Using Interactive Simulation to Model Driver Behavior Under ATIS

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USING INTERACTIVE SIMULATION TO MODEL DRIVER BEHAVIOR UNDER ATIS

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ABSTRACT

This paper discusses the development and implementation of FASTCARS (Freeway and Arterial Street Traffic Conflict Arousal and Resolution Simulator), an interactive microcomputer-based animated simulator designed for in-laboratory experimentation and data collection to assist in the estimation and calibration of predictive models of driver behavior under the influence of real-time information.

Limited real-world implementation of Advanced Traveler Information Systems (ATIS) technologies has made it difficult to analyze the potential impact on driver behavior. It is contended here that in-laboratory experimentation with interactive animated route choice simulators can substitute for the lack of real-world applications and provide a useful approach to data collection and driver behavior analysis.

The advantages of using FASTCARS over other data collection methods to study driver behavior are realized through the program's flexibility and completeness. FASTCARS combines a real-time interactive driving simulation program using a graphics-type interface with visual and audio effects to imitate enroute travel decision making. The simulation encompasses the entire driving process from pre-trip planning through arrival at the destination. Players are required to make a broad range of choices including goal specification, route and lane changes, and whether to use available information technologies. To model the impacts of real-time traffic condition information on driving behavior, FASTCARS emulates three types of ATIS: Variable Message Signs, In-Vehicle Navigation Systems, and Highway Advisory Radio.

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INTRODUCTION

Interactive simulation is a powerful tool for conducting stated preference studies, especially with regard to route choice. The role of a good simulator is to recreate real-world scenarios and elicit from participants responses that are similar to those expected under real-world conditions. This ability to model choice is based on (1) the manner in which a simulator can effectively translate the real world situation to the simulation environment (2) the manner by which physical elements of the real world that play an active role in the choice process are represented. In considering route choice and travel decisions, simulation can be a productive method to isolate choice components and obtain subjective estimations of choice factors (Bovy and Stern, 1990).

The main reason for using computer-based interactive simulation rather than field studies to model driver choice under ATIS is that there have been relatively few advanced information technology systems implemented in the real-world. It would therefore seem difficult for drivers to answer hypothetical questions about technologies they have not yet experienced. Alternatively, interactive simulation provides the opportunity to study revealed behavior by simulating advanced technologies within a controlled environment. With faster and more powerful personal computers, it is now possible to recreate or emulate ATIS technologies in-laboratory and model driver choice with simulation.

Interactive computer-based simulation is growing in popularity among transportation researchers. Programs have been developed to analyze individual choice as well as system performance impacts. Examples include the Urban Driving Simulator (UDS) (Leiser and Stern, 1988) that was developed to study subjective time and speed estimations, and IGOR (Interactive Guidance On Routes) (Bonsall and Parry, 1991) that was implemented to study drivers' compliance with route guidance advice. Ayland and Bright (1991) developed a gaming simulation tool, programmed around a commercially available computer game, to study the impacts of in-vehicle driver information.

FASTCARS DRIVING SIMULATOR

FASTCARS is an interactive computer-based simulator that has been developed for in-laboratory experimentation to gather data for estimating and calibrating predictive models of driver behavior under conditions of real-time information. The simulation integrates a model of multiobjective goal specification and evaluation, a hypothetical traffic network, simulated real-time information technologies, and interactive driver travel choices. FASTCARS is designed to model enroute travel decision making. FASTCARS provides an artificial environment that replicates spatial and temporal situations that arouse conflict and motivation during travel. The combination effects
of perception, conveyed through visual representation of traffic conditions, and prediction, through real-time information availability, form the background choice domain. A scoring and evaluation format, based on weighted additive utility models, provides a basis for analyzing behavior and preference. Its purpose is not to study the actual driving process, but rather to focus on the decision-making aspects of travel, including goal specification, route choice, diversion, and information search.

