HUMAN INTERFACE REQUIREMENTS FOR VEHICLE NAVIGATION AIDS

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BIOGRAPHICAL SKETCH

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ABSTRACT

The development of vehicle navigation aids has been facilitated by advances in microprocessor, display, and data storage technologies. While many of the problems associated with creating these devices have fallen to technological developments, several questions remain. These arise when people must use the devices. Navigation aids must be designed with the human user and the driving environment in mind. As the basic technology of processing navigation information comes to maturity, the remaining questions depend for answers on understanding human cognitive and perceptual parameters of the navigation task.

INTRODUCTION

Navigation aids for drivers should provide support, in the form of information, which will assist drivers in traversing geographic space. In addition to informing the driver of the vehicle's current position, usually with reference to the street grid and on a map display, these systems may display trip origins, destinations, and pre-selected or optimal routes. Other information, such as the location of the nearest hospital, police station or hotel could be found, given a properly constructed database. All of these functions have been provided, in the past, by a human navigator using printed street maps.

Microprocessor-based electronic navigation aids, are capable of storing and displaying map information. The advantage of a vehicle navigation appliance (VNA) over a printed map lies in the additional capabilities the former may offer beyond the printed map. Computing technology allows navigation aids to include map-use and navigation expertise as well as map information in the system. Such tasks as: route selection, route optimization, continuous real-time position tracking, and deciding on the next action to be taken in following a route, can be performed by the navigation aid. This potentially frees the driver from at least some of the effort required for navigation. Resulting benefits may include safer, more efficient, and less stressful travel.

We may conceptually divide a VNA into two functional components: an underlying spatial data processing system, and a human interface. Data structures, storage medium, positioning system, and the content of the spatial database will be included in the underlying system. The interface is a facade, through which the driver interacts with the underlying system. Both of these components depend on software and hardware subsystems to support their functions. In practice, the two components are interdependent.

It is reasonable to expect that the basic hardware technologies and data processing techniques to support the spatial data processing components of different brands of commercially available VNAs will be comparable. Different information bases may be used for different applications (e.g. tourists, salesmen, and firemen may each have databases suited to their specific needs). Oil companies, fast food concerns, hotel chains and the like may well vie to have their franchises incorporated into databases. It seems likely that very similar databases will be available for VNAs produced by different manufacturers. The area where VNAs will be most free to differ, and therefor, to attract users (and garner market share) will be the interface they present to users.

The remainder of this paper deals with the interface component of vehicle navigation aids. It considers the technological basis available for the interface and concentrates on the creation of a useful and supportive navigation aid. This area presents interesting challenges for cartographers in the future development of VNAs.

THE INTERFACE

Function

The function of the human interface of a VNA is to facilitate communication between the VNA's underlying processing component and the driver. This will entail information flowing both ways; the driver must be able to control (to some extent) the VNA's processing and the VNA must be able to present information to the driver. These flows should be comfortable and natural. It is clear that the information should be provided in a useful format and should be tailored to the driving environment. The style of communication must not interfere with the driving task.

Input to the VNA, (such as queries for particular information, parameters to control a search, or commands to abandon a task) present challenges which will only be mentioned here. Obvious technologies include keyboards, pointing devices, and voice activation. Each has some associated disadvantage. Keyboards require space and are not usable with the vehicle underway. Light-pens would be a nuisance; while capacitance-based touch screens (and keyboards) would not work with gloved hands. Pressure sensitive touch screens are appealing but accurate pointing/touching may be difficult in a moving vehicle; and made more so by small target areas.

The output from the VNA must meet several requirements. The first is that the information must be perceptible to the driver. Second, the information must be useful, i.e. support the driver. Third, the information must be presented in such a way that the driver need not spend undue effort decoding the message.

The first requirement deals primarily with matching perceptual abilities of the human visual system with available display technologies. Concern for sufficient symbol size and contrast to ensure visibility is indicated. This type of basic system parameter is relatively well understood (see, for example, Silverstein 1982).

The second requirement, that the information is useful, is less well understood. It is task dependent and undoubtedly unstable through time. It is very difficult to presage all of the information that may be of use to the driver. Toyota has considered on-line automobile owner's manuals, automobile condition monitoring, real-time traffic reports, navigation information and commercial television broadcasts as information worthy of display (Shoji 1986).

The third area is concerned with the form, as opposed to the content, of the information presentation. It is probably the least understood of the three requirements. Meeting this requirement will entail an understanding of cognitive aspects of direction giving and receiving. It is relatively simple to create a VNA interface which looks like a conventional street map. The vexing question is how to use the technological power to go beyond the limits of that map. It is difficult to envision new forms of spatial information displays based not on the limits of static printed maps but rather on the palette that current technology provides.

Cognitive Load in the Driving Environment

Driving is a highly visual activity (Hughs and Cole, 1986). It requires a driver to use a large amount of sensory information to constantly assess the current condition of the vehicle and its situation with respect to the road and other traffic. Further, knowledge of the current situation, a route to be followed, the operation of the vehicle, and applicable traffic laws and conventions must be combined to decide the next action the driver will take.

Psychologists have indicated that there are limits to how much information a person can attend. The processing demands on the driver are such that "... 1 in 10 traffic signs are noticed" (Hughs and Cole 1986 p. 389). Still, those authors found that between 30 and 50% of the attention of drivers was being allocated to non-driving-related objects (p. 388).

Perceptual Requirements

Independent of the form or content of a message from the VNA to the driver, it is crucial that the driver be able to pick the message out of the sensory noise found in the driving environment. The message must be sufficiently conspicuous to gain the driver's attention, be processed, and finally, used to support navigation. The human visual system is of most interest for transmitting navigation information. The performance of this system is effected by the amount of non-informative stimulation received by the sensor.

