An Intuitive Navigation System: Augmented Reality on the Car Windshield

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Resumo

Sistemas de assistência à condução e navegação em automóveis tornaram-se ubíquos nos últimos anos. No entanto, o modo de interacção mais comum destes sistemas foi avaliado por diversos estudos como tendo um considerável potencial de distracção e de risco da segurança.

Modelos alternativos de interacção têm sido apresentados na academia e na indústria, melhorando aspectos de atenção e de usabilidade, mas continuam a apresentar insuficiências que podem prejudicar a sua eficácia e segurança. Este projecto avalia uma potencial abordagem a dispositivos de assistência a navegação, baseada num head-up display (HUD) projectado no pára-brisas do carro, associado a uma componente de realidade aumentada (AR) para apresentar informação de navegação directamente sobreposta à rede viária.

Abstract

In recent years, driving assistance devices have become commonplace both as separate instruments and as built-in components of car equipment. However, the most widespread model of interaction for these devices has been proved to cause distraction and potential safety hazards.

Alternative devices have been proposed and even deployed in commercial settings, improving some of these security and usability aspects, but still present some drawbacks. This project aims to study the feasibility of a navigation assistance system that improves over these problems, using a windshield-based integrated navigation guidance head-up display (HUD), which presents routing information directly superimposed to the road, in the style of Augmented-Reality (AR) applications.

Keywords

windshield display, augmented reality, route guidance, head-up display, driving assistance.

1. INTRODUCTION

Driving assistance systems can generally be categorized as Head-Up Displays (HUD) and Head-Down Displays (HDD). HDDs are by far the most common modes of display, encompassing instrument panel (dashboard) indicators, and side-displays such as portable GPS devices. However, while their advantages are well established through controlled evaluations of driving performance and validated by commercial adoption, a body of research has revealed that they are more likely to create safety hazards due to the loss of visual contact with the road, the cognitive processing delay caused by the context switch and delayed reaction times to critical warnings [Steinfeld95, Green93].

Audio feedback has become common in the form of both spoken routing instructions, and warning sounds for various potential dangers such as high speed, proximity of obstacles, etc. This alleviates the aforementioned problem, but doesn't entirely solve it, given the human dependency on visual input for situational awareness.

This research project focuses on Augmented Reality (AR) displayed onto windshield-based HUDs, superimposing the informational elements directly into the driver's field of view. HUDs have been proven to be more efficient and secure than HDDs, since they don't require the driver to shift their gaze away from the road. The main cited disadvantages of HUDs are the cost and the potential for visual clutter distracting the driver, but focused research should inform the properties that define a non-intrusive implementation of a HUD-based navigation assistance system.

Several projects (and even commercial systems) have implemented the display of iconographic or textual information on the windshield [Doshi09]. However, since the presentation of floating virtual elements directly superimposed on the scene can distract the driver, the current project targets integrated displays that fuse the virtual elements into the real scene, thus implementing an AR system. The specific application studied is navigation assistance through display of the planned route directly over the driver's view of the road.

2. STATE OF THE ART

While HUDs are less common than HDDs in driving assistance systems, HUDs that present turn-by-turn navigation assistance (as opposed to icons or text) are even rarer. BMW presented such a system in 2011, but makes little attempt to visually integrate the routing icons into the real scene.

On the other hand, AR approaches have also surfaced in the industry, such as in the systems commercialized by Blaupunkt (2008) and Wikitude (2009). These are, however, HDDs: essentially, portable GPS devices with an integrated camera that displays live video from the road and superimposes a virtual route on top of it. Blaupunkt's system doesn't track the road and relies on the device being positioned in a central location so that the arrows will generally fit in. The Wikitude system attempts to do some visual tracking, but the lack of real 3D information makes the route float above and sometimes slightly off the actual road.

Finally, more recent systems have attempted to include both techniques (AR and HUD). To the author's knowledge, only two such commercial systems exist: MVS's Virtual Cable[1] (2011), and Pioneer's Cyber Navi[2] (2012). The AR component of these systems, however, is based on similar principles as the Blaupunkt system mentioned above: they rely on the imprecise GPS positioning and use a "virtual cable" metaphor to avoid having to follow the roads accurately.

3. SYSTEM OVERVIEW

The hypothesis to be evaluated by this project is that precise positioning of the virtual elements is crucial to reduce decision errors and delay, especially in complex intersections.

As such, one of the main components that needs to be implemented is a system for detecting the position and orientation of the car with high precision and responsiveness, so that the virtual overlay covers the correct places of the real world.

Secondly, such high-precision positioning of the virtual elements will need to adapt to the driver's position, so that the perspective is always correct. This will provide motion parallax, which is one of the most important features of visual spatial perception, especially at the medium-to-long distances usually involved in driving landscape. In windshield-based HUDs, motion parallax can be implemented either by head tracking [Doshi09], or by applying autostereoscopic properties to the windshield, such as lenticular screen technology [Takaki11], to convert it into a multi-view display.

Also, elements of 3D vision must be taken into account to produce an effective HUD. If the driver is looking at the road, their eyes will converge at a distance, and any element located closer to the eye will appear blurred (unfocused) and in double vision. To merge these two images, the eyes must converge and focus at the windshield. This type of focus shift is undesirable and causes similar problems to HDDs. If a stereoscopic pair of images is displayed (each perspective properly directed at the appropriate eye) then the eyes can converge in the road without seeing a double image [Doshi09]. This needs to be addressed by a system that allows projecting different images to each eye, which drives up the cost and complexity of the system.

The proposal advanced by this project is that a workaround for this stereoscopy requirement could involve projecting the route not as a continuous line, but as a series of horizontal strips. Since eye separation is mostly horizontal, no vertical unalignment should be visible; and since no continuous vertical border exists, any of these horizontal lines, when seen in double due to the driver focusing on the road, will fuse easily into a single line, somewhat longer than the original and fading out at the ends.

Such a system can be implemented using off-the-shelf components, namely:

1. A standard **GPS receiver**, to obtain global positioning information and allow the calculation of the routing.
2. An **outer camera** to recognize salient features of the environment and make adjustments to the 3D model of the surroundings;
3. A **projector + mirror** setup to display the virtual elements on the windshield, similar to the system implemented in [Sato06].
4. A **processing unit** would naturally be included to perform the calculations and control the system
5. An **inner camera**, which will be mounted on the ceiling of the car, to track the head of the driver and adjust the perspective of the projected elements to produce correct head motion parallax.

This system is very similar to [Doshi09], who used a laser-based display, and [Sato06], who used, as mentioned above a projector + mirror setup. However, neither attempted to provide the AR environment, instead focusing on the display of informational icons.

4. REFERENCES

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