Second Life Prototyping of Augmented Automobile Navigation Assistance

Kar-Hai Chu, Samuel R. H. Joseph

Abstract— **The automobile industry has produced many cars with new features over the past decade. However, the interaction between the driver and the car has not changed significantly. The information being delivered – both in quantity and method – from the car to the driver has not seen the same improvements as there have been "under the hood." This paper proposes immersing the driver inside an additional layer of traffic and navigation data, and presenting that data to the driver by embedding display systems into the automobile windows and mirrors. Furthermore, we present a new technique for testing prototypes of such systems; an alternative to custom simulators or cars retrofitted with elaborate testing components. Our method of using the online virtual world Second Life to conduct driving simulations has the advantages of faster development time, lower costs, and simpler setups than many of the alternatives.**

I. Introduction

Automobile companies have been quick to take advantage of advances in information and communication technology (ICT). Global Positioning System (GPS) receivers depend on satellites to help drivers navigate, while other commercial products such as GM's OnStar utilize cellular technology to support automatic

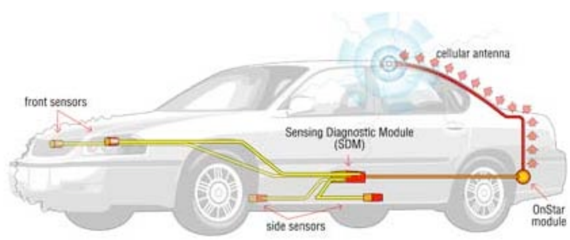

Fig. 1. GM's OnStar Technology.

communication between car and call center to fix problems with the vehicle and provide support in an emergency[1]. However, few automobile systems have taken advantage of breakthroughs in other technology-focused fields. Research in human-computer interaction (HCI) has transformed personal computing, while augmented reality (AR) has the potential to radically change many different technology related fields. In this paper we describe how these technologies could be used to support car drivers through controlled information distribution. We propose an automobile heads-up display (HUD) integrated with a connected network of vehicles to improve awareness in driving and navigating. We will also present a new method of testing and evaluating our concept design.

A. A Scenario

One storyboard scenario is driving to a location for the first time. "Jane" will need to travel along suburban roads, city streets, and a major freeway to reach her destination. Jane's GPS system has already plotted a path, so an illuminated directional arrow appears in the car's HUD. As Jane enters the freeway, an accident has just occurred ahead, blocking off all but one lane and slowing traffic down. Almost instantaneously, new information appears in the car's HUD. The estimated time under the original arrow (which is pointing straight ahead along the freeway) blinks rapidly in red and now reads "110 minutes." A second arrow has also appeared; this new arrow is pointing away from the freeway, toward the next exit. Underneath the new

Fig. 2. An A-HUD mockup. A driver is looking straight ahead and seeing navigation directions based on traffic.

arrow is another time estimate, reading "72 minutes." Jane follows the new arrow to the exit; different signs continue to be augmented to show the path that Jane needs to follow to reach her destination.

Manuscript received May 30, 2008.

Kar-Hai Chu is with the Information and Computer Sciences Department, University of Hawaii at Manoa, Honolulu, HI 96822 USA (e-mail: karhai@hawaii.edu).

Samuel R. H. Joseph is with the Information and Computer Sciences Department, University of Hawaii at Manoa, Honolulu, HI 96822 USA (e-mail: srjoseph@hawaii.edu).

[1] http://www.onstar.com

Several of the technologies mentioned in the previous scenario are commercially available. However, the means by which they are integrated along with new technologies creates a system that offers much more than today's devices. For example, GPS units can provide step-by-step instructions on how to travel from one location to another, but they are not seamlessly integrated with a HUD. Similarly, there are several different methods for traffic monitoring, but as of this writing, only the Dash Express[2] uses wireless broadband to collect real-time driving information from other vehicles. Some details of the different components of the system are discussed below, but a more comprehensive description, including potential applications, can be found in the authors' technical report [12].

