Improving Emergency Vehicles' Response Times with the Use of Augmented Reality and Artificial Intelligence

K. F. Bram- Larbi[1], V. Charissis[1[0000-0002-4195-843X]], S. Khan[1], D.K. Harrison[2] and D. Drikakis[3[0000-0002-3300-7669]]

[1] Glasgow Caledonian University
Virtual Reality Driving Simulator Laboratory
School of Computing, Engineering and Built Environment,
Glasgow, UK

[2] Glasgow Caledonian University
Department of Mechanical Engineering
School of Computing, Engineering and Built Environment,
Glasgow, UK

[3] University of Nicosia
Defence and Security Research Institute,
CY-2417 Nicosia,
Cyprus

Abstract. The rapid mobilization of Emergency Services (ES) could be particularly challenging for ES drivers and staff that have to navigate and manoeuvre through various traffic and weather conditions. Driving, in high speeds through dense traffic is a particularly demanding psychomotor task for the ES drivers and could result in collisions and even fatalities. Current attempts to support the driver and reduce the potential driving hazards had limited success. The paper presents the design rationale of a prototype system that utilises Augmented Reality (AR) in the form of a Head-Up Display (HUD) to superimpose guidance information in the real-life environment. The paper will discuss also the requirements for an Artificial Intelligence (AI) system that could analyse the driving conditions and present the best manoeuvring options whilst maintain the road users' safety. Finally, the paper presents the requirements' framework for the development of the proposed AR/AI system based on the feedback and suggestions of ten ES drivers. Their feedback will be presented and discussed in detail as it provided essential insight into the everyday challenges of ES operations.

Keywords: Augmented Reality, Emergency Services, Artificial Intelligence, Collision Avoidance, Head-Up Display, Smart Cities, Simulation

1 Introduction

Emergency Services (ES) utilise a large and diverse fleet of customized vehicles, offering multiple solutions for ambulance, police and fire brigade services. The main objective of these services is to ensure that citizens in-need receive support efficiently and in a timely manner. The latter parameter requires high-speed manoeuvring through dense traffic, in various adverse weather conditions and road networks. These requirements increase greatly the collision probability [1].

Current technological advances in computing and telecommunications enable modern vehicular systems to assist the driver's decision-making process. Existing solutions to alleviate this issue are based on the acquisition of information, usually attained by vehicular sensors, GPS and/or Vehicular Ad hoc Network Systems (VANETS). In turn, the data is presented to the driver through several in-vehicle screens and projection conduits with mixed results.

The demanding operating environment of the ES and the constant provision of traffic, incident and patient information through a plethora of screens, interfaces and buttons burden further the driver's cognitive load. Typically a co-driver is required, in order to split the incoming information load and support the driver in the main task. Yet, the co-driver has to reiterate the received information both verbally and gesturally in some cases, dividing further the driver's attention.

Emerging technologies such as Augmented Reality (AR) are well placed for superimposing crucial information on the real environment aiming to improve human responses. Previous work with AR systems aiming to reduce collision probability under adverse conditions has successfully demonstrated the efficiency of AR in the automotive field [2, 3].

The utilization of such technology on inherently more hazardous situations, like fast police pursue or ambulance emergency, however, requires additional support for the driver, beyond the visual guidance. In such cases, the provision of visual guidance should be updated rapidly and offer alternative options following the traffic patterns. Such requirements could only be provided by an Artificial Intelligence Co-Driver which could receive, distil and present crucial information at a swift pace following the driving conditions and traffic patterns [4].

Adhering to the above observations, the proposed work investigates the use of AR in the form of a prototype Head-Up Display (HUD) interface designed for the enhancement of safety, improvement of response times and navigation through traffic for emergency vehicles. In addition, a prototype AI Co-driver aiming to enhance the quality and timing provision of the crucial navigation data to the driver is presented.

Initial system designs and preliminary evaluations in a full-scale VR driving Simulator have been promising as the AR-AI system provides manoeuvring and navigation information promptly and superimposed in scale 1-1 on the external environment.

The paper will present the framework of requirements for the development of the proposed AR/AI system based on the feedback and suggestions of ten ambulance drivers. Their feedback will be presented and discussed in detail as it provides essential insight into the everyday challenges of ES operations. Based on analysis of specialist input, the latest AR/AI HUD interface development will be discussed and will explore the usability benefits and issues in accident scenarios acquired by the local traffic police department. In conclusion, the paper will present a tentative plan of future work aiming to optimize the proposed system and reduce routing collisions through traffic.

2 Current ES Driving Issues

A multitude of hazards is potentially faced by ES professionals, contributing to the degree of risk associated with such professions. Inherent hazards such as exposure to infections or hazardous materials are well mitigated for by the use of personal protective equipment, whilst others such as exposure to public violence or traffic-related hazards are somewhat difficult to mitigate for and still remain amongst the highest risks faced by emergency personnel. In particular, high-speed emergency driving in challenging traffic or weather conditions accounts for the majority of fatal ES accidents.

2.1 Speed Related Issues

In many countries, including the United Kingdom, ambulances are granted several exceptions to road traffic laws that are mandatory for civilian drivers. No statutory provision imposing a speed limit on motor vehicles shall apply to any vehicle on an occasion when it is being used for fire and rescue authority purposes or for or in connection with the exercise of any function of a relevant authority as defined in section 6 of the Fire (Scotland) Act 2005, for ambulance or police purposes [5].

