Validation of Testing Results for Vehicle Control Software

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PATH

The automatic vehicle control systems used in PATH experimental vehicles are safety-critical, since they control forces with serious potential for harm. PATH researchers test and formally (i.e., mathematically) verify the vehicle control software to improve their understanding of the effect of systems hazards, such as sensor failures, on vehicle system performance.

The primary function of the automatic lateral control system used in PATH experimental vehicles is vehicle lane tracking by automatic steering. The control system comprises three components: the sensing and reference system, the steering actuator, and the computer system. (See Peng et al. 1992 for a description of the system.)

A Hall-effect magnetometer senses the magnetic field of magnetic markers positioned every 1.2 m along the center of a test track and estimates the lateral position of the vehicle relative to the center of the desired path. The computing platform, which is on board the vehicle, is a hardened IBM-PC compatible computer. The control system software, implemented in the C programming language, runs under the QNX real-time operating system. A Frequency Shaped Linear Quadratic (FSLQ) preview control algorithm uses the lateral position data and the output from other sensors onboard the vehicle to produce steering commands carried out by the steering actuator.

State space and system testability

The testability of the lateral control system software is, in part, a function of the number of degrees of freedom in the control system algorithm: the more degrees of freedom, the more system states to be tested. Basically, for each additional degree of freedom in a software program or module, there is a corresponding decrease in testability in terms of state-space complexity. One measure of degrees of freedom is the number of channels (i.e., sensor inputs) used by the program or module. The PATH test car, a 1986 Pontiac provided by General Motors, has seven input channels: actuator position, lateral acceleration, yaw rate, left and right vertical components of the mag-

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netio field, and center vertical and horizontal components of the magnetic field.

PATH lateral-control system software is complex in terms of its state space. The size of each sensor input is 12 bits, and sensor values are sampled every 2 ms. For 2 ms and 1 s of system operation there are 26,672 (7 × 4096) and 6.4 × 10^{12} (28,672^{12}) input states, respectively. Under nominal vehicle and roadway conditions, a vehicle traveling under automatic lateral control on an automated highway system (AHS) may operate continuously for a period lasting from minutes to hours. Although it is theoretically possible to exhaustively test the control system for such operating intervals using a white-box or black-box testing approach, it is impractical.

An alternative approach is to test according to an operational system profile. We have applied a Monte Carlo black-box testing approach to the PATH lateral-control system software (Michael and Segal 1994). By Monte Carlo testing, we mean the application of random inputs to black-box code. The rationale for choosing black-box testing is that white-box testing typically involves partitioning the system input space with structural or data flow criteria rather than according to an operational profile.

Monte Carlo Black-Box Software Testing

Our approach consists of both a nonsequence and dynamic component. (By "nonsequence" we mean testing over a single time sample, as opposed to "static," i.e., code inspection or symbolic execution.) Testing begins with a single time sample of seven channels of Monte Carlo data. Using this sample, we search for patterns in the lateral control system software behavior indicative of software errors. The next step consists of repeating the test, first using 10 of real data to initialize the software routines and then using one Monte Carlo sample of all seven channels. The purpose of the second step is to test the code for nonsequence anomalies. If the nonsequence testing shows no anomalous or incorrect behavior, we then apply a sequence of test data to one of the seven control system input channels. In this way we stimulate the malfunction of a lateral control system sensor.

**Experimental setup.**

Real data is used to initialize all seven channels for 10 s, and for the other six channels while test data is applied to the acceleration channel. We initially ran 50 samples (100 ms) and 3,000 trials to estimate the performance of the software. A Uniform Normal Gaussian random number generator provides random inputs for the testing. Next, statistical analysis is used to determine if the lateral control system displays anomalous or incorrect behavior.

**Experimental results.**

The lateral control system exhibits robust performance in response to any single sample. We attribute this result to the real-time nature of the signal processing and control algorithms: these algorithms require several seconds of data for initialization purposes. In addition, the approximately 30 Hz filtering performed by the software on all seven channels results in the output steering angle of the test data being the same as the output steering angle of the actual vehicle. In this case, the filtering effect results in data normalization. (Robust control system performance does not necessarily mean no software errors: Richardson and Thompson (1993) point out that filtering of data can result in coincidental correctness, no failure being detected even though one or more faults are executed.)

