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Katarzyna JEZIERSKA-KRUPA, Maciej KRYSIAK, Wojciech SKARKA*
Silesian University of Technology, Institute of Fundamentals of Machinery Design,
Faculty of Mechanical Engineering
Konarskiego 18A Street, 40-019 Gliwice, Poland
**Corresponding author*. E-mail: wojciech.skarka@polsl.pl

ADVANCED DRIVER SAFETY SUPPORT SYSTEMS FOR THE URBAN TYPE VEHICLE

Summary. Smart Power Team is currently working on the design of an urban electric vehicle designed to compete in the Shell Eco-marathon. One important aspect of this type of vehicle characteristics is it safety. The project of advanced driver assistance systems has included some proposals of such systems and the concept of their execution. The first concept, BLIS (Blind Spot Information System), is to build a system of informing a driver about vehicles appearing in the blind spot. The system constitutes a second concept, CDIS (Collision Detection and Information System), and it is designed to detect a vehicle collision and inform the team. Further systems are: DPMS (Dew Point Measurement System) - a system which does not allow a situation, where the windows are fogged, OHRS (Overtaking Horn Reminder System) - a system which checks overtaking and MSS (main supervision system) - a supervisory system. These concepts are based on the assumption of the use of laser sensors, photoelectric, humidity and temperature, and other commercially available systems. The article presents a detailed description of driver assistance systems and virtual prototyping methodology for these systems, as well as the numerical results of the verification of one of the systems.

ZAAWANSOWANE UKŁADY WSPOMAGANIA BEZPIECZEŃSTWA KIEROWCY DLA POJAZDU TYPU MIEJSKIEGO

Streszczenie. Zespół Smart Power pracuje przy budowie elektrycznego pojazdu miejskiego, projektowanego na potrzeby zawodów Shell Eco-marathon. Jednym z aspektów charakteryzujących pojazd jest jego bezpieczeństwo. Projekt systemów wspomagających kierowcę zawiera kilka propozycji systemów i koncepcji ich wykonania. Pierwszą koncepcją jest BLIS (Blind Spot Information System), którego zadaniem jest informowanie kierowcy o pojazdach pojawiających się w martwym punkcie. Drugą koncepcję stanowi CDIS (Collision Detection and Information System) i jest projektowany do wykrywania zderzenia pojazdów i informowania o tym zespołu. Kolejnymi systemami są: DPMS (Dew Point Measurement System) – nie dopuszcza do sytuacji, w której szyba jest zaparowana, OHRS (Overtaking Horn Reminder System) – system wykrywający wyprzedzanie pojazdu oraz MSS (Main Supervision System) – system nadzorczy. Koncepcje zakładają użycie czujników: laserowych, fotoelektrycznych, wilgotności oraz temperatury, a także innych systemów stosowanych komercyjnie. Artykuł przedstawia szczegółowo opisane systemy wspomagania kierowcy oraz metodologie wirtualnego prototypowania dla tych systemów, a także wyniki numeryczne weryfikacji jednego z systemów.

1. INTRODUCTION

This paper focuses on the safety support systems which are designed for the needs of the race Shell Eco-marathon. These systems will be part of the draft for a team of Smart Power [6] vehicle “Bytel“ (Fig. 1).

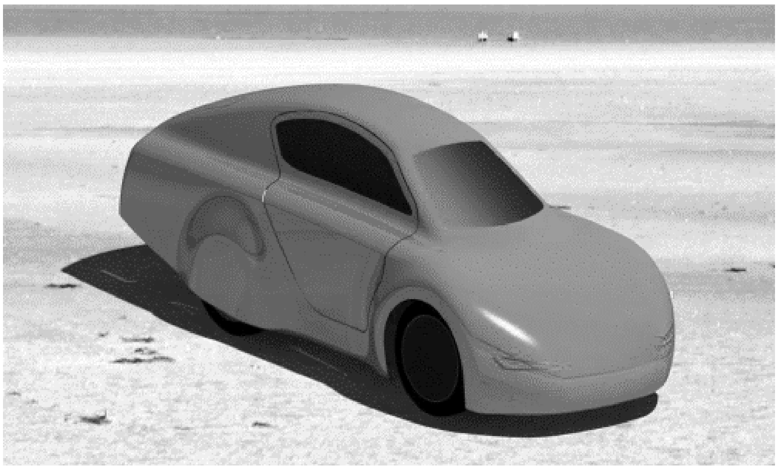


Fig. 1. Model of “Bytel” race vehicle designed for SEM
Rys. 1. Model pojazdu wyścigowego “Bytel” projektowanego na zawody SEM

