Road Database System for Road Traffic Simulation

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Abstract In order to simulate congestion of road traffic system, it is indispensable to describe vehicles having their own decision-making capabilities, and to have detailed and correct road condition data on the road system. The road system is composed of such roads as streets, avenues and highways, and their intersections. In this study, we represent it by a network in which roads are arcs and intersections are nodes. The road-network itself has two kinds of attributes; the physical attributes and the logical attributes. The former are ones of the roads themselves such as their varying widths, shapes, slopes, traffic lanes and their channels. The latter are ones which depend traffic regulations such as signals and traffic signs. The former is called road itself information and the latter is road traffic regulation information in the road-network. Almost all road traffic simulations using a microscopic model have been carried out through a locally fixed road-network information database system. However, these systems are not effective. A general-purpose road traffic database system is therefore desired to analyze traffic jams in all areas. Because such a general-purpose system is very voluminous, speedy input of road network attributes should be taken into consideration, and the addition of some effective error-correcting method. We propose a new concept whereby the shape of the road-network can be represented approximately by a combination of lines, circles and clothoid curves allowing speedy calculation. We developed a general-purpose database system to describe road information except for the road traffic regulation information. The database system adopts an interactive input method through human communication. This paper describes concept, modelling and human interface of this system.

1. INTRODUCTION

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

A need exists for a general-purpose simulation system to analyze road traffic congestion of arbitrary wide areas for accurate analysis. The 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 signals and road signs. A road system is generally described as a network in which the road is an arc and an 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 a road system composed of lanes on which vehicles are running, we also built a track model based on our concept of the road network model. 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. Thus vehicles could run freely as under actual traffic conditions.

A road has a number of attributes, such as width, form, traffic signs and signals at an intersection. These attributes can be divided into two classes: physical, concerning to physical features of the road itself, and logical, concerning to road traffic regulations. We built models for the former and developed a database system for them. This system includes all the information on the road itself 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 road model in section 2, modelling for road system in section 3, human interface in section 4, and concluding remarks in section 5.

2. CONCEPT OF ROAD SYSTEM MODEL

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

An effective human interaction system, using 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 condition of the road system should be also used for the animation on the display screen during simulation.

2. 1 Requirement for Road Database System

An important element controlling the vehicle run in road traffic is the information concerning with the road itself as well as traffic sign and signals at a intersection. 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 three-dimensional detailed behaviors of vehicles running on a slope. 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 has its own decision-making capability. The way in which the road model is built is the most important point in the development of the road traffic simulation system.

The data for describing the 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 involve minimal processing time.

2.2 Concept of Model-building

A road has generally a uniform width as measured from a center line. Also, a road network can be generally defined by the center line using a combination of straight line and circle. But we chose a clothoid curve for more precision. The clothoid curve is a locus drawn by the vehicle's run, based on the movement of the steering wheel. Hence, we built our road network model using a combination of straight lines, circulars and clothoid curves. This is the principal concept of our road network model.

The road itself is two-dimensional, but here we employ a modelling concept in which a locus drawn by the vehicle's run on a lane can be approximately replaced by a line centered along a lane. Vehicles run along this line. Such a line is generally described by segments of straight line and curves. The track of vehicle's run 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 simulation's execution time.

According to this concept, it is possible to describe the behavior of a vehicle passing another moving or parking 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 on the side of road.

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

3. MODELLING FOR ROAD SYSTEM

The important information needed for simulating the congestion of a road traffic is the general form of the model (Figure 1), the width of the road system, and a set of lanes on which the vehicles will run. In the following subsections, we describe our road network model and track model.

3.1 Road Network Model

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

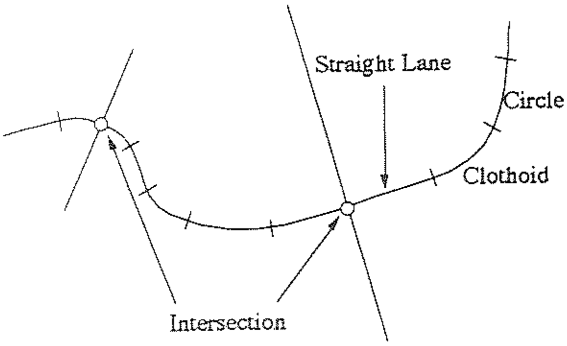


Figure 1 General Form of the Model

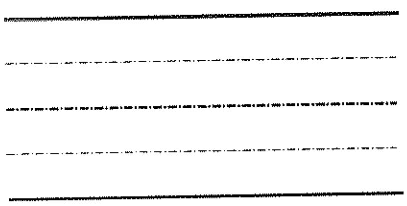


Figure 2 Standard Width

(1) Fixed and symmetrical in relation to the centerline.
(2) Partially varying and not symmetrical to the centerline (Fig. 3). Example: bus stop, vehicle rest station.
(3) Partially varying and symmetrical to the center line (Fig. 4).
(4) Partially varying and not symmetrical to the center line (Fig. 5).

