PB2001-106205

Microscopic Car Modeling for Intelligent Traffic and Scenario Generation in the UCF Driving Simulator

Year 2

FINAL REPORT

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1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Microscopic Car Modeling for Intelligent Traffic and Scenario Generation in the UCF Driving Simulator – Year 2		5. Report Date
		6. Performing Organization Code
7. Author's Harold Klee		8. Performing Organization Report No.
9. Performing Organization Name and Address Center for Advanced Transportation Systems Simulation University of Central Florida P.O. Box 162450 Orlando, FL 32816-2450		10. Work Unit No. (TRAJS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation Research and Special Programs Administration 400 7th Street, SW Washington, DC 20590-0001		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

A multi-year project was initiated to introduce autonomous vehicles in the UCF Driving Simulator for real-time interaction with the simulator vehicle. In the first year, a traffic network consisting of several one and two-way roads, an outer loop and intersections with traffic control devices was created and populated with vehicles moving in a random manner. The network is completely defined in terms of a set of nodes and links. Using a Windows PC, the scientific and engineering program MATLAB was used to calculate positions and headings of the simulated vehicles with respect to the link/node coordinate system of the network. MATLAB was chosen because of its powerful data analysis, visualization and programming environment, extensive library of mathematical functions and its capability to produce easily customizable GUI's.

Initial traffic densities on the links are set by the user as are the arrival patterns of new vehicles entering the network at the source nodes. An onscreen map of the network displaying the simulated traffic movement, with zoom and scroll is useful for off-line software development purposes. The link/node vehicle coordinates are transformed in the PC to x,y and heading coordinates for communication to the simulation control program running in the host computer. The traffic generation frame rate is a function of the number of cars and other factors which affect the computational load on the PC. Traffic generation output is interpolated to synchronize with the basic simulator frame rate which is dictated by the vehicle dynamics model.

During the last year, some intelligence has been added to the driving patterns of the ambient traffic. This report describes the algorithms employed to accomplish this. It concludes with a brief discussion of the remaining work to achieve a fully interactive driving simulator with intelligent traffic.

17. Key Words	18. Distribution Statement
driving simulator, intelligent traffic	No restrictions – this report is available to the public through the National Technical Information Service, Springfield, VA 22161.

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	8	

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ABSTRACT

A multi-year project was initiated to introduce autonomous vehicles in the UCF Driving Simulator for real-time interaction with the simulator vehicle. This report describes the progress during the second year.

In the first two years, a traffic network consisting of several one and two-way roads, an outer loop and intersections with traffic control devices was created and populated with vehicles moving in a random manner. The network is completely defined in terms of a set of nodes and links. Using a Windows PC, the scientific and engineering program MATLAB was used to calculate positions and headings of the simulated vehicles with respect to the link/node coordinate system of the network. MATLAB was chosen because of its powerful data analysis, visualization and programming environment, extensive library of mathematical functions and its capability to produce easily customizable GUI's.

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INTRODUCTION

The UCF Driving Simulator, shown in Figure 1, has evolved since the mid 1990's into a midrange simulator with the potential to conduct research in transportation, human factors and real-time simulation. A view from the simulator is shown in Figure 2. Certain types of roadway improvement projects related to road geometry, sight distances, sign placement, traffic calming, etc. could be tested in the simulator. However, the absence of vehicular traffic in the visual data base precludes its use as a training device or as a testbed for studies involving traffic operations where traffic interaction is essential.

A multi-phase research study was initiated to create ambient traffic movements viewable by the driver in the simulator and also develop a limited scenario generation capability. In the initial phase, there was no attempt to introduce autonomous vehicles, i.e. vehicles whose movements reflect an awareness of each other's presence as well as that of the simulator vehicle. Instead, the primary focus was assuring that all vehicles remain properly registered with respect to the centerlines of each road. In the second phase, vehicles were programmed to exhibit autonomous driving behavior, however there is still more intelligence necessary in order to simulate realistic ambient traffic movements.