Thus the law does not set a defined speed limit during an emergency call to facilitate an unrestricted mobilisation speed. In turn, the ambulance driver is tasked to perform the required manoeuvring and to adapt the appropriate speed, taking into account the relations among speed, crash risk and the patient's need for a fast response [6]. Notably, speed is an important factor in traffic accidents, and there are an exponential function and a power function between speed and crash rate [7]. The above reference tends to be valid for ambulance drivers, thus the risk of road accidents increases with increased driving speed. However, speed itself is not the determining factor of a potential collision. Selection of appropriate routes and manoeuvring choices within different traffic and weather conditions could affect significantly the collision probabilities [3, 8].

Traffic accidents also occur during ambulance transportation, both in emergency use and non-emergency use, and several studies reveal that emergency driving at high speed is riskier and causes more accidents than non-emergency driving [7, 9, 10]. This has sparked a worldwide discussion about the advantages versus the disadvantages of ambulance emergency high-speed driving. Several investigations suggest that the time saved is marginal in emergency driving compared to non-emergency driving. Sometimes these manoeuvres cause accidents without involving the ambulance, i.e. wake-effect accidents [11, 12]. This is a major issue, as these accidents occur with a greater frequency and many of these accidents result in damage, serious injury or death [11].

The mean time saved is in the order of 1- 4 min, including both urban and rural environments [13]. The benefits when driving ambulances at high speed using lights and sirens are supposed to be rather limited, as this kind of transportation is dangerous for patients, personnel and fellow road users due to inadequate siren direction localization [9, 14]. Therefore, the use of warning lights and sirens has become a controversial issue [13].

2.2 Spatial and Situational Awareness

Emergency driving at high speeds is not only a major key point to be taken note of, but it is also a stressful situation for patients and personnel, as well for the driver. These situations result in unsafe vehicle operation to a greater extent, especially among less experienced drivers [9]. The urgency of transporting patients, personnel or equipment in various locations and encountering different traffic and weather conditions can increase dramatically the cognitive workload of the ES drivers. The spatial and situational awareness of the driver can be challenged by the required multitasking and attention division between map-navigation, suggested route, fast-paced manoeuvring and a plethora of additional incoming information presented through other Head-Down Displays (HDD).

Driver's attention can be further challenged by adverse weather conditions that could diminish spatial awareness or could affect the external environment visibility (i.e. fog, heavy rain, glare and snowfall). As such the distance misconception and obstacle masking could occur, resulting in a reduced situational awareness. In this case, the provision of map and route information through contemporary methods (i.e. HDD) is inefficient as it cannot be correlated to the external scene [15]. Current provision of information within the ES vehicles could distract the driver particularity in occasions that require rapid driving and manoeuvring in condensed traffic flow. The majority of the ES in-vehicle systems are engulfing the driver's position with several screens that deliver various information.

2.3 Driver Distraction

Besides the navigation and POI information presented to the driver by the in-vehicle screens, the nature of the emergency response is distracting in itself. Rear seat passengers can be un-restrained so as to be able to medically intervene whilst the vehicle is in transit and on multiple occasions a patient may not remain stable throughout the journey to a centralized facility. Thus, action occurring in the rear compartment of an emergency vehicle, especially an ambulance, can have a hugely distracting effect on the driver.

Previous studies have demonstrated the impact of rear-seat passengers' activity on driver distraction [16, 17], but this issue is amplified, in most ES situations, as the co-driver, normally assisting in navigation, is often required to aid a patient and thus cannot offer assistance with the multitude of tasks in the driver's cabin.

Adhering to suggestions and observations by the ES staff, the proposed systems aim to embed an AI Co-Driver that could take over from the human co-driver and assist the driver in the main task of arriving promptly and safely to the required destination. This element of the system will be further discussed in the following sections.

3 Current Solutions

Several emerging technologies have been employed to curb the collision occurrences in vehicles such as Vehicular Adhoc Network systems (VANETS), small-estate HUDs, visible (i.e. side mirrors), auditory (i.e RDS broadcasting method) and haptic warnings amongst others [18 - 21].

The use of VANETs and Vehicle to Vehicle (V2V) communication could provide the exchange of a multitude of information between vehicles and Vehicle to Infrastructure (V2I) that could warn well in advance traffic flow issues or for other potentially hazardous situations. As such the promptly provided information could prevent a collision and consequently alleviate the driver's anxiety [19, 20].

Yet the real-time acquisition of data requires a fast and efficient conduit for transferring the information to the driver in a meaningful and simplified fashion. To tackle the data presentation and visualisation issue, new interfaces have been devised which utilise audio related and haptic methodologies to decrease the driver's cognitive workload and consequently expand safety while driving [21, 22].

The driver's decision-making process could be further enhanced with the provision of variable speed limits and open/close lanes as required. This is typically offered by smart motorways infrastructure.

Another system based on V2I is the direct communication of the ES in-vehicle system to the Urban Traffic Management Control (UTMC) centres, requesting for adaptation of traffic lights and routes to support the swift movement through urban and motorway traffic [23, 24]. These systems offer a useful addition for the support of the driver as they could reduce the traffic or create alternative routes. However, these systems cannot support the decision-making process for the correct manoeuvring through traffic.

