ARTIFICIAL NEURAL NETWORKS

12.4.2020

RECAP: METHODS

	Supervised (given X & y, learn X→y)	Unsupervised (given X, learn its structure)
Continuous (output is real numbers)	Regression	PCA
Discrete (output is discrete classes)	Classification	Clustering

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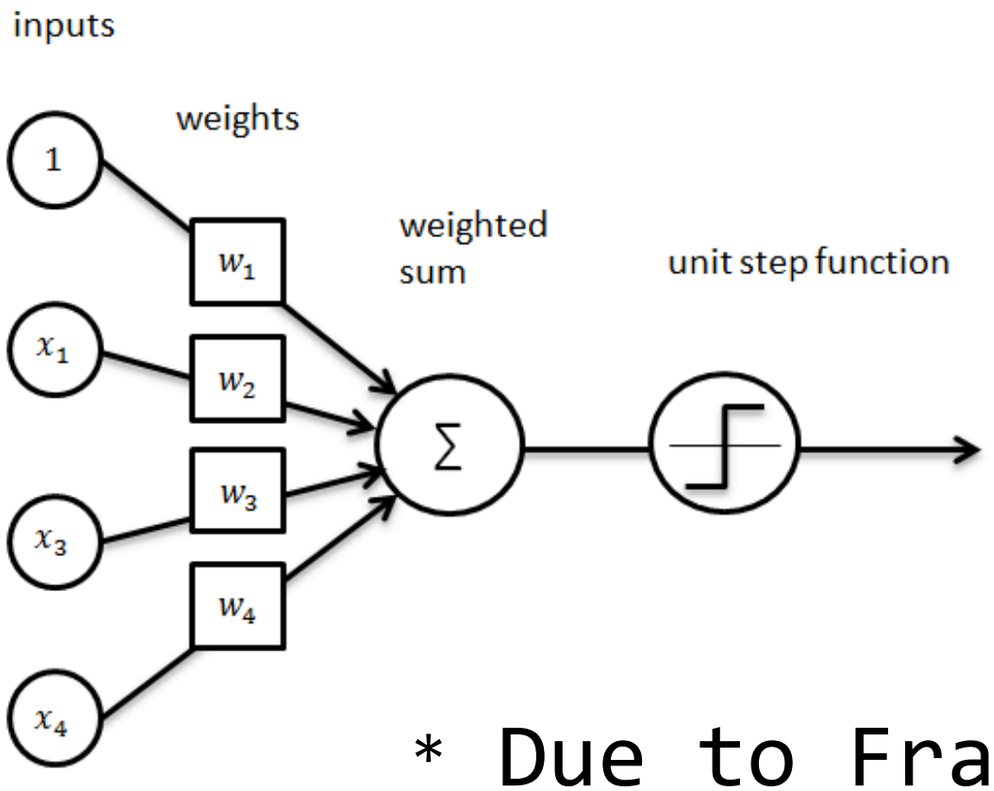
Artificial Neural Networks Lol

