NAVIGATION: *Journal of The Institute of Navigation*
Vol. 34, No. 3, Fall 1987
Printed in U.S.A.

The Evolving Roles of Vehicular Navigation

ROBERT L. FRENCH
R. L. French and Associates, Fort Worth, Texas
Received June 1987

ABSTRACT

This paper examines existing and potential applications of navigation technology to motor vehicles that operate primarily upon streets and highways. Applications are described and representative systems approaches are outlined in three broad categories; driver information, traffic management, and fleet management. Driver information systems include those that develop and present navigation information in various forms to aid the driver in reaching the desired destination. The traffic management category includes navigation systems that consider real-time traffic conditions in determining optimum routes and, consequently, contribute to the overall improvement of traffic flow. Fleet management applications include automatic vehicle location monitoring systems (which do not necessarily provide navigation information to vehicle drivers) as well as systems which provide routing or step-by-step route guidance. The most comprehensive fleet management applications of vehicular navigation may also include command and control functions.

INTRODUCTION

Motor vehicle navigation has traditionally been accomplished by reference to external road signs and landmarks while traveling over routes constrained (unlike sea, air and space navigation) to finite networks of streets and roads. Commonly used in-vehicle navigation aids have essentially been limited to road maps, the odometer, and an occasional magnetic compass.[1] Except for a brief flirtation with mechanical route guides starting around 1910,[2] automobile navigation received little attention until the late 1960s, when the Federal Highway Administration's short-lived Electronic Route Guidance System (ERGS) project[3] presaged a wave of research on similar proximity-beacon route guidance and information systems which spread to Japan and Europe during the 1970's.[4] The 1980s have brought extensive development work on a new generation of automobile navigation systems based upon dead reckoning, radio location and map matching, in addition to further development of proximity-beacon systems.[5]

Advances in microelectronics, computer, space, and cartographic technologies permit the development of vehicular navigation systems with unprecedented capabilities. Figure 1 shows improvements in position accuracy achieved by radio location as compiled by Luse and Malla.[6] Although not strictly comparable because their accuracies are expressed relative to digitized maps rather than absolute location, the accuracies of ARCS and Etak dead reckoning augmented by map matching are included in Figure 1.[7,8] While each of the accuracy values plotted in Figure 1 is subject to qualifications and exceptions, the overall trend is inescapable—we are entering an era in which vehicle location may be pin-pointed to individual streets and intersections.

The navigation technologies available, or that are in the process of becoming available, support the development of vehicular systems for performing such a wide variety of useful functions that the taxonomy of systems applications is not yet well established. However, the following broad categories provide a useful framework for examining some of the more important functional roles that are evolving, and for outlining examples of various systems approaches to vehicular navigation that are applicable to these roles.

