Maps that Move

In-vehicle navigation systems: Neat, but is there a need?

By Michael L. Sena

You're late for a business appointment in the next town. As you're about to rush out the door, you realize you've misplaced your handwritten directions. Unworried, you get into your car, switch on the electronics panel, press a destination button, and state your desired destination (city name and street address). A monitor mounted in the car's dashboard immediately displays a color map that shows your current location and your desired destination. You then dial a traffic control number on your cellular phone, and the day's trouble spots are written to your street database. You turn the ignition, the dashboard monitor displays a detailed map of local streets, and an on-board computer automatically calculates a route that avoids traffic delays and overlays it on the street map. You begin your journey while a voice synthesizer instructs: "Turn left. Turn right." You reach your destination in record time, and as you pull up to the building, your in-vehicle navigation system signs off with the encouraging words: "You have arrived."

Though this scene may sound like a fantasy from the year 2001, actually, we're likely to see cars equipped with such in-vehicle navigation systems by 1992. In fact, one company, Etak Inc. (Menlo Park, CA), has been offering to car buyers its Etak Navigator system for the past few years. The Navigator can't do *everything* described in the opening paragraph, but it is the only commercially available navigation system on the market in the US, and Bosch Blaupunkt, the West German electronics giant, has already licensed it and is offering it to European car buyers as an option called the Travelpilot. For the moment, it's a high-priced luxury car option. But as traffic congestion escalates to unbearable proportions everywhere, the luxury may become a necessity.

Commercial in-vehicle navigation systems are quite similar to other computer graphics systems: Their system architecture includes processors, display devices, and storage media; they can create and display a graphics model and provide an interface between the model and the system operator; and they have built-in functionality for working with and analyzing the model.

However, navigation systems add to these components the concept of relative position and movement—the system operates with respect to a precise geographic location, and the model conforms to the model subject: the real world.

Navigation systems use many techniques to create a precise match between a map model and the real world. For example, tests

A color display screen combined with radio and mobile telephone communication comprise Mazda's Car Communication in-vehicle navigation system. Digitized map data is recorded on CD-ROM.

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have been conducted with electronic transmitters embedded in a roadway which constantly send geographic coordinates to the vehicles moving above; the transmitters also receive such data as traffic speed and volume. Sensors in the vehicles then pick up the coordinates and match them to coordinates stored in the map database.

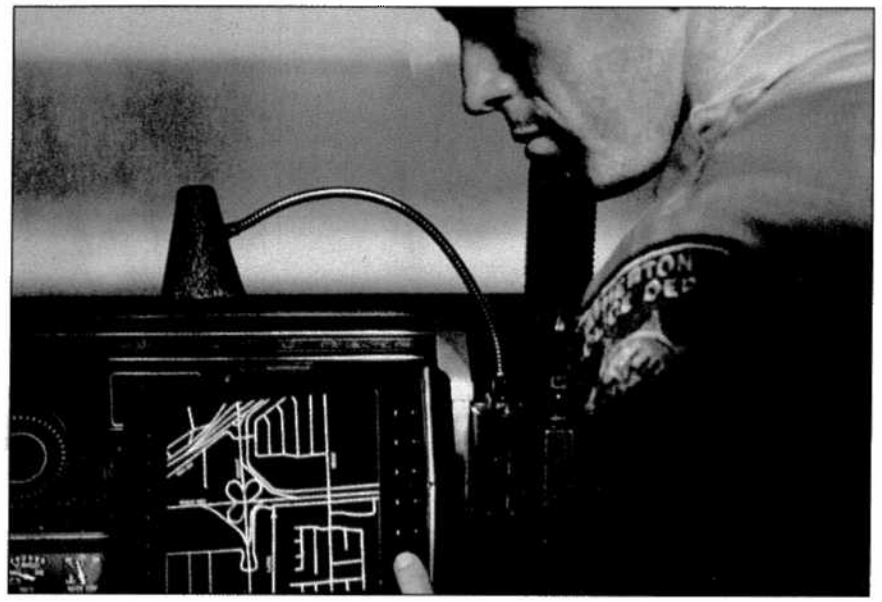
Another method for obtaining correct position is called the Global Positioning System (GPS), which uses a constellation of NAVSTAR (Navigation by Satellite Timing and Ranging) satellites to provide continuous, all-weather, precise navigation. While GPS is still in the testing stage and isn't expected to be fully operational for a few years, it will likely play a major role in future navigation systems.

Most of the in-vehicle navigation systems under development use the Dead Reckoning and Map Matching technique. As the vehicle moves, an electronic compass measures the direction of the vehicle, and wheel sensors measure the distance moved. The measured position is regularly compared with the electronic map to correct the position and calibration of the compass and wheels. Because they're self-contained, these systems don't need large investments in external infrastructure, as do road transmitters and satellites. In fact, such new car features as electronic anti-lock braking system wheel sensors

can actually serve double duty for navigation system purposes.

