User Interface Design and Verification for Semi-Autonomous Driving

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ABSTRACT

This paper presents a project in its early stages of development, in which we propose a solution to the problem of human interaction with autonomous vehicles. We have devised a method for design of a user interface that displays sufficient and crucial information to the driver. Our contribution in this work is (i) identifying different modes of driving behavior, (ii) building an expectation model of a driver, and (iii) implementing an interface system.

1. INTRODUCTION

Recently, there has been a great deal of research and media attention focused on the future of the car industry, primarily concerning autonomous vehicles. Since Google announced commercialization of the Google Car [1] by 2018, nearly all major car manufacturers have invested in research promising fully autonomous vehicles in the next five to ten years [1].

Many function specific automations are available in cars today. For example, Volvo's city braking system intervenes if a collision is unavoidable [1], and BMW's self-parallel-parking feature handles only steering maneuvers when engaged [2]. The major difficulty in these semi-autonomous systems is the interaction with the human driver, as there is often disparity between how the system functions and how the human *expects* the system to perform. When the system does not perform expected, drivers tend to either abuse the functionality or reject the system entirely [3].

In order for these autonomous systems to be well-received and be completely integrated into our everyday lives, many important questions need to be answered. Here, we focus on one imperative question: How do we guarantee a safe interaction between the human driver and the autonomous car to improve driver experience and comfort?

This work in progress suggests an innovative, practical solution to assist the intercommunication between human and autonomous systems. By modeling these human-in-the-loop systems and using formal methods to develop provably correct user interfaces (UIs), we can relay crucial information that will improve driver performance and experience in this autonomous environment.

2. METHODS

We propose developing a system that incorporates driver, vehicle, and environment data with user interfaces to act as a communication medium between the driver and autonomous systems. The following subsections describe our approach.

2.1 Data Integration.

The data that needs to be presented to the driver through the UI in the vehicle includes information about the driver, the surrounding environment, and the vehicle. This information can be collected using different methods. We gather our data from three sources:

Vehicle-to-Vehicle (V2V) Communication: Nearby vehicles can communicate states and status to the ego vehicle (i.e. the vehicle in which the driver of interest resides).

Sensory Information: Data is collected from front and side radar, LiDAR, and CAN bus readings. The collected data gives us information about the surrounding environment and the state of the vehicle.

Driver Monitoring: Eye trackers[4], cameras, the MS Kinect[5], optical tracking setup[6], and steering wheel touch sensors are used to monitor driver behavior.

From the collected data, we can estimate the driver state to provide appropriate information, by learning an individual's behavior using past driving data, estimated mental and

[1]http://en.wikipedia.org/wiki/Google-driverless-car
[2]http://www.bmw.com/com/en/newvehicles/7series/sedan/2012/showroom/convenience/park-assistant.html
[3]http://online.wsj.com/news/articles/SB10001424052748703734504575125883649914708

[4]http://www.eyetracking-glasses.com/
[5]http://www.xbox.com/en-US/KINECT
[6]http://www.naturalpoint.com/

HiCoNS'14, April 15–17, 2014, Berlin, Germany.
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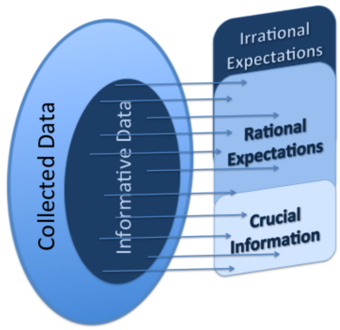

Figure 1: One-to-one mapping from the informative part of the full data collection to the rational expected and the crucial set.

perception state, and the outside environment. As described in [4, 6], driver modes can be identified to predict driver behavior using the described dataset. In our previous work, we have estimated the driver behavior using the k-means clustering algorithm, where each cluster corresponds to a specific driving behavior.

2.2 Meeting Expectations of the Driver.

The UI must satisfy the following criteria: (i) meet the expectations of the driver; (ii) avoid mode confusion by displaying the correct data for a given driver state; (iii) display concise and informative data; and (iv) present information in a user-friendly manner. In addition, an expectation model that identifies what information the driver desires must be generated from surveying drivers.

Acknowledging that not all expectations can be met and that the driver might not be aware of crucial information she needs while driving, the data presented through the UI will be a portion of the expected data in addition to crucial information in a given mode. Figure 1 shows the mapping from the collected data to what needs to be displayed to the driver. Additionally, not all the data collected is useful and informative to the driver. Therefore, we create this one-to-one mapping from the informative part of the collected dataset to the data that must be presented to the driver.

3. EXPERIMENTAL SETUP

To carry out experiments and collect data, we setup a force feedback car simulator [7], equipped with software to simulate all the sensory data and V2V communication. This setup provides a realistic driving platform that guarantees safety of the user, while allowing complete control over the experimental conditions [2]. Additionally, we have a set of eye tracker glasses that provide accurate gaze detection [8]. With these tools and setups, we gather all necessary data described in Section 2.1 for monitoring and modeling the human behavior as well as evaluating our UI.

[7] http://www.force-dynamics.com/
[8] http://www.eyetracking-glasses.com/

4. IMPLEMENTATION AND VALIDATION

To implement the models and UI, a variety of mediums that can be used in a car are to be tested, including mobile applications that can be mounted in a vehicle; mobile applications that can use audio and haptic feedback; simulated windshield displays; and new wearable computers like Google Glass [9]. Once the systems are developed and methodically tested for usability, the methods can be systematically compared to evaluate the performance. We define logical properties that represent the brevity and clarity of the UI model and the one-to-one mapping previously described. We use formal methods and verification techniques to validate the correctness of our model as motivated by Sturton et al. in evaluating UIs for electronic voting machines [5]. Then, to ensure effectiveness of the UI, driver performance is quantified by applying probabilistic model checking techniques and verifying logical properties on performance models before and after using the UI, as demonstrated in our previous work [3].

5. CONCLUSION

In conclusion, the autonomous vehicle race has begun and will eventually affect our everyday lives. While in transition, we present a high impact project to assist drivers as well as increase the public's acceptance of autonomous vehicles. In developing this unique, verifiable, and accurate interface, we provide the drivers insight to the autonomous system's intent without overloading them with unnecessary information. With the proposed UI from integrated data, we believe that we can improve driver performance and address many of the important questions that are raised by the autonomous movement.

6. ACKNOWLEDGMENT

This work is supported by the NSF grants CCF-1116993 and CCF-1139138.

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[9] http://www.google.com/glass/start/