Introduction to Neural Networks and Deep Learning

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University of Colorado Boulder
Spring 2025

https://dannagurari.colorado.edu/course/neural-networks-and-deep-learning-spring-2025/

Today’s Topics

- Applications
- History of neural networks and deep learning
- How does a machine learn?
- Course logistics

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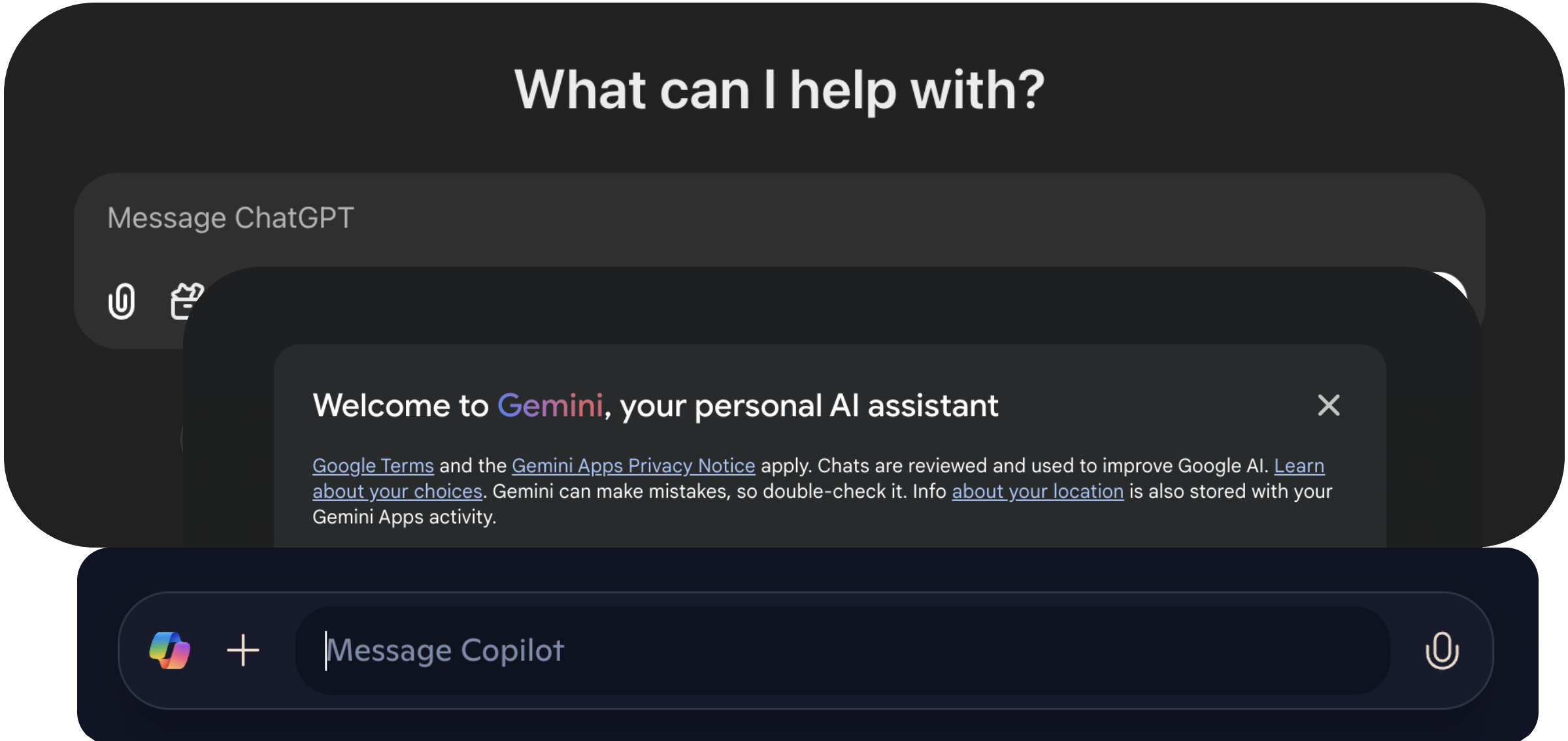
Key Motivation

Systems that support humans by either
improving upon existing human capabilities
or ***providing new capabilities***

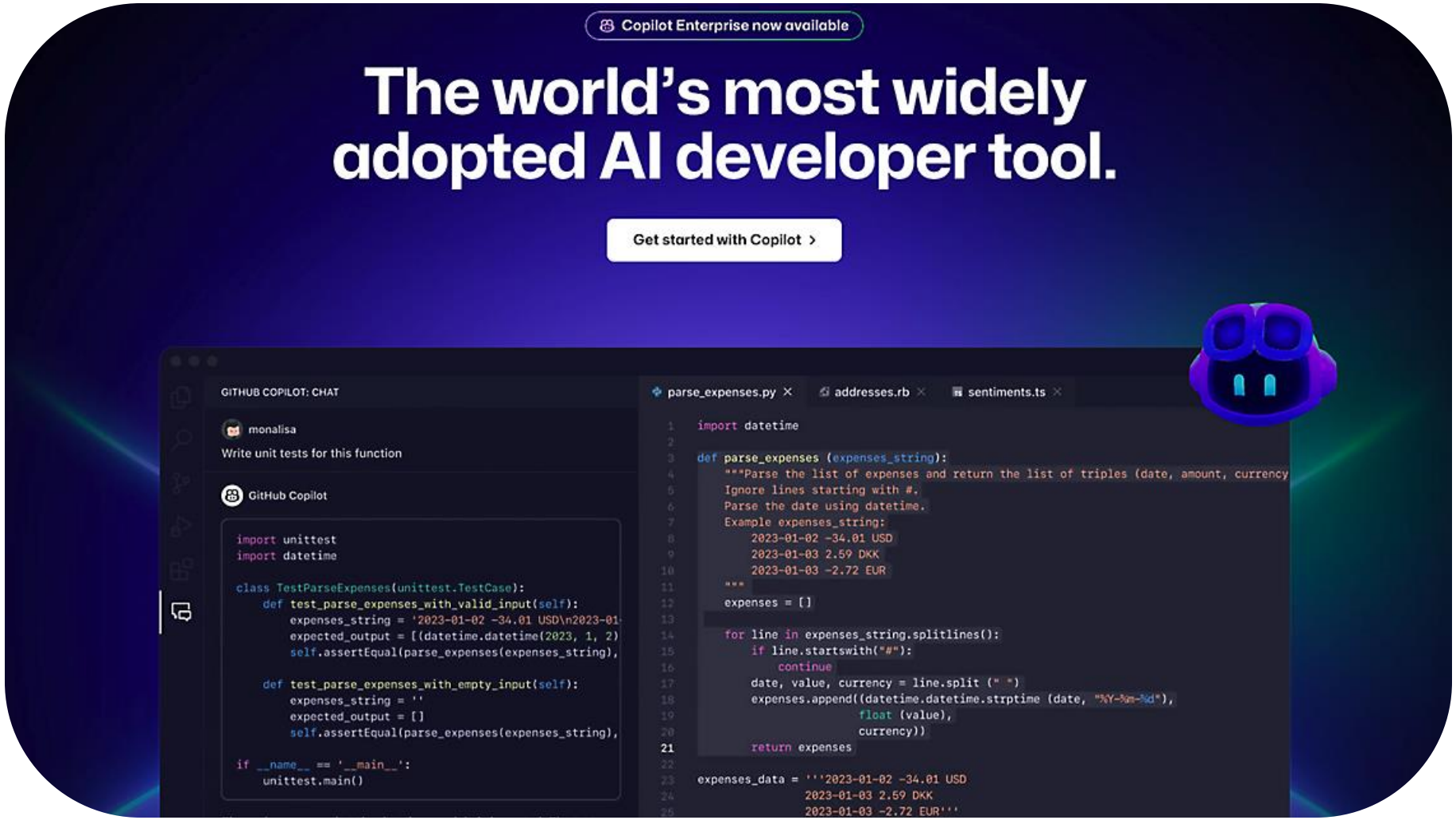
AI Companions; e.g.,



Speech-Based Text Messaging

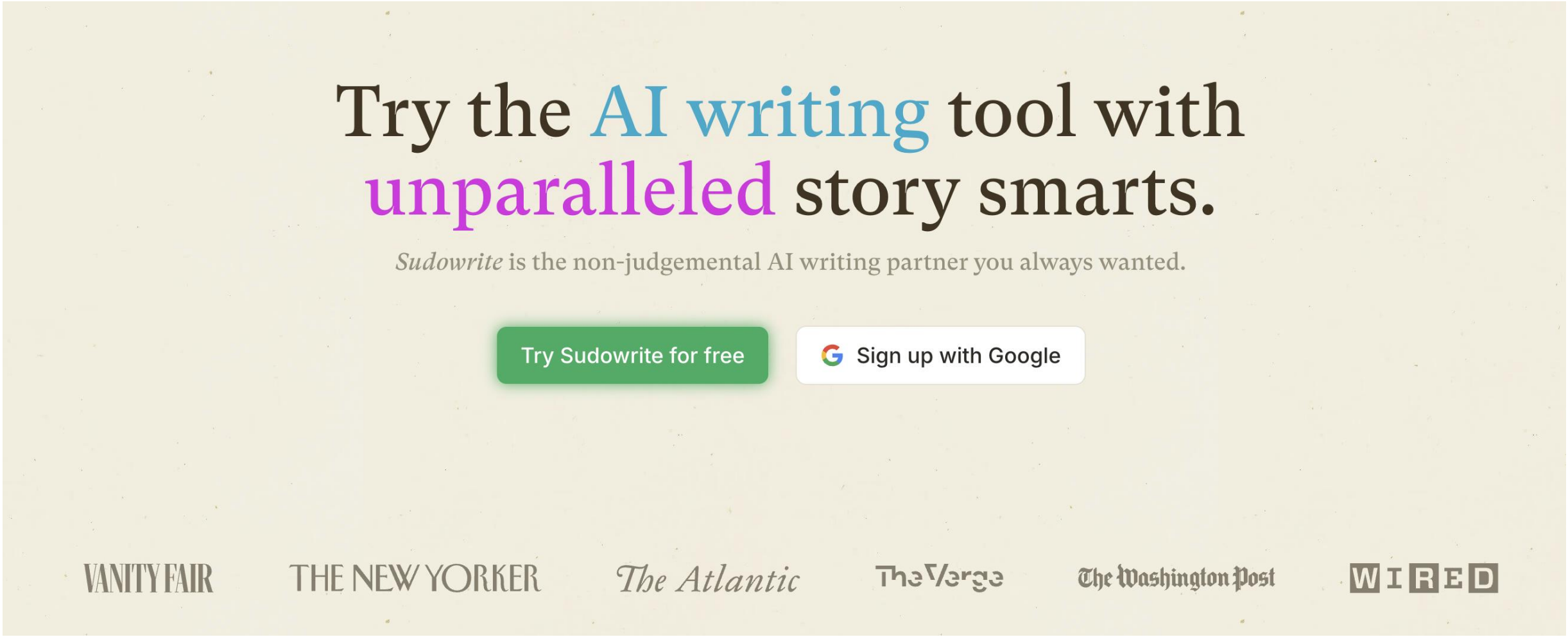
https://play.google.com/store/apps/details?id=com.speechtotext.speak.voice.chat.write.converter.notes

Coding Assistants; e.g.,



https://azure.microsoft.com/en-us/products/github/copilot

Writing Assistants; e.g.,

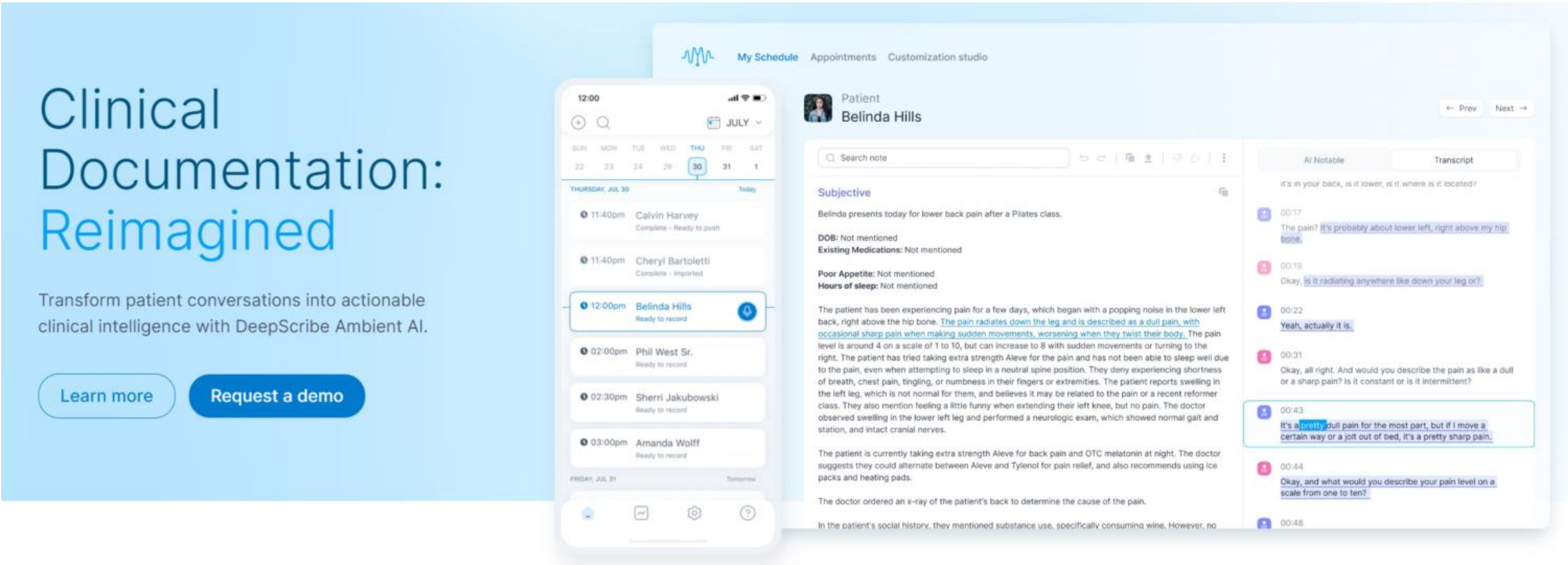


https://www.sudowrite.com/

Meeting Summaries; e.g., Zoom

https://news.zoom.us/zoom-iq-meeting-summary-chat-compose-free-trial/

Meeting Summaries; e.g., Doctor's Visits



https://www.deepscribe.ai/

Self-Driving Vehicles; e.g.,

Waymo Self-Driving Taxi

https://www.nbcnews.com/tech/innovation/self-driving-car-sf-taxi-waymo-cruise-california-vote-cpuc-rcna97540

