Introduction to AI

Kickstarting your data-driven and medical AI projects

November 28th, 2024

Sira Sriswasdi, PhD

- Research Affairs, Faculty of Medicine, Chulalongkorn University
- Computational Molecular Biology Group (CMB)
- Center for Artificial Intelligence in Medicine (CU-AIM)

About myself

Background in computational biology: mathematics, computer sciences, and molecular biology

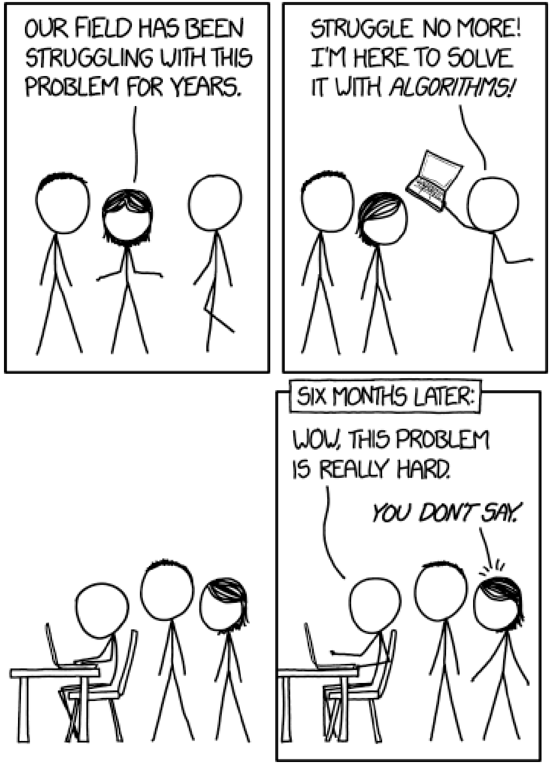
Learned but never use ML/AI until 2017

CMB
CHULALONGKORN
Computational Molecular Biology

CU
AIM

Form Computational Molecular Biology and AI in Medicine Centers at Chula

Like to apply computational thinking to any problem



https://xkcd.com/1831/

Talk plan

- Day 1
  - Introduction to AI
  - Roles of medical practitioner in the AI era
  - Federated learning workshop

- Day 2
  - How to become an AI-ready hospital?
  - Practical experiences on AI-assisted CXR workflow

What is AI?

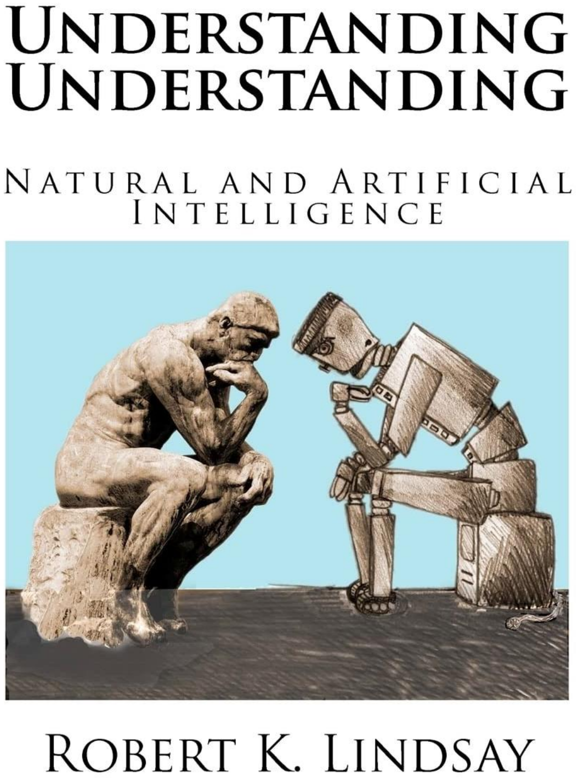
Natural vs artificial intelligence

- AI is the result of computer algorithms mimicking the natural learning process

- Measure of intelligence
  - Ability to generalize to unseen data
  - Ability to create things
  - Ability to reason with cause and effect

Single cortical neurons as deep artificial neural networks

David Beniaguev,[1,3,*] Idan Segev,[1,2] and Michael London[1,2]
[1]Edmond and Lily Safra Center for Brain Sciences (ELSC), The Hebrew University of Jerusalem, Jerusalem 91904, Israel
[2]Department of Neurobiology, The Hebrew University of Jerusalem, Jerusalem 91904, Israel



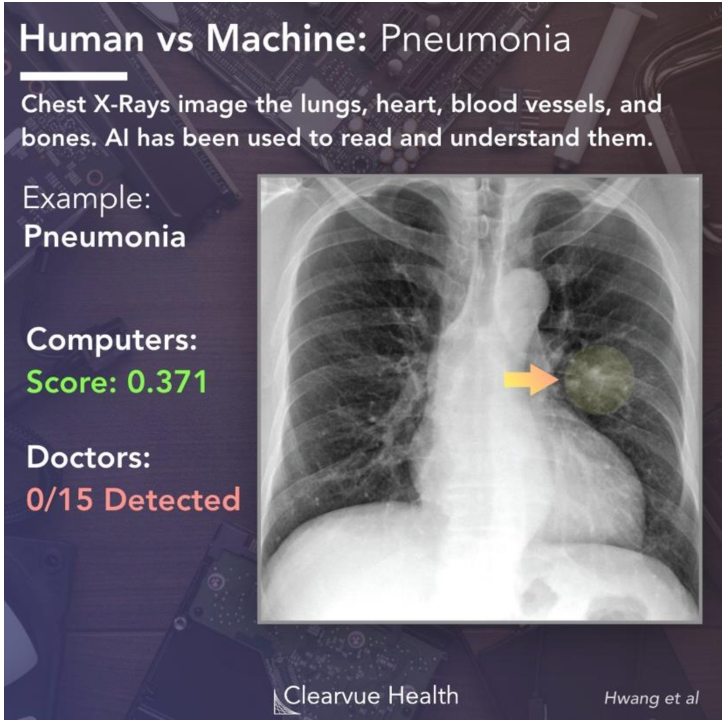
Mechanism of learning

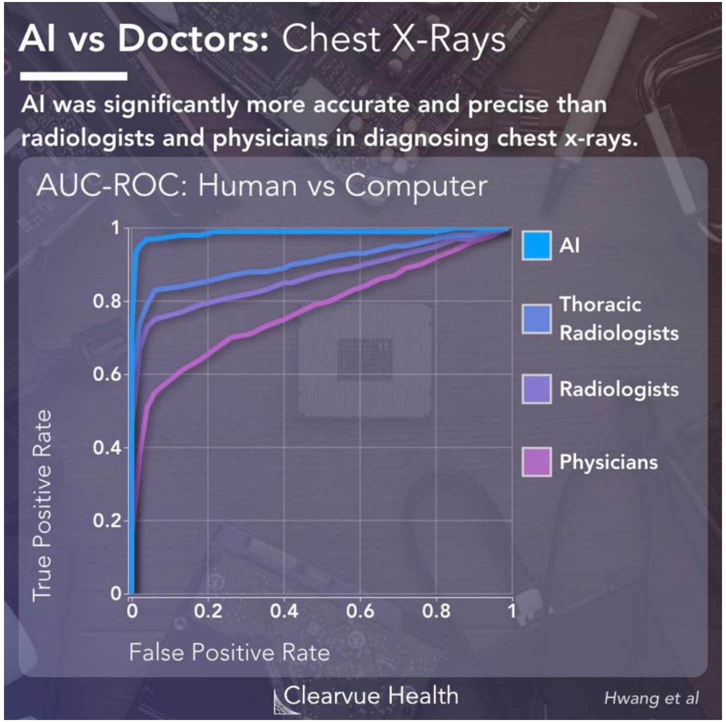
	Human	Machine
Memorization	✓	✓✓✓
Pattern recognition	✓	✓
Trial and error	✓	✓
Generalization/Reasoning	✓✓✓	✗
Information compression	?	✓✓✓