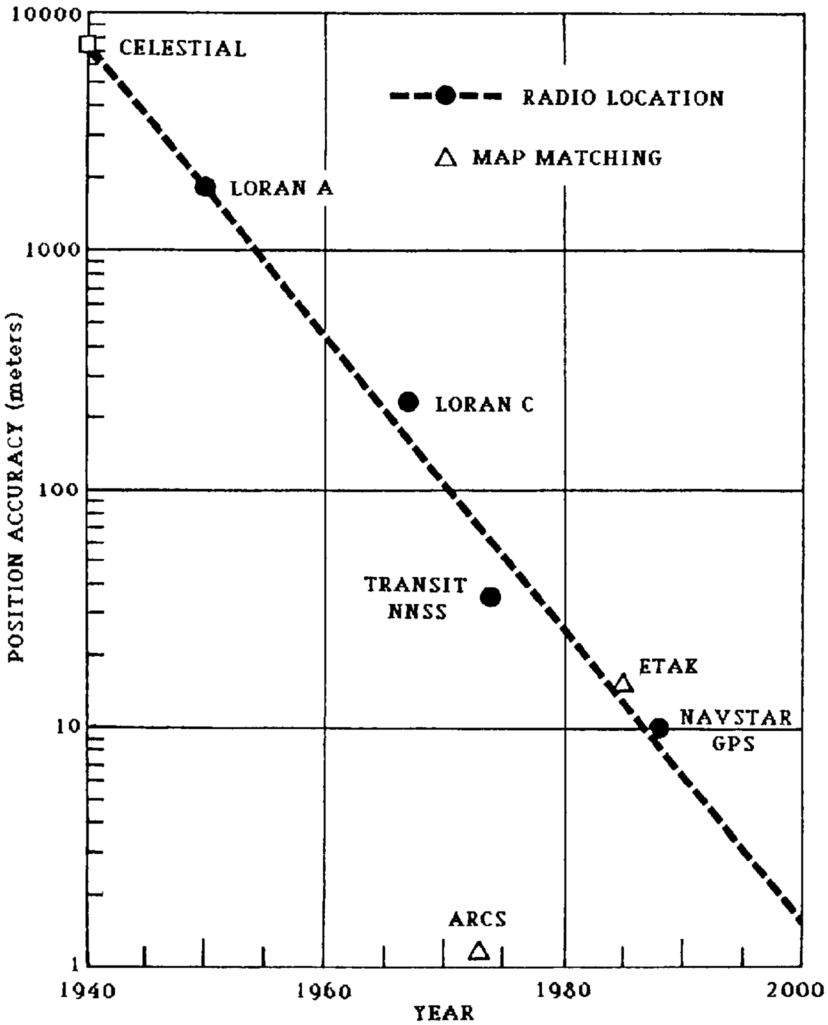

Fig. 1—Improvements in Position Accuracy.

DRIVER INFORMATION

This category includes systems that develop and present to the driver various forms of navigation information useful in determining how to reach the desired destination. This may range from minimal information regarding the direction and line-of-sight distance to a specified destination, to real-time step-by-step route guidance instructions for reaching the destination. Intermediate levels of driver information systems may provide a complete plan and position indication on a map display.

Use of conventional road maps as a navigation aid requires several cumbersome and error-prone steps. Users must first identify their location and destination on the map. A reasonable route between these two points must then be determined by inspection. Finally, the user must be able to successfully follow the planned route. Research indicates that 64 percent of the general population has difficulty in reading maps, and that navigation aids that replace conventional map reading and following processes by voice instructions are the most effective.[9]

The wide range of vehicular navigation aids in the driver information category is illustrated by the following systems, some of which are already on the market.

VDO City Pilot

A dead-reckoning system called "City Pilot" is currently on the European market. Developed by VDO Adolf Schindling AG, it uses an earth magnetic field sensor and an odometer distance sensor.[10] Like virtually all other dead-reckoning processes included in vehicular navigation systems, City Pilot integrates measured increments of travel with corresponding heading measurements to continuosly estimate the vehicle's coordinates relative to an initial location.

Prior to a journey, the driver uses a light pen to read bar-coded starting and destination coordinates on a special map. Using the sensor inputs and destination coordinates, a microcomputer continuously calculates and displays the direction and line-of-sight distance to the destination. LCD arrows show the driver which general direction to take, while numerals indicate the remaining distance. Test results reveal that drivers using the system reach their destinations with an accuracy of 97 percent (i.e., within 3 percent of the distance traveled).

Etak Navigator™

The first commercially available automobile navigation system based on dead reckoning augmented by map matching is the Etak Navigator™ now marketed in California. Map matching applies artificial-intelligence pattern recognition concepts to correlate measured vehicle paths with road maps which are digitized and stored in computer memory. With map matching, sensed mathematical features of the vehicle path are continuously associated with those of roads encoded in a map data base, just as a driver associates observed landmarks and road features with those depicted on a paper map to recognize position.[5] Dead-reckoning errors are thus removed by automatic reinitialization at each turn.

The Etak system uses a flux-gate magnetic compass as well as differential odometer for dead reckoning. The differential odometer is essentially a pair of odometers, one each for the wheels at opposite ends of a common axle. When the vehicle changes heading, the outer wheel travels farther than the inner wheel by an amount (ΔD) that is equal to the product of the change in heading ($\Delta\phi$) and the vehicle's width (W): $\Delta D = W\Delta\phi$. Thus, by real-time analysis of the differential travel of opposite wheels, a vehicle's path and heading relative to its starting point may be computed using algorithms based on the above equation.[2]

The Etak system uses 3.5-MByte tape cassettes to store digital map data approximately equivalent to two paper street maps.[8] The vehicle's location relative to its surroundings is continuously displayed on a monochrome CRT map presentation which may be zoomed to different scales. A fixed symbol below the center of the CRT represents the vehicle position, and points to the top of the display indicating vehicle heading as indicated in Figure 2. As the vehicle is driven, the map rotates and shifts about the vehicle symbol to maintain an orientation corresponding with the driver's view through the windshield.

