# Map Inference with In-Vehicle Cameras

# What can we infer from in-vehicle cameras?

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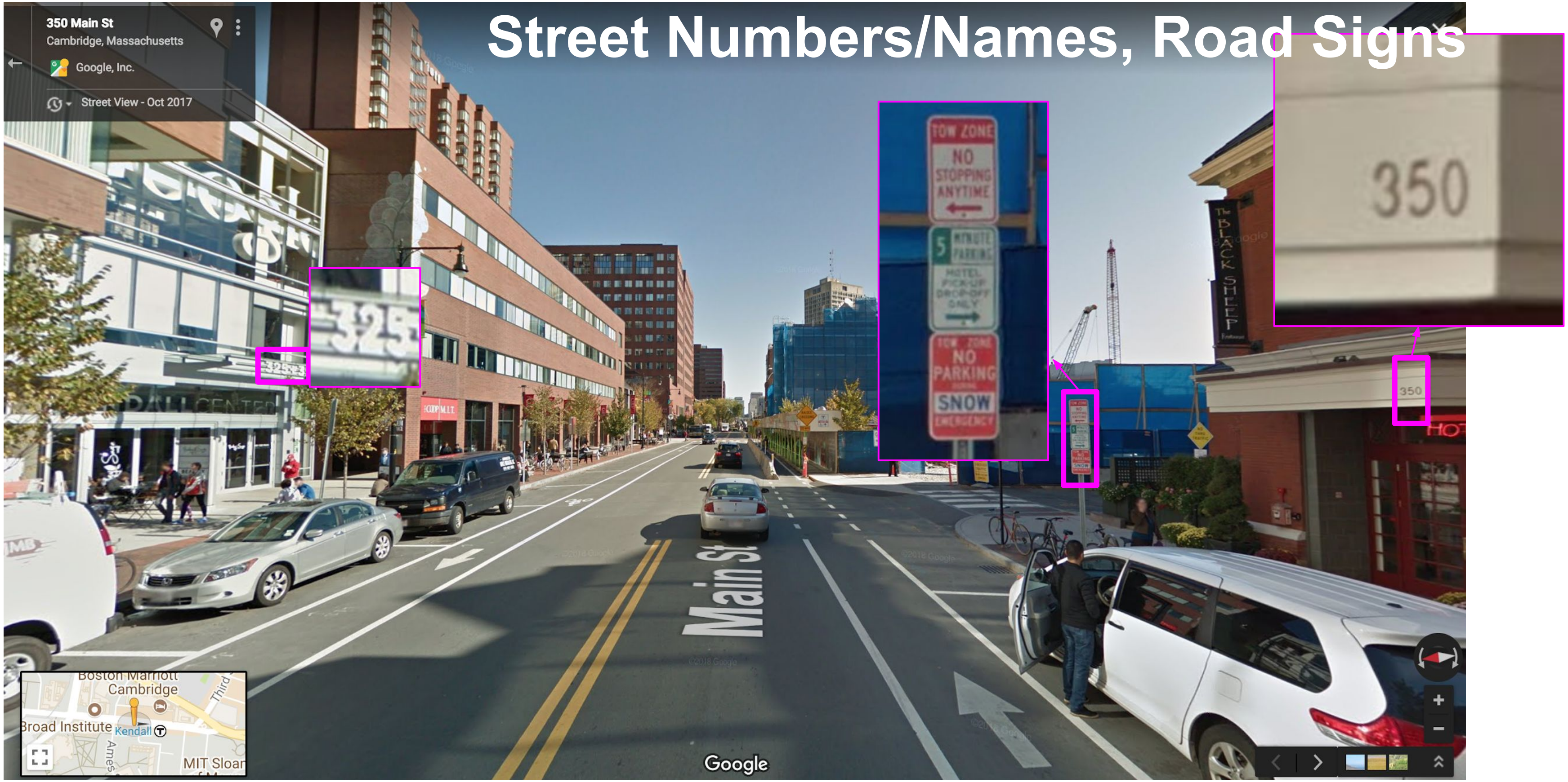

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- Road signs, street numbers and names, business names
- Detecting opening parking spaces
- Road Marker SLAM
- 3D Maps Pipeline