Memorization and information compression

https://www.youtube.com/watch?v=P18EdAKuC1U

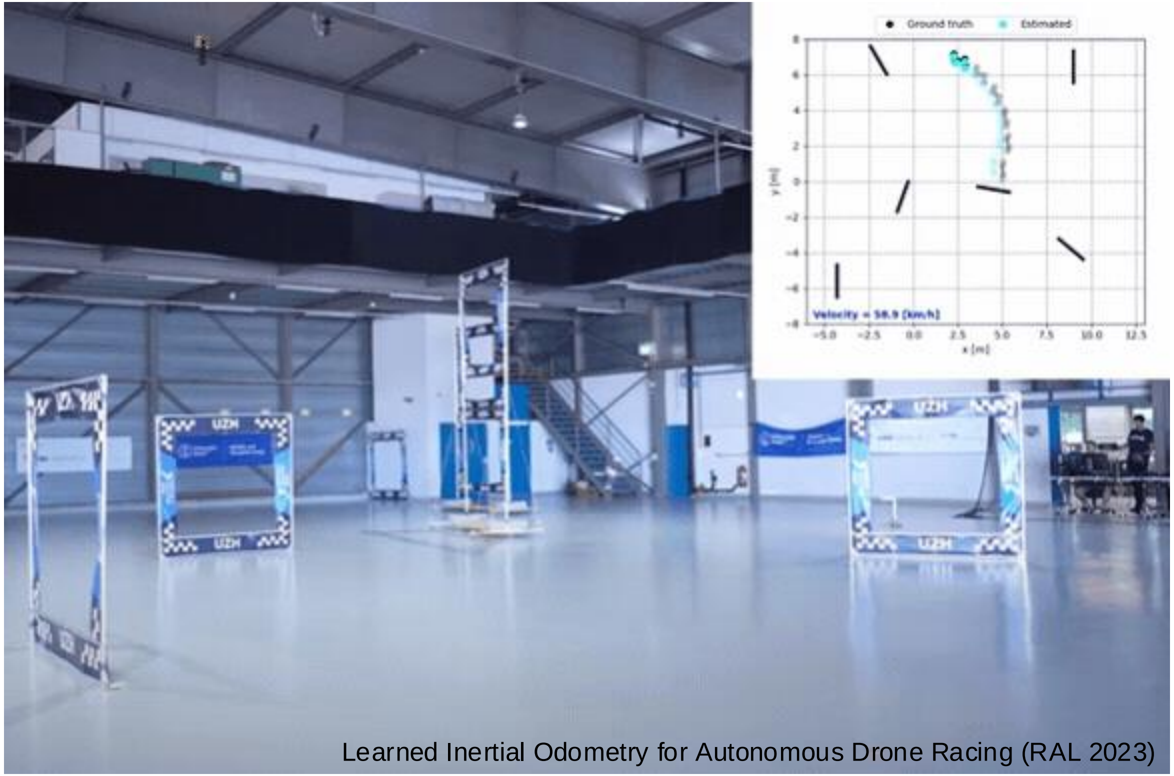
Pattern recognition





https://www.clearvuehealth.com/b/ai-radiology-xray/

Trial and error



Learned Inertial Odometry for Autonomous Drone Racing (RAL 2023)

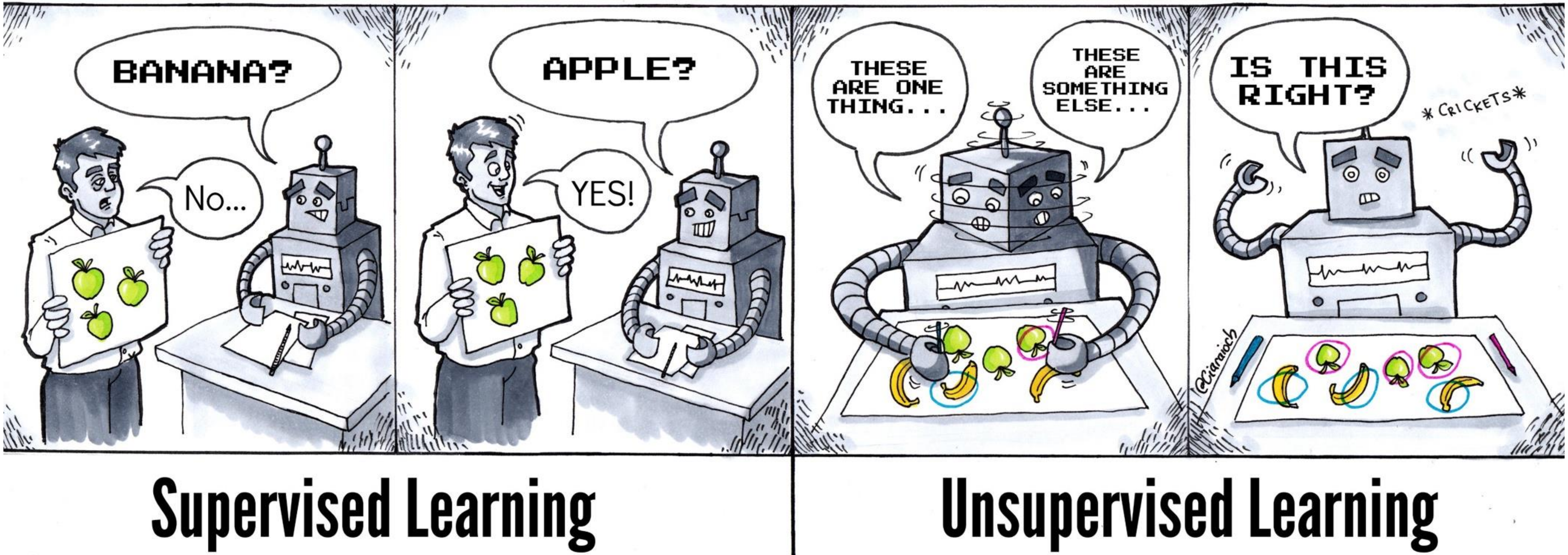
Google DeepMind's AlphaGo computer beats top player Lee Sedol for third time to sweep competition

Machine learning (ML), the engine behind modern AI

Internet search: AI without ML

https://www.cloudaccess.net/fresh/blog/entry/2018/12/07/wait-what-google-isn-t-the-only-search-engine-on-the-web.html

Supervised and unsupervised learning



Find decision functions with high accuracy

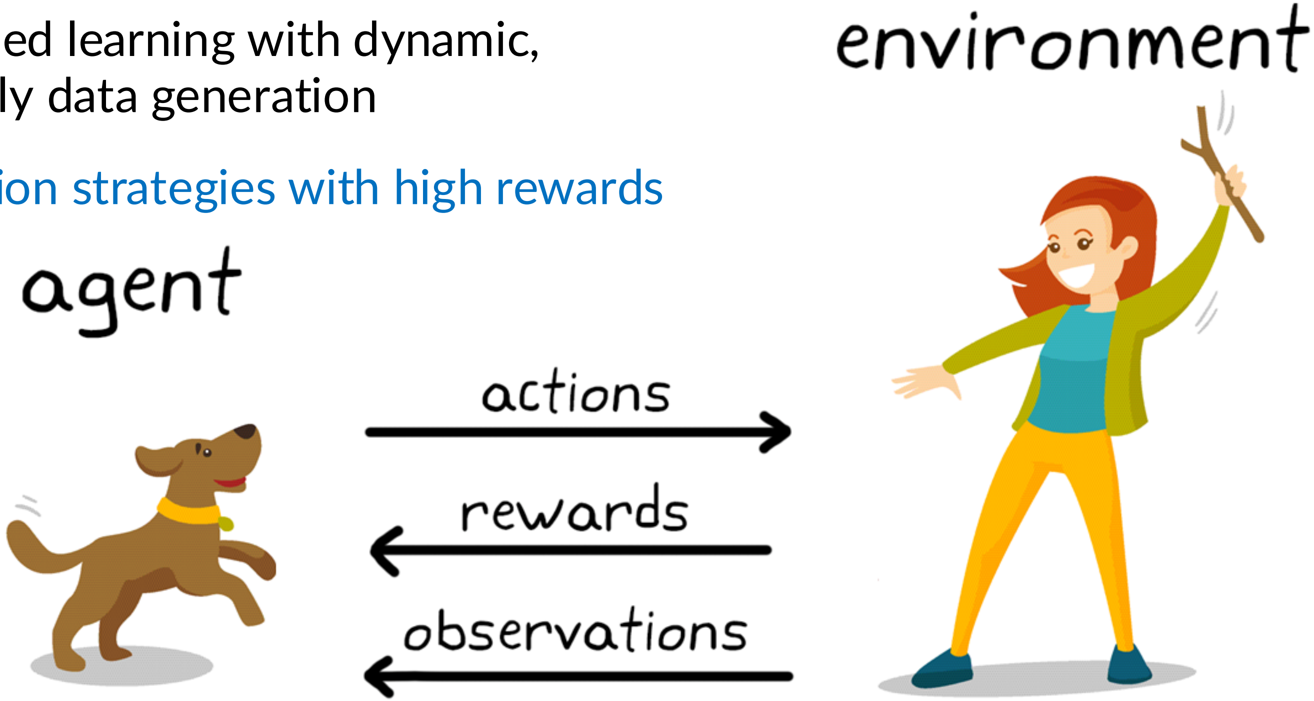
Find patterns and similarities among data

https://x.com/athena_schools/status/1063013435779223553/photo/1

Reinforcement learning

Supervised learning with dynamic,
on-the-fly data generation

Find action strategies with high rewards

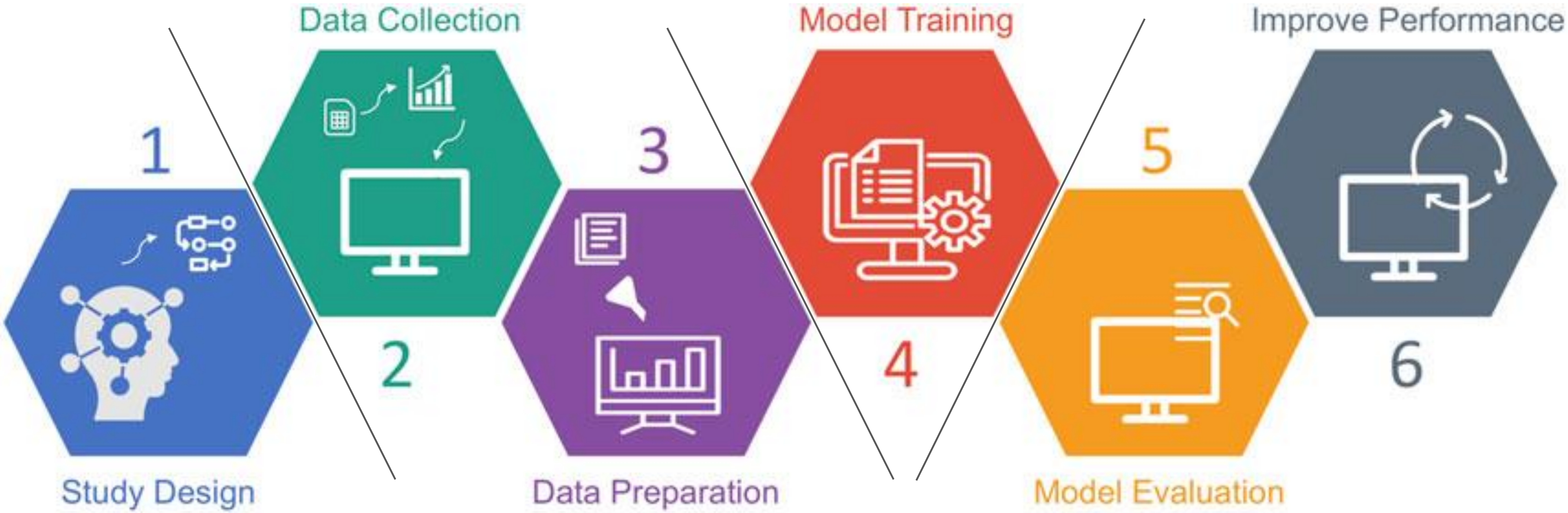


https://www.linkedin.com/pulse/mastering-art-learning-comprehensive-guide-jagarlapoodi

