Technical University of Munich
School of Engineering and Design
Department of Mobility Systems Engineering
Chair of Traffic Engineering and Control

Predicting Pedestrian Crossing Intention at Signalized Intersections Using Roadside LiDAR Sensors

Santiago Álvarez-Ossorio Martínez[1], Martin Margreiter[1]

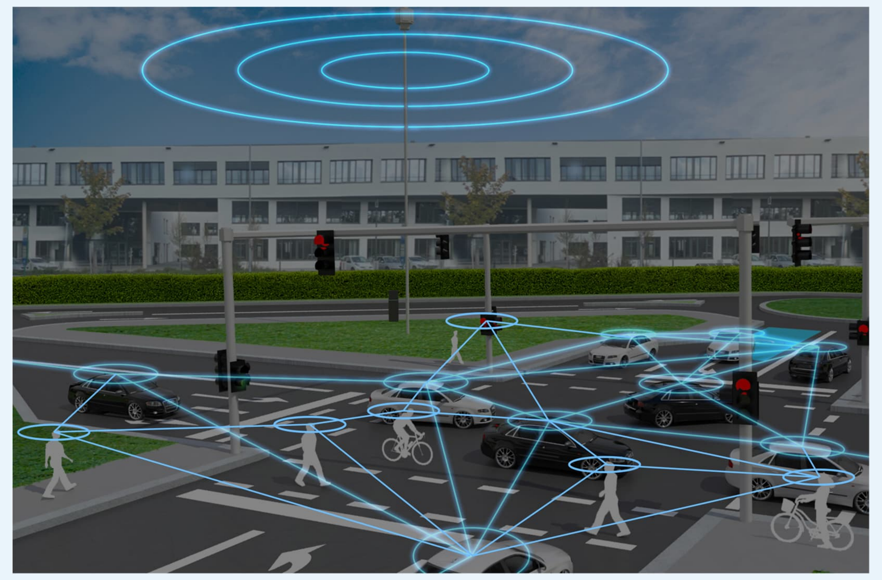
[1]Chair of Traffic Engineering and Control, Technical University of Munich

Motivation

- The detection and monitoring of all traffic participants in urban areas is necessary to implement advanced traffic control measures and to enable the future operation of automated driving vehicles.
- LiDAR sensors could be a solution to detect and track vulnerable road users while respecting their privacy.
- LiDAR tracking data could be employed to anticipate pedestrian behavior.

Research Questions

- Are roadside LiDAR systems adequate to detect and track pedestrians?
- Is it possible to predict pedestrian crossing intention at signalized intersections using LiDAR tracking data?
- Which features and model types are relevant for predicting the crossing intention?



Rendering of the future TUM test bed for connected and automated driving, where the crossing intention algorithms will be tested

Contact information & Paper download

Santiago Álvarez-Ossorio
santiago.alvarez@tum.de
SCAN ME

Martin Margreiter
martin.margreiter@tum.de
SCAN ME

Paper download
TRBAM-23-03327
SCAN ME

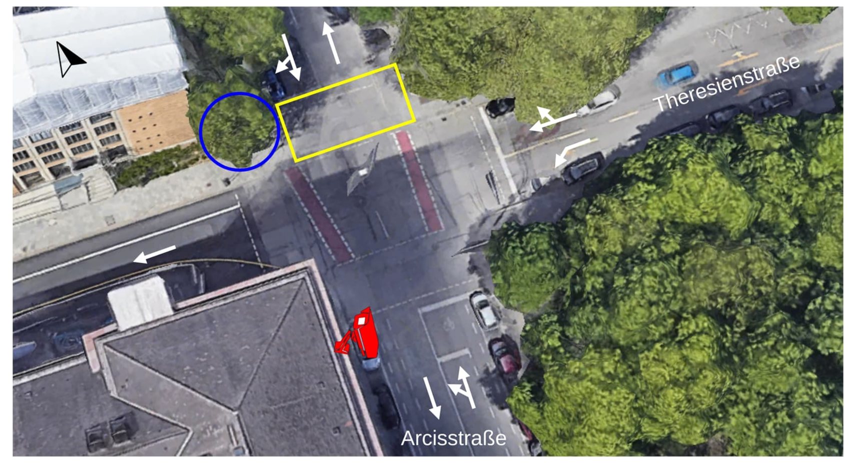
Information about TUM test bed for connected and automated driving
SCAN ME

Acknowledgements

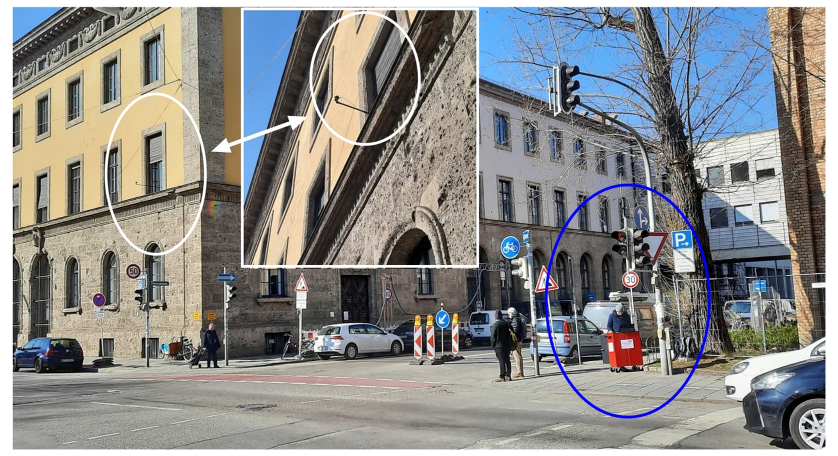
The authors would like to thank LiangDao GmbH for collaborating in the data collection and providing us with the data.

