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Intelligence Testing for Autonomous Vehicles: A New Approach

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***Abstract*—In this paper, we study how to test the intelligence of an autonomous vehicle. Comprehensive testing is crucial to both vehicle manufactories and customers. Existing testing approaches can be categorized into two kinds: scenario-based testing and functionality-based testing. We first discuss the shortcomings of these two kinds of approaches, and then propose a new testing framework to combine the benefits of them. Based on the new semantic diagram definition for the intelligence of autonomous vehicles, we explain how to design a task for autonomous vehicle testing and how to evaluate test results. Experiments show that this new approach provides a quantitative way to test the intelligence of an autonomous vehicle.**

***Index Terms*—Autonomous vehicles, intelligence testing.**

I. Introduction

AUTONOMOUS vehicles usually refers to self-driving vehicles that can fulfill main transportation capabilities of a traditional vehicle [1]–[4]. Such vehicles are viewed as a promising answer to traffic congestion, accident and pollution problems that disturb people around the world; because the movements of vehicles could be controlled in a smoother, safer and economical manner, if the vehicles are built "intelligent" enough.

To reach this goal, some prototypes of autonomous vehicles had been designed and tested during the last few decades. For example, Google and Tesla had demonstrated their autonomous cars can run on road recently [5]–[6]. More companies claimed that they will have their own autonomous vehicles running on road within the next 5 years.

An important question naturally arises as: "*how could we prove an autonomous vehicle is capable to drive in live traffic?*" The accidents that were made by not fully tested Honda cars [7] had demonstrated the disastrous consequences of improper testing. So, unless their reliability and safety can be thoroughly tested and ensured, autonomous vehicles cannot be put into market.

To find an answer, the Defense Advanced Research Projects Agency (DARPA) had sponsored a series of competitions for autonomous vehicles [8]–[9]. The first two "Grand Challenges" had been held in 2004 and 2005 to check whether autonomous vehicles could travel long distances in off-road terrain. The third "Grand Challenges" had been held in 2007 to foster innovation in autonomous driving in busy urban environments [10]–[11]. These tests fired researchers with keenness for autonomous driving.

Similar autonomous vehicle competitions had also been held in Europe and China. National Science Foundation of China had spent over 30 million dollars to support seven "Intelligent Vehicle Future Challenges" that had been held in different cities of China, through 2009 to 2015 [12]. Several prototype vehicles had successfully passed these competition tests.

Notice that competition tests cannot replace real road tests, several countries allowed autonomous vehicles to be tested on ordinary roads since 2010s [13]–[17]. This had triggered a debate on whether it is safe to allow under-testing autonomous vehicles runs into live traffic.

The origin of this debate lies in a long-term hassle to current autonomous vehicle research: *there is no clear definition for "intelligence" of autonomous vehicles*. Generally, intelligence of autonomous vehicles can be viewed as a specialized subfield of artificial intelligence. It can be more generally described as the ability of autonomous vehicles to perceive information, retain knowledge, and adopt adaptive behaviors within an environment [1], [18]. The intelligence of autonomous vehicles has its unique meanings and refers to a set of methodologies dedicated to implement the capabilities of a traditional vehicle.

There were already some initial discussions on autonomous vehicle testing [19]. However, performing tests that produce quantitative, repeatable and comparable results remains challenging for autonomous vehicles, since we do not have a detailed and testable definition of intelligence of autonomous vehicles.

To solve this problem, we provide an exhaustive discussion of intelligence testing for autonomous vehicles in this paper. In the following Section II, we first show that existing testing approaches can be categorized into two kinds: scenario-based testing and functionality-based testing. After discussing the shortcomings of these two kinds of approaches, we propose a new intelligence testing framework to combine the benefits of them in Section III. In Section IV, we discuss how to build adaptive simulation platform for autonomous vehicle testing, using parallel transportation systems. In Section V, a numerical

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