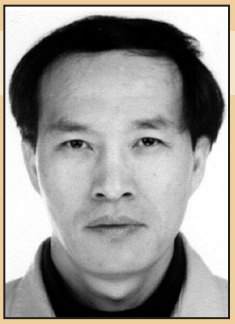

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ITSC 05: Current Issues and Research Trends

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The IEEE held its eighth annual International Conference on Intelligent Transportation Systems last September in Vienna, Austria. This was ITSC's first time in Europe and its first time as the annual conference of the IEEE Intelligent Transportation Systems Society (previously the IEEE ITS Council). The conference featured over 200 papers and hosted approximately 300 attendees, representing 35 countries. Furthermore, it exemplified the extraordinary progress ITS theory and applications have made over the last decade toward improving transportation systems' safety, efficiency, and quality. Here, we review the topics covered at ITSC 05, providing a broad overview of the field's current research programs and projects.

Intelligent systems methods

Intelligent systems methods are cost effective in dealing with the functions, dynamics, and complexity of today's transportation systems. At ITSC 05, quite a few interesting methods emerged for theoretical analysis as well as for actual applications.

Petri nets

Petri nets have become an attractive option for traffic modeling and control. Four ITSC 05 papers addressed this topic, covering

- a switching modeling system to represent and control urban traffic,
- the formal design of public transport stations based on hybrid Petri nets,
- a human-computer interface modeled with Petri nets for reporting on disabled transportation, and
- traffic-signal priority and preemption control with colored Petri nets.

Figure 1 shows the Petri net model for an urban traffic area consisting of two intersections and 12 roads.[1] Petri nets have proved to be effective for both analytical modeling and graphic representation for many other intelligent systems, especially computer-integrated manufacturing systems. However, their effectiveness in traffic applications can quickly recede in the face of tedious notations and complex analysis, as figure 1 shows. Future work must introduce modular design and hierarchical representation.

Computational intelligence

Computational intelligence can help predict traffic, operate and maintain traffic-control systems, and monitor human behaviors. A major issue discussed at ITSC 05 was short-term traffic prediction using fuzzy c-means and cellular automata. Presenters also considered neural or neural-fuzzy approaches for tracking school field trips, identifying the state of traffic, and detecting when a driver is drowsy. Another major issue discussed was using genetic or evolutionary methods to locate automatic vehicle-identification readers and to enable automated highway systems to assign lanes. Such methods can also help traffic controllers create a dynamic origin-destination matrix for traffic demands and distributions in a network, estimating in real time the ratio of turning movements in different directions at intersections and solving the single-vehicle pickup and delivery problem with specified time windows.

Data mining and analysis

The conference included three sessions on data mining and analysis for ITS. Major topics included

- identifying rear-end crash patterns on instrumented freeways,

Editor's Introduction

This issue summarizes the major ITS developments and projects presented at the 2005 IEEE International Intelligent Transportation Systems Conference, held in Vienna, Austria. As the President of IEEE ITSS, I invite you to attend our annual conference ITSC 2006, to be held September 17-20, 2006, in Toronto, Canada.

—Fei-Yui Wang

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- identifying and analyzing journeys using data collected from electronic fare systems,
- using cluster analysis to determine highway flow patterns,
- forecasting traffic flow,
- predicting travel destinations using frequent crossing patterns from driving history,
- identifying the fastest paths on urban networks using rule-based prediction,
- identifying time-of-day break points for traffic signal timing plans using k-means clustering, and
- collecting level-of-service information from induction loops for variable-message-system displays.

Two groups reported on real-world data mining applications. The first group used archived induction-loop-detector data to study bottleneck activation for a 30-km section of the northbound Autobahn 5 near Frankfurt, Germany.[2] The researchers equipped the Frankfurt study site with induction-loop detectors (D1 through D30 in figure 2) in each lane and on most ramps. The detectors recorded separate counts and velocities for autos and trucks at one-minute intervals. Figure 2 shows speeds averaged across all lanes for each interval, with time as the *x*-axis, distance as the *y*-axis, and speed variation in color. The group mapped in time and space the activation of 15 bottlenecks along Autobahn 5 on 19 September 2001 (G1 through G15 in figure 2). With the increasing availability of reliable freeway sensor data, it's important to continue the systematic empirical analysis of freeways to reveal the spatial and temporal aspects of dynamic freeway traffic-flow phenomena.

