

# An Ontology based Map Converter for Intelligent Vehicles

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**Abstract.** Sophisticated digital map is an essential resource for intelligent vehicles to localize and retrieve environment information. However, the open map resource do not contain enough information for decision making during autonomous driving. Although comprehensive commercial map can provide precise map knowledge, the data format is not in a machine-readable format. Therefore, we retrieve useful knowledge from high-precision commercial map and convert it into ontology based data to help intelligent vehicles perceive driving environment and make decisions at various traffic scenarios. Furthermore, the converted map data can be used as a golden standard for evaluating traffic sign detection, road mark detection, and automatic map construction.

**Keywords:** ADAS Ontology, Map Converter, Intelligent Vehicles.

## 1 Introduction

Developing intelligent or autonomous vehicles is beneficial to the society not only for assisting disabled or elderly people, but also for improving safety and transportation efficiency. One of the most challenging problems is to enable intelligent vehicles to drive safely by perceiving driving environments. In order to make intelligent vehicles think as human drivers do, we have to represent environment information in a machine-understandable format. Ontology can be used to represent environment information in a machine-readable format for intelligent vehicles to make safety decisions [3].

Without sophisticated map information, it is impossible to make intelligent vehicles drive safely on urban roads. Current public map data lack detailed map information such as lane information and road signs. Although, precise commercial map data can provide high-precision map information, it is difficult to access knowledge for performing reasoning because of its specific data format. In this paper, we introduce ADAS ontology for autonomous driving tasks and ADAS ontology-based map data, which is automatically constructed by retrieving knowledge from comprehensive commercial map data.



Fig. 1: Map ontology extension for ADAS ontology.

## 2 ADAS Ontology

The TTI core map ontology<sup>5</sup> was introduced to develop a decision making system for intelligent vehicles [2]. The map ontology contains concepts of road networks and relations among the concepts. However, the map ontology cannot cover all the necessary knowledge for safe driving such as traffic signs, road marks, and accurate positions of lanes and intersections. Therefore, we constructed ADAS ontology for autonomous driving tasks by extending the TTI core map ontology. We added additional concepts and properties that are contained in the commercial map data as shown in Fig. 1. The concepts with prefix “map:”<sup>6</sup> indicates imported original TTI core ontology and concepts with “adas:”<sup>7</sup> indicates new knowledge added in ADAS ontology.

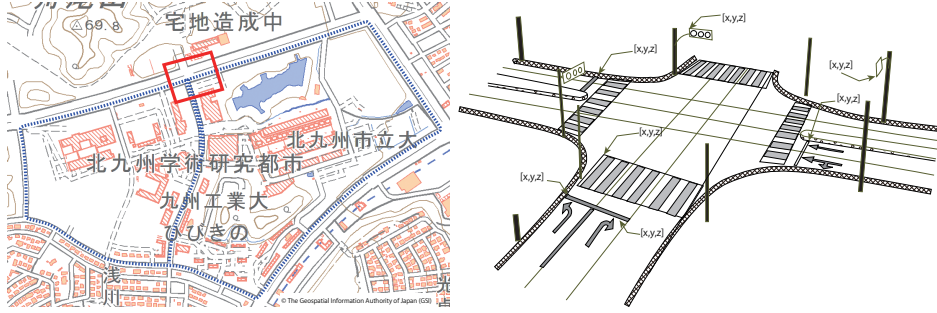
The ADAS ontology contains 93 classes, 21 object properties, and 39 data properties. As shown in Fig. 1a, we added various types of lanes such as AcceleratingLane, DeceleratingLane, LaneExJunction (lanes that exit a junction), and LaneInJunction (branching lane and merging lane inside a junction). Various types of lanes can help intelligent vehicles perceive environment at junctions and choose a proper lane to run safely. StopLine and TrafficSignArrow are also added as the subclass of InstructionSurfaceSign and TrafficSignal, respectively.