The advantages of using FASTCARS over other data collection methods to study driver behavior are realized through the program's flexibility and completeness. The program encompasses the entire driving process from pre-trip planning through arrival at the destination. Players are required to make a broad range of choices including goal specification, route and lane changes, and whether or not to use available information technologies. Furthermore, many system variables, such as network conditions and information content, can be altered to represent different driving conditions. These features allow FASTCARS to replicate and model many of the decisions common to the trip-making process.

FASTCARS was programmed with Turbo Pascal 6.0 for PC machines running DOS. The program requires that the host computer be equipped with at least a 386-33 MHz configuration, math coprocessor, and VGA graphics. To take advantage of the highway advisory radio emulation feature the machine must also be equipped with a Voice Board. The program can be run with or without HAR capabilities. In addition, the program (without HAR capabilities) is easily portable and may be stored on a single high-density diskette. The run-time version of the program without radio message files, as being tested, takes about 1.5 MB of hard disk space; the radio messages take up significantly more disk space.

SIMULATION OVERVIEW

FASTCARS can be used to study a variety of trip making behavior. It models all phases of trip making from pre-trip planning to enroute travel to post-trip evaluation. Currently, FASTCARS is being used to study special event trips. In each session players are told that they are leaving their home at 6:30 p.m. and are on their way to the stadium to watch the ball game that begins at 7:30 p.m. The distance to the stadium is approximately 24 miles so one hour provides plenty of time to make it to the stadium on time.

Travel in the simulation is conducted around a hypothetical city consisting of a network comprised of freeways and surface arterials. Freeways have three or four lanes and faster free flow speeds. Arterials are characterized by having two lanes, slower speeds and traffic signals. The network is laid out in a near-grid and follows some basic conventions. North-south freeways are odd-numbered with higher numbers in the west; east-west are even numbered with higher numbers in the south.

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There is also a beltway, a freeway with four lanes in each direction that circles the city. North-south arterials are numbered streets increasing westward; east-west arterials are named after U.S. Presidents.

A hypothetical network was adapted to allow the study of familiarity as a variable. To emulate player experiences, network information is provided on maps that can be referenced throughout the game. (see Figures 1 and 2). Maps are stored PCX files that are accessed from the hard disk. To distinguish a player's knowledge of network configurations and traffic condition information, there are three levels of familiarity (novice, intermediate, expert), one of which is assigned to a player during a session. A novice user is given a series of maps that display only a portion of the freeway network. Intermediate users are provided with the entire freeway network and a subset of the arterial network. In addition, intermediate users are provided with some basic traffic flow information. Expert players are provided with detailed maps listing all freeways and arterials in the network. Moreover, they are provided with detailed descriptions of expected freeway and surface street traffic conditions as well as probability of incidents.

**Pre-Trip Planning**

In pre-trip planning, players set their travel objectives and select an initial route. It has been suggested that several factors influence route choice including drivers knowledge of alternate routes, specific route attributes, and driver preferences (Antonisse et al., 1991). FASTCARS models travel performance and route selection through a multiobjective goal set. Each player is rated according to relative success in maximizing utility over a goal set consisting of five predetermined goals. The five goals that are considered are: (1) arrive at destination 20 minutes early, (2) minimize travel time, (3) minimize number of stop lights encountered, (4) minimize number of road changes, and (5) minimize trip distance.

At the end of the program, the player is scored from 0 (worst) to 100 (best) based on meeting these goals. To capture individual behavioral differences and preferences among players, each player is permitted to assign a set of subjective weights totaling 100 to the goal set, with at least 60 percent of the weight allocated to the first two goals. In total the maximum possible score a player can achieve is 10,000 points.

