Augmented Reality AI Co-Driver: Impact on Drivers' Perceived Experience and Safety

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Keywords: Augmented Reality, Artificial Intelligence, Head-Up Display, User Experience, Human-Computer Interaction.

ABSTRACT

This project investigates the use of an AI codriver that could support the driver's decision-making process. The information is presented through AR HUD and audio. The evaluation by 20 users in a VR driving simulator presented both encouraging outcomes and potential issues of the driver's perceived experience and safety.

1 Introduction

The infusion of Artificial Intelligence (AI) in various human activities has increased exponentially in the last few years. Supporting humans with time-consuming or complex tasks is currently the main aim of AI use. However many concerns have been raised about the prospect of the complete replacement of the human element within the decision-making process or production of goods and services [1-4]. Previous studies have presented positive outcomes when the human decision-making process was coupled and supported by AI [5-8]. Current developments of Machine Learning and AI in the field of automotive navigation have provided new opportunities that could enable current and future vehicles to act fully or semi-autonomously depending on the autonomous level provided. The information gathered by the sensors and other navigation and vehicular conduits are typically transferred directly in the vehicle driving process whilst minimal information is presented to the driver through infotainment systems [5]. However, this tends to disassociate the driver from the actual process, which is called only to intervene when the AI cannot perceive correctly the driving situation and conditions. These actions are increasing driving anxiety and mistrust of the AI capabilities of an autonomous vehicle (levels 1-4) [9].

This project aimed to investigate the potential usability of an AI co-driver that could interact with the user in real-time whilst providing crucial guidance information. It could be argued that the current navigation systems provide traffic and route information through auditory and visual information. However, these systems lack the ability to interact with the driver and suggest real-time, alternative manoeuvring options for collision avoidance. The proposed system further enhances the AI interaction with real-time guidance information through a full-windshield Augmenter Reality (AR) Head-Up Display (HUD) something that was tentatively explored in different scenarios and previous projects [10-12]. The proposed system was evaluated in contrast to existing navigation systems, by 20 drivers aiming to identify the user experience (UX) and safety as perceived by the users. In turn, the paper discusses the results of the evaluation and concludes with a future plan for further development based on the users' subjective feedback.

2 Multimodal Human-Machine Interaction

The use of multimodal HMI ensures the conveyance of information to the user in cases where an overload of stimuli could hinder human cognition and delay the decision-making process [5]. To enhance the provision of information to the user a guidance system is typically designed to provide a step-by-step instruction in various forms of audio, visual and tactile feedback. This has been utilised in numerous fields and applications to ensure the timely and efficient information and/or knowledge transfer [13,14]. The employment of gamification further improves this process and reduces the users' anxiety [15,16].

Fig. 1 Screenshot of AR HUD collision avoidance route suggestions by AI Co-driver [18]

3 Proposed AI Co-Driver system

Adhering to the above, the proposed User Interface (UI) design and functionalities follow previous work aiming to improve the overall user experience (UX) and increase the perceived safety provided by the AI co-driver [5,17].

As such this AI co-driver is designed to guide the driver by emulating a human co-driver guidance by suggestions in real-time. The system suggests the optimal collision avoidance route and manoeuvres in real-time by analysing rapidly the crucial information from the vehicular sensors and GPS. To enhance the provision of information to the driver the system employs visual guidance through a prototype Head-Up Display System that superimposes the data onto the existing real-environment. This Augmented Reality (AR) visual support is coupled with audio guidance aiming to reinforce the urgency of the guidance suggestion.

The design of the AI co-driver aims to support and enhance human driver responses in imminent accident scenarios and reduce the probability of collisions or the ferocity of accidents, potentially improving safety on the road. The AI co-driver can continuously monitor the road conditions, surrounding vehicles, and various sensors within the vehicle to provide the driver with early warnings and alerts about potential hazards or impending accidents. This can help the driver react faster and appropriately to the situation. Being able to rapidly process and analyze data from cameras, radar, and other sensors can determine the best course of action. A future option could be enabling the AI co-driver to take full control of the vehicle, temporarily, to avoid an accident, changing the status of the vehicle from human-driven to AV. The system could take a variety of actions significantly faster than the human driver and can assist in emergency situations by applying brakes automatically or realigning the vehicle in case the lane departure warning is activated.

