Introduction to Deep Learning

Paul Drăgan

February 22, 2018

Research in Cluj

Machine Learning

What is machine learning?

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To learn = algorithmically find the choice of parameters that best explain the data.

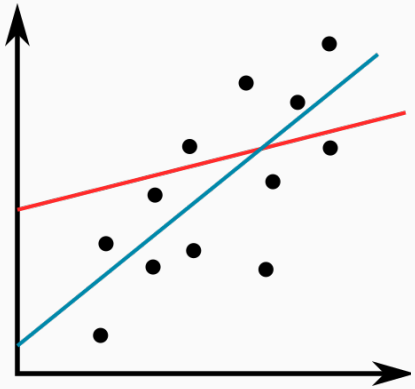
What is machine learning?

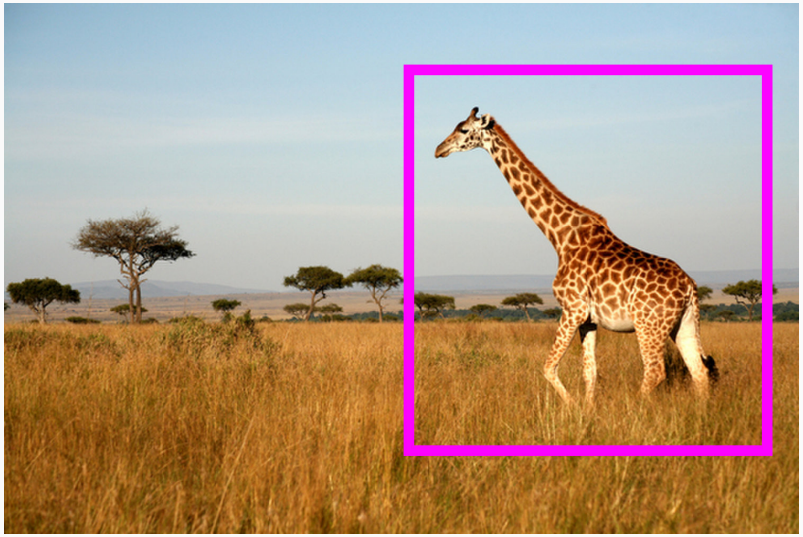
To learn = algorithmically find the choice of parameters that best explain the data.

Example learning tasks

Find the line that best fits the points.

Find giraffes in pictures.





Machine learning - Where are we now?

Current uses of ML algorithms in industry:

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- medical diagnosis
- language understanding and translation

Machine learning - Where do we want to be?

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- increase robustness

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- algorithms that learn what to learn

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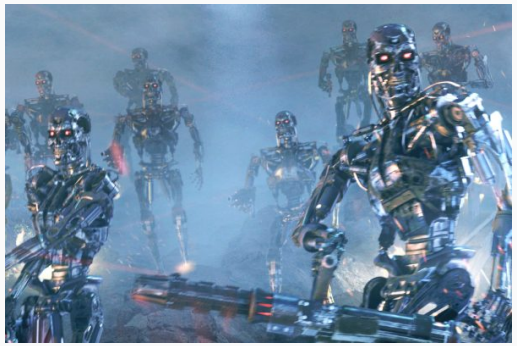
In the long term:

- algorithms that learn what to learn
- general AI?



Machine learning - Common algorithms

Commonly used algorithms are:

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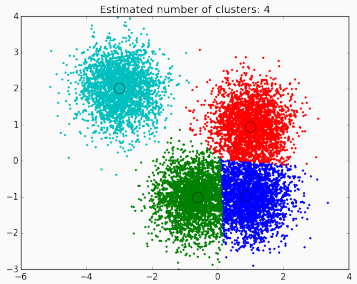
- K-means clustering



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Commonly used algorithms are:

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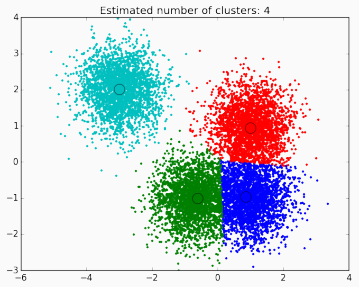

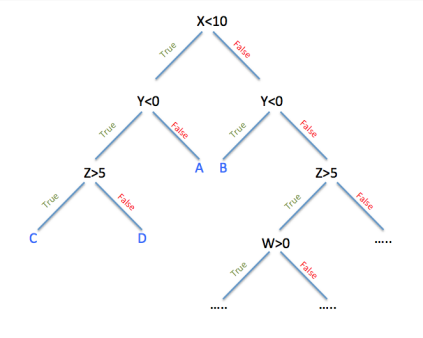

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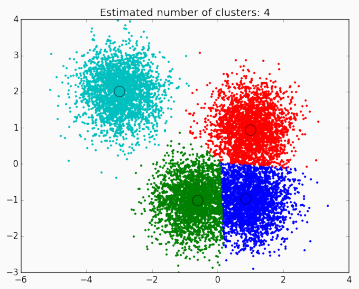

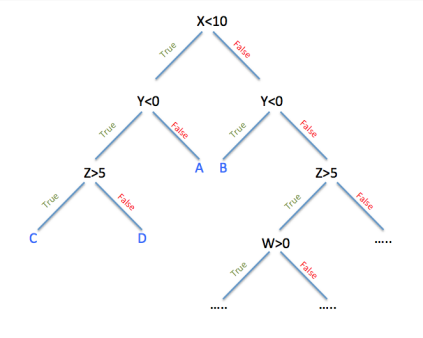

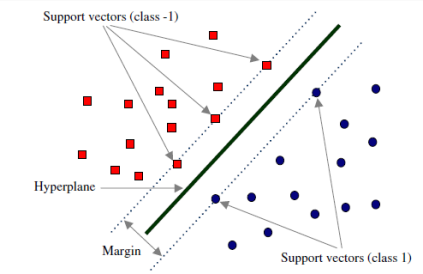

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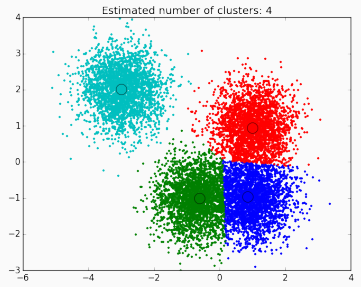

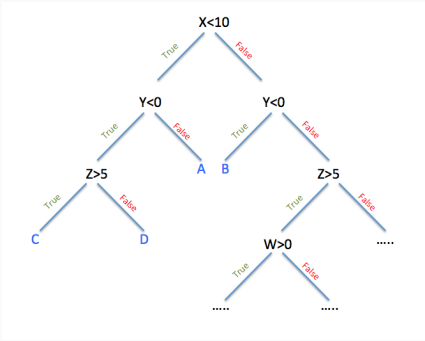

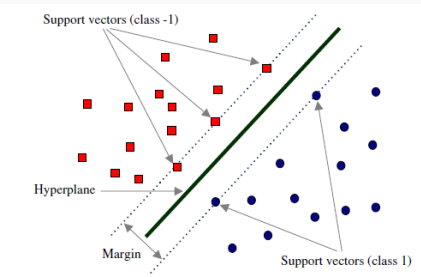

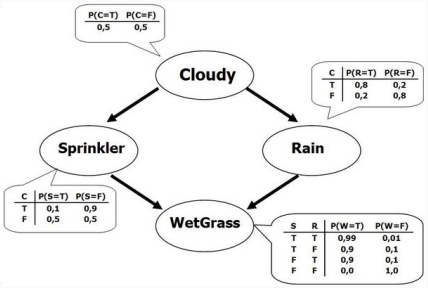

Machine learning - Common algorithms

Commonly used algorithms are:

- K-means clustering
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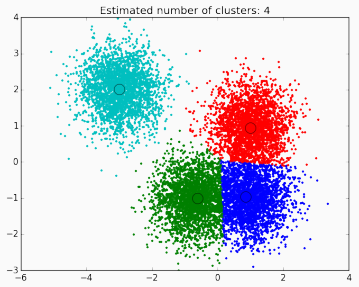
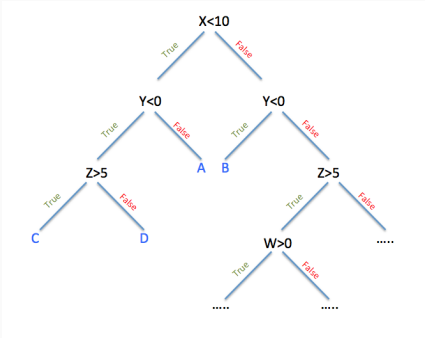
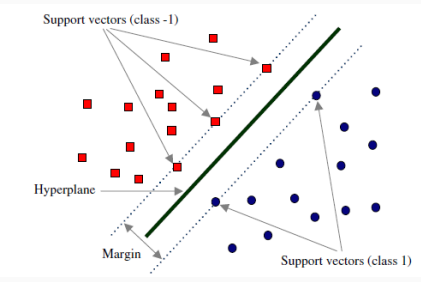
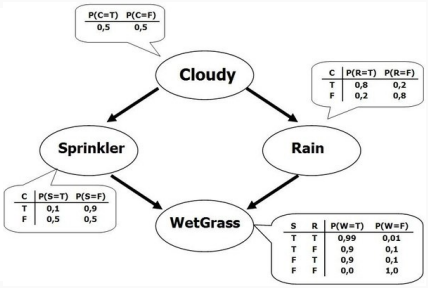
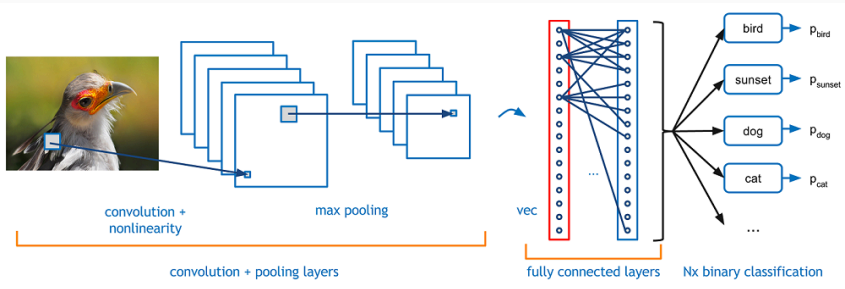
- Bayesian networks
- Deep learning / Neural networks











Deep learning

Deep learning - What is it?

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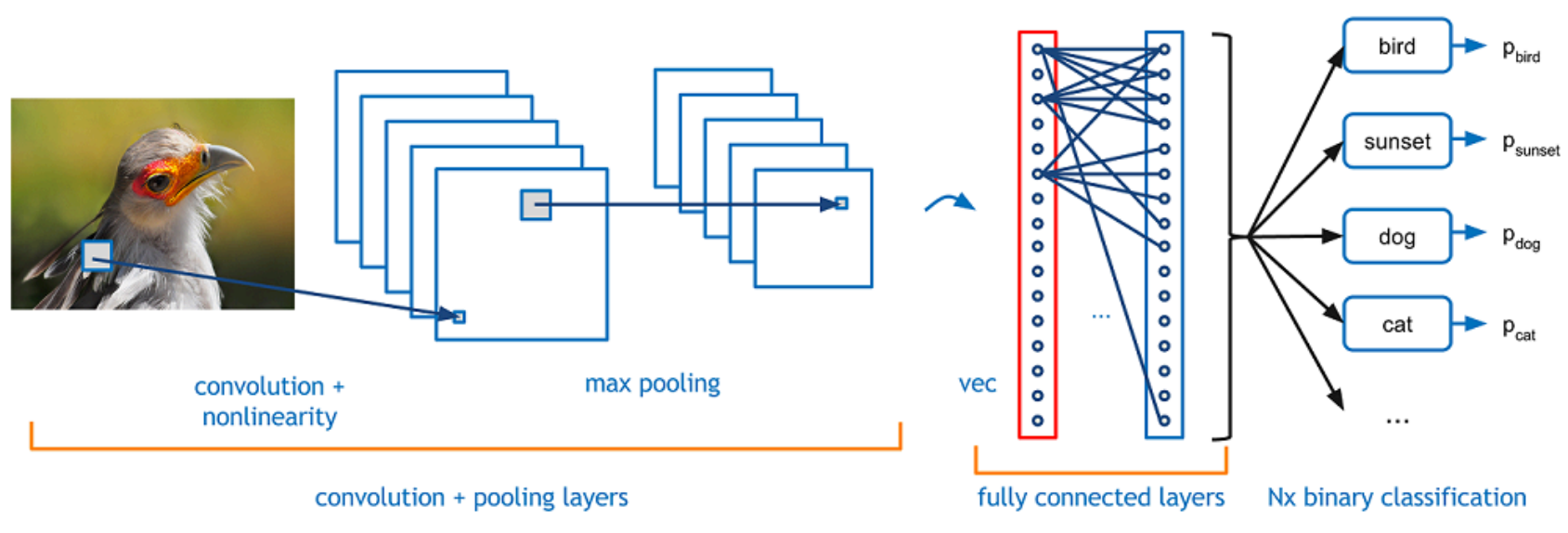
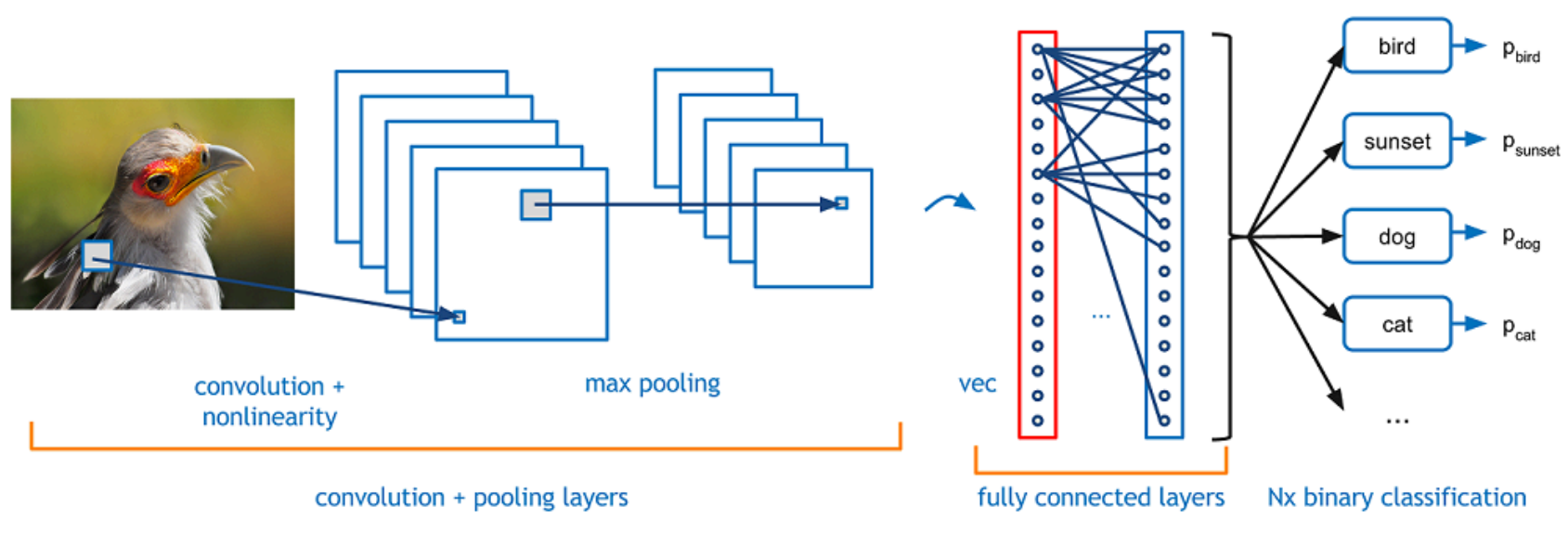


Figure 2: Arguably complicated figure that you won't understand.

