Evaluation of a New System in Future L4 Vehicles: Use Cases and Methodology for the SUaaVE European Project

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Abstract: The current era is experiencing an epochal technological advancement in the automotive industry, with electrification, automation and connectivity driving research and innovation. Various disciplines involved in the design and development of vehicles are affected by this progress and new aspects, such as acceptance, trust, ethics and emotions which will become fundamental components of the market. All these aspects will be investigated in the project SUaaVE. SUaaVE is a European project aiming at improving the users' acceptance, trust and comfort of future Level 4 automated vehicles by involving the user in the development of the concept of a new system called ALFRED. This paper will describe the methodology developed for the evaluation of ALFRED, by representation of future vehicle use cases to be used as a means for assessment.

1 INTRODUCTION

The introduction of autonomous vehicles is set to disrupt the automotive industry and market (Diels et al., 2017). Without the driver, future research in almost all the fields concerning automotive will have to change its point of view (Diels et al., 2017). New aspects of, for example, comfort, security, ethics and design must be introduced. This paper aims at expanding the knowledge on future automated vehicles. More in details, it describes the methodology for the validation of a new conceptual system for a L4 automated car. This system, called ALFRED (Automation Level Four+ Reliable Empathic Driver) is being theorised in the European project SUaaVE (SUpporting acceptance of automated VEhicle). The system aims to be a user centred technology able to adapt to the user state considering concepts like acceptance and ethics. This work is focused on the construction of the use cases and the methodology underlying the evaluation of ALFRED concept.

This paper refers to L4 vehicles. L4 vehicles have the capability of being full automated and do not require a driver to be present. However, the vehicle has limitation in its ability to drive autonomously in aspects like type of roads, type of environment or general conditions. L4 cars are able to detect the limitations and safely manage any situation where it is not possible to drive autonomously. The conditions when L4 vehicles drive autonomously is known as an Operational Design Domain (ODD).

1.1 The SUaaVE Project

SUaaVE aims at solving the gap between technological advancement and public acceptance by adopting a Human-Driven Design (HDD) approach, enhancing synergies in social science, human factors research and automotive market by means of an iterative process of assessment, co-design and prototyping. The main outcomes will be:

1. A new paradigm of automation: ALFRED, that aims at "colouring the decision-making processes of the CAV with human emotions" with: (a) an EMpathY Unit to understand the emotional and cognitive state of the passenger and (b) an Adaptive, Cognitive and Emotional Interface with a set of services (vehicle dynamics, ambient and postural comfort) to enhance passenger experience.
2. An immersive Virtual Human Centred Design (V-HCD) platform, allowing the simulation of CAV.
3. Guidelines to support Public Authorities, representing a breakthrough in the public acceptance of future CAVs for both the society and for all road users.

This paper is concerned with the first point, with this being focussed around the methodology for the evaluation of ALFRED concept.

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1.2 The ALFRED Concept

ALFRED concept is intended to intelligently respond to users' states by means of a series of models, whose development forms a key part of the SUaaVE project. These models set out to take a series of user-based components into account, with the intention of adapting the system in a way that will improve vehicle behaviour across several different functions. The ALFRED concept will control these varied components considering user acceptance, ethics, emotions, and comfort.

2 USE CASES

A key part of the development of any product or service involves careful thought of how it will be adopted and used once released into the real world. Within the field of Human Factors, this process closely considers the needs of the end user and their points of interaction (Wilson and Sharples, 2015). This methodology provides a mean by which design and development can consider real scenarios under which something might be used by creating solutions that are relevant to end users. Use cases define generic and/or specific scenarios under which a product or service eventually be used. They are often comprised of a series of steps which define typical events based around interactions between a user and a system (Möller, 2014).
This method will be used for the evaluation of ALFRED. Throughout development of the system it is necessary to offer relevant scenarios to its eventual use. In terms of research studies conducted, this involves investigation around components of acceptance, ethics, emotions, and comfort.
Use cases must offer controlled scenarios with defined variables, whilst maintaining the context of eventual use. Each of the use cases must offer definitions for users, context of use, the environment, and events.