The second group, Robert Bertini, Spicer Matthews, Steven Hansen, Andy Delcambre, and Andy Rodriguez, reported on the recent development of archived-data user service in their paper, "ITS Archived Data User Service in Portland, Oregon: Now and into the Future." (This and other ITSC 05 papers referenced in this department appear in *Proc. 8th IEEE Int'l Conf. Intelligent Transportation Systems*, IEEE Press, 2005.) They discussed the hardware and software used to build that system and the basic functionality of the data archive. They also gave an update on future design plans and described several of the data archive's features, comparing them to other systems being implemented elsewhere.

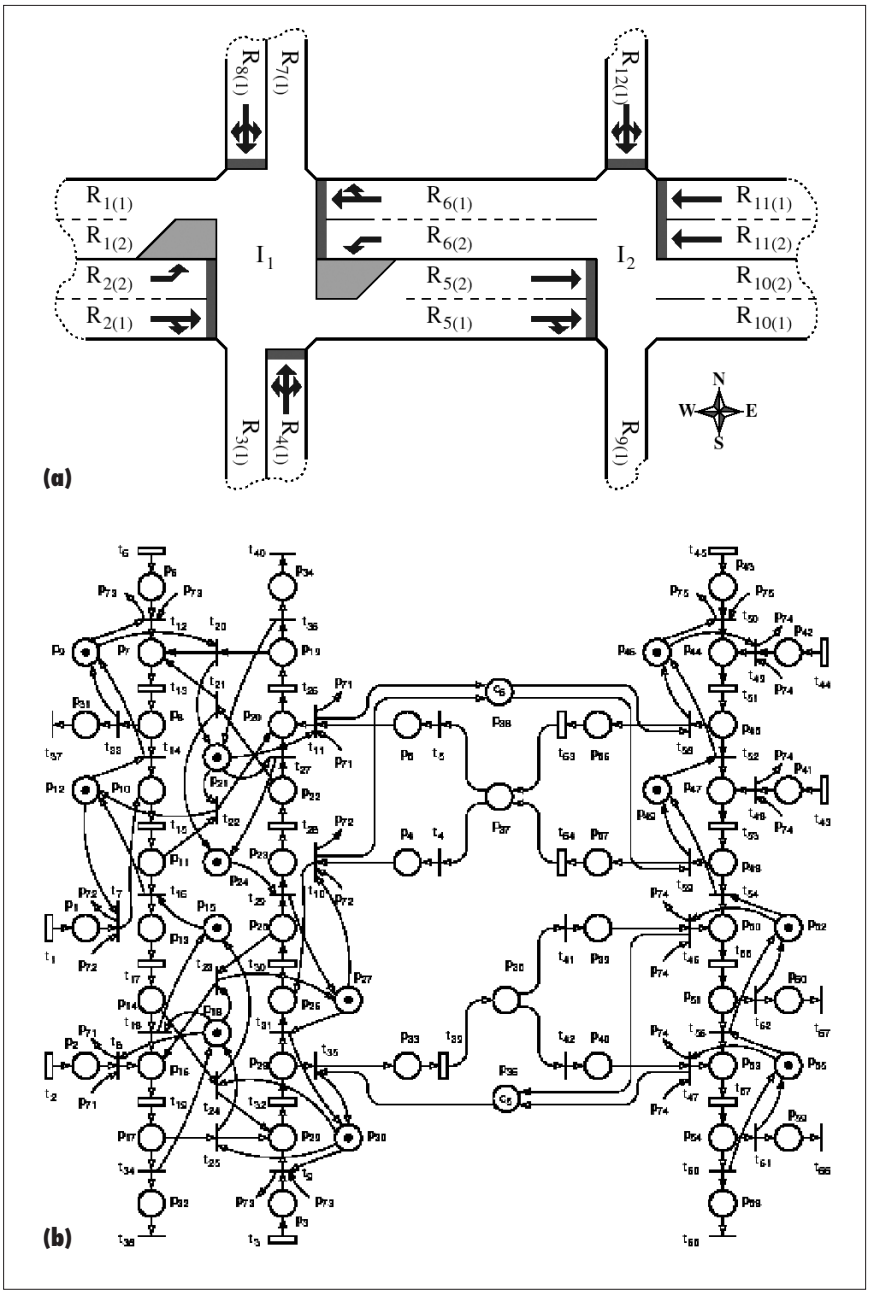

Figure 1. A Petri net model for an urban traffic area: (a) an urban traffic area consisting of two intersections and 12 roads, and (b) the Petri net representing that area.[1]

Agent technology

Several papers discussed how to apply agent technology to dynamic vehicle routing and to route-guidance problems, as well as to simulations of driver behavior. In "MADARP: Multi-Agent Architecture for Passenger Transportation Systems," Claudio Cubillos, Franco Guidi-Polanco, and Claudio Demartini proposed a multiagent architecture for passenger transportation systems. The architecture provides agents that implement basic planning and control functionality to process transport requests coming from different users.

Driving safety and assistance

This was one of the hottest topics at ITSC 05, with five sessions covering it. Several papers discussed safety concerns, including pedestrian guidance, detection, and protection using various sensing methods and landmark designs.