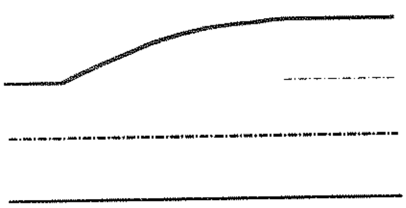


Figure 3 Varying and not Symmetrical Width

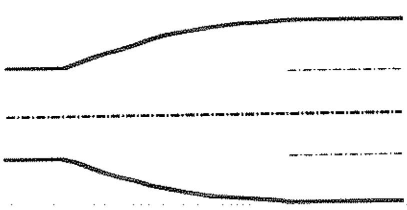


Figure 4 Varying and Symmetrical Width

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

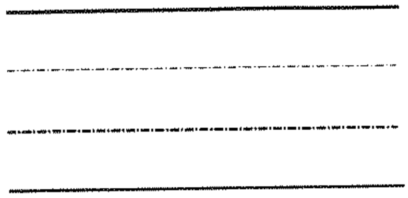
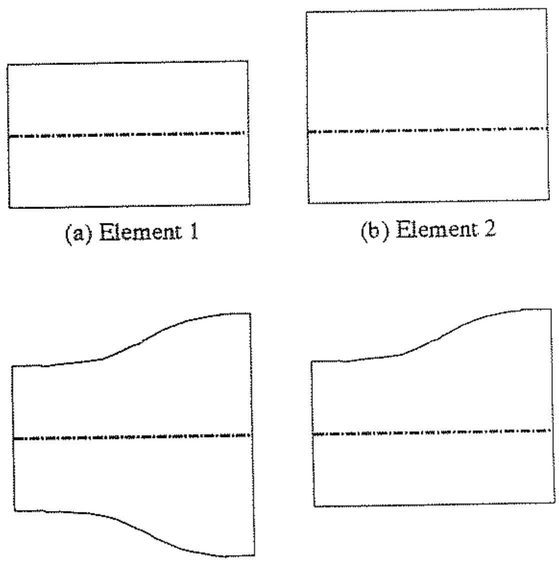


Figure 5 Varying and not Symmetrical Width

corresponding to the fundamental road.

According to the modelling concept, all road systems are represented by some combination of four basic patterns: element 1, element 2, element 3, and element 4, depicted in Fig. 6(a), 6(b), 6(c), and 6(d)) respectively. These elements were built as a result of analysis for the road systems constructed, and are described as follows.

(1) Element 1: subroad width is fixed and is symmetrical for the centerline.
(2) Element 2: subroad width is fixed and is not symmetrical for the centerline.
(3) Element 3: subroad width is not fixed and is symmetrical for centerline.
(4) Element 4: subroad width is not fixed and is not symmetrical for centerline.



(a) Element 1 (b) Element 2

(c) Element 3 (d) Element 4

Figure 6 Four Kinds of Elements

Accordingly, all road systems are represented approximately by a combination of element 1, 2, 3, and/or 4 and an intersection. Intersections are addeo at the stage when widths are input into the road network model. This is a road network model. It gives the general line and widths and construction of the subroads.

3.2 TRACK MODEL

The lanes can be described on the road network model. In general, vehicles proceed in regular manner along the lanes of the road system. But they can run non-irregularly, e.g., by transferring from one lane to another lane when passing another moving or parked vehicle. These models are built to include the temporary provision of a pseudo-lane for such transfers. The use of pseudo-lanes can easily represent such non-regular running as the passing and parking.

Using the pseudo-lane, the vehicle's free run in a two-dimensional area can be represented more realistically and precisely. In addition to this concept of lane, we employ the modelling which the vehicles run along a centerline of the lane (Fig. 7). Vehicles must run along the centerline of the lane. We call it a track (Fig. 8). This is our track model. It represents approximately and more exactly the behavior of vehicle. The track model considerably contributes to the reduction of the execution time in the simulation.

