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Traffic Management

PATH – Partners for Advanced Transit and Highways – is a joint venture of Caltrans, the University of California, other public and private academic institutions, and private industry, with the mission of applying advanced technology to increase highway capacity and safety and to reduce traffic congestion, air pollution, and energy consumption.

CALIFORNIA PATH

California's ATMIS Testbed: Expanding the Frontiers of Traffic Management

Baher Abdulhai, PATH Center for ATMIS Research, UC Irvine

California's Advanced Transportation Management and Information Systems Testbed Program, headquartered at the University of California, Irvine (UCI), in Orange County, provides a unique real-world environment for evaluating the potential of new technologies and strategies in the management of advanced transportation systems. The program was initiated in early 1991 under research agreements between the California Department of Transportation (Caltrans), UCI, and the California Polytechnic State University, San Luis Obispo (Cal Poly). The Testbed facility is an electronic superhighway in its own right, providing real-time and historical data links between the transportation management centers of Caltrans District 12 and the cities of Irvine and Anaheim, and the dedicated ITS research laboratories at UCI and testing facilities at Cal Poly. To take advantage of these Testbed capabilities, PATH recently established the PATH Center for ATMIS Research at UCI. The Center currently maintains a limited full-time research staff focused on ATMIS research and development utilizing the testbed environment. The staff also facilitates access to the Testbed by other PATH researchers.

The Testbed network integrates surveillance information from freeways, major arterials, and transit and traffic operations centers. It encompasses two contiguous sub-areas in Orange County that include virtually all of the major decision points for freeway travelers in the region. The City of Anaheim sub-area is centered around two of its designated "smart streets," Harbor Boulevard and Katella Avenue, and encompasses the City's major special event traffic generators. This area is particularly suited to network-wide applications of advanced technologies in traffic management. The City of Irvine sub-area provides freeway access to a myriad of business and office complexes on both sides of the I-5 freeway, and is particularly suited to corridor-level integration of real-time communication and control in traffic management.

Three factors work together to make the Testbed an ideal environment for advanced traffic management research: 1. Availability of comprehensive real-time surveillance data from the network, 2. A comprehensive ATMIS research program, with the goal of building a prototype integrated ATMIS system for real-world applications, and 3. Decision support feedback into the network.

Collectively, these factors enable continuous monitoring of the network, research into new and inno-

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IN-TUC: A New Integrated Traffic Responsive Urban Corridor Control Strategy

Christina Diakaki and Markos Papageorgiou, Dynamic Systems and Simulation Laboratory, Technical University of Crete, Greece

IN-TUC's aim is to provide integrated control measures based on current traffic conditions.

Traffic congestion in urban highway networks is notoriously increasing, but rapid evolution of information technologies, together with methodological advances in Automatic Control and Optimisation theories, are making efficient new strategies feasible for optimal use of the available highway infrastructure. Past attempts to optimize traffic flow locally have involved developing independent control systems for such measures as ramp metering, variable message signs, and signal control. However, isolated control actions may have major effects on the surrounding traffic network. Ideally, traffic problems should be addressed by integrating the application of a variety of control measures with each traffic network's operational objectives and user needs.

Simulation studies of Glasgow, Scotland's M8 corridor network, conducted in the European DRIVE II project EUROCOR (EUROpean urban CORridor control), showed that integrated control measures may significantly ameliorate traffic conditions (Diakaki et al.1997a). These positive initial results led to research within the European DRIVE III project TABASCO (Telematics Applications in BAvaria, SCotland and Others), culminating in the development and field implementation of an integrated traffic responsive urban corridor network control strategy called IN-TUC (INtegrated - Traffic responsive Urban corridor Control).

The IN-TUC strategy

The aim of the IN-TUC strategy is to provide traffic-responsive settings at suitably defined constant control intervals for the various control elements included in a corridor network area. These settings are based on real-time measurement data collected from detectors located within the controlled area (Diakaki et al. 1998). IN-TUC is built upon well-known methods of formulating control problems and deriving feedback control laws. The strategy is robust and simple: robust enough with respect to measurement inaccuracies to react correctly to current traffic conditions even in cases of insufficient data, and simple enough to permit the execution of all required calculations in real time. Moreover, IN-TUC has been developed in a generic way, so that it may be transferred with minor modifications to networks with traffic problems similar to Glasgow's.

IN-TUC's first version consists of three basic parts: urban traffic control, variable message sign control, and ramp metering. These parts are formulated as follows:

Urban traffic control. The problem is formulated as a Linear Quadratic optimal control problem based on a store-and-forward type of mathematical modelling initially proposed in Gazis 1991. The control objective is to balance (i.e. equalize) the number of vehicles within the urban links approaching urban signalized intersections. The method used is to change the split of the traffic light cycles – the time each signal is, for example, red or green – around some nominal values, in a coordinated manner. IN-TUC traffic control strategy decisions are based on current traffic conditions within the considered network part. This formulation enables the solution of the problem using well-known Linear Quadratic methodology that leads to a simple control law.

Variable message sign control. A feedback control law is applied, based on the concept of equalising the travel times between two alternative routes, resulting in optimal user conditions.

Ramp metering. ALINEA (Asservissement LINéaire d'Entrée Autoroutière), a local feedback control law derived by use of classical Automatic Control methods, is used (Papageorgiou et al. 1991).