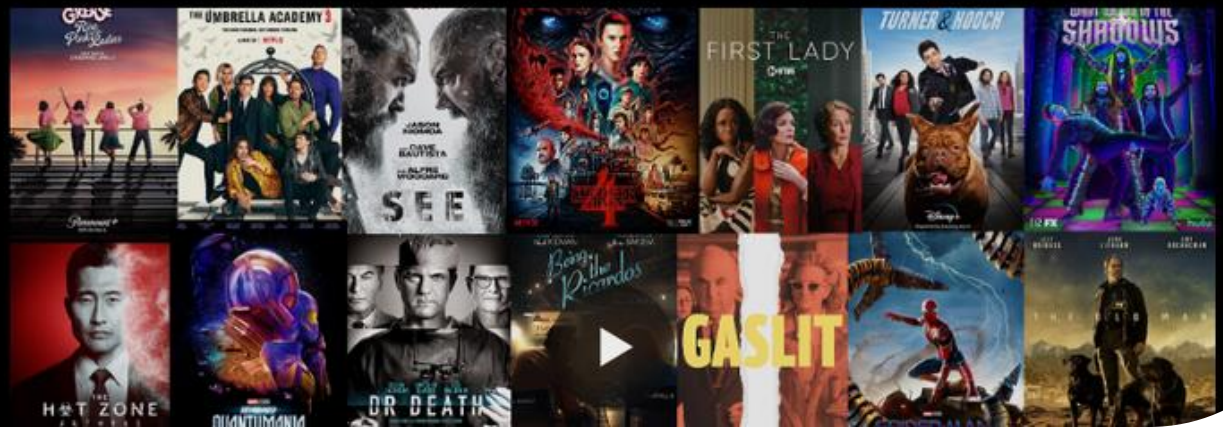
Appearance Editor; e.g., for Movies

VANITY AI

Book a Demo

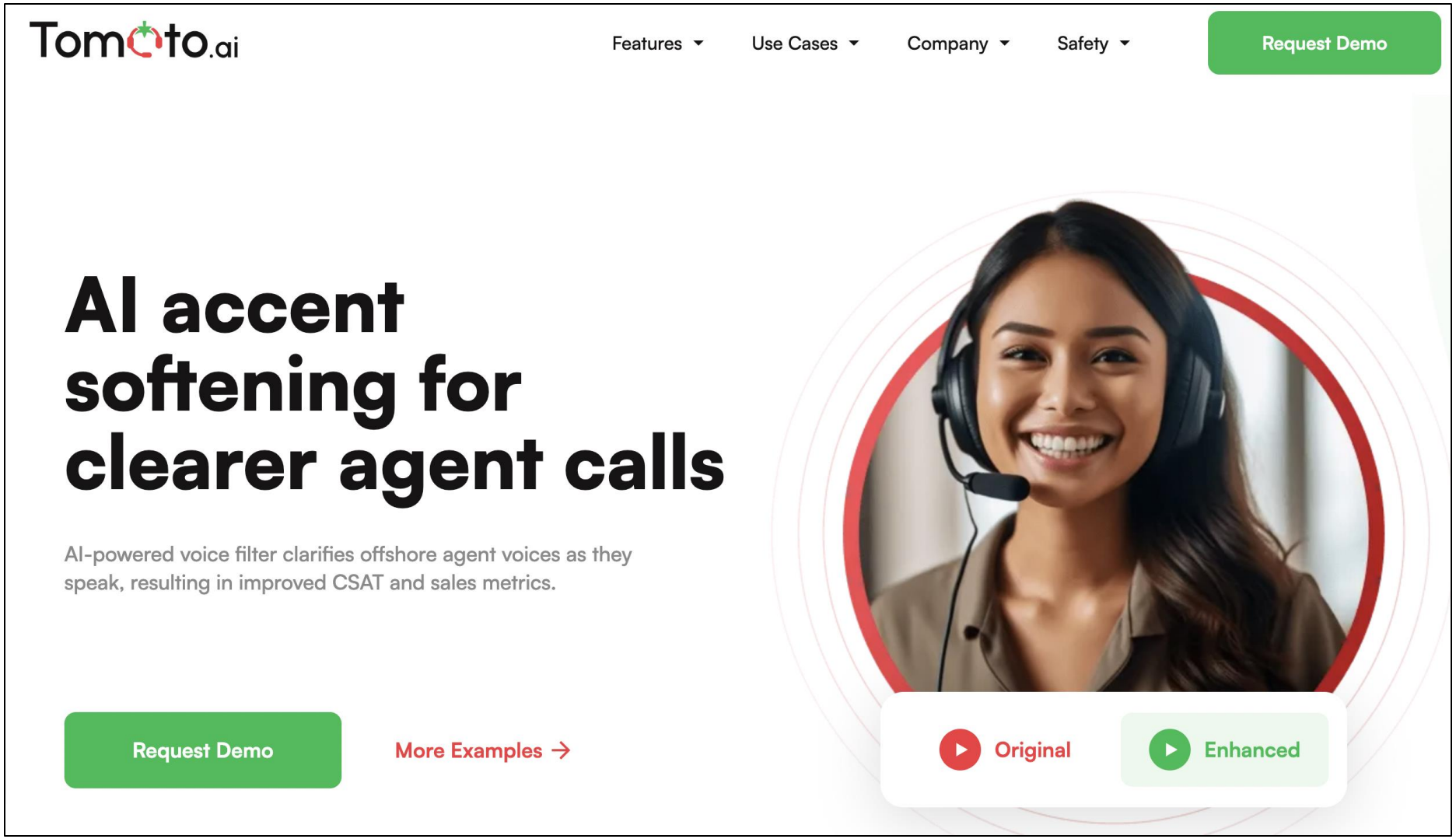
The world's first end-to-end AI solution for Hollywood VFX.

Vanity AI is a production-ready solution that empowers VFX teams and Hollywood to deliver large volumes of high-end 2D aging, de-aging, cosmetic, wig, and prosthetic fixes. The technology is up to 300 times faster than traditional VFX



https://theresanaiforthat.com/ai/vanity-ai/

Accent Editor; e.g., for Customer Support

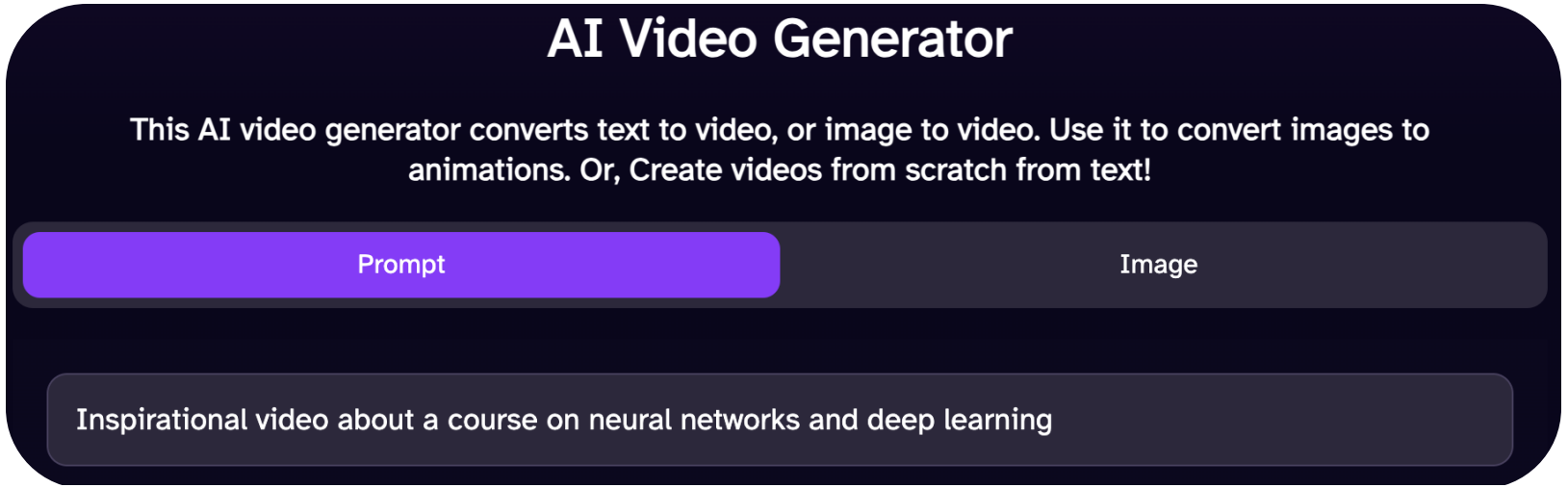


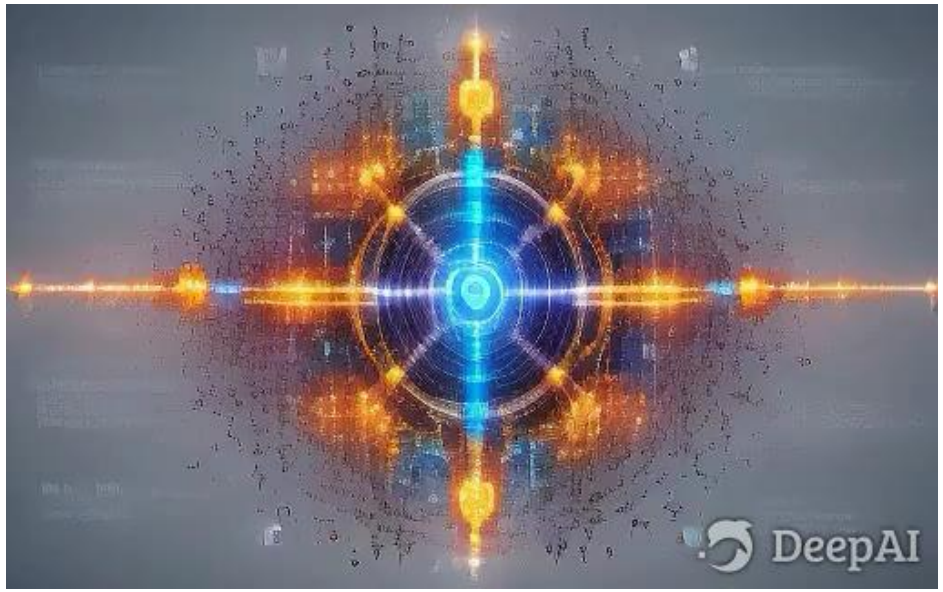
https://tomato.ai/

Music Composer; Demo with Suno

https://suno.com/

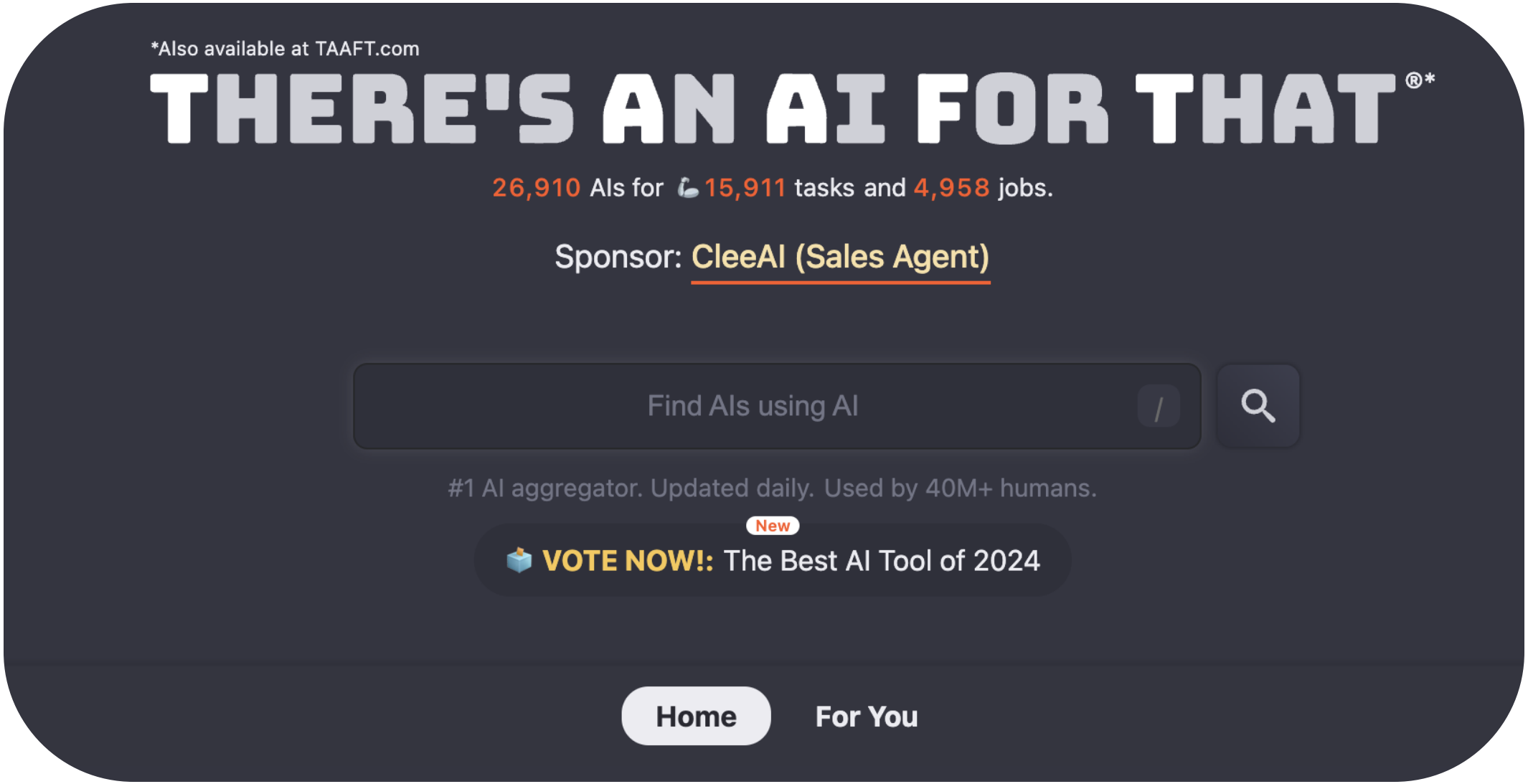
Video Generation; Demo with DeepAI





https://deepai.org/

And Many More Applications…



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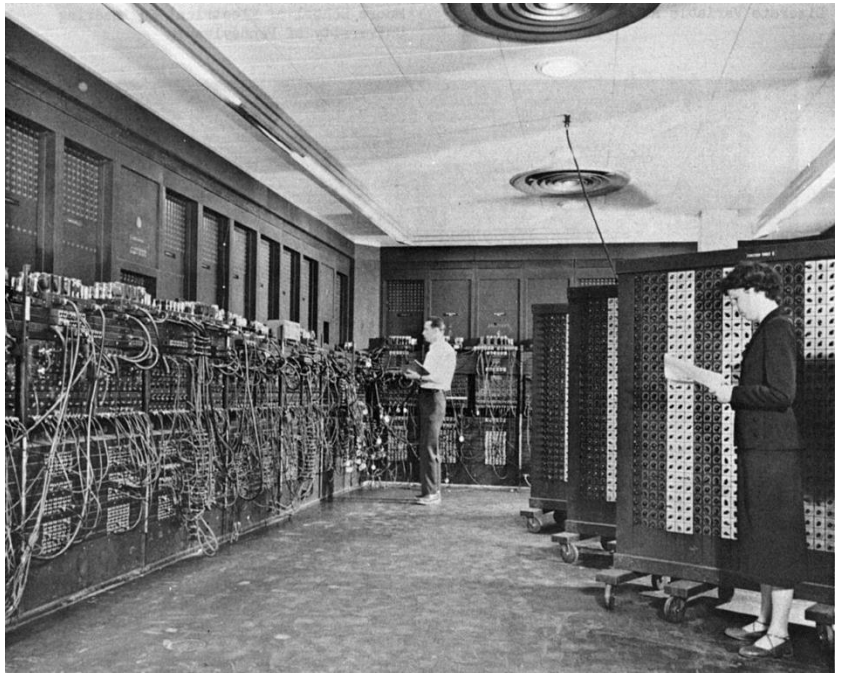
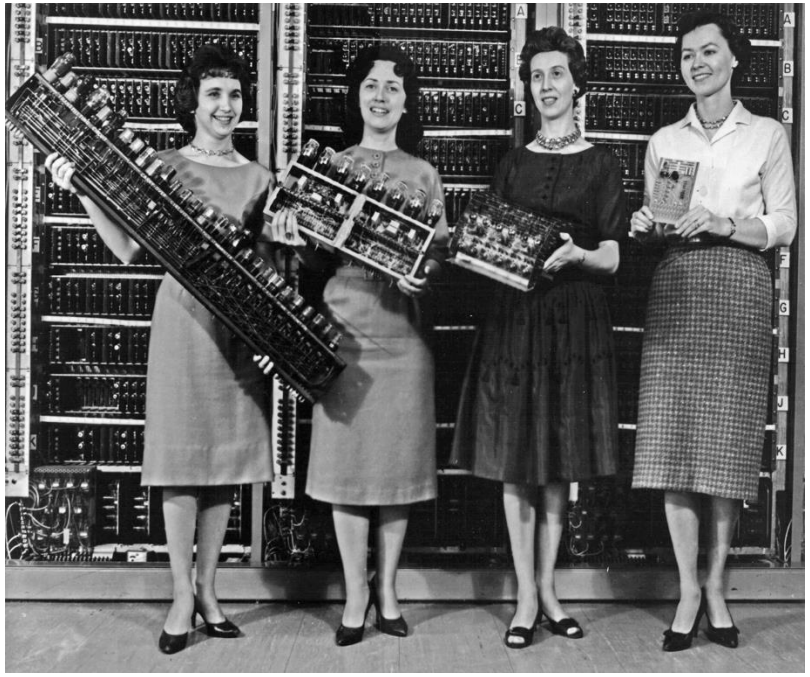
Origins: Computers

