A Demonstration of AutoVis: Enabling Mixed-Immersive Analysis of Automotive User Interface Interaction Studies

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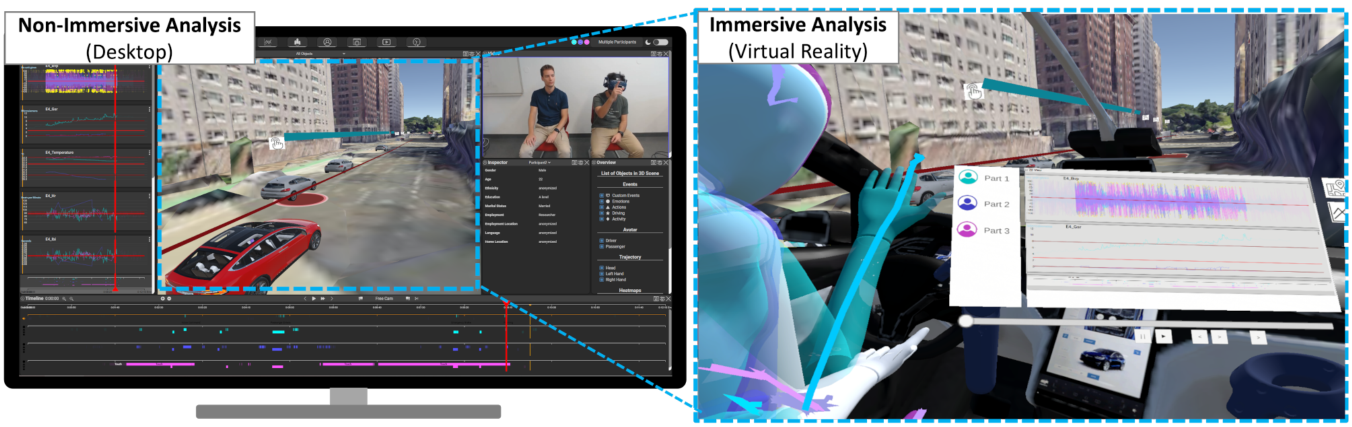

Figure 1: AutoVis [11] combines an immersive VR view with a non-immersive desktop view for analyzing automotive user interface studies. In VR, analysts can re-experience and analyze studies in a replicated study environment. On the desktop, they can analyze aggregated study data. A virtual tablet visualizes the desktop view in VR.

ABSTRACT

In this demonstration, we present novel interaction modalities and use cases for AutoVis, a tool for the mixed-immersive analysis of automotive user interface (AUI) interaction studies. AutoVis uniquely enables exploration of AUI studies' multilayered spatio-temporal interplay between humans, vehicles, and their surroundings by combining a non-immersive desktop view with a virtual reality view. It facilitates the analysis of passenger behavior, physiology, spatial interactions, and events within replications of study environments, employing avatars, trajectories, and heatmaps. To extend AutoVis and streamline interactions with it, we created a novel concept for gaze and gesture-supported analysis control. In addition, we conducted an exemplary use case study in the context of traffic accident reconstructions to explore the applicability of AutoVis apart from AUIs. By demonstrating these extensions, we contribute to the underexplored area of immersive analytics for AUIs and promote a more efficient and effective understanding of human-vehicle interaction.

CCS CONCEPTS

• Human-centered computing Visual analytics; **• Human-centered computing Ubiquitous and mobile computing systems and tools**; **• Human-centered computing Virtual reality**;

KEYWORDS

immersive analytics; interaction analysis; visualization; virtual reality; automotive user interfaces

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1 INTRODUCTION

As driving automation and vehicle system technologies advance, human-vehicle interaction analysis becomes more complex. Today's AUI development considers numerous factors like vehicle environment [1], user behavior [16, 24], and multimodal interaction [12]. Furthermore, vehicles can interact with other road users via external human-machine interfaces [3, 5]. Large volumes of heterogeneous, spatio-temporal data must be visualized and analyzed to gain insights. Such analysis may benefit from tools that link in-vehicle passenger behavior with the environment.

However, current AUI analysis tools (e.g., [6, 25]) are non-immersive and limited to desktops, distancing analysts from complex vehicle environments. When lacking the right tools, AUI study analysis can be time-consuming (e.g., see [10, 17]), and data patterns may be missed from a fixed point-of-view. Besides, many datasets only include videos (e.g., [13]), making manual analysis incomplete or requiring extensive processing. Current tools also lack support for each driving automation level (see SAE [22]) and the various forms of multimodal in-vehicle interaction.