ARTIFICIAL NEURAL NETWORK

* Simplest/oldest version: a ***perceptron***



$$y_i \in \{0, 1\}$$

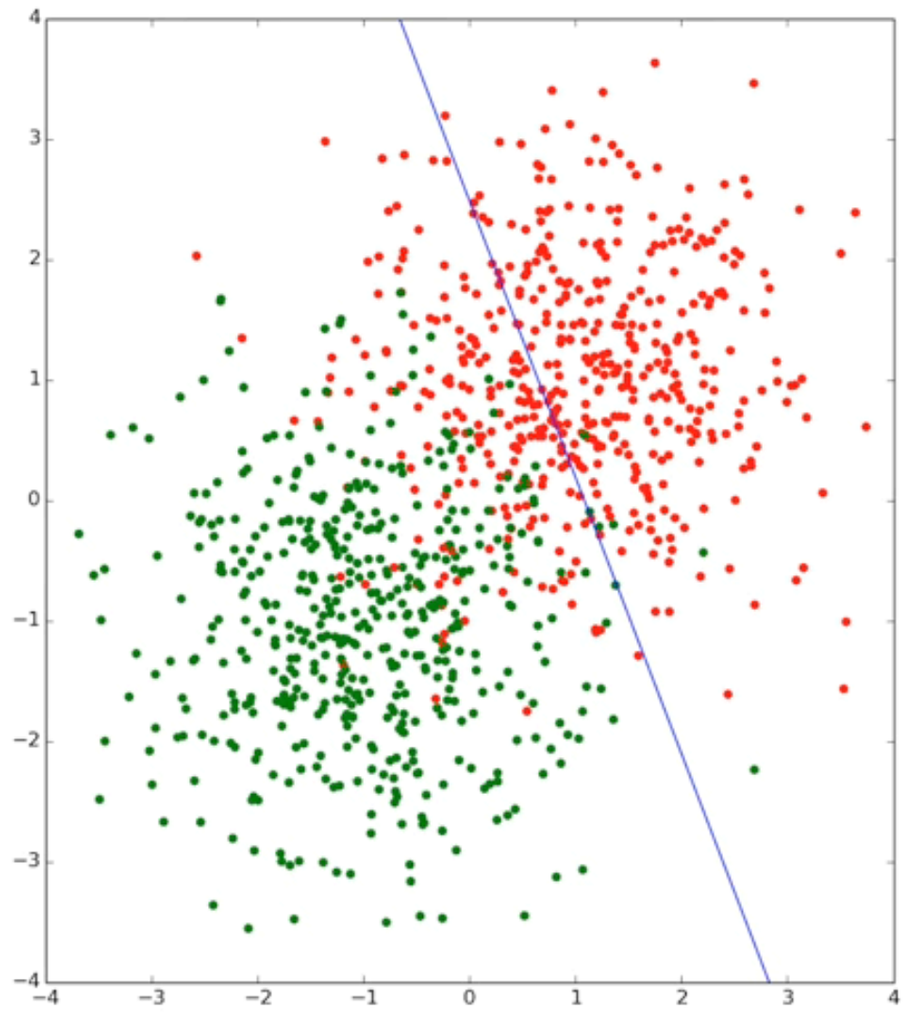
$$X_i \in \mathcal{R}^p$$

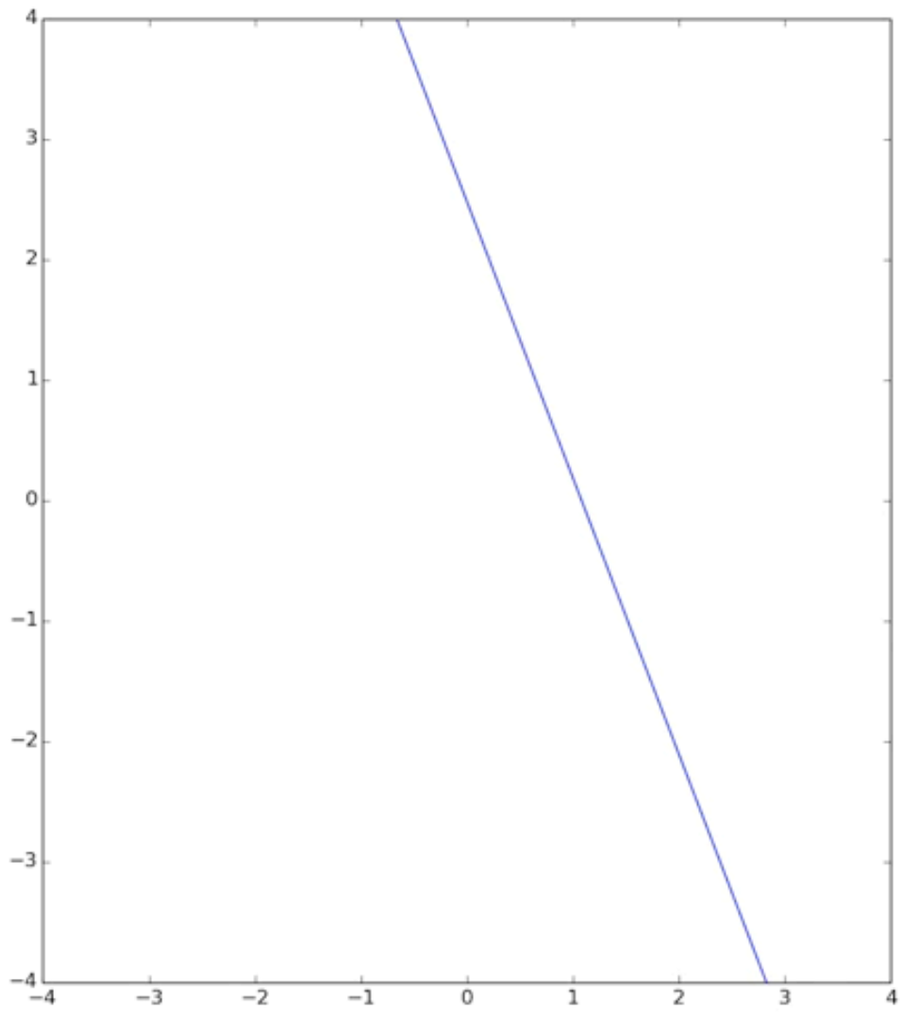
$$\hat{y}_i = H(X_i w)$$

* Due to Frank Rosenblatt (1958)

