

Microscopic Car Modeling for Intelligent Traffic and Scenario Generation in the UCF Driving Simulator Year 1

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 first year.

A traffic network consisting of several one and two-way roads, an outer loop and intersections with traffic control devices was created. It 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 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.

INTRODUCTION

The UCF Driving Simulator 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. In 1995, a joint UCF research team began a project to enhance the capabilities of the simulator to incorporate modern hardware and software technology. A Silicon Graphics Onyx Reality Engine with two 200 MHz MIPS processors, two raster managers and 192 MB of memory was acquired and installed as the central host

computer for the system. It was upgraded in 1999 with two additional 200 MHz MIPS processors and two more raster managers. The system runs a real-time version of the Unix operating system and is sufficiently powerful to control system I/O, integrate a sophisticated vehicle dynamics model, perform data logging operations, and run a 3-channel color video display with 960 x 680 fixed resolution on each channel. Three video projectors were acquired, and a wrap around curved screen providing a 160-degree field of view was installed. The UCF Driving Simulator is shown in Figure 1. 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 in 1999 to create external 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.

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.

A previous real-time traffic simulation study (Balfour and Andrews 1998) utilized 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. A cell array L with 140 rows, one for each link (see Figure 3), stores the complete set of link properties, some of which are entered directly by the user and others which are calculated internally.

- L{i, 1}: Link Identifier ('L1', ... , 'L140')
- L{i, 2}: Link Type ('ST', 'RT', 'LT', 'UT')
- L{i, 3}: Link Start Node ('N1', ... , 'N209')
- L{i, 4}: Link Start Node Type ('SRC', 'INT')
- L{i, 5}: Link Start Node Road ('R1', ... , 'R8')
- L{i, 6}: Link End Node ('N1', ... , 'N209')
- L{i, 7}: Link End Node Type ('INT', 'SNK')

- L{i, 8}: Link End Node Road ('R1', ... , 'R8')
- L{i, 9}: Link Upstream Links ('L1', ... , 'L140')
- L{i, 10}: Link Downstream Links ('L1', ... , 'L140')
- L{i, 11}: Link Transition Probabilities ([0], [P1, P2], [P1, P2, P3])
- L{i, 12}: Link Length (ft), calculated from link node data for 'ST' links or (h, k, r, θ) for 'RT', 'LT', and 'UT' links
- L{i, 13}: Link Speed Limit (mph)
- L{i, 14}: Link Start Node x,y coordinates
- L{i, 15}: Link End Node x,y coordinates
- L{i, 16}: Heading (rad) with respect to positive x axis for 'ST' links or (h, k, r, θ) for 'RT', 'LT', and 'UT' links

Running on a Windows PC platform, MATLAB (ver 5.3 Math Works) was used to calculate positions and headings of simulated vehicles with respect to the link/node coordinate system of the network. MATLAB was chosen because of its powerful data analysis and visualization, extensive built-in library of mathematical functions, programming environment, and its capability to produce easily customizable GUI's.

Uniquely identified vehicles are initially placed on each of the 140 links according to a default or user's initial density specification. 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.

New vehicles entering the network are introduced at source nodes 'N100', 'N101', ... , 'N109' (see Figure 3) in a stochastic fashion based on default or user defined average arrival rates. Current vehicles are removed when and if they arrive at sink nodes 'N200', 'N201', ..., 'N209'. On the PC side, an onscreen map of the network displaying several different views of the simulated traffic movement, frame by frame, is useful for off-line software development purposes. The view selection menu allows the user to track a specific vehicle, view selected links, view the entire network, or track the simulator vehicle. An individual frame snap shot showing traffic at one of the intersections is shown in Figure 4. The network map is not rendered when the simulator is running in order to minimize the traffic generation cycle time on the MATLAB PC.

The vehicle dynamics model executes on the host at the basic simulator frame rate of 30 Hz. Currently, the simulator's positional coordinates from the vehicle dynamics model is not processed by the MATLAB traffic generation software. Consequently, the externally generated traffic does not respond to the presence of the simulator vehicle.

