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Position Paper

Digital Maps in the Worldwide Automotive Context

Applications of Digital Maps in Cars and Other Land-based Vehicles

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Position Paper

Purpose of the Position Papers

The Position Papers are intended to generate discussion within the Intelligent Transportation Systems (ITS) community. The community is defined in its broadest scope, and includes environmental and city planners and map and travel guide publishers, as well as the individuals associated with organizations that have thus far been the drivers behind ITS efforts. This widening of the forum for discussion is a recognition of the important role that can be played by those who are responsible for designing the environments in which ITS solutions will operate, and by those who have traditionally provided the tools used for human orientation and wayfinding.

Each paper expresses the personal views of the author, with a focus on the interrelationships between the design of the systems, services and infrastructure which are proposed to improve personal and collective mobility, and the planning and design of our habitat. The fundamental premise of these papers is that land use and built form policies are inseparable from traffic and transportation policies.

Traffic congestion in and around our cities is a symptom of ill-considered decisions about the placement of origins and destinations for the people who live, work, shop and recreate in city regions. The increased number of vehicles on our roads is the result of people moving between dispersed origins and destinations in a way that can no longer be accommodated by point-to-point collective transportation systems. Whether it was the automobile that enabled the dispersion, or the desire of families and businesses to move out of cities that created the need for more private travel, is a subject of debate. There is no debate on the simple fact that traffic congestion and its side effects are a problem in almost every corner of the world.

Unless an holistic view is taken to the problem of personal mobility, a view which accepts that where people begin and end their journeys must be addressed simultaneously with how they will move between these locations, ITS solutions will not be able to deliver their full potential benefits.

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Applications of Digital Maps in Cars and Other Land-based Vehicles

Introduction

Digital map databases eventually will be essential for effective mobility in every country in the world. Effective mobility must include a sustainable road transport policy that is coordinated with residential settlement, commercial and industrial location policies, as well as with other forms of transportation (air, rail, water). A sustainable road transport policy is one that provides for the movement of people and goods between increasingly dispersed population, commercial and employment centers, and within densely populated urbanized areas. A sustainable road transport policy is one that can be paid for without excessive taxes or road usage fees.

Effective mobility in the future will depend more on the planning and management of our vehicular journeys than on the independent and unrelated decisions taken by the drivers of these vehicles. Today, cars and most truck are driven in very much the same way as they were driven almost a century ago when they were invented. The driver decides where and when to go, and how to get there, at any time of the day, in any type of weather or traffic conditions. Within the rules and regulations determined by the authorities, the driver has complete freedom of movement.

It is this freedom of movement which is the principal advantage of automobiles for personal mobility and trucks for commercial mobility, compared to fixed rail and fixed route transportation alternatives. It is the comfort of being in a warm enclosure in the winter, or a cool one in the summer, shielded from the elements from door to door, with only those one chooses for company, with one's own thoughts, one's own music, that makes the private car and truck such an irresistible choice for most adults in the industrialized parts of the world, from the time we learn to drive and earn our license, until the time we are forced by age or infirmity to give up this privilege.

However, it is just this uninhibited freedom of movement that has created problems for vehicular travel. We have made steady improvements in car and truck safety, vehicle control, drivability and comfort. We have increased fuel economy (although not yet enough) and reduced the environmental impacts of vehicle emissions. We have improved road surfaces, lighting, signage and barrier safety. While the driving experience inside the vehicle has gotten better and safer, the ability to enjoy the experience has worsened in almost every city region in the world. Traffic is a pervasive and insidious problem found in most of the world's medium-to-large cities and their surrounding regions. In extreme cases, it can cause drivers to act in irrational and sometimes violent ways.

Responses to the problems caused by traffic congestion have been to restrict vehicular travel, to increase car and truck ownership taxes, raise fuel taxes and institute road usage fees. These measures have the net effect of increasing the costs of mobility with no consideration given to the ability to pay or the need to use the roads.