h/t http://ataspinar.com/2016/12/22/the-perceptron/

PERCEPTRON LEARNING



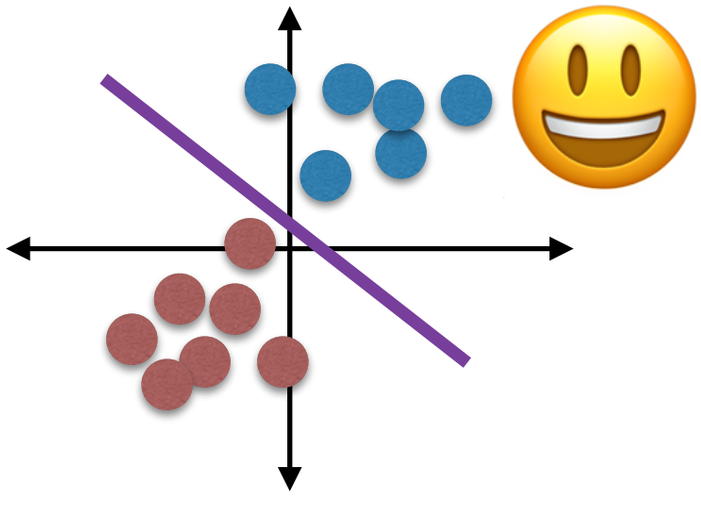


h/t https://github.com/ayusek/Perceptron-Animation

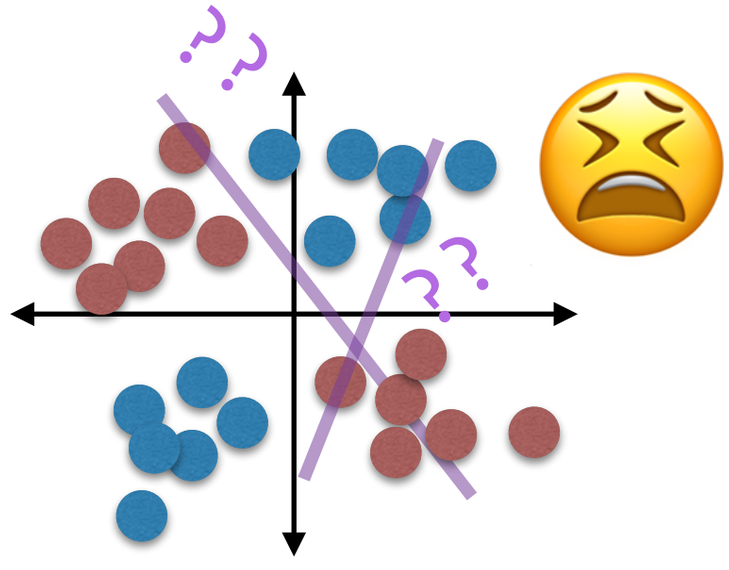
PERCEPTRONS

* “You dumdums, single perceptrons can’t even solve something as simple as ***XOR***, how could they possibly recognize images or walk or talk or be conscious?!”
  – Minsky & Papert, basically, 1969

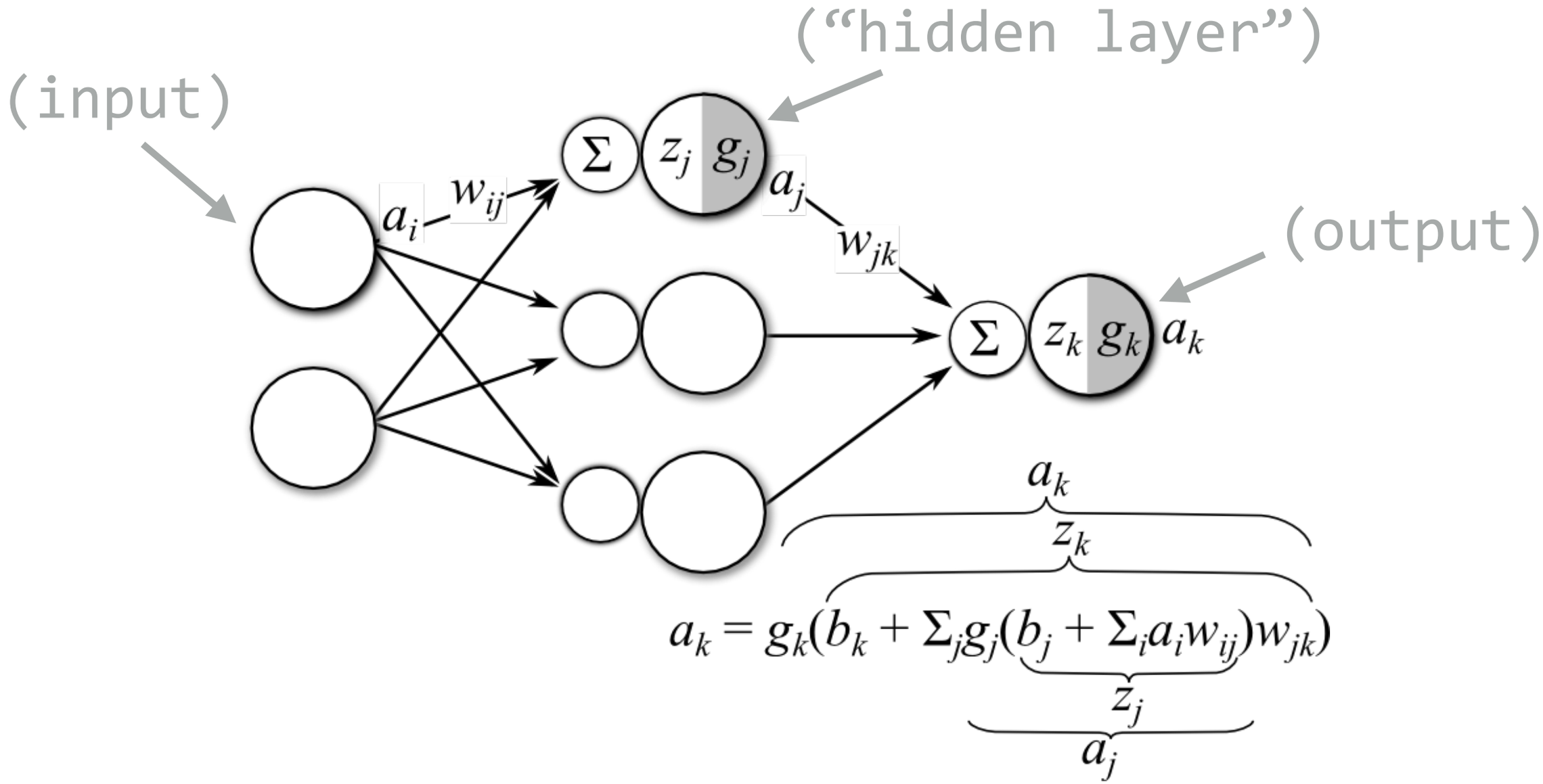
* –> “AI winter” of 1974-1980



vs.



MULTILAYER ARTIFICIAL NEURAL NETWORKS



h/t Dustin Stansbury

MULTILAYER ARTIFICIAL NEURAL NETWORKS

* But how to learn weights??