Some contemporary attempts to reduce this infobesity issue has been through the combination of different sources in one in-vehicle data terminal screen. This offers a cost-efficient solution by reducing the multiple providers, interfaces and aftermarket services.

Yet, combining the majority of the incoming information in one system tends to have an impact in the Human-Machine Interface (HMI) design. The latter, increases in complexity and as with the previous systems that attempt to reduce the driver's cognitive workload, they still cannot guide directly and efficiently the driver or support the split-second decision-making process.

Additionally, siren localization has been highlighted as another area that could be improved to warn efficiently the passenger vehicles in the ES vehicle's path. Previous studies have shown that current siren systems do not offer a clear localization of the incoming ES vehicles. As such drivers are not aware of the ES vehicle position and direction or speed of movement [14, 25].

Thus far, such attempts although in theory alleviating partially the driver's cognitive workload had limited success and lack correlation with input from real-time ES vehicle drivers.

4 Proposed Solution: AR/AI system

The design of the proposed AR system employs design elements from previous work related to AR HUD and collision avoidance system. However, the previous systems were predominantly developed to assist drivers under adverse weather conditions by presenting in real-time the positions of the neighbouring vehicles [3, 15, 26].

In the ES case, the high-speed manoeuvring and navigation through different states of traffic required, necessitate the use of calculation of relative speeds between the neighbouring vehicles, close-proximity obstacles ahead and road changes/closures amongst other to propose in real-time potential paths of vacant road spaces (see Fig.).

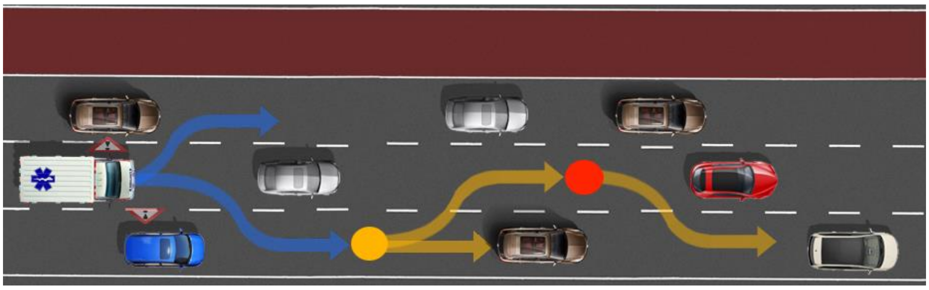

Fig. 1. Selection of alternative routes, in dense traffic on motorway environment.

Yet, the information provided in real-time to the driver should be stripped down to the bare minimum, maintaining only the proposed manoeuvring information and speed required to utilise the traffic-flow gaps (see Fig.). Due to the unpredictable pattern of traffic flow gaps requiring the instant provision of options to the driver, any other information is irrelevant to the main task. For this reason, the primary function of this proposed interface is to enhance the driver's response times by enhancing the spatial and situational awareness through a simple and clear guidance interface. The utilisation of AR to superimpose the fastest and safest route at any given moment could improve human responses and consequently reduce collision probability as previously demonstrated [8, 15, 20]. To achieve this, the project currently is in the process of embedding an Artificial Intelligence Co-Driver for analysing current conditions both in micro and macro traffic flow [27]. In turn, the AI will utilise the AR interface to highlight directly on the driver's Field Of View (FOV) the suggested options and desired speed to utilise the traffic gap without jeopardizing road users' safety.

This "*slalom driving approach*", will be employed by the human driver and AI only if there is no alternative option available and only if the sirens and blue lights are activated. In different countries, the regulations regarding the ES vehicles movement on the road vary and as such, this project examines a holistic approach without developing the system for one country explicitly [28]. The proposed system intends to enable the driver to maintain a consistent speed and navigate safely through traffic, rather than providing peak-to-peak speed fluctuations and abrupt manoeuvring options. The latter would put additional strain on the ES driver and the vehicle whilst create unnecessary stress to the neighbouring vehicle's' drivers.

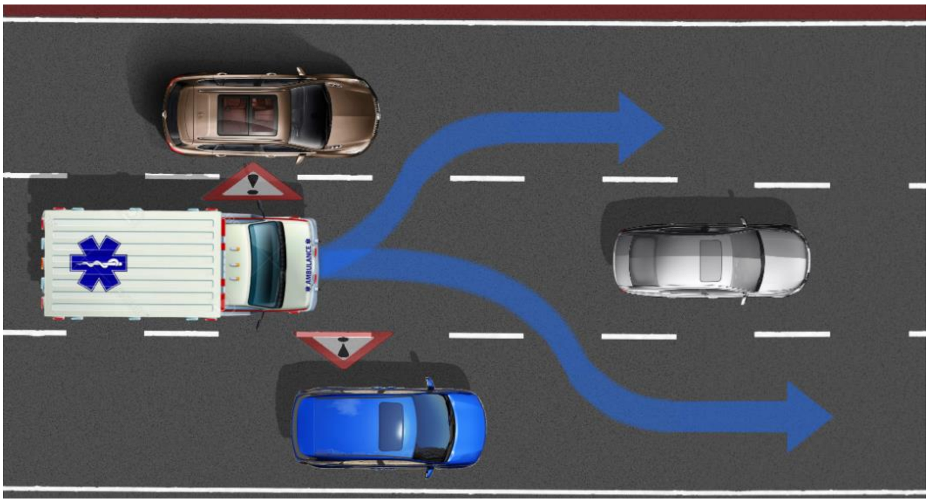

Fig. 2. Close up in the selection of alternative routes, whilst ES vehicle is circumventing dense traffic on motorway environment.

