BENEFIT OF "DYNAMIC USE CASES" TO EARLY DESIGN A DRIVING ASSISTANCE SYSTEM FOR PEDESTRIAN/TRUCK COLLISION AVOIDANCE

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ABSTRACT

The common approach to express Driving Assistance Systems (DAS) functionalities is often based on use cases that explain driving context and required assistance. However, DAS design requires temporal consideration of driving situation evolution when using the assistance, in order to define when the assistance is activated and which decision criteria is used. Driving situation complexity and its temporal progress cannot be easily appreciated without tools taking into account all actors (pedestrians, driver, vehicles…) and assistance effects on the scenario evolution.

This paper describes a software application that offers designers a light and simple way to early design, tune and test DAS functioning on progressing situations. This tool is developed in the VIVRE 2 project to support the early design of a DAS that warns truck drivers to avoid pedestrian collisions. In this context, the tool permits to test the DAS functioning by running "dynamic use cases" (static use cases enriched with additional inputs to reflect the temporal evolution). It allows the designer to build scenarios with specifics parameters about driver, truck, pedestrians and assistance. It also proposes replay and trace features that help the analysis of the "dynamic use cases" combination. These iterative tests and adjustments of DAS allow determining decision criteria that works in all targeted situations.

To further efficient early design, the tool must stay light and easy to use. As a consequence, the temporal evolution models of actors are kept simple. Once the DAS functioning is validated, another design phase in more realistic conditions is required; to make sure that no unanticipated behaviour occurs, which may reduce the functioning.

This approach is crucial for early designing of a DAS to bring continuity to the use cases and to evaluate the consequences of any decision criteria modification on the global functioning in order to ensure driver warning efficiency.

INTRODUCTION

The approach to design assistance systems is most of the time based on "use case" (UC). These UC are developed to share a common view of system functioning between all partners in charge to design, to develop and to test the driving assistance. In fact, the functioning can not be easily defined by rules but has to be replaced in its context of use to understand the real wanted performance and the different factors which can influence or modify the final running. Some projects have defined some format to describe UC. For example, in AIDE project (which goal was to design a system to manage the information flow to the driver), the UC described the road context, the signals to be send, and the expected system functioning. For this application, the time constraints are not precise and a textual description was enough. But for others systems which have to deliver some urgent warnings like anti-collision warning, the time constraints are very important and textual description can only give qualitative functioning like "if a pedestrian is in front of the vehicle, the warning is diffused by auditive mode . In order to refine the functioning rules with quantitative values, some simulations are needed.

The purpose of this article is to present an approach developed in the VIVRE2 project. This approach was used during the design phase to tune a driver's assistance system which warns truck drivers to avoid pedestrian collisions. This approach combines different use cases with different driver behaviours and different system tunings.

CONTEXT

The truck traffic increase is particularly critical in urban areas where the cohabitation between as different users as pedestrian and trucks creates a lot of critical situations. From a technical point of view, a lot of sensors are designed to run in less

complex road situations like on highways or in rural areas where mobile entities are easier to detect (big size) and where the number of objects to detect is limited. From a user's point of view, the pedestrian situation awareness is often incorrect due to his lack of knowledge about truck driving [1]. To evaluate risks, the pedestrian uses his driving knowledge which results from his experience as a car driver. He doesn't know the place and the size of dead zones around the truck. For example, the dead zone just in front of the vehicle can mask a too close pedestrian. A car front blind zone is small and can not mask objects taller than 50 cm. A truck front blind zone is higher and can mask objects taller than 1m like a child. Pedestrians do not realize that the trajectory of the backward part of the truck during a turn does not follow the trajectory of the front wheels and he can be surprised by the nearness of this part. A pedestrian does not picture the truck inertia and its braking length and he may make the decision to cross the road too late according to the truck speed and distance. Another aspect concerns the different situation awareness of actors depending on whether one considers the pedestrian's or the truck driver's point of view. In urban areas, trucks have to give way to pedestrians and pedestrians think that trucks have to stop. In this case, if the truck driver cannot or does not perceive the danger, the pedestrian will be quite within his rights but dead.

