DECOMPOSING THE MAP: USING HEAD-UP DISPLAY FOR VEHICLE NAVIGATION

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ABSTRACT

The mobility of people is ever increasing, with a sense of being able to travel to any destination they wish. Utilising the GPS and computer technology created for the use within vehicles for guidance purposes allows people to do this, without the thought of Where am I? or Where do I go now? These systems warrant the need to look at the display for excessive periods of time, causing drivers to remove their vision from the road. A possible solution could be the introduction of military aviation technology, specifically Head-Up Display (HUD), to compliment the current system, by presenting modified navigational information on the windscreen.

This paper looks at background theory associated with the technology being investigated and its proposed implementation. It then provides an overview of the information obtained to date. Problems that may occur with such an implementation are discussed and further research to be undertaken outlined.

INTRODUCTION

Since the introduction of the first motor vehicle, crafted independently by Germany’s Gottlieb Daimler and Carl Benz in 1886 (Mercedes-Benz, 2003), there has been a general improvement in personal mobility. The motor vehicle allowed people to travel to destinations of choice, and they usually navigated there with the aid of a map or map book. Over the years, navigation tools improved as new cartographic techniques were developed and employed. During the 1970s, “… efforts to develop in-vehicle route guidance systems were initiated” (Adler and Blue, 1998, p. 158) with the first project being the Electronic Route Guidance System (ERGS), funded by the U.S. Federal Highway Administration, “…aimed at providing drivers with in-vehicle directional guidance” (Adler and Blue, 1998, p. 158). Maps migrated towards electronic delivery in the 1980s, mainly due to improvements in computer technology (Adler and Blue, 1998), allowing for the growth of electronic vehicle navigation. Recently, In-Car Navigation systems have allowed drivers to maintain their mobility, but only with the assistance of improved navigational and locational (electronic) methods.

Current display methods for vehicle navigation systems require the driver to look towards the dash for maps and navigational instructions, looking away from the road. This then reduces the driver’s awareness of the road and also degrades the driver’s ability to scan the external environment for obstacles in their path. By incorporating technology that presents the graphics on the windscreen, Head-Up Display (HUD), navigable instructions can be provided to the user to view whilst driving and at the same time maintain their vision with the outside driving environment.

Simply presenting the same information shown on the current In-Vehicle Navigation displays as a HUD would distract the driver, as they would not be able to concurrently view the road and the projected information at the same time, causing them to focus more attention on the navigation display than on the road. To compensate for this, the use of a HUD, designed to facilitate the delivery of appropriate information could aid in the removal of the negative aspect of current In-Vehicle Navigation systems – the driver’s sight being directed away from the road towards dashboard-mounted instrument panels. By modifying the cartographic information being presented to the driver, a navigation system that can be more efficiently used whilst the vehicle is in motion could be possible.

Developing a HUD that provides navigational information in the form of a modified map would allow for vehicle navigation instructions to be viewed at the same time as looking at the road. This would allow drivers to determine their current location, by simply shifting their vision from one part of the windscreen to another and then back to the road without a need to move their focus point too far. With this concept in mind, a research programme has begun to explore the potential of such a system. The following section provides an overview of the programme.

RESEARCH PROJECT

The research project is investigating the use of a variety of technologies from military applications, both land and aviation based segments, as well as technology created for civilian purposes. More specifically, it focuses on the incorporation of Head-Up Display (HUD) in automobiles. This project looks at the prospect of exploiting HUD technology to display navigational in a vehicle to support an In-Vehicle Navigation system.

The research project will look at the feasibility of such a system and how it would operate to provide maps and
geospatial information. It will have as its focus to develop guidelines for the design of navigational information for use in a HUD. This involves assessing current guidelines used for In-Vehicle Navigation displays and determining how appropriate these are when employed with a HUD. Current guidelines will most likely need amendment, as not all of the guideline elements may be applicable unchanged. A set of guidelines will be proposed and a ‘proof-of-concept; prototype developed to evaluate how an effective in-vehicle system might be delivered.

Developing guidelines is a major component of the project, however, development of an interface is an essential component, as the Human-Machine Interface (HMI) will provide the user with the main information input/output tool. An appropriate interface and a complementary delivery system able to enhance usability will be designed and tested.

