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Design methodology of advanced driver assistance systems for urban electric vehicle

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ABSTRACT
The article presents the design methodology of Advanced Driver Assistance Systems (ADAS) for electric vehicles. As an example the Blind Spot Information System (BLIS) is described, which was created for an urban electric car - Bytel, the vehicle constructed within the Smart Power project. A specialized software was used, TASS PreScan, the software created for the purposes of advance driver's assistance systems design. The article discusses the following stages of ADAS system creation - the needs analysis, the designing and the model testing. Within the needs analysis there are such subcategories as the needs definition, the project goals and the project planning . The designing part focuses on two aspects: choosing the proper tool for designing and testing ADAS model and creating the system model, including data processing system and control system. The model testing section includes test planning and testing procedure description. The article ends with conclusions and future directions of the proposed model development

Keywords: ADAS, Blind Spot Information System, electric vehicle, PreScan, urban vehicle, TASS, Bytel, Smart Power

1. Introduction

Advanced Driver Assistance Systems [1], [5], [13] are defined as systems, which partially or entirely take over the tasks associated with driving a vehicle. These systems are tools that help keeping the traffic safe and that provide drivers with comfort. In modern automotive systems are already used many different types of ADA systems such as brake assistance [7], lane assistance [6], various warning systems [8]. Nowadays however it is also common to recognize their value in increasing the traffic fluency and minimizing the energy consumption.

The aim of this article was to discuss the Advanced Driver Assistance Systems design methodology in terms of their application in electric vehicles. As an example the Blind Spot Information System (BLIS) [13], [16] design process is described, which was created for urban electric car Bytel, a vehicle constructed within the Smart Power [3] project. Bytel was qualified for 2014 Shell Eco-marathon competition and finished the race successfully.

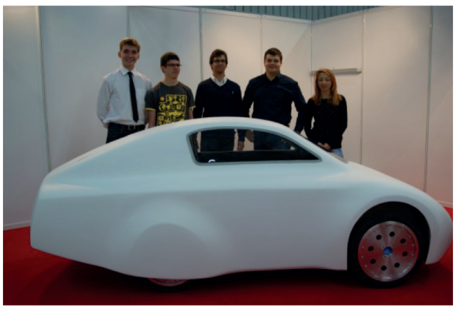

Fig.1. Bytel Urban Concept Race Car [own study]

2. Need analysis

2.1. Need definition

As mentioned above, Bytel was constructed by Smart Power Team [3] which operates under the Institute of Fundamentals of Machinery Design of the Department of Mechanical Engineering at the Silesian University of Technology. The team has been formed in order to design and construct highly efficient electric vehicles aiming to be driven in Shell Eco-marathon competition. The main activities of the team is to optimize the design features [4], [12] of the vehicle and driving strategy[10], [14]. Important tasks is to support the unpredictable human factor which is a driver working in difficult conditions of the race.

Although the competition puts a great attention towards safety it is recommended to apply additional precaution measures if only possible. The most dangerous manoeuvre common for SEM competition is overtaking. Because of small sizes of participating vehicles and no requirements regarding the presence of rear window, the driver purview tends to be extremely limited, causing high risk not only for an overtaken vehicle's driver but also for overtaking vehicle's driver. In addition, SEM race as opposed to the usual race each race starts passing vehicles separately at another time. Each driver obeys the team strategy and continues driving with his own speed profile independently of other vehicles. The result is a lot of traffic on the track and continuous overtaking of vehicles. In order to minimize this risk an Advanced Driver Assistance System was designed. Basing on the experience of building such systems, in particular the BLIS system in another Prototype race MuSHELLka [3], [5], [9] [10], the team decided to include also a similar system in Urban Concept vehicle taking into account the significant differences in the structure of the vehicle itself and the race in this class.

2.2. Project goals

A concept of ADA system supporting Urban Concept Car driver includes first of all– Blind Spot Information System (BLIS) the most efficient in this kind of race system [9], [13]. BLIS was supposed to inform the Bytel's driver of any other vehicles that could be invisible for the driver or may result in driver's distraction. The goal of the described project was not only to create a detailed model of the system that could be easily implemented later on but also to prototype functionality of the system with Virtual Prototyping methods.