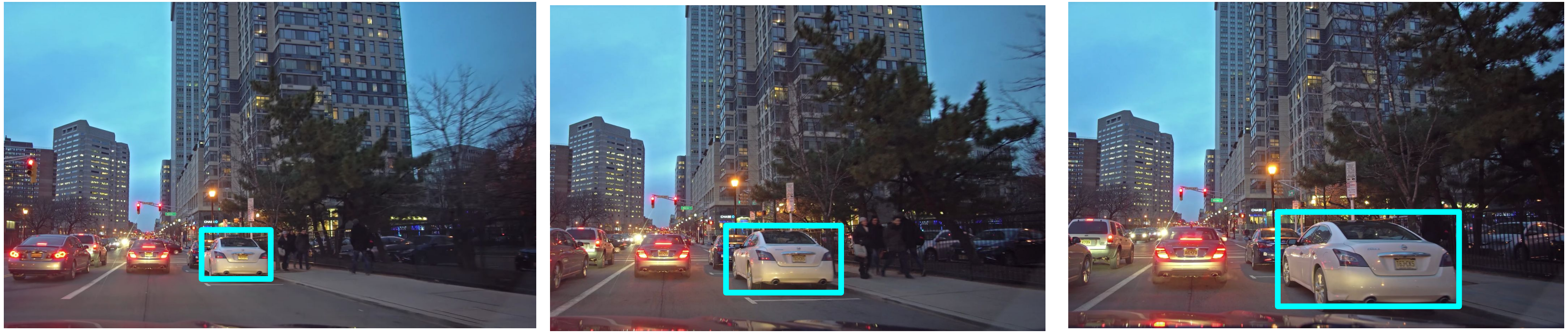
# Detecting Open Parking Spaces


Goal: Counting the number of cars parked on each road.

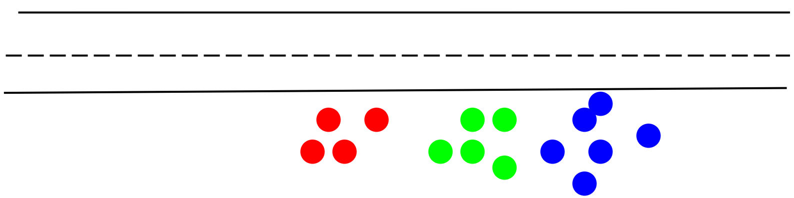
A car may appear in several consequent frames of the video.

ParkMaster: An In-Vehicle, Edge-Based Video Analytics Service for Detecting Open Parking Spaces in Urban Environments.
Giulio Grassi, Paramvir Bahl, Kyle Jamieson, Giovanni Pau.

# Detecting Open Parking Spaces



Localize each car in each frame. Map the location to lat-lon. Use clustering algorithm to infer the number of cars.



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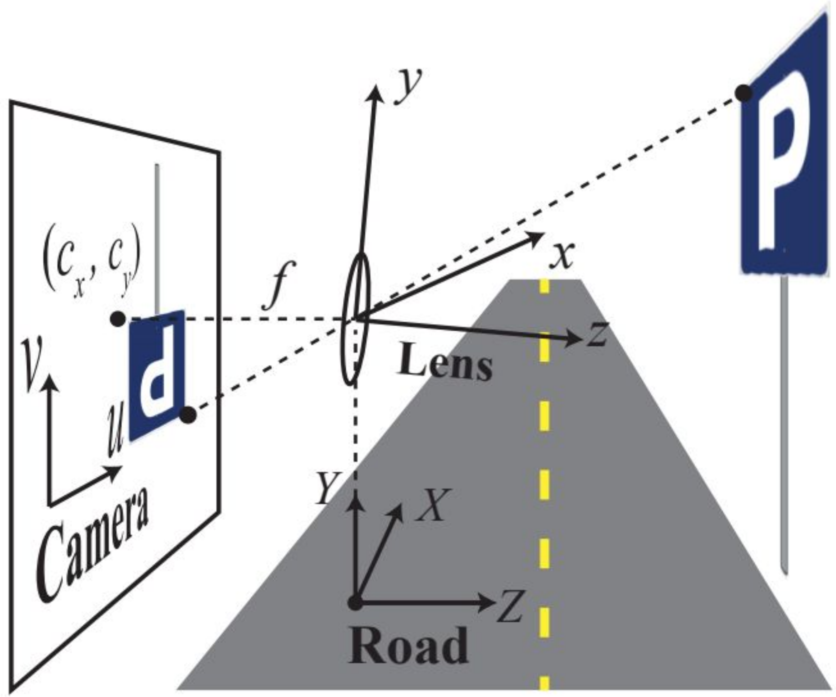


