Implications for Interactions Between Micromobility and Autonomous Vehicles

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Abstract

This work discusses potential interactions and impacts between autonomous vehicles and micromobility. While fully automated privately owned AVs are not yet commercially available to the public, robotaxis, shuttles and delivery bots are becoming increasingly common, especially in densely populated urban areas. New types of micromobility devices, such as e-scooters are also being introduced into the same areas. While extensive research and safety testing exist for both domains, potential interactions between these two types of mobility in real world environments requires consideration. By exploring the current state of both technologies and early evidence currently available, we catalogue the potential implications of their interactions, particularly with respect to communication, expectations, infrastructure, risky behavior, and the impact of data limitations.

Introduction

Micromobility

Micromobility refers to "a category of modes of transportation that includes very light, low-occupancy vehicles such as electric scooters (e-scooters), electric skateboards, shared bicycles, and electric pedal assisted bicycles (e-bikes)". U.S. Department of Transportation Bureau of Transportation Statistics.

e-Scooters

Issues such as space sharing and safety concerns have negatively influenced public perceptions of e-scooters. Some common issues include:

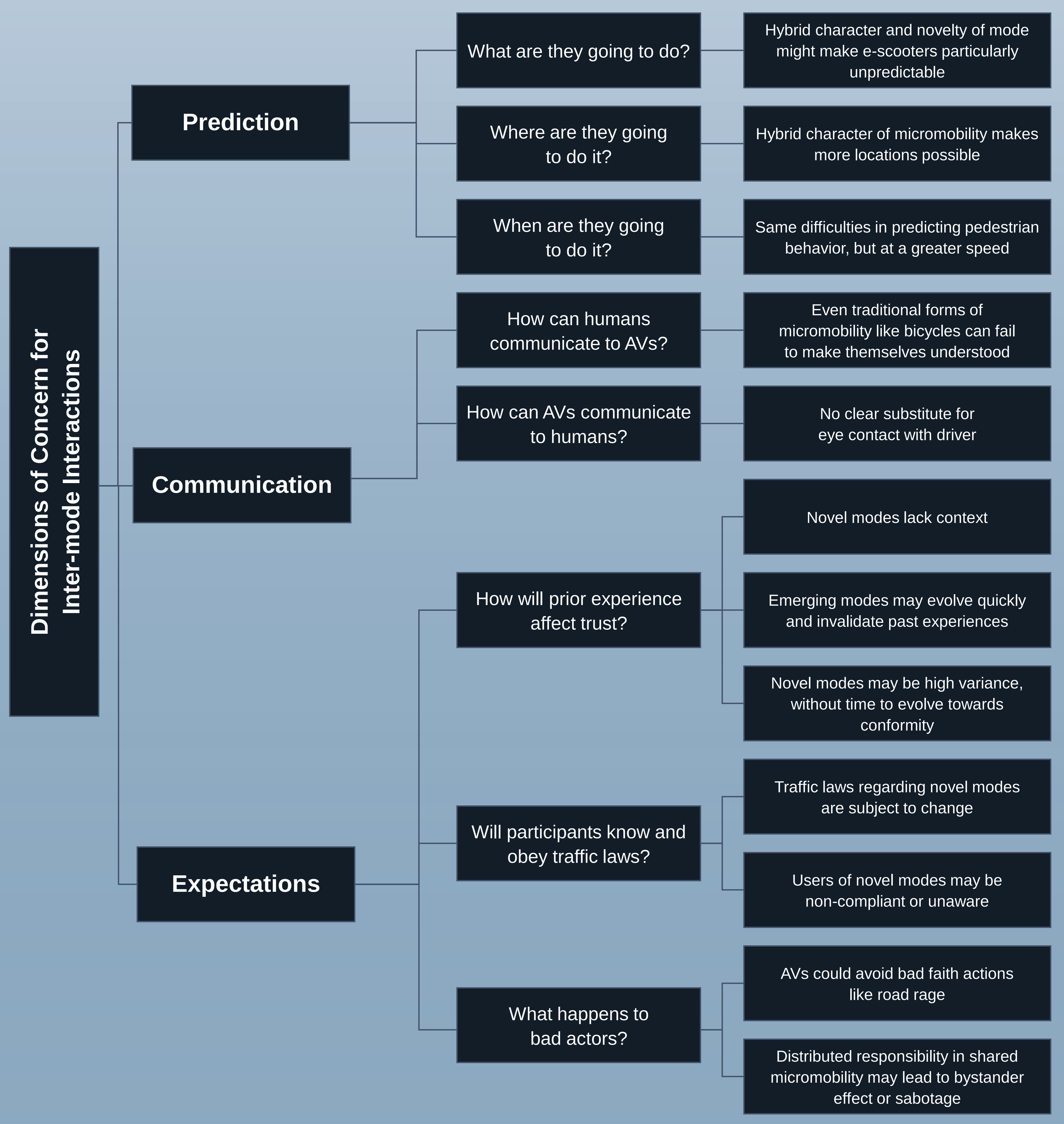
- Parking
- Sidewalk riding
- Safety
- Inconsistent regulations