* **Gradient backpropagation!**

* This has probably been discovered in some form a few times in different fields

* In ML we usually credit Rumelhart, Hinton, & Williams (1986)

MULTILAYER ARTIFICIAL NEURAL NETWORKS

* What can networks with hidden layers do?

* **Universal approximation theorem (Cybenko, 1989):** These networks can do *literally anything* (*as long as there is a non-polynomial output nonlinearity)

MULTILAYER ARTIFICIAL NEURAL NETWORKS

* From 1980's to 2010's there was lots of theoretical progress, but NNs were not the *best* solution to any problem…

* Two main issues:

  * **data:** NNs require *SCADS* of data

  * **compute:** NNs require *INSANE* amounts of computer time to train

Fei-Fei Li

* **ImageNet:** a database of ~15 *million* images from thousands of categories

  * Organized as a yearly competition

  * Developed by **Fei-Fei Li** & her group @ Stanford

IMAGENET COMPETITION

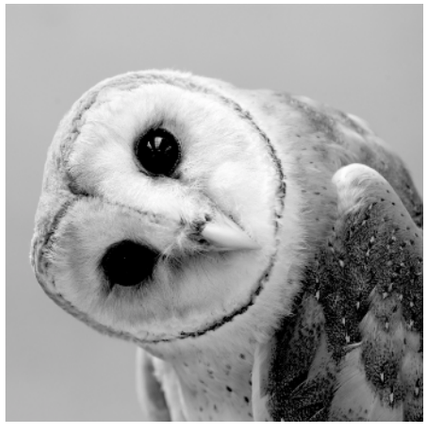
* **The goal**: given an image, say what it is an image of

  * *(Classification!)*

* 1000 categories, ~1200 images per category = 1.2M images to train on!