Another response is to use advances made in technologies to make cars and trucks an integrated part of the transportation infrastructure, not merely users of roads. The automobile and car electronics industry is ready to do this. Over the past decade, intelligent transport systems (ITS) have been developed that attempt to increase mobility on our existing road networks. What makes possible the planning and management of vehicular journeys is, in part, digital databases of the road networks, databases that include as much information as can be collected about the roads and the places that can be reached via these roads.

Evolution

Applications of digital maps in cars and trucks are still in the first stage of their use in Europe and North America. In Japan, where in-vehicle navigation systems have been on the market for several more years, these applications are in transition from the first to the second stage. The first stage, **Mark I**, is characterized by systems which perform single functions, such as map display, route guidance, traffic messaging, emergency alert or position notification. Autonomous route guidance systems, with on-board computers, peripheral devices and map data, are one example of Mark I systems. The data is stored on a removable CD or DVD or on a hard disk. Each system is stand-alone with proprietary software and data formats. There is no interoperability of data, interchangeability of application software, or sharing of system components with other in-vehicle applications. Mark I systems also include centralized automatic vehicle location, in which a vehicle's position is determined by an on-board GPS device and sent via telecommunications interface to a remote tracking location. Telematics systems, which include two-way data and voice communications, and traffic data transmission via RDS-TMC or DAB, are also included in these Mark I systems.

Mark II applications require an off-board infrastructure to communicate dynamic information to the vehicle, and an on-board system which can process this data and re-calculate routes. Dynamic information includes temporal data, such as traffic incidents and roadworks, and static data, such as permanent changes to the geometry, attributes and relationships of the road network and other physical features. The on-board system must be able to add, delete and modify static data and store the temporal data in relation to the static data. These applications require that both the on-board and off-board data are completely synchronized, either being constructed from the same version of one supplier's database, or by applying a standard location referencing system.

The off-board infrastructure for Mark II applications is in place in limited regions of Japan, and is currently being built in Europe. The Vehicle Information Communication System (VICS) in Japan offers drivers information about road conditions, traffic jams, accidents, traffic regulations and parking availability. The system employs three data transfer methods: FM multiplex broadcasting, radio microwave beacons and infrared beacons. Specially designed in-vehicle systems highlight levels of congestion along roads covered by the VICS traffic sensing technology. Alternate routes are recommended by the central server to avoid traffic problems.

It is the standardized database source in Japan and cooperation among Japanese car manufacturers, system developers and public authorities which makes these services possible. Four years after the introduction of VICS, almost one-quarter of the four million in-vehicle systems on the road in Japan are equipped with VICS functionality.

Mark III applications are developing outside the vehicle context, in wireless handsets and PDA's. These applications consist of centralized services delivered to thin on-board clients. In the vehicle context one example of this would be off-board route guidance, in which all of the route planning and directions provision is performed at the central server and the directions are provided remotely to the driver. The principal advantages of the Mark III systems are that the central database can be maintained to a higher degree of content up-to-dateness than on-board data media, and digital map media distribution, with all of the cost and logistical complexity, is eliminated.

These thin-client applications are ideal for hand-held devices with limited storage capacity and restricted display capability. They work well when a one-time transfer of the user's position and a one-time download of a route are sufficient. The user can page through the instructions when he or she has reached a decision point. Applying this model to in-vehicle applications is problematic. Providing similar turn-by-turn instructions in a moving vehicle requires synchronization between the guidance instructions and the vehicle's position. A driver can do this manually by requesting the next instruction when a maneuver has been performed, but this is less than optimal, particularly when compared to the immediacy of instructions in the on-board devices. Constantly updating the vehicle's position back to a server application to achieve similar performance characteristics (i.e. on line all the time) would involve costs to the user for connect fees, and place heavy computational demands on the server—especially when the number of users expands to expected levels.

