DEMYSTIFYING ARTIFICIAL INTELLIGENCE FOR HEALTH PROFESSIONALS

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Intelligence Artificielle: Santé et Société

University of Geneva, 10th March 2022

Lecturer (about me)

- Doctoral Assistant in Computer Science at University of Neuchâtel, Switzerland
  - Research on Post-Deep-Learning: Knowledge Representation and Reasoning over a consensus-based World-Model to handle unforeseen-data and generate knowledge using Human-like Intelligence
- Experience in Academic and Industry
- Teaching experience
  - *TA in Mathematics, and Databases classes*
  - *Lecturer in AI and Distributed-Computing classes*
- Master Thesis:
  - *Open-Domain Question-Answering Conversational-Chatbot by building sub-knowledge graphs from Wikidata*

Participants (about you)

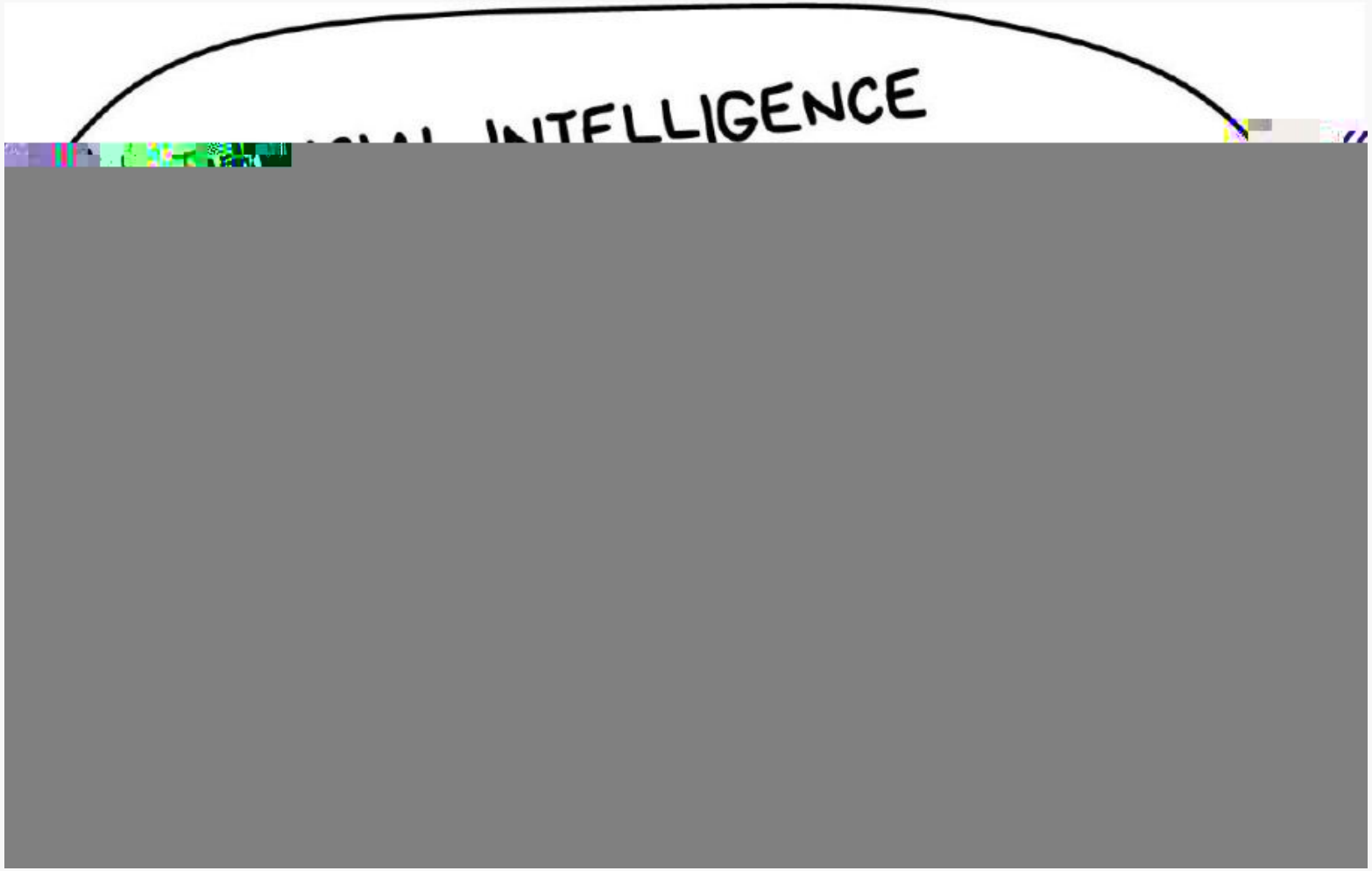
- Who are you? Why did you choose Healthcare?
- What is your experience in informatics, computer science, and mathematics/stats?
- Give me 1-2 key concepts you learned during the first two classes?
- From your point of view, what is Artificial Intelligence (AI) and its applications?
- What is the future of AI, and how will it change our lives?
- How AI currently used in Healthcare, and will it be used in the future?

Goals of the lecture

- Get grounded-bases of Artificial Intelligence
- High-level understanding of AI nowadays
- Getting critical about emerging AI technologies, and the media vulgarization
- Anticipate new tools, particularly in Healthcare

Summary

- Narrowed history of Artificial Intelligence (AI) / State of the art (SOTA)
- Get a brief understanding of ground technologies used nowadays
- Types of learning
- AI applications
- Demystification check-up
- The future of AI
- Questions and Discussion



What is Artificial Intelligence all about?

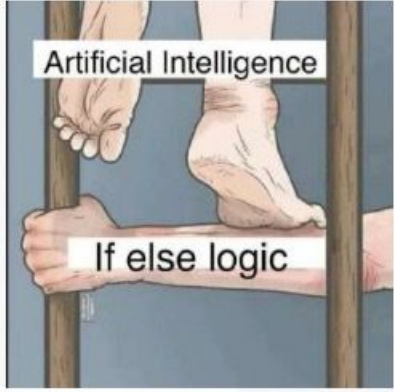
15 Handpicked AI SOTA checkpoints

- 1943 Threshold logic, algorithmic model for Artificial Neural Networks (ANN)
- 1950 The Turing Test
- 1956 The “Artificial Intelligence” term
- 1958 Perceptron, a bi-layers ANN
- 1964 Eliza, the chatbot
- 1980 Neocognitron, multi-layers ANN
- 1989 Deep Learning, Deep Neural Networks
- 2012 AI achieve human performance at recognizing cats
- 2015 OPEN AI, 1B founding
- 2016 Face expression swaping
- 2017 Deepmind beats GO champion
- 2018 Adversary learning
- 2019 Pre-trained Language Models
- 2020 Bio-Robots made with AI
- 2021 AI masters games without training nor knowing the rules

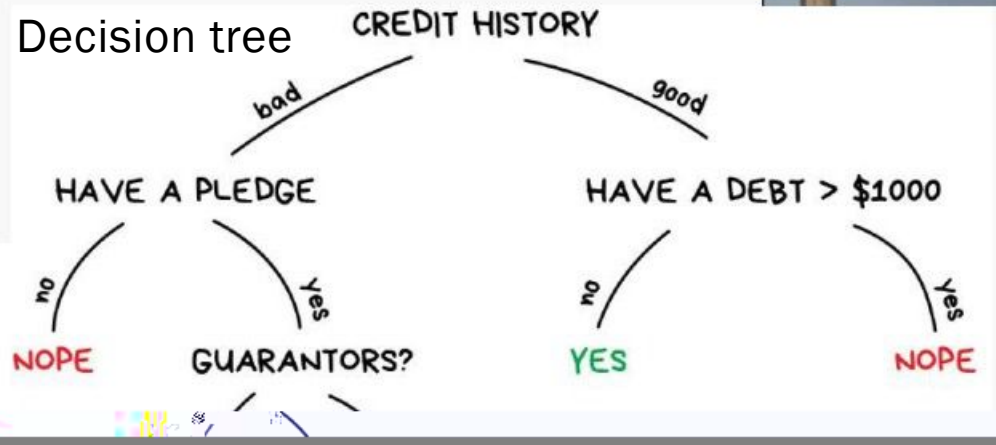
What is Artificial Intelligence?

- Term introduced by McCarthy during the Dartmouth Conference in 1956.
- Artificial: Made by humans
- Intelligence:
  - *Skilled use of reason and abstraction*
  - *Ability to apply knowledge to manipulate one's environment*
- Algorithm: A finite set of unambiguous instructions
- Natural Intelligence: Intelligence displayed by animals
- Artificial Intelligence:
  – *An algorithm made by humans and acting like humans or other animals*

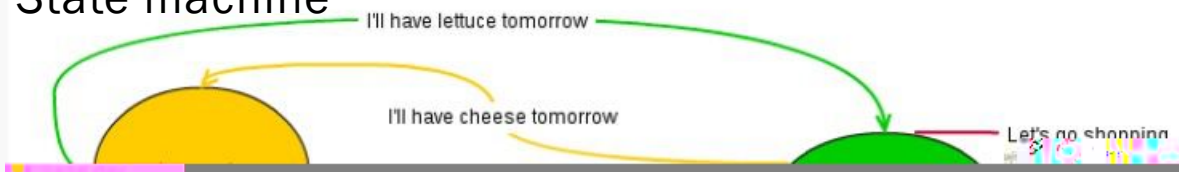
Conditional AI: Scenario-based logic



Decision tree

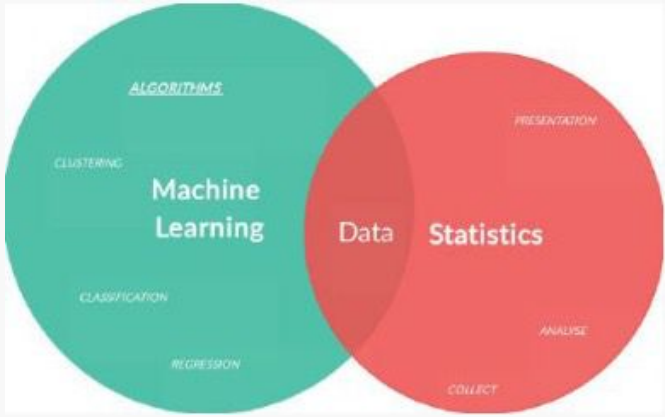


State machine

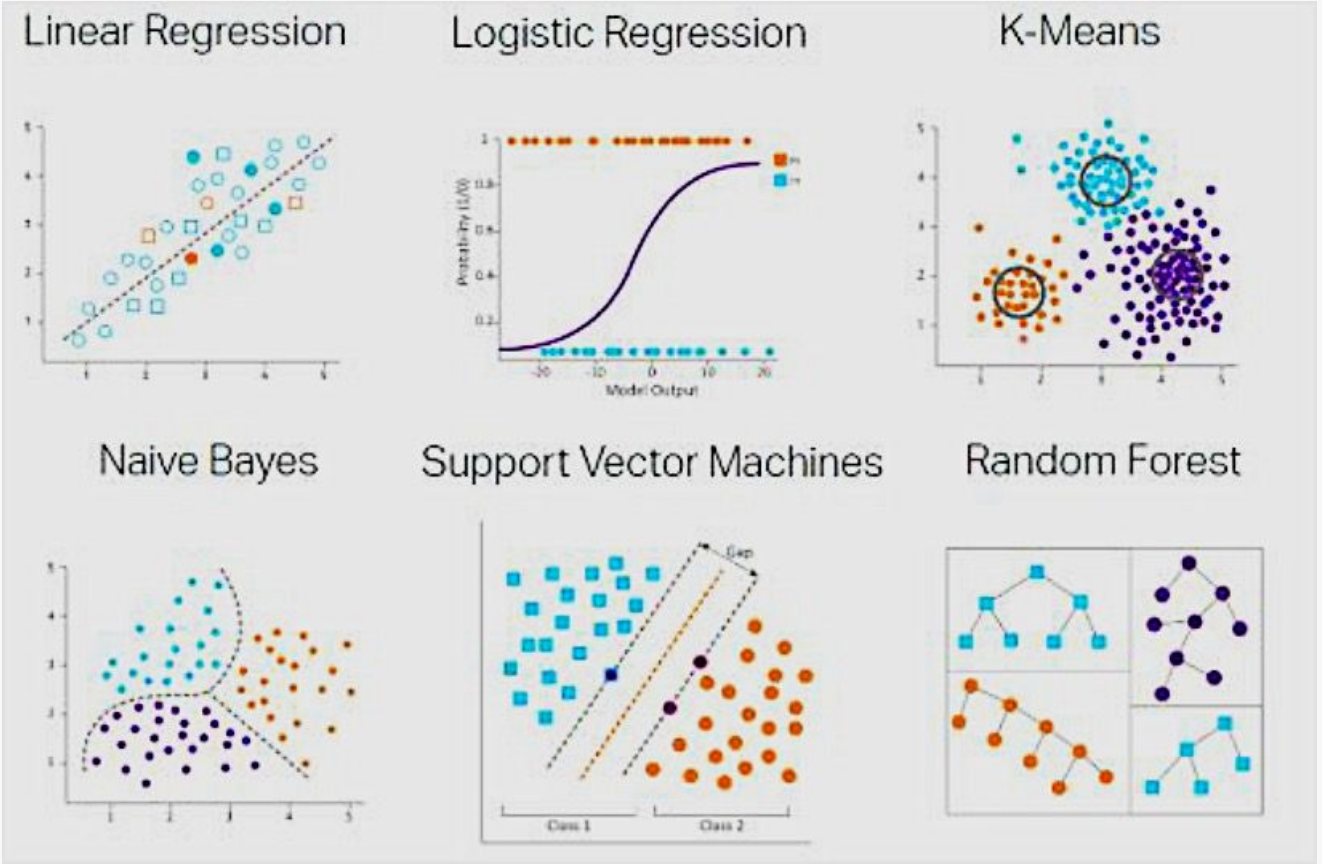


Conditions (if, else if, else)

Learning AI: Machine Learning

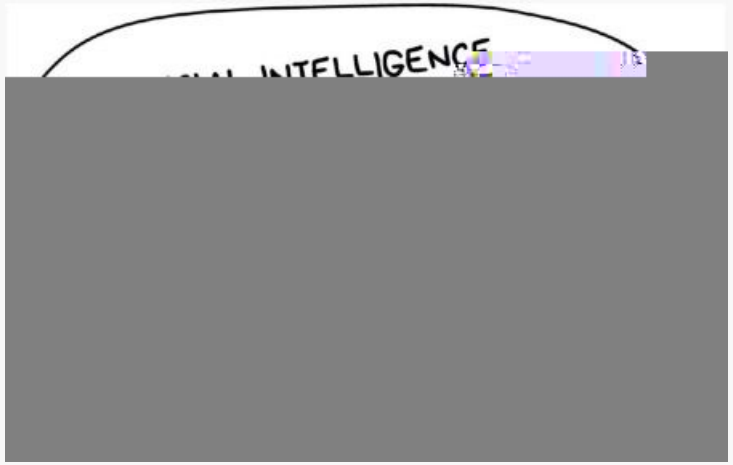


- Closely related to Applied Statistics but uses different approaches for the same problems.
  - *goodness of fit vs model skill*
- Make Models
  - *simplified representations (or abstractions) of reality*
- Focus on predictive modeling and algorithms
- Let the algorithms discover patterns (formulas) by themselves



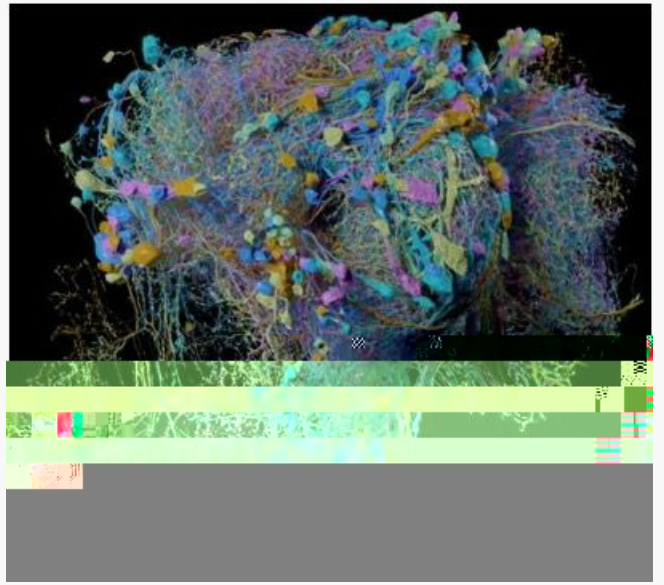
Deep-learning: Neural-Networks on steroids

What is Deep Learning (DL)

