Lecture 1: ECE C147/C247, Neural Networks & Deep Learning

General info:

ECE C147/C247, Neural Networks & Deep Learning
Winter quarter, UCLA AY 2022-23

Instructor:

Prof. Jonathan Kao
OH: TBD

TAs:

Tonmoy Monsoor
Pan Lu
Rakshith Ravindra Gore
Kalaivani Kamalakannan
Shivam Patel
Sindhu Narasarama Rao
Naveen Vikraman
Mahmoud (Ramin) Essalat

Some high-level thoughts about this class:

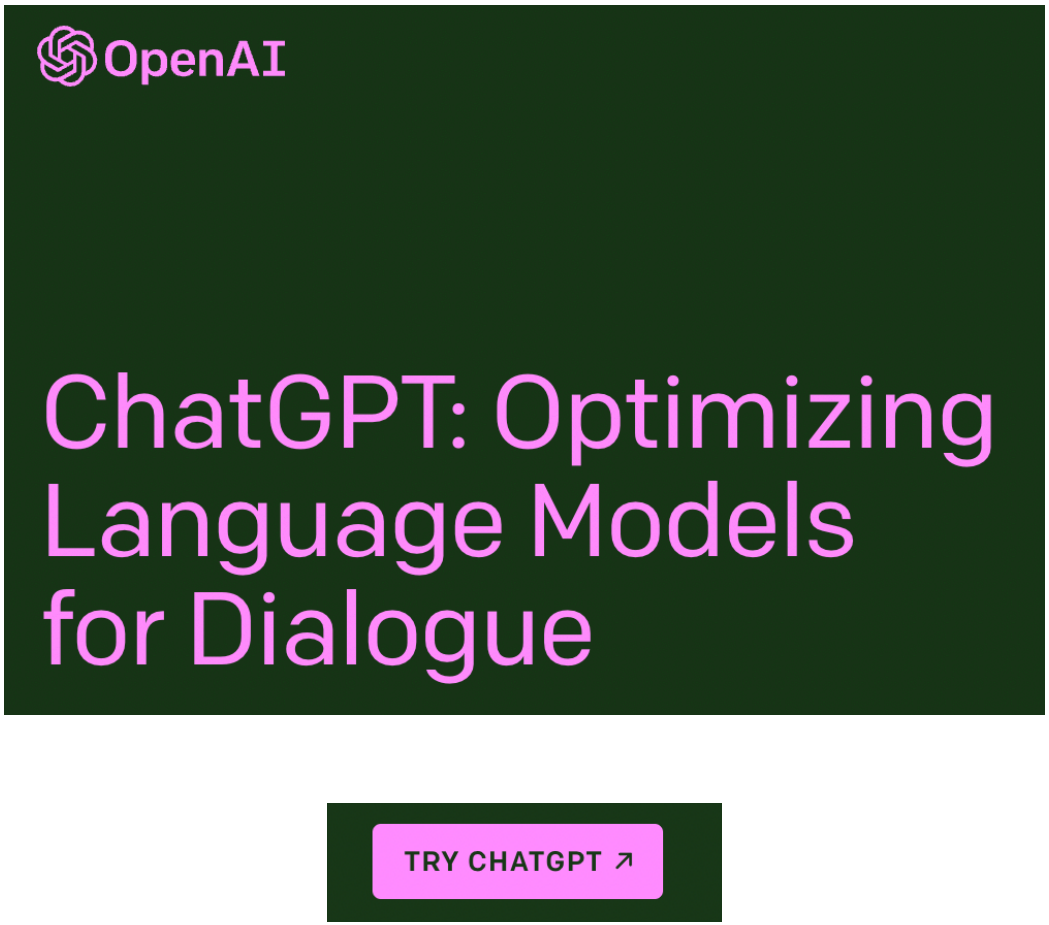
- Deep learning is a very relevant topic for many different applications today, and we hope this class will be useful for people going to a diversity of areas.
- This class will (hopefully) be fun, but also a lot of work.
- Ask questions!

Zoom online lectures

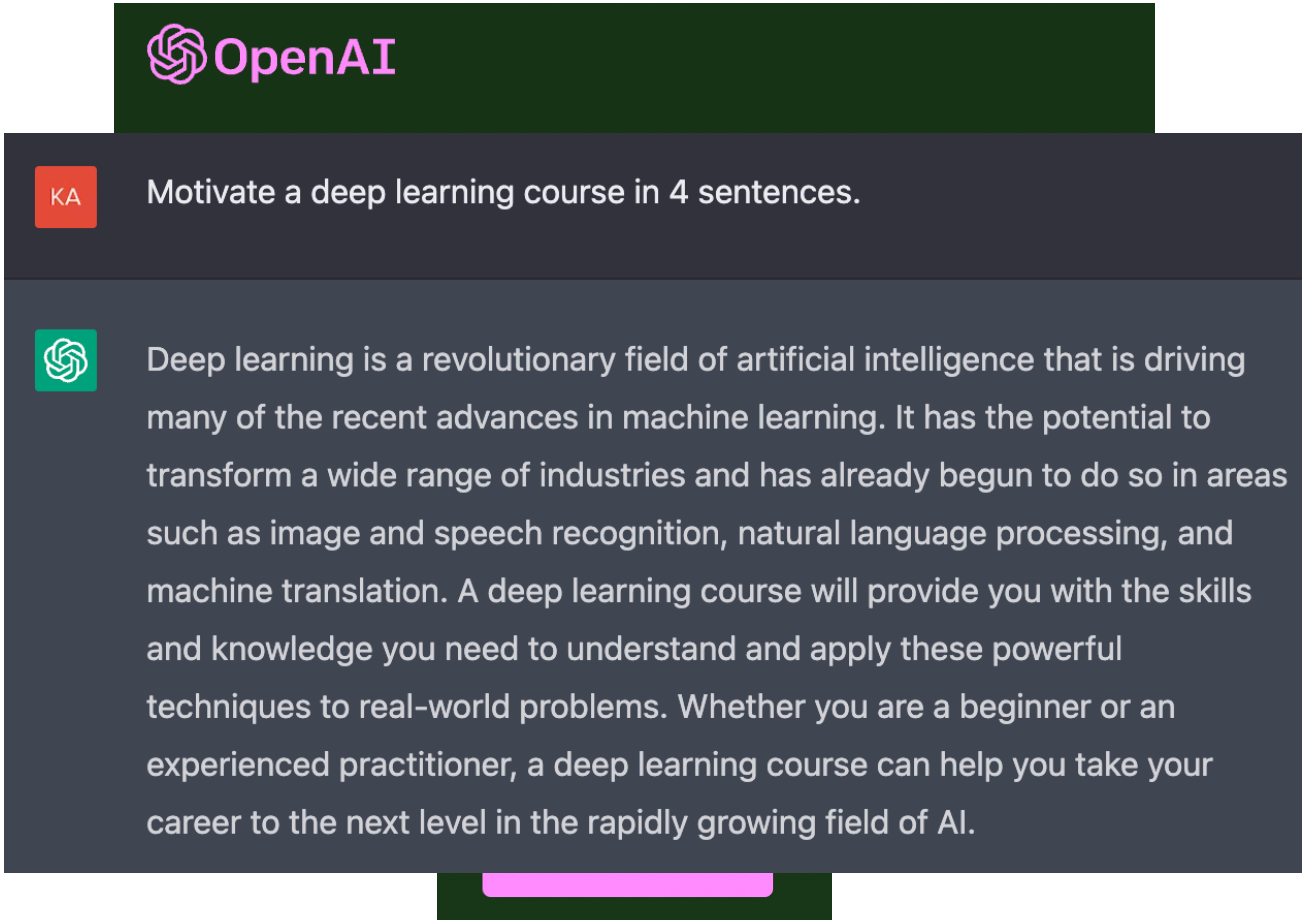
This course will be recorded by BruinCast. We will also open a Zoom room at `https://ucla.zoom.us/j/91554310633` during live lecture so MSOL students can participate remotely.

By default, all students will be muted in the Zoom room. We will not pause to take verbal questions over Zoom. However, at least one TA will monitor the chat on Zoom and answer questions in the chat.

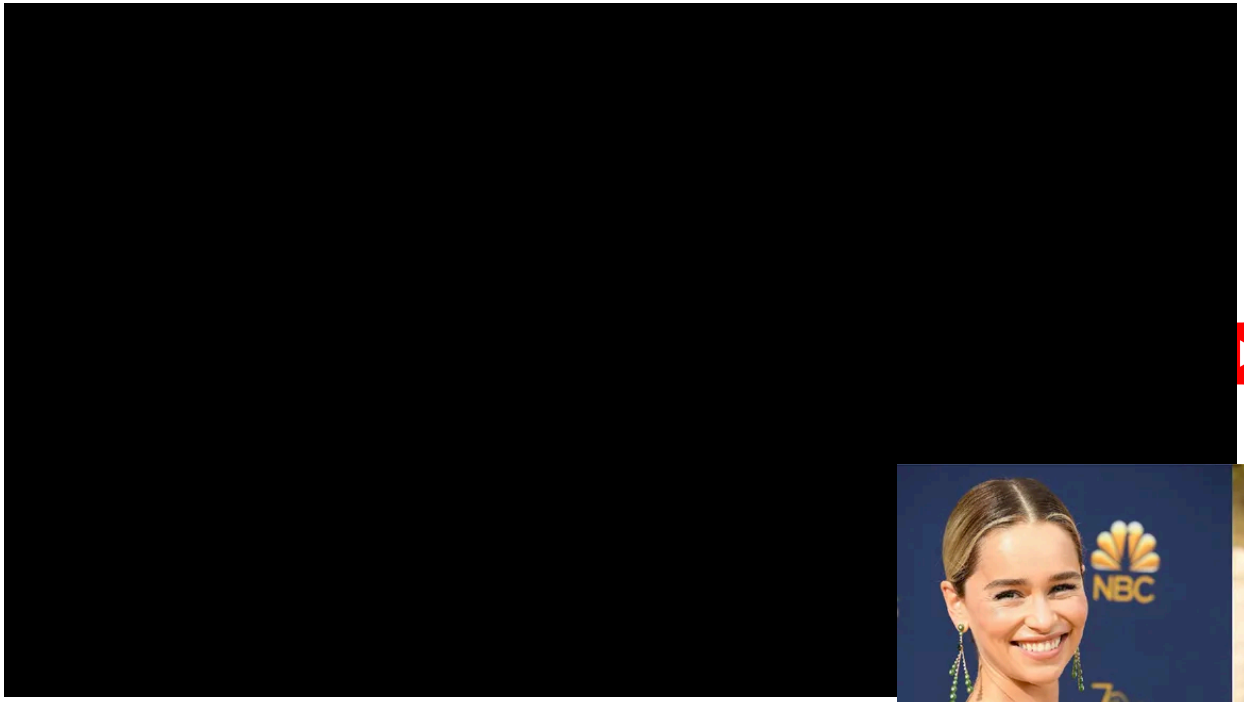
Lecture 1: ECE C147/C247, Neural Networks & Deep Learning



Lecture 1: ECE C147/C247, Neural Networks & Deep Learning

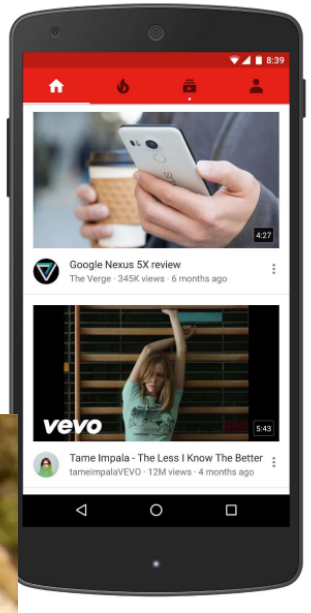


Deep learning is regularly used in modern AI.



https://engineering.fb.com/2016/06/01/core-data/introducing-deeptext-facebook-s-text-understa

YouTube



esearch.google.com/en//pubs/archive/45530.pdf

Meta

https://www.forbes.com/sites/bernardmarr/2016/12/29/4-amazing-ways-facebook-uses-deep-learning-to-learn-everything-about-you/?sh=478f6eddccbf