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# Street Numbers


Multi-digit Number Recognition from Street View Imagery using Deep Convolutional Neural Networks
Ian J. Goodfellow, Yaroslav Bulatov, Julian Ibarz, Sacha Arnoud, Vinay Shet

# Street Numbers

We assume that the identities of the separate digits are independent from each other, so that the probability of a specific sequence $\mathbf{s} = s_1, \ldots, s_n$ is given by

$$P(\mathbf{S} = \mathbf{s}|X) = P(L = n \mid X)\Pi_{i=1}^{n} P(S_i = s_i \mid X).$$

Input Image    # of digits

Convolutional Neural Networks

P(S_i = s_i | X) for all i and s_i
P(L=n | X) for all n

$$\mathbf{s} = (l, s_1, \ldots, s_l) = \text{argmax}_{L, S_1, \ldots, S_L} \log P(S \mid X).$$

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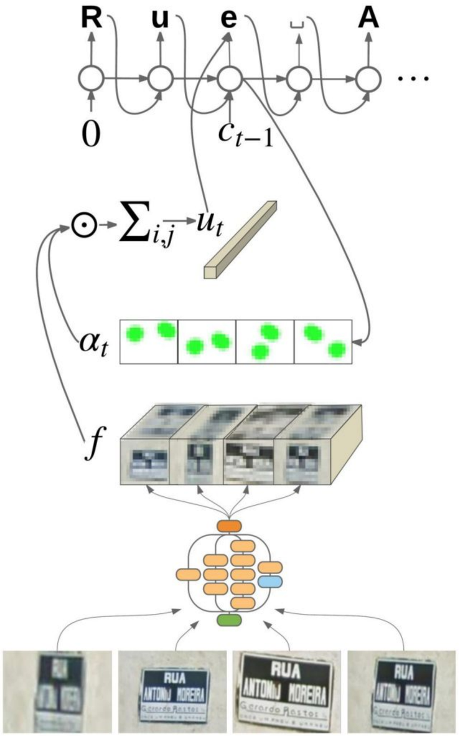
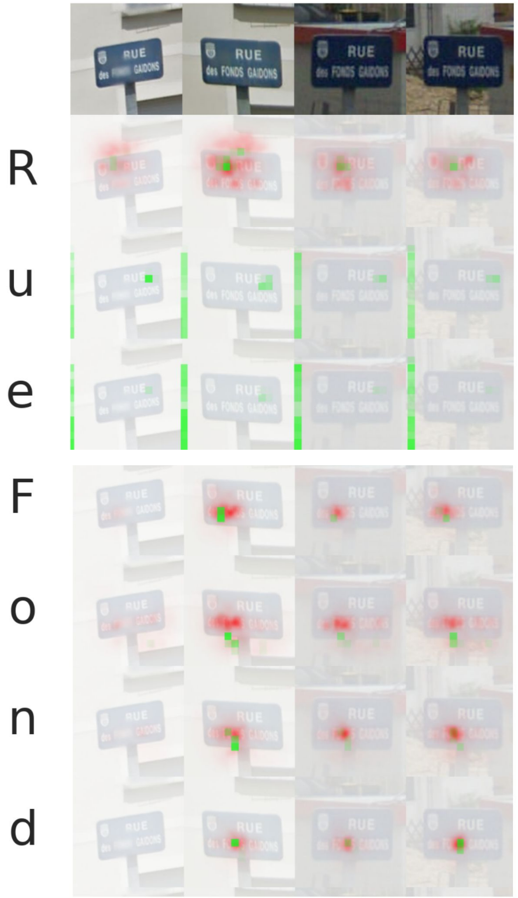
# Street Names


Attention-based Extraction of Structured Information from Street View Imagery
Zbigniew Wojna, Alex Gorban, Dar-Shyang Lee, Kevin Murphy, Qian Yu, Yeqing Li, Julian Ibarz

