



Self Driving Cars

A study in deep learning applications

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What and why?

Traffic kills 1.25 million people worldwide per year

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 2014:

3,000,000,000,000

U.S crash fatalities:

32,675 (*1 in 90 million*)

Tesla Autopilot miles driven:

1,557,000,000

Total fatalities: 5

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

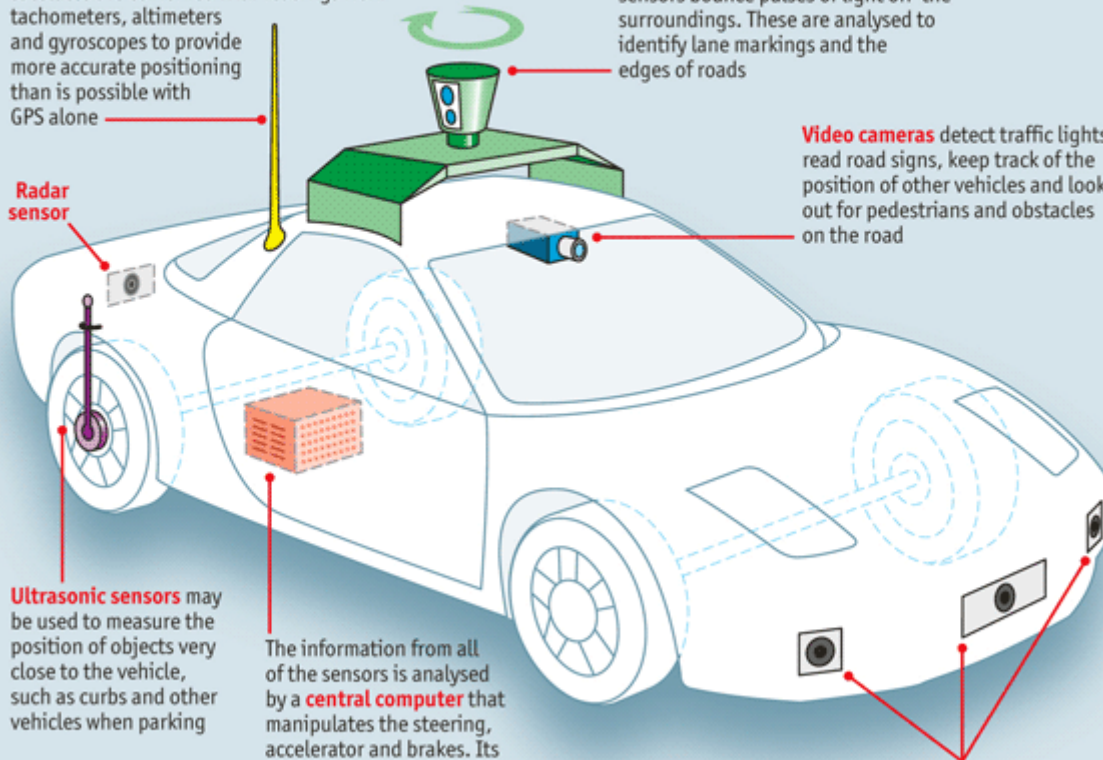
Radar sensor

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



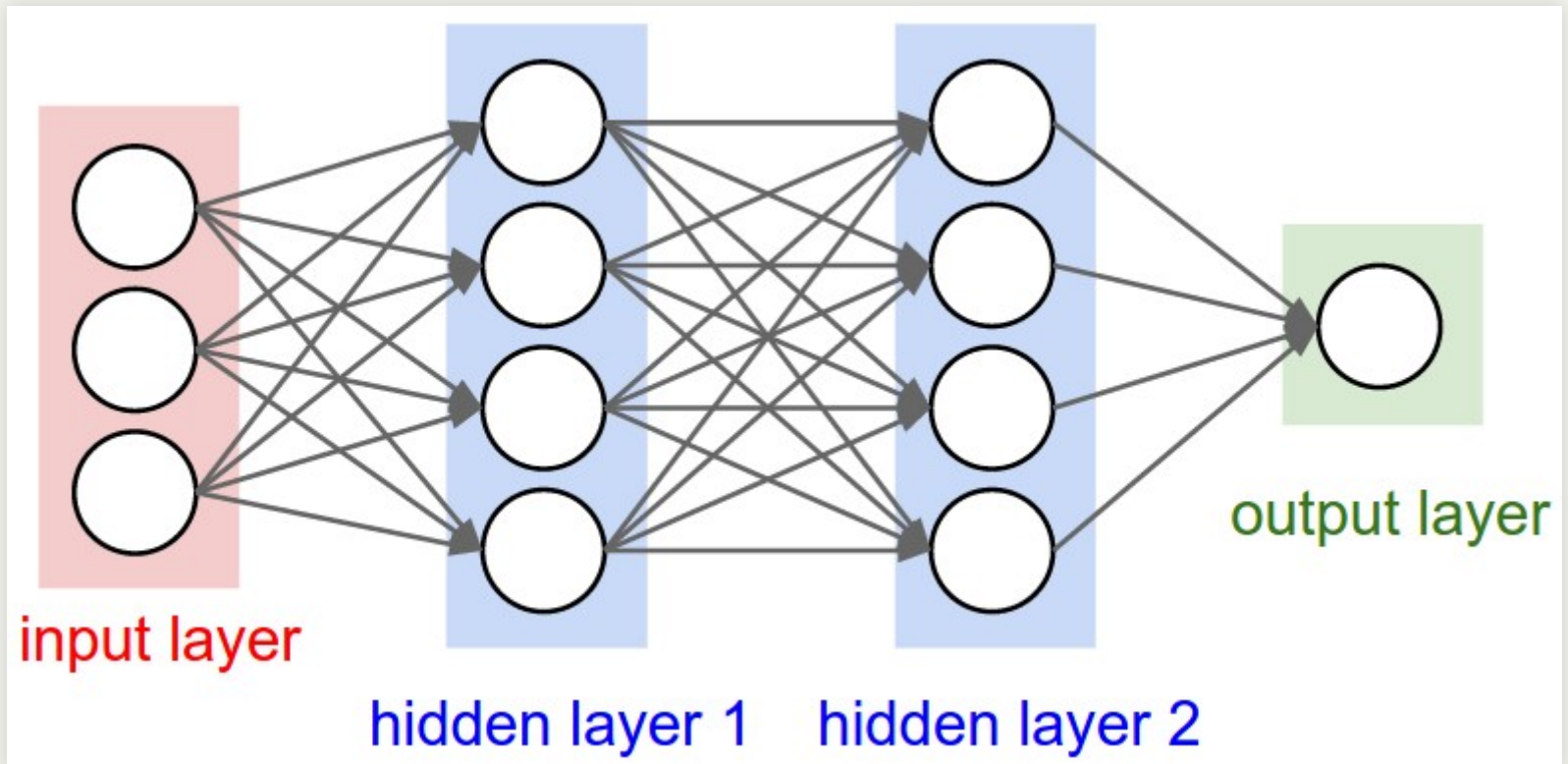
(~1GB of data per second)

Deep Learning!

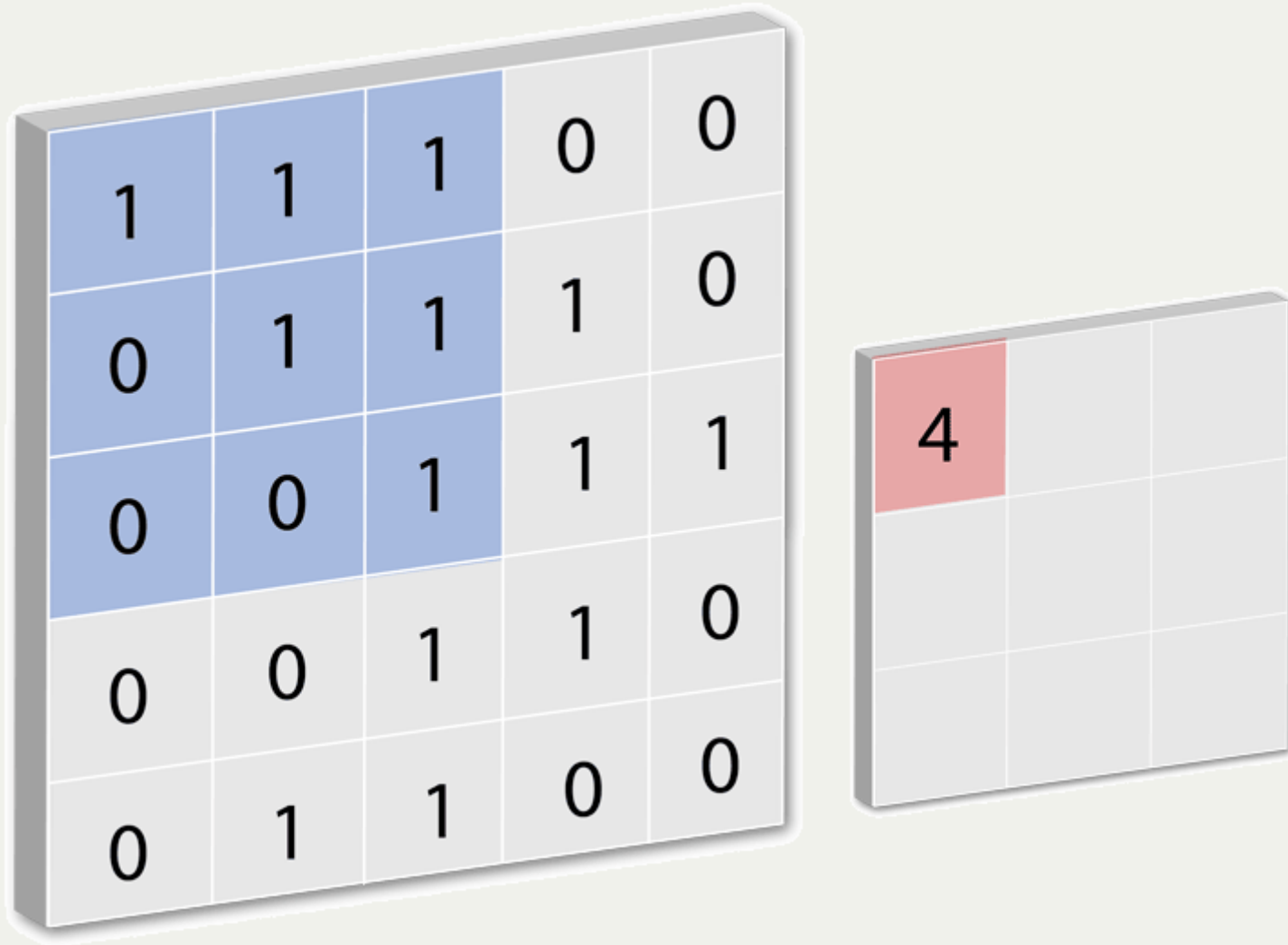
These are the tools we need:

- Convolutional Neural Networks
- Recurrent Neural Networks
- Reinforcement Learning

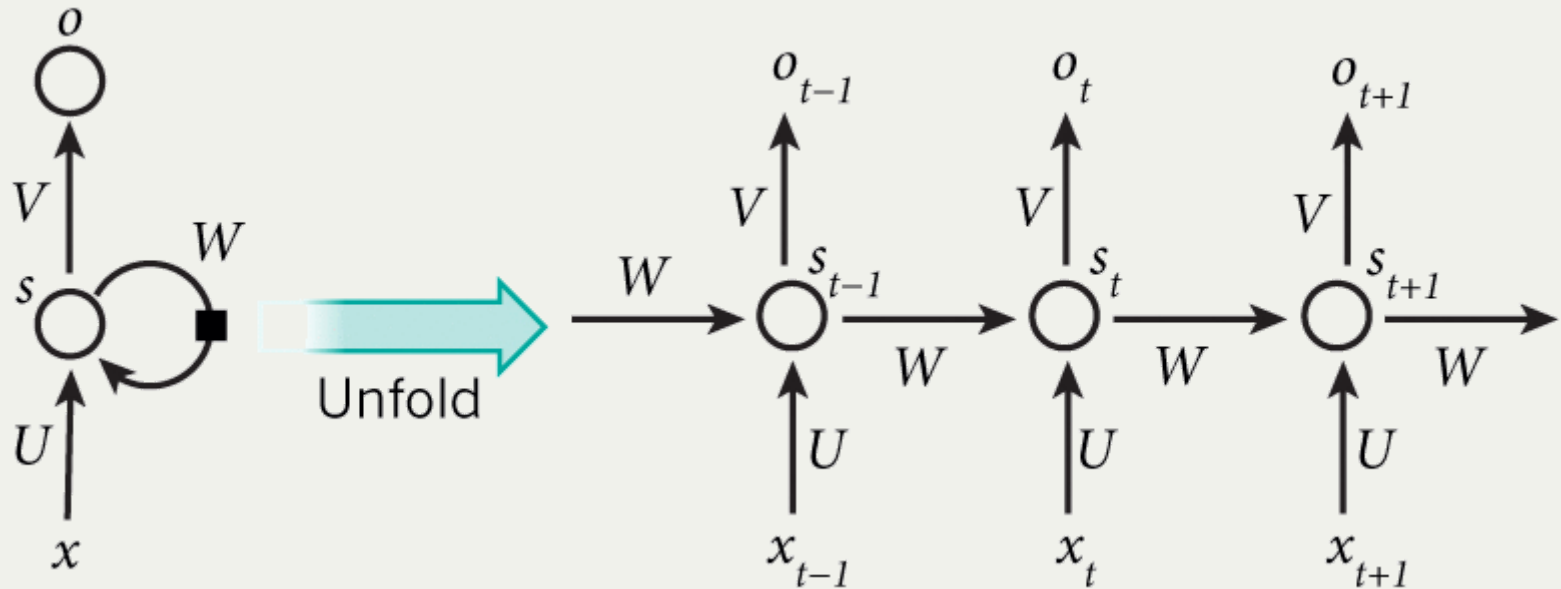
Traditional Neural Networks



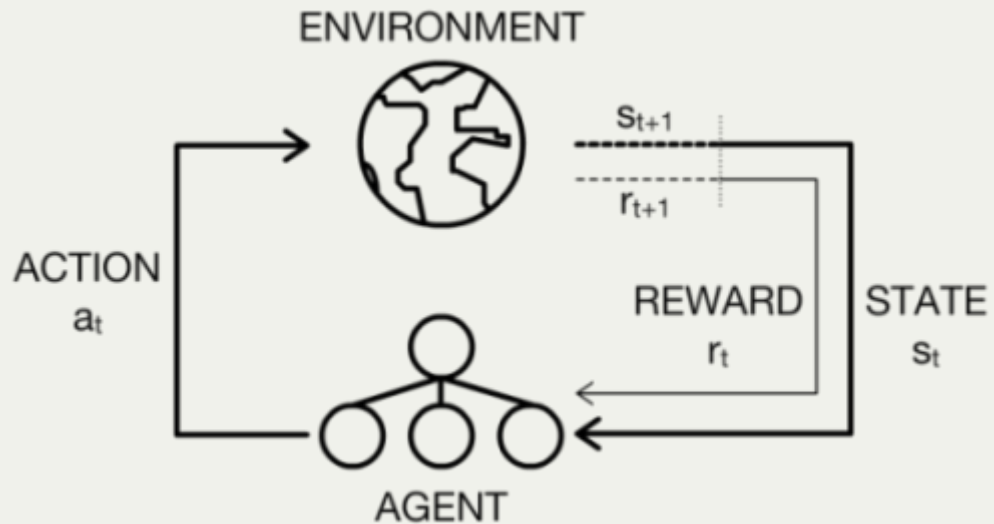
Convolutional Neural Network



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...

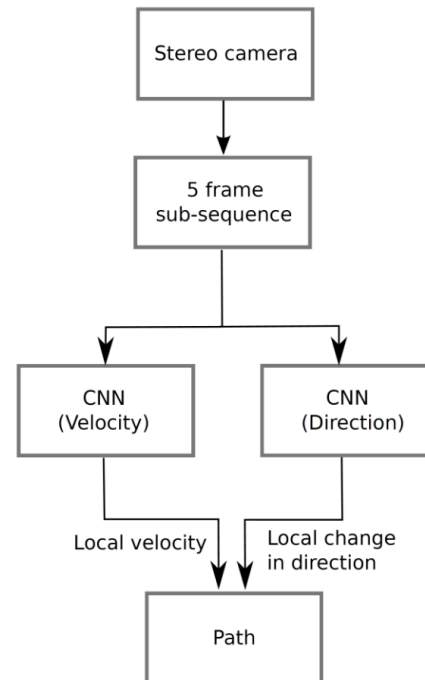
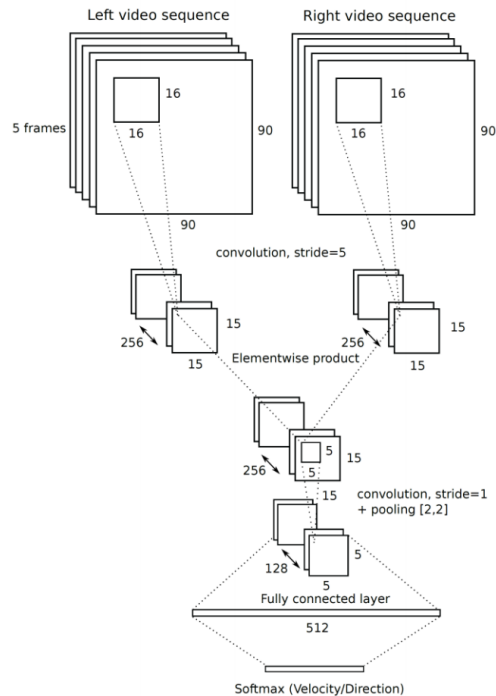