1945

First programmable machine



ENIAC (Electronic Numerical Integrator and Computer) created during World War II
(could compute 5,000 additions in one second)



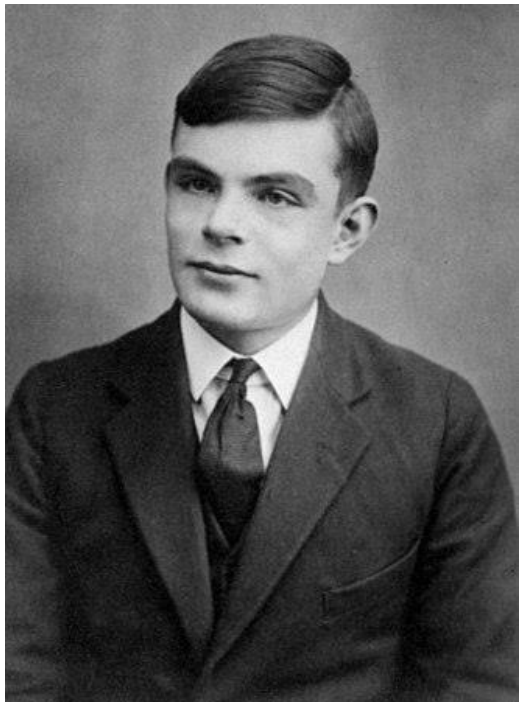
First programmers

Origins: Conceptual Framework

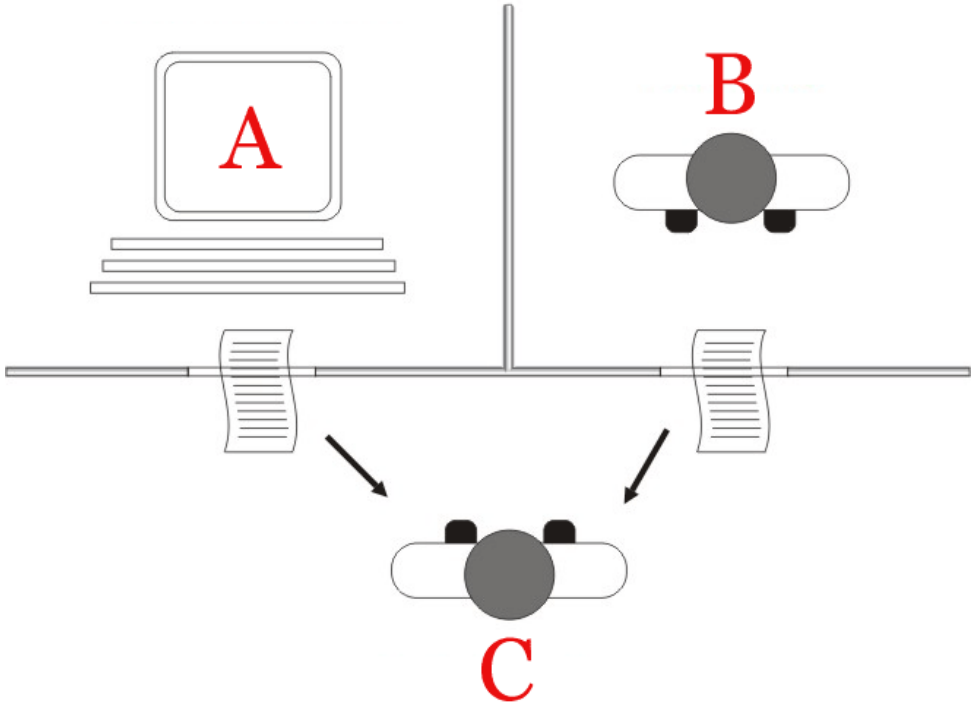
1945 1950

First programmable machine

Turing test

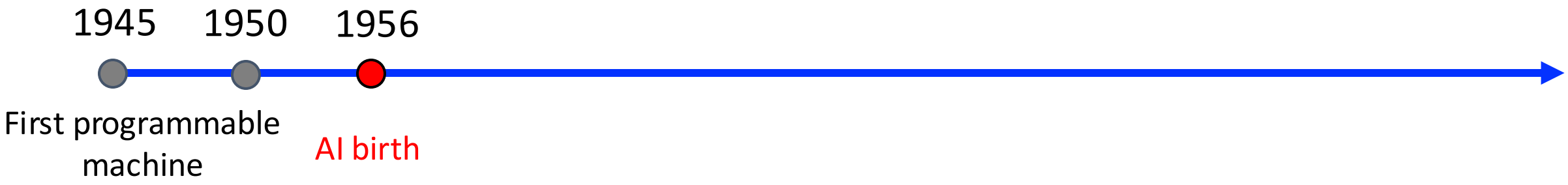


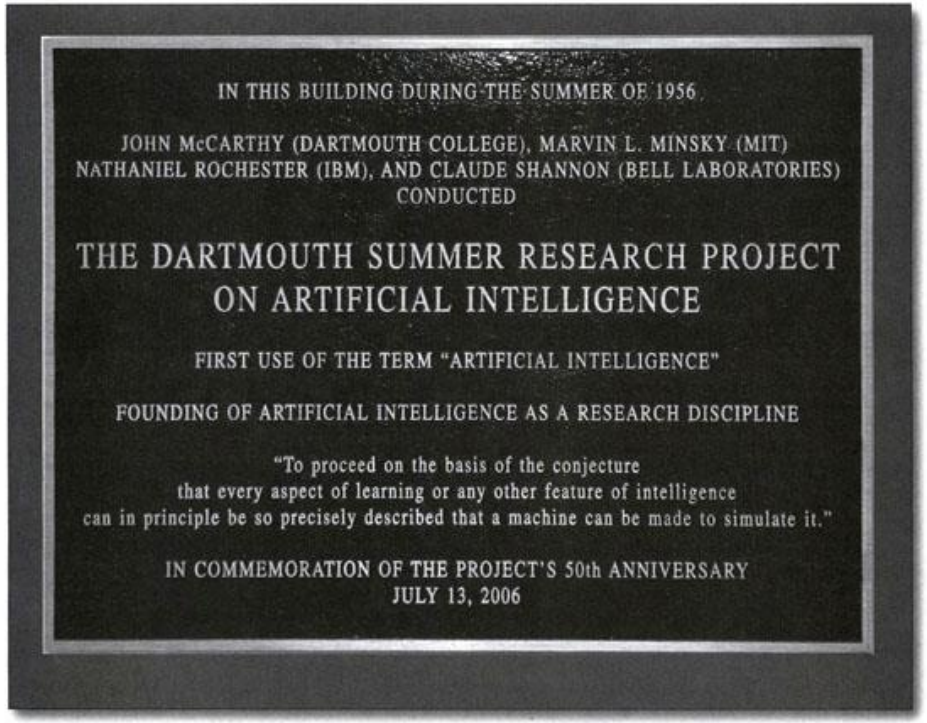
Alan Turing
(1912-1954)



Turing Test: can ”C” decide whether text responses come from a machine or human

Origins: Conceptual Framework

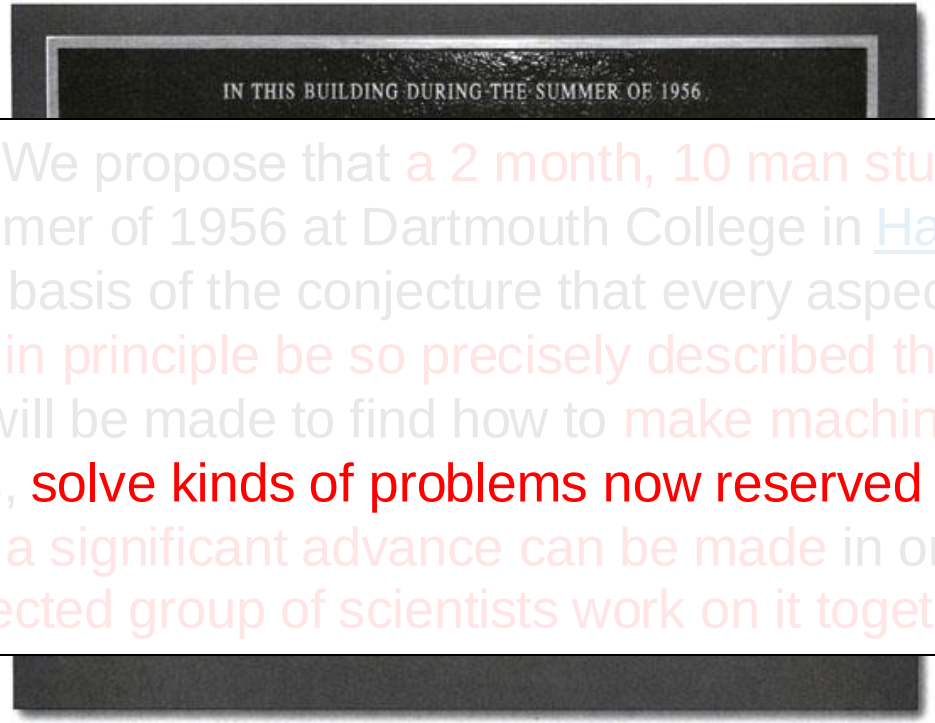




"Artificial intelligence" established as a field at a workshop

Origins: Conceptual Framework

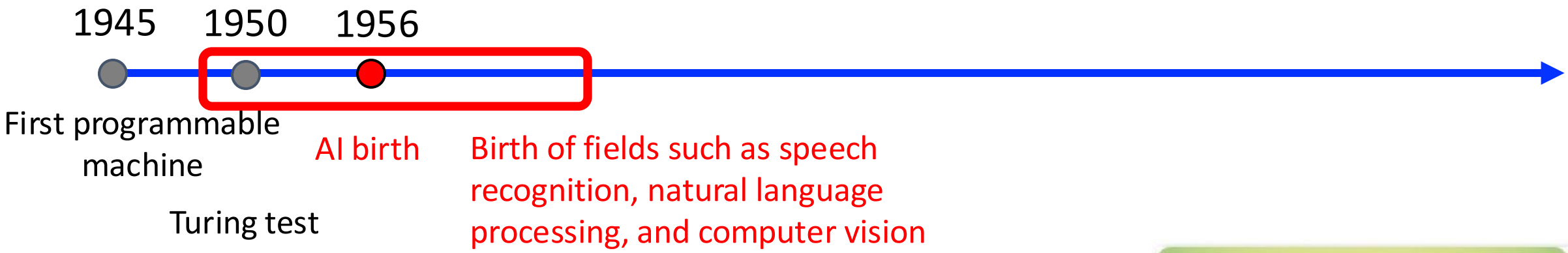
Turing test



Workshop Proposal: "… We propose that a 2 month, 10 man study of artificial intelligence be carried out during the summer of 1956 at Dartmouth College in Hanover, New Hampshire. The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it. An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves. We think that a significant advance can be made in one or more of these problems if a carefully selected group of scientists work on it together for a summer…"

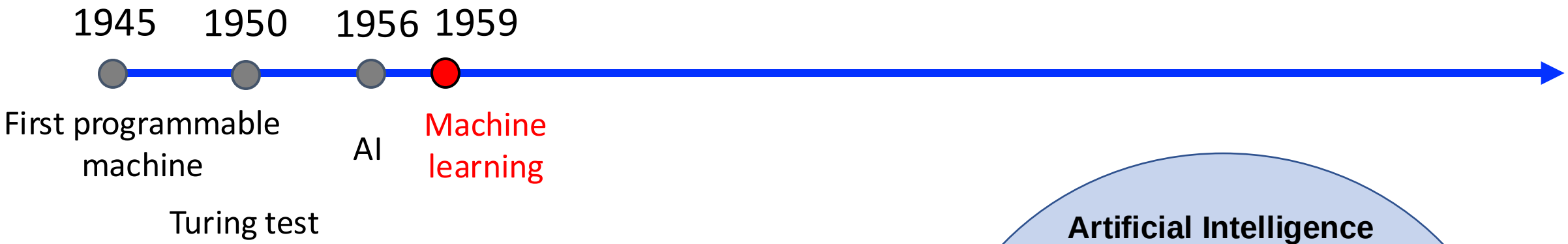
"Artificial intelligence" established as a field at a workshop

Origins: Conceptual Framework



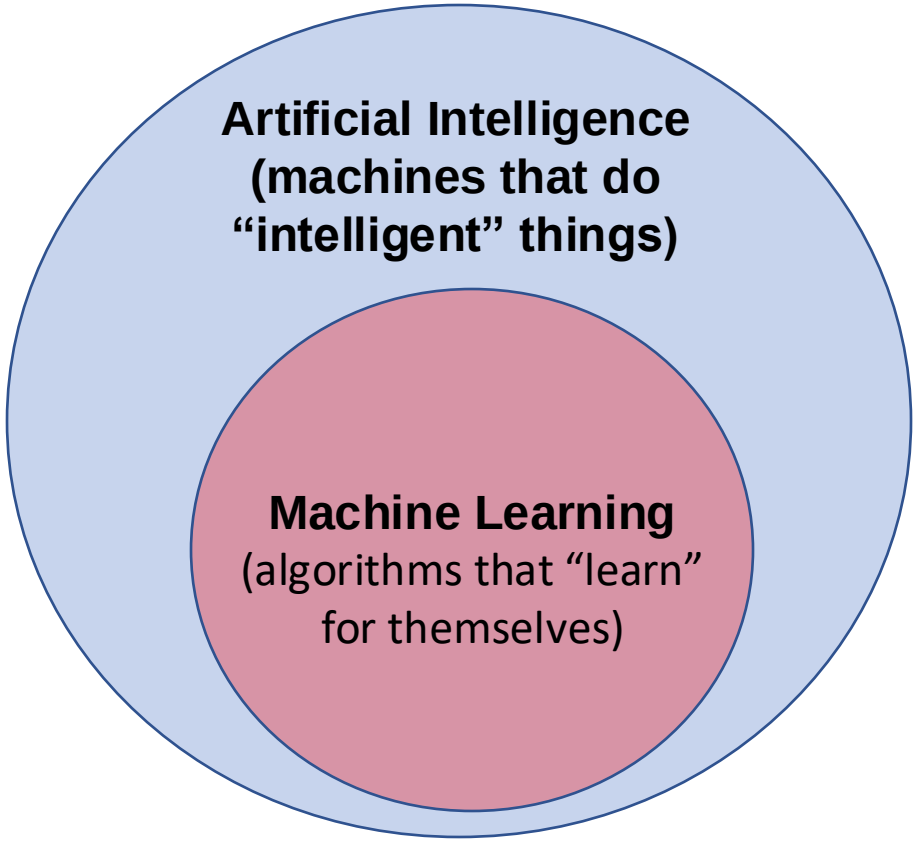
What human intelligence might computers imitate?

