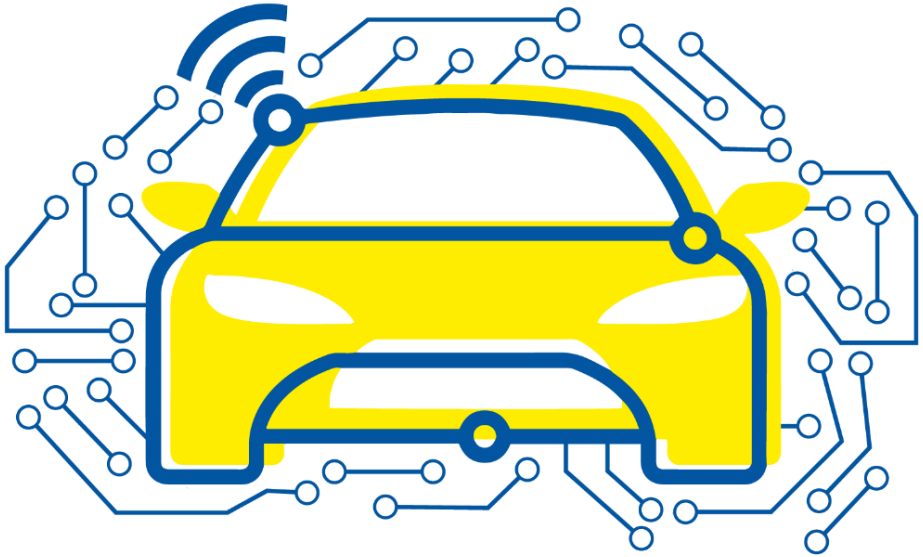
Automated and Connected Driving Challenges

Section 2 – Sensor Data Processing

Semantic Point Cloud Segmentation

Deep Learning



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Semantic Point Cloud Segmentation – Deep Learning

Overview

- Modern **Deep Learning** methods often have improved performance over traditional machine learning methods when it comes to complex, high dimensional data, e.g. point clouds.

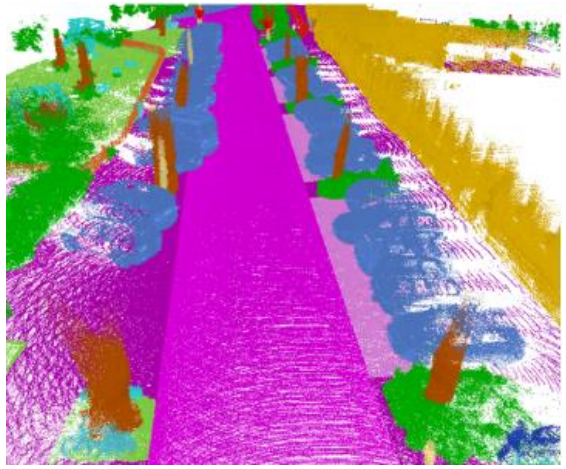


Image: Semantic Kitti

- **Supervised learning**
  - Input + desired output
  - Input: Point cloud as e.g. range view representation
  - Output: Segmentation map as e.g. range view representation

- E.g. Convolutional Neural Networks
  - Encoder-Decoder Architectures with skip connections

