Projection Mapping for Implementing Immersive User Scenarios in Autonomous Driving: Insights from Expert Interviews

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Abstract. We propose the use of projection mapping as a prototyping tool to create an experimentation environment to design, evaluate, and control immersion experience in future autonomous vehicles. As the first step, we conducted expert interviews with professionals in the automotive industry to understand the general implications of prototyping tools in future mobility solution development and their usefulness in concept test settings. The interview results reveal that projection mapping is one popular prototyping method for automotive professionals to demonstrate immersive future user scenarios. The paper includes additional insights from the interviews and current work-in-progress.

Keywords: Expert Interview, Immersive User Scenario, Autonomous Vehicle, Sensor Integration, Flexible Experimentation Environment

1 Introduction

The automotive industry is looking towards autonomous vehicles as the next platform for innovation. Without the need for a driver, autonomous vehicles provide an opportunity for new experiences based around the concept of mobility. In order for autonomous vehicle companies to dissuade an influx of tech companies into their market, autonomous car experiences should not rely on tablet or screens and should enhance the experience of travel. Automotive companies are proposing the use of projection mapping for displaying visual effects and driver assistance [1,2] and HCI (Human Computer Interactions) researchers have been using projection mapping as a rapid prototyping technique [3]. In the field of autonomous vehicle research, an auditory based system of keeping user's aware of on-road events in autonomous vehicles was explored. This system lacked in the sense that the user's comfort, familiarity levels, or situational awareness with the vehicle did not change [4]. Research from the MIT AgeLab suggests that adults between the ages of 25 to 34 are more likely to be comfortable with full autonomous driving. It is also seen that older generations are less likely to be comfortable with relinquishing full driver control. It is suggested that the gradual adoption of assistive technologies would be beneficial to the acceptance of full autonomous driving [5]. Future mobility experiences should be explored beyond the themes of comfort,

safety, or notifications by creating new meanings. For instance, a research team at the University of California, Berkeley has investigated in developing a new concept: a car seat with a haptic array on an armrest that produce different patterns of motion to make passengers feel as if they are at sea [6]. This exploration of novel experiences in the autonomous vehicle space allows for the forging of future implementations of technology in the user's experience.

In order to create a platform for exploring said novel experiences in autonomous vehicles, we propose an exploration into the immersion provided by multiple sensors during a daily commute and an exploration of the following overarching question: *Does projection mapping portray a compelling immersive environment for subjects to accurately visualize mobility concepts?* As the first step, we conducted 5 expert interviews with current employees in the automotive industry to understand general implication of prototyping tools in future mobility solution development and their usefulness in user test settings. The results of the expert interviews are included. We end our paper by showing a work-in-progress experimental setting that will be used to explore the effect of immersion on the user's trust with the autonomous vehicles as part of future research.

2 Methods and Analysis

2.1 Preliminary research

We hosted a demo day at the Richmond Field Station, the location of our experimental location, and several experts from the automotive industry were invited to attend. Preliminary feedback on the concept of projection mapping and connected sensors in future mobility solutions was collected. Some expressed a concern with the safety of such technologies which lead us to pursue the sub question of how the feeling of safety, more specifically *trust*, can be addressed inside autonomous vehicles. We also presented a lower fidelity version of our experiment environment at the 3rd International Symposium for Academic Makerspace (ISAM) at Stanford [7]. Our testing scenario consisted of individual sensors being compared to a holistic sensory experience and our feedback suggests that users prefer the combination of visual and audio sensors. It was also suggested to incorporate a reclining option to the chair and combine it with ceiling projections; The test results are integrated in developing questionnaires for the expert interviews (section 2.2) and current work (section 4).

2.2 Expert interviews

To obtain insight into industry methods, expert interviews were conducted with 5 individuals with positions in the mobility industry. The current use of projection mapping and techniques for building future mobility scenarios in autonomous vehicles were topics of interest. Expert interview participants were selected and recruited with a key criterion that they had multiple years of experience in the automotive industry or experience in future mobility innovation projects. Participants were recruited through emails sent throughout personal networks. Participant experiences ranged from concept car

development to full projection mapping inside of a concept car, to human-centered design ambassador in their organization and Human-Machine Interaction prototyping. The participants' work experience ranged from 2 years to 17 years, and current job responsibilities ranged from User Experience Designer to Product Design Engineer to Prototyper. We conducted semi-structured interview procedure by ask the following primary questions:

a) What kinds of mobility solutions (e.g., futuristic mobility solutions, interior, exterior, security, etc.) does his/her company deal with?
b) What prototyping or mock-up tools (e.g., visual, haptic, auditory, etc.) does your company employ? What do you use them for?
c) What do you know about projection mapping?