II. System Overview

The Automobile Heads Up Display (A-HUD) is a combination of developments in ICT, specifically within the fields of HCI and AR. The A-HUD attempts to advance augmented reality usage beyond those used in aircraft simulations and supplement many of the information gauges inside cars.

A. HUD

Fig. 3. The HUD from a BMW.

Traditionally, automobile digital information screens refer to either the display directly in front of the driver, or a smaller supplemental screen in the center of the dashboard. They can give drivers an assortment of information; usually the data is simple, limited to gauges for speed, gas remaining, directional orientation, etc. However, as cars become more computerized, more information has been made available to the driver. Engine health, tire pressure, and navigation are among the plethora of information that is at the driver's disposal.

[2] http://www.dash.net

Fig. 4. A driver shifting his sight to use a GPS navigator.

In recent years, HUD's have been incorporated into more cars. Popular in airplanes, both real and simulated, HUD's provide information to the driver (or pilot) without forcing them to shift their line of sight. HUD's are not a new concept in cars, having been seen as early as 1988[3]. However in the past 20 years, advances in technology have allowed more information to be displayed, and in considerably better quality. Today, several different car companies - including BMW, Lexus, and GM to name a few - have built HUD's into their vehicles. For cars without built-in HUD's, one can purchase 3rd party systems that can be installed to perform similar tasks.[4]

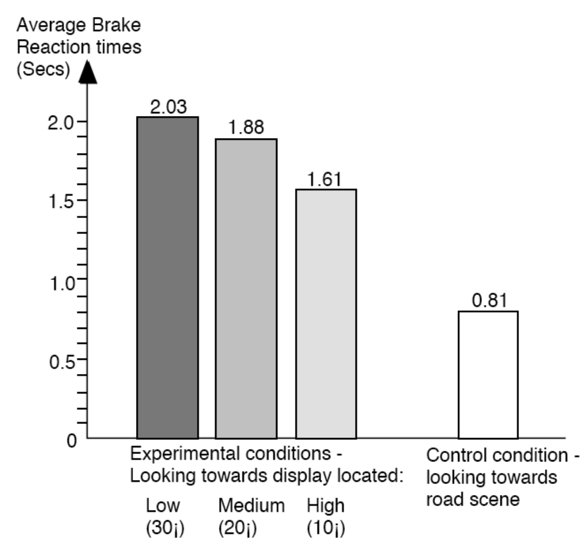

Fig. 5. Average brake reaction time when viewing navigation display in different positions [4].

HUD's are an obvious choice to use as an interactive interface inside cars, although there are some safety concerns that should be addressed. Perceptual tunneling,

[3] http://www.oldsclub.org/History/PaceCars/IndyOldsPaceCars.htm
[4] http://www.gtop-tech.com/index.asp?pid=309

cognitive overload and disruption, focal distance, and obscuring road information are all potential risks for the driver and require additional research [18][19]. However, there is also much evidence of their benefits. Their location is in the driver's direct line of sight and does not require the driver to move their head. Studies have shown that HUD's increase driver performance [6] while non-HUD navigation displays can result in much slower reaction times [5][7]. The use of HUD's inside automobiles has opened up various possibilities for research [8][9].

B. *Putting it together*

Today's car HUD's primarily display their data on the driver side windshield. The amount of information available to the driver is limited to systems within the car, e.g. speed, gear, turn signal indicators, etc. One major reason for this is that as a driver's cognitive load increases, it severely impacts their response time [2]. The A-HUD expands upon traditional HUD's in two major characteristics. First, it will make available information from the outside world. The system will take advantage of its high-speed wireless connection to retrieve real-time data about other cars, road and traffic conditions, navigation, etc. This information can better inform the driver the best way to reach their destination. This approach can integrate not only all of the systems within the car, but also combine it with outside data to provide a clearer picture of the roads to the driver.

The second improvement is the use of the windshield as the HUD. Information will not reside in a small area immediately in front of the driver; instead, we intend to utilize all of the windshields and windows to display information to the driver. With the information being received in the method mentioned above, there needs to be a way to process and deliver it in an organized and understandable manner. We do not want to overload the driver with an excess of raw information, but rather specific data organized to exactly what the driver needs, when they need it.