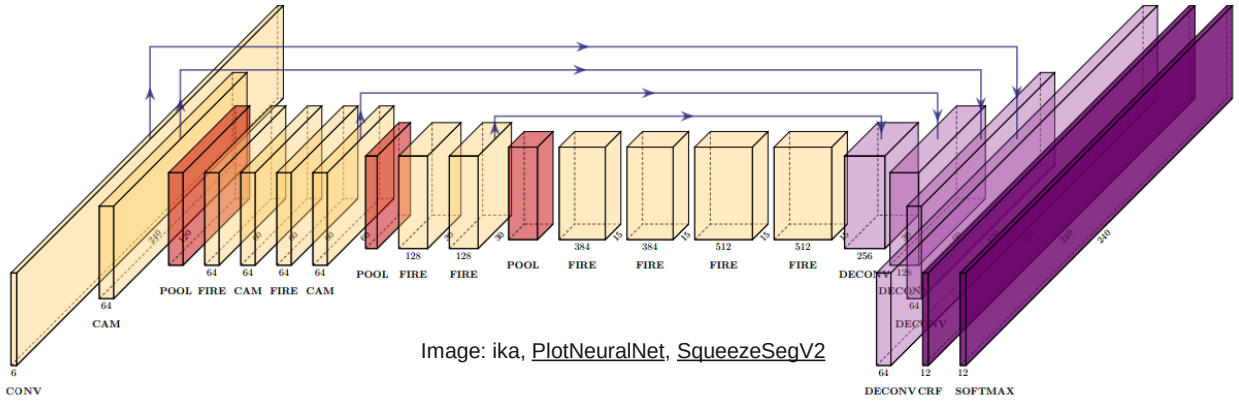


Image: ika, PlotNeuralNet, SqueezeSegV2

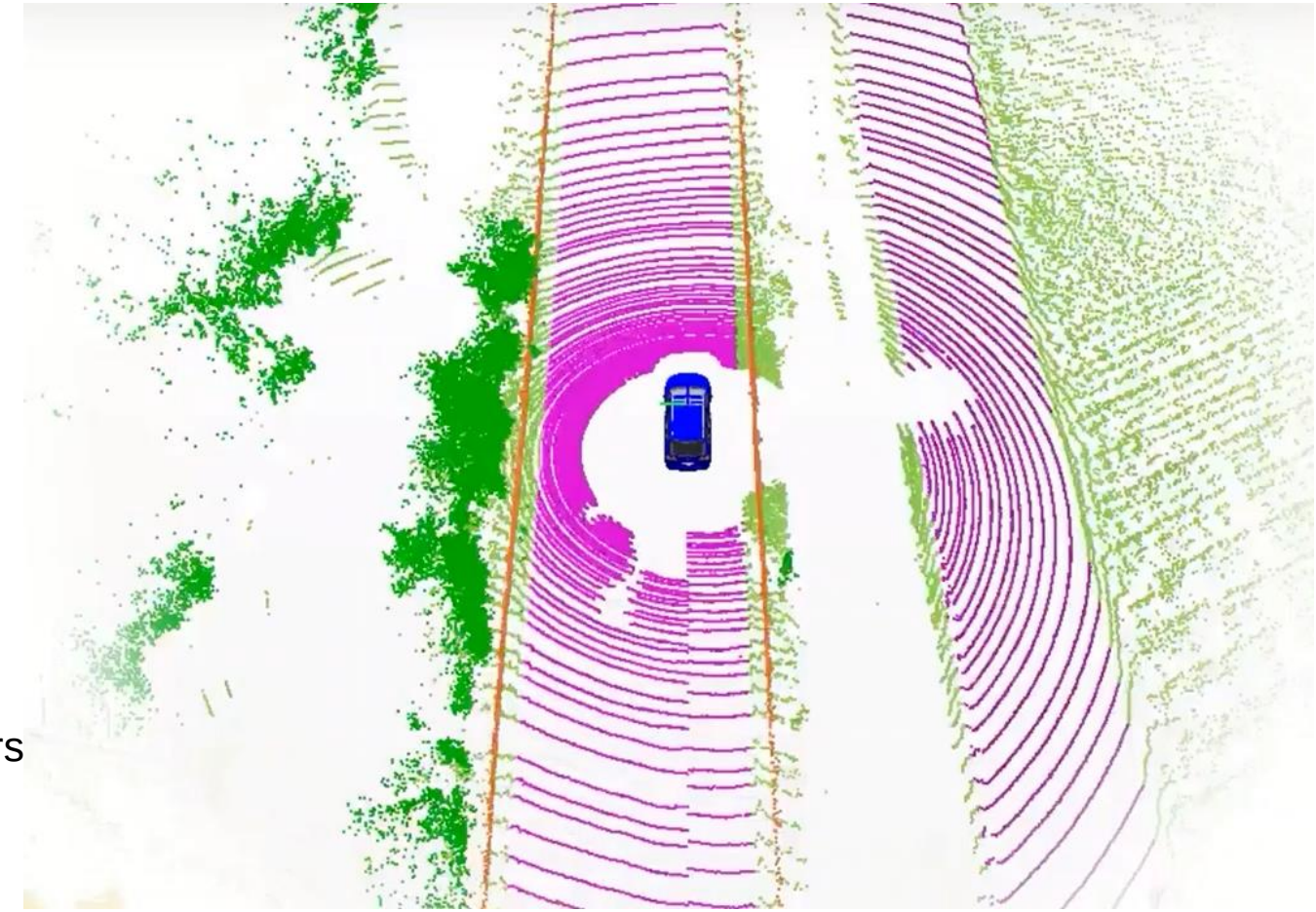
Semantic Point Cloud Segmentation – Deep Learning