In the VIVRE2 project, a driving assistance system (DAS) was developed to prevent collisions with vulnerable users in urban areas, especially during delivery truck manoeuvres. This kind of truck has to drive into cities to deliver goods and must manoeuvre on urban roads.
In this project a truck driver needs study done by project partners (LEACM, INRETS, Renault TRUCKS) gives some information to determine the most critical situations and a set of classical Use Cases including the expected system functioning.

OBJECTIVES

To design this DAS, these Use Cases (UC) give the main functionalities to be included in the system (temporal sequences of warning display according to the road situation) but did not take into account all possible sequences.

The objective of this work is to create a tool and a method that take into account most of the possible case of assistance that system can provide in all different situation. It permits to synthesize and to harmonize all the needs of assistance in most of the target situations.
This is a way to enrich the classic Use Case generally used in DAS design.

DYNAMICS USE CASE DESCRIPTION

The main advantage of the DUC is to add easily variability to driving situation. It is composed by some elements coming from classical Use Case like a driving context (infrastructure, dangers to avoid); by the initial position and speed of major actors. But some other components, like a driver behaviour model, allow to increase the number of expected assistance system functioning variant according to the driver reaction at some system warning.

For the dynamic use case, a lot of variations can be added to test the DAS in several situations. The initial value of the truck speed can be 0 to 10 km/h. The initial pedestrian speed can be from 0 to 10, and the initial position can be on the road or on the walkway, at 1.5 or 10 meters

Then the functioning of the system is different. At 1 meter in front of the truck this is a start inhibit situation. At 10 meters in front of the truck, if the pedestrian is moving quickly enough not to be hit by the truck, the alarm will not go off. This shows that different combinations or variable values induce very different system functioning. Temporal aspects must be taken into account to efficiently design a driving assistance system.

The complexity of combinations of all parameters requires the use of a tool to generate the DUC but also to run them.

"DYNAMIC USE CASE RUNNER" ARCHITECTURE

This tool is composed of two principal parts (Figure 1Figure 1):

- The generic part is composed of several modules focused on DUC temporal deployment.
- The specific part concerns the driving system assistance itself.

The main tool functionalities are:

- To define the scenario.
- To manage all objects involved in the UC. It concerns the equipped vehicle, the different actors like pedestrians, bicycles, cars, trucks.

To deploy the UC dynamic at each time step, the generator has to:

- Calculate the position of all mobile objects including the equipped vehicle. The dynamic of the equipped vehicle is also defined by driver reaction given by a driver behaviour model.

- Run the driving assistance (DA) on this time step.
- Use the DA decision to modify the equipped vehicle dynamics (acceleration, orientation) to be use into the next time step.
- Display the information to be sent to the truck driver.
- Display curves which describe the temporal evolution of the situation.