During dynamic testing, the system exhibits both anomalous and incorrect behavior: if the accelerometer provides erroneous data, the control system will work properly for 35 ms, after which it fails to steer the vehicle correctly. When perturbed from the real data steering angle, trial output steering angles monotonically increase. This behavior, combined with a failure of the vehicle’s accelerometer, poses a system hazard from a software safety perspective, since the vehicle may veer off course.

Validation experiments

The PATH test car, running the real-time lateral control software, was used to validate the results from the black-box testing of the lateral control software. As described, software testing used data collected from the test vehicle, which we modify to generate points of the performance surface. Unfortunately, the points of the performance surface, though valid, do not necessarily correspond to physical vehicle experimental trials. To determine the relationship between the performance surface results from software testing and from actual vehicle testing, experiments were run to validate the software testing results.

**Experimental setup.**

We inject random inputs into one of the seven input data channels for the lateral control software. (The same version of the control system software used in the black-box testing was used in the validation experiment.) A Uniform Normal Gaussian random number generator provides random inputs for the testing. Initially, the y-accelerometer data channel is chosen to illustrate the effects of injected signals. To validate the software testing results, we modify the test car real-time data collection module in order to replace y-accelerometer channel data with randomized inputs.

The primary difference between the software testing trials and test car trials is the feedback of vehicle dynamics in the other six sensor channels. Since the control system has a latency time to react to changing inputs, we expect that the two results would be the same for the latency time and would diverge afterward.

**Experimental results.**

Several trials were run to develop an understanding of the effects of running the real-time control software with degraded input data. Figure 3a shows the results of an experimental trial where the system was run in normal operating mode; the plot shows y-accelerometer channel data plotted against in-road marker numbers. (In all the plots the in-road markers are used to calibrate the various data.)
PATH Research Presented

Below is a list of some of the conferences or workshops where PATH sponsored research was or will be presented.

**The 2nd World Congress on Intelligent Transport Systems '95**
Yokohama, Japan, November 9-11, 1995
- Mark Hickman, Stein Weissenberger, and Hong K. Lo from PATH will present "A Methodology for Systems Architecture Evaluation."

**International Conference on Software Engineering**
Seattle, Washington April 26-28, 1995
- Mats Heimdahl and Nancy Leveson of the University of Washington presented "Completeness and Consistency Analysis of State-Based Requirements."

**INFORMATS**
Los Angeles, California, April, 1995
- Carlos F. Dagostino of UC Berkeley presented "A Convergent Approximation Of The Kinematic Wave Model That Avoids Negative Flows."

**Association of American Geographers 91st Meeting**
Chicago, Illinois, March 1995
- Professor Reginald Golladay of UC Santa Barbara presented "Disabilities and Movement Behavior."

**ORS/TIMs**
New Orleans, October 1995
- Professor Reginald Golladay, Michael Castanone, and Jim Marston of UC Santa Barbara will present "Mass Transit Needs of Disabled People."

**International Conference on "The New Distributional Ethics: Differentiation and Discrimination"**
Boston, Massachusetts, November 7-9, 1994
- Professor Reginald Golladay of UC Santa Barbara gave an invited paper "Disabilities, Barriers and Discrimination."

**17th Annual Applied Geography Conference**
Kent State University, Akron, Ohio, October 1994
- Professor Reginald Golladay of UC Santa Barbara gave an invited paper "Navigation Aid for the Blind."

**SAE Future Transportation Technology Conference and Exposition**
Costa Mesa, California, August 8, 1995.
- Bret Foreman from PATH presented "A Survey of Wireless Communication Technologies for Automated Vehicle Control."
- Bill David from PATH presented "Frequency Modulated Continuous Wave Sensors for Longitudinal Control of Vehicles."
- Dr. Greg Maclean and Karl Hedrick of UC Berkeley presented "The Effect of Vehicle Braking Characteristics on IVHS Capacity."
- James Bret Michael, Andrew C. Segal and Satyajit Patwardhan from PATH presented "Validation of Software Testing Results for Real-Time Vehicle Control Software."
- J. Forbes, T. Huang, T. Kanawaza and Stuart Russell of UC Berkeley presented "The ARTmobile: Toward a Bayesian Automated Text."
- Karl Hedrick is the Organizer and Chairperson for the "Advanced Vehicle Control Systems in ITS" session of the conference.