Shell Eco-marathon is the world's largest race for energy efficient vehicles. The race is held annually in the world's three editions for Europe and Africa, the Americas and Asia. Euro African edition took place in Rotterdam and the next races are planned in London. In each edition more than 200 teams that participate and over 3,000 students. The race is organized with a great flair as evidenced by more than 50 thousands of spectators watching the races in Rotterdam/

Vehicles for the race are prepared in strict accordance with statutory requirements in two size classes - Prototype (small vehicles) and UrbanConcept (large vehicles). There are different categories of power system: gasoline, alternative fuel, diesel, CNG, battery electric, hydrogen in each category of vehicle size. Smart Power team competes in three categories: Prototype (battery electric), UrbanConcept (electric battery) and UrbanConcept (Hydrogen). Achieved by a team of smart power results put us in the top ten best teams in the world. Bytel vehicle represents a UrbanConcept (battery electric) category.

2. BREAKDOWN OF SAFETY SUPPORT SYSTEMS

Safety support system can be classified into two main types described below.

- **Active safety -** "include everything that affects the safety of the driver and passengers" [2]. An example of such system is the ABS (Anti-lock Brake System) anti-locking braking system which activates automatically;
- **Passive safety** - "Passive safety is determined by providing technical solutions in the event of a collision, the maximum protection of persons inside the vehicle" [2]. Here, for example, airbags, laminated glass or rounded edges of the vehicle are used.

  The Smart Power team plans to use 4 driver support systems in the Urban type vehicle, and they include:
- **Blind Spot Information System -** designed to detect vehicles behind the driven vehicle and negate blind spot behind the vehicle [5];

- **Overtaking Horn Reminding System -** overtaking recognition system and a driver's reminder to use the audio signal during this maneuver [7]. The use of the audio signal when overtaking during the race is required in the regulations. Failure to comply with the rules of the race will result in being disqualified [3];
- **Dew Point Measurement System -** A system whose task is to detect evaporation of water on the windshield and remove this effect;
- **Crash Detection and Information System** – it's purpose is to detect a collision or accident, and warn the team,
- **Stereo Vision System -** for intelligent vehicles to avoid forward car collision [8];
- **Main Supervision System -** supervisory system, which verifies the operation of the equipment and informs the driver about the exceeded parameters detected by the additional sensors. This is our version of Adaptive Drive Assistant System [1].

3. CONCEPTS OF DRIVER POWER SAFETY SYSTEMS

In this chapter concepts of safety support system are shown. Some concepts of Advanced Driver Assistance Systems proposed for "Bytel" race vehicle are advanced versions of ADAS systems, previously designed and tested in MuSHELLka race car which was built by Smart Power team for SEM race in 2012, 2013 and 2014.

3.1. Blind spot information system (BLIS)

BLIS is a development of the system known from applications in passenger cars and race car MuSHELLka designed and built by the Smart Power team in previous seasons of Shell Eco-marathon [4 - 6].

The first concept involves the use of 9 photoelectric sensors with a range of 5m. The use of nine sensors will be able to detect vehicles in the blind spot. Fig. 2 shows the location of the sensors for the first concept.

