ADVANTAGES OF A DRIVER MODEL USE IN THE DESIGN OF A DRIVING ASSISTANCE SYSTEM TO PREVENT COLLISIONS BETWEEN DELIVER TRUCKS AND VULNERABLE ROAD USERS

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ABSTRACT: this paper presents the approach used in the French project vivre 2 to develop, on a driving simulator, a driving assistance system aiming to prevent collisions between delivery trucks and vulnerable road users. The chosen approach to design and develop this assistance system is based on "adaptive technology" which adapts the alarms and active controls of the system to the behaviour of the driver. The system merges the output of a spatial representation of driving situations and of a driver's intention model to select the nature of the assistance (warning, active control) and the warning intensity. Thus, the system functioning is based on the combination of two finite state diagrams, one for driver activity modelling and one for truck external environment modelling. The objective of this paper is to explain how situation representation by finite state diagrams reduces the complexity of the hmi activation and provides a synthetic view of system functioning.

1 INTRODUCTION

During year 2006[1], accidents involving trucks killed 685 persons in France. These accidents are critical in terms of seriousness, with 14.2 killed for 100 injury crashes, whereas accidents in general have 5.86 killed for 100 injury crashes. Accidents with trucks involving vulnerable road users are the most critical: pedestrian (24 killed for 100 injury crashes), bicyclist (14.5 killed for 100 injury crashes), and motorcyclist (12.4 killed for injury crashes). To avoid such accidents, a solution is the development of driving assistance systems that alert the truck drivers of vulnerable user presence around the truck. French project vivre 2 address this issue as it aims to develop, on a driving simulator, a driving assistance system to prevent collisions between delivery trucks and vulnerable road users.

2 CONTEXT

The project consortium was composed of two human factor laboratories LESCOT, LEACM, two technical laboratories CEESAR, ENTPE and two industrial partners INGELUX, Renault Trucks. In the scope of this project, LESCOT team has used its knowledge and experience in the domain of driving activity analysis and cognitive processes linked to driving (situation awareness, executive functions, attention, mental representations…) to design and develop an assistance system that adapt its alarms and active controls to the behaviour of the driver.

The design process of vivre 2 assistance system was inspired by a human centred design approach which started with the analysis of the truck driver's activity (in[2]). This analysis delivered driver needs in terms of assistance and formalised a set of use cases that describe the expected system functioning according to road situations and actions of the driver. In order to adjust the activation and the intensity of alarms for all the of target situations where the system had to be helpful, we chose to build an adaptive system which adapt the human machine interaction (HMI) functioning according to driver behaviour.

3 ADAPTIVE TECHNOLOGY APPROACH

This approach consists of modelling driver's activity to adapt the interaction between the driver and the system according to the driver's actions. The system adaptation to driver is discussed since several years. The European project GIDS (generic intelligent driver support) [3] has describe some conceptual views for driver-adapted warning on the basis of the behaviour model of driving.

Models were also used to design systems. For example, a driver cognition model has been selected as a reference for designing and testing the whole EUCLIDE system and its human machine interface. [4]. Other models were implemented in real time to be used to adapt HMI in driving assistance systems. The PROLAB demonstrator informed the driver about potential or real risks depending on his/her own state, his/her situation on the road, the situation of the other vehicles, bicycles or pedestrian [5]. The daisy system (driver assisting system) adapted its warning messages to warning thresholds acceptable to the driver and included a model of the actual driver and a situation analyse module[6]. More recently, this approach was used to manage the flow of information between the systems and the driver, for example in European projects CEMVOCAS (centralised management of vocal interfaces aiming at a better automotive safety [7]) and aide (adaptive integrated driver-vehicle interface [8][9]), or to adapt HMI on an anti-collision system [10] to estimate adequacy between driver behaviour and the road situation when approaching slow vehicles.

To design adaptive system two kinds of modules are needed: the diagnostic modules to analyse driving situations and the management modules that use the diagnostic modules output to adapt the HMI interaction to the situation. These modules are depending from driver's needs and system finality which are defined by ergonomics analysis. Diagnostic modules use observable data on driver behaviour (control actions), on vehicle dynamics and on the vehicle environment (cartographic data, others road users). The natures of diagnostics are defined by the system needs (road situation categorisation, driver's intention, error detection…). Management module objectives are to identify the road situations where assistance is needed and to adapt the system/driver interaction according to the road context. In vivre2 system, the analysis of the truck driver's activity showed that the system functioning was depending from what the driver intends to do just in the next seconds. And this system was focused on slow speed manoeuvres. Then, the diagnostic modules have to analyse the driver intention during low speed manoeuvres and the management module have to select the HMI according to diagnostic modules output and to the road environment.

