# Connected car applications

x Safety critical

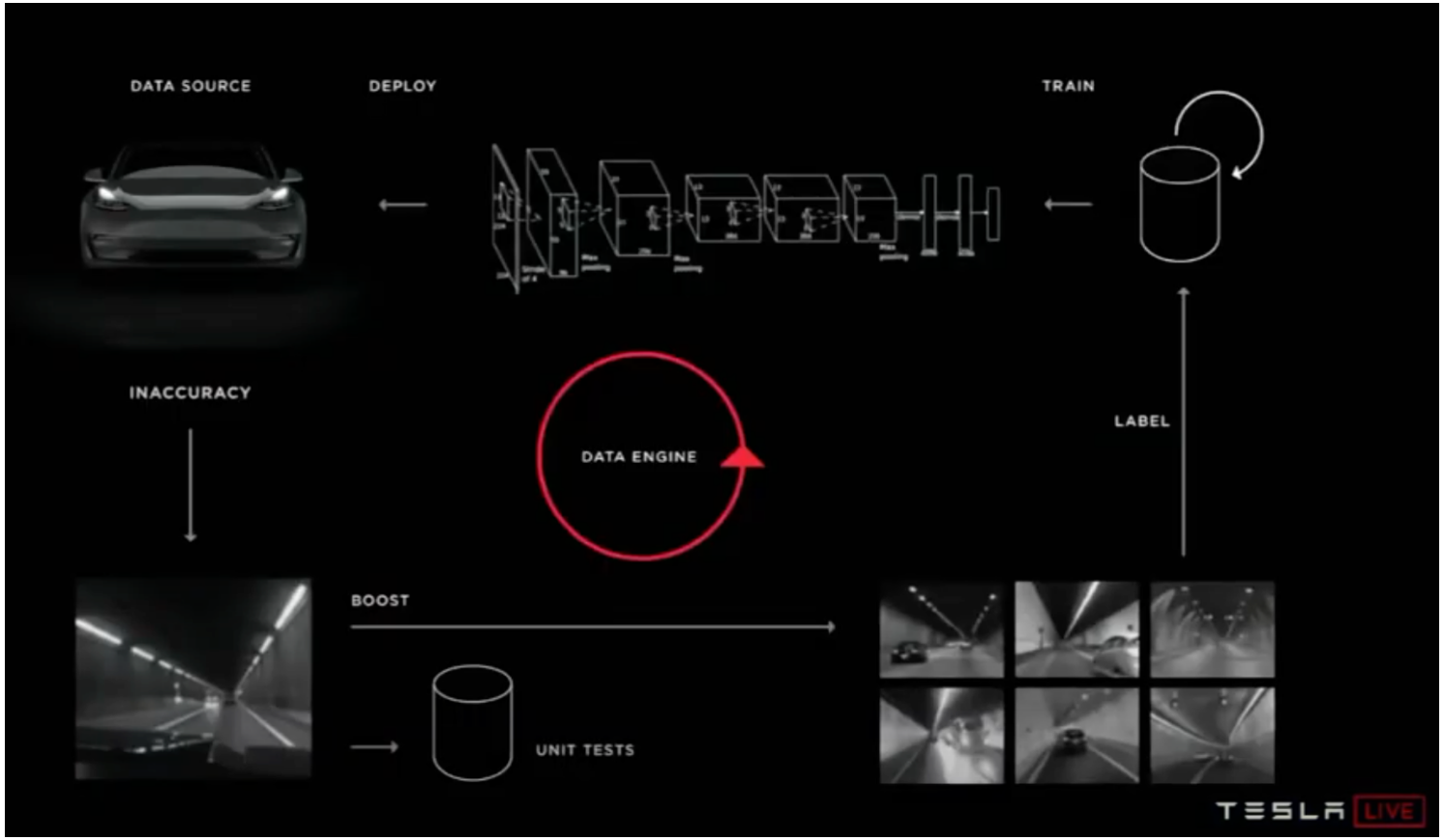
- Even considering the use of wifi+lte, offload seems not useful to me in this context

✓Infotainment

- Customets are reluctant to pay the extra costs associated with embedded connectivity
- Car manufacturers are turning to smartphone integration

✓Autonomy oriented

- high-profile companies uses two main approaches:
  - Computer vision & environment sensing (like Tesla)
  - HD mapping