Datasets

- **Semantic KITTI**
  - Annotated classes as in Cityscapes
  - Velodyne LiDAR sensor
    - 64 layers
    - 10 Hz

- Point cloud characteristics depend on the **specific sensor configuration**

→ Models trained on this dataset **not easily transferable** to other sensors



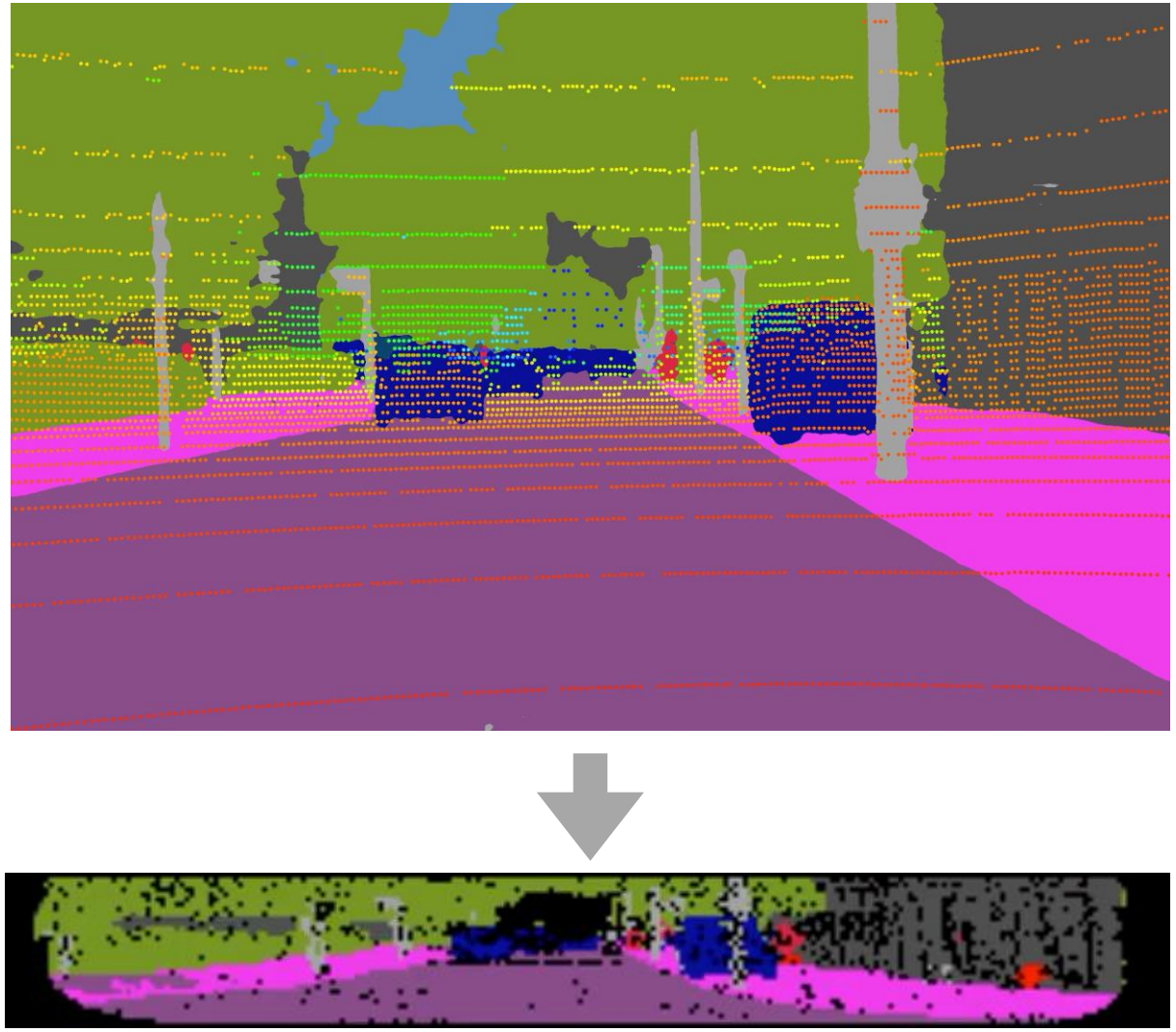
Video: Semantic Kitti

Semantic Point Cloud Segmentation – Deep Learning

Datasets

- Manual annotations are expensive

- **Cross-Modal Label Transfer**
  - Use a **semantic image segmentation** to transfer the label annotations to the point cloud
  - Point cloud is **projected** on the segmented image
  - **Copy** the **label** information for each point
  - Store automatically annotated point clouds as new dataset