TRAFFIC GENERATION

A traffic network consisting of several one and two-way roads, an outer loop and intersections with traffic control devices was created and shown in Figure 3. This roadway network is purely fictitious and was created as a prototype for evaluation of the traffic generation routines.

Real-time traffic simulation uses a link/node type of description for a network of roads. The nodes are placed along the network at locations which define the permissible traffic patterns. The nodes are connected by links which allow the vehicles to be properly registered on the roads. A link/node description of a roadway network is not unique, however regardless of its definition, it is a starting point for the process of artificially generating vehicles for insertion in the network.

A database of link properties was created to describe the entire network topography, i.e. node types at either end (source, sink or intermediate), neighboring links, transition probabilities for moving from link to link, and relevant geometrical data.

INTELLIGENT TRAFFIC GENERATION

Running on a Windows PC platform, microscopic traffic flow models are used to calculate positions and headings of simulated vehicles with respect to the link/node coordinate system of the network. Link/node vehicle coordinates, consisting of the link number, distance along the link from the upstream node, and heading are transformed in the MATLAB PC to x,y and heading values in the coordinate system of the 3D modeling software used to create the visual database. This transformation guarantees the vehicles will be properly registered with respect to the centerlines of the roads. These coordinates are communicated over a network to the simulation control program running in the host computer, a Silicon Graphics ONYX computer. New link/node vehicle coordinates are established each frame, i.e. a complete pass through the traffic generation loop.

In the last year, microscopic traffic flow models have been developed for vehicles approaching intersections with traffic lights or stop signs, and for driving on sections of roads with posted speed limits. Intelligent vehicles have the ability of making correct decisions and choosing appropriate responses dynamically as conditions change. For example, vehicles attempt to maintain safe headways on the open road, slow down accordingly in the vicinity of stop signs and traffic signals in the R or Y phase. This is accomplished through the use of constraints on the vehicle's acceleration. That is, the current traffic environment is recognized and an appropriate acceleration is chosen.

There are two constraints on the acceleration of vehicles which are not in the vicinity of an intersection. One is based on the speed limit of the link and the other is determined from a car following algorithm. Furthermore, there are two speed limits the vehicle must consider. One is the speed limit of the current link; the other is the speed limit of the link that the vehicle will be transitioning to when the vehicle reaches the end of the current link.

As vehicles approach an intersection with a stop sign, they are forced to decelerate to a complete stop. If there is a traffic signal with a G or Y phase at the end of the link, the vehicle's acceleration is determined by whether or not it can pass safely through the intersection. When the vehicle approaches the end of a link with a traffic signal in the R phase, it decelerates to a complete stop.

Thus, there are five factors which influence a vehicle's acceleration in this model

1. Speed limit of the current link
2. Speed limit of the subsequent link
3. Acceleration based on car following algorithm
4. Presence of a traffic signal
5. Presence of a stop sign

Recognizing these five conditions leads to five different accelerations. For safety purposes, the governing acceleration is selected to be the mathematical minimum. A vehicle may be accelerating based on the speed limit model at one point and decelerating later on according to a car following rule.

Car following algorithms assume various forms. The basic intent however is to position vehicles on a single lane of traffic with safe headways or gaps between them. The initial algorithm which was tested and produced acceptable traffic flow is

$$a(t) = A[v_l(t) - v_f(t)] + B\{[(x_l(t) - x_f(t)] - H_{des}\}$$

where $a(t)$ is the computed acceleration of the following vehicle

$v_l(t)$ and $v_f(t)$ are the speeds of the lead and following vehicles

$x_l(t)$ and $x_f(t)$ are the positions of the lead and following vehicles

$x_l(t)$ - $x_f(t)$ is the headway between the vehicles

H_{des} is the desired headway of the following vehicle

A and B are suitably chosen constants

When a vehicle intending to go straight at an intersection approaches the end of a link with a traffic signal, it encounters one of three possible conditions and responds accordingly.

