Radar-based traffic analysis in smart cities
In demand during the pandemic: anonymous, affordable traffic monitoring
Application examples of radar

- Easily acquired statistics of urban mobility, e.g. to monitor the spread of the pandemic and current willingness of the population to stick to the rules
- Tracking of bicycle traffic: where to build or not to build new bike lanes?
- Smart traffic lights, safer & faster intersections
- Dynamic highway use regulation depending on the time of the day
A bike lane is needed.

253 cars per minute.

Trucks in a residential area.
Visualization
Data: challenges

- a very small dataset (375 radar maps, mostly one target)
- overlapping boxes
- resolution often not sufficient for pedestrians
- the classes are not equally represented (5 pedestrians, 66 cars, 332 trucks)
- no directional information (only range)
- high noise background
Solution 1: decision tree on higher feature vectors

1. CFAR to detect peaks (preceded by Gaussian filter). Count objects
2. Place bounding boxes of uniform size around peaks
3. Extract higher feature vector containing box statistics
4. Train decision tree classifier on higher feature vectors
5. Simultaneously evaluate object detection and classification
How is accuracy defined?

- True positive
- False positive
- False negative
Solution 1: results

- Pure classifier accuracy: **92.9%**
- Detection + classification accuracy: **70.7%**
- Counting accuracy: **73.1%**
Solution 2: peak detection → CNN classification

1. Optional: detect peaks to generate bounding boxes, e.g. using DBscan

2. Pad bounding boxes of targets to make them uniformly sized

3. Apply CNN classifier to cutouts

4. Result: Class 3 (truck)
CNN architecture

Doppler Image

conv2D  conv2D

Dense  Dense  Dense

Soft-max
Solution 2: results

model accuracy

Confusion matrix

pedestrian
car
truck

accuracy
epoch

(0.0000 0.0833 0.0093)
(1.0000 0.5000 0.0640)
(0.0000 0.4167 0.9259)
Solution 3: R-CNN for simultaneous detection and classification

- Problem: number and size of radar targets not fixed
- Solution: region based CNNs: region detection and classification
- We used: Fast R-CNN (2015)

Outlook and remaining tasks

• More pedestrians and cars needed in the data to test the classifiers
• More data needed to train Faster R-CNN. May need to change significant parts
• Bottleneck: error-prone peak detection.
• Solution: try new peak/blob detection algorithms, preprocessing of radar images in advance, or forego peak detection completely
The radarheads

Yulia Kostina  
TUM  
TopMath

Vladislav Klass  
TUM  
Robotics, Cognition, Intelligence

Arthur Kosmala  
LMU & TUM  
Theoretical and Mathematical Physics

Marc Machaczek  
LMU & TUM  
Theoretical and Mathematical Physics

Massin Guerdi  
LMU  
Physics