An Investigation into the Use of Virtual Reality Technology for Passenger Infotainment in a Vehicular Environment

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Abstract

This paper presents a novel Human-Computer Interaction design approach for an automotive direct manipulation interface, aiming primarily to act as a younger passengers' interactive infotainment system in order to minimize driver distraction. The proposed design is applied in the peripheral windscreens with the use of a novel Head-Up Display system. The system evaluation by twenty users offered promising results discussed in the paper.

Key words: HCI, HUD, Interface Design, Virtual Reality, Driving Simulator

Introduction

Recent developments in vehicular manufacturing have rendered Head-Up Display (HUD) interfaces an increasingly viable alternative to traditional Head-Down Displays (HDD). These interfaces present fresh opportunities for the presentation of information using symbolic/alphanumeric representation and feature a larger viewing area than was previously possible. They have been designed mainly for the driver with a view to enhancing his/her information-retrieval capacity whilst minimising the distraction caused by external factors whilst driving.

Novel HUD design interfaces and devices have significantly mitigated this issue of the driver's attention being diverted from his/her field of view, as shown in previous studies [1,2,3]. Yet, the requirements of the passengers' user group have not been adequately explored. In particular, rear seat passengers, specifically children, can seek to attract their parents' attention during long distance trips or while commuting. Such actions have a detrimental impact on the driver's attention, and could potentially lead to an accident. Notably a UK survey in 2013 collected the opinions of 2000 British parents about their children's behaviour while they were driving. The results show that around 62% of the parents were more relaxed without their children in the car, 43% felt tense and irritated with their children, and about 55% admitted to losing their temper while driving long distance [4]. Furthermore, some parents used mirrors not to check external road conditions but to glance at and check their children's behaviour in the back seat.

Evidently this action could lead to hazardous driving, and could cause traffic accidents [5]. In light of the aforementioned facts and observations this project aims to collate and explore the current state of technology in infotainment car devices, as a base for launching the design and evaluation of the Human-Computer Interaction (HCI) for applications to rear-side HUD displays which would enhance passenger's entertainment in the vehicular environment and provide visual and auditory information regarding the external environment. The utilization of HUD draws from our previous experiments with collision avoidance interfaces that achieved significant results towards the reduction of the collision probability in adverse weather conditions [2,3].

Overall, the paper is organised as follows: The target group and current issues are presented and the requirements framework used for the development of the proposed interface is clarified in the initial section. This is followed by a description of the proposed system and evaluation process and consequently, preliminary evaluation results with ten users are discussed. Finally, conclusions are summarized and a future plan of work is presented.

Current In-vehicle Distraction Issues

Long-distance journeys in a car, force family members to stay in a confined space (generally parents in the front and children in the back) and spend time together, such as by chatting, singing songs or playing on mobile phones [5]. Adults and children, however, frequently have different expectations during travel time, with children being inclined to expect the time to be enjoyable and playful, while adults prefer it to be relaxing and quiet [5]. Children usually start becoming bored and losing interest after about 30 minutes of long distance driving, resulting in negative feelings of parents as noted above, with 60% of parents dealing with these situations by lying about the journey time and 70% choosing to buy food and drinks in an attempt to resolve this situation [4]. Furthermore, 43% of the parents feel tense and irritated with their children, and about 55% admit they will lose their temper in a long distance driving situation [4]. Evidently the in-vehicle interactions between the passengers, particularly the younger ones, can distract a driver's attention and increase

dramatically the collision probability. As such, the following section will present a potential solution to this issue that could be mutually beneficial for both the driver and passengers.

Proposed System

The proposed system aims to offer a combination of activities for the rear passengers in order to avoid in-vehicle distractions that could affect driver's performance and concentration. The system is designed to facilitate both educational and entertainment activities with particular focus on the younger passenger age group.

A. Software requirements:

The HUD system is comprised by a generic interface that allows the rear-passengers to access information in real-time through the navigation GPS. The navigation type of information can vary from maps and navigation, distance covered, estimated time of arrival and highlighted on-route