In contrast, immersive analytics offer spatial analysis of interaction and movement data in augmented reality (AR) and virtual reality (VR) environments [2, 9, 14, 15, 21]. However, such tools are currently nonexistent in the AUI domain. While non-immersive tools are suited for overview tasks, we argue (in line with Hubenschmid et al. [9]) for combining immersive and non-immersive tools to effectively and efficiently analyze AUI studies.

In response, we proposed AutoVis [11], a mixed-immersive analysis tool[1]. AutoVis is built with Unity and combines immersive VR with a non-immersive desktop view. The AutoVis prototype and sample datasets are available as an open-source project[2] on GitLab.

The VR view (see Figure 1) enables interactive exploration of AUI studies by recreating the study environment and behaviors. A virtual tablet provides scene controls, a timeline, and study metrics. The VR view 3D visualizations of avatars, movement trajectories, and gaze, touch, and finger-pointing heatmaps in the vehicle and environment. As AUI domain-specific visualization, AutoVis displays spatio-temporal events and annotations along the driving path, indicating the location and orientation of actions, emotions, and activities.

AutoVis also enables to leverage real vehicles using passthrough VR in an in-situ analysis process. The passthrough VR view overlays 3D visualizations on the real interior.

In addition, the desktop view (see Figure 1) offers an overview of study session data. It also includes a 2D window into the VR scene. AutoVis supports transitions between synchronized VR and desktop view, allowing collaborative use of AutoVis in various levels of immersion, time, and space.

For this demonstration, we extended the AutoVis VR view with a *gaze+pinch* control to remove the need for controllers and ease transitions between desktop and VR. Additionally, we explored traffic accident reconstruction as a novel AutoVis use case beyond AUIs.

2 ENABLING GAZE AND GESTURE-SUPPORTED INTERACTIONS

Inspired by previous studies on VR interactions (e.g., [20]) and upcoming devices like the Apple Vision Pro, we anticipate gaze and hand interactions to be vital for future VR applications. Accordingly, we extended AutoVis to include eye and gesture-tracking to facilitate interactions with the virtual tablet and 3D visualizations and to avoid dependence on controllers. This also eases transitions between desktop and VR view, as users do not have to switch between VR controller and keyboard/mouse frequently. We employed the HTC VIVE Pro Eye's built-in system to enable eye-tracking and attached a Leap Motion Controller to the VR headset's front for gesture tracking (cf. [4]).

However, previous work showed that pure gaze-based interaction can induce eye strain [8] and may negatively impact interaction quality [18]. Likewise, gesture-based interactions can lead to arm fatigue [7]. Therefore, we developed a system that combines gaze and pinch (*gaze+pinch*) for multimodal input (see Figure 2 a), similar to [20]. Users first gaze at an object for quick and precise selections, such as driving path events. Afterward, a pinch gesture confirms their selection. They can do this close to the body, reducing arm fatigue. As this system does not require gaze to confirm the selection, users do not need to hold their gaze for extended periods, which prevents additional eye strain. Besides, for user convenience, the user can toggle the virtual tablet by hand rotation, making a VR controller unnecessary. The virtual tablet is activated when the palm is visible to the user (see Figure 2 b).

3 USE CASE: TRAFFIC ACCIDENT RECONSTRUCTION

Traffic accidents are complex events that require detailed analysis for effective reconstruction [26]. This is critical for emergency response teams, evaluating traffic safety measures, and insurance. Traditional accident reconstruction methods (e.g., see [19]) do not provide an extensive and interactive view of the accident, also focusing on specific in-vehicle actions. However, this may hinder the comprehension of accident dynamics and the recognition of contributory factors, such as environmental distractions for drivers.

In contrast to AUI analysis, traffic accident reconstruction typically disregards AUI interactions. Still, we chose this use case, as there is a large intersection with AUI research regarding accident-related in-vehicle events, such as driver emotions, activities, and posture, linked to environmental events, such as other road users' positions.

