It Is Not Always Just One Road User: Workshop on Multi-Agent Automotive Research

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ABSTRACT

In the future, roads will host a complex mix of automated and manually operated vehicles, along with vulnerable road users. However, most automotive user interfaces and human factors research focus on single-agent studies, where one human interacts with one vehicle. Only a few studies incorporate multi-agent setups. This workshop aims to (1) examine the current state of multi-agent research in the automotive domain, (2) serve as a platform for discussion toward more realistic multi-agent setups, and (3) discuss methods and practices to conduct such multi-agent research. The goal is to synthesize the insights from the AutoUI community, creating the foundation for advancing multi-agent traffic interaction research.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; • **Computing methodologies → Modeling and simulation**.

KEYWORDS

Multi-agent research, Automotive, Interfaces, Design, Modeling, Psychology, Automated driving, Road Users, VRU

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1 INTRODUCTION

By leveraging advanced sensors and intelligent algorithms, automated vehicles (AVs) are expected to navigate our roads safely. However, before achieving full automation (SAE Level 5 [20]), mixed traffic scenarios will prevail. Here, multiple agents—such as AVs, manually driven vehicles (MDVs), and vulnerable road users (VRUs)—share the road, often with conflicting interests.

AVs, MDVs, and VRUs might not only differ in their goals but also in their situation awareness (SA), i.e. knowing what is going on around them [8, 12, 13]. When multiple road users interact, SA becomes a shared construct. The theory of Distributed Situation Awareness (DSA) [22] states that safety in mixed traffic can only be achieved via shared knowledge among all involved agents. DSA must be computed in real time through multidirectional information transfer among individual agents to handle complex traffic scenarios effectively. However, current research predominantly focuses on the interactions between single road users. The communication dynamics in a multi-agent mixed traffic environment, with varying levels of SA, remain underexplored.

Real-world traffic involves multiple road users with different states and intentions. When multiple users are present, new types of interactions may emerge, including group dynamics [14] or altruistic cooperative behaviors (e.g. an AV warning a VRU about an oncoming third vehicle) [23]. These situations also present scalability challenges in communication [4, 24]. For instance, in scenarios involving multiple VRUs, the clarity of recipients can be compromised if an external Human-Machine Interface (eHMI) displays the message "Walk," without specifying which individuals it is directed towards [4, 5].

Furthermore, multi-agent environments challenge joint decision-making under uncertainty and necessitate multidirectional communication. This situation calls for AI methods capable of managing and interpreting information from multiple agents efficiently. Such approaches ensure consistency in behavioral responses among various road users (e.g. not displaying "Walk" when other cars do not intend to stop for VRUs). Additionally, computational modeling provides insights into human environmental perception and decision-making [6, 7, 11], as well as cognitive processes [19], thereby enhancing our understanding of how behaviors adapt to dynamic traffic conditions. Initial efforts in modeling driver and VRU behavior [15, 25] show promise. Consequently, discussing how computational modeling can support multi-agent research is highly relevant.

In short, the interactions between multiple road users in mixed traffic environments are complex and crucially important areas for investigation. While existing studies provide a foundation, they often limit themselves to simplistic scenarios (e.g. [10, 16, 21]). Recognizing these challenges, a workshop at AutoUI 2024 is essential to advance the discourse, fostering collaboration among researchers on finding suitable methods and practices to conduct multi-agent research.

2 RELATED WORK

Though few, attempts exist to move to more realistic multi-agent simulations. Bazilinskyy et al. [2] developed an open-source coupled simulator (Figure 1). This tool allows a virtually unlimited number of participants to meet and interact in a simulated scenario. Linking data from multiple agents allows 'observing' a traffic scenario from different perspectives. The simulator was used to investigate multi-agent collaboration in (1) an experiment visualizing eye contact between an AV passenger and a pedestrian (Figure 2) [17] and (2) an experiment where, in critical driver-pedestrian encounters, an eHMI instructed a VRU how to evade the collision [3]. Additionally, Feng et al. [9] introduced an innovative virtual reality (VR) setup that facilitates real-time interaction between two pedestrians using physical movements in a fully immersive setting.

From a cognitive psychology perspective, the impact of group dynamics on factors such as SA, workload and trust in AVs remains largely unexplored. A recent study by Momen et al. partly addressed this issue by analyzing conversations among groups of participants during rides in a Tesla Model X equipped with Autopilot [18]. The study found that most groups (94%) experienced feelings of risk and vulnerability, leading to shared negative emotions. Additionally, drawing on various sources such as direct observations, anecdotes and media reports, many groups (94%) engaged in discussions to explain and predict the vehicle's behavior. The authors suggest that these discussions facilitated the formation of shared mental models, potentially enhancing appropriate trust levels among group members. However, conclusions in the work of Momen et al. lack support from more objective behavioral indicators. This gap is currently being addressed by ongoing research of Bazilinskyy et al. [1]. In an immersive multi-agent driving simulator study, the authors employ three VR headsets to study how passengers in AVs interact and how these dynamics may influence their trust in the automated system. By analyzing participants' eye movements in relation to specific traffic situations, conversations, and seating positions, this study aims to identify new, effective methods for measuring trust within controlled group settings.

3 SCHEDULE AND ACTIVITIES

The workshop will consist of three sessions, as outlined in the tentative schedule and activities presented in Table 1. Required support includes desks, power sockets, a projector screen for sharing presentations, flip charts, markers, pens and sticky notes for use during group discussions.