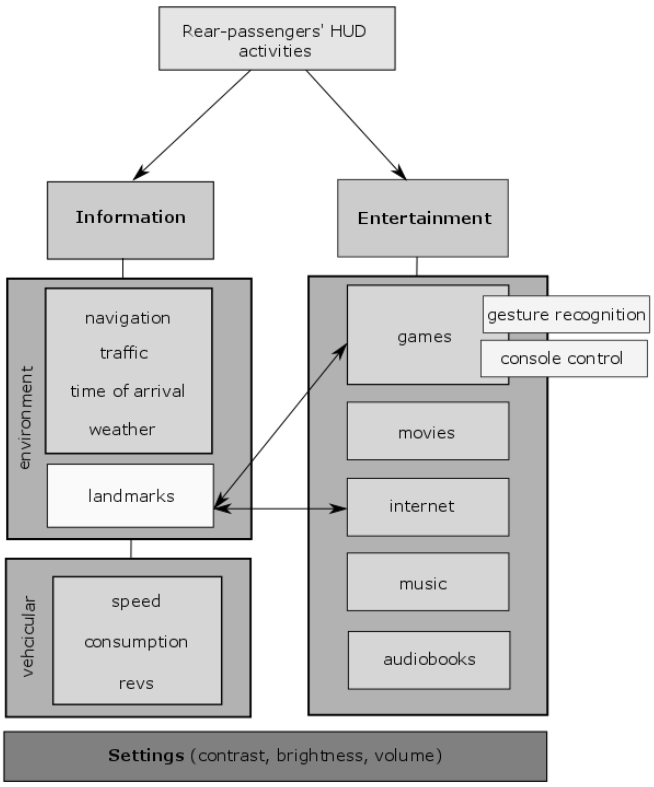

Fig. 1 Schematic representation of the rear passenger's HUD offered activities.

landmarks (i.e monuments, churches, castles etc.). The latter can be accessed in real-time, through online connectivity.

The landmark related specifics can be superimposed through the side HUD to the landmarks providing succinct information. This aims to keep the rear passengers occupied throughout the travelling time whilst educating them with regards to the surrounding environment.

Additionally, the system offers an overview of the vehicle functions such as speed, consumption, revs amongst other, that might be of interest for the passengers.

The second arm of the interface offers the entertainment suite which entails games, movie, internet, music and audiobooks. The audio related data can be provided by individualized headsets so as to avoid further in vehicle sound distractions. On the entertainment section we have primarily targeted the younger audience with a set of onboard games that could be augmented in the external window scenery. As such we have developed (a) a platform flying game and (b) a historic Augmented Reality (AR) game.

In the first game the user commands a superhero flying over the scenery whilst avoiding and shooting back a flying villain. As the scenery constantly changes both rival characters' battle in different terrains and weather conditions (figure 2).

The second game aims to entice the upper age limit of the passengers as it utilizes the external scenery and landmarks as temporary objects for the game. The game employs the external scenery of a real castle (i.e. Stirling Castle) for the duration that the user can see the castle through his/her window. In turn the user has to complete a set of challenges, such as assaulting the castle with the use of a 3D catapult. If the catapult shots are successful, the user gathers some points and continues to the next landmark and task. This can obviously be altered depending on the country, landmarks and activities that the user wishes to access and interact with.

In this paper we examine the overall user experience in regards to the HUD interface and the first game.

A. Hardware requirements:

Overall the interface is based on a side window HUD system. This output has been simulated with side projection on a driving simulation environment. The projector superimposes both the external view and the HUD interface (game and generic interface) in a side window of a full scale vehicle as presented in Figure 2. The system is run by a custom server PC in a CAVE environment. The gesture recognition software is utilizing a Motion Leap device and the games are developed in Unity3D game engine, exclusively for the evaluation of the proposed HUD system.

System Considerations

Adhering to the situations noted above, the proposed in-vehicle games should be able to entice the users to play for the duration of long distance runs whilst providing interesting information for the surroundings [4]. Due to the nature of these games, the in-vehicle activities should abide to a number of considerations in order to have the expected positive results according to Broy's research [6].

The preservation of driving safety, is a primary consideration, as the risk of the game distracting the driver by sound or virtual effects should be minimized.

Secondly, in-car games are not like traditional games or computer games, as they require a different playing environment, and should function steadily and effectively in a vehicular environment.

Additionally, motion sickness should also be taken into account, as some passengers feel uncomfortable when they read during travel, so it may be more comfortable and effective to use pictures and/or sound to present the information [6, 7]. Furthermore, Brunnberg's report provided evidence to suggest that, due to high speed travel, the view from the rear seat will pass by very quickly. It is therefore difficult for the device to pick, search and present the information, and this may be one

of the most difficult technological challenges to be faced and overcome during the design process [7]. It should also be noted that passengers of different age groups (young children, teenagers, parents) have varying levels of ability in terms of reading and understanding; hence, the game's level of difficulty needs to be carefully considered [7].

Adhering to the aforementioned considerations, some in-car games have already been designed for short-distance drives situation. These include “Backseat Playground”, “nICE” and “Mileys”, which use special equipment, phones or touchpads to play the game [2,4 & 5]. Similar studies have been conducted, in 2011 and 2012, by Toyota and General Motors (GM) respectively, utilizing enhanced versions of their backseat entertainment systems. Notably, GM used motion and optical sensor technology to transfer the rear seat window into a gesture touch panel [8 &9]. However, there has been limited - if any at all - employment of HUD and gesture recognition technology, which could offer a more immersive and subtle way of interaction for the users. The ultimate purpose of this combination is to offer attention seeking infotainment to the passengers so as to reduce the level of distraction for the driver. All the current systems mentioned above have their own features and utilize their interfaces with multiple types of equipment, but without gesture recognition and typical console controls. Hence, the above, highlights the need for a new passenger infotainment and communication system that could alleviate the level of distraction of the driver. To this end, this work proposes a novel interface that occupies the side window and presents information through a side Head-Up Display system.