The urban traffic control, variable message sign control, and ramp metering parts of the IN-TUC strategy are integrated in the sense that there is a mutual exchange of measurements and decisions. This approach better facilitates possible expansions of any of the parts of the strategy than would a totally integrated approach (where all

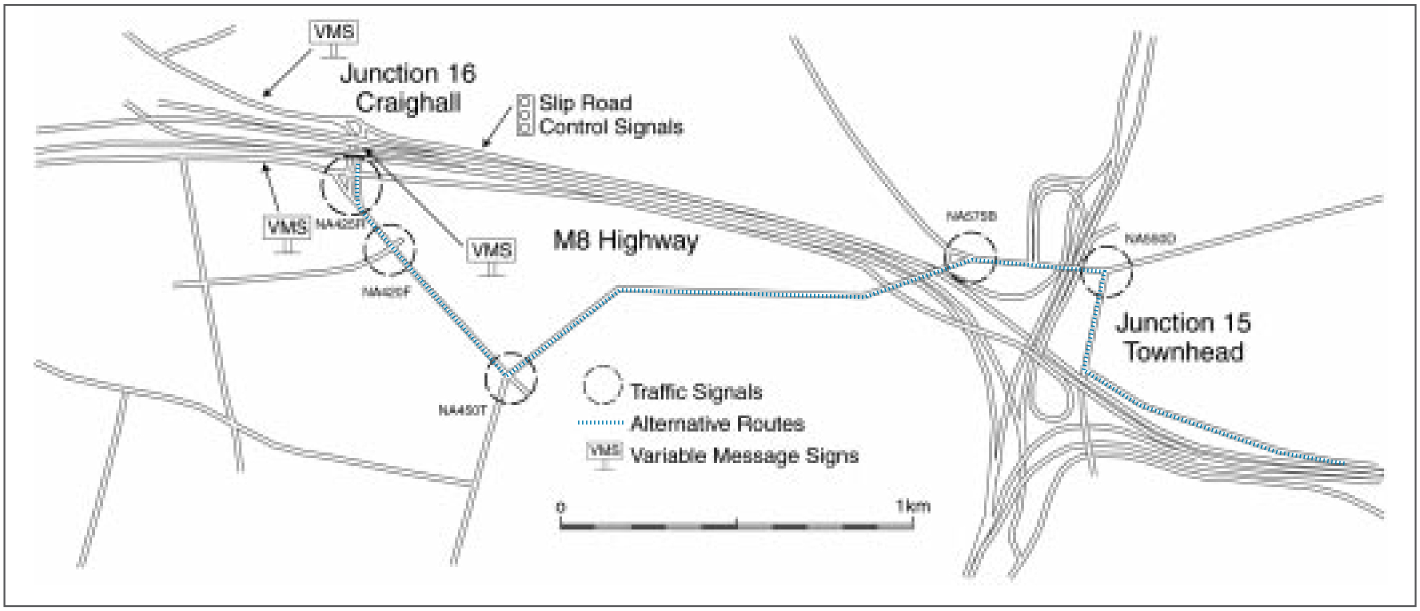

Figure 1. M8 corridor network in Glasgow, Scotland.

three parts would be manipulated by a unique control law). Additionally, this approach allows for the completely independent use of each part (e.g., the urban traffic control strategy may be used alone).

Applying the IN-TUC strategy in Glasgow

The M8 corridor network in Glasgow suffers from major congestion, especially during daily business peak hours. Figure 1 shows the network area and the control elements used to reduce congestion These are ramp metering at the Craighall onramp, three variable message signs installed in the urban area around Junction 16, and signal control of urban intersections along the city-street alternatives to the M8 urban routes.

In order to apply the IN-TUC strategy to the M8 corridor network in Glasgow, the part of the network under consideration was modelled according to the strategy requirements, and a software implementation was developed. The IN-TUC strategy is run in real time every two minutes, as the flow diagram of Figure 2 displays (for the detailed strategy structure see Diakaki et al. 1997b).

In the Data Processing block, the data collected from the network detectors over the previous two minutes are suitably processed so as to provide the input data required by IN-TUC's control laws. Possible detector failures are considered within this block, and any missing data are appropriately replaced, to allow a graceful degradation of the control system.

In the Application of Control Laws block, the control laws of the strategy are applied in order to calculate new control settings.

In the Control Decisions block, the final control decisions are taken, considering institutional and other constraints that are pertinent to the particular (Glasgow) application of the strategy.

Preliminary Results and Conclusions

To assess the strategy's input before implementing it in real life, a simulation model of an area significantly greater than the one displayed in Figure 1 was developed using METACOR, a macroscopic modelling tool for simulating traffic flow on corridor

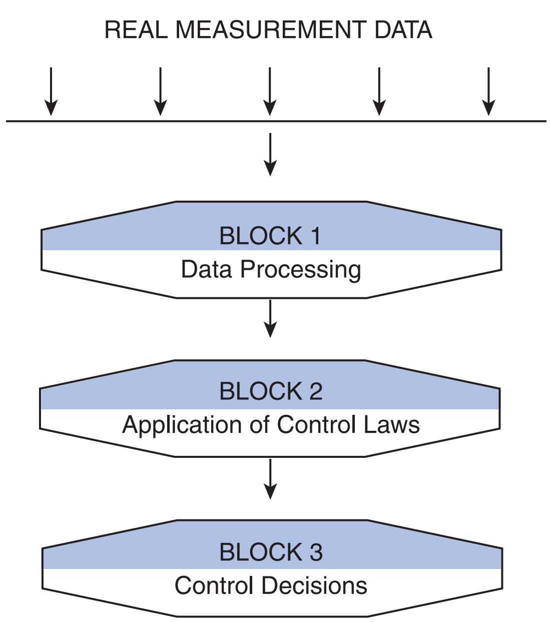

Figure 2. IN-TUC strategy flow diagram.