Deep learning - What is it?



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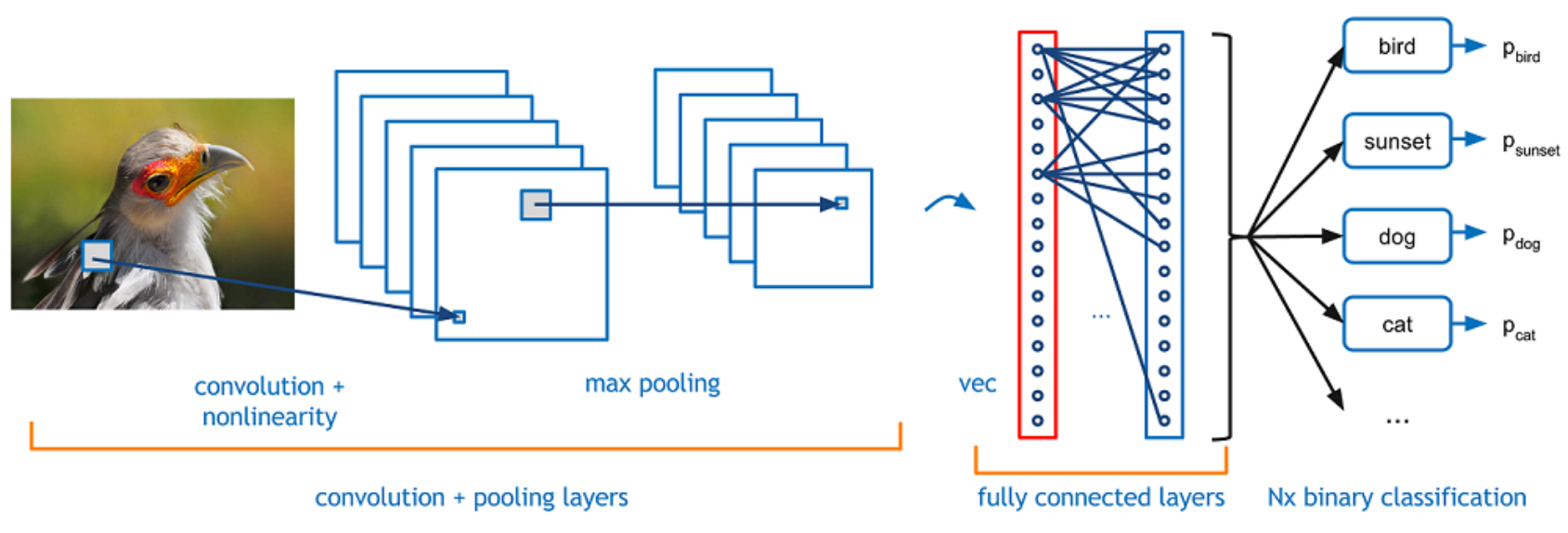

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Deep learning:

- A particular subset of ML algorithms a.k.a. "enhanced neural networks"

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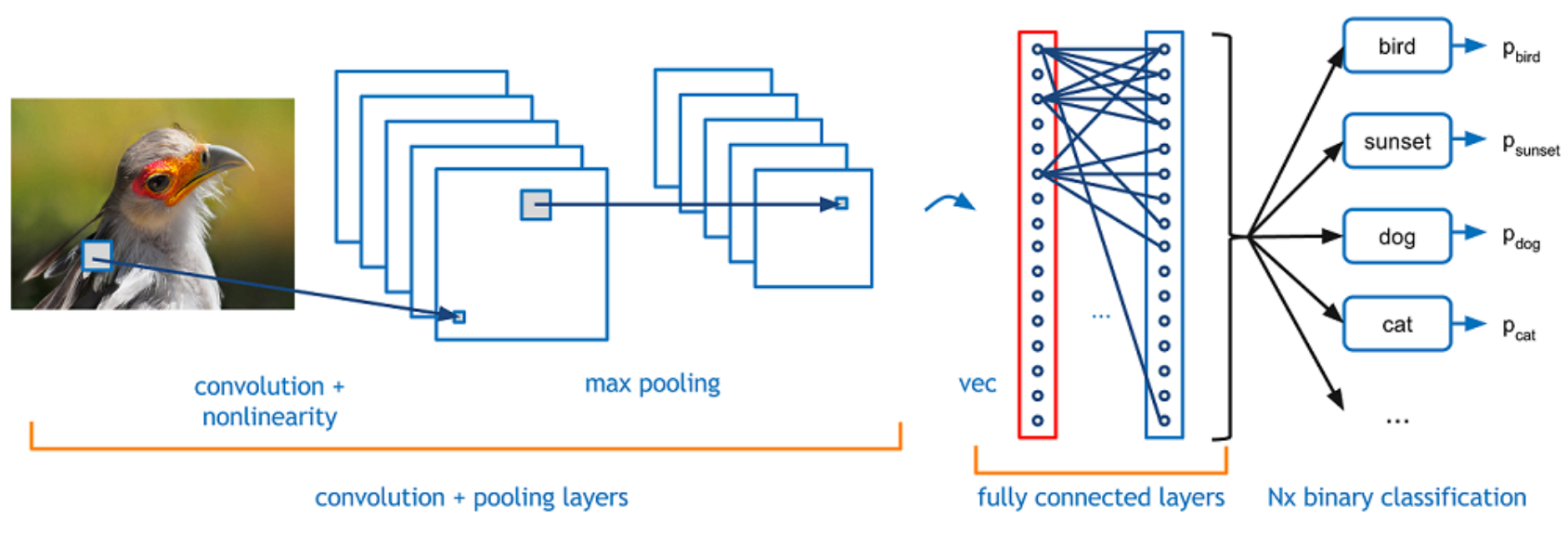

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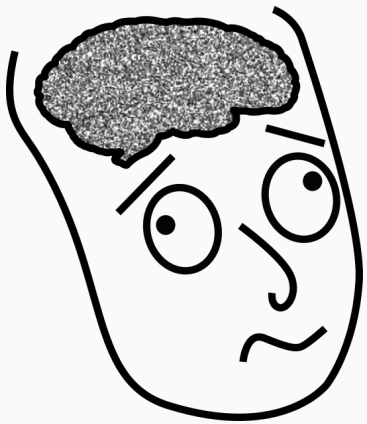
Deep learning:

- A particular subset of ML algorithms a.k.a. "enhanced neural networks"
- The closest to an ideal learning agent

Ideal learning agent



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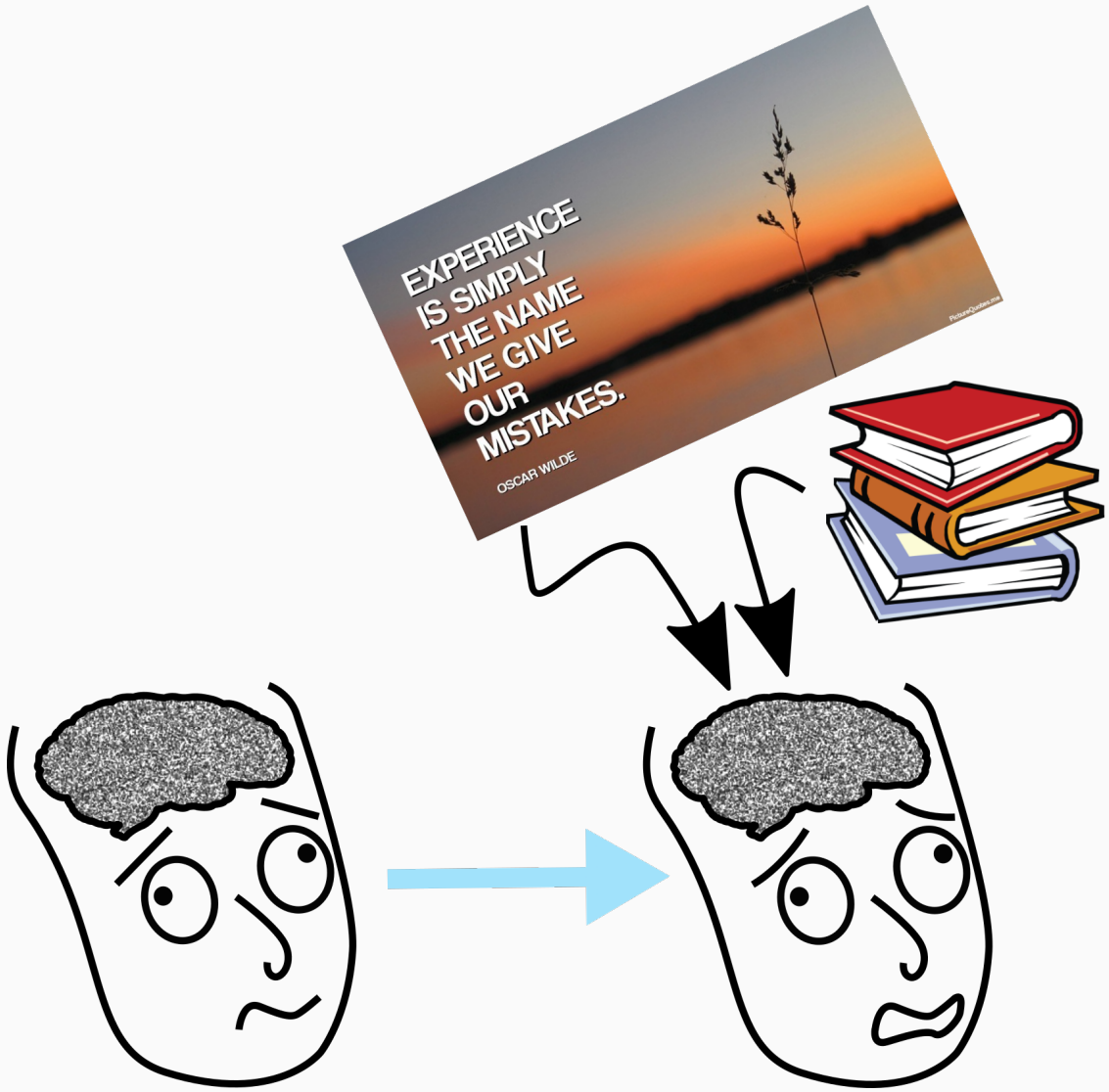

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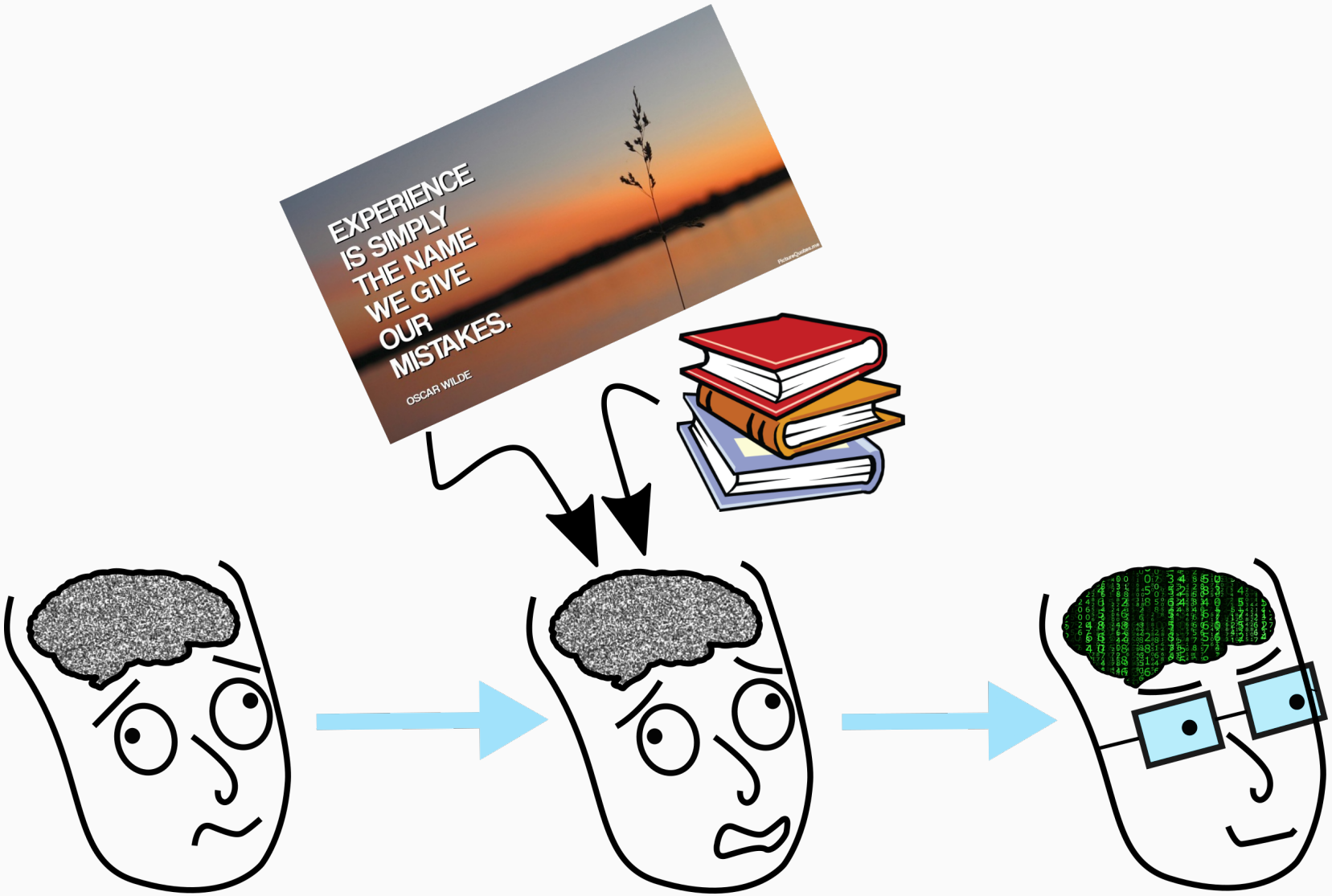

Enhanced neural networks

Enhanced neural networks

“Deep learning” can be translated to: “enhanced neural networks”.