A head-tracking device will constantly monitor where the driver is facing. Based on the orientation of the driver's head, the system will project information in the windshield HUD wherever they are looking. A driver might see their speed and gas while they are looking ahead on the road, but if they turn to look for road signs, additional information such as traffic conditions or navigation data can be overlaid on the highlighted sign that they are facing, whether on another part of the windshield, a side window, or the rear window. This keeps information limited to only what the driver needs, and when they need it. Both recommended changes, the increased displayable area and extra information, would be seamlessly integrated in such a way that they will not significantly increase the driver's cognitive load. In our introduction scenario, the registration and highlighting of a road sign is an example of adding a minimal amount of data for the driver to process while still providing valuable information.

There are other similar projects that propose using large scale HUD's for driver information [10]. However, many details still need to be worked out to make use of the entire windshield area. AR can be implemented without full-scale use of a windshield HUD, for both data gathering and research into different prototypes. There is research [11] that not only discusses this gap and how to bridge current technology to future potentials, but also how persons other than the driver can benefit from these systems.

III. RELATED WORK AND APPLICATIONS

One straightforward application for A-HUD is traffic monitoring. Real-time information is expected to reach over 83 million drivers by 2012[5]. Current traffic monitoring devices include FM stations, satellite radio, road sensors, and traffic message channel (TMC). TMC is a popular choice inside GPS receivers. Its signals are sent via FM that cannot normally be picked up by standard car radios. Data in the United States is collected and broadcasted by companies such as Inrix, an aggregator of traffic information. In many cases, the data is integrated into a GPS receiver to help drivers find alternate routes when there are traffic congestions.

The major sources of traffic information come from a combination of traffic reports, road sensors, and more recently, mobile phones and fleet vehicles equipped with GPS. However, even when combining multiple sources of information, the amount of coverage that traffic monitors offer is still very limited. Two major companies in the United States with GPS receivers that integrate traffic monitoring are Magellan and Garmin. As of this writing, Magellan provides traffic coverage for 50 cities in North America[6]; Garmin, through XM NavTraffic, offers reporting in 78 cities[7]. However, even those numbers can be deceiving; Coverage in most of those cities is usually very sparse, and in some cases restricted to only a few major highways. This is not a North American problem; Traffic monitors have similar limitations in Europe as well. The difficulty appears to that there are a limited number of road sensors that can provide accurate information and installing more is costly and time-consuming.

There have been different attempts at alternate sources of information. IntelliOne has developed a system that tracks users via their mobile phones[8]. TomTom[9] is a navigation

[5] http://www.gpsbusinessnews.com/index.php?action=article&numero=543
[6] http://www.magellangps.com/products/traffic_service.asp
[7] http://www.xmradio.com/navtraffic/market_coverage.xmc
[8] http://www.intellione.com
[9] http://www.tomtom.com

device that has released a new version called High Definition Traffic. The device itself, called "TomTom One XL HD Traffic," claims to cover 10 times more roads than information sent via FM. One of the innovations incorporated into the new receiver is TomTom's collaboration with Vodafone. This partnership also supports tracking of mobile phones within the Vodafone network, providing more accurate and current data. There is some research in developing a P2P network to communicate vehicular information [3], where ad-hoc organization and scalability might prove superior to a server-client system. The TraffoMeter System[10] is another idea that takes advantage of mobile phones to send information on traffic conditions. Based on a server-client model, data from mobile phones can be used by companies such as Inrix to provide real-time traffic information. Google, Yahoo, and several other companies also provide traffic information aggregation systems.

Aside from traffic monitoring, additional practical uses include speedy communication with other drivers, improved travel information, and ability to self-detect and repair minor mechanical problems. We also do not limit our invention to the confines of the car. AR glasses could continue to update the driver with information if they exit their vehicle. This simultaneously allows the driver to maintain any communication they have and continue to receive real-time information about their car (e.g. diagnostics report).

