Pervasive Computing in Intelligent Transportation Systems

EDITOR'S INTRODUCTION

This issue's Works in Progress department features 10 interesting ongoing intelligent transportation systems projects. The first five projects (TIME, Sentient Transport, EVT, DynaChina, and TrafficView) focus on traffic and vehicular data collection, transmission, and analysis. The sixth project aims to provide intelligent-copilot services for drivers, while the seventh focuses on asset identification and data collection for railroad environments. The eighth and ninth projects are building application development environments for automobiles, and the tenth project is designing a multimodal biometric identification system for travel documents.

—Anthony D. Joseph

TIME FOR BETTER TRANSPORT

Alastair R. Beresford and Jean Bacon, University of Cambridge Computer Laboratory

The UK transport network needs help: congestion costs the economy 20 billion British pounds per year, fossil fuel use and longer commutes harm the environment, and suburban housing construction generates ever-increasing demand on the road network. In the Transport Information Monitoring Environment (TIME) project, we're exploring how technology can help reduce transportation's economic and environmental impact. We're using Cambridge as a testbed, but we aim to build systems that apply to other cities in the UK and beyond.

Traditional intelligent transport applications are vertically integrated; for example, interactive street signs use GPS equipment on buses to estimate arrival times for passengers, but these data aren't available to other applications. We're building an open, pervasive computer system to gather transport data from sensor, wired, and wireless networks and to make the data available via an open but controlled interface. This will make applications quicker and cheaper to build and will enable integration and inference from several sensor sources. Using our system, public bodies and private companies can collect, buy, share, and sell transport-related data; applications can use real-time data and historical archives to build novel services; travelers can make informed decisions on when and how they travel; and government bodies can use the historical corpus of data for long-term planning.

For more information, contact Alastair Beresford at arb33@cam.ac.uk or see www.cl.cam.ac.uk/Research/TIME.

A RESEARCH PLATFORM FOR SENTIENT TRANSPORT

David N. Cottingham, Digital Technology Group, University of Cambridge Computer Laboratory

The University of Cambridge Computer Laboratory's Sentient Transport project integrates sensors into vehicles with which we record engine status, communications performance, vehicle position, and meteorological parameters. The system identifies drivers using an RFID card reader and enables interaction via touch-screen displays. The platform is extensible, and we have already used it to aid research driver facial-expression recognition. The system can operate entirely autonomously, accommodating drivers who aren't familiar with the computer equipment's details.

During the past year, the vehicle's drivers have contributed more than two million data points, with most of their journeys taking place in Cambridge. We use these data for applications such as automatic map generation, wireless-coverage mapping, and vehicle tracking (see also this issue's article "Scalable, Distributed, Real-Time Map Generation," by Jonathan Davies, Alastair Beresford, and Andy Hopper, on page XX). Data management techniques include autonomous offload and context-aware sampling rate control.

Our experiences have highlighted how wireless communication for sentient transportation is both important and challenging. Urban wireless propagation environments are complex and highly variable. Previous research has concentrated only on idealized scenarios; we're seeking to extend this in more

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realistic urban settings. One result is that packet loss rates are greater at low speeds than at higher velocities, which significantly reduces the throughput of Transmission Control Protocol streams. Reliable communication will also require handover between different networks. We're therefore beginning to deploy wireless coverage along several roads to study how we can optimize such handovers.

Jonathan J. Davies and Brian D. Jones (Digital Technology Group) also collaborated on this project. For more information, contact David Cottingham at david.cottingham@cl.cam.ac.uk or see www.cl.cam.ac.uk/Research/DTG.

AN ELECTRIC-VEHICLE TERMINAL

Haitao Guo, *Institute of System Engineer and Control, Beijing Jiaotong University*

Because electric vehicles have no emissions, they provide a feasible solution to the pollution problems caused by fuel-based vehicles. They're becoming an important method for improving urban air quality and a research direction for the automotive industry. Electric-vehicle use in the 2008 Olympic Games in Beijing is an important component of Beijing's concepts of "Green Olympics" and "High-tech Olympics."