– Paul Drăgan, some minutes ago

Artifical neuron

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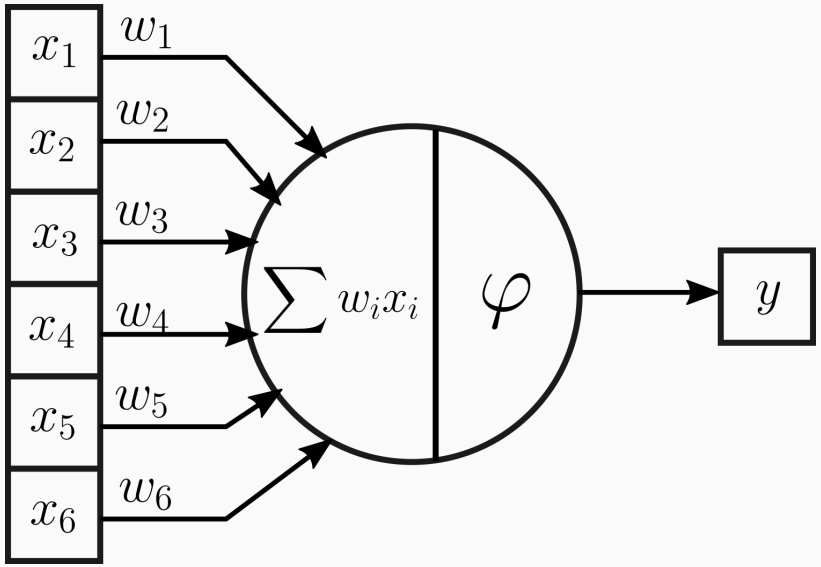
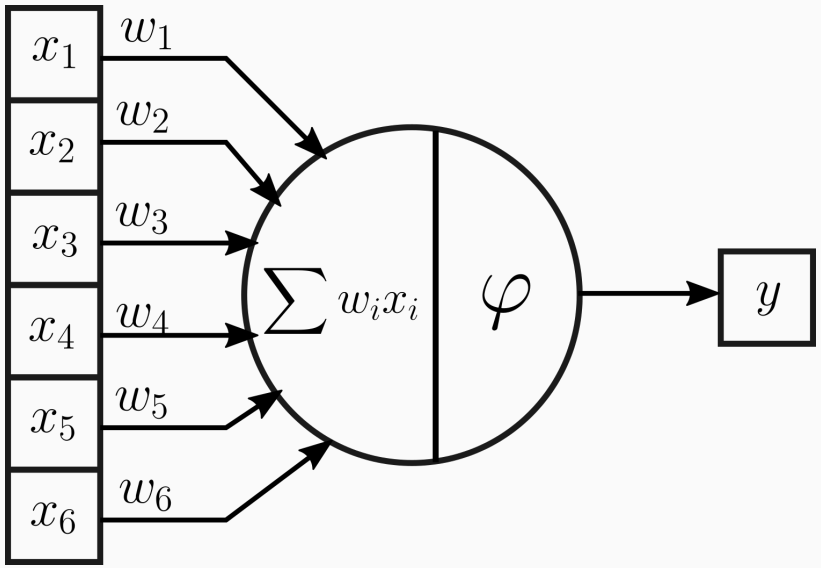


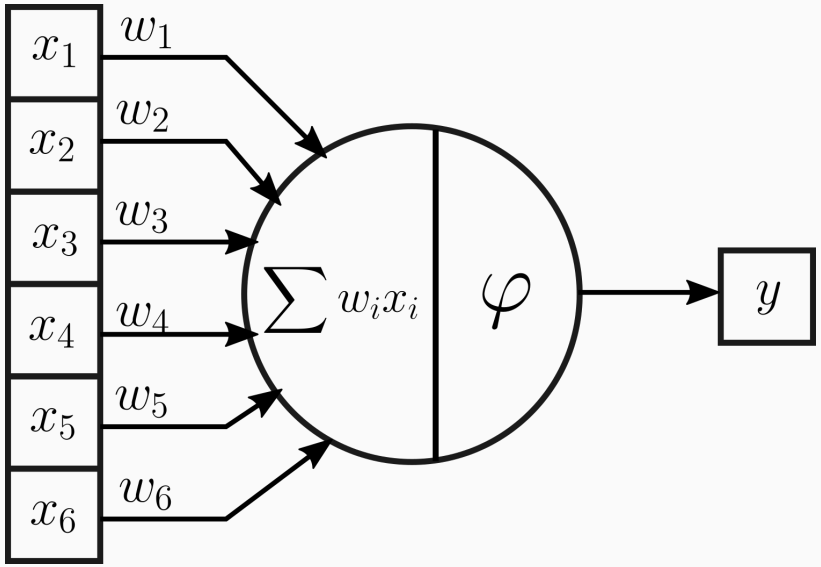
Artifical neuron

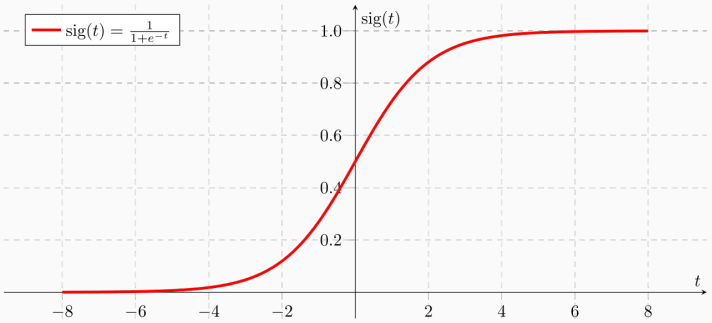


Where:

- x_i are the inputs
- w_i are the weights
- φ is the activation function
- y is the output

Artifical neuron





The sigmoid activation function φ.

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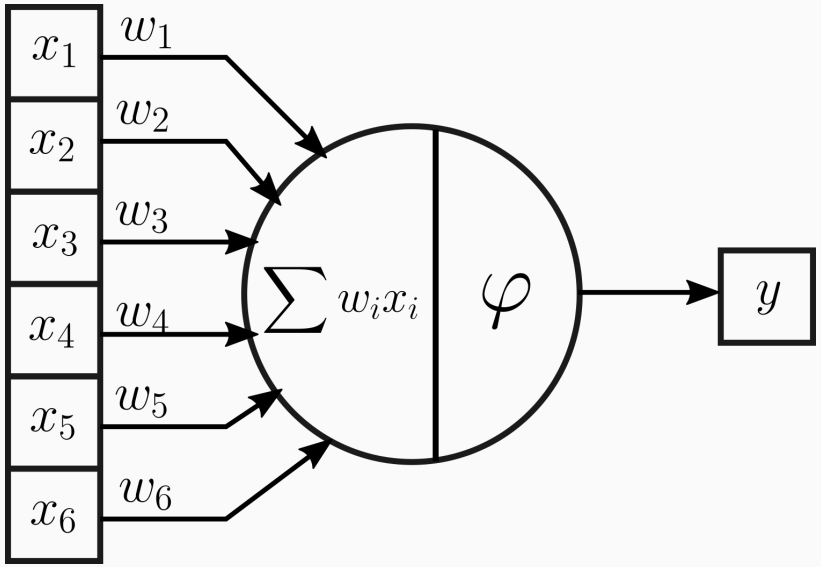

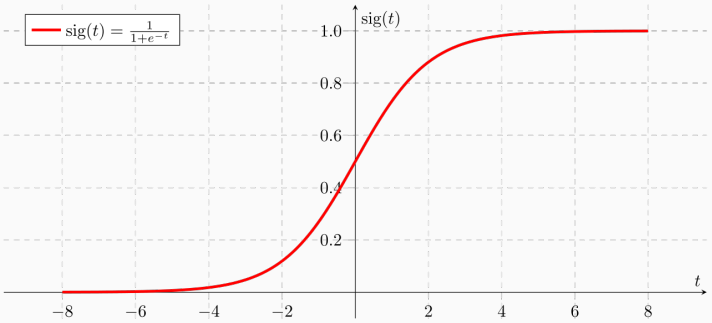

The sigmoid activation function φ.

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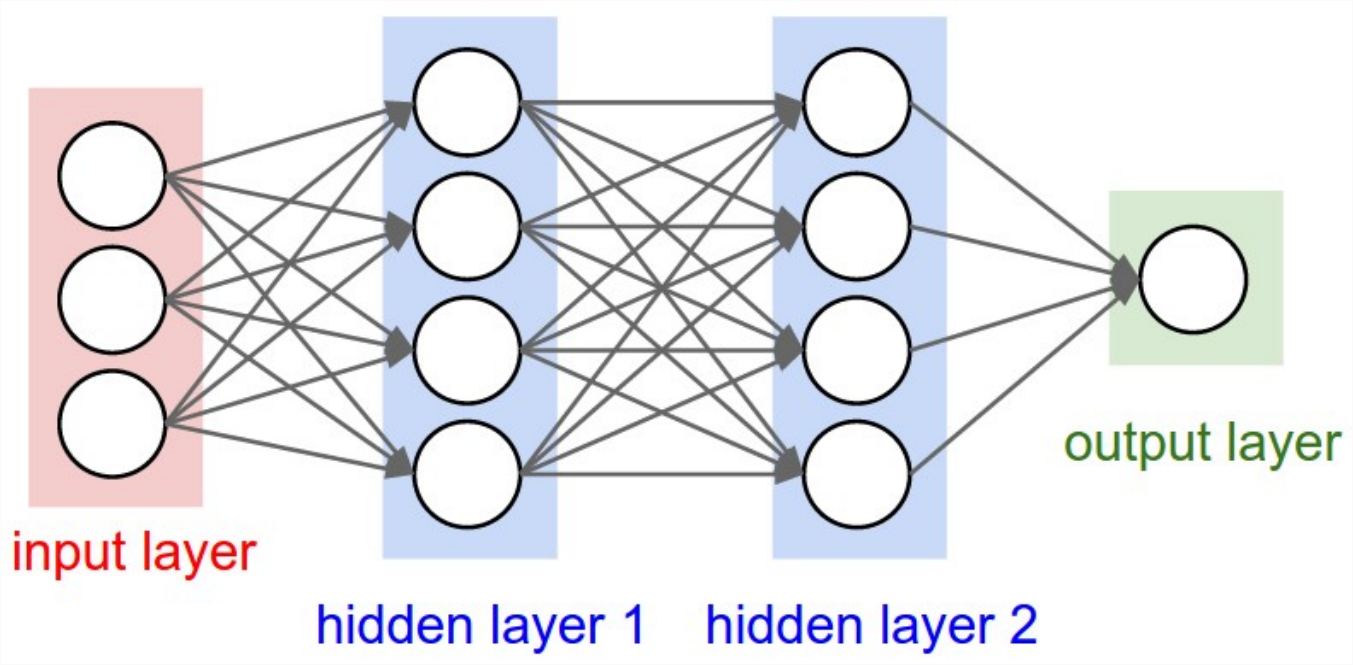
The weights w_i are free parameters -> they can be trained / learned.

Neural networks



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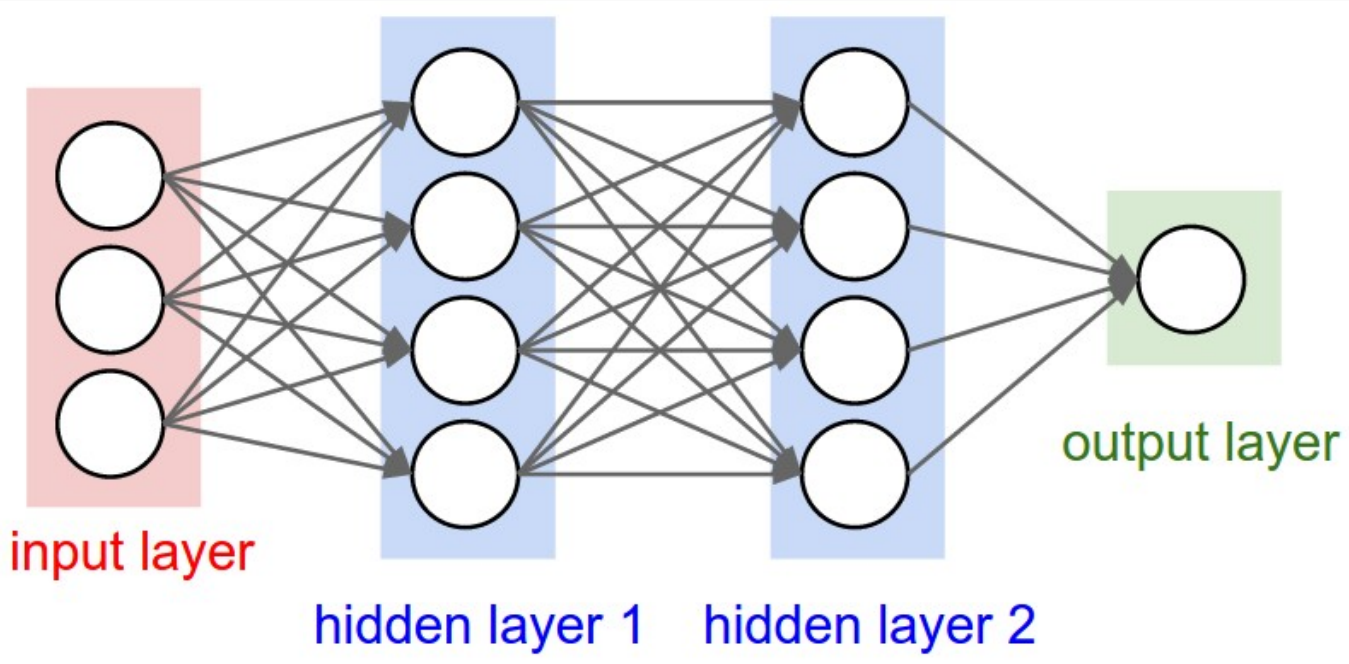

Neural networks are theoretically guaranteed to be universal function approximators.

