Microscopic Car Modeling for Intelligent Traffic and Scenario Generation in the UCF Driving Simulator Year 3

FINAL REPORT

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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 third 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.

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.

Work was initiated at the beginning of the third year to convert the MATLAB code for traffic generation to C in order to improve execution time and make the software portable to other computing platforms. The conversion required several months to accomplish. In addition, intelligence was added to the vehicles movements resulting in their recognition of other vehicles and the ability to stop or proceed at signalized intersections depending on the phase (R,G,Y) of the traffic signal. The new code was successfully implemented in the original driving simulator.

Midway through the final year, a new driving simulator was purchased with a more turn-key mode of operation than the previous driving simulator. In addition to superior vehicle dynamics modeling, better visuals and a motion system, the new simulator included scenario definition software to control vehicle movements of external vehicles. This report describes several studies which were made possible because of the robust features of the scenario generation software.

In the Spring of 2002 a new driving simulator was acquired. The developer, GE Capital ISIM has been producing high-fidelity driving simulators for twenty years. A thorough description of the new simulator will be included in the Final Report for the related project entitled "Infrastructure Support for the Driving Simulator". One of the features of the new simulator which bears directly on this study is the scenario generation software which facilitates the process of populating the simulator's driving environment with intelligent vehicles.

The learning curve for applying the scenario generation tools is extensive. However, once mastered it expedites the procedure for creating traffic scenarios. Despite the considerable amount of work devoted to creating intelligent traffic in the first generation UCF driving simulator (see Final Reports for Years 1 and 2) the effort was abandoned with the acquisition of the new simulator and associated scenario generation software. With the new system, vehicles can be programmed to follow specific routes, adhere to certain driving patterns, appear at specific way points according to a predefined schedule or be triggered based on other events within the simulation. Furthermore, another class of vehicles can be defined which serves as ambient traffic with random movements that make the overall driving experience in the simulator appear more realistic.

Passing is permitted and driver aggressiveness is under the user's control. The original simulator traffic management software had not progressed to the point of implementing either of these features. The roadway network in the original simulator is configured by a database of links and nodes making it possible, although time consuming, to create a new visual database of roads and intersections. The new simulator lacks the flexibility to create a new visual database, however it is delivered with several extensive databases which include rural, urban and freeway settings. Different types of vehicles (passenger cars, buses, ambulances, police cars, trucks, etc) are user selectable for scripted and random movements through the database.

The visual databases are complemented by roadway databases (RDB) which contain road properties (speed limits, elevation, banking, surface material). Several of the students working in the new driving simulator lab have received instruction on the use of the scenario generation software and how to create new RDB's for existing roads. It will be necessary to create RDB's for the UCF campus database roads as well before they can be converted to a format for use in the new simulator. Work is proceeding in this direction to assure the sizable amount of man hours devoted to building the UCF campus database in the old simulator is not wasted.

The main purpose of this report is to describe two ongoing research projects made possible by the existence of the scenario generation software in the new driving simulator. The first concerns evaluation of a prototype system to improve driving safety while the second pertains to a traditional area from traffic engineering.

Evaluation of a Safety Warning System

Researchers from Georgia Tech Research Institute (GTRI) visited the new driving simulator facility in April and discussed the types of scenarios needed for their US DOT funded study on a safety warning system (SWS). The SWS consists of a transmitter and radar receiver which mounts on the windshield of a vehicle and alerts the driver using prerecorded messages about the presence of a school bus, work zone, RR crossing, etc. GTRI has contracted UCF for time on the simulator to evaluate the effectiveness of the SWS.

An experimental test plan, developed by GTRI and UCF researchers, is outlined below.

Introduction

This test plan outlines the key points of the Safety Warning System (SWS) effectiveness human factors simulation study. The SWS radar system provides an inexpensive and efficient warning system for drivers. It uses well-established radar technology allowing specially equipped SWS radar detectors to display and enunciate via synthesized voice over 64 different warning messages. Over the last 2 years more than 4 million SWS enabled radar detectors were sold in the United States. The SWS system can provide warning to drivers, potentially having a crash reduction impact.

This study utilizes the new UCF driving simulator to evaluate driver responses and behavior to SWS warnings under various scenarios and traffic incidents.

Study Objectives

The objective of this study is to explore whether driver reaction and performance is affected by SWS warnings, especially at low driver awareness levels. If the information provided by the SWS warnings is useful the driver should have shorter reaction times and make better decisions.

The study is designed to answer the following questions:

1. Does the warning SWS tone and context sensitive message improve driver awareness when compared with no information?
2. Does SWS affect older and younger drivers equally?

Driver awareness will be evaluated using measured variables such as driver reaction time, average speed, etc.

Method

Subjects

A total of 96 subjects are expected to participate in this study. The group is segmented so that half is between the ages of 18 and 35 years and the remaining are over the age of 65, with the genders evenly represented. Table 1 displays the assignment of the subjects into the test groups.

