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AN ADVANCED TRAFFIC MANAGEMENT SYSTEM SIMULATOR FOR INTELLIGENT VEHICLE-HIGHWAY SYSTEMS RESEARCH

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ABSTRACT

This paper provides an overview of an Advanced Traffic Management System (ATMS) Simulator developed at Georgia Tech and being used as a research tool to help answer various questions that arise as Intelligent Vehicle-Highway System (IVHS) technology makes its way into tomorrow's Advanced Traffic Management Systems. The architecture, capabilities, technical challenges and implementation decisions associated with the development of this simulator are summarized. Brief descriptions of the traffic model, database, displays and associated simulated traffic video coverage are provided.

1 INTRODUCTION

The IVHS era has brought high technology to traffic management. For example, larger numbers of more capable sensors, automated control devices, automated monitoring devices, automated dispatching systems, advanced information systems, predictive traffic modeling systems, and various other support systems will incrementally find their way into Traffic Management Systems (Vostrez et al. 1992). The rapidly approaching IVHS era brings many technical challenges and questions related to the design, implementation, operation and maintenance of future Advanced Traffic Management Systems. In order to start addressing many of the issues related to future IVHS-era ATMSs, simulation of the full ATMS environment is indicated. Simulation can help answer questions related to sensor coverage, design of support systems, appropriate degree of automation, and various human factors issues associated with vehicular, highway and traffic management center (TMC) systems. In order to meet this need, especially for the case of research into human factors issues associated with the design of future traffic management centers, we have developed a TMC simulator and are currently using it to conduct an intensive program of such research. As the research program continues, the capability of the TMC simulator is continuing to evolve.

In this paper we will present an overview of the TMC simulator, a brief discussion of a few of the technical challenges addressed, a survey of the hardware and software implementation decisions made on the basis of an extensive trade study, and a summary of initial performance observations.

2 OVERVIEW OF THE TMC SIMULATOR

The simulator provides real-time, interactive operation, and is rapidly reconfigurable to allow for a wide variety of user interfaces and displays, ATMS reconfiguration, a variety of control methods, and varying degrees of automation. It provides simulated TMC inputs including traffic and roadway sensors, visual CCTV sensors, probe vehicles, cellular telephone dialog, voice communication systems, and database services. It provides simulated TMC outputs associated with intersection control devices and algorithms, roadway access devices and control algorithms, variable message signs, highway advisory radio, commercial TV and radio, cable TV traffic channel, traffic bulletin board, and voice communication output. Operator support systems include adaptive traffic control, predictive traffic modeling, incident detection and location, response advisory, and information dissemination systems. The traffic model (AUTOS) was developed at Georgia Tech and is based on the Greenshield's speed-density flow model. The CCTV traffic video simulation (AUTOGRAPH) was also developed at Georgia Tech and is hosted on a Silicon Graphics Onyx / Reality Engine 2 system, making heavy use of the graphics-rendering hardware on this machine.

An overview of the hardware architecture is provided in Figure 1. The computer systems in this configuration (counter-clockwise from upper left) include a Video Simulation Server, four Operators' Workstations (labeled "Op WS"), four touchscreen-equipped PCs, an

