METHOD OF DRIVING ASSISTANCE SYSTEM DESIGN TO IMPROVE HUMAN-VEHICLE INTERACTIONS AND SAFETY TECHNOLOGIES DEVELOPMENTS FOR TRUCKS

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ABSTRACT

This paper presents a method to develop coherently a Driving Assistance System (DAS) and its supporting technologies in order to reach efficiently the best added value in terms of Human-Vehicle interactions and technology specification.

This method is an iterative development process based on a Human Centred Design approach. It requires a driving simulator and a development framework in order to simulate technologies.
The first step of the method is to validate the DAS prototype through 3 iterative tasks: Study of the drivers needs, Design of the DAS with "perfect" technologies, Evaluation of driver-vehicle interactions to validate the effectiveness of the assistance.
Then the second step is to obtain the best trade off between effectiveness of the assistance and technological requirements through 2 iterative tasks: Modification of the technology performance by changing the specifications (toward existing, emerging or futuristic technologies), Evaluation of driver- vehicle interactions to validate that the assistance is still effective.
This guides the final decision for the DAS production: use existing technologies, or develop better safety technologies.

This method is developed inside VIVRE 2 project, which aims to design an innovative DAS to help truck drivers engaged in low speed manoeuvres in urban areas.
We first developed a prototyping platform, which we then used along with the method to design the DAS and to determine the best compromise in terms of Human-Vehicle interactions and technology specification.
Even if the method inherits of the limitations of simulated environments, it permits a "driver in the loop" development of innovative DAS which would be difficult otherwise.

Instead of using the classical approach "From technologies, to DAS design, to DAS evaluation", this approach shift the problem to "From driver needs, to DAS evaluation, to technologies".

INTRODUCTION

With the massive arrival of electronics, systems designed to support and assist the driver in his/her driving activity (like ABS, Navigation systems…) started to be implemented inside vehicles. These systems raised different research questions not only in the field of technological development, but also in the field of drivers' needs in terms of assistance. However, as the number of DAS inside a single vehicle increase and as they are designed and implemented separately, it becomes more and more difficult to determine the impact of the sum of these assistances on the driving activity. In order to avoid a negative impact of these systems on the driving activity, a detailed study of the interaction between the human and the vehicle systems is required. Human Factor research provides the key concepts to tackle this issue. Thus, the design of DAS becomes a joint work for engineers and Human Factor researchers.
In this context, we propose a DAS design process based on a Human Centred Design approach that permits to develop coherently a driving assistance system and its supporting technologies in order to reach efficiently the best added value in terms of Human-Vehicle interaction and technology specification.
In this paper, we present in details this design process and its results through the case of VIVRE 2 project which aims to design an innovative DAS to help truck drivers engaged in low speed manoeuvres in urban areas.

METHODOLOGY

Human Centred Design Approach

While developing a DAS, thorough technical specifications have to be made, as the safety of drivers and other road users are engaged.
The usual way of working starts by identifying what safety issue could be solved by a DAS.
Then, it consists in finding which technology could be employed to solve this issue. Then, in developing a prototype and testing its functioning in all situations in which it is designed to work.
After the validation of the functioning, when the

technology is considered as mature enough, the DAS is spread on the market. This type of method is called technology driven approach, as it consist to start from a technological description of the problem, and solve it via a technical solution.
This method is thorough, efficient and safety-proof. These criteria are sufficient for a DAS manufacturer who needs to be sure a technology is safe and can be used by drivers.
However, this approach does not guarantee that the DAS is useful, and that it is correctly used by drivers. In order to solve these issues, DAS designers have to consider the drivers' feedbacks earlier in the design process: at its very beginning. Thus, they have to shift their way of doing from such a technology driven approach to a human centred design approach.