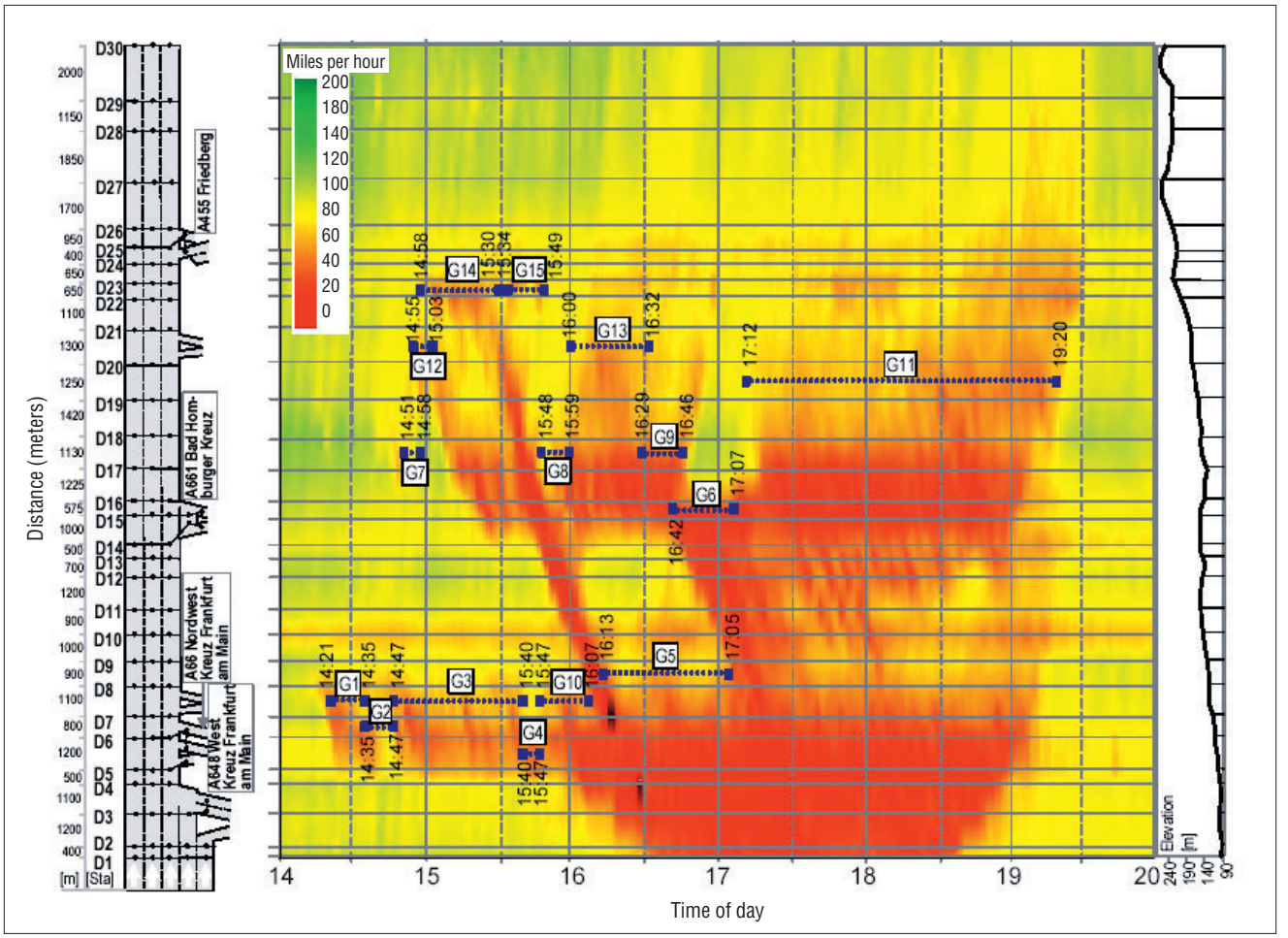

Figure 2. Northbound Autobahn 5 speed diagram.[2] G1 through G15 represent bottlenecks.

Driving-assistance issues included

- lane-departure warning and lane guidance,
- parking assistance,
- visual assistance by virtual mirrors at blind intersections,
- frontal-collision warning,
- virtual drivers and driver-in-the-loop assistance,
- networked environments for advanced assistance,
- sensor fusion,
- calibration of cameras and other sensors, and
- driving-assistance performance evaluation.

Figure 3 illustrates the functional specification for SASPENCE (*Sa*fe *Spe*ed and Safe Dist*ance*), a new approach in supporting driver functions, cofunded by the European Commission (see www.prevent-ip.org/en/prevent_subprojects/safe_speed_and_safe_following/saspence).[3] Another interesting project from Europe is the INTERSAFE, which focuses on intersection safety. INTERSAFE combines a bottom-up approach based on using state-of-the-art sensors, high-level maps, and infrastructures for vehicle communication, and a top-down approach based on a driving simulator (see figure 4).[4]

Traffic and traveler information services

Three ITSC 05 sessions covered this topic. Presenters discussed public-transport information requirements as well as passenger requirements for public-transport ticketing systems. They also discussed dynamic virtual-roadway-loop detectors, traffic information estimation using cellular network data, and traffic-state detection with *floating car data* in road networks. (Floating car data entails recording traffic data for a small number of vehicles that "float" with the traffic and serve as measuring stations. These vehicles are equipped with traffic telematics devices and record variables such as speed, position and direction of travel for a particular trip.) Other topics included validating predicted rural-corridor travel times from an automated license plate recognition system and using data fusion to examine traffic dynamics on freeways with variable speed limits.

One author, Christian Steger-Vonmetz, discussed how to help make more carpooling efficient. In his paper "Improving Modal Choice and Transport Efficient with the Virtual Ridesharing Agency," he reports on a virtual ridesharing agency in Austria called WIGeoPOOL. The heart of WIGeoPOOL is *corridor search*, a GIS-based intelligent matching algorithm.

Another interesting project in this area is Roncalli, which provides position-dependent, real-time information for drivers.[5] The in-vehicle client (see figure 5) for Roncalli services

- offers intelligent speed adaptation and displays the current speed limit at all times;
- warns the driver of poor skid resistance or deep ruts;
- warns the driver of areas (mostly crossings) with high accident rates;
- warns the driver about "atypical" road users who need special attention, such as children (for example, it alerts drivers when they're near a school during school hours); and
- helps drivers reduce fuel consumption and CO_2 production by teaching and judging eco-driving (environmentally responsible driving) using GPS data.