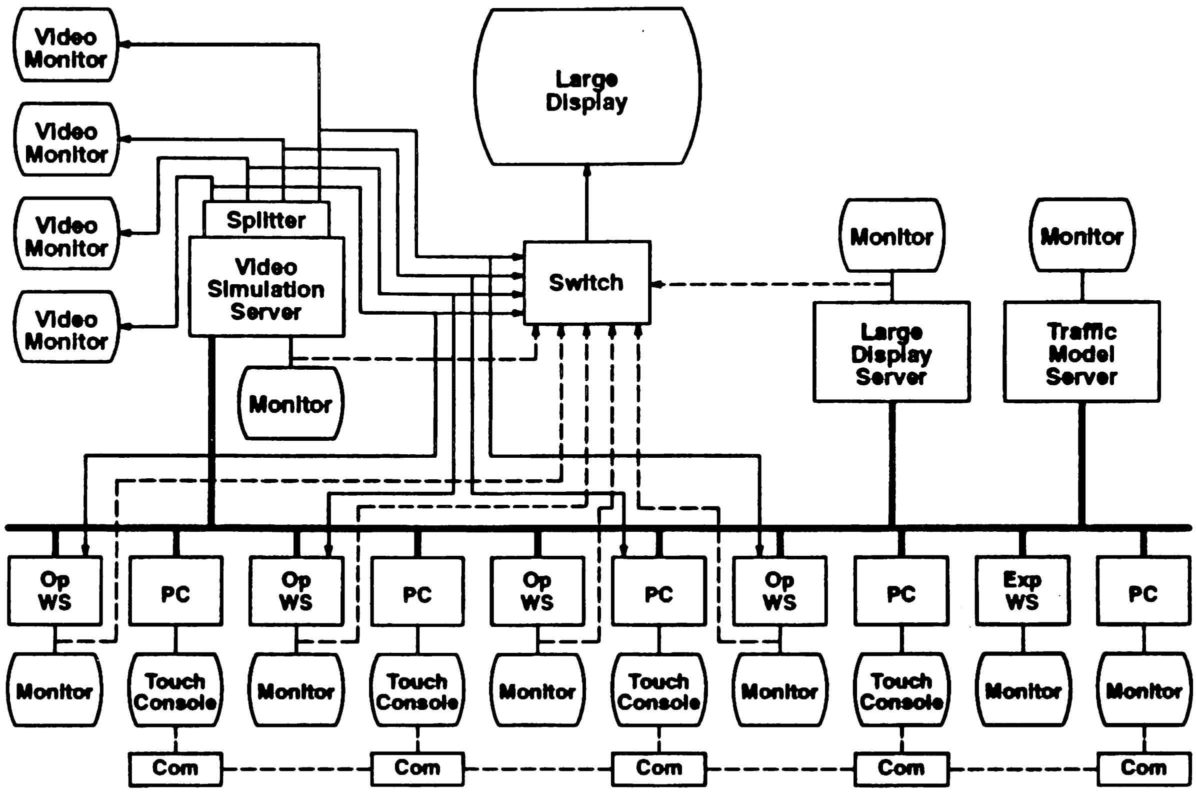

Figure 1: TMC Simulator Hardware Architecture

Experimenter's Workstation (labeled "Exp WS") and PC, a Traffic Model Server, and a Large Display Server. All of these computers are connected to a local area network. Also included are a large-screen display, several video monitors, sophisticated video switching systems, and a network for audio communications.

3 TECHNICAL CHALLENGES

Some of the major technical challenges encountered in the development of the TMC Simulator included satisfaction of the requirements for rapid reconfigurability, real-time operation, and responsive CCTV simulation. The solutions to these challenges are briefly summarized in the following paragraphs. More attention is given to the CCTV system simulation, since this proved to be the most interesting and challenging problem solved.

3.1 Rapid Reconfigurability

The requirements for rapid reconfigurability of hardware and facilities layout for the TMC simulator were achieved by unit modularity, a raised-floor laboratory, a flexible video switching capability, and versatile adjustable workstation furniture. Rapid software reconfigurability, including user interfaces, databases, displays, control devices, etc., was a bigger challenge. The use of a unified TMC database and related control processes to drive the traffic model, the video simulator and all operator displays, and support system inputs and outputs provided the setting for achieving flexible software reconfigurability. The development of a script language, based on the public domain tool command language (Tcl) from the Department of Electrical Engineering and Computer Science at the University of California - Berkeley, for use in prescribing scenarios and configurations and the use of user interface builder tools, such as VAPS (a Virtual APplicationS development tool sold by Virtual Prototypes, Inc.), contributed heavily to flexible user interface reconfigurability.

3.2 Interactive, Real-Time Simulation

An extensive trade study was done early in the simulator development program to locate and evaluate available commercial and government hardware and software for possible use in meeting various requirements of the simulator. None of the existing commercial or government traffic models met the interaction and real-time operation requirements, let alone ease of modification to allow for simulated support systems, etc. We opted, therefore, to start from an existing Georgia Tech traffic model called TERMINUS (Gilmore et al. 1992). Starting from this model, we created a much larger capacity, versatile model with hooks in place for the needed support systems. The resulting traffic model, called AUTOS, is a macroscopic flow model capable of running 5-10 times faster than realtime on a 5000-link network and 50 times faster than realtime on a 1700-link network. This performance permits us to use a copy of the model to achieve the simulated predictive traffic management support system.

3.3 Simulation of CCTV System

Perhaps the biggest technical challenge was achieving a responsive simulated traffic surveillance video capability. Options considered included manual emulation using video tapes, automatic cuing of on-line prerecorded video, automatic cuing of on-line prerecorded video with speed tampering, and video simulation using computer graphics. The only other traffic simulators we are aware of that attempt to include traffic video have used the first option. That is, the experimenter (perhaps in an adjoining room on the other side of a glass window) observes the actions taken by the TMC operator(s) in a research or training scenario. The experimenter tries to manually select prerecorded video to load in response to the operators selection of a simulated camera in the roadway network. When one considers all the variables associated with the simulation or emulation of a video traffic surveillance network, such as ability to pan and zoom cameras, availability of a variety of camera locations, the need for the video to correctly confirm traffic conditions (density and speed), weather conditions, time of day, presence or absence of incidents, and the desired ability of the operator to confirm responses to his actions in the form of variable message sign contents, timing and metering algorithm changes, dispatching of emergency vehicles to incidents, etc., it is clear that pre-recorded video, even enhanced by on-line cuing and speed tampering, will be woefully inadequate. Since our interviews with traffic management experts all over the country consistently underscored the importance of traffic surveillance video in present and future TMCs, we elected to implement high fidelity traffic video simulation using computer animation.

