Simulation-based requirements discovery for smart driver assistive technologies

Andreas Gregoriades
Dept. Computer Science & Engineering,
European University Cyprus
a.gregoriades@euc.ac.cy

***Abstract*.-Smart driver assistive technologies (DAT) have been developed to alleviate accident risk by either reducing driver workload or assessing driver attentiveness. Such systems aim to draw drivers' attention on critical cues that improve decision making. However, in some cases, these systems can have a negative effect due to the extra information load they incur to the driver. Therefore, in addition to specifying the functional requirements for such systems there is an urgent need to address the human requirements. This work describes a simulation-based requirements discovery method that utilises the benefits of a modular simulator that models future designs of DAT.**

***Index terms*-Requirements discovery, Simulation, Driver assistive technology**

I. INTRODUCTION

Human factors and requirements have a lot to share. Few studies however apply human factors knowledge to requirements engineering. While non-functional requirements (NFR) such as performance, security and maintainability are considered for software, NFRs for people, such as driver situation awareness (SA) and workload, have received less attention in requirements engineering. Such requirements have been proven very significant in preventing system failure which in traffic safety is articulated as an accident occurrence [1]. Therefore, the systematic analysis of these requirements prior to any DAT system implementation is considered vital. The main problem in evaluating these requirements is the need for an implemented hardware-software system prior to a holistic analysis of system behaviour under a number of test scenarios that involve people and tasks. This however is expensive and risky, hence the need for simulated environment.

This study focuses on the discovery of the requirements of future DAT with emphasis on SA enhancement systems. Firstly we aim to identify if there is a need for such as a system and secondly, proceed in specifying and validating its requirements. In traffic safety, SA constitutes a major critical factor, since it provides the driver with the ability to anticipate events given perceived driving and environmental conditions. The study is conducted with local drivers in Cyprus using a driving simulator designed for this purpose. The analysis is based on phenotype driver behaviour data such as lateral deviations, headways, speed, etc. collected through experiments in controlled settings. The assessment method used is task-performance based. An overview of the simulator and the research design employed is presented next.

II. DESIGNING THE DRIVING SIMULATOR

The first part of this work involved the design and development of a modular driving simulator that would enable the discovery of human requirements of future DAT. The use of a driving simulator is inevitable for such type of analysis for ethical and financial reasons and it allows experimentation under risky conditions. The simulator and its inherent models were, thus, designed to be generic, enabling the utilization of libraries of components representing assets that make up the driving conditions, DAT requirement specifications and road infrastructure characteristics.

The design and development of the driving simulator utilized Unity, City Engine, Maya and Tree[d].Unity 3D game engine, enables the development of 3D computer games and interactive virtual environments; it also enables changing the graphical environment and provides the designer with the ability to define behaviours through a powerful scripting language. City Engine, is a 3D procedural modelling software application, specializing in the generation of 3D urban environments through the manipulation of objects and existing GIS data. In our case City Engine was used to manipulate the XML file from OpenStreetMaps and the conversion of its 2D format into 3D using CGA Shape Grammar. Autodesk Maya graphics software was utilized for 3D modelling and animation, and in particular for the creation of vehicles and other static and dynamic models involving various assets (e.g. traffic lights, advertisement billboards). Tree[d] was used for the development of the surrounding environment and vegetation.

Additional car assets were imported in the simulator through car models from digital libraries, to provide variety. The selection of the car models was based on car types and brands currently used in Cyprus, in order to enhance the realism factor of the simulator.

The final part of the simulator design was the development of the functionality that would enable the interactivity between the user and the simulator. This was realised in Unit through JavaScripting. Upon completion, the user was able to drive the vehicle in the designed environment, by controlling its direction and speed using a steering wheel and pedals.

III. RESEARCH DESIGN

To discover the requirements of the candidate smart in-vehicle situation awareness enhancement system design, an experiment was conducted using the driving simulator, local road users and a virtual replica of the road infrastructure in Cyprus. The experiment utilised two combined conditions: roadside advertising billboards with a risky event and in-vehicle music with a risky event, at an accident black-spot in Nicosia (see Figure 1). The human requirement that were analysed focused on driver's SA and workload. These were assessed based on phenotype driver behaviours, with indicators such as lateral deviations and failure to recall important information of primary task after the experiment.

