



Self Driving Cars

A study in deep learning applications

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What and why?

Traffic kills 1.35 million people worldwide per year (2016)

That's about one person every 25 seconds

Self driving cars are an application of deep learning that can save lives!

Moravec's paradox

"It is comparatively easy to make computers exhibit adult level performance on intelligence tests or playing checkers, and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility"

Challenges...

- Real time requirements
- Sparse training data types
- Reflections, light changes
- Unpredictable pedestrians
- Construction zones
- Parking garages
- Weather

Human error: 0.000001%

...but it works!

Total miles driven in U.S. in 2018:

3,000,000,000,000

U.S crash fatalities:

36,560 (*1 in 82 million*)

Tesla Autopilot miles driven:

3,000,000,000

Total fatalities: 15 (*1 in 200 million*)

Technologies available

Under the bonnet

How a self-driving car works

Signals from **GPS (global positioning system)** satellites are combined with readings from tachometers, altimeters and gyroscopes to provide more accurate positioning than is possible with GPS alone

Lidar (light detection and ranging) sensors bounce pulses of light off the surroundings. These are analysed to identify lane markings and the edges of roads

Video cameras detect traffic lights, read road signs, keep track of the position of other vehicles and look out for pedestrians and obstacles on the road

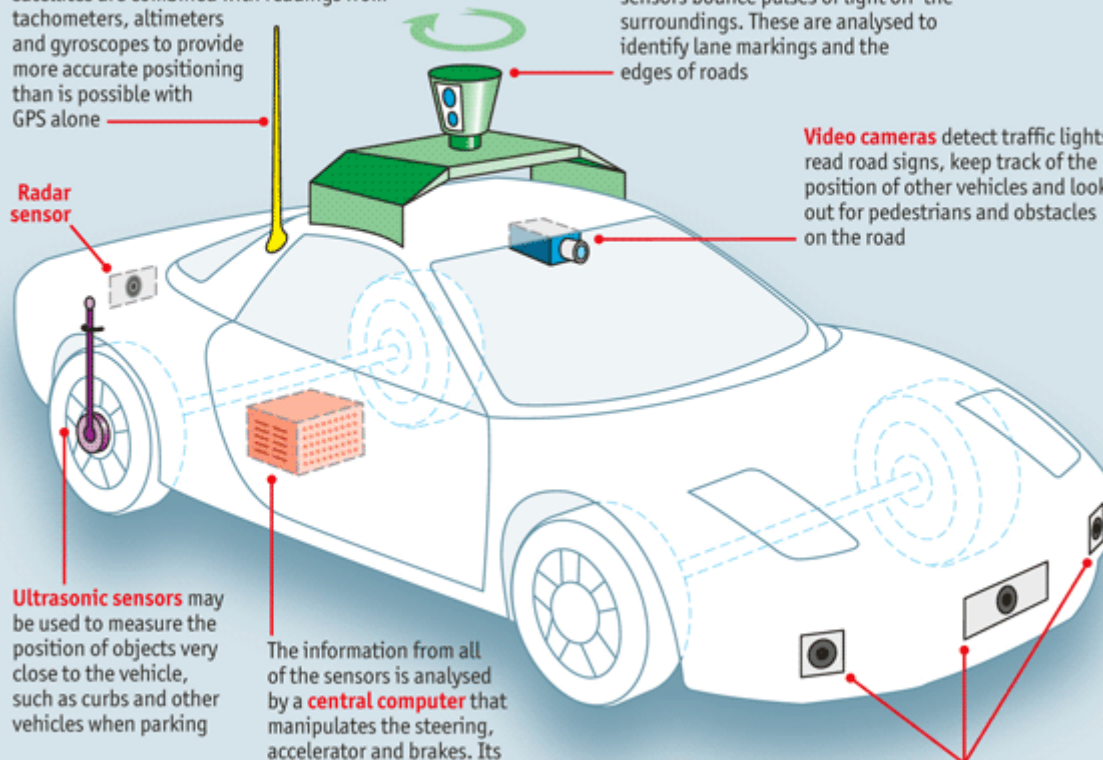
Radar sensor

Ultrasonic sensors may be used to measure the position of objects very close to the vehicle, such as curbs and other vehicles when parking

The information from all of the sensors is analysed by a **central computer** that manipulates the steering, accelerator and brakes. Its software must understand the rules of the road, both formal and informal

Radar sensors monitor the position of other vehicles nearby. Such sensors are already used in adaptive cruise-control systems