Vision-based technology

Six sessions dealt with vision-based technology, and another dozen or so sessions held related discussions. Despite this coverage, no new issues or applications emerged; presentations revealed that progress in this area has been incremental.

Discussions mostly focused on driving assistance and safety, although Bernhard Hulin and Stefan Schüßler presented an interesting vision-system application in their paper, "Measuring Vegetation along Railway Tracks." The system, mounted on a train, uses three multispectral cameras sensitive in both the visible and near-infrared spectrums. Using multispectral cameras is necessary for distinguishing between the green vegetation and the overhead contact system's green masts.

Communication and location-based services

Applications of ad hoc networks in transportation, especially for intervehicle communication (IVC), emerged at ITSC 05 as a fast-growing research area. Figure 6 presents a proposed functional architecture for in-car ad hoc networks.[6] When fully deployed, the IVC network will likely be one of the largest mobile ad hoc networks, so IVC network protocols must be able to scale to this large network size and high nodal densities. However, several other IVC issues exist. First, we need consecutive radio-zone DSRC (dedicated short-range communication) with an in-vehicle reactance diversity (which provides a high-speed wireless link for traveling vehicles). We also need intervehicle communication based on CSMA (carrier sense multiple access) with distributed and polling coordination. Furthermore, we need to explore adaptive space-division multiplexing and hybrid (both frequency-hopping and direct-sequence) spread-spectrum techniques. Finally, we need media-access-control protocols for integrated intervehicle and road-to-vehicle communications.

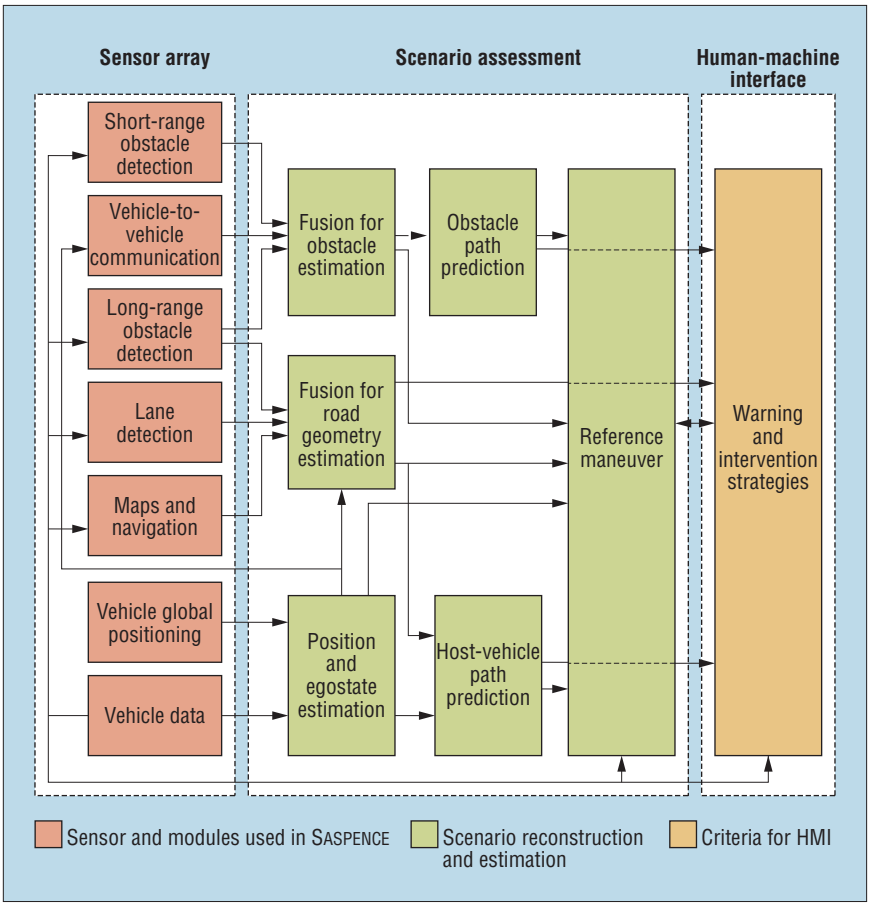

Figure 3. The functional specification for SASPENCE (Safe Speed and Safe Distance).[3]