Human Centred Design (HCD) approach places the users and their needs at the centre of the development process. The key principle of user centred approaches, as defined by Gould & Lewis (1985)[1] is to focus on users and tasks and to apply an iterative design.
In the case of DAS design, it consists in studying the driver and his/her driving activity all along the DAS development process.
HCD for DAS design consists in iteratively:

1. Studying the driving activity (e.g. through DVE model…)
2. Deriving the contextualised needs in term of assistance (related to safety, control, information, comfort…)
3. Formalizing the functional specifications of the DAS
4. Developing the DAS
5. Testing the impact of the DAS on the driving activity

Our Approach

General Overview – Considering that the driver might not use the DAS as the designers was expecting, or more generally, that the driver will adapt it's driving behaviour to the DAS, we adapted the HCD approach, in a way where we can evaluate the modified behaviour of the driver at the early stage of the development process.

We actually adapted the 5-steps development process loop into two different steps. The first one focuses on the interaction between the Driver and the DAS (leaving technological limitations aside). The second step consists in making the DAS realistic, by adapting the DAS to existing or forthcoming technologies.

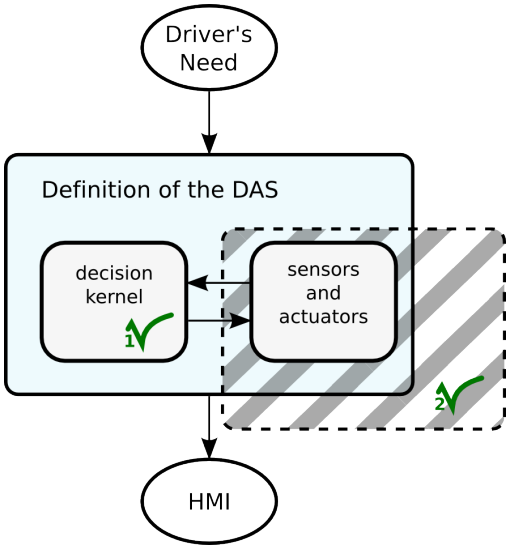

Figure 1: General overview of our approach.

The figure 1 illustrates this approach. We start from driver's needs, that have to be identified by ergonomics researchers studying driving activity. From this needs, we can design the kernel of the DAS. But we don't limit this DAS with technological constraints on sensors and actuators. And we test, at an early stage, the behaviour of both the driver and the DAS when put together.

Of course, this step can only be done on a driving simulator.

This steps should be executed in a loop until the drivers coupled to the DAS behaves satisfyingly. This validates the kernel of the DAS, and the effectiveness of the assistance.

Then, we can focus on the technological constraints. On this second step we expect to find a good trade-off between the effectiveness of the DAS and the technological requirements.
The kernel that was defined specify at some point the technologies that would be needed. But what if the technology selected to support this DAS is not efficient enough? For such reasons we could be interested in seeing how far from the “ideal” technologies we can get while the DAS stays satisfyingly efficient for the driver.

We will present in details these two steps in the following of this chapter.

First Step – Focus On Driver / System Interaction - The objective of the first step is to validate the effectiveness of the assistance system according to the drivers needs.

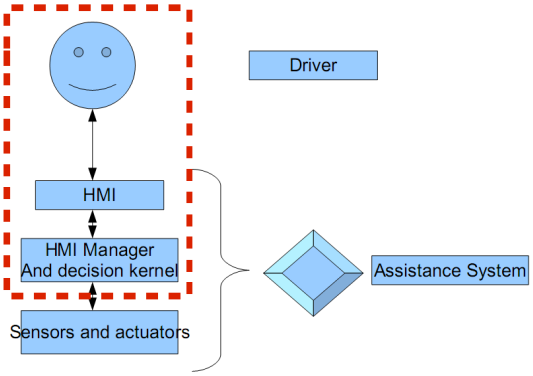

Figure 2: first step to Focus on driver / system interaction

The methodology for this first step is inspired from a human centred approach.
The first phase of this step consists in defining accurately what kind of assistance the driver needs in what situation. This knowledge is gained through a detailed analysis of the driving activity. Various scientific approaches can bring knowledge on the driving activity. Naturalistic observations or experimental observations in real traffic condition are specifically suited for this purpose.
Once the situations and the respective assistance that is needed by the drivers are defined, the design of the DAS can begin.

