Junction Models in OpenDRIVE Standard

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***Abstract*—The development of autonomous vehicles is one of the most dynamically developing areas nowadays and covers wide areas of applied research. The developments are extremely expensive and time-consuming, so to reduce these factors all the available techniques should be used. Analyzes can be performed using simulators, it can accelerate the testing process. Accordingly, the paper has a focus on the use of different junction description method.**

Keywords—junction, OpenX Standards, OpenDRIVE, automotive simulations

I. Introduction

Nowadays different simulations are gaining importance in many areas of life. Therefore, we need information about the real world to make these simulations as complete as possible. This is not different for anyone dealing with transportation issues. I have already dealt with the logical representation of traffic junctions from a security point of view [1]. Due to the increased traffic, improving road safety is one of the major issues in the transportation policies of most countries. Simulation is used in many contexts, there are also several non-professional applications. Simulation is a priority in various automotive development processes as it speeds up and completes development. An automobile simulator provides an opportunity to reproduce the characteristics of real vehicles in a virtual environment. It replicates the external factors and conditions with which a vehicle interacts. Nowadays all major manufacturers use simulators to develop and test new ideas and products [2]. Key issues in simulation include the acquisition of valid information source about the relevant selection of key characteristics and behaviors, the use of simplifying approximations and assumptions within the simulation. The conceptual and feasibility test provides a strong basis for automotive developments, which is carried out with the help of simulators. The relevant road network data have also been extensively utilized to verify and validate the autonomous systems in simulation. The automotive simulators can be grouped into three main categories: vehicular testing applications, driving simulators and traffic simulators. To feed the simulators, data about road geometry and related information is required.

The paper is organized as follows: Section 2 presents the simplified junction description methods. Section 3 gives an overview of the junction and road description in OpenDRIVE format. In Section 4 the obtained conclusion can be read and finally, references can be found.

II. Junction Description Methods

The easiest way to create a digital representation of a junction is to create a simple graph. A graph in this context is made up of nodes that are connected by edges (also called links or lines). A distinction is made between undirected graphs, where edges link two vertices symmetrically and directed graphs. The basic idea is to create an undirected graph first, where the junction branches replaced by simple centerlines. The centerlines can be matched with the nodes. The graph can be defined by a coordinate matrix and an adjacency matrix, and geometry is stored in a separate file. Using this modeling concept, arbitrary complex road junctions can be modeled. Figure 1. shows the simple centerline method to describe a junction.

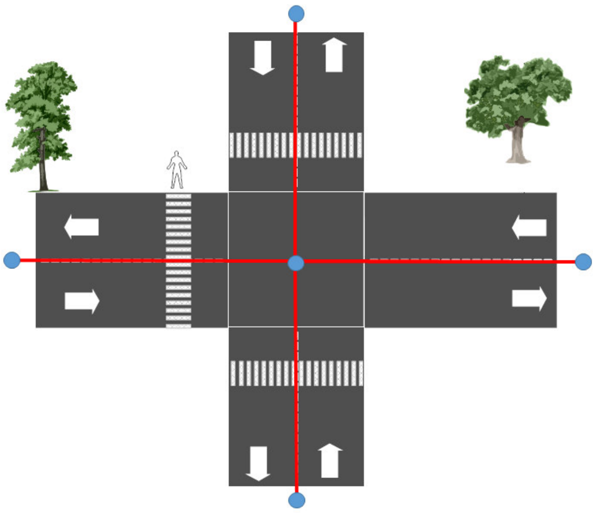
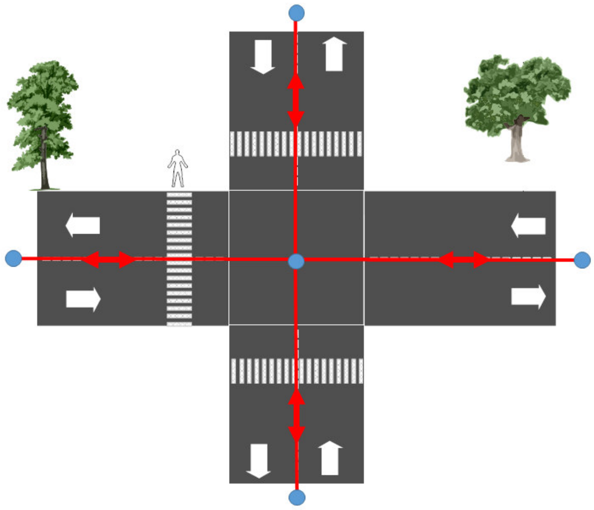
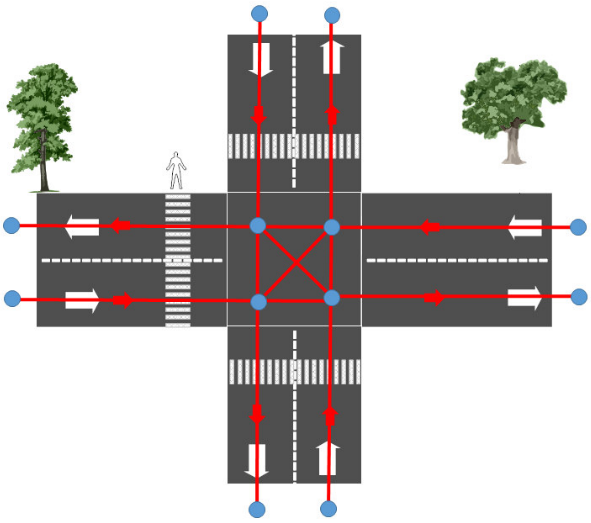