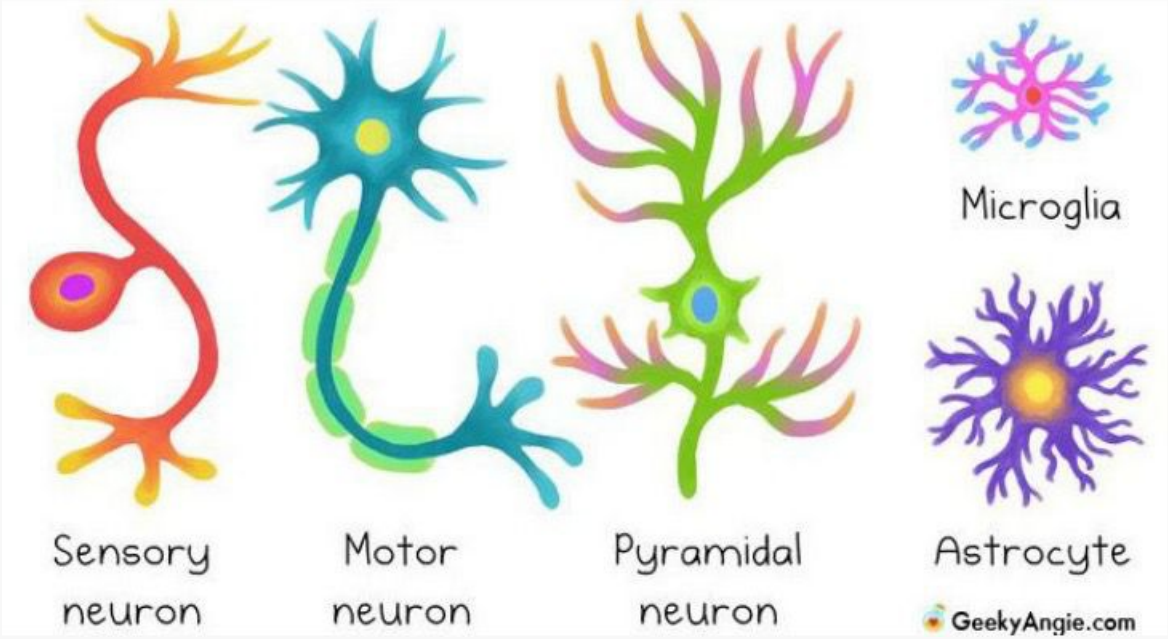


- In 1989, George Cybenko, suggested the first deep learning architecture.
- Based on the “Universal approximation” theorem
- – *Neural networks with a single hidden layer can represent various interesting functions when given appropriate parameters.*
- Until 2006, the results were worst then 1-2 layers Perceptrons.
- Uses multiple layers called “Hidden Layers”.
- Uses a recursive approach for layers to learn features.
- Designed to process huge amount of data and make models with patterns in data

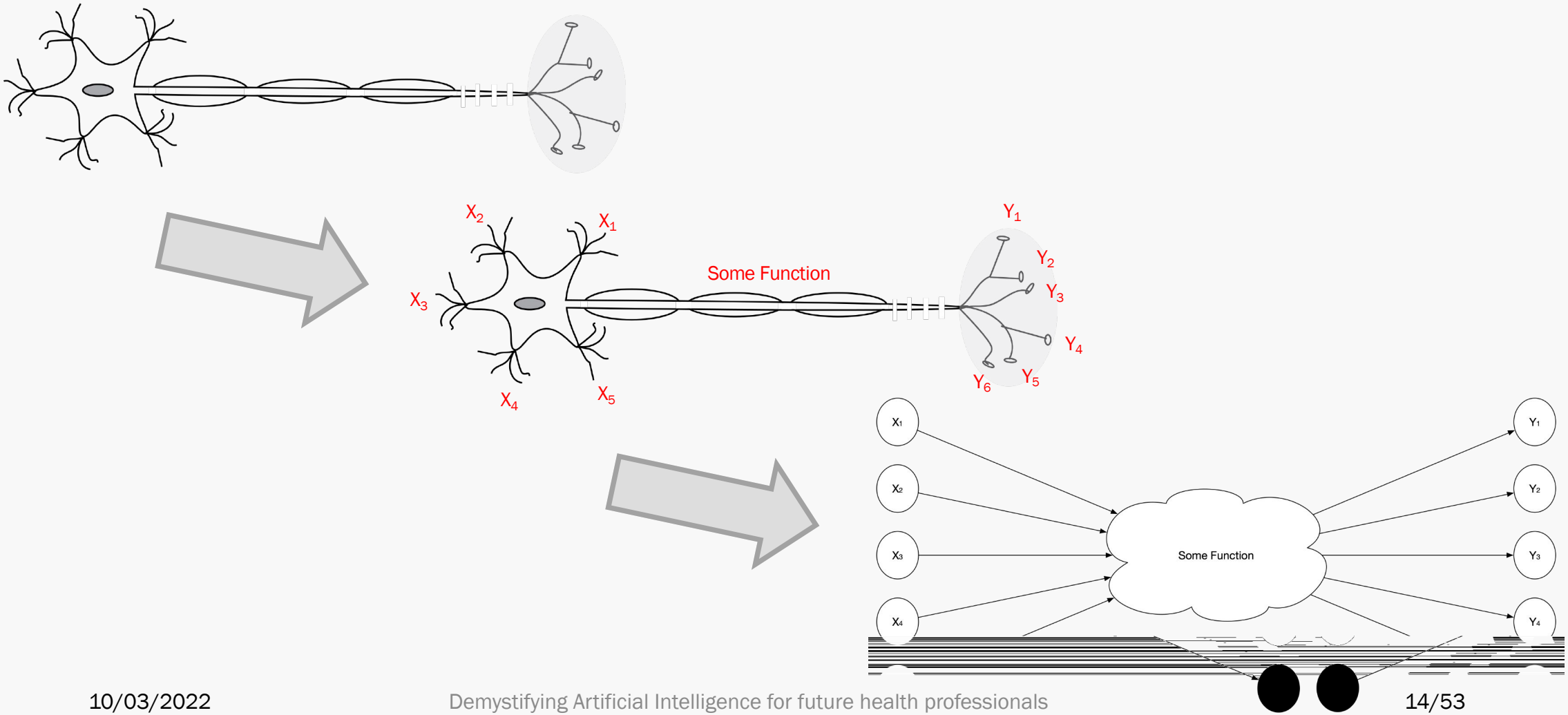
Neural Networks



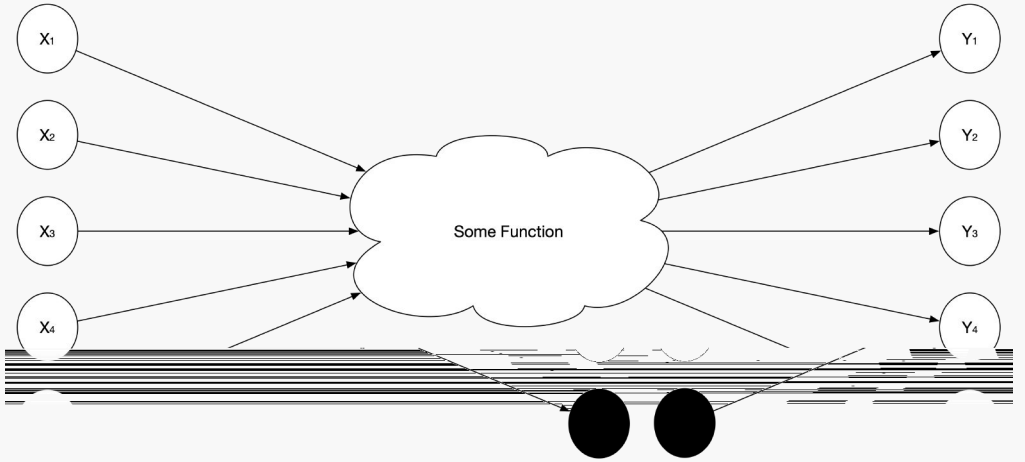
- Based on Biological Brains
- Concept introduced in 1943 as Hebbian network
  - *Based on Neural Plasticity*
- Computational model in 1954 by Wesley A. Clark

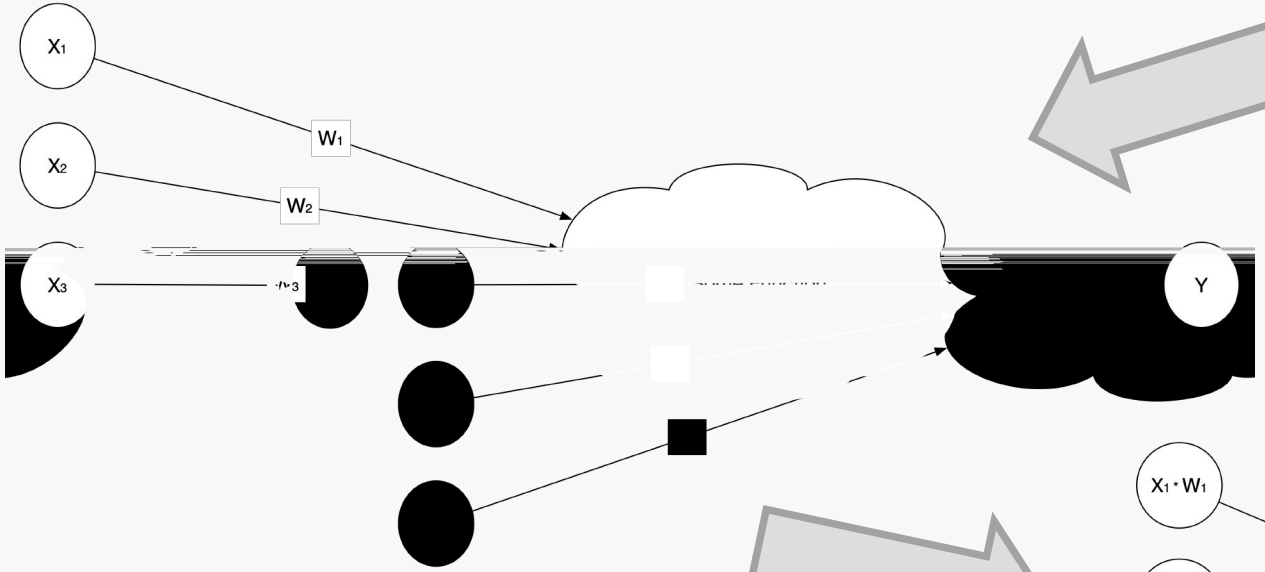


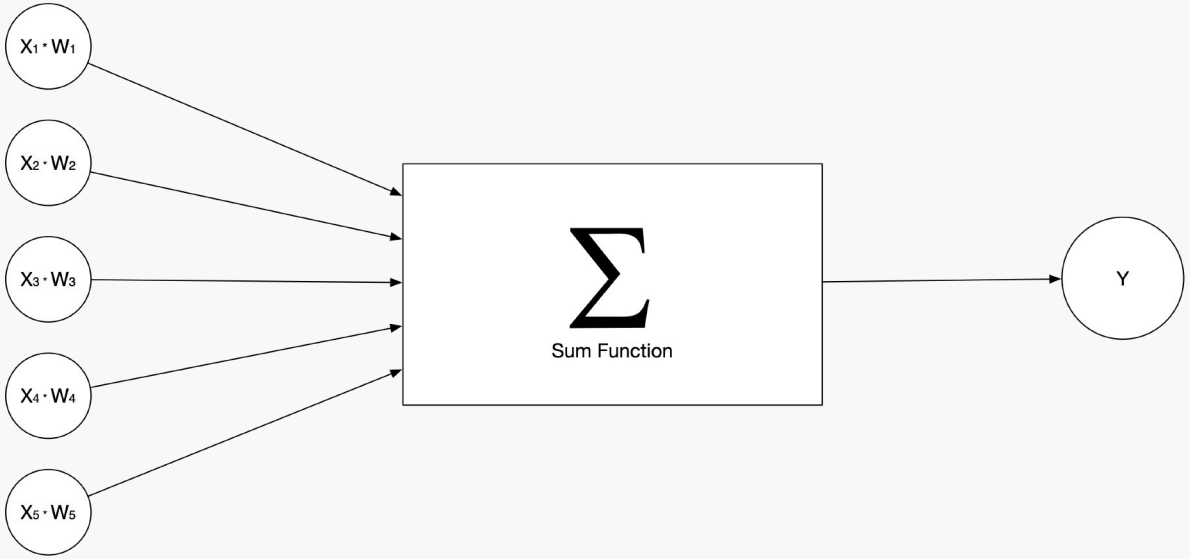
Artificial Neural Network (ANN)



From ANN to Perceptron

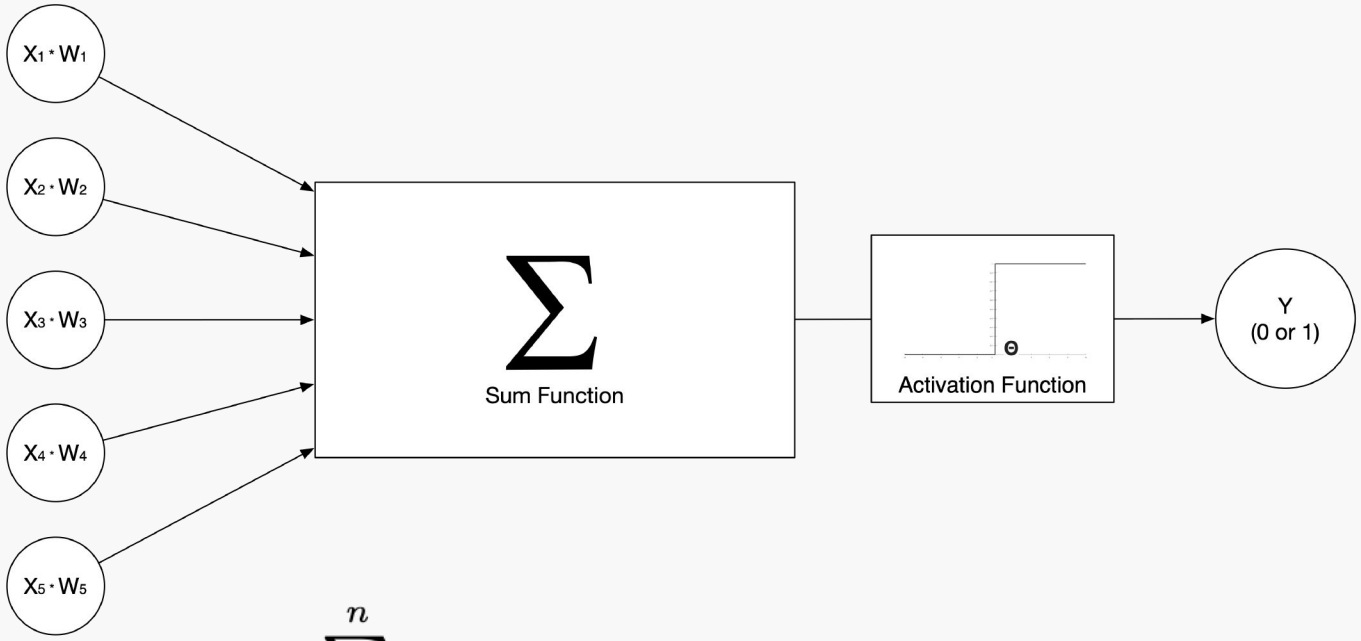






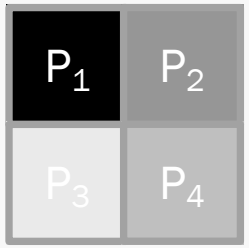
Rosenblatt's Perceptron

- Rosenblatt's perceptron from 1958

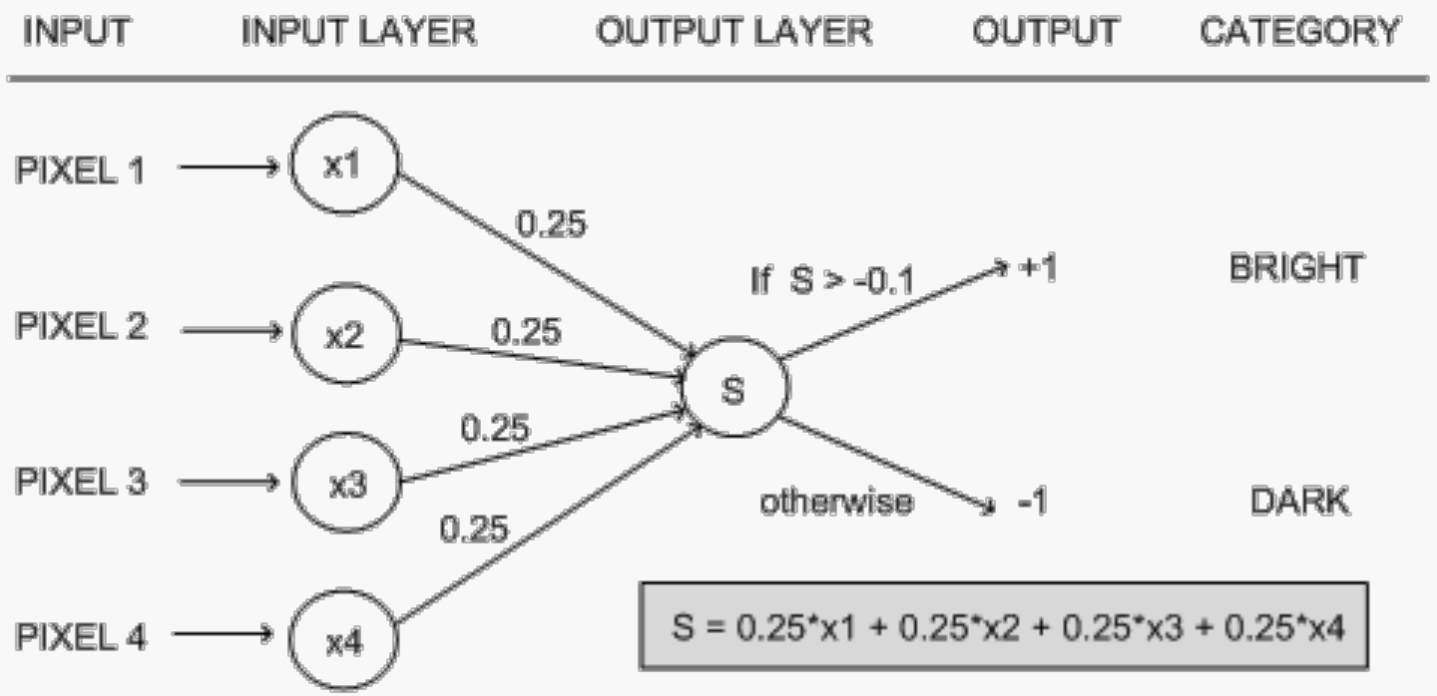


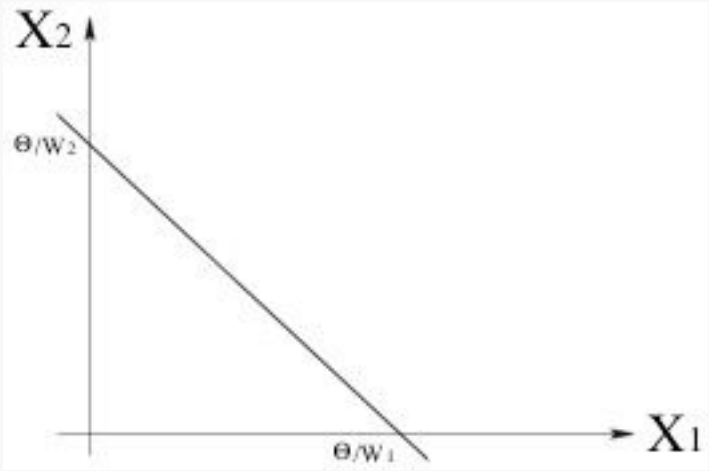
$$\text{if } \sum_{i=1}^{n} x_i w_i > \Theta \text{ then } y = 1, \text{ else } y = -1$$

Perceptron Example



Is this 4x4 pixels picture bright or dark?