Additional object properties (Fig. 1b) and data properties (Fig. 1c) are also added to assign semantic knowledge of map. “entryLane” and “exitLane” are specified for lane connections and “relatedTrafficSign” is used to describe relations between lanes and traffic signs. We added extra data properties (allowLaneChangeLeft and allowLaneChangeRight) to assist lane changing and added identification codes, coordinates, and ids for traffic signs and traffic lights.

<sup>5</sup> <http://www.toyota-ti.ac.jp/Lab/Denshi/COIN/Ontology/TTICore-0.1/>

<sup>6</sup> <http://www.toyota-ti.ac.jp/Lab/Denshi/COIN/Map#>

<sup>7</sup> <http://www.semanticweb.org/example/ontologies/ADAS00#>



(a) Map data area. © 2016 Geospatial Information Authority of Japan (GSI). (b) A schematic illustration of the high precision 3D map for automated driving.

Fig. 2: High precision commercial map.

```

“Header”: {
  “Prefixes”: {
    “map”: “http://www.toyota-ti.ac.jp/Lab/Denshi/COIN/Map#”,
    “adas”: “http://www.semanticweb.org/example/ontologies/ADAS00#” } },
  “Subjects”: [ {
    “Key”: “LaneID”,
    “DefaultType”: “map:Lane”,
    “TypeMap”: {
      “1”: “adas:AcceleratingLane”,
      “2”: “adas:DeceleratingLane” },
    “Properties”: [ {
      “Key”: “SpeedLimitH”,
      “PropertyName”: “map:maxSpeedLimit”,
      “InstanceMap”: {
        “40”: “adas:SpeedLimt40”,
        “100”: “adas:SpeedLimt100”, } } ... ] ] ]

```

Table 1: Structure of JSON for map converter.

### 3 Map Converter

The commercial map data covers the road networks (blue dot line) shown in Fig. 2a, which is around Wakamatsu Campus of Kyushu Institute of Technology in Japan. It’s a part of ZENRIN high-precision map designed in the aim of automated driving and advanced driving assistant systems, provided by ZENRIN Co., Ltd.. The high-precision 3D map data contains lane-level information and precise positions of objects such as traffic signs and traffic lights. Fig. 2b visualizes the 3D high-precision commercial map data (an intersection in red rectangle in Fig. 2a), which we converted for developing decision making systems.

JSON (JavaScript Object Notation) is used to convert the commercial data format into ontology format, which is a text format that facilitates structured data interchange between all programming languages [1]. JSON mainly contains two structures: a collection of <key : value> pairs and an ordered list of values as shown in Table 1. The example of JSON structure shows some part of the mapping concepts from the commercial map data to the ADAS ontology.

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```

<Lane.00001>
adas:fid "00001" ;
rdf:type adas:AcceleratingLane ;
rdf:type map:Lane .
<Lane.00002>
rdf:type adas:DeceleratingLane ;
adas:fid "00002" ;
rdf:type map:Lane .
<Lane.00003>
rdf:type adas:LaneInJunction ;
adas:exitLane <Lane.00004> ;
adas:exitPoint "-26505.5255,58752.8618,58.5555" ;
adas:enterPoint "-26551.1700,58352.6761,55.2657" ;

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Table 2: An example of ADAS ontology based map data.

The map converter implemented using Python converts commercial map data into ADAS ontology-based map data automatically. The converter outputs data in Turtle (Terse RDF Triple Language) format as shown in Table 2. The converted data specifies types of lanes and precise coordinates of enter and exit points of each lane. Lanes in a junction are connected with lanes outside of a junction using the property “adas:exitLane” and “adas:enterLane”.

This map converter retrieves essential parts of the features in commercial map data, that are useful for intelligent vehicles to perceive environment information. This ADAS ontology-based map data will be used to develop collision avoidance, decision making, or adaptive control systems for autonomous vehicles.

## 4 Conclusion and Future Work

We introduced ADAS ontology, which was used to convert precise commercial map data into ontology-based data. JSON was used to interchange commercial map format to ADAS ontology concepts. We will use the ADAS ontology-based precise map data to develop decision making systems, which will use the knowledge of lane connections at junctions, traffic signals, and traffic signs.

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