2.1 Definition of the Operational Domain

The specification of use cases will follow some general guidelines set out by the definition of an ODD.
The proposed components of the ODD for the SUaaVE are as follows:

- Rules for the physical boundaries where vehicle is able to operate (on what roads can it travel)
- Rules for vehicle journeys (level of user control, pick-up and drop-off locations and possibilities for route override)
- Rules for operational conditions (weather and lighting conditions)
- Rules/norms for interaction with other road users (external) – common method of communication between autonomous vehicles and other road users, within the operational domain

2.2 Definition Process for Use Cases

The first step in the definition of the use cases process is the definition of external factors, which is the definition of the factors affecting ALFRED's operation and its occupants.
The definition of the external factors takes place in parallel to the development of the ODD. The external factors can be grouped by:

- **Variable Environmental Factors**. (E.g. route, operational zones, obstacles.)
- **Fixed Environmental Factors. (**E.g. visibility, temperature, weather, traffic)
- **Variable Vehicle Operation Factors. (**E.g. speed, dynamic behaviour)
- **Fixed Vehicle Operation Factors. (**E.g. dynamic, visibility, comfort)
- **Situational User Factors (Variable). (**E.g. journey purpose, activities)
- **User Profile Factors (Fixed). (**E.g. personality, preferences, experiences, physical capability, cognitive capability)

2.2.1 User, Context, Environment and Events

Regarding the type of users who will interact with ALFRED, they were divided into two groups: primary and secondary.
The primary users are the ones directly interacting with the vehicle. These are the users inside the vehicle when ALFRED is functioning.
The secondary users are users not directly interacting with ALFRED, such as Virtual Road Users (VRUs), other vehicles drivers, service users and transport management personnel.
The journey context characteristics are:

- The start and finish location.
- The journey stop(s).
- Purpose of the journey

- User activity before/after the journey.
- User activity during journey.

The interaction between the vehicle and the environment will affects the user experience, emotion, acceptance, trust and comfort. During the scenarios, ALFRED will respond to change in the operational environment, and this will trigger different perception by the users. In details, the operational environment is composed by:

- The physical ODD zones.
- Domain rules and norms: regulations and the general behaviour patterns within the operational environment.
- Weather.
- Infrastructure.
- Road condition.

The events happening during the scenario have been developed in order to trigger controlled reaction to the user emotional state and perception. More in depth, the events are used to investigate the reaction that the users have to certain situations. There are two types of events, generic and specific.

Generic events refer to the type of situations that are usual and often occur during a normal journey. They will be comparable between use cases.

Specific events will be events that do not usually occur in a normal journey and are proposed to trigger change in the user status (emotional, psychological and physical).

2.3 Distinction between Use Case Types

As previously stated, there is a demand for different types of use cases dependant on specific application. Within SUaaVE, use cases are to be applied across multiple investigative and developmental phases, with distinct applications depending on stage and methodology.

To meet all of the demands for investigation, development, evaluation, and demonstration, a system of categorisation for use cases have been defined from the outset.

1. Trip use cases

Trip use cases encompass user journeys and define scenarios from a standpoint of generalised use. Following the process set out above, they comprise of a definition of specific users, a context for use, and a defined environment. Underneath this, are set out a series of individual events which take the form of a long scenario. The events defined under a trip use case are applicable to the scenario context and specify general occurrences.

These longer use cases can be used when carrying out assessment regarding the whole system. This is done by presenting a real-world applicable scenario.

2. Situational use cases

Situational use cases provide the tightly defined and controllable scenarios required by scientific investigation and provide the means for specific demonstration and evaluation. They include defined users, specified context, and information regarding the environment. The sequence of events within them defines more specific occurrences, although these still join to form a scenario.

Situational events within the use case framework fall under two main categories:

a. General Events

General events are taken directly from the scenario defined within the trip use cases. These are applied within all the longer journey scenarios, although the exact sequence is dependent on the specific use case. They define normal occurrences within the use of the ALFRED vehicle which, although intended to provoke a user response, will always be regarded as common happenings.

b. Exceptional Events

Exceptional events define scenarios that can be regarded as falling outside of normal operation. These might involve clear discretions by other transport users or could involve situations in which the vehicle leaves its functional domain or encounters an error in its operation. Being situational use cases, exceptional events always from short scenarios which are applicable for specific experimentation or for demonstration and evaluation of special operating conditions for the ALFRED concept.

2.4 Example of ALFRED Use Cases

Following the method described in the section above and after the contribution of all the partners for the SUaaVE project, the ALFRED use cases have been developed and included as a reference for both the first and second loop of evaluation. An example of a trip use case and of a situational use case are depicted in the images below (Figure1 and Figure 2).

More in details, figure 1 details all the events that have been chosen to be part of the scenarios. As explained in the section above, in the situational use cases, one or more events can be included and the use cases can be different depending on which specific aspect is under investigation.