Origins: Conceptual Framework



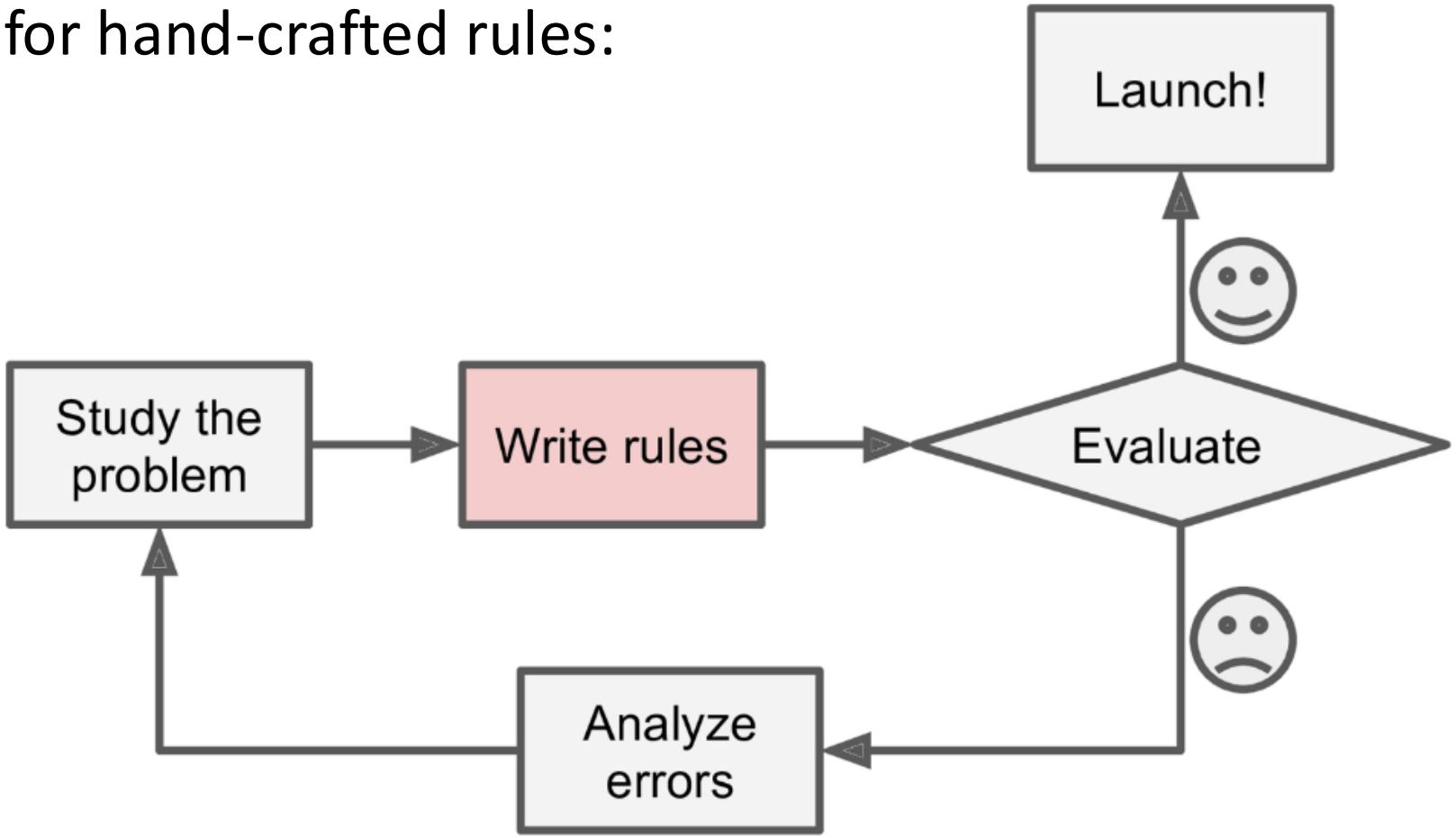
AI researcher Arthur Samuel coins the term "machine learning" as:

"Field of study that gives computers the ability to learn without being explicitly programmed."



Motivation for Machines that “Learn”

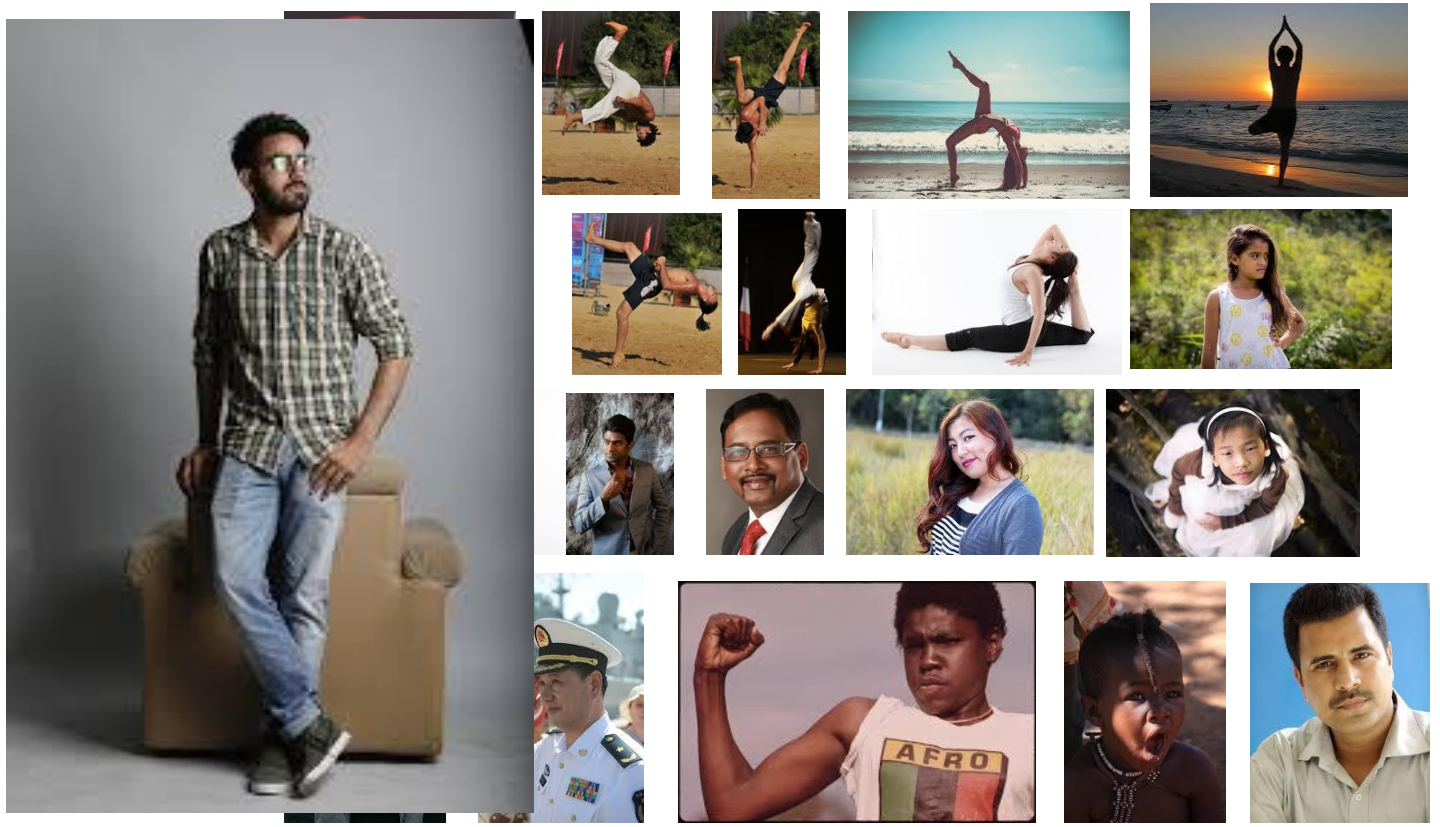
- Process for hand-crafted rules:



https://www.oreilly.com/library/view/hands-on-machine-learning/9781491962282/ch01.html

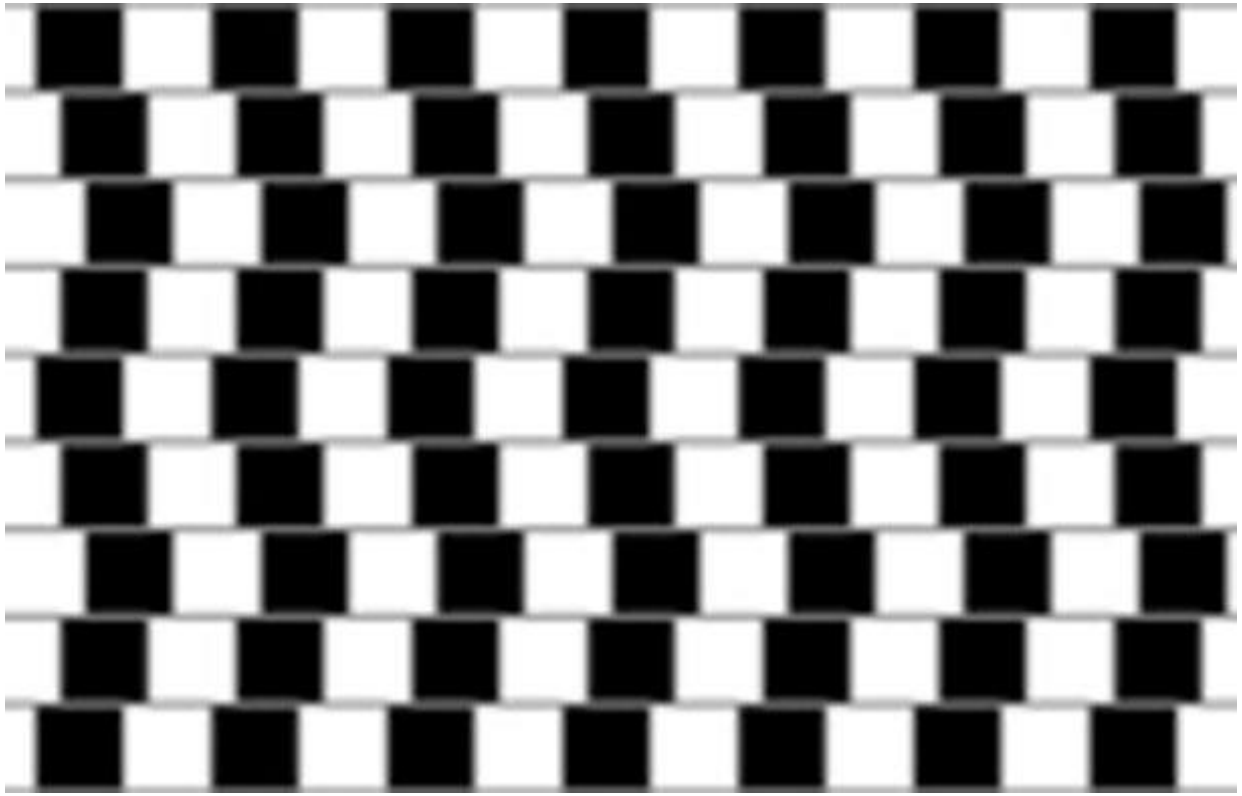
Motivation for Machines that “Learn”

e.g., What rules would you use to answer: “Is a person in the image?”



Motivation for Machines that “Learn”

e.g., are the horizontal lines parallel?



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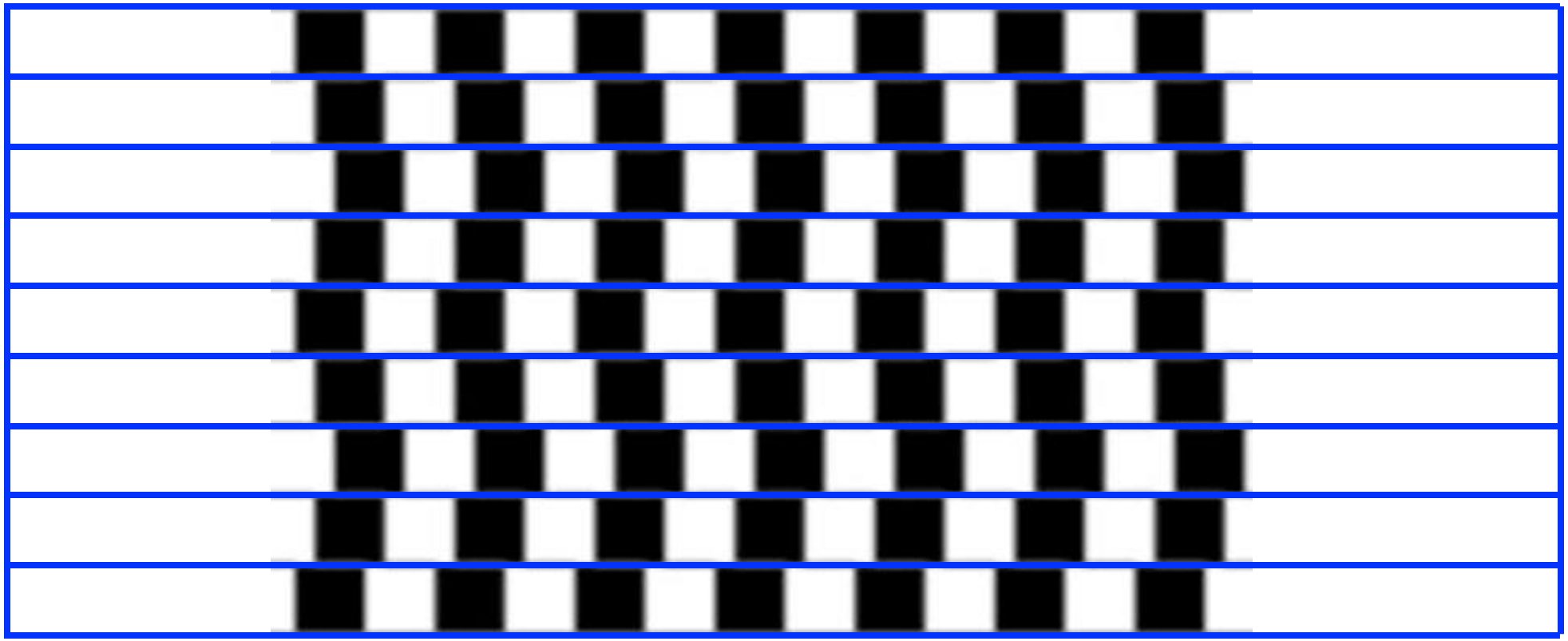
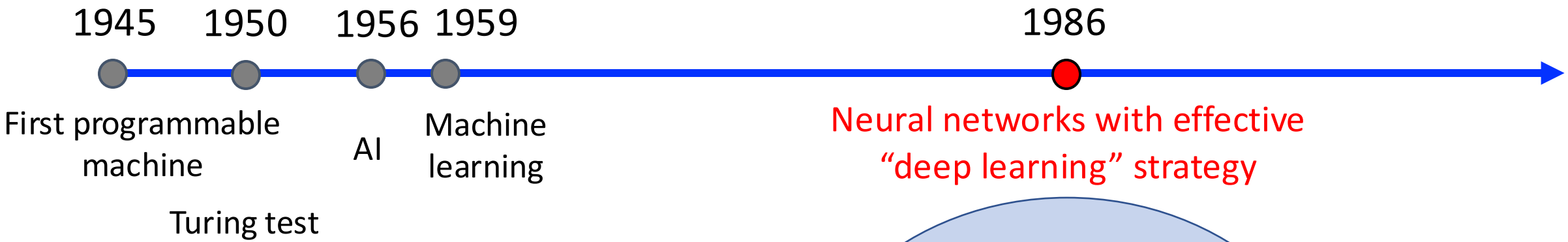