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Improved Vehicle-Actuated Traffic Signal Control

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Wide-area detection can substantially reduce delay – by as much as 50 percent.

Green light, yellow light, red light: this cycle of a traffic signal is regulated by a controller that changes the signal display to allocate right of way to vehicles approaching the intersection from various directions. Many controllers use a straightforward strategy of changing the signal after a fixed time interval for each direction. Other controllers are vehicle-actuated: the controller responds to varying demand using information from vehicle detectors. PATH researchers have recently been investigating ways to improve vehicle-actuated traffic signal control using both traditional impulse detectors, which can only monitor discrete points on the road, and a developing technology: wide-area detectors that will be able to monitor vehicles over a large region of the intersection. These improvements should result in delay reductions and increased safety for all users (Cassidy & Coifman 1998).

Practical wide-area vehicle detectors should become available in the near future (Malik & Russell 1997). In anticipation of this hardware development, we have developed a control algorithm based on the assumption that such detectors are fully functional, and have used computer simulation to compare new control strategies against the current state of the practice. We have found that wide-area detection can substantially reduce delay — by as much as 50 percent — at isolated intersections. (The scope of our work is restricted to isolated intersections because control issues are different for isolated intersections and for arterials.)

G. F. Newell, in his 1989 work Theory of Highway Traffic Signals, noted that vehicle-actuated (VA) control offers two advantages over fixed-time control. The first is the capability of responding to cyclic fluctuations in the rate at which vehicles arrive at an intersection. The second is the capability to reduce time lost when changing the signal indications from green to red, where the lost time is the interval after all waiting vehicles (the queue) have been served, but before the signal changes to red. Although VA control has been in use for over 40 years, conventional systems fail to utilize the second capability. Conventional VA strategies change the signal from green to yellow a specified time after the last queued vehicle has passed through the intersection. Consequently, the green changes to yellow a fixed time after the demand reduction has been detected. As a result, this practice can reduce intersection throughput.

The remainder of this article will present the conventional VA control strategy in contrast to our improved control strategies, briefly compare their performance, and finally discuss implications for operators and for detector design.

Conventional impulse detector control

During the green indication, the signal controller monitors the time interval between vehicles passing over an impulse detector — the headway — until a measured headway exceeds some prespecified critical headway, indicating that the queue has dissipated. When a critical headway is observed, or if the green has reached its specified maximum time, the controller changes the signal to yellow. Usually, the impulse detectors are placed too close to the intersection. As a result, the last vehicle has passed through the intersection before the critical headway is detected.

Following conventional practice, the impulse detectors in adjacent lanes are wired together, as shown in Figure 1A Thus, the controller looks for the critical headway across all lanes simultaneously. On intersections near saturation, it is uncommon to observe a large headway across all lanes, even after the queue has passed. Thus, the green phase can reach its limit (set at 61 seconds for this study) before the controller changes the signal. Often, the lanes in one direction are wired together with the lanes in the opposite direction as well, but this practice was not included in our study.

Improved impulse detector control

This control strategy incorporates several theories proposed by Newell (although not yet adopted as standard practice) for improving intersection efficiency using conventional detectors. Here, the