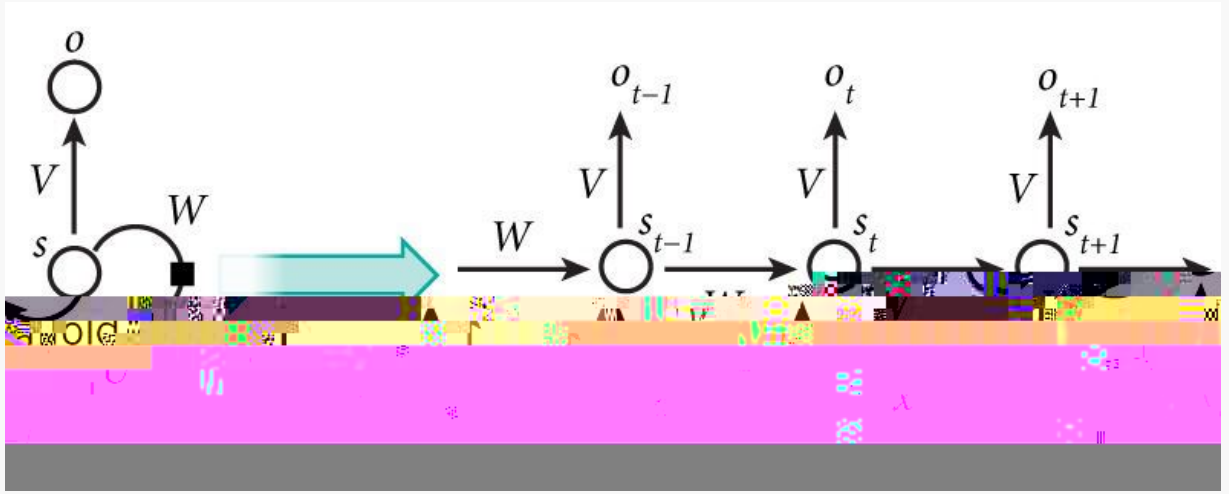


[Pictures from Sagar Sharma]

Recurrent Neural Network (RNN)

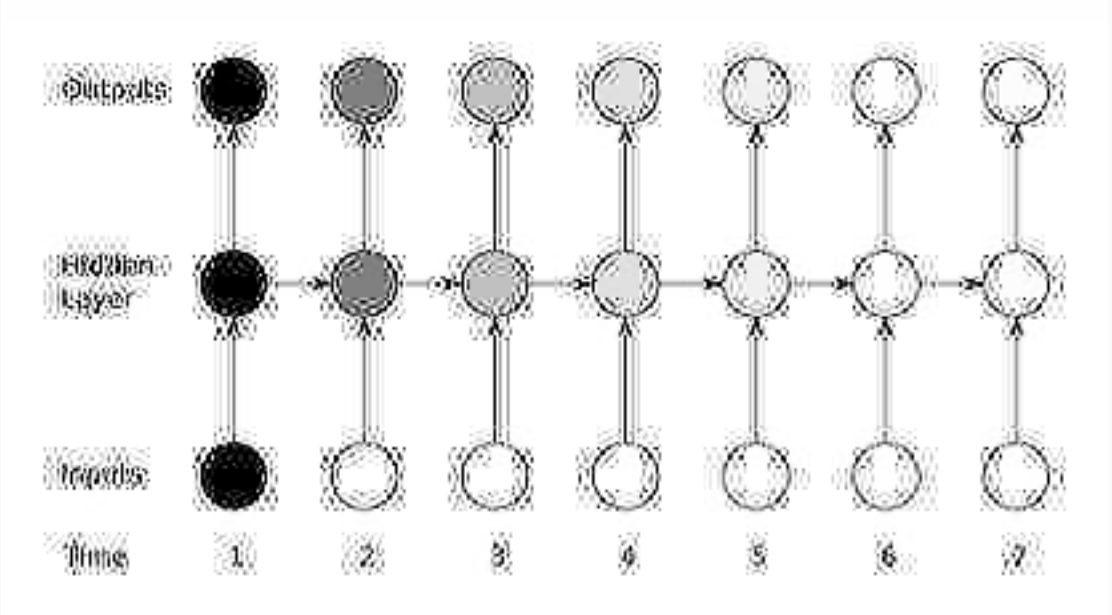
- Designed to use previously calculated states for the next state.

- For the example: k=3, each training pattern consists of [x(t), x(t+1), x(t+2) ; y(t+3)]
- U, V, and W are weights. S is the pondered memory. X is the input. O is the output.

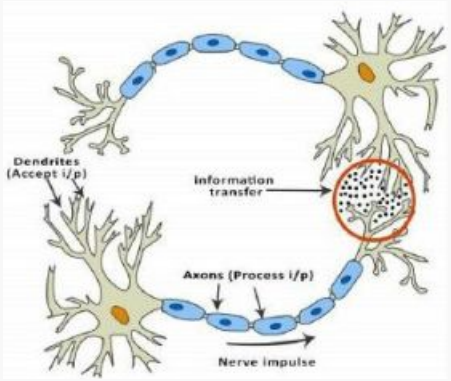


RNN: Example

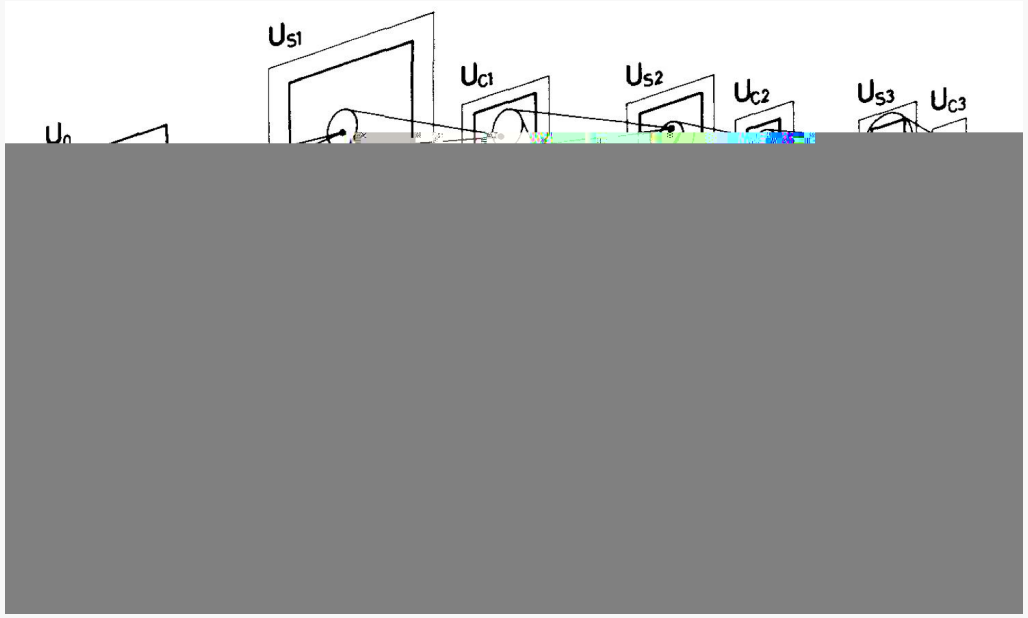
- We show here the decay over time as the network forgets iterations.

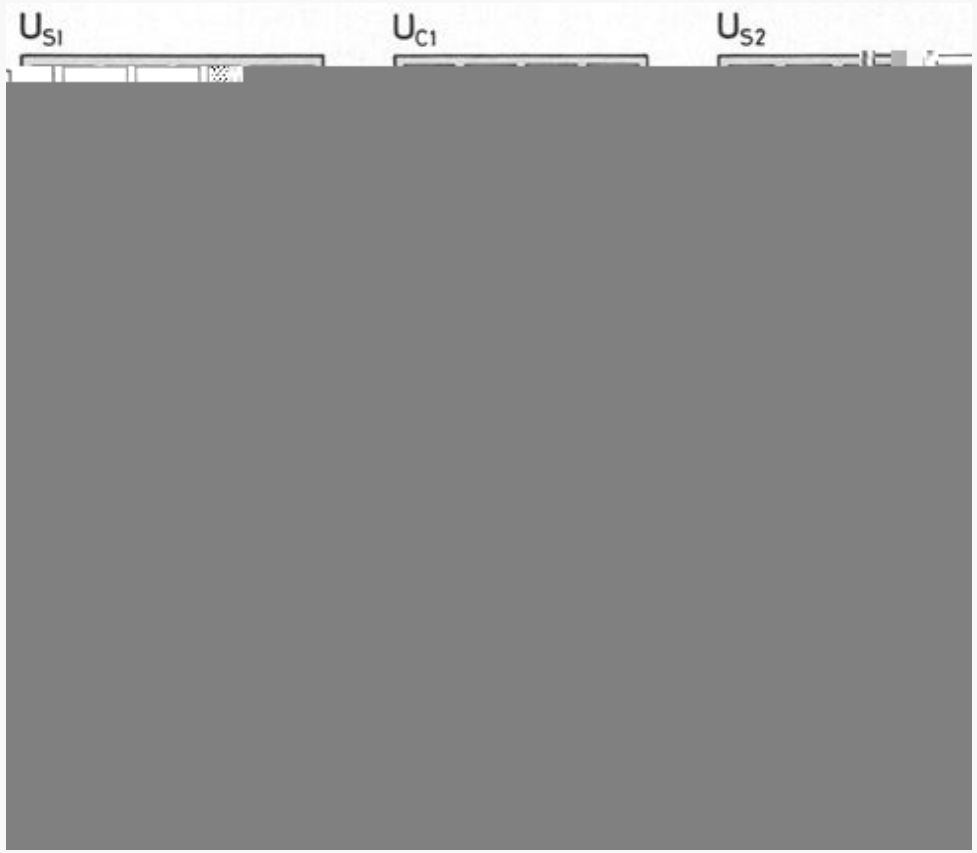


Neocognitron



- Published by Kunihiko Fukushima, in 1980.
- Multi-Layers ANN used to recognize visual patterns.
- Uses a filtering approach to extract features.





[Pictures from Kunihiko Fukushima]

Pause and Checkpoint

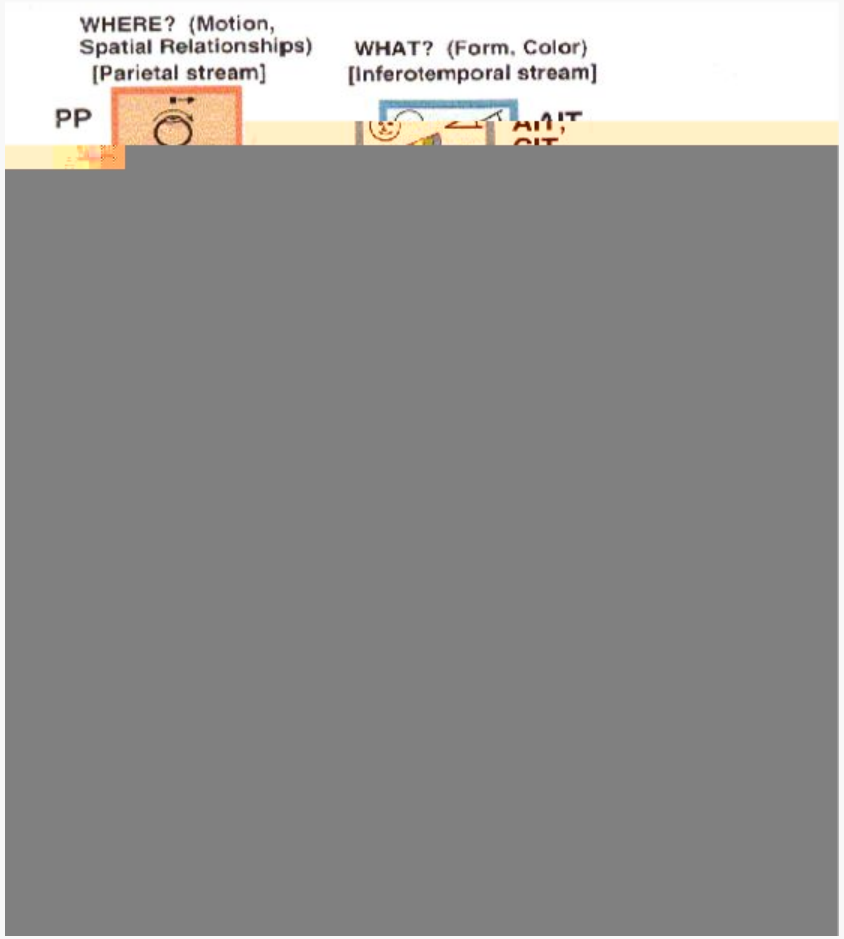
- Let's take a break to process the content

- Leaving you with a twisting open question to thinking about:
  - *We train Artificial Neural Networks to perform tasks (e.g., pictures classification) but if we ask humans to perform the same tasks aren't they also training a neural network? What would that imply? What type of inputs and outputs are we using and producing? Are humans also building models?*

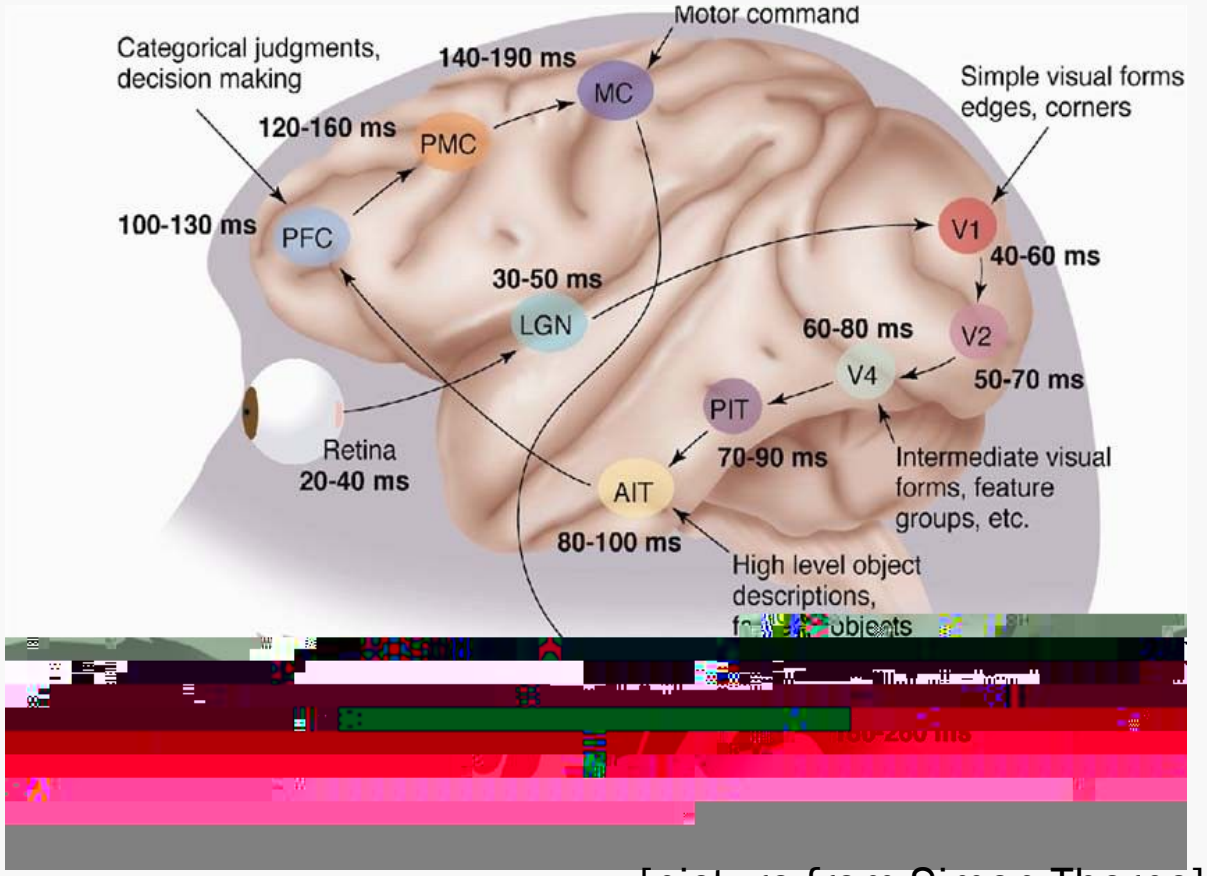
Resume lecture

- Do you have any questions related to the previous part?
- Do you have any questions non-related to the previous part?
- Tour of arguments for the open twisting question:
- *– We train Artificial Neural Networks to perform tasks (e.g., pictures classification) but if we ask humans to perform the same tasks aren't they also training a neural network? What would that imply? What type of inputs and outputs are we using and producing? Are humans also building models?*
- Were you interested or surprised by a topic in particular, why?
- Would you like to talk about specific topics in more details?