# Street Names

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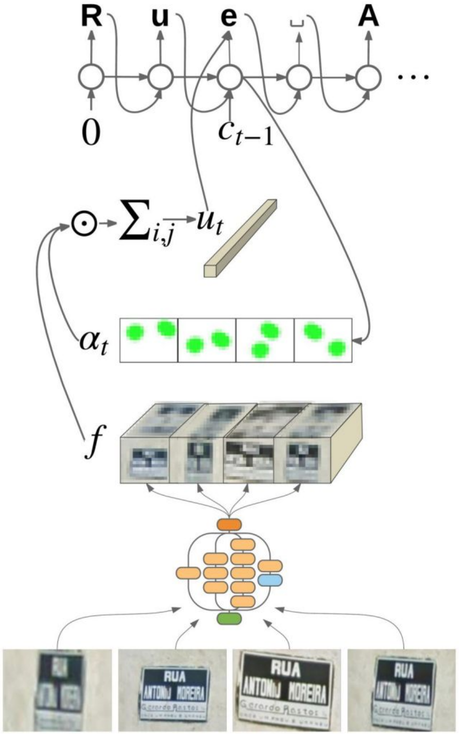
# Business Front Sign Detector


Large Scale Business Store Front Detection from Street Level Imagery
Qian Yu, Christian Szegedy, Martin C. Stumpe, Liron