The Visual Representation and Acquisition of Driving Knowledge for Autonomous Vehicle

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Abstract. In this paper, the driving knowledge base of autonomous vehicle is designed. Based on the driving knowledge modeling system, the driving knowledge of autonomous vehicle is visually acquired, managed, stored, and maintained, which has vital significance for creating the development platform of intelligent decision-making systems of automatic driving expert systems for autonomous vehicle.

1. Introduction

The expert systems have more applied in the field of automobile industry than others. And their development prospect is more optimistic. The technologies which are more mature, including the evaluation of automobiles overall performance, automobiles overall design, automobiles fault diagnosis, vehicle dispatch and so on. [1-5].

The expert systems of automated driving for autonomous vehicles imitate the experienced driver's action to drive. The systems applied in common vehicles which provide advice and dangerous warning to reduce driving workloads make drive easily [6-9]. The systems applied in unmanned vehicles, could simplify the control programs, provide reasonable decision-making schemes and control more easily [10-12]. So studying the methods that acquire, manage, store and maintain driving knowledge for unmanned vehicles has vital significance for creating the development platform of intelligent decision-making systems of automatic driving expert systems for autonomous vehicle.

2. Visual acquisition and representation of driving knowledge

The driving knowledge can be divided into three categories including the traffic rules knowledge, the driving experience knowledge and driving case knowledge. And we do different processing for the three different categories of knowledge. In the driving knowledge base, we build three different kinds of knowledge bases for the three driving knowledge which are traffic rules library, driving experience library and driving case library. In order to model, express and store the knowledge, the project intends to adopt the method combined semantic web with knowledge hypergraph to achieve visualization management, storage, maintenance of the driving knowledge and facilitate the expansion of the knowledge base.
Traffic rules knowledge mainly comes from the traffic laws and regulations. And it mainly includes road traffic safety, road traffic regulations, road traffic accident treatment regulations, motor vehicle driving claims and the use rules, etc. These laws and regulations specify the various rules in effect at the time of vehicles on the road and the matters needing attention. It also uses text language for qualitative description of various traffic rules. And description of the same or similar events has different expression in different legal provisions. Nevertheless, it is a big challenge for today’s unmanned vehicles to understand and identify these terms because of distinct quantitative expressions.

Figure 1 shows extraction process of the traffic rules knowledge. Collect all kinds of traffic laws and regulations in the first place. Then experts analyze these documents to extract the directly related traffic rules for driving, and select the key words that can express these rules by using the brainstorming method. The knowledge of traffic rules is transformed into the traffic rule knowledge model through the knowledge acquisition method of knowledge hypergraph. And it will use the method of concept analysis to define the concept of these words, determining the properties of vocabulary and the scope of words, making its quantitative description of the characteristics, defining the logical relationship between words, carrying on the standardization representation and finally forming the traffic rules formalization.

![Figure 1. Traffic rule knowledge extraction process](image)

The law of the ministry of public security

The original

Data processing

Brainstorming

Define words and logical

Extract the key words

Knowledge of traffic rules text

As the knowledge of traffic rules involves more content, and the results are more complex, but the analysis of different forms will find that they have a certain structural and hierarchical. In order to make full use of the structure of the knowledge unit structure and the hierarchical structure of the knowledge unit model, the system carries on the visualization way to the knowledge modeling. The basic process of multidimensional knowledge hypergraph visual modeling mainly includes the following two parts.

- Knowledge unit division
  The problem is first divided into many sub-problems, and then those sub-problems continue to subdivide until you can solve or facilitate the solution so far. With the refinement of the problem, the corresponding knowledge domain is also constantly subdivided to form knowledge units at all levels. Through the framework of the knowledge unit to describe step by step, the formation of the problem by layer decomposition.