Supervised learning framework

3. Build the model

4. Evaluate & improve



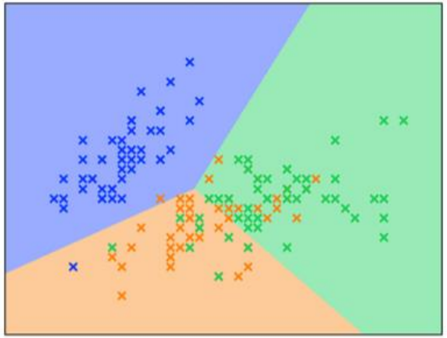
1. Pick the right task

2. Prepare quality data

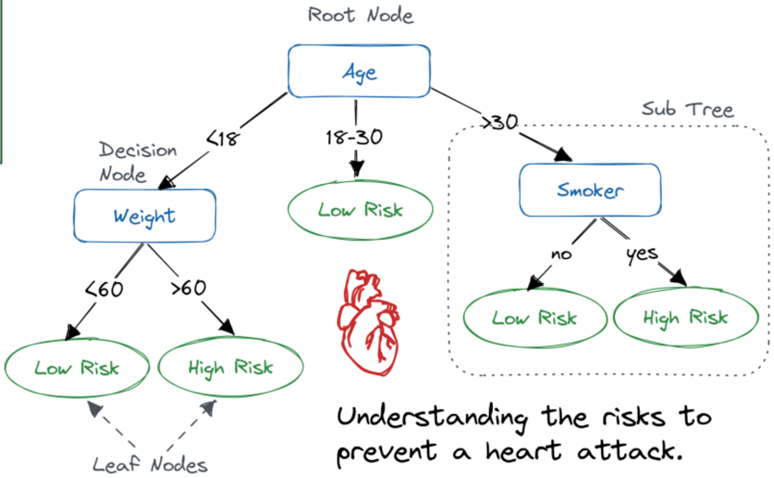
Peng, J. et al. Front. Pharmacol. 2021

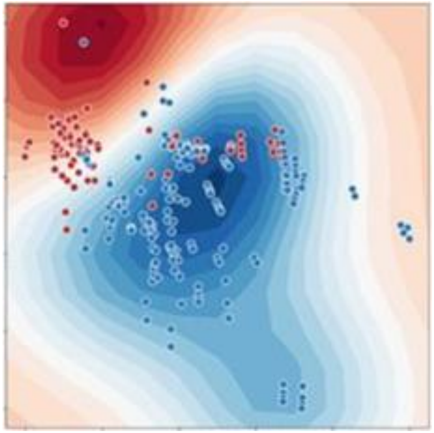
Some classical ML models

Linear: Score = $(\text{input}_1 \times w_1) + \ldots + (\text{input}_n \times w_n)$



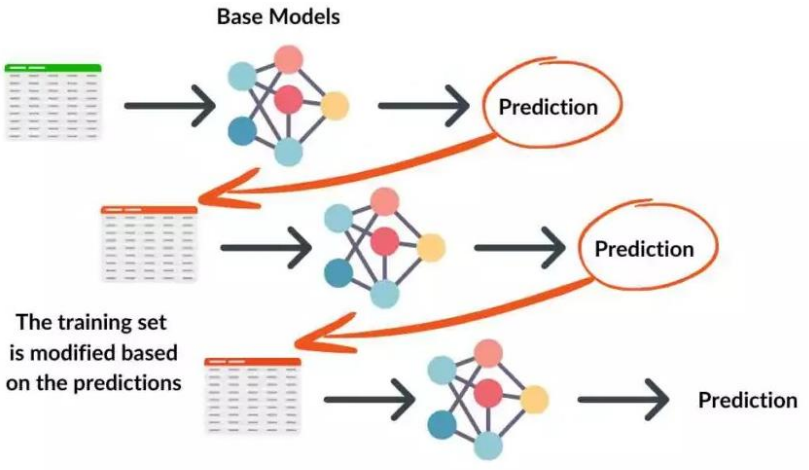
Tree: Collection of decisions





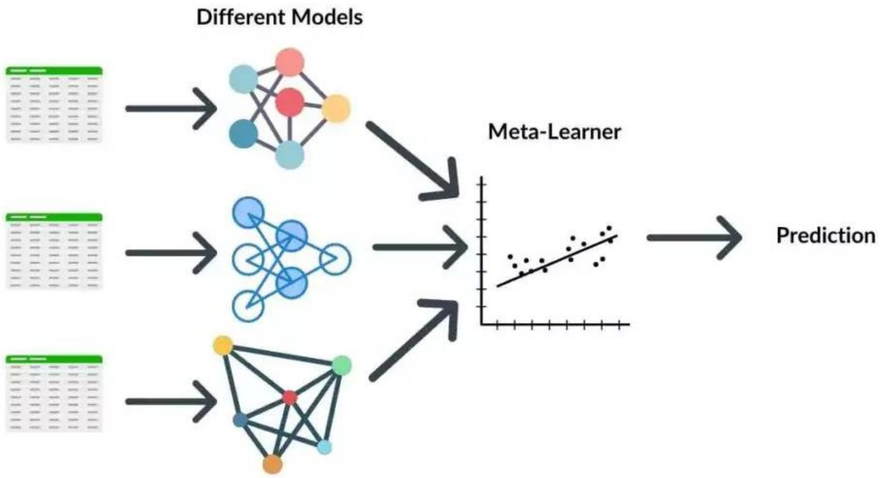
Neighbor-based: Predict using similarity to past observations

Ensemble approaches



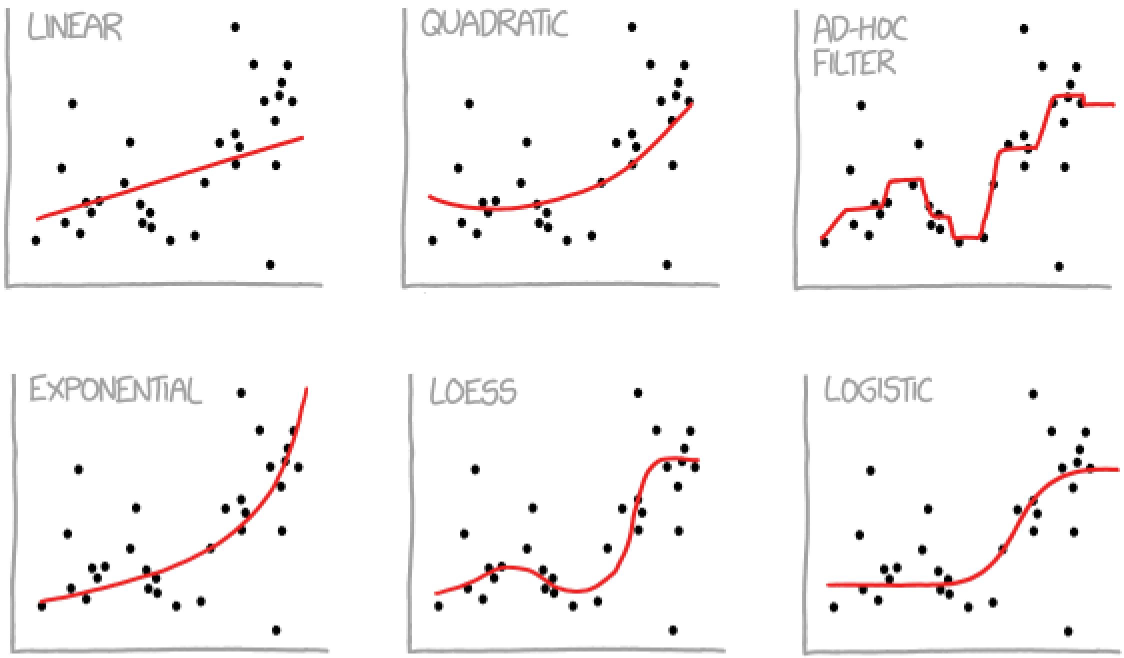
Boosting: Iterative improvement with additional models

Stacking: Combine multiple models with different capabilities



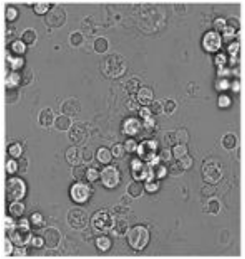
https://spotintelligence.com/2024/03/18/bagging-boosting-stacking/