Mark II and Mark III applications will develop in parallel during the next three to five years and follow advancements in wireless technology. Standards for data transmission, location referencing and map data formats will evolve to a stage when interoperability of data and interchangeability of software an components will be possible. On-board data communications will also be standardized on a vehicle data bus that will allow device sharing and the passing of mission-critical data to multiple applications. During this time, map data suppliers will have substantially completed coverage of all vehicle-intensive countries. They will also have begun the difficult and expensive task of improving the quality of their data to support advanced driver assistance applications.

When the infrastructure, systems and data are at a stage when basic system functionality can be proven, within four to six years, the introduction of **Mark IV** systems will begin. These systems will be a combination of on- and off-board functions, thin- and thick-clients. Map data required for mission-critical applications and turn-by-turn guidance will be downloaded as required and used locally. Dynamic updates of temporal information, like traffic flows, weather-related road conditions, live camera views of interchanges, will be provided en-route. (See diagram on Page 10.)

Recent Developments

Map data is one of the four cornerstones on which the increasingly sophisticated in-vehicle applications are built. The other three are the in-vehicle technology, data processing systems in and outside of the vehicle, and the communications infrastructure. Recent developments in each of these areas, and in the related business environments, will have an impact on how quickly the industry moves to Mark III and Mark IV implementations. The following recent developments are significant.

Consolidation Within All Industries

Car manufacturers, system suppliers, map data suppliers and telecoms have been consolidating. The April 2000 purchase of Etak (US) by Tele Atlas (Belgium/Germany) provides Tele Atlas with one navigable database (Great Britain), and the potential to challenge NavTech in the North American market. Etak was never able to muster the financial resources from its two previous owners, News Corp. or Sony, to add navigable attributes to its North American data, thereby leaving NavTech as the sole supplier of navigable data to in-vehicle and server-based systems for address-to-address, turn-by-turn applications. It remains to be seen whether the owners of Tele Atlas, Bosch and Janavi Holdings—and its public shareholders since its introduction to the Frankfurt stock exchange—will fund this activity. In a response to the markets and its customers, NavTech immediately announced that it would double its coverage of the US and Canada, which has been stalled at the bare minimum for the past few years. Denso announced that it would license a US dataset from Geographic Data Technology, which is not completely navigable but which does include every street in the US with addresses. GDT has begun to add certain navigation attributes, such as one-way streets, and perhaps with more deals like that with Denso, the company will be encouraged to speed up its attributing process. Denso will integrate this data with NavTech's data so that its customers will at least be able to find every street, even though Denso will not provide turn-by-turn directions on non-NavTech streets.

The number two in-vehicle system supplier in Europe and North America has changed owners again. Mannesmann VDO, formerly Philips Car Systems Automotive Division, has been sold by Vodafone Airtouch, the new owners of Mannesmann. Siemens is the purchaser. Siemens has seen its market share of the in-vehicle systems market grow, partly at the expense of VDO, and it is about to take a dominant position in the industry.

As the European navigation industry is consolidating, the Japanese system suppliers are making inroads into Europe and North America. This has the potential of tipping the balance of power between the two data suppliers heavily in favor of NavTech since most of the Japanese companies are NavTech customers. Zenrin, the principal supplier of map data in Japan and an investor in NavTech, has established offices in Europe and North America to function as the intermediary between NavTech and the Japanese system suppliers. They are also adding three-dimensional data of buildings and other structures to support 3-D view navigation, no popular in Japan and gradually coming to the European and North American markets.

Mergers and acquisitions in the automotive OEM sector will reduce the number of potential customers for both map data and system suppliers. There is strong evidence that system development activities, both for navigation systems and telematics, are moving toward centralized coordination at Ford (Ford, Jaguar, Volvo, Aston Martin and Land Rover), GM (GM's US and European brands along with Saab and Fiat), Volkswagen (VW, Audi, Scania), Volvo Trucks (Volvo, Renault, Mack), and Daimler Chrysler (Mercedes and Chrysler cars and trucks).