AI co-drivers can analyze real-time traffic data to suggest alternative routes or detours in the event of accidents or traffic congestion ahead. This can further assist the drivers in avoiding potential accident-prone areas and reduce the likelihood of being involved in a collision.

4 System Evaluation

4.1 Evaluation Method

The efficacy of the AI Co-Driver in conjunction with the AR HUD was evaluated against typical Head-Down Display (HDD) navigation in a VR Driving simulation environment described below. A Pre-test questionnaire gathered the demographic users' information. A post-test questionnaire gathered the subjective feedback based on a custom Technology Acceptance Model (TAM) previously used in simulations aiming to identify the usability of such emerging technologies in a vehicle [10]. A five-scale Likert system was utilised to measure the users' responses.

In this paper, we analyse a selection of two of the main TAM constructs namely perceived UX and perceived safety. To maintain consistency with our previous experiments we used a rear-collision scenario in which the driver is challenged to avoid the accident either by abrupt braking or manoeuvring. The drivers experience the events with and without the proposed system [14-16].

4.2 Evaluation - Hardware and Software

The system has been evaluated in a scale 1:1 VR Driving Simulator laboratory that entails a full-scale Mercedes A-Class 2003 model, surround 3D projection (CAVE) and audio to increase the driver's immersion. The simulation is developed with the use of the Unity engine. The VR simulation environment presents an extensive motorway triangle of 28 miles between Glasgow, Stirling and Edinburgh routes which have the highest probability of collision, particularly during rush hour.

4.3 Participants

Twenty users participated in this experiment. The drivers held a valid UK driving license and were aged between 18 and 60 years old (8 female – 12 male). They had various social, economic, and professional backgrounds.

5 Results & Discussion

The post-questionnaire users' feedback provided valuable subjective feedback that accentuated some experiences, concerns and future requirements for future system iterations. The post-questionnaire statements are presented in Table 1 below.

Table 1. Post-Questionnaire Characteristics

Q1.(-)	I felt comfortable/safe without the AI Co-Driver's assistance.
Q2.(-)	I felt that the AI Co-Driver was distracting.
Q3.	The AI Co-Driver interface (visual and auditory) was simple and informative.
Q4.(-)	The AI Co-Driver interface should provide more information.
Q5.	The AI Co-Driver HUD interface uses familiar visual symbols.
Q6.	The AI Co-Driver interface uses familiar sounds.
Q7.(-)	The AI Co-Driver was stressful.
Q8.(-)	The AI Co-Driver was not useful.
Q9.	The AI Co-Driver was offering a relaxing experience
Q10.	I trust the AI Co-Driver's manoeuvring suggestions.