Instead, for each frame of traffic generation, previously recorded simulator vehicle profile data (t,x,y,heading) is read from an external file to account for the location of the simulator vehicle. This is done to test the MATLAB algorithm for locating the nearest link to the simulator vehicle, a requirement

for future integration of the real simulator vehicle and intelligent traffic generation. There is no intelligence in the simulated traffic as the vehicles are either randomly advanced along the links each frame or deterministically placed for purposes of creating specific scenarios.

The traffic generation frame rate is a function of the number of cars and other factors which affect the computational load on the PC. Initial results of timing the traffic generation loop subject to various loads indicate a sustainable frame rate in the neighborhood of 1 Hz. Interpolation is used to produce vehicle traffic coordinates synchronized with the basic simulator frame rate to assure smooth trajectories of the rendered vehicles. A single frame lag is the penalty associated with using interpolated values based on "old" traffic coordinates to determine the current positions of the simulated vehicles. A snapshot of traffic viewed from inside the simulator is shown in Figure 5. Video clips of the PC traffic generation output and the view of traffic from the simulator are available for downloading at the CATSS (Center for Advanced Transportation Simulation Systems) website (<http://www.ucf.edu/catss>).

Despite the absence of intelligent traffic, as a result of the first year's research, specific scenarios can be programmed to evaluate driver's responses to various types of stimuli. A recently initiated study is investigating the situational awareness of elderly drivers and their ability to perform routine driving tasks. Subjects were asked to travel along a prescribed path in the network shown in Figure 3 with scripted external traffic movements viewable in both directions. Driving characteristics such as ability to maintain longitudinal and lateral control, traffic sign recognition, behavior at signalized intersections, obeying speed limits, car-following tendencies, gap acceptance at intersections are the primary components to be monitored and evaluated. The traffic generation routine for this scenario was developed along with the required data logging routines. Other possible scenarios involve programmed vehicle movements where one or more vehicle trajectories pose a threat to the simulator driver.

FUTURE RESEARCH

The next phase of the research will address the issues of intelligent movement of traffic and recognition of the simulator vehicle. The primary objective during the first year was creating a framework for describing a traffic network and producing vehicles in a visual scene which are properly registered with respect to the roads in a real-time simulation environment. In the future, with intelligent traffic populating the visual database, alternative designs for moving traffic safely and expeditiously can be evaluated in a simulated environment. The actual (or proposed) roads and surrounding features displayed in the simulator will be generated from existing CADD files and digital photography.

REFERENCES

Balfour, R.; Andrews, B. 1998. "3-Dimensional Roadway Traffic Simulation and Modeling for Design, Public Education and Conflict Resolution: A New York Case Study." Report by The National Aviation and Transportation Center, Long Island, New York.



