Light Skeleton Detection:

Utilizing vehicle light positions for angle agnostic signal state detection

Jonas Benjamin Krug, Martin Ludwig Zehetner & Yuan Xu
Distributed Artificial Intelligence Laboratory, Technical University of Berlin, Germany

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AI for autonomous mobility

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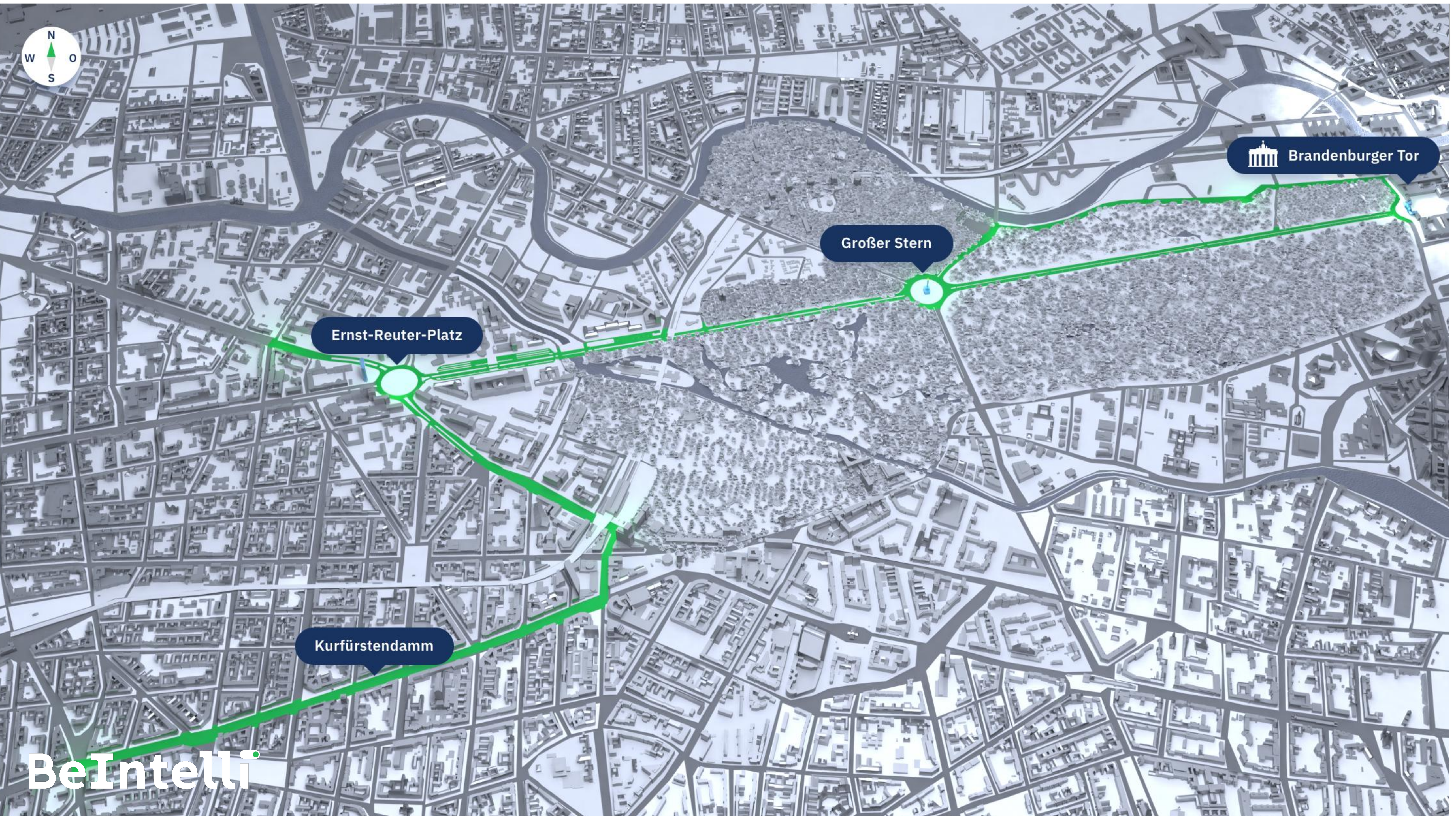


Introduction

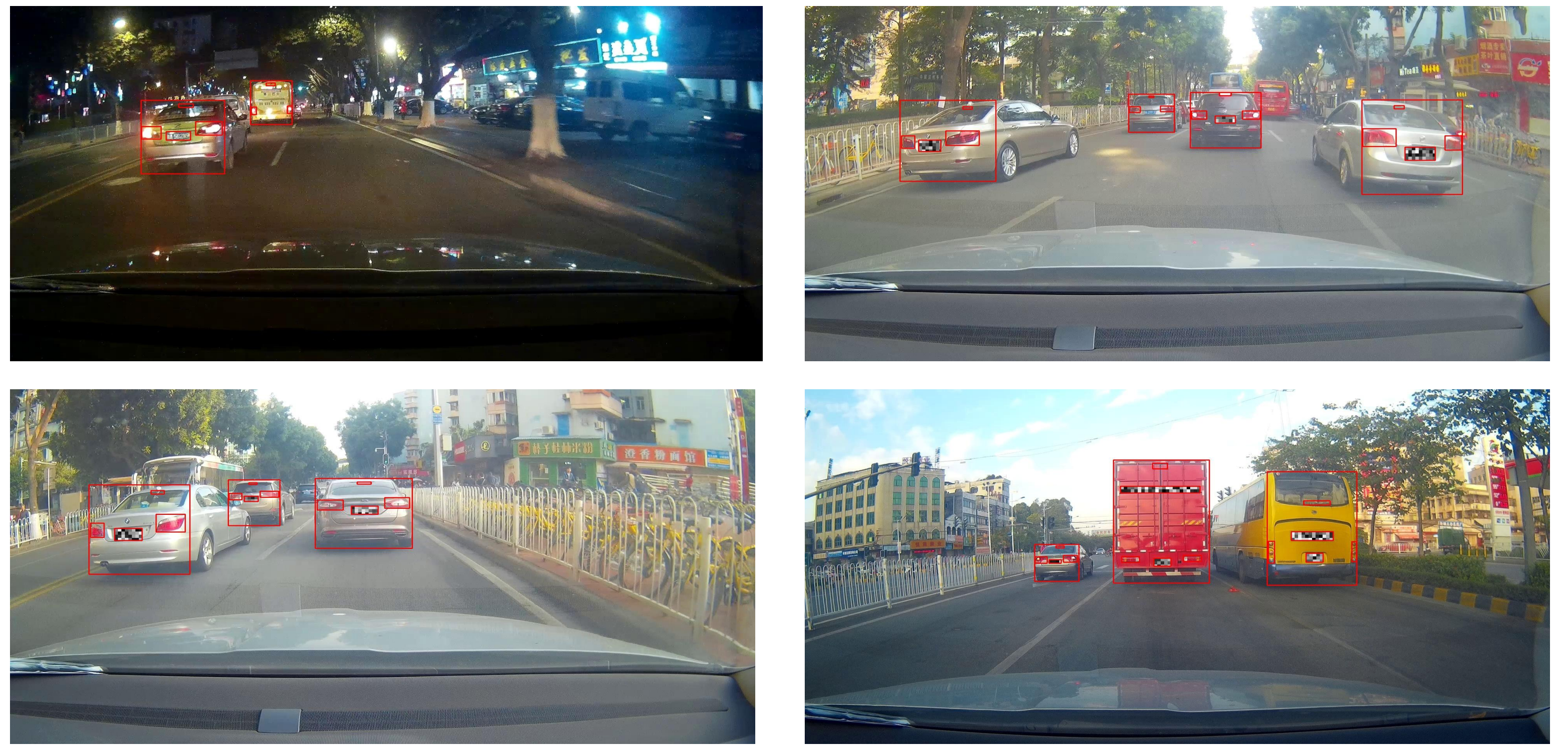
- A vehicle's lights can give critical insight about its intended behaviour
- Autoware currently has no module to detect such lights and their state