2.3. Project planning

The planning of the project was a crucial step, as there was a fixed deadline – Shell Eco-marathon competition took place in May. Planning enforced also project consideration and careful analysis. Below the final project plan is presented, which could be applied in any ADA systems designing process.

1. Needs analysis
   - Needs definition and project goal definition
   - Project planning
   - Research
   - Determination of the project requirements
2. Designing
   - Detailed system concept
   - Tool choice
   - Creating system model
3. Testing
   - Test planning
   - Test performing
   - Results and conclusions

3. Designing

3.1. Detailed system concept

In order to move on with creating the model it was needed to prepare detailed system concept. assumptions had to be made regarding the sensor to be used and its positioning. There were many sensors considered, but eventually Hokuyo lidar was chosen.

The sensor is characterized by high resolution (1080 samples for 270°, which gives 4 samples for every 1°), high sampling frequency (40 Hz) and wide scanning angular range (270°). The project assumed using the lidar of 30 m range. This kind of sensor not only meets the first safety class, which allows using it in Shell Eco-marathon competition, but is also characterized by low weather conditions sensitivity (sun, rain, snow, mist), which is crucial for competition taking place in the open air such as SEM. Other sensor advantages were easy installation and high reliability.

Positioning of the lidar was quite obvious – BLIS was supposed to scan the area behind the vehicle, so it was necessary to place the sensor at the rear end of Bytel. But accurate positioning of the sensor led to some questions and doubts . Concerning the correct position and proper signaling cooperating with side mirror. Such design problems have to be addressed carefully in virtual testing phase.

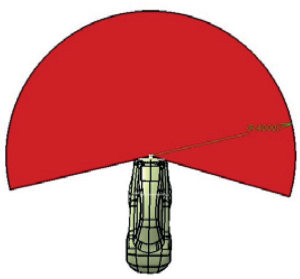

Fig.2. Hokuyo lidar position and range [own study]

3.2. Method and tool choice

For design and analysis of ADAS the method of simulation-driven virtual prototyping was chosen [2]. There are not many software programs dedicated especially for Advanced Driver Assistance Systems available on the market. For this particular project TASS PreScan [15] was chosen. Designing BLIS model was performed in 4 steps, as recommended by TASS.

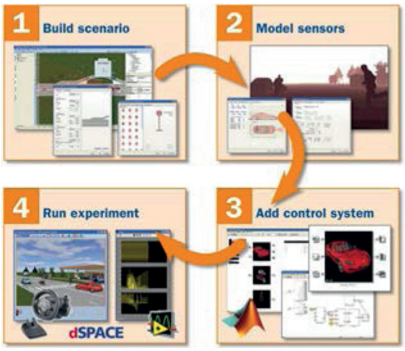

Fig.3. TASS PreScan designing procedure [own study]

Choosing this particular software was an important decision, because of the fact that the time for the project was limited and PreScan compatibility with Mathworks MATLAB eliminated the necessity to learn an entirely new software. Also, PreScan visualization module - VisViewer, enabled easy verification of system performance. First step was to build the scenario in PreScan GUI – placing infrastructure elements, adding trajectory for test vehicles and setting experiment conditions. PreScan offers a sensor model, that is extremely flexible in terms of configuration – TIS (Technology Independent Sensor), which could be easily adapted to represent Hokuyo lidar. Having modelled the sensor, the system model was created.

3.3. Model of the system – data processing

When modeling the system, there were two basic stages defined: data processing and control system.

The main task in data processing part was to calculate and verify data needed for BLIS, such as object distance, object velocity, etc. and handle the BLI system itself. Taking the above into account, the data processing part was divided into three subparts: calculation, verification and BLIS.

In Calculation subsystem the following parameters were calculated: Object Position, Time To Collision (TTC) and Object Velocity. These parameters were calculated based on input values that were provided as TIS outputs.