Videos: ika

Semantic Point Cloud Segmentation – Deep Learning

Point Cloud Representation

- **Unstructured Representation**:
  - **List of Points** with coordinates and additional data
  - E.g. **Coordinate**, **Intensity** and **Ring**: [X, Y, Z, I, R]
  - Difficult to process with DNNs

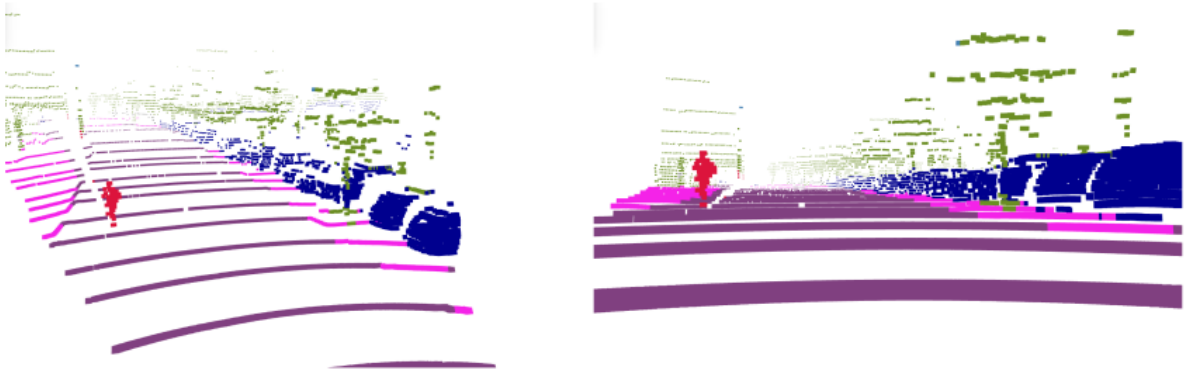


Image: ika

- **Structured Representation:**
  - **Range View**
  - Native representation from the viewpoint of the sensor
  - 2D image like tensor
  - Efficient processing with CNNs possible

Image: ika

Semantic Point Cloud Segmentation – Deep Learning

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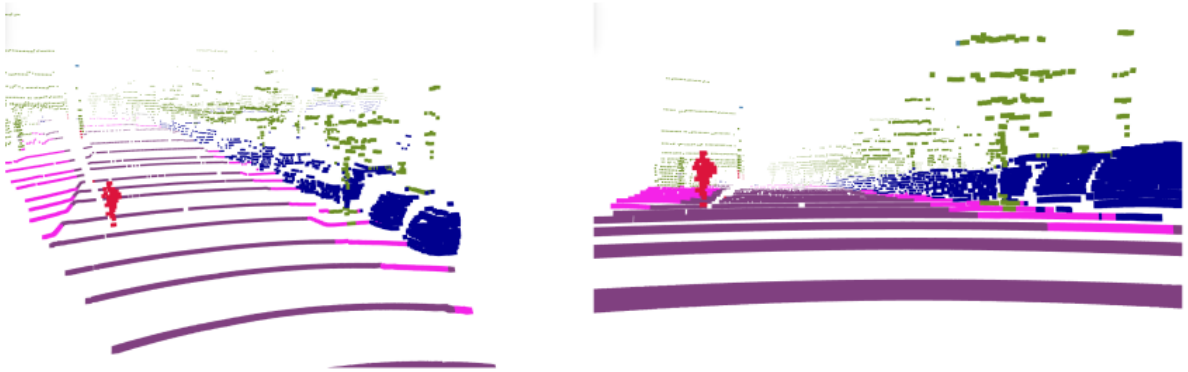