IV. Second Life

After developing the A-HUD concept, our next step was to select an environment by which we could test and evaluate A-HUD. Several options were considered as possibilities, but most were eventually rejected. Developing our own simulator would give us freedom of customization and control, but would have taken considerable amounts of programming time. Using existing automobile simulators offered the most realism, but was impractical given the complexities to setup, and the A-HUD had not reached an advanced level of development. Customizing a real car was neither practical nor cost-effective.

We chose to explore the possibility of using Second Life as a simulation environment. As described by its website, "Second Life is a 3-D virtual world entirely created by its Residents. Since opening to the public in 2003, it has grown explosively and today is inhabited by millions of Residents from around the globe."[11] The world inside Second Life attempts to mimic many real world properties. For example, it has gravity, physical contact between users and/or artifacts produce the expected collisions, etc. Second Life's physics are generally realistic and the environment simulates many properties of the real world.

Various organizations have begun utilizing Second Life for business, educational, or other specific purposes. Educators and researchers alike have taken advantage of the opportunities Second Life provides to study different forms of social interaction in a virtual environment. Medical education [15], business [16], online learning [17], and many other fields have used Second Life to conduct their research.

Second Life users can employ a combination of GUI tools and a scripting language to create objects in the virtual world. The GUI tools enable users to create primitive objects (called prims), and then alter any number of its physical properties. Prims can be joined together to build more complicated objects. Users can then create scripts using the Linden Scripting Language (LSL).[12] LSL is built for use exclusively inside the virtual world. Users can create complex scripts and attach them to prims, making them behave in many different ways.

Vehicles are not necessary to traverse through Second Life, as walking and flying are just as, and sometimes more, effective. Instead, vehicles are usually designed for recreation and entertainment. Anyone can create vehicles in Second Life to their own specifications. LSL provides a set of functions to help Second Life users design unique vehicles.

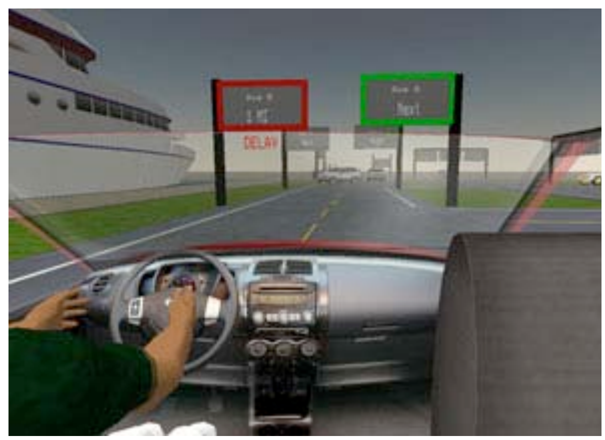

Fig. 6. Second Life simulation of A-HUD

V. Second Life as a Simulator

We determined that the Second Life environment offered the most practical and effective solution for prototyping A-HUD. With many real world physical properties, we could test different driving concepts. Vehicles are already an inherent component within Second Life, such that specialized functionality is included in its scripting

[10] http://csdl.ics.hawaii.edu/~johnson/traffometer.html
[11] http://secondlife.com/
[12] http://wiki.secondlife.com/wiki/LSL_Portal

language. We could customize many of the features that would be impossible in the real world, such as traffic, streets, signs, trees, etc.

We purchased land in Second Life, and began building a virtual closed course to test the A-HUD. Streets and signs were built, and natural terrains such as trees were added for effect. The functionality of A-HUD was programmed partly into the vehicle, and in some cases, into the environment. Our environment was a realistic, customizable, closed course where we could test A-HUD's functions, change the design as needed, and continue to develop new ideas. With complete control over the structure and design of our environment, we are able continue to refine the A-HUD until it has matured to warrant a more realistic simulator.

Within a short period of time, we can already investigate different A-HUD HCI components using our vehicles in Second Life. In the following section, we demonstrate how the Second Life test course can be used for automobile technology testing by simulating the A-HUD in a vehicle.