The main IVC applications presented at ITSC 05 were

- a complete simulator architecture for IVC-based intersection warning systems,
- a vehicle-to-vehicle-based traffic information system,
- traffic modeling and cost optimization for transmitting traffic messages over a hybrid broadcast and cellular network,
- a collision-avoidance and warning system for automobiles based on signals from global-navigation satellite systems, and
- a T4 telematic system architecture for transparent transports based on the open services gateway initiative.

Finally, researchers reported on two interesting but primitive projects on location-based services: location-based ticketing for public transportation and Web-based ubiquitous location-based services. The concepts and methods proposed in those projects have great potential in the age of a connected world, but more testing and evaluation are needed before their deployment.

Traffic modeling, simulation, and control

This is a traditional research area in transportation, and most papers presented in this area solve problems using conventional methods. However, several studies in traffic modeling and simulation are applying new methods and concepts to traditional problems:

- hardware-in-the-loop simulation of embedded automotive control systems,
- a simulator of intelligent transportation systems,
- the GESTRAF cellular-automata-based traffic simulator,
- the DisTrain train-dispatching simulator, and

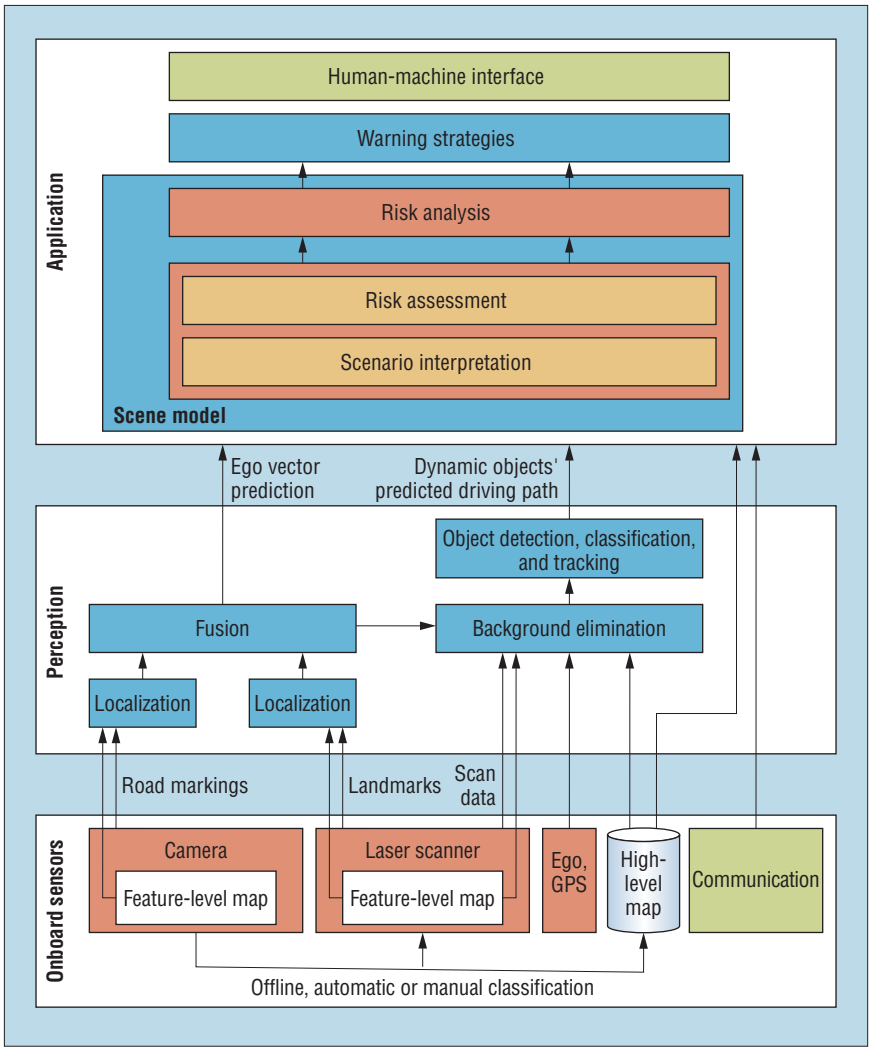

Figure 4. The INTERSAFE system architecture.[4] The architecture includes object detection, road-marking detection, and navigation based on natural landmarks.

- dynamic equilibrium assignment with microscopic traffic simulation and simulation-based dynamic traffic assignment.

Four studies with the PARAMICS simulation tool are very interesting. The first study is developing and calibrating an integrated freeway and toll-plaza model for the New Jersey Turnpike. The second is modeling and simulating an unconventional traffic circle, and the third is developing a distributed, scalable, and synchronized framework for large-scale microscopic traffic simulation. The final study is modeling distributed large-scale traffic networks. A new development presented at ITSC 05 is the extension of computer simulation to computational experiments based on artificial transportation systems for ITS studies.[7,8]

