AI-based High-Level Decision Making in Highway Autonomous Driving

JIACHEN GONG

Technische Universität München

SUMMER SCHOOL 2023

ai.uni-jena.de

INTRODUCTION

Modern advances in data science have enabled the practical application of artificial intelligence (AI), especially in automated systems such as vehicles. These advances have brought many benefits to various fields. However, the complexity of dynamic situation management in self-driving vehicles exposes the limitations of traditional mobile robot planning. When self-driving vehicles interact with humans, whether as shared road users or full-scale transportation, they must consider social norms, legal consequences, and potential risks to health and life. Artificial intelligence algorithms in self-driving cars have evolved with perception, planning, and control as separate components. Control usually involves approximate reasoning, while perception relies heavily on learning algorithms. Decision making in autonomous systems is moving towards taking more responsibility. Decision-making levels for self-driving cars are standardized by the SAE, where levels 0 to 2 remain under the control of the driver, and levels 3 to 5 are monitored by the system, possibly overriding the driver entirely at level 5. Higher levels of autonomy rely on low-level path planning, as well as higher-level decisions based on reasoning and learning. The aim of this study is to investigate existing algorithms used in the field of artificial intelligence for self-driving cars, with a special focus on their application in highway driving scenarios. Self-driving cars require advanced decision-making capabilities to effectively perceive and react to their surroundings. The research focuses on individual, collective and cooperative decision making in highway driving scenarios. Considering the structure and constraints of the driving scenario, this study compares the advantages and limitations of the described approaches. In addition, the study raises some open questions to stimulate further exploration and development of decision-making systems for next-generation self-driving vehicles.

THE HIGH-LEVEL DECISION MAKING CONSIDERATIONS FOR HIGHWAY DRIVING

- **Arcgitecture**

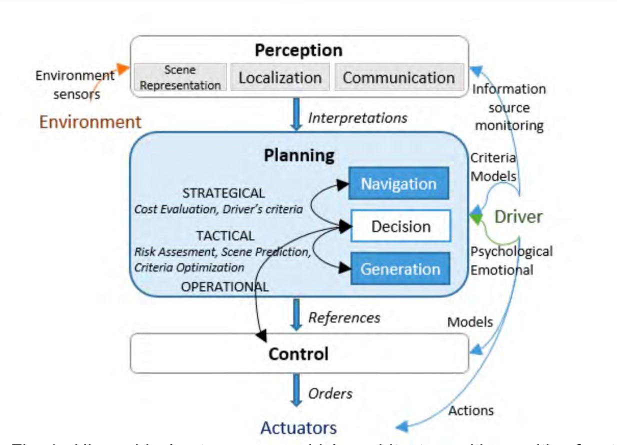

Fig. 1 : Hierarchical autonomous vehicle architecture with cognitive functions and driver models [1].

- **Situation during a highway trip**

a. Lane following
b. Car following
c. Lane changing
d. Passing
e. Overtaking
f. Merging
g. Highway toll

AI-based high-level decision-makers algorithms

In this section, we focus on the main contributions of AI- based algorithms to high-level decision making for autonomous vehicles. The AI domain is classified depending on the uses and applications it targets. In the context of this study, four families of reasoning can be applied to the decision mechanism: (i) Boolean, (ii) heuristic, (iii) approximate logic, and (iv) cognitive. Moreover, we identify three techniques for decision making: the individual, the collective, and the driver cooperative decisions.

A. knowledge-based inference engines

One approach to decision-making in self-driving cars is to use knowledge-based reasoning engines, such as rule-based reasoning algorithms (expert systems) and finite state machines (FSMs). These systems use deductive reasoning and state transitions triggered by environmental changes. However, it also contains some drawbacks: acquisition and maintenance of knowledge base, generation of experts, discretization of variables and limited decision margin. When under uncertainty, dynamic Bayesian networks based on probabilistic states and transitions are generally used.

B. Heuristic algorithmus

Heuristic algorithms provide efficient solutions to optimization problems by finding approximate or partial solutions. They are faster and less computationally intensive than exhaustive methods and are therefore suitable for complex problems. However, the partial solutions provided by heuristic algorithms may not guarantee global optimality. These methods are usually applied to intelligent autonomous agents that adapt to their environment and exhibit rational and social behavior. It also includes learning methods such as Support Vector Machines (SVMs) and evolutionary algorithms that enhance the decision-making process by combining information search and mimicking the natural evolutionary process.

C. Approximate reasoning

Approximate reasoning methods utilize fuzzy logic, unlike traditional Boolean logic. They provide approximate solutions by assigning truth values with approximate dimensions. These algorithms excel at handling complex problems due to their wide range of values. The key advantage of approximate reasoning in decision making is its flexibility and adaptability to uncertain data and rules. Artificial neural networks and belief networks are examples of approximate reasoning algorithms that can learn without expert input. However, there are challenges in ensuring correct learning and adapting to different road and infrastructure conditions across countries. These methods require large amounts of labeled data to improve accuracy and struggle with isolated use cases.

Promising research is being conducted in deep learning methods to process data at different scales and levels of granularity for better understanding and decision-making.