Two characteristics distinguish in-vehicle navigation systems. The first, the display type, provides visual cues to the vehicle operator. Three types of map displays are currently under development:

- Analog Maps: A paper map is scanned and stored in raster format with geographic reference coordinates (latitude and longitude).



Ambulance, police, and fire-fighting personnel can use systems such as Etak's Navigator to quickly get them to an accident scene.

Sections of the map are then presented to the driver as required to show the vehicle's position and the surrounding area. One drawback to raster data storage is the amount of disk space the images occupy—a city region the size of Chicago can take up to 300 megabytes of disk space, or half the capacity of a CD-ROM disk.

- Vector Stick Maps: Roads, geographic features, and street and place names are scanned or digitized from source materials, such as United States Geological Survey topographic maps, and stored in vector format, while road intersections are stored as nodes with latitude and longitude. Links connect nodes to each other, and the combination of links and nodes forms a network for routing the vehicle, with feature centerlines and associated text displayed as required. The disk storage space needed for such a map of Chicago would be less than 1/10 of one percent of a raster image.
- Virtual Maps: A variation of the vector stick map, the virtual map is enhanced to simulate an analog map. Roads are given width, buildings are shown as shapes, and areas are given color and pattern.

These displays can be combined with any one of three levels of functionality:

- Map Display Only. The vehicle operator sees a map that changes scenes as the vehicle moves. Because the operator must visually check position and direction, this type of system is better described as an automated map display rather than a true navigation system.
- Position and Direction. The relative position and the direction of the vehicle are displayed in real time as the vehicle moves. This is the current level of functionality of the Navigator. The driver selects a destination, and the system displays the direction toward that destination using a symbol for the vehicle's current location. The driver selects the route of travel.
- Automatic Routing. Once the driver selects a destination, a recommended route is calculated on the basis of shortest travel distance or shortest time to the destination. The route is displayed as an overlay on the road network, and the driver's job is to keep the vehicle moving along the path of the selected route.

Most computer graphics systems are designed to meet a real need—either they perform a function that can't be performed manually or with physical models, or they perform it at a lower cost, at a higher level of quality, or in less time than manual techniques.

Thus, it's reasonable to ask whether there's a real need for in-vehicle navigation systems, or whether they're frivolous consumer electronic toys designed to increase the price of cars. What's wrong with using printed maps and atlases, as drivers have always done?

The perceived failure of printed

maps as navigation aids is often cited as one reason why in-vehicle navigation systems were invented. Few would argue the point that reading a printed map while driving solo is difficult. Sheet maps are unwieldy, the print is often too small to read at a distance, and the reader must keep track of the vehicle's location on the map while taking note of road signage.

Atlases are a slight improvement over sheet maps, as they're more convenient to hold and are often at a larger scale. However, the destination is rarely on the same page as the driver's location.

The American Automobile Association's (AAA) TripTiks are one of the few printed map products that guide the driver along a predefined route in an easy-to-use driving format. But, TripTiks aren't available for in-city driving.

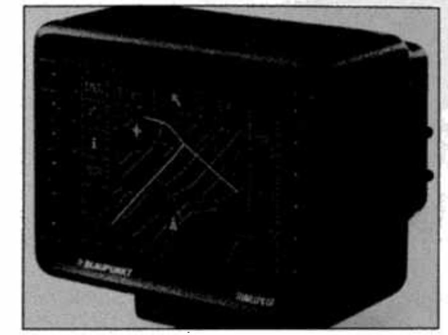
A more compelling reason for in-vehicle navigation systems than the failure of printed maps is traffic management—even if printed maps were completely accurate, readable, and easy to handle, they're merely a snapshot of static information. Printed maps can't be updated continuously to show new roads, construction delays, or accidents, and they can't route a driver from one point to another.

Furthermore, traffic congestion is worsening. In fact, the Motor Vehicle Manufacturer's Association has projected that by the year 2005, with annual growth rates of 3 percent for vehicle miles traveled and 2 percent for registrations, there will be 40 percent more vehicles and 65 percent more traffic than today, resulting in 3.8 billion hours of time wasted in traffic. The private sector automotive industry and government agencies view in-vehicle navigation systems, driver information systems, traffic control, and vehicle control as the best options for managing traffic in the future.

Those in the Know

Japan has most aggressively attacked the problem of traffic management through the use of technology. A consortium of public agencies and 51 private companies there are participating in a program called AMTICS (Advanced Mobile Traffic Information and Communication System). The project began in 1987 with the objective of integrating on-board electronic vehicle navigation with traffic information communicated to the vehicles in 74 cities in Japan.