1. Signal is in R phase and vehicle decelerates to a complete stop.
2. Signal is in G phase and vehicle proceeds through as if traveling in open road conditions.
3. Signal is in Y phase and vehicle proceeds through if sufficient time remains before R phase is active, otherwise vehicle decelerates to a complete stop.

The above scenarios apply to intersections with protected left turns on G as shown in Figure 4. A view of traffic at a signal controlled intersection is shown in Figure 5.

All traffic flow approaching a stop sign decelerates to a complete stop. If the intersection is clear of vehicles and no other vehicles are about to enter the intersection, the car is allowed to proceed.

After the acceleration of a vehicle is determined (from the minimum of several competing traffic models), its speed and position (relative to the starting node of its current link) from the previous frame is updated. In this way, ambient traffic can be simulated and appear to the driver in the simulator to be behaving in an intelligent fashion.

FUTURE RESEARCH

Before the driving simulator is capable of serving as a robust tool for acquiring knowledge in the areas of transportation research it must acquire several additional capabilities. In order of importance, these are:

1. Ambient traffic vehicles must have knowledge of the position and speed of the simulator vehicle to properly position themselves when in the vicinity of the simulator.
2. Time for creation of link/node databases from roadway drawings must be reduced.

3. Traffic scenarios involving the ambient vehicles must be easily programmed to facilitate the implementation of new research studies in fields such as human factors, traffic flow, ITS, etc.
4. Vehicles must have the abilities to switch lanes.
5. Synthetically generated vehicles should exhibit individualized characteristics so vehicle movements are less predictable. This requires the use of randomized parameters for factors such as driver aggressiveness and vehicle performance.

Some of these issues have been addressed. Algorithms for recognizing the presence, i.e. the coordinates of the simulator in the link/node coordinate system are being tested. Additional work and testing is planned to assure the reliability and accuracy of the algorithms. Since the simulator vehicle's position is not constrained to an existing link, the car-following algorithms which rely on the distance separation between adjacent vehicles on the same or contiguous links are not directly applicable.

Lane changing poses similar problems since vehicles in transition from one lane to another are no longer identified with a specific link. Furthermore, the array which keeps track of the vehicles on each link, every frame, must account for vehicles (other than the leading vehicle) disappearing from a link or new vehicles suddenly appearing (other than the trailing vehicle) on a link.

Creation of a link/node description for a roadway network is time-consuming and prone to error. Several commercial traffic flow programs including Paramics and CORSIM create the links and nodes using front-end GUI's (graphical user interfaces). A similar approach is being explored to expedite the process of creating the link/node database for the UCF driving simulator traffic generation models.