Consolidation within the telecom industry is also causing ripple effects in the in-vehicle system sector. In the case of Mannesmann Passo, a telematics service provider, it has meant a merger into a new division formed with Mannesmann's computer services company. The new division, called Mannesmann TeleCommerce is going international and has already made an investment in a US company, ATX, the telematics provider to Ford, Mercedes-Benz, Jaguar and Infinity. Telecom mergers could have another positive effect on the provision of data to vehicles: they could lead to borderless wireless coverage. National/regional network providers and roaming fees are one of the major inhibitors to seamless coverage for telematics services. Fees and service provision vary greatly across coverage areas. The problem is worse in Europe than in the US or Japan, even though Europe's digital-based GSM technology has better coverage than any of the technologies competing in the North American market.

Internet/Multimedia Invasion of the Automotive Cockpit

The automotive platform is following the home/office computer cycle. On-board data delivered via CD-ROM is currently the primary media mode, just as it was in the PC and music sectors. Downloadable software and the Internet are quickly replacing the CD in both of these sectors. The same progression will also occur in the automotive environment. Single-function devices (e.g. route guidance, traffic display or telematics systems) are being replaced on the platforms now in development by modular entertainment/mobile office/infotainment systems, with route guidance or mayday applications as one of many functions offered to the driver. Once the Internet is in the vehicle, having entered for mobile office, safety and convenience applications, like e-mail and traffic information, it will provide the foundation for new map data transfer methods and navigation applications.

On-board/Off-board Route Guidance

With the exception of VICS, all in-vehicle route guidance systems today use on-board map data. If the conversion to off-board data is dependent solely on the automotive market, it would probably be a few vehicle generations before off-board systems appeared in any great numbers. However, developers of wireless devices, including PDA's like the Palm Pilot and Psion, as well as mobile telephone handsets, along with telephone network service providers, have recognized the importance to consumers of location-based services. They are described as "killer applications" and wireless developers are racing to get them to market. The server-based systems required to deliver off-board routes are being developed by companies like MapQuest.com (recently acquired by AOL), Vicinity and Webraska. In the case of Webraska, this information is being delivered via the Wireless Application Protocol (WAP), a quickly-emerging standard for accessing the Internet with wireless devices.

A larger market than the automotive industry starts to make the economics of server-based applications of map data look favorable for the data suppliers. They are currently testing various pricing models for the Internet. They are adapting their business models to transaction-based cost recovery, rather than adhering strictly to the on-board media strategy.

Public Authorities Join the Race

One of the reasons Japan is so far ahead of the western markets with respect to system evolution is that the Japanese government mapping agencies supported the industry from the beginning, working closely with industry and forming the Japan Digital Road Map Association (JDRMA). This group built and continues to supply the base road network data and most of the navigable attributes on Japan's roads. There is a single database structure which is used in all systems in Japan. The situation has been very different in other markets. NavTech, Etak and Tele Atlas began producing navigable map databases because there were no other data sources, public or private, which could meet the needs of the emerging European and North American navigation industry. With the exception of Japan, the public sector has either been a passive, low-cost supplier of data or base material, as in the US, or an expensive source provider with a focus on protecting their own intellectual property, as in Great Britain.

The public sector in Europe, alone or in conjunction with private companies, is finally beginning to deliver data and appears to be adopting a more cooperative attitude with respect to the primary data suppliers. Sweden, Finland and Norway already have or are in the process of creating official versions of street-level databases which they will license to the database suppliers at reasonable costs. The Belelux countries' mapping agencies have been working cooperatively with both NavTech and Tele Atlas. The Ordnance Survey in Great Britain finally appears to be softening its hard-line approach to data licensing and use.

The public sector is also playing a role in the industry through the establishment of regulations. Some of these regulations will have an impact on the design and even the provision of systems. Concerns over driver distraction are resulting in the banning of mobile phone use while driving, and this could extend to navigation systems as they become more prevalent. Implementation of the "fifteen second rule" proposed by the Human Machine Interface Committee of the SAE could mean that all interaction with a navigation system would either have to be executed while the car is motionless, or completely through voice control. Voice control systems re not yet at the stage in their development which allows smooth error-free interaction.