The central question is to determine the best possible way to provide the driver with the relevant assistance: the right information/action at the right moment.
So the second phase of this first step focuses on the design of the Human/Machine Interface. This second phase consists in an iterative process with 2 tasks. The first task is to develop an HMI and an HMI manager that give, for the target situations, the relevant assistance to the driver. The second activity is to study the interactions between the driver and the assistance system and to evaluate the effectiveness of the system. These two tasks have to be repeated until the cooperation between the driver and the system reaches the targeted objectives.

At this stage, the development of the assistance decision kernel is based on technologies that have an ideal functioning, and that are always capable of delivering perfect information to the HMI manager.

This first step permits to design a DAS and to assess very quickly if the DAS suits the drivers needs in terms of driving assistance.

Though this first step is meaningful to validate a concept of assistance, it is disconnected from the constraints of the technological offer. Therefore, a second step is necessary to tackle this issue.

Second Step - Focus on system / sensors interactions - The objective of the second step is to materialize the DAS in order to determine the best technological specifications to support its functioning.

To reach this objective, two tasks have to be realised as an iterative process. The first tasks is to simulate technologies that can provide the assistance kernel with informations. These technologies does not necessarily have perfect performances (sensors range, decision algorithms...). When changing their specifications, from ideal technologies toward existing, emerging or futuristic technologies, the modifications might have an impact on the global functioning of the assistance. Therefore, the second task consists in evaluating driver-vehicle interaction to validate that the assistance is still effective and that its functioning was not significantly reduced.

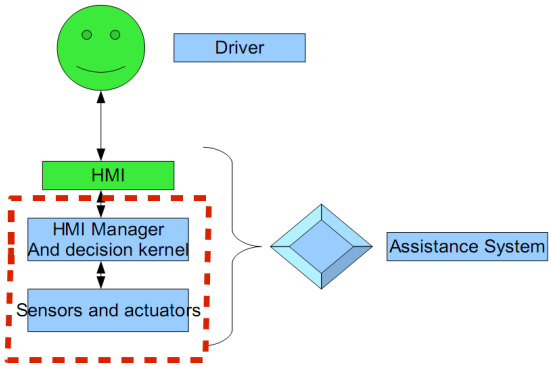

Figure 3: second step to Focus on system/technology interactions

Through the iterations, it is possible to find out the best compromise in terms of Human-Vehicle interactions and technology specification.

RESULTS: CASE STUDY ON VIVRE II PROJECT

Context

VIVRE2 project focuses on reducing the number of accidents involving trucks and vulnerable road users (pedestrians, cyclists…) in urban areas [2]. Part of the project consists in designing and testing on a Renault Trucks simulator called "SCOOP", a system assisting truck drivers engaged in low speed manoeuvres.

SCOOP simulator runs various applications from Oktal. This software is controlled by specific Labview diagrams. These diagrams give an easy access to several parameters that describes driving activity, such as information on driver's actions, truck dynamics, dynamics of mobiles around the trucks, properties of these mobiles and roads characteristics.

Development of a Framework that Support our Methodology

To support our design process, tools are necessary. These tools should offer flexibility for the DAS development : a dedicated architecture for the DAS HMI manager and decision kernel, a dedicated architecture to easily simulate technologies, and a feature to connect the DAS to driving simulators. Thus, the development of a dedicated prototyping platform would be useful. That is why we specified and created a framework platform with the features required to support the design process we described in chapter 3. This framework is based on a architecture composed of several dedicated modules: Two specific interface modules (that transfer and translate data from simulator to prototyping platform back and forth), a module to pilot the HMI of the DAS, a module with the DAS decision kernel and finally different modules that simulate technologies required by the DAS.