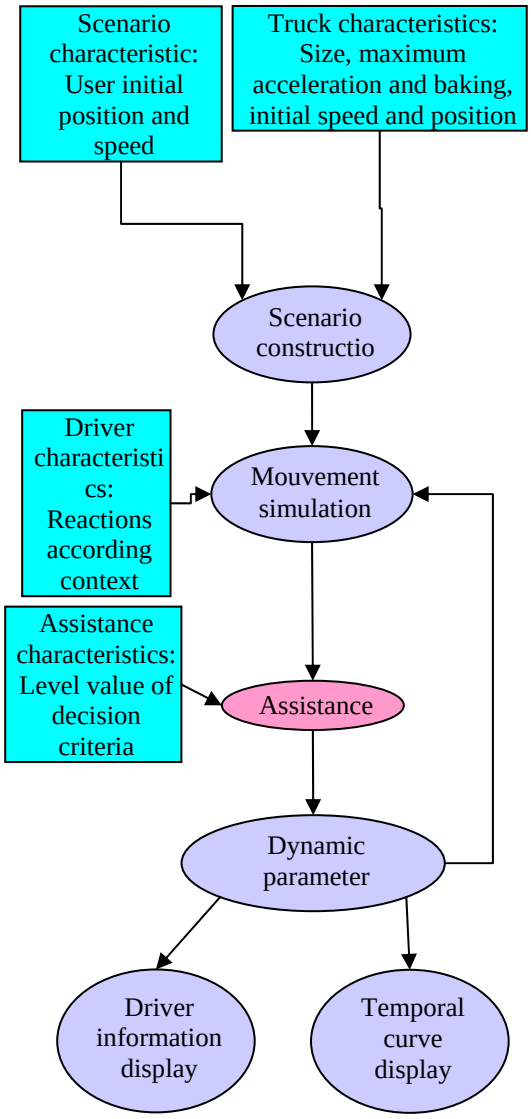

Figure 1. "Dynamic Use Case Runner" architecture

"DYNAMIC USE CASE RUNNER" PARAMETERIZATION

To run the UC, some parameters can vary to describe different UC variants. These parameters are classified in several categories according to their use by the generator.

For the first module which creates the UC, the parameters are:

- Truck characteristics like size, acceleration maximum, braking maximum, initial position, initial speed.
- Scenario characteristics like position and speed of mobile object (vulnerable user, other vehicle).

For the module which simulates the mobile dynamics, the variable parameters concern:

- The driver characteristics which include the desired speed, the desired acceleration and some behaviour modifications according to Assistance System information like "stop acceleration after 1 second when warning occurs".
- The trucks characteristics like acceleration maximum, …

For the module which calculates the driving assistance decision, the variable parameters concern the different criteria of decision levels.

Another constraint was induced by this project. The system had to be validated on truck simulator with final users. The system integration on simulator had to be taken into account at the beginning of the project [2]. But the time necessary to develop the simulator database did not allow us to test the system functioning at an early stage; hence the "dynamic use case runner" was created to permit parallel developing of the database and of the system design phase.

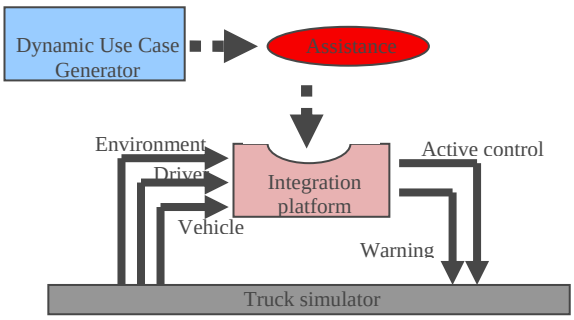

Figure 2 : integration principle

An integration platform (Figure 2) was then designed to manage the interaction between the truck driving simulator and the assistance system. Moreover, to avoid software translation problems and to gain some time, it was decided to use the same code for the "dynamic use case runner" and the integration platform.

This integration platform allows us to collect data, to replay data and to connect the driving assistance to the truck driving simulator.

"DYNAMIC USE CASE RUNNER" OUTPUT

The assistance is based on using several areas around the truck. Some of them monitor the front of the truck, others the truck rear and some of them the truck's right side. The presence of a vulnerable user in one of these areas is transmitted to the decision module. This module also uses the driver activity analysis to adapt the warning level to make the decision.

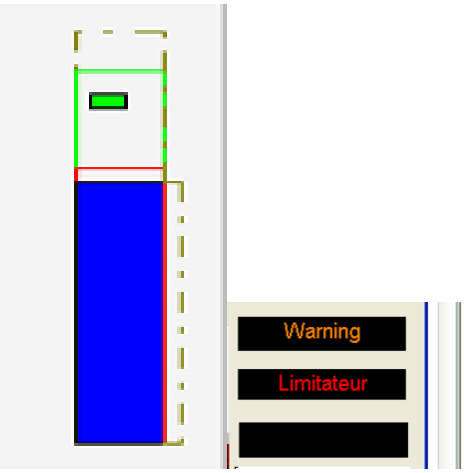

Figure 3. DUC runner Output

The tool presents (Figure 3) the truck on the road (blue rectangle) and displays the survey areas around the truck. The nearest is the "Braking zone" (red solid line), the further is the "speed limiter" zone (dotted line) and the intermediate is the "warning" zone (green solid line) . One "warning" zone is also in the right side of the truck

The Assistance decision is display when active controls or warnings occur.