Table 1

Advantages and disadvantages of BLIS first concept

Advantages	Disadvantages
Small dimensions	Possible interference of sunlight
Low Price	Low Accuracy

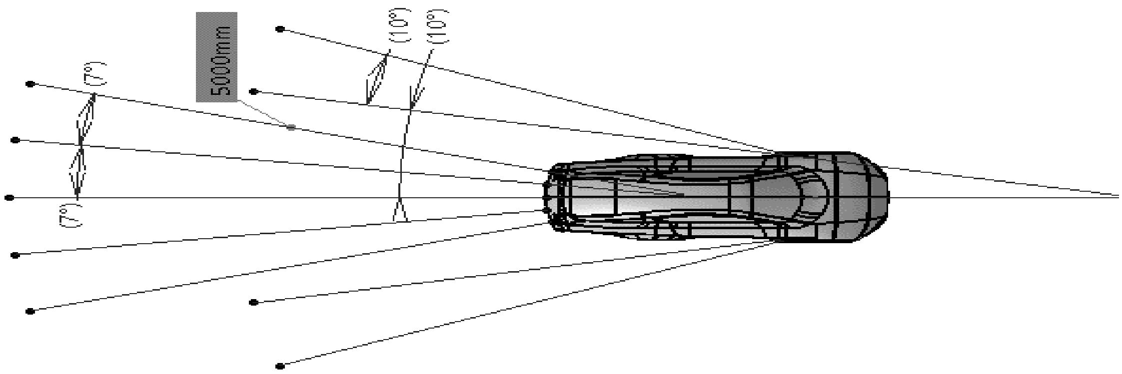


Fig. 2. The idea of using photoelectric sensors for the BLIS system
Rys. 2. Koncepcja zastosowania czujnika fotoelektrycznego dla system BLIS

The second concept involves the use of Microsoft KINECT 4 devices. With the built infrared scanner it is possible to obtain high-resolution scanning. Dimensions of the device may disrupt the aerodynamics of the vehicle and direct sunlight can disrupt the infrared scanner. In addition, devices are characterized by Kinect dead center to a distance of 0.4 m from the device. Fig. 3 shows the potential for Kinect device spacing BLIS.

Table 2

Advantages and disadvantages of BLIS second concept

Advantages	Disadvantages
High scan resolution	Large size of equipment
Relatively low cost of scanning equipment	Possible interference of the sunlight

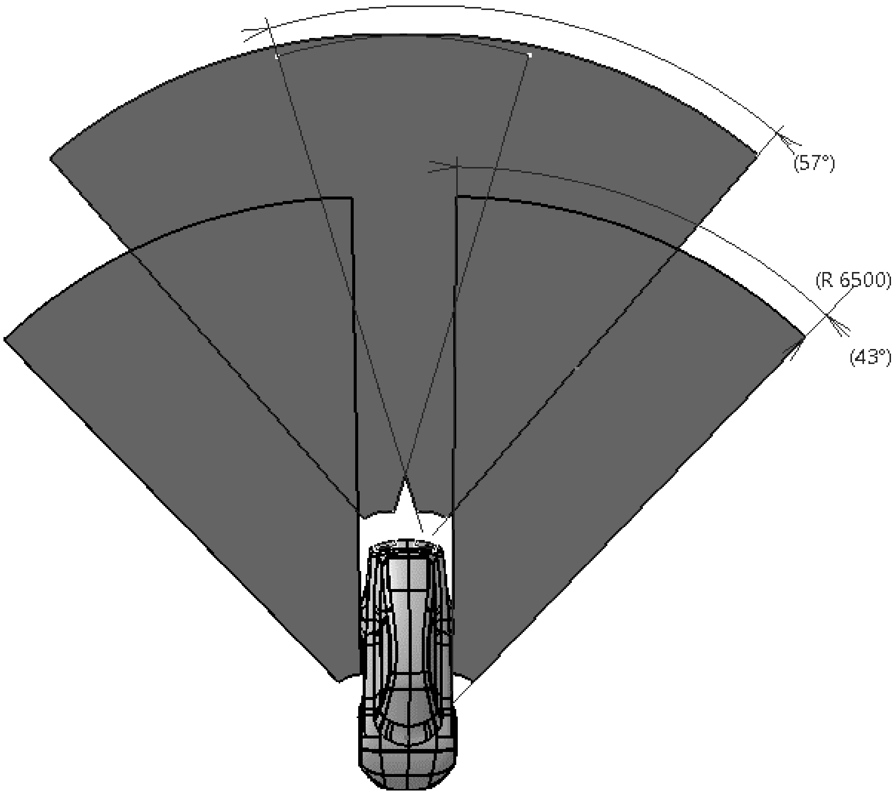


Fig. 3. BLIS system concept with the use of Kinect devices
Rys. 3. Koncepcja system BLIS z zastosowaniem urządzenia Kinect

The third concept is the use of the Hokuyo laser scanner with a first class safety. In this concept, one laser scanner is to be used to get the desired effect. The device is characterized by a wide angle and
a high frequency operation of the scan. The location of the sensor and the range of activities is shown in Fig. 4.