Source: *The Economist*



World in LIDAR

Visualization of LIDAR data



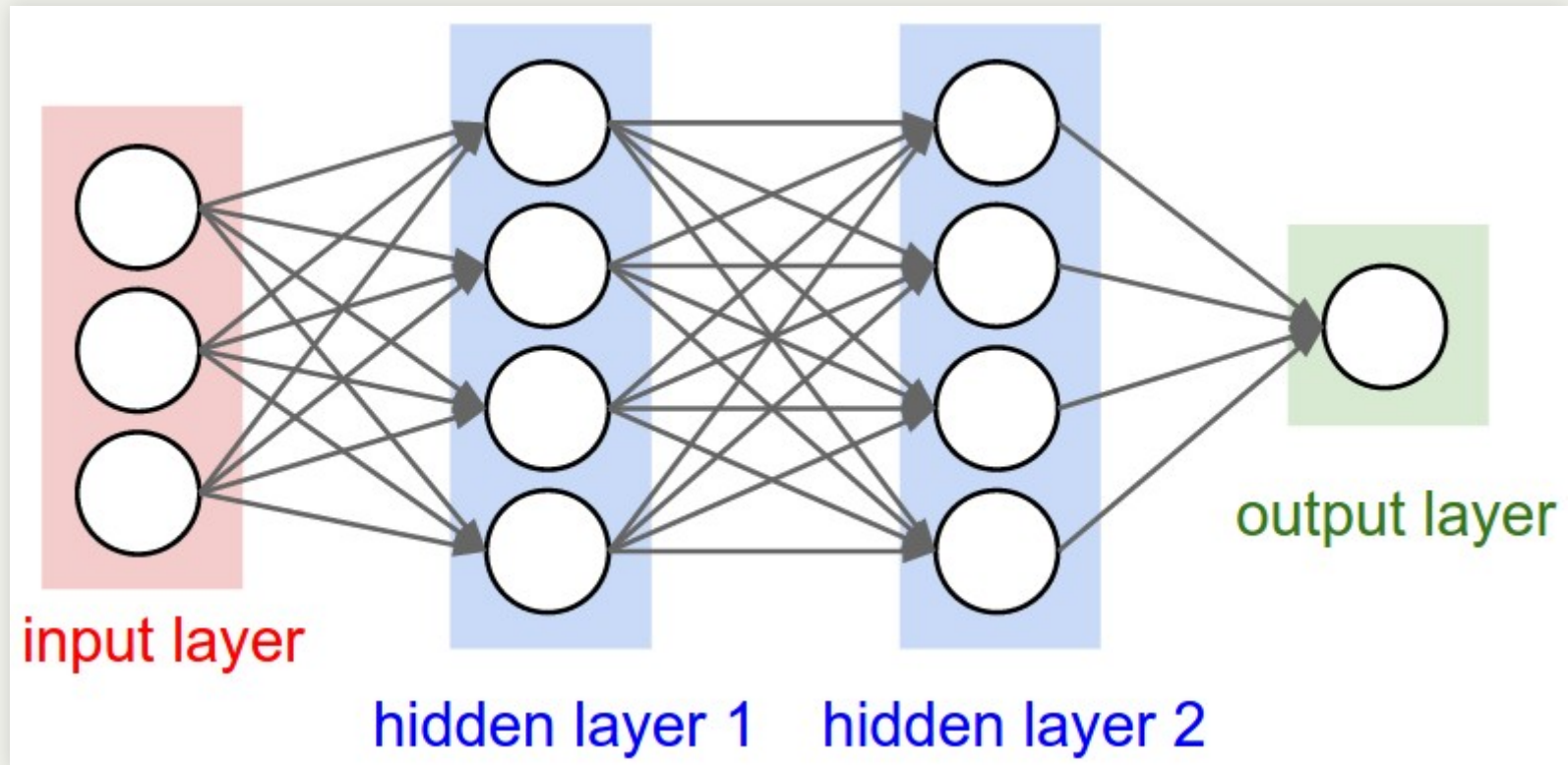
(~1GB of data per second)

Deep Learning!

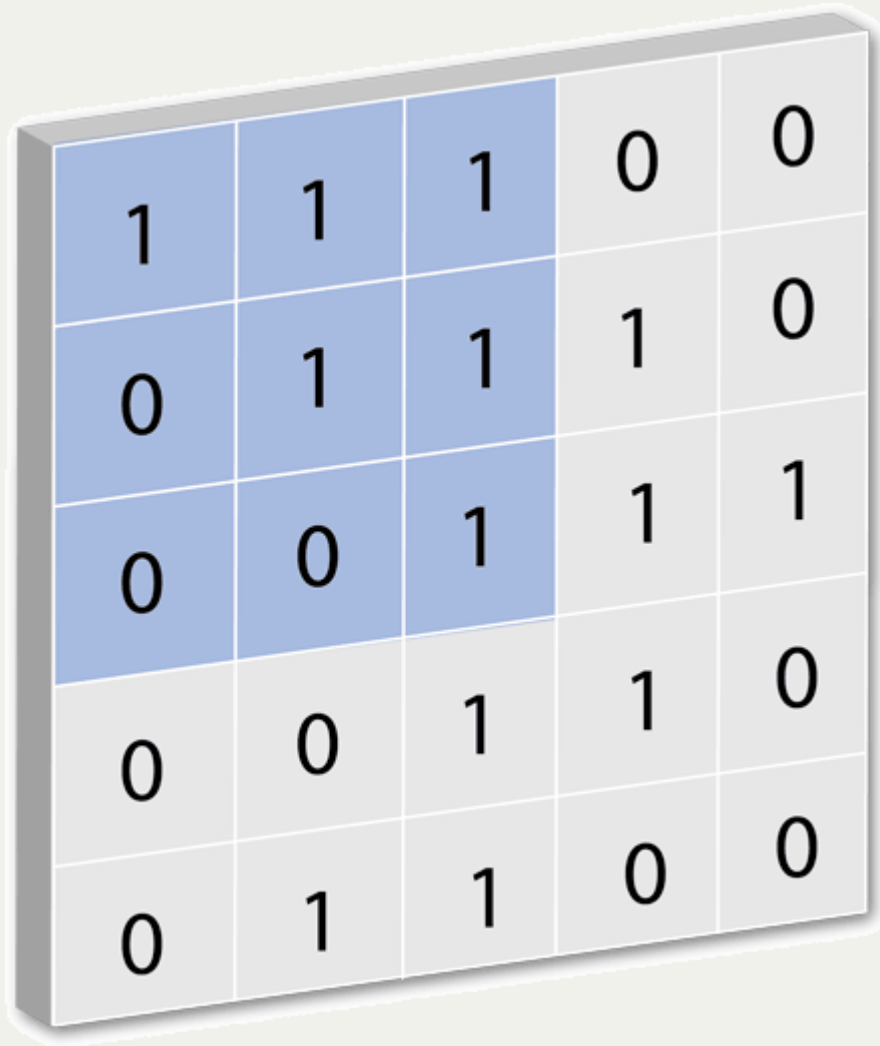
These are the tools we need:

- Convolutional Neural Networks
- Recurrent Neural Networks
- Reinforcement Learning

Traditional Neural Networks

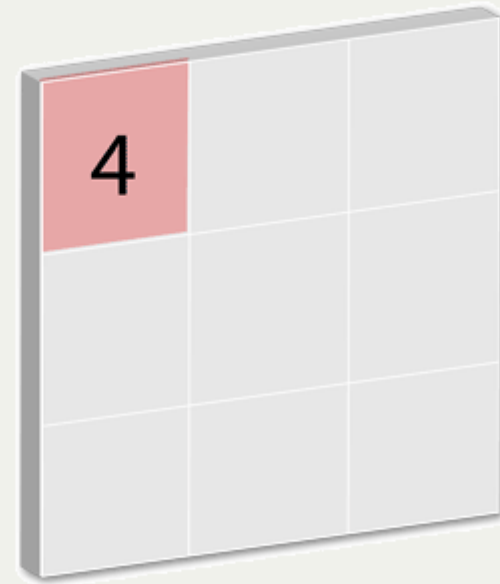


Convolutional Neural Network



A 5x5 grid representing an input image. The top-left 3x3 subgrid is highlighted in blue. The values in the grid are:

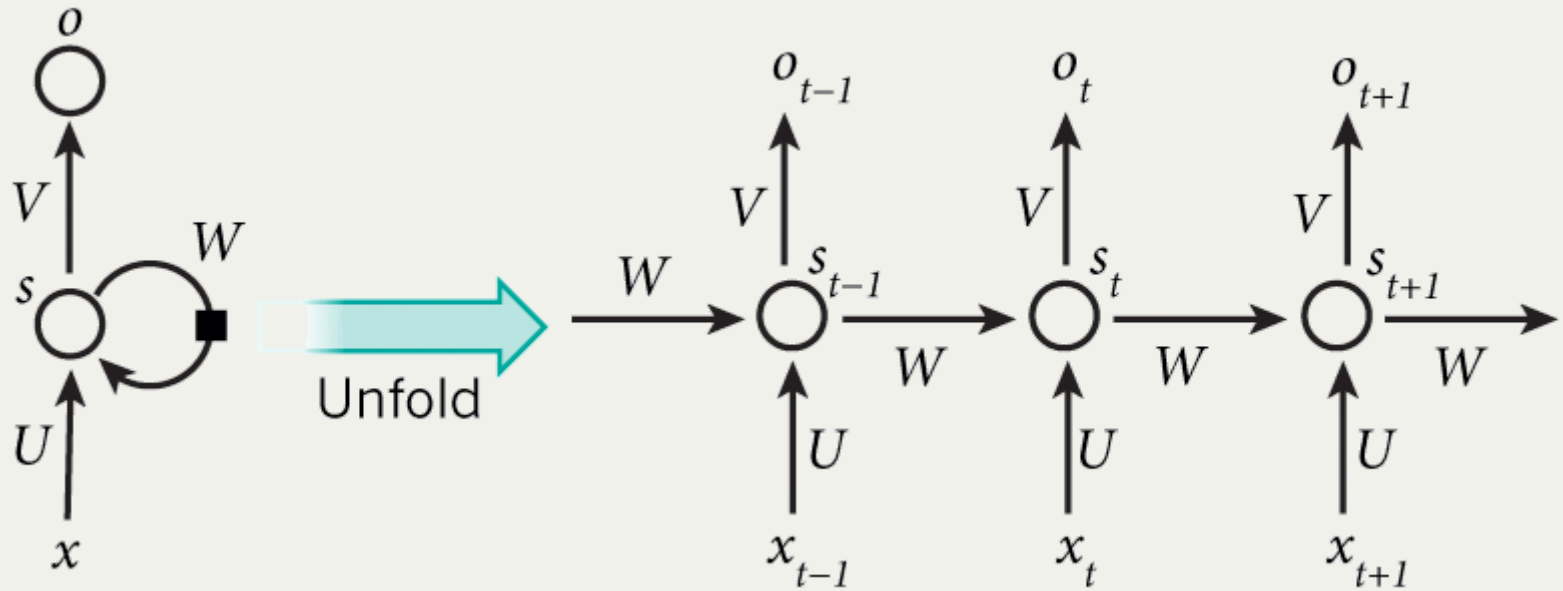
1	1	1	0	0
0	1	1	1	0
0	0	1	1	1
0	0	1	1	0
0	1	1	0	0



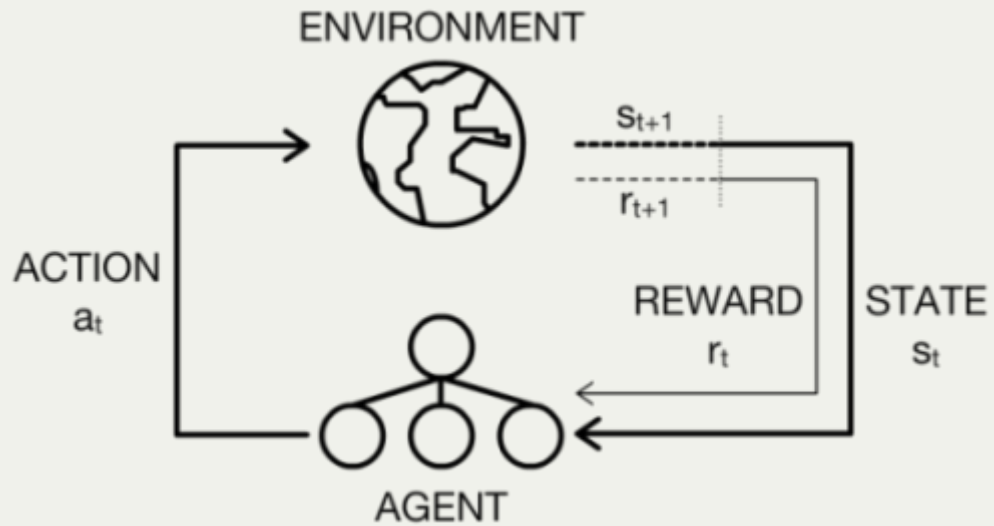
A 3x3 grid representing the output feature map. The top-left cell is highlighted in red and contains the value 4. The other cells are empty.

4		

Recurrent Neural Network



Reinforcement Learning



How much deep learning?

Two approaches to utilizing DL:

1. Task-orientated deep learning
2. End-to-end deep learning

Google Self Driving Car



Task-orientated

Use deep learning for specific tasks:

- Localization and mapping
- Scene understanding
- Movement planning
- Driver state

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Visual Odometry

100 fps & Very Low Drift Visual Odometry - New College Da...

