Researches on Expert System for Automatic Driving Traffic Rules of Unmanned Vehicle

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Abstract. The automatic driving expert system of unmanned vehicles is one of the research hotspots in the field of automatic driving for unmanned vehicles. An expert system is introduced to the knowledge management of traffic laws and regulations for autonomous driving of unmanned vehicles. The traffic knowledge base for unmanned vehicle is designed and established. According to the knowledge representation, fusion and sharing technology based on semantic knowledge hypergraphs, the visual knowledge modelling and visual knowledge reasoning system is developed. The visual acquisition, management, storage, maintenance and multi-level master-slave reasoning mechanism for autonomous driving traffic laws and regulations of unmanned vehicles are realized. The effectiveness of the system is proved by the application example. And it is of great significance to build an intelligent decision system development platform for automatic driving of unmanned vehicles.

1. Introduction

In the late 1960s, the expert system has been an active branch of artificial intelligence. An expert system is defined as: a knowledge and reasoning process is used to solve intelligent programs that require outstanding professionals to solve. The knowledge necessary to solve the problem at this level, coupled with the reasoning process, can be considered to be a simulation of the level of experts engaged in the field. On the other hand, the expert system can reason and analyze the complex problem of human natural language description and solve it.

In the automotive industry, it is necessary to combine the accumulated experience knowledge and the necessary theory to solve the actual problems. Therefore, the expert system can be well applied in the automotive industry.

The research of expert system in the automotive industry began in the late 1970s. The United States, Japan, Germany and other countries have conducted research and development works in this area. The areas involved mainly include automotive CAD intelligent design [1], automotive fault diagnosis [2], vehicle performance prediction [3], and so on. Although China's research in expert systems started relatively late, since the early 1980s, the development of expert systems in the automotive industry has been started. Tsinghua University [4], Huazhong University of Science and Technology [5], and Tongji University have successively conducted research and development of automobile expert system.

The typical automotive industry expert systems developed abroad are as follows: American General Motors has developed the engine cooling system noise identification and diagnosis expert
system. Japanese Toyota Motors has developed the automotive fault diagnosis system. M.L. Smith has developed the automotive emergency brake balance system for Eaton Company. German Volkswagen has used the knowledge-based intelligent design software VMLAYOUR for the design of automotives. American Ford Motor Company adopts PDGS system with PRIME as hardware platform, and uses ADMS and other special design software packages for product design and kinematic analysis [6-9].

The typical automotive industry expert systems developed in China are as follows: Tsinghua University has developed the automotive transportation planning and dispatching system. Huazhong University of Science and Technology has developed the vehicle driving transmission scheme selection expert system and components CAD system. Xi’an Jiaotong University has developed the gear transmission design expert system. Tongji University has developed the automotive overall layout expert system. And so on. At the same time, the development tools of the expert system are also developed. The more successful development tools include the RETRIEVER developed by Shanghai University of Technology and the MES developed by Jilin University [10-13].

Expert system for unmanned vehicle driving is an imitation of an experienced driver. It is convenient for driver to provide driving advice and danger warning to reduce the drivers’ workload. Applied to unmanned vehicles, it can simplify the control procedures of unmanned vehicles, provide reasonable decision-making solutions, and make it easier to achieve precise control.

When the driver is driving, he gets information from the outside to his brain through the eyes, ears, and other parts of the body. The brain thinks about this information and makes decisions, then gives orders to hands and feet to drive the vehicle. This allows the vehicle to drive in the direction provided by the orders. There is also a process, that is, after receiving information from the outside world, the brain directly gives hands and feet the reflexive action instructions for information without analysis and judgment. In the driving process, the above two modes are mixed and alternated. Inexperienced drivers do not need to explicitly think about most external information, or just think about judgments subconsciously. They will promptly issue orders and habitually make reflections.