We implemented the traffic video simulation by taking 360° photographs at 38 key traffic locations in Atlanta. These photographs were digitized, existing traffic was removed, background and foreground images were separated, lane paths were defined, and animated traffic using texture-mapped graphical techniques were applied to produce animated traffic flowing between the background and foreground planes. We were able to achieve a very realistic animation, with densities, speeds and vehicle-type mix controllable by the traffic model and model control processes. Incident scenarios are easily choreographed and emergency vehicles (police, ambulance, tow trucks, etc.) arrive in accordance with dispatching actions. Where other visual confirmations are possible, such as variable message signs, these features are also depicted in the traffic video simulation. Smooth lane changes are also rendered. Some atmospherics are implemented, although this aspect has been at low priority to date. Many sites can be concurrently ready for display at any time and up to four sites can be concurrently rendered for viewing on any number and combination of monitors, video windows, or on the large screen display. The operators have full control of camera selection, 360° pan and zoom (1X to 6X). This traffic video simulation, called AUTOGRAPH, integrated with the traffic model has already attracted attention from traffic engineers, managers and researchers from many countries and has led to requests to extend the capability to include additional features, such as tunnels and bridges. Figure 2 provides a high level depiction of the model and display process interfaces.

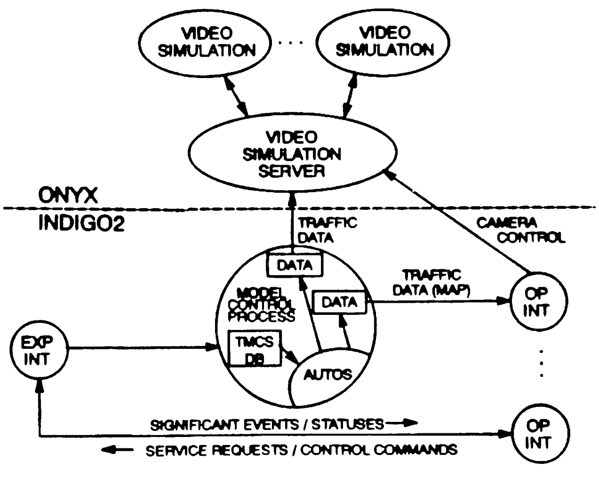

Figure 2: Model / Display Process Interfaces

4 IMPLEMENTATION DECISIONS

A detailed Trade Study (Ingle et al. 1993) led to choices of hardware and software items to be used in the TMC simulator implementation. A wide range of performance, versatility, and supportability issues were taken into account in the multitude of studies for various hardware and software needs. In addition, it was necessary to develop a lot of custom software in order to implement various parts of the simulator. Some of the fundamental implementation decisions for hardware and software are summarized in this section.

4.1 Hardware Architecture

After conducting detailed requirements and performance studies, the hardware architecture indicated in Figure 1 was implemented using Silicon Graphics Indigo2 XZ machines for the four Operators' Workstations, the Experimenter's Workstation, the Traffic Model Server, and the Large Display Server. As discussed earlier, a Silicon Graphics Onyx / Reality Engine 2 was used as host machine for the simulated traffic video system (AUTOGRAPH). The additional bank of video monitors, whose configuration varies with experiments, uses Sony Trinitron PVM-1350 color video monitors. A Barco Retro Graphics 801 serves as Large Display and a plethora of video switching and converting devices are used in the implementation of a flexible video assignment and display system. The Operators' and Experimenter's Stations are rounded out with 486 PCs equipped with resistive membrane touchscreens which are configured as control panels and displays. These are generally associated with communications interfaces. An audio communications network with wireless headsets, Metamorphosis adjustable desks and Hag ergonomic task chairs complete the hardware used to implement the simulator.

4.2 Software Architecture

A top-level depiction of the software architecture is shown in Figure 3. The Experimenter's Interface is an X Window System application built using the Motif development tool UIM/X. Implementation of the Operators' Interface makes extensive use of C++ custom software and displays developed using the VAPS user interface builder tool. The various support systems are implemented using a combination of C++ processes and the script language mentioned earlier. The TMCS Database, Model Control Process, Traffic Model and Video Simulation Model are all implemented using the C++ language.