→ cat

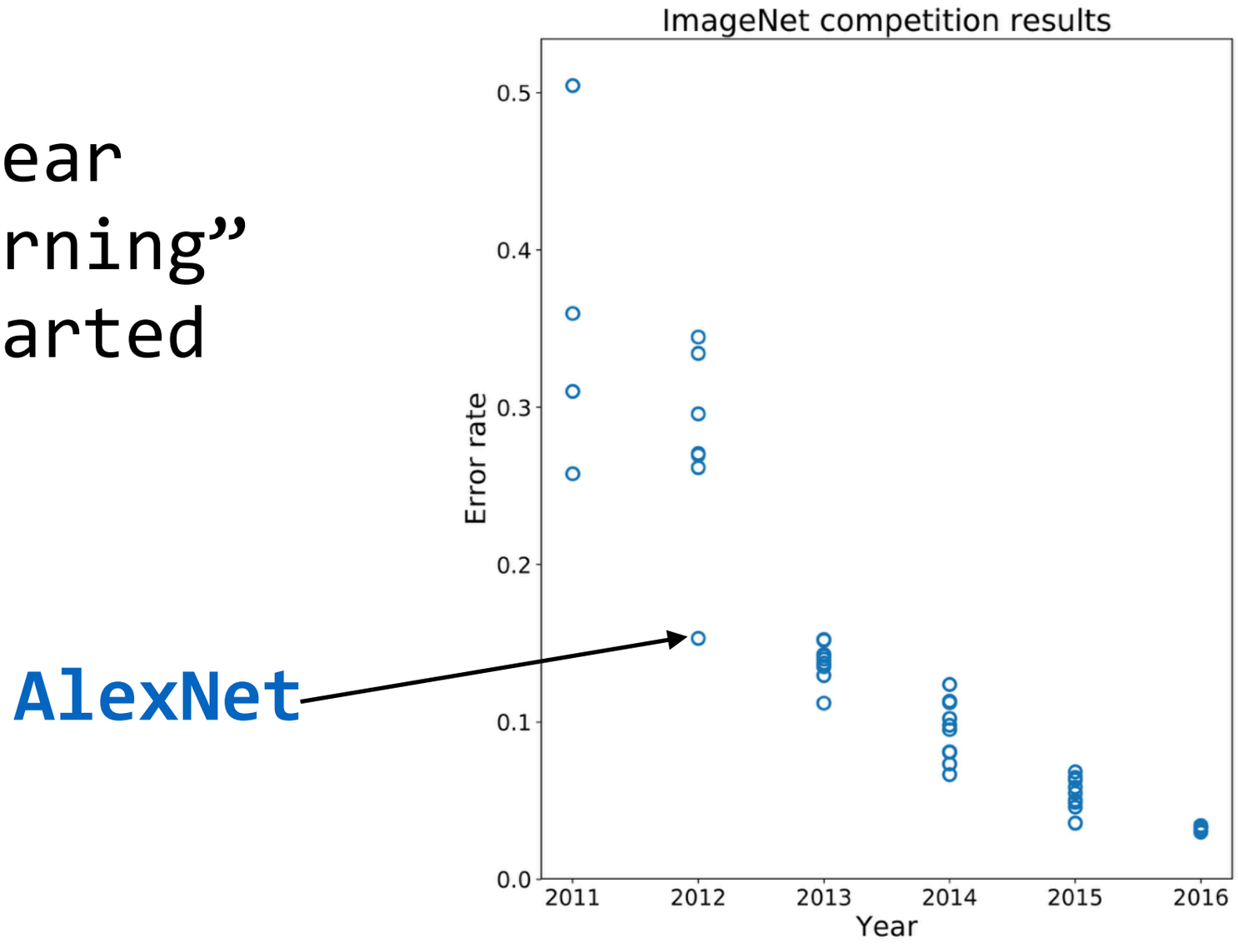
→ dog



→ owl

IMAGENET COMPETITION

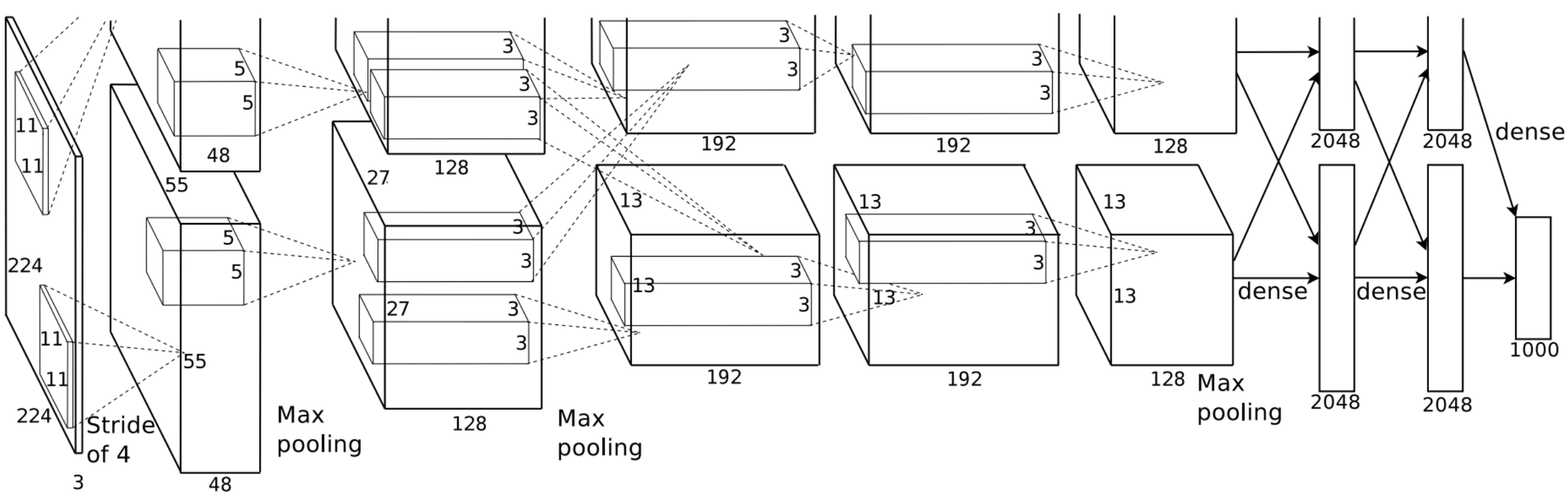
* 2012 is the year the “deep learning” revolution started



https://en.wikipedia.org/wiki/ImageNet#/media/File:ImageNet_error_rate_history_(just_systems).svg

ALEXNET

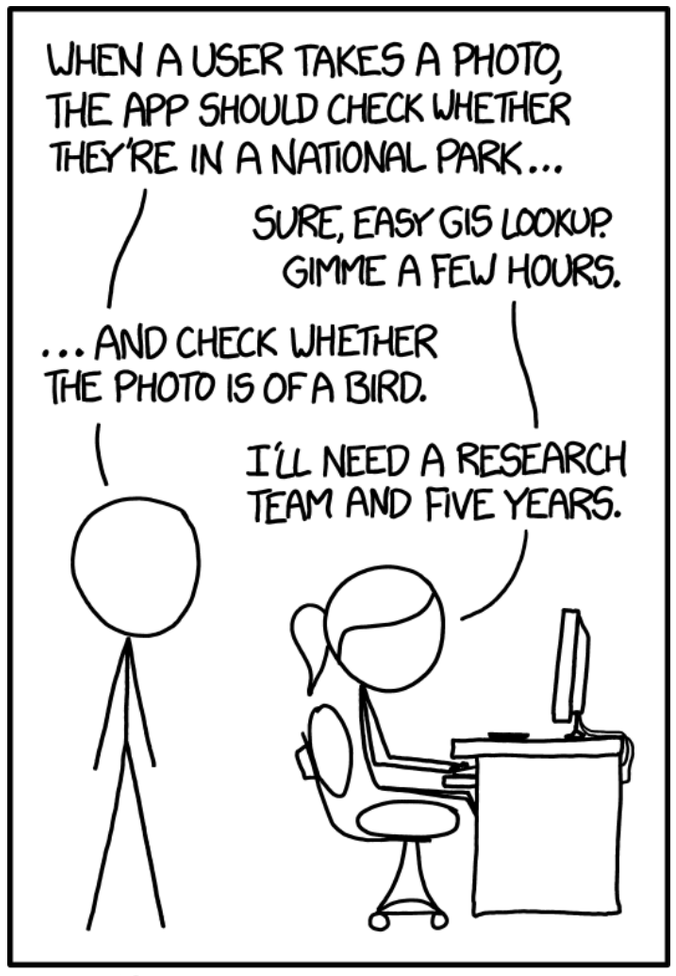
* Lots of tricks + GPU compute + ImageNet came together in AlexNet (Krizhevsky, Sutskever, & Hinton, 2012)



ALEXNET

* The first really successful deep neural network model

* Showed that artificial neural networks (with the right bag of tricks!) can actually do things (at least somewhat!) that we thought were computationally “hard”