https://viso.ai/computer-vision/deepface/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     "surprise":7.103817571484745e-13,
     "neutral":4.4851553027136504e-08
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  },
  "dominant_race":"white"
}
```

Why a class on deep learning?

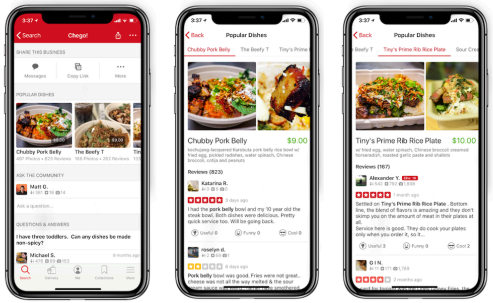
https://www.youtube.com/watch?v=40riCqvRoMs

Deep learning is regularly used in modern AI.

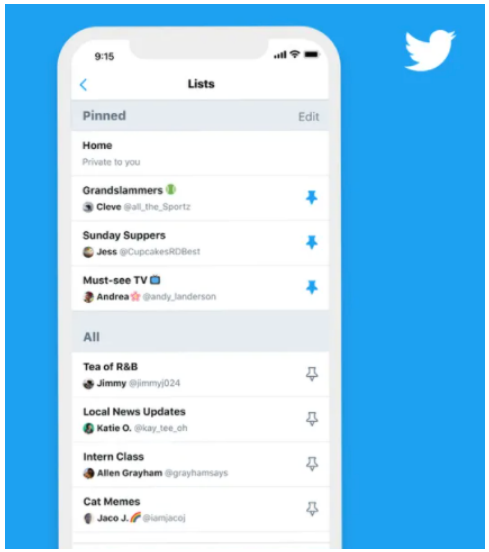
Discovering Popular Dishes with Deep Learning

Introduction

Yelp is home to nearly 200 million user-submitted reviews and even more photos. This data is rich with information about businesses and user opinions. Through the application of cutting-edge machine learning techniques, we're able to extract and share insights from this data. In particular, the Popular Dishes feature leverages Yelp's deep data to take the guesswork out of what to order. For more details on the product itself, check out our product launch blog post.

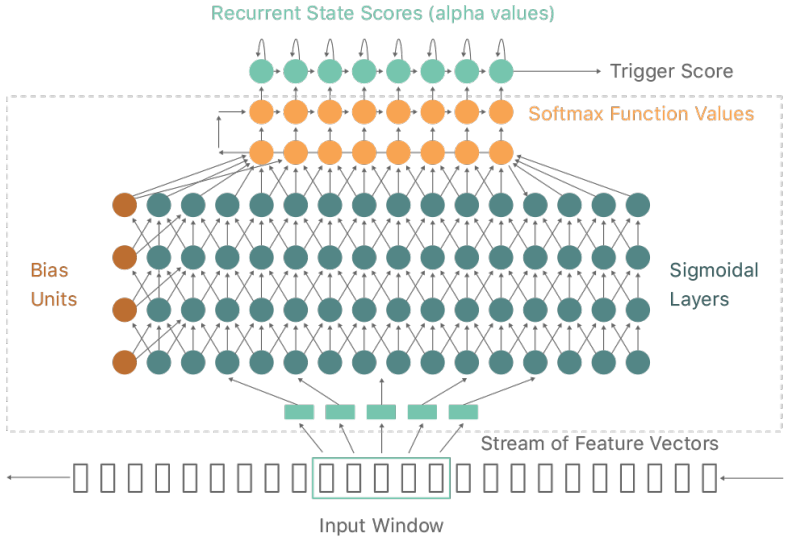


https://engineeringblog.yelp.com/2019/10/discovering-popular-dishes-with-deep-learning.html



https://blog.twitter.com/engineering/en_us/topics/insights/2017/using-deep-learning-at-scale-in-twitters-timelines

Alexa, Siri, Cortana

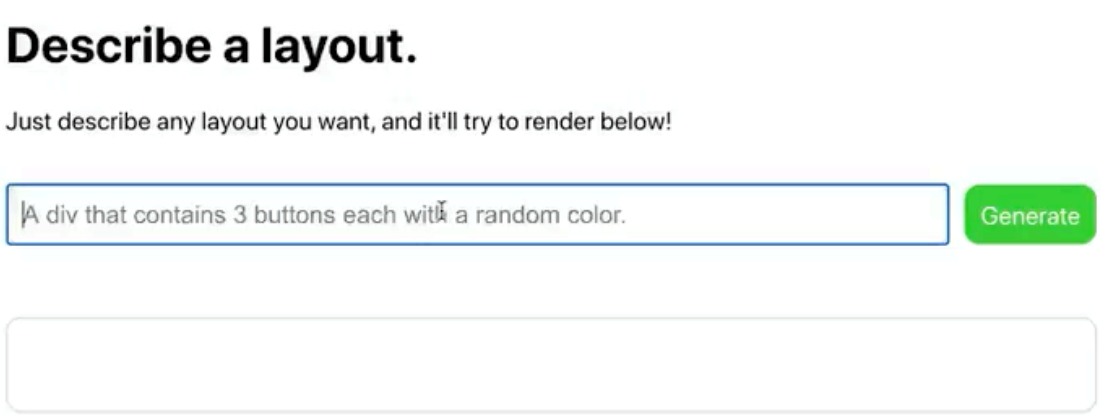


https://machinelearning.apple.com/2017/10/01/hey-siri.html

NETFLIX

Netflix vectorflow (https://medium.com/@NetflixTechBlog/introducing-vectorflow-fe10d7f126b8) and likely recommendation (https://becominghuman.ai/how-netflix-uses-ai-and-machine-learning-a087614630fe)

Deep learning is regularly used in modern AI.



Deep learning is regularly used in modern AI.

TEXT PROMPT an illustration of a baby daikon radish in a tutu walking a dog

AI-GENERATED IMAGES

TEXT PROMPT an armchair in the shape of an avocado. . . .

AI-GENERATED IMAGES

TEXT PROMPT a store front that has the word 'openai' written on it. . . .

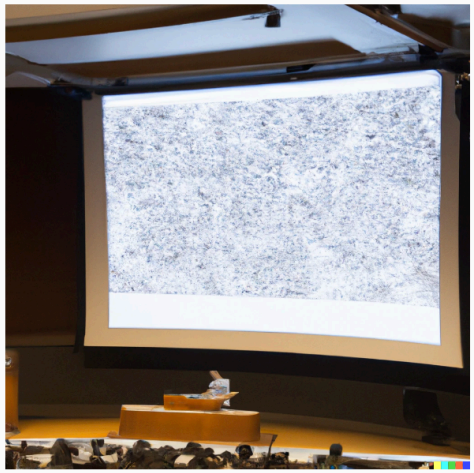
AI-GENERATED IMAGES

https://www.machinecurve.com/index.php/2021/01/05/dall-e-openai-gpt-3-model-can-draw-pictures-based-on-text/

Deep learning is regularly used in modern AI.

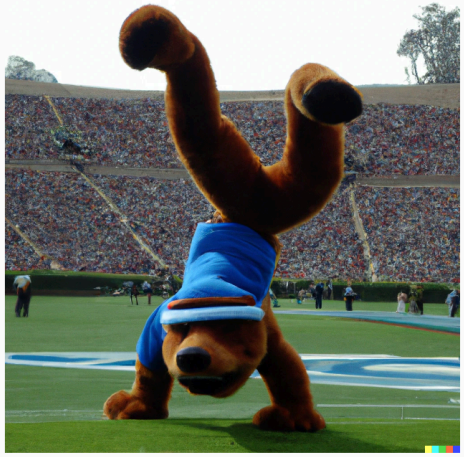
a UCLA professor teaching deep learning in a large lecture hall | Generate



Deep learning is regularly used in modern AI.

joe bruin doing cartwheels at the rose bowl | Generate

Why a class on deep learning?

Its applications are diverse.

Why a class on deep learning?

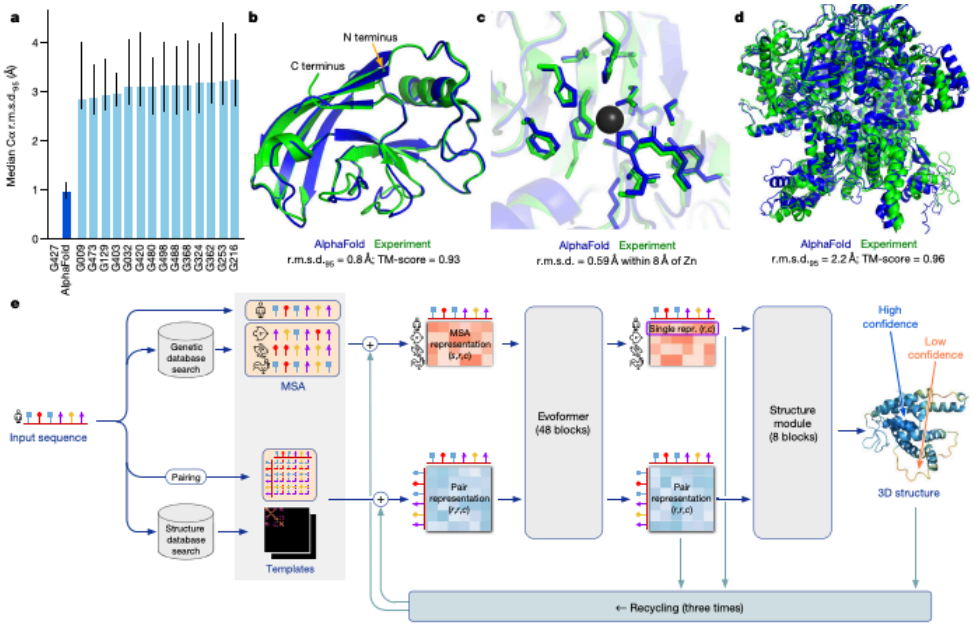
Its applications are diverse.

https://www.youtube.com/watch?v=4HCE1P-m1l8

Why a class on deep learning?

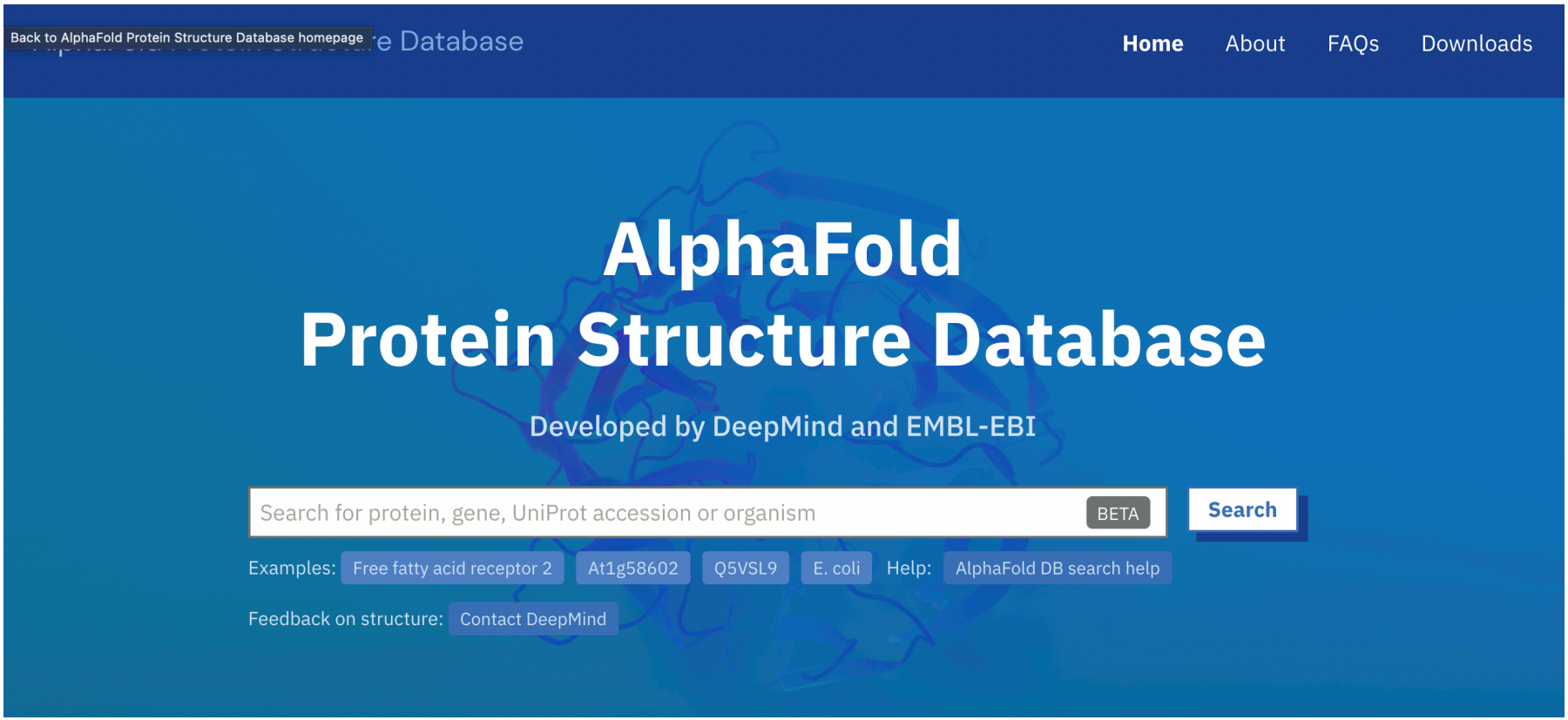
Deep learning in important applications.

- Fraud detection (e.g., https://www.technologyreview.com/s/545631/how-paypal-boosts-security-with-artificial-intelligence/)
- Many medical endeavors, including:
  - Cancer moonshot: http://candle.cels.anl.gov/
  - Drug discovery (e.g., http://onlinelibrary.wiley.com/doi/10.1002/minf.201501008/full)
  - Protein folding (https://www.nature.com/articles/s41586-021-03819-2)



Why a class on deep learning?

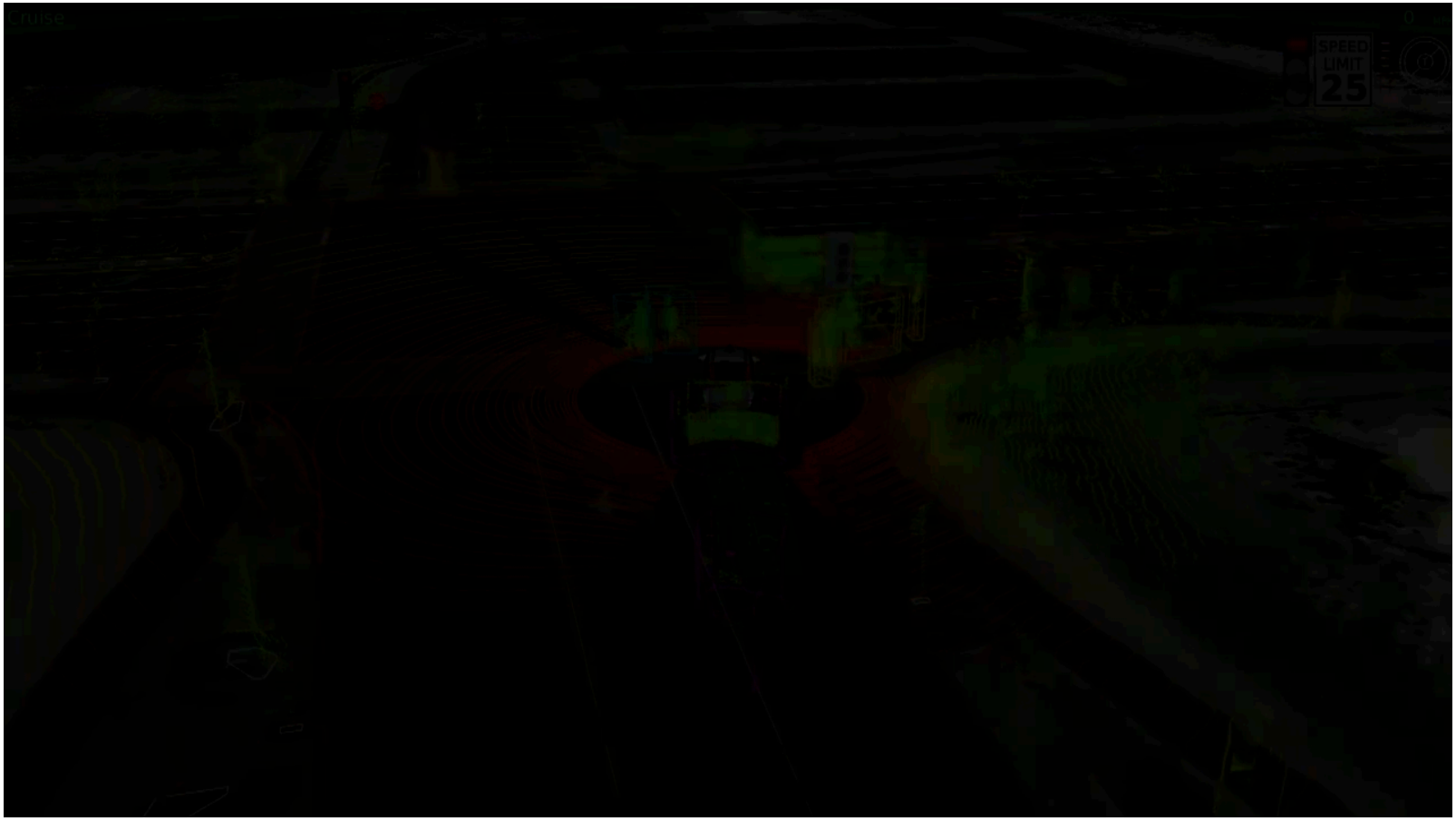
Deep learning in important applications.



Why a class on deep learning?

New technologies.

- Self-driving vehicles.