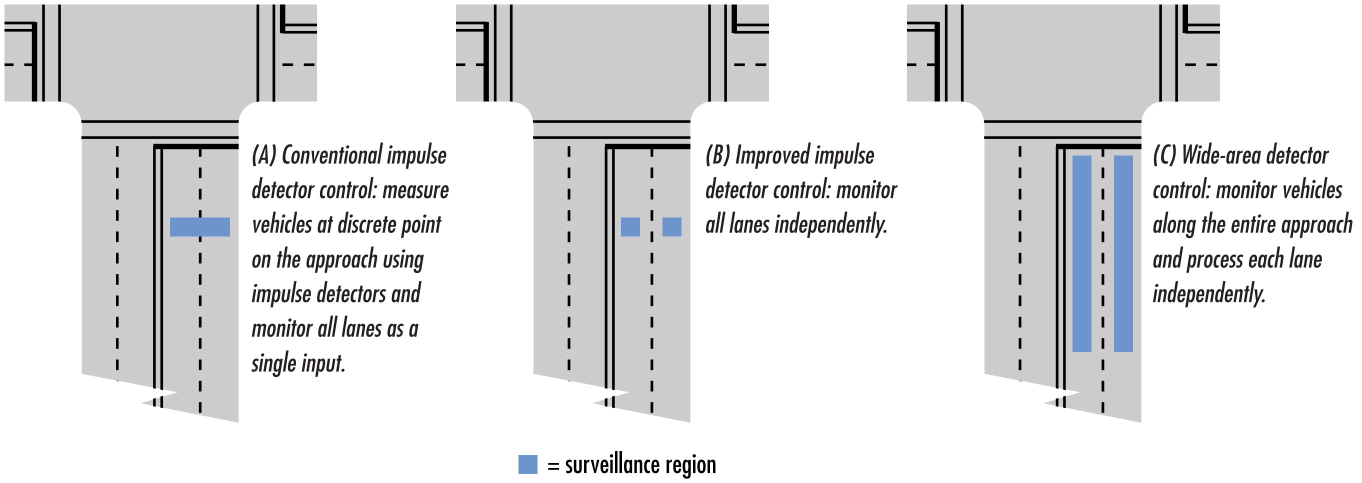

Figure 1. Vehicle detection strategies

detectors are decoupled and monitored independently, as shown in Figure 1B. During the green phase, the controller looks for a critical headway in each lane, independent of the other lanes. When that headway is reached in at least one lane, the queue is assumed to have passed for that direction and it is regarded as clear. Thus, the controller responds as soon as demand drops. It does not have to differentiate between a shorter than critical headway in a single lane and a subcritical headway caused by vehicles in two different lanes. On one-way streets, the controller changes the signal to yellow as soon as a given direction clears, while on two-way streets, the controller waits for both directions to clear before changing the signal. Finally, the detectors are placed sufficiently upstream of the intersection so that the critical headway is detected before the last vehicle has entered the intersection, thus allowing the controller to change the signal to red as soon as demand drops.

Wide-area detector control

Extending Newell's theories to wide-area detection, the controller monitors vehicles along the entire intersection approach, as shown in Figure 1C. Each queue of vehicles is monitored using the same principles: the first non-queued vehicle is added to the queue when the vehicle decelerates below the free flow velocity or when the vehicle's headway falls below a threshold, regardless of the vehicle's location on the approach to the intersection. Once a vehicle has entered the queue, it is considered part of the queue until it passes the stop bar. Thus, disturbances within the queue as it moves through the intersection (e.g., an inattentive driver with a long headway) do not cause premature termination of the green. In practice, some modification would be necessary to allow for vehicles' leaving a queue for parking or mid-block turning maneuvers. Note that in this strategy, the controller only needs to know the spatial position and velocity of the end of the queue in each lane. It need not keep track of the number of vehicles.

As soon as a queue has dissipated in at least one lane in both directions, the controller changes the signal from green to yellow. Here queue dissipation is defined as the instant when the last vehicle in the queue has passed its minimum stopping distance, i.e., the first instant when the last driver cannot stop short of the intersection at a given velocity, assuming a reasonable value for maximum deceleration.

Simulation results

In our study, eight different intersection configurations were simulated, each with different approach attributes (e.g., different free flow velocities, different demands, etc.). Table 1 shows the results from three of the scenarios. Scenario I examines the intersection of two one-way streets, while Scenarios II & III examine two-way streets. The greatest improvement is seen in Scenario I, where the wide-area controller reduced delay by 50 percent. In Scenario II, where opposing approaches have unbalanced demand [800 vphpl (vehicles per hour per lane) north and west, 480 vphpl south and east], the improved impulse controller performs almost as well as the wide-area controller. Both strategies reduce delay by approximately 30 percent. Finally, in Scenario III, the high demand

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Scenario	Number of Approaches	Number of Lanes	Free Flow Velocity (mph)	Demand (vphpl)	Detection and Control	Average Green (sec)	Average Delay (sec)	Percent Improvement
I	2	2	30	800	Impulse: conventional	57.2	32.8	-
					Impulse: improved	24.6	23.3	29%
					wide area	10.8	16.5	50%
II	4	2	40	800	Impulse: conventional	60.9	38.6	-
					Impulse: improved	44.0	35.2	9%
					wide area	30.5	29.6	235
III	4	2	40	480/800	Impulse: conventional	60.3	32.6	-
					Impulse: improved	25.9	23.7	27%
					wide area	18.6	21.7	34%

Table 1. Simulation results from three different intersection scenarios.

on opposing approaches reduces the probability that the controller can exploit an early queue dissipation in one direction.

Perhaps not surprisingly, the greatest benefits from wide-area surveillance were realized at intersections near saturation. When demand is high, it is rare that a critical headway is observed across both lanes simultaneously in a given direction. Under high demand, the conventional controller reaches the maximum allowable green and "times out" in virtually every cycle (as is evident from the long green times). In other words, conventional VA control is not particularly responsive to drivers.

Using the improved control strategies, almost all vehicles stop at the intersection; however, the average delay across all drivers is reduced relative to the conventional strategy. The intersection operates more efficiently under the improved strategies because more vehicles pass through per unit time. Thus, an intersection that is oversaturated using conventional control may become undersaturated by decoupling the lanes and by judiciously applying wide-area vehicle detection.

Implications for operators

For some of the scenarios considered in this work, using the wide-area controller reduced delay on the order of 50 percent relative to the conventional control strategy. These benefits are realized because the controller can respond as soon as demand drops. However, wide-area detection is not cost effective for all intersections, and in some cases, judicious use of impulse detectors can yield performance improvements similar to the wide-area detector. It is important that operators reexamine how they use the existing detector infrastructure. This work has shown that monitoring lanes independently, rather than wiring multiple detector inputs together, can yield substantial delay reductions. The scenarios examined in this study showed as much as a 29 percent delay reduction when the impulse detectors were decoupled.