In the driver-vehicle closed-loop system, the control behaviour of the driver is a comprehensive reaction of the driver to the manipulation of the vehicle under the influence of the road traffic environment information, the vehicle’s own movement state information, the traffic regulation information, and the control of vehicle system under the influence of physiological and psychological factors of the driver himself. Therefore, the expert system is introduced to the knowledge management of traffic laws and regulations for driving unmanned vehicle. The traffic laws and regulations knowledge base for unmanned vehicle is designed and established. The standardized representation, fusion and sharing of many kinds of knowledge, such as decision model and rule, are studied. The visual knowledge modelling system is developed. The visualization acquisition, management, storage, maintenance and multi-level master-slave reasoning mechanism for unmanned vehicle driving traffic laws and regulations knowledge are realized. They are used to build an intelligent decision system development platform for automatic driving expert system of unmanned vehicle. They have great application potential in improving road capacity and improving vehicle active safety.

2. Traffic Rules Knowledge Acquisition
Traffic rules are mainly derived from traffic laws and regulations, mainly including: Road Traffic Safety Law, Road Traffic Management Ordinance, Road Traffic Accident Regulations, Motor Vehicle Driver’s License Claim and Use Regulations, and so on. These laws and regulations stipulate the various rules and precautions when the vehicle runs on the road. These laws and regulations all use the text language to describe the various traffic rules qualitatively; and in different legal provisions, there are different degrees of expression for describing the same or similar events. Due to the lake of well-defined quantitative expression, the understanding and recognition of these terms expression is undoubtedly a great challenge for the existing level of unmanned vehicle.

Figure 1 shows the extraction process of traffic rules knowledge. First, various traffic laws and regulations are collected and collated. Then the brainstorming method is used to analyze these documents by relevant experts. The core traffic rules, which are directly related to vehicle driving, are extracted. And the key vocabularies that can express these rules are abstracted. Use the method of
conceptual analysis; define the concept of these vocabularies; determine the attributes of these vocabularies; assign the values to these vocabularies; determine the range of values of these vocabularies to make them characterized by the quantitative description; define the logical relationship between vocabularies; and standardize these vocabularies to form the formal description of traffic rules [14].

![Figure 1. Traffic rules knowledge extraction process.](image1)

3. Knowledge Representations of Traffic Rules

The formalized modelling, expression and storage of acquired traffic rules knowledge is an important basis for decision-making reasoning. It is also the core task of constructing the knowledge base of unmanned vehicle driving traffic regulations. Constructing the knowledge base needs to meet: knowledge is easy to express and storage; knowledge is easy to search and retrieve; knowledge is easy to maintain and has good extendibility; visual knowledge management can be realized. It is difficult to achieve fine modelling, expression and storage by using a single method due to the variety of driving knowledge and complex structure. After analyzing the advantages and disadvantages of the existing methods, this project adopts the method of combining semantic web and knowledge hypergraph, namely, semantic hypergraph to construct unmanned vehicle driving knowledge base.

Hypergraphs are generalized in a topological structure by a common graph. They can effectively model the multiple relations of knowledge, express the hierarchical and non-hierarchical structure, and describe the most general discrete structure relationship. The knowledge of traffic rules, the knowledge of human driving experience and the knowledge of driving case have different forms and hierarchies. This acquired knowledge is modelled using the method of building a hypergraph model. However, hypergraph is difficult to store and retrieve. The semantic web contains a standard language that describes knowledge and the relationship between them. It is simple, openness, easy to expand exchange and integrate. Using it to express and store the knowledge base can realize the maintenance and expansion of knowledge. But the semantic web is developed on the basis of graph theory. Compared with the hypergraph, its modelling ability is limited. The combination of the two methods can integrate the strengths of both and avoid their respective shortcomings. Thus it is more effective to model, express and store unmanned driving knowledge. Figure 2 gives the construction process of the unmanned driving knowledge base.

![Figure 2. Unmanned vehicle driving traffic regulations knowledge base construction process.](image2)
The architecture of the proposed semantic hypergraph based knowledge base for unmanned vehicle driving traffic regulations is shown in figure 3.