Background

Number of openly available datasets in relevant task domains (e.g., Vehicle Light Detection, Signal State Detection, etc.) is small & existing datasets largely share some common drawbacks:

- existing datasets focus mainly on the rear or front of observed vehicles
- often only a (single) front mounted camera is used to capture traffic scene
- annotated side views or different angles are often severely underrepresented or non-existent

Vehicle Lights Dataset @AUT

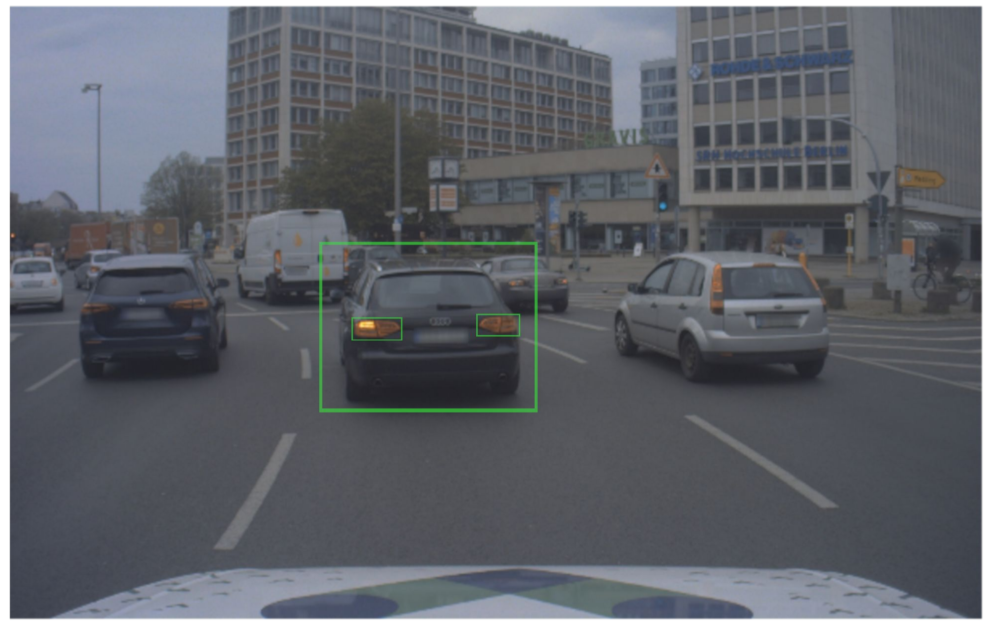


Vehicle Light Signal (VLS) Dataset

Background

Proposed solutions overwhelmingly (partly due to nature of available data) focus on detecting brake or turn signals based mainly / solely on the rear lights of observed vehicles:

- ❖ Solutions typically utilize (implicitly or explicitly) two-phase approach



Vehicle and/or Vehicle Light Detection

Leverage

Signal State Detection

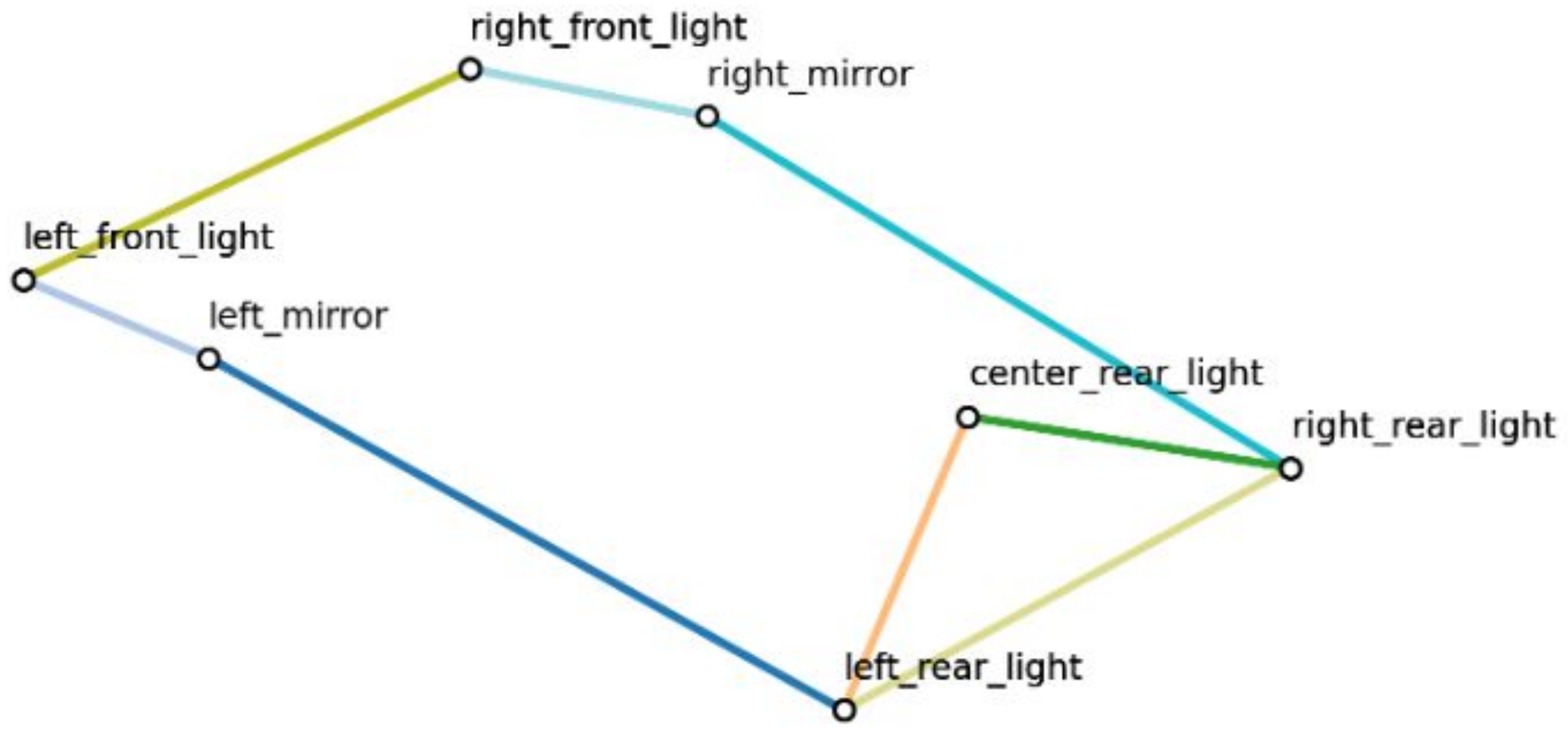
Currently, Autoware lacks any implementation for detecting vehicle lights / signal states