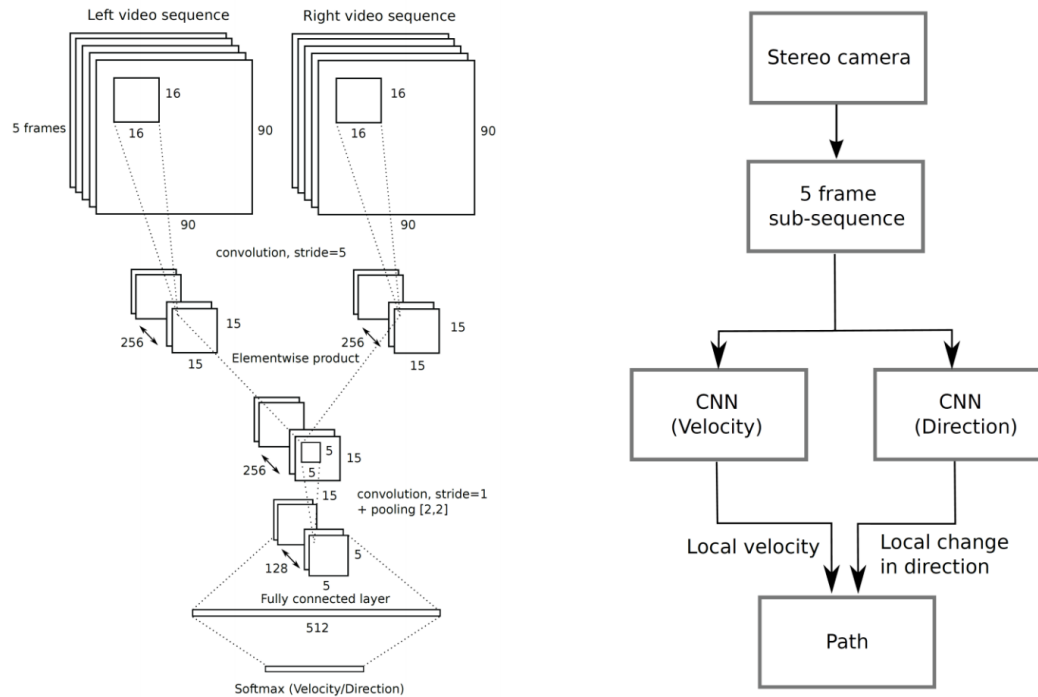


(Cars also have GPS / accelerometer / etc..)

Traditional Approaches

1. Undistortion / rectification
2. Disparity map computation
3. Feature detection (SIFT)
4. Feature tracking (KLT)
5. Trajectory estimation

Deep Learning Approaches



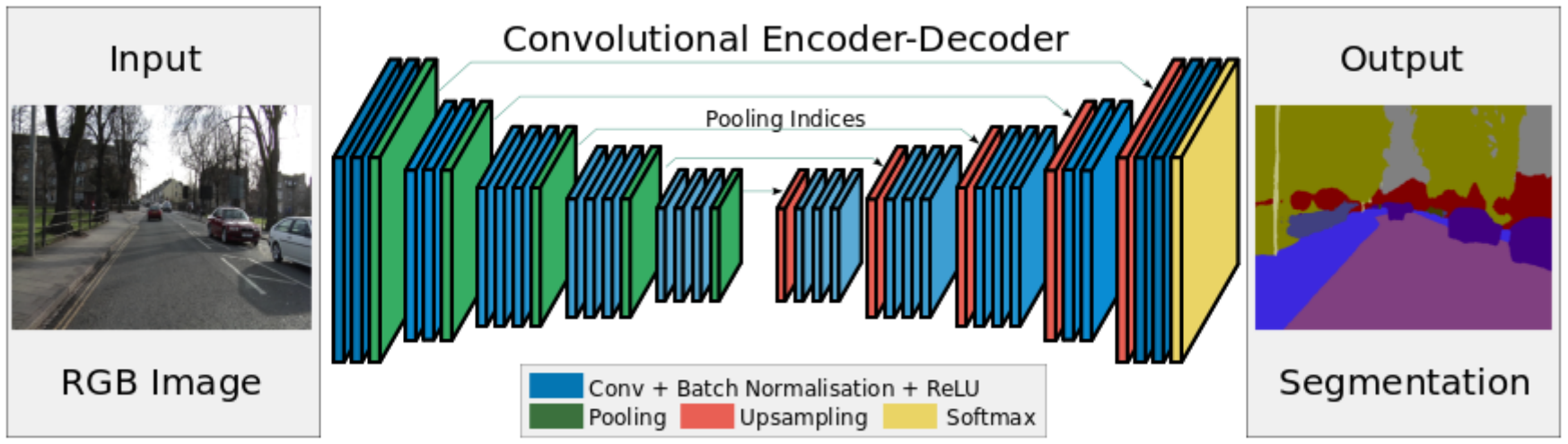
Konda, Kishore, and Roland Memisevic. "Learning visual odometry with a convolutional network." *International Conference on Computer Vision Theory and Applications*. 2015.

Task-orientated

Use deep learning for specific tasks:

- Localization and mapping
- **Scene understanding**
- Movement planning
- Driver state