Figure 1. Simple graph representation of the sample junction

In mathematics, a directed graph is a graph in which edges have orientations. In Figure 2. section a) presents a detailed traffic junction information by adding possible traffic directions to the centerlines of the road. The possible driving directions are strictly necessary to run analyses. The number of nodes in the graph does not change compared to the previous version, but the stored matrix is more complex. If the carriageway contains multiple lanes, lane recording is also required for more realistic analysis. As described above, a simple model of the intersection can be implemented as shown in Figure 2 (b). The number of the nodes is increasing since the lane-level registration requires more information for the nodes than providing a simple centerline. This type of logical description of the traffic junction provides sufficient information for many analyses. In the world of simulators, there is a shift towards open source standardized formats. Such a collection of standards is provided by the OpenX standard package.



a) Graph representation by directions



b) Graph representation by lanes

Figure 2. Detailed graph representation of the sample junction

III. The OpenDrive-way for junctions

OpenX standards is a collective term that is used to refer to OpenDRIVE [3], OpenCRG [4] and OpenSCENARIO [5]. These three open-source formats were started to standardize how road data was described and formatted. OpenX began with OpenDRIVE and later evolved to include OpenCRG and OpenSCENARIO to keep pace with industry development. OpenDRIVE was the first open format to prescribe the logical descriptions of roads and road networks in 3D environments. The OpenDRIVE project has been introduced in the market since 2006 as a German company, the VIRES Simulationstechnologie started building visual databases for various driving simulators. Later other big companies joined and the main contributors in designing and developing the standard are Audi Electronics Venture, BMW Group Research and Technology, Daimler, Deutsches Zentrum für Luft- und Raumfahrt, Fraunhofer IVI, Mercedes-Benz Technology, Realtime Technologies, TESIS DYNAware, Technische Universität München, VIRES Simulationstechnologie, VTI – Swedish National Road and Transport Research Institute. OpenDRIVE was managed by VIRES Simulationstechnologie GmbH until November 2018, the assets and maintenance responsibility of OpenX standards were handed over to the Association for Standardization in Automotive and Measuring Systems (ASAM). The OpenDRIVE standard is reviewed and released by a core team of driving simulation experts. Today OpenDRIVE has become an international standard that contains the logical description of the road network. It has an own file format, the OXDR with a hierarchical structure and is available in XML format, which helps the data exchange between different data types. The specified file format contains the precise analytical description of road networks, the main parts are the road segments, the junctions, and the controllers. Roads are described by their centerline. The geometry has three main elements: line, spiral, and arc.