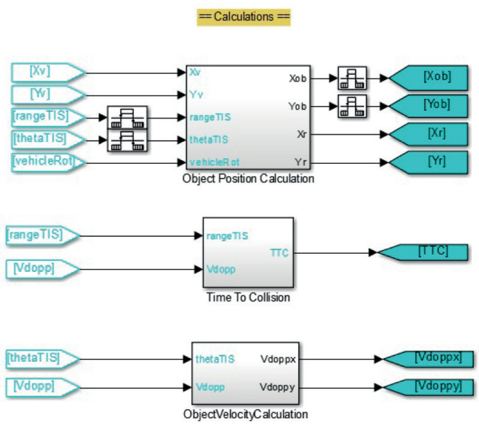

Fig.4. Calculation subsystem [own study]

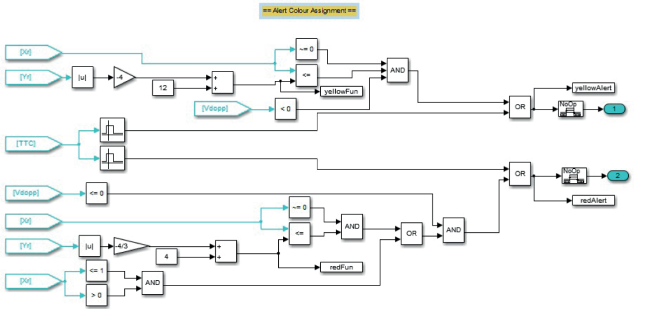

Fig.5. Alert colour assignment [own study]

All the calculated parameters were verified by comparing them with artificial values provided directly by PreScan software, which would be impossible to be collected in real world without additional systems.

The BLIS system was built as two subsystems: range assignment, which determined area where the detected vehicle appeared and colour assignment – yellow colour for further distance and red colour, that suggested increased attention, for closed distances.

3.4. Model of the system – control system

The Control System was designed to indicate the position of the overtaking vehicle and its distance by lighting the adequate LEDs. There were 5 LEDs in total – each LED corresponded specific angular scanning range.

For each LED there was a control system created deciding when to activate the LED and a color assigning system deciding in which color should the LED lit up.

4. Testing

4.1. Test planning

In order to test the modelled system a detailed test plan was created. Planning was based on thorough system analysis and consideration of system's most vulnerable elements. In order to prepare testing phase, the following questions were raised:

1. Questions clarifying what should be tested.
   - What are the system inputs?
   - What are the system outputs?
   - How were the inputs transformed into outputs?
   - Which of these transformations concern variables unrelated to created model itself?
2. Questions going back to project assumptions.
   - What should the system do?
   - What kind of information should the system provide the user with?
   - What the system should not do?
3. Questions about the used algorithm.
   - How the system should work?
   - What are the systems inputs/outputs ranges and kinds?
   - By what functions is the system characterized?

Based on these questions a test cases sheet was prepared, which made a base for the testing process.

Table 1. Test cases sheet [own study]

