VEHICLE NAVIGATION APPLIANCES

Donald F. Cooke, Chairman
Geographic Data Technology, Inc.
13 Dartmouth College Highway
Lyme, New Hampshire 03768

BIOGRAPHICAL SKETCH

Donald Cooke was a member of the Census Use Study team that developed the DIME method of map encoding in 1967. He was a founder of Urban Data Processing, Inc, a company that sells geographic data analysis services and software to commercial clients. Since 1980 his present company has served as an author and publisher of digital maps supporting thematic data display, vehicle routing and in-car navigation. His publications include a series of technical comic books written for the Census Bureau. He is a member of ACSM, URISA and the Wild Goose Association.

ABSTRACT

A Vehicle Navigation Appliance (VNA) is a device installed in a car which displays information such as location of the car in relation to a chosen destination. No longer a "James Bond" novelty, VNAs are currently on the market and could be showroom options before 1990. Consumer acceptance will depend on having a great body of useful and entertaining information stored in the vehicle and indexed to an on-board digital map. Probable use of compact audio disks for map distribution presents an unprecedented map publishing opportunity because of the enormous amount of data which can accompany the map.

INTRODUCTION

Vehicle Navigation Appliances -- devices that keep track of the location of a vehicle and display the location in map form -- are no longer the stuff of James Bond movies. Honda has had it's "Gyrocator" system on the market in Japan since 1982. ETAK's "Navigator" is for sale as an after-market auto accessory in California. Most automobile manufacturers have navigation systems in their concept cars and promise systems as showroom options by the end of the decade.

The technology required to build navigation appliances stems from personal computing, high-fidelity music, administering the decennial census and guiding airplanes and missles. The most probable VNA hardware designs and the most promising marketing strategy for VNAs together present an unprecedented map publishing challenge to cartographers and a unique opportunity for electronic publishing of large volumes of information. This paper briefly surveys VNA technology and concentrates on the map publishing challenge it presents.

DEFINITION

Two functions define a vehicle navigation appliance: 1) it

must be able to locate the vehicle on the ground and 2) it must be able to display the location in a familiar and useful form.

VNAs now on the market provide these functions which satisfy gadget buffs and commercial fleet operations. However to reach a broad consumer market a VNA must also: 3) provide useful and entertaining information related to the location of the car or the desired destination.

VNA HARDWARE

This functional definition of a VNA requires six hardware sub-systems for implementation: 1) a location device, 2) a computer, 3) an output facility, 4) an input facility, 5) map storage and 6) storage for "other" information.

Location Devices

Three location techniques seem promising for locating land vehicles: Loran, Satellite, and Dead Reckoning. Although "electronic signposts" serve to monitor buses along fixed routes, they are dismissed for supporting a broad consumer market because of the cost of the infrastructure required to work nationwide.

Loran. A Loran set receives coordinated radio signals from three fixed ground stations. It measures the time differences in the arrival of the signals. The time differences serve as coordinates, which can be looked up on special maps with time-difference coordinate overlays or converted to latitude and longitude.

About 250,000 ships and boats have Loran sets costing between $700 and $2500 for navigation. Loran transmitters cover not only the coastal and offshore waters but also the Great Lakes and the majority of the continental land area. Loran sets adapted for general aviation use are being well received; some units have thousands of locations of airports and navigation aids stored internally for recall and use by the pilot.

Loran manufacturers are also investigating land vehicle installations as another market. Loran accuracy is affected by a seasonal temperature-related drift and more drastically by local electrical disturbances. On land, the best-case accuracy will discriminate between most adjacent street intersections; use of a locally-broadcast differential signal reportedly improves accuracy to 15 feet.

Satellite. Three proposed satellite systems may be able to support vehicle navigation: Geostar, Startech and the Navstar Global Positioning System (GPS). Geostar and Startech are both private ventures which would have to charge users a fee for system access. Both have demonstrated their concepts, Geostar with simulated satellites on mountaintops and Startech with a facility currently in orbit. Each system appears to yield sufficient accuracy for land vehicle location.

On the other hand, GPS/Navstar is a Defense Department

system planned for operational deployment between 1986 and 1988. The mature system will consist of 21 satellites; six test satellites are currently available for testing. GPS is really two systems: a highly accurate military one with coded signals unusable by civilians. The open channel will be deliberately degraded for national security reasons to yield a location accuracy that is marginal for land vehicle location. Ironically, it appears possible to determine and broadcast a differential correction signal, or even generate a "pseudolite" that would look to a GPS receiver like another satellite, further increasing accuracy. Either of these corrections would make GPS adequate for VNA use. The issue of user fees remains unresolved, with sentiment for a free system generated in part by the KAL flight 007 disaster.

Dead Reckoning. Dead reckoning is a "position keeping" rather than "position finding" technology; a DR device keeps track of how far and in what direction a vehicle has gone to compute location relative to a known starting point. Dead reckoning hardware can be quite simple and inexpensive: an odometer and a heading indicator. Heading can be sensed by a magnetic compass, a differential odometer or inertial sensor. A combination of compass and differential odometer is used by most current systems.