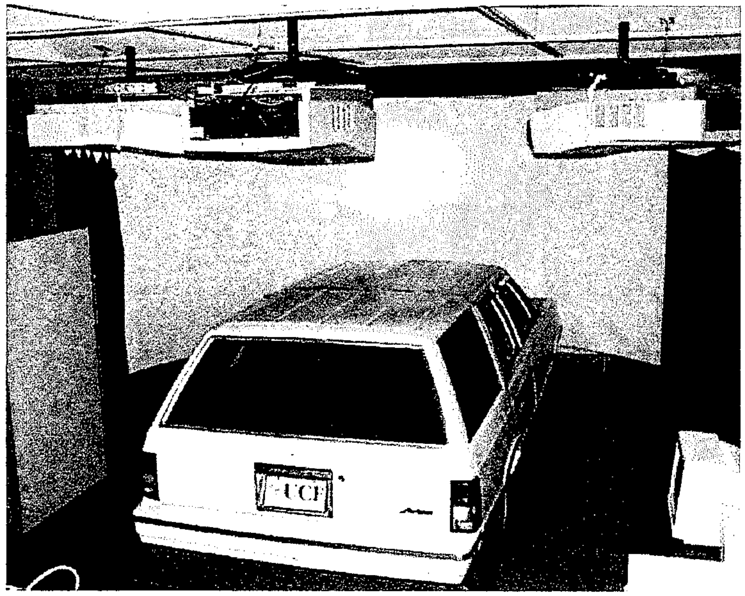

Figure 1 The UCF Driving Simulator

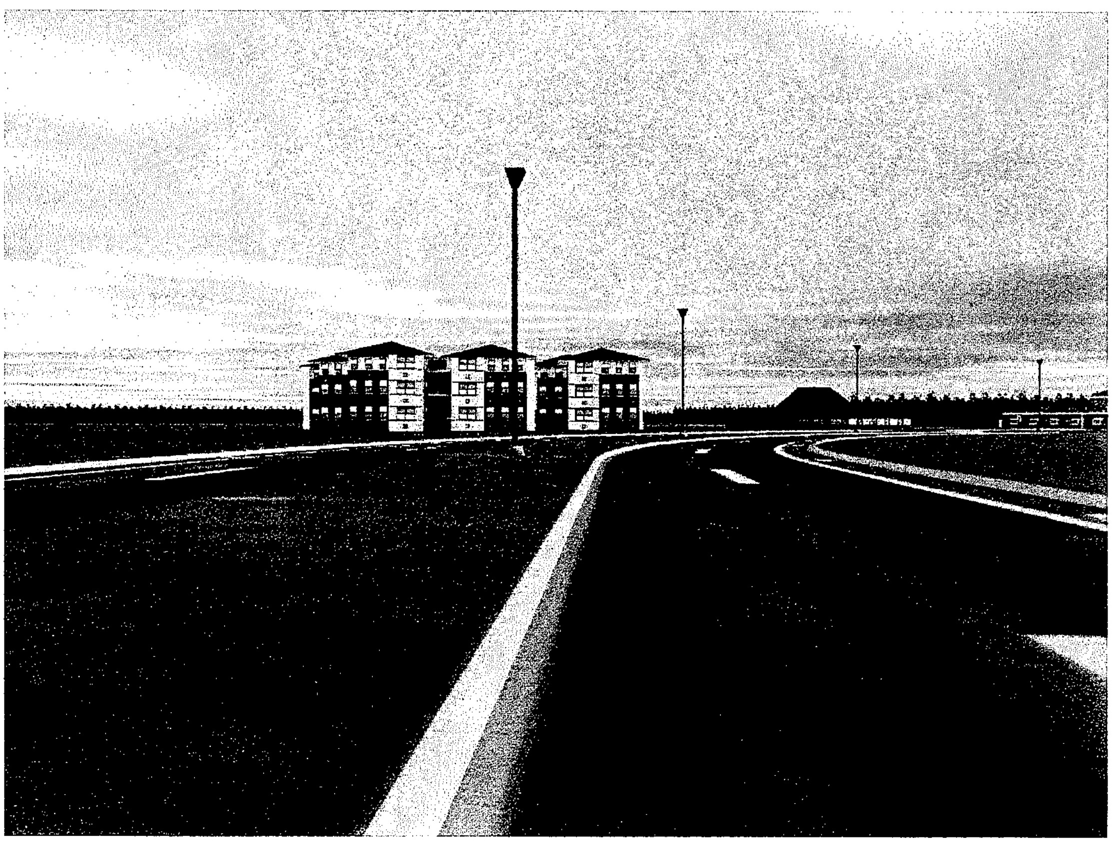

Figure 2 View From Inside the Simulator