"DYNAMIC USE CASE RUNNER" INTERFACE

The software window (Figure 4) is split in three parts:

- The first one concerns the DUC description including the driver, truck, assistance and scenario parameters.
- The second one represents the context situation which *changes over time.*
- The third one displays the temporal curves. The first two curves display the truck speed and the maximum acceleration authorised by the assistance. The last two curves display the level of assistance in terms of active control (no control, speed limiter and urgency braking) and warning level (no information, danger indication or warning).

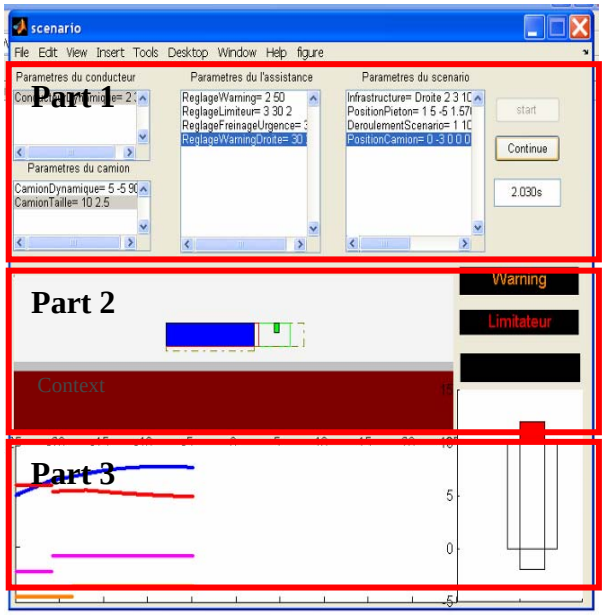

Figure 4. Software interface

DYNAMIC USE CASE RUNNING

The DUC used in these examples is located on a straight on line with walk side. The pedestrian is on the walkway and is heading for the road when the truck starts. In the first example, the pedestrian speed is 5 Km/h and in the second one it is 2km/h. These two examples are different variant of the same DUC.

Example 1: Speed limitation.

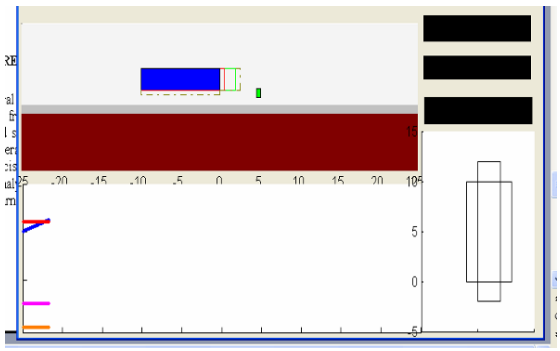

Figure 5: Speed limitation UC step 1

At the beginning (Figure 5), the pedestrian is on the walkway and is heading for the road at 5 km/h. The truck has just started and its initial speed is 0 Km/h.

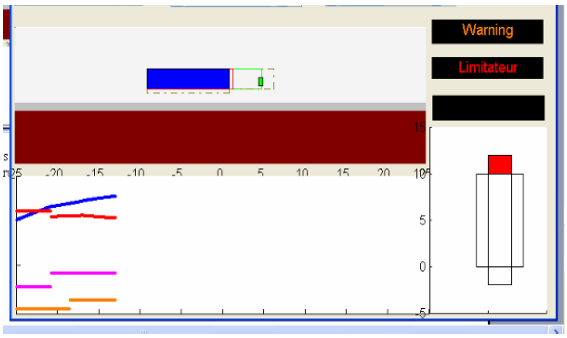

Figure 6: Speed limitation UC step 2

The pedestrian is then in the warning and speed limiter areas (Figure 6Figure 6). The maximum acceleration allowed by the system is decreased and the active control and warning levels are increased.