VI. Evaluating A-HUD inside Second Life

A. Setup

We conducted a simple evaluation study on A-HUD's usability to see whether Second Life would be a feasible simulator for testing automobile development. A small test course was created inside Second Life. The course had several intersections, with road signs that displayed street information. Testers used a joystick controller to navigate a simulated vehicle around the course. They were instructed that the signs would be highlighted with augmented information that would direct their travel to a pre-determined destination. The augmentations were a combination of text and symbols (e.g. arrows) that would become visible when the driver was nearing the sign. Our independent variable was the distance at which the road signs would be augmented with information. Of the eight testers, two experienced the augmentations at 20 meters, three at 25 meters, and three at 30 meters (distances inside Second Life are roughly proportional to distances in the real world). We used the Morae[13] software application to record each of the sessions for evaluation.

B. Results and Future Work

As expected, the reaction times of the testers who saw augmentations from 30 meters performed slightly better than those at 20 and 25 meters. They braked earlier for turns, and their turns were smoother. During informal discussions with the testers, we also gained unexpected insight into the augmentation designs. At one of the last intersections, there was a sign whose text read, "Avenue C, right." The majority of the testers had made a turn on that intersection even though the augmented directions were bright arrows under the sign directing the driver to continue straight ahead. After the test, we discovered that most of the testers gave higher priority to the original text on the sign rather than the virtual augmentations. This leads us to believe that given a conflict between "real" and virtual information, drivers will more likely follow the former. Users were also distracted by some of the virtual directions that gave instructions *not* to go in a particular direction by using red colors, and suggested they be removed entirely.

Although we cannot make any general statement from such a simple evaluation, there is evidence that both A-HUD is a viable concept, and that Second Life can serve as a rapid prototyping platform for testing and evaluating automobile concepts. We plan to continue expanding both ideas; A-HUD development can proceed to the next level of prototyping. We plan on developing the ability to augment real world traffic signs in real time to support a more realistic driving experience. We also plan to continue our development of Second Life to further demonstrate its ability as a driving simulator. Our immediate plan is to replicate different testing studies that have been conducted with different and more realistic simulators (e.g. [13][14]), and attempt to reproduce the same results. These replicated tests will give a more substantive answer as to whether Second Life is a reasonable alternative to more expensive and time-consuming car simulators.

Second Life also offers an opportunity for many different users driving inside the simulation, all interacting in real time and with real effects. Studies could be conducted on real life driving situations between large numbers of users instead of virtual driving programs. Collaborations between different automobile technology research labs could be made possible within Second Life.

VII. Conclusion

A-HUD will display various types of information viewable by the driver without needing to shift their focus to a display console or GPS screen far from their point of view. It will fully immerse the driver within their car, displaying speed, traffic, navigation, and other data from any available windshield. It offers significantly more data than most navigation systems or HUD's available today, while still maintaining a minimalist display method by tracking the driver's line of sight.

We used the virtual world Second Life to test the A-HUD concept. Currently, we know of no other research that uses Second Life for the purpose of testing automobile HCI designs. Compared to developing an in-house simulator or purchasing/leasing existing car simulators, Second Life takes considerably less development time and costs much less money. It provides a functional environment where we can develop freely using LSL, customize any artifacts, and

[13] http://www.techsmith.com/morae.asp

perform tasks that would not be practical in the real world. In our evaluation study, we have demonstrated both that A-HUD is in principle a viable concept, and that Second Life can successfully serve as an early level prototype and assessment tool. We acknowledge that Second Life does not replace more realistic automobile simulators and do not recommend it as such, but rather as a low-cost, rapid development platform.

References

[1] Androutsellis-Theotokis S. and Spinellis D. A survey of peer-to-peer content distribution technologies. ACM Computing Surveys, 36(4):335–371, December 2004. Ding, W. and Marchionini, G. 1997 A Study on Video Browsing Strategies. Technical Report. University of Maryland at College Park.

[2] Wolffsohn J. S., McBrien N. A., Edgar G. K. and Stout T. (1998). The influence of cognition and age on accommodation, detection rate and response times when using a car head-up display (HUD). Ophthalmic and Physiological Optics 18 (3), 243–253.

