Final Report

Infrastructure Support for the UCF Driving Simulator

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ABSTRACT

In the decade of the 1990's, the University of Central Florida operated a driving simulator which was used primarily for research in simulation and human factors. In early 2002, a new driving simulator was acquired with significantly more capabilities, most notably a motion platform, additional video channels and extensive traffic scenario software for creating controlled experiments. This report describes the simulators and the research conducted with each one, with emphasis on two recent studies involving the new simulator.

1990-2001

The original driving simulator was assembled by integrating the various systems for simulating vehicle dynamics, creation of synthetic databases, visualization and traffic management. The last component was the subject of a multi year effort to populate the network of roads with autonomous vehicles interacting with the simulator vehicle in real-time (Klee). Figures 1 and 2 show the simulator and a roadway scene from the simulator's visual database.

Figure 1 Original UCF Driving Simulator

Figure 2 Scene in Visual Database

A road network was created for testing the traffic management software. The network is shown in Figure 3. The roads are uniquely defined by a set of nodes and links. Straight links are characterized by a 'Start' and 'End' node along with a heading and curved links are defined by a 'Start' and 'End' node and a geometrical curve connecting the nodes. 'Source' nodes and 'Termination' nodes are used to introduce vehicles and remove them from the network. Traffic management software constrains vehicle movements to points along a link, assuring proper registration along the centerline of roads. Car-following algorithms maintain proper separations and avoid collisions of vehicles. Additional logic controls vehicle movements at intersections with traffic control devices.