Implications for detector design

Machine vision, or video image processing, promises to be the first viable wide-area detector. Image-processing vehicle detectors currently on the market fall into two categories: second-generation systems, which mimic impulse detectors, and third-generation systems, which attempt to track discrete vehicles. The second-generation systems do not provide sufficient information for true wide-area control, while the third-generation systems tend to be too complex and run into problems when segmenting vehicles on the intersection approach. The wide-area controller needs to know where the queue ends spatially and how fast it is moving, but the controller does not need any information about how many vehicles are in the queue. Modifying an existing third-generation detector to track moving objects (platoons of unknown numbers) could allow the detector to extract the spatial end of queue while bypassing the difficult task of segmenting discrete vehicles.

References

Cassidy, M., and B. Coifman. 1998. Design of a Machine Vision-Based Vehicle Actuated Traffic Signal Controller. University of California, Berkeley: Institute of Transportation Studies, California PATH Program.

Malik, J., and S. Russell. 1997. Traffic Surveillance and Detection Technology Development: New Traffic Sensor Technology Final Report. University of California, Berkeley: Institute of Transportation Studies, California PATH Program. UCB-ITS-PRR-97-06

Newell, G. 1989. Theory of Highway Traffic Signals. University of California, Berkeley: Institute of Transportation Studies.

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networks. The model was validated against real data and was found to realistically reproduce the traffic conditions in the part of the network being modeled (Diakaki et al. 1997c).

For the urban traffic control part of the strategy, comparing the initial simulation results with fixed-time urban traffic control plans indicates that during the four-hour evening peak period, the total time spent by all vehicles within the urban subnetwork of the simulated area was reduced by 1-2 percent. In the area actually manipulated by the IN-TUC strategy, the reduction may be in the range of 5-10 percent. A further amelioration is achieved by using all of the available control measures.

In general, the investigations indicated that the overall performance of the strategy depends upon the current traffic load pattern in the network. Further diversion of traffic at other network locations, and via routes not considered in the current application, may therefore prove beneficial for the improvement of the overall traffic conditions even in cases of major congestion around the ramp merging area. (This is a subject of current investigation.)

The IN-TUC strategy was launched early in December 1997. It currently operates in open loop, meaning that although the strategy is fed with real measurement data and the results are checked regarding their correctness, the decisions are not yet forwarded for site implementation. So far, the strategy decisions seem rational, and only the adjustment of minor parameters has been required.

The strategy has proved to be very fast from a computational point of view. Because the control laws employed are very simple, the required computational effort increases only slowly with increasing complexity of the application network.

Completion of the real-life evaluation of the IN-TUC strategy development is now underway. The next steps include expansion and generalisation of the urban traffic control part of the strategy in order to obtain a stand-alone urban traffic control strategy, possibly without the need for nominal signal settings.

Acknowledgments

This work was partially supported by the European Commission under the Telematics Applications in Transport Project TABASCO (TR1054). The authors are also thankful to the site owners, the Glasgow City Council.

References

Diakaki, C., M. Papageorgiou, and T. McLean. 1997a. Simulation studies of integrated corridor control in Glasgow. Transportation Research 5C, 221-224.

Diakaki, C., M. Papageorgiou, T. McLean, and partners of the Transport Telematics Project TABASCO (TR1054). 1997b. Urban Integrated Traffic Control: Implementation Strategies.. Brussels, Belgium: Report for Transport Telematics Office.

Diakaki, C., Y. Pavlis, G. Vardaka, M. Papageorgiou, T. McLean, and partners of the Transport Telematics Project TABASCO (TR1054). 1997c. Sites, User Needs and Traffic Model Verification Report. Brussels, Belgium: Report for Transport Telematics Office.

Diakaki, C., M. Papageorgiou, and T. McLean. 1998. Applying integrated corridor control in Glasgow.

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vative ATMIS approaches, and testing/evaluating these approaches' potential benefits before any major deployment in the field.

Real-time surveillance data availability at UCI labs is one of the products of a fiber optics communication network linking UCI, the City of Irvine Transportation Research and Analysis Center, and Caltrans' District 12 Transportation Management Center (TMC). Plans are in place to extend this network to include the City of Anaheim TMC and the Cal Poly laboratories. Researchers can access real-time freeway video and loop data at the UCI labs via a Common Object Request Broker Architecture (CORBA) interface. The CORBA interface allows Testbed researchers to use real-time, on-line traffic data to test any ATMIS module, as well as to feed output back to the field. Historical data (up till current) can also be downloaded via a web-page-like interface for off-line research and development. Researchers can select a location, direction, date, and time, and with a click of a mouse button download the corresponding traffic data. Surface street data is expected to be similarly available soon.

Researchers can access real-time freeway video and loop data and feed output back to the field.