SegNet: Road Scene Segmentation

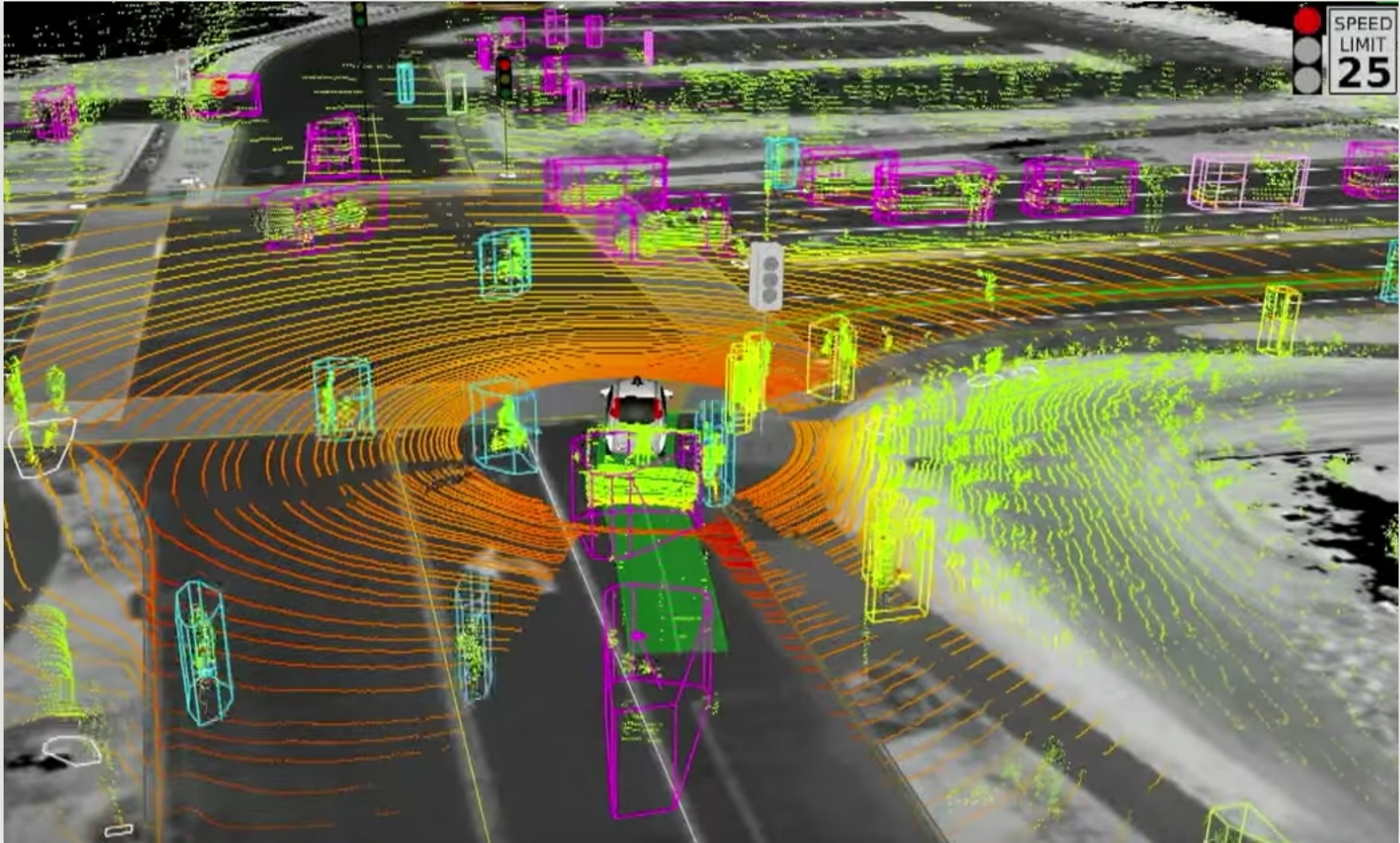


SegNet: Road Scene Segmentation

SegNet: Road Scene Segmentation



LIDAR object classification

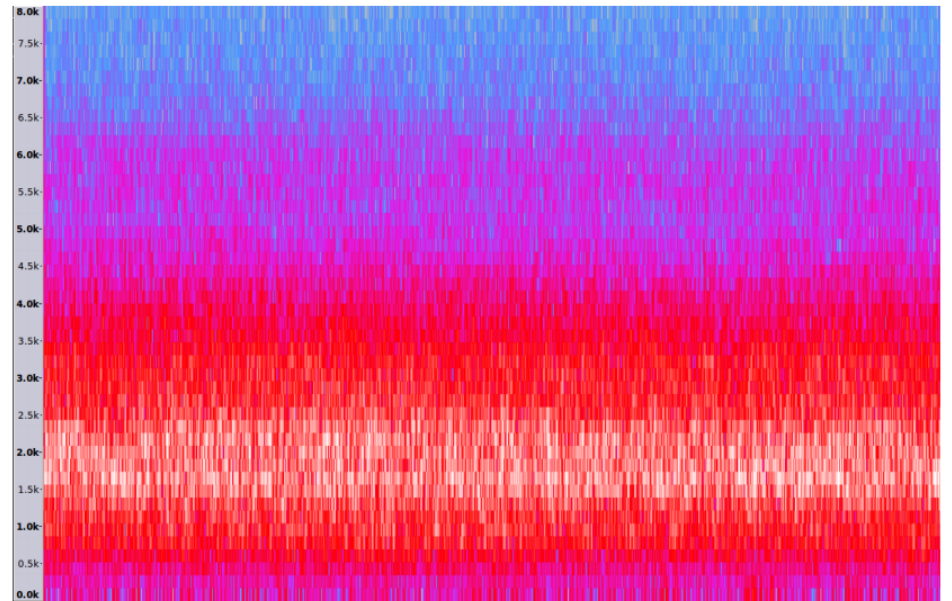
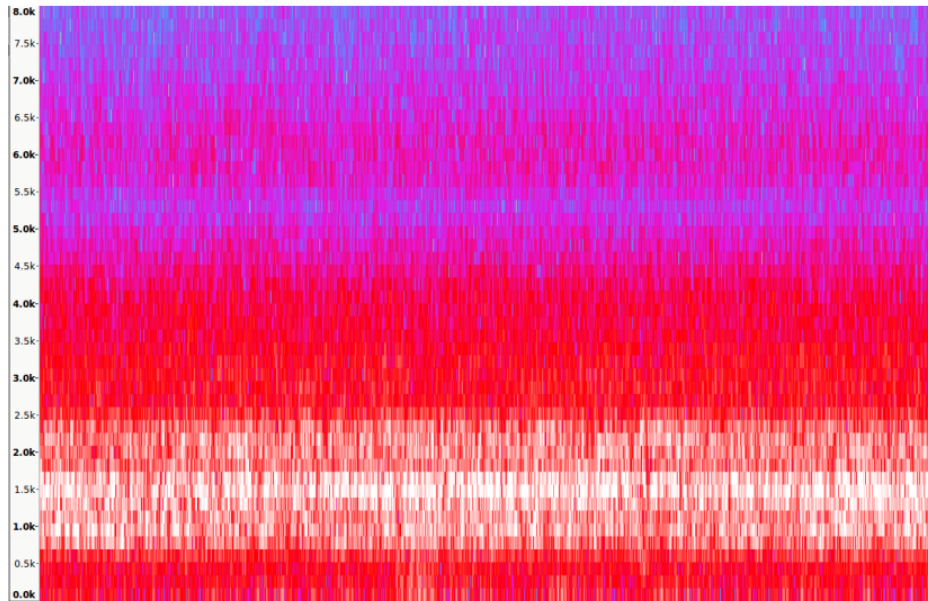