Our main goal in developing an electric-vehicle terminal is to provide secure, reliable electric-vehicle operation. Additionally, the EVT can improve electric vehicles' manageability. We focused on deploying an EVT in the 2008 Olympic Games, especially for athlete and media commuting. For efficiency and security, the EVT should provide real-time supervision and intelligent management of the electric vehicles' operation. We've designed the EVT hardware and software systems and the interface between the EVT and peripheral devices.

Wei Guan (Institute of System Engineer and Control) also collaborated on this project. For more information, contact Haitao Guo at jeffrey.guo1982@gmail.com.

DYNACHINA: REAL-TIME TRAFFIC ESTIMATION AND PREDICTION

Houbing Song, *Civil Engineering Department, University of Texas*

The success of intelligent transportation systems relies on the availability of timely, accurate estimates of prevailing and emerging traffic conditions. The need for a traffic prediction system is strong, and the ability to predict traffic is desirable. Dynamic traffic assignment is a critical component of such systems. Researchers have developed several simulation-based prototype systems, including DynaMIT and DYNASMART, but these systems can't be deployed in China because China is a developing country with unique local traffic characteristics.

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We're the principal developers of Xi'an Jiaotong University's traffic estimation and prediction system (TrEPS) project, initiated in 2001. After five years of intense R&D, we developed DynaCHINA (Dynamic Consistent Hybrid Information Based on Network Assignment). DynaCHINA can predict a traffic bottleneck and then direct traffic to other routes to mitigate congestion and provide faster, more efficient routes. DynaCHINA provides this guidance in real time, addressing potential congestion situations before they develop into serious traffic jams. DynaCHINA's unique features include mixed traffic (that is, motorized and nonmotorized vehicles) and special driver behavior modeling, data fusion involving floating car data, an anisotropic mesoscopic supply simulator, and true origin-destination flows.

DynaCHINA is China's first and only TrEPS. It will be used to mitigate traffic congestion during the Beijing 2008 Olympic Games. Initial field deployments are being conducted at Beijing, Jinan, and Guangzhou.

Yong Lin (Shandong Academy of Sciences Intelligent Transportation Systems Lab) also collaborated on this project. For more information or a demo of DynaCHINA or XJTUSIM (a microscopic traffic simulator for evaluating the performance of intelligent transportation systems), contact Houbing Song at hbsong@ieee.org.

TRAFFICVIEW PROJECT MOVES OUTDOORS

Liviu Iftode, *Rutgers University Computer Science Department*

Rutgers University's TrafficView project uses car-to-car communication to exchange both immediate and distant traffic-related information for real-time safety warning, route planning, and traffic congestion mitigation. Each participating vehicle gathers and broadcasts information such as speed and location about itself and other vehicles, in a peer-to-peer fashion, aggregating it for distant road segments when necessary. The aggregation algorithm, dissemination mechanism, and broadcast rate are key to guaranteeing timely delivery of accurate information between vehicles.

In hazardous driving conditions or during a sharp turn, TrafficView helps the driver get a better view of the road ahead. The *near-view panel* displays the cars immediately ahead and warns the driver when they brake (see figure 1). TrafficView audibly alerts the driver when his or her time to brake to avoid the collision reaches a critical value. This can help avoid chain collisions on high-speed roads.

Figure 1. TrafficView's near-view panel displays cars as green or red rectangles, depending on their speed relative to the current car. In the picture, the car in front of the SUV brakes and becomes red in the panel.

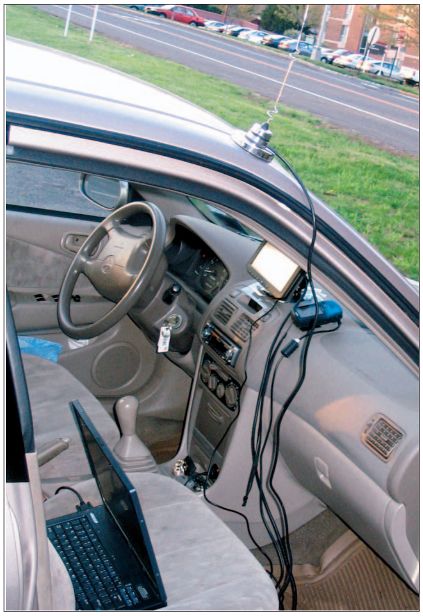

Figure 2. A car equipped with TrafficView.