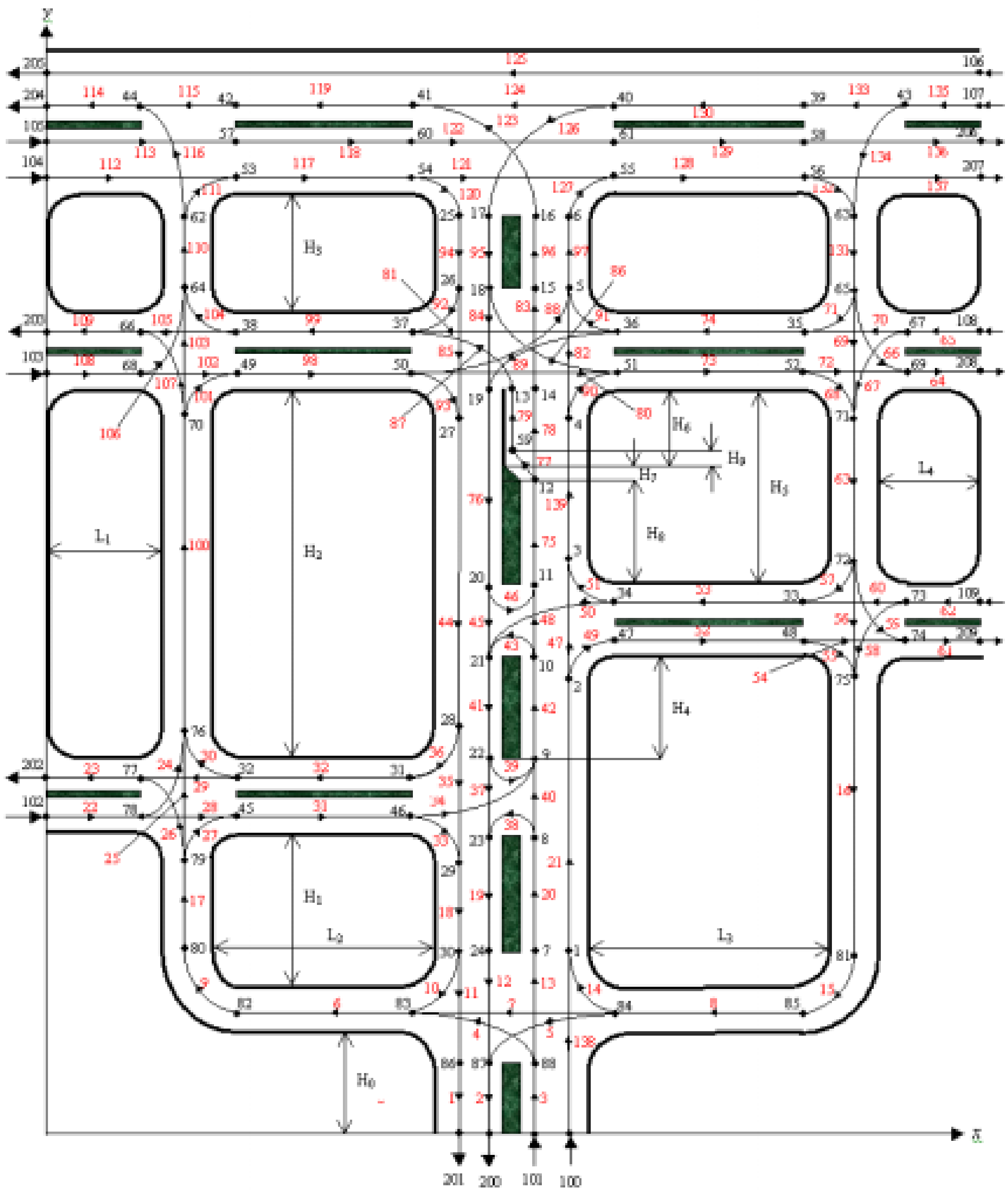

Figure 3 Roadway Network for Traffic Generation

Vehicle locations are uniquely described by a link number and the distance from the 'Start' node of the link. The link/node vehicle coordinates are transformed in the traffic management PC to *x*,*y* and heading coordinates in the visual database coordinate system and communicated to the simulation control program for rendering by the visual system in the host computer (see Figure 4). The traffic generation frame rate is a function of the number of cars and other factors which affect the computational load on the PC. For heavy loads, traffic generation output is interpolated to synchronize with the

30 Hz simulator frame rate dictated by the vehicle dynamics model. 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.

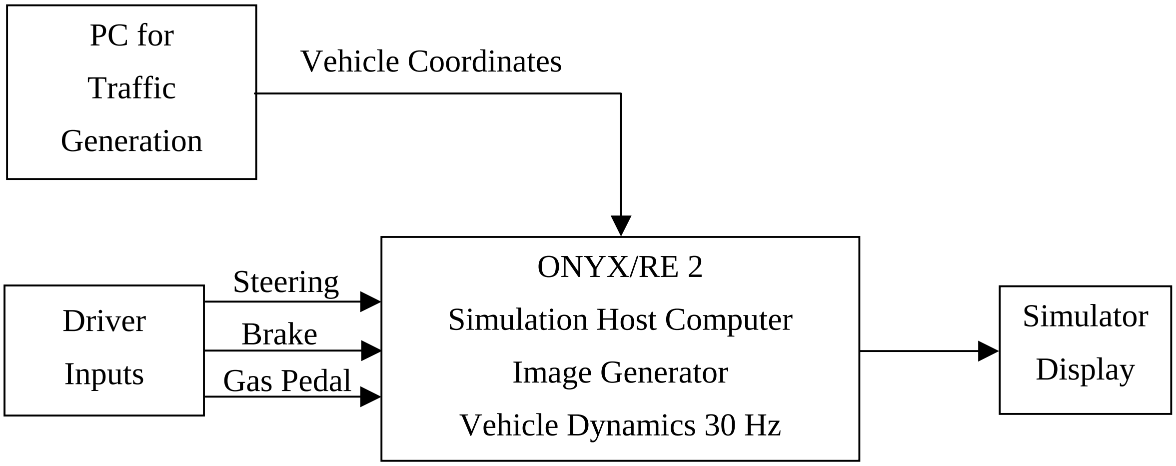

Figure 4 Traffic Generation PC and Host Computer in the Visual Loop

Figures 5 and 6 show snapshots of traffic viewed from outside and inside the simulator vehicle.

Figure 5 Outside View of Traffic

Figure 6 Traffic View from Inside Simulator

<u>2002 – Present</u>

In Sping 2002, The Center for Advanced Traffic System Simulation (CATSS) acquired a reconfigurable driving simulator placed in a high bay lab. A late model truck cab (Figure 7) or passenger vehicle cab (Figure 8) is mounted on a motion base capable of operation with 6 degrees of freedom. It includes 5 channels (1 forward, 2 side views and 2 rear view mirrors) of image generation, an audio and vibration system, steering wheel feedback, operator/instructor console with graphical user interface, sophisticated vehicle dynamics models for different vehicle classes, a 3-dimensional road surface model, visual database with rural, suburban and freeway roads plus an assortment of buildings and operational traffic control devices, and a scenario development tool for creating real world driving conditions.

Figure 7 New Simulator with Truck Cab on Motion Platform

Figure 8 Two Views of New Simulator with Passenger Vehicle on Motion Platform

Despite the considerable amount of work devoted to creating intelligent traffic in the first UCF driving simulator, 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 new simulator lacks the flexibility to easily 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.