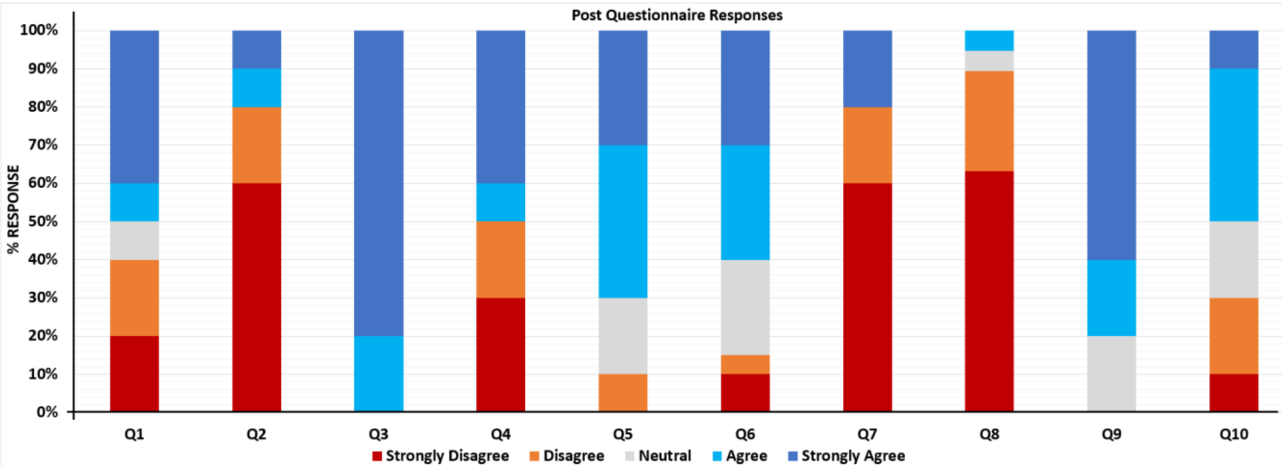

Fig 2. Post Questionnaire Responses – AI Co-Driver and AR HUD system vs Traditional navigation

The negative questions introduced on the questionnaire (Q1, Q2, Q4, Q7 and Q8) presented an overall positive outcome for the proposed AI Co-Driver/AR HUD system as illustrated in Figure 2. Only Q1 had mixed responses where the level of comfort with and without the proposed AI/AR system scored almost equally for both responses formed largely the agree and disagree groups. This might be attributed to the fact that the drivers and the overall driving population are not yet familiar with such in-vehicle systems. The Q2 presented a positive outcome as 80% of the participants responded that the proposed AI/AR system was not distracting during driving. This reinforces the hypothesis of the AI CoDriver, by emulating a human co-driver compliments the driver's decision-making process rather than replacing it completely as per level 5 AVs. Question Q3 regarding the simplicity and user experience of the system's UI scored 100% combining the agree and strongly agree responses.

The Q4 related to the amount of information that should be provided by the AI system divided the users' opinions. This is a concerning response that will require further investigation with a larger group of participants to produce better granularity on the results. The Q5 presented a more homogenous response regarding the familiarity of the HUD interface symbols, receiving 70% positive responses, 20% neutral and 10% negative. Similarly, the sounds are familiar to the users as presented in Q6 responses that scored 60%. In turn, the negative question/statement Q7, as well as Q8 stating that the proposed system is stressful and not useful respectively were opposed by the vast majority of the users as presented in Figure 2. Particularly the responses to Q7 appear to contradict the responses of Q1 as the vast majority of the users (80%) consider the AI /AR not stressful.

The assumption that the AI/AR system offers a comfortable drive with significantly reduced stress for the user presented in Q7 is further reinforced with a similar high score of 80% in Q9. Finally, Q10 explores the level of human trust in the AI decision-making process. The results are more encouraging in comparison to similar questions related to full AVs [9,18,19]. Still, the drivers seem concerned about the ability of a computer to suggest or in some cases fully control their vehicle [20]. Yet, this increase in trust of 50%, highlights the potential of humanised AI systems and the AR HUDs to circumvent such trust concerns [21]. The correct and timely suggestions of the system decreased the imminent collisions on the simulation and increased the perceived safety by the users as appears in Q10.

6 Conclusions

This paper presented a prototype system that aims to incorporate an AI-codriver that could assist the driver in potential collision scenarios. The preliminary evaluation of the system presented some encouraging results regarding the overall user experience (UX) but still some drivers are skeptical about the trustworthiness of AI support either in the form of a co-driver or a fully autonomous system. Notably, the gentle approach and suggestions of the AI Codriver were perceived as better than a fully AV mode that excludes the drivers from the process.

This finding potential could form a temporary bridge between fully AV and AI-Codriver-supported vehicles. It's important to note that while AI co-drivers can provide valuable assistance, they are not meant to replace human drivers entirely. The ultimate responsibility for safe driving still lies with the human operator.

However, AI co-drivers can serve as a valuable tool to enhance driver responses and mitigate the risk of accidents, whilst introducing a more acceptable form of AV at this stage. A future plan of work on this system will include the evaluation of false-positive suggestions and warnings that could challenge the users' trust in the system and identify alternative methods to compensate on such occasions.

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