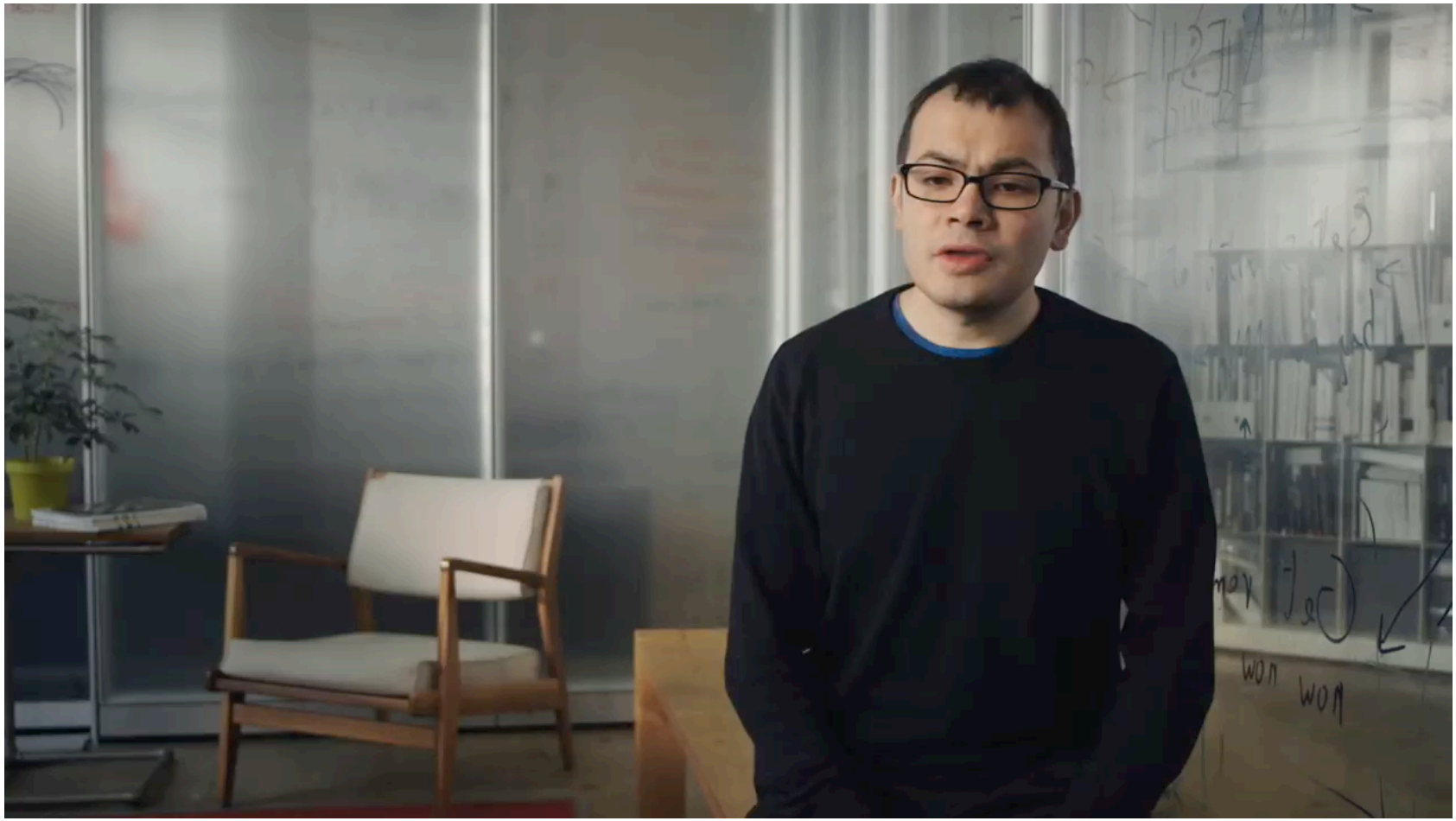


Chris Urmson TED talk, https://www.youtube.com/watch?v=tiwVMrTLUWg

Why a class on deep learning?

Things of the future becoming real today.

- The game of Go.

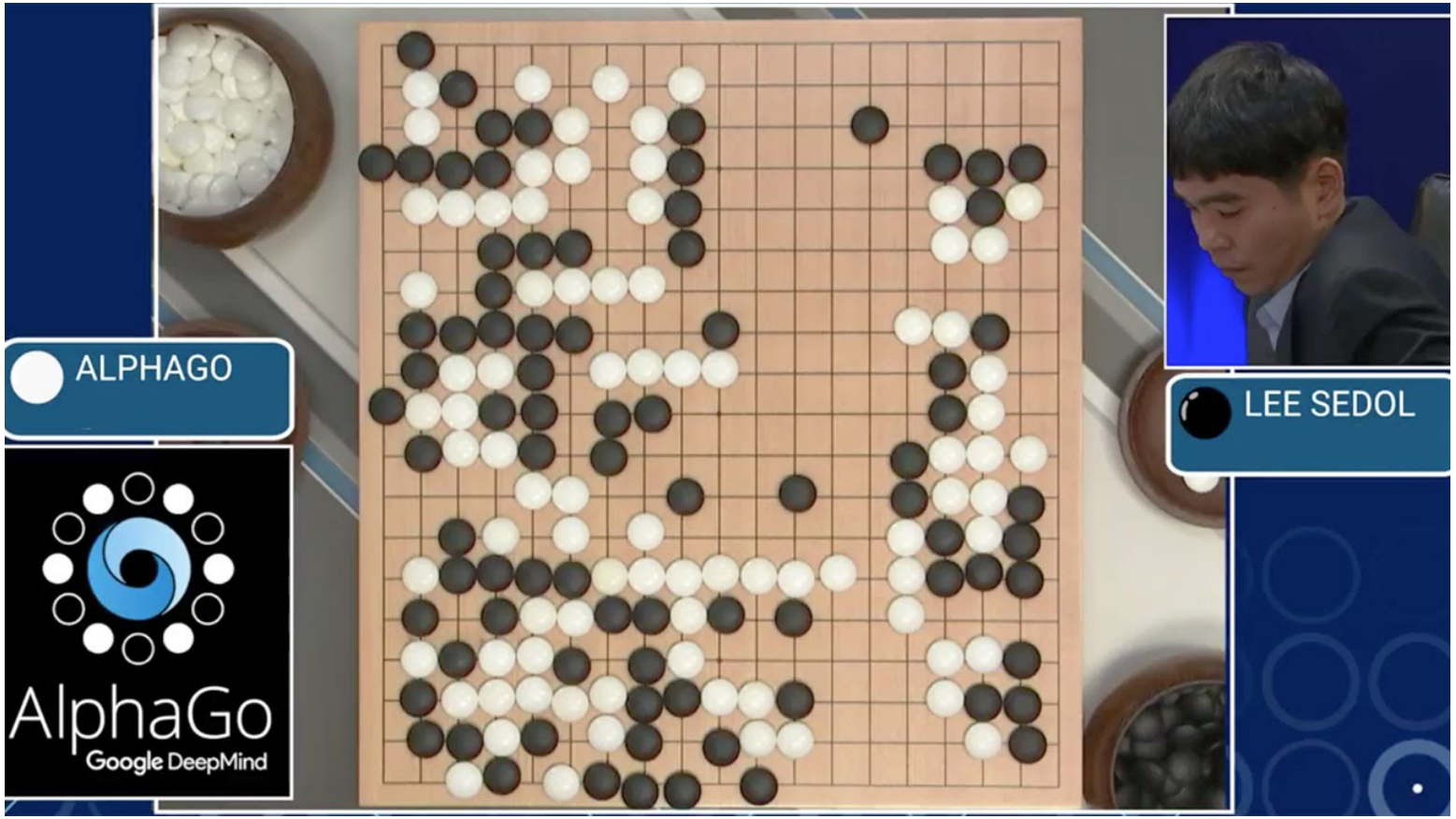


https://www.youtube.com/watch?v=SUbqykXVx0A

Why a class on deep learning?

Things of the future becoming real today.

- Game of Go solved. (AlphaGo def Lee Sedol 4-1, 2016.)



Game 3 of AlphaGo vs Lee Sedol, https://www.youtube.com/watch?v=_OV0Hlj8Fb8

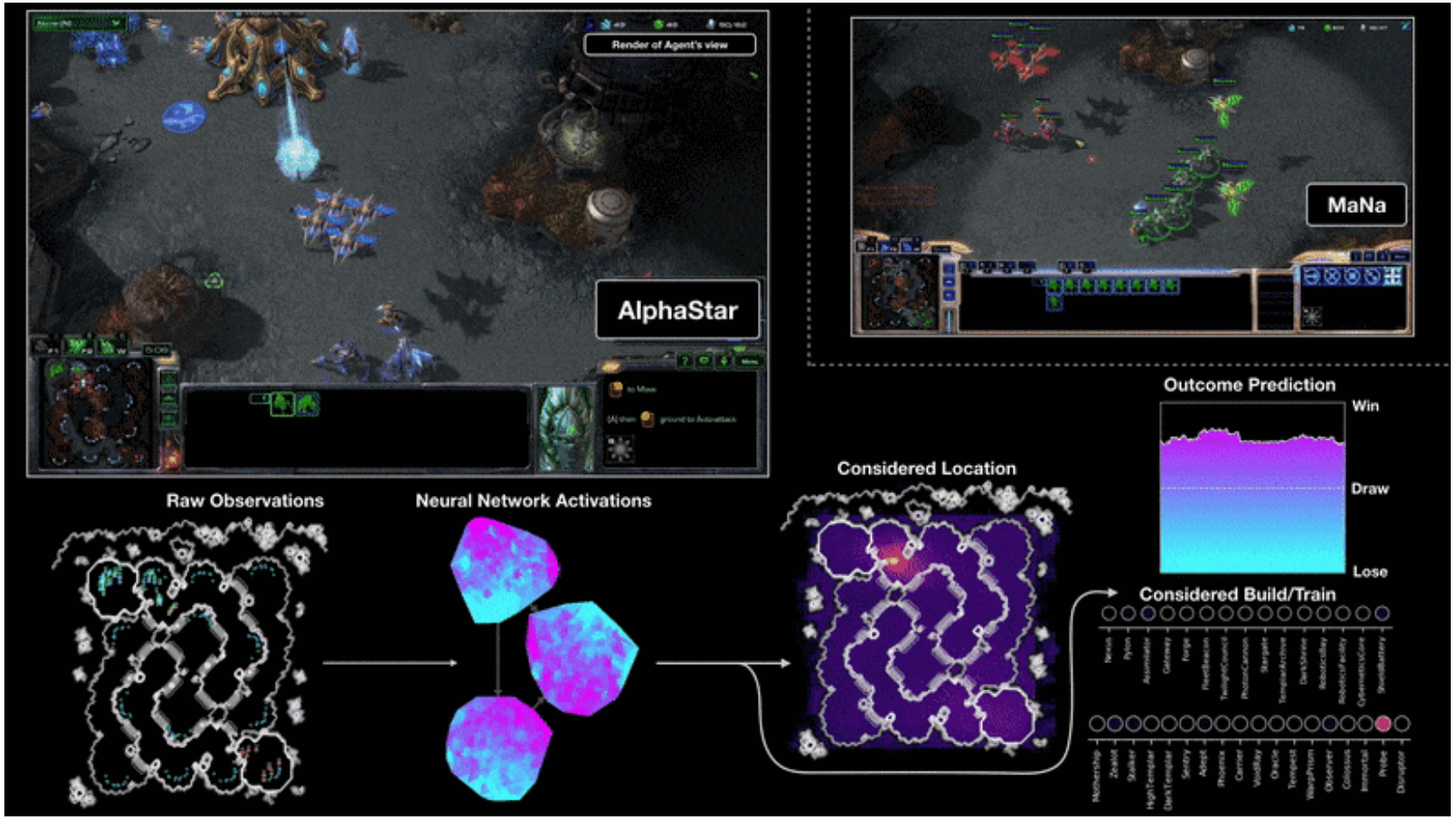
Why a class on deep learning?

Things of the future becoming real today.

- AI's not even requiring human expert data anymore.

Why a class on deep learning?

AI starcraft (https://deepmind.com/blog/article/alphastar-mastering-real-time-strategy-game-starcraft-ii)

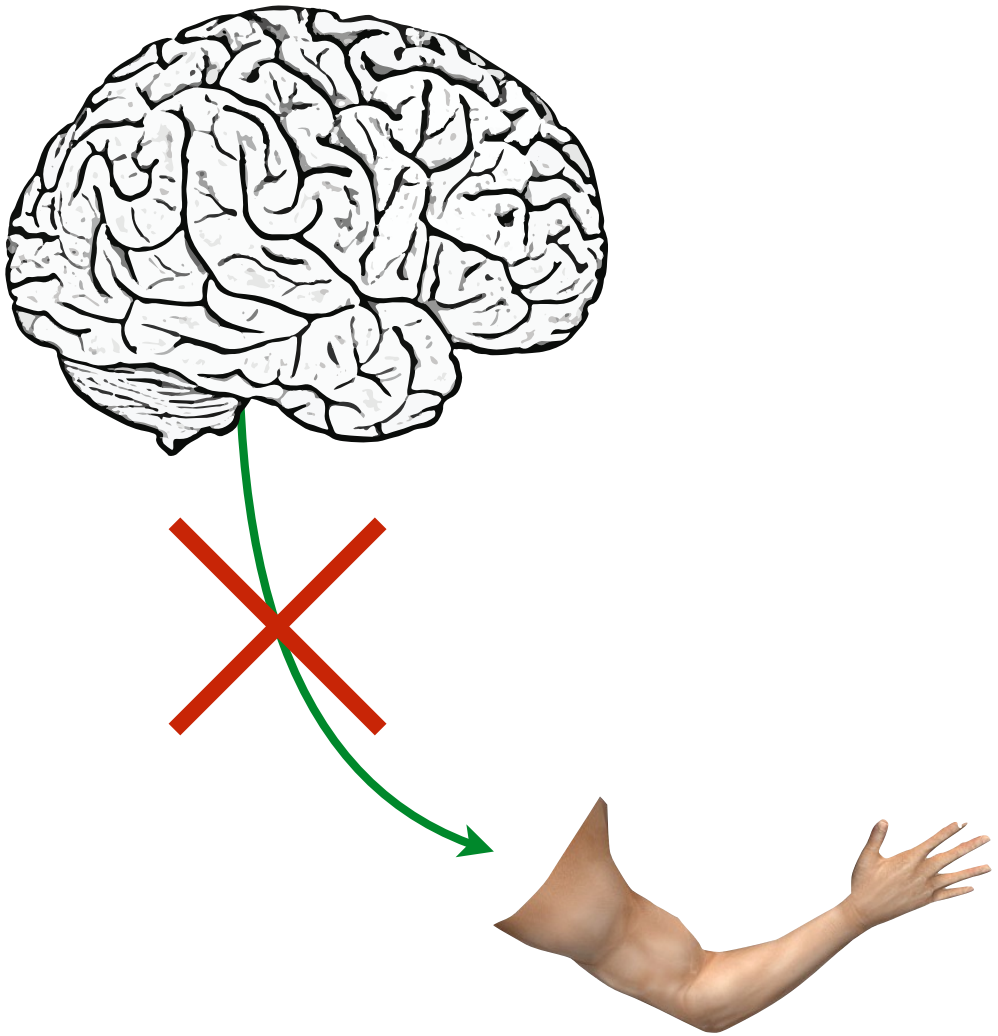


Why a class on deep learning?

Something closer to my area of expertise:

- Brain-machine interfaces.

Why a class on deep learning?



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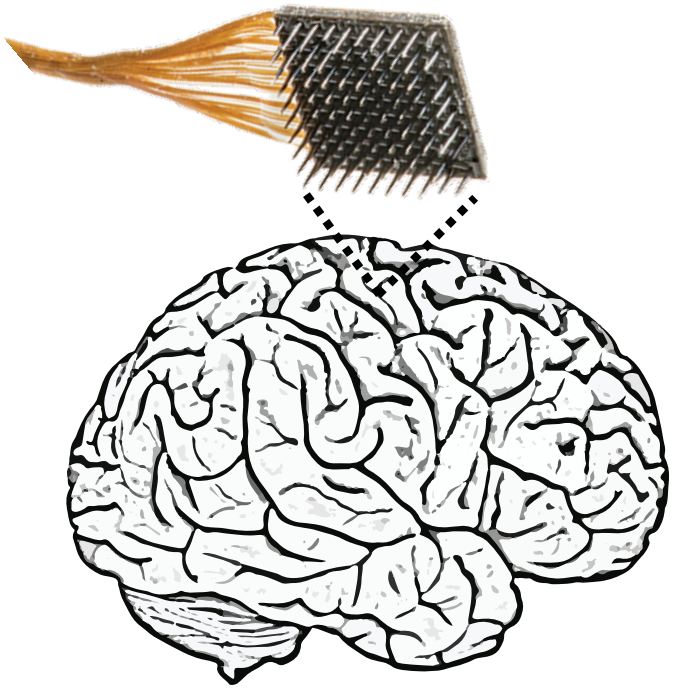

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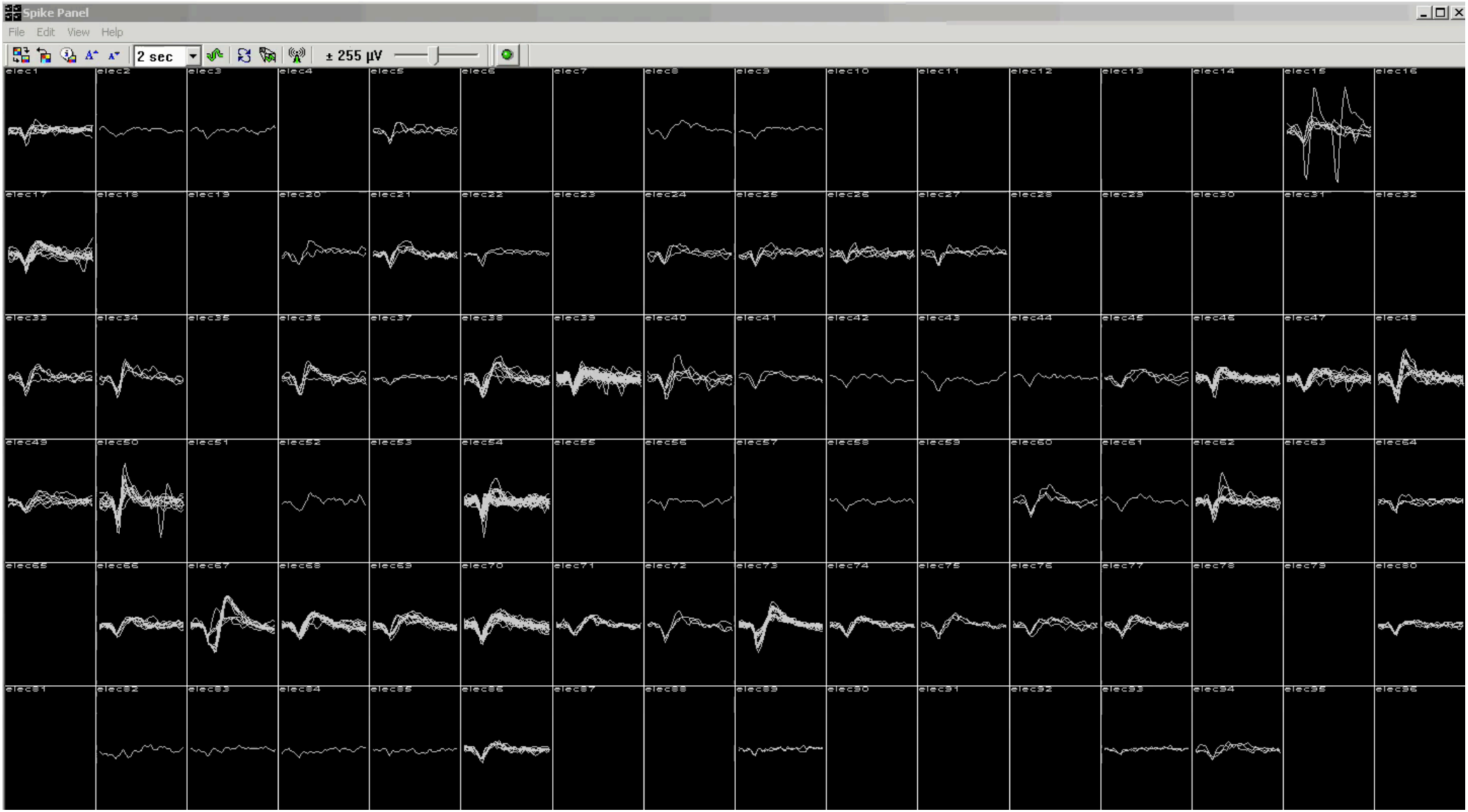

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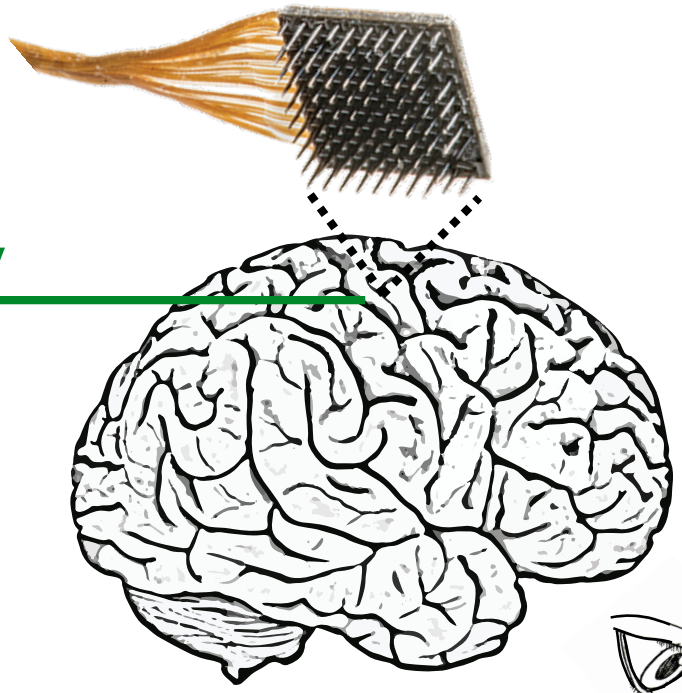
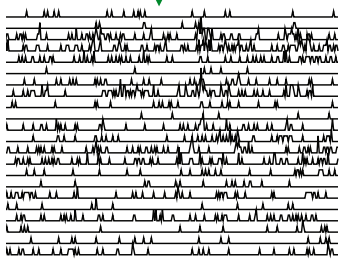
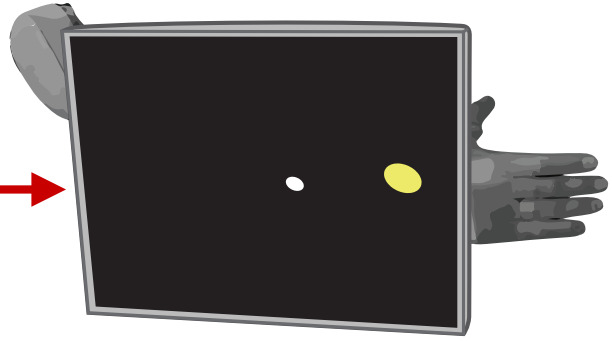


neural activity



Decoder

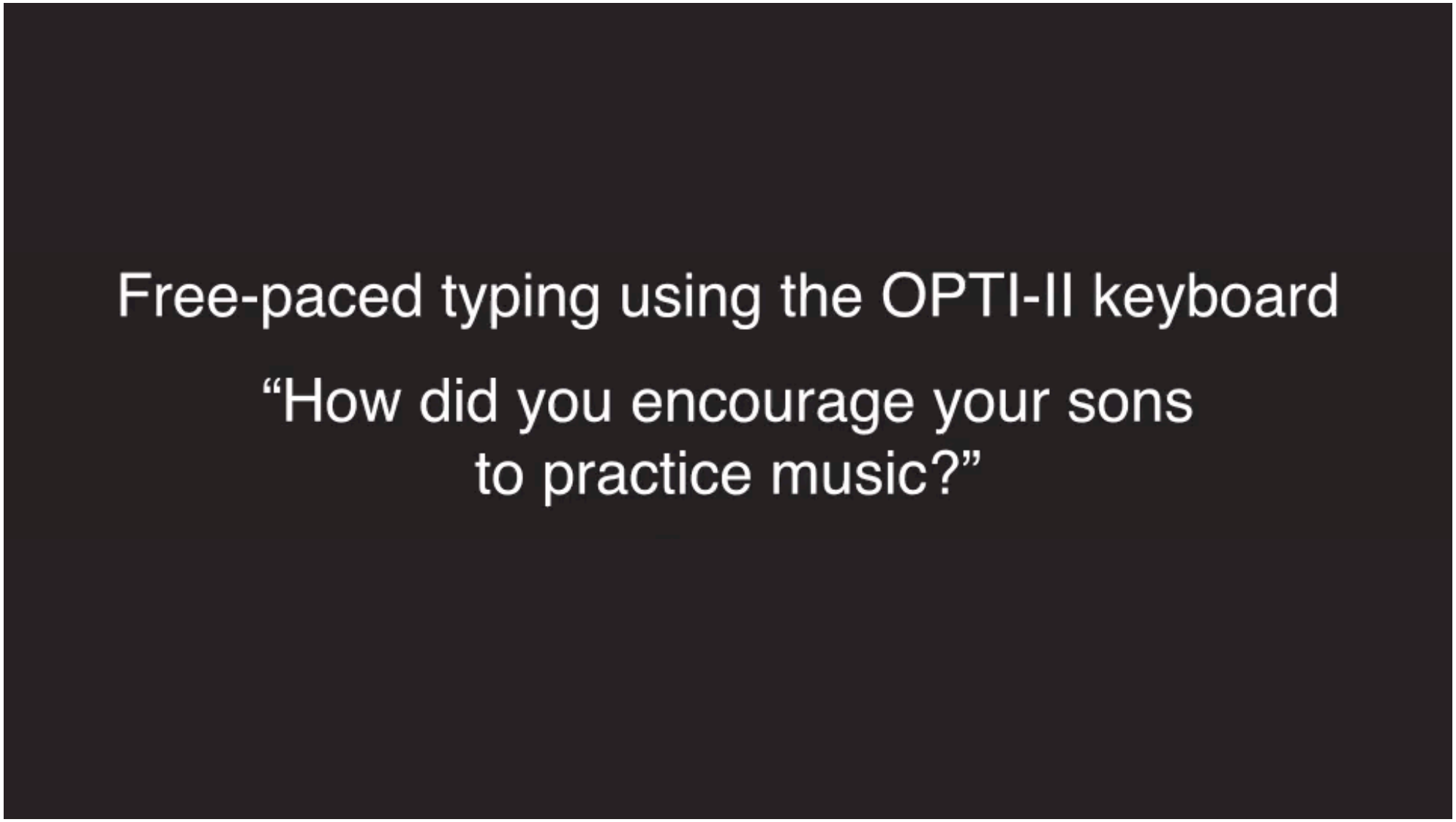
control signals



visual feedback

- Wessberg...Nicolelis, *Nature*, 2000
- Taylor...Schwartz, *Science*, 2002
- Serruya...Donoghue, *Nature*, 2002
- Carmena...Nicolelis, *PLoS Biology*, 2003
- Hochberg...Donoghue, *Nature*, 2006
- Velliste...Schwartz, *Nature*, 2008
- Kim...Black, *J Neural Eng*, 2008
- Ganguly & Carmena, *PLoS Bio*, 2009
- O'Doherty...Nicolelis, *Nature*, 2011
- Ethier...Miller, *Nature*, 2012
- Hochberg...Donoghue, *Nature*, 2012
- Collinger…Schwartz, *The Lancet*, 2013
- Wodlinger…Collinger, *J Neural Eng*, 2015
- Aflalo…Anderson, *Science*, 2015

Why a class on deep learning?



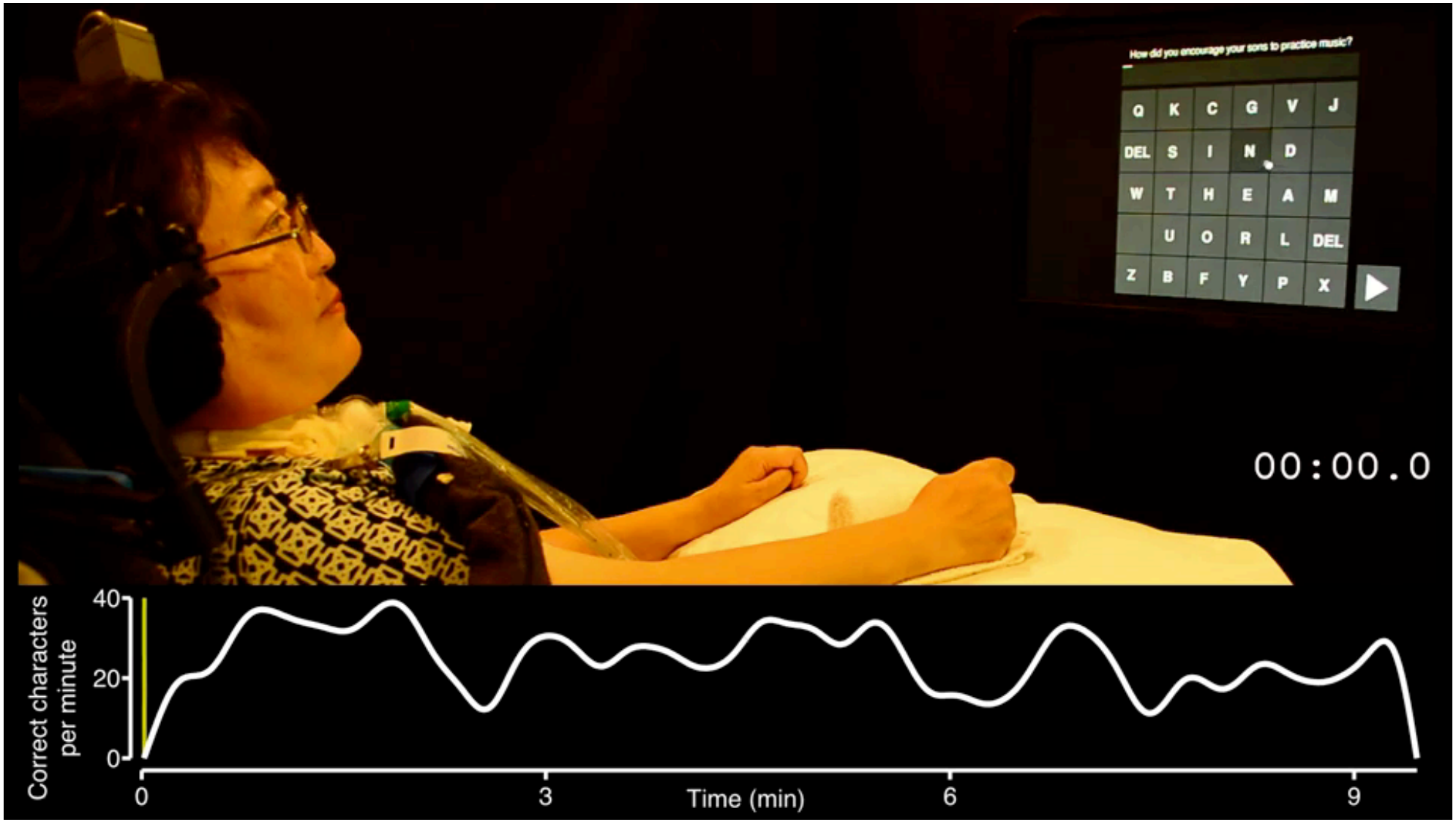
Algorithm: ReFIT-KF + HMM

(Kao, Nuyujukian*, et al., IEEE TBME 2016)*

Pandarinath, Nuyujukian*, et al., eLife 2017*

BrainGate2 Pilot Clinical Trial at Stanford University
Caution: Investigational Device.
Limited by Federal Law to Investigational Use.

Why a class on deep learning?



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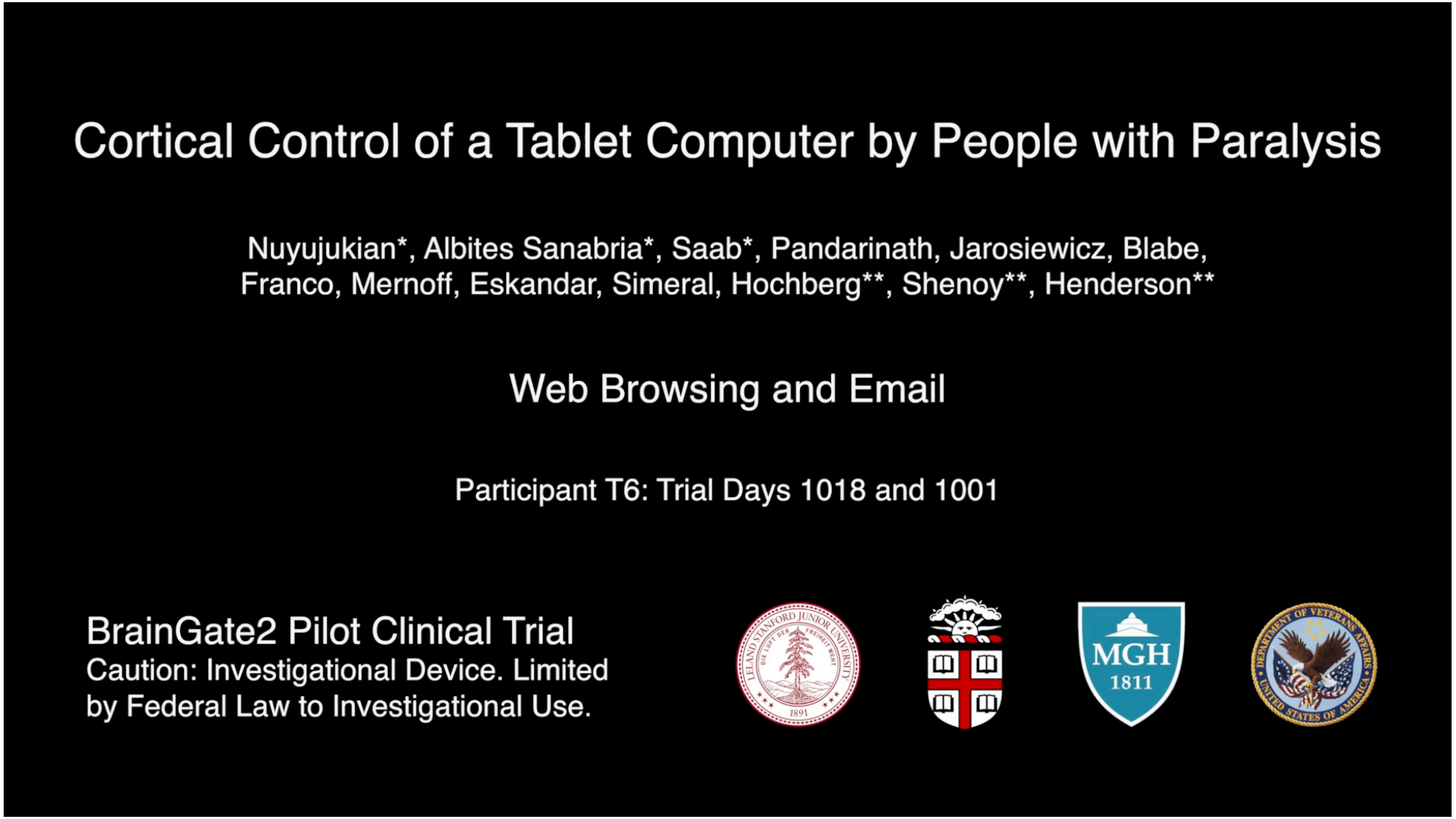

Nuyujukian et al., PLoS ONE, 2018

BrainGate2 Pilot Clinical Trial at Stanford University
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Why a class on deep learning?

Center-out-and-back task (8 targets)

EEG control, executed movements
December 1, 2022

(for internal and limited distribution, not public)

UCLA *Neural Engineering and Computation Lab (Kao Lab)*

Deep Learning is becoming ubiquitous

- We see that deep learning is enabling AI's to become an everyday part of life.
- It has resulted in key breakthroughs in many areas; in many different fields, many groups are looking towards deep learning to achieve better performance.
- Deep learning may be useful to research in your area / future work.

We will study deep learning in the context of computer vision