**The 7th World Conference on Transport Research**
Sydney, Australia, July 16-21, 1995
- Bin Ran of MIT, H.-S. Jacob Tsao from PATH, and Chien-Chung Liao of UC Berkeley presented "Estimation of Time-Dependent O-D Matrices for Transportation Networks."
- Bin Ran of MIT and Hong K. Lo and Bruce Hoagland from PATH presented "A Dynamic Traffic Assignment Model for Real-Time Incident Management."

**American Control Conference**
The following were not included in the last issue:
- D. Swartrop from PATH and Karl Hedrick of UC Berkeley presented "Strong Stability of Interconnected Systems."
- Satnam Algo, Kai Goebel, and Alice Aggoun of UC Berkeley presented "A Methodology for Intelligent Sensor Validation and Placement Used in Tracking and Avoidance of Objects for Automated Vehicles."

**IEEE International Symposium on Intelligent Vehicles**
Detroit, Michigan, September 25-26, 1995
- Bill David from PATH will present "Cooperative Ranging/Communication System for Automatic Vehicle Control."

**Joseph Weber of UC Berkeley and the European Computer-Industry Research Center will present "New Results in Stereo-based Automatic Vehicle Guidance."**

**IEEE's 6th International Conference on Vehicular Navigation and Information Systems (VNIS)**
- Hong Lo, Stein Weissenberger, and Mark Hickman from PATH presented "A Structured Approach for ITS Architecture Representation and Evaluation."
- Hong Lo, Stein Weissenberger, and Mark Hickman from PATH presented "A Methodology for Evaluating System Architectures."

**Beijing, China**
July 1995
- PATH Researcher and Technical Director of the National Automated Highway Consortium Wei-Bin Zhang and Dr. Bin Ran of MIT were invited to give a seminar at Tsinghua University in China. Wei-Bin Zhang gave an overview of ITS activities in the United States and Dr. Bin Ran described the ITS system architecture program. Wei-Bin also presented a talk at the Northern Jiaotong University.
Institutional Challenges to ITS Deployment: Research Results and Future Directions

Thomas A. Horan
The Claremont Graduate School

Investigations of the technical requisites of Intelligent Transportation Systems (ITS) deployment have, so far, outpaced investigations of its policy and institutional implications. Engineering considerations have understandably attracted most of the attention and funding, but the ITS community is beginning to recognize that the broad range of institutional, legal, and societal challenges known collectively as “institutional constraints” may ultimately play just as influential a role in ITS adoption and deployment as straightforward matters of technical performance, systems integration, and cost.

Several national research efforts have recently been undertaken to better identify and understand the range of these institutional factors. As a result, the literature is now replete with inventories of potential institutional constraints. The author and his colleagues at the Claremont Graduate School have just completed an examination of these issues within the California context, funded by the California PATH program. (Horne, T.A., L. G. Hempel, and M. Rowes, Institutional Challenges to the Development and Deployment of ITS/ATIS Systems in California. 1995. Berkeley, Calif.: Institute of Transportation Studies, California PATH Program. PATH Research Report UCB-ITS-PRR95-17. 103 pp. Available from the Institute of Transportation Studies Publications Office, University of California, 109 McLaughlin Hall, Berkeley CA 94720. FAX 510-642-1246). Our study comprises a wide-ranging series of interviews, literature reviews, and related data collection activities. The goal was to identify major institutional and policy challenges confronting the California ITS program, with an eye to generating and prioritizing actions that need to be taken to ensure ITS success.

Three Areas for Action

Our analysis leads us to believe that policy and research attention should center on three areas. They are:

- research collaboration
- regional integration
- stakeholder acceptance

These efforts must be taken to ensure the overall success of ITS in California and nationally.

Table 1 provides an overview of these three areas, as well as exemplary cases and studies both from California and nationally.

**Research Collaboration**
Collaboration on ITS research between the private and public sectors in California is characterized by dynamic relationships between a variety of actors. As figure 1 shows, the parties bring different interests, priorities, and goals to this partnership.

For example, the private sector is oriented toward market demand, and the public sector toward public goals. Because the nature of the ITS program places high value on bringing the private sector into partnerships with Caltrans and other public sector agencies, there is a need for these agencies to understand the interests and concerns of ITS-related industries, while at the same time maintaining their own commitment to public goals.

An important industry concern, expressed by several of the private sector representatives we interviewed, is to have the State articulate its priorities in the advanced technology area, so as to inform the private sector of investment priorities, reduce development uncertainties, and facilitate collaboration with industry. The State's performance of objective, unbiased evaluations was also seen as helping the private sector to prioritize products and services on the basis of social, economic, and market trends, and as providing a basis for sound market analyses by suppliers.