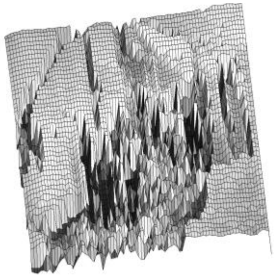
Limitation of classical ML



- Unable to fit complex relationships

- Unable to handle raw data like text of image



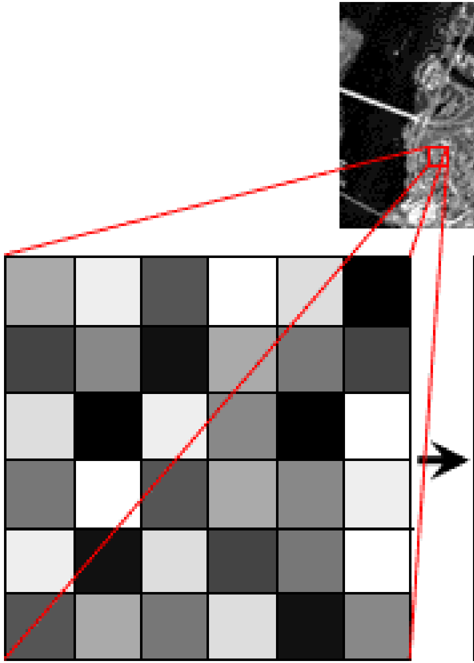


https://www.xkcd.com/2048/

Naïve representation is not useful

	1	2	3	4	5	6	7	8	9
man	1	0	0	0	0	0	0	0	0
woman	0	1	0	0	0	0	0	0	0
boy	0	0	1	0	0	0	0	0	0
girl	0	0	0	1	0	0	0	0	0
prince	0	0	0	0	1	0	0	0	0
princess	0	0	0	0	0	1	0	0	0
queen	0	0	0	0	0	0	1	0	0
king	0	0	0	0	0	0	0	1	0
monarch	0	0	0	0	0	0	0	0	1

Image from hackermoon.com

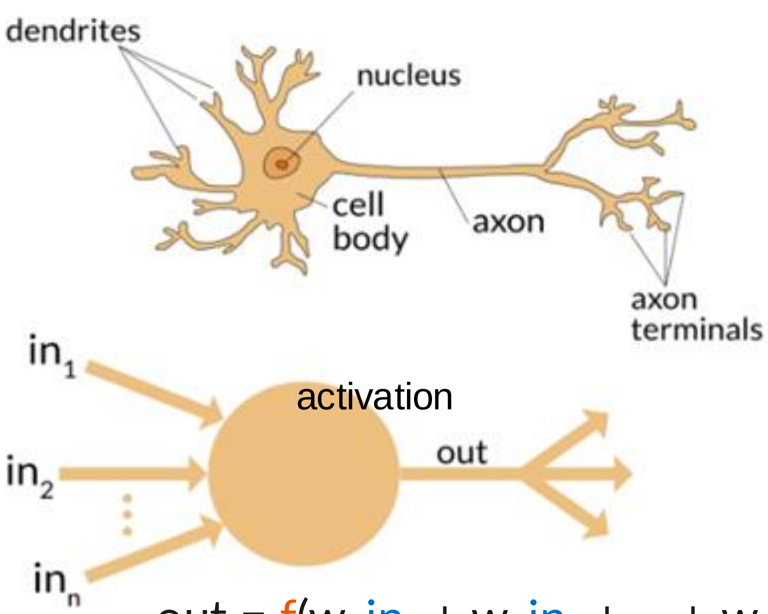


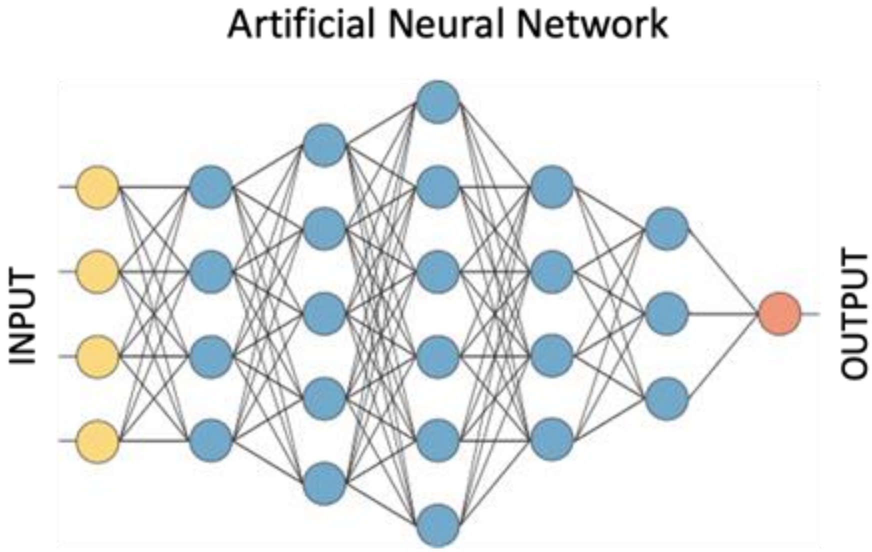
170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

Image from naushardsblog.wordpress.com

Artificial neural network (ANN)

Inspired by biological neurons





$out = f(w_1 in_1 + w_2 in_2 + \ldots + w_n in_n)$

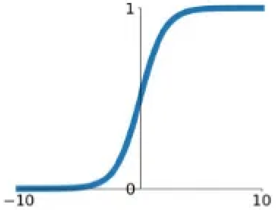
$f(\,)$ is an activation function

Flow of signal/computation

Activation function

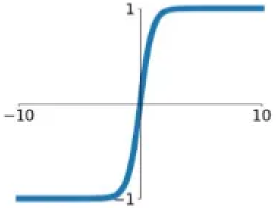
Sigmoid

$$\sigma(x) = \frac{1}{1+e^{-x}}$$



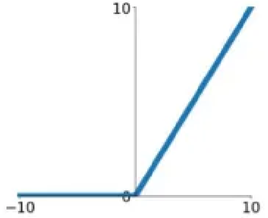
tanh

$$\tanh(x)$$



ReLU

$$\max(0, x)$$



- Simple, non-linear function
- Mimic the activation of a biological neuron
- Without non-linear activation function, ANN is just a linear regression

https://medium.com/@shrutijadon/survey-on-activation-functions-for-deep-learning-9689331ba092

Universal approximation theorem (Cybenko 1989)

Universal Approximation Theorem: Fix a continuous function $\sigma : \mathbb{R} \to \mathbb{R}$ (activation function) and positive integers d, D. The function σ is not a polynomial if and only if, for every continuous function $f : \mathbb{R}^d \to \mathbb{R}^D$ (target function), every compact subset K of $\mathbb{R}^d$, and every $\epsilon > 0$ there exists a continuous function $f_\epsilon : \mathbb{R}^d \to \mathbb{R}^D$ (the layer output) with representation

$$f_\epsilon = W_2 \circ \sigma \circ W_1,$$

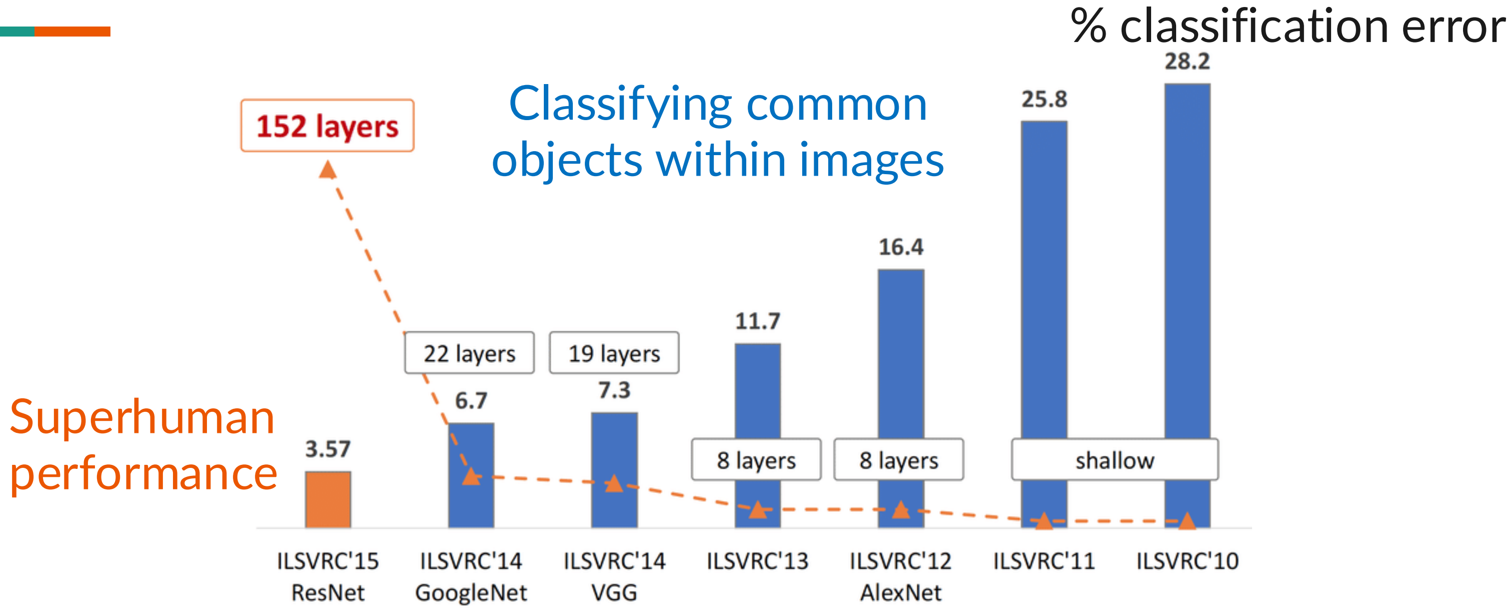
where W_2, W_1 are composable affine maps and $\circ$ denotes component-wise composition, such that the approximation bound

$$\sup_{x \in K} \|f(x) - f_\epsilon(x)\| < \varepsilon$$

holds for any ϵ arbitrarily small (distance from f to f_ϵ can be infinitely small).