The main purpose of this file format is the use is in simulation applications, which require exact road geometry descriptions, including surface properties, markings, signposting and logical properties such as lane types and directions. Road data may be manually created from road network editors, conversion of map data, or originate from converted scans of real-world roads [6][7][8] [9]. **Hiba! A hivatkozási forrás nem található.** illustrates an example junction created by OpenDRIVE description.

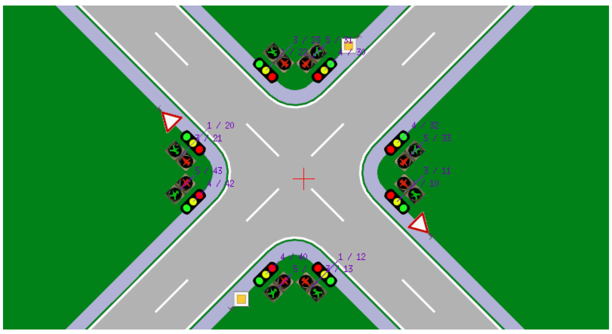


Figure 3. The example junction in OpenDRIVE

In OpenDRIVE format, each road element is described independently. All roads consist of a reference line that defines the basic geometry (arcs, straight lines, and spiral). Along the reference line, various properties of the road can be defined. These are, e.g. elevation profile, lanes, traffic signs. The used layout elements such as reference lines, lanes and other features are illustrated in Figure 4. Roads can be linked to each other either directly when there is only one connection possibility between two given roads. Junctions help to resolve otherwise ambiguous predecessor-successor relationships between the elements when more than one connection is possible from a given road to other roads.

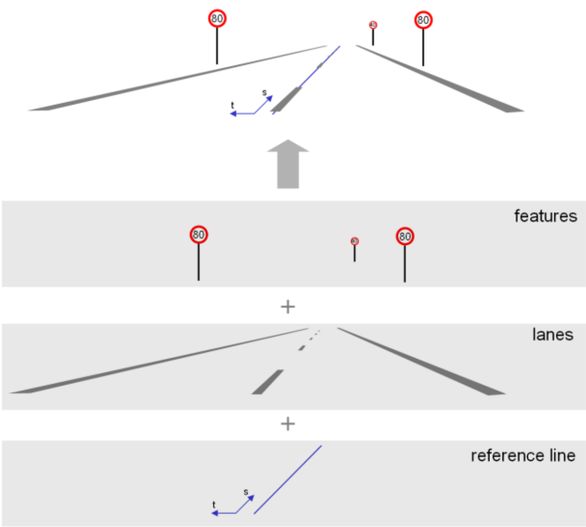
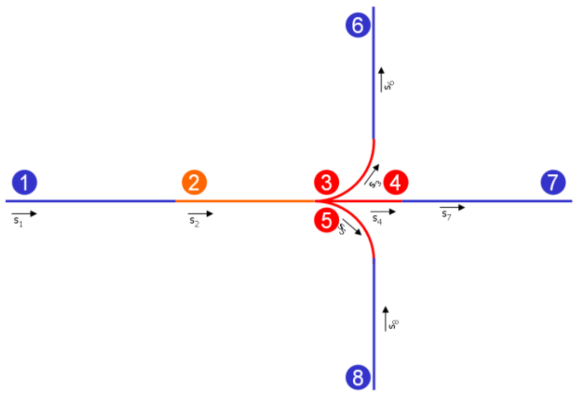


Figure 4. OpenDRIVE layout elements

In order to navigate through a road network, the application must know about the linkage between different roads. Two types of linkage are possible: one is a successor – predecessor linkage or the junctions type. When the linkage between two roads is clear (see Figure 5. road 1 to road 2), a standard linkage information is sufficient. A junction is required when the successor or predecessor relationship of a road is ambiguous. In this case, one of several possibilities must be selected. In the OpenDRIVE standard, the connecting roads could be incoming, outgoing or connecting roads depending on the direction and the number of roads. Figure 5 illustrates some of the possible connections within a junction. The roads No. 3, 4 and 5 are connecting roads. For them, road No. 2 is an incoming road. Roads 6, 7 and 8 are outgoing roads and they could act as incoming roads for other connections.