Autonomous Vehicles (AVs)

AVs rely on machine learning (ML) models to predict and understand their environment. Recent advancements in ML allow AVs to perform well in predictable situations or on known routes. However, limitations and lack of transparency in AV ML raise risks, including:

- Domain shift (drift between the original context of the data and the application of the model) and cybersecurity vulnerability
- Lack of information/misinformation among both consumers and car salespeople, worsened by advertising terminology (e.g., "autopilot")
- The transition between driver-in-control and the automation-in-control
- Adversarial attacks: Black-box attacks that function as a mirror of the original model –reverse engineering the AV ML mode to create deceptive input that the model will classify incorrectly

Concerns



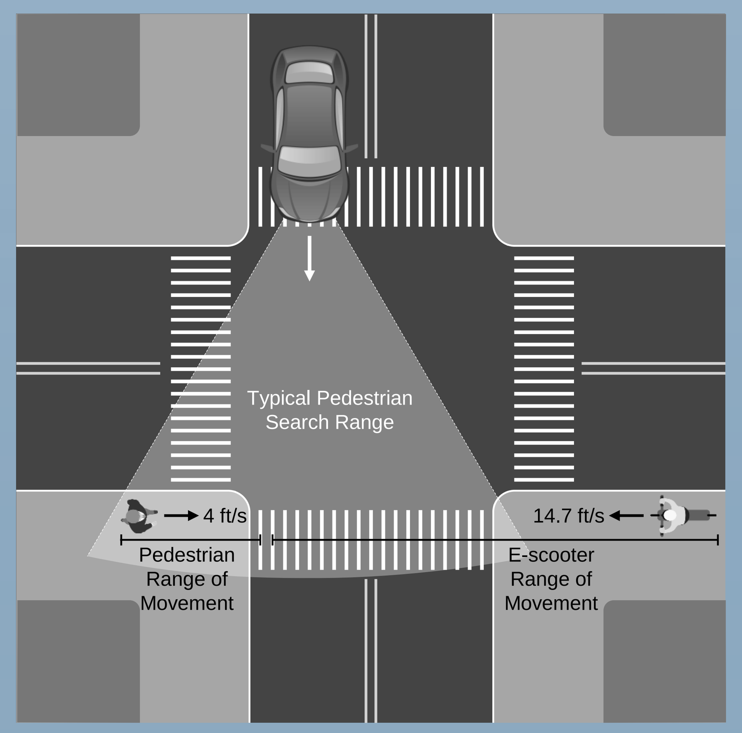
Communication

- Even in a scenario with a highly automated vehicle able to detect vulnerable road users (VRUs), the VRUs may have no way of knowing if they have been detected or even realize they are interacting with an AV. Human drivers and VRUs often communicate their intentions non-verbally, such as nodding or eye contact. Without a way to replicate these cues, AVs must be designed to communicate their intentions in other ways.
- Micromobility users must also be able to communicate their intentions to other road users, which will include AVs. While hand signals common to cyclists exist, they may be challenging for novice e-scooter riders to use. One solution for this issue involves including using signaling mechanisms on micromobility devices so riders could better communicate their intentions, however these have not been widely employed.