4 SYSTEM DESCRIPTION

4.1 System functionalities

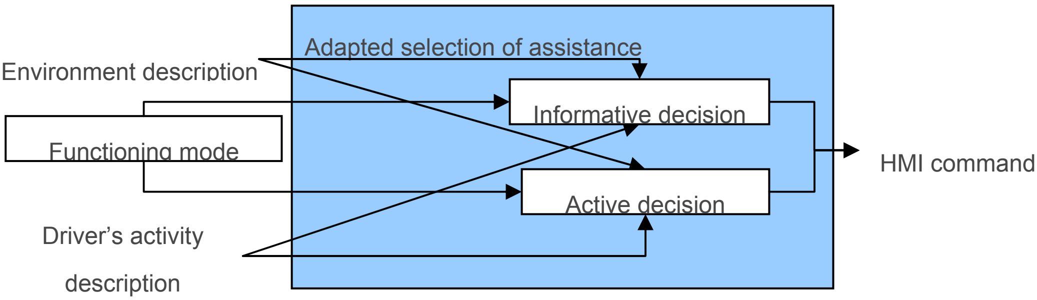

Fig.1. System functionalities

In order for the system to detect the critical driving situations, and to select adequate assistance, two information sources are used: the driver's activity description and the environment description related to the surrounding road users., thus, the system selects the most relevant assistance to provide to the driver according to the presence of vulnerable road users around the truck and according to the driver activity in this driving situation. The result of this selection depends also on the mode of functioning of the system: informative or active (partial automation of the truck).

4.2 System architecture

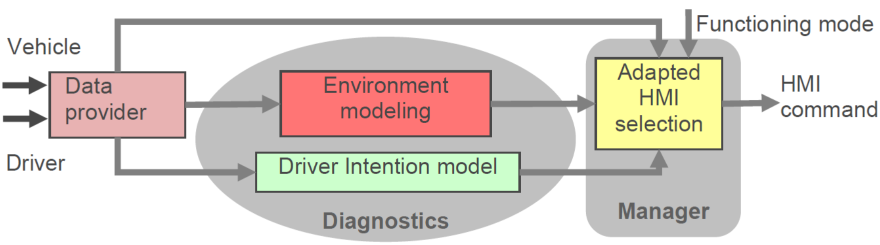

Fig.2. System architecture

To have a reflection of the activity of the driver, a specific software component wad created, the driver intention model, which gives a usable representation of driver's behaviour. In parallel, the system needs to have a representation of the environment. This representation is based on the use case analysis and gives the various conditions where the system had to be activated. These conditions are defined by the vulnerable user presence around the truck. The chosen approach is to divide the space around the trucks in several spatial zones. These two modules: driver intention model and environment are diagnostic modules; they send their output to the management module.

The adapted HMI selection module merges the two types of information (environment and driver's activity) to select the best command to the hmi.

4.3 Driving activity modelling

The objective of this model is not to analyse the driver's behaviour in all its complexity but to provide a good estimation of the driver's activity to manage its interaction with an assistance system. Thus, the model characteristics are defined by the expected assistance ofthe system and not by the driving activity. Two criteria have to be taken into account. The first one is the granularity of the model in terms of level of activities which have to be distinguished. The second one concerns the type of road situations which have to be processed.

To determine the model granularity, the target functioning principles of the system have been taken into account. The results of the driver's needs analysis gives use cases of interactions. We have notice that some differences in term of system functioning have to be done when the truck is stopped. For example, in vivre 2 system, when the truck is stopped, the system has to give different information according to the driver's intentions (no intention: driver stay parked, intention to start: driver changing gear, and beginning of the start: driver accelerating), thus the stopped state had to be divided in three states. Otherwise, the system has the same functioning when the truck is moving, independently of its speed, so the driving state can be unique.

The second criterion is to limit the modelling at the use cases specified for this assistance. In vivre 2 system, the concerned use cases are focused on low speed manoeuvres and are reduced to three main driving activities: straight on, reverse and turn to right

Using these two criteria, we obtain a driver's intention model with 10 states: one for the stopped state and one for each combination action/driving activity. Each state was also defined by the relevant driver's actions which estimate it (gear position, acceleration pedal position, speed …).