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Giraffe detection:

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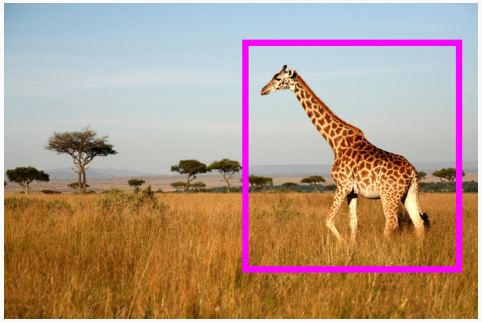

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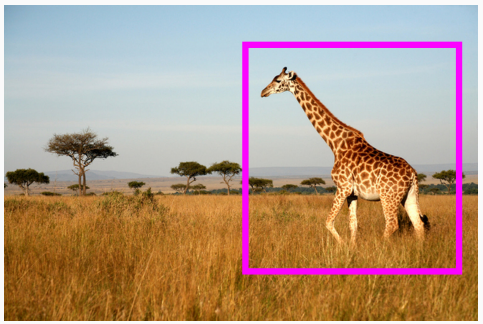

Robot trajectories:

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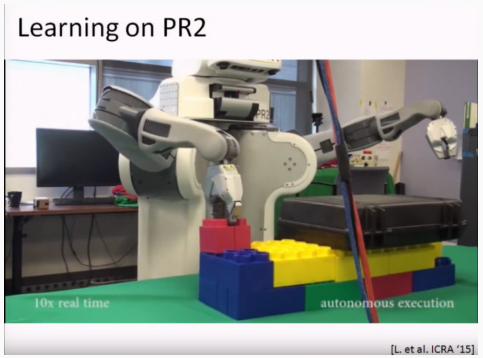
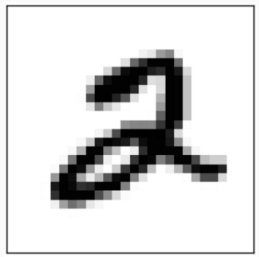


Training neural networks



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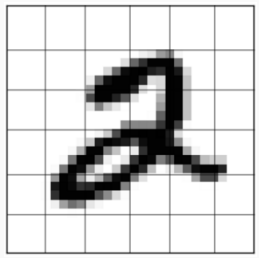

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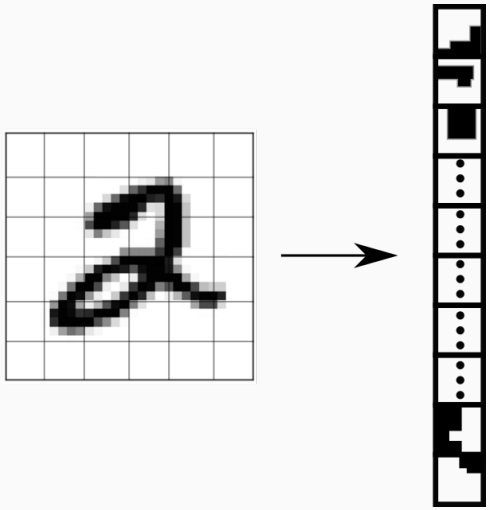

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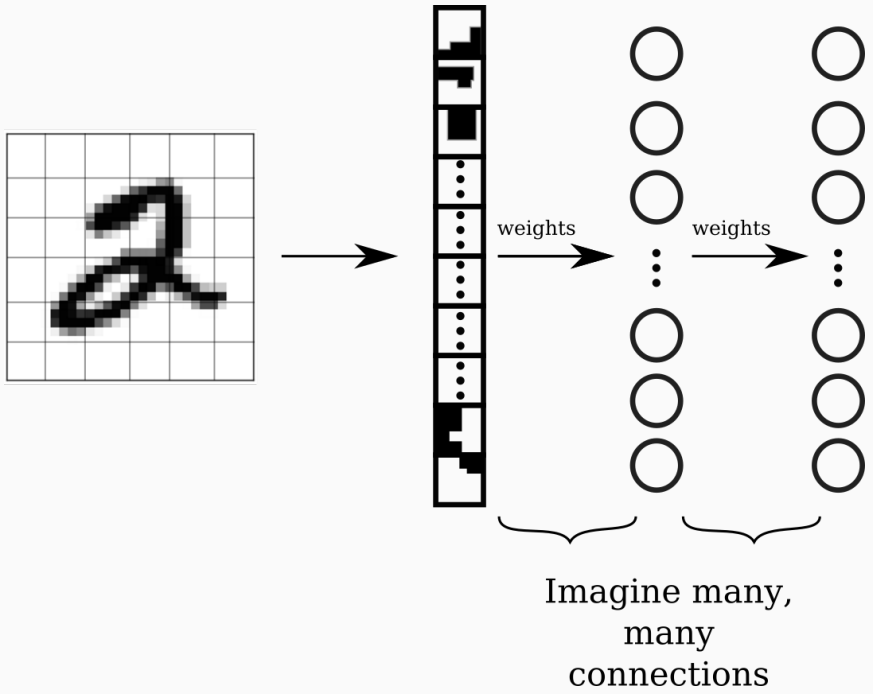

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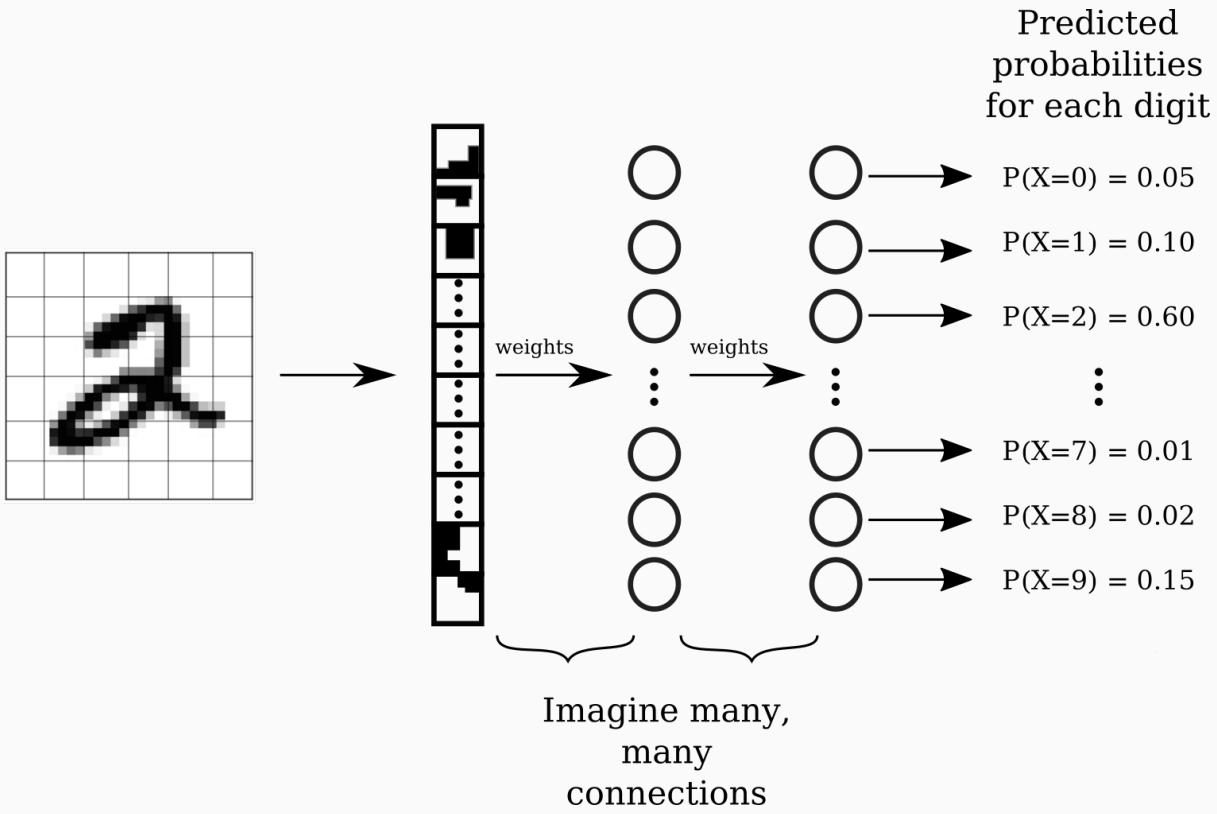

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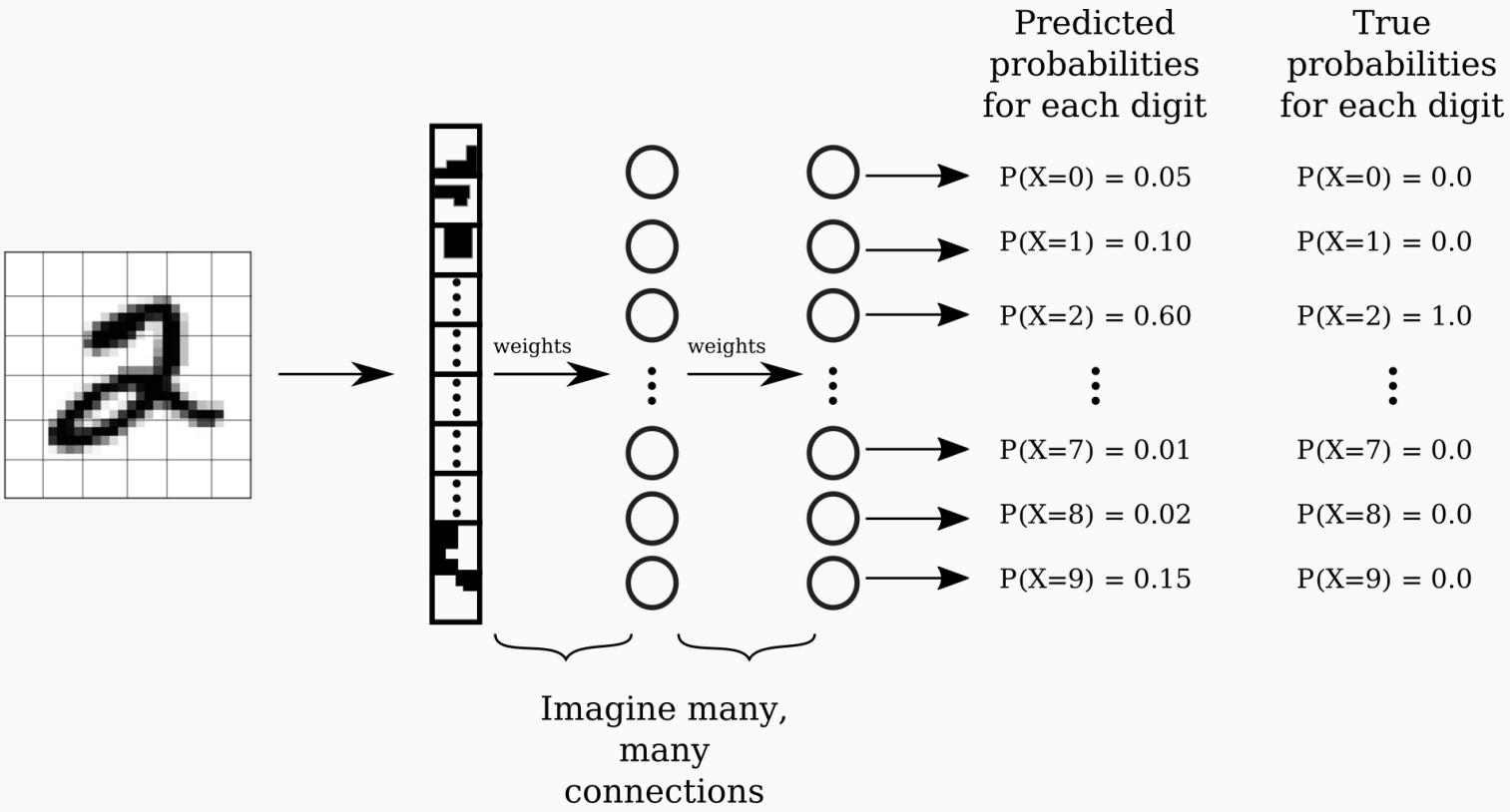

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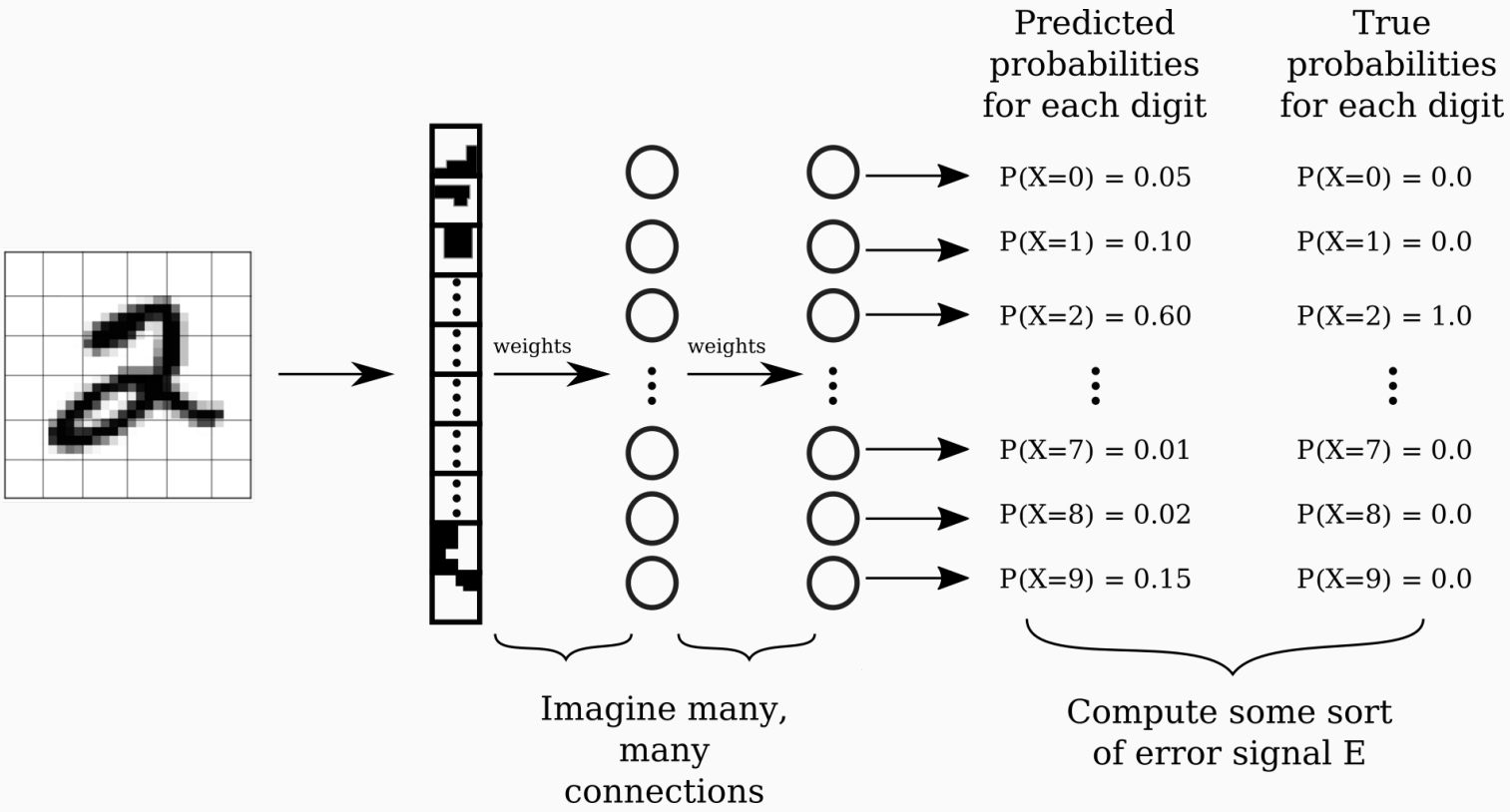