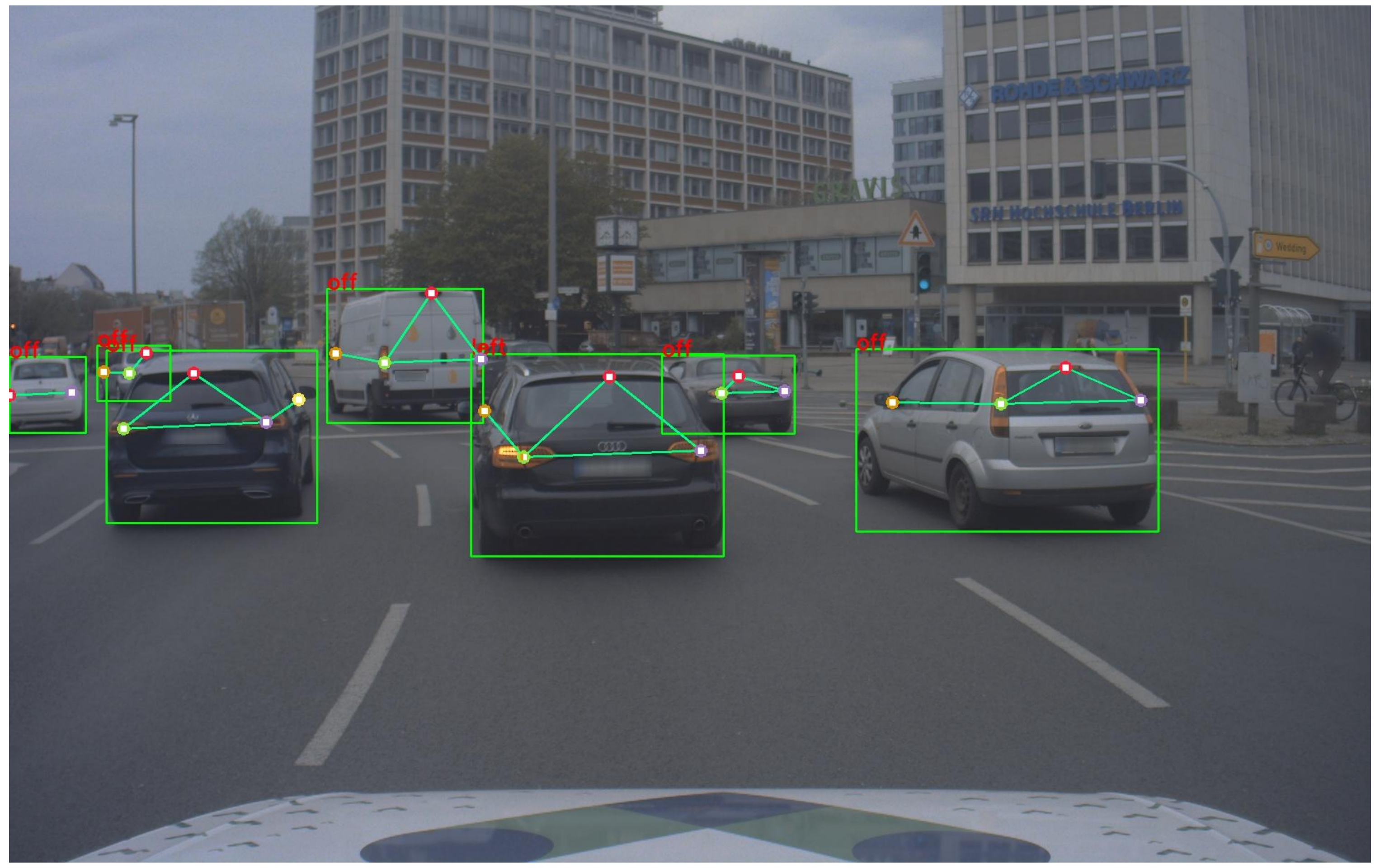
&

Proposed solutions can be seen as inherently limited as they generally lack the holistic consideration of the entire surrounding environment, e.g., vehicles viewed perpendicular

Proposed Solution

- Light Skeleton Detection (LSD)
- Detect the location of each cars lights and their states individually
- Not constrained to the back of vehicles

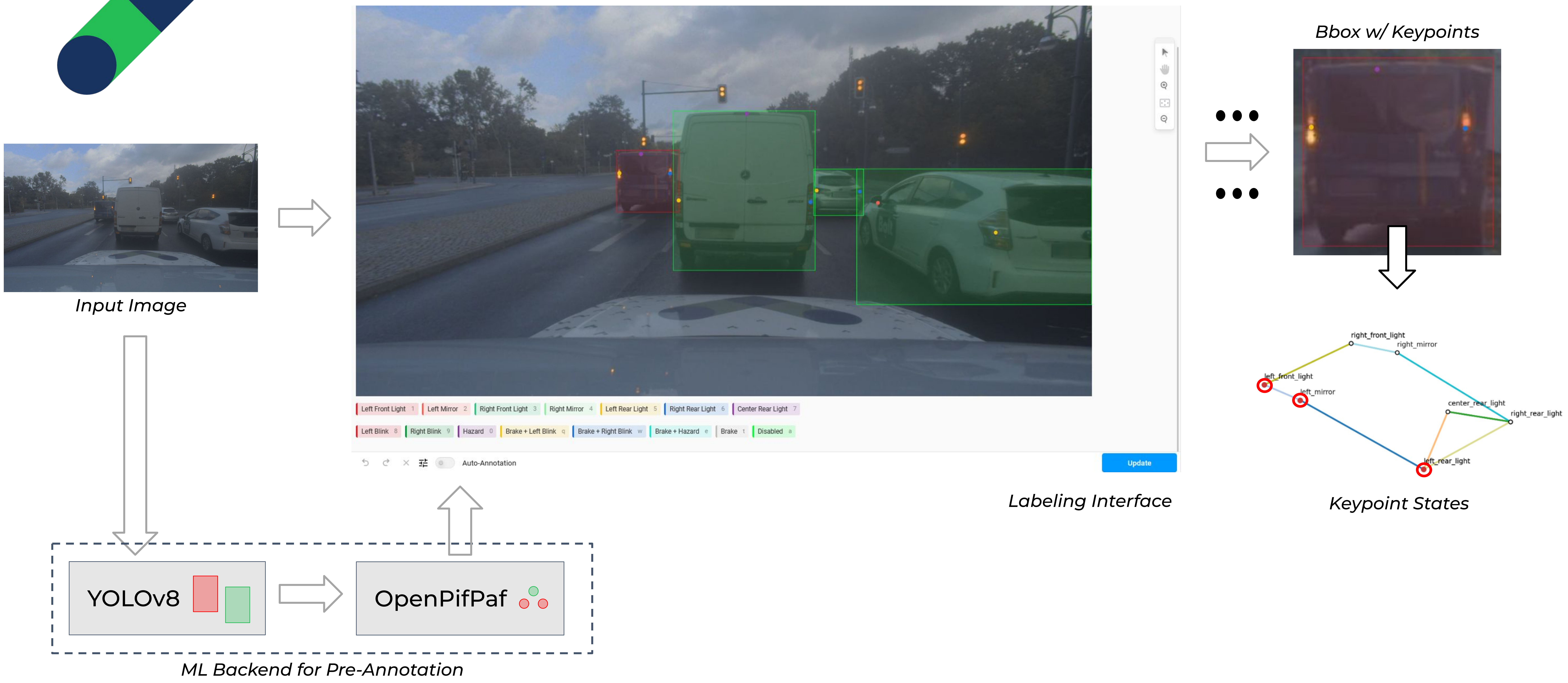




Data Capture

- Surround view (capturing vehicles from all angles)
- Custom daytime dataset
- Custom labeling setup with ML Backends