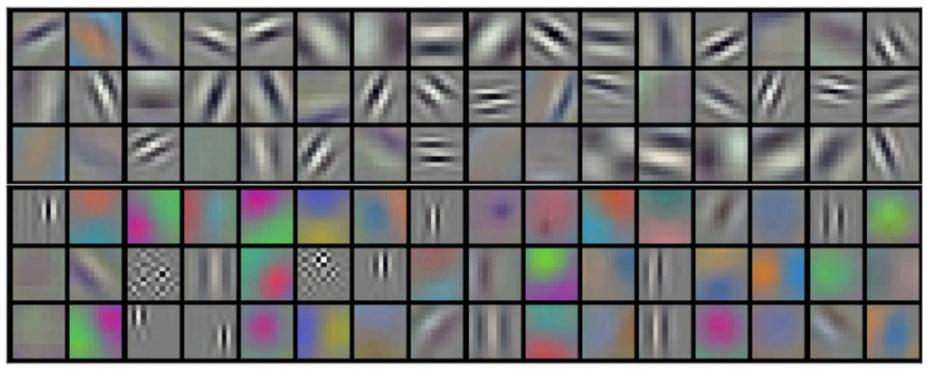
ALEXNET

* Does it solve the problem the same way that our brains do?

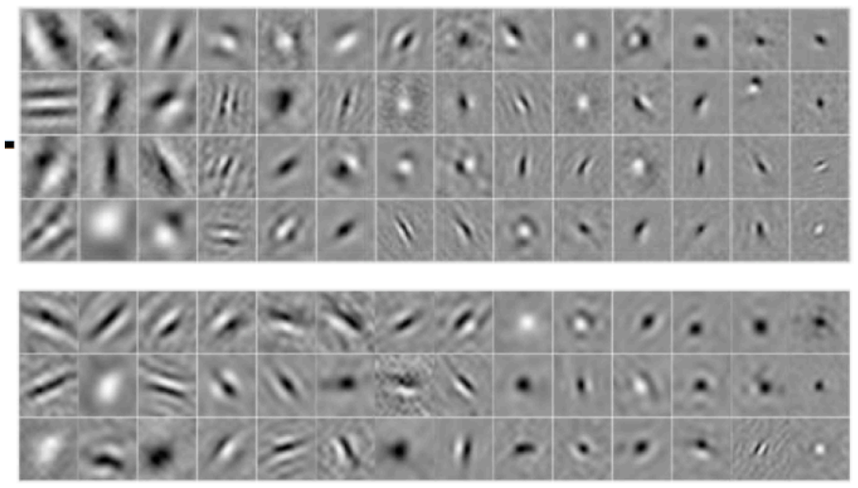
* How would we know?

ALEXNET

* Features learned by 1st layer of AlexNet



* Receptive fields of V1 neurons from a macaque



FMRI EXAMPLE

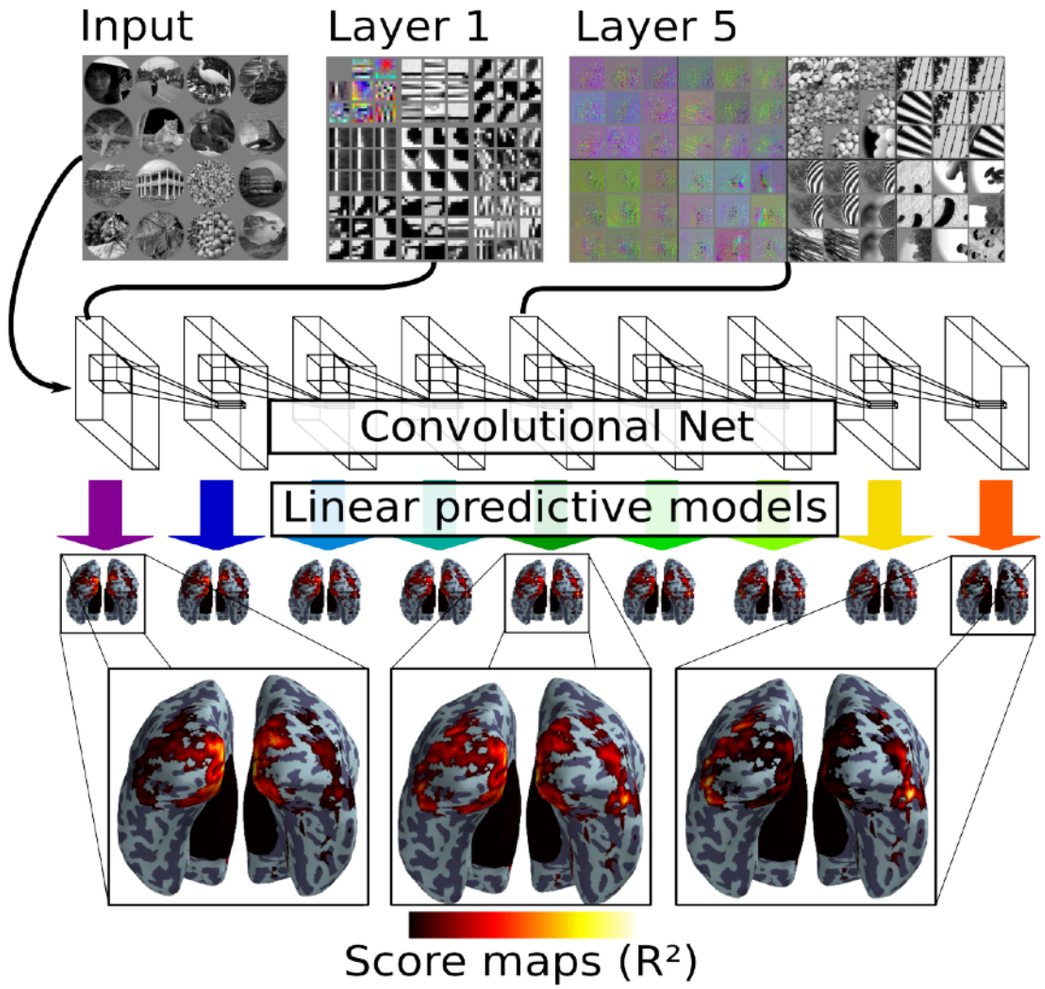
* Eickenberg, Gramfort, Varoquaux, & Thirion (2016) Seeing it all: convolutional network layers map the function of the human visual system. *Neuroimage*

