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The aim of this project is to combine DIS (Distributed Interactive Simulation), database, and computer visualization technologies with knowledge about transportation engineering in order to create synthetic environments in which alternative ITS( Intelligent Transportation Systems) designs can be simulated and thier performanace displayed.

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# Distributed Interactive Simulation for Intelligent Vehicle Highway Systems

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## Abstract

The aim of this project is to combine DIS (Distributed Interactive Simulation), database, and computer visualization technologies with knowledge about transportation engineering in order to create synthetic environments in which alternative ITS (Intelligent Transportation Systems) designs can be simulated and their performance displayed. The principal results are summarized below.

The I-880 database is available online over the World Wide Web, together with a set of "filters" that can be used to retrieve the data at various levels of temporal and spatial aggregation. The data have been used by researchers around the country.

Versions 2 and 3 of SmarthPath were released. SmartPath is an automated highway systems simulator. It includes a 3-D animation package to visualize the highway and vehicles. SmartPath is also available over the Web. It has been used by many researchers and to explain to the public what an automated highway system might "look" like.

A versatile hybrid systems simulation language called Shift has been developed and released. It permits the modeling of a dynamically variable interconnected family of hybrid system components. Shift is currently used in four collaborative projects at Berkeley and by other groups worldwide.

This work was also supported by the California Department of Transportation (Caltrans), the Federal Highway Administration, and the National Science Foundation.

## Statement of the problem

The aim of this project is to adapt and combine DIS (Distributed Interactive Simulation), database, and computer visualization technologies with transportation engineering models in order to create synthetic environments in which alternative ITS (Intelligent Transportation Systems) designs can be replicated, modified, simulated, and their performance displayed in a variety of forms.

## Summary of results

There is significant agreement that the current highway system has reached a performance and productivity plateau. There is also agreement that automation technologies can usefully be applied towards the design of the next generation of highway systems, called "Intelligent

Transportation Systems" or ITS. But there is disagreement over the appropriate scope, public acceptance, and expected social benefits of automation among the many "stakeholders": researchers, transportation authorities, automobile and electronics industries, legislative bodies, and citizen groups. This makes rational discussion about transportation system options very difficult.

To the extent that the three environments we have built are successful, it will make the alternative ITS designs understandable to various stakeholders, help to make more objective comparisons among those alternatives, and thereby contribute to a more informed public debate.

Our work contributed to three software systems: the I-880 online database, SmartPath and Shift. We believe that all three systems are very successful.

## I-880 database

In a Caltrans-funded project we collected detailed data on a 8-mile section of I-880. The dataset consists of loop-detector data, probe vehicle data and incident data. The data were carefully cleaned: errors were removed, missing data were interpolated. A set of "filters" were developed, permitting users to retreive the data at different levels of temporal and spatial aggregation. The data and the processing filters can be accessed via the World Wide Web at : http://www.path.berkeley.edu/FSP/

A description of the I-880 experiment and database is given in [1]. The data have been used in at least eight doctoral dissertations around the country. The data were also used to develop novel statistical methods for estimating travel times [2]. The data are currently being used to develop algorithms for travel time prediction and incident detection.

## SmartPath

SmartPath is a a simulator for automated highway systems. The structure of SmartPath is based on the architecture described in [3]. Users specify the traffic conditions and capabilities of the vehicle controllers. The resulting simulation can be viewed using a 3-D animation. Versions 2 and 3 have been released and also available through www.path.berkeley.edu. Descriptions of SmartPath are in [4, 5, 6]. A distributed version of SmartPath was investigated [7].

SmartPath has been used in two ways. First, researchers designing vehicle control strategies use SmartPath to simulate those strategies and analyze the results to debug and tune their strategies. Second, SmartPath animations have been used by the NAHSC in public forums to help non-technical audiences understand what an automated highway system might "look" like. SmartPath animations have been aired over several TV news programs.

## Shift

SmartPath led us to build a more general-purpose simulation environment. The first effort focused on the development of an object-oriented database [8, 9]. The chief deficiency of this effort was a lack of a formal model. That deficiency has been overcome in Shift, a programming language for describing dynamic networks of hybrid automata. Such systems consist of components which can be created, interconnected and destroyed as the system evolves. Components exhibit hybrid behavior, consisting of continuous-time phases separated by discrete-event transitions. Components may evolve independently, or they may interact through their inputs, outputs and exported events. The interaction network itself may evolve.

Shift offers the proper level of abstraction for describing complex applications such as automated highway systems, air traffic control systems, robotic shopfloors, coordinated submarines and other systems whose operation cannot be naturally captured by conventional models.

A compiler translates a Shift program to a C program, and the Shift run-time system provides an executable program. The executable program, when run, simulates the design specified in the Shift source program. Shift is available at www.path.berkeley.edu/shift. A description appears in [10].

Shift is being used in four collaborative projects at Berkeley: automated highways, air traffic control, coordinated control of autonomous submarines for marine exploration, and advanced copying machines with automatic detection and handling of faults such as paper jams. Several other groups worldwide are using Shift for design and simulation of hybrid systems.

## Cooperation with other organizations

The three environments described above have been supported or used by several organizations listed below.

Automated Highway Systems Consortium (NAHSC)—a USDoT-funded program. NAHSC members use SmartPath and Shift.

The California PATH program is a partnership of California universities, industry and state and local agencies, seeking to improve the supply of transportation services. PATH researchers make extensive use of the I-880 database, SmartPath and Shift.

An NSF-INRIA grant supports exchanges between our group and the group of Verimag in Grenoble, France, led by Professor Sifakis. Dr. Sergio Yovine of Verimag is an expert in hybrid systems and is visiting us for one year.

Graduate students in NEXTOR (FAA Center for Excellence) use Shift to model air traffic control schemes.

Graduate students in Mechanical Engin are using Shift to model an advanced Xerox machines and to study hybrid control strategies.

## Personnel

The following students were supported from this contract: Mireille Broucke, Akash Deshpande, Aleks Gollu.

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