Group	Males 18-35	Females 18-35	Males 65+	Females 65+	Number of Subjects
Total	24	24	24	24	96

Table 1 – Subject Assignment

Experimental Design

A driving scenario consists of a 5-6 minute session in the driving simulator with 2 of the 6 events enumerated in Table 2 occurring.

Events	*Description*
(#1) Train/SWS	Train approaching crossing such that gates start down before driver reaches crossing forcing driver to make decision on "beating the train" or stopping. SWS present.
(#2) Roadside Parked School Bus/No SWS	School bus with flashing lights simulating picking up children. No SWS present.
(#3) Work Zone/No SWS	Two lane rural highway. Work zone is located after a curve or hill such that there is limited line of sight. NO SWS present.
(#4) Roadside Parked School Bus/SWS	School bus with flashing lights simulating picking up children. SWS present.
(#5) Train/No SWS	Train approaching crossing such that gates start down before driver reaches crossing forcing driver to make decision on "beating the train" or stopping. No SWS present.
(#6) Work Zone/SWS	Two lane rural highway. Work zone is located after a curve or hill such that there is limited line of sight. SWS present.

Table 2 – Simulation Events

All subjects face the same set of 3 driving scenarios, denoted *A*, *B* and *C* shown in Table 3. The scenarios are presented in different orders (ABC, BCA, or CBA chosen at random) so that the data collected in later scenarios are not biased by learning from earlier scenarios. There is a short delay (approximately 2 min) between scenarios.

Scenario	*Events*	*Elapsed Time to Event*
A	(#1) Train/SWS (#2) School Bus/No SWS End Scenario	1 min 5 min 6 min
B	(#3) Work Zone/No SWS (#4) School Bus/SWS End Scenario	2 min 5 min 6 min
C	(#5) Train/No SWS (#6) Work Zone/SWS End Scenario	1 min 4 min 5 min

Table 3 Scenarios for Experiment

Display Conditions

An SWS receiver is mounted on the vehicle windshield. One of two SWS conditions is in effect for each event. They are

1. No SWS: Control condition with no SWS warnings
2. SWS: SWS context sensitive message using synthesized speech

The control condition does not broadcast any SWS messages. The control condition is used to determine if SWS signaling positively or negatively affects the subject's responses to the simulated scenarios. The second condition uses synthesized voice to give context sensitive SWS information about the type of hazard the driver is about to encounter. The work zone scenario broadcasts the message, “Highway Work crews Ahead.” The railroad crossing scenario broadcasts the message, “Train Approaching at Crossing.” The school bus scenario broadcast the message, “School Bus Loading or Unloading.”

Procedure

Upon arrival, the subjects are given an informational briefing. In order to avoid driver bias, the participants are informed that the objective of the study is to assess the fidelity of the simulator. Each subject is escorted to the simulator cabin and informed about the SWS receiver during the normal simulator orientation. A demonstration of how the SWS receiver looks/sounds is given and the subject is required to repeat a sample message. A short practice period (~ five minutes) is provided. No SWS message occurs during the practice period.

Dependent Measures

The statistical analysis will focus on driver reaction to incoming SWS warnings and the environmental cues provided by the simulator.

Number of Collisions

A crash is defined as the subject’s vehicle striking the rear or side of the lead vehicle. The purpose of this measure is to determine if the SWS system can reduce the number of vehicular crashes.

Speed on Impact

The speed of the subject’s vehicle whenever a collision occurs.

Accelerator Behavior

The raw accelerator input is recorded at a 30 Hz sample rate. This variable, coupled with the brake input data and SWS message activation data, provides a measure of the subject’s reaction time to the scenario.

Braking Behavior

The raw brake input is recorded at a 30 Hz sample rate. This variable, coupled with the accelerator input data and SWS message activation data, provides a measure of the subject’s reaction time to the scenario.

Steering Behavior

The raw steering input is recorded at a 30 Hz sample rate. The variability of this data during the scenario provides a measure of evasive action taken by the subjects.

X,Y Coordinates

The X,Y coordinates of the vehicle is recorded at a 30 Hz sample rate. From this data, the velocity and acceleration of the vehicle can be derived. The data will be used to compare velocity and acceleration profiles between SWS and non-SWS instrumented scenarios.

Several scenes from the finished scenarios are shown below.

Figure 1 Scene from Scenario with Construction Work Zone

Figure 2 Scene from Scenario with Railroad Crossing

Figure 3 Scene from Scenario with Stopped School Bus

There have been 53 subjects processed as of this date. The raw data has been given to GTRI for data reduction and analysis of results. GTRI will publish results of this study in the Spring of 2003.

