INTRODUCTION

Driving simulators are tools widely used for research purposes. Research conducted with the use of driving simulators mainly concerns the influence of driver behaviour on traffic safety [1,2,3]. There are few published studies on road infrastructure, concerning geometry design. Therefore, we see a great potential for traffic simulators on that field. The problem of road designing for simulation seems to be solvable with the use of OpenDRIVE standard.

Authors of this article are involved in project EYEVID, which main goal is to apply effective methods for visibility studies in both: real and simulated traffic environments.

1. ROAD MODELLING - DRIVING SIMULATORS ENVIRONMENT’S POTENTIAL

Recently, the use of simulation environment in road research is raising its popularity. Simulators are on one side top-level world-class research instruments, like full-size simulators of Daimler or Toyota and on other side they can consist of simple desk stands equipped with screen, steering and control devices. Reasonable compromise seems to be fulfilled by high class research simulators, which provide good quality of simulation environment with not very high system complexity.

Fig. 1. Examples of high-class research simulators of a passenger car, and a truck or bus (Motor Transport Institute)

High class research simulator consists of a full sized and fully functional vehicle cabin, visualization system and motion platform. Additionally, mechanical stimuli (vibrations of the cabin and vibrations of the driver seat) and sound effects could be generated inside the cabin. All these raise the reality of simulation and allow to simulate the process of driving a vehicle as realistically as possible.

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Simulated environment should also allow to perform experiments in different traffic conditions with full control of other users of the road and ongoing events. It should also provide full control of all environment conditions like weather (rain and snow) and light conditions (day, night, twilight) [7].

High-class simulators could be used not only for academical research studies, but could be an effective way to perform specialised analysis for road designers and supervisors. One of the most important advantages of simulators use could be relatively low, in relation to the cost of investment, cost of preparing scenario based on plans and road design and planned roadside environment. Also, on-going studies could be performed in relatively safe laboratory environment.

Unfortunately, presently there are no tools dedicated for performance of such studies. Nonetheless, there are some tools which mainly are used for designing simulation scenarios and environment, and the proper use of them could allow to conduct studies on taken-from-reality roads. Such perspective simply indicates also possibility of using simulation environment to study non-existent, planned roads.

Simulated world is a combination of separate elements of the real world conditions. This separation includes one or several features, which generally are related to one or few real-world features. Following this, for designing real-world conditions in simulation environment, we need to separate and describe these features and next combine them as one simulated scenario. The use of simulation world as a tool for road designers and road safety studies has its implication in significantly limited list of features which are necessary to determine:

- terrain topography,
- road design,
- roadside elements,
- roadside environment,
- vehicle or vehicles dynamic models.

Combination of these features creates simulation world which is sufficient to perform studies on relations between road users and road environment.

2. SIMULATED ENVIRONMENT AS A TOOL FOR ROAD DESIGN

In EYEVID project, the main goal is to apply effective methods for visibility studies in both real and simulated traffic environments. It concerns existing and planned roads. For driving simulation studies, a proper modelling of the road, seems to be a crucial issue.

There are several plans of differentiated details on each stage of a new road planning and designing. There are several programs and algorithms which help to choose the best localization of the road at preliminary stage. An example of such algorithm is the simulation modelling approach to assess the safety performance of roads, developed in Australia [9]. Researchers have used statistical analysis, numerical modelling using Newtonian Mechanics, and micro simulation models to assess roads safety performance. In this study, these three methods were combined to improve the assessment of safety at road locations compared to previous works. However these methods do not concern the road geometry.

There are some applications and methods which support the road designer to fulfil the law requirements. A good example is work made in United Kingdom. This research was made to develop a generic road shape modelling algorithm for simulation of traffic scenes [6]. This algorithm simulates horizontal road alignment, according to the road geometry design standards, in the form of alternating straight sections and curve segments arrangement (Figure 2).

In this work a genetic algorithms was utilized to optimize the road shape with regard to real road design considerations such as road curvature and visibility distance. The input to the system is a set of critical points representing points with extreme road curvature. The output is the two-dimensional coordinates of the road centreline (alignment), optimized for driver's safety and comfort. The algorithm produces successful results for various road types and shapes, and exhibits good tolerance to noise [6].
At the final stage of road design, construction plans are required where all the parameters of road geometry are defined. With the use of a driving simulator it will be possible to test the road before it is build and, therefore, to omit some errors, which still occur in the process of road design. This new approach is planned to be implemented in EYEVID project.

For research on existing roads, the geo-specific road modelling is an important aspect. There are some successful approaches, made in the United States of America, to generate a proper road image from satellite photo [5].

In this research, the problem of how to quickly develop 3D road databases for driving simulation is addressed. Researchers proposed a framework based on image processing techniques. The input to this framework is a set of aerial photos with a high resolution between 0,2-0,3 meters per pixel and the United Stated Geological Survey data. A collection of road centre line point coordinates, are used to tell where the roads are in the computer programs. The output is 3D road models. These models contain both the geometric information and colour information. The software implementation of the framework contains two modules:
- image processing module (mean-shift clustering algorithm),
- 3D modelling module.

The algorithm of image processing module segments the whole road area into smaller uniform areas. Then these smaller areas are classified into either pavement area or non-pavement area based on their average saturation values. The borders of the pavement and non-pavement areas are identified as the road boundaries. However, this method is not fully automatic. The road boundaries still may need manual adjustment to remove errors [5].
3. SIMULATED ROAD ENVIRONMENT

In road infrastructure research with the use of driving simulators, the most important issue is a proper model of road and its characteristics. As stated before, simulation environment is a combination of features which are a representation of real-world road, roadside and road environment conditions. Each of these features could be represented in a specific way that should be the most efficient for the desired purpose. In the following chapter, authors present possibilities of road designing with the use of OpenDRIVE format.