Table 3

Advantages and disadvantages of BLIS third concept

Advantages	Disadvantages
Compact design	High cost of equipment
High frequency scanning	

High resolution scanning	

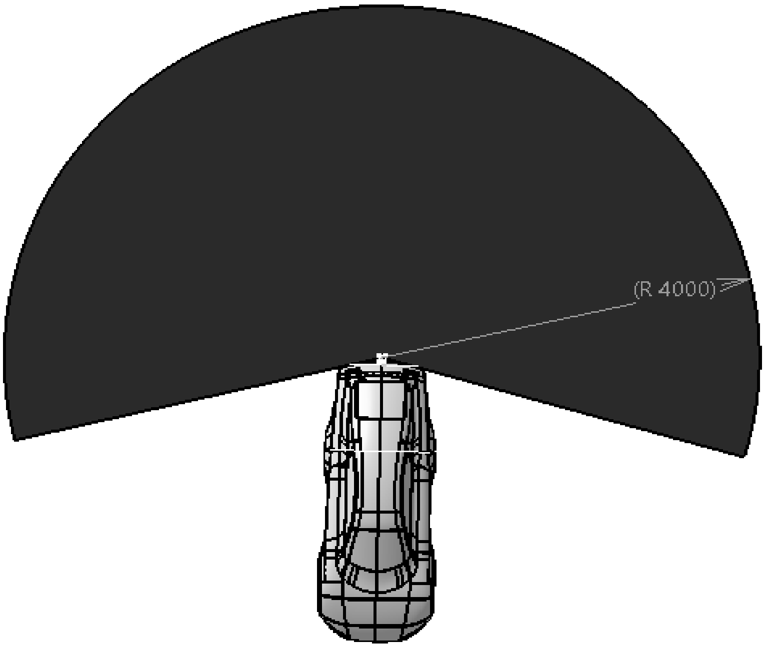


Fig. 4. The idea of using the Hokuyo sensor
Rys. 4. Koncepcja zastosowania czujnika Hokuyo

For further design works the third concept was selected, due to the lack of interference, high frequency and resolution activities.

3.2. Overtaking Horn Reminder System (OHRS)

OHRS system was previously proposed and tested in MuSHELLka race vehicle. In Bytel concept OHRS was totally changed. In OHRS system, data acquisition is similar to BLIS system, therefore three concepts will be based on the same sensors as in the previously described system. The first concept (Fig. 5) assumes the use of 5 photoelectric sensors whereas the second concept (Fig. 6) uses a Microsoft Kinect 2 devices and the third concept (Fig. 7) uses one laser scanner Hokuyo.