# What we now from the "Autonomy day"

- Tesla uses their fleet to improve their system in various tasks
- One key idea: use techniques that doesn't require human labelling*
  - To fully exploit the fleet potential
  - 650,000 HW2/3 cars on the road (approximately 1,000 miles per month each or 650 million miles as a fleet)
  - Since there is no need for human labour, Tesla can train its neural networks on as much useful data as it can collect.
    - To me, the bottleneck seems connectivity
- Training data are stored and sent later using Wifi

Event video Summary

# What we now from the “Autonomy day”

- Object detection – this one requires labelling
  - Ask the fleet for rare images (e.g. animals on the road, construction sites, boats, debris)
  - the fleet responds with images with the same patterns
- Prediction – everything automated
  - In predicting car/pedestrian trajectories, you have “free ground truth”
  - Upload only the instances where Tesla’s predictor fails
  - Always upload cut-ins
  - Fleet-learning (& shadow mode)
- Path planning – automated
  - Imitation learning
  - Uploads when the prediction fails, when human driver takes over the autopilot
  - interesting replays like:
    - sudden braking or swerving, automatic emergency braking, crashes or collision warnings
    - ML techniques like *anomaly detection* and *novelty detection*
    - Extend imitation learning to more tasks over time (e.g. upload all the left turns at intersections)

Uploads:

- A lot of potential triggers
- It could be useful to update also basic knowledge
  - Random sampling
  - Aged based update

- It seems they get images/videos

# Connectivity

- Connectivity has been a flagship feature of Tesla's offering in the auto industry
  - features for customers
  - collect data from the fleet
- It used to be free for the owner, it nows require a subscription
- FSD beta users reports uploads up to 4 GB after one day of driving
- Missing connectivity could potentially waste lot of useful data (this is true also for HD maps)
  - You miss an entire car data when:
    - The car usual spot is far from a wifi source
    - The user is not willing to pay for embedded connectivity
    - If you try to use users' smartphone connectivity, they will probably disable data sharing
- Use of CarFi from the manufacturer perspective:
  - Reduce the cost of connectivity allows to:
    - Prevent losing data
    - Upload more data
    - Give features to the users

- We can use questionaries to strenghen the claims
  - E.g. Have you a wifi source near to your car spot? Will you chose a different car brand if they will give you free embedded connectivity? …

# HD maps

- Usually 3d maps. In general, “maps containing details not normally present on traditional maps”
- They are getting attention from big players
- Provided by ad-hoc cars, but attention is moving to crowdsensing

# Companies that uses HD map (crowdsensing)

- Mobileye (intel)
    - Millions of Mobileye-equipped ADAS vehicles sending data to the cloud in small data packets (10kb/km)
- HERE HD live map
    - The base map is the foundation of HERE HD Live Map. Captured via a highly precise industrial process using our HERE True Vehicles equipped with LiDAR, collecting 28TB of data everyday – with accuracy down to centimeters.
    - Using crowdsourced vehicle sensor data, we collect drive paths, lane markings and more. Combined with multiple data sources like satellite imagery helps us maintain a fresh HERE HD Live Map.
- NVIDIA + HERE
    - DRIVE Mapping uses the perception capabilities of vehicles on the road to help update cloud-based HD maps of NVIDIA mapping partners. NVIDIA DRIVE perception capabilities detect semantic features and new landmarks (e.g., road boundaries, lanes, signs, poles, traffic lights) in the vehicle's environment to compare with those from the HD mapping provider. Using DRIVE MapStream, that data is uploaded to the cloud, updating the map with any new or changed features on the roadway.
    - Map creation (It is not uploaded)
- DeepMap

# Crowdsensing [1]

- Allows to map more places
- Allows to have live updated maps
- Connectivity is the main issue
- The more the passes of the same environment, the more the precision of the map