The proposed AR interface exploits the full windshield to highlight directly on the existing environment the optimal manoeuvre option (see Fig.). Previous work has indicated that the small-estate AR projections through HUDs might confuse drivers' as they attempt in real-time to mentally position the small HUD information to the real-life and scale environment [27, 29].

Fig. 3. Close up in the selection of alternative routes, whilst ES vehicle is circumventing dense traffic on motorway environment.

This human-machine collaboration could improve the speed of the vehicle whilst able to identify potential collision obstacles and occurrences. By only displaying pertinent information on a HUD system, faster response times have been demonstrated in previous studies [3, 15, 26].

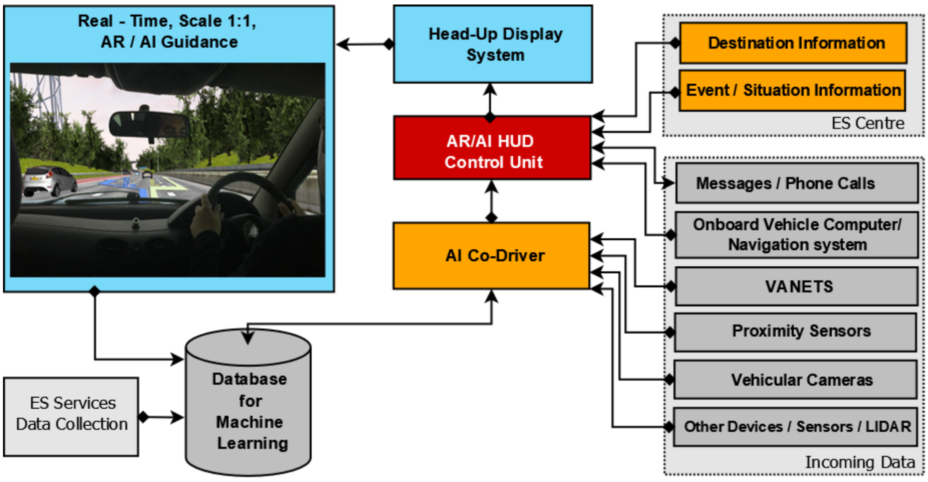

Fig. 4. Block diagram of the proposed system's operational framework.

On the proposed system the AR/AI Guidance is projected directly on the real-life environment through a full-windshield HUD (see Fig.). The incoming plethora of information (VANETS, proximity sensors, vehicular cameras, and other devices and sensors) feed directly into the AI CoDriver which in turn, updates the provided guidance to the driver (see Fig.). Notably, the onus is always on the ES driver to utilise the proposed information and execute the suggested manoeuvre in a safe manner.

However, if the AI assistance is not required, the HUD Control Unit could present other collision avoidance and navigation information as per previous work [2, 3, 8, 20]. In case that both the AI and the AR HUD systems are not required, they could be deactivated.

At the current stage of the proposed system development, a fully autonomous capability is not included as concurrent studies have presented a hesitance from the majority of the drivers to relieve the command of their vehicles completely to an AI system [30].

This tendency and feeling are reinforced by the lack of any high-level Autonomous Vehicles (AV) available on the market. Also, a typical human trait is the preference to continue using familiar systems and technologies rather than explore new options. By increasing the market penetration, the AVs and AI would gradually become more acceptable.

However, the responses of the survey that follows support this notion of hesitance and the hybrid option of human-machine collaboration is currently a more acceptable choice. By training the AI system and updating the road network with the required infrastructure, fully autonomous versions could be required in the near future and will be further investigated [31].

5 Preliminary Evaluation and Feedback by ES Staff

At this stage of the project development, a preliminary consultation with ten ES vehicle drivers follows previous focus groups discussions with ES staff which presented an initial overview into the emergency vehicles' traffic navigation issues. Also, the prototype system design has benefited by previous evaluation of 50 civilian drivers' analysis of distractions that prevent them to see or hear incoming ES vehicles [25]. The in-vehicle distractions, varying from infotainment to passenger interferences, can render the incoming ES vehicles completely invisible, despite the activated siren and blue lights' warnings [2, 16, 25]. Notably, the civilian drivers' reduced attendance to the swiftly fluctuating traffic-flow conditions was highlighted as the most threatening aspect of the safety and speed operation of the ES vehicles.

5.1 Driving and Collision Scenario

A hypothetical scenario based on existing traffic police information was utilised following on from previous AR guidance systems and collision avoidance interfaces' evaluations [2, 3, 15, 17]. This was considered necessary for maintaining consistency in the future evaluation process of the proposed full-windscreen AR/AI HUD interface. The proposed system's rationale, design and functionality were presented to the 10 volunteers currently working as ES drivers.

5.2 Survey Rationale and Structure

Firstly, a two-fold questionnaire was presented to the users. The first arm of the questionnaire was concerned with the demographic information of the group and their current experience and beliefs related to navigation and guidance systems as presented in Table 1. Secondly, a mock-up interface in action acted as a visual aid for explaining the system's functionality to the drivers before conducting the survey (see Fig.).