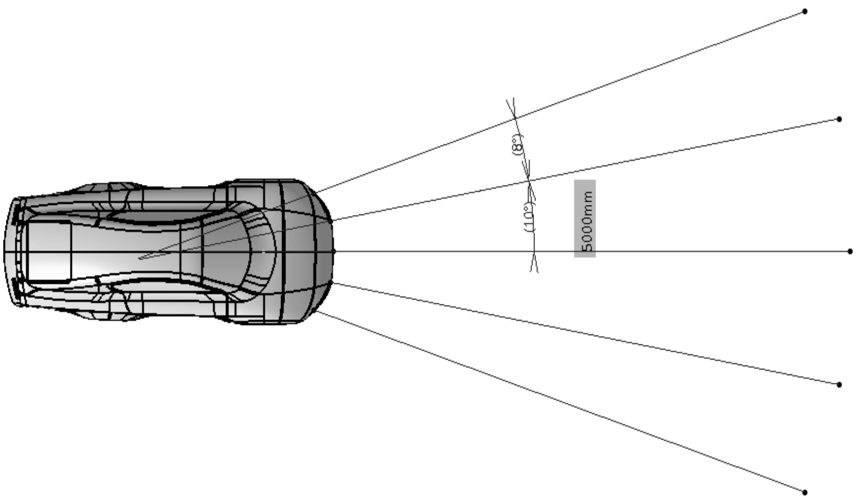


Fig. 5. First concept of OHRS system

Rys. 5. Pierwsza koncepcja systemu OHRS

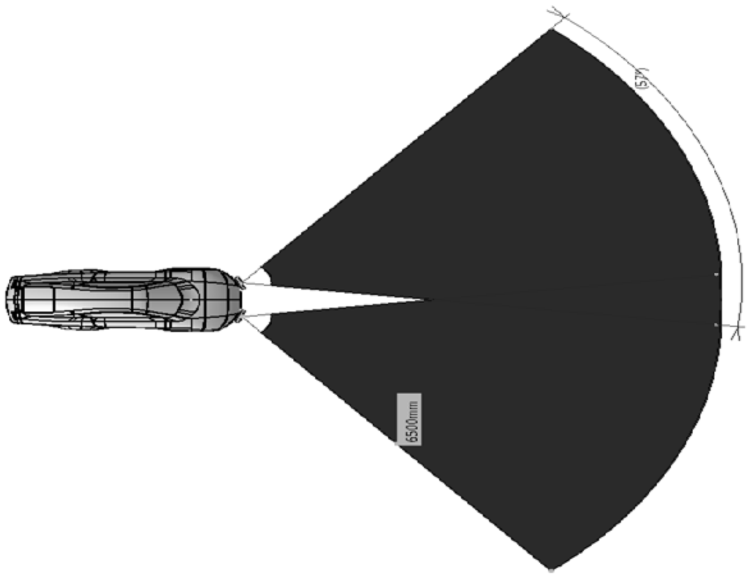


Fig. 6. Second concept of OHRS system
Rys. 6. Druga koncepcja systemu OHRS

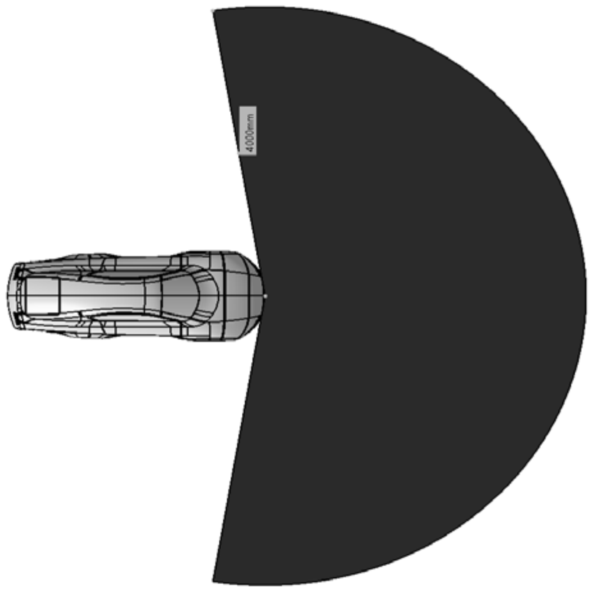


Fig. 7. Third concept of OHRS system
Rys. 7. Trzecia koncepcja system OHRS

In the process of creating the field of possible solutions laser scanner was selected as the most suitable device.

3.3. Dew Point Measurement System (DPMS)

DPMS system was for the first time proposed for “Bytel” race car. The concept of this system is quite new even in current applications.

The first concept involves the use of humidity and temperature sensor to determine the dew point temperature and heat from the heater. Such a system is inexact due to the varying temperature in the area of the glass.

Table 4

Advantages and disadvantages of DPMS first concept

Advantages	Disadvantages
Compact design	Inaccuracy
Low energy consumption	High cost

The second concept includes six temperature sensors and one relative humidity sensor. Temperature sensors are based on OneWire bus. It enables to connect up to 255 sensors on one wire so the system can be easily expanded by a greater number of sensors needed. The relative humidity is constant, therefore, one sensor is enough. Separate humidity and temperature sensors are cheaper than a system combining both functions. The heating device in such a system may be an infrared or radiant heater.