**Regional Deployment**

The need to consider the impact of transportation investments on an entire metropolitan transportation system, as well as on other community goals (e.g., air quality), and to encourage a range of public participation has been enhanced by legislation in recent years, notably by the Clean Air Act Amendments of 1990 and especially the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991.

Our study indicates that regional deployments need to be considered in three stages: as visions, as plans, and as implementation. The first stage, regional vision, is hard to quantify and easy to underemphasize. ITS implementation will involve an ambitious attempt to deploy an advanced communications layer onto the regional transportation system. The question of how this initiative fits within the overall vision of a region's future inevitably arises. Efforts such as the national systems architecture project are providing input into the national technical vision for ITS. However, the public each region, including California’s major metropolitan areas, must consider the role of ITS and related advanced technologies within its own community. For example, those living and working in the Southern California Priority Corridor will need to understand the impact of various social and demographic forces on regional transportation priorities.

Several of the public sector representatives we interviewed remarked on how the institutional complexity of the myriad counties, cities, and towns through which ITS must be deployed necessitates strong leadership and partnerships to overcome organizational inertia. Here, incorporating the private sector can assist in expediting projects as well as in developing new sources of funding for projects (at least, for projects with strong market components).
Cameras, action: visitors flock to PATH

PATH researcher Eric Johnson explains longitudinal vehicle control to a delegation from the Government of Malaysia (1 to r) Havinder Kaur, Economic Planning Unit, Office of the Prime Minister; Ah Eng Teh, Ministry of Finance; Mohd. Salleh Mohd. Jh, Deputy Secretary General, Ministry of Science, Technology, and Environment; Abdul Jalil Khalid, Public Service Department.

BBC TV series Jr/TV Necker Work, which focuses on innovative technology, won a BAFTA (British EMMY) in 1993. Prof. Karl Hedrick (right) describe a magneto meter to BBC presenter Joan Nelson.

"EPCOT - a Journey to Discovery," a one-hour Disney TV special about people's daily lives in the future, will feature PATH research. Kevin Roberts (of Zilhoon Mayfield Productions) shoots action footage from the lateral control car on the Golden Gate Fields test track.

PATH researcher Satyajit Patwardhan uncovers test track magnet for Celeste Spier, Public Affairs/Outreach Manager, NARSIC Program Office.

Donald Dean, New Technology and Research Program, Caltrans; PATH researcher Satyajit Patwardhan; Georg Otto Geduld, Advanced Development Group, Transportation Sensors, Leica (with camera); PATH Program Director Steven Shladover; Wes Lam, New Technology and Research Program, Caltrans; Elaine King, Senior Program Officer, Transportation Research Board, Washington D.C.

Uwe Albrecht (right), Technology Manager, Positioning and Navigation, of Maunusmann Pilotentwicklung mbH (Munich) inspects magnetic tape with PATH researchers Satyajit Patwardhan and Han-shue Tan.

Hans-shue Tan, Akio Hosaka, Senior Manager, IVHS, Nissan Research Center (Japan); Kunihiko Kumomi, Principal Staff Engineer, IVHS, Nissan Research and Development, Inc. (USA).
Institutional Challenges

Institutional Challenges (continued from page 7)

ments). Such innovative partnerships could require special training on the part of governmental organizations: the literature is replete with examples of organizational barriers to the effective use of the private sector.

Stakeholder Acceptance

The transportation system environment represents a confluence of interest groups, public and private sector organizations, and various segments of the public. For ITS systems to be successful, they must be seen as desirable and workable by these factions. Thus, a key to acceptance is building coalitions for ITS systems involving groups that have a stake in the type of system being deployed. A related aspect is incorporating public desires and preferences into the design of ITS systems, considering issues such as environment, equity, and privacy.

We identified at least three levels of stakeholders who could affect the successful deployment of ITS in California: interest groups, the general public, and users/markets. The most active and visible component of the host of interest groups that could raise institutional and policy concerns associated with ITS is likely to be environmental interest groups, given the role they already play in the transportation arena. According to several of the experts interviewed, acceptance or opposition by environmentalists will be a wild card, whether in or out of the ITS program's hand. However, the constructive outcomes of several national forums indicate an opportunity to establish similar mechanisms for dialogue with California environmentalists.