TrafficView's *map view panel* helps drivers plan their routes by propagating and displaying traffic density on the road farther ahead. The driver can also query traffic on other roads using the Vehicular Information Transfer Protocol, an application layer car-to-car communication protocol similar to http but designed to support ad hoc location-aware services. Supplementing the car-to-car communication is a publish-subscribe protocol that uses third-generation (3G) cellular communication to exchange data between disconnected herds of cars.

The TrafficView prototype is Java-based and platform independent. Each vehicle is equipped with an embedded computer, a GPS receiver, an On Board Diagnostics interface, and a wireless-networking device augmented with an omnidirectional antenna (see figure 2). Both near and map view maps are drawn using the publicly available Tiger/Line database.

Currently, we're conducting field trials with cars to better understand the behavior of various TrafficView components and improve their design. In the process, we're also testing the limits of 802.11x and 3G in supporting vehicle-to-vehicle communication under real-life conditions that are hard to simulate.

Mohammad Alam, Nishkam Ravi, and Pravin Shankar (Rutgers University Computer Science Department) and Tamer Nadeem (Siemens) also collaborated on this project. For more information, contact Liviu Iftode at iftode@cs.rutgers.edu.

A MACHINE-VISION-BASED CONTEXT-AWARE COPILOT

Simone Fuchs, Bernhard Lamprecht, and Kyandoghere Kyamakya, *Alpen-Adria Universität Klagenfurt, Transportation Informatics*

Our research group's main goal is to develop an intelligent copilot system that supports a human driver. We based the copilot on a context-aware machine-vision component that can perceive the environment much like a human driver would and that can filter relevant traffic information necessary for driving. We deliberately left out irrelevant details to achieve real-time capability.

A context-aware machine-vision component percepts the traffic situation and passes information to an expert recommender system. Traffic regulations, as specified by law, must be transformed according to a semantic model to be developed. The copilot system adds them to the expert recommender system's knowledge base. The behavior-recognition component constantly monitors the driver's behavior and responses to certain situations and updates the knowledge base with this information, thus enabling context-based learning from experienced drivers in situations that traffic regulations don't clearly cover. A central expert recommender system infers decisions for the current driving situation on the basis of information from both the machine-vision component and the knowledge base. It either communicates deduced recommendations to the driver via an appropriate human-machine interface or uses them to actively intervene in the driving process, depending on the driver's experience and condition and traffic context. A black box records context, recommendations, and driver behavior. Therefore, the copilot builds on four pillars: context-sensitive environment perception, knowledge of traffic rules, learning from experienced drivers, and adaptation of support levels according to both a specific driver's needs and traffic context. The research's goal is a robust, reliable system that can work under difficult conditions (including real-time requirements, extensive information volume, and a highly dynamic complex environment).

For more information, contact Simone Fuchs at simone.fuchs@uni-klu.ac.at.

MANAGING RAIL FREIGHT ASSETS

Jorge González Fernández, *Transportes Ferroviarios Especiales S.A.*
Juan Carlos Yelmo García, Yod Samuel Martín García, and Jorge de Gracia Santos, *Universidad Politécnica de Madrid*

Railway vehicle maintenance is time consuming. It requires checking many individual—often inaccessible—mechanical parts. But what if vehicle components could check themselves? Combining auto-ID technology and sensors means that parts could self-check and request service or replacement according to their age, mileage, or wear.

Building on existing software, we created an event-driven middleware that links RFID hardware and sensors to corporate information systems. Figure 3 shows the test setup, including RFID equipment for range measurements, using 2.5 cm × 2.5 cm tags on moving targets. During checkups, the middleware delivers information about individual moving parts, with no need to access them physically or to manually check records. We couple this with a system of smart RFID readers that can process and filter some of the data and thus bring the business logic closer to the network edge.

We envision an environment where maintenance and logistics information systems could track and trace all serviceable parts. However, demanding onboard conditions preclude tagging many parts for now. To tag as many as possible, our infrastructure must tackle several obstacles concerning tags, including

- less than a square inch of room for placement;
- exposure to dust, moisture, chemicals, wear, vibrations, and extreme temperatures;
- required state-of-the-art reading ranges;
- service lifespan matching that of the (often long-lasting) identified parts; and
- metal mounting and environments that make reading cumbersome.