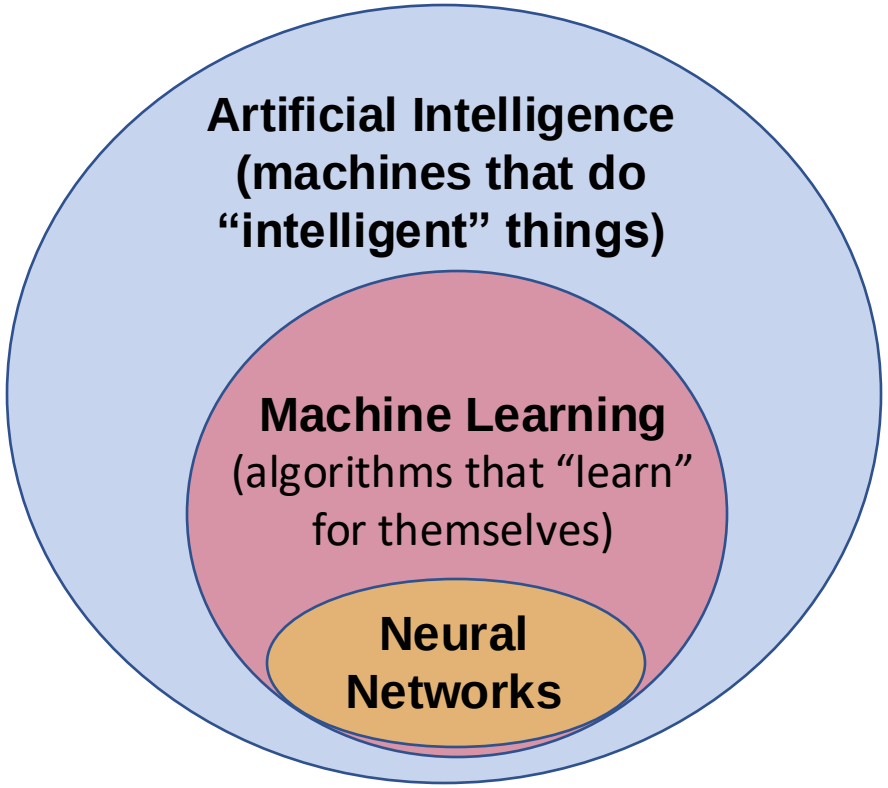
Motivation for Machines that “Learn”

1. It is hard to hand-craft a complete set of rules

2. We, as humans, may not devise the best rules for a machine since our brains (unconsciously) pre-process the data we sense

Origins: Neural Networks with Deep Learning



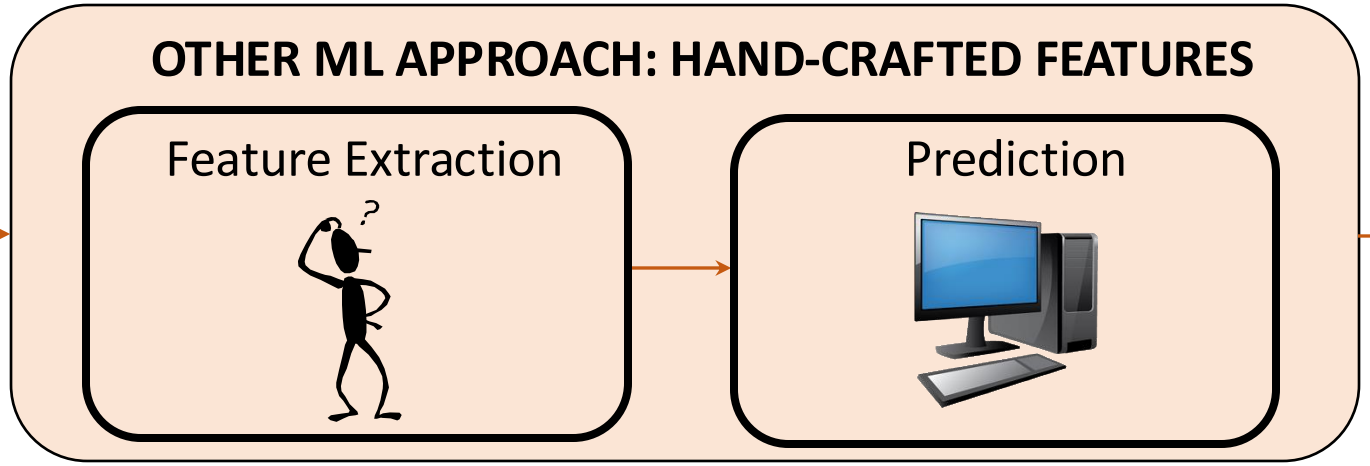


Motivation for Neural Networks (NNs) Over Other Machine Learning (ML) Approaches

INPUT

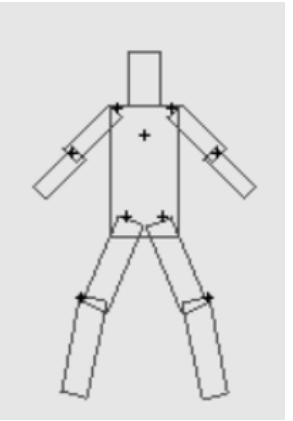
e.g., Is a person present?

OUTPUT



Features that may help predict yes/no:

e.g., corners, lines, and model of expected body parts as connected shapes



e.g., Pedro F Felzenszwalb and Daniel P Huttenlocher, IJCV 2004

Motivation for Neural Networks (NNs) Over Other Machine Learning (ML) Approaches

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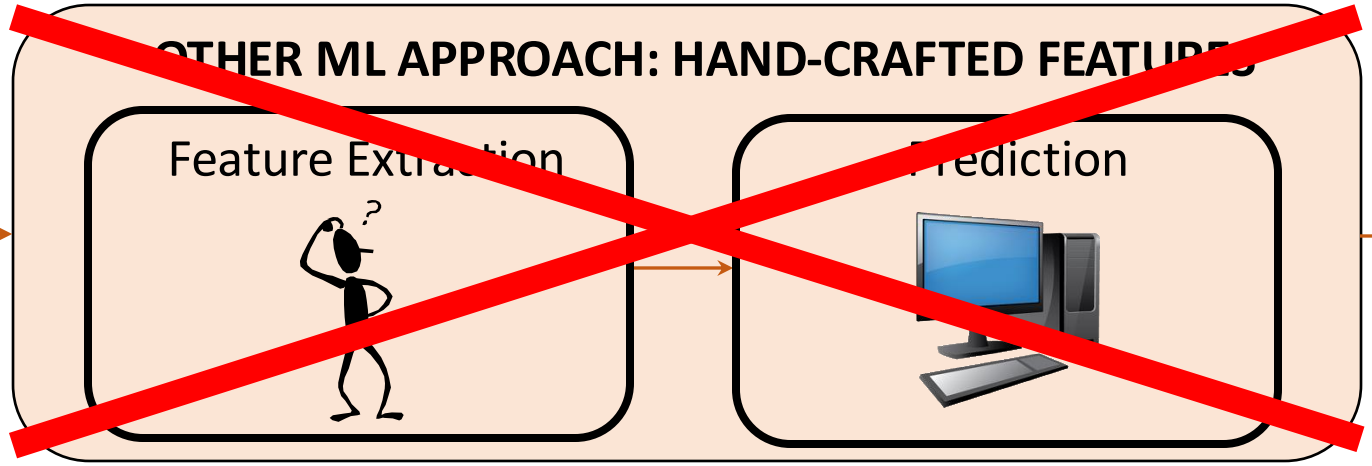
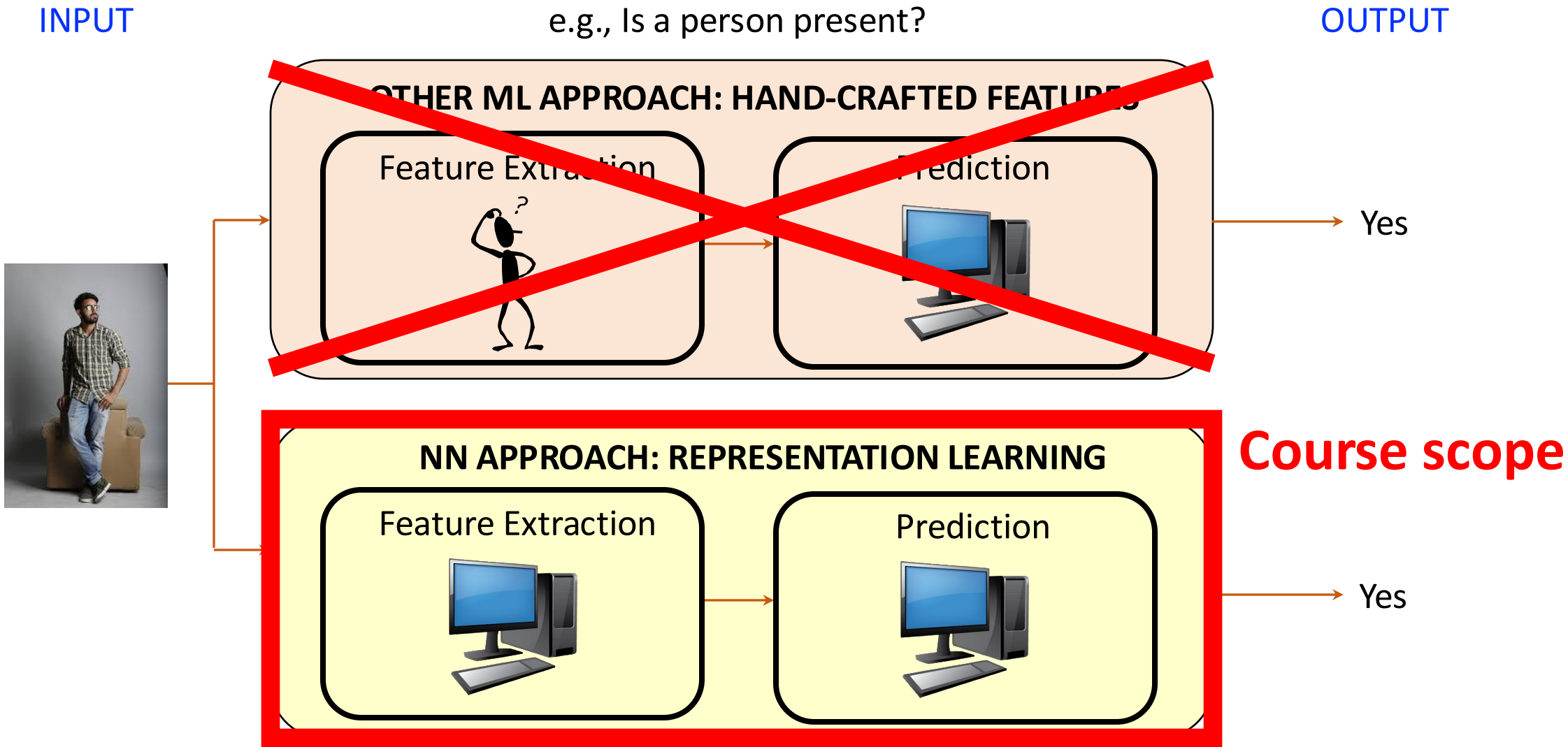


Yes

Challenging to hand-craft features!

Motivation for Neural Networks (NNs) Over Other Machine Learning (ML) Approaches



Origins: Rises/Falls of Neural Network Popularity

1945 1950 1956 1959 1986

First programmable machine

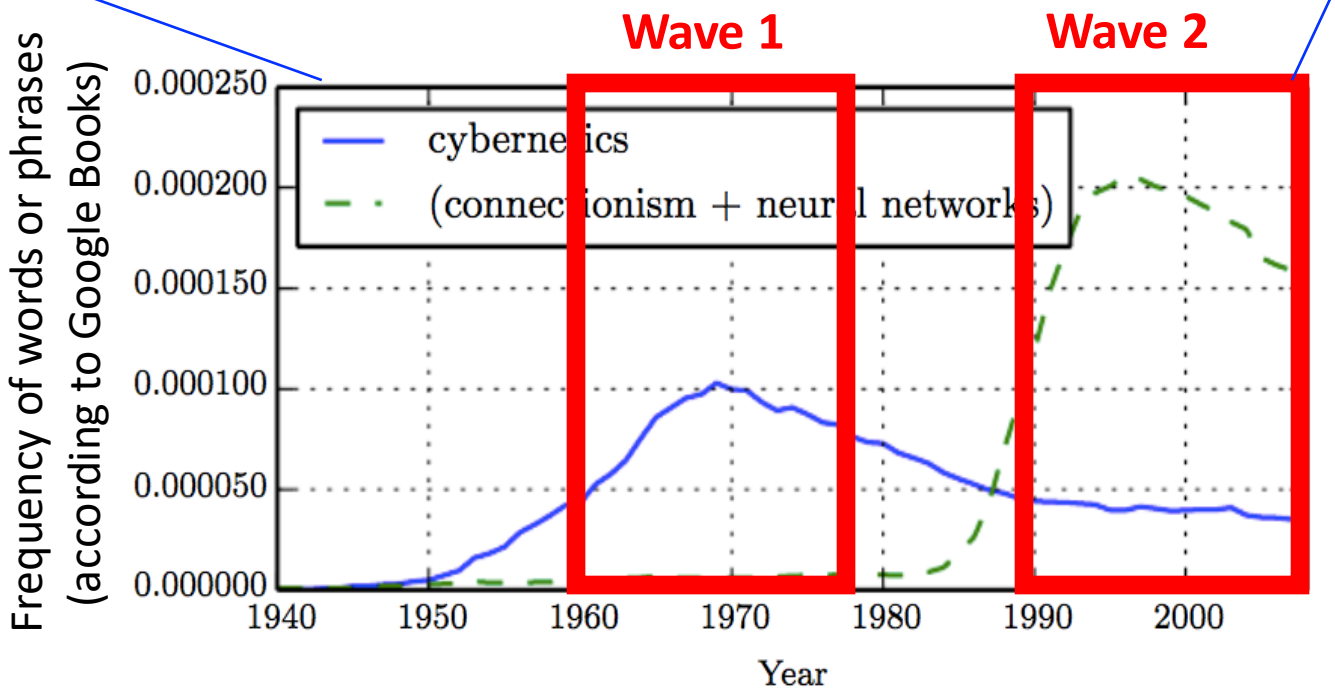
Turing test

AI

Machine learning

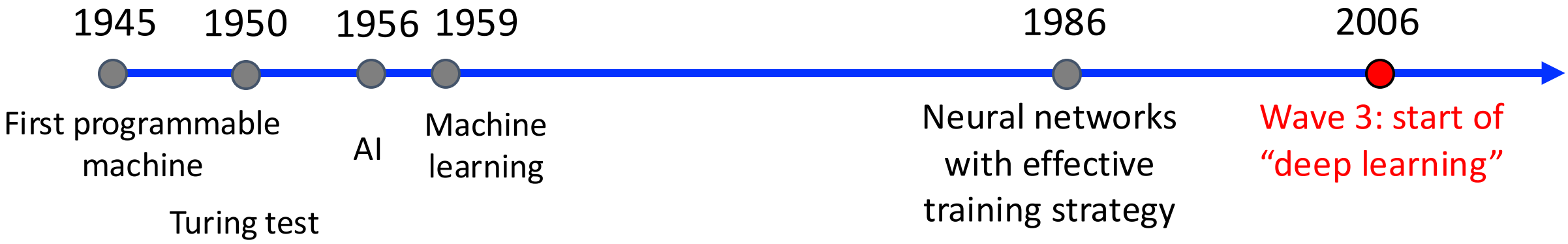
Neural networks with effective "deep learning" strategy

Neural networks have been called many names:

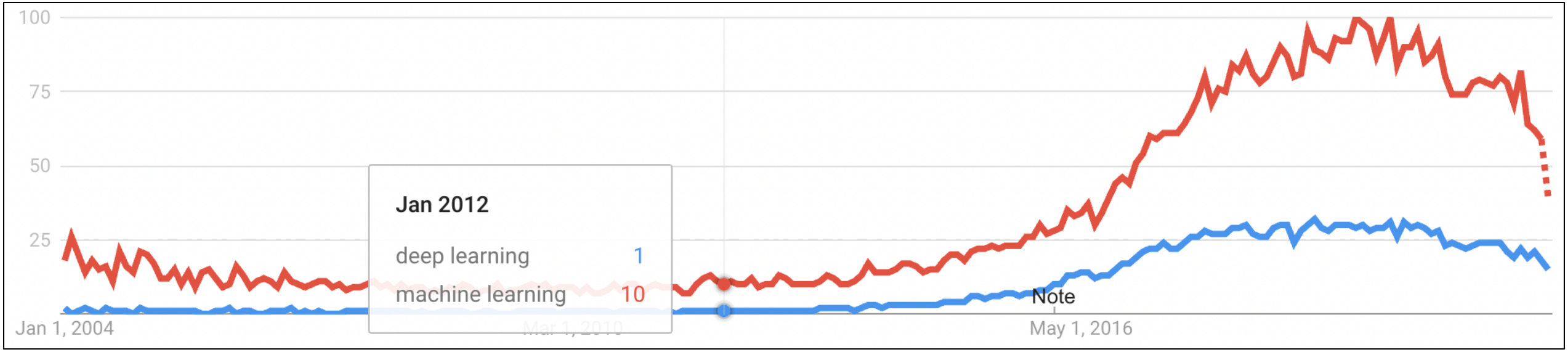


Ian Goodfellow, Yoshua Bengio, and Aaron Courville; Deep Learning, 2016

Origins: Rises/Falls of Neural Network Popularity



(Google Trends)



Machine learning popularity has paralleled rise of deep learning popularity

Why Are Neural Networks and Deep Learning So Popular? – Its Success in Practice!