Object identification

traffic light recognition by deep neural network



Wet road classification



Task-orientated

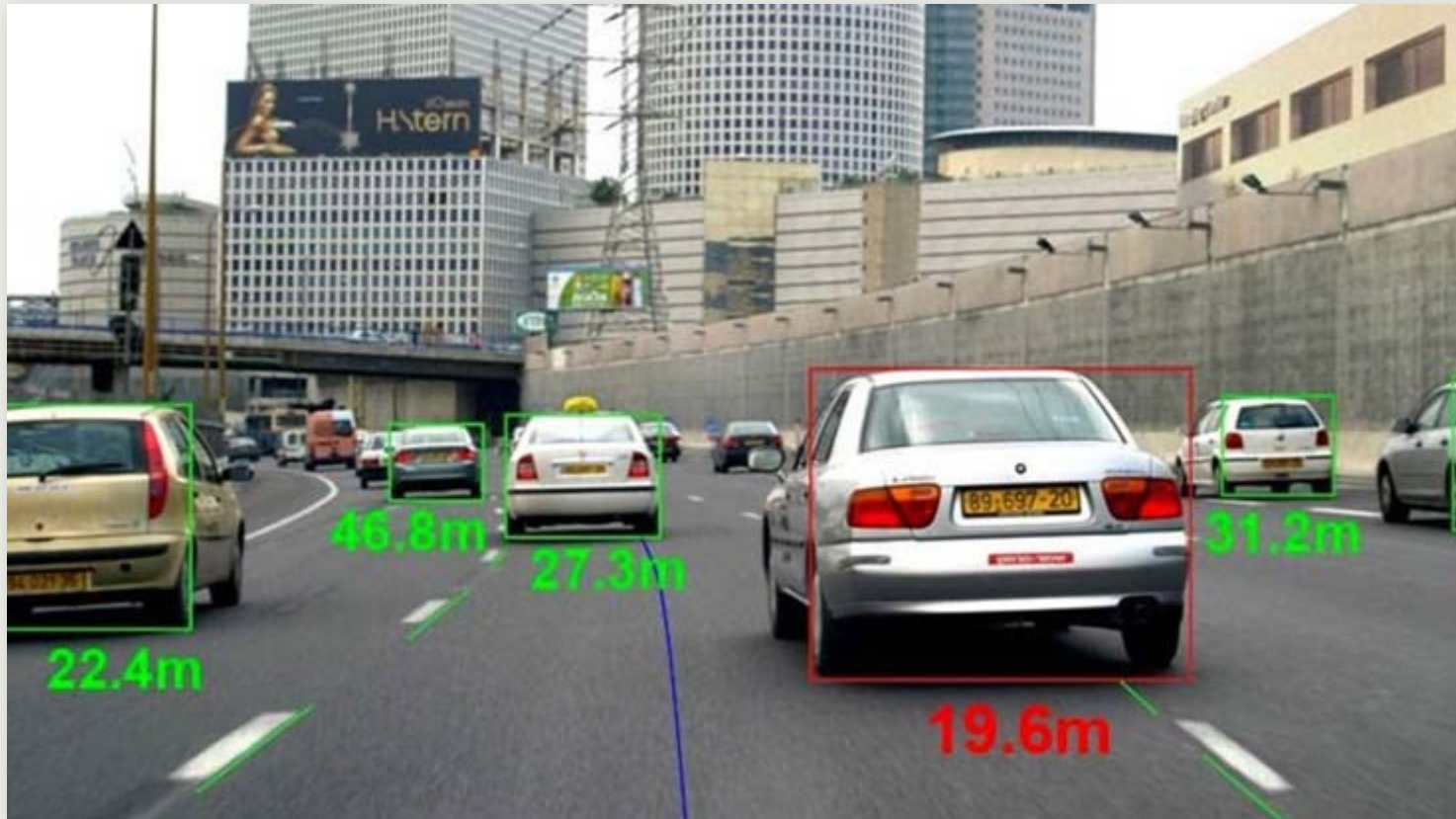
Use deep learning for specific tasks:

- Localization and mapping
- Scene understanding
- **Movement planning**
- Driver state