Concerns

Prediction

- Human behavior can be difficult to predict, even for humans; models have also struggled to accurately describe human behavior and often generalize poorly.
- E-scooter users often switch between travelling with traffic, against traffic, on the sidewalk, in the crosswalk, and in the road. These kinds of novel behavior could be particularly unexpected to AVs, which may incorrectly apply context clues like "is standing" and "is travelling on sidewalk" to misclassify a micromobility user as a pedestrian.
- Timing may also pose a challenge. While many models use datasets that focus on a time-to-event horizon such as 1 second or 2.5 seconds, an e-scooter will be moving at a very different speed. **A pedestrian walking at 3 miles per hour is only moving at 4.4 feet per second, covering about 11 feet in that 2.5 second window; an e-scooter going 10 miles per hour is covering 15 feet per second and would cover 38 feet in that same window. The difficulty of this geometry is illustrated below.** This not only makes the prediction task more difficult because of the difference between the training data case and such a scenario, but it also means the prediction must be done that much faster to avert a crash.



Expectations

- Interactions in the transportation system are largely dictated by expectations, formed by prior experience and predefined routine actions.
- AVs of today are trained on data gathered from human-driven vehicles, rather than other AVs. This means that the datasets are limited to containing information about how other transportation users behave with human-driven vehicles – not how they will behave with AVs – and that human response to AVs will vary considerably between individuals.
- The higher the level of trust, the greater the potential for exploitation from bad actors. A pedestrian who knows that an AV can and will always stop for them has little incentive not to jaywalk, and VRUs have already reported engaging in exactly such risky behavior.

Recommendations

Current evidence suggests that AVs cannot detect VRUs as well as they can detect other vehicles and cannot detect micromobility devices as well as they can detect pedestrians. Researchers should continue to evaluate the needs of both nascent technologies as they develop and interact, and the infrastructure needs for each become clearer. Some recommendations include:

Infrastructure

- Historically, road networks have prioritized motor vehicles over VRUs. Micromobility crashes often result from a lack of safe infrastructure (such as connected bike lanes). This is especially important to micromobility users because poor surface conditions put them at risk of destabilization.
- Potential solutions include creating street types specifically devoted to VRUs and slow-moving automated vehicles; implementing AV toll lanes that would require human-driven vehicles to pay, but not AVs, offering increased separation between AVs and VRUs; and integrating "smart city" technologies to improve communication between AVs and infrastructure.

Safety Data

- As there is no universal repository of crash data in either the domain, researchers are left to acquire data piecemeal through medical and police reports. This means that their work tends to be limited, incomplete, and relies non-standardized methods.
- Potential solutions include developing data sharing partnerships that include researchers, regulators, and developers and traceable data logging that is tied to specific hazards. Methods for gaining and standardizing existing data should be developed, and procedures for widespread reporting investigated.

Risky Human Behavior

- Prioritization of non-occupant safety could create tension between AV occupants and non-occupants. While some have suggested VRUs should moderate their behavior to behave more predictably, this has been met with criticism – as one promise of AVs has been that they would increase safety, suggesting this can only happen if human behavior also changes effectively limits the benefit of AVs.
- AV technology could give rise to poor behavior on both the part of micromobility users (e.g., behaving unpredictably/failing to follow rules) and AV users (e.g., bypassing safety systems) that could interact and have disastrous consequences.
- Potential solutions could include investigating methods of increasing rule compliance and studying previously observed misuse in both domains to understand how those behaviors might interact.

Communication and Expectations

- It is not yet clear how AVs will communicate with others. Communication methods that exist for interactions between VRUs and human drivers (e.g., eye contact and body language), do not translate well into the AV domain.
- Potential solutions include exploring which methods of communication are most effective between AVs and VRUs. These solutions should be easy to understand by the full spectrum of VRUs (e.g., children, people with disabilities, and people with language limitations) and should not put the burden on VRUs. It will be important to continuously evaluate evolving expectations and update AV models based on emerging behaviors.