- Neural network research dates back to 1943 (McCullough and Pitts, a logical calculus of nervous activity) and 1958 (Rosenblatt's perceptron)

- Example video from 1989 of using a multi-layer perceptron (fully connected neural network) to do classification of digits.

- Fukushima's NeoCognitron (1982), Yann LeCun's "LeNet" (1998) which is the modern convolutional architecture, existed well before today's deep learning renaissance.

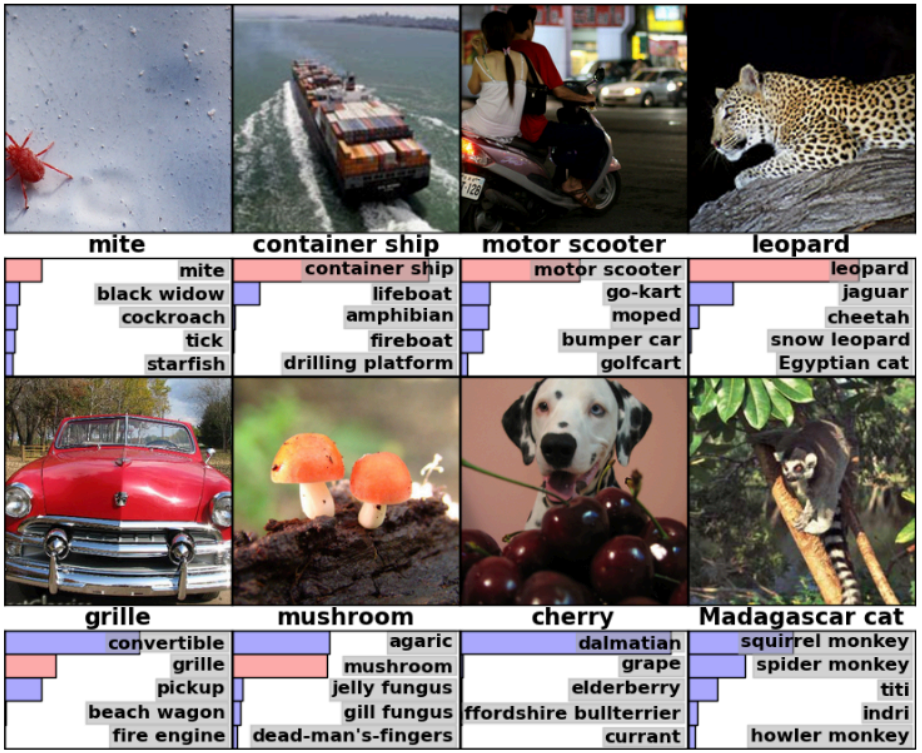
Tackling computer vision

- IMAGENET

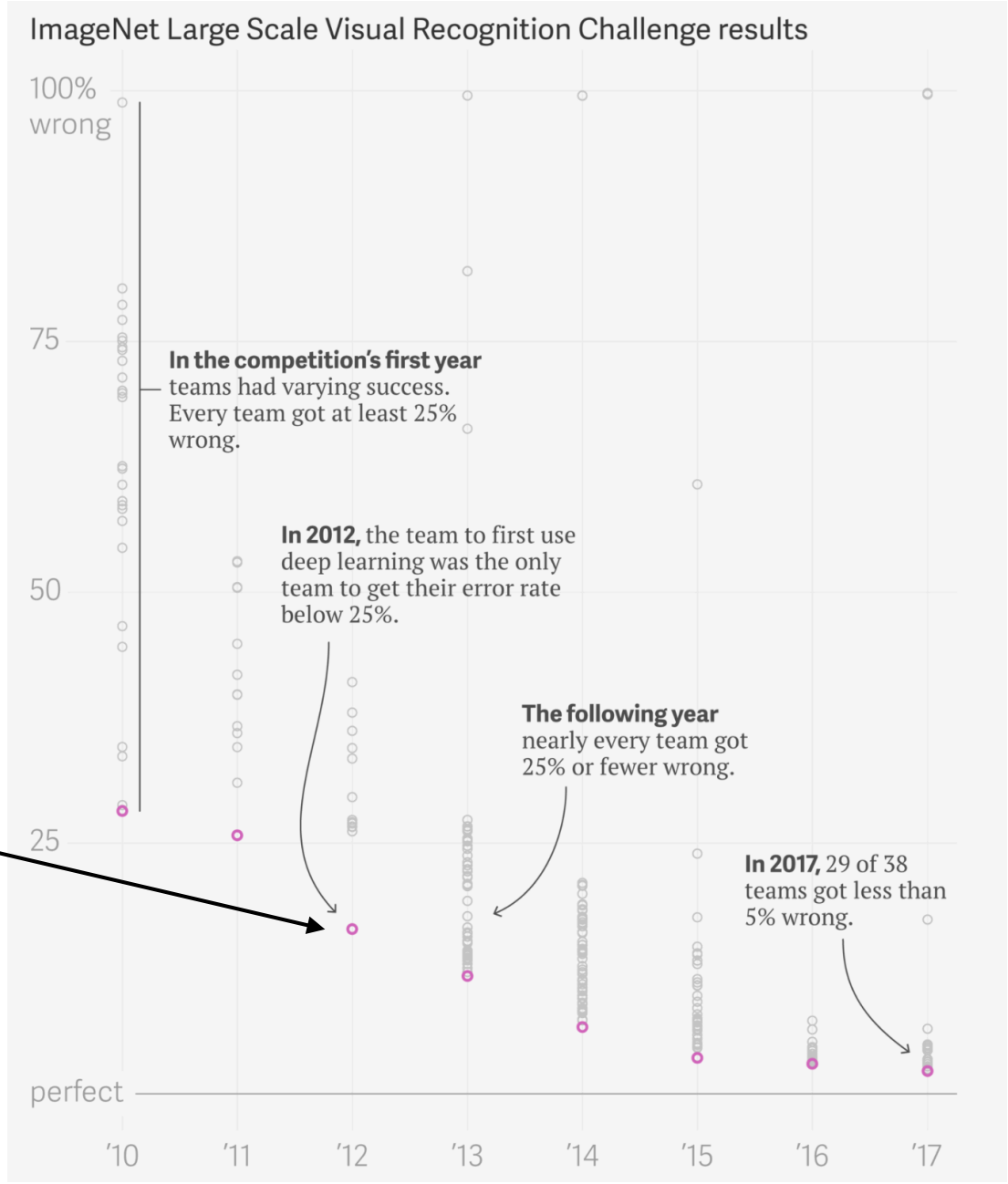
Overall

- Total number of non-empty synsets: 21841
- Total number of images: 14,197,122
- Number of images with bounding box annotations: 1,034,908

http://image-net.org/about-stats



A big splash



AlexNet

Data and technology

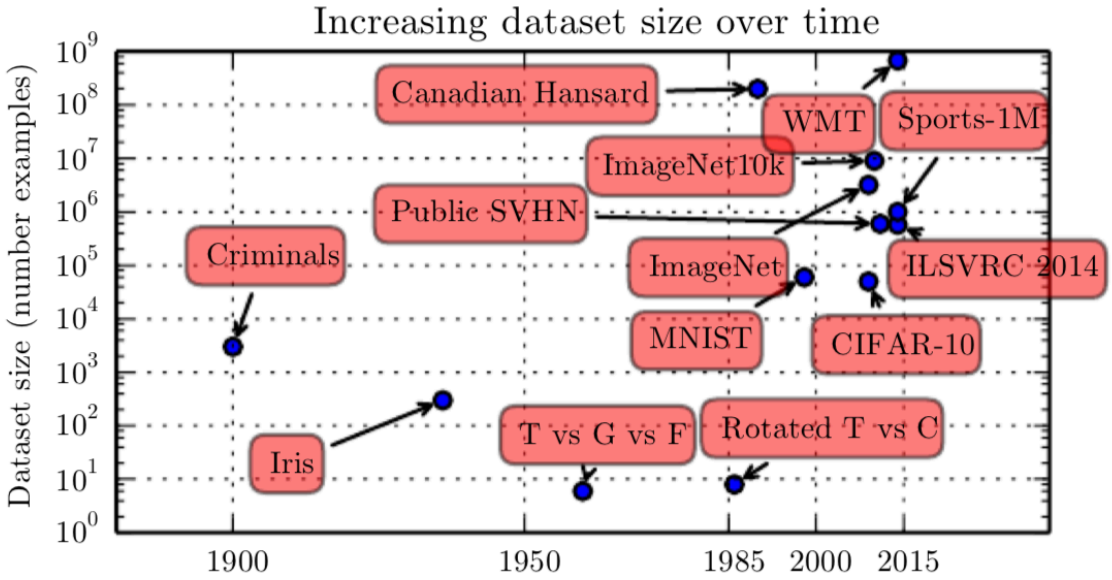
- Part of what has driven deep learning today is the amount of data we have and the computational power we have to process it.

- This includes larger models as computing infrastructure improves.

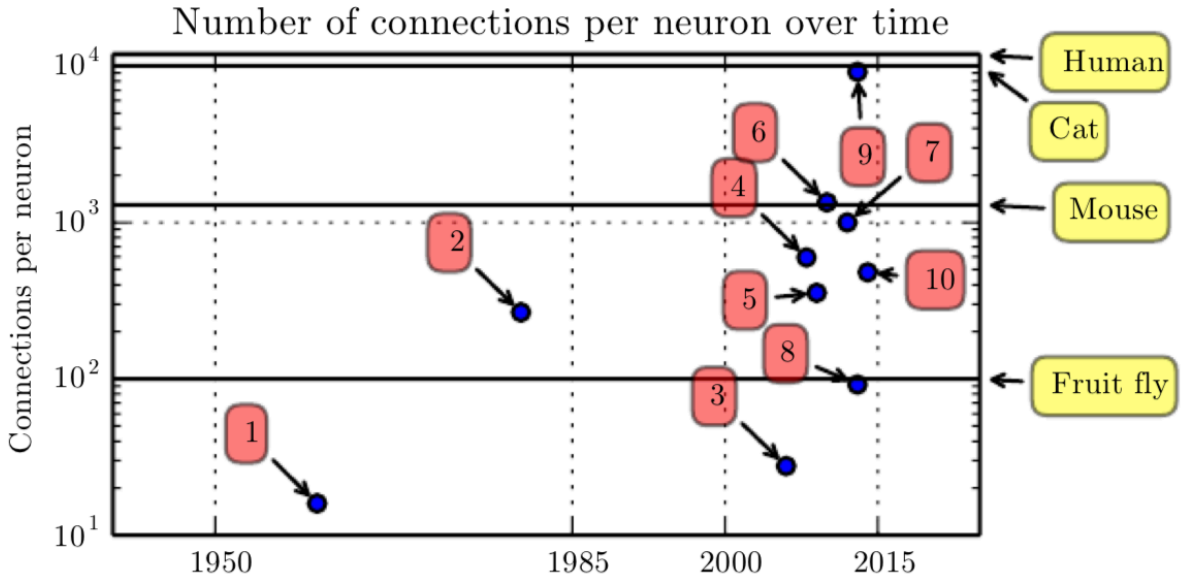
Fortunately, the amount of skill required [to get good performance from a deep learning algorithm] reduces as the amount of training data increases.
(Goodfellow, p. 18)

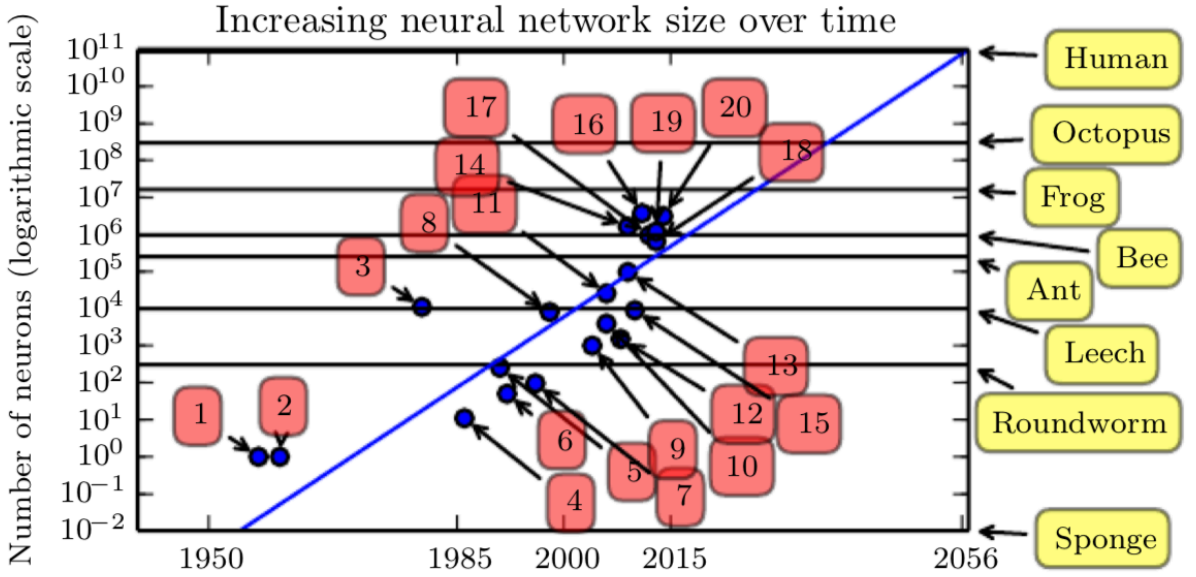
Larger dataset sizes

Fortunately, the amount of skill required [to get good performance from a deep learning algorithm] reduces as the amount of training data increases.
(Goodfellow, p. 18)



Larger networks



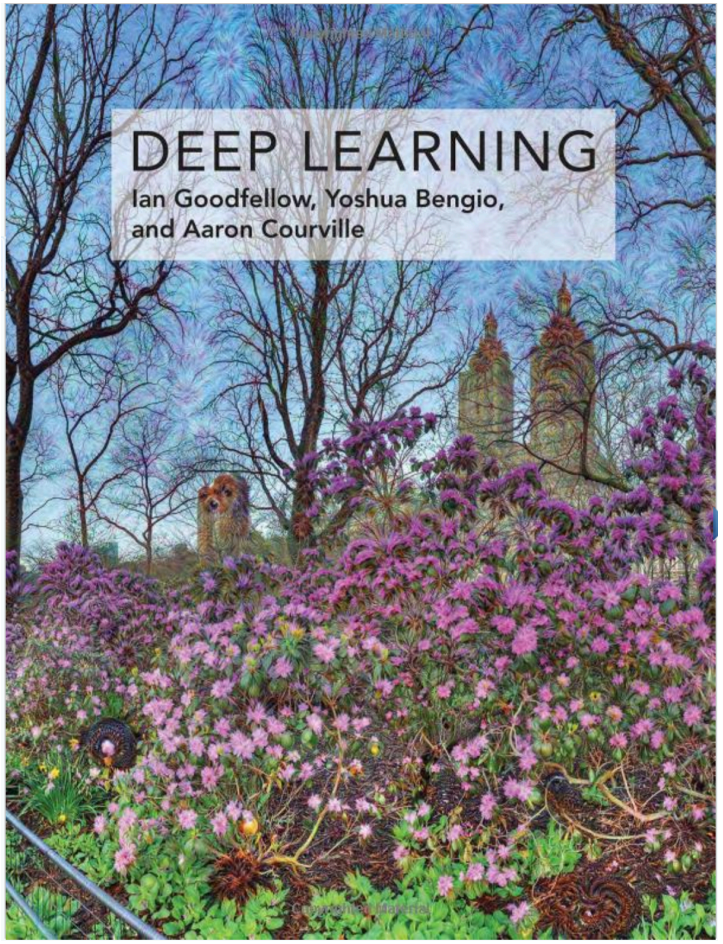


Breaks.

- I plan to give a 5 minute break in the middle of lecture.
- I will show a timer up here on the screen.

Rough class schedule

Date (2023)	Lecture	Content
09 Jan	1	Overview to deep learning
11 Jan	2	Machine learning refresher I
16 Jan	-	No class (MLK holiday)
		HW #1 released
18 Jan	3	Supervised Classification & Gradient descent principles
23 Jan	4	Fully connected neural networks
		HW #2 released
25 Jan	5	Backpropagation
30 Jan	6	Regularizations for training neural networks
		HW #3 released
01 Feb	7	Optimization for training neural networks
06 Feb	8	Convolutional Neural Networks I
		HW #4 released
08 Feb	9	Convolutional Neural Networks II
13 Feb	10	Convolutional Networks III
		HW #5 released
15 Feb	11	Recurrent Neural Networks
20 Feb	-	Veteran's day holiday
22 Feb	M	Midterm, in class
		Project released
27 Feb	12	Recurrent neural networks II
01 Mar	13	PyTorch and Tensorflow
06 Mar	14	Variational autoencoders
08 Mar	15	Generative adversarial networks
13 Mar	16	Survey of advanced topics in deep learning
15 Mar	17	Overview



http://www.deeplearningbook.org/

For MSOL students: we will organize a remote exam on Saturday, Feb 26.

Class logistics

- The class will be done entirely in Python and we will provide resources for setting up Python 3, as well as packages needed to be installed for each assignment.
- We will post a set of “formal notes” on Bruin Learn.
- Lecture notes “in class” are informal and not publicly posted. I ask that you please not publicly post them, though we will distribute them on Bruin Learn.

On discussion sections

- We have many discussion sections, but in our experience, the discussion sessions are not robustly attended, especially graduate sections.
- We will hold **some** of these discussion sections as live discussion sections based on a poll we send out to the class.