Simulation Research Methodology for Gap Acceptance at Stop-controlled Intersections

The goal of this project is to use the driving simulator as a vehicle for quantifying minimum acceptable gaps for a left turn from a minor road at a stop controlled intersection and compare the findings to published results.

The scenario for left turn from the minor road is defined as Case B1 in the AASHTO (2001). According to the geometric design policy of AASHTO (1994), Intersection Sight Distances for a left turn is based on models of the acceleration and deceleration behavior of the potentially conflicting vehicles. Compared to the AASHTO (1994), the section on Intersection Sight Distance has been completely revised in the AASHTO (2001), which is based on a time gap acceptance methodology. A gap is the time headway between two vehicles on the major road into which a minor-road vehicle may choose to turn. The intersection sight distance in both directions should be equal to the distance traveled at the design speed of the road during a period of time equal to the time gap which drivers accept to make right or left turn or crossing maneuver.

This study will utilize the UCF driving simulator to test the critical minimum gap acceptances under scenarios of Case B1 with different traffic speeds on the major road.

Data is collected in the UCF driving simulator while subjects are in the process of making a left turn from a minor road with a STOP sign onto a major road with various levels of traffic flow. The following parameters will be recorded directly or calculated:

(1) Gaps in major-road traffic (for 25 mph and 55mph) that are accepted by the minor-road drivers.

(2) Behavior of minor-road drivers at intersections, including their speeds, accelerations, and decelerations and the same for the following major-road vehicle when a gap in major-road traffic is accepted by the minor-road driver.

(3) Speed reductions by major-road drivers to accommodate the turning vehicle and the minimum separation between the minor-road vehicle and the following major-road vehicle at any point during the maneuver.

The data will be used to assess the effects of traffic speeds, age and gender on the minimum acceptable gap. Using confidence intervals and statistical analysis, a total of 73 participants is required to estimate the mean minimum acceptable gap with an error of no more than 0.5 seconds at a 95% confidence level. The numbers in each age group (Table 2) is based on the age distribution of the American population. All participants must have a valid driving license with a minimum of 1-year driving experience.

Age	**18-55**		**56-75**		**75 +**		**Total**
Gender	Male	Female	Male	Female	Male	Female	
Sample	25	24	8	8	4	4	73

Table 1 Age and Sex Distribution of the Sample

All subjects will face the same set of 2 driving scenarios, denoted A, B shown in Table 3. The scenarios will presented in the order A-B-A-B-A-B or B-A-B-A-B-A with a 2 min delay between scenarios.

Scenario	Traffic speed on the major road	Elapsed Time
A	25 mph	2 min
B	55 mph	2 min

Table 2 Scenarios for Experiment

There are several stages for the driver making the left turn from the minor road. In the first stage, the simulator vehicle is driven 400 meters along the minor road. When the simulator vehicle approaches the intersection, vehicles on the major road begin to move. In the second stage, the driver stops at the intersection and waits for an acceptable gap to make a left turn. The third stage occurs when the simulator vehicle enters the major road and accelerates to the speed of the traffic on the road.

Stage	Description
#1	Driving the simulator for 400 meters along the minor road.
#2	Stopping the simulator in front of the stop sign at the intersection and waiting for the proper gap to make left turn.
#3	Making left turn from the minor road onto the major road.

Table 3 Simulation Stages

A straight undivided two-lane collector is selected as the major road. Its length is 3000 m and lane width is 12 ft. Stop signs are present on the two-lane minor road (see Figure 4). The sequence of gaps seen by the stopped vehicle attempting a Case B1-Left turn are recorded. The major road speed limit is either 25 mph (Scenario A) or 55 mph (Scenario B).