BACKGROUND THEORY

This section covers information attained from literature research and looks at the systems that are to be incorporated – Vehicle Navigation and Head-Up Displays. It also looks at Augmented Reality and its association with the proposed incorporated system, as well how the technology will be incorporated.

Vehicle Navigation

The basic modules of an in-vehicle navigation system include various computer-based components necessary for calculating and displaying the users position within the vehicle. These modules include: Digital Map Database; Positioning; Map Matching; Route-Planning; Route Guidance; Human-Machine Interface; and Wireless Communication devices (Zhao, 1997) (Refer to Figure 1). Incorporating all these modules assists the user in following a pre-planned route that is selected before actual vehicle movement occurs. The system determines the vehicle location, and using the Human-Machine Interface (HMI), a map or other appropriate information can be displayed. Whilst in motion the system is able to provide the driver with instructional assistance (navigation information), guiding them to their desired destination. This route is then closely monitored by the system, allowing the driver to be alerted if they are travelling off-course. All components listed in Figure 1, with the exception of the Wireless Communication device, are essential components for the in-vehicle navigation system to work effectively. These modules allow the vehicle driver to navigate themselves to their selected destination without the need to open a street directory or read a map.

![Figure 1: Basic modules (building blocks) for a location and navigation system (Redrawn from Zhao, 1997, p. 7).](image)

Head-Up Display

HUD technology originated in military aviation applications and allowed for navigational, armament and vehicle information to be displayed upon an aircraft’s windscreen directly in the pilot’s forward field of view (Newman, 1995; Defence Science and Technology Organisation, 2003). The application of this method of information provision allowed pilots to maintain their forward field of view, as well as see aircraft information. This resulted in an improvement in pilot efficiency (Newman, 1995). This allowed for an alternative means for information display, allowing critical information to be relayed in-flight by projecting it onto the windscreen. This system was beneficial to pilots, as they no longer needed to look below their line of sight to read specific instruments critical to their mission (Newman, 1995; Defence Science and Technology Organisation, 2003; General Motors Corporation, 2003).

Since the late 1960s, HUD technology has been seen as a possible solution for improving the negative aspects associated with complex in-dash displays (Evans et al., 1989; Zhao, 1997). Using this technology, information can be presented to the vehicle driver without their need to move their eyes from the road, and, as a result, improving driver awareness (Todoriki et al., 1994; Troxell et al., 1997). By projecting graphics in front of the driver’s direct line of sight, the concurrent display of computer generated information with information from the outside world can be combined (Evans et al., 1989; Newman, 1995; Hooey and Gore, 1998). This image projected onto the windscreen allows drivers to maintain their attention on the road by presenting the information within their forward field of view. A reduction in the eye-off-road time is achieved, allowing for increased awareness of what is happening on the road (General Motors Corporation, 2003).
As the “… HUD is an electro-optical device that presents both static and dynamic symbology and/or graphics in the driver’s forward field of view (FOV)” (Hooey and Gore, 1998, p. 3), the basic principles of optics are employed. The virtual image presented to the driver is created by a projector or display source and presents the information to the driver by superimposing the image “… over some portion of the external driving scene” (Hooey and Gore, 1998, p. 4). Using a series of lenses and mirrors, the optical image is projected onto a combining surface which allows the reflection of the HUD image into the drivers forward FOV (Hooey and Gore, 1998). This is illustrated in Figure 2.

![Figure 2: A simple HUD consisting of the four elements discussed by Hooey and Gore (1998) (Adapted from Merryweather, 1990, p. 4/4)](image)

Current vehicle navigation systems using Head-Down Displays (HDDs) require the driver to remove their vision from the road, thus “… when receiving related information provided by the HDD, drivers need to keep their eyes off the road, which would seriously influence driving safety” (Liu, 2003, p. 157). As an alternative, the use of a HUD to present navigational information can reduce the time the eyes are taken off the road, allowing “… information to be "floated" on the windshield near the driver's natural line of sight … eliminating the need to re-focus down onto a dashboard display” (General Motors Corporation, 2003).

**Augmented Reality**

According to Azuma et al. (2001), AR dates back to Ivan Sutherland’s work during the 1960s, developing a see-through Head-Mounted Display to present 3D graphics. This introduced an alternate way to present computer graphics within the real world. AR changed the way some people thought about and viewed the world (Bonsor, 2001), allowing for the enrichment of “… a users real environment by adding spatially aligned virtual objects” (Regenbrecht and Wagner, 2002).

