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A Hardware Platform Framework for an Intelligent Vehicle Based on a Driving Brain

Deyi Li [a], Hongbo Gao [b,c,*]

[a] Department of Computer Science and Technology, Tsinghua University, Beijing 100084, China
[b] State Key Laboratory of Automotive Safety and Energy, Tsinghua University, Beijing 100084, China
[c] Center for Intelligent Connected Vehicles and Transportation, Tsinghua University, Beijing 100084, China

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ABSTRACT

The type, model, quantity, and location of sensors installed on the intelligent vehicle test platform are different, resulting in different sensor information processing modules. The driving map used in intelligent vehicle test platform has no uniform standard, which leads to different granularity of driving map information. The sensor information processing module is directly associated with the driving map information and decision-making module, which leads to the interface of intelligent driving system software module has no uniform standard. Based on the software and hardware architecture of intelligent vehicle, the sensor information and driving map information are processed by using the formal language of driving cognition to form a driving situation graph cluster and output to a decision-making module, and the output result of the decision-making module is shown as a cognitive arrow cluster, so that the whole process of intelligent driving from perception to decision-making is completed. The formalization of driving cognition reduces the influence of sensor type, model, quantity, and location on the whole software architecture, which makes the software architecture portable on different intelligent driving hardware platforms.

1. Introduction

Intelligent vehicle test platform is a recent theory. It is the practical achievement of several academic fields, including cognitive intelligence, artificial intelligence, and control science. This test platform also provides a foundation for intelligent driving theory and technique studies. In 1950, the American company Barrett Electronics Corporation conducted research on unmanned vehicles and developed the world's first autonomous navigation vehicle [1,2], although this concept originated from the Defense Advanced Research Projects Agency of US Department of Defense, which is one of the world's leaders in this area of study. European countries have been developing unmanned driving technologies since the mid-1980s; considering these unmanned vehicles to be independent individuals, these countries tested these vehicles in normal traffic flow [3]. In 1987, the Programme for a European Traffic of Highest Efficiency and Unprecedented Safety (PROMETHEUS Project) was jointly launched by Bundeswehr University Munich, Daimler-Benz, BMW, Peugeot, Jaguar, and other popular R&D institutions and automotive companies, significantly influencing the global automobile industry [4,5]. The Advanced Cruise-Assist Highway System Research Association, which is affiliated with the Japan Ministry of Land, Infrastructure and Transport, has launched advanced safety vehicle projects since the 1990s to support research initiatives on unmanned driving technology every five years [6,7]. In China, research on unmanned driving technology started in the late 1980s, supported by the National High-tech R&D Program (863 Program) and by a related research program of the Commission on Science, Technology, and Industry for National Defense [8]. Several Chinese researchers have been addressing the future challenges of intelligent vehicle since 2008, with support from the National Natural Science Foundation of China. In spite of the increasingly difficult competition, more and more teams take part in the future challenge of smart cars in China every year. Car enterprises are gradually improving their R&D for the rapid application of unmanned driving technology to domestic cars [9].

Sensors are configured to perceive external and internal environments, including the surroundings, state, orientation, and location of the intelligent vehicle; therefore, sensor configuration is the foundation

* Corresponding author.
E-mail address: ghb48@tsinghua.edu.cn (H. Gao).

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for driving intelligent vehicles. However, there is no uniform standard strategy for sensor configurations; therefore, intelligent vehicle test platforms with various sensor configurations, types, and installation locations are based on different strategies. Certain research teams, such as the teams from VisLab at the University of Parma in Italy [10] and the Karlsruhe Institute of Technology [11], use visual sensors; by contrast, other research teams, such as Google's self-driving vehicle team [12] and those from the Munich University [13], adopt radar sensors. A decision-making program is necessary when configuring sensors. Several essential redundancies and capabilities are also used to improve the reliability of environmental perception and minimize the costs of sensor configurations. Finding a single or final solution for the sensor configurations and types is infeasible. In this paper, we introduce a self-driving vehicle technical framework based on a driving brain to embody human cognition in the framework design. The proposed framework improves the current practice of using different sensor quantities, types, and installation locations. As a result, the driving-brain-based technical framework can be relocated to different smart vehicle platforms despite variations in sensor installations.

Research on intelligent vehicles and intelligent driving technology is conducted to improve transportation safety, prevent and reduce traffic accidents, reduce fuel consumption, minimize environmental pollution, and accelerate social intelligence. An intelligent vehicle is a kind of wheeled robot, and its application combines cognitive intelligence, artificial intelligence, and control sciences, as well as several other advanced and novel technologies. In general, the goals of intelligent vehicle research are as follows: to realize human and machine dual-motor driving and control, to achieve human- and machine-driving harmony, to improve vehicle driving safety, and to promote the development of the intelligent vehicle industry.