Yatziv, Vinay Shet, Julian Ibarz, Sacha Arnoud

# Business Front Sign Detector→Business Name Map


+

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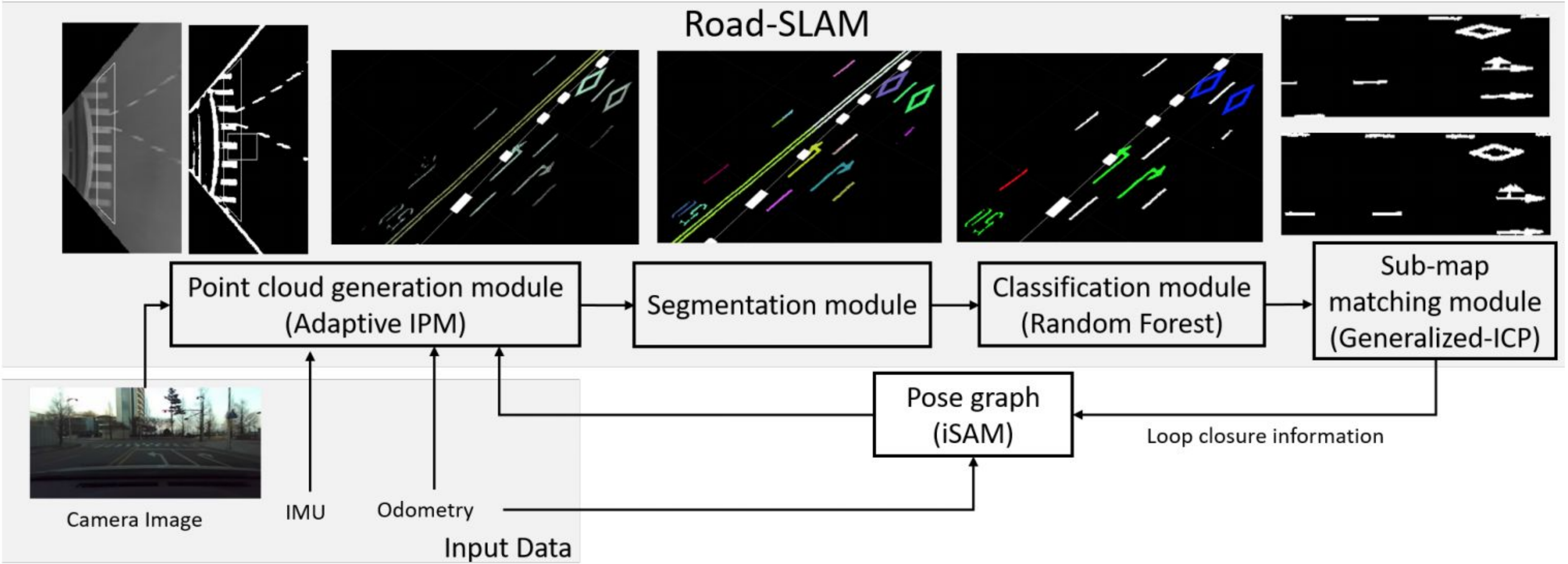
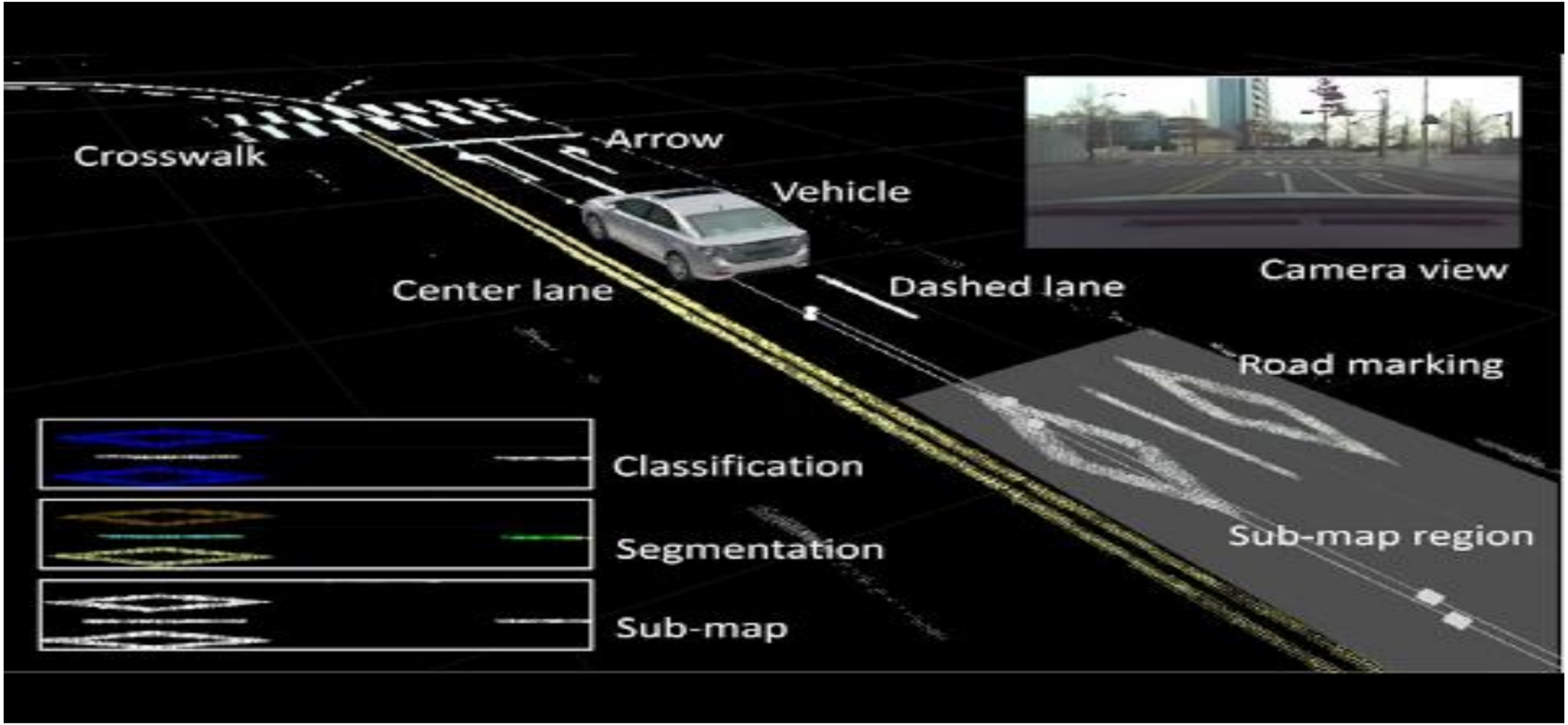
# Road Marker Map