Fig. 2 This is a sample figure. Captions exceeding one line are arranged like this. The figure presents the screenshot presenting the projection in the side window and the related HUD interface

System Evaluation

The evaluation of the proposed system was implemented in two different experiments, which investigated the travel information and the passengers’ games respectively. Notably, the aim of the particular in-car game is to improve the quality of long-distance travel time, particularly for children and younger passengers [2].

The experiment hosted two different games as mentioned above, that utilized gesture recognition and typical console controls. The latter has been selected as an alternative to the gesture recognition due to the limited fatigue benefits that could provide the passengers during long period of use. This paper presents the experiment process and evaluation results derived from the first experiment in which twenty users aged 12-13 participated. The playtest methodology comprised the use of real-time data collection, observation and subjective feedback survey. The system was also evaluated with the use of a customized for purpose Technology Acceptance Model (TAM) which identified the enjoyment, experience value and attitude towards the system [10]. The game was considered successful if it was managing to captivate the passengers’ attention for more than 10 minutes per play-level. This was estimated as the maximum playable time per level which increased in difficulty and thematic elements. The games

could facilitate an infinite number of combinations and levels as they were adapting to the external environment which is constantly changing. Yet six levels would be sufficing for the average duration of one hour, long-distance-commuting in daily basis and typical trip duration [11]. The game was designed by the Games Design undergraduate students in Glasgow Caledonian University and tested in the Virtual Reality and Simulation Laboratory (VRS Lab) Driving Simulator.

Results

The evaluation results in this age group were promising and yielded a great deal of positive and useful feedback as presented in Figure 3. The first AR game received consistent approval and positive reactions from the participants. Yet certain issues were also pointed out regarding mainly the gesture recognition system which required significant stamina from the users in order to operate it. This issue arose primarily from the demanding task to maintain the arm lifted in order to operate the game on the side window. As an alternative the system can be operated with a console wireless controller in order to avoid this issue.

Overall, as the data show, 90% of the participants gave the game a high score, which is a major sign of approval to the trial. Furthermore, analyzing all the comments, gesture control is the focal point, with 80% of the participants enjoying the function of gesture control in the game, and 50% of those with no prior gesture control experience describing the gestures as hard initially, but acceptable and appropriate after a period of familiarization.

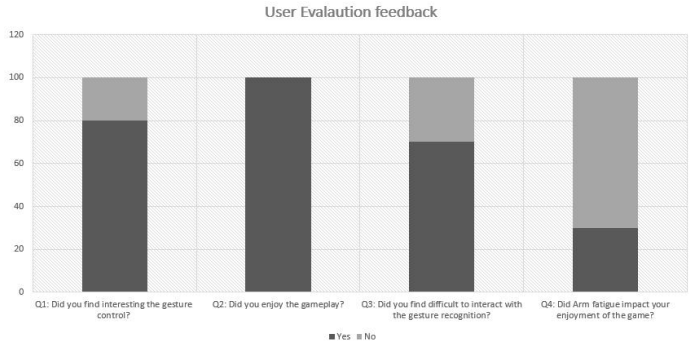

Fig. 3 The graph presents the subjective feedback in the four questions regarding the HUD gameplay

Interestingly, despite expecting users to identify arm fatigue as the main problem caused by the hand gestures, the overwhelming response from the users was that arm fatigue did not significantly affect the participants' enjoyment of the game. 70% of the participants did not consider arm fatigue as an influencing factor in their enjoyment of the game. This result is not only contrary to the initial expectation but is also in contrast to the result of the test with the younger age group.

Although the participants did not think that arm fatigue affected their enjoyment the game, they suggested that a pause button could be useful in extensive duration game-play.

Finally, the HUD system and AR game managed to captivate the audience for the duration of the first level (10 minutes per level) and in some cases the users continued in the subsequent game-levels, achieving the 100% target for occupying the passengers for the duration of typical long distance commute or trip [11]. Evidently this result has direct benefit to the driver's attention.

Conclusions

This paper presented an evaluation of a prototype Human Computer Interaction design for automotive HUD to entertain and inform the young passengers in the rear seat younger passengers. To facilitate an appraisal of the system, the experiment hosted two different games that utilized gesture recognition and typical console controls. The results indicate that the participants were satisfied with the game's performance, with 80% of the participants having enjoyed the function of gesture control in the game, and half of the players who had no gesture control experience thinking that the gestures were hard at the start, but it was fine after getting used to them. Markedly, the problem of arm fatigue caused by hand gestures was proven in the experiments. Yet, despite the positive outcomes of the presented work, it is apparent that the games need to be customized for the particular environment and take into consideration the duration of the trips, counteract the road-surface disturbances and adapt to the external weather conditions. Our tentative plan for future work entails the update of the games' and HUD interface's functionality in order to comply with the aforementioned observations and results. Consequently, further testing of the updated HUD system will be required in order to determine the optimal system parameters that will allow the system to facilitate lengthy interactions with minimal fatigue.

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