Road	Predecessor	Successor
1	-	2
2	1	ambiguous
3	2	6
4	2	7
5	2	8
6	3	-
7	4	-
8	-	5

Figure 5. Road linkage in OpenDRIVE

In OpenDRIVE specification, the area of the connecting roads is called the junction area or simple junction (see Figure 6). The basic idea is very simple; the junction links the incoming roads with the outgoing roads. The connecting roads are modeled as roads, so they have reference line with lane sections, etc. (see Figure 7). Junctions consist of a connection matrix which indicates all possibilities to enter a connecting road from a given incoming road. If the traffic junction has U-turn possibilities, it must be modeled as individual connecting roads, in consequence adding one more possibility to the connection matrix. All intended possible connections between roads must be defined via connecting paths; a missing connection means that there is no connection available. In certain situation, several junctions belong to a bigger traffic junction, in this case the traffic rules could be implemented more efficiently, OpenDRIVE standard allows to put junctions into a single group.

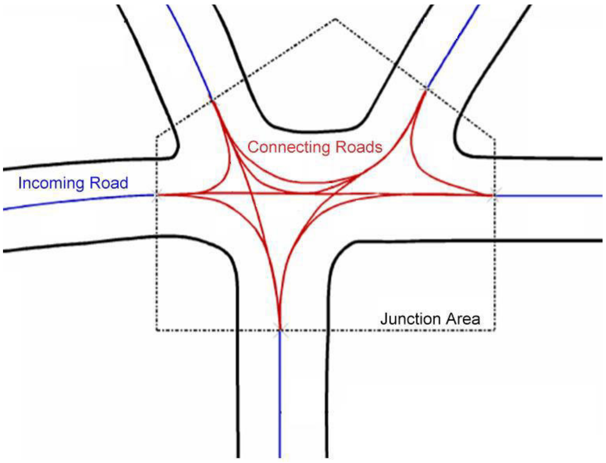


Figure 6. OpenDRIVE junction schema

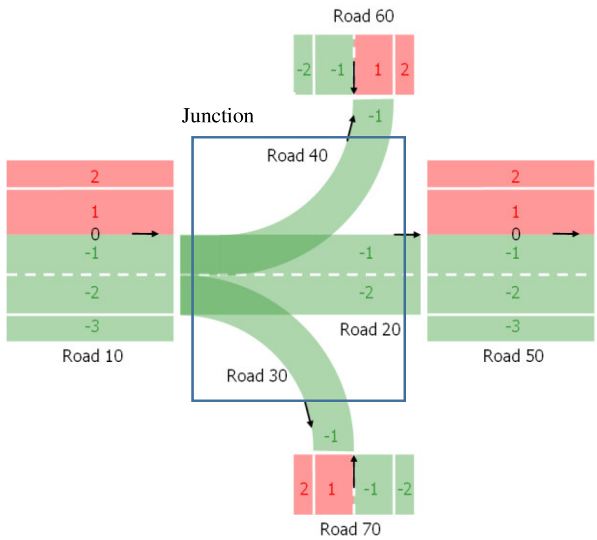


Figure 7. OpenDRIVE road junction model with lanes

Visualization of the OpenDRIVE format data is presented in Figure 8. Detailed information such as lane marking, traffic lights, green vegetation, building, etc. also could be described in a standard way.

Figure 8. Vires, Virtual Test Drive example junction

IV. CONCLUSIONS

The simulation is primary in the vehicular development process as it allows time-efficient testing. In autonomous driving, road network data is a necessity. These simulation applications require exact road geometry description that needs to be created and shared in a common format. The need for Open Standards from autonomous car manufacturers is growing. Having industry-wide standards makes it much easier for manufacturers to test and improve the self-driving vehicles. The consistent logical description of road sections based on the OpenDRIVE format allows the use in different simulators, as this format is supported by almost all automotive simulators. The benefits of standardization of road descriptions are clear, one format for many applications allows the exchangeability of information between various user. The OpenDRIVE standard contains exact descriptors about the road environment (road segments, lanes, lane markings, etc.). The standard allows for creating homogeneous road databases which based on the needs of the industry can be used in heterogeneous simulation environments.

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