Finally, the third arm of the survey aimed to acquire drivers' subjective feedback that could inform the development of the final version of the proposed interface presented in Table 2.

Table 1. Pre-questionnaire for the ES staff.

Pre-Questionnaire
Q1. What age group are you in? ☐18-24 ☐25-34 ☐35-44 ☐45-50 ☐50+
Q2. What is your gender? ☐ Female ☐ Male
Q3. How many years do you work in the ES? ☐ 0-5 ☐ 5-10 ☐ 10-15 ☐ 15+
Q4. Do you think that the information provided by EV contemporary navigation systems can *guide you safely in dense traffic*? ☐ Yes ☐ No

Q5. Do you think that the information provided by contemporary EV navigation systems can guide you safely in *adverse weather conditions*? □ Yes □ No
Q6. Do you think that the information provided by contemporary EV navigation systems can guide you safely and provide the *fastest route* available? □ Yes □ No
Q7. Do you think that the information provided by contemporary EV navigation systems can provide you with *real-time manoeuvring options through traffic*? □ Yes □ No
Q8. Would you be interested to have real-time guidance suggestions by an AI system? □ Yes □ No
Q9. Have you ever had any collisions (minor or major)? □ Yes □ No
Q10. Do you find the in-vehicle provided information distracting? □ Yes □ No

Table 2. Post-questionnaire for the ES staff.

Post-Questionnaire
Q11. Did you find the *interface design simple and clear*? □ 1 □ 2 □ 3 □ 4 □ 5 (1 Very Simple – 5 Very Difficult)
Q12. Do you think that *interface design and colour coding* would be useful to convey the manoeuvring information? □ 1 □ 2 □ 3 □ 4 □ 5 (1 Very Useful – 5 Not Useful at all)
Q13. Would you be interested to have ***AR*** *navigation/guidance system in the* ***ES vehicle***? □ 1 □ 2 □ 3 □ 4 □ 5 (1 Very Interested – 5 Not Interested at all)
Q14. Would you be interested to have ***AI*** *navigation/guidance system in the* ***ES vehicle***? □ 1 □ 2 □ 3 □ 4 □ 5 (1 Very Interested – 5 Not Interested at all)
Q15. Would you be interested to have ***AR*** *navigation/guidance system in the* ***civilian vehicles***? □ 1 □ 2 □ 3 □ 4 □ 5 (1 Very Interested – 5 Not Interested at all)
Q16. Would you be interested to have ***AI*** *navigation/guidance system in the* ***civilian vehicles***? □ 1 □ 2 □ 3 □ 4 □ 5 (1 Very Interested – 5 Not Interested at all)
Q17. Would you be interested to have *real-time guidance suggestions by an AI/AR system*? □ 1 □ 2 □ 3 □ 4 □ 5 (1 Very Interested – 5 Not Interested at all)
Q18. Do you think that the *AR/AI proposed system could replace other guidance systems*? □ Yes □ No
Q19. Do you think it would be a helpful system (AI/AR) to *integrate into future ES vehicles*? □ Yes □ No
Q20. Do you think it would be a helpful system (AI/AR) to *integrate into future civilian vehicles*? □ Yes □ No
Q21. Do you have *any other suggestions, comments or thoughts* regarding the proposed AR/AI system? If yes please use the space below to write your comments. □ Yes □ No

Table 1 Questions 1-2 were concerned with basic demographics and demonstrated a wide range of sampled ages. Gender distribution was to some extent skewed with 7 male and 3 female drivers. Yet due to the small sample, these variations did not correlate with any significant pattern related to the given responses on the post-assessment questionnaire. Questions 3 and 9 related to the previous driving experience in ES and captured the drivers' prior collision history. Responses to both questions demonstrate a fairly uniform sample of drivers with no significant association between driving experience and incidences of collision.

Questions 4-10 presented the views of the staff regarding the current equipment and future expectations (see Fig.). Responses to Question 4, in particular, highlighted the potential guidance issue of current systems, as 70% of the drivers suggested that the current systems can provide navigation but cannot guide them. Similarly, the vast majority of the group responded that the current systems could not guide them safely under challenging traffic and weather conditions (Questions 5 and 7). In Question 6, 60% of the drivers felt that the contemporary EV navigation systems can guide them safely and provide the *fastest route* available. However, a significant percentage (40%) questioned the efficiency of the current systems to fulfil this role.

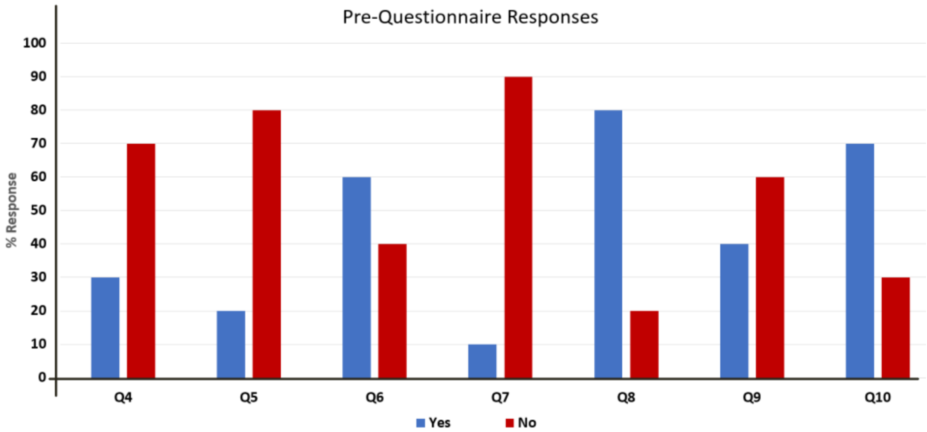

Fig. 5. Pre-Questionnaire Results for Questions 4-10.

