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## Driving into the Future with ITS

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**O**ver the past two decades, intelligent transportation systems have integrated a broad range of AI-based technologies into both the transportation infrastructure and vehicles themselves. Although the future of ITS is promising,

the field is anything but futuristic. Various ITS products and services are already at work throughout the world, significantly improving transportation safety, mobility, and productivity.<sup>1</sup>

Still, the wide and deep application of intelligent systems in transportation represents a true revolution in the way we think about mobility. As new concepts, methods, tools, and devices continue to emerge in communication, information, automation, and electronics, ITS will provide an increasingly important and exciting platform for AI research and development, especially in applied intelligent systems.

### Smart cars on smart roads

Cars will be more than computers with wheels. They already include many different kinds of sensors, CPUs, software systems, and communication capacities.<sup>2</sup> In the next few years, active in- and out-vehicle environment sensing will become standard features, enabling intelligent driver and passenger assistance at various levels for driving safety, efficiency, and comfort.

Although it will be difficult to make significant changes in road infrastructures in the near future, several technologies are available to give vehicles additional information for safer operations and better performance. Examples include remotely controllable, locally activated variable-message systems; RFID-type roadside sensors; and embedded barcode-like road marks.

The quest for smart cars on smart roads provides a challenging but ideal platform for R&D in various AI-based methods and techniques. Some of these areas are well established, such as computer vision, pattern recognition, computational intelligence, machine learning, data mining, and intelligent control. Others are newer, such as applied cognition, advanced message display and user interface design,

monitoring driving behaviors, and predicting drivers' physical and mental states.

### Traveling in intelligent spaces

Intelligent spaces are environments that can monitor what's happening in them, communicate with their inhabitants and neighborhoods, and act on the basis of decisions they make. The MIT Oxygen Project ([www.oxygen.lcs.mit.edu](http://www.oxygen.lcs.mit.edu)) and Philips HomeLab ([www.research.philips.com/technologies/misc/homelab](http://www.research.philips.com/technologies/misc/homelab)) are just two cases of research to implement ambient intelligence with human-centered ubiquitous or pervasive computing.

Embedding such intelligence in an automobile would be a natural next step for intelligent vehicles. Current in-vehicle applications of GPS, ad hoc networks, and sensor networks have already led the way. Future cars will behave more like intelligent agents traveling in intelligent spaces; traffic control at intersections could employ cooperative-driving technologies implemented over ad hoc networks, instead of relying on traffic lights. Such technologies aim for roads with zero fatalities.

Incorporating intelligent-space technology into transportation can help lay the foundation for a connected lifestyle where vehicles, roads, homes, offices, and services can all exchange information. Clearly, such large-scale mobility will pose significant R&D challenges with respect to personalization, adaptation, networking, and security.

### Agent-based control

Traffic control and vehicle monitoring were among the first applications of agent technology.<sup>3</sup> As connectivity becomes ubiquitous, agent-based control offers an ideal approach to transportation management, addressing its geographically distributed and alternately busy-idle operating characteristics. Intelligent, autonomous agents will traverse traffic control centers, road intersections, highways, streets, vehicles, houses, offices, and so on. They will use the Internet as well as wireless and ad hoc networks to collect the right information at the right times and to make smart decisions.

Agent-based control essentially transforms centralized

operational algorithms to distributed operational agents, letting networked transportation systems operate on a management-on-demand or service-on-demand basis. This approach can provide a cheap, reliable, and flexible way to control traffic and transportation systems in connected environments. It can also improve ITS performance at low cost while reducing the modifications required for system upgrades.

To implement agent-based ITS control, we must develop a comprehensive operational framework based on the emerging Internet gateway infrastructure. Such a framework would connect networked traffic devices, letting them seamlessly communicate with each other and receive a variety of traffic-related services from providers. To this end, we must address various issues related to the theoretical foundation and software and hardware requirements for applying agent-based technologies to transportation devices and systems. Clearly, distributed AI methods will be essential in those efforts.

### Artificial transportation systems

Computer simulations have always played a significant role in transportation research. Analytical models alone can't handle the complexities in transportation operations, especially of human activities. *Artificial transportation systems* go a step beyond computer simulations to computational experiments. The ATS concept is derived from *artificial societies*, proposed by Rand researchers to study the social effects of information infrastructures.<sup>4</sup> It's an idea perfectly suited to complex transportation problems when testing and validating with real systems is either economically or legally prohibitive.

An agent-based ATS is a large, integrated transportation model including analytical descriptions of traffic flow models as well as rule-based human and vehicle behaviors and social and natural events. An ATS allows transportation activities to "grow" in a bottom-up fashion, providing an alternative to real systems for experimental investigations and thus "elevating" simulations to experiments.<sup>5</sup> New computing techniques, such as peer-to-peer and grid computing, could support an open ATS on the Internet for modeling transportation operations in artificial cities. Researchers could test and evaluate different traffic management systems in a way similar to playing games on the Internet.

A transportation operation center could also run both real and artificial transportation systems in parallel. In addition to testing and experimenting, parallel execution implementations could support system training and learning; real-time hardware-in-the-loop, rolling-horizon optimizations; and adaptive control for transportation problems. They could even act as a backup mechanism.

We can expect the "sciences of the artificial," introduced by Nobel laureate and AI founder Herbert A. Simon,<sup>6</sup> to play a significant role in future ITS research, especially in developing sustainable transportation systems.

**G**ood transportation systems are fundamental to effective societies. Many existing transportation problems still call for AI techniques to achieve cost-effective solutions, and emerging issues will depend even more on AI solutions. From highways to railroads, port automation to free space flight, and national security to new weaponry, AI will play a critical role in our drive to future intelligent transportation systems. ■

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