So far, 12 Japanese companies have developed operational pilot systems, including Sony, Toyota, Nissan, Honda, Mazda, Mitsubishi, and Sanyo. Toyota has been selling a system as an option on its luxury Crown model since 1987, and its latest system includes a virtual map with automated routing and intersection instructions. Honda's system displays a vector stick map with location and directions, while Clarion has adapted Etak's Navigator to include traffic control information.



The 4 1/2-inch screen of Bosch Blaupunkt's Travelpilot shows vehicle location (arrow), destination (star), major streets (heavy line width), and secondary or connecting streets (lighter line width). Buttons surrounding the screen let the driver select the scale of the map, recalibrate the system, and choose destination points. Distance to travel, direction to destination, and other data are displayed with the map.

Another program feeding navigation system technology is Eureka. Initiated in Europe in 1985, Eureka is designed to enhance the competitiveness of European enterprises worldwide. Over 400 organizations and 19 countries are participating to aid in the commercialization of high technology-intensive products and services. Almost 15 percent of Eureka's $5 billion budget is devoted to intelligent vehicle and highway information systems and is supporting projects in digital audio broadcasting and digital electronic mapping.

In the US, as part of the High Priority National Program Area, the Federal Highway Administration has initiated a program called Advanced Motorist Information Systems for Improved Traffic Operations to determine the technical feasibility, design guidelines, cost-effectiveness, and practical utility of real-time, in-vehicle navigation and motorist information systems. The only official field experiment being conducted is called Pathfinder, for which the FHWA, General Motors Corp., and the California Transportation Agency are cooperating in a test of in-vehicle navigation and motorist information systems along the Los Angeles/Santa Monica Freeway.

Made in the USA

So far, US automakers GM, Ford, and Chrysler are studying the possibilities of in-vehicle navigation and are undertaking projects to develop systems. While Chrysler showed a concept car with a system using scanned AAA maps in 1984, none of the companies has planned to introduce production models with systems before 1992.

The technology is here, and the need is established. What's keeping these systems from going into mass production and distribution?

One factor holding back their implementation is market uncertainty. There are apparently no clear results from the limited tests performed to date that consumers will purchase the systems. Currently, the systems are relatively expensive (the Navigator costs about $1400 in the US, Bosch Blaupunkt's Travelpilot sells for about $2000, and Toyota's system reportedly adds around $4000 to the sticker price of a car). The general concensus is that the price of systems must drop to the $500 range before they gain wide acceptance.

Legal barriers must also be hurdled. In-vehicle map displays—or any screen that can be viewed while a vehicle is moving—aren't being greeted with wild enthusiasm in all circles. So far, there have been no restrictions placed on the devices in the US, but heated debates are ongoing in Europe contesting whether a display is a distraction to the driver and a possible safety hazard. (In answer to this unrest, alternatives are being developed that substitute voiced instructions or print out driver directions. Other solutions in the prototype stage turn the display toward the front passenger seat where the presumed navigator will read the display.)

But the biggest issue is the cost and time it takes to produce the databases. Map models for in-vehicle navigation must be accurate and geographically precise; the data must be organized to form a topologically structured network of roadways; roadway geometry must be faithful to the actual curvature of the road; and street addresses, place names, and major destination points must be referenced to precise geographic coordinates.

Only a few private companies and public agencies have produced data that can be used directly for in-vehicle navigation. Two US companies that have specialized in building navigation-quality databases are Etak and Navigation Technologies Inc. (Sunnyvale, CA). Etak developed its own techniques to quickly capture roadway geometry in vector format and merge street names and addresses. During the next year, Etak claims it will have digitally converted the 100 largest metropolitan areas in the US and Canada.

Navigation Technologies developed a countertop driver instruction device called the DriverGuide that uses standard digitizing techniques but includes attributes in the database on turning restrictions, one-way streets, speed limits, and other value-added data. While collecting this information is labor-intensive and time-consuming, the added detailed information is necessary for in-vehicle navigation systems if they're to address the traffic management issue.

Justifications Exist

In 15 years, a driver making a trip to the market or picking up the kids from school probably couldn't justify purchasing an in-vehicle navigation system on the basis of increased productivity, even if the trip does take five times as long as it would today. But lives are saved or lost on the speed of response to emergencies by ambulance, police, and fire fighting personnel, and millions of dollars are squandered in wasted travel by delivery vehicles. Individuals who depend on their vehicles for their livelihood can't afford delays.

At this point, it doesn't appear that the automotive industry is convinced that in-vehicle navigation devices are going to be a popular consumer item, such as cruise control or air conditioning, whether they'll maintain their status as a luxury car option, or whether they'll capture the imagination of the consumer at all. Nevertheless, everyone seems to want to be ready with a system when and if conditions warrant their existence. *CGW*