Deep-Learning: Biological Approach

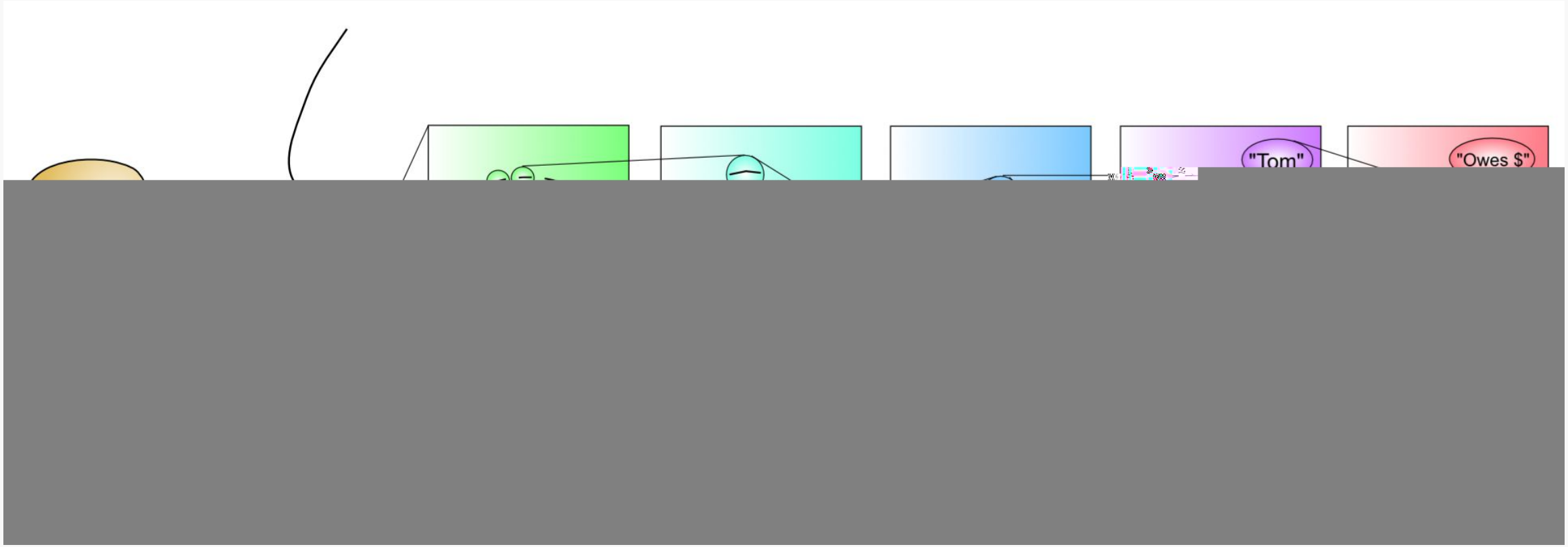


[picture from Gallant & Van Essen]



[picture from Simon Thorpe]

DL: Biological to Deep-Learning Layers



Deep-learning layers

DL: Hierarchies examples

- Image recognition:
  - *pixel -> edge -> texton -> motif -> part -> object*
- Text processing:
  - *character -> word -> word group -> clause -> sentence -> story*
- Speech:
  - *sample -> spectral band -> sound -> phoneme -> word -> ...*

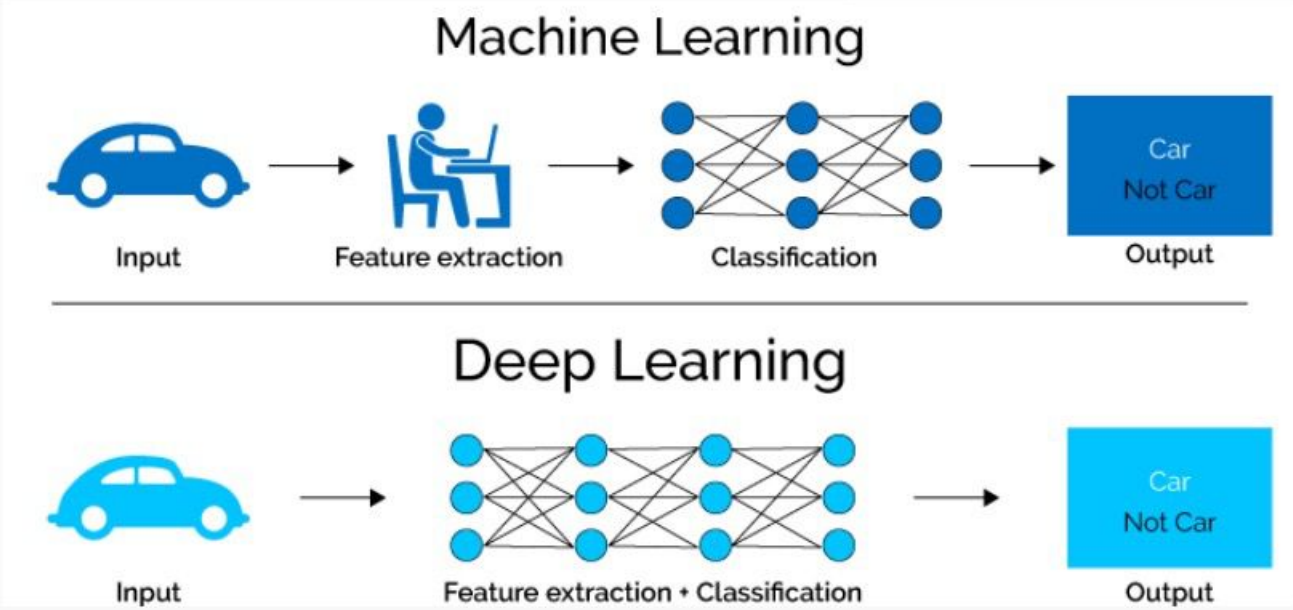
- "Anything humans can do in 0.1 sec, the right big 10-layer network can do too"
  - *Large Scale Deep Learning by Jeff Dean (Google)*

DL: demos

”Deep learning is Artificial Neural Networks on steroids”

- https://playground.tensorflow.org/
- https://cs.stanford.edu/people/karpathy/convnetjs/index.html

StAcK MoRe LaYeRs



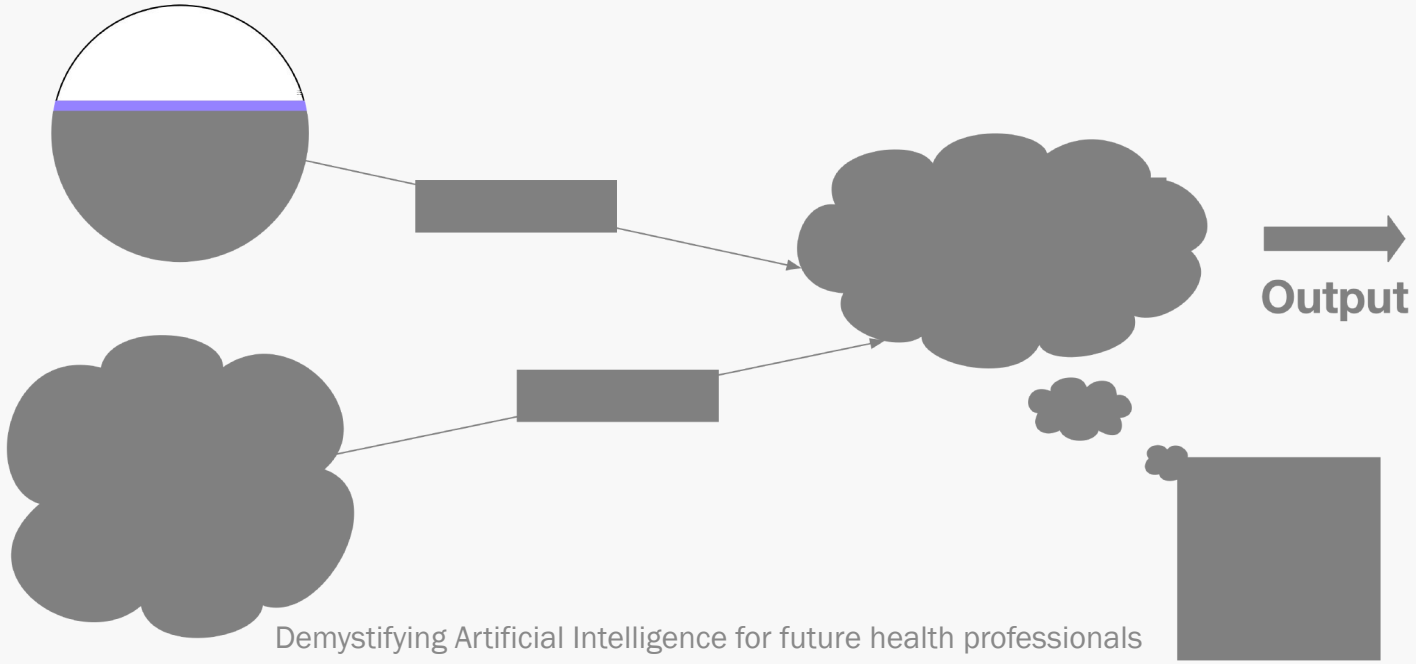
Deep-learning: let’s talk applications

Generative Adversarial Network (GAN)

- Publish in 2014 by Ian Goodfellow.
- One of the most important breakthroughs in AI since Deep Learning.
- Particularly popular nowadays as “Deepfakes”.
- The concept:
  - *Giving the ability to machines to learn to fool themselves.*

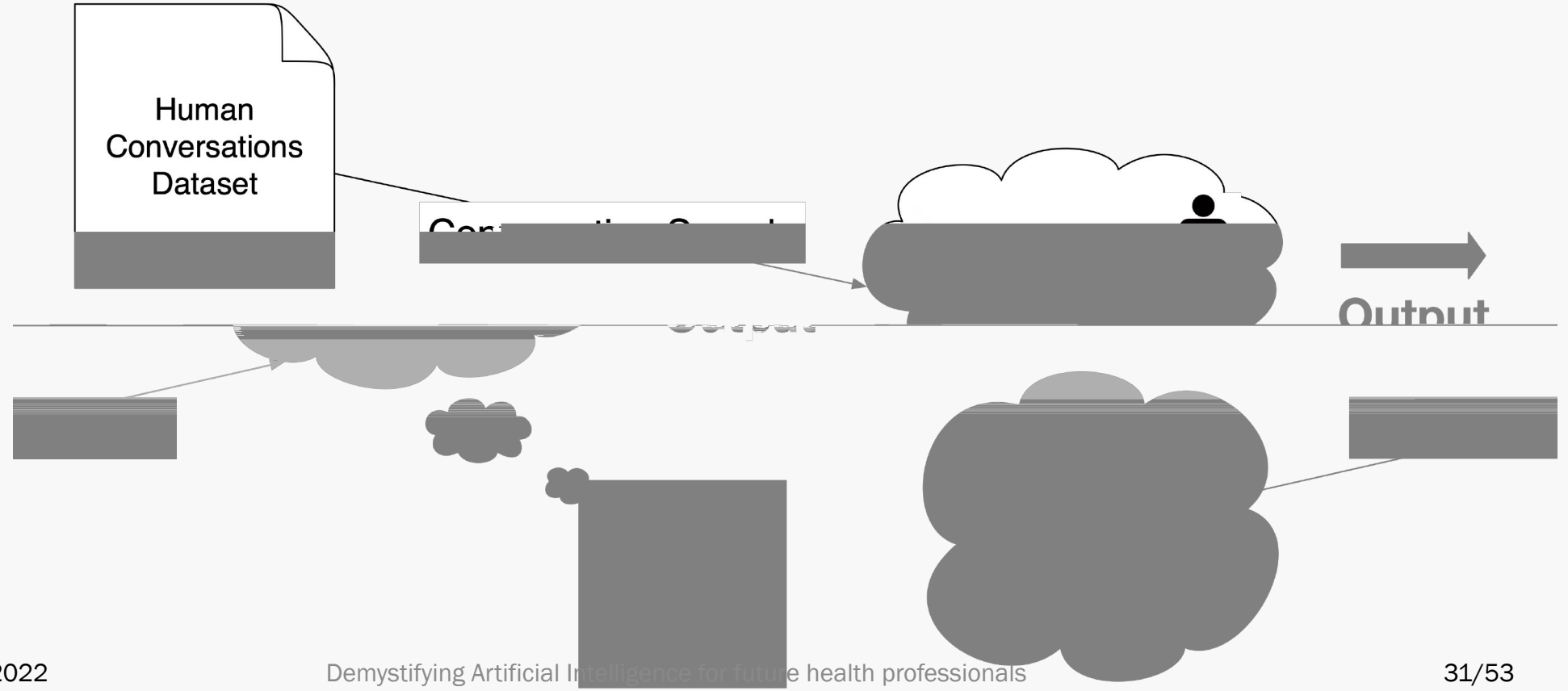
Turing Test: Evaluate AI via a chat

- *Alan Turing* and *Joseph Weizenbaum (Eliza)*, are considered as the fathers of AI.
- In 1950, they forecasted human-like communication with computers.
- *Alan Turing* proposed a test to differentiate humans from machines, the Turing Test.