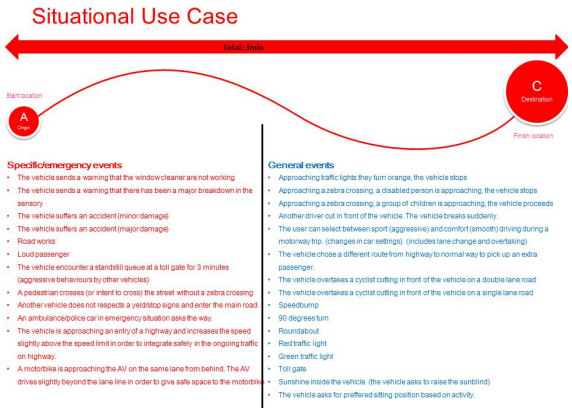

Figure 1: Example of a situational use case.

Trip use cases are more defined and are the same for all partners. Figure 2 depict an example of a use cases that has been proposed. The trip use cases will be prone do modifications depending on the results of the first loop of evaluation (section 3).

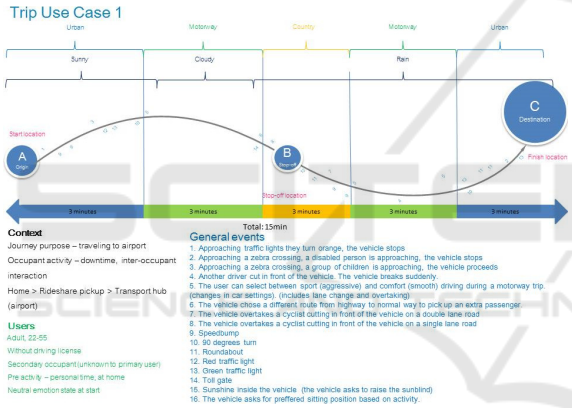

Figure 2.

3 USE CASES AS PART OF THE EVALUATION FRAMEWORK

The evaluation framework is based upon the testing of ALFRED with a comparison being made against a normal connected automated vehicle (CAV) through multiple phases.

The use cases forming the evaluation framework will provide detailed definitions joined to the end use of the vehicle to provide a relatability to the test outcomes. The use cases will be the reference for the construction of scenarios for the evaluation of the acceptance of the vehicle by the users, the emotions triggered by the events, and the ethics implications in the use of the vehicle.

At a high level, assessment will comprise of two main phases of testing known as first loop and second loop. These two phases encompass formative testing of the models and of vehicle systems, and subsequently provide the basis for summative testing following completion of their development. These two loops can be viewed following the aforementioned concept of situational use cases and use cases defining journeys

3.1 First Loop of Evaluation

The outcomes of this first loop testing will provide a series of comparative data between the models developed for integration into ALFRED and the corresponding response of the CAV. In addition, it involves the first assessments of the ACE interface and the performance of the dynamic model, both of which will be individually evaluated with comparison made to the CAV response under the same conditions. These will be the basis for conclusions on the success of the projects' first developmental phase. In line with the project aims, this will be with regards to the way that models can respond to and manage specific situations in terms of the users.

In this case, the use of situational use cases offers the means for evaluation under a specific scenario with closely defined conditions. Like with the investigative and development phase, this will provide controllable and repeatable variables within defined test scenarios.

3.2 Second Loop of Evaluation

The second loop will take a more global view of the system assessment, seeking to evaluate how the system performs in terms of users when experiencing its use across an entire trip. Like with the first phase this will include testing against the CAV, but with more outcomes given more focus regarding to how the ALFRED concept might perform in the real world. This stage will include the final evaluations of the vehicle system, with conclusions assessing the overall success of the concept.

With this in mind, use cases for second loop testing will principally take the form of trip scenarios which are representative of an entire user journey.

4 CONCLUSION

The advancement in the automotive industry require a massive and rapid change of focus for most of the disciplines involved. The transformation of the driver

to a passenger require new systems, new design and new features, both from the technological point of view and the user centred part. On the Human Factors point of view, additional aspects such as acceptance, ethics and trust must be taken into consideration and other attributes like comfort must be rethought. The SUaaVE project aims to investigate a new concept for L4 autonomous cars, a system that adapt to the users' emotional state, and considers acceptance, trust, ethical issues and comfort. This system concept, called ALFRED, is currently under development. This paper described the proposed methodology to evaluate it. More in details it described the process of construction of the use cases, useful to contextualise the system in a possible real-life scenario and to elicit specific emotions through predetermined events. The next phase of the project will include the formative evaluation (first loop) in driving simulators and through videos with potential users. The results of the formative evaluation will guide the further development of the system and will lead to the summative evaluation (second loop).

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