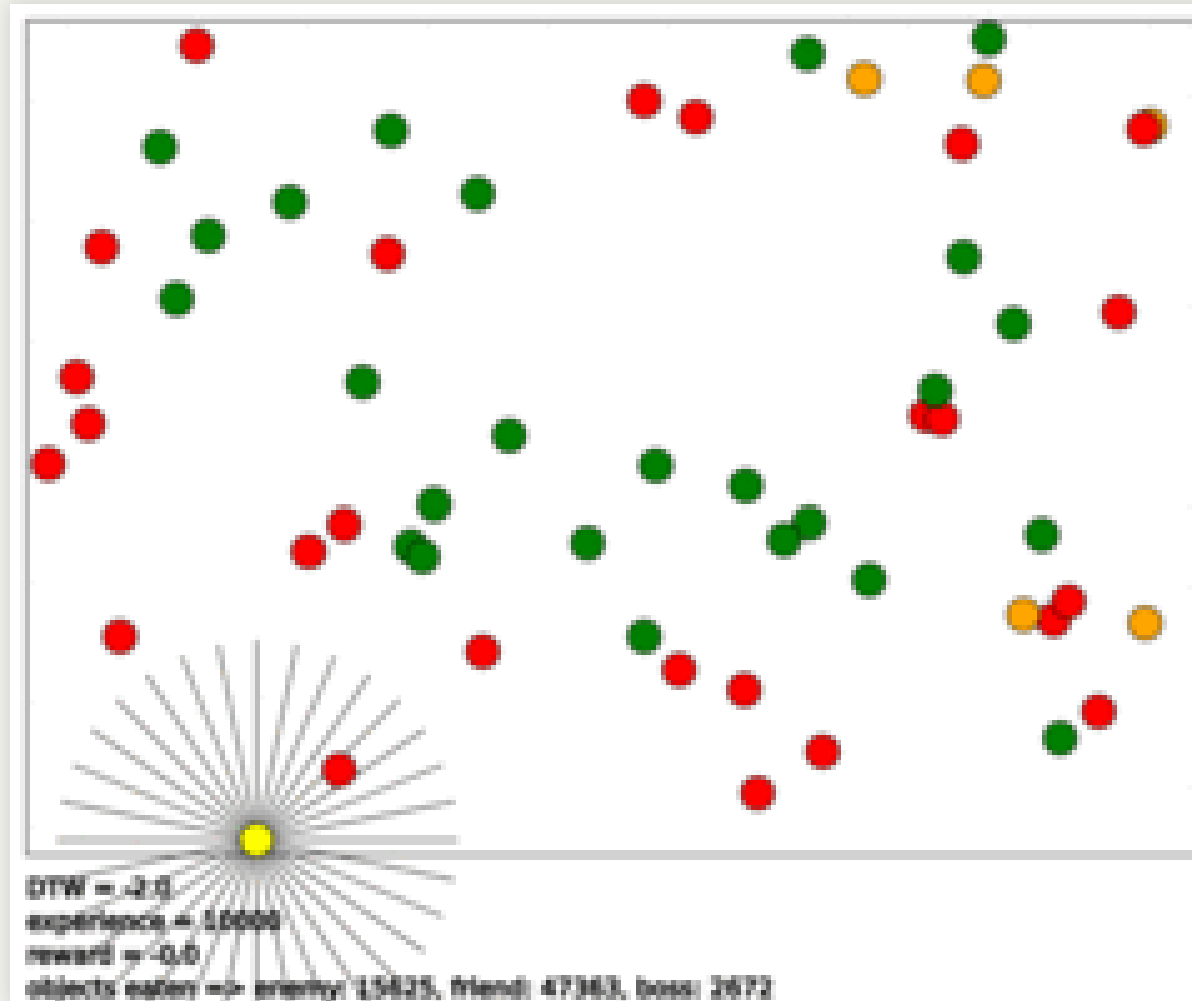
Movement planning problems:

- Optimal lane to use
- How far / close to drive to others
- Poorly defined conditions

Distance



Object avoidance



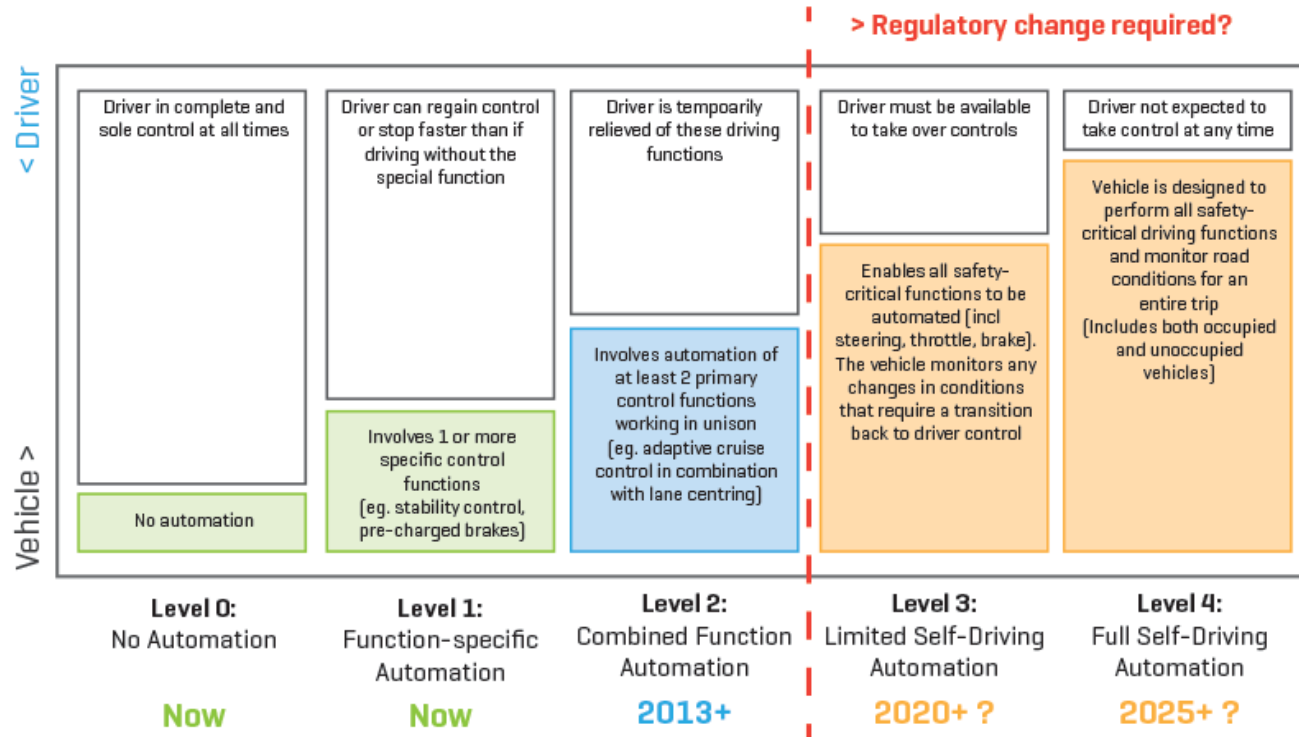
Task-orientated

Use deep learning for specific tasks:

- Localization and mapping
- Scene understanding
- Movement planning
- **Driver state**

NHTSA Car Classifications

Levels of driving automation (NHTSA)



Source: NHTSA (Modified)

Building Blocks

Self driving cars are going to be an incremental process

Some people love to drive their own cars!