This representation has two advantages. Firstly, it reduces the complexity of behaviour to take into account. Secondly, it gives a semantic representation of driver's activity which allows a best communication with human factor experts to discuss about the use cases.

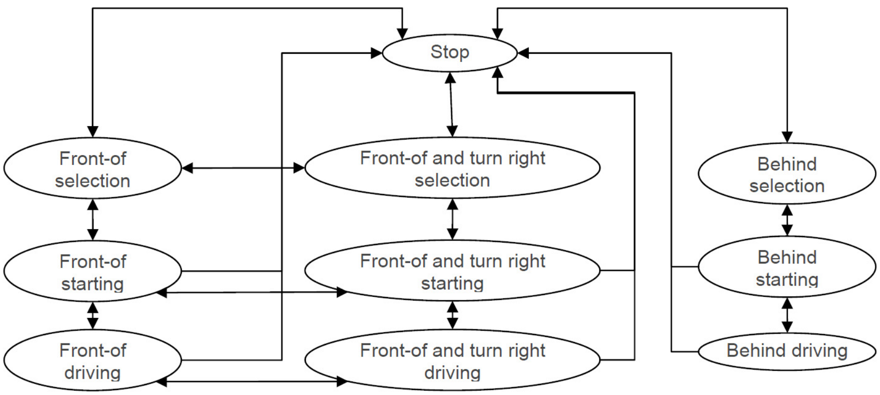

Fig.3. Driver's intention model

4.4 Environment modelling

The use case analysis gave the conditions where the system has to be activated. These conditions are defined by the vulnerable user presence around the trucks. The space around the trucks can be divided in several spatial zones. Some of them concern "very critical situations" when the driver does not have enough time to react and the system has to take control of the truck. Other ones concern the "critical situations" when the driver has to take into account a new danger to react quickly. The last ones concern the "potentially critical situations" when the driver has to identify a VU which can becomes a danger quite quickly. These zones are located in front of, behind or on the right side of the truck. Thus, we have 8 zones.

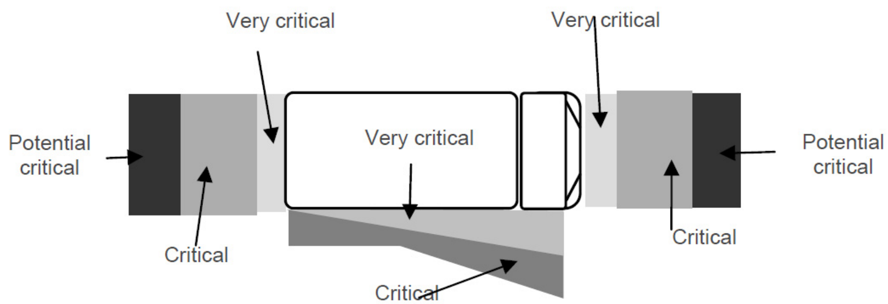

Fig.4. Environment spatial representation

For front-of and behind directions of hazards, we have 4 states (nobody, very critical, VU critical, VU potentially critical) and for the right zone 3 states (nobody, VU very critical, VU critical). The front-of and behind states are not considered at the same times according to the direction of the truck moving. Then, the combination of the VU position in the zones gives 12 possibilities. Then only 12 states have to be considered.

4.5 System output for HMI activation

The HMI commands are classified in terms of assistance needs. The first condition is based on the road situation criticality (focused on the distance of vulnerable users) and gives the type of command. Two types of command are active controls, very intrusive:

- si: "start inhibit" (if the truck is stopped) when a vulnerable user is located in the very critical zone. In this case, the truck is not allowed to start.
- eb: "emergency braking" (if the truck is moving) when a vulnerable user is located in the very critical zone for which the size is proportional to the speed. In this case, the truck is automatically stopped. The two others ones are less critical:
- w: "warning" when a vulnerable user is located in the critical zone. In this case, the danger in indicated to the driver with an intrusive alarm (visual+ auditive).
- inf: "indication" when a vulnerable user is located in the potential critical zone. In this case, the danger in indicated to the driver with a no-intrusive alarm (only visual). The second condition is the direction of hazard,
- front : one or more vulnerable users only in front of the truck,
- behind: one or more vulnerable users only behind the truck,
- right: one or more vulnerable users only in the right of the truck,
- front and right: one or more vulnerable users in the front and in the right of the truck.