The public is the end-user for ITS, and the ability to craft services around user needs is a fundamental requirement of the program. California is or will be a test market for many products. The TravInf test, for example, is seen as a major examination of this market for traveler information. Other commercial products for traveler information are also being tested and deployed around the state. Such tests will represent an opportunity to develop important information on public acceptance of ITS.

Research Implications

Based on our study findings, we targeted one research issue of pressing importance from each core area, as follows:

• Research collaboration
  Identification of private sector interests and concerns about establishing effective public/private partnerships, including the institutional changes needed to encourage collaboration.

• Regional Management
  Incorporation and synthesis of innovative institutional and market mechanisms in corridor and field operational tests in order to develop a firmer understanding of institutional and market potential for ITS.

• Stakeholder Acceptance
  Development of a structured forum to solicit and consider Californian environmental interests and concerns about ITS, and to determine the extent to which these are supported through available technical data on ITS environmental impacts.

The Claremont Graduate School is following up on our initial review, focusing on the environmental and related public acceptance of ITS. This phase of our study, also sponsored by PATH, will entail a structured review of the emerging literature on ITS impacts on the environment, followed by three focus groups with environmental activists and professionals in different areas of California. These focus groups will provide a window on perceptions of the potential impact of ITS on environmental quality. They should also be valuable in developing policy and program strategies to ensure environmental compliance during ITS deployment. A later phase of the project will compare and contrast these perceptions with the empirical literature on ITS environmental impacts.

Other Related Institutional Efforts

Our study has also provided a basis for other California related undertakings. The Automobile Club of Southern California has initiated a project with the Claremont Graduate School to examine both the attitudes and perceptions of the driving public about ITS, and the policy implications of a more consumer-driven transportation policy. This collaboration with the American Automobile Association (AAA) will allow for a closer interaction with the representatives of the traveling public than was possible in our initial study. It may also lead to the performance of priority research that funding constraints might otherwise have made impossible.

Work from our study was also employed by the Rockwell Architecture team (which includes both PATH and the Claremont Graduate School) in the institutional analysis and evolutionary deployment strategy of the national systems architecture project, a major attempt to analyze the communications, transportation, and institutional requirements for full ITS deployment. This analysis will continue during Phase II of the architecture project, as well as extend into California architecture developments.

Conclusion

California's era of highway construction was marked by strong public sector guidance and funding. ITS comes at a time of changing transportation and economic conditions. These include: high expectations for ITS (not only transportation impacts, but economic impacts as well), pronounced budgetary and administrative constraints, complex metropolitan institutional arrangements (e.g., Los Angeles and San Francisco), and unparalleled diversification of the marketplace (e.g., skyrocketing immigration). The California research program's great challenge is to develop information to help transportation policy makers chart a practical program of activities and policies that can result in significant benefits. Our report aims to be a useful first step in this direction, and we look forward to working with the PATH program to advance this important aspect of the ITS solution.
Validation Testing

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Figure 2 is a plot of the output steering angle for the lateral control system vs. the road marker.

The results show that normal operation and the trial with injected γ-accelerometer data have very similar performance.

Figure 3 shows a plot calculated by subtracting the two steering angles on a marker-by-marker basis. This reveals that there is no systematic oscillation in the steering angle. We can explain the oscillatory behavior by comparing figure 3 with the results from Richardson and Thompson (1993) in figure 4.

The plot shown in figure 4, which is the result from software testing without physical feedback from the vehicle, is a slice of the overall performance surface generated by applying the test state vectors to the black-box code. This figure shows that after a latency period of approximately 35 ms the output steering angle starts to drift. The same effect is seen in figure 3 except that once the steering angle has drifted long enough, the drifting feed back through the other six channels and the control system responds by modifying the steering angle. The drifting then starts again, resulting in the oscillation.

This result is different from the lateral control system performance predicted with software testing alone, since the vehicle dynamics are not used to modify the other six channels. However, from a software testing viewpoint, both cases are possible input scenarios. Both types of trial are also valid scenarios, since the control system software cannot distinguish between data generated by the vehicle and synthetic data (i.e., data generated via Monte Carlo simulation). Any combination of input values can occur upon large scale implementation of an AHS, depending on the specifics of the vehicle dynamics. The goal of this work is to detect anomalous and incorrect system behavior over the entire input data space. In future work, we plan to test over wider ranges of the input space (i.e., for different input data channels), using formal methods and database discovery techniques to assist us in identifying anomalous or incorrect behavior.