(Cars also have GPS / accelerometer / etc..)

Traditional Approaches

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

Deep Learning Approaches



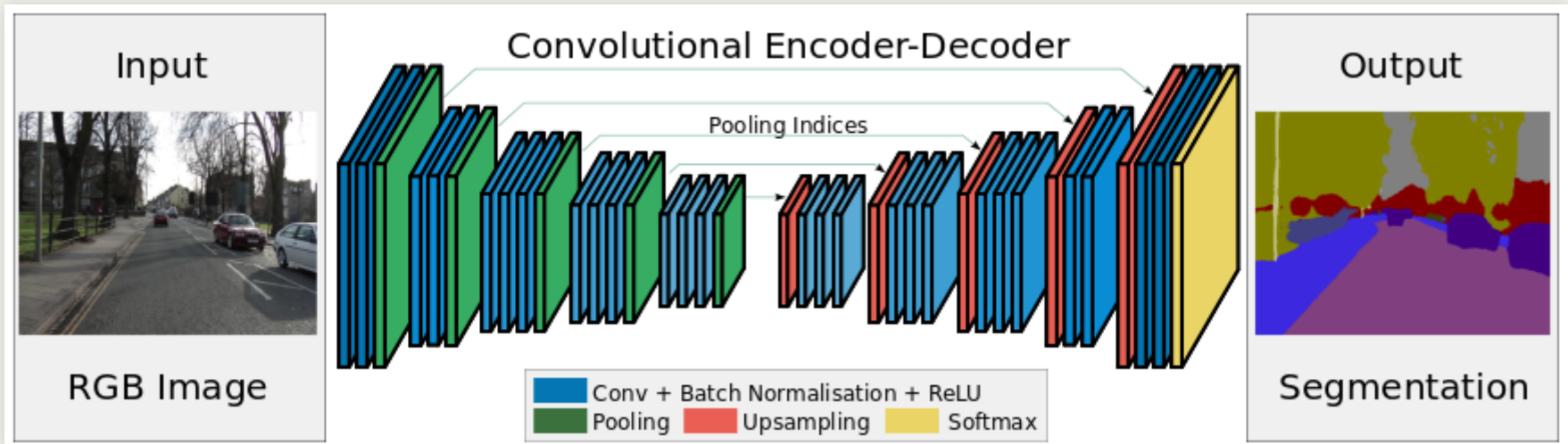
Konda, Kishore, and Roland Memisevic. "Learning visual odometry with a convolutional network." *International Conference on Computer Vision Theory and Applications*. 2015.