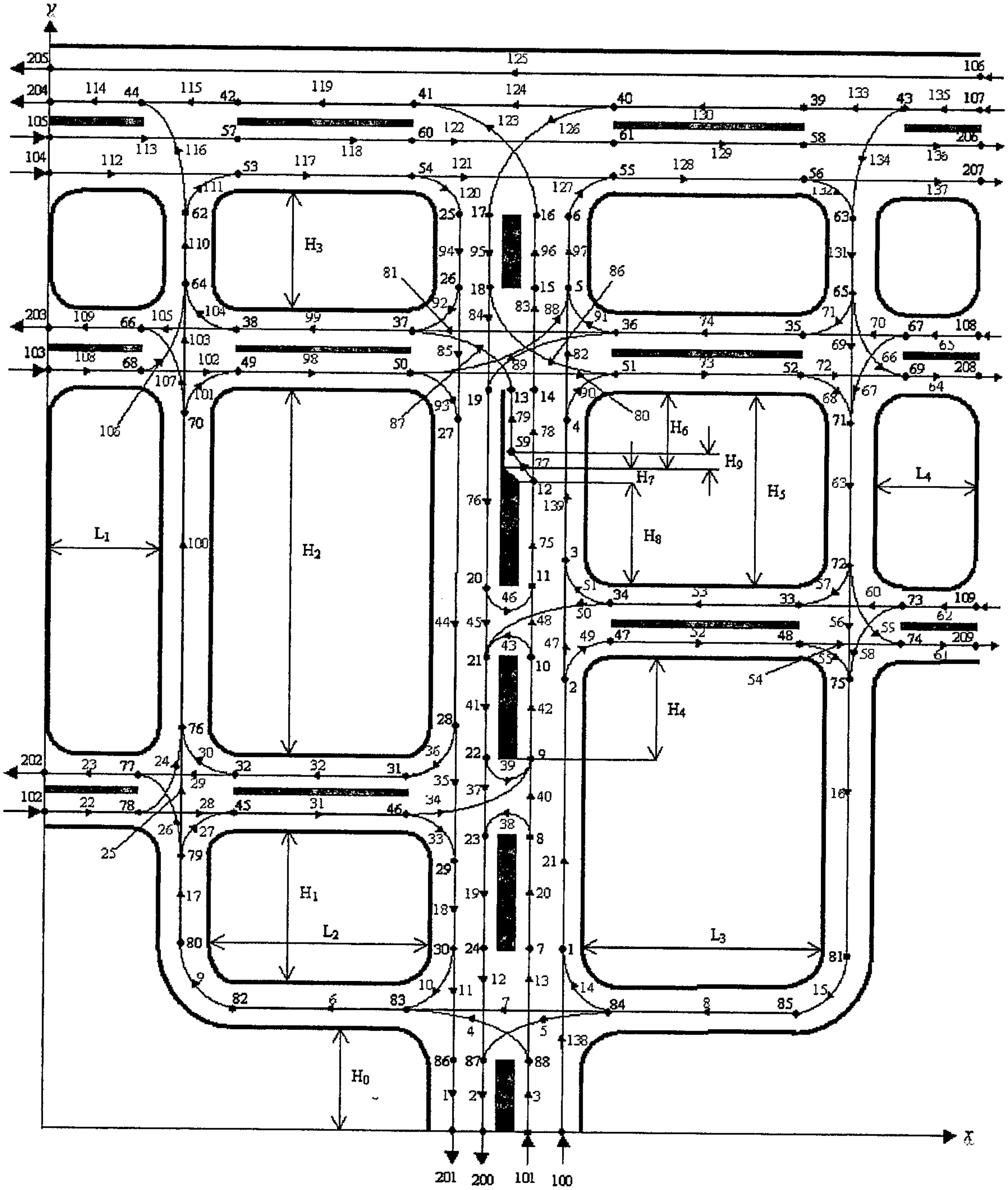

Figure 3 Roadway Network for Traffic Generation

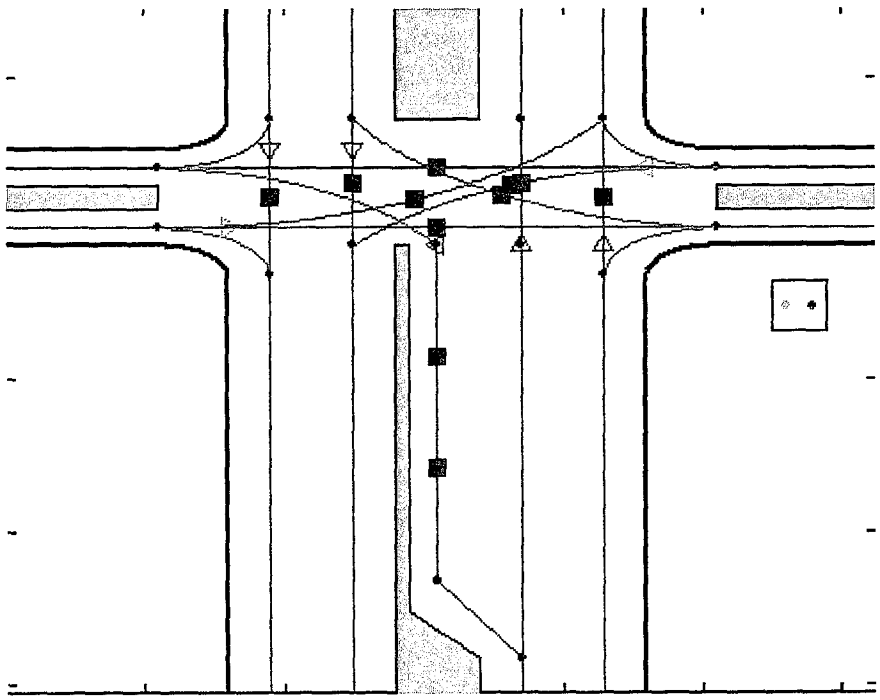

Figure 4 Traffic Generation