Other features include the ability to implement vehicle system malfunctions, limited visibility conditions and controllable weather (sunny, rain, snow, etc). Extensive data logging of driver inputs and vehicle motion is available. Figure 9 shows a signalized intersection viewed from inside the simulator. Figure 10 shows a snapshot of a view from above and behind the simulator vehicle and Figure 11 shows an overhead view. Other camera angles are available for playback of a recorded simulator session.

Figure 9 View from Inside Simulator at a Signalized Intersection

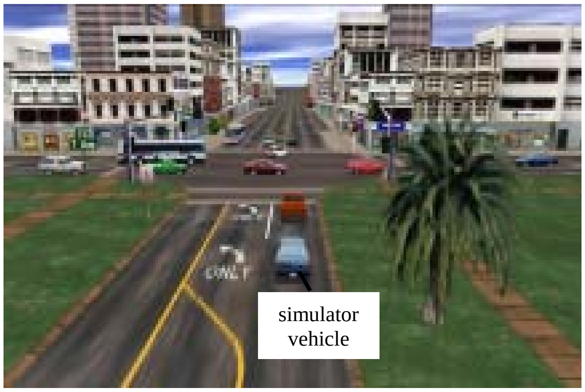

Figure 10 View from Above and Behind Simulator Vehicle

Figure 11 Overhead View of Intersection

The simulator session is controlled from an operator's console in an adjacent control room. Scenarios are created with the scenario editing software on a screen showing the locations of roads, buildings, traffic control devices, pedestrians, etc. Figure 12 shows an arterial road with several traffic lights to be used for creating a scenario to evaluate the Level of Service for different signal timing algorithms.

The five video channels are monitored on computer screens in the control room (Figure 13). A road map of the database is viewable on the operator's console showing movement of the simulator vehicle and other vehicles which are present (see Figure 14).