Data Labeling



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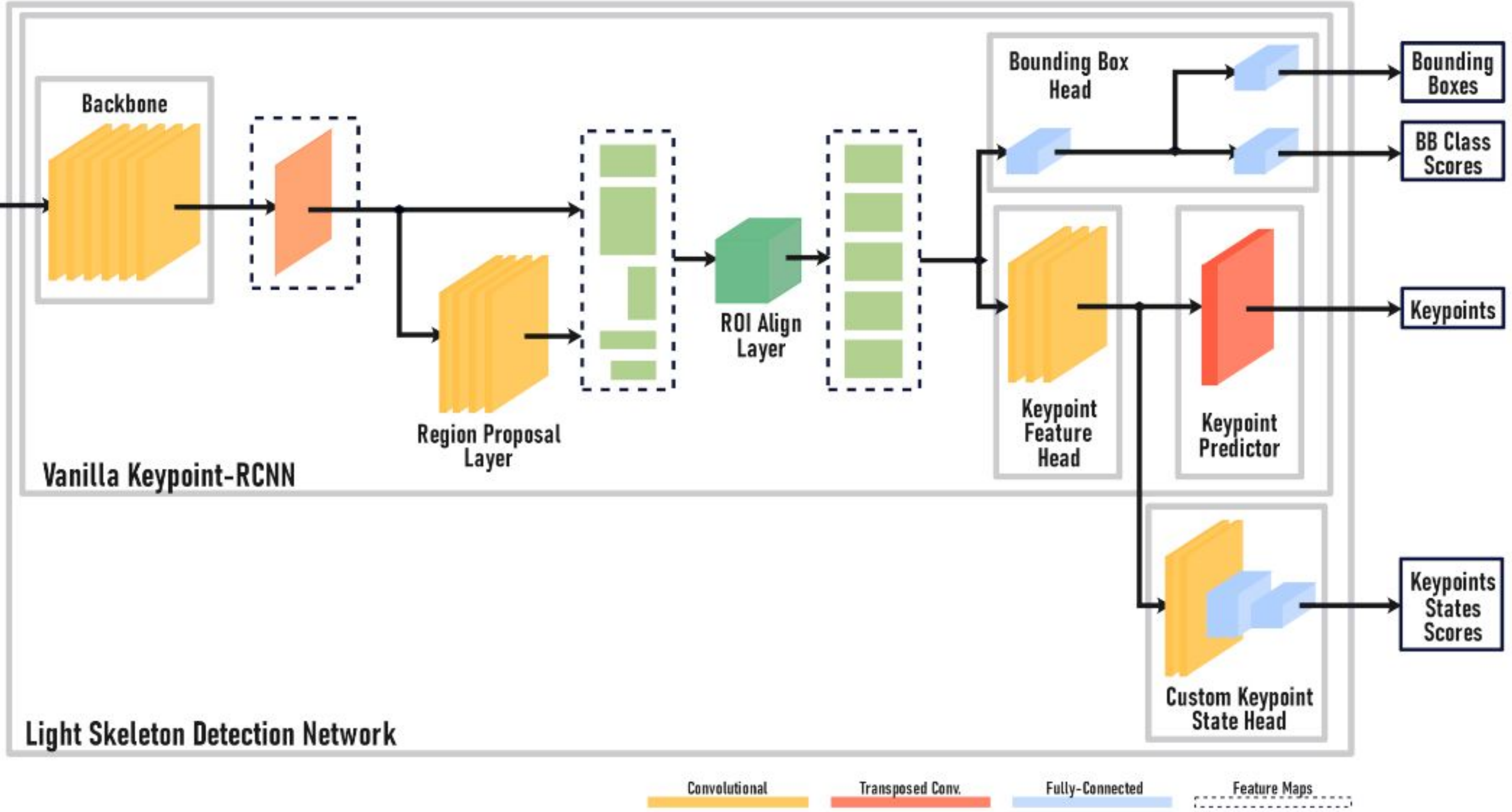
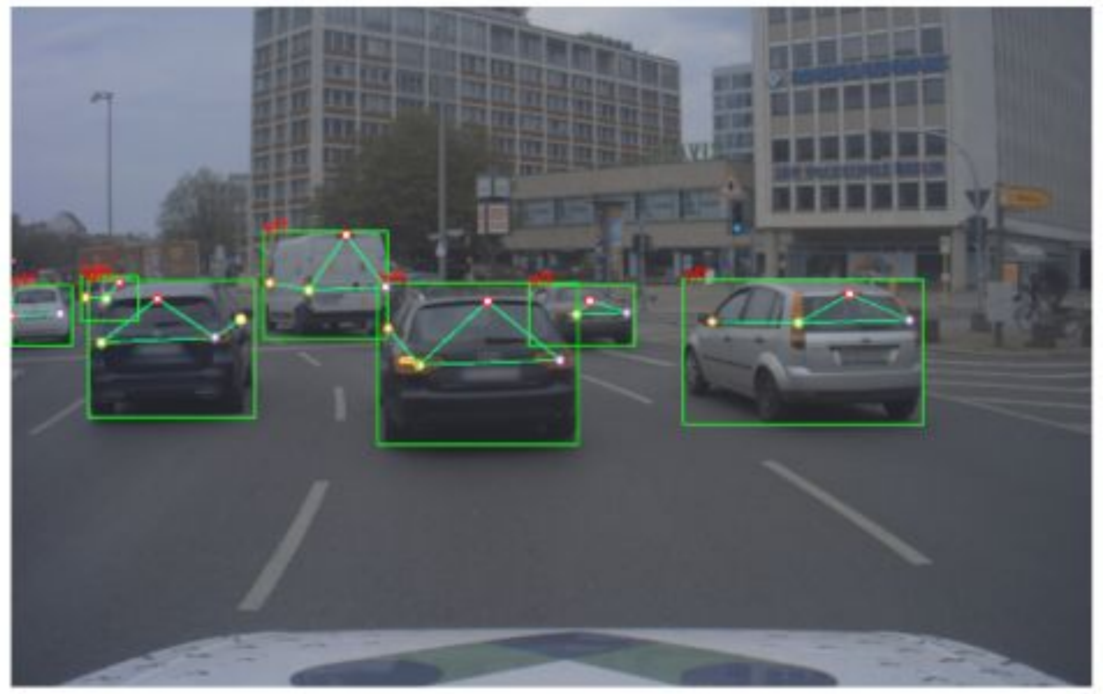
Model