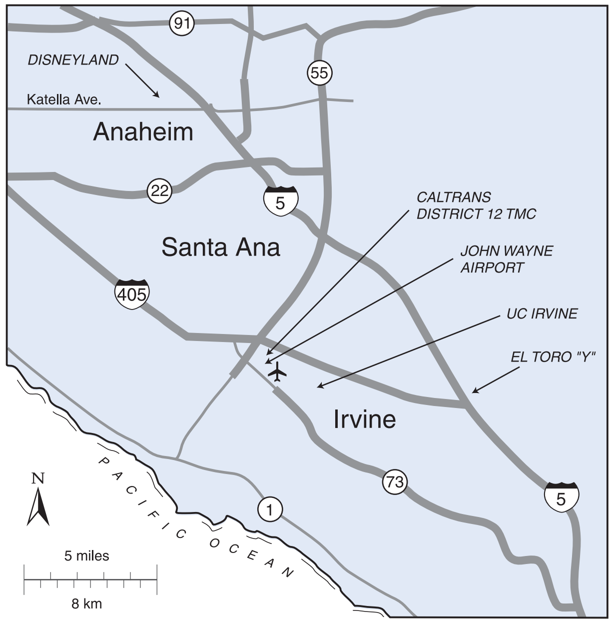
To complement the Testbed's surveillance capabilities, approximately fifteen portable video image processing (VIP) systems and a supporting wireless communications infrastructure are being installed at selected sites. Each VIP sensor node is capable of generating vehicle count, speed, occupancy, density, and queuing data. Additional data on estimated vehicle length, vehicle tracking on the roadway, and digitized video imaging may also be available from each VIP system. The architecture of this system is designed to permit both applied research as well as additional operational capability for the District 12 TMC.

ATMIS research and development in testbeds in general, and at UCI in particular, is geared towards building an integrated ATMIS system capable of managing dynamic transportation networks in real time. The overall system is composed of individual modules, each of which is responsible for a specific set of tasks. A central communications module is responsible for coordinating the operation of the individual modules. The central module's tasks include supplying each module with the proper inputs and redirecting the outputs accordingly. Each module relies on surveillance data and/or outputs from other modules. Examples of current components include:

1. Adaptive intersection signal control and fast traffic prediction techniques;
2. Adaptive freeway ramp control techniques;
3. Real-time origin-destination trip-demand estimation modules;
4. Freeway incident detection algorithms based on neural networks;
5. Incident management expert systems for freeways and arterials;
6. Real-time optimal/equilibrium traffic as signment techniques;
7. A comprehensive system of fault-tolerant traffic control based on distributed processing;
8. Dynamic assignment models;
9. Distributed processing framework for net work optimization;
10. Image processing algorithms for vehicle-tracking and incident detection.


These modules, together with the communication modules, form a single framework within which they communicate in real-time both with each other and with the Testbed, with appropriate transfer of information over Ethernet. Flexible protocols have been developed for adding and deleting modules, and for interfacing with field devices.

Ultimately, decision support produced by these modules can be fed back into the network for implementation. Examples of decision support include changing ramp metering rates, changeable message signs, signal settings, and the like, as necessary to implement the advanced traffic management decisions recommended by the system. This feedback is designed to be achievable from UCI labs in a fully secure environment.



A comprehensive set of advanced traffic simulators are also available in the UCI labs, to complement field data. The role of these simulators is to replicate the real world and drive the ATMIS components. Paramics, a state-of-the-art ITS-ready microscopic traffic simulator, has been recently acquired by UCI. Current efforts are in progress to model the Testbed network in Paramics and to calibrate and validate its underlying models to guarantee local real-world-like performance.

To illustrate the operation of the overall system, one can imagine the following scenario: The incident detection module operates on traffic data passed to it from the central communicator, which in turn obtains the data either from the real world or from the background simulator. As the detection module captures an incident in the network, it reports the detected incident and related congestion information to the central communicator. The central communicator then passes the information to the incident management module for further action. The incident management module operates on this incoming incident information and other direct information from the communicator to infer neighboring traffic conditions. The incident management module triggers other modules as needed to reroute traffic, transit fleets, and commercial fleets in the area. All other modules are called upon to assign the diverted traffic to the appropriate alternative routes, reoptimize signal settings and ramp metering rates to accommodate the diverted traffic, and communicate their results back to the central communicator. The central communicator then completes the cycle by feeding back the routing and control decision in the network for implementation.

In summary, the Testbed provides a true multi-jurisdictional, multi-agency transportation research, development, and operations environment. The advanced ATMIS technology emerging from this pioneer effort should help us to fulfill California's transportation management needs as we move into the twenty-first century.

Pictured below: Changeable message sign near John Wayne Airport, PATH researcher Baher Abdulhai at UC Irvine Testbed headquarters, El Toro "Y" junction of I-5 and I-405, Caltrans District 12 TMC, flyover lanes at El Toro "Y."

PATH Goes to the Netherlands

Steve Shladover, PATH

Substantial international interest in PATH's vehicle automation work, generated by the prominent role PATH research played in the NAHSC Demo '97 in San Diego, has led directly to our participation in two important demonstrations of automated vehicles in the Netherlands.

Demo '98 will bring together the latest developments in advanced vehicle control and safety systems from the major European manufacturers and research programs.