It's success was realized with the relatively recent onset of:

1. **Big data**: originally, often from the Internet
2. **Better hardware**: faster hardware and more storage enabled practically fast "deep learning"

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Neural Networks: Key Ingredients for Success

An **algorithm** learns from **data**
on a **processor** the patterns that
will be used to make a prediction

Analogous to a Love Story of Partnering Up and Road Tripping Somewhere

Neural Networks: Key Ingredients for Success

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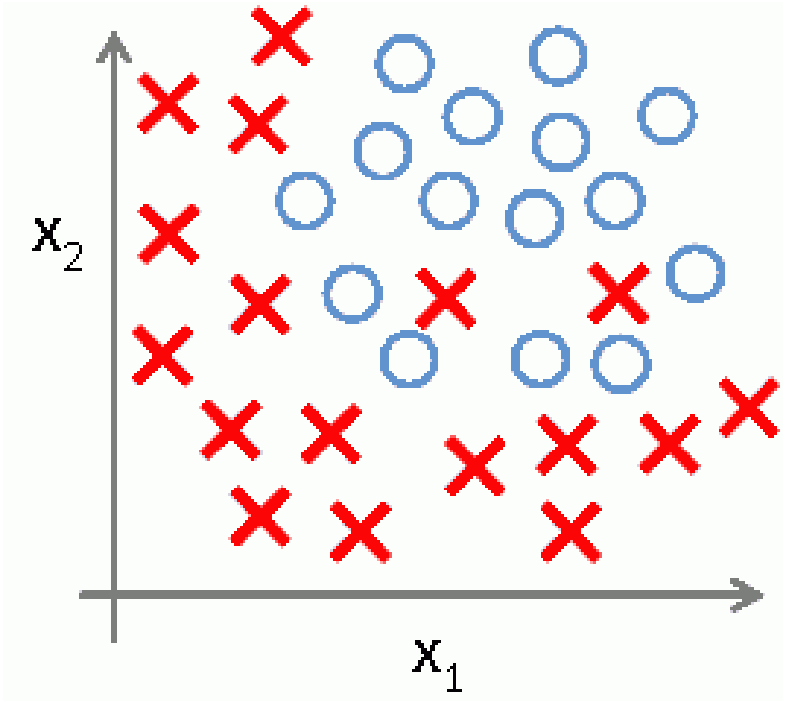
Analogous to a Love Story of Partnering Up and Road Tripping Somewhere

Algorithm Design: Model-Based

- e.g., create model to separate x from o

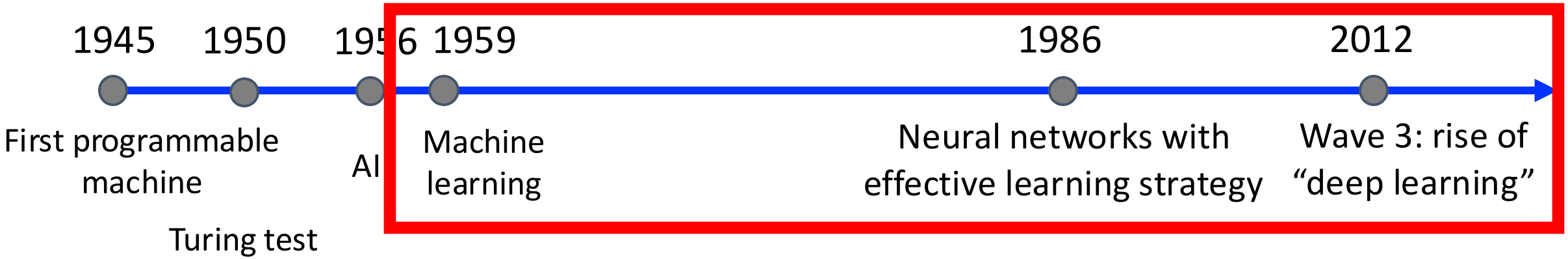


Class volunteer:
1) Draw a straight line (linear equation)
2) Draw a parabola (quadratic equation)
3) Draw any curve

Models with increasing representational capacity

https://medium.com/greyatom/what-is-underfitting-and-overfitting-in-machine-learning-and-how-to-deal-with-it-6803a989c76

Algorithm Scope for Course: Last 65 Years



We will cover the history of deep learning because modern algorithms use techniques developed over the past 65 years.

Neural Networks: Key Ingredients for Success

An algorithm learns from **data**
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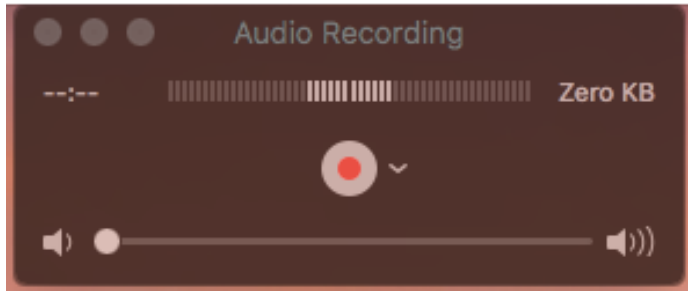
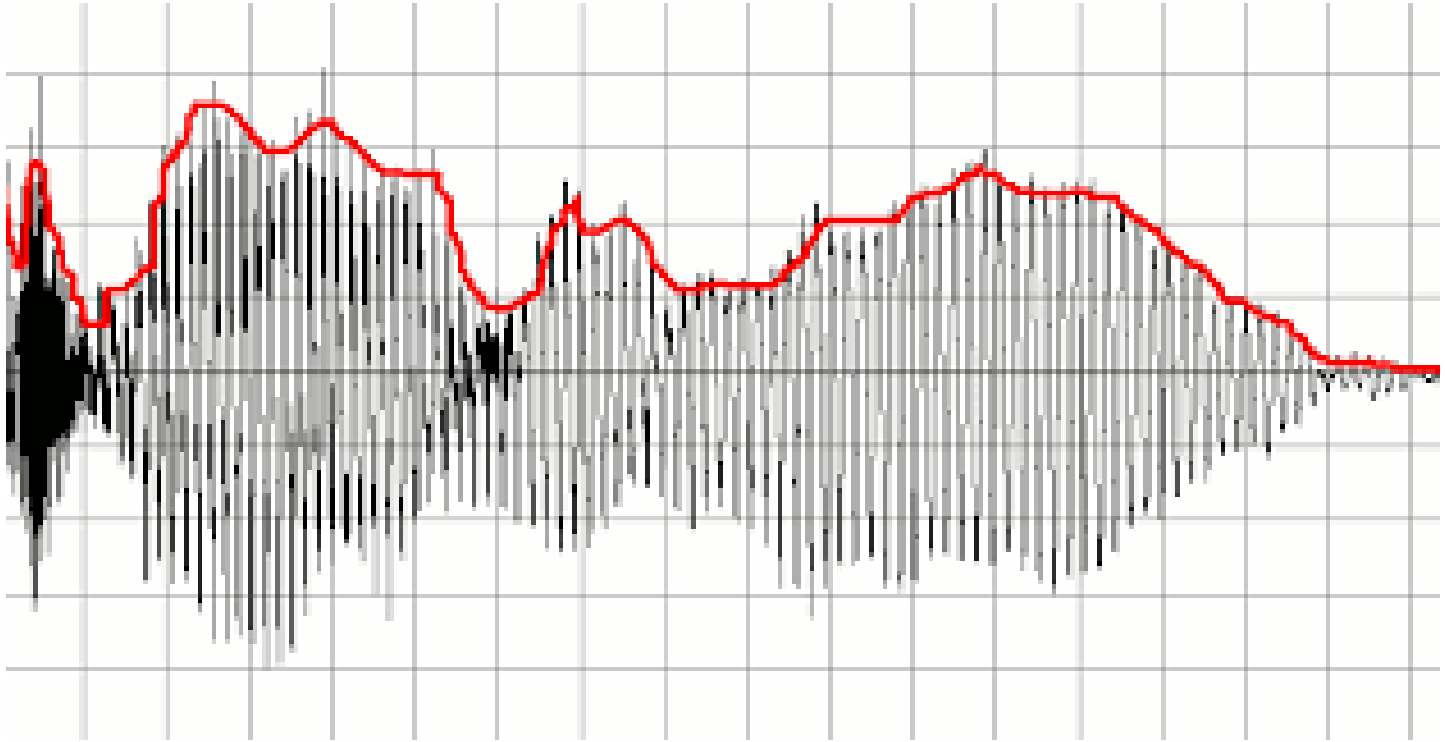
Analogous to a Love Story of Partnering Up and Road Tripping Somewhere

Data Types: What a Machine Learns From?

- Audio
  - Input?



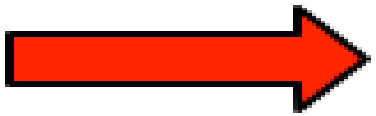
e.g.,

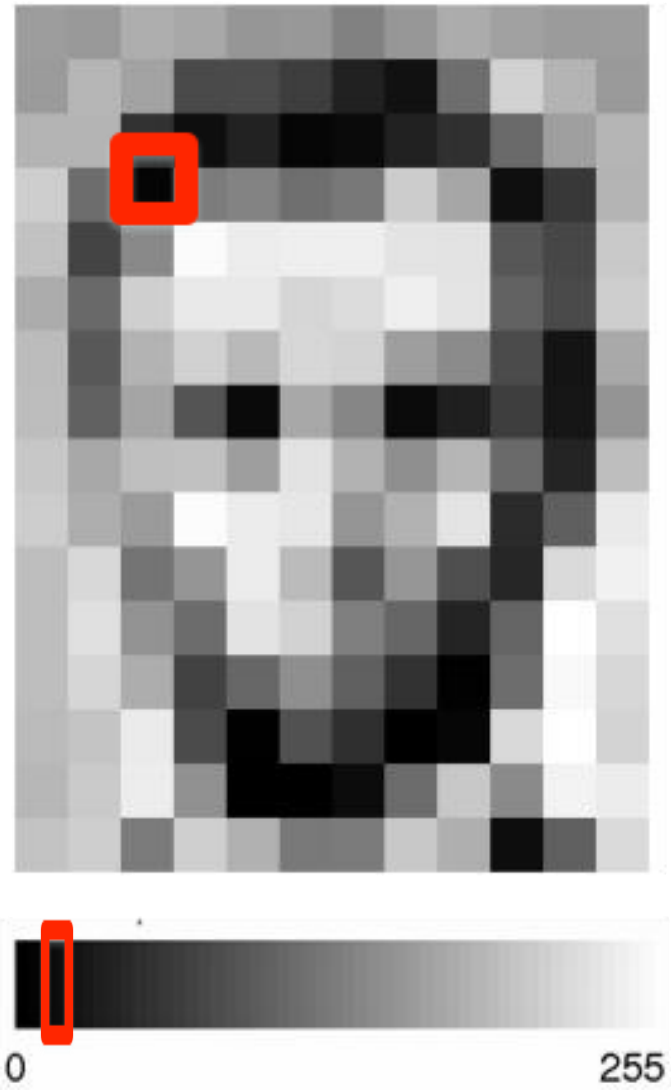


Data Types: What a Machine Learns From?

- Audio
  - Input?
- Images
  - Input?

157	153	174	168	150	152	129	151	172	161	155	156
155	182	163	74	75	62	33	17	110	210	180	154
180	180	50	14	34	6	10	33	48	106	159	181
206	109	5	24	131	111	120	204	166	15	56	180
194	68	137	251	237	239	239	228	227	87	71	201
172	105	207	233	233	214	220	239	228	98	74	206
188	88	179	209	185	215	211	158	139	75	20	169
189	97	165	84	10	168	134	11	31	62	22	148
199	168	191	193	158	227	178	143	182	106	36	190
205	174	155	252	236	231	149	178	228	43	95	234
190	216	116	149	236	187	86	150	79	38	218	241
190	224	147	108	227	210	127	102	36	101	255	224
190	214	173	66	103	143	96	50	2	109	249	215
187	196	235	75	1	81	47	0	6	217	255	211
183	202	237	145	0	0	12	108	200	138	243	236
195	206	123	207	177	121	123	200	175	13	96	218