- We will take the remaining time we would have spent holding discussions and instead hold extra OH. We will post a full office hours schedule by end of week after completion of our polls.

Grading

You will be graded on three components:

1. **Homework (40%)**. Homework will contain both written components as well as `Python` components.
   - Assignments are due (i.e., submitted to Gradescope) by 11:59pm on the day they are due.
   - To accomodate for unexpected or unforeseen circumstances, we will give *three late days* to every student. These late days should only be used in extenuating circumstances. We will not grant additional late days beyond these.
   - You may use **at most** 2 late days on any given assignment.
   - Any assignment more than two days late receives a grade of **zero**.
2. **Midterm exam (30%)**, in class.
3. **Final project (30%)**, details to be released.

Grading (cont.)

The class is graded on an absolute scale. The scale may be relaxed but it will not be made more stringent.

Final score	Letter grade
93 – 100	A
90 – 93	A-
86 – 90	B+
83 – 86	B
80 – 83	B-
76 – 80	C+
73 – 76	C
70 – 73	C-
66 – 70	D+
63 – 66	D
60 – 63	D-
< 60	F

- We award A+ to the class's top students.
- I will not change your final grade unless I made a calculation error, in accordance with UCLA Academic Senate Regulation A-313 and strict rules governing the integrity of the grading process.

Grading (cont.)

In addition to these grading scales, we will also award bonuses on top of your final grade as follows.

Bonuses (2 points)

- (Feedback) You earn a bonus of +0.5% for filling out the class evaluation at the end of class.
- (Piazza) You receive a bonus of at most +1.5% for participating on Piazza. While your answers to others will be anonymous, they will be known to the instructors, who will determine an appropriate number of points for instructor-approved student replies. Your bonus will be based on your participation on Piazza, which will be curved.
- (Piazza, cont.) Please do not conspire to post and answer questions for extra credit. We will be able to detect this. We do not want the Piazza forums to be spammed; this makes it more difficult for all students to find helpful questions.

Some notes on the class

- Piazza should be the primary means of asking and getting questions answered in the class. We would like Piazza to be student-driven. TAs will answer any questions that other students are unable to answer.
- If you have other course-related questions that are not appropriate to Piazza, please e-mail the entire teaching staff (rather than any one of us individually). If you have any personal matters to discuss, please e-mail Prof. Kao directly.

Some notes on the class

- Planned 5 HW assignments.
- Assignments will contain both written components as well as coding components.
- Code in the HW will walk you through Jupyter Notebooks, and usually it'll be clear if you're doing things correctly or not.
    - Note, we will release solutions for written HW ~~exams~~ qs, but we will **not** release solution code for HW's.
    - These assignments are planned to be used in future years.
- HW will be submitted via Gradescope; they are due at 11:59PM Pacific Time on the stated due date.