At the start of the program, the player is given the opportunity to look at the map set and select an initial route choice strategy. The map set available is based on the level of player familiarity. The first time a "driver" plays the simulation, the program randomly selects a level of familiarity. After playing the simulation a number of times, the level of familiarity is increased to the next level. Knowing level of familiarity provides some insight to the driver's route choice and information acquisition behavior. Over repeated trips, as drivers acquire knowledge of the network, it is possible to study the effects of learning and memory on driver choice.
Figure 1. Map of Hypothetical City

Figure 2. Map of Freeway Average Speeds
Once the initial route has been selected and the goal set established, the travel sequence begins. FASTCARS models travel on a link-by-link basis, ignoring system-wide traffic and focusing on traffic around the player. Play is conducted on a visual display depicted in Figure 3. This display has four components: the network viewer, the control panel, road-side information viewer, and the in-vehicle navigator.

**Network Viewer**

The lower right-hand box, the biggest section of the display, is the network viewer. Players are provided with a bird's eye view of a road section, approximately a three-fourths of a mile view of a link section. Cars are displayed as small rectangles moving in lanes. The player's vehicle, or cursor car, is shown as the solid rectangle. At the bottom of the road section, the current road is labeled. Cars move by lane, each lane has a specific speed, and generally, lanes to the left have higher speeds.

Players control two basic car movements, lane changing and road changing. Lane changes are initiated by a single keystroke. The cursor car turns into an arrow indicating direction of desired lane change. After a calculated lane-switch delay that accounts for travel conditions, the cursor is moved to the desired lane.

Road changes are available when the viewer displays a cross street. Available turning movements are indicated by arrows on either end of the cross street. The name of the cross street and turning direction is indicated next to the street. When a driver wants to make a turn, two steps must be followed. First, the driver must move to the correct lane. All turns from freeways are made from the rightmost lane. On surface streets, however, right turns are made from the rightmost lane, left turns from the leftmost lane. Second, the driver indicates the turning direction with a single keystroke. The cross street changes color and the arrow indicator blinks. When the cursor car intersects the cross street, it is guided automatically through the turn. If the cursor car is still in the wrong lane when the cross street is reached, the turn will not be executed.

The cursor car is moved to the next road section when it creates a successful turn, passes an intersection without turning, or when it reaches the halfway point on the display. There are a set of next display markers along the roadway to inform drivers when the display will be reset. Surface streets are distinguishable by traffic signals, two lanes, and generally lower speeds. Signals have set timings and on the red cycle, cars caught behind the stop line will queue and wait for the green cycle.
Control Panel

The control panel, on the lower left of the display, lists important system information. At the top of the display are the current simulation time and cursor car speed. Below that, the set of five goals are listed. To the left of each goal is the player’s selected goal weights; to the right is the accumulated score for each goal weight. These scores will be normalized at the end of the program to values between 0 and 100.

At the bottom of the control panel there is an indicator for penalty units assessed. Players are assessed penalties for using ATIS technologies. These penalties, which are subtracted from the player’s score at the end of the game, are introduced to reflect the cost of information acquisition. It is expected that with no penalty units, players would use the information sources indiscriminately.
Emulating ATIS

FASTCARS presents drivers with two types of information: basic road signs and advanced traveler information systems. The upper left box in the display is used to showcase basic roadside information signs as well as variable message signs. Basic road-side information signs were provided in the visual display to ensure that players have "standard" information regarding their current position relative to the basic network configuration. These basic signs include "next exit" signs for freeways and general directional signs such as "Stadium Next Right" or "Freeway Junction Ahead".

FASTCARS is equipped to emulate three types of advanced traveler information systems: variable message signs (VMS), highway advisory radio (HAR), and in-vehicle shortest time navigation system (IVNS). These were selected on the basis of their diversity of presentation and message content.

In the simulation, variable message signs are displayed at certain freeway locations as to provide drivers with brief reports on the local traffic conditions on the current link. At points where messages are selected to be displayed, the program searches several miles ahead on the current freeway to gather data on the traffic conditions that are scheduled to be encountered. An appropriate message sign is then posted.

Highway Advisory Radio is the second information technology simulated. FASTCARS utilizes a Voice Adapter which allows players to activate pre-recorded radio messages containing relevant information on highway conditions and on the availability and accessibility of alternate routes. In the current version of FASTCARS, incident probabilities and speed distributions are assigned to network links. Before beginning data collection, a series of network profiles that distribute incidents on the network may be generated. Based on these network files, HAR files can also be prepared. At the start of the game the simulator randomly selects a network profile and set of HAR files to be used.