Task-orientated

Use deep learning for specific tasks:

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

SegNet: Road Scene Segmentation



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LIDAR object classification

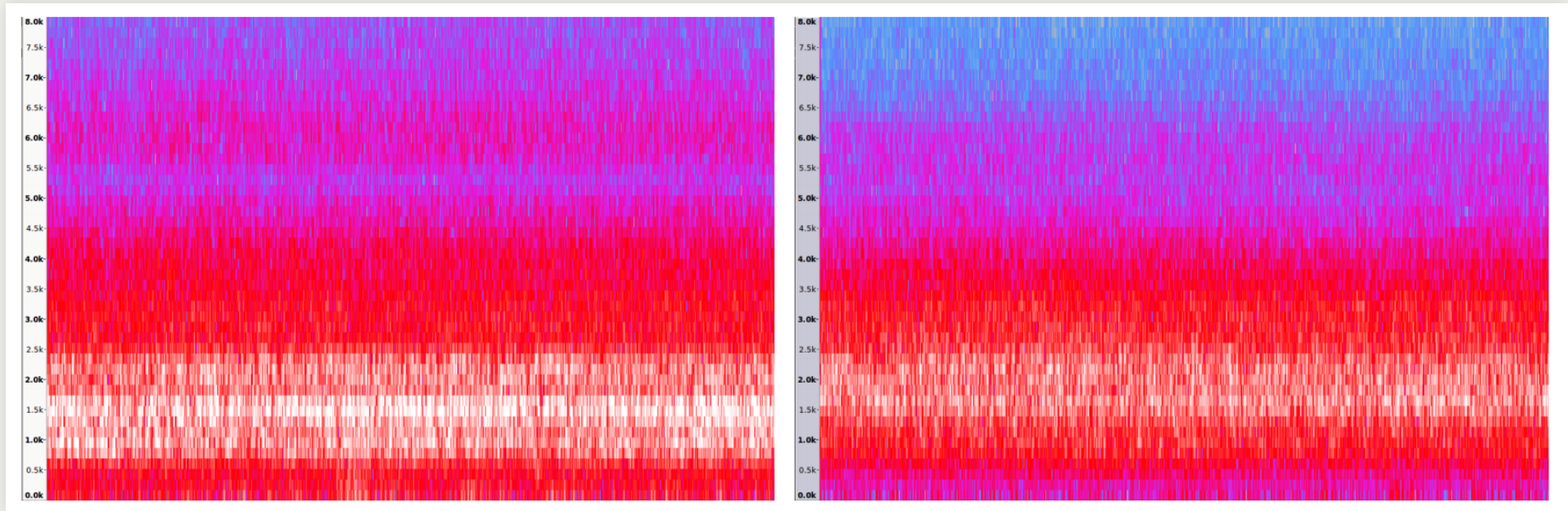


Object identification

traffic light recognition by deep neural network



Wet road classification



Task-orientated

Use deep learning for specific tasks:

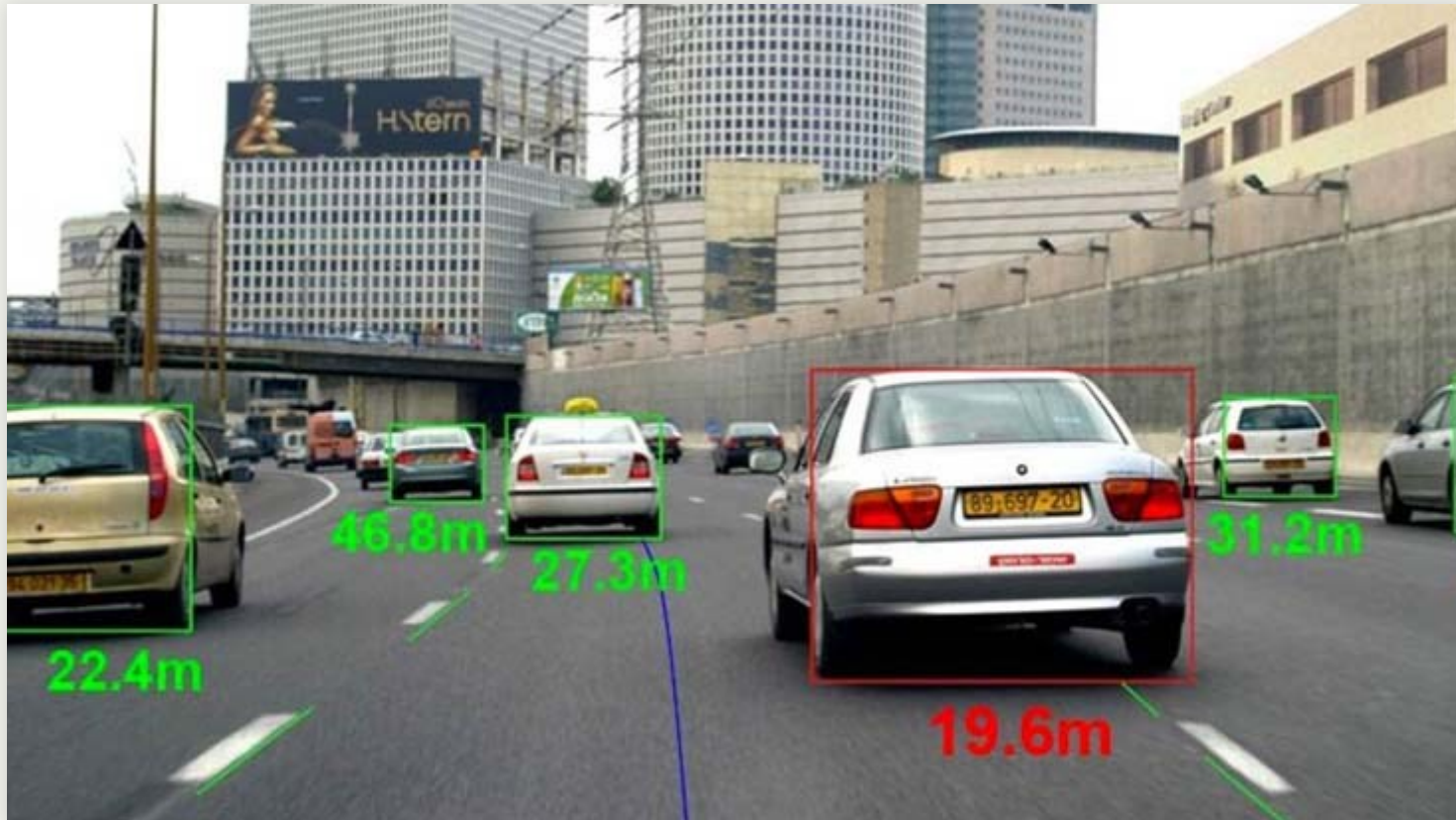
- Localization and mapping
- Scene understanding
- Movement planning
- Driver state

Movement planning problems:

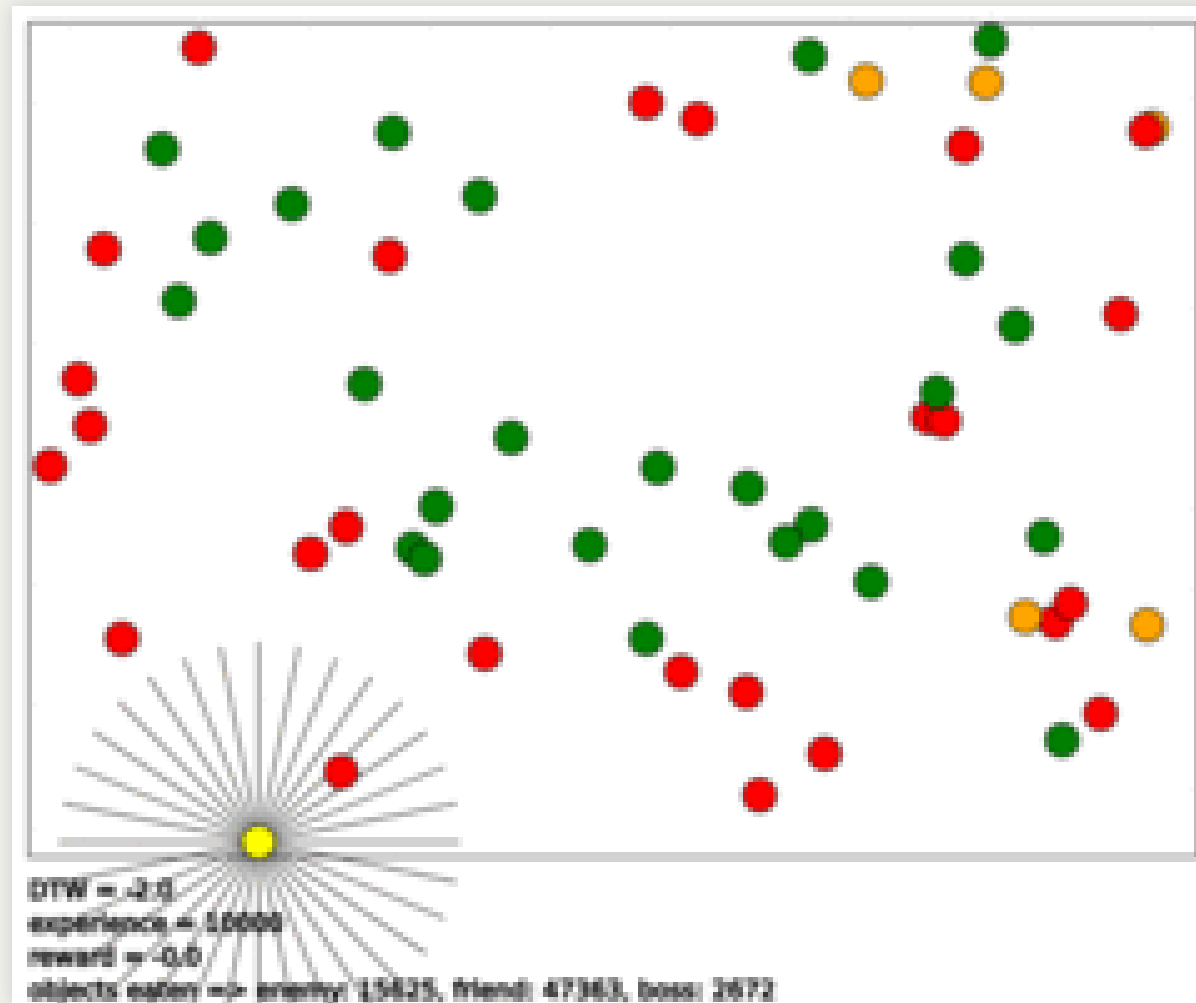
- Optimal lane to use
- How far/close to drive to others
- Poorly defined conditions