- Knowledge unit model integration
  Only through the loop, control, description, modeling assignments and other basic units to establish broad statement mapping between the evidence and the target, and there is no call other unit mode, the established knowledge unit mode is defined as the basics of unit mode. The higher-level knowledge unit model established by the basic unit model is combined with the basic knowledge unit model. The knowledge model combining the two-level knowledge unit model is defined as the three-level knowledge unit Model, and so on, for the entire knowledge base to form a multi-level knowledge unit model composed of a variety of knowledge models.
Production rules knowledge as a basic knowledge of unit cell pattern mode, part of, kind of, instance of, attribute of four kinds of basic knowledge integration relations and achieve integration with the integrated knowledge of rules of thumb, model knowledge and knowledge of the case.

After the knowledge unit is divided, the knowledge unit model is integrated from the bottom through the guidance of the framework knowledge unit, and finally the various multi-level knowledge models needed by the users will be built. The integration process of the multi-level knowledge unit is done by the visualization of the visualization. Therefore, after the completion of multi-level knowledge model will also form a comprehensive knowledge base on the knowledge of hypergraph.

After the decomposition of knowledge unit, the integration of knowledge unit model and the integration and sharing of multi-knowledge, the process of knowledge unit editing and knowledge modeling is completed. Finally, it will realize the orderly and complex knowledge of knowledge service from quantitative calculation to qualitative reasoning effective and useful.

It has difficulties in modeling, expressing and storing if we use a single method in that the diversity of driving knowledge and the structure is complex. After analyzing the advantages and disadvantages of existing methods, the project intends to use the method combined semantic web with knowledge hypergraph to build the knowledge base of the unmanned vehicle.

The hypergraph can effectively model the multiple relationships of knowledge, express hierarchies and nonhierarchical structural relationships. The knowledge we got has different forms and hierarchies, and building the hypergraph model can model these knowledge. But there are some shortcomings in hypergraph such as difficult to store and retrieve.

The semantic web is simple, open and easy to expand, exchange and synthesize. And it contains a standard language that describes the relationship between knowledge and their relationship. Using the semantic web to express and store the knowledge base can be maintained and extended. But due to the development of the semantic web is based on the graph theory, its modeling capabilities are limited compared to the hypergraph. If we combine the two together, we can combine strengthen of the two methods to avoid shortcomings, allowing for more efficient modeling, expression and storage of the driving knowledge. Figure 2 shows the process of building a knowledge base.

![Figure 2. The build process of the construction of the knowledge base](image)

The architecture of the proposed unmanned vehicle knowledge base is shown in Figure 3.

![Figure 3. The unmanned vehicle knowledge base architecture](image)
- **Knowledge integration layer**
  
  The knowledge integration layer is the core of the entire framework which combined the semantic web and hypergraph. We can realize knowledge sharing, reuse and innovation through knowledge integration, and make the knowledge can be automatically analyzed, understood, and processed by computer.

- **Knowledge application layer**
  
  Knowledge application layer supports the application of the unmanned vehicle and it also can provide all kinds of knowledge base required including the traffic rules library, driving experience library and driving case library.

### 3. The knowledge acquisition case

#### 3.1. The extraction of knowledge

China’s modern road traffic signs are divided between the main signs and the auxiliary signs, and there are 100 kinds of road traffic signs.

#### 3.1.1. Main signs.

The main signs can be divided into the following four kinds:

- **Warning signs**: the signs are used to warn vehicles and people pay attention to dangerous place and there are 23 kinds of it. The shape of the signs is an equilateral triangle vertex angle, and its color is yellow, black and black pattern.

- **Ban signs**: it is used to ban or restrict the traffic behavior of vehicles and pedestrians, and there are 35 kinds of it. Its shape is divided into road and equilateral triangle vertex angle downward. And its color is white and red circle, black design and pattern bar, except for individual signs.

- **Indication signs**: its shape is divided into circles, rectangles and squares, and it is used to indicate the pedestrians and vehicles to get started. And there are 23 kinds of it.

- **Direction signs**: there are 20 kinds of it. And this is a sign of direction of the road, location and distance information. It is shaped by a rectangle and a square, except for the spot identification mark. And its color besides the milestone, one hundred meters of pile and the road boundary monument, the general road is the blue bottom and white design, while the highway is the green and white pattern.