With the aim of AR to present computer generated graphics along with the real world, making them blend and feel associated with each other, it is capable of providing differing possibilities and impressions of the users view (Tatham, 1999; Regenbrecht and Wagner, 2002; Vallino, 2002). The computer-generated graphics presented as part of the AR are overlaid on top of the real world, supplementing the environment with additional information that can be processed by the user. As AR is formed on top of the real world, the information available to the user for processing is increased, allowing them to also view the real world at the same moment in time.

According to Azuma et al. (2001, p. 34), “Milgram defined a continuum of real-to-virtual environments, in which AR is one part of the general area of mixed reality” (Refer to Figure 3). AR lies towards the “Real environment” as it supplements the real scene with information, whereas the “Virtual environment” consists of a completely computer generated environment.

![Figure 3: Milgram's reality-virtuality continuum (Redrawn from Azuma et al., 2001, Adapted from Milgram and Kishino, 1994)](image)

With the development of Geographical Information Systems (GIS) and Geographical Visualization (GeoViz) techniques, it was predicted that the use of Augmented Reality (AR) could be used with associated wearable computing technology for the purposes of field-based Geographic Information System(s) (Pundt and Brinkkötter-Runde, 2000). According to Pundt and Brinkkötter-Runde (2000, pp. 53-54), AR is described as being “…a combination of real scene viewed by the user and a virtual scene generated by the computer”. Therefore, using the wearable computing device, real world with support information can be supplemented for specific GIS applications that are field-based. By using AR within a vehicle (installing the wearable computer) and presenting information with a HUD (via a windscreen
projection), the real world can be supplemented with augmented information, providing formidable information about the users location which would be beneficial for an in-vehicle navigation system. This system would allow the user to monitor external information that may affect their progress, such as traffic density and delays. Figure 4 shows an example of how AR can be used within the vehicle developed by Siemens VDO. The driver’s view is populated with computer graphics, fusing the real world with computer generated images to form a singular display (Siemens, 2004). In this example, the path to be taken to continue along the pre-determined route is presented to the driver to be followed so as to be able to reach the desired destination (as shown by the yellow line overlayed on the road and the vehicles in the driving environment).

![Figure 4: Siemens VDO Augmented Reality - fusing real world and computer images together in one display (Siemens, 2004).](image)

The use of AR to add additional information to the world the user is viewing, creates a mixed reality, enticing the user to process the information with what they would normally see. Using varying display technologies, including Head-Mounted Displays (HMDs) and Head-Up Displays (HUDs), AR is possible. The display technology allows the user to be able to view the computer-generated images overlayed on top of the real world environment, allowing additional information to be integrated to increase situational awareness (Scott-Young, 2003).

The real-world environment the view is constantly changing when a vehicle is moving. The driver scans the environment to be aware of anything that could demand the vehicle direction, speed or location to be changed. Providing AR information would not require the viewing direction to be known, as the information provided to the user would not need to be shifted with head movements. Instead, the information display would remain in the same location, allowing the user to scan the outside environment without the AR information following their head movements, which could cause distraction. Implementing AR methods for displaying navigational information with HUD technology allows the presentation of geospatial information to the driver.

### Incorporating the technology

Incorporating the technologies of Vehicle Navigation, Head-Up Displays and Augmented Reality is a challenging task due to the individual needs of each system and their associated drawbacks. Linking available technologies can provide an invaluable tool for presenting navigational instructions to drivers within their viewing area, but, simply ‘dropping’ a map into the projected area is not enough. Display methods used in current in-vehicle navigation systems are inappropriate for ‘best-practice’ use. It is argued by many (Todoriki et al., 1994; Ward et al., 1994; Zhao, 1997; Wolffsohn et al., 1998; Burnett, 2000) that the incorporation of HUD with existing Vehicle Navigation systems can benefit users in such a way that they improve driver awareness and driving ability. Using a HUD system allows the driver to maintain their vision of the road, but also allows them to navigate and to determine their location whilst mobile.

The implementation of HUD with vehicle navigation systems needs an investigation of all aspects of HUD technology and the associated relationships with vehicle drivers due to the provision of driver-critical information using a HUD whilst the vehicle is in motion (Evans et al., 1989; Ward et al., 1994; Wolffsohn et al., 1998; Burnett, 2000; Lee, 2002). This research is vital in the step for incorporating HUD within vehicles, as it determines how efficient and effective it will be for the user to read projected information.