* Two human subjects viewed 1000s of images while BOLD signals were recorded from visual cortex using fMRI

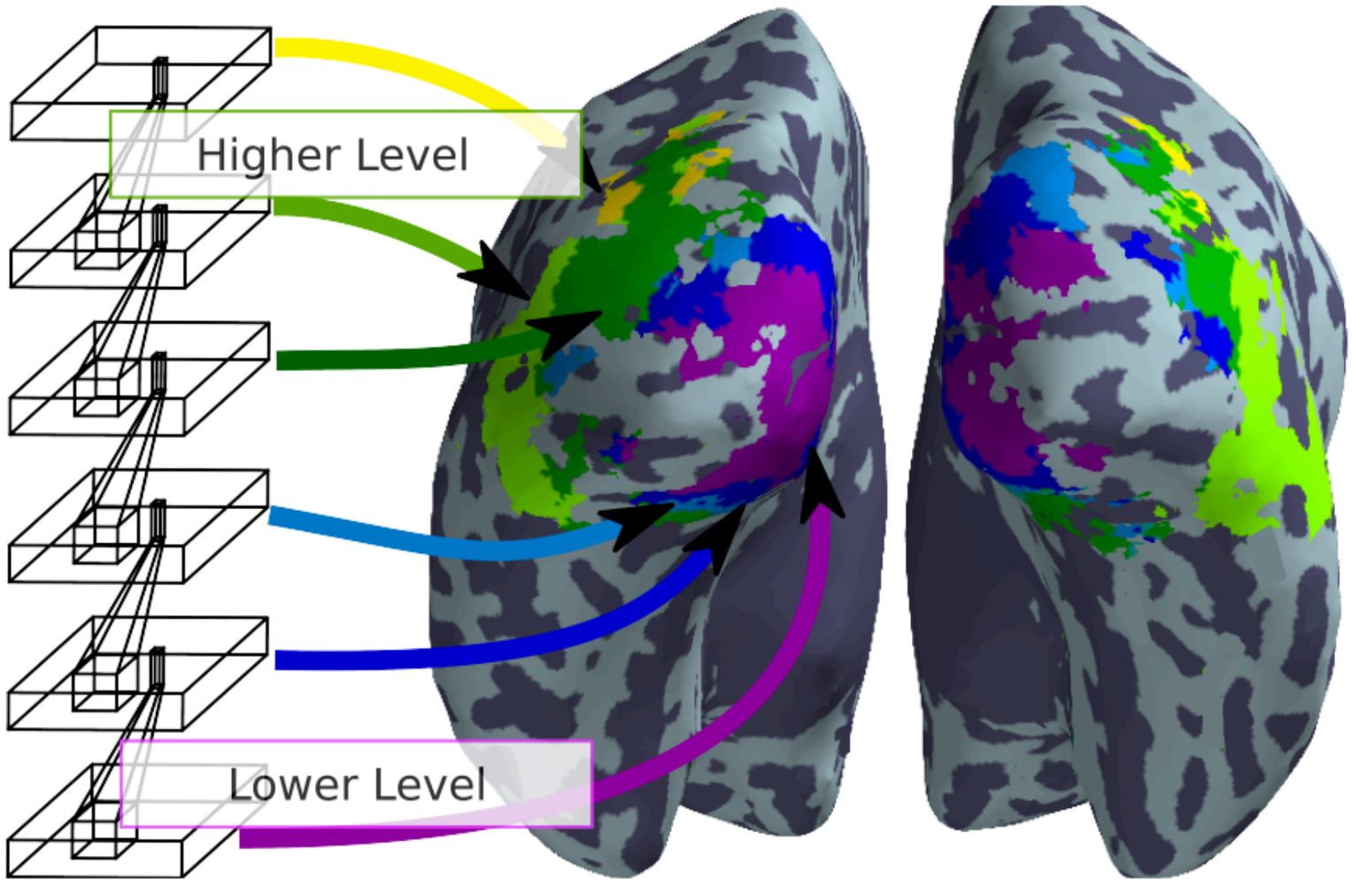
FMRI EXAMPLE

* Used neural network similar to AlexNet

* Built model for each voxel using **activations** from each layer, then tested on held-out data