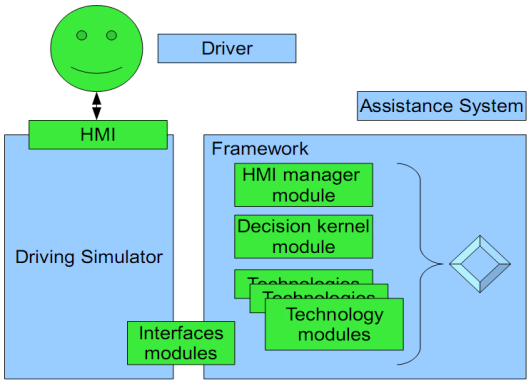

Figure 4: Architecture for DAS design

These modules act as containers for DAS algorithms and are connected according to the architecture.
Using this framework, the DAS designer focus on creating the relevant algorithms of each module.

Application of the Methodology Through the Framework

To design VIVRE 2 DAS, the ergonomics researchers of the project defined the needs in terms of assistance and the target situations. They also started the design of the HMI to provide the driver with the assistance.

At first, we focused on the development of the interface modules algorithms in order to be able to receive data from the simulator, and to pilot the HMI.
Then, we drafted the HMI manager algorithms and the decision kernel algorithms, and developed them until they corresponds to the expectations of the ergonomics researchers and prove their effectiveness on a sample of drivers. At this stage, the technology modules algorithms only deliver perfect information from the simulator (exact position of the pedestrians, infinite range of perception...).
This achieve the first step of our methodology, that focus on driver/system interaction.
To continue, we selected a set of sensors that could support this DAS (laser scanners and ultrasonic sensors) in a real implementation. We modified the technological modules algorithms accordingly, by adding physical constraints that simulate the behaviour of these sensors.
This is the second step of our methodology. At the time we write this paper, we are testing the effectiveness of the assistance with this selected set of sensors on a sample of drivers.
The following steps will be to take into account the feedbacks of the drivers to validate the specification of the technologies : either the technologies are sufficient to support the correct driver/assistance interaction, or new specifications are required to support the driver/assistance interaction. These new specifications can come from another set of sensors, or from the suggestion of specifications improvement.

CONCLUSIONS

Instead of using the classical approach "From technologies, to DAS design, to DAS evaluation", we shifted the problem to "From driver needs, to DAS evaluation, to technologies". Indeed, we developed a DAS design process inspired from a Human Centred Design approach and we successfully applied it to a real case. This design process consists in 2 different steps. To support this method, we developed a framework.
This framework proposes a reference architecture for DAS design.
It permitted us to quickly realise the first step of the method, focused on driver/assistance interaction, and to obtain a prototype that provide the driver with an effective assistance.

Then, it permitted us to begin with the tasks of step 2, focused on assistance/technologies functioning. Experimentation with drivers are currently performed to complete step 2. The overall objective is to obtain, through this method, the best compromise in terms of Human-Vehicle interactions and technology specification.

DISCUSSION

To be optimal, this method requires a high number of iterations and tests with drivers, which is costly and time consuming. This is a first limitation of this design process. This parameters has to be taken in to account during the development in order to optimise the number of iterations. However, the modification between each iteration can be done very quickly and easily, which accelerate the general design process.
Even if the tests on drivers inherits of the limitations of simulated environments, it permits to evaluate innovative DAS which would be difficult otherwise.
This "driver in the loop" development can only be achieved by considering the couple driver and assistance. A step further would be to develop a driver model, that simulates the behaviour of a real driver, in order to rationalise this couple and to be able to perform more iterations for the system evaluations.

REFERENCES

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[2] VIVRE2, "Véhicule Industriel et usagers Vulnérables de la RoutE", PREDIT GO4 project proposal, 2005