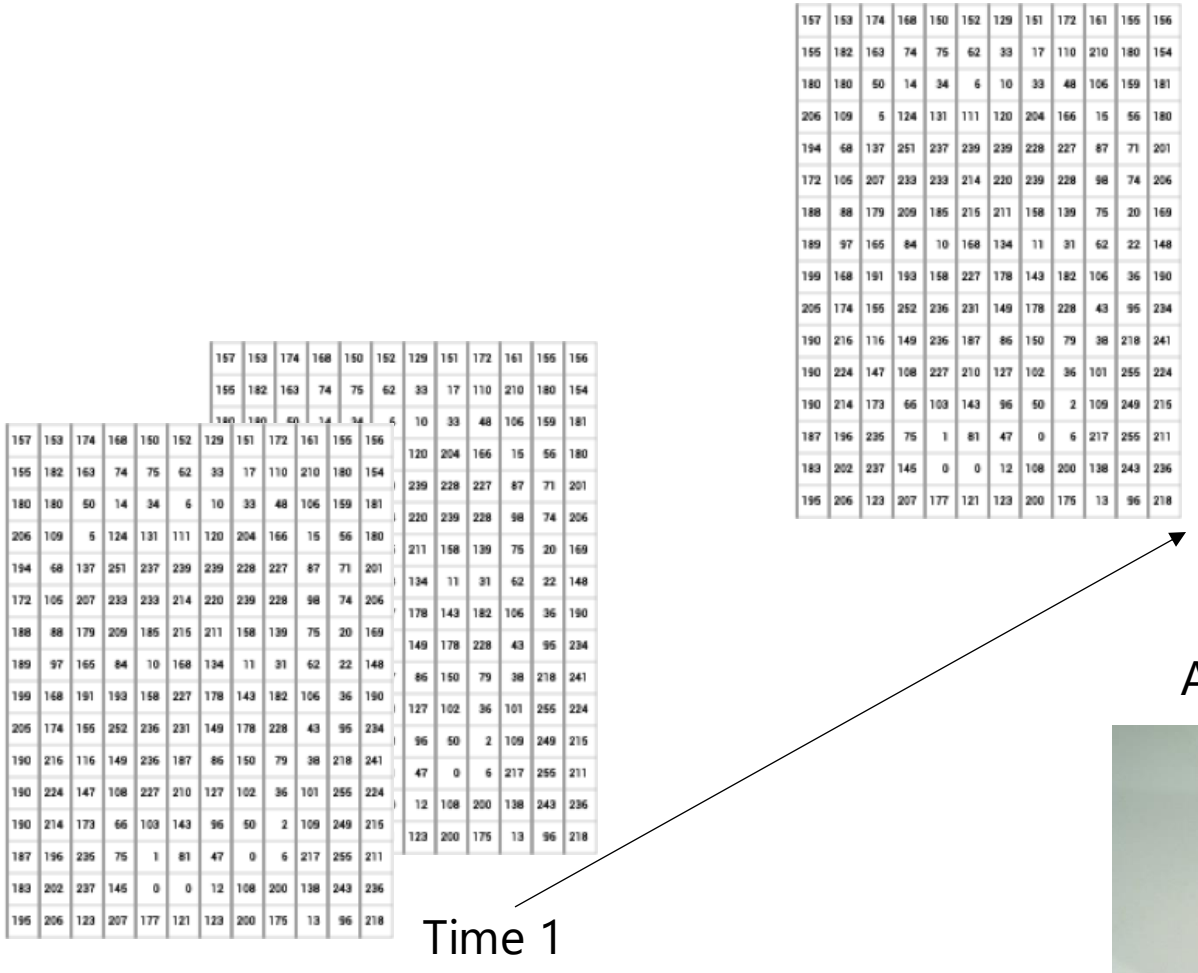




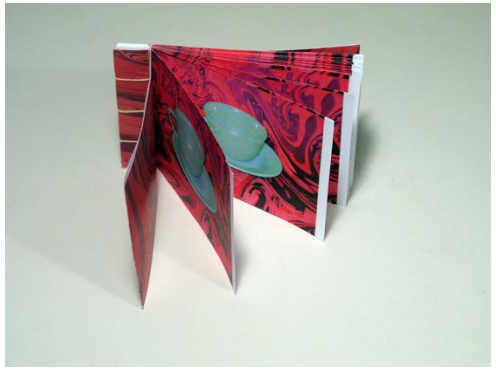
https://ai.stanford.edu/~syyeung/cvweb/tutorial1.html

Data Types: What a Machine Learns From?

- Audio
  - Input?
- Images
  - Input?
- Video
  - Input?



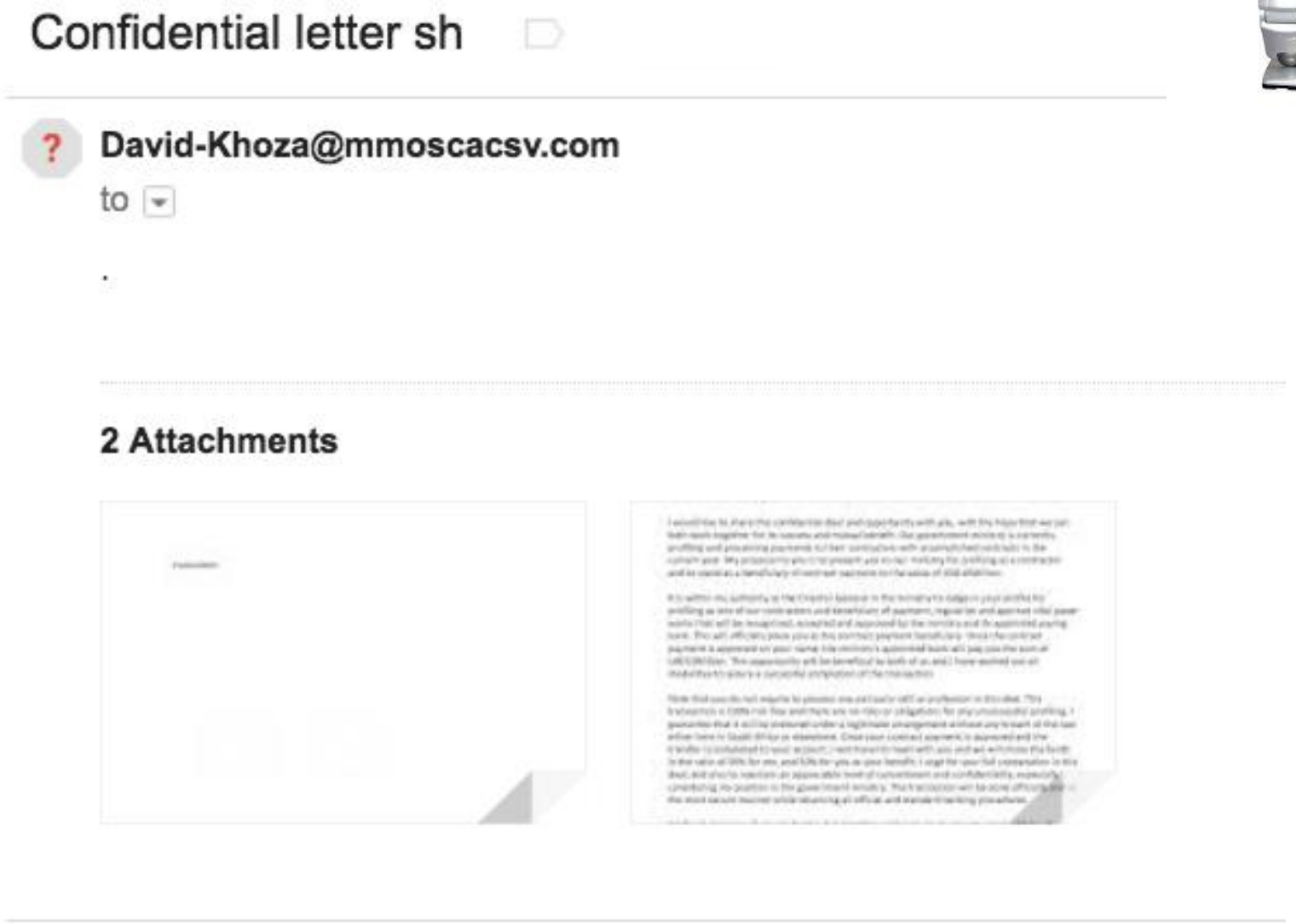
Analogous to:



Data Types: What a Machine Learns From?

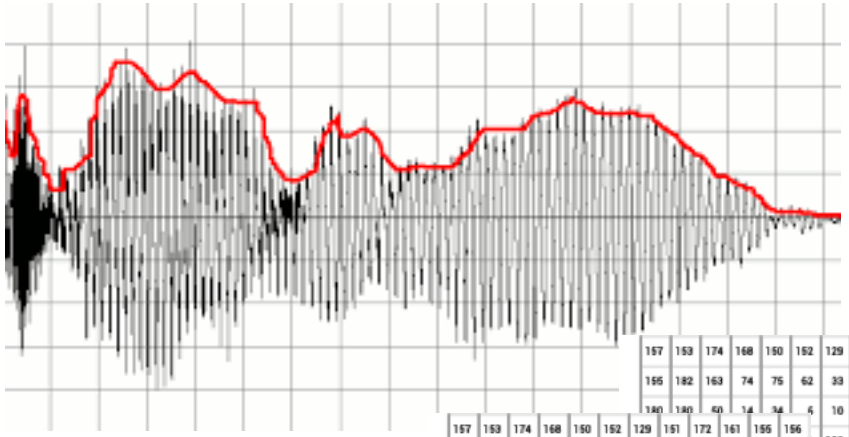
- Audio
  - Input?
- Images
  - Input?
- Video
  - Input?
- Text
  - Input?

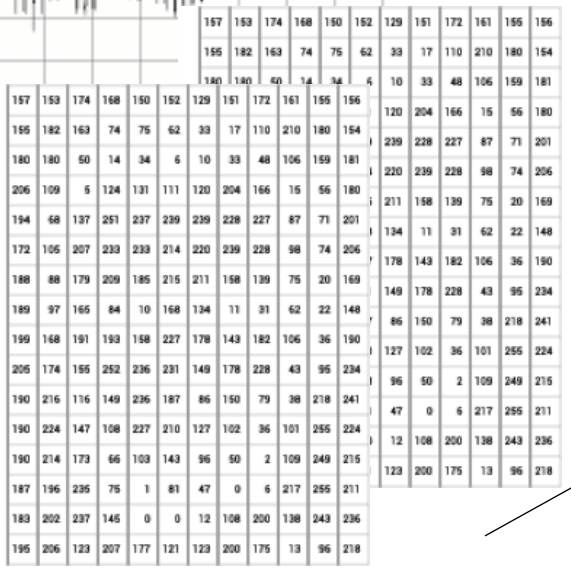
e.g.,

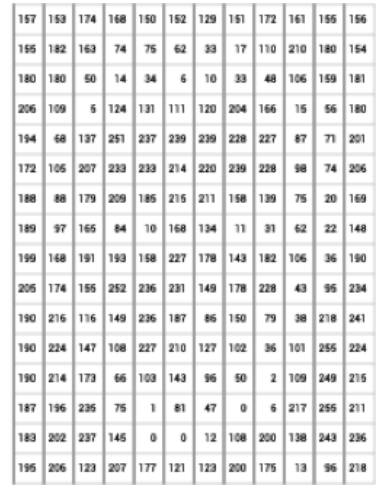


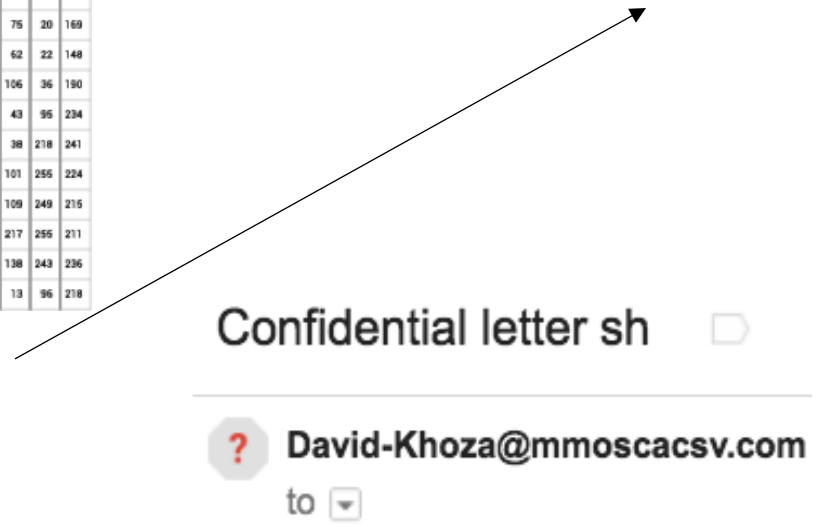
Data Types: What a Machine Learns From?

- Audio
  - Input?
- Images
  - Input?
- Video
  - Input?
- Text
  - Input?
- Multi-modal
  - Input? - combination of the above









Data Types: Many Public Datasets Available

- Dataset creation is beyond the scope of this class
- We will benefit from other people's efforts:
  - Google Dataset Search
  - Amazon's AWS datasets
  - Kaggle datasets
  - Wikipedia's list
  - UC Irvine Machine Learning Repository
  - Quora.com
  - Reddit
  - Dataportals.org
  - Opendatamonitor.eu
  - Quandl.com

Neural Networks: Key Ingredients for Success

An algorithm learns from data
on a **processor** the patterns that
will be used to make a prediction

Analogous to a Love Story of Partnering Up and Road Tripping Somewhere

Neural Networks: Key Ingredients for Success

e.g., Train Algorithms Using
GPUs (think Porsche) Instead of CPUs (think Golf Cart)

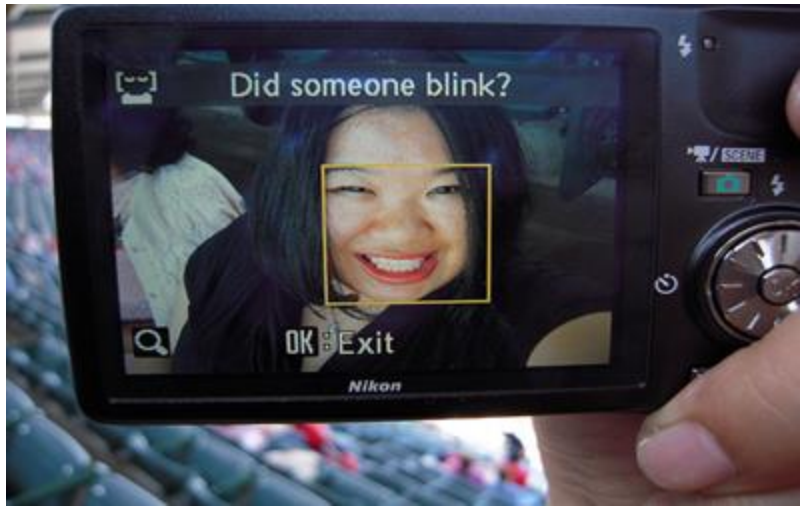
Summary

An **algorithm** learns from **data**
on a **processor** the patterns that
will be used to make a prediction

Analogous to a Love Story of Partnering Up and Road Tripping Somewhere

Key Challenge: Where Will You Go?

https://www.theverge.com/2015/7/1/8880363/google-apologizes-photos-app-tags-two-black-people-gorillas



"Two kids bought their mom a camera for Mother's Day… when they took portrait pictures of each other, a message flashed across the screen asking, `Did someone blink?'"

http://content.time.com/time/business/article/0,8599,1954643,00.html

Today’s Topics

- Applications
- History of neural networks and deep learning
- How does a machine learn?
- Course logistics

Course Objectives

- Understand the key concepts for designing deep learning models:
  1. Characterize the key architectures used in designing neural networks
  2. Recognize techniques used to train and evaluate deep learning models
  3. Identify strengths and weaknesses of different neural network architectures

Course Objectives

- Apply deep learning models to perform various AI tasks:
  1. Develop deep learning models from scratch
  2. Experiment with established deep learning libraries
  3. Evaluate deep learning algorithms for tasks in various application domains, including for analyzing text and images

Course Objectives

- Conduct and communicate about a novel project:
  1. Propose a novel project idea
  2. Design and execute experiments to support the proposed idea
  3. Create a presentation about the project
  4. Write a report about the project

Course Resources

- Website with Syllabus:
  - https://dannagurari.colorado.edu/course/neural-networks-and-deep-learning-spring-2025/
- Lecture Slides: hyperlinked from course website
- Lecture Recordings: available on Canvas immediately after each lecture

Q&A: “How does this course differ from other courses?”