- Any late assignment will receive a grade of **zero**.
- We understand that life happens. We are giving **three late days to every student**, with the intent that these are to be used only in extenuating circumstances. You may use at most 2 late days on any given assignment.

Some notes on the class

- C147 and C247 students will be graded on different scales.
    - C147 students will also have one question of one homework be optional.
    - The classes are otherwise the same.
- All HWs are to be submitted to Gradescope.
- In general, I will post the non-annotated versions of the slide prior to lecture, so you can take notes if you want. I will always post the annotated version of the slides as well as the lecture videos (unless there are technical failures).
- We will list readings in the textbook at the start of each different lecture topic.
- This class has 8 total TAs. These 8 TAs will service the whole class, and you are welcome to attend any of their office hours. Note that by policy, TA Pan Lu is a TA for the MS online version of the class will prioritize questions from MS Online students first.

Some notes on the class

- This class will focus on implementation of neural networks and on algorithms to train them.
- It will **not** cover theory of deep learning (CS 269).
- It will **not** be a theoretical class in general.
    - We aim to be rigorous in our use of notation and math.
    - But we won't be doing proofs.
    - We're more focused on application and equipping you with tools that may be helpful in your research or future industry positions.
- This is not a statement on the importance of theory. It merely reflects the priorities for this class alone.

Academic integrity

UCLA embraces the core values of integrity, excellence, accountability, respect, and service through the True Bruin program

`http://www.truebruin.ucla.edu`

I take academic integrity very seriously; students caught cheating or violating these principles will face disciplinary action. Please refer to the UCLA student conduct code:

`https://deanofstudents.ucla.edu/student-conduct-code`

In this class, unacceptable behavior includes plagiarizing the work of others, plagiarizing code, and copying another person's exam. In accordance with UCLA policy, any instance of suspected academic dishonesty will be immediately reported to the Dean of Students Office and zero credit will be given for any work determined to be dishonest.

What I assume you know

Pre-requisites

This class requires a solid understanding in probability (131A) and linear algebra (133A or 205A), as well as prior exposure to machine learning (M146). This class will be very difficult (but not impossible) if you do not have prior machine learning background. We will spend two lectures doing machine learning review to ensure we are familiar with concepts we will expand upon in machine learning.

It also requires coding experience. The class will be taught entirely in `Python`. If you have only had exposure to `MATLAB`, there will be ramp up time to familiarize yourself with `Python`. You should factor this into your course load.

Pre-requisite topics I will **assume** you know.

- Probability: independence, conditional probability, Bayes rule, multivariate Gaussian distribution, marginalization, expectation, variance