Table 1: The tentative schedule of the workshop.

Activity	Time slot	Description
Introduction	09:00–09:30	Introduction of workshop topics and instructions for interactive online questionnaire. Introductions of organizers and participants.
Session 1	09:30–10:00	**Presentation**: Existing multi-agent automotive research.
Coffee break	10:00–10:15	Live demo of the coupled simulator [2] and networking.
Session 2	10:15–11:30	**Group work 1**: Do we need multi-agent automotive research?
Coffee break	11:30–11:45	Live demo of the coupled simulator [2] and networking.
Session 3	10:45–12:30	**Group work 2**: How can we advance the state of multi-agent automotive research?
Closing	12:30–13:00	Presentations of group work activities and wrap-up. Collection of the expression of interest to contribute to the positioning paper.

3.1 Initial engagement and introduction

Upon arrival at the workshop, participants will receive an interactive online questionnaire. They will be asked to share their opinions on the current state of multi-agent automotive research and on the necessity of advancing from single-agent studies to more realistic multi-agent investigations. The workshop will begin with the organizers' introduction, covering the anticipated topics and outcomes. Following this, participants will briefly introduce themselves, and their ideas on the state of single- and multi-agent automotive research.

3.2 Presentation: Existing multi-agent automotive research

Some of the organizers and/or invited guests will share their own experiences with multi-agent research and briefly present previous multi-agent studies they have been involved in.

3.3 Group work 1: Do we need multi-agent automotive research?

Participants will be divided into groups based on their research focus areas (e.g. human factors, psychological research, eHMI design, modeling). The organizers will guide discussions on topics including scalability, realism, policy, testing, and validation. The objective of this activity is to gather opinions from experts in both academia and industry to determine if there is a consensus on the necessity of conducting multi-agent studies in the automotive sector.

3.4 Group work 2: Actionable activities to advance the state of multi-agent automotive research

The various groups will engage in discussions aimed at advancing the state of multi-agent research within the AutoUI community. The major topics we aim to address are:

Figure 1: Multi-agent crossing scenario in coupled simulator [2]: AV passenger, MDV driver, and pedestrian (top); views of the three agents (bottom).

Figure 2: Laser visualizing eye contact between AV passenger (top) and pedestrian (bottom) in coupled simulator [17].

(1) How to reduce the complexity of conducting multi-agent research? Are there tools that exist/need to be created that can facilitate the design of such studies?
(2) How to make sure that current theories in the sub-fields of automotive research translate to the multi-agent paradigm?
(3) What algorithms and methods need to be updated/created to allow for multi-agent research in automotive?
(4) What are the implications of stepping up from the single-agent paradigm to the multi-agent paradigm in on-road research and simulator-based research?
(5) What are the consequences for data analysis when multi-agent interaction studies inevitably generate vast and complex datasets that are no longer within the bounds of traditional statistical modeling?

3.5 Wrap-up and post-workshop activities

The post-workshop activities will build upon the results of the workshop. In particular, we hope that the participants of the groups that worked together will engage in further discussion on the topic of the group discussion. Given that AutoUI is a small community, we anticipate that participants will develop concrete plans for conducting studies that replicate existing single-agent experiments or start new studies based on investigating research questions that require multi-agent setups.

4 ATTENDANCE

We are planning a half-day workshop and expect 15–20 participants (excluding the organizers). We will reach out to researchers and practitioners within our networks who may have an interest in the workshop topic, particularly attendees from the industry, in addition to the regular AutoUI participants.

5 EXPECTED OUTCOME

The workshop will provide the AutoUI community with a valuable assessment of the current state of multi-agent research in the automotive domain. Additionally, it will offer insight into whether practitioners see the need to "step up" to conducting research on automotive interfaces and human factors, featuring more than one human traffic participant. The results of the workshop will be summarized in a position paper, which will include openly available supplementary material containing summaries of the group discussions.

6 BIOGRAPHIES

Pavlo Bazilinskyy is an assistant professor at TU Eindhoven focusing on AI-driven interaction between automated vehicles and other road users. He finished his PhD at TU Delft in auditory feedback for automated driving as a Marie Curie Fellow, where he also worked as a postdoc. He was the head of data research at SD- Insights. Pavlo is a treasurer of the Marie Curie Alumni Association (MCAA).

Patrick Ebel is a Junior Research Group Leader at the Center for Scalable Data Analytics and Artificial Intelligence (ScaDS.AI) at Leipzig University. He received his PhD. in Computer Science from the University of Cologne and his MSc in Automotive Systems from the TU Berlin. His research focuses on the analysis of large naturalistic driving data and computational models for human-vehicle interaction.

Francesco Walker is an assistant professor at Leiden University (NL). He received his PhD from the University of Twente (NL), with a dissertation focused on the assessment and calibration of driver trust in automated vehicles. In Leiden he founded the HAT Lab, a research group that studies how Humans interact with Art and emerging Technologies.

Debargha Dey is a postdoctoral researcher at Cornell Tech, with a research focus on human-automation interaction. He received his PhD in Industrial Design from TU Eindhoven and has 8+ years of experience in the domain of human factors for automated driving and traffic behavior.

Tram Thi Minh Tran is a postdoctoral researcher at the University of Sydney, Australia. She holds both her Master's and PhD degrees from the same university. Her research explores the applications and implications of emerging technologies, with a particular focus on AR/VR and autonomous mobility.

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