In this use case, AutoVis enables to *relive* an accident from different perspectives and reconstructs an accident scenario by importing data of vehicles involved. Lacking such data, we created an exemplary dataset of a traffic accident in New York City (NYC). We chose this environment because NYC typically has many traffic accidents per year [23], making it a realistic analysis environment. In our scenario, a manually driven car heads towards Central Park on Manhattan's 6th Avenue (see Figure 2 c). At the intersection of 6th Ave and W 57th St, another car comes from the right, ignoring

[1]The AutoVis demo website: https://autovis-demo.onrender.com/
[2]The AutoVis repository: https://gitlab.com/Pascal-Jansen/autovis

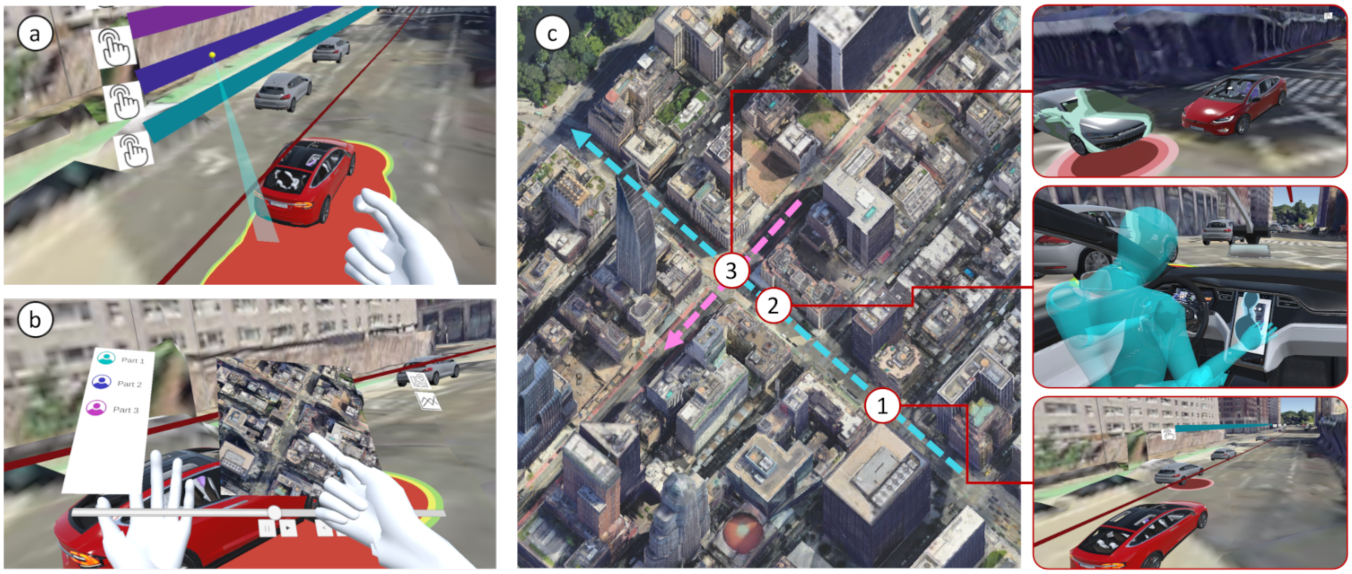

Figure 2: (a) Selecting a touch event on the driving-path event line via *gaze+pinch* in VR. (b) Hand interactions with the virtual tablet attached to the left palm. (c) Traffic accident reconstruction use case: (1) the driver heading towards Central Park (cyan line), (2) the driver gets distracted by the infotainment system and touches it, and (3) the driver crashes with another car (pink line) at the intersection.

the right of way, causing both cars to crash. We employed the same recording setup for this example dataset as in the previous publication of AutoVis (cf. [11]). To incorporate NYC into AutoVis, we utilized the Google Map Tiles API with our Cesium implementation in Unity.

In AutoVis, the VR view facilitates the reconstruction of the driving environment before, during, and following the accident. Avatars visualize drivers' seating positions, and gaze, touch, and gesture heatmaps highlight the drivers' attention. It becomes evident that the driver who neglected the right of way was distracted by the infotainment system before the accident (see Figure 2 c 2). AutoVis also indicates where drivers looked during the accident and when they saw the other vehicle (see Figure 2 c 3). This ability to link vehicle and environmental context could make determining who is at fault in accident scenarios easier.

4 DEMONSTRATIONS

Besides showcasing the three use cases from Jansen et al. [11], we present the following extensions to demonstrate the advantages and challenges of employing AutoVis:

(1) A prototype for *gaze+pinch* interaction in VR, enabling users to select events on the spatio-temporal driving path and control the virtual tablet.
(2) An example use case for traffic accident reconstruction in which two manually driven cars collide at an intersection in Manhattan, NYC.

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