The passenger compartment of an automobile is subject to fluctuating levels of lighting. The illuminance in an automobile may fluctuate over a wide range. Bailey (1982 p. 58) estimates this range to be from 0.0001 millilamberts in a garage or under starlight to 10,000 millilamberts under the midday sun. The human visual system exhibits adaptation to the level of illumination. This adaptation impacts the visual system's ability to detect small symbols (Murch 1985 p. 2).

Carter and Carter (1981) indicate that high conspicuity increases the likelihood of any particular piece of information being attended. Visually encoded VNA information must be visible i.e., have sufficient conspicuity to facilitate its use. Symbol conspicuity is a function of the contrast ratio in the display. Acceptable contrast ratios range from 3:1 through 50:1 with 10:1 being optimal (Murch 1985 p. 3). Murch (p. 5) indicates that contrast ratios of 3:1 can be maintained on avionics CRTs with up to 6500 footcandles ambient illumination while maintaining acceptable display luminance levels. Shoji (1986) indicates that CRTs are also useful under very low levels of illumination.

Competing Technologies

It is possible to present the information on either a directly viewed device or to project it on the vehicle's windshield, a heads up display (HUD). The systems currently available in this country rely on directly viewed display screens mounted within the driver's compartment. Mitsubishi Motors Corporation has tested a LCD-based prototype HUD for passenger car use (Horikiri _et al_. 1986).

Several display technologies could be used to for directly viewed display devices. The most likely are CRT, LCD and LED devices. While all three could support graphic displays, the rugedness, range of luminosity, resolution, and color capability of the CRT indicate it will be predominant for some time (Bailey 1982). The required mounting depth for CRTs limits their positioning within the driver's compartment, but CRT depths are being reduced (Shoji 1986).

Information Requirements

The information actually required to guide a driver through a street network is quite limited. Research, by Benjamin Kuipers (1978), by Streeter (1985, _et al_. 1985) and by Riesbeck (1980), suggests that, at each point in the navigation task, it would be sufficient to indicate to the driver: 1) what action to take next; and 2) when to take it. The overview perspective inherent in a conventional map is not needed to follow a route. Assume that the processing component of the VNA has already selected (or been provided) a route to follow, and that this route has been decomposed into actions to take at recognizable places (Kuipers' view-action pairs). Some sort of warning of an impending action (turn left or right) and an indication of the place to take the action would be adequate. A VNA with this ability would be as handy as a passenger familiar with the route telling the driver the same information. This approach to direction giving closely mimics the way human route expertise is often provided: as needed. The VNA's utility would be greater if it could recognize deviations from a planned route and generate a new sequence of instructions leading from the current position to the destination, with the same facility as a human expert.

Other potentially useful information will vary widely for specific uses of VNAs. The range of this information was indicated above. The result of this diversity of desires may be a proliferation of special purpose databases capable of supporting user's queries. The commercial value to service industries of being listed in "drivers' GISs" is considerable. It alone is apt to ensure that third party venders will supply customized databases for VNAs.

Form of Presentation

The form of information presentation used by a VNA is at the heart of the human interface. This discussion concentrates on using the human visual system (as opposed to the auditory or tactile systems) to give information to the driver. There are several ways in which spatial navigation data might be visually presented. These can be ordered along a contiuum of abstraction from the underlying geographic reality. Different levels of abstraction may require different amounts of effort for the driver to understand the message. One concern is to maintain stimulus-response compatibility. The message to the driver can, by its form, suggest the next action to be taken.

At the most abstract end of the continuum, spatial information could be encoded as verbally, as words, on an alphanumeric display. Instructions such as 'Turn left at the next intersection' could describe navigation procedures. The presentation would be essentially aspatial. This approach requires relatively low display technology but a high degree of sophistication in the spatial data handling subsystem. Reading of alphanumerics is better understood than reading spatially structured (map) displays.

A more pictorially oriented display could be used to indicate the next action to be taken. The Nissan Cue-X HUD system provides an arrow pointing in the direction the driver should turn (Okabayashi and Chiba 1986). This form of message should exhibit good stimulus-response compatibility. Symbols indicating 'prepare to turn left' or 'use the left lane' might be color coded versions of the stronger 'turn left here' type of message. An 'on course' indicator could provide comforting feedback to the driver.

Further along the continuum, a display might provide a simplified schematic view of the route to be followed. Such a custom map might dispense with streets which are not part of the route to be followed. The topological structure of the route, may be emphasized over the planimetry. A position indicating symbol would desirable (perhaps necessary) in such a display. This type of display presents more information than the driver needs at any instant for route following. Subsequently, higher processing demands are placed on the driver. The display device would have to be flexible and support graphics output. The processing subsystem could be relatively unsophisticated; once it has found a route, it need only map stored coordinate data for each of the street segments to be traversed into display device coordinates.

Planimetrically correct map displays of complete street networks are the least abstract display class. They closely mimic the geographic reality, consequently they may require the driver to do more of the navigation work - potentially as much as would a printed street map. The processing capability required is fairly low; display a 'you are here' symbol, possibly a 'destination' and the street segments from the database. There are, of course, questions of scale and area covered, tracking style (north-up vs. heading-up, move the 'you are here' symbol on the street network or the street network under the symbol) and map design (e.g., the use of color, symbol selection, and inclusion and placement of street and place names).

CONCLUSION

My expectation is that the VNA which presents the simplest appearance to the driver will, in the long run, be the most successful. It may also be difficult to market because of its simple appearance. The appearance will belie, and be inversely related to, the underlying data processing system. Both processing capability and database will be highly sophisticated and extremely reliable. The driver will follow simple instructions trusting them to be correct. The VNA must recognize deviations from its instructions and take them in stride.

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