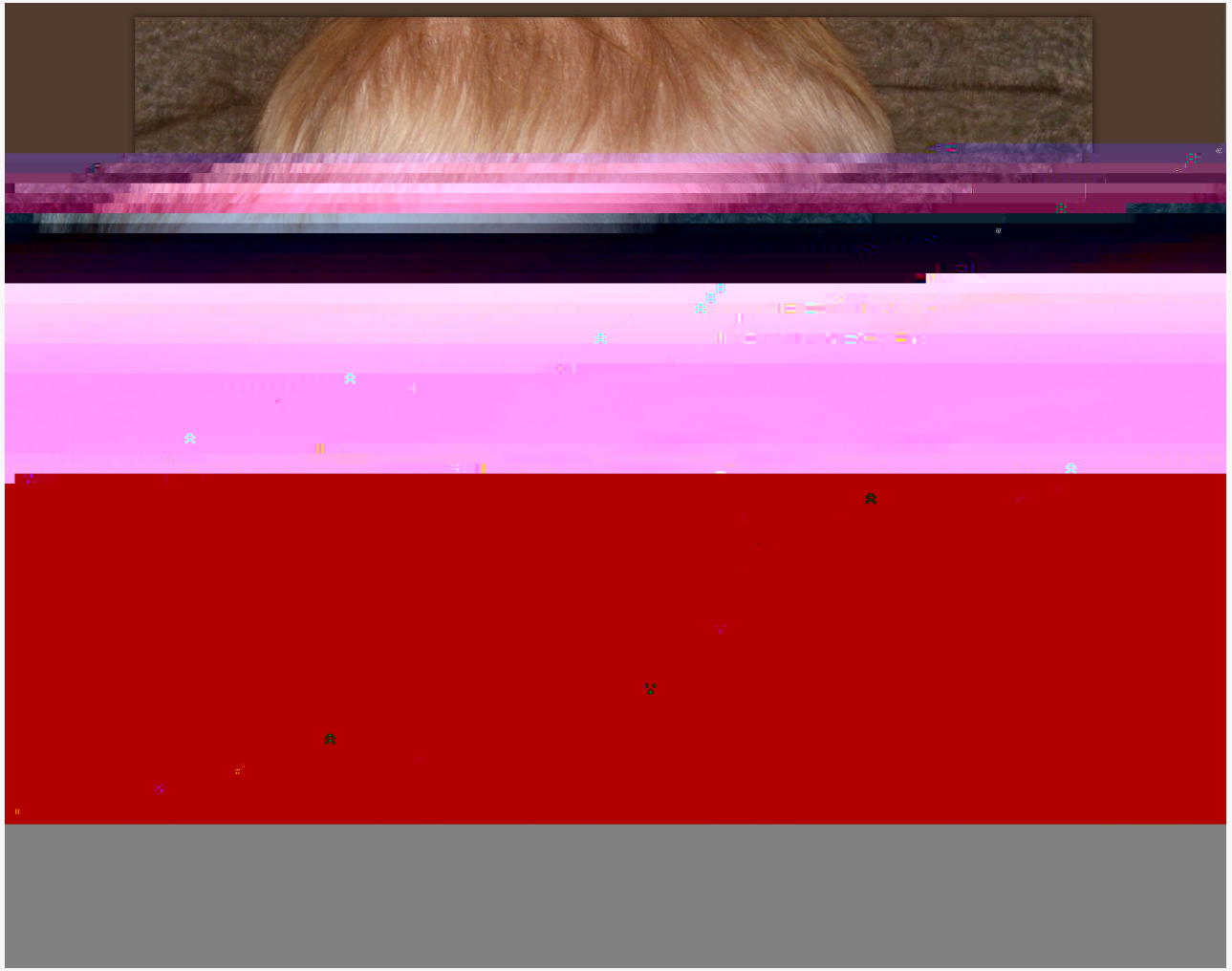


GAN: Turing test Example

- Learns by itself to perform the Turing test.



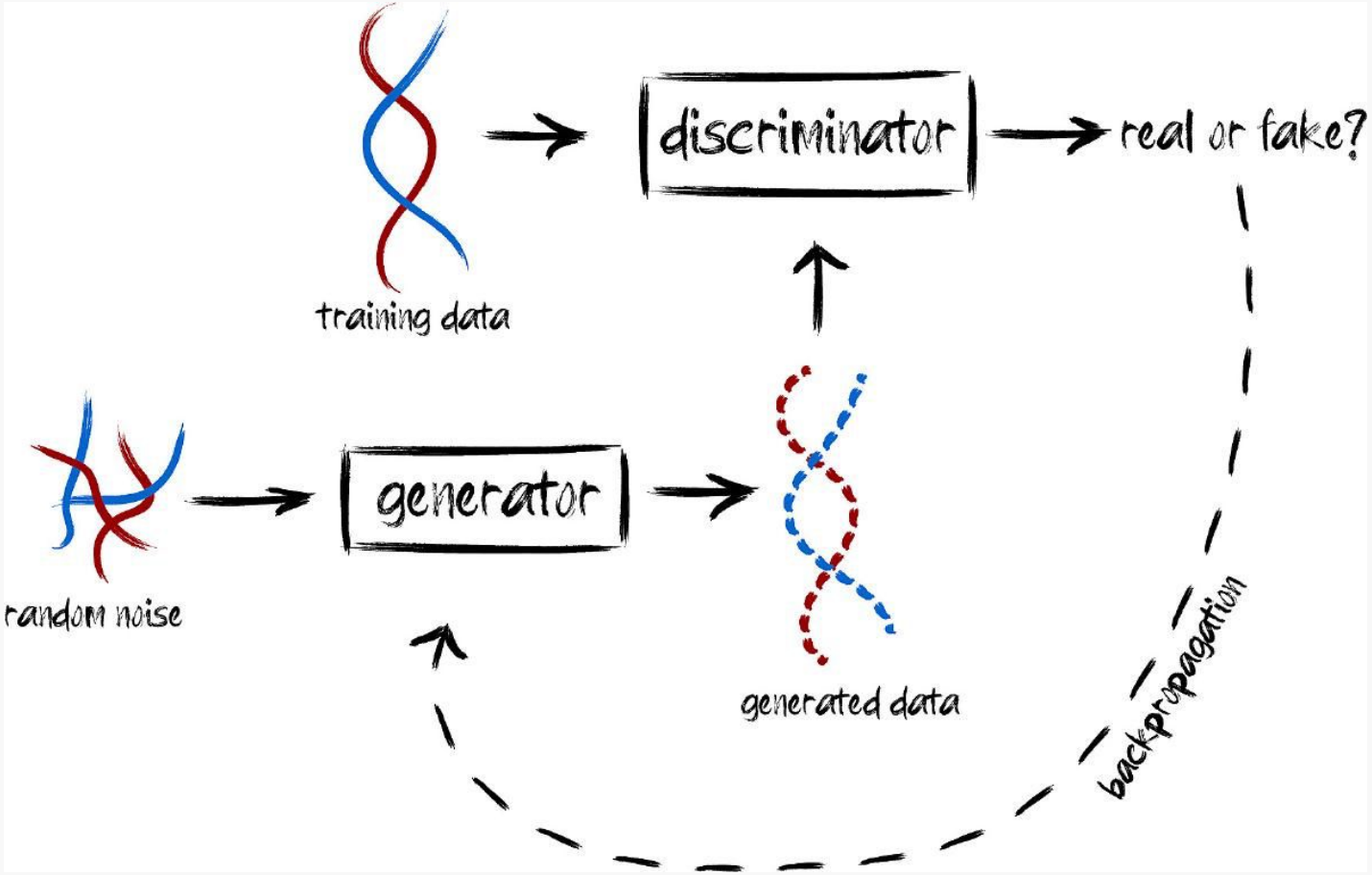
GAN: Face generation Example



https://thispersondoesnotexist.com

GAN: Making human genomes

https://journals.plos.org/plosgenetics/article?id=10.1371/journal.pgen.1009303



Pre-trained Models

- Introduced in 2019 by Google.
- The technique comes from the Natural Language Processing (NLP) field.
- During training, the goal is to capture all features and generalize a specific domain.
- In the case of NLP, the whole language is captured
  - *Vocabulary, Context, Semantics, Syntax, Grammar, and probably more.*
- Has the ability to be easily customized for specific tasks.
  - *Classifying, Find documents, Paraphrasing, Question Answering, etc.*
  - *Chatbots, Generate natural language sentences, etc.*

Pre-trained Language model Example

- In **bold**, the initial input. The following has been generated by the algorithm

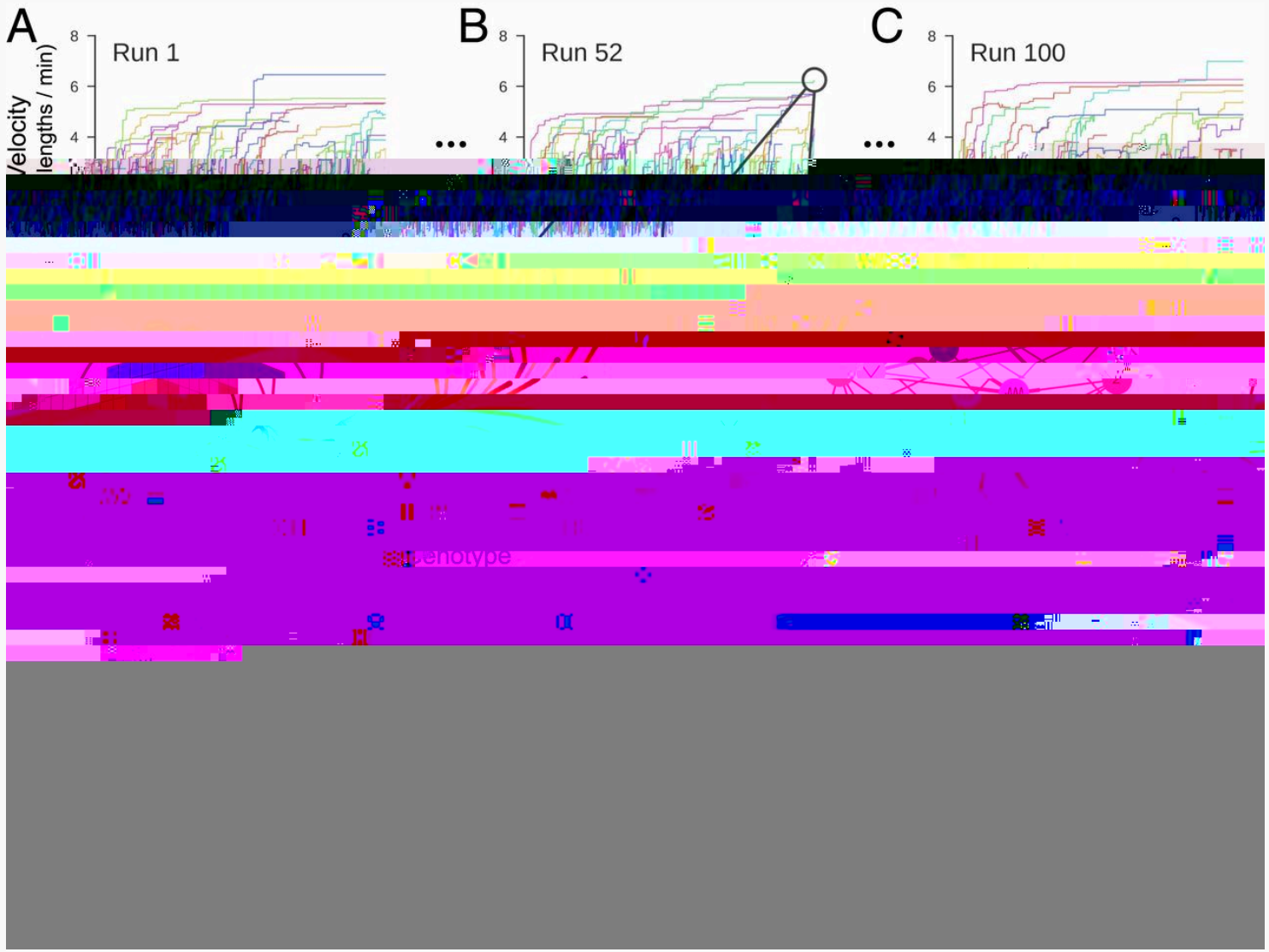
"**On the 10th March 2022, Romain is giving a lecture to the future professionals at the University of Geneva.** He could just be telling them how to be a better professional or he could be telling them how to be a better candidate.

He's about to mention a term used in his field called 'clinical dysphoria'. It's a condition that leaves some doctors asking themselves: what kind of person would want to become a doctor?"

https://talktotransformer.com

Xenobots

- “A scalable pipeline for designing reconfigurable organisms”
- Using AI to design processes to build living robots
- https://youtu.be/V8FiSIPf4dA?t=157
- https://www.youtube.com/watch?v=q_Vg7-23PAQ

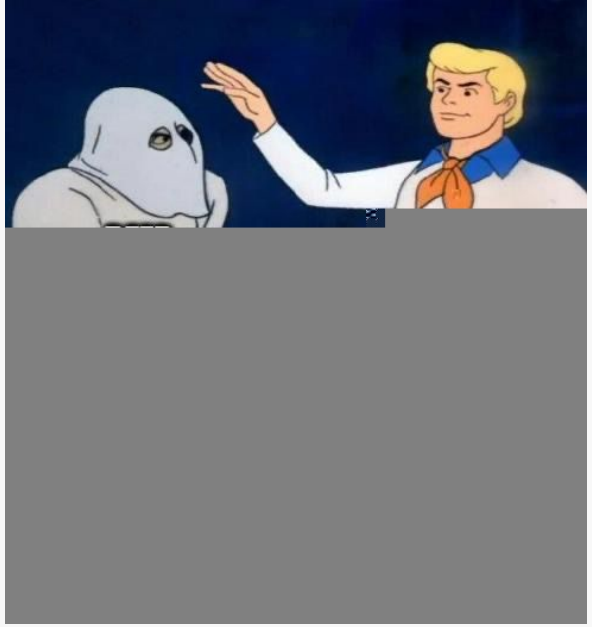


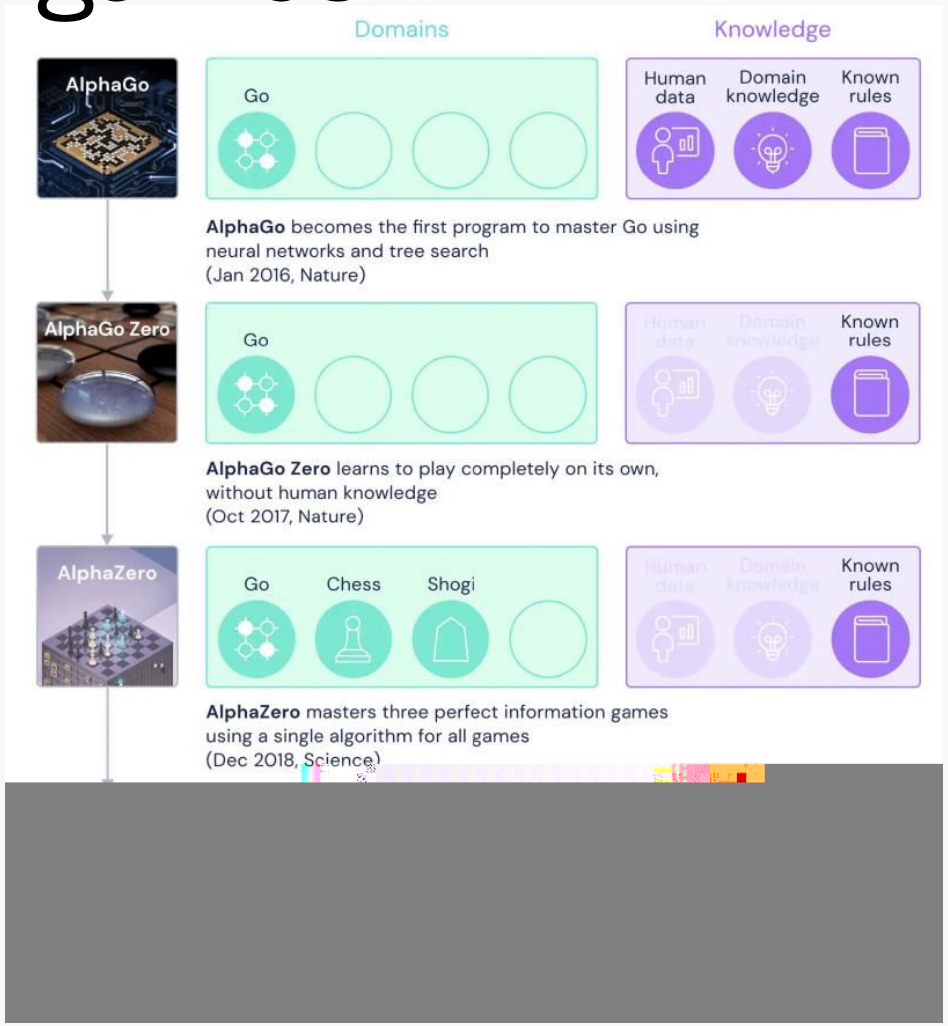
See next slide for details

Xenobots example: explained

- (*A–C)* 100 evolutionary trials were simulated. Each line represents the velocity.
- (*D, E*) Dictates anatomy and behavior by determining where and how voxels are combined, passive (cyan) or contractile (red).
- (*F*) are a result of randomly perturbing the actuation of each contractile cell during each evaluation period. Originates from blue and moves to final red destination.
- (*G*) Run simulations
- (*H*) As genotypes are scale-free, the anatomical resolution of any design can be increased while preserving geometry (but not necessarily behavior).
- (*I*) Run more simulations. And keep the best.