In-vehicle navigation systems offer drivers a direct source for finding the shortest path to their destination. Through a computerized system, IVNS typically gathers real-time information and instructs the driver where to turn. With IVNS, drivers do not receive traffic information nor do they have to make any predictions or calculations - they merely follow directions. The benefit of IVNS is that drivers who are unfamiliar with the network can adhere to the advice and take a shorter path to the destination. It does not, however, relate explicit traffic conditions; the best path may still be along a congested corridor.

FASTCARS emulates IVNS with a prototype in-vehicle navigator that gathers travel time information. The navigator is displayed in the top right corner of the visual display. When a new link is entered, FASTCARS calculates the shortest time path to the destination. This information is used to display in-vehicle navigation information.
While activated, the navigator displays three pieces of guidance information based on the calculated shortest path: (1) suggested action for next intersection or freeway exit, (2) expected shortest travel time to the destination, and (3) distance from the current location to the destination via shortest time path. The guidance is presented both textually and graphically. Graphically, arrows point to the direction in which the driver should continue at the next intersection or freeway exit to follow the shortest time path. The same information is presented in sentence form. As with VMS and HAR, IVNS provides players with perfect information based on the game administrator's design of the network.

**DATA INPUTS**

Inputs to a FASTCARS program are stored in a variety of external files that are read at the start of the program. This makes FASTCARS extremely flexible and adaptable. All of the needed files are read in through one main file 'basecars.dat'. This file lists the network database, player information database, goals set database, start time, desired arrival time, and origin and destination nodes.

The network is coded by links and street identifiers. Street information is stored in one file containing street id numbers and names. The link database lists link specific data including from node, to node, an assigned direction (one or two-way), number of lanes, length, mean speeds in each direction, incident probability in each direction, variable message sign indicator (1 if exists), road side sign indicator, and user familiarity level. A sample network coding is shown in Figure 4.

```
*****
52933 91931 2 3 1.8 50.0 50.0 0.025 0.050 0 0 0 2 93
91933 53931 2 3 1.1 50.0 50.0 0.025 0.050 0 8 8 2 93 ** SAMPLE RECORD
53933 54931 2 3 1.1 50.0 50.0 0.025 0.050 1 0 0 2 93
54933 55931 2 3 1.3 50.0 50.0 0.025 0.050 0 10 8 2 93
55933 93941 2 3 1.1 50.0 50.0 0.025 0.050 0 0 9 2 93
54923 55921 2 3 1.3 45.0 45.0 0.025 0.050 0 10 0 1 92
55923 92941 2 3 1.1 45.0 45.0 0.025 0.050 0 8 8 1 92
92963 90921 2 3 1.4 50.0 50.0 0.025 0.025 1 0 0 1 92
390923 58921 2 3 1.2 50.0 50.0 0.010 0.010 0 0 0 1 92
*****
```

Figure 4. Sample Network Coding

To identify intersections, each node is assigned a number corresponding to the cross streets that intersect there. For example, notice the sample record in Figure 4 (labeled with a series of asterisks). This link connects two intersections 9193 and 5393. The node 9193 represents the intersections of the streets 91 and 93 (the corresponding names for 91 and 93 are indexed separately). The last digit of each node number (i.e.,
91333) indicates the directional connection of the network. Each node is allotted up to four links entering/leaving it (1=North, 2=East ... and so on); the 3 in 9133 indicates that the link is connected to the south direction from node 9133.

FASTCARS simulates incidents in real-time by adding an incident queue to the event simulation. This allows for real-time radio reports to be updated as incidents occur or are removed from the system. Incidents are stored in separate files listing the link, incident type, severity, staring time, duration, and associated radio file. Several incident files can be prepared from each network using the incident probability fields in the link database. A separate module of FASTCARS creates these incident files.