A simplified push button arrangement allows destinations to be input by street number and name, or by street name and nearby cross street. The current destination is shown on the Etak screen as a flashing star. When off the

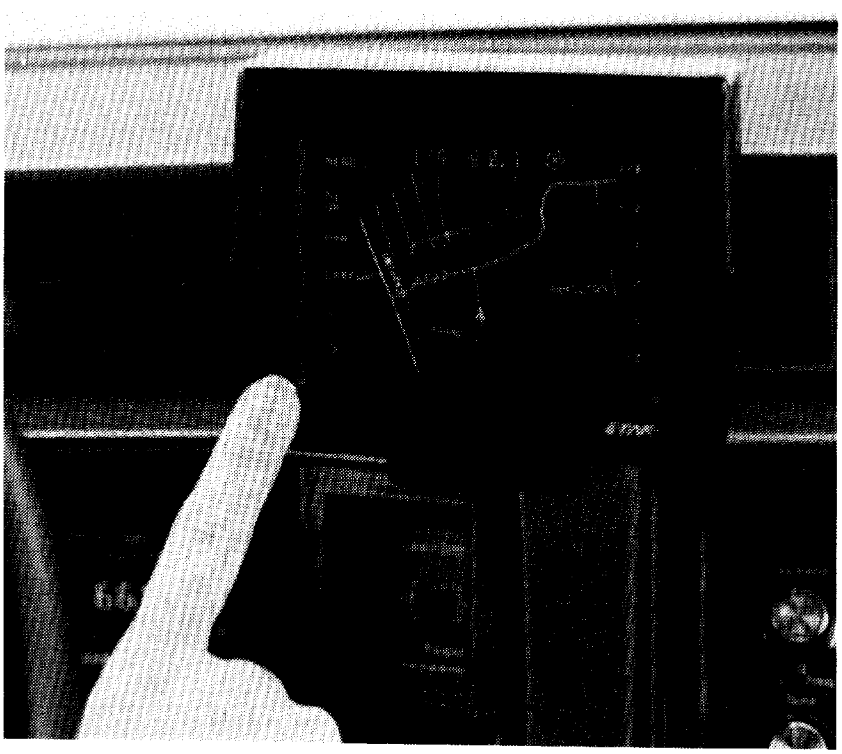

Fig. 2—Etak Navigator™ Display.

displayed map scale, the direction and distance to the destination is shown on the margin of the screen. Up to 16 destinations may be stored for sorting and quick recall.

Blaupunkt EVA

Bosch-Blaupunkt has developed a map-matching system called "EVA" which uses a differential odometer and includes route-search software to generate an optimum route to input destinations.[11] Turns at intersections, lane changes, etc. are specified on an LCD in the form of simplified diagrams which show lane boundaries and displays arrows to indicate the path to be taken. Synthesized voice capability is included, and is used to confirm destination entries as well as to articulate turn-by-turn, real-time route guidance instructions.

The first version of EVA (Figure 3), which has been tested and demonstrated since 1983, has a digital map of the test site (the small city of Hildesheim in West Germany) stored in EPROM with a capacity of approximately 109 KBytes. Like the Etak system and most others that use digital maps, the EVA map represents streets by straight segments that connect node points whose coordinates correspond to intersections. Intermediate nodes, known as shape points, are used to approximate street curvature between intersections. Since optimum routes are determined by algorithm, the EVA map data must also define traffic attributes such as one-way streets and turn restrictions.

An enhanced version of EVA which is slated for testing late this year has been designed to use CD-ROM for storing map data. Since CD-ROM has a storage capacity of approximately 550 MBytes, one compact disc could accommodate all streets and roads in West Germany plus extensive "yellow pages" and other directory features.

Navstar GPS

The Navstar Global Positioning System (GPS), which is being implemented by the Department of Defense, has been investigated as a basis for automobile navigation systems by General Motors,[12] and was the basis for CLASS, the Chrysler Laser Atlas and Satellite System, a concept displayed at the 1984 World's Fair in New Orleans.[13] CLASS included a nationwide set of maps stored

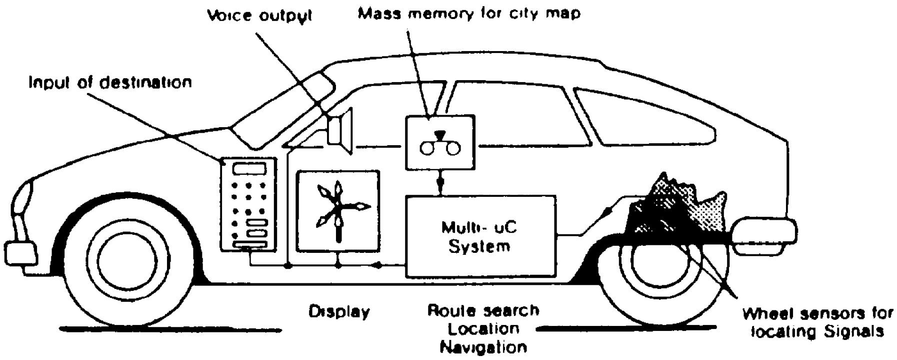

Fig. 3—Blaupunkt EVA System Concept.

DOCKET ALARM

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.

WHAT WILL YOU BUILD? | **sales@docketalarm.com** | **1-866-77-FASTCASE**

fastcase® Smarter legal research.