Deep Traffic

Distance



Object avoidance



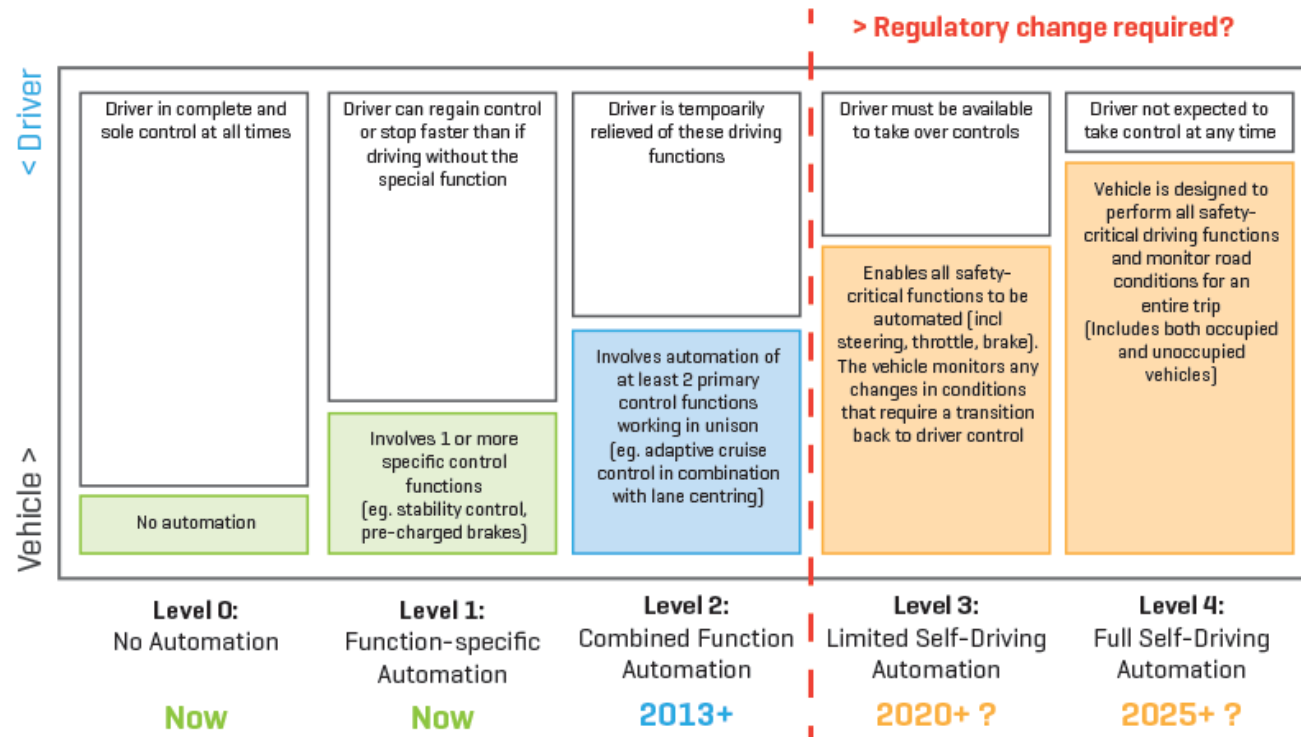
Task-orientated

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?