Road-SLAM : Road Marking based SLAM with Lane-level Accuracy

# Road Marker Map




Road-SLAM : Road Marking based SLAM with Lane-level Accuracy

# 3D Maps

https://blog.mapillary.com/tech/2017/07/26/improving-3d-reconstruction-with-semantic-understanding.html

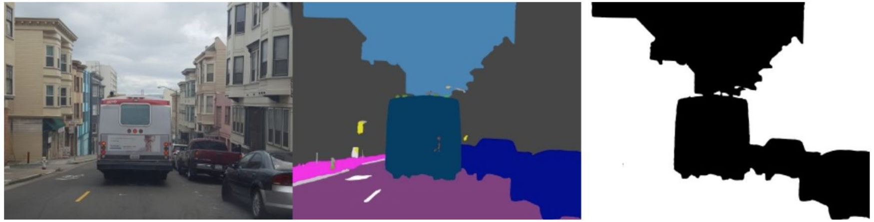
# 3D Maps - Remove moving objects

### An example

Let's take a look at an example. The sequence below shows nine images taken roughly ten meters apart along a straight road in San Francisco. The mapper was unfortunate to end up behind a bus that takes up a large part of the images.

### The solution

**With the help of sematic understanding of the captured scene, it is possible to resolve the problem of most moving and temporary objects.** By making use of highly accurate machine-genereated semantic segmentations, we can determine which keypoints belong to potentially moving objects. We can then **do the reconstruction using only keypoints on static object classes** like buildings and roads. The result is a 3D reconstruction that depicts the important non-moving parts of the scene and the camera motion with respect to them.



*Creating a keypoint mask. Left: original sequence image. Middle: sematic segmentation for the image. Right: binary mask with white for included segmentation classes and black for excluded. Excluded classes are vehicle, pedestrian, and sky, among others.*

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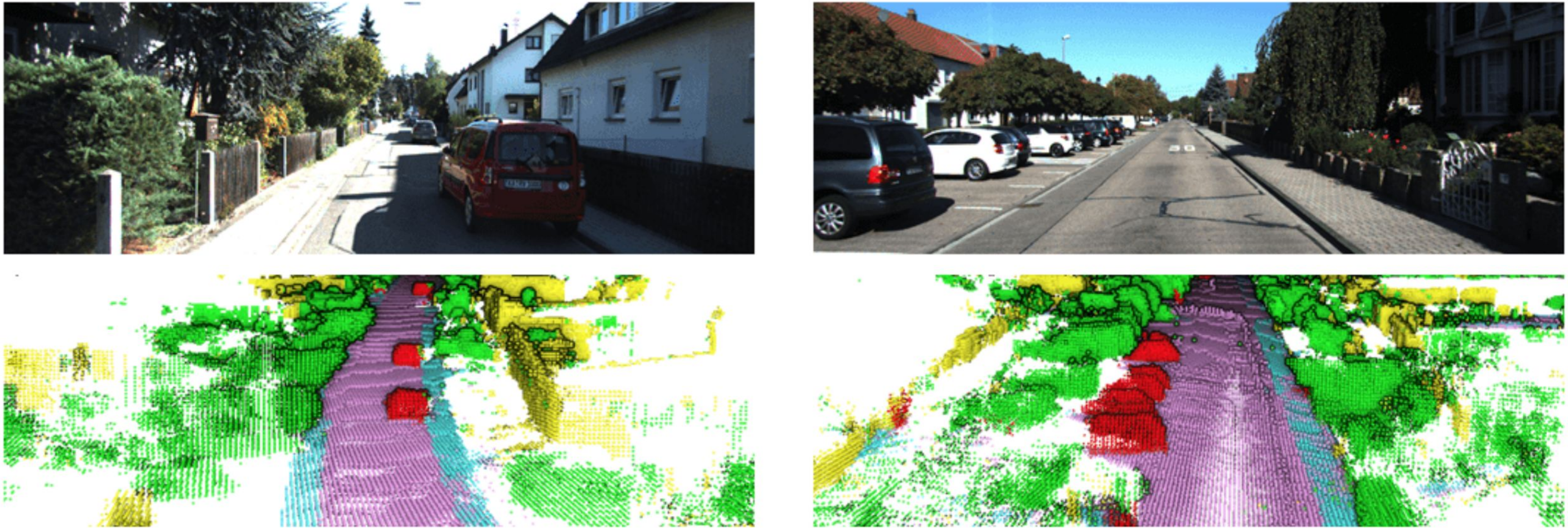