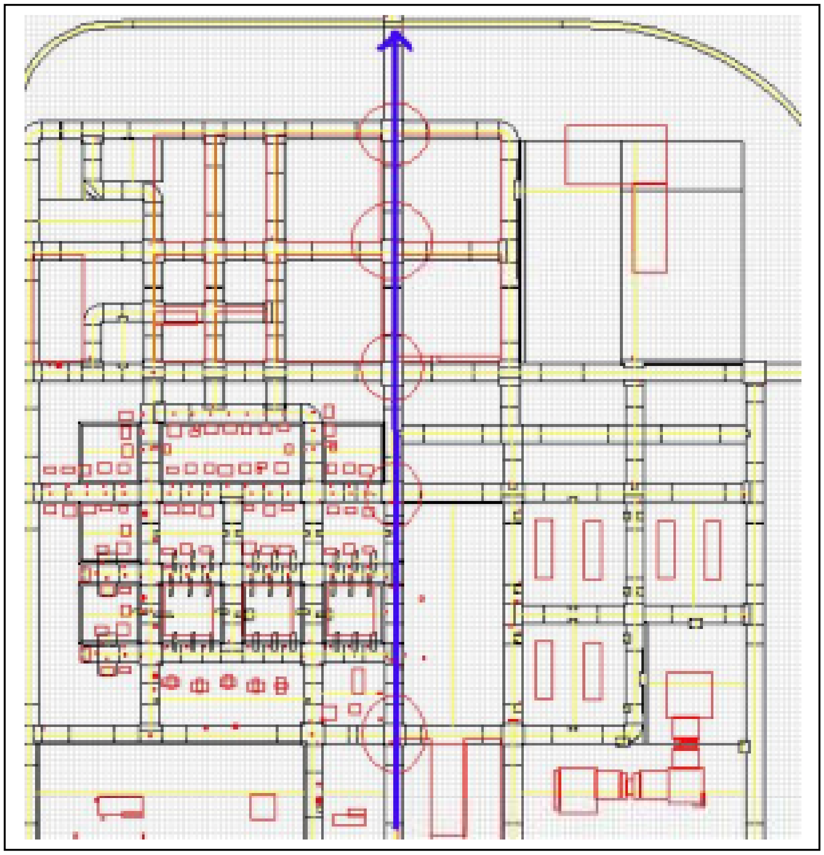

Figure 12 Creating a Scenario to Test Traffic Flow

Figure 13 Inside the Control Room

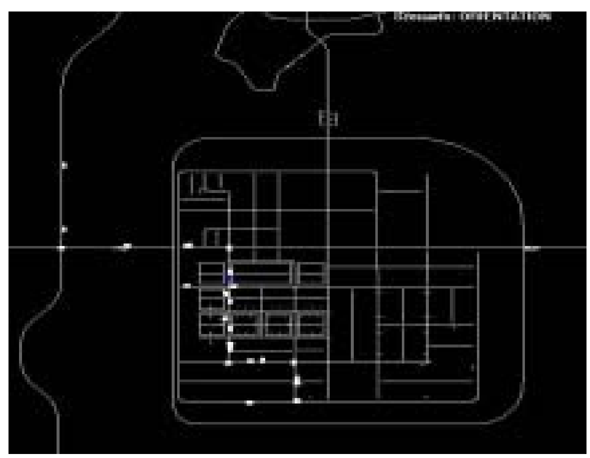

Figure 14 Real-time Map Showing Movement of Simulator and Other Vehicles

The new simulator is capable of supporting research in driving simulation, driver training, human factors and traffic engineering. Two research projects, made possible by the scenario generation software, have been conducted 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. A brief description follows.

Evaluation of a Safety Warning System

Researchers from Georgia Tech Research Institute (GTRI) conducted a US DOT funded study on a safety warning system (SWS) which provides an inexpensive and efficient warning 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.

A test plan was formulated by GTRI and UCF researchers to utilize the new UCF driving simulator to evaluate driver responses and behavior to SWS warnings under various scenarios and traffic incidents. The objective of this study was 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.

A description of the events encountered by drivers in the simulator is shown in Table 1.

Event	Description
Train/SWS	Train approaching crossing. Gates start down before driver reaches crossing forcing driver to make decision on “beating the train” or stopping. SWS present.
Roadside Parked School Bus/No SWS	School bus with flashing lights simulating picking up children. No SWS present.
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.
Train/No SWS	Train approaching crossing. Gates start down before driver reaches crossing forcing driver to make decision on “beating the train” or stopping. No SWS present.
Roadside Parked School Bus/SWS	School bus with flashing lights simulating picking up children. SWS present.
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 1 Listing and Description of Events Created with Scenario Editor

One of two SWS conditions was in effect for each event.

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 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 broadcasts the message, “School Bus Loading or Unloading.”

All subjects experienced the same 3 driving scenarios, denoted A, B and C shown in Table 2. The scenarios were each approximately 5 minutes in duration. Drivers were instructed with prerecorded messages to follow a route which included two of the events in Table 1. The scenarios were presented in different orders (ABC, BCA, or CBA chosen at random) so that the data collected in later scenarios were not biased by learning from earlier scenarios.

Scenario	Events in Scenario
A	Train/SWS School Bus/No SWS
B	Work Zone/No SWS School Bus/SWS
C	Train/No SWS Work Zone/SWS

Table 2 Events Included in Scenarios A, B and C

The SWS receiver was mounted on the vehicle windshield (see Figure 15).

Figure 15 Safety Warning System Inside Simulator Vehicle

Scenes from the finished scenarios are shown in Figures 16-18.

Figure 16 Scene from Scenario with Railroad Crossing

Figure 17 Construction Work Zone Scene

Figure 18 Stopped School Bus Scene

Ninety-three subjects completed a 5-minute orientation scenario and the three scenarios A, B and C. Gender and age of the group completing the experiment was roughly 57% male, 43% female ranging in age from 18 to 65 (most between 18 and 50).

Data collection included number of collisions, accelerator, braking, and steering inputs and time stamped *x*,*y* coordinates of the simulator vehicle. Velocity and acceleration of the vehicle was derived from its time-stamped position coordinates. Differences in velocity and acceleration profiles of the drivers for each event are being analyzed at GTRI to determine the effect (negative or positive) of having the SWS warning system. A written survey of the driver's opinions about the SWS was administered at the end of the driving session.

Gap Acceptance at a Stop-Controlled Intersection

The second project used 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 compared the findings to published results. The scenario for a left turn from a minor road (Figure 19), Case B1 in AASHTO (2001), was simulated in the driving simulator. The scenarios included different traffic speeds on the major road.