The RFID market uses EPCglobal serial-number schemes, whereas the transportation industry already uses others. We needed to accommodate both.

We hope that pushing RFID technology's limits will lower maintenance costs and optimize asset tracking in the railway industry. We needed to accommodate the latter to EPCGlobal standards.

For more information, contact Jorge González at jorge.gonzalez@transfesa.es.

Figure 3. Our test setup, showing RFID equipment for range measurements, using 2.5 cm × 2.5 cm tags on moving targets.

A SOFTWARE MODEL FOR VEHICULAR APPLICATIONS AND AGENTS

***Milind Nimesh**, JSS Academy of Technical Education, Noida, India*

Dynamic mobile agents and static programs inside vehicles will implement pervasive computing software in transportation. Both require an efficient software model that can isolate various modules and encourage code reuse.

The proposed software model for vehicular applications and agents incorporates anticipated future software development areas. It also facilitates rapid development of applications by separating each application's common and unique processes. An important aspect of the model is the existence of a working environment inside each vehicle. I can use the environment to design the underlying code libraries, failure modeling, and component architecture.

I'm using the model to build prototype applications that will demonstrate interaction between a mobile phone and a vehicle. The focus is not only on what the prototypes do but also on their construction. The prototypes' coding follows the software model's uniform structure.

For more information, contact Milind Nimesh at milind.nimesh@yahoo.com.

A SMART SPACE IN THE AUTOMOBILE

***Gang Pan**, Computer Science Department, Zhejiang University*

Making the automobile a comfortable, convenient, and safe environment can be challenging. Compared with other smart spaces such as meeting rooms and houses, the automobile's interior is mobile, is small, and must frequently communicate with the outer environment. Our research team at Zhejiang University has developed software and network infrastructure for a pervasive computing environment for the automobile. We created a middleware platform, named ScudWare, whose main characteristics are autonomy, adaptability, scalability, and semantic integration. ScudWare supports complex, mobile situations in automobiles (such as device-adaptive task migration or user information exchange between two high-speed moving vehicles). The network infrastructure combines four network types: a ZigBee wireless sensor network that connects all minisensors (such as the temperature or the acceleration sensor); the Car Area Network, a serial-bus system for communicating mechanical nodes (such as the engine and steering system); a WLAN 802.11a/b/g network for digital devices; and a CDMA 1xRTT network for wide-area, anytime Internet access at speeds of up to 100 km/h. We implemented the network and software infrastructures in an automobile equipped with a microphone, a camera, GPS, and other devices. We're also designing context-aware applications in automobiles.

Zhaohui Wu, Qing Wu, Jian Lu, Zhenyu Shan, and Jie Sun (Zhejiang University) also collaborated on this project. For more information, contact Gang Pan at gpan@zju.edu.cn or see www.cs.zju.edu.cn/~gpan/pervasive/smartcar.htm.

TAMPER-PROOF IDENTITY VERIFICATION FOR ITS

***Muhammad Khurram Khan and Jiashu Zhang**, Sichuan Key Lab of Signal & Information Processing, Southwest Jiaotong University*

A hot research topic in intelligent transportation systems is the use of biometrics-based identity verification for driver's licenses, traveling documents, automatic border controls, and passports. Biometrics systems could eliminate duplicate and fraudulent documents and aid cooperation between law enforcement agencies for criminal identification. However, their measurements at different instances are inherently dynamic and inconsistent because of background noise, signal noise and distortion, and environment or device variations. For example, fingerprint biometric matching results can vary owing to sensor pressure, moisture, and cuts on the finger, and some systems are vulnerable to spoofing. So, a single biometric system isn't a panacea for the problem of genuine authentication.

We've developed a multimodal biometrics authentication system for space-limited tokens such as driving licenses and traveling documents. The system encrypts fingerprint templates and encodes them into face images so that the features used in fingerprint and face matching don't significantly change during encoding and decoding. So, the verification accuracies are similar to the original forms. Initial experimental and simulation results show that the proposed scheme is an efficient, inexpensive solution for space-limited tokens without degrading overall system decoding and matching performance. Our proposed identity verification system could help increase security and efficiency more than unimodal biometric authentication, and spoofing our system would be difficult because we use the two distinct biometric traits.

For more information, contact Muhammad Khurram Khan at khurram.khan@scientist.com.