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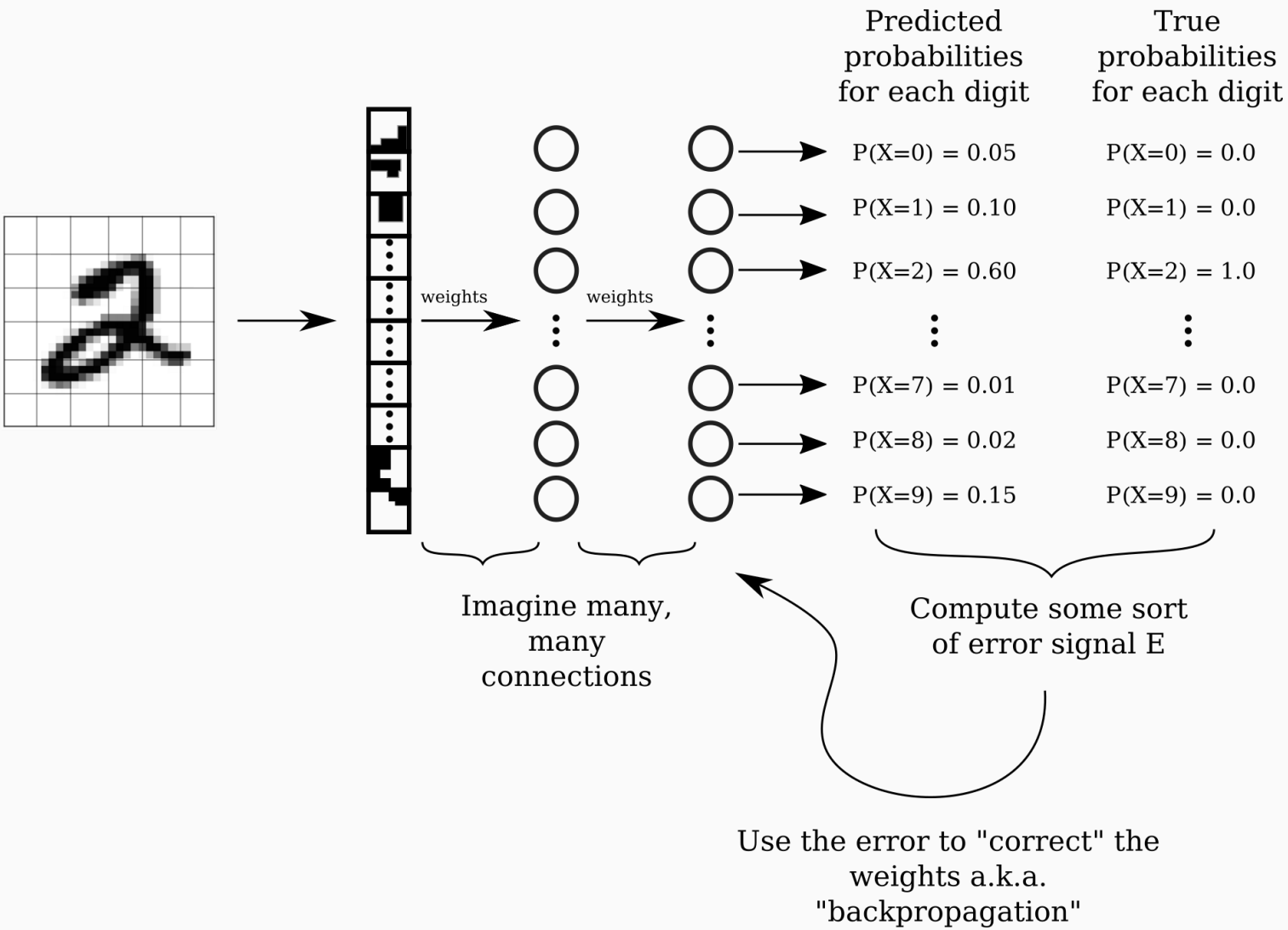

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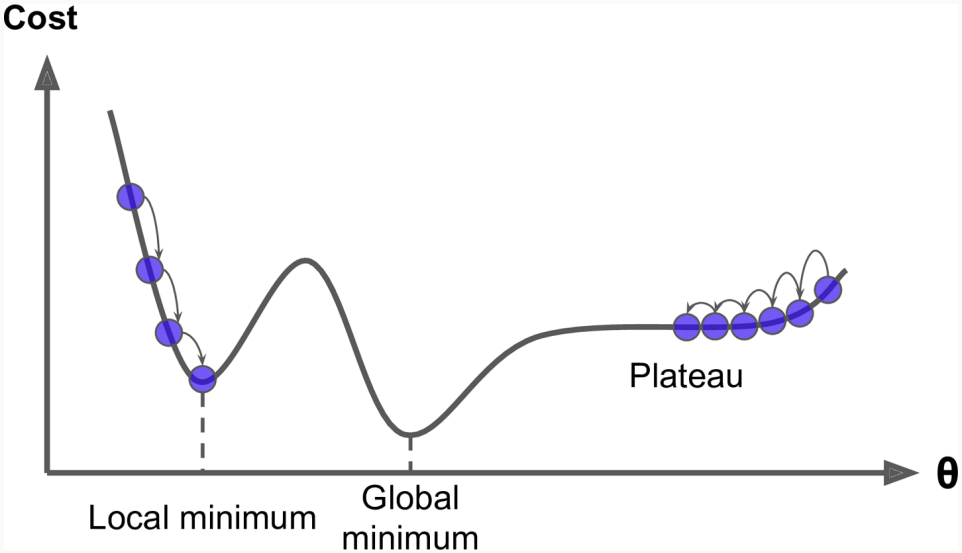
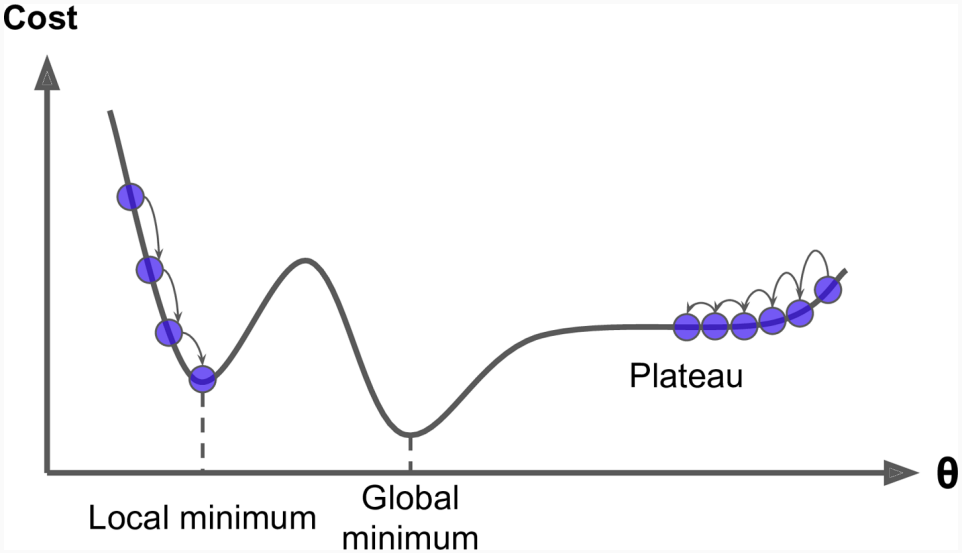


The backpropagation algorithm is based on gradient descent

Training neural networks



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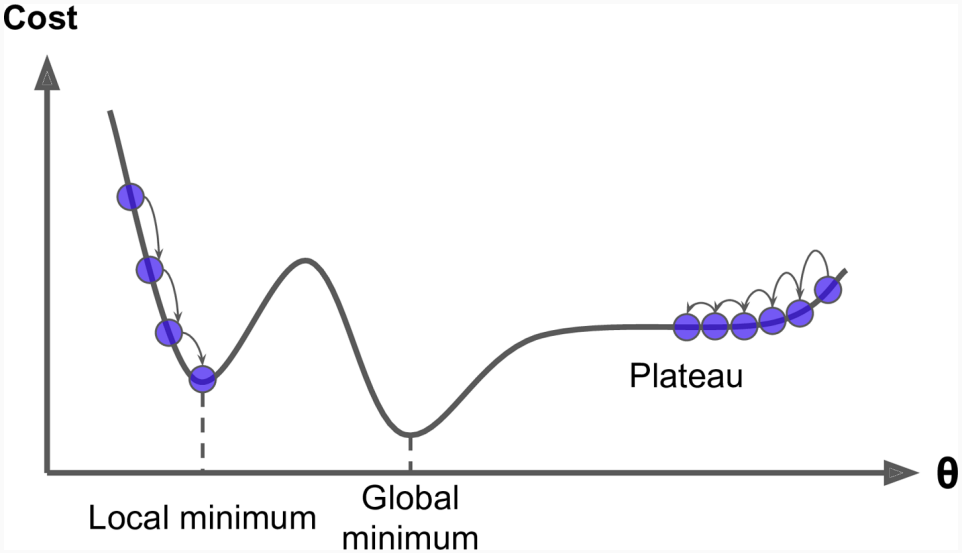

The backpropagation algorithm is based on gradient descent, i.e. the parameters are updated based on their current value and on their "influence" on the error.

$$\theta_{t+1} = \theta_t - \eta \frac{\partial E}{\partial \theta_t},$$

where η is the learning rate.

How to deep learn? The naive approach

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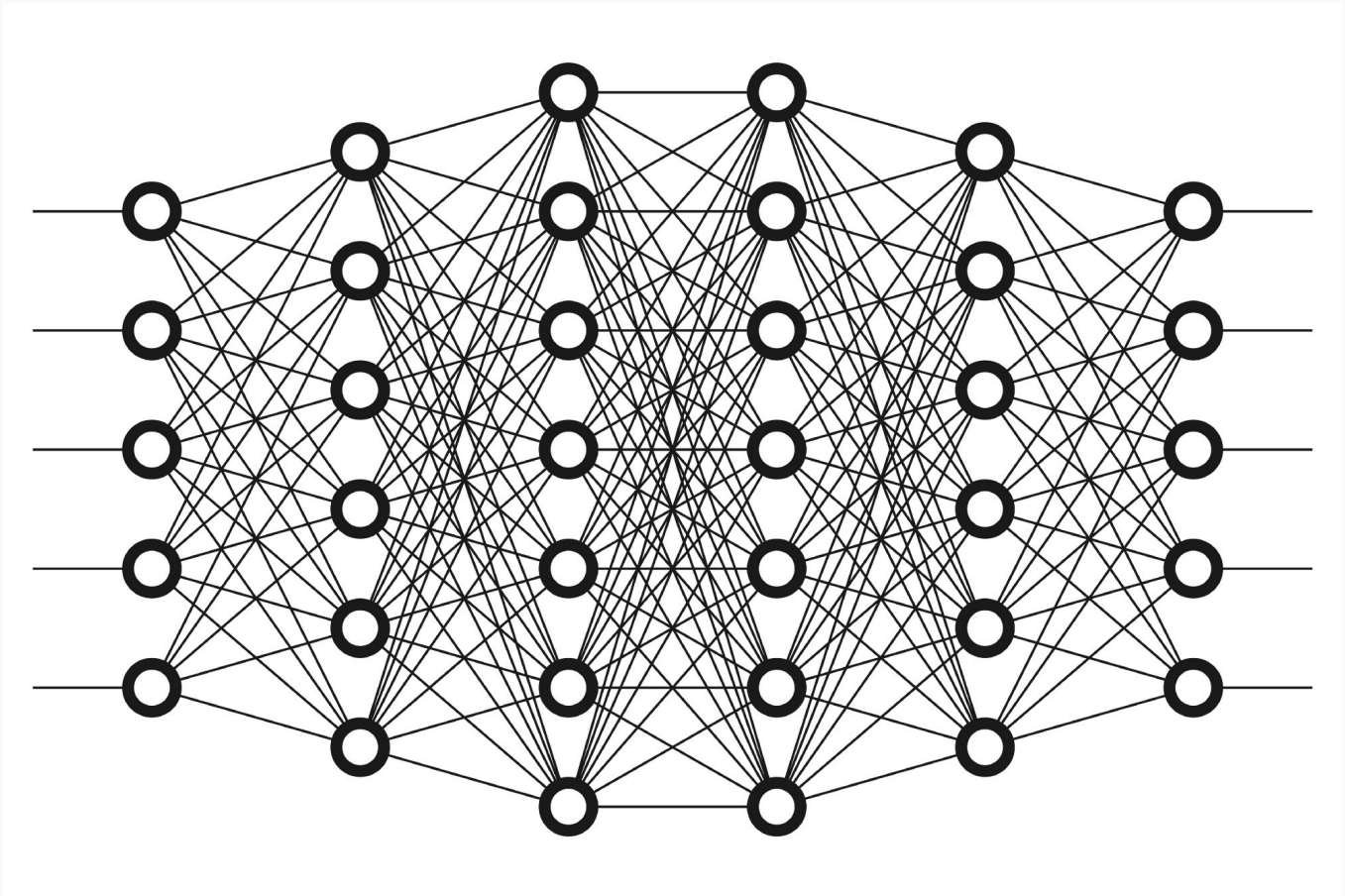