![Figure 3. Unmanned vehicle driving knowledge base architecture.](image)

(1) Knowledge integration layer
The knowledge integration layer is the core of the whole framework. The method of combining semantic web with knowledge hypergraph, that is, semantic hypergraph is realized. Through the transformation of data, the modelling and expression of knowledge, the purpose of knowledge integration is achieved. The sharing, reuse and innovation of knowledge can be realized. The knowledge can be automatically analyzed, understood and processed by computer.

(2) Knowledge application layer
The knowledge application layer is a specific application for unmanned vehicles. The various repositories that they need, including the traffic rules, can be provided.

4. Knowledge Reasoning
Traditional rule-based reasoning has a very low reasoning efficiency when the rule base is too large. And it is difficult to realize incremental learning of knowledge. The reasoning mechanism of knowledge hypergraph can realize the stratification and classification management of knowledge base and improve the reasoning efficiency.

4.1. Reasoning Process of Knowledge Hypergraph Numbering
The search process of knowledge hypergraph embodies the basic idea of solving the problem by human experts: The original problem is decomposed into a number of smaller sub-problems. The sub-problem is then subdivided into a number of smaller sub-problems. This process is recursively done. Until the sub-problem is small enough, it can be solved directly. Finally, the solution of the original is obtained by combining all the solutions of the sub-problems.

![Figure 4. Frame unit tree.](image)
The frame unit tree is shown in figure 4. The complex problem “frame unit 0” is divided hierarchically into three layers of frame unit nodes “frame unit 1” to “frame unit 12” by dividing the problems. Each frame unit references a knowledge unit. Therefore, the frame unit tree can be transformed into a knowledge unit tree for reasoning and solving, as shown in figure 5.

![Knowledge unit tree](image)

**Figure 5.** Knowledge unit tree.

The directed line segment in the knowledge unit tree corresponds to the frame unit tree, but in the opposite direction. It is used to describe the solution dependency between the knowledge units. The knowledge set of the knowledge unit is defined within the node of the tree. Each knowledge unit corresponds to a specific goal or condition. The solution of a solving target depends on several other conditions and other knowledge units. If a certain knowledge unit can be solved without other conditions, it can be considered that such a knowledge unit is a terminal knowledge unit. If the solution of a knowledge unit is also dependent on other knowledge units, it can be considered that such a knowledge unit is actually an intermediate knowledge unit. At the same time, a number of knowledge units can also be used for a solution of the intermediate knowledge unit or terminal knowledge unit.

Figure 5 also shows the reasoning process of the knowledge unit. Through this digraph, the final rule knowledge unit “knowledge unit 0” is solved by “knowledge unit 1”, “knowledge unit 2” and “knowledge unit 3”. To obtain the value of “knowledge unit 1”, it is necessary to know the value of “knowledge unit 4”, “knowledge unit 5” and “knowledge unit 6”. Finally, the solution of “knowledge unit 0” is transformed into the solution of “knowledge 4”, “knowledge unit 6”, “knowledge unit 8”, “knowledge unit 9”, “knowledge unit 10”, “knowledge unit 11” and “knowledge unit 12”. In the end, if we want to know the value of “knowledge unit 0”, the system will turn to the knowledge unit tree for reverse reasoning, find the set of the knowledge units that must be known for the solution process, and prompt users to input the corresponding computing prerequisites of these knowledge units. As to how to solve the terminal knowledge unit and the intermediate knowledge unit by the user given these prerequisites and finally solve “knowledge unit 0”, this depends on what kind of content the experts have assigned to these knowledge units in the knowledge acquisition phase, namely “knowledge set”. These contents are often a variety of knowledge forms such as reasoning rules, calculation expressions, external links, and so on.