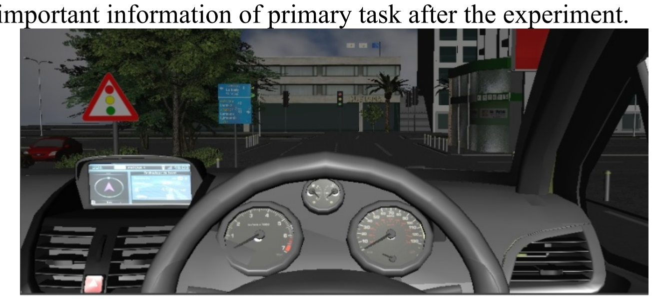

Figure 1. The interface of the developed driving simulator in the virtual road design

Participants drove a pre-specified route in the designed road network both with and without billboards and in-vehicle music at a safety critical point. Data were collected at different stages (i.e. before, during and after the experiment) to capture participants' background information, their engagement and recollection of the conditions, as well as their driving behaviour and workload and SA level indicators. The goal of the experiment was to identify cognitive gabs in drivers' mental models that could indicate low SA.

IV. Design Specification for a Future Smart Situational Awareness Enhancement System

Results from the experiments highlight the need for SA enhancement through automation. The system should be providing drivers with extra critical information that will make driving safer and less stressful. Results revealed that the highest percentage of accidents occurred at the section where the traffic was increased. This is not surprising since at these locations drivers are expected to process increased volume of information. This highlighted the need of a SA enhancement system that would alleviate the workload of drivers at such situations by helping them to concentrate critical information cues. The criticality of these cues is defined by proximity to other vehicles, other vehicle trajectories, predicted trajectory of surrounding vehicles and their projected impact. Another important finding is the effect of the vehicle's blind spot on SA. Blind spot is the area to the back side of the vehicle where driver's view is obscured by the vehicle's middle pillar.

A smart SA enhancement system should support the information needs of drivers by reducing their workload. The challenges in designing such systems are many. The one addressed here is the design of the user interface so that it is not distractive. This could be achieved by providing drivers with important situational cues that are critical for maintaining acceptable levels of SA. The type of automation selected for the future system should focus on information perception and dynamic risk assessment. This, in essence, could reduce the likelihood of accidents. The identified problems from the experiments point to the need of a system that will enhance SA and is not intrusive. To that end the use of augmented reality overhead display is considered as a suitable option. The visualisations of the display should aim to provide the driver with enhanced peripheral vision with a dynamic assessment of the most critical entities within the immediate periphery of the vehicle. Based on the above, a candidate design proposed and modelled in the virtual environment is depicted in Figure 2. The host vehicle is shown in the middle surrounded by red and green vehicles of different sizes. These correspond to high and low risk vehicles accordingly. Vehicles that are in the driver's blind spot are represented by big red cars. Low risk cars are depicted by small green icons. High proximity or hidden vehicles at intersections are also high risk and hence are big and red. Vehicles positions and speeds can be obtained from on-board sensors. Surrounding vehicles at intersections can be obtained through vehicle to vehicle communication protocol. The visualization metaphor presented in Figure 2 will be depicted on the vehicles windshield.

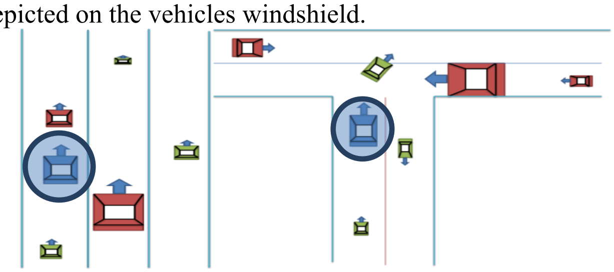

Figure 2. Visualization of the proposed system design in two traffic scenarios. The host vehicle is included in a circle.