No.	Test description	Initial conditions	Expected value	Result
1.	Calculation verification			
1.1	Xr position	rangeTIS ≠ 0	Xr ~= Xv-Xo	
1.2	Yr position	rangeTIS ≠ 0	Yr ~= Yv-Yo	
1.3	Yellow Critical Distance	rangeTIS ≠ 0	YCD = -4*abs(Yr) + 12	
1.4	Red Critical Distance	rangeTIS ≠ 0	RCD = -4/3*abs(Yr) + 4	
1.5	Time To Collision	Vdopp ≠ 0	TTC = -rangeTIS/Vdopp	
2.	Visual testing			
2.1	The vehicle approaches from the correct side	-	Left/right side, behind Bytel	
2.2	The vehicle enters the scanning range	-	The vehicle is in sensor range	
2.3	LED LL performance	vehicle in LL range, higher risk	LED lights up Y/R	
2.4	LED L performance	vehicle in L range, higher risk	LED lights up Y/R	
2.5	LED C performance	vehicle in C range, higher risk	LED lights up Y/R	
2.6	LED R performance	vehicle in R range, higher risk	LED lights up Y/R	
2.7	LED RR performance	vehicle in RR range, higher risk	LED lights up Y/R	
3.	Numerical testing			
3.1	Vehicle velocity / Bytel velocity	Vv ≠ 0	>=1	
3.2	Bytel velocity - vehicle velocity	Vv ≠ 1	<= 10 m/s	
3.3	Vehicle velocity	-	<= 12 m/s	
3.4	Bytel velocity	-	<= 10 m/s	
3.5	Yellow alert switching	TTC ≤ 10 and ≥ 4s or (Xr ≤ YCD and Vdopp < 0 and Xr ≠ 0)	yellowAlert = 1	
3.6	Red allert switching	TTC ≤ 4 and ≥ 0.1 s or (Xr ≤ RCD and Vdopp < 0 and Xr ≠ 0)	redAlert = 1	
3.7	Range LL control	48 ≤ thetaTIS ≤ 87.5	alertL = 1	
3.8	Range L control	7 ≤ thetaTIS ≤ 49	alertLL = 1	
3.9	Range C control	8 ≤ thetaTIS ≤ -8	alertC = 1	
3.10	Range R control	-49 ≤ thetaTIS ≤ -7	alertR = 1	
3.11	Range RR control	-87.5 ≤ thetaTIS ≤ -48.5	alertRR = 1	

4.2. Testing procedure

In order to test the BLIS model four test scenarios were created, that were supposed to verify the correct system performance in specific traffic situation.

1. Bytel is being overtaken from the left side
2. Bytel is being overtaken from the right side
3. The overtaking vehicle changes sides during the manoeuvre
4. False alarm

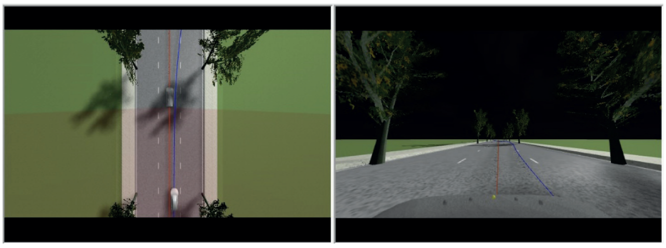

Fig.6. Example of system visual verification [own study]

Each of the test scenarios was analysed and documented based on the test cases sheet prepared. For each scenario to pass the tests, all test cases should end with positive result.

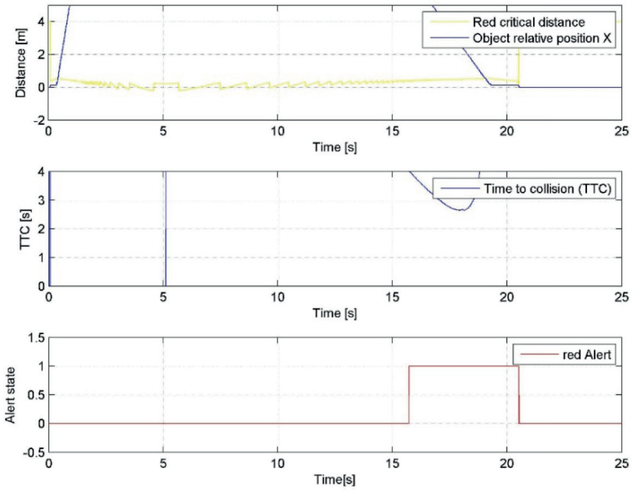

Fig.7. Example of system numerical verification [own study]

3. Conclusion

The process of designing Advanced Driver Assistance System needs to be carefully planned in order to minimize the risk of system failure. Correct designing methodology helps also with meeting project timeframes, which is often crucial requirement. The process should not only consist of actual designing, but also of thorough needs analysis and testing phase. As a result of carefully followed project plan, designing Blind Spot Information System for Bytel vehicle was completed successfully not only with regards to the system model quality but also to meeting all the requirements and deadlines.