Conclusions

The validation experimental results provide confirming evidence for the hypothesis that Monte Carlo black-box software results are representative of the actual performance of the PATH lateral control system. The experiment also validated the conclusions reported in Michael and Segal (1994) regarding the oscillation of the steering angle about the normal operating steering angle. Analyses of the feedback control system are consistent in the short run, but after the control system has time to compensate for errors, a possibly different artifact will be present.

References


Below is an update on some recent PATH publications.
A price list that includes research reports, working papers, technical memorandums, and technical notes can be obtained from:
Institute of Transportation Studies Publications Office
University of California
109 McLaughlin Hall, Berkeley, CA 94720
510-642-3558, FAX: 510-642-1246.

Abstracts for all PATH research publications can be obtained via the PATH World Wide Web home page on the Internet:
http://www-paithdee.berkeley.edu

**PATH Research Reports**

- UCITS-PR-93-14: Fuzzy Logic Traffic Controllers and Their Effect on Longitudinal Vehicle Motion Systems, M. Labar, Alex Yavorsky
- UCITS-PR-93-15: An Integrated Measurement Control and Design Experiment: Phase 1, J.K. Fredrik, Pamela Yager, V.K. Narain
- UCITS-PR-93-24: Traffic Safety in Smart Cars, Anil Ohtami, Mary Woyt, July 1993, $5.00

**PATH Working Papers**

- UCITS-WP-93-02: Configuration and Assessment in Safety-Consciously Designed IHS Configuration, Anthony Hirt, 1993, $5.00
- UCITS-WP-93-07: A Model Dynamic Bus Operational Route Choice: A Link-Based Variational Inequality Formulation, R.L. Martin, David E. Boyce, May 1993, $10.00
- UCITS-WP-95-09: Internal Control of Computer Systems, Paul D. Hahne, Alex Yavorsky
- UCITS-PR-95-10: Optimization Tools for Automated Vehicle Systems, Dr. Stiffler, July 1993, $10.00

**PATH Technical Notes**


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**PATH Seminars**

These interdisciplinary seminars are usually held every Wednesday at noon in 3120 Etcheverry Hall on the UC Berkeley campus. For an invitation, please contact Mirelle Brouillette, mirelle@moonlight.eecs.berkeley.edu.

PATH seminar announcements are available on the PATH World Wide Web home page, which can be accessed by entering the URL http://www-paithdee.berkeley.edu. For more information on a particular seminar, please contact the authors at their respective departments.

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**May 19**

Japanese Advanced Safety Vehicule Project and Advanced Road Transportation System Project

Alcin Hoakoff of the Electronics and Information System Research Laboratory, Nissin

This talk described the Japanese equivalent of the US AHS Program.

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**June 12**

SmartTraveler

Randolph Hall of USC

Professor Hall presented information on the SmartTraveler program which is a multi-modal and multi-media information system deployed in the Los Angeles region.

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**June 12**

Vision Systems for Safe Driving

Dr. May and Dr. Mellander of the Pattern Understand Group, Daimler-Benz Research Group

Dr. May and Dr. Mellander gave an overview of European projects aimed at safe and efficient driving (PRO-METHUS, Electronic Eye, CLEARFACERS Smart Vehicle, PROMOTE Chasecam). And information on lane and distance keeping, traffic sign recognition and obstacle detection.

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**July 31**

Platooning for Small Public Urban Vehicles

Pascal David and Michel Parenist of INRIA, France

The presenters described a fleet of homogeneous electric cars controlled using vision sensing. These cars, under supervision by a central computer, form a novel public transportation system now under development in France.

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**July 31**

Advanced Ferryboat Technologies and Opportunities

Lars Hallijag, Denmark

Three graduate students from Denmark gave a seminar regarding new ferry boat technologies and possible markets in the United States. A Finnish company is currently manufacturing a 99 - foot ferry boat that is capable of carrying over 1500 passengers and 400 vehicles at speeds up to 40 knots. While such technology has a growing market in Europe, the discussion at this seminar focussed on the possible markets for this technology in the United States, and in California more specifically.

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**Correction:**

In the last issue on page 3 we inadvertently made a mistake in the equation: **55mph equals 105kph.**
Coming Soon...

* A special issue on computer simulation tools for modeling and visualization, featuring innovations in SmartPATH and DYNAVIS

* Conference Updates

* New Publications

... and more!