vehicle. For this purpose we suppose a pseudo-lane, and additionally, we suppose another pseudo-lane as a parking area on side area of road, bypassing running vehicles on a narrow road. We call it this a pseudo-lane (Fig. 7).

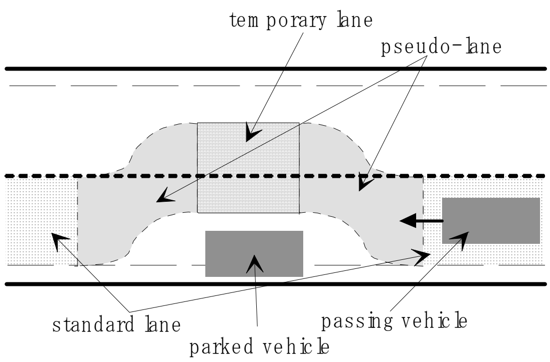

Figure 7. The model of passing vehicle for parked vehicle.

Moreover, the concept requires a pseudo-lane for transferring from one lane to another. We call this a temporary lane. The model is built to include the provision of a pseudo-lane (non-regular lane) and a temporary lane. The combination of these three lanes can easily represent such non-regular running as passing and parked vehicles.

Using their lanes, the various kinds of vehicles' runs can be represented approximately in a two-dimensional space.

4.2. Running Lines

In addition to this concept of lanes, we adopt model-building in which the vehicles run normally along the center line of the lane (Fig. 8).

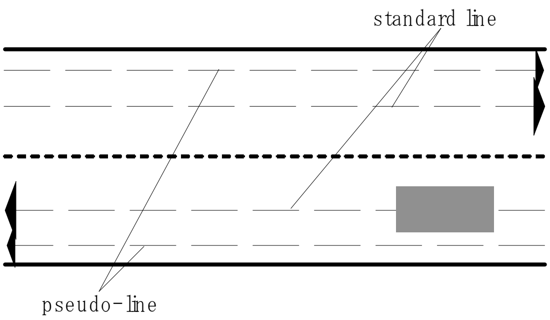

Figure 8. The Vehicles run normally along the center line of the lane.

Vehicles must run along the center of the lane. We call the locus of vehicle's running the running line (Fig. 1). That is, a vehicles' run along the locus of vehicle's running. This concept is fundamental to 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 (Fig. 8 and Table 1).

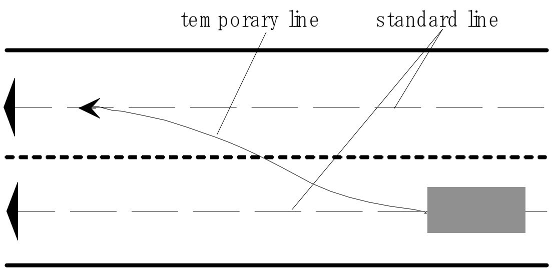

Figure 9. Temporary line to transfer from one running line to the other

Table 1. Architecture of running Line

running line		
non-regular running line	regular running line	temporary running line
locus of vehicle's run		

Of course, the running line of vehicles is represented using a combination of straight lines, circles and clothoid curves, and their application. The running line has information about its position (latitude, longitude) as its attribute.

This information is used to animate the simulation. It can represent the behavior of vehicles exactly. We call a set of running lines on the road network a model road system. This model contributes considerably to the reduction of the execution time in the road traffic simulation with a microscopic model.

5. INPUT SYSTEM

Input data for a road database system is, first, information on the road characteristics, namely the fundamental lines, widths, side-lines and lanes on the road. We use an electronic map (that is to say, a digital map [1/2,500]) for input, as shown in Fig. 10.

Figure 10. Digital map for inputting the road model.

This map can be read directly into the computer from an electronic map. But we are not able to obtain digital information at the required level of precision because all the digital information is described approximately in the line graph, that is, approximated by a combination of straight lines. Our running model of vehicles, the road system, requires a combination of straight lines, circles, and clothoid curves (Satoh *et al*. 1992, Maeda *et al*. 2004). Next, we create the curves from the line graph of the electric map. Here we employed a new method of making such curves approximately using software through human interaction. Third, we make the running lines on the road network model from the curves obtained above. Fourth, we make a road database from the data gained above. This method contributes toward reducing input processing time because it eliminates the need for inputting the coordinates (xi, yi) of the road attributes. 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 the road network through the road map on the display screen.

The data is input in the following phases: phase (a) is input using the image of the road map on the display screen; the output of phase (a) is to fit in road characteristics of the road survey officially. Exact road characteristics are obtained by phase (b). A set of lines in the broad network is obtained from the output of (b). Running lines are made by the output of (c). Finally, the road traffic simulation database is established.