https://arxiv.org/pdf/1802.10271.pdf

# TODO: GPS + Dashboard Camera (Association)

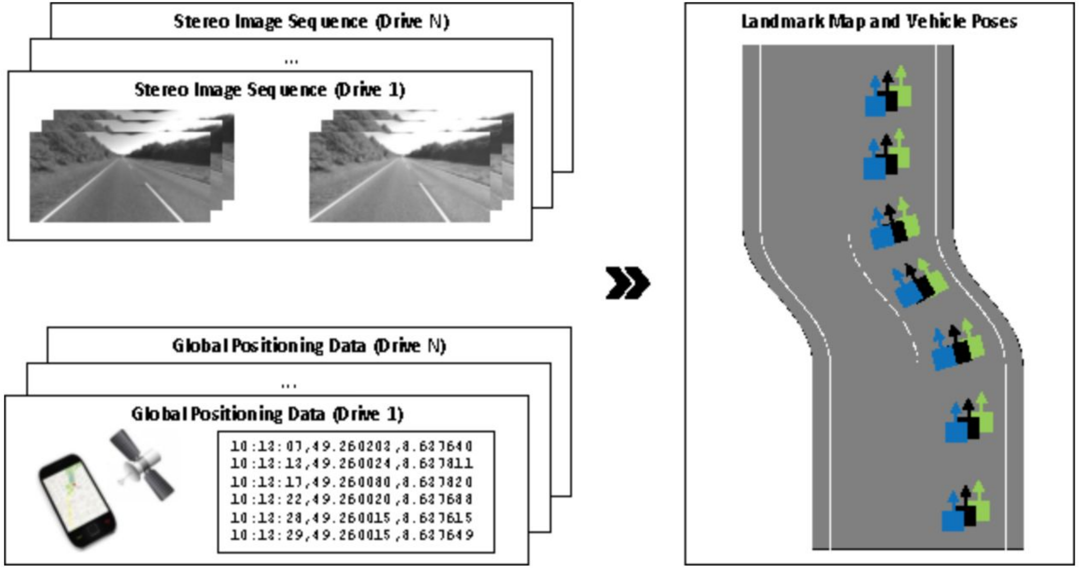
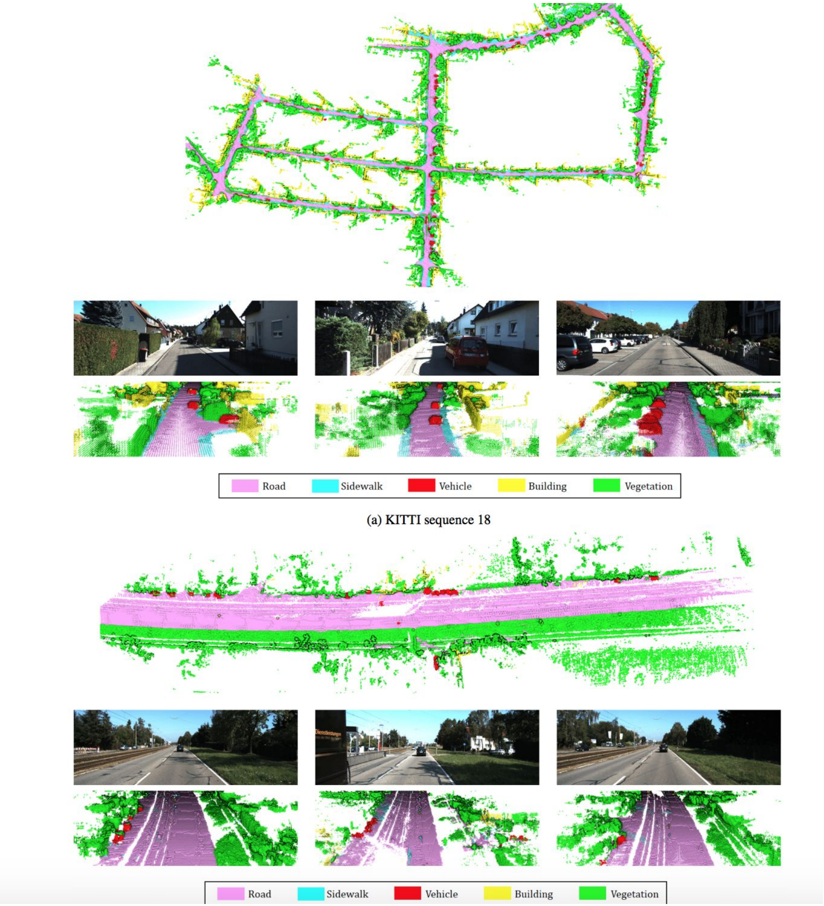



**Fig. 1. Overview of Input Modalities and Generated Output. For each drive, stereo imagery and GPS data is recorded.**

Schreiber, Markus et al. “Multi-drive feature association for automated map generation using low-cost sensor data.” 2015 IEEE Intelligent Vehicles Symposium (IV) (2015): 1140-1147.

# TODO: Camera + Lidar

https://arxiv.org/pdf/1802.10271.pdf

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# TODO: Other Papers

Monocular Visual Odometry and Dense 3D Reconstruction for On-Road Vehicles
https://pdfs.semanticscholar.org/52e9/4935e03936e2e9f1770fe5a960010f8576fe.pdf

Automatic lane-level map generation for advanced driver assistance systems using low-cost sensors

todo