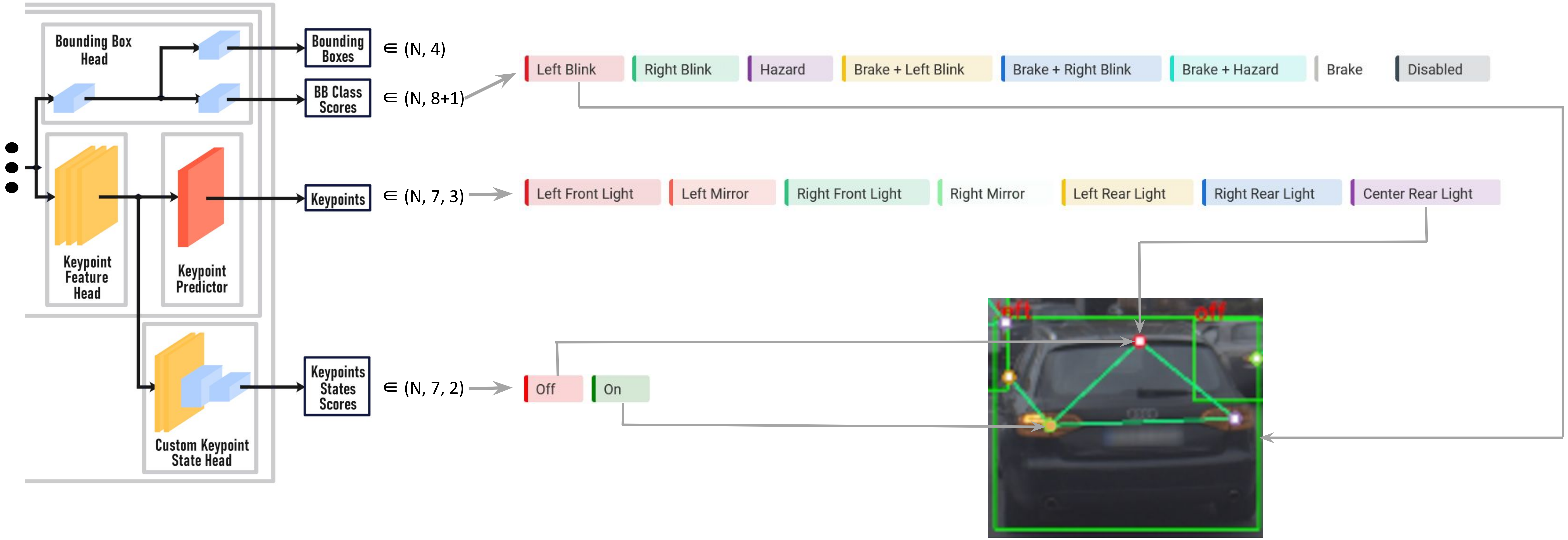




1. **Custom Keypoint State Head**
   Modified Keypoint-RCNN with custom head to predict two additional states per keypoint.

2. **Custom Output Classes**
   Set number of bounding box (bb) classes to 9 and number of keypoints (x, y, visibility) to 7 per bb.

Model



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Modified Keypoint-RCNN with custom head to predict two additional states per keypoint.

2. **Custom Output Classes**

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Results

On evaluation set...

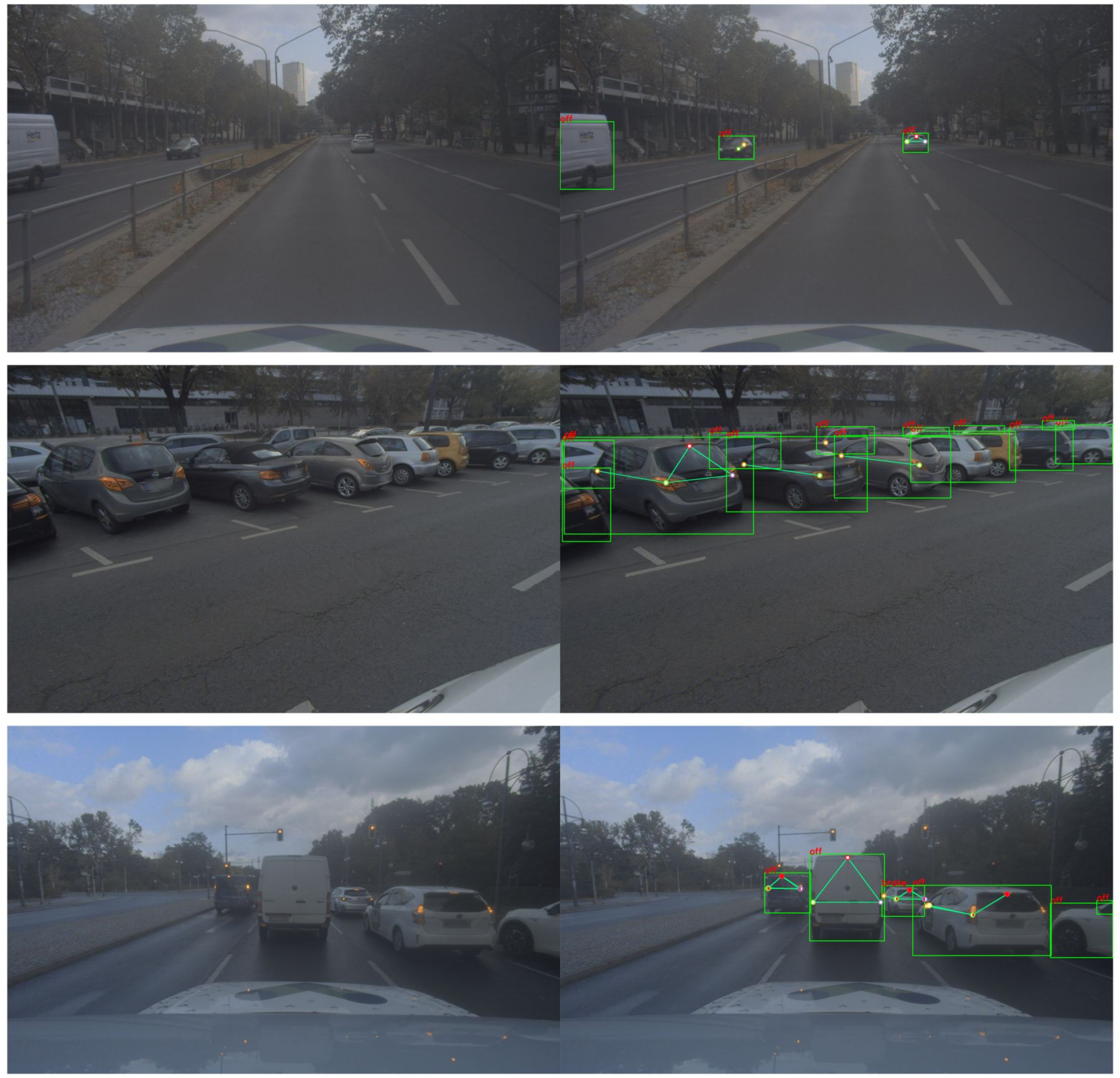
Metric	Average
IoU	0.891
Bounding-Box Label Accuracy	0.953
Split Light State Accuracy	0.984

Performance...