Ai in video-games





More fields of AI applications

- Healthcare
- Transportation
- Communication
- Robotics
- Mechanics
- Trading
- Web

Pause and Checkpoint

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- Leaving you with a twisting open question to thinking about:
  - *Who’s first, Chicken or the egg: Is Neuroscience helping Computer Science or is Computer Science helping Neuroscience to understand how the brain works*

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As of July 2021

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Trap: Weak-AI vs Strong-AI

- Optimizer, Classifier
- Autonomous, Perform better than humans
- Self-maintaining, Self-improving, Replicating
- Self-Aware / Consciousness

- Weak-AI: The system acts as it thinks
- Strong-AI: The system can think

- In current research progress, Strong-AI is still Science-Fiction

Weak-AI: Machine Learning (ML)

- All notions described previously are what we call “Machine Learning”.
- The goal is to do predictions based on data
- Learning methods
  - *Supervised (*labeled training data)
  - *Self-Supervised (unlabeled* training data*)*
  - *Semi-Supervised (use both labeled and unlabeled training data)*
  - *Reinforcement (reward base)*
  - *Grounded Symbolic (reason by induction)*
  - *Meta-Learning (generalizes the learning task)*
  - *Continuous learning (updating models on the go)*
  - *Sub-Models (consensus-based prediction)*

It’s all about Data

Sizes Types

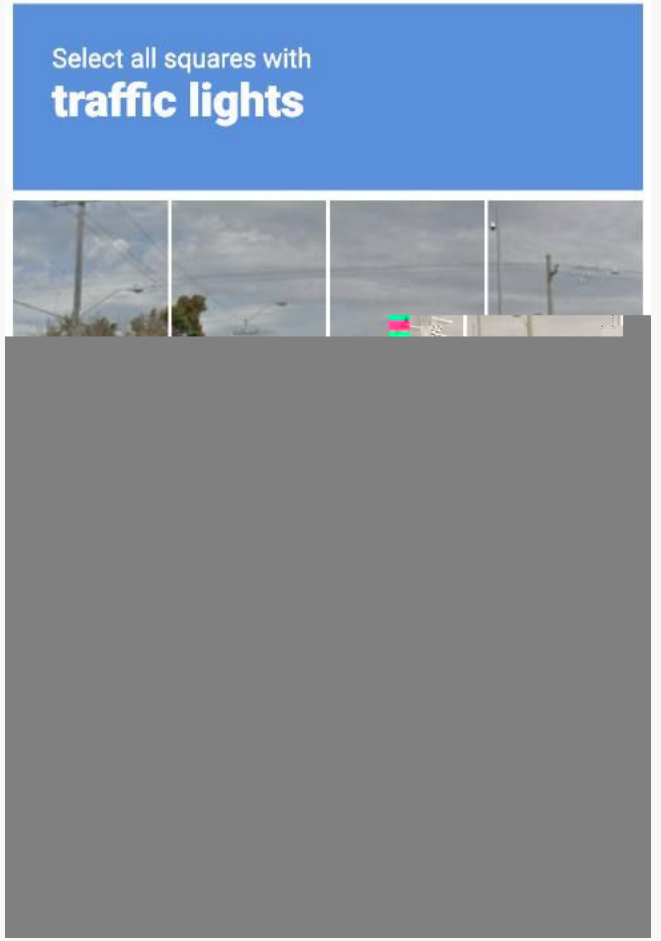
- *Large datasets*
- *Medium datasets*
- *Small datasets*
- *No datasets or few data rows*

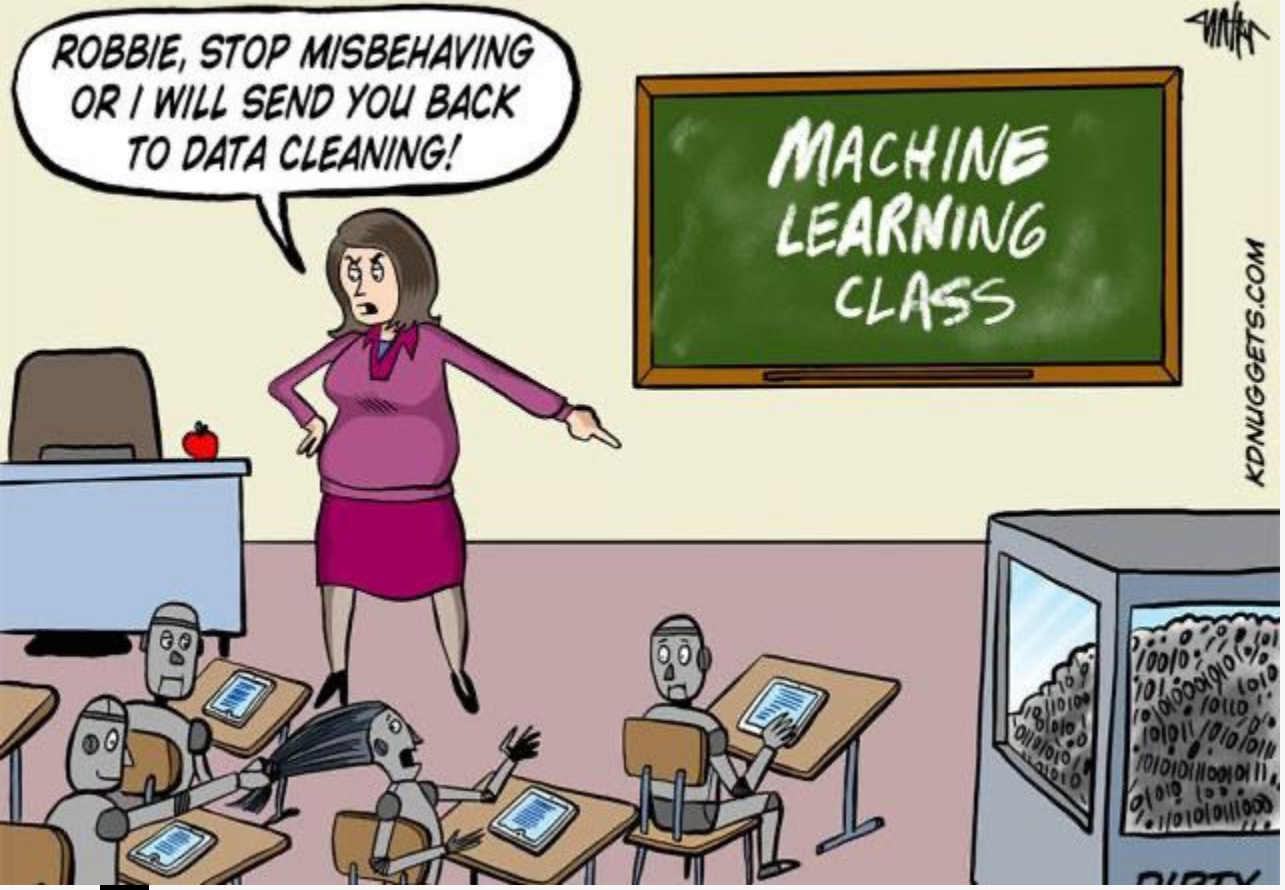
Big Data

- *Generic term for huge datasets*
- *Collecting multiple information for the same event*
- *Noises*

Types

- *Text*
- *Images*
- *Videos*
- *Geolocations*
- *Sensors*
- *Meta-information*

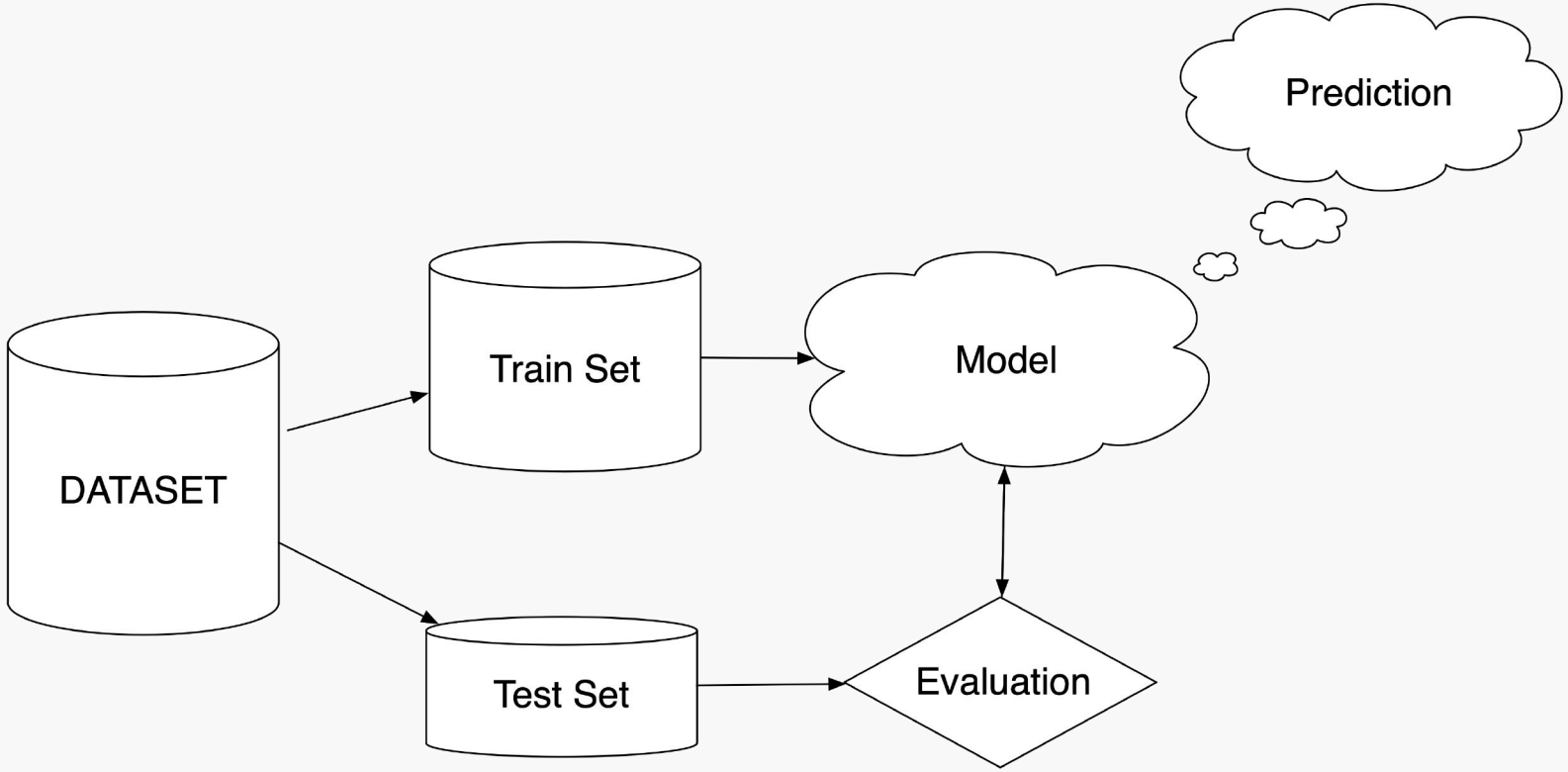




How machines learn

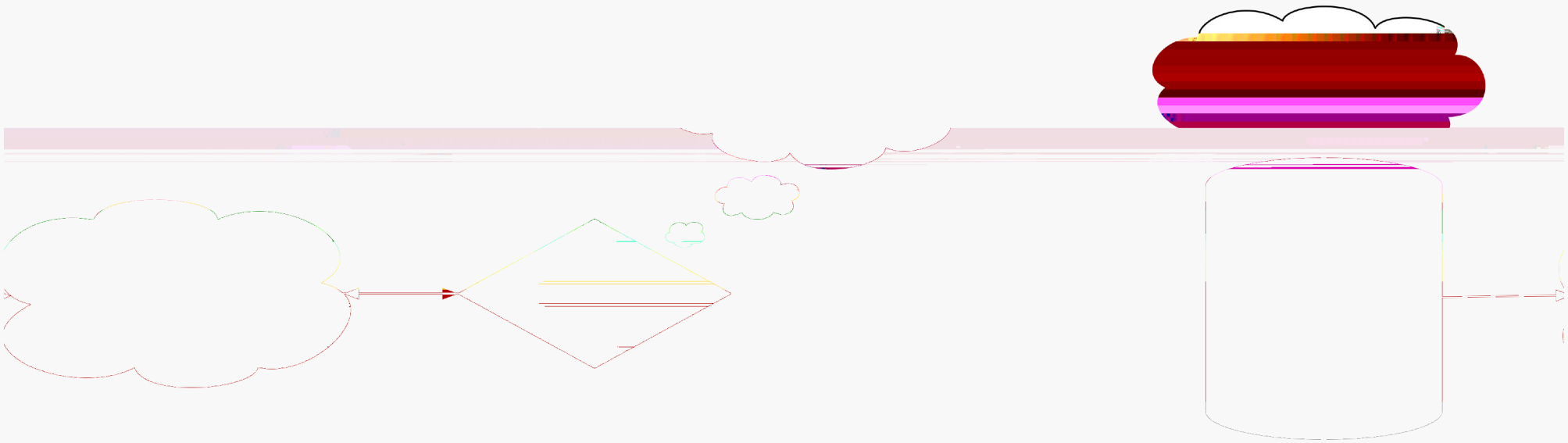
Supervised Learning

- Example: Image classification, object detection , face recognition, etc.



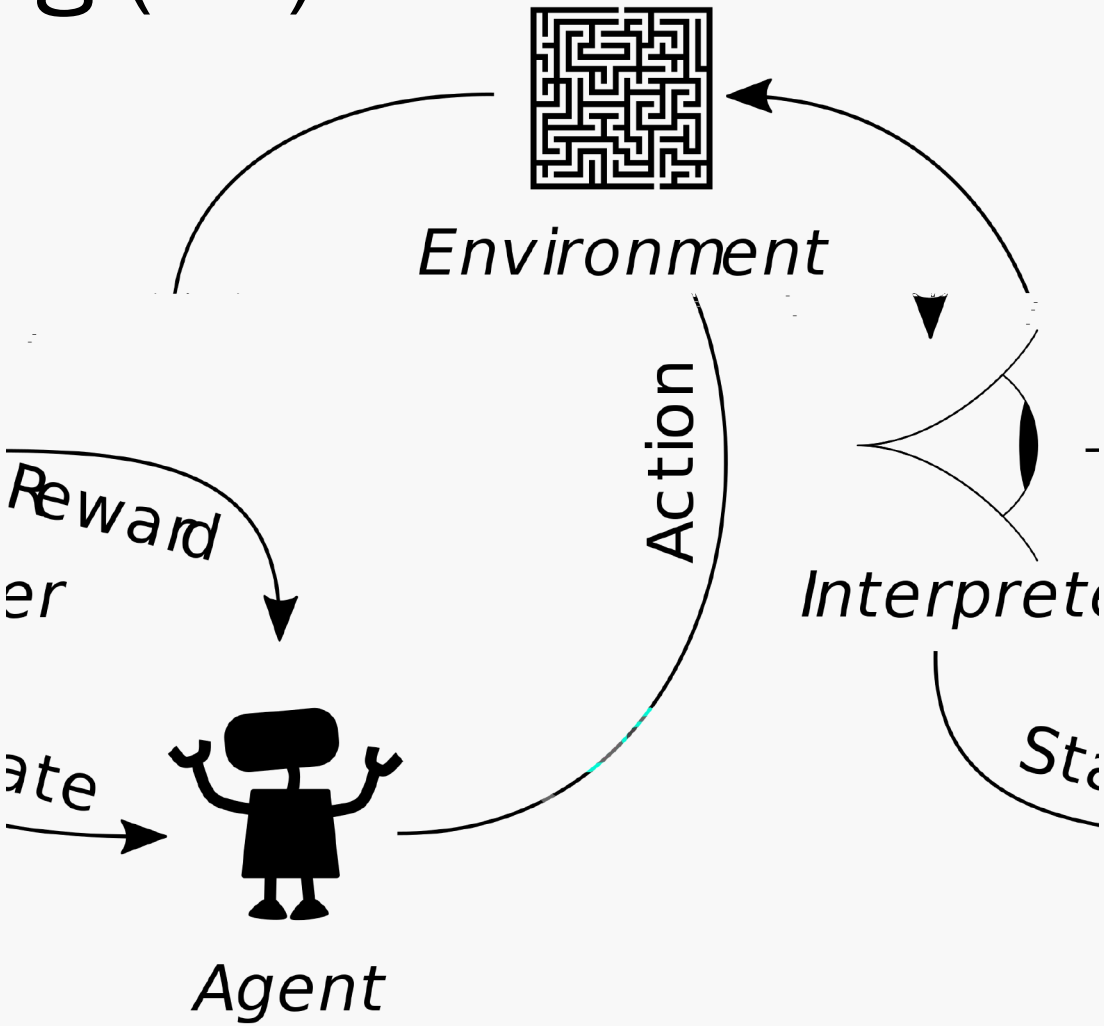
Self-Supervised Learning

- Examples: Word embedding, Image Resizing, etc.