Figure 1 The UCF Driving Simulator



Figure 2 View From Inside The UCF Driving Simulator During Validation Study

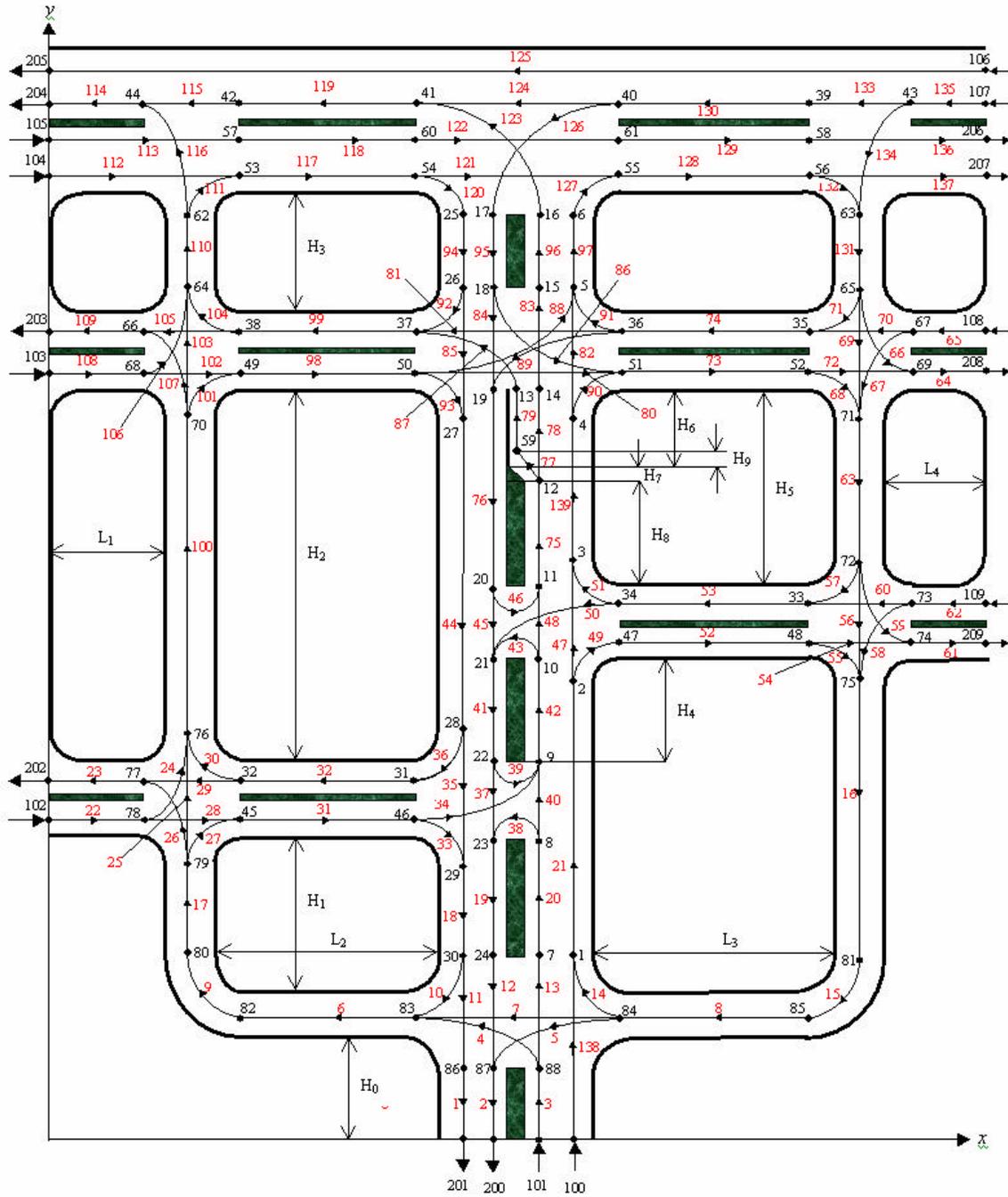


Figure 3 Roadway Network for Traffic Generation

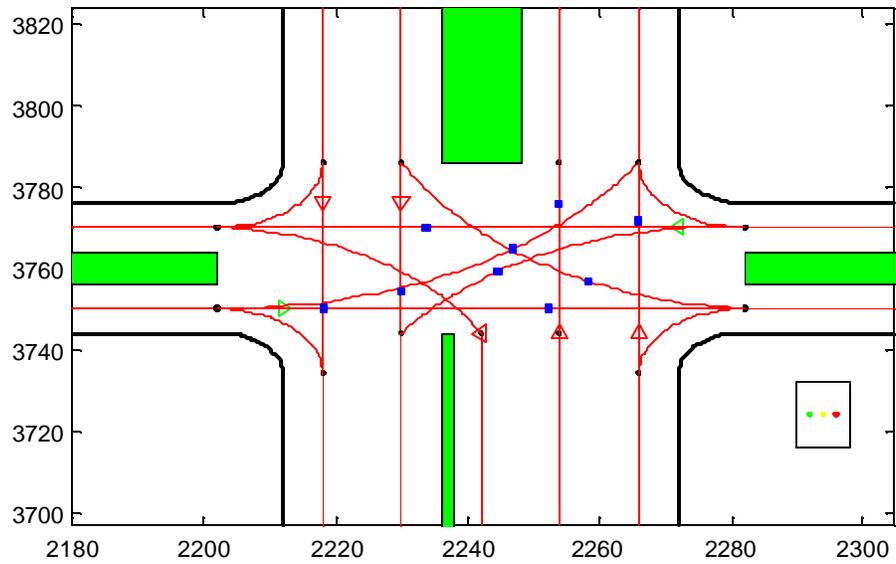


Figure 4 Snapshot of Roadway Network Intersection from PC Traffic Generation



Figure 5 View from Simulator of External Traffic