In this work, we establish a hardware platform for an intelligent vehicle based on driving brain theory. In particular, the driving activities of a human driver are analyzed. The main contributions of this paper are summarized as follows:

(1) An analysis of the working principles of brain cognition and the driving activities of a human driver is conducted, following the MengShi intelligent vehicle test platform, in order to establish the relationship between the different functional areas of a driving brain and the computer software modules. Thus, driving cognition is expressed in formal cognitive language; that is, a universal intelligent driving software architecture is developed for intelligent vehicles, with the driving brain as the core of the design.

(2) Various sensors are used by an intelligent vehicle. These sensors are installed in different locations. A uniform framework is therefore established for information consolidation. In this work, a method for low coupling between the intelligent decision module and the sensor is realized according to natural human cognitive laws and corresponding to the abovementioned design (that is, with the driving brain as the core).

This paper is organized as follows. In Section 2, we analyze human driving activities and establish the driving brain framework. In Section 3, we establish the hardware configuration and the connection of the MengShi intelligent vehicle based on a driving brain framework. In Section 4, we present the analysis of the MengShi intelligent vehicle sensors and configuration and the experimental result. Finally, Section 5 summarizes this paper.

2. Region correspondence of driving brain and human brain functions

Human and intelligent driving systems act in three areas; namely, perceptive, cognitive, and physical spaces. In the perceptive space, human and intelligent driving systems derive signals about the surrounding environment and their own states through various senses, such as vision, smell, and touch. In the cognitive space, the human and driving brains of self-driving vehicles initiate selective attention mechanisms to extract key traffic elements using signals in the perceptive space. The brain analyzes current and historical driving situations to make a decision by using acquired knowledge and experience. In the physical space, humans use their limbs to control the steering wheel, throttle, and brake; thus, the vehicle at or near the expected state can send signals to the perceptive space, thereby forming a closed-loop control. Self-driving vehicles perform similarly by using mechanical structures and electrical signals (Fig. 1).

A human brain accomplishes learning and memory processes to realize driving activities through the different parts of the brain working as a single unit. The driving brain uses computer technology to deconstruct activity mechanisms, analyze information, and complete driving tasks through functional modules [14]. The human brain comprises sensory memory, working memory, long-term memory, computing hubs and thinking, motivation, personality, emotion, and other functional areas.

Sensory memory completes the instantaneous storage of sensory information, which demonstrates extensive accumulation despite a brief storage time. Intelligent vehicles utilize sensors to derive images, send cloud and other raw signals (i.e., stored in buffer areas), and quickly produce new data from old data consistent with their task of perceiving their surrounding environments. This mechanism is similar to the working principle of the sensory memory [15].

The sensory information of the sensory memory can be analyzed quickly by computing hubs and thinking functional areas to extract current activity-related contents through selective attention mechanisms and then deliver these types of sensory information to the working memory. Pretreatment of the information-processing modules of a driving brain sensor is completed by analyzing all kinds of vehicle sensors and driving process information, such as lane lines, traffic lights and signs, surrounding vehicles, pedestrians, self-status, and position; information unrelated to the driving process is discarded [16].

Long-term memory stores important driving experience, knowledge, scenes, and other information related to intelligent driving maps and operation models. A driving map accurately records driving-related geographic information, such as lane width, traffic signs, and static obstacle information. A driving operation model comprises trajectory tracking, follow-up,

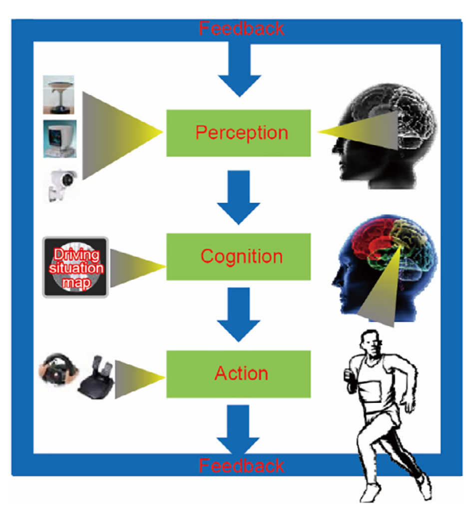

Fig. 1. Driving activities in the three spaces.