The combinaision of these two conditions gives 16 possible commands: sifront, ebfront, wfront, inffront, sibehind, ebbehind, wbehind, infbehind, siright, ebright, wright, infright, sifrontandright, ebfrontandright, wfrontandright, inffrontandright.

4.6 Adapted HMI selection

In the diagnostic modules, the driving activity is modelled by a state graph and the environment by a set of zones around the trucks which can be empty or contain a vulnerable user.

The descriptions of driver's activity and of environment with a finite number of states reduce the complexity of the reasoning to activate the adequate output in the manager module.

the principles used to activate the HMI are

1) to take into account the closest VU,

2) to increase the alarms when the driver actions does not show detection of the VU,

3) to manage the right zone alarm taking into account the fact than the driver turn right or not.

With the finite state approach of the two models, the reasoning to command the HMI can be synthesised in a specific table. One dimension represents the driver's intention model states, the second one the VU detections in the zones. This table defines for each case (given driver intention and given VU detection) which HMI command has to be sent. This formalism is helpful to verify that the selection principles are well followed.

Moreover, this table gives two possible temporal descriptions, one in term of driver action sequence, and one in term of VU moving. For example, in the first case in the table 1, for the driver action sequence, selection/starting/driving, the intensity of alarms increases, no assistance/ information / warning. For the VU moving, when the driver is in the state "front-of and turn right starting" (colon 6), and when the VU in the right zone (colon 2) approach from the truck (nobody/critical/ very critical) the IHM commands are information/warning/ start inhibit. These kind of temporal analyse allow the designers to verify the coherence of HMI evolution.

Table.1. Part of decision table for active system

VU detection		Driver's intention state					
VU in front-of zones	VU in Right zones	Front-of selection	Front-of starting	Front-of driving	Front-of and right selection	Front-of and right starting	Front-of and right driving
critical	nobody	No assis	InfFront	WFront	No assis	InfFront	WFront
critical	critical	No assis	InfFront	WFront	infD	WFront&Right	WFront&Right
critical	very critical	No assis	InfFront	WFront	infD	SiFront&Right	EBFront&Right

5 RESULTS

Vivre 2 assistance system, including a driver intention model module, an environment modelling module, and a HMI manager module, was design, implemented and evaluated in a trucks driving simulator. The global functioning was well accepted by the 15 drivers of the experiment. A comparative analyse with and without the system shown than 89% of accidents with UV were avoided with only informative system and 100% with informative and active controls.

6 SYNTHESIS

In this paper, we have presented our approach to design an adaptive assistance system to help the trucks driver to detect vulnerable users. This system is based on two diagnostics module, one focused on driver's activity, one on environment, and on a HMI manager module.

The driver's activity modelling is a large research area. To design adapted driving assistance system, it is necessary to reduce this modelling according to the real needs of the assistance. The approach is to model the driver activity to extract the most important behaviours in terms of driver actions which may induce or require various alarms. The criteria to extract the most important features are then derived from the assistance needs. In VIVRE2 system, the number of activities which have to be distinguished was limited to ten states.

Concerning the environment representation, road situations are also very complex. To design driving assistance, it is necessary to determine which kinds of information are needed for the system. The use case analyses are useful to find the minimum necessary information set. In our case, the presence of VU in 8 zones around the trucks was enough to model the environment for vivre2 application.

The last step concerns the decision level. The choice of using finite state approach to modelldriver's activity and environment reduce the number of combination which has to be taken into account. Thus, decision tables have been developed to design the system which allow a global overview of the system functioning.

7 CONCLUSION

Adapting the driving assistance to the driver's behaviour is now accepted as a necessity to improve the acceptance of the assistance system by the driver. The problem is to find a good description of driver's activity. Most of driver's models which analyse driver's activity take into account a lot of variability to explain all activities. The approach describes in this paper shown that when a model is designed for one specific system, it can be simple and usable by a manager module. This model can not be directly used for another assistance system but the same approach can be used. The first step is to identify the driver's activities which can induce various system functioning. The second one is to identify the road situations where the system has to be activated. The combination of these identifications defines the system needs in terms of driver's model states.

In terms of system design, this paper shown also that the modularity and the reduction of complexity by finite states allows system designers to have a good synthesized view of system functioning taking into account the temporal evolution of the situations.

Even if this approach is based on driver need analysis and is specific to one application, it could be reused in other projects using the general principles identified in this paper.

8 ACKNOWLEDGMENTS

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