(a) To get road characteristics (the fundamental lines, widths, side-lines and lanes on the road) from a digital map;

(b) To fit the road characteristics to one surveyed officially, modify them as necessary;

(c) To make running lines from lane information, side lines, and width of road;

(d) To make the road database (road system).

5.1. Extraction of Road Format Data

A part of the digital map is represented in the display of a personal computer, as shown in Fig. 11. We extract road characteristics (side line, center line and lanes) from the digital map through human interface. These road characteristics are approximated by a combination of straight lines, that is line graphs, on the digital map. We replace the line graph with a combination of straight lines, circles and clothoid curves by describing it on the line graph through human interaction with "V-nas" (Kawada Technosystem Co.,Ltd.) software (Fig.11). Finally, we obtain the road characteristics needed from digital map.

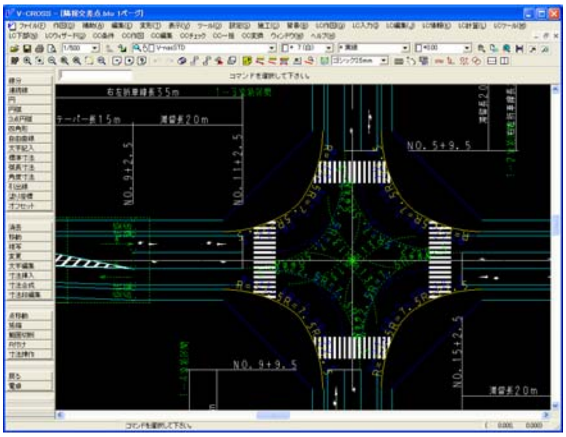

Figure 11. Software for inputting the lane.

5.2. Fitting the Road Characteristics to One Surveyed Officially

A digital map is normally made from aerial photographs. However, photographs generally have distortions in places, leading in some cases to distortions in the resulting digital maps. Thus, we needed to fit road characteristics gained from the digital map to those of road surveyed officially. Boundaries and side lines are more exactly described in maps [1/500] of roads surveyed officially (Fig.12). Lanes and center lines are fit into side lines or boundaries of roads, adjusted by official surveys of those roads.

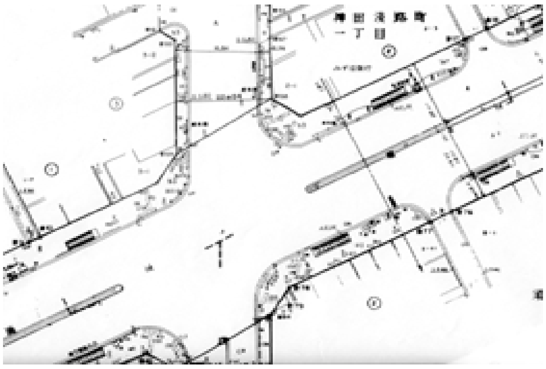

Figure 12. Road map [1/500] of an officially surveyed road

5.3. Running Line

All the running lines are made from the road characteristics gained previously. The running line is described in the center of the lane. We called it a regular running line. Next, an irregular running line is described using the side line lane and center line. Sometimes, we can use the width of the road in the case of a road without a lane. We establish all running lines in road network: that is, regular, irregular and pseudo-running line for vehicles' models. We called this our road system.

5.4. Database System

The road 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 (Fig.13).

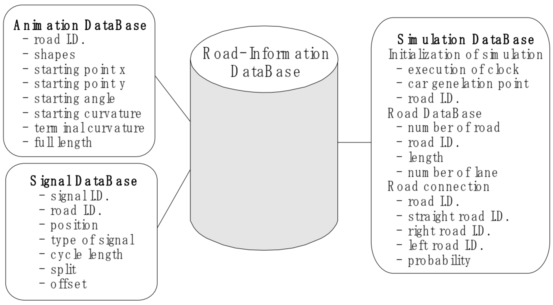

Figure 13. Database system of the road traffic simulation

6. CONCLUSION

A simulation for analyzing road traffic congestion requires a microscopic vehicle model that has its own decision-making mechanism. At the same time, it requires a running model of vehicles that represents the characteristics of a road network with greater detail, precision, and faithfulness to the actual road as well.

It is indispensable to develop an effective method that allows quick, easy, and precise input of road information. We proposed a new method to input these data from a digital map, and have developed a suitable input system for that purpose. The system has a human interface that allows quick, easy, and precise input of road information.

One issue needing to be addressed in the near future is how to apply our input system to other road networks. While our database and input system are limited to road networks in which the form of the center line is represented only by a straight line, it would be useful to develop a system applicable to any form of road network in the near future. We also need improvement of a function of automatically making running lines for vehicles from such road characteristics as side lines, lanes, and center lines on the digital map. This is currently processed through human interface. And finally, the human interface itself needs to be enhanced.

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