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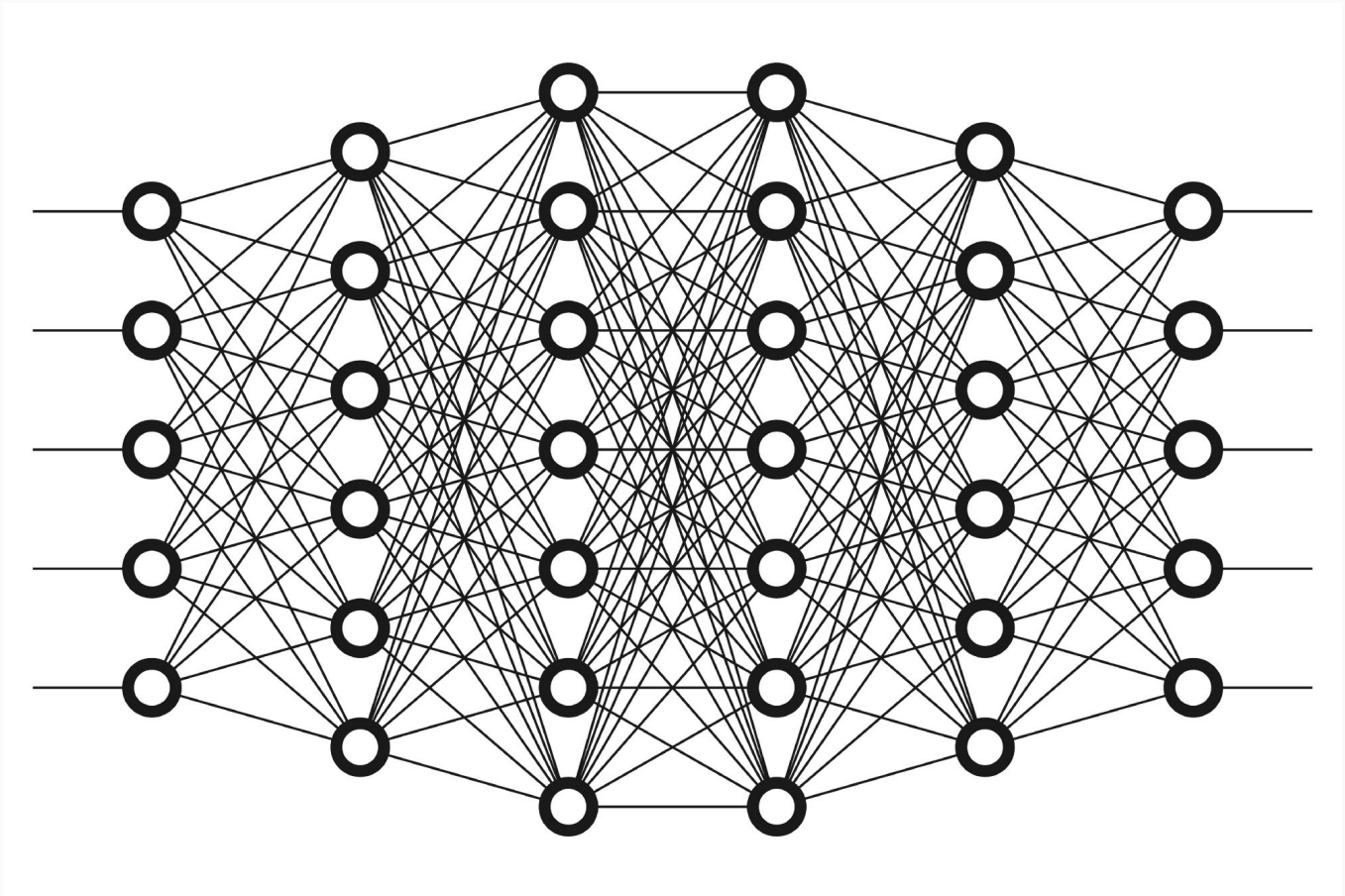

Just stacking more simple layers will result in a inefficient and difficult to train network.

Some of the new things

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Convolutional neuron

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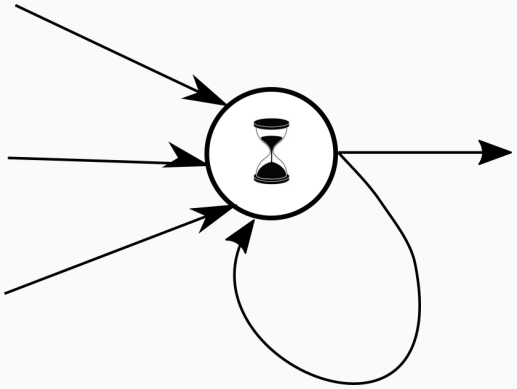
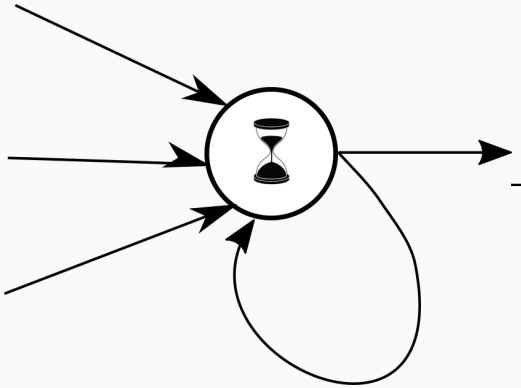
Convolutional neuron



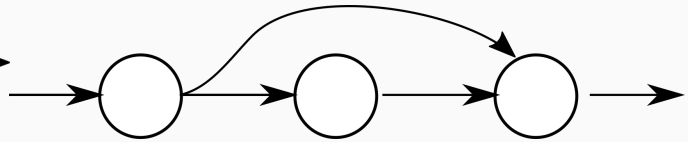
Memory cell neuron

Some of the new things

Convolutional neuron



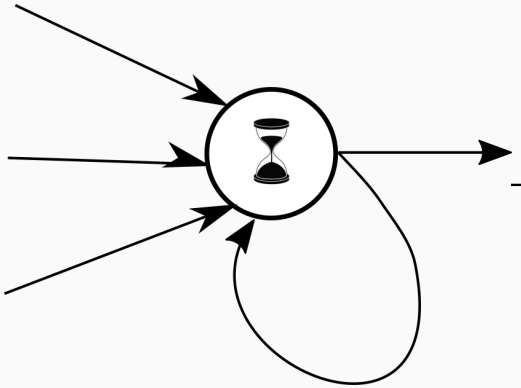
Memory cell neuron



Neuron with skip connections

Some of the new things

Convolutional neuron



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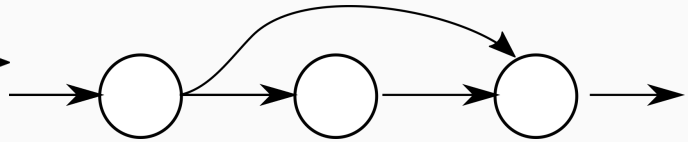
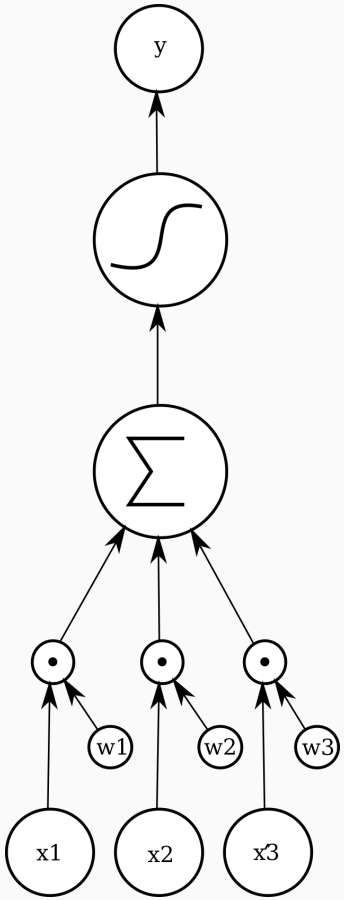


Neuron with skip connections

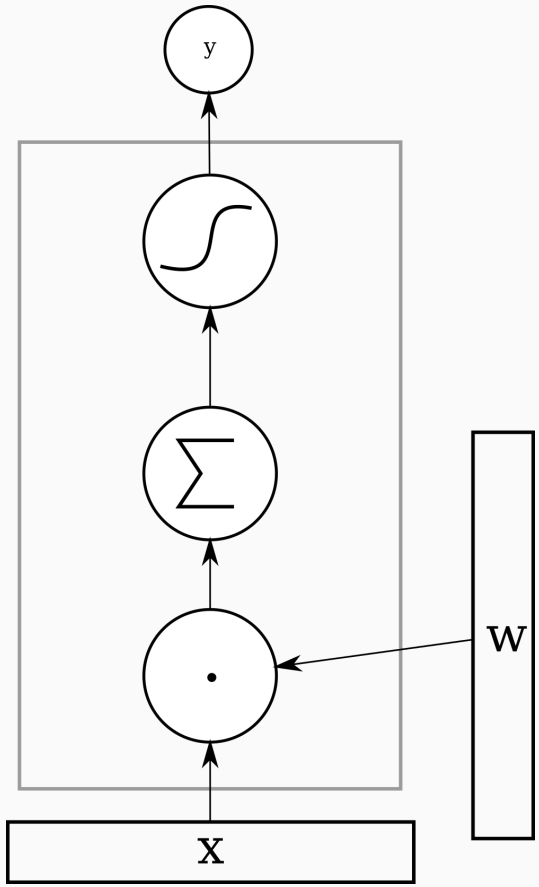
Any kind of differentiable function can be a neuron!

Deep learning networks as computational graphs

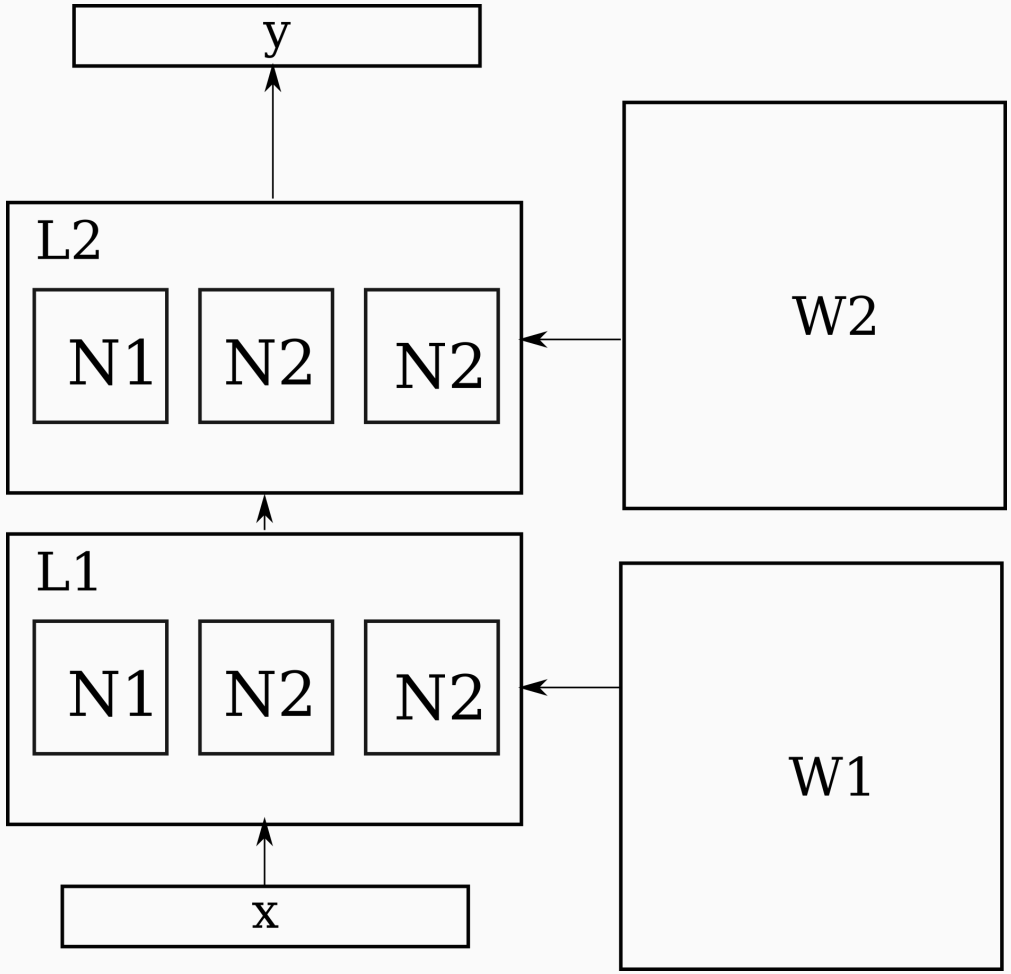
Deep learning networks as computational graphs



Deep learning networks as computational graphs



Deep learning networks as computational graphs



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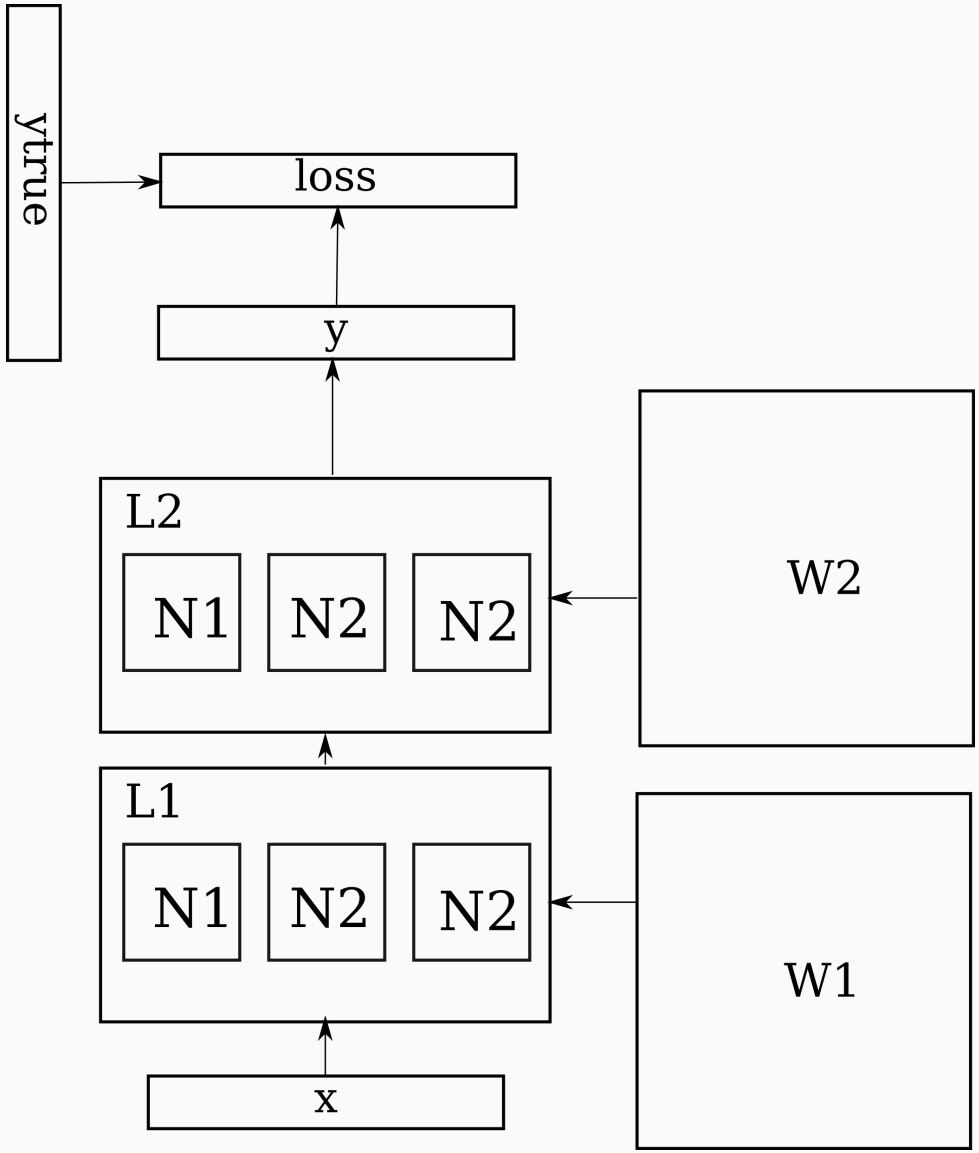