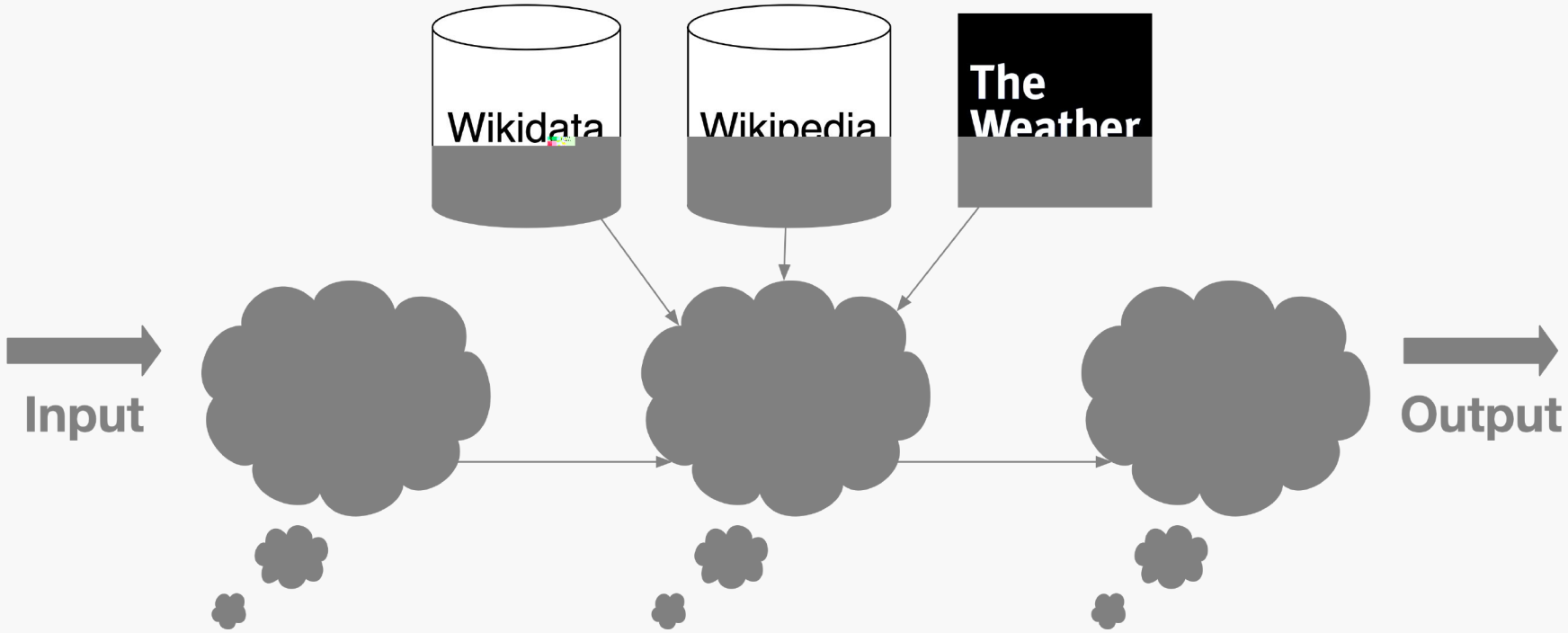
Reinforcement Learning (RL)

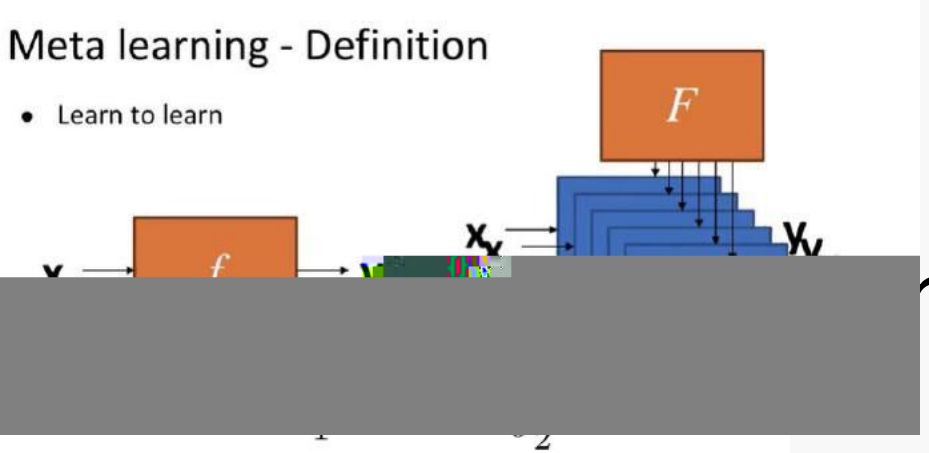
- Takes actions to maximize reward and minimize penalties
- https://cs.stanford.edu/people/karpathy/convnetjs/demo/rldemo.html



Grounded Symbolic Learning

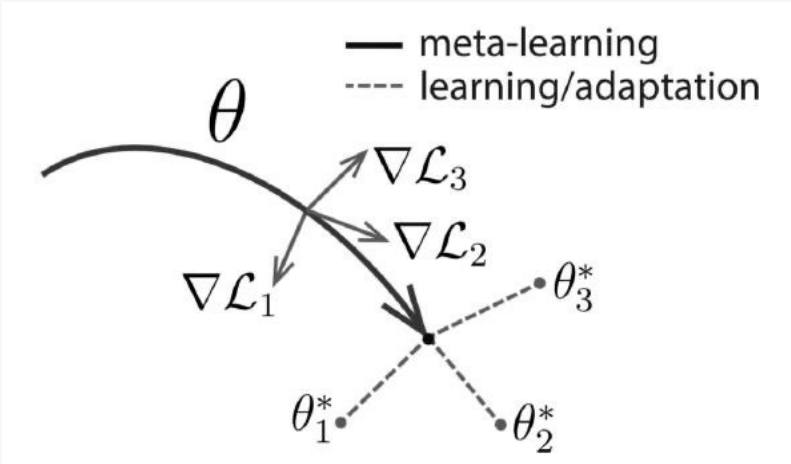
- Example: Combining Knowledge Bases with weather forecaster.
- Q&A “What is the color in autumn of a leaf in Switzerland?”

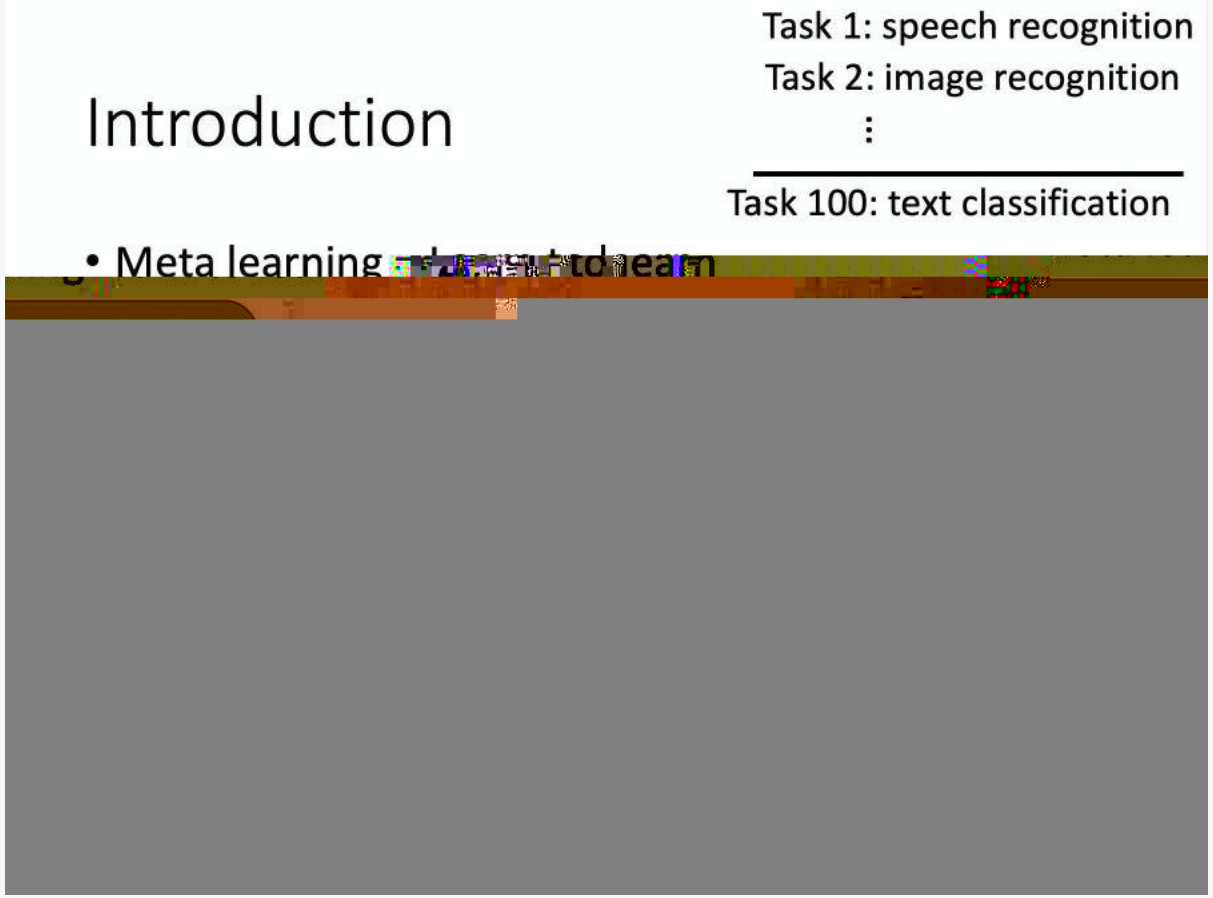


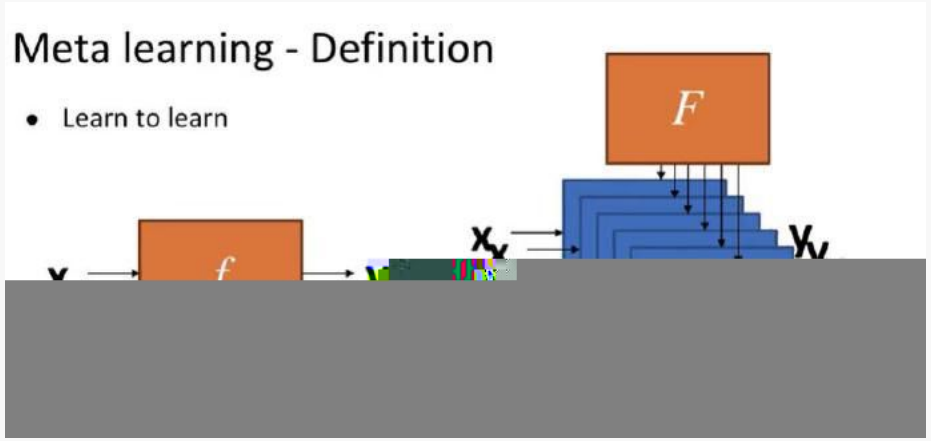


ng

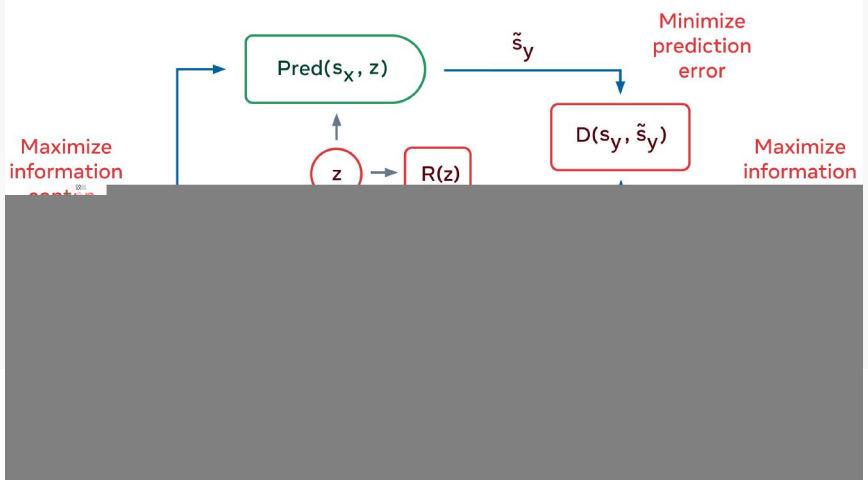
- Algorithm that learns to learn
- Let the algorithm modify itself (via parameterization) to adapt to heterogeneous data on-the-fly
- Can be specialized in multiple tasks



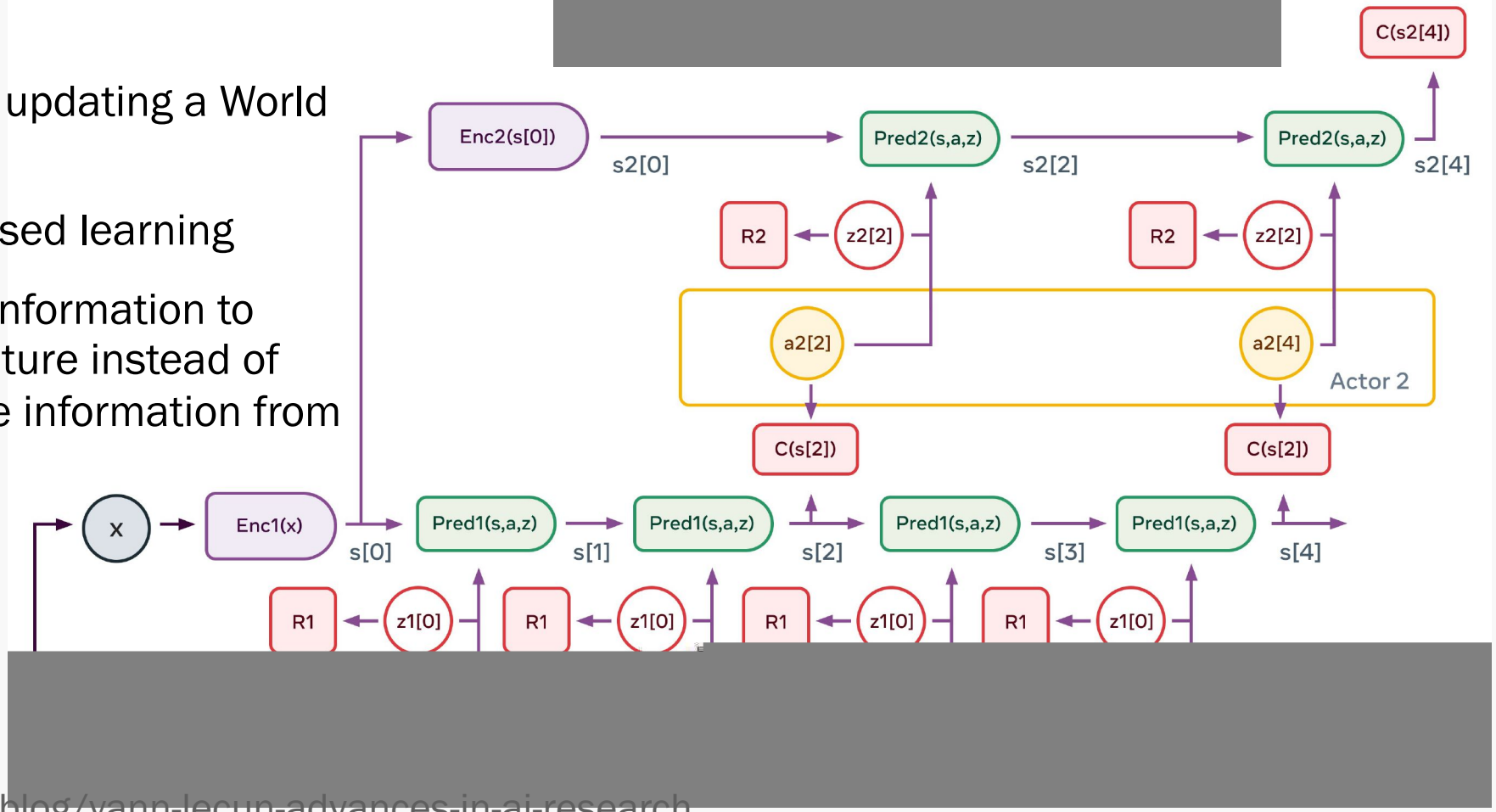




Continuous Learning



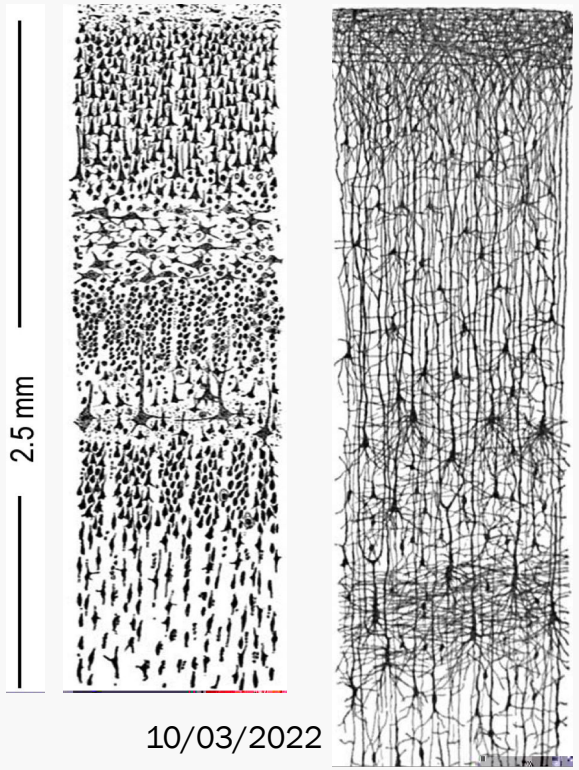
- Continuously updating a World Model
- Prediction-based learning
- Use present information to predict the future instead of using only the information from the past



https://ai.facebook.com/blog/yann-lecun-advances-in-ai-research

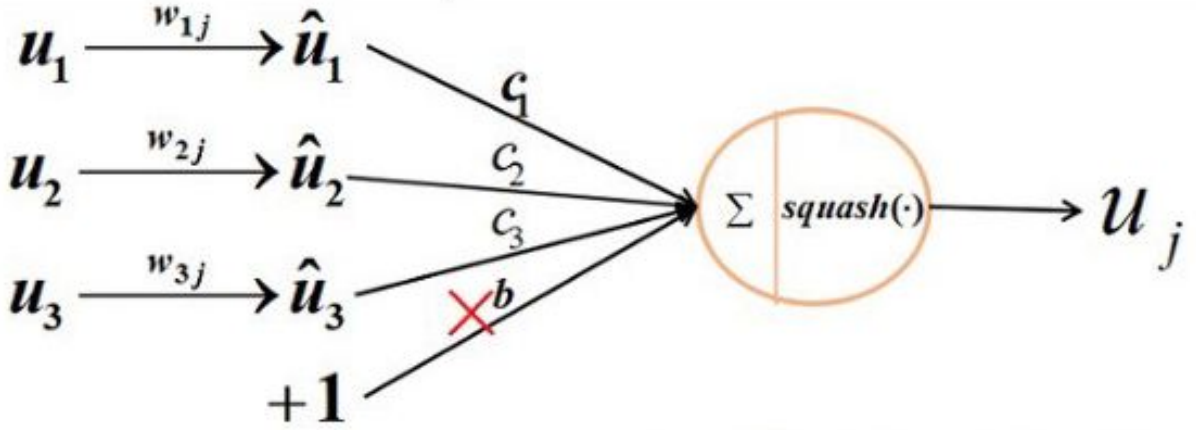
Sub-Models

- Consensus-based prediction
- Neocortex-like Cortical Columns



Cajal, 1899

Input from low-level neuron/capsule		vector(u_i)
Operation	Affine Transformation	$\hat{u}_{j\|i} = W_{ij} u_i$ (Eq. 2)
	Weighting	$s_j = \sum_i c_{ij} \hat{u}_{j\|i}$ (Eq. 2)
	Sum	
	Non-linearity activation fun	$v_j = \frac{\|s_j\|^2}{1+\|s_j\|^2} \frac{s_j}{\|s_j\|}$ (Eq. 1)
output		vector(v_i)