The TMCS Database contains all the details describing the traffic network. The Model Control Software handles incident scenario choreography, vehicle tracking (timing), and serves as driver for the Traffic Model, the Video Simulation Model and the traffic maps and displays. The

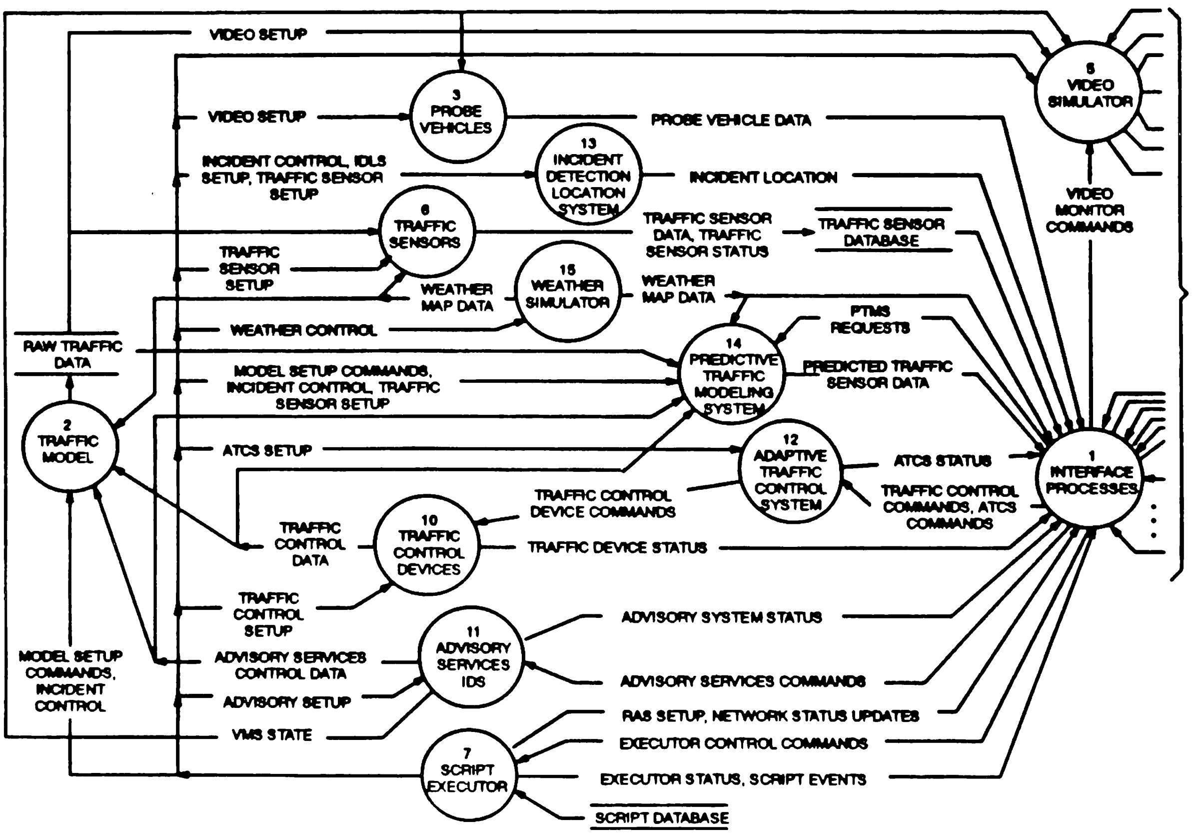

Figure 3: TMC Simulator Software Interfaces

Video Simulation Model was discussed in the section on technical challenges. The Traffic Model will be discussed briefly in the following paragraph.

The AUTOS model is implemented using C++ object-oriented design. It is driven by TMCS database map data and traffic specifications. AUTOS (Gilmore et al. 1994) provides a macroscopic model of traffic flow using Greenshield's speed-density flow model:

$$u = u_f(1 - k/k_j)$$

$$q = uk,$$

where q is flow, u is speed, k is density, u_f is free flow speed and k_j is the jam density. AUTOS models traffic flow on both freeways and surface streets and allows for various types of intersection control (uncontrolled, signed, fixed signal, actuated signal, fixed meter, actuated meter), signal phases, turning percentages, delays and various parameters of link control (directionality, number of lanes, length, free-flow speed, road condition factor, initial load, load deltas for rush hour build-up/down, current and maximum vehicle counts, etc.). In addition, parking lots, high occupancy vehicle lanes, reversible lanes and turn lanes are modeled.

5 SUMMARY AND RESULTS

A very capable ATMS Simulator has been implemented and is currently being used in a research program investigating human factors issues in the design of future TMCs. Simulation capabilities will continue to evolve over the next year and the simulator should be useful for a wide range of ATMS research and training purposes. The traffic model, AUTOS, is capable of running much faster than realtime for network sizes up to 5000 links. A sophisticated Traffic Video Simulator, AUTOGRAPH, is integrated with AUTOS and produces very realistic simulated traffic video animations. AUTOGRAPH taxes the current state of the art in graphical simulation to render four concurrent video simulations. It is anticipated that the next generation in Silicon Graphics compute power will allow this limit to expand.

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