Question 8, identified a potential appetite and requirement for a new technology that could employ AI to suggest guidance options in real-time, as 80% of the drivers were keen to experience such a system.

However the majority of them stated in the feedback section that the AI suggestions would be welcomed, however, they would be sceptical to use a full AV option (Question 21).

This confirmed previous focus group discussions in which the participants were reluctant to use full AV capabilities, particularly in busy urban environments. As such the hybrid option of AI/AR on the supportive role of the human driver was in par to the current expectations and was perceived as a more acceptable option. Finally, Question

10, highlighted the fact, that the current navigation systems are distracting the drivers, particularly in stressful situations as the ones encountered by the ES personnel.

The post questionnaire results presented some intriguing findings (see Fig.). In particular, the interface had encouraging scores with regards to the design and potentially functionality within the frantic situations encountered by the ES staff as illustrated in the responses of Questions 11 and 12. Question 13 revealed that 80% would be very interested and 20% interested to have an AR navigation/guidance system in the ES vehicles. Similarly, the same responses were provided on Question 15 for the civilian vehicles.

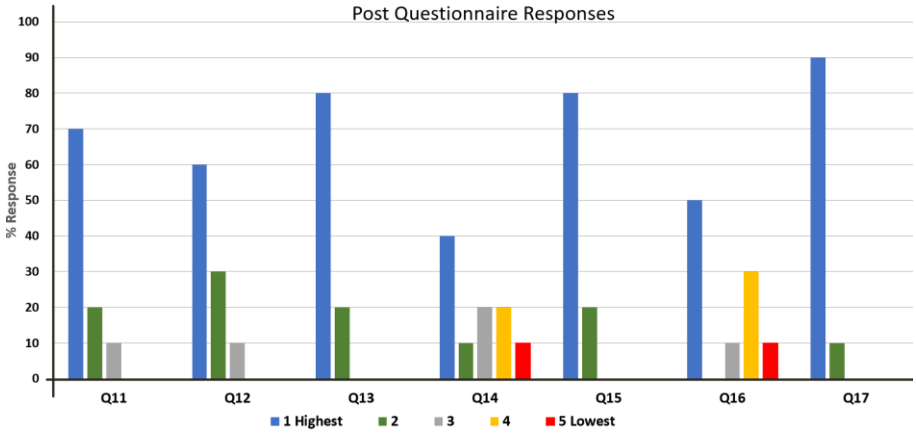

Fig. 6. Post Questionnaire Results for Questions 11-17.

However, the provision of AI for guidance and navigation, although overall positive, produced mixed results in the responses of Questions 14 and 16. Notably, the particular emerging technology is typically confused with full autonomous vehicle (AV) which has left unconvinced a large segment of drivers.

This confusion was also reflected in Question 21 where additional suggestions and comments were provided as stated above. Yet the combinatory approach of AI and AR system for the provision of guidance information was positively perceived by 90% of the drivers. This probably yielded positive results as the AI would propose and present information through the AR for the driver to follow or not. As such it was implied that the AI system would not take over the controls of the vehicle and as such the vehicle would not be fully autonomous.

The following three questions revealed similar positive responses with Question 18 achieving 90%, Question 19 100% and Question 20 80%, suggesting an indicative acceptance of the proposed technology both in ES and civilian vehicles.

To this end, further consultation and evaluation of the system with other ES groups such as police and Fire brigade might reveal additional system functionalities and requirements for different purposes. As such, the proposed system could potentially be useful as an in-vehicle aid for a variety of emergency services' activities.

6 Discussion

6.1 AR/AI for ES vehicles

The design rationale of the proposed system and the prototype demonstration has proven to be a desirable new aspect for the ES drivers. Notably, the system will have to be evaluated by a larger cohort of ES drivers to acquire statistically significant results and support future commercialization. The system's functionality will require further exploration and the development of different versions to correspond to the diverse requirements of the different ES vehicles and operations. In particular, the guidance capabilities and options of the AI/AR should cover aspects such as, how to efficiently manoeuvre in heavy traffic situations in adverse weather conditions and how to effectively regain control of the ES vehicle in challenging situations where adverse weather conditions affect the vehicle's stability. However, both of these situations will need the significant provision of data related to vehicle dynamics and drivers' methods to respond in such conditions, to enrich the machine learning process for the proposed system.

6.2 System Considerations

It has to be noted that the proposed system investigates currently the options to provide the guidance information to drive towards the Point Of Interest (POI) whilst maintaining all the legal requirements for navigating through traffic according to the instructions of the typical motorway legislations. The dispatch of ES staff from the ES vehicle to the accident scene is not a part of this work and there is official documentation which describes the correct process of staff and equipment deployment [28]. Also, the proposed system aims to support the driver in the decision-making process by calculating and presenting the optimal manoeuvres available. However, the manoeuvring process should be performed cautiously by the user according to the relevant motorway laws and regulations of each country.