Table 5

Advantages and disadvantages of DPMS second concept

Advantages	Disadvantages
OneWire bus	Long cable with sensors around the window
Low cost	
Low energy consumption	

For further work the last concept was selected.

3.4. Crash Detection and Information System (CDIS)

The first concept involved a built-in tablet 3 axis accelerometer and built-in GPS device.

Table 6

Advantages and disadvantages of CDIS first concept

Advantages	Disadvantages
Ready-built machine	Quality depends on the model of tablet
	Size of tablet
	Energy consumption

The second concept involves the use of external GPS systems, GSM and 3 axis accelerometers. These systems are used in Mushellka vehicle and can be used directly in Bytel.

Table 7

Advantages and disadvantages of CDIS second concept

Advantages	Disadvantages
Ready-programmed systems	need to interconnect systems
High accuracy	
Small size	

For further work the second concept selected.

3.5. Main Supervision System (MSS)

Many different safety subsystems inform drivers about important events which can cause information problems. The lack of one supervising system which would decide which information is more important and how to inform a diver, is particularly important when we have an increasing number of such systems. Therefore, information chaos may significantly reduce attention of a driver.

The first concept is based on the use of Unity language to write supervisory system. Unity System allows compiling programs written for the PC device to any operating system, e.g. Android. In this concept it is assumed that the MSS system will be installed on the TABLET device. The simplicity of the programming speeds up the process of programming through the use of environmentally friendly PCs, but communication between devices on various operating systems is completely different, which is why this process has been abandoned.

The second concept involves writing applications directly on the Android operating system. The problem in this case was the lack of support for Hokuyo devices, so the programmer would have to write the controller. Since low-level programming is too time-consuming, this concept was rejected.

Finally, the third concept uses one plate computer and the tablet as the display. The system will be programmed in LabVIEW environment because of the simplicity of programming. The tablet as the display device offers a high resolution display. Viewing will be carried using TeamViewer software.

3.6. Choosing the most appreciated system to implement

System	Pro implementation	Contra implementation
Blind Spot Information System (BLIS)	- minimizes the risk of accident during overtaking maneuver - helps to adapt the driving strategy during the race	- can result in driver concentration reduction
Overtaking Horn Reminder System (OHRS)	- Helps to respect the SEM rules - reduce risk of overtaking maneuver	- can result in driver concentration reduction
Dew Point Measurement System (DPMS)	- helps to provide the driver with perfect vision during rainy conditions	- it is rare to start the race in rainy conditions (SEM rules)
Crash Detection and Information System (CDIS)	- shortens the reaction time for the team in case of a crash	- the team often cannot access the accident area
Main Supervision System (MSS)	- simplify the UI of all safety systems	- cannot be implemented unless other systems are implemented

All concepts are considered in terms of their usability at Shell Eco-marathon. One of the most crucial problems accompanying these competitions is the low visibility range of vehicles behind the driven car. The importance of this disadvantage has been recognized by SEM organizers and therefore there has been even a rule implemented, that in case of overtaking there has to be a sound notification given by an overtaking vehicle. Still, this does not guarantee flawless operation run. After comparing the ADAS concepts with each other, the conclusion was made, that the most appreciated one would be BLIS.

4. VIRTUAL PROTOTYPING OF ADVANCED DRIVER SUPPORT SYSTEMS

Designing vehicle safety systems and comparing different concepts and performance evaluation of the proposed concept is very difficult without a prototyping system. The design work, estimation of the system and selecting the right system features significantly accelerates and facilitates virtual prototyping. Environment for virtual prototyping must be able not only to build a computer model of the car and the environment of the race but also to simulate different traffic situations and phenomena occurring during driving, including atmospheric phenomena. In addition, it is necessary to reflect automatic operation of the system and the ability to configure the features of the control system elements and logic of the system. Such assumptions, among others, are met by the PreScan system.