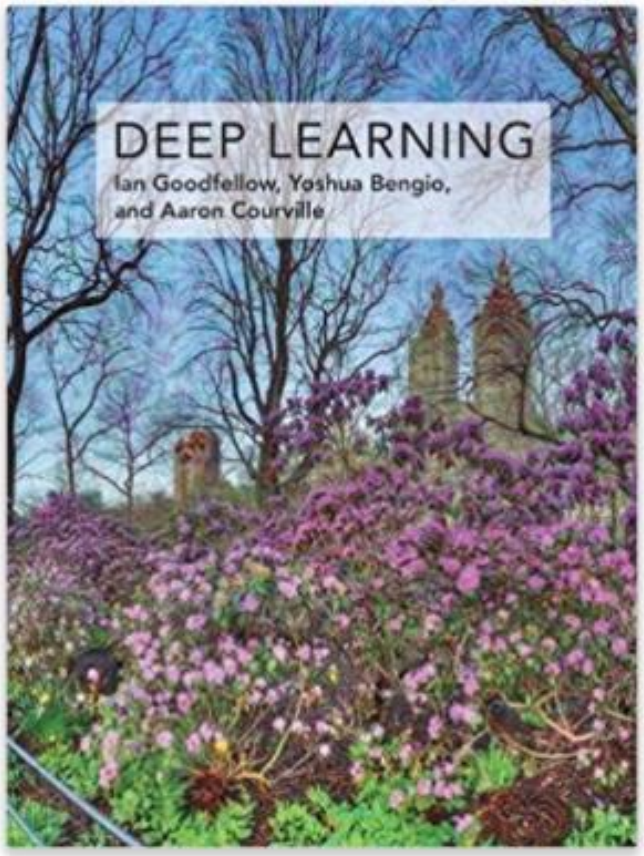
- Other courses also cover neural networks and deep learning, including about:
  - Computer vision
  - Natural language processing
- Unique benefit of this course:
  - Focus is on the fundamentals, analogous to learning how to build a car instead of only on how to drive a car

Q&A: “Do I have the appropriate pre-requisites/background?”

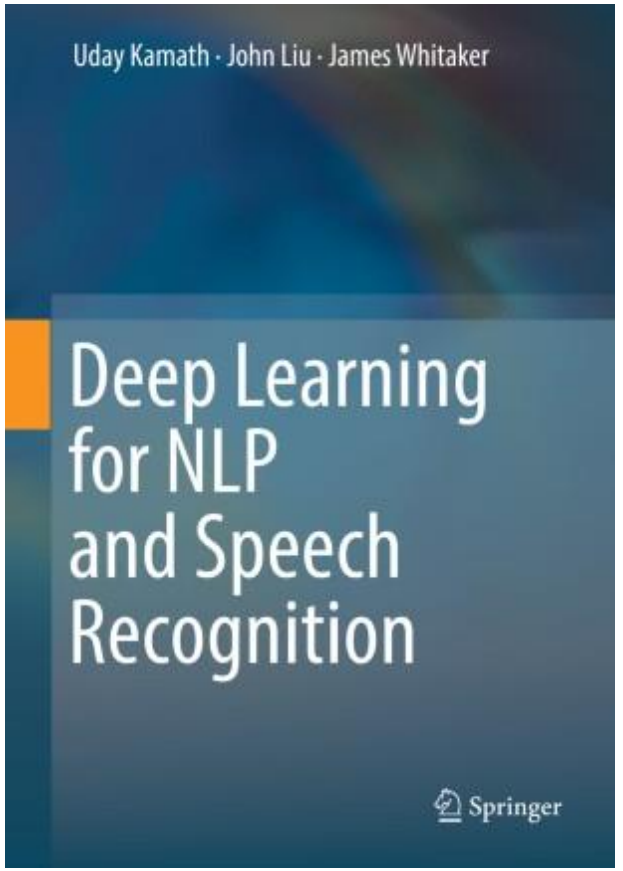
- Programming competency
- Experience with probability/statistics and linear algebra

Q&A: “What are required textbooks?”

(available online for free)



(available online for free when connected to CU Boulder’s network or VPN)



Q&A: “What are the assignments?”

- 4 problem sets (first assignment due in 2 weeks)
- 3 lab assignments
- Final project
  - Outline
  - Presentation
  - Peer evaluation
  - Final report
- Grading policies:
  - Late policy: Penalized 1% per hour for up to 2 hours and no credit afterwards
  - Regrade requests: must submit to TA within 2 weeks of receiving the grade
- Grading timeline
  - Due to the many students (150+), grades will be released ~1 week after submission

Q&A: “How is my final grade determined?”

	% of Final Class Grade
Problem Sets	35%
Lab Assignments	35%
Final Project	30%

Introductions

Instructor: Danna Gurari; aka, Dr. G; preferred pronouns: she/her:

Teaching assistants (will hold office hours)

- Everley Tseng; preferred pronouns: she/her:
(programming tutorials, Q&A on Piazza)

- Nick Cooper (preferred pronouns: he/him):
(assignment review sessions, regrade requests)

- Neelima Prasad (preferred pronouns: she/her):
(lead grader)

Grader: Mohammad Qazim Bhat

Q&A: “How Do I Get Answers to my Questions?”

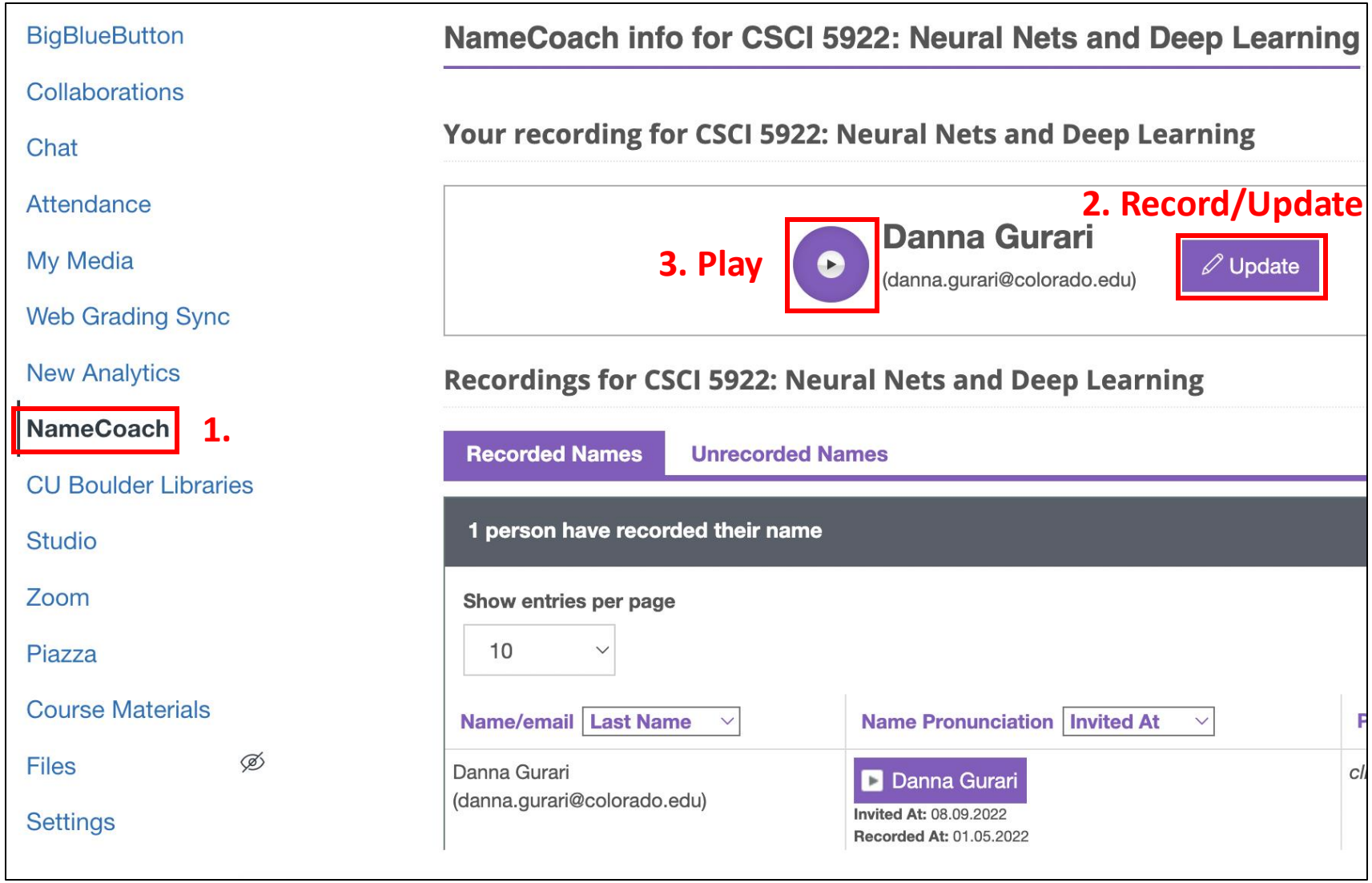
- **Questions for Instructor**: I will stay after each class lecture to answer questions.
- **Piazza:** We encourage you to first post any questions to Piazza. This approach can benefit other students who have similar questions, as they can view the answers on Piazza. It also provides an opportunity for peers to answer your questions.
- **Office Hours**: The TAs will host office hours every day of the week at times posted on the course website and Canvas. Instructions for how to attend are provided on the home page of Canvas.
- **Appointments**: For matters that cannot be addressed in office hours, first email the TAs Everley Tseng and Nick Cooper to make an appointment or solicit an answer. Please note that at least 24 hours notice will typically be needed before a TA will be able to meet. The TAs will involve the instructor for any items they are unable to address.
- **Regrade requests**: All requests must be emailed to the TA, Nick Cooper, within 2 weeks of receiving the grade to be considered.

Introductions

NameCoach: share your name pronunciation

To record your name:

1. Find NameCoach in Canvas courses page
2. Click on record button to start
3. Review recording by clicking on play button



My Experience

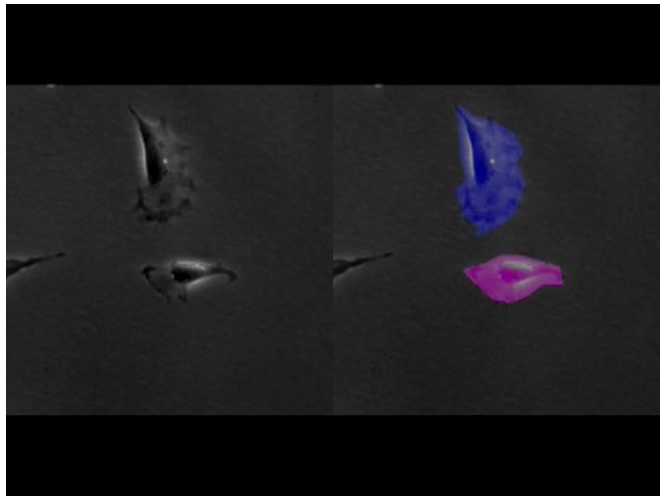
2007-2010

Software developer and project manager helping to record and analyze visible and infrared video

Source: Boulder Imaging

2010-2015

PhD student designing computer vision methods to segment and track cells in images and videos



2015-2017

Postdoctoral fellow conducting research projects related to vision and language problems

Is it edible or poisonous?

2017-Present

Assistant professor overseeing research projects related to many vision and language problems

e.g., image classification, object detection, semantic segmentation, object tracking, image captioning, visual question answering, style transfer, image inpainting, and image search

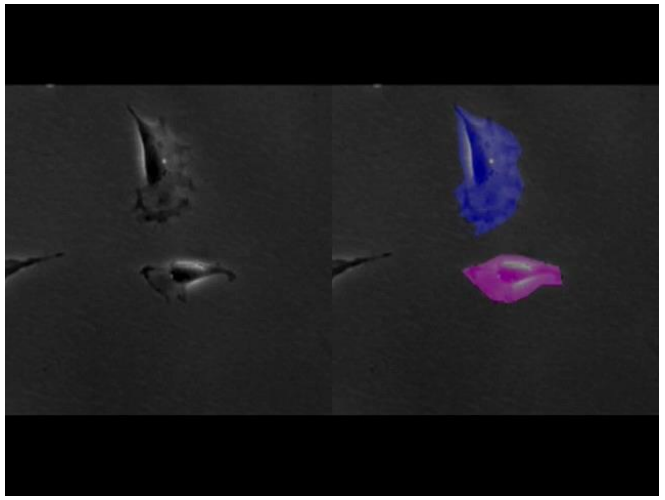
My Experience

2007-2010	2010-2015	2015-2017	2017-Present

Software developer and project manager helping to record and analyze visible and infrared video

Source: Boulder Imaging

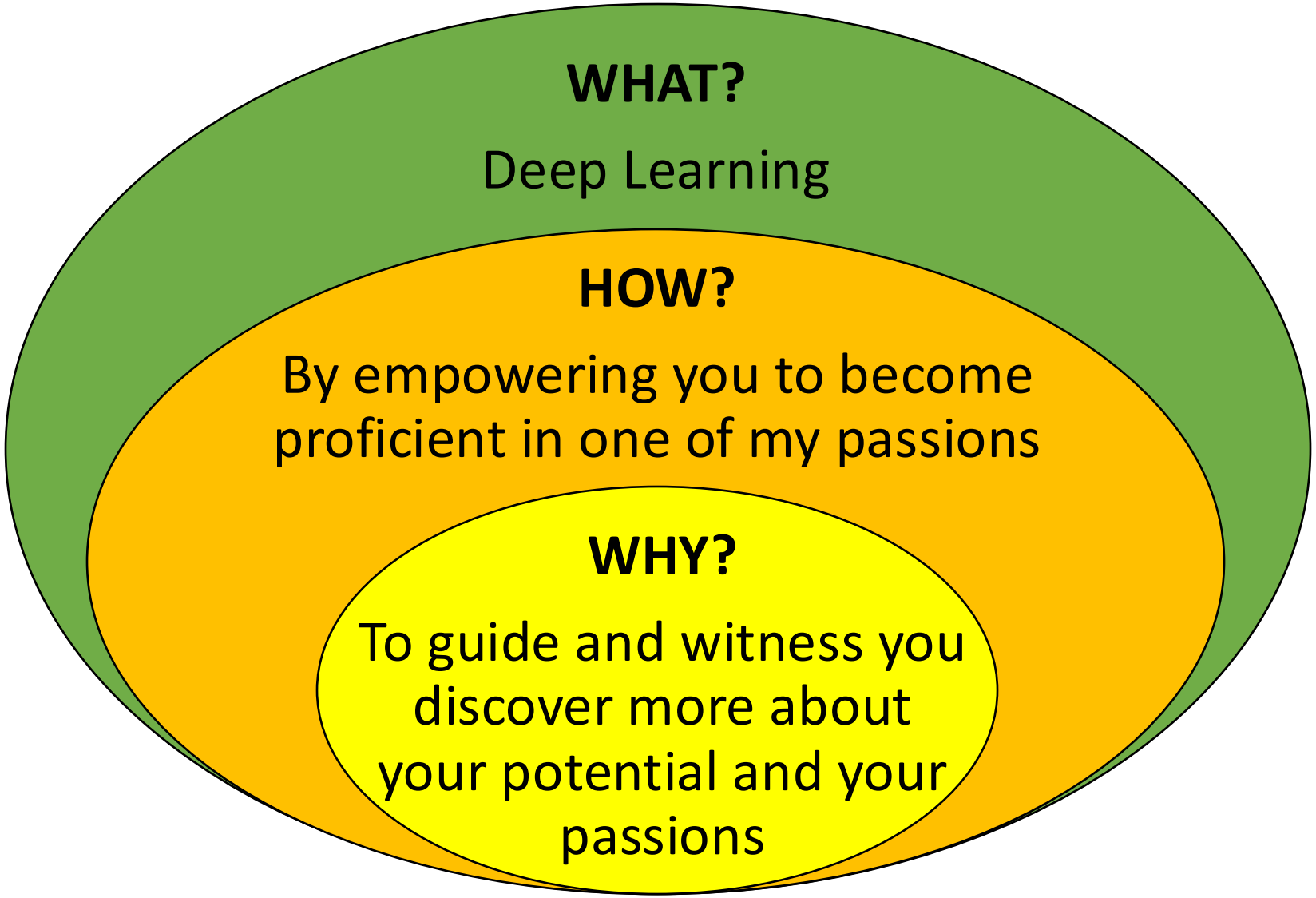
PhD student designing computer vision methods to segment and track cells in images and videos



34 publications involving deep learning

poisonous?

What is My “Why” for Teaching You…



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The End