Major new directions and applications for ITS control and management include

- a general framework for managing transportation systems affected by recurrent adverse weather conditions,
- a mathematical programming module for merge control in system optimal dynamic traffic assignment,
- control of spatio-temporal traffic congestion at highway bottlenecks,
- traffic synchronization in Central European upper airspace,
- a new incident-detection scheme developed in the Netherlands,
- design and evaluation of a roadway controller for freeway-traffic, and
- an adaptive freeway-traffic-state estimator.

Figure 5. A standard PDA as the in-vehicle client for Roncalli services. [5]

Another interesting direction is the idea of "soft control" in Variable Message Systems-based highway management. Examples include providing information as a control measure and the concept of line-control systems (a succession of VMSs with displays separated by 1 to 3 km along a roadway).[9] Also, in "A Novel Algorithm for Optimized, Safety-Oriented Dynamic Speed Regulation on Highways: INCA," Vukanovic and his colleagues discussed using variable speed and information displays to optimize the dynamic regulation of roadway traffic to increase traffic safety and to reduce unnecessary delays.

Emerging research and technologies

Emergency evacuation as well as transportation intelligence for security are two emerging research areas. Researchers at ITSC 05 presented a case study of a hurricane in Ocean City, Maryland, where they used an integrated emergency evacuation system for real-time operations. Related works at ITSC 05 include global monitoring and security assistance based on the next-generation Internet and dynamic handling of multiple incidents in traffic evacuation management. We should expect intensified research into emergency evacuations owing to increased concerns regarding terrorist attacks and natural disasters, especially after the major traffic jam in Houston, Texas, during Hurricane Rita.

A special session on security informatics and its application in ITS featured presentations on prospective spatio-temporal data analysis for security informatics, the identification of deceptive behavioral cues such as head movement or certain gestures extracted from video, and target-vehicle identification