- Chosing the right mapping algorithm is crucial

# HD map representation

- How to represent point cloud remains an open problem
- OctoMap seems the most promising in terms of efficiency
- The disadvantage of octree data is, similarly to voxels, failure to exploit the geometry feature of 3D objects, especially the intrinsic characteristics of patterns and surfaces
- Point cloud data can preserve the 3D geospatial information and internal local structure (useful for identifying features thus have precise localization)

| Map dataset | Mapped area ($m^3$) | Res. (cm) | Mem. 3D grid (MB) | Memory w. octree compression (MB) | | | File size (MB) | |
|---|---|---|---|---|---|---|---|---|
| | | | | None | Pruned | Maximum likelihood | Full | Lossy |
| FR-079 corridor | 43.7 × 18.2 × 3.3 | 5 | 78.88 | 73.55 | 41.62 | 24.72 | 15.76 | 0.67 |
| | | 10 | 10.01 | 10.87 | 7.22 | 5.02 | 2.70 | 0.14 |
| Freiburg campus | 292 × 167 × 28 | 10 | 5162.90 | 1257.57 | 990.66 | 504.76 | 379.70 | 13.82 |
| | | 20 | 648.52 | 187.93 | 130.24 | 74.12 | 49.68 | 2.00 |
| | | 80 | 10.58 | 4.55 | 4.12 | 3.09 | 1.53 | 0.08 |
| New College (Ep. C) | 250 × 161 × 33 | 10 | 5058.76 | 607.92 | 395.42 | 230.33 | 148.75 | 6.40 |
| | | 20 | 633.64 | 91.33 | 50.57 | 35.95 | 18.65 | 0.99 |
| | | 80 | 10.13 | 2.34 | 1.79 | 1.69 | 0.63 | 0.05 |
| freiburg1_360 (RGBD) | 7.9 × 7.3 × 4.6 | 2 | 252.99* | 159.97* | 45.52* | 20.05 | 21.59* | 0.52 |
| | | 5 | 16.19* | 11.24* | 4.55* | 2.52 | 2.11* | 0.07 |

# OctoMap

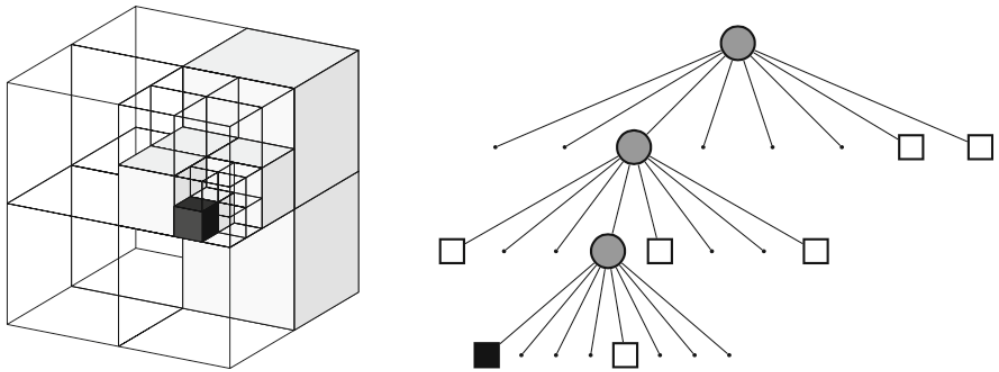


**Fig. 2** Example of an octree storing free (*shaded white*) and occupied (*black*) cells. The volumetric model is shown on the *left* and the corresponding tree representation on the *right*

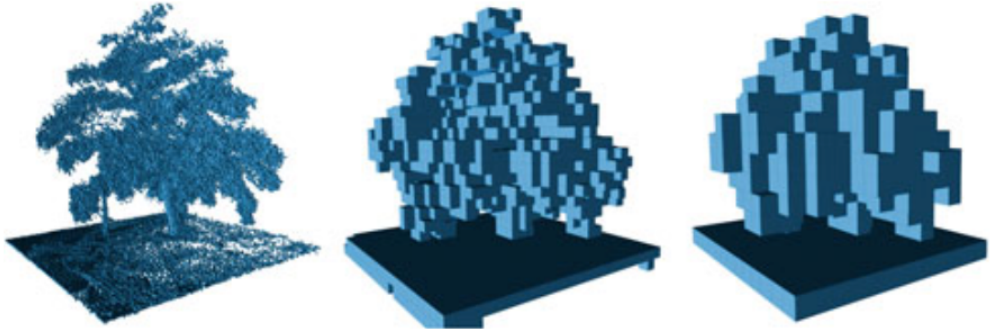


**Fig. 3** By limiting the depth of a query, multiple resolutions of the same map can be obtained at any time. Occupied voxels are displayed in resolutions 0.08, 0.64, and 1.28 m

- Probabilistic sensor fusion
  - The update formula depends on the current measurement and the previous estimate

# Zed 2 stereo lab – depth camera