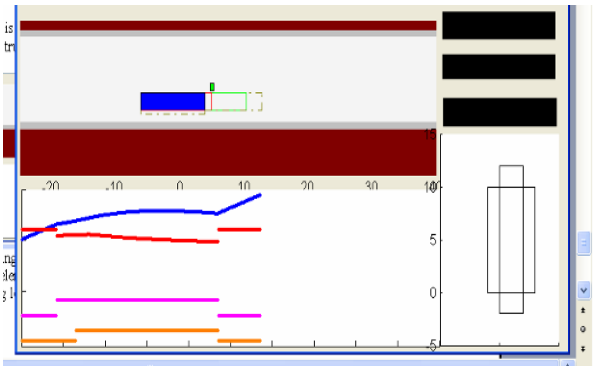

Figure 7: Speed limitation UC step 3

The speed limitation was sufficient to avoid the collision and all warning and active control have now disappeared (Figure 7Figure 7).

Example 2: Urgency Braking

The same UC is running except that the pedestrian speed is adjusted to walk slowly at 2 km/h.

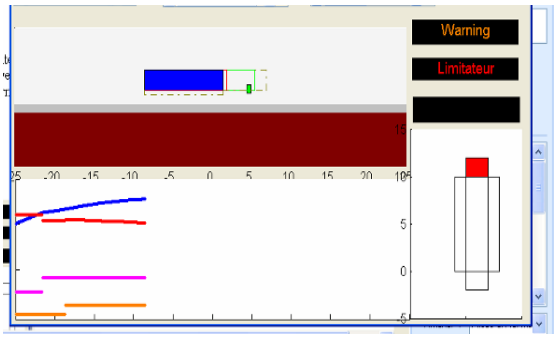

Figure 8. Urgency braking UC step 1

The beginning is the same as in example 1(Figure 8). The pedestrian enters in the warning and limitation zone.

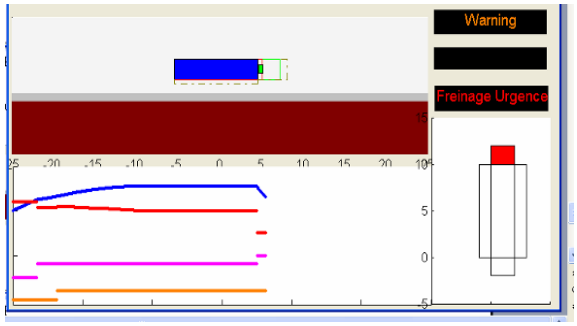

Figure 9. Urgency braking UC step 2

But the pedestrian is not walking quickly enough to leave the “Urgency Braking” area and the hard braking goes off (Figure 99).

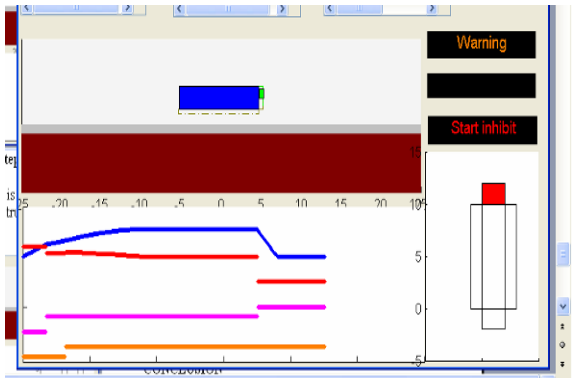

Figure 10.Urgency braking UC step 3

The “start inhibit” system is active since the pedestrian is just in front of the truck (Figure 10).