Simple open-loop DR yields a position measurement that degrades as the vehicle moves because of errors in distance and heading readings. At least four firms have overcome this deficiency by map correlation/matching or closed-loop DR. In closed-loop DR the navigation computer compares sensed evidence of distinct turns to bends or intersections in a digital map. The computer choses the most probable turn point and updates the vehicle's location, eliminating accumulated errors. Even closed-loop DR can get lost and require re-initializing if turns that allow position updating are too far apart; otherwise, closed-loop DR yields excellent accuracy.

Computer

Computing functions in a VNA include retrieving and displaying the appropriate map, updating the car's location on the display, managing queries from the operator, searching the directory of destinations, and supporting the dead-reckoning function, if used, including map correlation in the closed-loop case. Other navigation-related functions might include calculation of a shortest path and voice synthesis of directions. These requirements are typical of today's home and business computers; a car navigation computer could be a general device available also for entertaining children or business use, especially if linked to an office computer through a mobile cellular telephone.

Output Facility

The VNA output facility must have a screen to display maps and to present various directories of streets and destinations. The 1985 Buick Riviera has an optional touch-screen CRT; other cars such as recent Corvettes have full-color LCD instrument displays. Another appealing output device would be a voice-synthesis unit to read directions, instructions

or descriptive text to the driver while the car is moving.

Input Facility
The VNA user must be able to request a function, specify a destination, or search through information stored in the system. A touch-screen or several function buttons around the display screen should suffice.

Map Storage
Navigation systems to date have used three different methods of map storage: photographic, digital image and digital encoded.

Photographic. Honda's Gyrocator and Omni Devices' Navigator both use photographic map storage. Honda requires the user to slip a transparent map overlay over the display CRT. Omni stores maps in a film cartridge and uses a complex fiber-optical/LCD system to generate the display. Although Omni's system provides more flexible panning and zooming than Honda's it suffers from relatively low resolution: ETAK's CRT, for example, displays 50 times as many pixels.

Digital Image. The most publicized concept car, Chrysler's Stealth, uses videodisk images of paper maps in its "CLASS" (Chrysler Laser Atlas Satellite System). Others use videotape to achieve a similar effect. Chrysler reports having over 13,000 maps stored on its demonstration disk, covering the USA at several scale levels to permit zooming.

Digital Encoded. A digitally encoded map is a data file describing the street network by connectivity and coordinates, augmented by street and city names and address ranges. This flexible and compact recording form supports many functions: DR map correlation, map display, specification of origin for dead reckoning, and selection of destination by street address or intersection. The digitally encoded map provides the most flexibility in windowing and zooming, and can support shortest-path route-finding computations.

All three of these options presume that the map is stored on board the car, although Boeing's FLAIR (Fleet Location and Information Reporting) system was supporting closed loop DR for 200 cars with central computing and map storage eight years ago. ETAK stores maps on audio cassette, taking advantage of a familiar medium and an inexpensive read mechanism. This has two disadvantages: limited storage capacity and sequential access. Current "floppy" disks have about the same capacity as cassettes, but their virtue of random access is offset by a ten-fold cost disadvantage for the hardware unit.

A panacea for map storage in vehicle navigation systems appears to be the compact audio disk used as a read-only memory for digital data. "CD-ROM" players are on the market for automotive music systems; only a modification to the error detection and correction circuitry is needed for data storage. Philips -- a promulgator of the CD standard -- is proposing automotive CD players wired for both in-car entertainment and information. Each CD-ROM disk holds 500 million bytes of data, more than enough for a digital map of

all streets in the USA.

Storage of "Other" Information
Only the CD-ROM or other laserdisk like Chrysler's holds out the possibility of storing much information beyond the basic map. The point to establish here is that one CD-ROM disk can store a complete digital map of every street in New England plus 300 unabridged copies of "Moby Dick".

HARDWARE SUMMARY

Anticipating the hardware environment of 1988 or 1989 (dates usually mentioned in the popular press) one can project vehicle navigation appliances built around a computer with roughly the power of a 256K IBM PC, using a color CRT screen and sharing a CD player for storage of both map information and music. Although it is tempting to predict that GPS will be the predominant location technology, there are too many successes with inexpensive DR and too much uncertainty with GPS cost, accuracy and timing to do so. All location techniques have drawbacks: Loran and GPS won't work in tunnels; DR only yields a relative position and needs initializing and occasional resetting. A reliable and trouble-free system would ideally use two complementary techniques: either GPS and DR or Loran and DR.

MAPPING CONSIDERATIONS

Although it is easy to build digital map images by scanning existing paper maps at various scales, image storage is inferior to digital encoding for three main reasons: images do not support closed-loop DR, they are inflexible for zooming and panning and they require a separate index for looking up addresses of destinations. On the last point, note that the index required to support an image database is almost equivalent to the full content of a digitally encoded map.