Can deep learning still help?

Where is the driver looking?

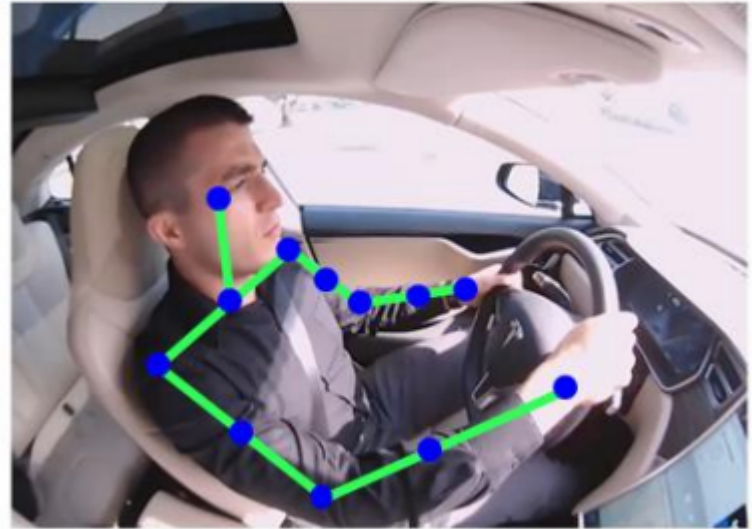
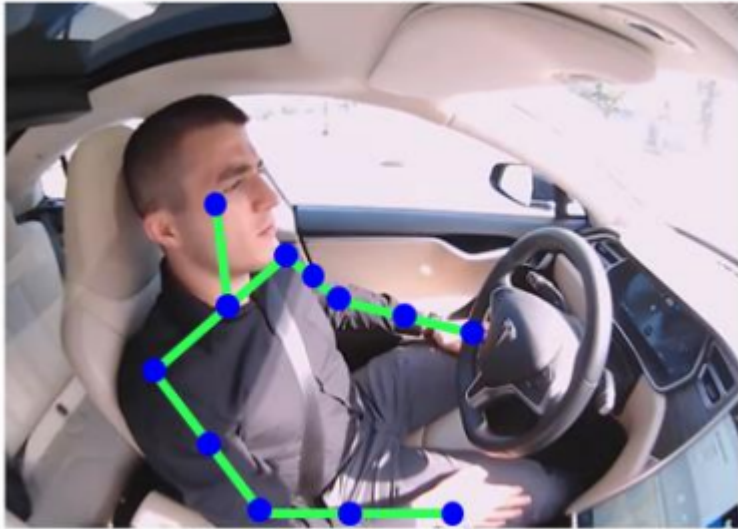


Latest gaze classification:

Right



How is the driver sitting?



Is the driver tired?



Webcam



Video Stream

Low
Cognitive Load

Medium
Cognitive Load

High
Cognitive Load

NVIDIA Self Driving Car

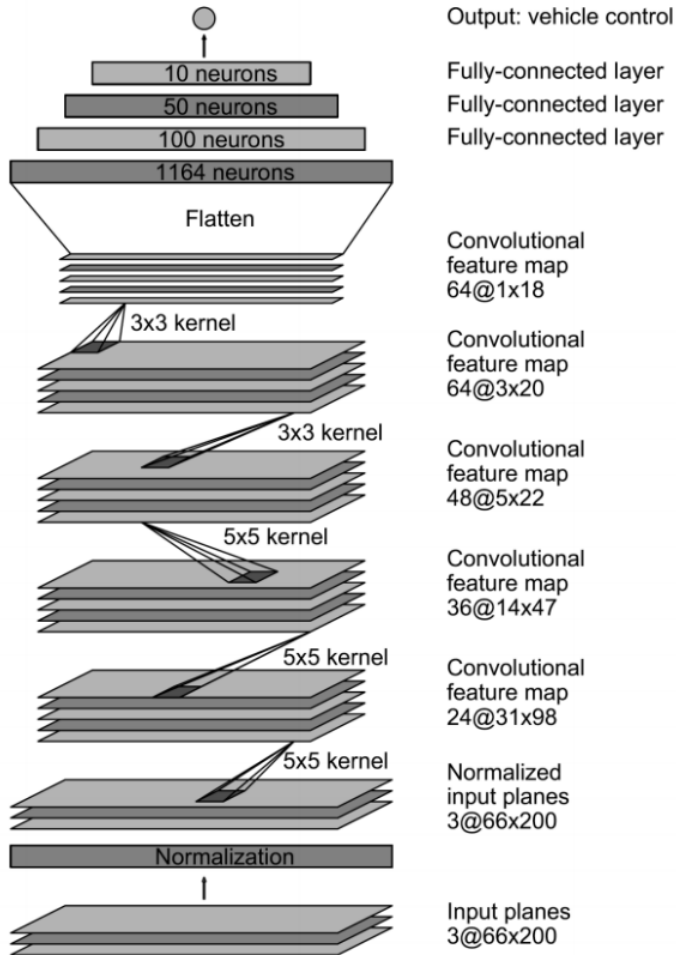


End to End Deep Learning



End-to-end deep learning maps sensor data directly to vehicle controls

End to End Deep Learning



- 9 layers
 - 1 normalization layer
 - 5 convolutional layers
 - 3 fully connected layers
- 27 million connections
- 250 thousand parameters

Prediction targets:

- Steering wheel position
- Accelerator or break strength
- On/off of various signals

CNN Applications

NVIDIA AI Car Demonstration



RNN Applications

Udacity Open Source Self Driving Car Challenge #2 - Video ...



Summary

- Deep Learning is an important tool in self driving
- Self driving cars can use it end-to-end, or as a tool
- We have the building blocks: CNN's, RNN's, and RL
- This is an important problem for deep learning!

Thanks!

Sources

- Deep Learning, Chapter 10
- Understanding LSTM Networks
- Recurrent Neural Networks Tutorial
- The Unreasonable Effectiveness of Recurrent Neural Networks
- CS231N Lecture 10 - Recurrent Neural Networks, Image Captioning, LSTM