The HUD needs to be designed specifically for the type and amount of symbols/content presented. “More information should be added only if it significantly improves driver performance, awareness or safety” (Wolffsohn et al., 1996; University of Melbourne, 1999). Therefore, by developing guidelines that govern the amount and type of information...
displayed, the amount of distractive information being presented can be limited, and hopefully a system can be established that effectively presents navigational instructions to the driver via a windscreen projection. These guidelines can be used to govern how information is displayed, where it is placed and when it should be presented.

The incorporation of HUD within vehicles can enhance the display of critical information, warning/notifying drivers of system errors or required directional changes. This system therefore could assist driving awareness. Nevertheless, the negative aspects of this technology must also be explored, to ensure the design of a safe usable system. According to Wickens et al. (1998, p.E32-2), the “...presentation of any information head up ... invites the possibility that HUD imagery may obscure the view of critical hazards”. This as a result can lead to “... the compellingness of the head-up display ... (to) invite the unwanted and total capture of the ... (drivers) attention ...” (Wickens et al., 1998, p.E32-3). This leads to non-visual awareness of the road and hazards in the vehicles forward path, and the “... withdrawal of attention manifests itself in both degraded vehicle control and degraded object and event detection” (Tijerina, 2001, p.2).

By investigating and developing guidelines, as well as looking at alternate ways of displaying information to the user, we will be able to assess and determine if the use of HUD technology with vehicle navigation systems are a viable option for enhancing navigation tasks. The actual provision of such a device that includes HUD and In-Car Navigation will depend upon the guidelines developed for displaying the information within the driver’s forward field of view. They will be tested and evaluated so as to better understand the overall effectiveness and usability of such a system. The incorporation of HUD within vehicles cannot be considered issue free, as it is believed that they present considerable performance and safety issues (Hooye and Gore, 1998). Therefore, we need to investigate the effects such a system can have on drivers and their situational/spatial awareness.

WHAT IS SO FAR KNOWN

Implications of using Head-Up Displays to navigate users

Todoriki et al. (1994, p. 480) believe “... that HUDs can serve as a good visual interface for drivers because they allow shorter recognition time and easier eye accommodation”. Even though this may be the case, the use of HUD can create some problems with their use. This may affect different drivers in different ways, especially those first time users, and older users whose mental processing skills are deteriorating. It is also stated by Liu (2000, pp. 166-167) that “Previous studies have shown that older drivers experience more attention demand, and have poorer perceptual/cognitive abilities”, thus “... all information should be kept as simple as possible”. To solve this problem of attentional demand, the use of multi-modal displays “...appears to go some way significantly toward improving ... older drivers’ information processing capabilities” (Liu, 2000, p. 167). These multi-modal displays incorporate both visual and audible information to the driver. However, the provision of audible information can, in some circumstances, be too informing, resulting in drivers having difficulty in determining which pieces of information to remember, and when to use that information (Liu, 2000).

HUDs when used in automobiles allows the elimination of “... the need to rotate the eyes between the panel and the space where a possible target may show up” (Lee, 2002, p. 2), thus reducing the reaction time needed to respond to events requiring the driver to change direction/movement of the vehicle. According to Liu (2003, p. 157), “HUD can reduce the frequency and duration of the driver’s eyes-off-the-road by projecting the required information in front of the driver”. These multi-modal displays incorporate both visual and audible information to the driver. However, the provision of audible information can, in some circumstances, be too informing, resulting in drivers having difficulty in determining which pieces of information to remember, and when to use that information (Liu, 2000).

