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**LARGE-SCALE INTELLIGENT TRANSPORTATION
SYSTEMS SIMULATION***

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Abstract

A prototype computer system has been developed which defines a high-level architecture for a large-scale, comprehensive, scalable simulation of an Intelligent Transportation System (ITS) capable of running on massively parallel computers and distributed (networked) computer systems. The prototype includes the modelling of instrumented "smart" vehicles with in-vehicle navigation units capable of optimal route planning and Traffic Management Centers (TMC). The TMC has probe vehicle tracking capabilities (display position and attributes of instrumented vehicles), and can provide 2-way interaction with traffic to provide advisories and link times. Both the in-vehicle navigation module and the TMC feature detailed graphical user interfaces to support human-factors studies.

The prototype has been developed on a distributed system of networked UNIX computers but is designed to run on ANL's IBM SP-X parallel computer system for large scale problems. A novel feature of our design is that vehicles will be represented by autonomous computer processes, each with a behavior model which performs independent route selection and reacts to external traffic events much like real vehicles. With this approach,

one will be able to take advantage of emerging massively parallel processor (MPP) systems.

Introduction

The Intelligent Transportation System (ITS) program of the U.S. Department of Transportation (U.S. DOT) is designed to use advanced computing and communications technologies for proactive control and management of traffic flow and transportation facilities in order to improve traveler's safety and mobility, reduce congestion, minimize energy consumption and negative environmental impact, and promote economic competitiveness of the U.S. industry. Currently, U.S. DOT is in the early stages of developing a common framework or system architecture for ITS intended to promote nation-wide compatibility. Some of the elements of the ITS architecture under consideration include in-vehicle navigation systems; Traffic Management Centers which provide travel advisories and other information via roadside kiosks, variable message signs, and directly to appropriately instrumented vehicles; probe vehicles and roadway sensors for travel time and traffic flow measurements; real-time, adaptive traffic control systems; and communication systems.

Due to the complexity of ITS and the far reaching impacts on public safety and productivity,

care must be taken to ensure that any systems developed are properly designed and function appropriately, are suitable for use by human operators, and in fact improve the efficiency of our transportation system. Sophisticated simulators can play a key role in the testing, evaluation, and refinement of ITS designs.

Simulator Objectives and Scope

The ITS Simulation effort at Argonne National Laboratory is directed at advanced modeling and simulation needed to support emerging ITS technologies. A prototype simulator has been developed to define the architecture for a large scale, comprehensive simulation of an Intelligent Transportation System running on distributed or parallel computer systems.

One objective of this effort is to be able to model scenarios involving mixed traffic of conventional vehicles and instrumented "smart" vehicles possessing in-vehicle navigation and 2-way communications with TMC's. Such a pilot program called ADVANCE is currently being deployed in the Chicago area involving up to 3,000 instrumented test vehicles. The broader scope of our simulator project is to be able to support other evolving ITS programs, including the modeling of Automated Highway Systems (AHS). This also includes human factors studies in support of safety and operational research.

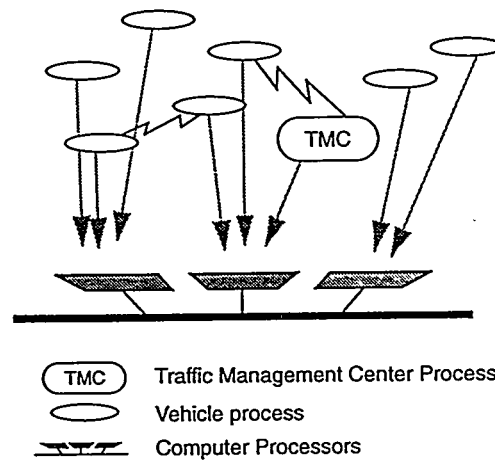
Computing Architecture

In formulating an architecture for our simulator, we elected to take a clean-slate approach so as not to be encumbered by existing code and strategies that might limit achieving a general, extensible framework to support large-scale, comprehensive ITS simulations.

Another tenet of our architecture was to design from the beginning for distributed/parallel computing.