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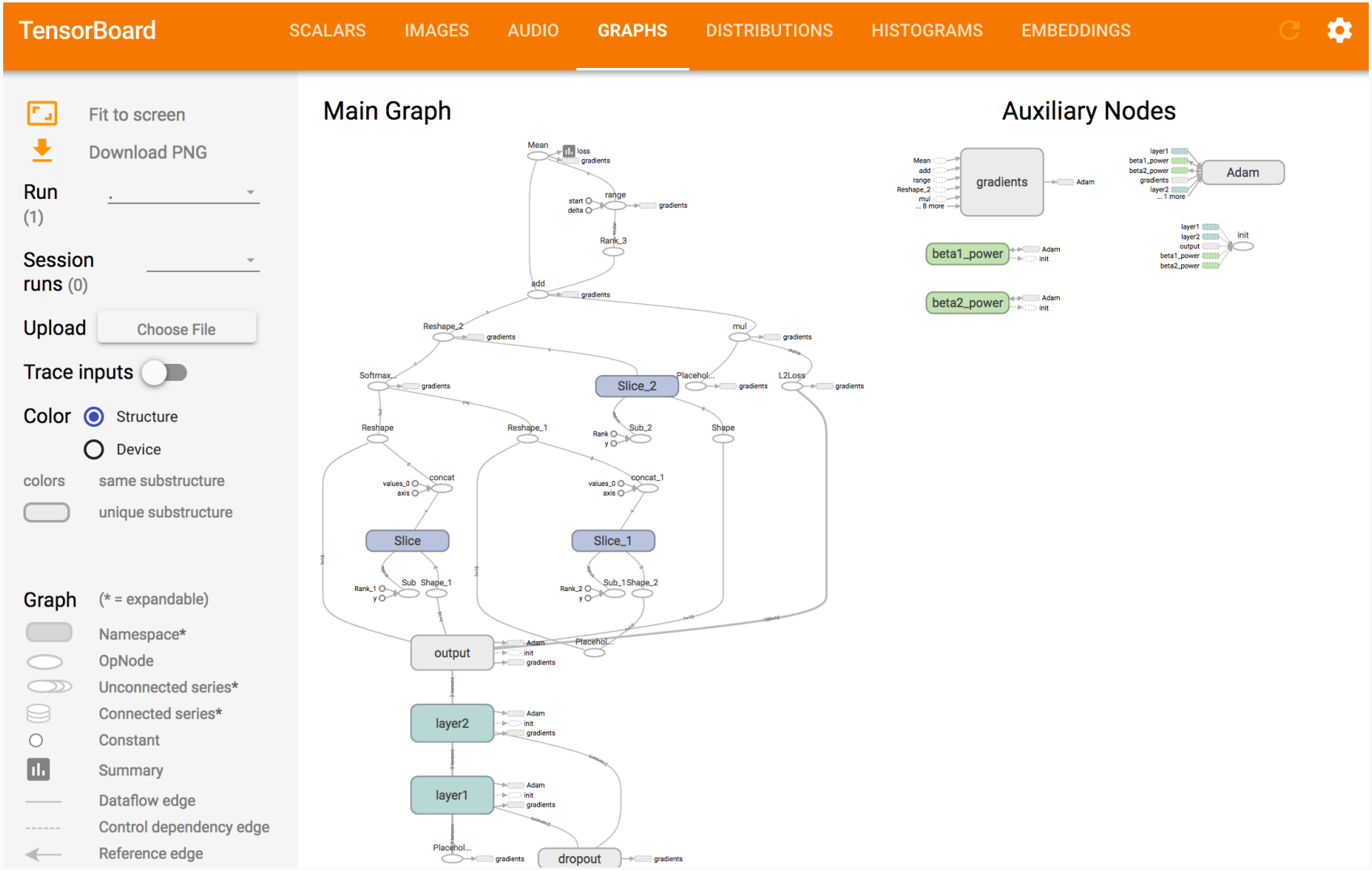
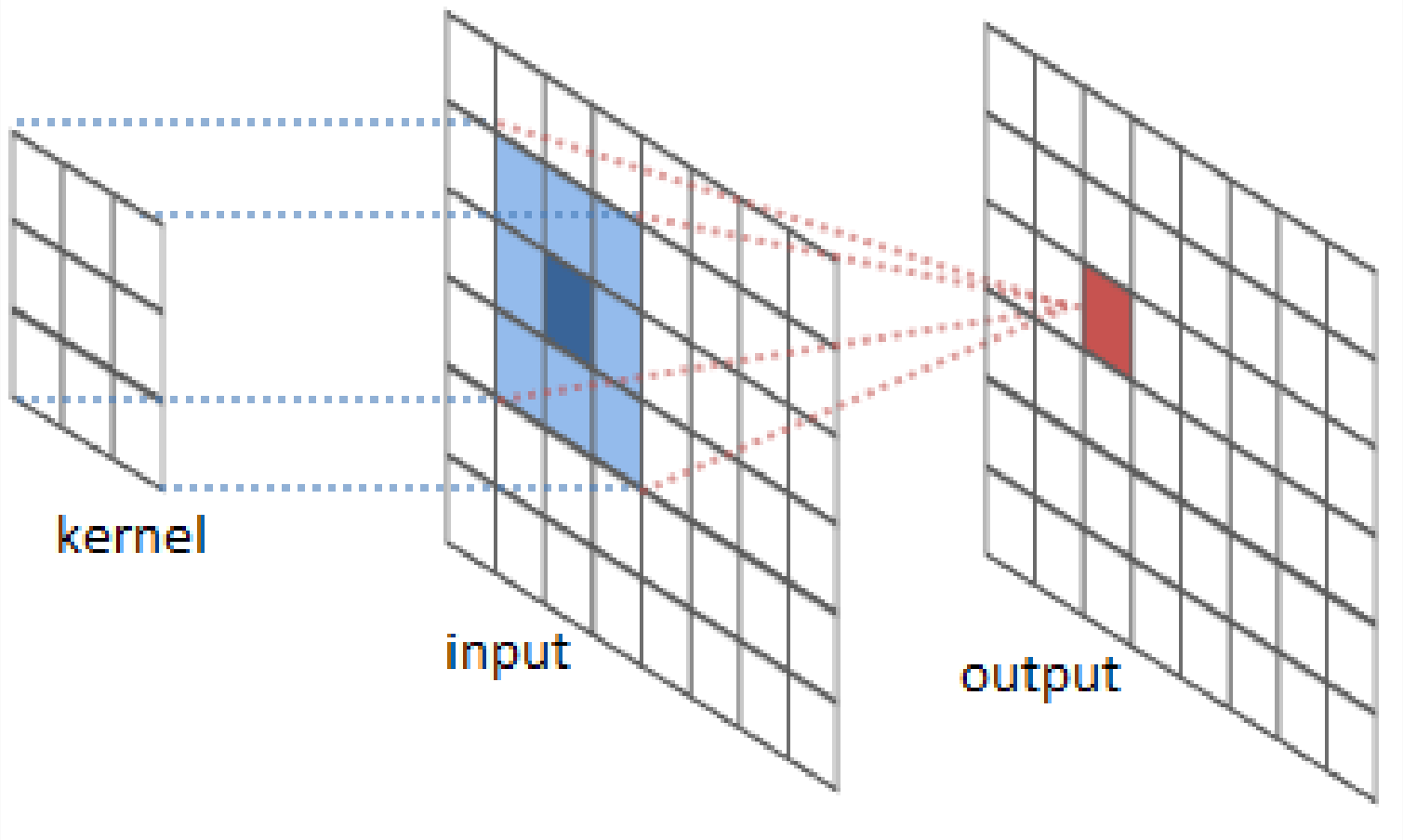
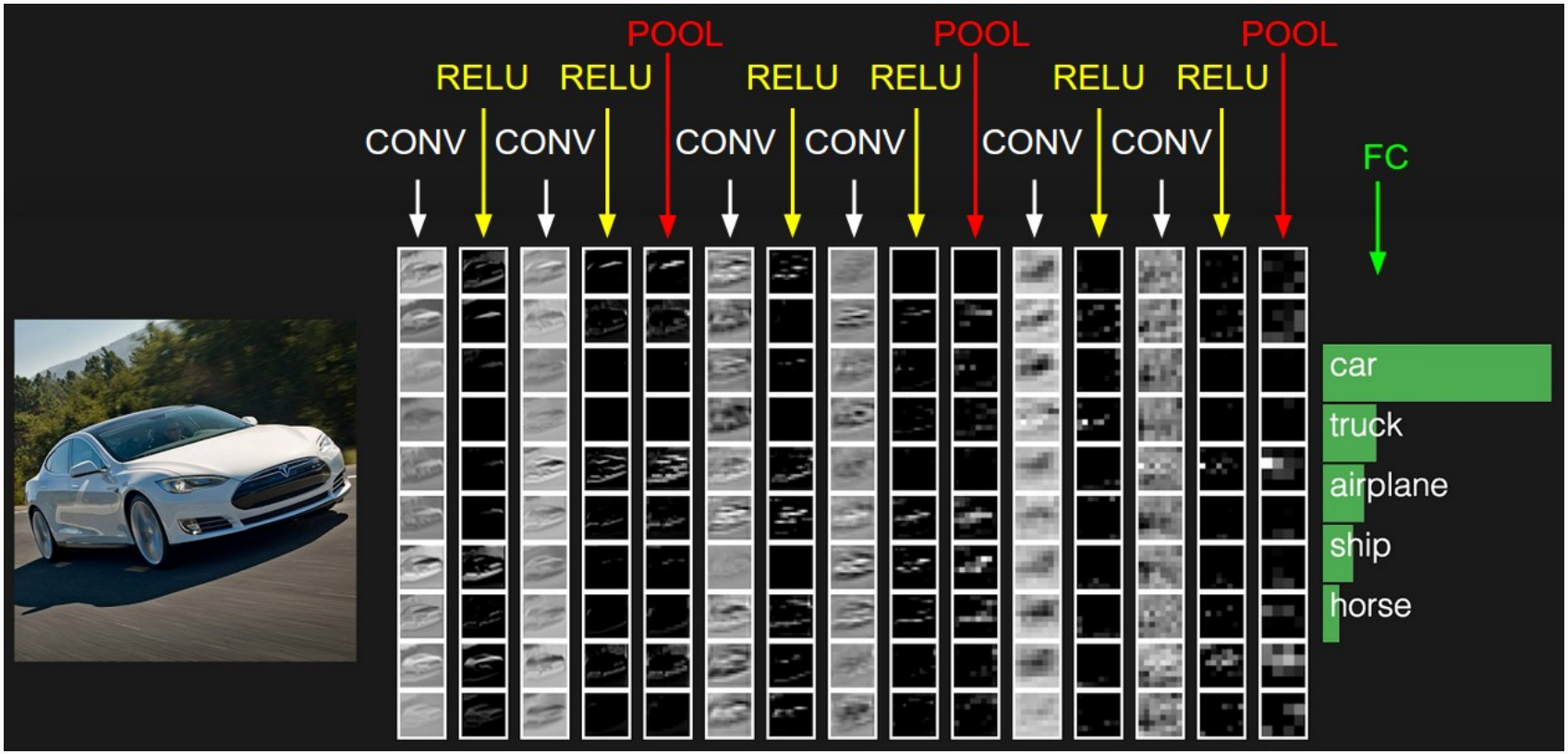


The convolution operation



The neuron in this case is actually the kernel. Each value in the kernel represents a weight. Each weight is learned.

A classification network



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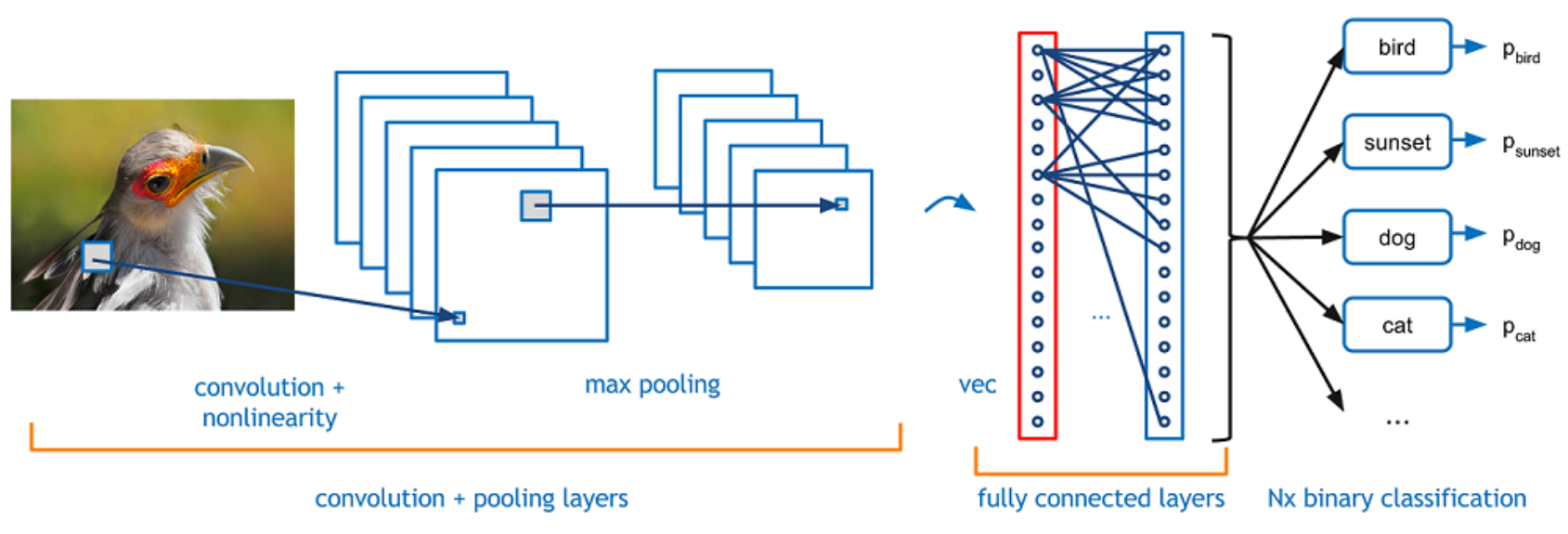
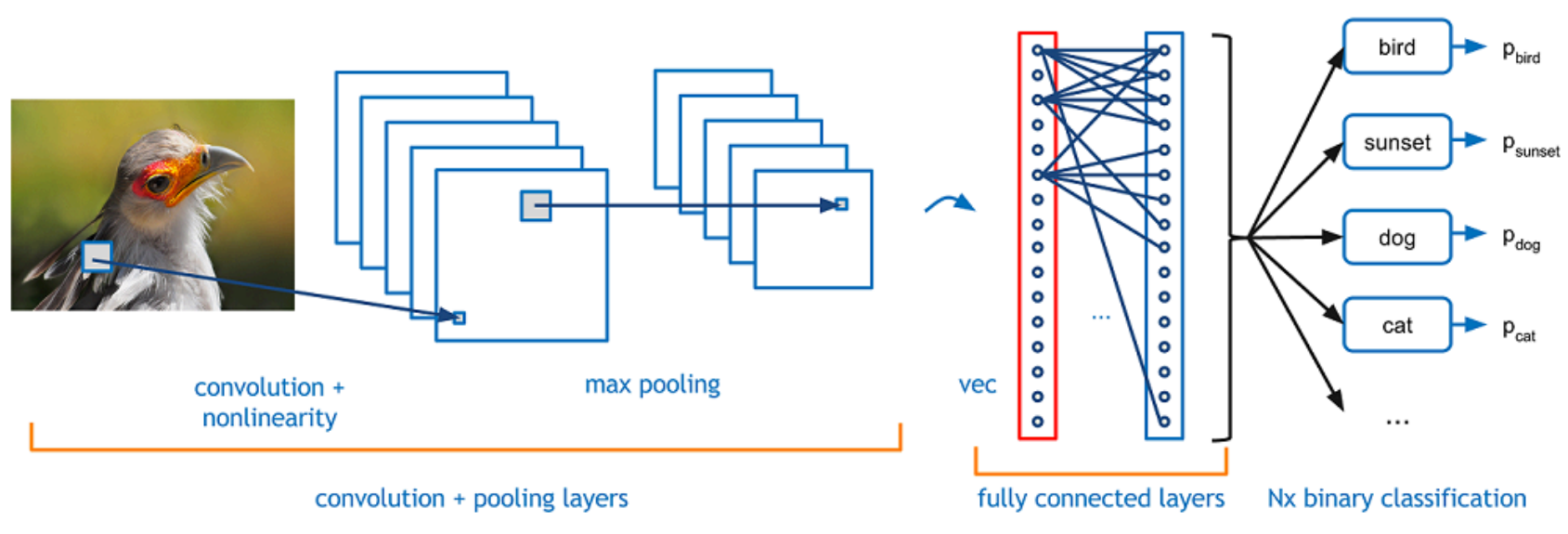


Figure 6: A deep classification network using convolutional neurons.