Hooye and Gore (1998, p. 4), believe that HUDs have “... the potential to improve driving performance and driver safety in a variety of ways”. This is supported by several authors including Wolfsohn et al. (1996), Troxell et al. (1997), University of Melbourne (1999), General Motors Corporation (2003), Liu (2003) and Scott-Young (2003). The HUD in front of the driver’s direct line of sight, “... allows the driver to sample both vehicle and driving information without the same accommodative shift required by conventional instrument clusters or HDDs”, allowing a reduction in “...accommodation demands when shifting gaze between the visual scene and in-vehicle displays” (Hooye and Gore, 1998, p. 4). It is also believed that HUDs also provide the possibility of reducing the eye-off-road time, as the information is presented in their forward FOV, within the direct line of sight of the driver, which in effect removes the need for the driver to look at the dashboard, hence reducing eye-off-road time. Several authors commenting on this relationship between HUDs and reduced eye-off-road time of drivers all believe that it is an effective way to negate looking at the dashboard while the vehicle is in motion (Evans et al., 1989; Azuma et al., 1994; Hooye and Gore, 1998; Lind et al., 1999; Burnett, 2000; Ross and Burnett, 2001; Belloti et al., 2002; Lee, 2002; Siemens - Johannes Winterhagen, 2002; General Motors Corporation, 2003; Liu, 2003). These authors address the possibility of using HUD to reduce the effect of eye-off-road time in order to improve driver safety, situational awareness, and information delivery.

Another advantage that HUDs has is that those with “... reduced accommodative capabilities”, particularly older drivers who have difficulty in deciphering information from current navigation screens that are fairly small in size, will benefit as the optical image is projected at some “... distance of 2-3 m” from the drivers seat (Hooye and Gore, 1998, p. 4). As the image is projected some distance in front of the vehicle, it can allow for increased identification, as well as improved reaction timing to events that occur on the upcoming section of the road they are travelling upon.
As “The intended purpose of Head Up Displays (HUDs) is to allow the user to continue attending to the outside scene whilst taking in information more quickly from a display” (Burnett, 2000, p. 3.1.7), it is quite appropriate that they can present navigational instructions to the driver to improve safety, situational awareness, and information delivery. As stated by the General Motors Corporation (2003), “For drivers, HUDs increase driver awareness - and reduce(s) “eyes-off-road” time that could lead to an accident”, however it is also extremely important to consider the effects that such a system may have on drivers. According to Lee (2002, p. 2), “It is important to realise that HUDs may affect attention in different driver populations uniquely”, causing situational problems that may endanger all occupants on the road.

The use of “HUD in automobiles likely requires further investigation as both the content and context of the design can place drivers at risk … for making an error that could have tragic consequences” (Lee, 2002, pp. 3-4). By looking at driver distraction, the feasibility of HUD use with in-vehicle navigation systems can be determined.

**Driver Distraction**

The introduction of the In-Car Navigation system has seen an improvement in navigation support, allowing users to view information like current location electronically whilst mobile. Using mobile computing power and electronic displays, users are provided with locational information relevant to the road network they travel upon, and display their position on an electronic map within the display device. The location of the current display methods for in-vehicle navigational instruments is below the direct line of sight of the driver, within the centre console of the vehicle (refer to Figure 5). This location then reduces the time spent looking ahead at the road, therefore, the primary task of driving the vehicle is compromised. Ross and Burnett (2001, p. 668), noted the results of Burnett and Joyner (1997), in which they state that users “…took longer to complete a route and spent less time looking towards the road ahead and mirrors”. The time looking straight ahead is greatly reduced, which is a negative element with current methods of display and is also commented upon by Todoriki et al., (1994) and Belloti et al. (2002). As a result alternative displays have been suggested, with various authors (Todoriki et al., 1994; Ward et al., 1994; Zhao, 1997; Wolffsohn et al., 1998; Burnett, 2000) suggesting the incorporation of HUDs within current vehicle navigation systems to display navigation information to the user. All suggest that the use of HUD can benefit users of such systems as they can improve driver abilities and their awareness on the road. Using a HUD system allows the driver to maintain their vision of the road, but also allow them to navigate and to determine their location whilst moving.

**Figure 5: Navigation display location and direct line of sight.**

There are various concerns with the introduction of HUD technology within an automotive vehicle, all of which may affect the task of driving the vehicle to its required destination. The following are some major concerns when using a HUD linked with an in-vehicle navigation system.

- **Overwhelming feeling** – The HUD may unwillingly invite the user to pay more attention to it rather than the road, and thus impact the driver’s performance on the driving task (Hooey and Gore, 1998).

- **Drivers with long reaction times may take longer again to respond** – As the HUD is being presented in the forward field of view, users who take longer to react to certain events, may in fact take even longer to respond to a situation (Ward et al., 1995; Hooey and Gore, 1998).

- **Scanning Patterns** – The user’s normal methods of scanning the driving scene for potential dangers could be changed due to the display being presented into the driver’s line of sight (Burnett, 2000).