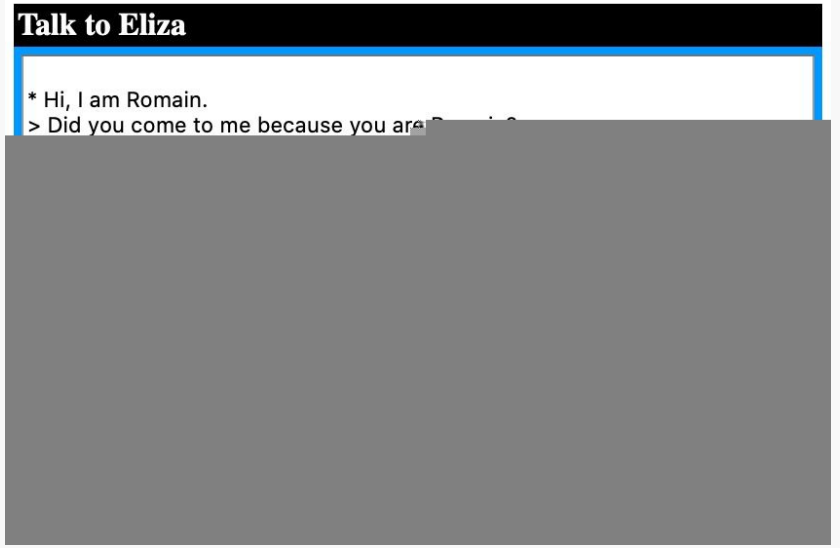


To train or not to train

- Non training
  - *Rule-based*
- Training
  - *Classifications*
  - *Predictions and Optimizations*
  - *Generation*
- Retraining
  - *Fine-tuning*
  - *Context-based learning (few-shots learning)*

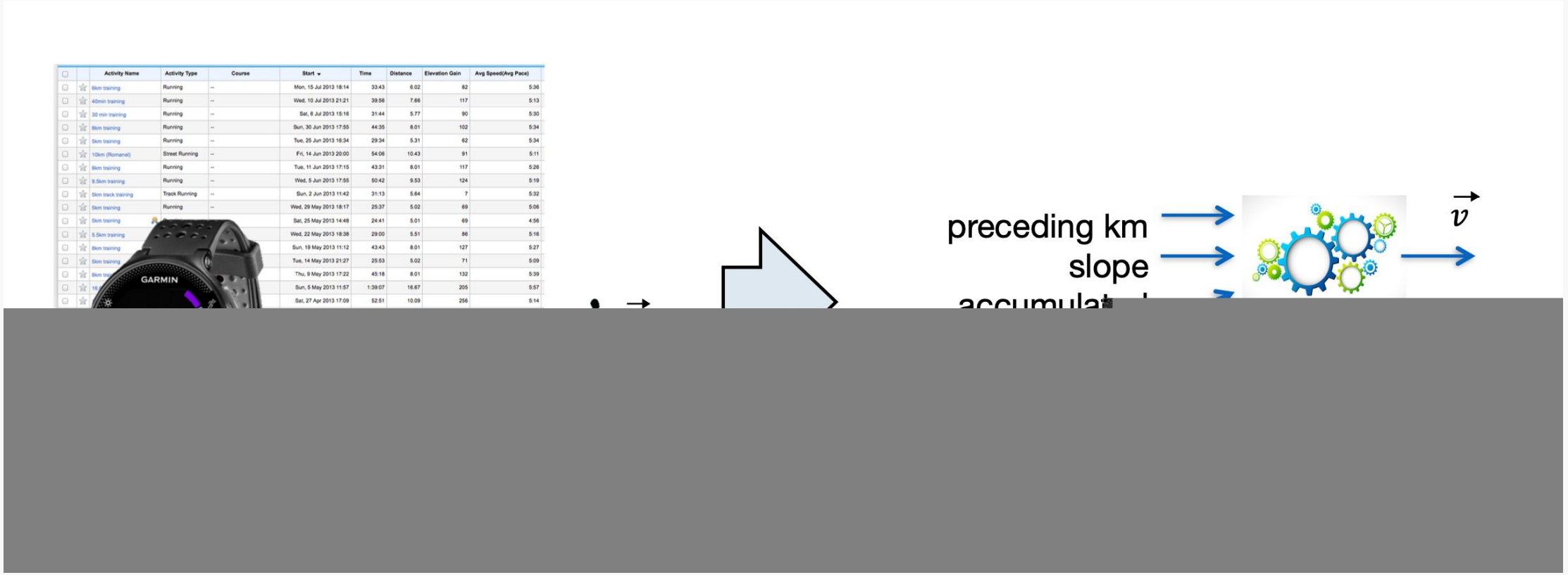
Example:
Rule-based algorithm: Eliza Chatbot

- In 1966, *Joseph Weizenbaum* wrote Eliza.
- Computer program simulating a psychotherapist.
- One of the first well-documented chatbot designed to pass the Turing test.
- Not performing particularly well in all contexts, due to technical restrictions.
- It is still possible to play with the program online.



http://psych.fullerton.edu/mbirnbaum/psych101/Eliza.htm

Example:
Trained on Healthcare Bigdata



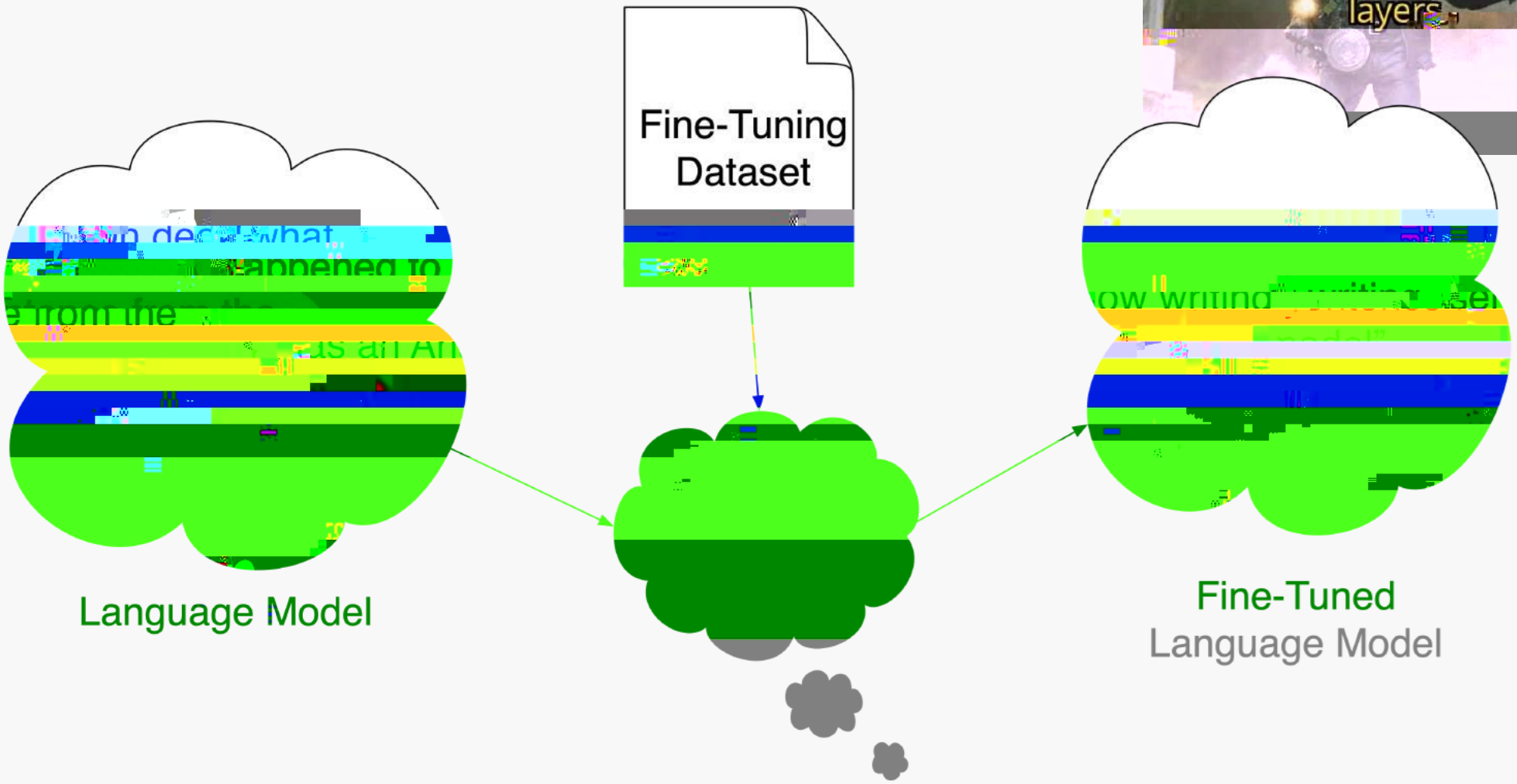
Training bottlenecks

- Time
  - *From minutes to months.*
- Power
  - *CPUs are enough for school cases*
  - *GPUs are required for large projects*
  - *Dedicated hardware designed for ML (ASICs)*
- Cost
  - *Hourly renting of cloud hardware*
  - *Training state of the art models costs in average USD 50’000 (as of 2021)*

Training Tricks

- Parallelizable
  - *New algorithms are designed for parallelization*
  - *Reducing time by increasing the hardware*
- Transferable
  - *New architectures allow the reuse of current models for new models*
  - *The more generalized the model is, the better it is transferable*
- Customization
  - *Fine-tuning*
  - *From a general model, extract specific knowledge, and make the model smaller*

Example: Fine-Tuning



Pause training and Checkpoint

- Let’s take a break to process the content

- Leaving you with a twisting open question to you:
  - *Are humans thinking or acting like they think? What does it mean for AI?*

Resume training

- Do you have any questions related to the previous part?
- Do you have any questions non-related to the previous part?
- Tour of arguments for the open twisting question:
  - *Are humans thinking or acting like they think? What does it mean for AI?*
- What do you think about the current state of machine learning?
  - *Power and Cost*
- Were you interested or surprised by a topic, why?
- Would you like to talk about specific topics in more details?

Let’s sum up AI

- Based on the first part of the lecture, what is AI for you?
- How will AI be useful to you as an individual?
- How will AI be useful to you in healthcare?

Let’s design an AI Application

- What is the field of application?
- Describe briefly your application. What does it do?
- What is the type of data and how large is your dataset?
- Are you training it? What approach would you take?

- Let’s discuss

- Be creative ☺

Let’s talk about the future of AI

- In your opinion, what will be the future breakthroughs in AI?
  - *Short-term*
  - *Long-term*
  - *Very long-term / Science Fiction*
- How would you evaluate if a machine is intelligent?

Short-term Breakthroughs

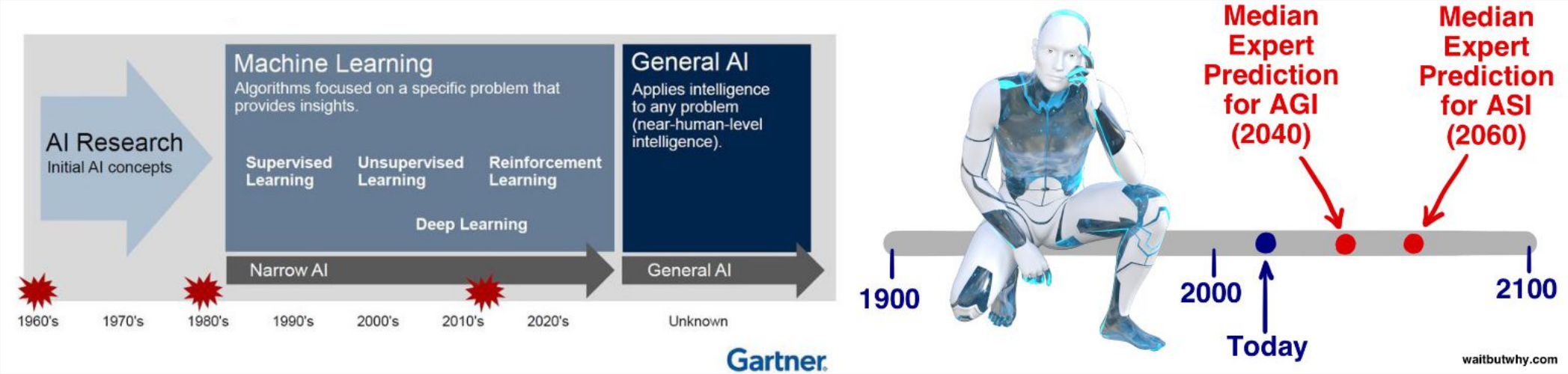
- Explainable AI (XAI)
- Automation: Self-driving cars, trains, buses; Delivering robots
- Healthcare: AI-Assisted diagnostics
- Healthcare: AI-Made Vaccines
- More efficient energy production
- Unified tools and new standards for ML
- Better filtering techniques and cross domain transfer learning
- Automated Machine Learning

Long-term breakthroughs

- Custom medications, Custom food, etc.
- Xenobots-assisted: targeted medications delivery and operations
- Self-programming / Self-optimization
- Genetics: Human modifications, upgrades
- Quantum computing: one more state (0, 1, 0/1) is good for ANN optimization
- Graph Neural Networks
- ML on low power devices such as IoT, via distribution
- Empathic reasoning

Very long-term / Sci-fi breakthroughs

- Artificial General Intelligence
- Artificial Living Form
- Artificial Super Intelligence



Measure Machine Intelligence

- Common Human Intelligence tests [IQ, etc.]
  - *Logics*
  - *Verbal comprehension*
  - *Visual-spatial comprehension*
  - *Fluid reasoning*
  - *Working memory*
  - *Abstract thinking*
- Cognitive Reflection tests (override the “gut” response) [CRT]
- Rationality Thinking tests (making good decisions) [CART]

Questions and Discussion

- Don’t be shy; all questions are good questions!
  - *Your neighbors probably do not know the answer*
- Do you need clarifications on the presented subjects?
- Do you have questions on non-presented topics?
- Do you have any questions that interest you in particular?
- Interested in a constructive debate?
- Suggestions for the next lecture
- Feel free to email me your questions if something pops in your mind afterward

Thank you for your attention

- Last twisting question:
  - *What would you prefer, computers passing the turing test or expecting them to fail the test in purpose?*

Recommended Readings

- Hawkins, J., & Dawkins, R. (2021). *A thousand brains: A new theory of intelligence*. Basic Books. (first half of the book)
- Alexandre, L. (2018). *La Guerre des intelligences: Comment l'intelligence artificielle va révolutionner l'éducation: Intelligence Artificielle Versus Intelligence humaine*. J.-C. Lattès.
- Zarkadakis, G. (2015). *In our own image: Will artificial intelligence save or destroy us?* Rider.
- Hawkins, J., & Blakeslee, S. (2004). *On Intelligence*. Times Books.

Further Readings

- 3Blue1Brown. (n.d.). *YouTube*. Retrieved March 8, 2022, from http://www.youtube.com/channel/UCYO_jab_esuFRV4b17AJtAw

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- Sharma, S. (2019, October 11). *What the hell is Perceptron?* Medium. Retrieved March 8, 2022, from https://towardsdatascience.com/what-the-hell-is-perceptron-626217814f53
- *The staggering cost of training Sota AI models*. Synced. Retrieved March 8, 2022, from https://syncedreview.com/2019/06/27/the-staggering-cost-of-training-sota-ai-models/
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