6.3 Future Implications for Passenger Vehicles

Adhering to the survey results and comments related to the different future usage of an AI/AR HUD guidance system, presented an indicative, yet interesting view. The ES drivers were keen to have the system embedded on their work and civilian vehicles, but only if the system provides suggestions regarding the potential manoeuvring and speed options. In contrast, the misconception that the AI would enable a full AV mode was not perceived as a favourable possibility. However, as mentioned previously this view will gradually change given the market penetration and volume of new and used vehicles with AI/AR capabilities, available in the near future. Currently, these emerging technologies might be considered odd or not required. Yet the complexity of the road network on large urban environments and other infotainment technologies will deem these technologies necessary and part of the new smart cities ecosystem.

7 Conclusions

The paper presented the background rationale for the development of a prototype AI/AR system that will utilise a full windshield HUD system to superimpose guidance information in a real-life environment and real-scale, opposed to small estate HUDs.

Also, the paper presented current attempts to resolve collision issues and delay factors currently hindering the rapid mobilization of ES vehicles. In turn, this work described a preliminary yet informative appraisal of the prototype systems' functionalities by ten ES drivers. Their suggestions are in accordance with previous consultations with a focus group and civilian drivers' responses on fast approaching ES vehicles.

Furthermore, the paper analysed and discussed the findings of the aforementioned qualitative study, offering suggestions for further system development. In conclusion, the tentative plan of future work will include the finalising of the proposed system, based on the previous and current specialists' feedback and commence a large scale evaluation that will provide clear indications to the benefits and drawbacks of such systems. The evaluation of the proposed system in an urban environment and particularly in road intersections that tend to result in the majority of ES accidents will be pursued. Finally, an analysis of future introduction to passenger vehicles will be also commenced.

References

1. Hsiao, H., Chang, J., Simeonov, P.: Preventing Emergency Vehicle Crashes: Status and Challenges of Human Factors Issues, Sage, Vol. 60 no. 7, pp. 1048-1072 https://doi.org/10.1177/0018720818786132, (2018).
2. Lagoo, R., Charissis, V., Harrison, D.K.: Mitigating Driver's Distraction: Automotive Head-Up Display and Gesture Recognition System, IEEE Consumer Electronics Magazine, vol8, no 5, pp 79-85, DOI: 10.1109/MCE.2019.2923896, (2019).
3. Charissis, V., Papanastasiou, S.: Human-Machine Collaboration Through Vehicle Head-Up Display Interface, International Journal of Cognition, Technology and Work, P. C. Cacciabue and E. Hollangel (eds.) Springer London Ltd Volume 12, Number 1, pp 41-50, DOI: 10.1007/s10111-008-0117, (2010).
4. Frank, M., Drikakis, D., Charissis, V.: Machine Learning Methods for Computational Science and Engineering, Computation (Journal), Computational Engineering Section, MDPI, 8(1), 15; https://doi.org/10.3390/computation8010015, ISSN 2079-3197, pp 1-36, (2020).
5. Fire (Scotland) Act 2005 - Scottish Parliament Bill, Legislation.gov.uk, (2005).
6. Albertsson, P., Sundström, A.: Evaluation of Insight Training of Ambulance Drivers in Sweden Using DART, a New E-learning Tool, Traffic Injuries Preventions, Dec;12 (6): 621-9, (2011).
7. Smith, N.: A National Perspective on Ambulance Crashes and Safety: Guidance from the National Highway Traffic Safety Administration on ambulance safety for patients and providers, NHTSA Report, EMS World, pp. 91-94 (2015).
8. Charissis, V., Papanastasiou, S., Vlachos G.: Interface Development for Early Notification Warning System: Full Windshield Head-Up Display Case Study. In: Jacko J.A. (eds) Human-Computer Interaction. Interacting in Various Application Domains. HCI International 2009. Lecture Notes in Computer Science, vol 5613. Springer, Berlin, Heidelberg, (2009).