The System designed by a Smart Power team are based on PreScan software that allows simulating multiple sensors such as radar, Laser / Lidar, Video Camera, IR, Ultrasonic sensors, antenna, GPS [3]. Simulation of sensors is formed as a result of four main steps:

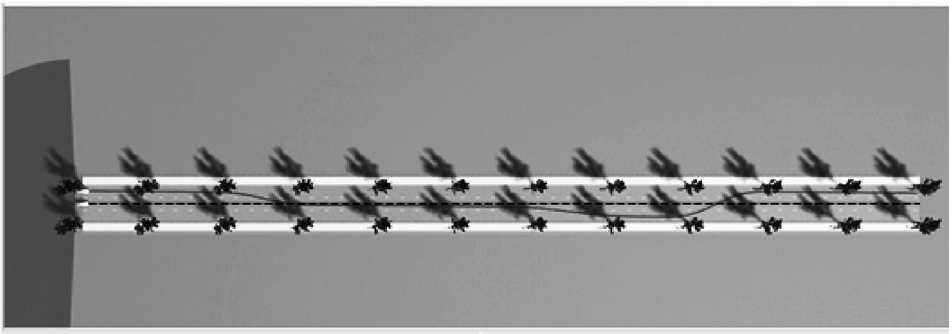
- Building environment - in this section the following should be prepared: route, and model of vehicle that can be imported from the CAD program,
- Modeling sensors - select the type of sensors used and their location on the modeled vehicle,
- Adding control systems - In this step, the proper operation of the system is assigned on the basis of established sensors,
- Starting of the experiment - the last part is the start of the experiment and analysis of the results.

5. AN EXAMPLE OF THE APPLICATION OF PRESCAN VIRTUAL DESIGN SYSTEM

Blind Spot Information System (BLIS) for Bytel was based on one lidar – Hokuyo sensor. The sensor's range of 240 degrees and the sampling frequency equal to 30 Hz enable to estimate the approaching vehicle distance and location very accurately.

For designing the safety system BLIS there was the TASS Co. software - PreScan used. Although PreScan enables the user to design a lidar sensor for the experiment, in this case TIS (Technology Independent Sensor) module was used. It was forced by extremely long processing time for lidar. The user can modify a wide range of characteristics for TIS sensor, so it was possible to design it to be very similar to lidar.

The software give us an opportunity to simulate the angle value (in sensor area) of the detected vehicle. On Fig. 8 we can observe an image of the trajectory of vehicles on the road and a diagram seen, which shows the dependency between vehicles’ trajectories and the angle of detected vehicle.



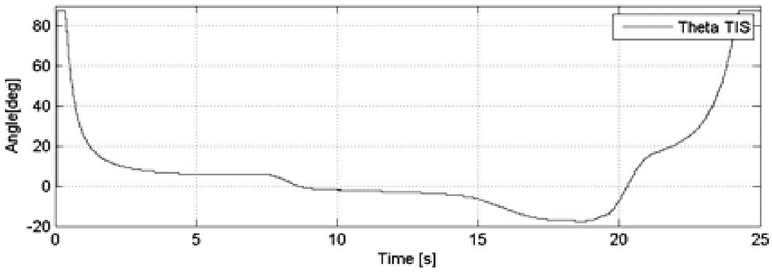


Fig. 8. Dependency between vehicle's trajectories and the angle in which detected vehicle appears
Rys. 8. Zależność między torem jazdy pojazdu i wartością kąta od osi pojazdu, na którym zaobserwowano drugi pojazd

What can be also calculated and verified is for example the velocities difference between two vehicles. On Fig. 9 there is compared the calculated velocities difference (Bytel Velocity – Object Velocity) with the ideal value generated by PreScan (named Doppler Velocity). The diagram refers to the experiment visualized above.