- Linear algebra: basic matrix operations, span, rank, range and null space, eigenvalue decomposition, singular value decomposition, pseudoinverse

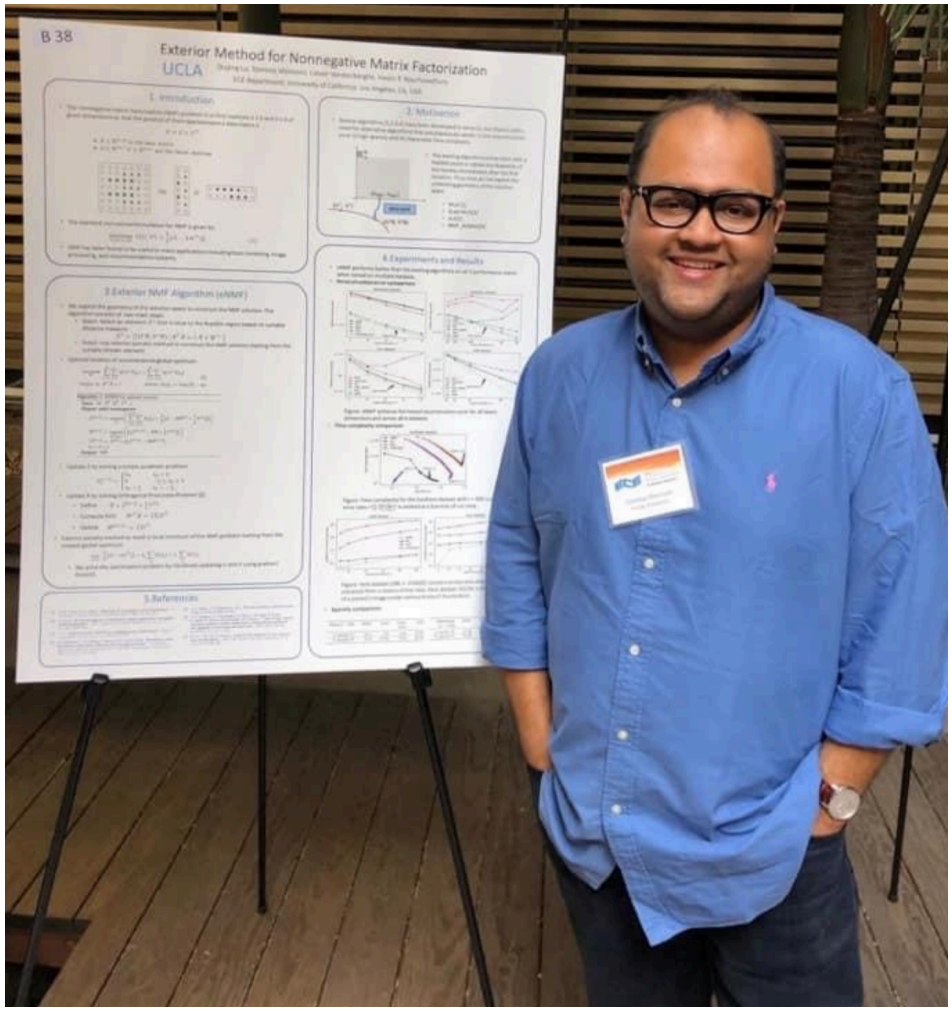
A few last notes about this class

- Common student feedback is that, even if they were familiar with `MATLAB`, it was still time-consuming to transition to `Python`. Please consider this seriously as you plan your schedule for assignments. `Python` is the standard language for machine learning research today, and the best deep learning packages are specifically designed for `Python`.
- We know, and consistently receive feedback, that this class is a lot of work and is time-consuming. I want to state this up front so you can plan accordingly. We will aim to keep the stated HW schedule, following the assignments and schedule used last year.

About me

- This is my sixth time teaching this class at UCLA.
- Though this class focuses on deep learning for engineering purposes, I'm interested in deep learning because of its ties to the brain.
    - I am primarily a computational neuroscientist and neural engineer.
    - My work includes brain-machine interfaces and applying machine learning to understand how neurons in the brain communicate.
    - We use deep learning as a model to understand the brain and build brain-machine interfaces.

Tonmoy Monsoor



- Graduate student researcher at Big data and Complex Networks Group
- Fourth year Ph.D. student advised by Professor Vwani Roychowdhury
- Research interests
  - Reinforcement learning
  - Distributed optimization
  - Pattern extraction in dynamic networks
- Favorite classes at UCLA
  - Convex optimization, ECE 236B
  - Neural signal processing, ECE 243A

Pan Lu

- Fourth-year Ph.D. candidate in Computer Science advised by Prof. Song-Chun Zhu
- Research Interests
  - Large language models
  - Mathematical reasoning
  - Trustworthy NLP models
  - Multimodal learning in vision and language
- Fourth time as a TA (second time for this course)

- I'm here to help you!

Rakshith Ravindra Gore

- I am a second year MS student with the department of ECE. My interests include Machine Learning, Wireless Comm. Systems, and Food :).

- I enjoy teaching, and I am looking forward to interacting, discussing and learning from all of you. Please don't hesitate to reach out and ask questions. Let us together make this ECE 102 journey a memorable one. Once again welcome to the course and all the very best!!

- Favorite Classes at UCLA:
  - Neural Signal Processing, ECE 243A
  - Wireless System Design, ECE 233
  - Neural Networks and Deep Learning, ECE 247

Kalaivani Kamalakannan

- I am Kalai, a second-year graduate student with the ECE Department.
- My research interest includes wireless communication, signal processing, and information theory augmented with machine learning. I am also passionate about music, nature, and food.
- I am glad to be able to contribute to your learning experience. I look forward to our vibrant and hopefully enriching discussions and interactions. I can't wait to meet you all in person. Do feel free to get in touch! Welcome to EC 102! We hope to make this an amazing learning experience. I hope you have a great Fall 2022

Sindhu Narasarama Rao

Hello there !

