OUALITY ELECTRONIC MAP DISPLAYS FOR APRS MOTOR VEHICLE NAVIGATION

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> "What place would you advise me to visit now?" he asked.
> "The planet Earth," replied the Geographer. "It has a good reputation."
> -- from The Little Prince, by Antoine de Saint-Exupéry, New York, 1943: Harcourt Brace Jovanovich, Publishers

Monitoring Motion and Improving Safety

GPS receivers calculate speed and direction of travel as well as location. Coupled with APRS systems, that motion information opens exciting new applications. Changing traffic conditions can be monitored. Drivers can be alerted about speed zone changes and special traffic regulations about lane utilization and turning at intersections. Even though the electronic map system can and should contain large amounts of data, a properly-designed display system should not distract the driver with so much detail that it becomes a traffic hazard.

Problems with Paper Maps

Large folded paper maps are inconvenient to use at the best of times. In a motor vehicle they are a real traffic hazard. Even maps which are conveniently packaged as a page in an atlas must include much more information than a driver needs to solve any given navigational problem. The golden nugget which the driver needs is lost in a river of irrelevant ink. (See Tufte 1983.)

New Kinds of Maps

The advent of electronic mapping allows us to think of maps in new ways. Paradoxically, electronic maps can be much more complex and data-rich while they display only a minimal amount of information at any one time. When we change from paper maps to electronic displays, we can thereby cross a threshold of radically-improved legibility. The placement of the display is critical.

Integrated Visual Display

The wave of the future is not an external screen mounted precariously off on the passenger side. Such an arrangement takes the driver's attention off the road and interferes with important items like gear shifts, passenger-side airbags and two-meter rigs! Our visual displays should be front and center, fully integrated with fuel, oil pressure and temperature gauges, speedometer, odometer and tachometer. Incidentally, those functions need not be displayed unless they are actually needed. Does the screen need to be cluttered with a fuel gauge when you filled the tank ten minutes ago? Do we really care how fast we are going when stuck in bumper-to-bumper traffic? The speedometer reading normally becomes important only when we approach the legal speed limit. Our navigation system will know where we are and what the speed limit is. After we have set our cruise control, why take up space on the display with speed information?

A well-designed integrated visual display should automatically change the information it displays according to different situations, but the driver should also be able to call up information at will using simple control panel commands.

The best model for future motor vehicle visual displays is the kind used in state-of-art commercial aircraft. The flight deck of a Boeing 777 has five 8-inch square color liquid crystal displays. Two are duplicated and are used by each pilot. One more LCD screen sits half way between both pilots as a shared resource. In addition, a heads-up display uses combiner glass with a sandwiched layer which serves as a mirror for a particular green wavelength. Additional information is projected at that wavelength and focussed at infinity, so the pilots can simultaneously see out the windscreen and capture the green readout. (Craig 1998)

Map Data Sources

Currently most vehicle navigation software used in the United States is based on a detailed, but conceptually primitive, mapping system called TIGER, which gives block-face street data compiled for the US Census Bureau. A "block face" is one side of a street between two intersections or between an intersection and the end of a dead end street. TIGER is an acronym for topologically integrated geographic encoding and referencing system. Maps based on TIGER are reasonably accurate topologically, and provide an excellent source of place name information, including streets and roads (Clarke 1997: 119-120). With some exceptions, streets which are shown connected by the system are actually connected on the ground. Since the block face information includes a range of numbers, the location of any particular address can be designated within a block of its location relative to the nearest intersection. When viewed at large scale, say, 1: 10 000 or larger, the geographical inaccuracies of the TIGER data become evident. Curved streets look straight and distances between any two points on the map are not reliable.

In the United States, geographically-accurate data can be obtained best from the United States Geological Survey (USGS). Recently the USGS has made its 1:24 000 and 1:25 000 topographical maps available on CD-ROMs. The CD-ROMs cost considerably less than the equivalent maps in paper form. Some private companies have begun to release software based on USGS topographical data. The biggest problem with USGS data is that place names, including streets and roads, are poorly represented.

To develop a new kind of electronic map, therefore, we need to begin by integrating the street address place names data of TIGER with the superior geometric accuracy and elevation data from the USGS mapping system. Then we need to enhance the resulting data with information which is important for motor vehicle navigation. We have to collect data on speed limits, on one-way streets, on roadway dimensions and lane designations.

Managing Traffic

Monitoring the motion of a motor vehicle can go considerably beyond tracking its coordinates and tracing that motion on a map. Motion monitoring can be used to help manage traffic congestion. If a GPS receiver is linked with a sophisticated geographic information system (GIS) through APRS, the system in the vehicle can telemeter traffic congestion to other vehicles with no intervention by the drivers when it determines that the vehicle is traveling on an arterial at a speed which is markedly slower than normal.

When properly implemented, the system will be able to tell, for example, that regular southbound lanes on Chicago's Kennedy Expressway are crawling at about 10 MPH just north of the Eisenhower Expressway, but that the express lanes are operating normally. On a snowy morning in downtown Boston, drivers will be warned to avoid using steep Joy Street to climb Beacon Hill. Oregon drivers will learn that part of US Highway 26 has been closed due to mudslide hazard associated with increased volcanic activity on Mount Hood. The navigation system in a pizza delivery car in Fort Worth which is already exceeding the city speed limit will warn its harried driver with a loud audio alarm and visual display that she is fast approaching an active 20 MPH school zone.

Inaccuracy Problems

The system envisioned here presupposes accuracies of both map and navigational measurements which are better than those generally available today. First, the geocoding of the electronic maps should be accurate with a resolution of one meter or less. Such accuracy will allow positive identification of a particular traffic lane on any road. County and municipal engineering staffs generally maintain survey information about road networks under their jurisdictions which are accurate within a few inches (Carpenter 1998). A reasonable goal would be to attain accuracy resolutions of about one decimeter or about four inches for road networks. We need to gather such geographic information for our databases and keep it updated..