A key element of our architecture is that *vehicles and ITS infrastructure elements are modeled as autonomous computer processes; vehicle processes interact with each other and ITS components by exchanging messages.*

Figure 1
HIGH LEVEL SYSTEM ARCHITECTURE



Some of the implications of this approach are that it

- More closely mirrors reality
- Naturally fits distributed/parallel computing model
- Inherently possesses limited fault tolerance
- Inherently scales to large problem sizes
- Supports placement of hardware-in-the-loop and live data feeds
- Promotes integration, maintainability and extensibility
- Platform independent
- Lightweight processes
- Load balance through process migration

Simulator Prototype

The major functional elements of the prototype include a map database, scenario generator, TMC, and instrumented "smart" vehicle model. The distributed simulation environment is implemented in a manner that achieves limited fault tolerance. Smart vehicle processes broadcast probe data to TMC processes, while TMC processes integrate information and broadcast advisories to vehicles. If a TMC process fails, another may be started without affecting existing vehicle processes. Similarly, vehicle processes may fail without impacting other vehicle or TMC processes.

Information is communicated between processes by a combination of IP network communications and through NFS file access. Networked Unix workstations support processing needs and graphical displays. Both the in-vehicle navigation module (Figure 2) and the TMC (Figure 3) feature detailed graphical user

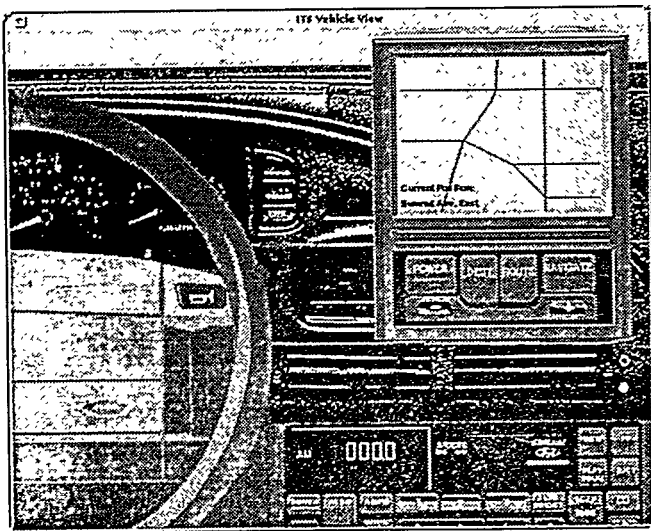


Figure 2 The smart vehicle module, which features functionally and visually realistic controls and navigation system, couples with other components of the simulator and is useful for human factors studies.

interfaces to support human-factors studies. The standard graphical user interfaces run on X11-based graphical workstations; however, a World Wide Web interface has been developed to provide access to the prototype. A future port is planned to Argonne's IBM SP-X parallel computer to permit larger problems to be simulated and to perform scalability studies.

The instrumented "smart" vehicles consist of a driver behavior model, optimum route planning capabilities, and 2-way communications with TMC's. Vehicle processes can be started either from a traffic scenario generator panel (shown in Figure 3) or the detailed smart vehicle module display (Figure 2). The scenario generator is designed to generate relatively large numbers of vehicle processes to populate the simulation map quickly, although it can also start individual vehicles by selecting origin and destination from a scrolling list of choices, and then selecting vehicle type, route strategy, and driver behavior from a series of check boxes.

The detailed smart vehicle module (Figure 2), on the other hand, is geared more to human factors studies, and features visually and functionally realistic automobile instrumentation and controls. The in-vehicle navigation/route guidance system functions like actual commercial prototypes. The system shows current location on a small map display, prompts for the destination using street names and intersections, then performs route planning to achieve optimal routing to the selected destination. During the simulation, the current vehicle position is continually shown on both the navigation system and the TMC displays.