The Rijkswaterstaat (Ministry of Transport, Public Works and Water Management) has organized an international demonstration of "Automated Vehicle Guidance" to be held June 15-19, 1998 at the construction site of a new highway near Rijnwoude, the Netherlands. This event, "Demo '98," will bring together the latest developments in advanced vehicle control and safety systems from the major European automotive manufacturers and EU-sponsored research programs. Visitors from the media, industry, public agencies, and the general public will have the opportunity to see technical exhibits and to take demonstration rides in the vehicles. The organizers of this event were so impressed by our demonstration in San Diego that they invited us to participate in their event, so that a broader European audience could be exposed to our work, and the Rijkswaterstaat sponsored PATH's efforts to bring four of the Buick LeSabres that PATH and its partners developed for Demo '97 to Demo '98.

Two cars will provide an automated platoon demonstration ride at full highway speed on the available 5.5 km-long demonstration roadway. Another will offer automated "mini-demo" rides at low speed on a short closed course. The shorter demonstration course and smaller number of cars make this demonstration considerably simpler than San Diego's, but it has still required new work by PATH researchers to adapt the vehicle systems for the different operating conditions in the Netherlands. This includes modifying the vehicle-vehicle communication system to be compatible with the different spectrum allocation available in Europe, waterproofing sensors for operation in the Dutch climate (a lot wetter than San Diego in August), and redefining the demo scenario to fit the shorter length of roadway.

In parallel with Demo '98, the Netherlands' Combi-Road consortium will be demonstrating an automated, driverless truck that features PATH technology for hauling shipping containers on their own test track near Rotterdam. Based on the success of Demo '97, Combi-Road were encouraged by the Rijkswaterstaat to explore the technologies used in San Diego. This led to a contract for PATH to implement its magnetic marker lane guidance system on the Combi-Road truck and track, and PATH post-doctoral researcher Hung Pham's making several trips to the Netherlands to implement the system for Combi-Road. This work is proceeding in parallel with PATH's current efforts in California to automate a heavy commercial tractor/trailer we have on loan from Freightliner. The Combi-Road effort is an opportunity to learn how to implement the magnetic guidance technology in a different and more challenging environment, on a special track heavily equipped with steel reinforcing rods and in a vehicle with a high-power electric propulsion system. This work should help to show how PATH technology can be applied in very diverse situations, as well as to provide us with prominent exposure in Europe.

The Nederlands Ministry of Transport Web site is: http://www.minvenw.nl/rws/wnt/avg/index-uk.html

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ASCE 5th International Conference on Applications of Advanced Technologies in Transportation Engineering. Newport Beach, California, in press.

Gazis, D.C. 1991. "Network modelling and control: Store-and-forward approach." Concise Encyclopedia of Traffic and Transportation Systems, M. Papageorgiou, Ed. Oxford: Pergamon Press. 278-284.

Papageorgiou M., H. Haj-Salem, and J.M. Blosseville. 1991. ALINEA: A local feedback control law for onramp metering. Transportation Research Record 1320, 58-64.

This article grew out of a series of seminars given by Professor Papageorgiou while a visiting scholar during the fall semester at the Institute of Transportation Studies, UC Berkeley.

PATH Database Named "Top 5" Web Site

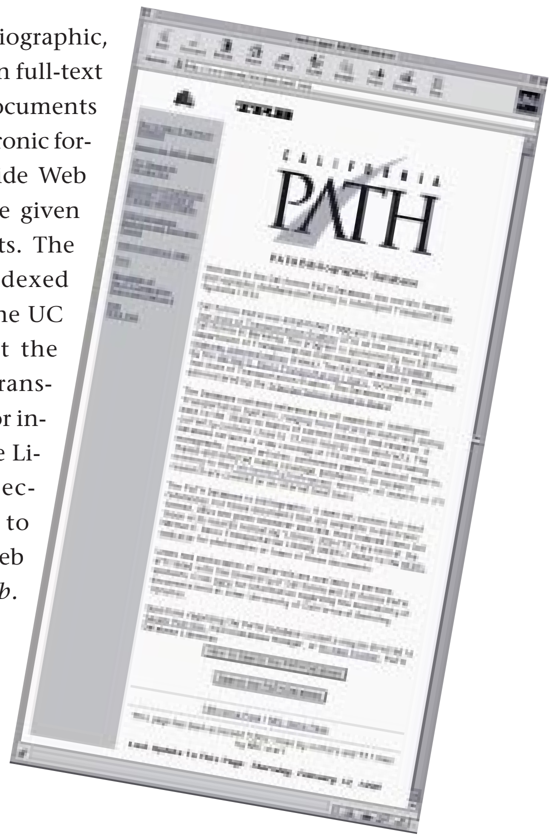
In its April issue, ITS World magazine, the only US periodical devoted entirely to intelligent vehicle systems, named the PATH database as one of the five best web sites of more than 100 sites for ITS professionals surveyed.

The PATH database, the world's largest bibliographic database pertaining to ITS (Intelligent Transportation Systems), is now available on the Transportation Research Board (TRB) web site *(http://www.nas.edu/trb)*. This partnership between PATH and TRB will improve access to the vast collection of research material relating to ITS. To access the PATH Database directly use the URL: *http://www.nas.edu/trb/about/path1.html*

The PATH Database contains references to all aspects of Intelligent Transportation Systems, ranging from historical materials dating back to the 1940s to topics of current interest and research. It currently contains over 13,000 records with abstracts. The Database reflects a wide coverage of ITS information including monographs, journal articles, conference papers, technical reports, theses and selected media coverage. Although emphasis is on research relating to the California PATH Program, the Database provides international coverage of ITS research and applications.