In addition, we also asked them questions regarding individual cybersecurity perceptions with respect to the risks around the data collection through the sensors inside of the vehicles. The thematic analysis [8] was used to uncover common themes in the interview transcripts. In this research, we aim to carry out emerging trends in implication of prototyping tools in future mobility concept development and how useful they are in the setting of concept tests.

3 Results

The audio data collected from each expert interview were transcribed in 110 code lines and independently reviewed by three coders. The results of review uncovered four themes that were compared to examine emerging trends. In this section, we report the common themes mapped with our primary research questions provided in the interview scripts.

Areas of future mobility solution design

The areas of future mobility concept development embrace a wide range of spectrum from commercial vehicles to concept cars. Front-end prototyping development platforms are used to facilitate not only the development of the entire concept vehicle development, but also the visual/sensorial representation of the partial user experience inside/outside of the vehicle environment. One participant addresses that their company does business in a full product line of commercial products. The new concepts are conceived in the innovation center they are involved in and the proved concepts are transferred to the company headquarters. Another participant mentions their company deals with not only automotive vehicles, but also micro-mobility services such as e-bikes and an eco-system development around sustainable mobility solution. The organization they are involved in particularly addresses they employ human-centered design in the process of creating better features for customers across all areas of future mobility exploration phases.

Main purpose of prototyping tools

Prototyping tools mentioned by the experts tended to vary based on the team they were involved with. Those in UI/UX working with software-driven prototyping tools focused on idea generation or feasibility, while those working in hardware design tended to heavily use 3D printing or CAD software to rapidly build physical prototypes. Their choice of methodology or tools for prototyping mainly relied on the effectiveness to rapidly develop the prototype as fast as they can to go through many iterations. One mentioned, while describing tools for visual prototyping, the use of integrating projectors to visualize whether or not an immersive environment would improve the user experience. Several experts mentioned the term, 'immersive experience', as a main purpose of the prototyping tool development to demonstrate futuristic concept of user experience.

Effectiveness of projection mapping

We asked the professionals about their knowledge of projection mapping and how effective this method is in demonstrating concepts and user testing. They all knew and have seen projection mapping used as a prototyping or showcase tool, while two have used projection mapping currently or previously, before professionally, in their prototyping process. Projection mapping appears to mainly be used to provide an immersive visual environment for the target groups in order to create a realistic scene of vehicle content and road context, whether for the purpose of showcasing a new concept car or even conducting a performance test. One of the participants mentioned about using projection mapping for immersion effectiveness:

> *We don't want that [HMI/UI experiences] to be tested in a vacuum where you're sitting in someone's office pushing buttons on a screen. So, we project certain things like basically the road or the drive. – Participant 2*

These experts mentioned that projection mapping UX tools are used to identify user experiences to begin with. It was noticed that the projection mapping was useful as they are generally easy for users to navigate the interaction flow through the display. Projection mapping was good enough to show animation and wireframes, hence it is powerful software tool to illustrate future user scenario with a low-cost investment.

Risk around data collection under immersive mobility environment

Several participants address possible concerns in passenger's privacy risk and safety issues when the autonomous driving arrives in the market. One participant mentioned that during user testing their company have previously collected personal passenger data on fingerprints, eye movements, facial recognition, heart rate and foot tremors. All participants mentioned how the movement towards autonomous vehicles in the automotive industry creates more risks in the automotive space (such as cybersecurity or vehicle hacking with increasing amount of software). The automotive industry struggles or does not focus on these issues since autonomous vehicle technologies are not fully developed. Therefore, there is difficulty in effectively implementing safeguards against these problems that are not currently present. One of the participants addresses:

While our company does work with cybersecurity and understands the importance of it, it is hard to integrate data protection and privacy at this moment without running fully autonomous vehicles and test it out. – Participant 3

Hence, to reflect the emerging concern in users; privacy and safety issues while sitting in the inside of vehicles, we will continue examine potential risks around the data collection through the sensors inside of the vehicles.

4 Current Work

In tandem with the expert interviews, we propose the use of projection mapping as a prototyping tool to create an experimentation environment to design, evaluate, and control immersion experience in future autonomous vehicles. We currently explore the following sub questions to examine the implementation of immersive in car user scenarios in future autonomous driving using projection mapping:

a) What are the consequences of sensorial inputs (e.g. *visual with projection mapping, sound, and tactile)* within an environment and impact on user's immersion?
b) What's the line between a compelling immersive environment and an autonomous vehicle environment that users can trust?