Although there are no restrictions yet on the display of maps, system developers are preparing for the completely voice controlled system with no visible maps. This will place an even greater emphasis on accuracy and the inclusion of all landmarks. The reason why viewable maps have been essential is to provide positive feedback to the drivers that they have made the correct maneuver. This has been in the absence of landmark information. A voice instruction will have to be more complete: *You are on Tyco Brahe Way. Turn left at the intersection with Copernicus Boulevard. After the turn, the Newton Elementary School will be on your left.*

Map Data Standards Debate

Digital map data standards of Intelligent Transport Systems (ITS) applications is the responsibility of ISO/TC 204 Working Group 3. This working group has been active since 1992. There are four areas in which standards are being developed:

- Map Data Transfer Format – The Geographic Data Files (GDF) transfer format, developed originally by the European system suppliers and proposed to the ISO by the European standards body (CEN), it is intended as a format for moving data from the map data suppliers to the systems developers. It is finally ready for an ISO vote—six years after it was submitted. Unfortunately, GDF has found little acceptance outside of the in-vehicle industry. The national land surveys have been especially cool to it—even hostile. They have been attempting to develop their own worldwide data interchange data model and format. This has limited the ability of data suppliers other than NavTech and Tele Atlas to deliver data directly to the system suppliers. Writing GDF conversion programs is not trivial, and none of the GIS system vendors support the format. The data suppliers also continue to support their own, proprietary formats and deliver data as well in an industry de facto standard Arcinfo format.

- Physical Storage Format (PSF) – There has been no observable progress on reaching agreement among the principal industry groups who have been taking part in the physical storage format standards activities. The PSF is for the data stored on the CD, DVD or hard disk. Before a PSF standard could be developed, each in-vehicle route guidance system manufacturer created its own format to work with its selected operating system, applications software and data access routines. This means that each system has its own PSF. It would be similar to buying audio CD's which only played on Sony CD players—not dissimilar to the video game players, but in a much smaller market. The result is no media interoperability, no economies of scale in map data production, and restricted choice for consumers.

  The Japanese delegation to ISO, who are the leaders of the committee that is responsible for PSF standardization, submitted a proposal for a standard PSF several years ago. This has evolved into what has been called the KIWI format. Most of the Japanese suppliers have adopted the KIWI format or are in the process of doing so. No non-Japanese companies have yet developed a KIWI-based system.

  At the same time, NavTech has developed a suite of application software called NavTools, and data access routines and a physical storage format called SDAL. Several companies, including Japan-based Pioneer, Panasonic and Clarion, along with US-based Magellan, are applying SDAL and have built systems based on SDAL with NavTools or with their own application software.

  Unfortunately, it does not appear at this time that either side is ready to drop their format in favor of achieving a single international standard. The leading European and US suppliers, Bosch and VDO, have shown little interest in a standard PSF since it would mean further investments to convert their software to the standard and essentially erase the lead they have built with their proprietary formats. It would be possible to combine KIWI and SDAL if the respective supporting groups resolved to cooperate. The formats have more in common than they have differences, although there are certain fundamental principles which are quite different, such as the way that data is pre-processed for display. The Automotive Multimedia Interface-Collaboration (AMI-C) group will decide on a standard for its members within one year, and, unless a new contender appears, it will most probably be either KIWI or SDAL. The chairperson for AMI-C is the former CEO of NavTech.

- Application Programming Interface (API) – This is the layer between the applications programs and the data access library. Several companies, including Microsoft, have focused on the standardization of the API in order to achieve a minimum level of interoperability of media. With API standardization, it would be possible for several system developers to agree to place their own proprietary data access libraries on the media for each system. The DAL would be adapted to the API. Each system developer would still create its own proprietary PSF for its system, but would include the DAL of the cooperating vendors. A System A media source in a System B would be able to provide the necessary data from the System A dataset for basic navigation. This is the theory. It is far short of interoperability. It is like Sony and Philips agreeing to make audio CD’s interoperable on their respective systems, but their CD’s could not play on their competitors’ systems, nor could the CD’s that did play on their competitors’ play on theirs. Efforts being applied to API standardization detract from the PSF efforts, particularly because there are only a limited number of experts who have been funded for these activities.