Metric	Average
ROS2 Node Frequency (RTX3070m)	11Hz
Model Latency (RTX3070m)	81.5ms

Results

- Should only be seen as a proof of concept, since the training set is quite small
- Shows generalization performance



Results

❖ Accurately detects vehicle lights

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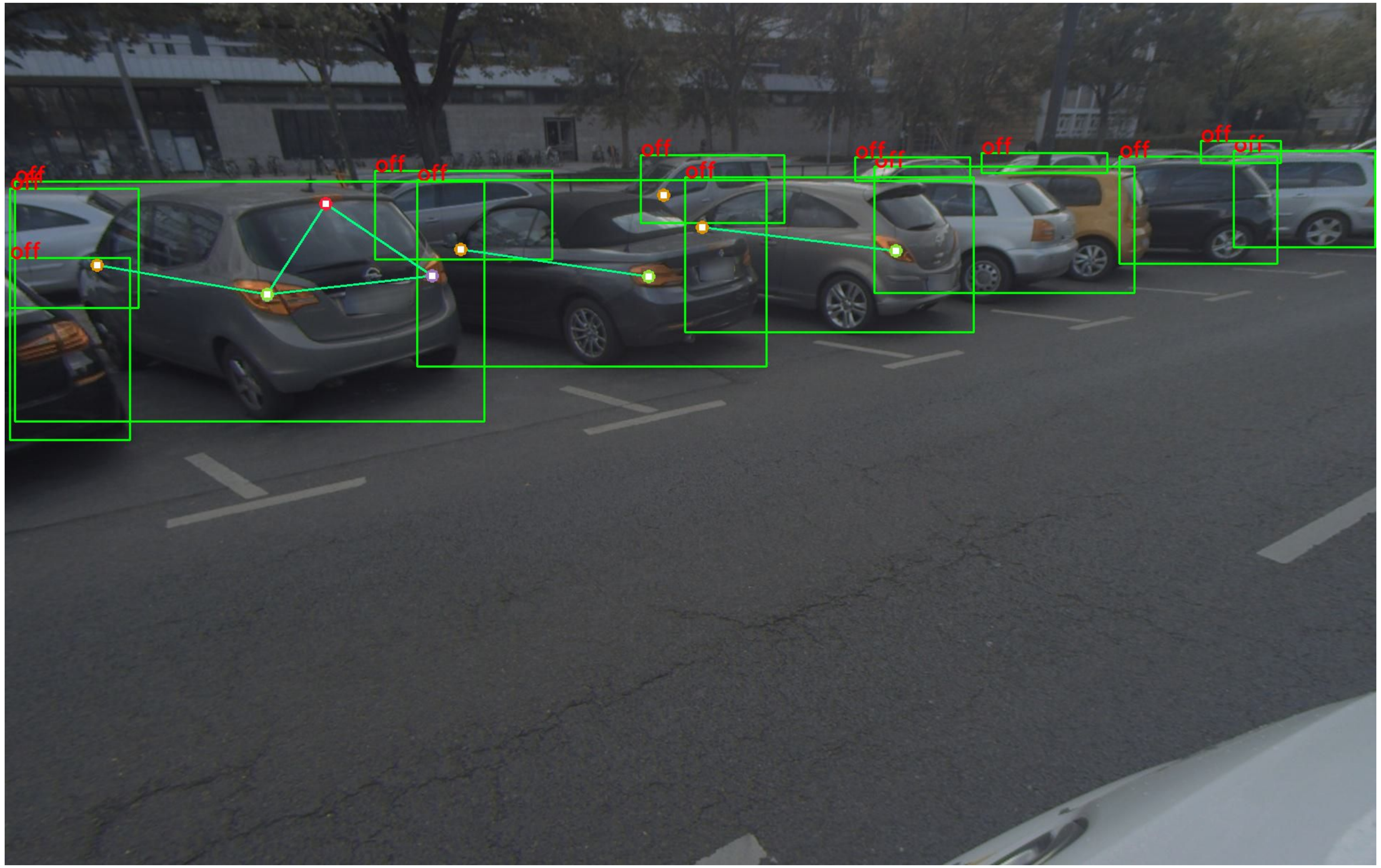
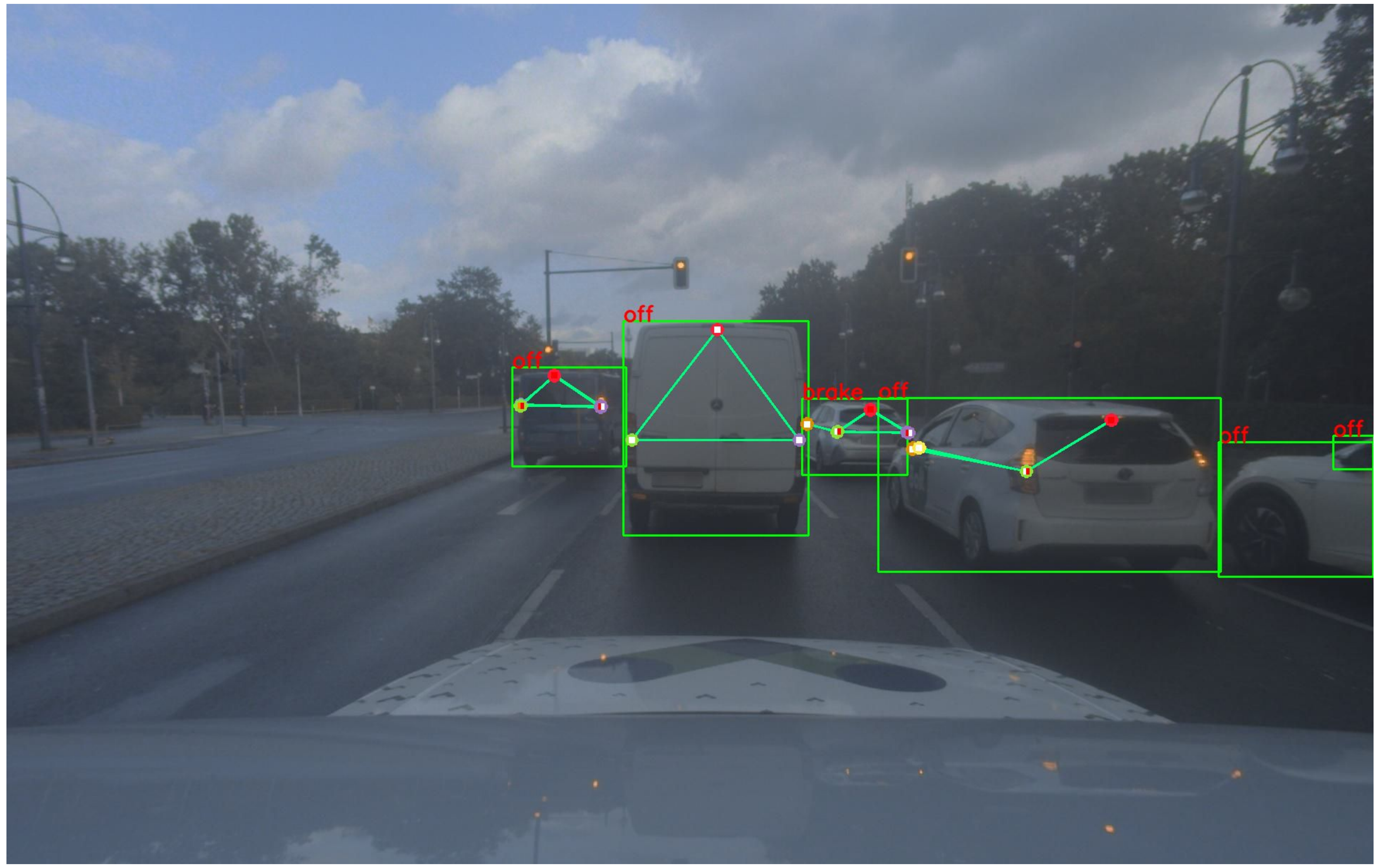
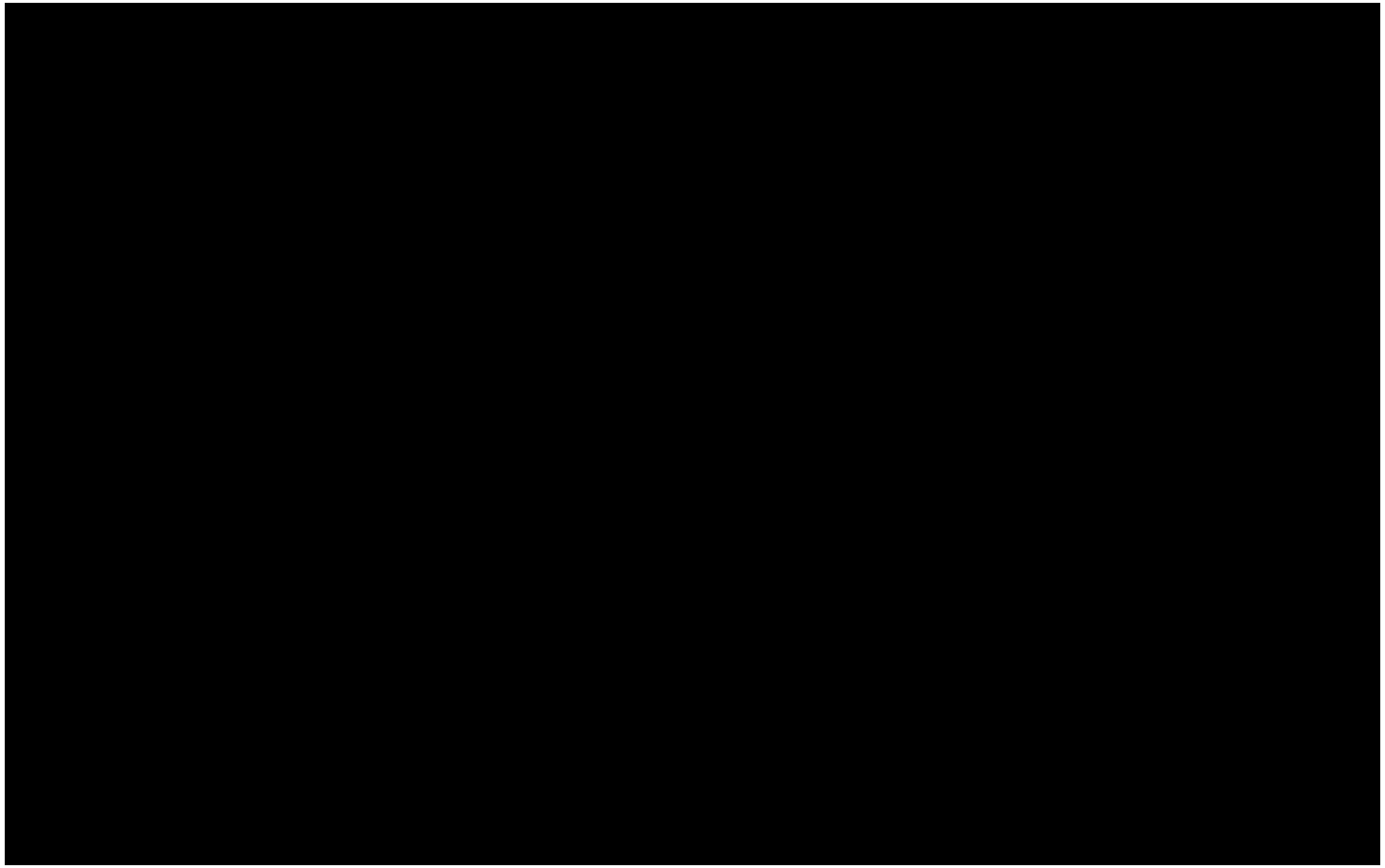