Bibliography

[1] AMMON D., SCHIEHLEN W.: Advanced road vehicles: Control technologies, driver assistance. In Schiehlen W. (ed.): Dynamical Analysis of Vehicle Systems. Theoretical Foundations and Advanced Applications, pp. 283-304. Springer, Wien, New York (2009)

[2] BELBACHIR A., et al.: Simulation-Driven Validation of Advanced Driving-Assistance Systems. Transport Research Arena – Europe 2012, vol. 48, pp. 1205–1214 (2012)

[3] CHOLEWA A., et al.: Electric Vehicle for the Students' Shell Eco-Marathon Competition. Design of the Car and Telemetry System, in Mikulski J. (ed) Telematics in the Transport Environment, Springer Verlag, Berlin Heidelberg, CCIS 329, pp. 26-33 (2012)

[4] CICHOŃSKI K., et al.: The comparative study of drivetrain of high-performance electric vehicle. In: Diagnostyka 2014, vol. 15 no. 2, pp. 65-70 (2014)

[5] OTRĘBSKA M., et. al.: Designing safety systems for electric race car, in Mikulski J. (ed) Activities of Transport Telematics, Springer Verlag, Berlin Heidelberg, CCIS 395, pp. 139-146, (2013)

[6] COŞKUN F., et al.: Vision System Based Lane Keeping Assistance Evaluated in a Hardware-in-the-Loop Simulator. In: ASME ESDA 2010, Engineering Systems Design and Analysis Conference, pp. 289-297. İstanbul, Turkey (2010)

[7] FLÓREZ S. A. R., et al.: Multi-modal object detection and localization for high integrity driving assistance. Machine Vision and Applications, December 2011. Springer-Verlag (2011)

[8] GIETELINK O.J., PLOEG J., DE SCHUTTER B.: Development of a driver information and warning system with vehicle hardware-in-the-loop simulations. In: Mechatronics, The Science of Intelligent Machines, An International Journal, A journal of IFAC, The International Federation of Automatic Control, vol. 19, issue 7, pp. 1091-1104. (2009)

[9] JEZIERSKA-KRUPA K, KRYSIAK M., SKARKA W.: Comparison of two versions of blind spot information systems in Bytel and MuSHELLka two race vehicles. In: Zesz. Nauk. Inst. Pojaz. PWarsz. 2014 z. 3/99, pp. 119-124 (2014)

[10] PRZYSTAŁKA P., et al.: Velocity Planning of an Electric Vehicle Using an Evolutionary Algorithm, in Mikulski J. (ed), Activities of Transport Telematics, Springer Verlag, Berlin Heidelberg, CCIS 395, pp. 171-177, (2013)

[11] Shell. Rules and regulations chapter 1., http://www.shell.com/global/environment-society/ecomarathon/for-participants/generalinformation/rules.html [date of access: April 20,2014]

[12] SKARKA W.: Application of numerical inverse model to determine the characteristic of electric race car. In: Tools and Methods of Competitive Engineering (TMCE) Symposium, pp. 263-274. Budapest, Hungary (2014)

[13] SKARKA W., et al.: Advanced driver assistance systems for electric race car. In: Tools and Methods of Competitive Engineering (TMCE) Symposium, pp. 1487-1494. Budapest, Hungary (2014)

[14] TARGOSZ M., SKARKA W., PRZYSTALKA P.: Simulation And Optimization Methodology Of Prototype Electric Vehicle. In: Proceedings of the 13th International Design Conference DESIGN 2014 ed: Marjanović D., Štorga M., Pavković N., Bojčetić N., pp. 1349 – 1360. Dubrovnik, Croatia (2014)

[15] TASS International. Prescan: Simulation of adas and active safety.

[16] https://www.tassinternational.com/prescan [date of access: April 20,2014]

[17] WUA B.-F., et al.: A vision-based blind spot warning system for daytime and nighttime driver assistance. In: Computers and Electrical Engineering 39, pp. 846–862 (2013)