- ANN with just one layer of neurons and a non-polynomial activation function **can capture any continuous mathematical relationship**

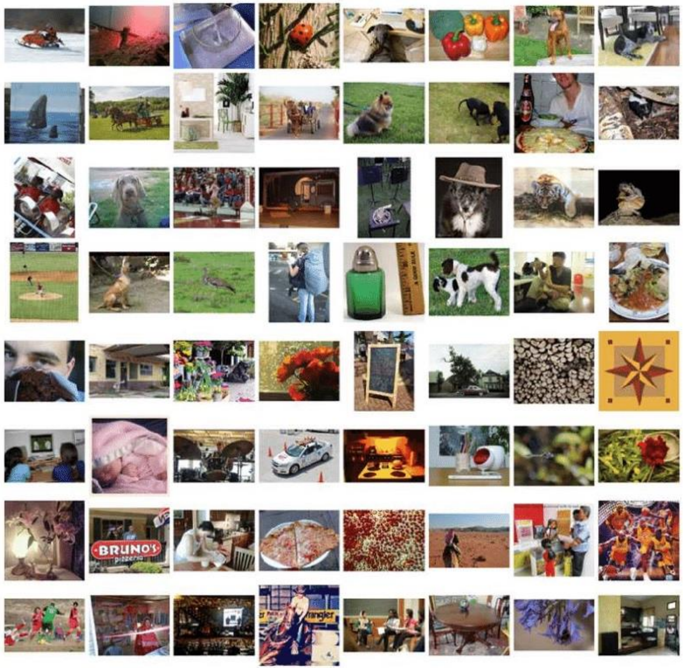
The rise of ANN

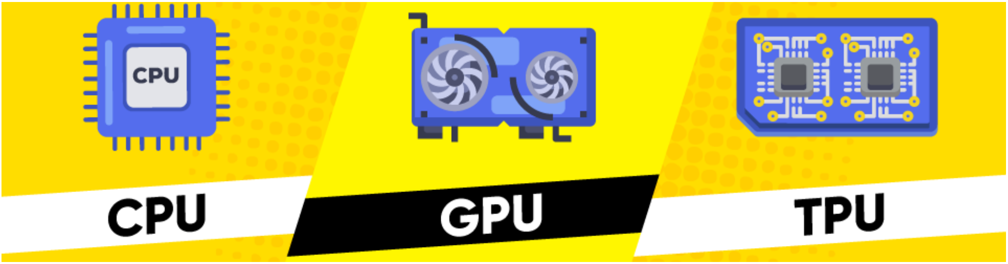


- During 2010-2015, ANN suddenly improved from 28% error to superhuman performance. **Why?**

Data and computing resources

ImageNet





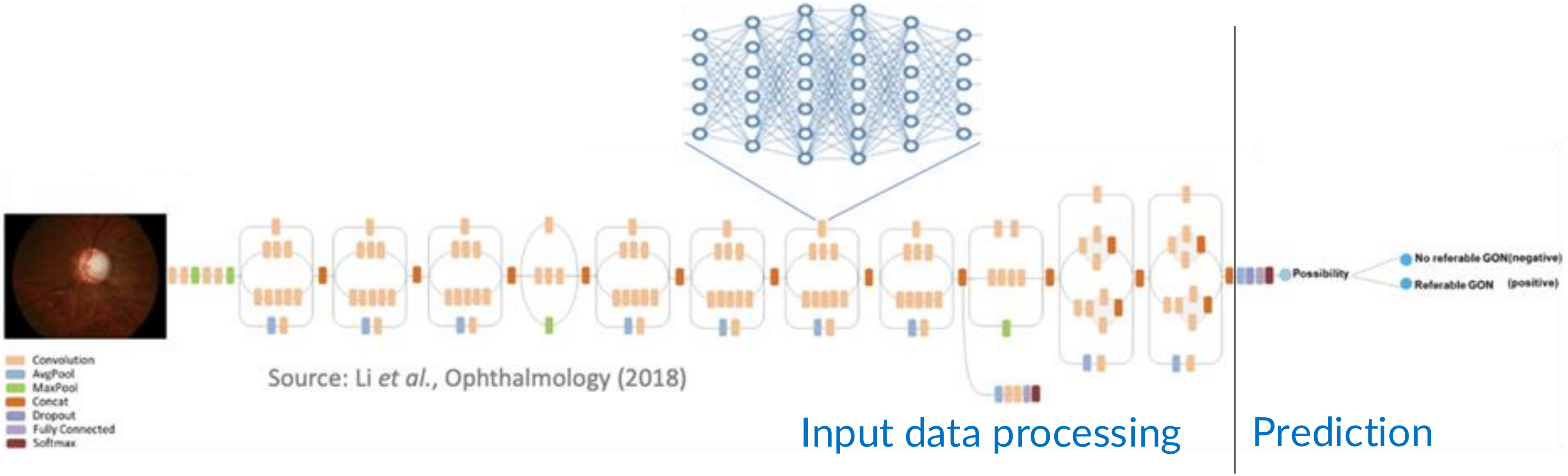
https://serverguy.com/cpu-vs-gpu-vs-tpu/

- **Data:** Internet and digital technology
- **Compute:** Faster, more optimized for ANN training (GPU and TPU)

Deep learning


THAT'S NOT ENOUGH
WE HAVE TO GO DEEPER

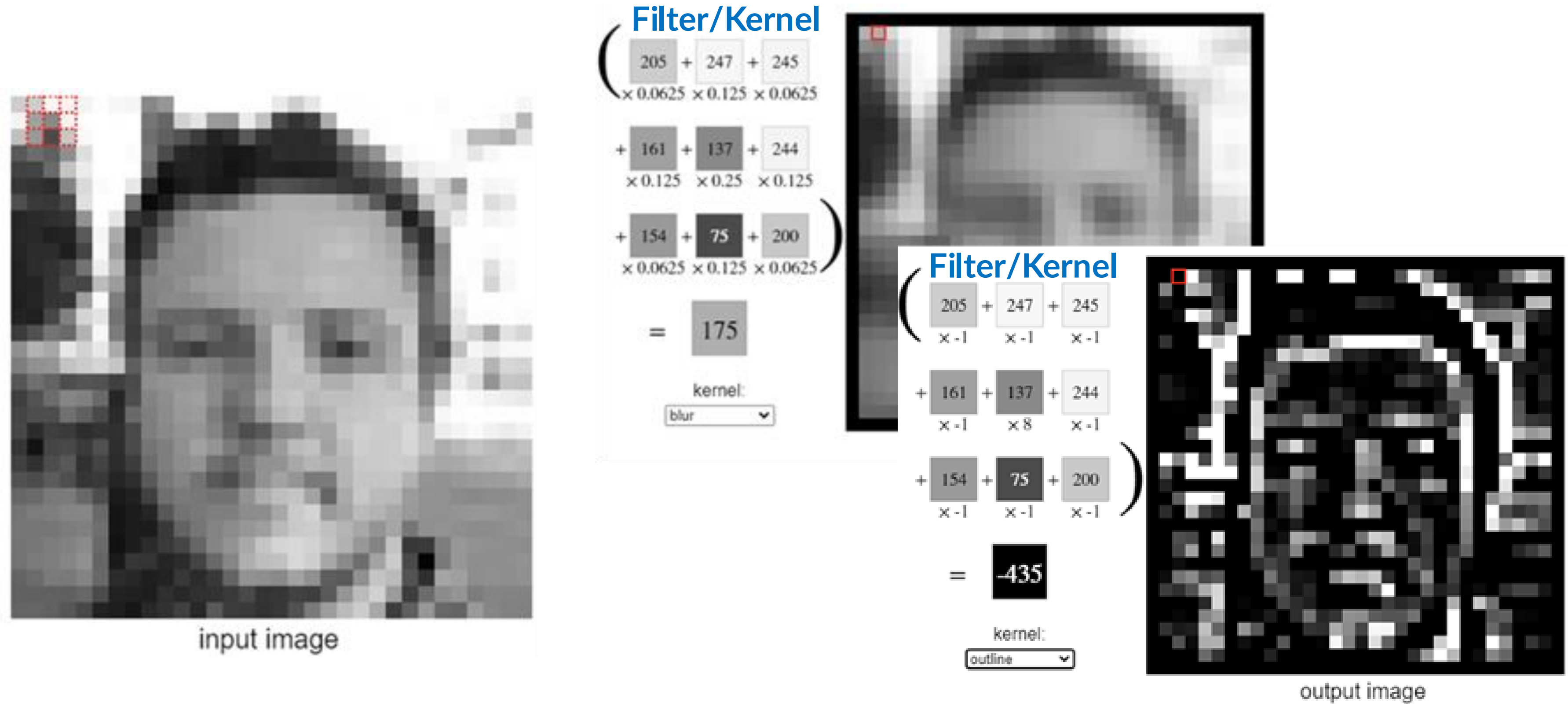
Deep ANN is needed to process raw input data



