Where do we go from here? Predictability in tomorrow's traffic.

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Abstract

This extended abstract explores the various aspects contributing to predictability in a traffic environment, and how these aspects drastically change through the introduction of automated driving systems. Such automated systems will need to share the environment with humans, raising questions about how predictability can be achieved in such a way that automated systems can predict human behaviour and humans can predict the behaviour of automated systems. The talk presents an overview, research questions and a preliminary framework as a basis for discussion.

Predictability is the holy grail of safety research, as the correct anticipation of other agents' behaviour is crucial for adequate trajectory planning. A lack of predictability, in contrast, increases cognitive load and restricts the attentional focus, which can have fatal consequences when neglecting additional events and road users.

Within complex traffic and road use environments, predictability of different actors is foremost determined by simply understanding objects and their laws of physics. More notably, however, predictability is further increased by applying a) road rules/laws in combination with infrastructure (e.g., stop at red light), b) communication of intention between actors (e.g., indicating a turn), c) social and cultural norms, and more recently d) technologies such as C-ITS applications and in-car HMIs that extend the awareness horizon.

The introduction of automated driving systems drastically changes the notion of predictability in traffic environments, which are now shared between humans and essentially robots. This perspective raises critical research questions: How do we need to change the road rules and the design road of infrastructure so that human behaviour is easier to be predicted by machines and also, machines' behaviour can easily be predicted by humans? Is the latter desirable or will it lead to driving robots being bullied by human road users? How are intentions communicated between the automated car and the driver in both directions within the car as well as other road users outside the car? How do social and cultural norms need to be embedded in automation algorithms, and how do automated systems challenge and change those norms? In what way can novel HMIs be designed to support these aspects?

This talk presents an overview of the current state of the art and research in those areas. It presents a preliminary framework of predictability based on motion patterns and means of explicit communication, but also accounting for the impact of general rules and individual expectations. This framework (depicted in Figure 1 and summarised in Table 1) is suggested as a foundation for modelling actions and reactions in diverse types of traffic participants, including both automated and non-automated agents. It takes into account information previously analysed to identify behavioural patterns, but also refers to novel concepts currently investigated. It furthermore gives an outlook on potential supplementary technologies, which can represent an additional source of information in the case of automated driving. Current and future concepts are evaluated with regard to their respective value for real-time judgement in complex traffic scenarios featuring multiple agents, highlighting potential shortcomings and open issues.

Table 1. Prediction framework between AVs and various human road users

<table>
<tr><th>Directed Prediction</th><th colspan="2">Information Sources</th><th>New Technologies</th></tr>
<tr><td>1. AV operator predicts AV</td><td>• HMI
• Trajectory
• Previous experience of driver with automation
• Navigation and Routing
• Automated driving style settings (eco/fast/…)
• Known limits of automation</td><td rowspan="9">• Laws of physics
• Weather, visibility & day time
• Traffic Rules
• Cultural behavior
• Infrastructure</td><td></td></tr>
<tr><td>2. AV predicts Operator</td><td>• Driver state modelling (drowsiness, gaze behaviour, reaching and grasping, …)
• Driver model (driver classifiation, previous experience based on machine learning)</td><td></td></tr>
<tr><td>3. AV predicts Cyclist</td><td>• Trajectory
• Verbal & Gestures
• Cyclist state modeling (Head and gaze direction, …)</td><td rowspan="4">New ways of communication (V2X, V2V) and data fusion (backend information about traffic participants) might enhance the AVs ability to predict traffic out of sensor reach.</td></tr>
<tr><td>4. AV predicts Pedestrian</td><td>• Trajectory
• Verbal & Gestures
• Group dynamics
• Pedestrian state modeling (Head and gaze direction, …)
• Demographics</td></tr>
<tr><td>5. AV predicts Car</td><td>• Signals (indicator, brake lights, horn, flash lights)
• Trajectory
• Driver gestures
• Vehicle to vehicle communication
• Driver state modeling</td></tr>
<tr><td>6. AV predicts Tram</td><td>• Vehicle to everything communication
• Tracks
• Signals (indicator, horn)</td></tr>
<tr><td>7. Cyclist predicts AV
8. Pedestrian predicts AV
9. Car predicts AV
10. Tram predicts AV</td><td>• Signals (indicator, brake lights, horn, flash lights)
• Trajectory
• Driver gestures
• Driver state modeling</td><td>• External HMIs
• New road infrastructure
• V2V, V2X</td></tr>
<tr><td>11. AV Operator predicts traffic</td><td>• Trajectory
• Verbal & Gestures
• Demographics
• Group Dynamics
• Signals
• Tram Tracks
• State Modeling
• Experience in Traffic</td><td></td></tr>
<tr><td>12. Traffic predicts AV Operator</td><td>• Verbal & Gestures
• Driver State</td><td></td></tr>
</table>

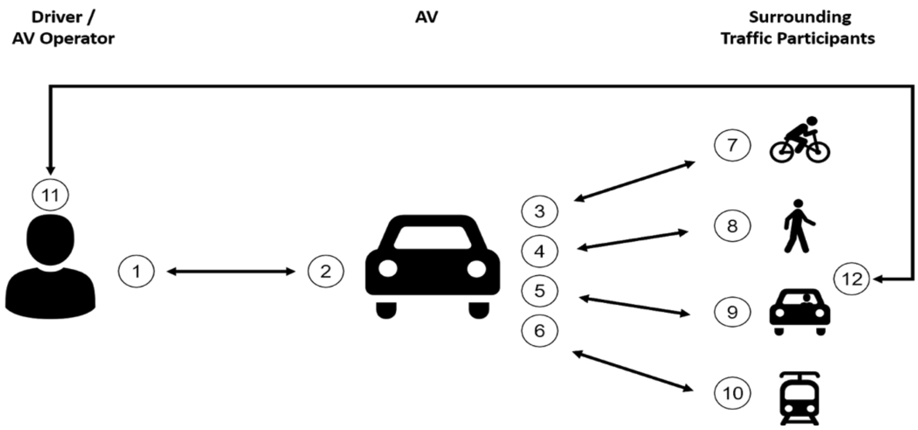

Figure 1. Where AVs might influence predictability in a future traffic mix