Another classification network



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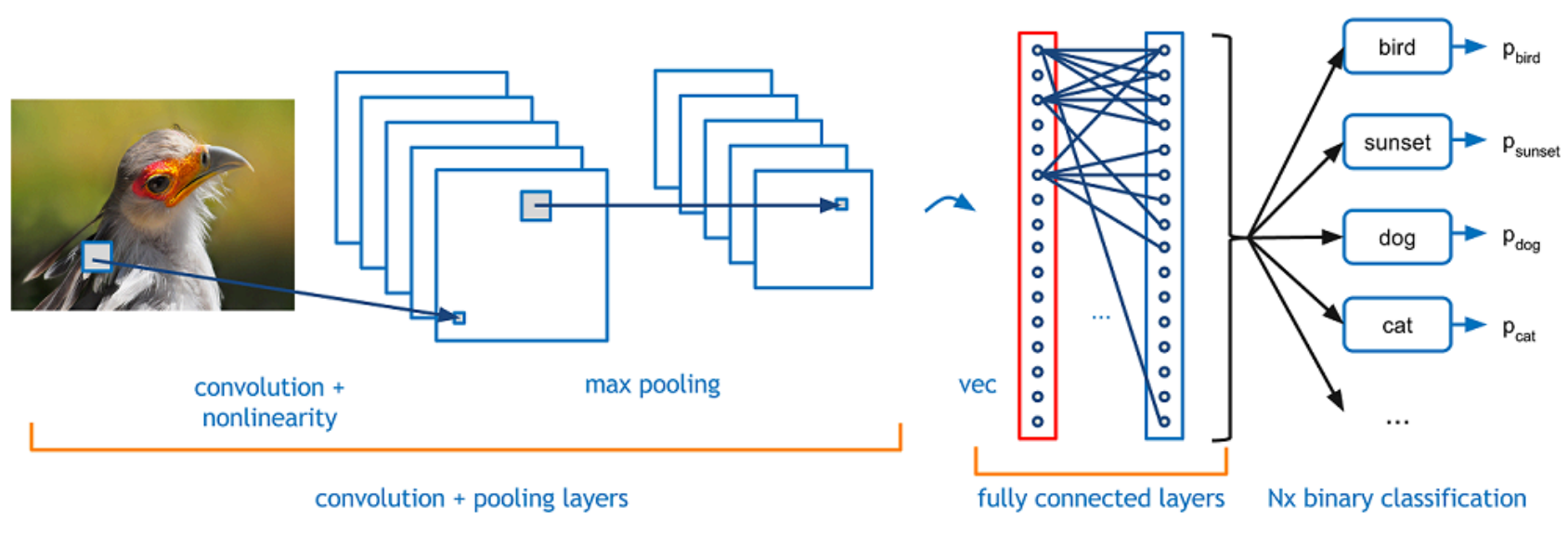
Super powers of deep learning:

Another classification network



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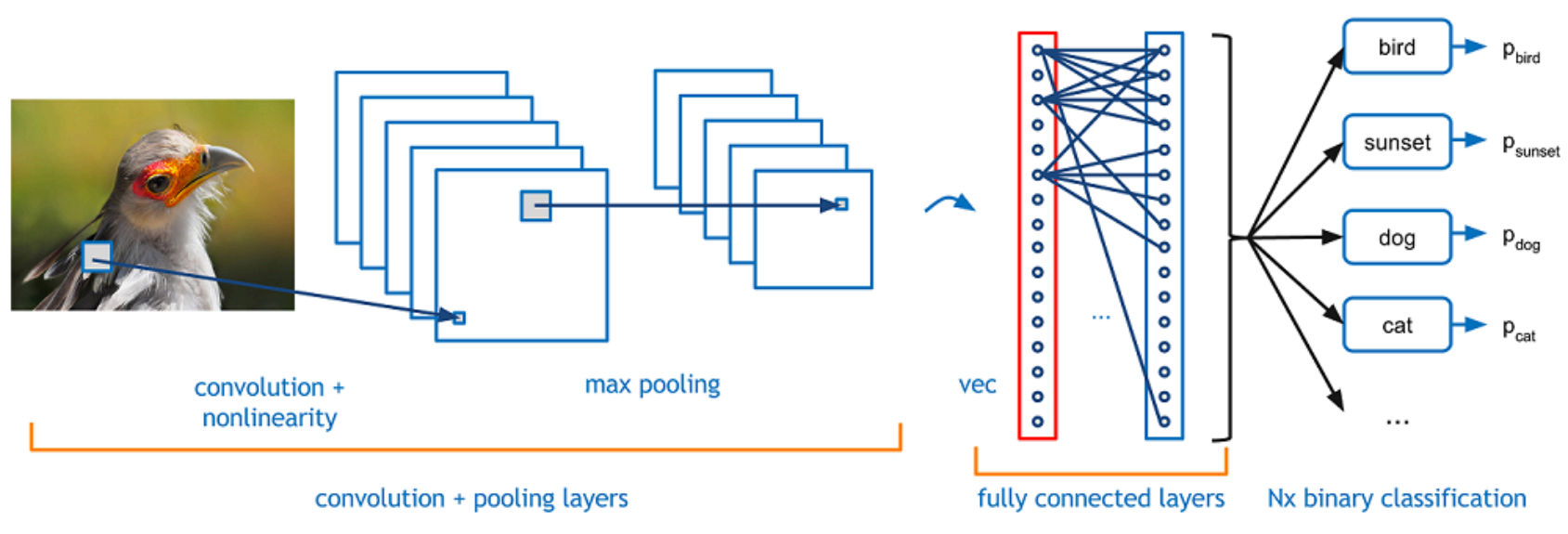
Super powers of deep learning:

- general framework

Another classification network



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Super powers of deep learning:

- general framework
- efficient structure

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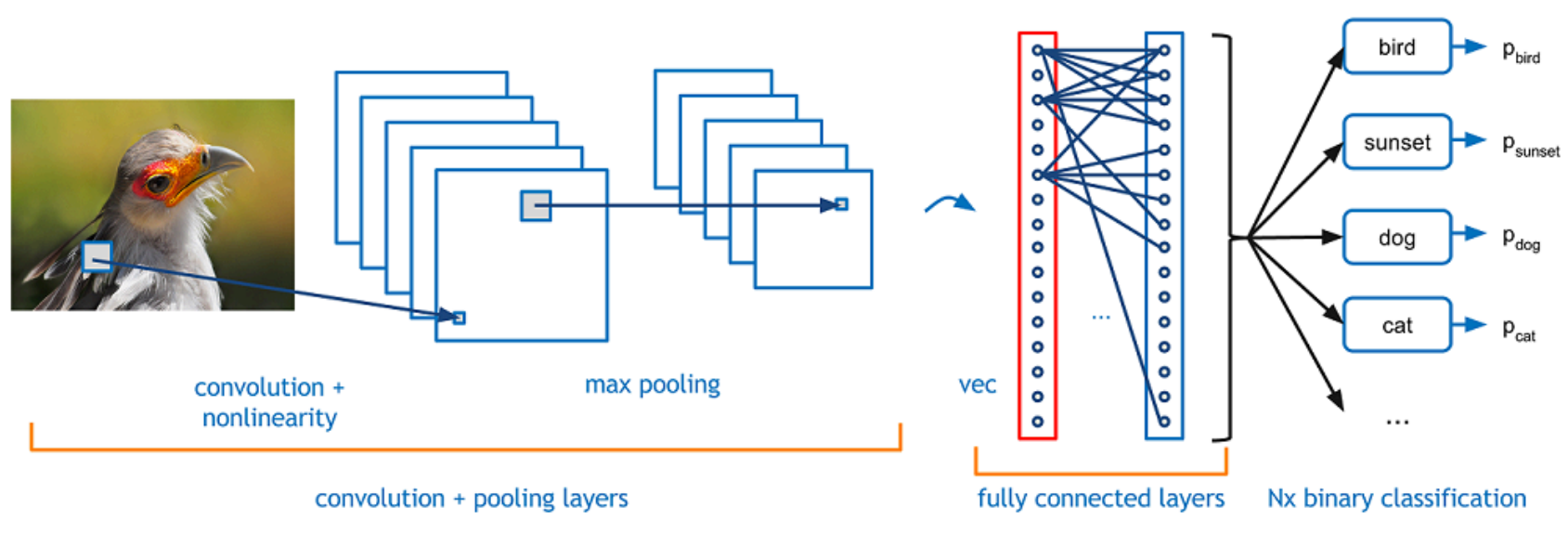

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Super powers of deep learning:

- general framework
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- well performing

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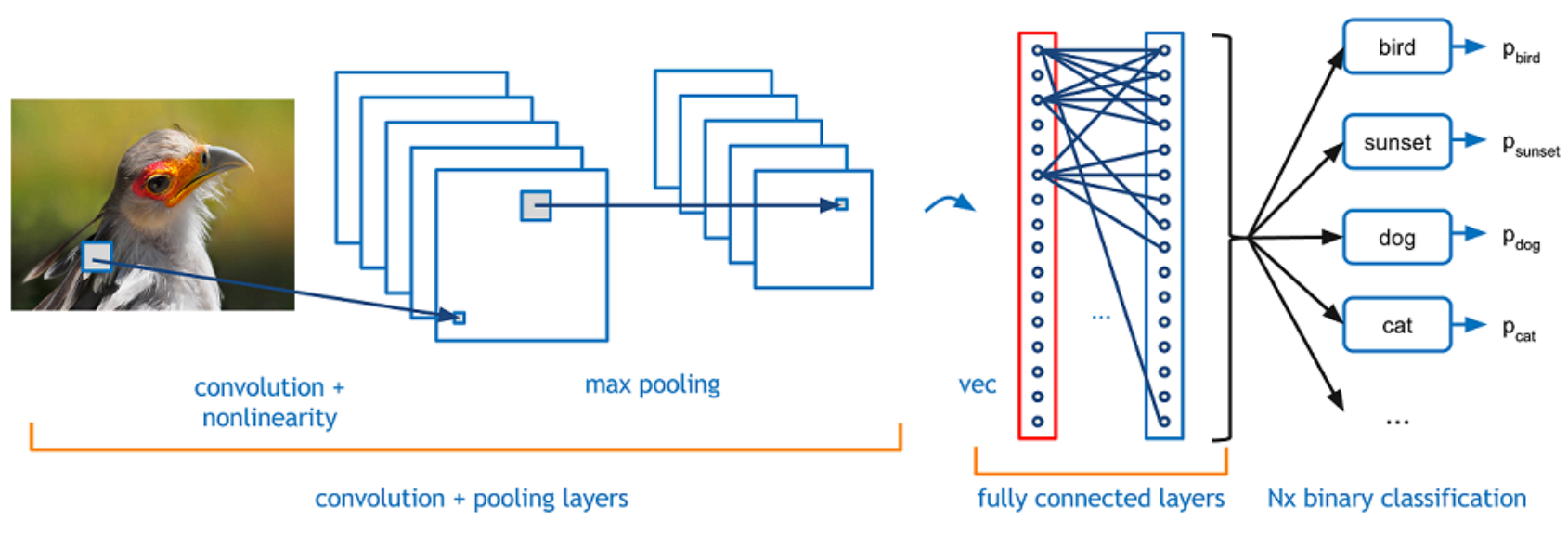

Figure 6: A deep classification network using convolutional neurons.

Super powers of deep learning:

- general framework
- efficient structure
- well performing given the right circumstances

Do they really use it?

Applications of deep learning

Applications of deep learning

Image processing:

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Image processing:

- image classification

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- object detection

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Applications of deep learning

Control related (reinforcement learning):

Applications of deep learning

Control related (reinforcement learning):

- game playing

Applications of deep learning

Control related (reinforcement learning):

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- robot manipulation

Applications of deep learning

Medicine, biology and chemistry:

More interesting applications can be found **here** and **here**.

Applications of deep learning

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- tumor identification in medical imaging

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Medicine, biology and chemistry:

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More interesting applications can be found **here** and **here**.

Let’s view some nice examples

- YOLO object detection
- Pix2Pix demo and Twitter hashtag
- Pix2PixHD
- Automatic image colorization
- Pose estimation
- Atari game playing
- Super Mario
- Robotic manipulation

Deep learning and me

Is deep learning right for you?

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- you have access to quite large amounts of data

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- the problem is reasonably complex, in a high dimensional space

Is deep learning right for you?

You should consider deep learning if:

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- the problem is reasonably complex, in a high dimensional space
- no hard constraints or hard logic

Where do I start?

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Frameworks and software (usually require GPUs):

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- more at **this** link

Thank you for your attention!

Questions?

Slides can be found at `www.github.com/pauldragan`.
You can also find me on Twitter @PaulDraganNow