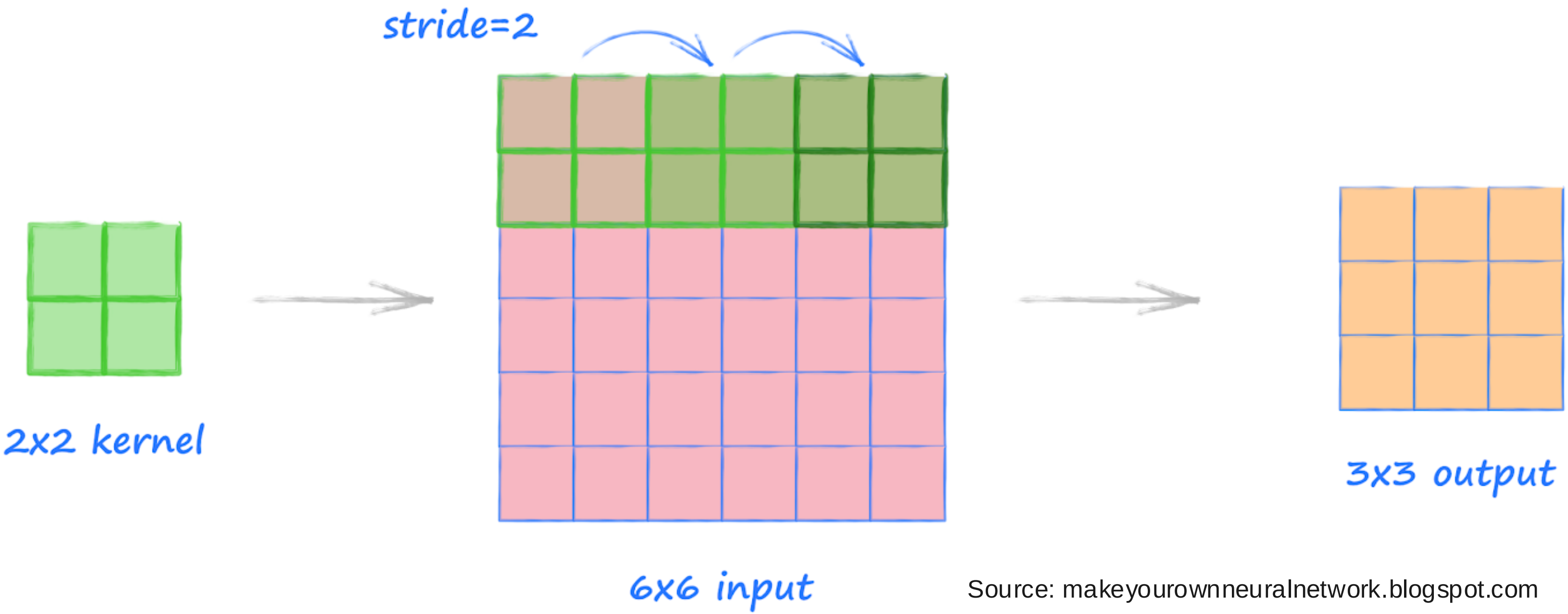
Source: Li *et al.*, Ophthalmology (2018)

- Millions to billions of parameters
- **Deep learning** = ML techniques for deep ANN

Extracting information from image (pixel data)



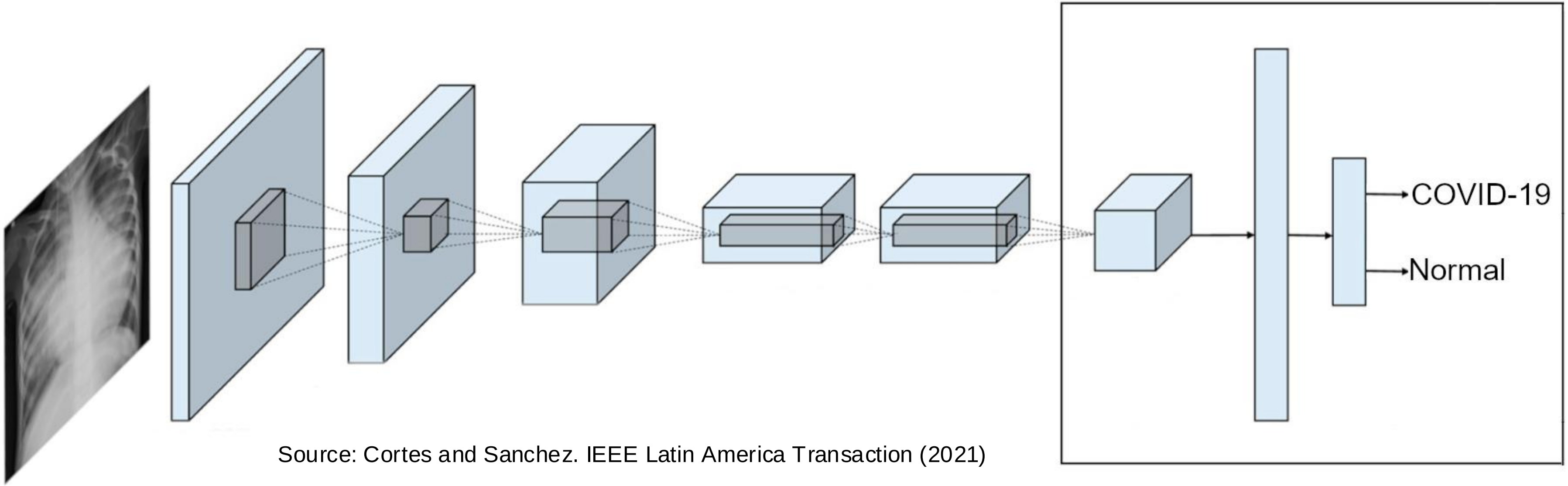
Convolutional operation



Source: makeyourownneuralnetwork.blogspot.com

- Scan through the image to identify local patterns

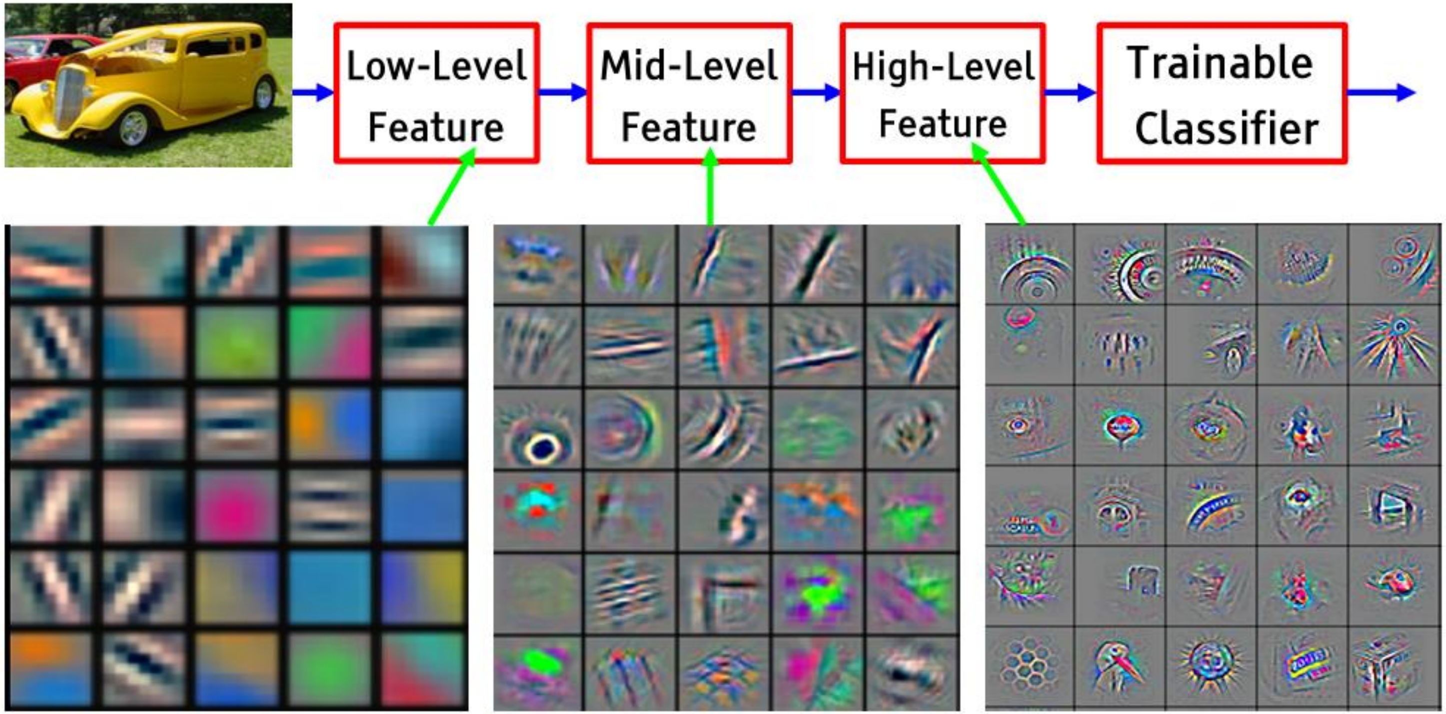
Convolutional neural network



Source: Cortes and Sanchez. IEEE Latin America Transaction (2021)