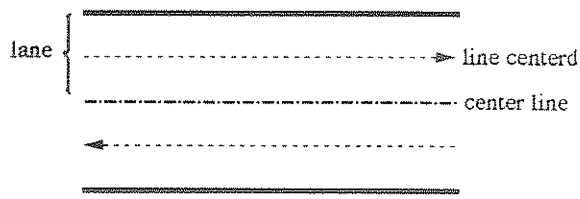


Figure 7 Locus Model of Vehicle's Run

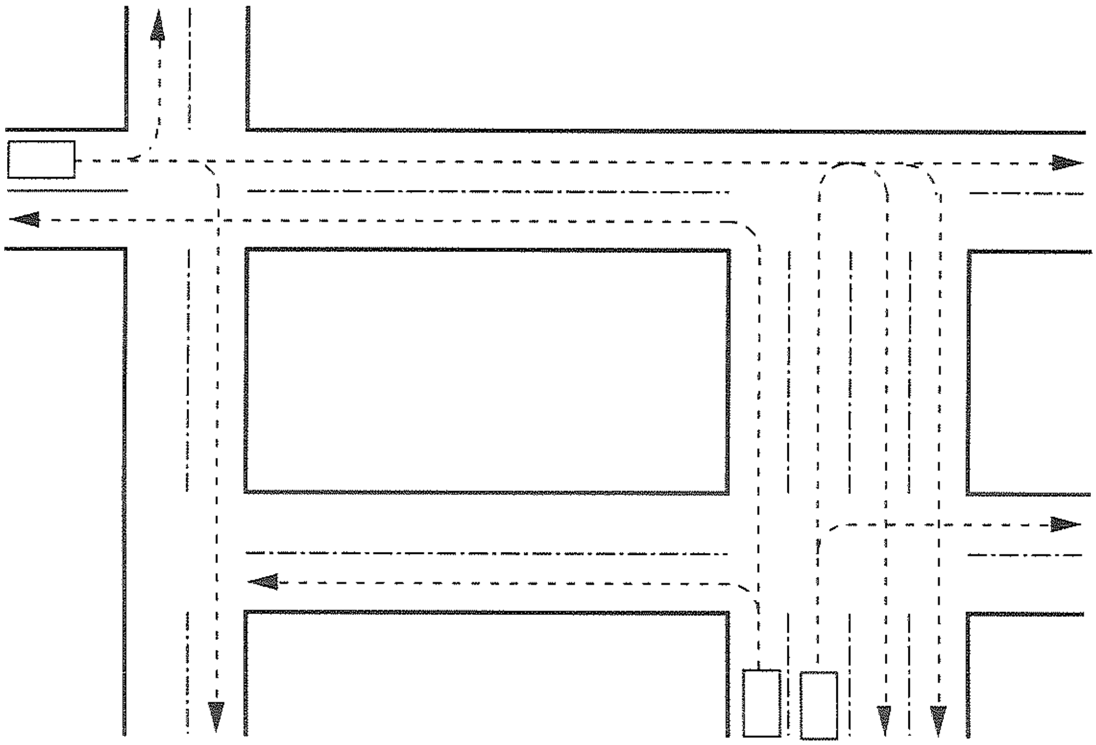


Figure 8 Tracks

4. HUMAN INTERFACE

The input data for a road database system is first information on the road itself, namely the general lines and widths. We used a road map for input, as shown in Fig. 9. This map can be read directly into computer by an image scanner, but were not able to obtain the 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 (xi, yi) of the road information, except for input of a starting point (0, 0). 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 three stages. Stage (1) and (2) are input by using the image of the road map on the display screen.