Image: ika

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Video: ika

  - **Voxel Representation (“3D Grid”)**
  - Discretization along the X, Y and Z coordinates
  - Processing with CNNs possible
  - Fine grained details are lost due to discretization

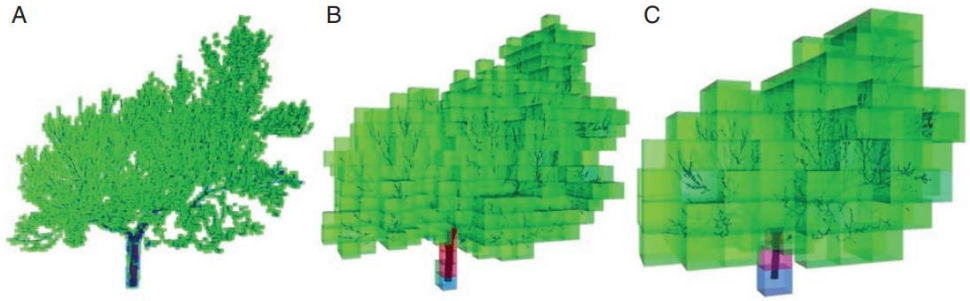

Image: oup

Semantic Point Cloud Segmentation – Deep Learning

Range View Representation

- Cylindrical point cloud projection
- 2D image-like representation
- Shape: [Height, Width, Number of Channels]
- **Height:** Number of laser rings
- **Width:** FOV discretized with horizontal resolution
- **Channels:** X, Y, Z, Intensity, Depth, Timestamp…

→ Easy and efficient processing with CNN

Image: arxiv

Semantic Point Cloud Segmentation – Deep Learning

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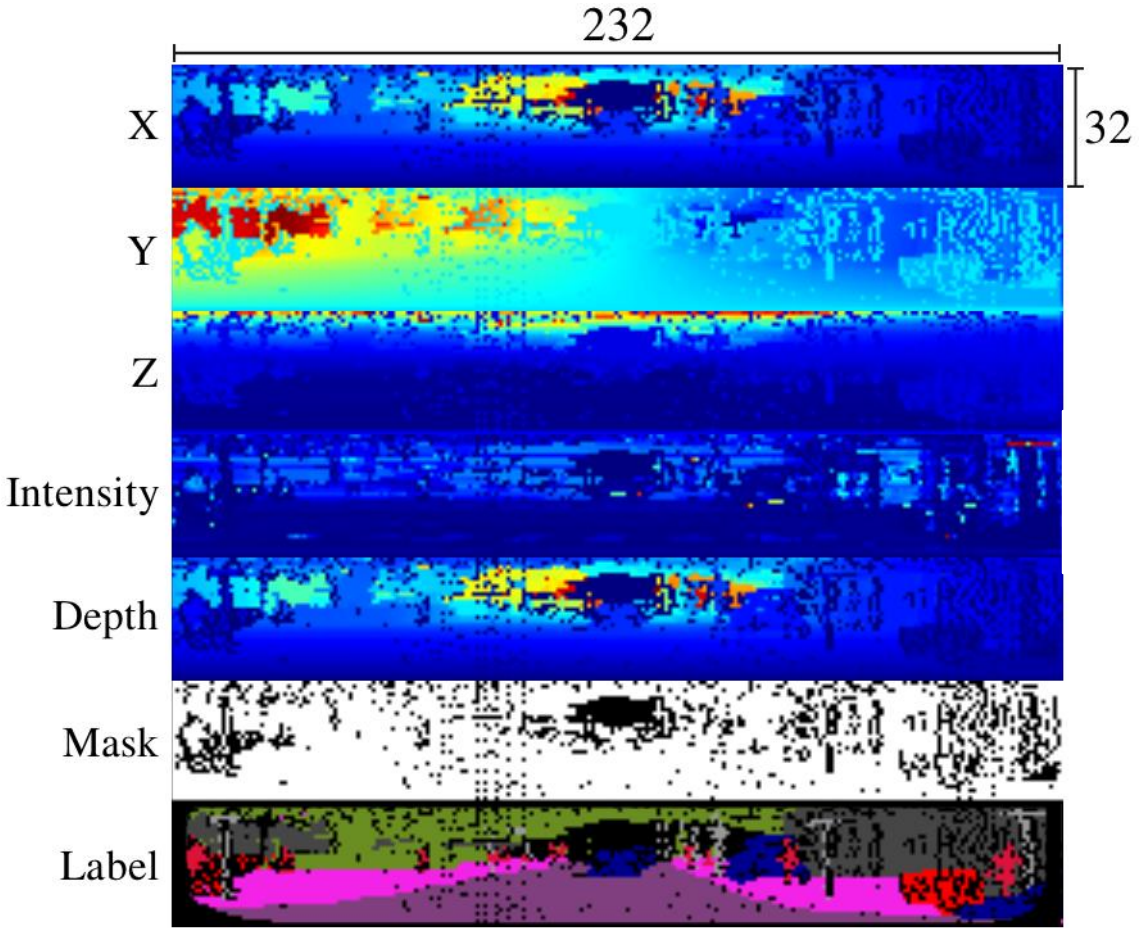