#### 3.1.2. Auxiliary signs.

The auxiliary signs have five kinds of symbols, which are attached to the main sign and the role of it is to assist. And the auxiliary signs cannot be used and set up alone. Auxiliary signs according to their use are divided into the representation of time, the representation of the vehicle types, the representation of regional distance, the representation of warnings and ban reason of auxiliary sign as well as several kinds of composite auxiliary sign. Its shape is rectangular, and the color is white, black and black border. In addition, there is a kind of traffic information signs can change. It displays Information in a timely manner to the vehicle’s drivers and pedestrians.

#### 3.1.3. The geometry of a traffic sign and its meaning.

In the case of the same size, the order is: the triangle, the diamond, square, regular pentagons, the hexagon, the circular and the octagon when the effect is good and it is easy to recognize. In the draft of the international security and safety standards, the regular triangle indicates a warning, a circular representation forbids and limits, and squares and rectangles are indicated. If the circular pattern has a slash, it is also forbidden.

#### 3.1.4. The types of traffic line markings.

Road traffic line can be divided into vertical lines, horizontal lines and other traffic safety lines. It has seven kinds of twenty-one species, including seventeen of them, and the rest are other traffic safety facilities. Roadway centerline, center dotted lines, solid, single center double solid line and the actual line belong to a vertical line. And the parking line, the deceleration and the crosswalk are horizontal lines.
3.2. Vocabulary, rule and knowledge meta

According to traffic rules, laws and regulations above, related vocabulary is defined, the properties and scope of the vocabulary is determined and the logical relationship between the words is defined in order to standardize them to represent the traffic rules.

After the vocabulary is defined as Figure 4, the rule is defined as Figure 5 and knowledge meta reference rule such as Figure 6.

The vocabulary unit, the rule unit and the knowledge meta form a complete hypergraph model.

Figure 4. Vocabulary definition

Figure 5. Regular expression

Figure 6. Knowledge super-element reference

3.3. Hypergraph knowledge base

Driving knowledge base of unmanned vehicles is established through our research and development of knowledge visualization modelling system. Firstly, we categorize driving knowledge into several sub-task, then determine the relationship of each sub-task, express the form of each sub-task node, and establish a corresponding relationship to form the hypergraph knowledge base.

Figure 7 is an example of hypergraph knowledge base of traffic behaviour.
Traffic behaviour can be two large tasks. And they are basic traffic behaviour and advanced traffic behaviour. They can also be subdivided into the following sub-task.

- Start
- The right side of passage
- Detecting point
- Lane point
- The speed limitation
- Abnormal parking
- Avoiding collision
- Safe distance

The advanced traffic behaviours include: 1. Traffic signs and traffic signs lines. 2. The recognition of traffic police commands and traffic police command--hand signals and other traffic command signals of using tools. 3. Lane changing. 4. Returning to the original lane. 5. U-turn. 6. Automobile meeting. 7. Autonomous parking, parking in the parking lot and roadside. 8. Dynamic path planning. 9. The degradation of GPS signals: inertial navigation. 10. Emergency braking. 11. Auditory cognitive. 12. Giving way to people. 13. Using the lights. 14. Traffic of intersection. 15. Turning. 16. Driving around the islands. 17. Traffic of overpasses. 18. Traffic of railways. 19. Overpasses and railways. 20. Overflow road. 21. Integrating into the traffic flow, etc.

![Figure 7. The hypergraph knowledge base of the traffic behaviour](image_url)

4. Conclusion
According to the basic and common driving behaviors of the vehicle, the driving knowledge base of expert system for the vehicle automatic operation is established. Especially we can also use the method combined semantic web with knowledge hypergraph to achieve visualization management, storage, maintenance of the driving knowledge and facilitate the expansion of the knowledge base. After gradually improving the knowledge base, the expert system platform of automatic driving of unmanned vehicles will be finished.

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