9. Kahn, C.A., Pirrallo, R.G., Kuhn, E.M.: Characteristics of fatal ambulance crashes in the United States: an 11-year retrospective study. Prehospital Emergency Care 5, 261–269, (2001).
10. Maguire, B.J., Huntin, K.L., Smith, G.S., Levick, N.R.: Occupational fatalities in emergency medical services: a hidden crisis. Annals of Emergency Medicine 40 (6), 625–632, (2002).
11. Clawson, J.J., Martin, R.L., Cady, G.A., Maio, R.F.: The wake-effect—emergency vehicle-related collisions", Prehospital and Disaster Medicine 12 (4), 274– 277, (1997).
12. Petzäll, K.: Trafiksäkerhet vid ambulanstransporter (Traffic Safety at Emergency Vehicle Transportation). Report 2005/94/90. The Department of Health and Social Sciences, Dalarna University, Falun, Sweden, (2006).
13. Ho, J., Lindquist, M.: Time saved with use of emergency warning lights and siren while responding to requests for emergency medical aid in a rural environment. Prehospital Emergency Care 5, 159–162, (2001).
14. Boslem, S., Moore, J. D., Charissis V.: Investigating the Improvement of the Localisation Propensity and Impact of the Emergency Vehicle Sirens", in Proceedings of the Society of Automotive Engineers (SAE) World Congress 2011, 12-14 April, Detroit, Michigan, USA, (2011).
15. Charissis, V., Papanastasiou, S., Mackenzie, L.: Evaluation of collision avoidance prototype head-up display interface for older drivers, Lecture Notes in Computer Science. 14th International Conference on Human-Computer Interaction, HCI International 2011, Orlando, 9-14 July 2011, vol. 6763 pp. 367-375, Springer, Berlin, Heidelberg, (2011).
16. Wang S., Charissis V., Harrison D.K.: Augmented Reality Prototype HUD for Passenger Infotainment in a Vehicular Environment", in Advances in Science, Technology and Engineering Systems Journal, Vol. 2, No. 3, 634-641 (2017).
17. Wang S., Charissis V., Campbell J., Chan W., Moore D.J., Harrison D.K.: An investigation into the use of Virtual Reality technology for passenger infotainment in a vehicular environment, In International Conference on Advanced Materials for Science and Engineering (IEEE - ICAMSE), pp 404 - 407, DOI: 10.1109/ICAMSE.2016.7840359, Beijing, China, (2016).
18. Kianfar R. et al.: Design and Experimental Validation of a Cooperative Driving System in the Grand Cooperative Driving Challenge, In IEEE Transactions on Intelligent Transportation Systems, vol. 13, no. 3, pp. 994-1007, doi: 10.1109/TITS.2012.2186513, (2012).
19. Flanagan S.K., He J. and Peng X.: Improving Emergency Collision Avoidance with Vehicle to Vehicle Communications, In 2018 IEEE 20th International Conference on High-Performance Computing and Communications; IEEE 16th International Conference on Smart City; IEEE 4th International Conference on Data Science and Systems (HPCC/SmartCity/DSS), Exeter, United Kingdom, 2018, pp. 1322-1329, doi: 10.1109/HPCC/SmartCity/DSS.2018.00220, (2018).
20. Charissis V., Papanastasiou S., Chan W., and Peytchev E.: Evolution of a full-windshield HUD designed for current VANET communication standards, IEEE Intelligent Transportation Systems International Conference (IEEE ITS), The Hague, Netherlands, pp. 1637-1643, DOI: 10.1109/ITSC.2013.6728464, (2013).
21. Lagoo R., Charissis V., Chan W., Khan S., Harrison D.: Prototype gesture recognition interface for vehicular Head-Up Display system", In IEEE International Conference on Consumer Electronics, Las Vegas, USA, pp.1-6, (2018).
22. Grane, C., Bengtsson, P.: Driving performance during visual and haptic menu selection with the in-vehicle rotary device. Transportation research part F: traffic psychology and behaviour, Vol. 18, pp.123-135. (2013).

23. Hui, C., Xianghui, W., Xiqiang, Z., Shaoli, Z.: The Evaluation of Chinese Urban Traffic Management System Application Based on Intelligent Traffic Control Technology, In 2014 7th International Conference on Intelligent Computation Technology and Automation, Changsha, pp. 791-795, doi: 10.1109/ICICTA.2014.191, (2014).
24. Li, N., Zhao, G.: Adaptive signal control for urban traffic network gridlock, In 2016 UKACC 11th International Conference on Control (CONTROL), Belfast, pp. 1-6, doi: 10.1109/CONTROL.2016.7737520. (2016).
25. Bram-Larbi K.F., Charissis V., Khan S., Lagoo R., Harrison D.K., Drikakis D.: Collision Avoidance Head-Up Display: Design Considerations for Emergency Services' Vehicles, In IEEE International Conference on Consumer Electronics (ICCE), Las Vegas, USA, (2020).
26. Charissis V., Naef M.: Evaluation of Prototype Automotive Head-Up Display Interface: Testing Driver's Focusing Ability through a VR Simulation, In IEEE Intelligent Vehicle Symposium, (IV '07), Istanbul, Turkey, (2007).
27. Charissis V., Papanastasiou S.: Artificial Intelligence Rationale for Autonomous Vehicle Agents Behaviour in Driving Simulation Environment, book chapter in the "Robotics, Automation and Control" Aramburo J. and Trevino, A., R., (Eds), I-Tech Education and Publishing KG, Vienna, Austria, EU, pp314-332, ISBN 953761916-8I (2008).
28. Aehlert, B.: Paramedic Practice Today: Above and Beyond, ECC Guidelines, (2010).
29. Okumura, H., Hotta, A., Sasaki, T., Horiuchi, K., Okada, N.: Wide field of view optical combiner for augmented reality head-up displays, 2018 IEEE International Conference on Consumer Electronics (IEEE ICCE), (2018).
30. Li, J., Cheng, H., Guo, H. et al.: Survey on Artificial Intelligence for Vehicles. Automot. Innov. 1, 2–14, https://doi.org/10.1007/s42154-018-0009-9, (2018).
31. Jing, P., Xu, G., Chen, Y., Shi, Y., Zhan, F.: The Determinants behind the Acceptance of Autonomous Vehicles: A Systematic Review. Sustainability, MDPI, 12, 1719, (2020).