The following figure 6 is an unmanned automatic driving knowledge model.
5. Knowledge Hypergraph Examples

The expert system of automatic driving traffic rules of unmanned vehicle adopts a general J2EE three layer structure. The interface presentation layer uses the JSP label technology and the Extjs component to express the interface elements. The business logic part uses EJB3.0 technology to encapsulate the business logic. With different functional modules as units, they are encapsulated into EBJ components. The components can be freely combined. The data layer uses Hibernate + spring to perform data manipulation access to Oracle.

The following is an example of the construction of a traffic rule knowledge hypergraph. A detailed description of the system’s management functions such as knowledge acquisition, knowledge modelling and knowledge reasoning is described in detail.

5.1. Knowledge Hypergraph Construction Example

Step 1: Determine the specific task. Determine what sub-task each task contains. And create a new hypergraph. Express the tasks and sub-tasks in the form of nodes. And establish the corresponding relationship that is connected. And form a knowledge hypergraph. For example, the basic traffic behaviour can be divided into sub-tasks: start, shift, vehicle safety distance, speed control, straight-line traffic, and traffic on the right. And sub-tasks can be subdivided into smaller sub-tasks. As shown in figure 7.
Figure 7. Example of hypergraph: vehicle driving knowledge base.

Step 2: Determine what solving problems each sub-task has. For example, the vehicle safety distance of a sub-task requires the vehicle to know the speed of the current vehicle and the preceding vehicle, and to determine which safety distance level belongs to the vehicle and how far the vehicle will be kept.

Step 3: Add the rules. As shown in figure 8. This rule is to determine the safe distance from the preceding vehicle based on the current speed of the vehicle. The safety distance is divided into several safety levels according to the speed of the vehicle. And then the specific safety level is judged by calling the matching rules according to the actual speed.

Figure 8. Rule unit editing interface.

Step 4: Create new knowledge super meta, and reference the corresponding rules. For example, the super meta name is engine starts. And the rule of the same name is referenced. After being referenced, the super meta establishes a calling relationship with the rule. When the system is reasoning the super meta, the corresponding rule is enabled. As shown in figure 9.

Figure 9. Knowledge super meta editing interface.
Step 5: Reference the corresponding knowledge super meta to each task and sub-task.
Step 6: The preliminary hypergraph is built, the hypergraph is preserved, the knowledge is compiled and passed, and the knowledge reasoning is carried out.

5.2. Reasoning Examples
Step 1: Open the knowledge base of the unmanned vehicle driving knowledge base, enter the reasoning interface, load the vehicle driving knowledge base hypergraph and start the reasoning. As shown in figure 10.

![Figure 10](image10.png)
Figure 10. Choose the reasoning hypergraph.

Step 2: Choose the problem in the knowledge hypergraph of the unmanned vehicle to be reasoning, such as: test vehicle safety distance. As shown in figure 11.

![Figure 11](image11.png)
Figure 11. Choose the reasoning problem.

Step 3: Carry out human-computer interaction reasoning. Input the fact parameters according to the specific problems to be solved. And then carry out the reasoning. For example, input data: current speed. As shown in figure 12.
Following distance is 25 meters.

**Figure 12.** Human-computer interface reasoning.

Step 4: Visualize the output reasoning results, and also view the reasoning log. For example: output the current distance to keep the vehicle safe. As shown in figure 13.

**Figure 13.** Reasoning result.

6. Conclusions
This paper is based on the thinking of modularization of knowledge engineering. An expert system for driving traffic regulations for unmanned vehicles is constructed. The method based on semantic network and knowledge hypergraph is used to model, express and store this knowledge. The visualization management, storage and maintenance of unmanned vehicle driving traffic regulations are realized. At the same time, it is easy to expand the knowledge base.

In the knowledge reasoning system, a multi-reasoning mechanism collaborative reasoning method based on knowledge hypergraph is used. It can simulate the input of the unmanned vehicle perception system and convert it into reasonable and effective decision information. The results can guide the safe and reliable operation of the unmanned vehicle control system.

There are still some details on the system at present. The follow-up research will continue to improve. It is expected to provide more swift orders to the unmanned vehicle control system.

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