My name is Sindhu (she/her) and I'm a second year Master's student in Electrical and Computer Engineering.

Major: Machine learning, deep learning

I'm currently working on machine learning model drift detection.

I enjoy teaching and this is my 3rd quarter as a TA at UCLA.

Feel free to reach out if you have any questions.

Sindhu Narasarama Rao

Shivam Patel

Naveen Vikraman

I am Naveen Vikraman, Second Year MS student in ECE in the Signals and Systems Track. I have prior experience as ML Engineer in BioMedical field and this is my 5th time TAing. Feel free to ask for help and I believe it is going to be a good learning process for me also. I can also help with Anime recommendations :)

Mahmoud (Ramin) Essalat

Hi! I'm Mahmoud (Ramin) Essalat. You can call me either way but I usually go by Ramin. I am a PhD student and I hope to graduate sometime mid this year! My area of research includes deep learning on time-series data and I have worked particularly with LSTM and Transformer models. I am proficient in both Matlab and Python and if you need to transition from Matlab to Python I can help you! For fun, I like to cook (italian is my fav!) and to play chess and poker!

Questions?

Lecture 2: Machine learning refresher

This lecture gives a refresher on key concepts from machine learning.

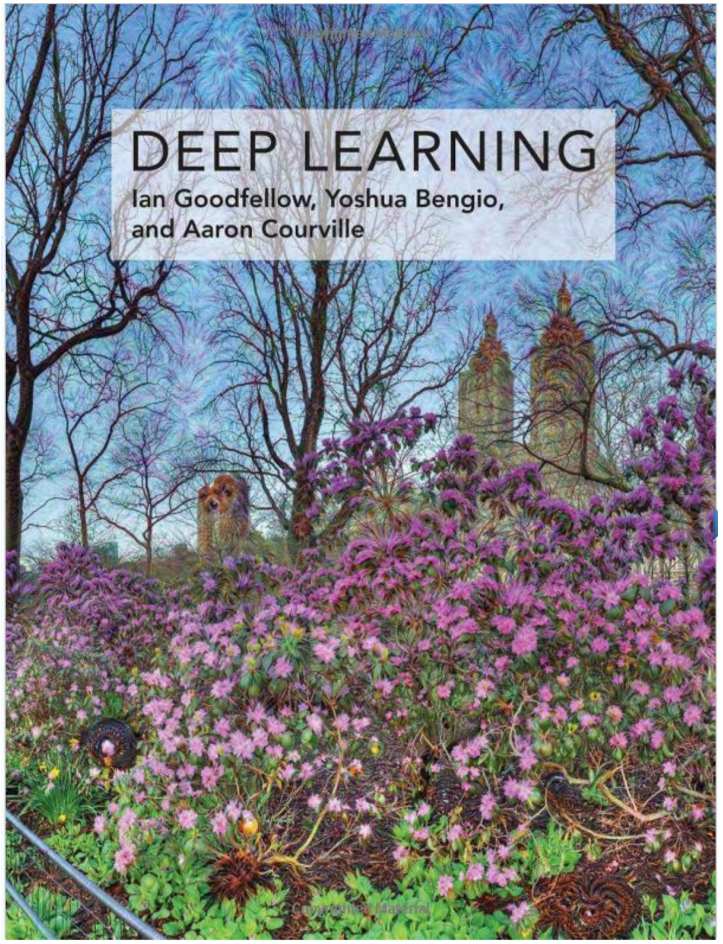
- Introduction to concepts in machine learning
- Cost functions
- Example: linear and polynomial regression
- Model complexity and overfitting
- Training set, validation set, test set
- Dealing with probabilistic cost functions and models
- Example: maximum-likelihood classification

Lecture 2: Basics of machine learning

Reading:

Deep Learning, chapter 5 (up to and including section 5.5).

To refresh your linear algebra and probability, look at chapters 2 and 3 respectively.



Focus of this class:

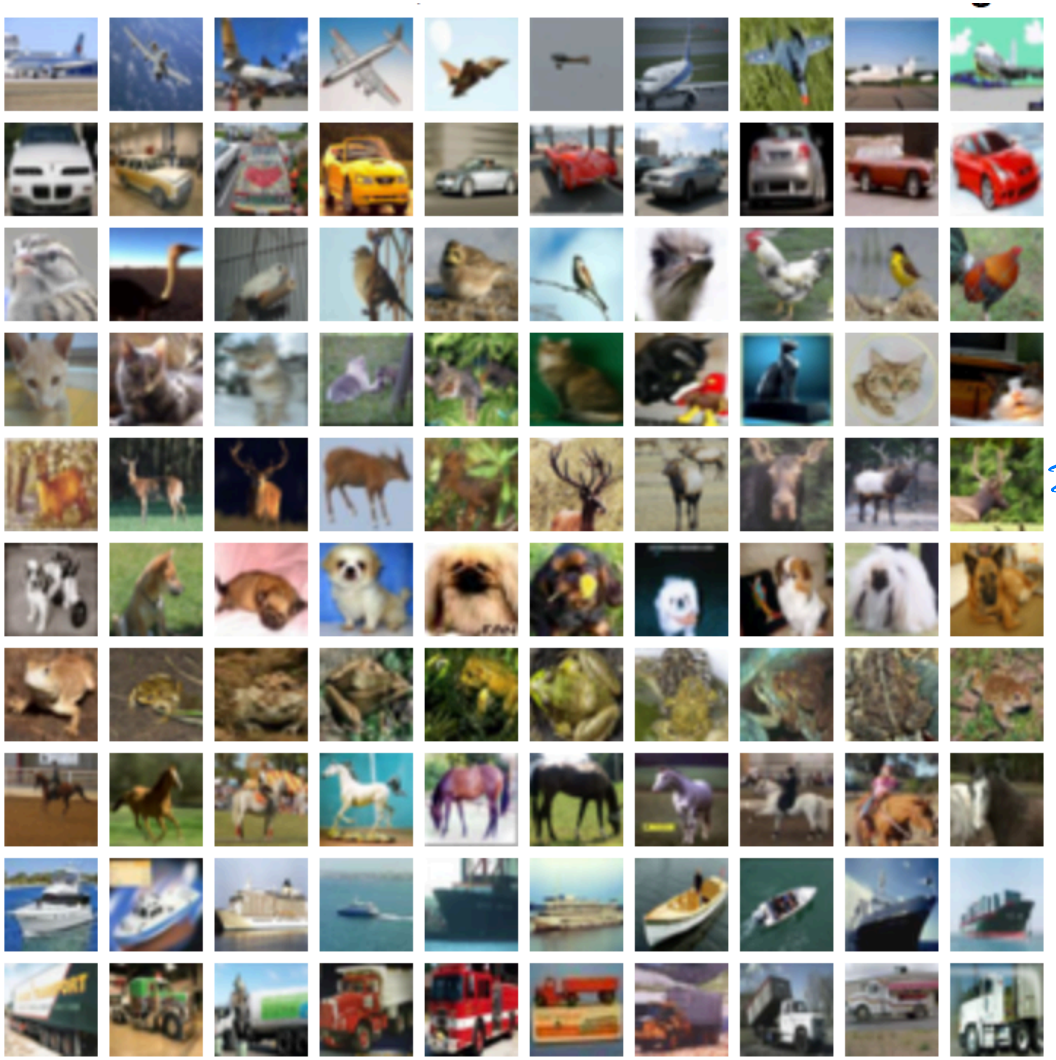
- This class will focus on **supervised** learning problems.
- This class will also focus on **classification** largely (e.g., when considering convolutional neural networks) as well as some instances of **regression** (e.g., when considering recurrent neural networks)

Supervised Classification

CIFAR-10

10 classes

airplane
automobile
bird
cat
deer
dog
frog
horse
ship
truck



$\vec{x}$

$32 \times 32 \times 3$

$\vec{x} \in \mathbb{R}^{3072}$

classification

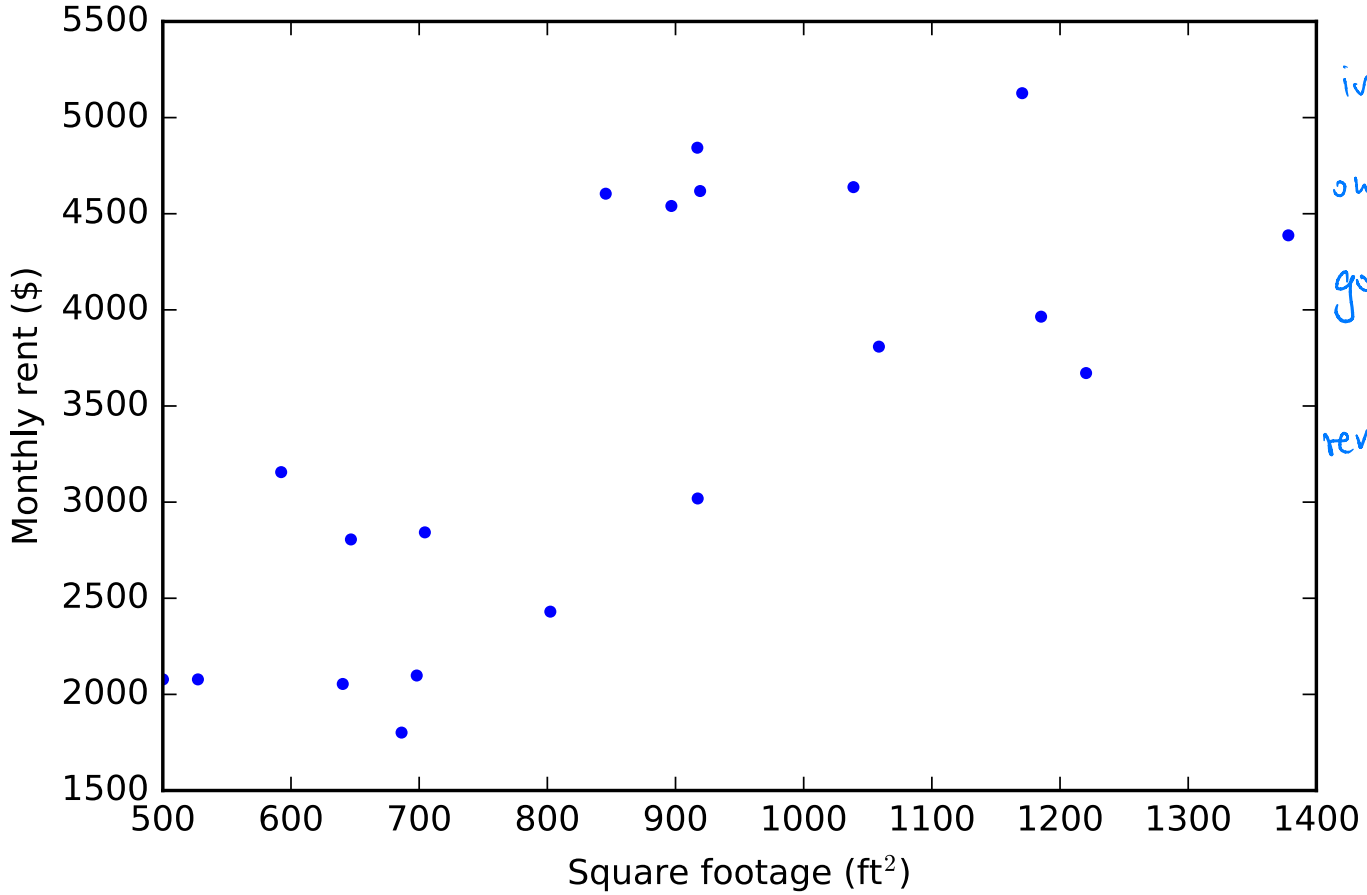
class $\leftarrow f(\vec{x})$

what class the image belongs to

CIFAR-10 dataset, https://www.cs.toronto.edu/~kriz/cifar.html

An example of supervised learning

Let's say we want to rent a home in Westwood, and we wanted to know if we were getting a good deal. **(Warning: this data is synthetic! Scrape the real data if you're curious.)**



input : sq. ft.

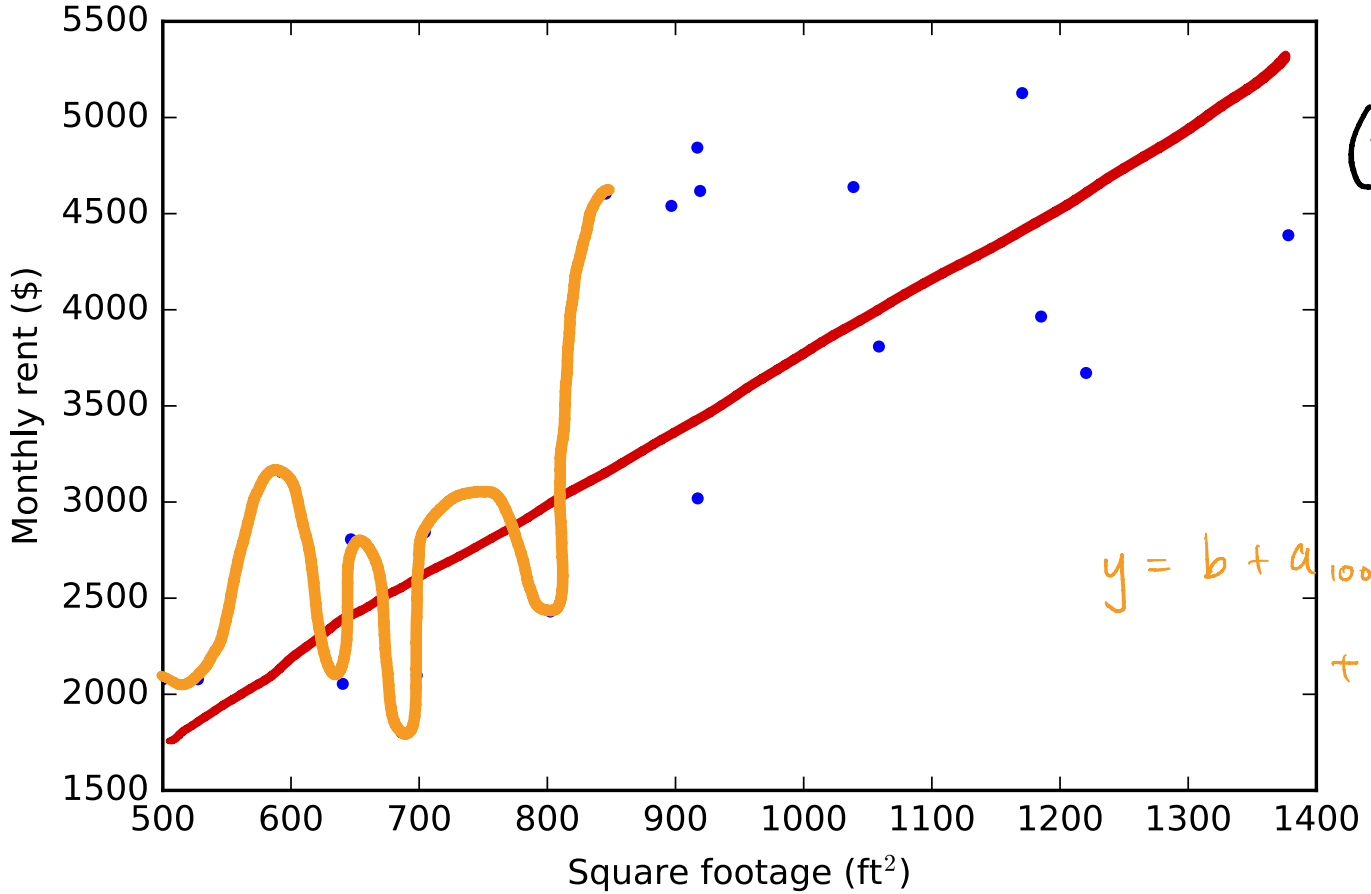
output : rent

goal : learn f

rent $\leftarrow f$(sq. ft.)

An example of supervised learning

$f(x) = ax + b$



y

x

parameters

$y = ax + b$

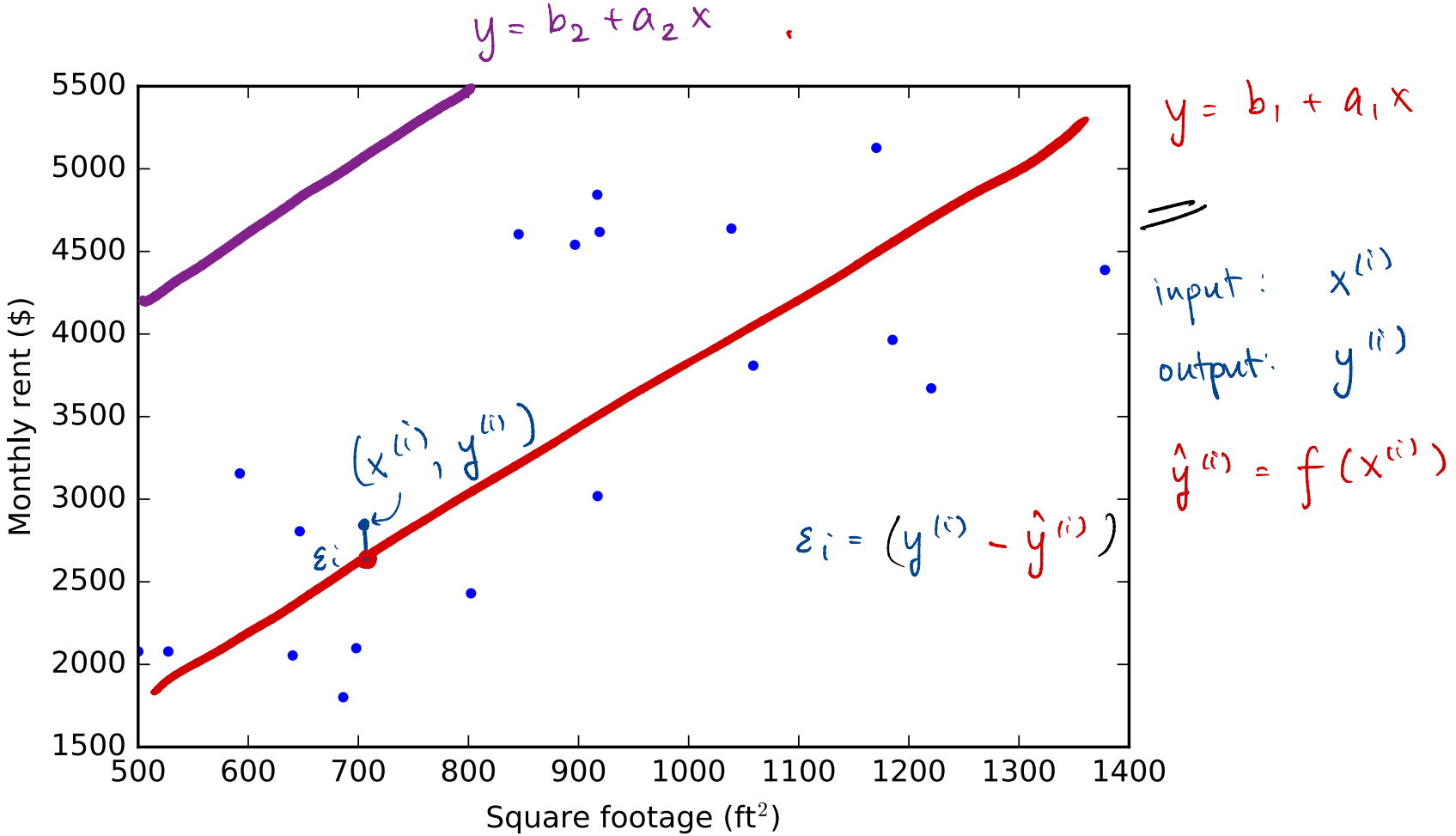
data

$y = b + a_{100}x^{100} + a_{99}x^{99} + \ldots + a_1 x$

How should we model this data?

- Inputs, **x**? Outputs, **y**?
- What model should we use?
- How do we assess how good our model is?

An example of supervised learning



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