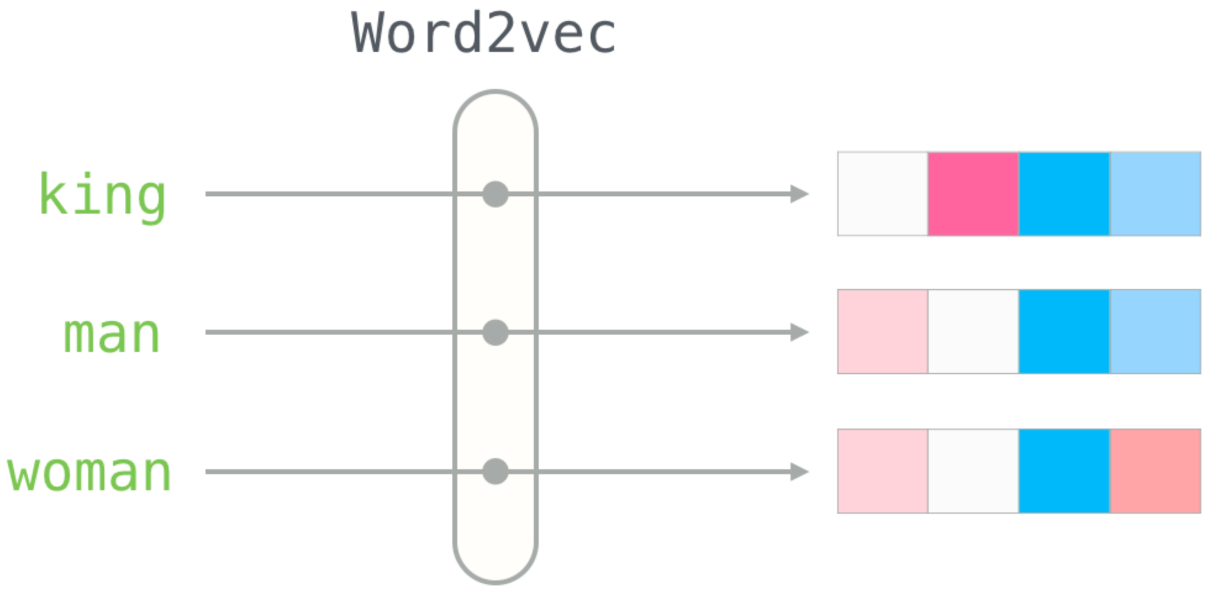
- Stacking of convolutional operations
- Early layers generate narrow, primitive patterns
- Later layers aggregate signals into larger, more complex objects

What does a CNN see in an image?



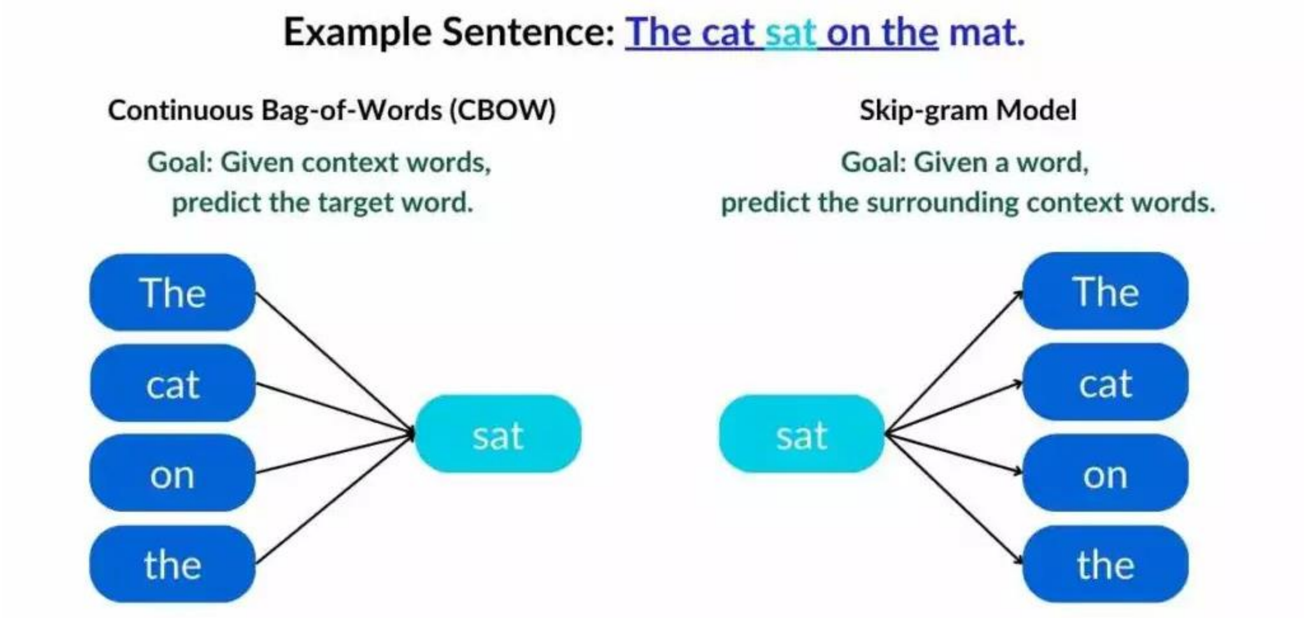
Hinton G, Bengio, Y, and LeCun, Y. NIPS2015

Word embedding



- Transformation of a word into a useful vector that captures its meaning and other characteristics. But how?

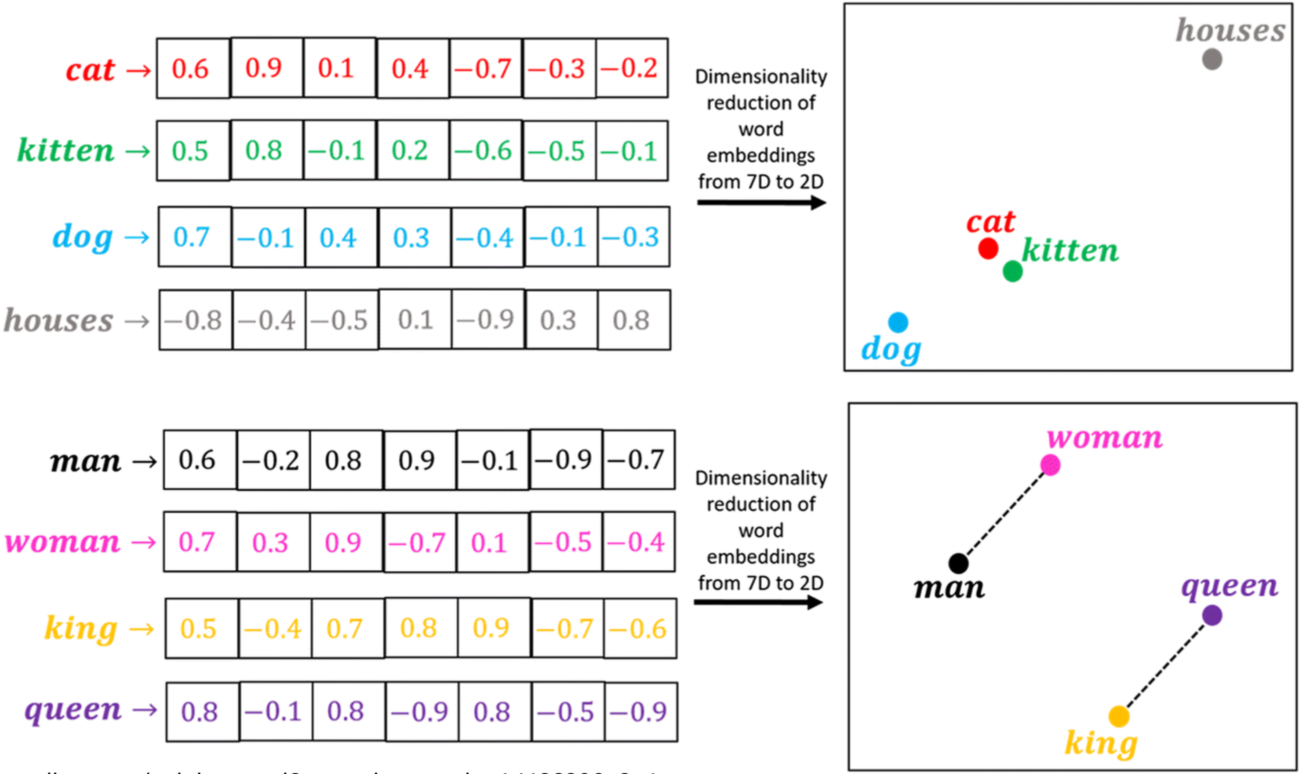
How to derive a good word embedding?