An ideal digitally encoded map would have all streets represented with accurate and visually pleasing coordinates, and sufficient housenumber and intersection information indexed to permit lookup of a precise street address or a street intersection. Additional useful information includes flagging one-way streets and turn restrictions and identifying highways and major arteries. These additions permit highlighting of expressways on the map display and improve performance of route-finding algorithms.

This basic map information, judiciously compressed, amounts to 120 to 150 bytes per street. Sixty percent of the USA population lives on about one million streets represented in the Census Bureau's "GBF/DIME" files, a series of digital maps prepared for administering the 1980 census. A simple extrapolation, allowing for rural streets that wiggle more than their urban counterparts, yields a nationwide digital map that fits easily on one 500 megabyte CD-ROM disk.

Though enticing as a resource for vehicle navigation, the GBF/DIME files have numerous errors in segment connectivity; they represent the street network of 1977; they cover only

one percent of the USA land area; the coordinate digitizing has a systematic clipping that causes straight streets to appear to wander back and forth and some new streets added just before the last census were scribed inaccurately enough to guarantee malfunction of a closed-loop DR system. The Census Bureau has acknowledged these deficiencies, but ironically its solution, the TIGER (Topologically Integrated Geographic Encoding and Referencing) system will not be in place in time to have an impact on the first wave of VNAs. Nevertheless, the GBF/DIME files are useful enough resources to serve as the starting point for proprietary vehicle navigation digital maps prepared by both ETAK and Geographic Data Technology, Inc.

From a marketing point of view, does it make sense to sell the whole country on one CD-ROM? The answer is no; split the map up into states, regions or metropolitan areas, and use the saved disk space to generate many custom editions and make multiple sales to VNA owners.

For example, target one edition for business travellers in rental cars or their own vehicles, containing a complete directory of all business establishments in the region. There is room for a lot more data on each firm than name and address (just delete 299 of the copies of Moby Dick); Dun and Bradstreet -- a candidate for map publisher -- could put its directory of business establishments for any state on one disk, along with the digital map. Augmented with appropriate indexes, this disk could display to a salesperson all businesses of a certain size, in a particular industry within five minutes driving time, including the names of officers and phone number for use with the cellular phone.

For the family market, substitute the kind of data found in the Yellow Pages and supplemented with more detail about each entry: hours of operation, product lines carried, or sample restaurant menus. This information would help in many family emergencies where a fast-food restaurant or a children's museum is needed in a hurry, or to take advantage of unexpected free time by querying for nearby antique book stores or those elusive outlets selling Liz Claiborn garments. The obvious publishers, the Yellow Pages operations, are restricted from publishing an "electronic yellow pages" until 1989. Whether distribution of an "annotated" map on CD-ROM is also restricted is an interesting question; if so, there may be an excellent opportunity for another company to compete in this highly profitable service.

The Yellow Pages is profitable because of the same mechanism that supports publication of most paper maps: both are really advertising media. The CD-ROM map with its huge capacity presents an unprecedented opportunity for advertisers.

The dynamic nature of the map display screen permits display of commercial logos at the location of facilities of various kinds. For example, Hyatt could buy the capability to display its logo at individual hotel locations as any car drove within range. Marketing executives for competing hotels would be hard-pressed not to pay for similar advertising of their facilities.

A final consideration regarding functions of paper maps concerns their potential for relieving boredom on a long trip. The physical limitations of a thirty inch square of paper restrict its entertainment and educational potential to listings of state birds and insects. Contrast this with the ability of a CD-ROM to store an immense amount of localized information, indexed to the map: schedules of summer playhouses, town histories, agriculture, or geology (sample: "In 1958, when this highway was under construction, dinosaur bones were unearthed right where you're driving"). Making the CD-ROM map into a tour guide would enhance its attractiveness and promote sales.

SUMMARY -- UNRESOLVED ISSUES

Vehicle Navigation Appliances are no longer a curiosity in James Bond movies. Potential technical, cost, and regulatory barriers are identified; none appear to prevent a robust competitive market developing by the end of this decade.

There is clearly technical groundwork still to be done such as defining the standards for broadcasting a GPS differential correction signal, or establishing formats and accuracy standards for the on-board map. Manufacturers have to settle on methodologies, build and test prototypes and set up production and marketing.

If CD-ROM is chosen for map distribution, the major unresolved issues of publisher and content of the "other" data remain. One must ask if a Magnavox or Texas Instruments -- motivated to sell GPS receivers -- is willing to enter the digital map/yellow pages business to effect the GPS sales? Might a General Motors or Ford take the lead and compete with the telephone companies? How does this opportunity sit with McGraw-Hill and its aggressive movement into electronic publishing, or Rand McNally and its century-plus experience in map publishing, or RR Donnelley -- a map maker that also prints the Yellow Pages, or Philips and Sony, both of which already sell CD's for music storage?

The answers to these questions -- which we practitioners of automated cartography can affect -- will change forever the largest use of maps: navigating private automobiles. The challenge we face is an unprecedented opportunity for innovative publishing of a new kind of map.

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