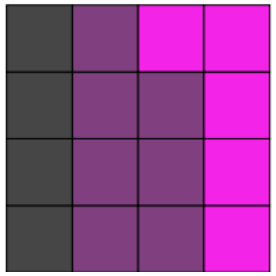
Image: ika

Semantic Point Cloud Segmentation – Deep Learning

Label Representation

- **How to represent the label of semantic segmentation ?**
  - **Color Encoding**
    - Each class has a specific **RGB Value**
    - Data format**: 3 x uint8**
    - Shape: [Height, Width, 3]
  - **Segmentation Map**
    - Each class has a specific **class ID**
    - Data format**: 1 x uint8**
    - Shape: [Height, Width, 1]
  - **One-Hot Encoding**
    - A class is represented as a one-hot vector
    - The i`th value is set to 1 all other values are set to 0. The index i corresponds to the i`th class
    - Data format**: Number of classes x Boolean**
    - Shape: [Height, Width, Number of Classes]

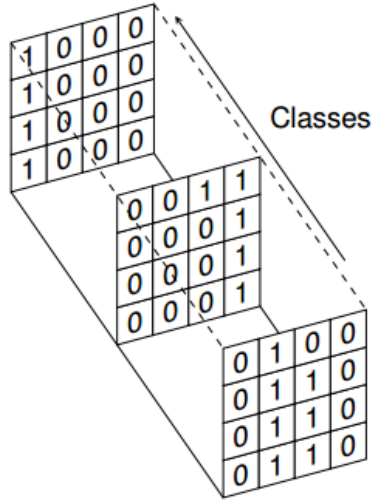
Example with 3 Classes:



Color Encoding

2	0	1	1
2	0	0	1
2	0	0	1
2	0	0	1

Segmentation Map



One-Hot-Encoding

Images: ika

Semantic Point Cloud Segmentation – Deep Learning

Network Architecture

- **Fully-Convolutional Network**
- Network as a sequence of convolutional layers
  - With **downsampling** and **upsampling** inside the network
- Make class predictions for all pixels **at once**