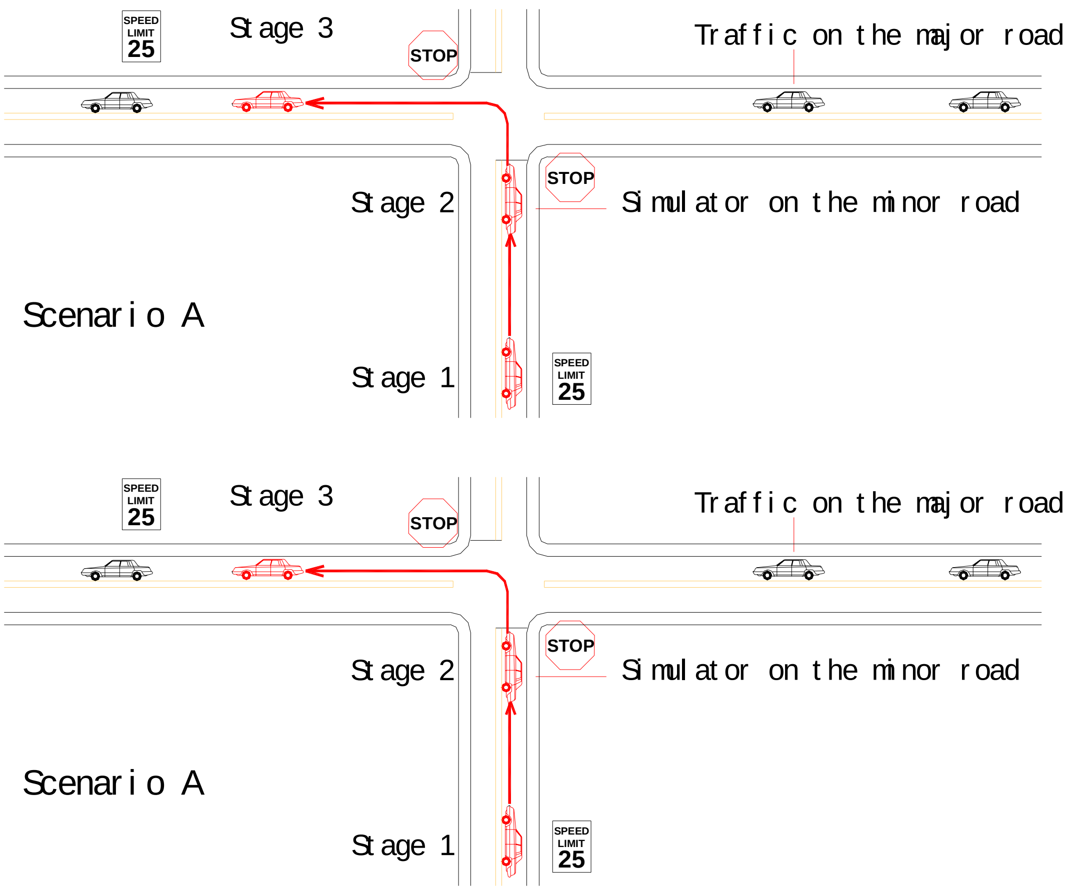

Figure 4 Scenarios of Traffic Simulation

The minimum acceptable gap for drivers in the simulator should be roughly the same as it would be in the actual situation. To accomplish this, oncoming traffic on the major road from the right is composed of two classes of intermingled gaps to make the traffic appear random (see Figure 5). The first gap classification is very small gaps (less than 3 seconds) that are unlikely to be accepted by the participants. The second class consists of increasing gaps in which the subsequent gap is one second larger than the previous one. This pattern assures that the selected gap is close to the driver's minimum acceptable gap. The uniformly increasing gaps range in duration from one sec to sixteen sec, a large enough variation to accommodate all drivers.

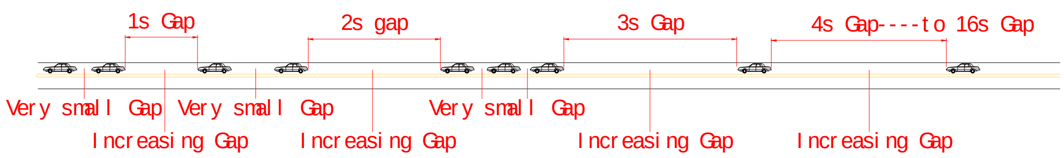

Figure 5: Illustration of Major Road Traffic Gaps

Using the scenario editing software, vehicles traveling on the major road are programmed to travel at a constant speed until they arrive at a fixed distance from the intersection. From that point they become autonomous, reacting to the possible presence of the simulator vehicle entering the intersection to make the left turn and merge with the major road traffic. Major road vehicles will decelerate from the posted speed limit, if necessary, to allow the simulator vehicle to negotiate the left turn. Consequently, the likelihood of a collision at or downstream from the intersection is minimized, however its still possible if the simulator vehicle enters the major road too slowly or selects an unusually small gap.

Positional coordinates of the simulator vehicle and driver inputs including steering, brake and gas are logged at 30 Hz. Major road vehicles x,y coordinates are also logged; however only the data for the vehicles comprising the accepted gap are retained. Logged data is time-stamped allowing for the calculation of speeds and accelerations of the simulator vehicle and the two major road vehicles of interest. Vehicle separations on the major road can be determined, in particular, the distance separating the simulator vehicle and the following vehicle after completion of the left turn.

Figures 6 is a snapshot of the simulator vehicle stopped at the intersection waiting for an acceptable gap and Figure 7 shows the simulator vehicle in the process of making the left turn on to the major road.

As of this date, a handful of subjects have been tested to evaluate the experimental protocol. The full fledged study is scheduled to commence in early Nov 2002. Preliminary results will be presented in the Quarterly report for CATSS project "Assessment of the Use of a Driving Simulator for Traffic Engineering Studies".

Figure 6 Simulator Vehicle Waiting for Acceptable Gap to Begin Left Turn Maneuver

Figure 7 Simulator Vehicle in Process of Making Left Turn Onto Major Road