OpenDRIVE is an open format for the description of road networks, which is free use, extensible and highly customizable. It was developed and is maintained by the team of simulation professionals with large support from the simulation industry. The first public appearance of OpenDRIVE was on 31 January 2006 [8].

This format was chosen by Audi Electronics Venture GmbH, BMW Group, DAIMLER, Fraunhofer and many other prestigious companies and research centres.

OpenDRIVE format describes road network logic. Its objective is to standardize the logical road description to facilitate the data exchange between different driving simulators. The main characteristics of OpenDRIVE format are as follows [4]:
- the use of XML format;
- hierarchical data structure;
- road geometry is analytically defined;
- road lanes are logically connected;
- a possibility to save data concerning road surface and roadside objects in the road format.

A functionality, which is considered to be the most important and which determines the universality of OpenDRIVE format, is the possibility to describe basic shapes, the connection of which can give as a result an image of every road and its environment. The basic shapes of OpenDRIVE format are as follows:
- straight line (shape factor equals 0);
- spiral (linear change of shape – an Euler spiral);
- arc (shape factor different than 0);
- polynomial curve (polynomial of third degree).

The first three shapes are sufficient to present straight sections of the road as well as different types of curves and transition curves. A combination of these three shapes is presented on Figure 4.

![Figure 4. Road logical design in OpenDRIVE](image)
OpenDRIVE format enables to describe the plan and profile road parameters. It is possible to map the vertical arcs and inclination of the road. The format bases on metric system with following parameters:
- position/distance in meters,
- degree in radians,
- time in seconds
- speed in m/s.

Modelling space in OpenDRIVE bases on three base axis (x, y, z), which accordingly to the needs can mean direction (forward, left, up) or geographical directions (east, north, up). That type of orientation allows to explicitly define orientation of each object with the use of rotation about a proper axis.

For describing road, three parameters are used: width, length, height (s, t, h).

![Figure 5](image1.png)

**Fig. 5.** Three-dimensional description of road in OpenDRIVE [8]

Additional parameters of the road are: superelevation and crossfall. The superelevation parameters reflect elevations of the road made for drainage purposes and to counteract the centrifugal force on curves, while crossfall parameter is used only for drainage purposes.

Roads and road sections are connected with logical connections in OpenDRIVE environment. This logic bases on XML method of predecessors and successors, which explicitly clarifies links of road sections and possible routes of journey.

![Figure 6](image2.png)

**Fig. 6.** Road lanes logic in OpenDRIVE [8]
There are different logical interactions between road lanes in the XML format of OpenDRIVE. In each section a number of lanes and their direction are defined. The centre of the road is described with “0” symbol. Lanes are numbered by positive or negative numbers, depending on their direction (Figure 6).

There is a simplified system of tagging and logic relations for road markings. A single line is defined by the following dimensions: length of line part, spaces between each part of the line, spacing form bank of the road (described with curve parameters), spacing from the beginning of a section and the beginning of the place where line becomes visible, and rule of driving.

In the field of the road visibility aspect also roadside markings and signs are the important elements necessary to complete simulation of real-world road. The way of road marking influences driver behaviour, chosen trip speed and driving strategy. Beside, road signs indicate speed limit, oncoming danger on the road, nearest intersection configuration. They play also an informative role.

In OpenDrive format specification, these features are assigned to road network reference lines. Also some road infrastructure elements like barriers could be implemented.

Due to computational effectiveness reasons, some features are described in a simple way. For example road markings are described by few component elements:
- length – line length (visible part);
- space – length of space between lines;
- tOffset – distance between the line and the edge of road;
- sOffset – distance between the beginning of the sector and the place where the line should start to be visible;
- rule – basic rules of traffic which occur on the line (no passing, danger, no rule).

Such components make possible to implement almost every kind of road markings which may occur in real world. Similar components may describe position and rules related to some road signs.

Physical layer of OpenDrive allows also to implement automatically serial elements as roadside stakes.

The possibility of road surface description is the important option offered by OpenDRIVE. Therefore, more realistic simulation can be implemented including vibrations simulator.
CONCLUSIONS

We have chosen OpenDRIVE as it is an open format for the description of road networks, which is free use, extensible and highly customizable. Its high potential for creating different types of roads in virtual environment will be crucial to implement the EYEVID project.

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Abstract

Driving simulators are tools widely used for research purposes. Research conducted with the use of driving simulators mainly concerns the influence of driver behaviour on traffic safety. There are few published studies on road infrastructure, concerning geometry design. Therefore, we see a great potential for traffic simulators application in that field. The problem of road designing in simulation environment seems to be solvable with the use of OpenDRIVE standard.

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REFERENCES


Modelowanie infrastruktury drogowej w środowisku symulacyjnym

Streszczenie

Symulatory jazdy są powszechnie stosowanym narzędziem badawczym. Badania prowadzone z ich wykorzystaniem najczęściej dotyczą wpływu zachowania kierowcy na bezpieczeństwo ruchu drogowego. Nieliczne publikacje dotyczą infrastruktury drogowej, a w szczególności geometrii drogi. Autorzy niniejszej pracy dostrzegają wysoki potencjał symulatorów w tym zakresie. Problem projektowania drogi w środowisku symulacyjnym może być z powodzeniem rozwiązany za pomocą użycia standardu OpenDRIVE.

Autorzy niniejszej pracy uczestniczą w projekcie EYEVID (NCBiR, PBS 1), którego celem jest opracowanie efektywnych metod badania infrastruktury drogowej pod względem widoczności, zarówno w symulowanych jak i rzeczywistych warunkach ruchu.

REFERENCES