Results

❖ Predicted light states can be more accurate than bounding box labels



Results

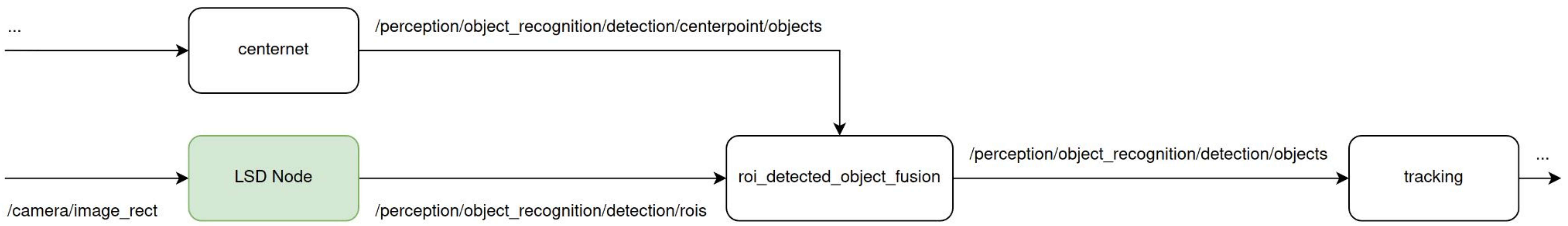


Autoware Integration

Publish custom classification in `DetectedObjectsWithFeature` message

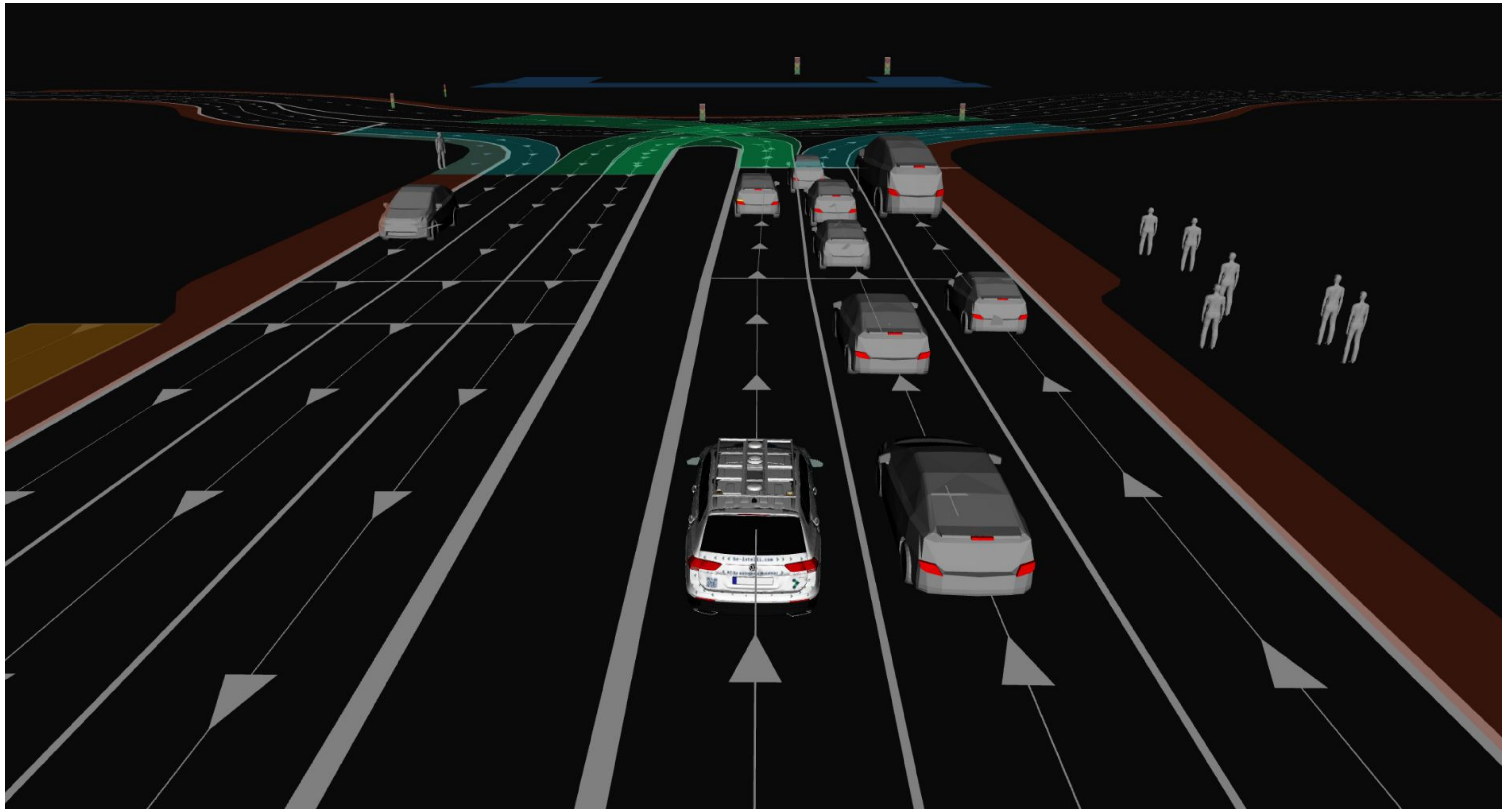
Classification label	Label value
Brake	100
Left indicator on	101
Right indicator on	102

- Fused to detected objects
- Disabled filtering of custom classifications in fusion node

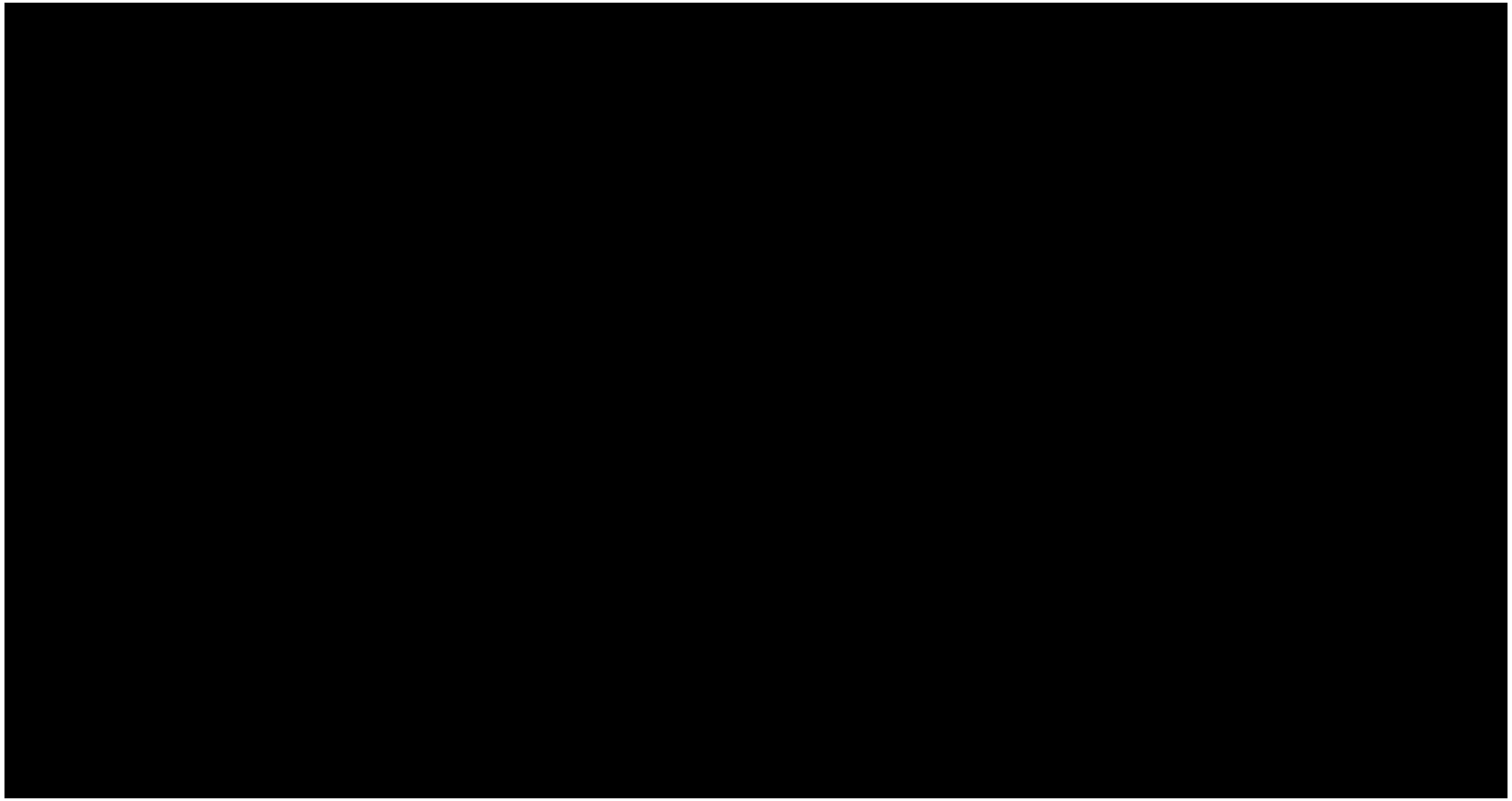


Autoware Integration

❖ RViz Visualization



Autoware Integration



Outlook

1. **Train on more data**

   To improve the models robustness

2. **Optimize the model for inference hardware**

   To improve the execution speed

3. **Extend the prediction model in Autoware**

   To utilize the light state predictions

Conclusion

1. **Novel approach for angle agnostic light state detection**

   Addressing a current gap in literature

2. **Evaluation on real world data**

   Showing promising results

3. **Integrated in to Autoware**

   And 3D visualization in RViz

Get in touch

Jonas.Krug@dai-labor.de

Srinivas.Ravuri@dai-labor.de

be-intelli.com