I. Conclusions

The simulation based requirements discovery method enables the design and customization of the road infrastructure for what-if analyses in a modular fashion. This enables the design of the experimental settings for the analysis of requirements under a variety of possible system designs. The use of situation enhancement technology such as the one specified herein could alleviate driver overloading problems. The validation of the requirements of the proposed designs however needs further experimental simulation studies.

II. Acknowledgements

This work is part of the IPE/NEKYP/0311/02 "VR CAVE" project and is financially supported by the Cyprus Research Promotion Foundation and the European Structural Funds. (http://www.vrcave.com.cy)

References

[1] A. Gregoriades, A. Sutcliffe, G. Papageorgiou, and P. Louvieris, "Human-Centred Safety Analysis of Prospective Road Designs," *IEEE Transactions on Systems, Man and Cybernetics, Part A,* vol. 40, pp. 236-250, 2010.

[2] B. Gault , A. Sutcliffe, N. Maiden, "ISRE: immersive scenario-based requirements engineering with virtual prototypes",*Requirements Engineering 10*(2): 95-111 2000.

APPENDIX

Some screenshots of the tool are attached below, in addition to the one presented in the extended abstract.

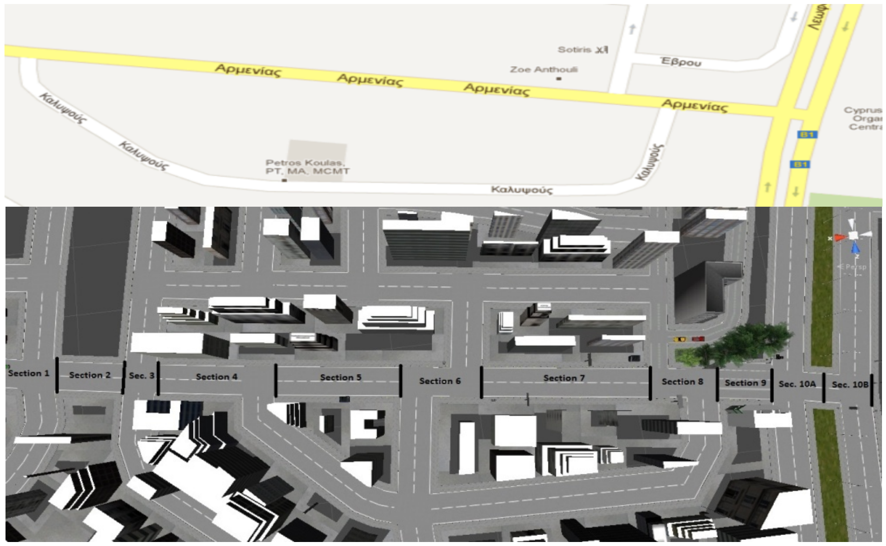

Figure 1. The GIS model of the black spot (top) and its realization in the 3D driving simulator, with the road divided into sections 1-10b (bottom)

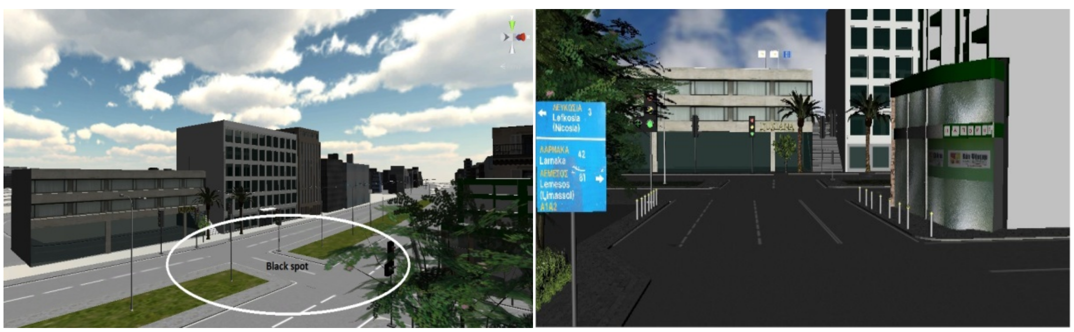

Figure 2. Screenshots of the virtual road design in Unity

Figure 3. Real photo of the black spot under study that verifies the similarity of the real and immersive environment shown in figure 2