(1) General line of road-network
(2) Width and intersection
(3) Lane

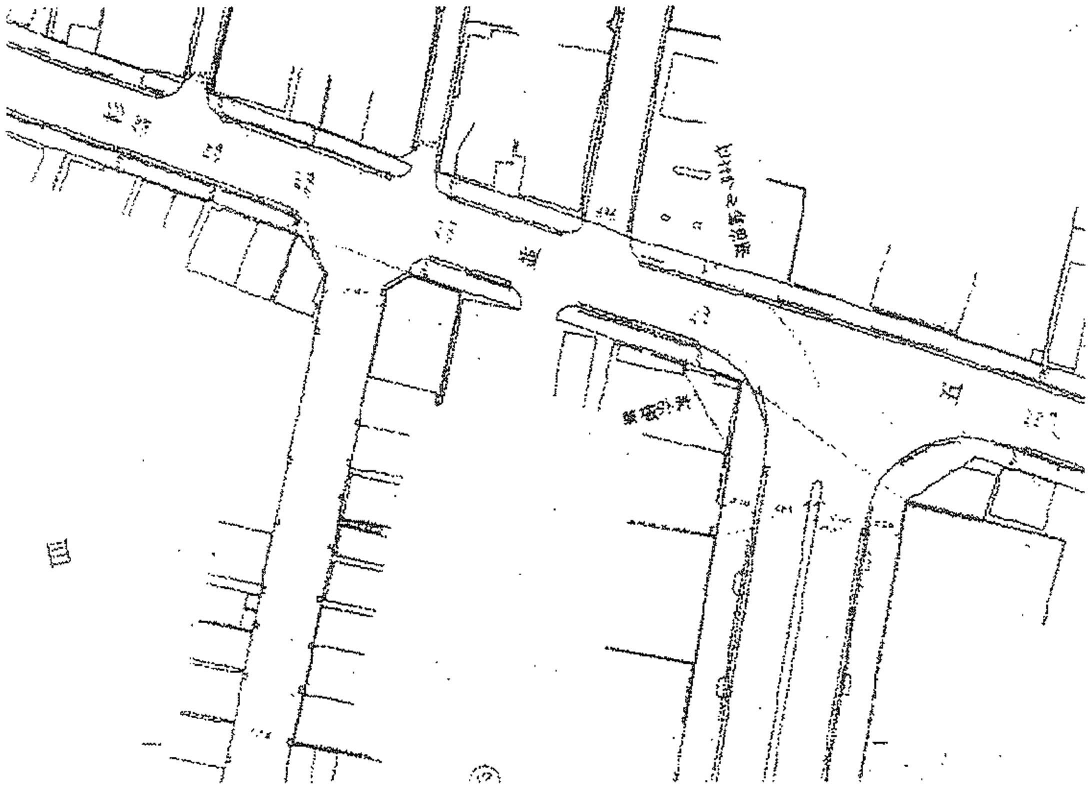


Figure 9 Map Read

4.1 Input of General Line

The centerline of the road network were approximately represented by a combination of straight lines, circulars and clothoid curves. Therefore the road network can be described by inputting general line on the segment basis. At this stage, the segment can be determined by user. But in order to get a good approximation of the road map, the user must divide the road network into smaller segments.

A segment is drawn automatically by specifying two pairs of data on 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. A general line is set up by connecting the input portions, one after another (Fig. 10). 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 coordinate) are input. These data are recorded in the database as digitalized information.

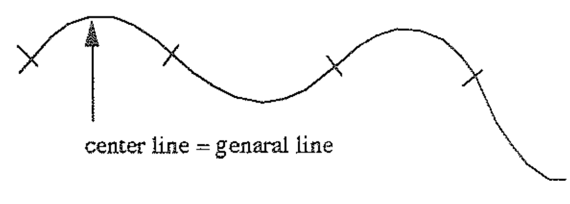


Figure 10 General Line Input at Every Segment

4.2 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. 6). If the width is set up along a general line, the road network becomes a two-dimensional geometrical form as shown in Fig. 11. Subroad is built based on the general line at every 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.

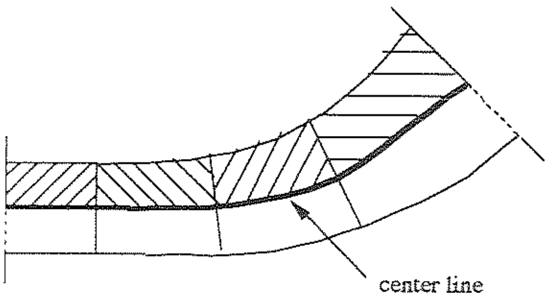


Figure 11 Form of Subroad

4.3 Input of Lane

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. The lanes are defined in every sub-road as shown in Fig. 12. If lanes merge or diverge, or right-turn lane exist, the sub-road is divided further into smaller subroads. The lanes in intersections are input automatically at this stage. As a result, once the process is completed, lane network is organized in the road network.

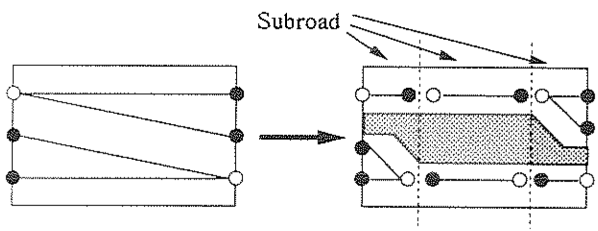


Figure 12 Lane in Subroad

5. 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 system model capable of describing the microscopic behavior of vehicles. We have succeeded in building a model that represents the condition of a road network with greater detail, precision, and faithfulness to the actual road system. We achieved this by using clothoid curves. Our model is composed of a network model and a track model, and includes all the information on the road itself for road traffic simulation, except for the traffic regulation information such as signals and signs. These models enabled us to develop a general-purpose road database for road traffic simulation. This system has a human interface to allow quick, easy, precise inputting of road information.

An issue to be addressed in the near future is improvement of the human interface and addition of traffic regulation information, e.g., signals and signs, to this system. Another items is that of enhancing the realism of the road network representation for three-dimensional features such as intersections.

6. ACKNOLEDGEMENT

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