Second, navigational accuracy needs to be higher than those achieved by standard civilian GPS receivers. Typical GPS receivers such as the older Magellan Trailblazer XL or the more recent Garmin GPS 12 XL display waypoint definitions using the Universal Transverse Mercator coordinates to a resolution of one meter. Basic GPS should normally be accurate within about 10 meters horizontally and 13 meters vertically, but the US Department of Defense (DOD) has imposed random accuracy degradation, called "selective availability," on civilian users of GPS, resulting in accuracies within about 40 meters horizontally and 50 meters vertically. [1]

Better accuracy can be achieved several ways. First, the DOD has announced that selective availability will be removed as soon as technology is developed to foil enemy use of the system in combat situations. Second, receivers can integrate signals from both the American GPS and the Russian GLONASS satellites (Daly and Misra 1995). Third, internal monitoring of vehicle tire motion and revolutions can supplement GPS navigation with dead-reckoning (French 1995: 284-286). Fourth, GPS calculations can be considerably improved through the use of differential GPS transmitters (Dahl 1993: 157-162), whose precisely known locations can be used to calculate errors in GPS transmissions caused by selective availability and inherent system errors such as variations in the ionosphere and signal multipathing (B. Hofmann-Wellenhof, H. Lichtenegger, and J. Collins 1997: 126-130). Finally, nearby fixed "pseudolites" (Elrod and Dierendonck 1995), or ground-based transmitters which mimic operational navigational satellites can improve accuracies when joining the chorus of the signals transmitted by the GPS satellite constellation.

Map Legibility

Legibility of maps is a cartographer's highest priority. Coupled with the motion-detecting capability of a GPS system, electronic maps need to display only a tiny portion of the information which they contain. A driver navigating the streets of Berkeley electronically can have access to much more detailed information than any paper map can provide without being burdened by unneeded clutter. For example, a Bay Area system can and should include topographic information. Drivers should not be expected to interpret the meaning of elevation contour lines. Rather, those contours can be left undisplayed, but the system can use the information to calculate the grade percentage of a particular road segment.

Place Name Precedence

Take a look at a globe with place names on it. You will very likely be able to find Barrow, Alaska. Now try to find Evanston, Illinois on a globe. According to the last census, Evanston had more than twenty-one times the population of Barrow, but you will not find it on any world

[1] These figures represent one standard deviation. They are actually 10.2 m horizontally and 12.8 m vertically without selective availability and 4 1.1 m horizontally and 5 1.4 m vertically with selective availability. (Parkinson 1994: 48 l-483)

map. Barrow holds the distinction of being the northernmost town in the USA, surrounded by the usually-frozen Chukchi Sea to the west, the Beaufort Sea not very far away to the east, and a lot of tundra to the south. Evanston also sits astride a big body of water, but on a map of the world, there is no room to print "Evanston." The space is probably already occupied by the first "C" in Chicago or the "L" in Lake Michigan.

Place names are important. When they are required on a given map, professional cartographers give them top precedence. It is acceptable to break a road or a river or a grid line or a boundary to make a place name visible, but never the other way around. Applying this classic cartographic principle on a moving electronic map can be tricky. Place names need to move as the map rotates so they are always legible. They must never overlap one another.

Maps produced by the National Geographic Society are good models for the use and placement of place names. Upper and lower case type is the rule. Only the largest regional features sport all capital letters. The reason is that upper and lower case letters, especially when they have to be small, are easier to read. When was the last time you read a novel printed completely in capital letters?

Speed-Driven Scaling

When planning electronic maps to be used in motor vehicles, we need to consider carefully which place names are needed for a given navigational job. For a vehicle traveling at highway speeds, only place name information which is relevant to upcoming intersections or exits needs to be included. As the vehicle accelerates, the scale of the displayed map should decrease, covering a wider area, and it should show , fewer place names. Conversely, as the vehicle slows down upon entering a residential or business district, the map scale should increase, showing a smaller area with more detail, including more place names.

Color Contrast Legibility

Some years ago, AEA built the MM-3 keyer, called The MorseMachine. The keyer was a well-engineered product which unfortunately is no longer in production. The designers put a command summary chart on the outside of The MorseMachine which includes good and bad color contrasts. The two worst are black type on a red background and black on green. Black on light blue is a bit better. Black on white is much better and black type on a yellow background gives the very best color contrast legibility. Highway caution signs are painted black on yellow for a very good reason.

When we design a visual display system for mobile electronic maps, we can and should include color contrasts. City streets could be color-coded by a smart mapping system based on whether the vehicle can turn onto it from a particular approach. The display in a vehicle heading north and approaching a one-way street set up for easterly travel might show the eastern street segment in yellow to show that a right turn there is possible, while the western street segment could be colored gray to indicate that a left turn there is not acceptable. Similarly, a very narrow crossing street might be colored gray in both directions for the system in a pickup truck which is pulling a long mobile home, indicating that the intersection is too tight for a wide-turning vehicle.

Less is More

To summarize, in order to produce quality electronic map displays for APRS motor vehicle navigation, we need to accomplish these steps:

-- Take advantage of the motion-monitoring capabilities of GPS to share relevant traffic conditions automatically with others in an APRS network.

-- Replace peripheral displays with comprehensive central displays.

-- Increase the accuracy of navigation hardware to one meter or less.

-- Increase the accuracy of geographic information databases to one decimeter or less.

-- Make displays more legible by using upper and lower case place names and carefully-designed color coding.

-- Supplement critical visual warnings with audio alarms.

-- Restrict to a bare minimum the amount of information displayed to that which is absolutely necessary for navigation.

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