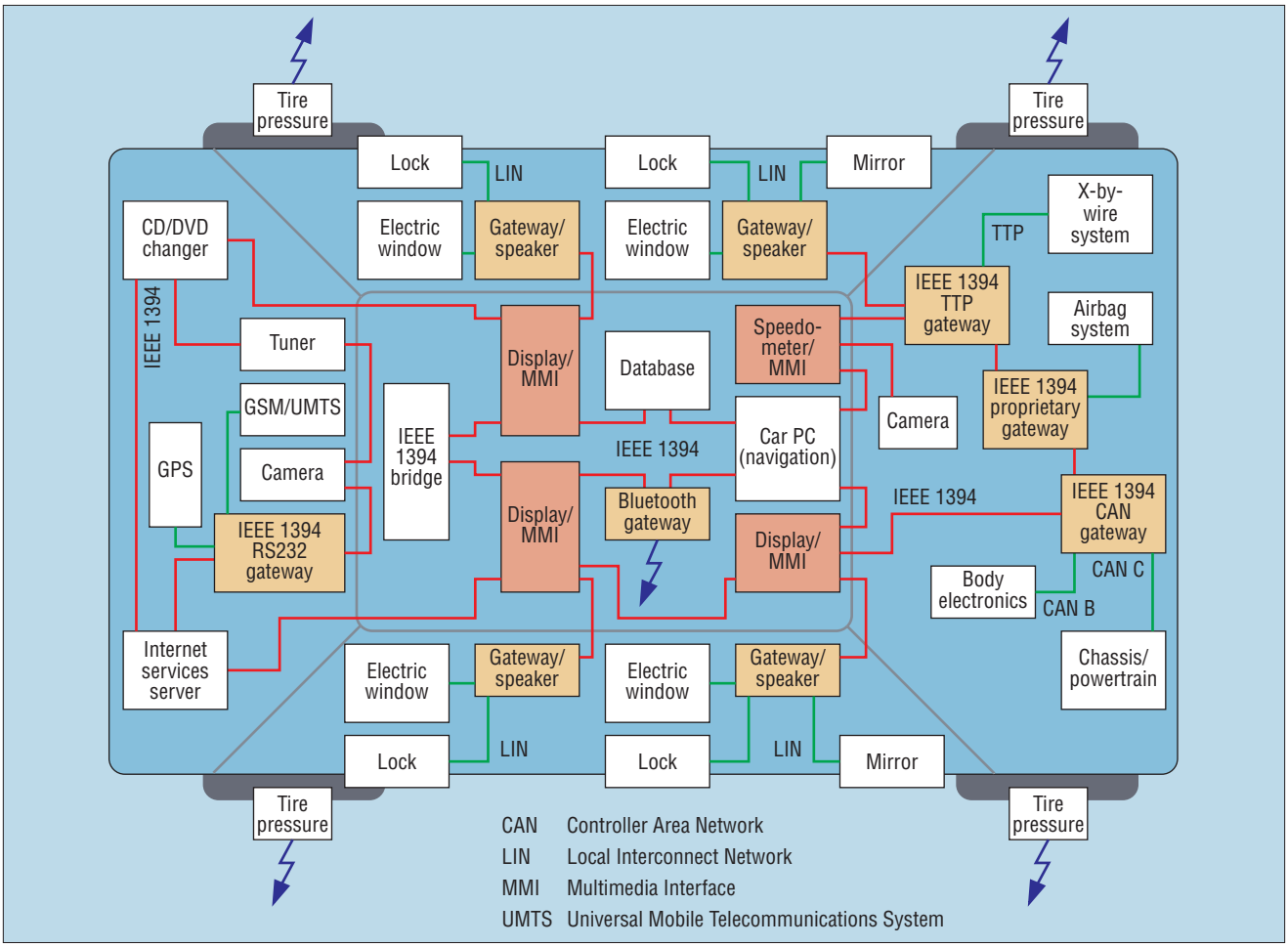

Figure 6. A proposed functional architecture for in-car ad hoc networks.[6]

for border safety using mutual information. Intelligence and security informatics for ITS will be a key technology for homeland security.[10–12]

ITSC 06 will run from 17 to 20 September 2006 in Toronto (see the "Conferences" sidebar). We hope to see more discussion on intelligent agent-based control for networked transportation systems. We also hope to see more research into using large-scale and new computing methods such as grid computing and peer-to-peer computing for real-world transportation analysis and decision-making. ■

Acknowledgments

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Conferences

ITSC 06: www.ewh.ieee.org/tc/its/itsc2006
IEEE Intelligent Vehicles Symposium: www.cvl.iis.u-tokyo.ac.jp/iv2006
IEEE Intelligence and Security Informatics Conference: www.isiconference.org/2006
2006 IEEE International Conference on Service Operation and Logistics, and Informatics: www.ssglobal.org/2006

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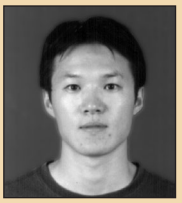

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