at Intersection With Protected Left Turn G Phase

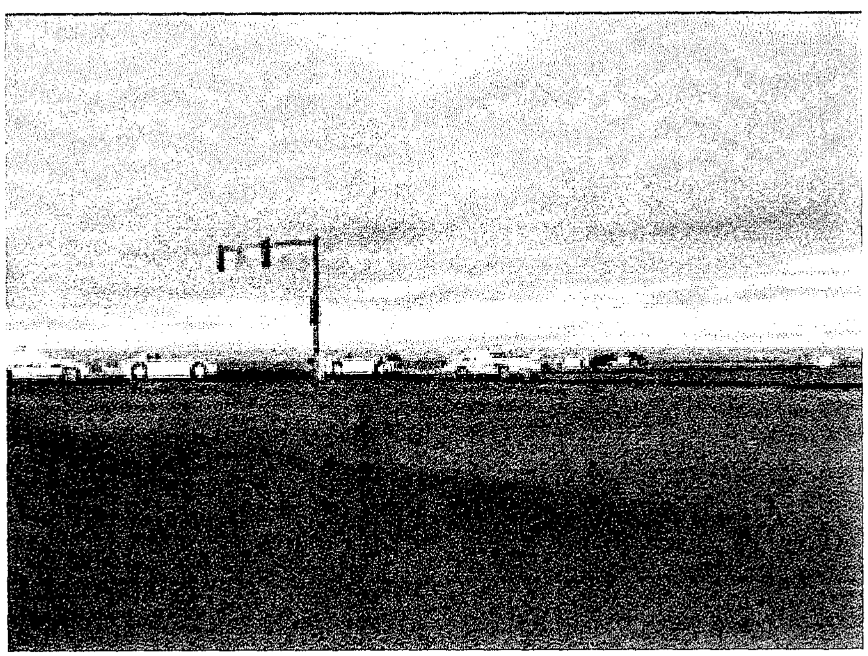

Figure 5 Rendered Scene of Traffic at Signal Controlled Intersection