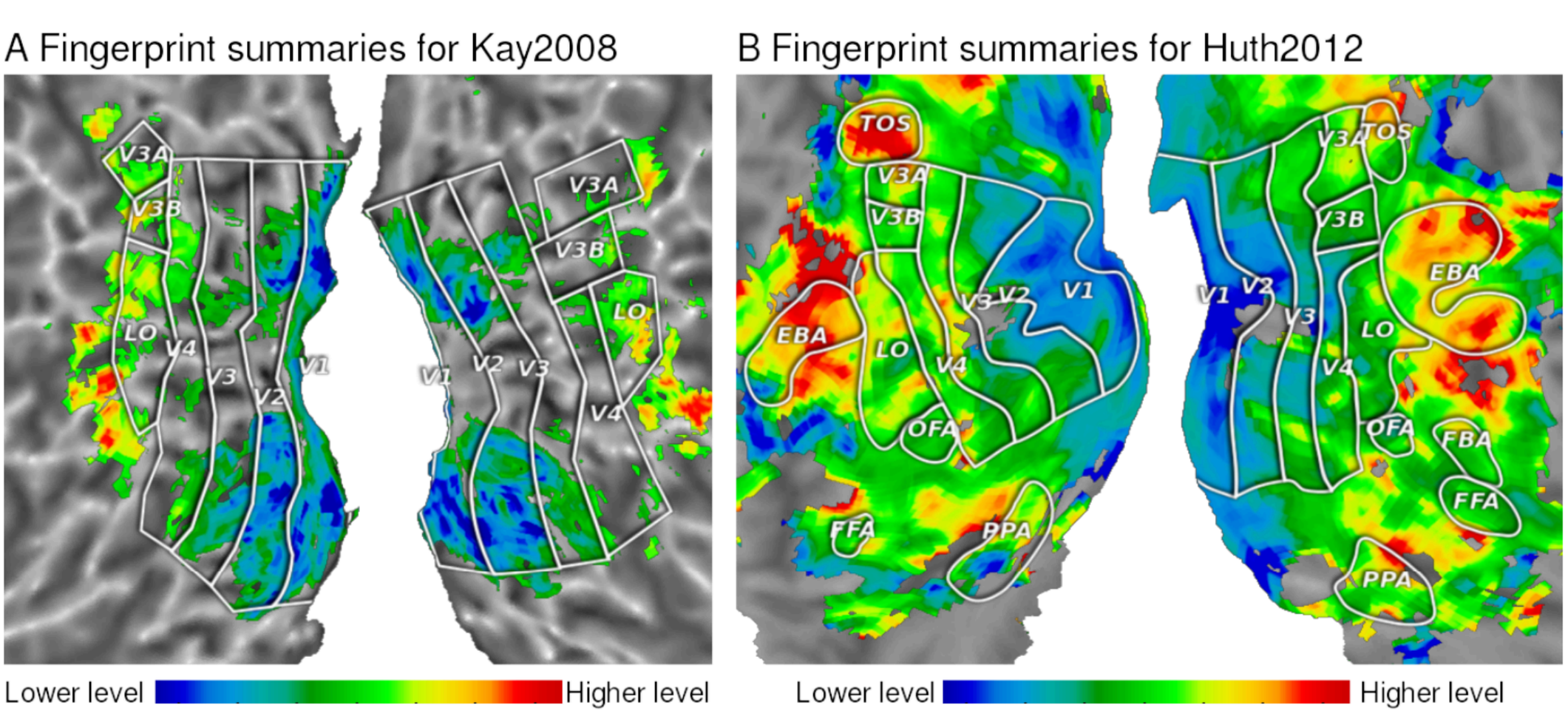


FMRI EXAMPLE



FMRI EXAMPLE

* ***Fingerprint:*** summary model performance metric giving something like “best layer”



FMRI EXAMPLE

* **Result:** Convolutional neural networks (like AlexNet) seem to mimic processing that happens in human visual cortex (!!!)

NEURAL NETWORKS FOR NEUROSCIENCE

* NNs are just starting to be used in neuroscience data analysis

* Mostly in the same fashion as the Eickenberg paper: train a NN to solve some problem, then test whether it uses similar representations to real brains

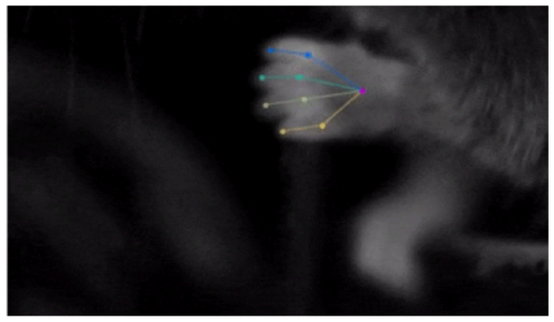
* But since NNs are (pretty much) taking over all of machine learning, there are likely many more things that they will be used for in the future!

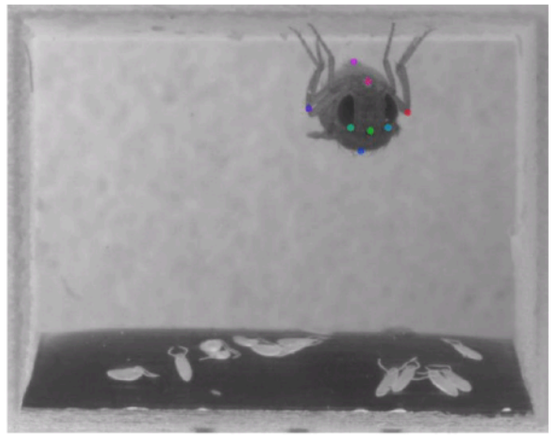
NEURAL NETWORKS FOR NEUROSCIENCE

DeepLabCut:
a software package for animal pose estimation

DeepLabCut™ is an efficient method for 3D markerless pose estimation based on transfer learning with deep neural networks that achieves excellent results (i.e. you can match human labeling accuracy) with minimal training data (typically 50-200 frames). We demonstrate the versatility of this framework by tracking various body parts in multiple species across a broad collection of behaviors.

The package is open source, fast, robust, and can be used to compute 3D pose estimates. Please see the original paper and the latest work below. This package is collaboratively developed by the Mathis Group & Mathis Lab at EPFL/Harvard.





THANK YOU!