4.1 Creation of the Experimental Environment

Airstream Projection Surface and Projection Mapping. A mock wall was designed to cover distracting features of our experimentation environment and provide an even projection surface; The wall was manufactured using panels of laser cut cardboard overlaid with projector screen material. With the Madmapper projection mapping software [9], we plan to manipulate each video to adapt on the projection surface, as well as edit the video for any additional visual effects required to accurately portray the scenario to the users.

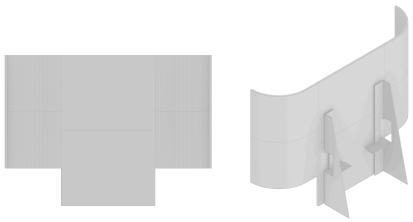

Fig. 1. The projection surface

Area of Projection. The projection surface will be separated into three sections to correspond with the driver's point of view. These sections will be labeled as seen in Fig. 2. Projection locations of the chosen scenario and of the street view will vary as described in Table 1. Trial 1 and 2 will address the overarching question of whether or not the user feels immersed inside of our experimentation environment.

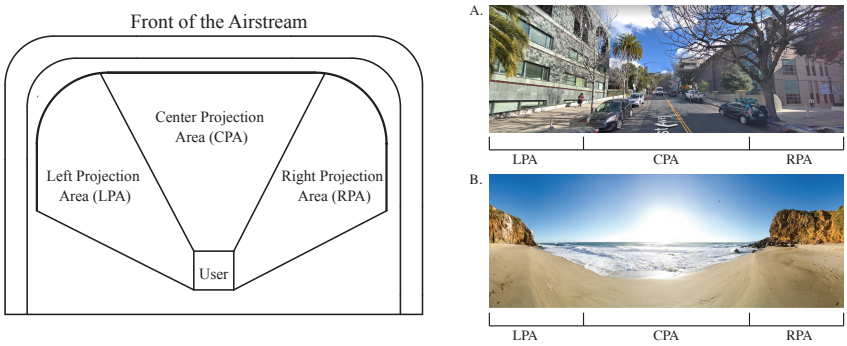

Fig. 2. Projection surface layout (Left) Scenario layouts A. Street view scenario [10] B. Beach scenario [11] (Right)

Trial	LPA	CPA	RPA
1 - No Immersion	Street	Street	Street
2- Full Immersion	Beach	Beach	Beach
3-Semi Immersed	Street	Beach	Street
4 - Reverse Semi Immersed	Beach	Street	Beach

Table 1: Projection layout for experimental trials

Audio and Haptic Sensors. Binaural audio speakers and speakers will be integrated into the headrest and base of the chair to create the audio sensors. The haptic sensors consist of a massage chair attachment and the bass boosted on the base speaker to create vibrations in the chair. The full immersion trial of all screens showing the same scenario will be used for visuals. Observations of user reactions and analysis of user interviews while varying the use of binaural audio, haptics, and projections will be used to determine is a paired experience is impactful on immersion. Trials will be conducted as seen in Table 2.

Trial	Audio	Haptic	Visual
1	X		X
2		X	X
3	X	X	X

Table 2: Sensor testing trials

4.2 Data Collection Methods

An initial survey will be conducted to determine the user's initial opinion on autonomous vehicles and immersive mobility environment. Then, video recording method (e.g., GoPro camera) will be used to capture the behavior during the user test. After the user test, we will record the audio of our expert and general user interviews to get their feedback on the overall satisfaction and reflections on their feelings of immersion, feeling of trust with an autonomous car, and overall experience.

5 Conclusion

This paper aims to shed light on the emergence of projection mapping as a prototyping tool to create an immersive experimentation environment for the exploration of opportunities in future autonomous vehicles. As an initial step, we conducted expert interviews with professionals in the automotive industry to apprehend the general usage of prototyping tools in future mobility concept exploration and testing. The expert interviews reveal that automotive companies have been using a variety of prototyping tools to demonstrate futuristic products, user interactions, user experience concepts, and concept testing. The projection mapping was one of the most popular methods among many in creating an immersive experience of unveiled concepts with a low-cost investment. We also found it notable to mention that there is a risk around implementing immersive user scenarios. Integration of connected prototyping tools and advanced sensors inside of future vehicles would result in collection of more personal data from users. Lastly, the current works-in-progress experimental environment setting is detailed as current research areas we focus on.

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