Analysis of Bicyclist Communication Patterns Using a Simulator Environment for AV Applications

Master's Thesis of Patrick Malcolm

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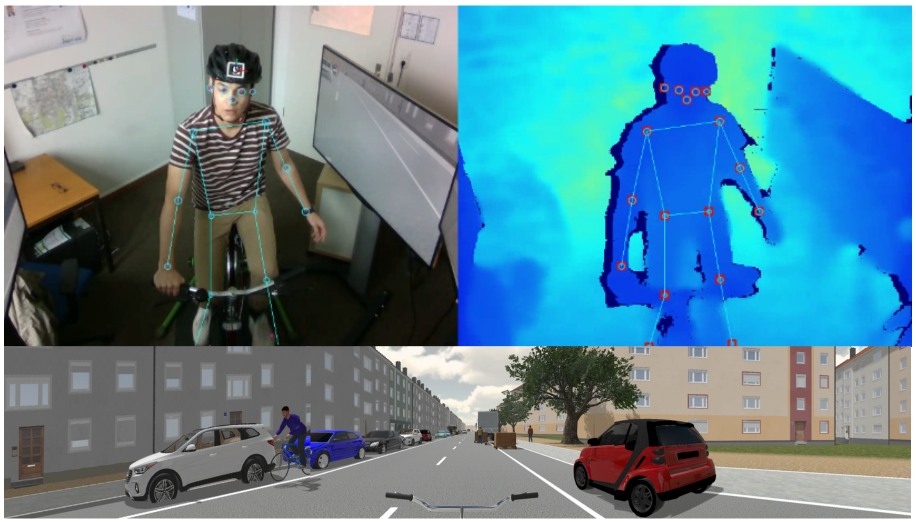

Fig. 1: Markerless motion capture using depth camera (top) and simulated traffic environment (bottom).

Autonomous vehicles promise to greatly improve the safety and efficiency of vehicular transportation, but there are a number of challenges which must be overcome before their widespread use is feasible, among which is accurate and reliable communication between the vehicle and other road users. Traffic, particularly in an urban setting, is a dynamic environment in which both formal and informal forms of communication between traffic participants is employed. In order for autonomous vehicles to operate effectively in such an environment, they must be able to detect and interpret the communicative behaviors of those around them. In particular, understanding cyclists' communication patterns is crucial for a number of reasons, including the fact that cyclists are vulnerable road users that often share common infrastructure with vehicles, and that bicycles are are typically not outfitted with standardized indicators, meaning that there is more room for variability and subtlety in the way they communicate.

This thesis consists primarily of a bicycle simulator study in which participants ride through various traffic scenarios in an urban environment in which explicit and implicit communication behaviors are expected. During the trials, participants are recorded by a depth camera, and a markerless motion capture technique is used to record their movements in three dimensions. From this data, gestures are extracted and analyzed and the communication patterns of the participants is compared between scenarios. Participants also filled out a questionnaire collecting demographic and cycling-related information as well as asking them to specify which communication behaviors they would perform in the various scenarios, and these responses were compared with the observed results from the simulator. In addition, the motion capture algorithm was adjusted based on the results of the data collection in order to detect arm signals in real time so that this information can be fed back into the simulation in future studies.

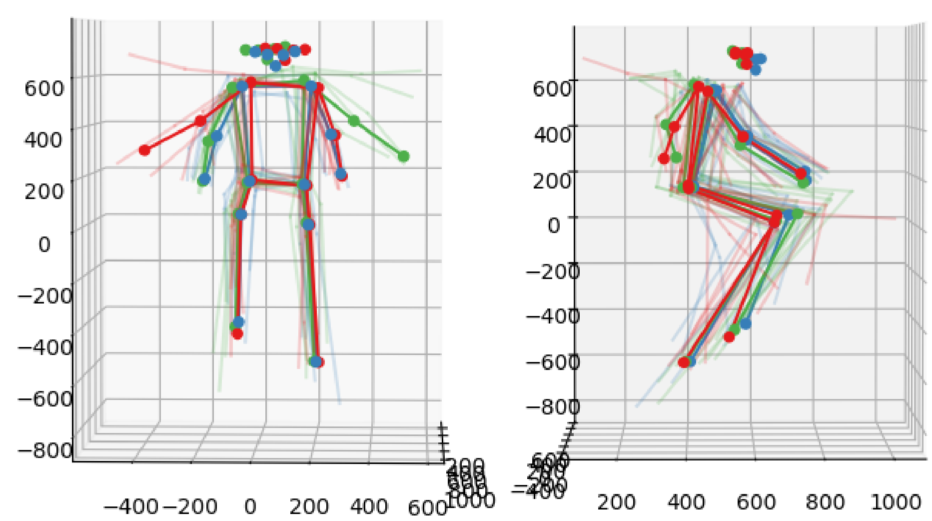

Fig. 2: Median poses for normal riding state (blue), left turn signal (green) and right turn signal (red). Front- and side-view.

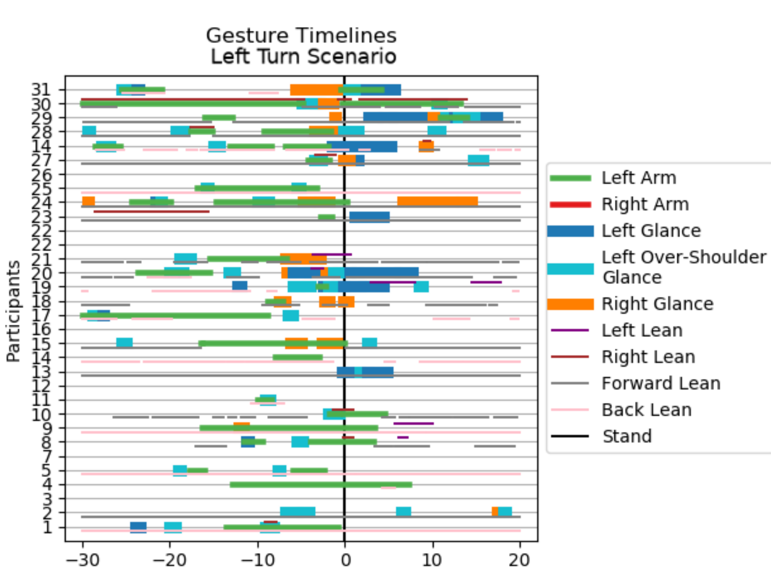

Fig. 3: Gesture timeline of each participant during left-turn scenario

The results of the analyses showed that even in clearly regulated scenarios, not all participants gave a formal signal of intent such as an arm signal. However, some informal cues show promise as indicators of intent in the absence of a formal signal, as a correlation between head movements and intended maneuver was found in some cases. Most notably, participants were significantly more likely to look over their left shoulder before turning or changing lanes to the left, for example. It was also determined that in order for autonomous vehicles to reliably detect both formal and informal cues of a cyclists, measuring or estimating the longitudinal component of the cyclist's pose is important, as the lateral and vertical components alone do not provide enough information in some cases to differentiate between gestures.