[3] I. Chisalita, and N. Shahmehri, (2002). A peer-to-peer approach to vehicular communication for the support of traffic safety applications, in 5th IEEE Conference on Intelligent Transportation Systems, Singapore, pp. 336-341, September 2002.

[4] May, A.J., Burnett, G.E. and Joyner, S.M. (1995). Integrating a Route Guidance Display Within a Vehicle: Safety Implications of Display Position (CEC EUREKA PROMETHEUS Programme BRIMMI CED 9: Dual Mode Route Guidance, Report 5.2). Loughborough, UK: HUSAT Research Institute.

[5] Burnett, G.E. (2000) Usable vehicle navigation systems: Are we there yet?, Vehicle Electronic Systems 2000 - European conference and exhibition, ERA Technology Ltd, 29-30 June 2000, pp. 3.1.1-3.1.11

[6] Burnett, G.E. (2003) A road-based evaluation of a Head-Up Display for presenting navigation information, In Proceedings of HCI International conference, Vol 3 (Human-Centred Computing), pp. 180-184

[7] Steinfeld, A. and Green, P. “Driver response times to full-windshield, head-up displays for navigation and vision enhancement.” Technical Report UMTRI-95-29, The University of Michigan, Transportation Research Institute, 1995.

[8] Pace, T., Ramalingam, S., and Roedl, D. 2007. Celerometer and idling reminder: persuasive technology for school bus eco-driving. In CHI '07 Extended Abstracts on Human Factors in Computing Systems (San Jose, CA, USA, April 28 - May 03, 2007). CHI '07. ACM, New York, NY, 2085-2090.

[9] Sawano, H. and Okada, M. 2006. Flat shading road versus photo realistic road for AR-based car navigation. In ACM SIGGRAPH 2006 Research Posters (Boston, Massachusetts, July 30 - August 03, 2006). SIGGRAPH '06. ACM, New York, NY, 153.

[10] W. Narzt, G. Pomberger, A. Ferscha, D. Kolb, R. Muller, J. Wieghardt, H. Hortner, and C. Lindinger. Pervasive information acquisition for mobile ar-navigation systems. In Fifth IEEEWorkshoponMobileComputing Systems and Applications, 2003.

[11] Marcus Tonnis, Rudi Lindl, Leonhard Walchshausl, Gudrun Klinker. 2007. Visualization of Spatial Sensor Data in the Context of Automotive Environment Perception Systems. The Sixth IEEE and ACM International Symposium on Mixed and Augmented Reality, Nara, Japan, Nov. 13 - 16, 2007

[12] Chu K., Brewer R. S. & Joseph S.R.H. (2008). Traffic and Navigation Support through an Automobile Heads Up Display (A-HUD), University of Hawai‘i Department of Information and Computer Sciences Technical Report. http://discourse.ics.hawaii.edu/records/show/3219

[13] Burnett, G.E. (2003) A road-based evaluation of a Head-Up Display for presenting navigation information, In Proceedings of HCI International conference, Vol 3 (Human-Centred Computing), pp. 180-184

[14] Lebram, M., Engstrom, H., Gustavsson, H. (2006) A Driving Simulator Based on Video Game Technology. 11th International Conference Information Visualization (IV’07), pp. 908-916

[15] Boulos , M.N.K., Hetherington, L., Wheeler, S. (2007). Second Life: an overview of the potential of 3-D virtual worlds in medical and health education. Health Information and Libraries Journal 24 (4), 233–24

[16] Alves, T. and Roque, L. (2005). "Using Value Nets to Map Emerging Business Models in Massively Multiplayer Online Games", in Proc. of the Ninth Pacific Asia Conference on Information Systems, PACIS 2005

[17] Childress, Marcus D. & Braswell, Ray. (2006). Using Massively Multiplayer Online Role-Playing Games for Online Learning. Distance Education, 27 (2), 187-196.

[18] Tufano, D. R. (1997). Automotive HUDs: The overlooked safety issues. Human Factors, 39(2), 303-311.

[19] Ward, N. J. and Parkes, A. M. (1994). Head-up displays and their automotive application: An overview of human factors issues affecting safety. Accident Analysis and Prevention, 26(6), 703-717.