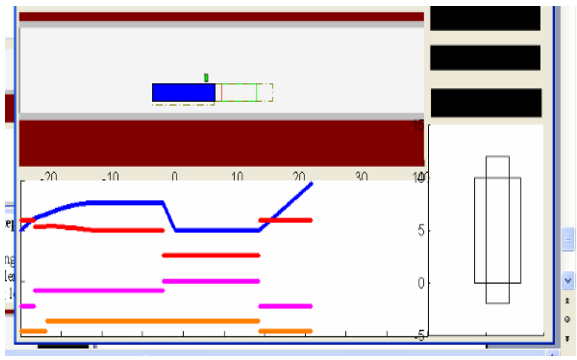

Figure 11. Urgency braking UC step 4

When the pedestrian leaves the zone, the warning message goes out (Figure 11).

Example 3: DUC on Intersection

Several types of infrastructure (figure 12) can be used in the DUC.

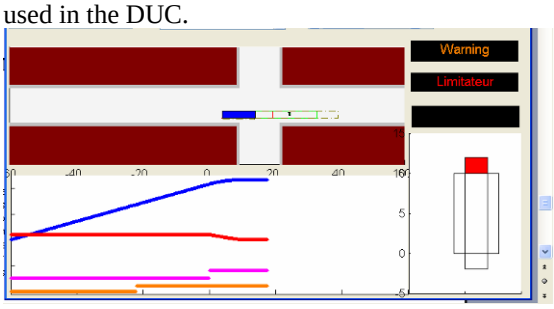

Figure 12. UC on intersection

DISCUSSION

As shown in the examples, a change in just one parameter value (in the example, the pedestrian speed) may induce a different system functioning. All theses changes cannot be described in classical Use case, due to too high a number of use cases. But most of the combinations have to be tested to validate the global system functioning. This tool allows to create "Dynamic Use Case" with several variants and testing for each of them, whether the real functioning corresponds to the expected one or not.

The DUC temporal aspect can be analysed using the curves. Moreover, additional functionalities like "pause" or "scenario speed" allow the designer to run the DUC either slowly to show some details or quickly to analyse long sequences.

Another advantage of this tool is to tune the driving assistance system. For example, the parameters which define the areas in front of the truck can be easily changed and all DUC variant can be validated with the new values. This set of variants can be considered as unitary tests to be applied after any change in the driving assistance system.

EXPERIENCE FEEDBACK

We have used this tool to design and develop a Driving assistance System. The early design phase was completed using this DUC generator and all major concepts were correctly designed. The software transfer into the implementation platform was immediate and the time gain was successful as planned. But some unexpected problems appeared. The first one concerns the dynamic model of the truck. The simple model used in the generator was not precise enough and some adaptation had to be done to take into account some truck specificity, especially to calculate the urgency braking distance. This problem was solved in one day during the implementation phase. The second problem affects the parameters used to describe driver activity. The driver model outputs were not the same as simulator one. For example, the gear box type (manual to automatic) can induce different driver actions. This problem was impossible to anticipate due to the fact that it was linked to the simulator model implementation. The last point concerns the system tuning. In the DUC generator the phase chain was correctly designed. But the final absolute values of the driving assistance system parameters had to be set according to the recommendation of ergonomics experts made during an expertise of the system before the final evaluation.

CONCLUSION

This design of Driving Assistance System (DAS) shows the contribution of a Dynamic Use Case generator which allows us to apprehend driving situation complexity and its temporal progress by taking into account all actors (pedestrians, drivers, vehicles…) and assistance effects on the scenario evolution.

This generator offers a light and simple way to early design, tune and test DAS functioning in progressing situations. It was validated by designing a DAS that warns truck drivers to avoid pedestrian collisions. It allowed us to build scenarios with specific parameters about drivers, trucks, pedestrians and assistance. The driver model will be improve to create some DUC variants which can explain some real situations.

To further efficient early design, the tool stays light and easy to use. As a consequence, the actor temporal evolution models are kept simple especially the truck model. Once the DAS functioning was validated, the expertise phase in more realistic conditions allowed finalizing the criteria adjustments in order to ensure the driver's warning efficiency. The final experiment is currently carried out to evaluate the final DAS with end users.

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