The Database is maintained at the Harmer E. Davis Transportation Library, located at the Institute of Transportation Studies, University of California at Berkeley.

The Database is bibliographic, and does not contain full-text references. Some documents are available in electronic format, and World Wide Web addresses (URLs) are given for these documents. The majority of the indexed items are held on the UC Berkeley campus at the Harmer E. Davis Transportation Library. For information about the Library and its collections, please refer to the Library's own web site at:*http:www.lib.berkeley.edu/ITSL*



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PATH Presentations

Recent and Upcoming Presentations of PATH Sponsored Research

Transportation Research Board (TRB) Annual Meeting, January 11-15, 1998

77th TRB Annual Meeting, Doctoral Student Presentation
• Prediction of Short-term Freeway Traffic Volume Using Recursive Least Squares and Lattice Filtering, Seungmin Kang, University of California, Irvine

Senior Citizen Driving And Mobility
• A Survey of the Elderly: An Assessment of their Travel Characteristics, 980001 Mohamed A. Abdel-Aty, University of Central Florida; Paul P. Jovanis, Pennsylvania State University

Characteristics of Congested Facilities
• A Simple, Generalized Method for Analysis of a Traffic Queue Upstream of a Bottleneck, 981292 Alan Erera, Tim W. Lawson, and Carlos F. Daganzo, Institute of Transportation Studies

Transit Management and Performance (Poster Session)
• Evaluating Interface Standards in the Public Transit Industry by M. Hickman, S. Tabibnia, and T. Day

Visions Of Automated Highway Systems
Steven E. Shladover, University of California, presiding

Teleshopping And Telecommuting
• Costs and Benefits of Telecommuting: A Modeling Framework and Illustrative Results Kevan R. Shafizadeh, Debbie A. Niemeier, and Patricia L. Mokhtarian, University of California, Davis; Ilan Salomon, Hebrew University, Israel

Highway Traffic Monitoring Technology
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• Vehicle Reidentification and Travel Time Measurement to Real-Time on Freeways Using the Existing Loop Detector Infrastructure, 981498 Benjamin A. Coifman, University of California, Berkeley

Control Strategies For Coordinated Signal Systems
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Automated Highway Systems
William Stevens, National Automated Highway System Consortium, presiding
• Automated Highway System Field Operational Test: Potential Sites, Configurations, and Characteristics, 980397 Randolph W. Hall and Viral Thakker, University of Southern California; Thomas Horan, Jesse Glazer, and Chris Hoene, Claremont Graduate University Research Institute

• Why We Should Develop A Fully-Automated AHS, 980641 Steven E. Shladover, University of California at Berkeley

• An Axiomatic Approach to Developing Pre-AHS Automation Concepts and the Concept of Partial Invocation of ACC and Vision-Based Lane Keeping, 981513 Hsiao-Shen J. Tsao, University of California at Berkeley

AVL Implementation Experience And Benefits To Transit And Customers
• Automatic Vehicle Location and Computer Aided Dispatch Systems: Commerical Availability and Deployment in Transit Agencies, 980793 Asad J. Khattak, University of North Carolina, Chapel Hill; Mark D. Hickman, Texas A&M University System

Shared Station Cars: Toward Community-Based Smart-Car Sharing
Daniel Sperling, University of California, Davis, presiding
• BART Car Sharing in the East Bay: Research Findings Suzan A. Shaheen, University of California, Davis

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• A Preprocessor Feature Extractor and a Postprocessor Probabilistic Output Interpreter for Improved Freeway

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Freeway Incident Detection

• The I-880 Field Experiment: Effectiveness of Incident Detection Using Cellular Phones, 981273 Alexander Skabardonis and Ted-Chira Chavala, University of California, Berkeley; Daniel Rydzewski, URS Consultants

Advanced Traveller Information System Design And Evaluation

• Commuter Response to Traffic Information on an Incident, 981457 Ronald Koo, Harvard University; Youngbin Yim, University of California, Berkeley

• A Comparative Analysis of Spatial Knowledge and En Route Diversion Behavior Across Chicago and San Francisco: Implications for ATIS, 980792 Aemal J. Khattak, Pennsylvania State University; Asad J. Khattak, University of North Carolina, Chapel Hill

PATH at UC Berkeley Open House

Right: PATH Publications Manager Bill Stone describes magnetic marker guidance system.
Below: PATH's Honda Project Manager Dan Empey shows Accord with vision system and laser rangefinder.

Cal Day, UC Berkeley's annual open house, attracted thousands of visitors to the Ber keley campus on April 18. Hundreds stopped by the PATH exhibit to look under the hoods and into the computer-filled trunks of the "hands-free and feet-free driving" cars.

On display were a Buick LeSabre and a Honda Accord, two of the PATH-automated platoon cars that had been used to give demonstration rides on I-15 in San Diego during Demo '97 last August. PATH engineers Dan Empey, Han-Shue Tan, and Wei-bin Zhang, plus PATH publications manager Bill Stone, were on hand to answer questions all day, the most frequently asked being "When will I be able to buy a car like this?" "How much extra will the automation cost?" "What happens when the car in the middle runs out of gas?" "Where are there automated highways now?" and the perennial favorite, "What happens when a cow walks out onto the road?"

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