

# Behavioural Analysis of Cyclist Gesturing in Relation to the Proximity of Other Road Users and Infrastructure

## Master's Thesis of Aleesha Robert Jerald

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### RESEARCH MOTIVATION

Gestures play an important role in **non-verbal communication** when formal traffic signals are absent.

Understanding how cyclists use gestures to communicate intent with other road users can improve:

- Road design
- Cyclist safety
- Human interaction with AVs

Where do cyclists gesture? (spatial distribution)

How does the speed change while gesturing?

Do cyclists gesture near a bus?

### STUDY FRAMEWORK

- Simulator-based cycling study (CAVE + SUMO, based on Böckle [2024]), around TUM campus.
- 8 urban traffic scenarios introduced:
  - With/without traffic,
  - With/without e-HMI (stop, arrow, floor projection).
- 30 participants completed the study.
- Gestures were integrated with simulator telemetry data.
- Consecutive TRUE frames = 1 Gesture event.
- 4 types of gestures detected: right and left-hand raises, right and left-head turns.



Fig 1. Gesture Recognition (Left Hand Raise)

### VISUAL ANALYSIS

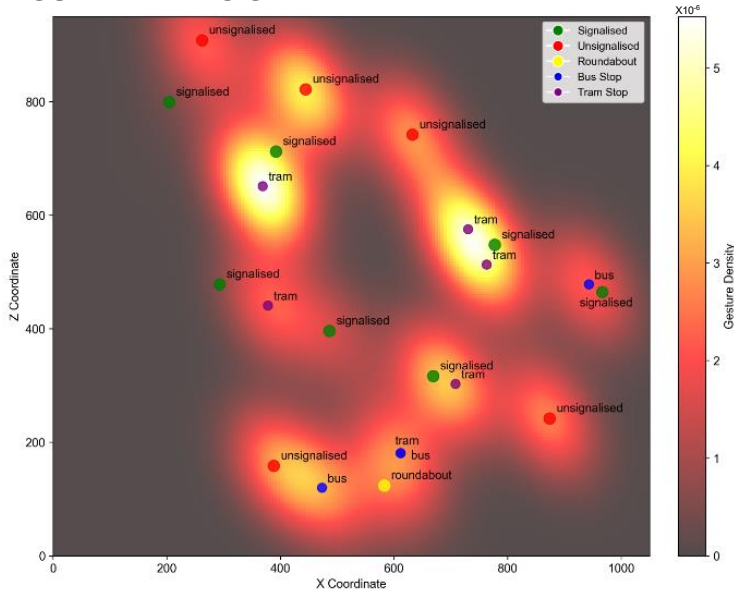


Fig 2. Gesture Event Heatmap

- KDE heatmap shows spatial gesture densities.
- 98% of gestures occur 50m of the intersection/stops.
- 40.1% gestures near intersections and 38.6% near stops.
- 20% occurred near intersections accompanied by stops.

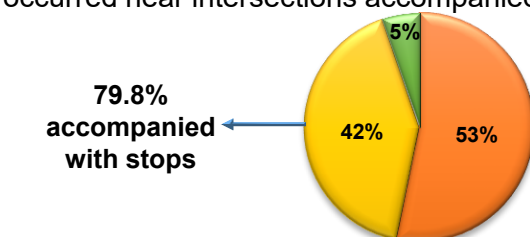


Fig 3. Gestures by Intersection Type

### Gesture Speed Analysis

- Compared the average cyclist speed during gesture and adjacent non-gesture events.
- Both calculated for the same time period.
- **Gestures are integrated with continuous motion.**

Gesture Behaviour

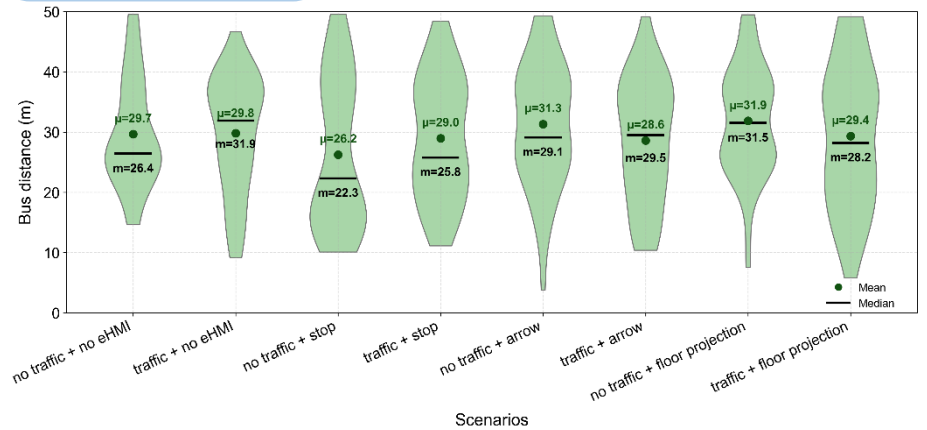


Figure 4. Gesture Events Near 50 m of Automated Shuttle Bus

- Cyclists gesture mostly when the bus is within 20-30m of them.

### RESULTS

#### Logistic Regression Model and Probability Plots:

A binary regression model with a 2300-sample space (1150 gestures and 1150 non-gestures) showed that cyclists gestured more when near an intersection/stop, and within 50m of an automated shuttle bus.

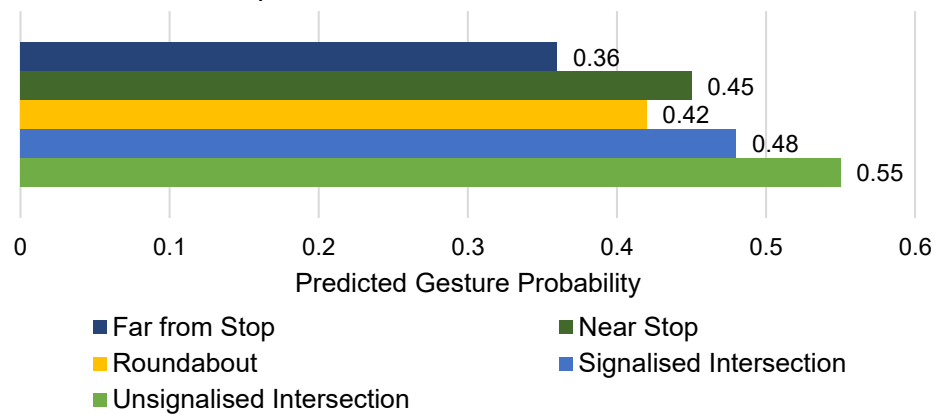


Fig 5. Probability of Gestures at Intersections and Stops

### Behavioural Model:

Low Complexity  
(Simple Environment)

High Complexity  
(Traffic + eHMI)

Anticipatory Gestures  
(Early • Far • Proactive)

Reactive Gestures  
(Late • Near • Responsive)

#### Spatial Context:

- Gesture clustering at signalized intersections along with nearer stops
- Highest density where interaction demand is more

#### Dynamic Context:

- Gestures integrated into motion (no Speed reduction)
- Continuous kinematic behaviour

#### Proximity Context:

- Gesture occurrence increases with proximity to busses
- Context – dependent, proximity driven signalling

#### Adaptive continuum:

Gestures shift from anticipatory to reactive as environmental complexity increases