- Location Referencing and Update Publishing – These two areas are potentially the most important for off-board routing and telematics, but have been given very little attention within ISO. Significant progress has been made by industry committees and project groups on the location referencing issue, both in the US and Europe, and this work has been submitted to ISO. At the same time, application-specific location referencing methods proliferate. Not enough pressure is being brought to bear by industry for completion of this standards work.

Future Trends

Here are the trends that will shape the future of digital maps in the worldwide automotive context:

- The automobile will be integrated into the wireless world. More significantly, it will contribute to the information base as a moving probe on the roads. It will collect data on traffic flows, road surface conditions, driving and maneuver restrictions. Cars—and trucks and buses—will become the primary data collectors of this data. Advanced wireless communications technology will allow this type of data collection to occur. GPRS, for example, will allow for the equivalent of on-line-all-the-time, making it possible for data to be sent to and received by the vehicle virtually continuously. However, the map database is the principal enabling technology. The map databases controlled by the current suppliers will be adapted for continuous, dynamic updating. The suppliers will have to develop, agree upon and implement the update publishing and location referencing methods which are currently stalled in committee review.

- New content will be provided for "mission –critical" and advanced driver assistance systems (ADAS) applications, particularly content with positional accuracy of under one meter:

    - Road centerline data with sub-meter positional accuracy
    - Side of road obstacles, such as tunnel abutments or bridge supports
    - Current and predictive road surface conditions
    - 3-D imagery for better driver information display
    - Live camera views of traffic flows and incidents

  Imagery and live camera views are already part of the data available in Japan. More advanced content collection and maintenance methods are in the development stages in Europe and the US. The applications are at least five years in the future if the data can be made available. Close cooperation with the public sector will be essential because they are the primary sources of more accurate and detailed road information.

  All roads will need to be included in the databases, not just roads that are fully attributed for navigation. The licensing by Denso of GDT data to supplement NavTech data is an indication that the system suppliers are beginning to recognize the essential nature of complete coverage. Unless the major data suppliers provide integration services to incorporate all road data into their offerings, new data suppliers will emerge who will aggregate NavTech and/or Tele Atlas data with complete coverages.

- The purpose of the vehicle changes with the perspective of different industries:

    - Automotive company-centered – Location-based services, information and entertainment are part of a complete and life-long service offering by the automotive manufacturer to the customer. The vehicle is the means for the auto companies to provide profit-generating services to its customer base.
    - Entertainment company-centered – The vehicle is an entertainment device which also serves the function of transportation. A Sony, Philips or Disney brand vehicle.
    - Information company-centered – The vehicle is one of many mobile information appliances. An AOL, Microsoft or Motorola brand vehicle.

There will be implications for data supply and the data suppliers. The database producers have been funded in Europe and North America by system suppliers Bosch and Philips, and, until recently, Sony, not by information companies or automotive companies. News Corp, an information company, briefly held Etak, but did little to extend its reach. The auto industry has indirectly financed the data through its purchase of systems. The scene is changing. With AOL's purchase of MapQuest, and the merger between AOL and Time Warner, and the strategic partnerships being established between the auto industry and major Internet portals, including AOL and Yahoo!, funding for map data will be shared among many industries. The data suppliers must become publicly traded companies in order to take advantage of these funding sources—Tele Atlas has taken a first step by entering the Frankfurt stock exchange—and to maintain their independence. NavTech is also committed to taking their company public. The only question is whether the markets—primarily the large institutional investors—will be able to grasp the importance of the content these companies hold and will pay for the privilege of owning their shares.

Next Generation In-vehicle Driver Information and Assistance System