D. Human like decision making methods

Humanoid decision-making systems aim to replicate human reasoning by integrating cognitive aspects. These intelligent systems possess knowledge of environmental rules and can handle complex situations. They use universal but challenging abstract representations. The risk function model is a decision model adapted to environmental predictions and is widely used in humanoid decision making. Taxonomic models focus on sequential relationships and measures related to driving tasks, considering behavioral and ability requirements. The learning approach is inspired by interaction models in game theory, where players observe each other's behavior and react strategically.

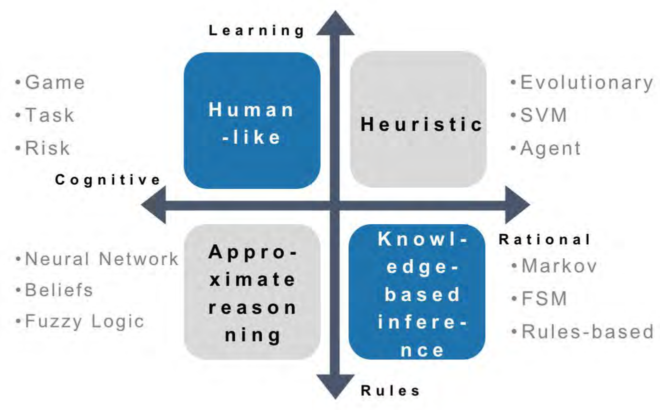

Fig. 2 : A map of AI-based high-level decision-makers algorithms.:

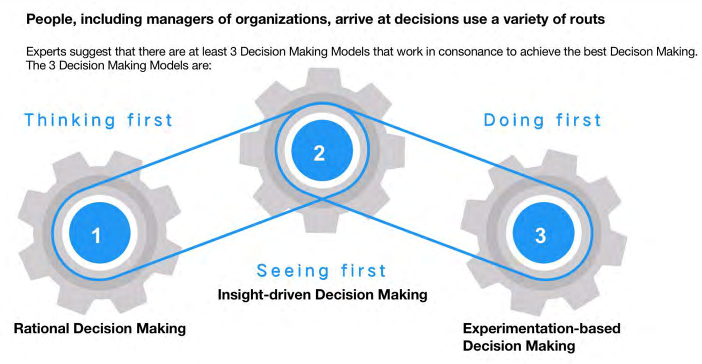

Fig. 3 : Human Decision Making process

DISCUSSION

The use of AI-based approaches for high-level decision making in self-driving cars has been relatively successful, but there are still important R&D challenges that require careful consideration. These include the quality and reliability of data in the perception and control phases, adaptation to non-ideal environments, ethical considerations, relaxation of rules in different scenarios, and integration of multimodal transportation services. The architecture of autonomous systems plays a crucial role in decision making, as the quality of perception and control directly affects the ability of decision makers to make the right choices. Mimicking human behavior and reasoning in robotic systems is challenging due to differences in perception and reasoning capabilities. In addition, the ethical implications of decision-making in automated systems need to be considered, as the interpretation of decisions made by AI algorithms can be complex. For AI, understanding how human drivers navigate and sometimes deviate from the rules of the road is critical to ensuring the safety of self-driving cars. Future transportation systems are likely to be multimodal, with vehicles providing a variety of services, which increases the complexity of the decision-making process. Not only that, but it is also critical to consider factors such as where, when and how vehicles travel, especially when certain vehicles (e.g., emergency vehicles) need to be prioritized on the road. The following table lists the performance of the different algorithms.

TABLE I. A COMPARAISON OF AI-BASED METHODS ADAPTABILITY TO REAL APPLICATIONS CONSTRAINTS

Methods		*Constraints Agreement*					
Class		*Multiple-objectives*	*Real-Time*	*Environment evolution*	*Traffic rules*	*Leeway*	*Stability*
Knowledge-based inference engines	Rules	+	++	-	+++	---	+++
	FSM	--	+++	-	++	--	+++
	Markov	+	++	+	++	+	++
Heuristic	Agent	++	+	++	++	++	+
	SVM	+	++	+++	++	+	++
	Evolutionary	++	-	+++	+	++	-
Approximate reasoning	Fuzzy	++	++	++	++	+++	+
	Neural Network	++	+	+	+	++	--
	Belief	++	+	++	+	++	-
Human-like	Risk	-	++	++	+++	-	+
	Task	+	+	+	+++	-	++
	Game	+++	+	++	++	+	++

CONCLUSIONS

Artificial Intelligence methods have been widely used in research on self-driving cars, especially in perception, control and high-level decision making. These methods are adaptable to environmental constraints and future transportation trends. However, there are important challenges that must be addressed before widespread implementation of autonomous driving in everyday vehicles. Issues related to safety, security, reliability and ethics need to be carefully addressed and resolved in order to ensure the success and acceptance of autonomous driving in real-world scenarios.

REFERENCE

[1] Laurène Claussmann, Marc Revilloud, Sébastien Glaser, Dominique Gruyer, “A Study on AI-based Approaches for High-Level Decision Making in Highway Autonomous Driving,” ,IEEE International Conference on Systems, Man, and Cybernetics (SMC) Banff Center, Banff, Canada, October pp. 5-8, 2017.

ACKNOWLEDGEMENT

I would like to express my sincere thanks to the authors of the articles mentioned in the references for enlightening me on the application of artificial intelligence in the field of autonomous driving. I also want to express my thanks to “ai.uni-jena,de” for giving me the chance to learn something about AI.