Data collection

- Data collected in March 2022 at a signalized urban intersection in Munich, Germany with high vehicle and pedestrian traffic levels.
- 118 pedestrians tracked at 10 Hz in the studied intersection crossing.
- Object list with the position and type of the road users (motorized vehicle, pedestrian, cyclist) generated with a commercial software used to fuse the point clouds of two LiDAR sensors (long-range OS1-64 and blind spot RS-Bpearl sensors).
- Traffic signal state (green/red) of the pedestrian crossing recorded simultaneously and included as a feature of the model.
- Additional video footage of the intersection to validate the trajectory of each pedestrian and to label them as crossing/non-crossing.



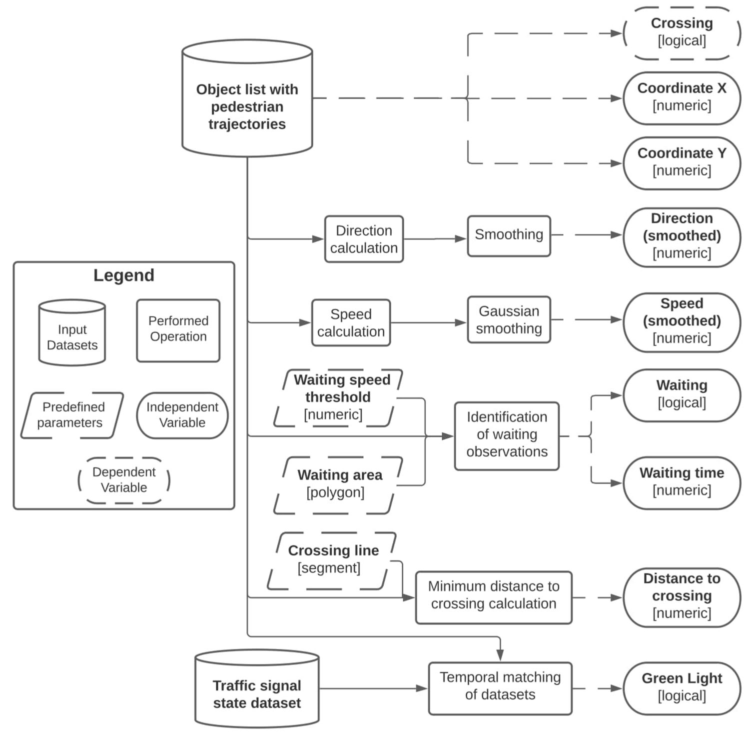
Location of the studied crossing (yellow), LiDAR sensors (blue), and camera (red)



View of the LiDAR sensors (blue ellipse) and camera (white ellipse) at the intersection

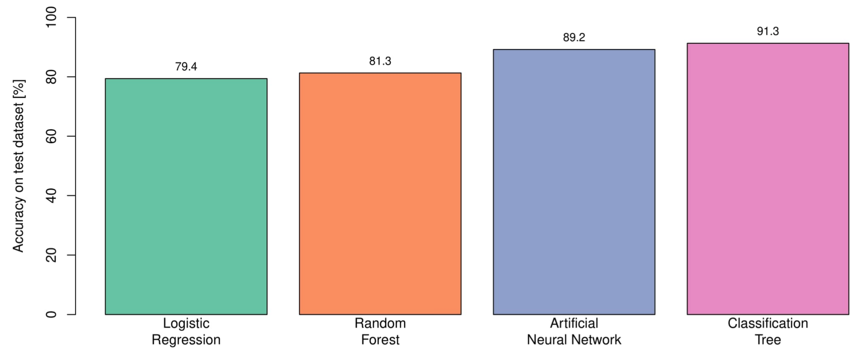
Feature generation process

- After individual inspection of all pedestrian trajectories, 78 trajectories (8,310 points) within 5 m from the crossing line were preserved.
- 39 crossing pedestrians and 39 non-crossing pedestrians.
- Generation of eight features using the LiDAR-obtained trajectories and the traffic signal state:
  - Five features adapted from existing studies for unsignalized intersections.
  - Three newly proposed features accounting for the pedestrian behavior at signalized intersections.



Prediction Models and Results

- Crossing intention considered as a binary classification problem (crossing/non-crossing).
- Following existing approaches in the literature, the algorithms generate a prediction for each individual frame and pedestrian.
- Thus, the prediction for each frame is independent of the previous/posterior predictions.
- Literature review and exploratory modelling to identify the four most relevant classifiers (random forest, logistic regression, classification tree, and artificial neural network).
- Ten pedestrians (five crossing and five non-crossing; 1,545 observations) randomly selected as test dataset. Train dataset containing the remaining 68 pedestrians (6,765 observations).
- Evaluation of the models' performance in terms of their accuracy on the test dataset.
- To improve the prediction accuracy against incorrect predictions occurring in a small number of frames, majority vote considering five frames (current and the preceding four).



Conclusions

- Pedestrians can be successfully tracked using roadside LiDAR sensors, but multiple sensors are needed to monitor the whole intersection and to reduce the effect of occlusions.
- Already-published pedestrian crossing intention formulations can be successfully adapted to signalized intersections.
- The ANN model and the Classification Tree provide more accurate predictions.
- Relevant features are proposed and tested for signalized intersections.
- The accuracy of the intention prediction models will remain limited by multiple factors, such as the motion variability of pedestrians, the reduced number of reflected points at large distances to the sensor and the limited accuracy of the pedestrian tracking.

Possible future applications

- Activation of pedestrian prioritization signal control measures
- Substitution of push buttons
- Triggering of warning signal for nearby drivers
- Communication of the pedestrian position and crossing intention to approaching vehicles (I2V) to adapt their trajectories and increase safety and efficiency of the traffic flow