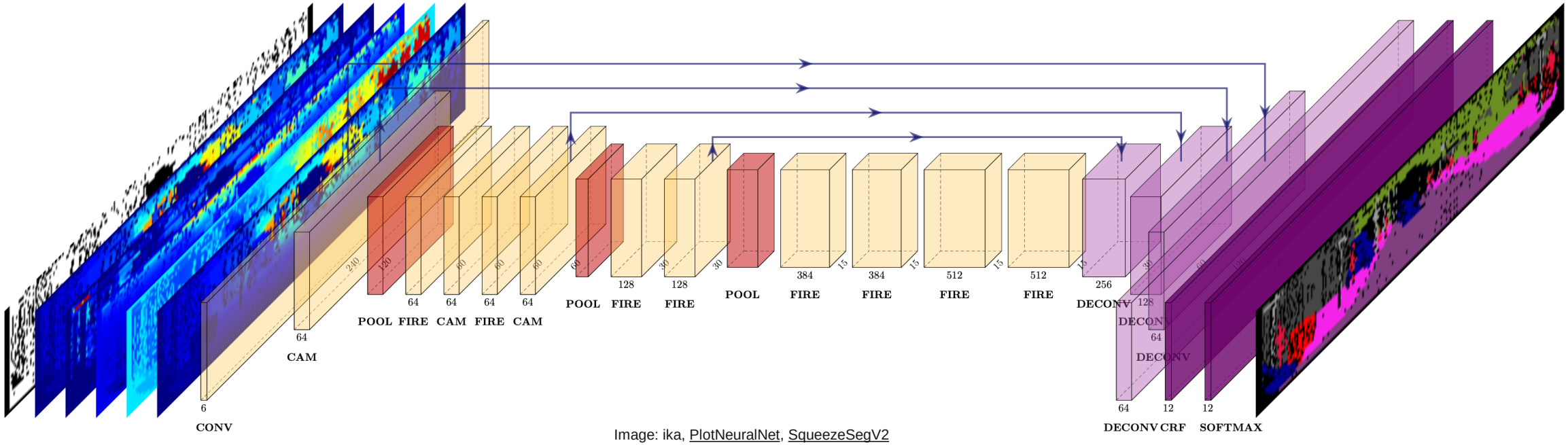


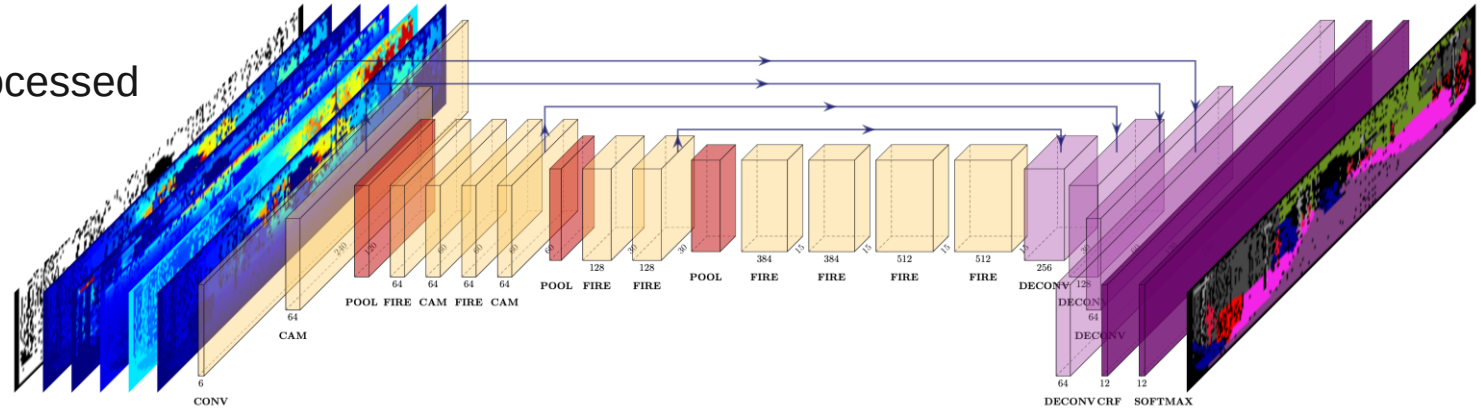
Image: ika, PlotNeuralNet, SqueezeSegV2

Semantic Point Cloud Segmentation – Deep Learning

Summary

- Lack of **public datasets**
- Possible to create you own dataset with **Cross-Modal Label Transfer**
- Transform point cloud to **range view** representation
- Point cloud and label can then be processed similarly to **image segmentation**
- **CNN** architectures can be applied

Image: arxiv



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