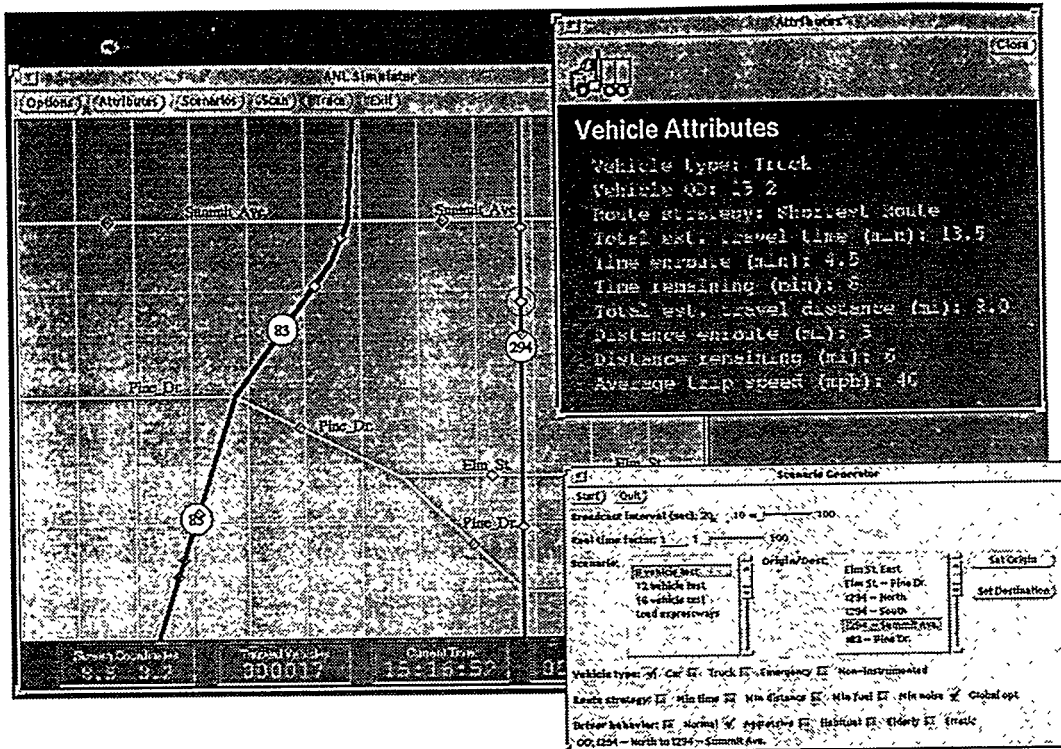


Figure 3 Traffic Management Center display showing tracking and attribute query functions. Panel at lower right is scenario generator interface.

Currently, the instrumented vehicles and TMC's are modeled as autonomous computer processes which communicate by exchanging messages. Conventional, non-instrumented vehicles can also be modeled as autonomous computer processes; however, for computational efficiency in the current prototype, non-instrumented vehicles are treated in a macroscopic, flow model approach. The instrumented vehicles thus move in a background flow of conventional vehicle traffic.

Maps for the simulator are currently input manually in the prototype. However, a map database module is under development. It will feature an interactive GUI for extracting the required maps from a NavTech database. A future goal is to have on-line, dynamic retrieval of required map information during

a simulation.

Currently, the TMC module monitors data originating from the simulated probe vehicles and static sensors. However, when fully implemented, the TMC module will detect and assess traffic problems and attempt to mitigate traffic congestion by issuing traffic advisories, link times, routing guidance, and by controlling ramp metering and traffic signal timing. At present, traffic incidents can be manually triggered at any time within a simulation by increasing travel times on links. The information is communicated from the TMC to instrumented vehicles, which then determine if the affected link lies on the route of travel. If it does, a route planning calculation is triggered to determine if a revised route is advantageous.

The current route planning capabilities are limited to minimum distance or minimum time calculations performed by individual instrumented vehicle processes using historical data and TMC traffic updates. The options will be expanded in the future to permit other optimization goals, such as minimization of fuel. We are also investigating the use of genetic algorithms for global optimization to enhance the TMC capabilities for traffic congestion mitigation.

Summary and Conclusions

The ITS Simulation effort at Argonne National Laboratory is directed at advanced modeling and simulation needed to support emerging ITS technologies. A prototype simulator has been developed to define the architecture for a large scale, comprehensive simulation of an Intelligent Transportation System running on distributed computer systems or massively parallel computer systems.

The prototype includes the modeling of instrumented "smart" vehicles with in-vehicle navigation units capable of optimal route planning and Traffic Management Centers (TMC). The TMC has probe vehicle tracking capabilities (display position and attributes of instrumented vehicles), and can provide 2-way interaction with traffic to provide advisories and link times. Both the in-vehicle navigation module and the TMC feature detailed graphical user interfaces to support human-factors studies.

Current efforts are directed toward the development of additional features such as the interactive GUI for the map database module, improved traffic optimization using genetic

algorithms, and the modeling of interactions between smart and conventional vehicles.

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