**PROGRAM OUTPUTS**

Each session is saved to an event file. An example of which is shown in Figure 5 below. This file records various data from the experiment. The main part of this file is the set of event records saved. Each time there is a significant event in the system, (i.e., road change, information acquisition...) the event is recorded to the file along with 19 system parameters. The listing includes event type, diversion indicator, from-node, to-node, goal statistics, cursor speed at event, indicators for VMS, HAR, IVNS, goal weights, and penalty units accrued.

```
5 - 22 - 1992  {/* date of simulation */
inputs\baselink.dat  {/* link data base */
inputs\goals.dat  {/* goal file used */
3  {/* incident file (1-10) */
6.30 7.30 2335.74 -108.56  {/* starting and departure time */
1058 103 2497 3 3 9264.60  {/* O-D Pair, player, trials, familiarity, score */
5 5 5 2 5 3  {/* behavioral statistics */
3 5 5 5 1 1 0  {/* post-simulation responses */

/* event records */
1 0 2 1058 1858 0.00 0.00 0 0 0.00 32.00 0 0 0 80 0 10 10 0 0
5 0 2 1858 45890 3420.32 179.50 2 0 1.09 33.00 0 0 0 80 0 10 10 0 0
5 0 2 45890 1758 3187.40 412.22 4 0 2.90 39.00 0 0 0 80 0 10 10 0 0
5 0 2 1758 5995 3071.98 527.52 5 0 3.69 34.00 0 0 0 80 0 10 10 0 0
3 0 1 5895 9596 2988.70 610.70 6 0 4.29 40.00 0 0 0 80 0 10 10 0 0
5 0 1 9596 5795 2943.66 655.69 6 1 4.97 56.00 0 0 0 80 0 10 10 0 0
5 0 1 5795 5695 2862.68 736.57 6 1 5.66 31.00 0 0 0 80 0 10 10 0 0
4 2 2 5695 5656 2250.88 1347.62 6 1 7.48 10.00 0 0 0 80 0 10 10 0 0
*****
```

Figure 5. Sample Output File

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DATA ANALYSIS AND APPLICATION

Currently FASTCARS is being utilized to collect data on driver behavioral choice (Adler et al., 1992). There have been over 60 game playing session completed so far in an ongoing research effort. The output event files are post-processed into separate data files that are being used to analyze driver choice. There are several data analysis efforts being conducted in parallel:

1. Analyzing the factors that influence enroute diversion.
2. Estimating a model of information acquisition - when subjects activate ATIS.
3. Longitudinal analyses of repeat players to study learning effects and changes or stabilization in driving behavior.
4. Running alternative modeling schemes including standard choice models such as logit and probit versus non-standard techniques such as neural network threshold models and rule-based approaches.

Preliminary analyses on diversion behavior show that several factors impact enroute diversion behavior including familiarity with potential alternate routes, visual information gathered from Variable Message Signs, changes in travel speed, and drivers' individual risk preferences.

Further results from these analyses and other studies will be used as part of the Advanced Traffic Management System Testbed Research Program being conducted in Irvine. Part of this effort is to assess the effectiveness of and traveler response to various advances traveler information systems under a broad range of implementation conditions. The collected data will also be useful in the efforts to develop a real-time simulation capability that can operate on-line to predict dynamic response under an integrated freeway-arterial ATMS/ATIS system. Predicting optimal or equilibrium assignment and effecting optimal real-time feedback control between freeway and arterial systems is dependent on driver behavior and response.

FUTURE STUDY AND ENHANCEMENTS

The flexibility of FASTCARS allows it to potentially be used for a variety of travel-related purposes. With minor adaptations, FASTCARS could be implemented to study other types of trip making, including commuter travel. More challenging tasks are to expand the program to include a wider range of pre-trip options such as departure time choice and acquiring real-time information. An enhanced graphical display is being considered to improve the map display and the in-vehicle navigation system. Future versions will have a next-generation IVNS system that provides more direct interface with the driver.
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