- **Cognitive/Attentional Tunnelling** – As the visual/spatial attention of the driver cannot focus on two tasks/objects at any one time, serious attentional constraints are placed upon the driver’s processing capabilities of both HUD and external information simultaneously (McCann et al., 1993).

- **Background Scene complexity** – As the environment in which the vehicle travels in is constantly changing and moving at various speeds, the cognitive tunnelling effect becomes more of a problem as the cognitive processes of the driver are increased.

- **Cognitive Processing** – Using a HUD could provide the driver with insecurity which could result in an increased cognitive load, disturbing other tasks during navigating the vehicle (Lee, 2002). This could result in the possibility
of missing events that may happen on the road, which may result in making an error that may lead to unfortunate consequences (Hooey and Gore, 1998).

- Displaying too much information – Cluttering the screen is a major concern when incorporating HUD technology within a vehicle, as there is a possibility that objects could be missed due to the image obscuring the view due to a reduction in transparency of the display. “Every information element shown on a HUD must serve a purpose and lead to improved performance” (Newman, 1995, p. 155).

- Driver Interaction Levels – Whilst driving the vehicle, interaction with the system should be kept to a minimum so as to not distract the driver whilst controlling the vehicle.

When using a HUD to present navigation information to the driver of the vehicle, then it is essential that they are not distracted in any way. Careful design is required when implementing HUD technology within the vehicle to compensate and ensure that driver awareness is never compromised. By making certain that:

- the display does not interfere with the driving task;
- cognitive processing is not excessive in that drivers cannot decipher information;
- no information overlaps or clutters the display; and
- the system interaction levels are not so high that it will distract the driver,

then the system will allow drivers to appropriately concentrate on the outside scene and detect obstacles and events that require evasive actions. “Lack of attention to the road and distraction are already major contributing factors in many road accidents, so systems which have the potential to add to this problem must be carefully designed” (Burnett, 2000, p. 3.1.2).

**RESEARCH PROGRAMME IMPLEMENTATION**

Investigation into the possible associated problems and effects of using HUD technology with In-Vehicle Navigation systems has been examined. The next step is to look at the associated guidelines with current navigation systems, and determining their appropriateness for use with a proposed integrated HUD system. This involves the investigation into which guidelines used for the design of current navigational information presentation will be applicable for use with HUDs. New guidelines will need to be developed, whilst some will need modification to suit the new display type (HUD), however all need to be sufficient to support the presentation of navigational information on the windsreen whilst the vehicle is moving.

To determine and understand if the guidelines developed are sufficient, the next step will be to test the guidelines and determine their relative importance. Using the guidelines developed, navigational information presentation basics can be established. In order to do this it will be necessary to design and develop a proof-of-concept model, which will allow for the visualization of the information being presented by the system, and also to ascertain how effective the guidelines developed actually are.

Findings from testing will assist in deciphering the appropriateness of HUD technology implementation with in-vehicle navigation systems, and aid in understanding the feasibility of introducing such a system. Analysing these results determine if the developed guidelines are sufficient for displaying navigation information. Guidelines that are useful and require no modification, which ones require modification and which ones need further development, will be determined from this process.

After the proof-of-concept model has been evaluated, it will be adapted to include the guidelines established. Then recommendations can be made to implement workable standards allowing for implementing the technology into vehicles.

**CONCLUSION**

The incorporation of HUD technology with In-Vehicle Navigation offers the prospect for negating the negative affects associated with current display methods for electronic navigational guidance. Using this technology can improve driver awareness due to the fact that drivers will no longer need to look below the visionary line of sight of the vehicle, and present navigational information in the form of a modified map on the windsreen.

Presenting any information on a windsreen whilst the vehicle is in motion has both positive and negative aspects,. However, the location of the screen and screen components is seen as a big factor in determining if these facets will affect the primary task of driving. Displaying the image in the middle of the screen will cause distraction for the driver, as they need to differentiate between what is on the windsreen and what is in fact actually a real object on the road. An optimal position needs to be determined for projected information display to allow for concurrent driving and information access.
Using current guidelines from current In-Vehicle Navigation systems and modifying them for use with HUD technology can improve the driving and navigation task. These guidelines will guide a cartographic design for windsreen-presented navigational information. Testing is needed to determine if this incorporation of HUD and in-vehicle navigation systems is feasible.

REFERENCES:


