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Using Simulation Method for Designing ADAS Systems for Electric Vehicle

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Abstract. Since 2012 the Smart Power Team has been actively participating in worldwide competition – the Shell Eco-marathon. From the beginning, the team has been working to increase driver's safety on the road by developing Advanced Driver Assistance Systems. This paper presents unique method for designing ADAS systems in order to minimize the costs of the design phase and system implementation and at the same time to maximize the positive effect the system has on driver and vehicle safety. The described method is based on using virtual prototyping tool to simulate the system performance in real life situations. This approach enabled an iterative design process, which resulted in reduction of errors with almost no prototyping and testing costs.

Keywords. ADAS, simulation method, virtual prototyping, electric vehicle, PreScan

Introduction

Conducting the design process of Advanced Driver Assistance Systems (ADAS) in an optimum way requires a specific approach to defining and solving problem [1, 5]. Profound research and analysis have to be carried in order to prepare well for this task. Sometimes it is impossible though, to identify and avoid certain mistakes in the process, without using a prototype [6, 8]. Currently there are more and more tools available for engineers that enable creating virtual prototypes and therefore optimizing the design process in terms of its effectiveness and fault minimization [2, 4] . Nevertheless in order to use these tools efficiently there needs to be a proper approach to design process adopted. The aim of this article is to present the approach to ADAS design process, which includes the use of simulation methods and virtual prototyping. Preceding the actual method description, there are some considerations included, whether there are reasonable grounds for using virtual prototyping tool and what other tools should be considered before making the final decision. Following sections of this article include the method description and the use case – design process of Blind Spot Information System for urban vehicle.

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1. Consideration of the retionale for using virtual prototyping tool

1.1. Defining the needs

First step that needs to be taken in ADAS design process is needs definition. What must be identified are the problems that a driver is facing and possibilities of finding the right solutions for them. The most effective way of finding them are interviews with actual drivers and analysis of traffic situations of great risk for driver, vehicle or third parts safety. What needs to be considered in this step are the most common conditions in which the driving task is performed [1, 2]. For vehicles dedicated for specific goals, such as competitions, these conditions can be described very precisely, which enables finding most actual problems and most effective solutions [4, 5]. The choice of prototyping tool, which would be used in further steps, needs to be based on tool possibilities in terms of reflecting reall environmental and situational conditions.

1.2. Defining the external constraints

Before making a decision about using virtual prototyping tool for ADAS design, it needs to be considered, whether a need for using such a tool actually exists. In order to answer this question the external constraints must be considered and it must be verified how the design process will be affected by using simulation methods.

There are multiple constraints, that must be taken into account, when thinking about designing ADAS. One of the most basic ones are: costs, time and quality. It is accepted that only two of these three constraints can be fulfilled at the same time.

1.3. Discussion of possible ADAS design methods

There are various methods of ADAS design available and it is crucial to choose the one that fits best the needs of the project. ADAS can be designed in following ways:

1. No prototype – which does not enable to verify its performance in real life situations until the system is implemented,
2. Virtual prototype – which, accordingly to chosen tool, enables to simulate the natural conditions in very but not perfectly accurate way, generates low costs and enables the iterative design process,
3. Real prototype – which enables absolute verification, but has also many drawbacks such as costs, production and construction time, difficult interaction.

When considering the virtual prototyping tool the above mentioned aspects must be included.

2. Design method

2.1. Project analysis

In order to minimize the need for changes in further steps of the ADAS design process it is recommended to define all internal constraints before working on an actual model. This approach enables to precisely set the goal of the designed ADA system and define the required constraints early enough to be included in the model. Using a virtual prototyping tool for such complicated systems as ADAS requires splitting considerations about the whole system into subsystems.

2.2. Designing and testing

Testing part of designed system is a step that must not be neglected. Thorough tests are the last step before real system implementation, that allow error detection without generating additional costs in manufacturing process. Correctly conducted testing enables also very accurate error identification and makes their correction easier.

In order to properly define test cases for ADAS virtual prototype testing, three system separate aspects must be considered, in which an error could appear:

1. Data processing – software
   - 1.1. What are the system inputs?
   - 1.2. What are the system outputs?
   - 1.3. What is the path of converting inputs to outputs?
   - 1.4. What values are independent from the system design and may not be tested?
2. Functional requirements – UI and usability
   - 2.1. What the system is supposed to do?
   - 2.2. What information is it supposed to communicate to the driver?
   - 2.3. What must the system not do?
3. Modesl design – the idea
   - 3.1. How should the system work?
   - 3.2. What inputs and outputs should it accept/generate?
   - 3.3. By what functions is the system described?

Such analysis enables to create test cases sheet that should be used in test experiments outcome evaluation. Only when every test case will end successfully i.e. the values will be corresponding with template values and the visual verification will be fulfilled, the system can be implemented.

For correct testing process of ADAS virtual prototype it is also needed to cover all possible situations in simulations, in which an error could appear. The test experiments should include both typical traffic situations of a higher risk and non-risky situations in order to test the system against false alarms.

3. Use case – BLIS for urban electric vehicle

The above described design method was used in design process of Blind Spot Information System (BLIS) [6, 14] for urban electric vehicle – Bytel [3, 4, 5] (Figure 1). Bytel is a vehicle created to participate in Shell Eco-marathon (SEM) [3, 11] competitions, the event which aims to encourage design of highly efficient vehicles by students and scientific organizations. Bytel has participated in SEM in 2014 and 2015 in two power source categories battery electric and hydrogen (hydrogen fuel cell) [9, 10, 12].

Figure 1. Bytel vehicle during Shell Eco-marathon race in Rotterdam (2015).

The steps described above were taken in order to successfully finish the process at minimal time and maximum quality, keeping the costs reasonable at the same time.

3.1. Considerination of the rationale for using virtual prototyping tool

The decision to develop BLIS for urban vehicle was made based on low viewing range, which is characteristic for common conditions for this kind of vehicles [4, 5], i.e. vehicles designed specifically for Shell Eco-marathon competitions. BLIS is the system that informs the driver about vehicles coming from the back of the vehicle, which are invisible to the driver due to its low viewing range. The need of creating such a system has been recognized based on analysis of many accidents and dangerous situations happening during the race and also after discussing the problem with drivers participating in SEM.

While deciding to use virtual prototyping tool, the crucial reason for using it was the necessity for parallel construction process. As the vehicle was still in development phase during the design of BLIS, there was no possibility of using real prototype in order to conduct tests and work on data processing improvement. This is equivalent to accepting time as the main external constraint that applies to this project.

The second constraint was quality of the system – as the vehicle purpose was to take part in SEM competition, i.e. in the race, it was considered extremely important to provide the driver with ADAS of best possible quality. The point was to help the driver keep safe and avoid active or passive participation in accident.

Last but not least, the adequate tool needed to be chosen for designing and conducting BLIS simulations. There were a few virtual prototyping tools especially dedicated to ADAS design which were considered. The final choice was TASS PreScan [13] due to its wide range of predefined sensors, very friendly user interface and great visualization capabilities.

3.2. Project analysis

3.2.1. Defining the internal constraints

Following the described method the first step after recognizing the need of creating BLIS and defining the external constraints, that lead to decision of using virtual prototyping tool, was defining the internal constraints of the designed system.

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1. The system cannot affect actively the breaking and/or steering system.
2. The system functions must be restricted to information/warning functions.

The self-imposed constraints of the project were also directly connected to Shell Eco-marathon assumptions, as the purpose of Bytel vehicle was to achieve best result possible in this competition (SEM is about developing highly energetic vehicles). In order to satisfy this goal there were the following constraint sets:

1. The weight of the system must be minimized.
2. The system should not consume relevant amount of power.

These constraints enabled to define the general approach to designed system.

At this point the decision regarding system parts has been made, which was vital to create the system model in TASS PreScan. There were two possible kinds of sensors considered: photoelectric sensors and lidar. Both kinds of sensors are available in predefined form in TASS PreScan, with a possibility of their configuration in very wide range. The decision was made to use Hokuyo lidar (Fig 2).

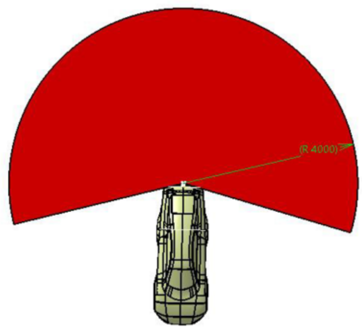

Figure 2. Hokuyo lidar in BLIS.

What was crucial when deciding about rejecting the photoelectric sensors option was their low resistance to environmental conditions – a high risk of inaccurate results was identified. Also, in case of photoelectric sensors, there would be a need for using at least 9 sensors in order to cover sufficiently the area invisible to the driver. Whereas, there was only one lidar needed to enable scanning this range.

3.2.2. Splitting system into subsystems

Defining the subsystems and splitting the system into them when developing a virtual prototype, made it not only easier to follow the design process step by step, but also made a good ground for tests analysis.

The main determinant of dividing line which would be used for splitting the system were assumed real life subsystems. This means, that it was needed to consider the separate parts of BLIS system, as they were meant to be implemented in real life. This is why the decision was made to consider BLIS in two subsystems: data processing subsystem and control subsystem.

The data processing system included also a verification subsystem, which uses the data generated in PreScan in order to compare the values between ideal ones and the ones that were received via data processing based on assumed input values. An example of such comparison can be seen in Fig. 7.

3.3. Designing and testing

The process of ADAS designing itself in TASS PreScan consists of four steps:

1. Building scenario
2. Modeling sensors
3. Adding control system
4. Running the experiment

The conditions for which the vehicle was designed were very specific, as they were determined in details by Shell Eco-marathon competition organizers [11]. This made it possible to create a virtual prototype with maximum coherence with real life conditions. The model of the environment can be seen in Fig. 4 [4, 5].

In the environmentprepared in this way, the vehicles and their trajectories were added. TASS PreScan allows to define the vehicle dynamics in very precise way which makes the simulation results extremely valuable. When assigning trajectories, the point was to imitate the real SEM conditions as accurately as possible, so all the dynamic parameters were designed adequately to real life scenario (Fig. 5).

The next step was modeling the sensors. Using virtual prototyping tool it was possible to model Hokuyo lidar in highly precise way – there could be location, orientation, range and beam specifications modeled (Fig. 3).

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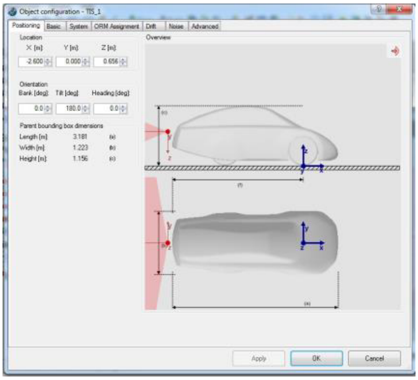

Figure 3. Modeling Hokuyo lidar in BLIS.

3.3.1. Data processing and control systems

First step in creating control system for BLIS was preparing the flow diagram of the system (Fig 6). This enabled us to make accurate work time estimation and reasonable task schedule and order.

The diagram included splitting the whole system into data processing system and control system. The control system consists of BLIS core system and visualization system. Each of these parts was crucial in terms of system final performance.

Data processing system converts the values received from lidar into input values of actual BLIS core system. The advantage of using virtual prototyping tool was particularly noticeable in this step, as PreScan gave the possibility to verify the end values and compare them with reference values (Fig 7).

The BLIS core system outputs two kinds of data regarding the detected vehicle that approaches from behind: the data defining risk level (i.e. distance) and position. This information is then passed to visualization system, which is responsible for generating correct inputs for each of LEDs that are used to inform the driver about current situation.

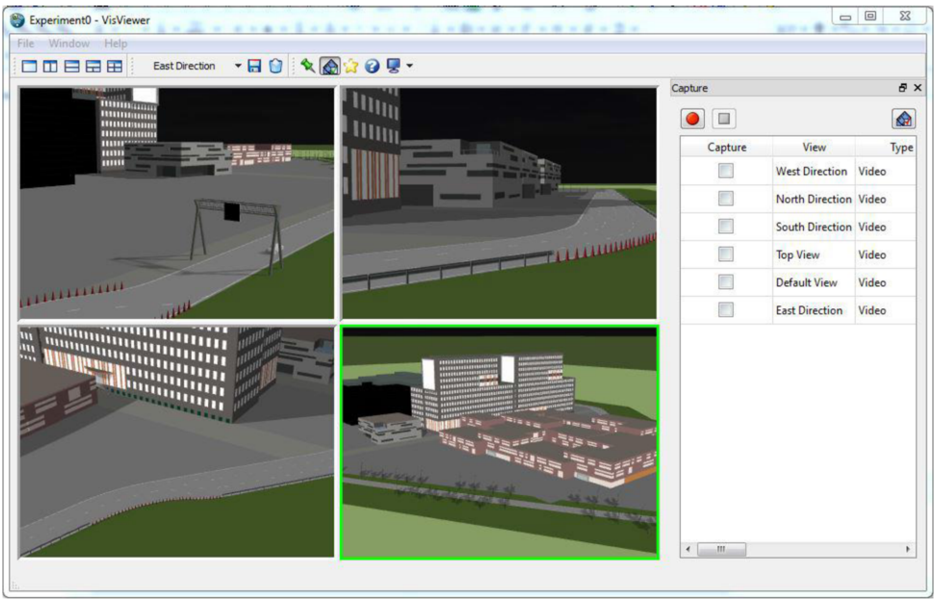

Figure 4. Model of the environment made in TASS PreScan.

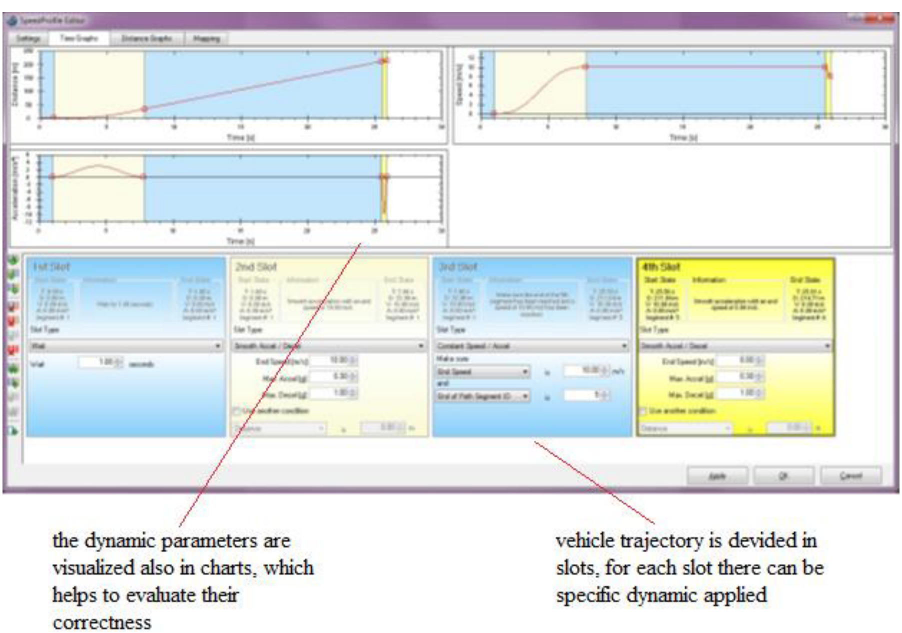

Figure 5. Speed profile for overtaking vehicle.

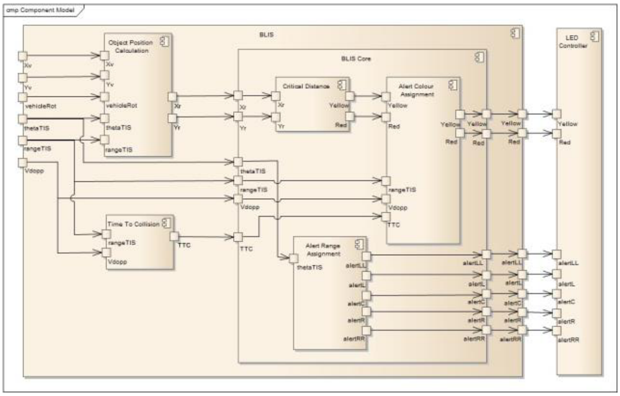

Figure 6. Flow diagram of BLIS on Bytel vehicle.

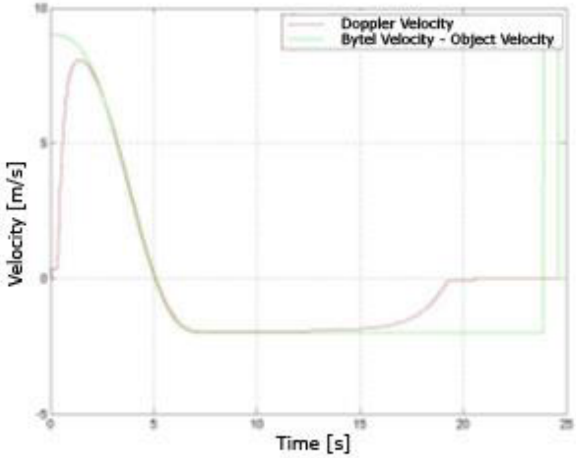

Figure 7. Comparison of two values – ideal one (Doppler Velocity) and the one achieved in data processing (Bytel Velocity – Object Velocity).

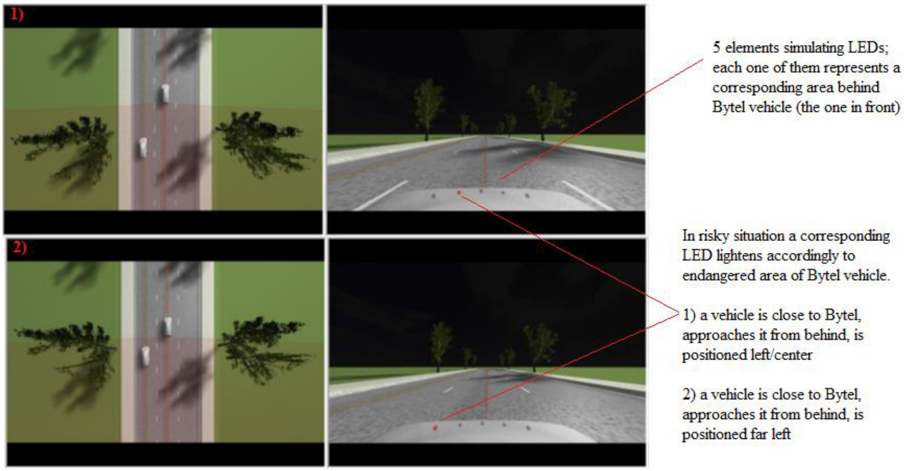

Figure 8. Example of visual verification.

3.3.2. Testing

The testing part has been conducted in three areas: calculation verification, visual testing and numeric tests.

Calculation verification has been made by comparing the end values of data processing part of the system with reference values that were generated directly by the software.

Visual testing was based on checking the behavior of virtually modeled elements that imitate LEDs meant to be used in real life system. What was tested is the color of the alert (yellow for low risk situation, red for high risk one) and the area for which the alert was generated (the blind spot was divided into 5 separate areas, each one was represented by individual LED) (Fig 8).

Numeric tests were needed in order to verify if the designed system works accordingly to project assumptions and idea of the designer.

3.4. Conclusions on BLIS design process

BLI system for urban electric vehicle has been successfully designed with the use of virtual prototyping tool and simulation method. The tests' results were correct and, although the real life system has never been build, the system design is finished and can be implemented at any moment.

4. Consideration of possible improvements

Although the final result of applying the described method was satisfying, there were still areas for the improvement. First of all there should be stronger emphasis put on the iterative approach to design, combining design phase with testing phase.

What also would be of a great value is system real life implementation and comparison of real life values with outputs received from simulation. This could help to identify the areas where the described method does not prove correct or needs improvement.

Similiarly as TASS, PreScan enables also creating experiments for various weather conditions and it would be valuable to test the designed system for different atmospheric conditions. It is especially true for systems that assume using sensors which output values are weather-dependent (eg. sonars, lidars).

5. Conclusions

The described method of Advanced Driver Assistance System design, with the use of virtual prototyping tool, has been applied in real life project. The outcome of taking this approach can be evaluated as successful, as the reasons for using this kind of method has been proven and the final results has been considered satisfying.

Using simulation method in ADAS design shortens work time, makes the iterative approach to design easier and faster, enables early error detection and identification as well as encourages parallel work. Therefore it can be stated, that using this method results also in costs reduction and system quality improvement.

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