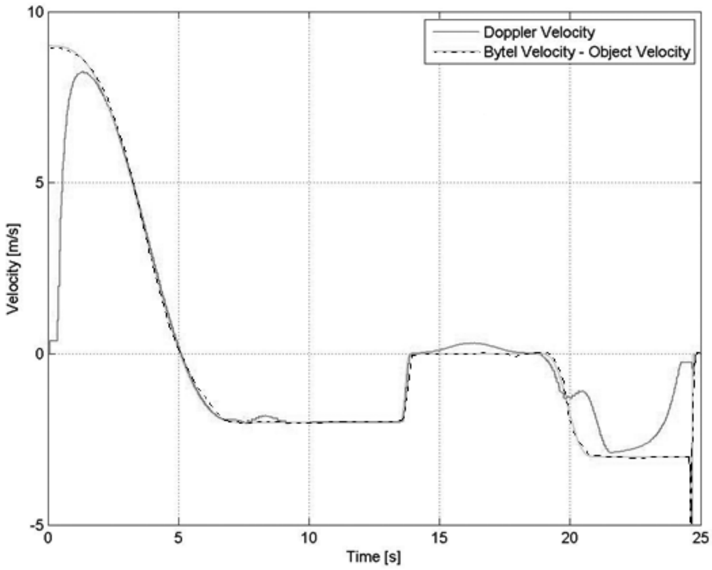


Fig. 9. Verification of calculated vehicles' velocities difference
Rys. 9. Weryfikacja różnic między prędkościami pojazdów – obliczoną i zaobserwowaną

By simulating the BLIS performance it was possible to adjust the alerts to inform the driver about risk only when there is actual need for that. In order to determine the moments and scale of danger there was Time To Collision (TTC) and Critical Distances (Red and Yellow) defined. After fulfilling at least one out of two conditions: crossing Critical Distance value or when TTC value was less than 4, there was an alert generated. The exemplary diagram for Red Alert state can be seen on Fig. 10.

The final data presentation can be done in two ways – there can be either the angle of the approaching vehicle and its distance presented or there can be three LEDs (left, center, right) used to show Bytel's driver that enhanced attention is recommended. The decision is to be made based on driver's personal preferences. Thanks to wide range of Hokuyo lidar, the BLIS for Bytel comparing to BLIS for MuSHELLka is much more dependable and accurate. It also enables the technical team to widely adjust the data presentation based on driver's actual needs.

CONCLUSIONS

- The designed system can be applied in designing autonomous vehicles. For example, CDIS allows you to quickly inform emergency services of the breakdown accident together with data from GPS navigation.
- The developed concepts are based on the known safety of the driver assistance systems. This allowed for the creation of concepts for improved existing ones.
- The use of simulation allows to accelerate the design of safety support system significantly and reduces the costs.
- Because the race is specific, it needs a special safety support system. That kind of a system can be adapted for an urban vehicle. The result of the system reconfiguration could be an automatic activating of turn signal during overtaking.
- As the most Appreciated system there was BLIS recognized, as it would significantly reduce the risk accompanying the overtaking maneuver, which is considered the most dangerous maneuver during the race.

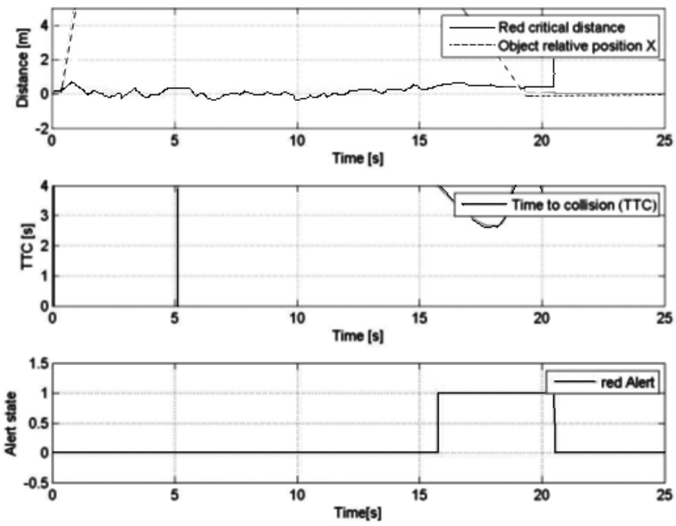


Fig. 10. Red Alert is generated after fulfilling at least one out of two conditions: crossing Red critical distance or when TTC value is less than 4 s

Rys. 10. Czerwony sygnał alarmowy uruchamiany po wypełnieniu co najmniej dwóch warunków: przekroczenie granicy odległości (czerwonej) lub wartość TTC (czas do kolizji) jest mniejsza niż 4 s

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