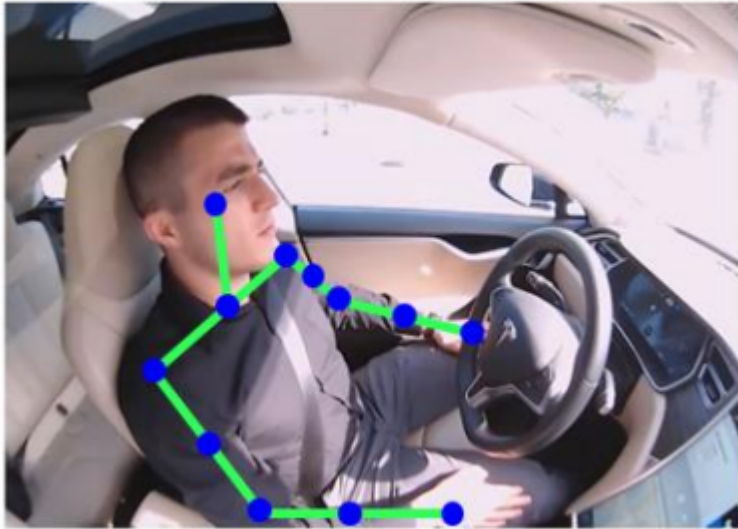


Latest gaze classification:

Right



How is the driver sitting?



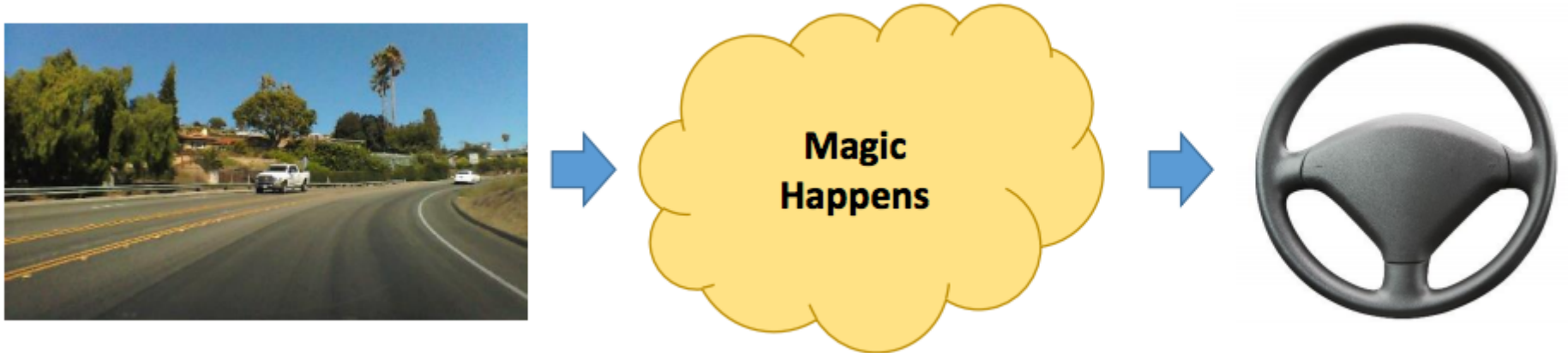
Is the driver tired?



NVIDIA Self Driving Car

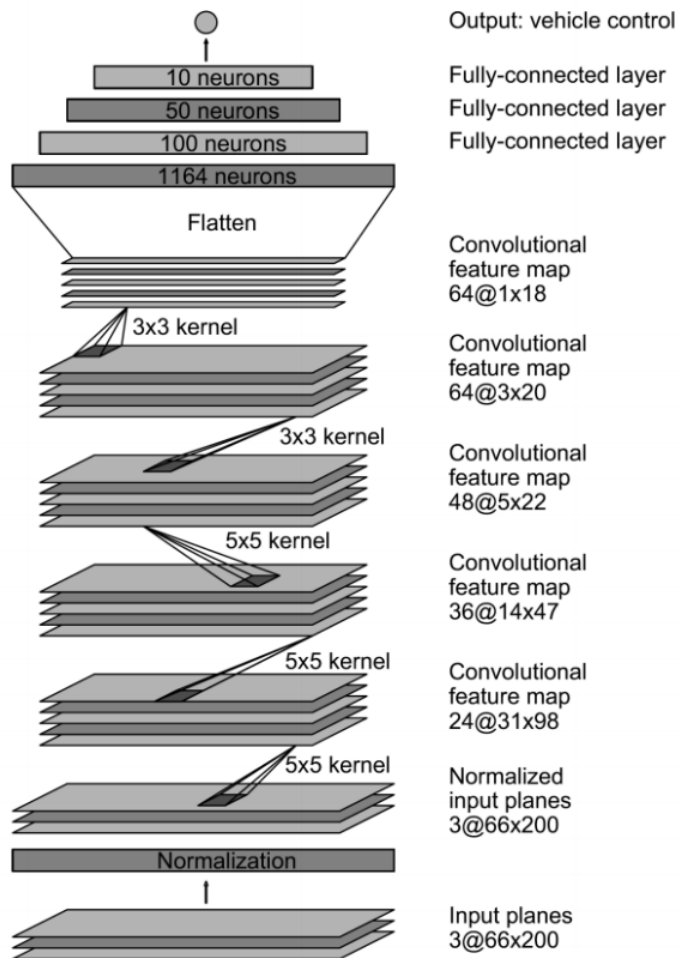


End to End Deep Learning



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 ...



Deep Tesla

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!