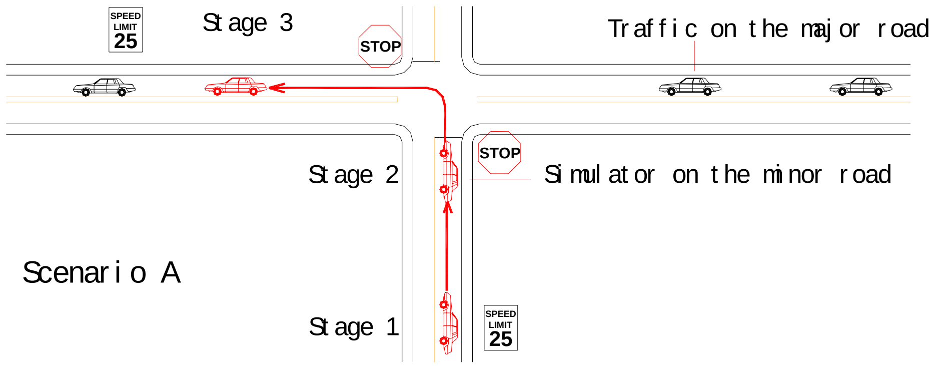

Figure 19 Left Turn from Minor Road at Intersection with STOP sign

The following parameters were 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 vehicles at intersections, including their speeds, accelerations, and decelerations and the same for the following major-road vehicle when a gap 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 was used to assess the effects of traffic speeds, age and gender on the minimum acceptable gap. Using 95 % confidence intervals from Statistics, a total of 73 participants were needed to estimate the mean minimum acceptable gap with an error of no more than 0.5 seconds. The numbers in each age group (Table 3) is based on the age distribution of the American population.

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

Table 3 Age and Sex Distribution of Drivers

All subjects faced the same set of 2 driving scenarios, denoted A, B in Table 4. The scenarios were 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 4 Scenarios for Experiment

There were several stages for the driver making the left turn from the minor road. In the first stage, the simulator vehicle was driven 400 meters along the minor road. When the simulator vehicle approached the intersection, vehicles on the major road began to move. In the second stage, the driver stopped at the intersection and waited for an acceptable gap to make a left turn. The third stage occurred when the simulator vehicle entered the major road and accelerated 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 5 Simulation Stages

A straight undivided two-lane collector was 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 19). The sequence of gaps seen by the stopped vehicle attempting a Case B1-Left turn were recorded. The major road speed limit was either 25 mph or 55 mph.

Oncoming traffic on the major road from the right was composed of two classes of intermingled gaps to make the traffic appear random (see Figure 20). The first gap classification was very small gaps (less than 3 seconds) that were unlikely to be accepted by the participants. The second class consisted of increasing gaps in which the subsequent gap was one second larger than the previous one. This pattern assured the selected gap would be close to the driver's minimum acceptable gap. The uniformly increasing gaps ranged in duration from one sec to sixteen sec, a large enough variation to accommodate all drivers.

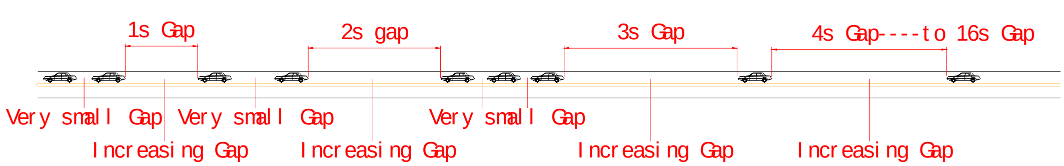

Figure 20 Illustration of Major Road Traffic Gaps

Using the scenario editing software, vehicles traveling on the major road were programmed to travel at a constant speed until they arrived 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 decelerated 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 was minimized, however it was still possible if the simulator vehicle entered the major road too slowly or selected an unusually small gap.

Position coordinates of the simulator vehicle and driver inputs including steering, brake and gas were logged at 30 Hz. Major road vehicles x, y coordinates were also logged; however only data for the vehicles comprising the accepted gap were retained. Logged data was time-stamped enabling the calculation of speeds and accelerations of the simulator vehicle and the two major road vehicles of interest. Vehicle separations on the major road could be determined as well as the distance separating the simulator vehicle and the following vehicle after completion of the left turn.

Figures 21 is a snapshot of the simulator vehicle stopped at the intersection waiting for an acceptable gap and Figure 22 shows the simulator vehicle in the process of making a left turn on to the major road.

Figure 21 Simulator Vehicle Waiting for Acceptable Gap

Figure 22 Simulator Vehicle Making Left Left Turn Onto Major Road

Data collection was completed in Jan 2003. Results will be published in Spring 2003 following data reduction and analysis.

UCF Campus Database

Work has continued on creation of a visual database of the UCF campus roads and buildings. Several buildings are shown in Figure 23. Once the database is complete and formatted to be compatible with the new simulator visual system, we will have the capability of conducting simulator validation experiments on a geospecific database. That is, data from driving an instrumented vehicle on a section of the campus can be compared with logged data from the simulator for the same roads.

Figure 23 Several Buildings Located on the UCF Campus for Use in Driving Simulator Visual Database

References

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2. Klee, H., "Test Plan for SWS Effectiveness Study", Aug 2002.

3. Yan, Xuedong, "Analysis of Minimum Acceptable Gap for Left Turn Maneuver Using a Driving Simulator", MS Thesis, Feb, 2003.