https://spotintelligence.com/2023/12/05/fasttext/

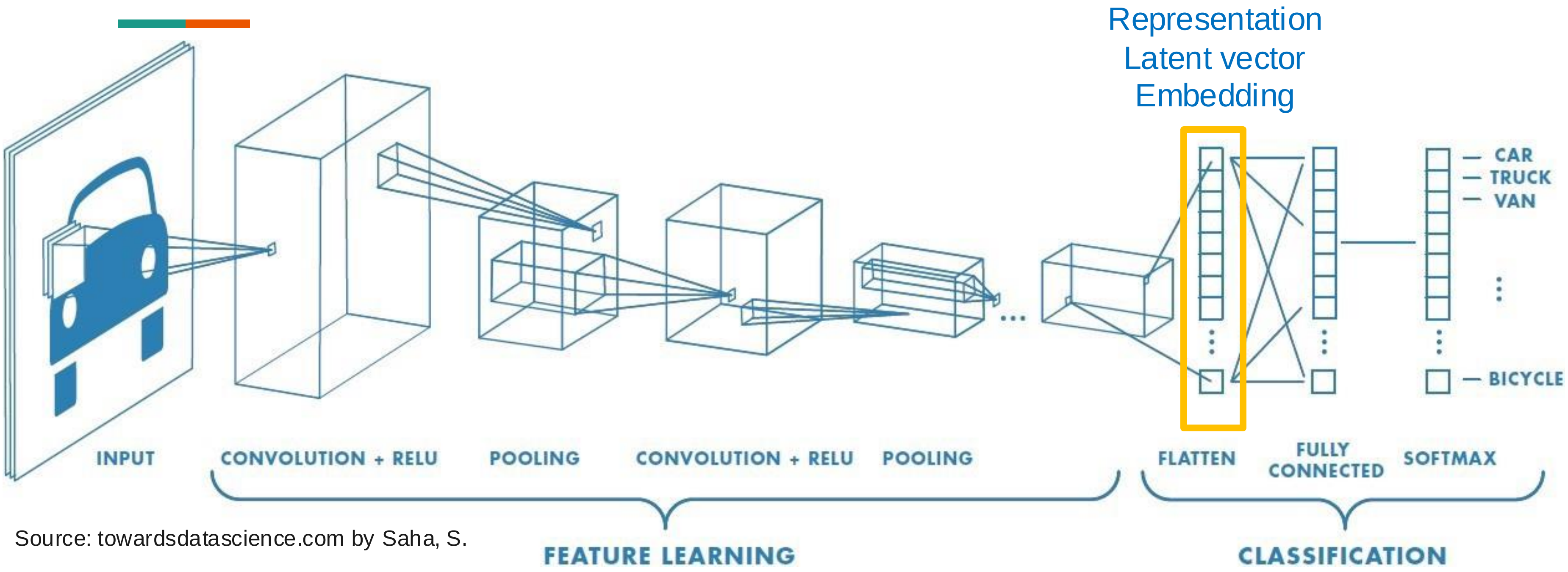
- Related words should have similar embeddings
- Embedding should enable prediction of related words, or the next words

Meanings captured by word embedding



https://swatimeena989.medium.com/training-word2vec-using-gensim-14433890e8e4

Encoder-Decoder perspective



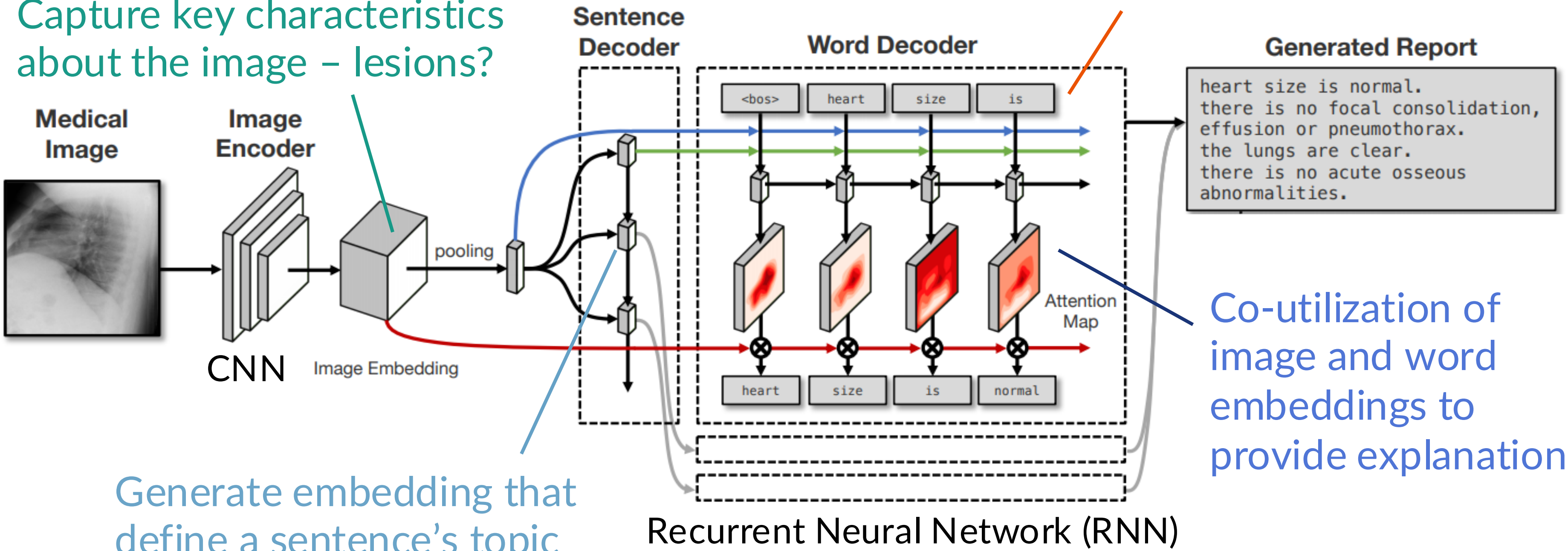
Source: towardsdatascience.com by Saha, S.

- **Encode** raw data into embedding
- **Decode** embedding into human-understandable terms

ANN design based on embedding interpretation

Sequentially generate words that follow the learned language and defined topic

Capture key characteristics about the image – lesions?



Co-utilization of image and word embeddings to provide explanation

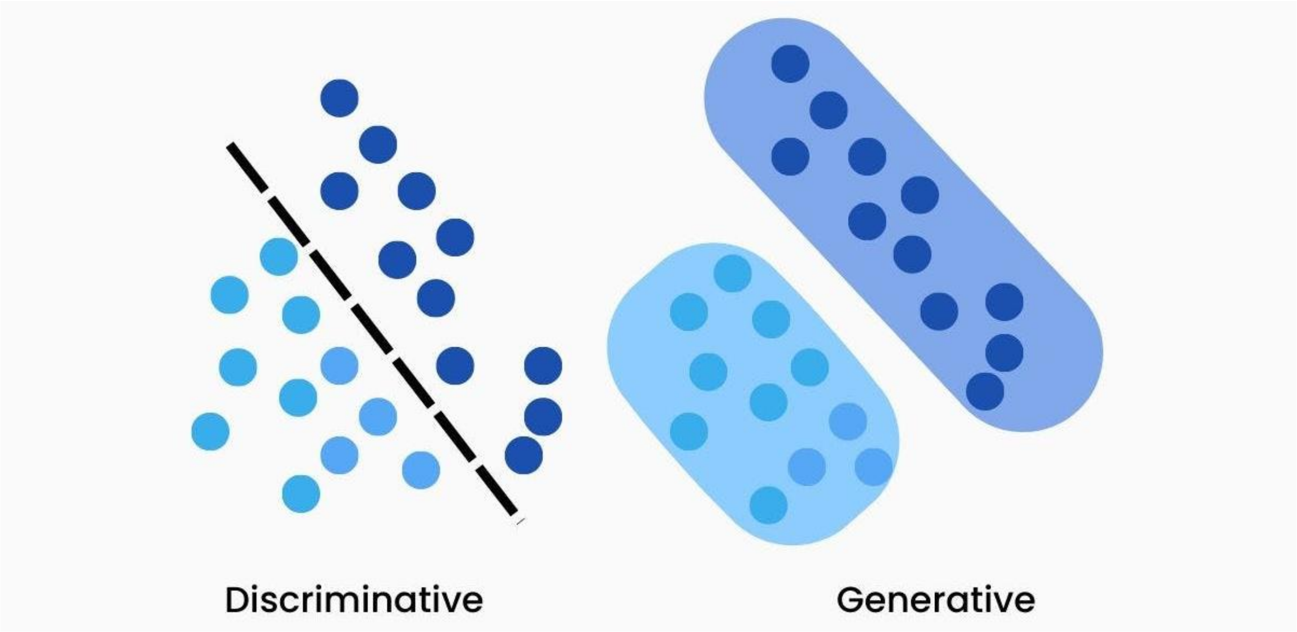
Generate embedding that define a sentence's topic

Liu et al. Clinically Accurate Chest X-Ray Report Generation (2019)

Generative models

Why generative model?

https://www.turing.com/kb/generative-models-vs-discriminative-models-for-deep-learning



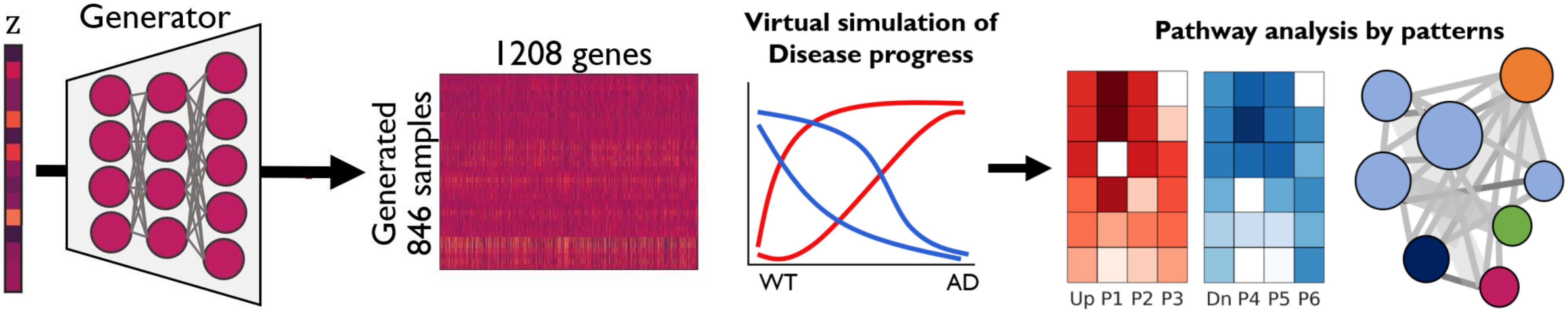
- Generative model captures more information than discriminative model

Why generative model?

https://developers.google.com/machine-learning/gan/gan_structure

- Generative model is a proxy of real-world mechanisms

Knowledge from simulated data



Park, J. et al. PLoS Computational Biology 16:e1008099 (2020)

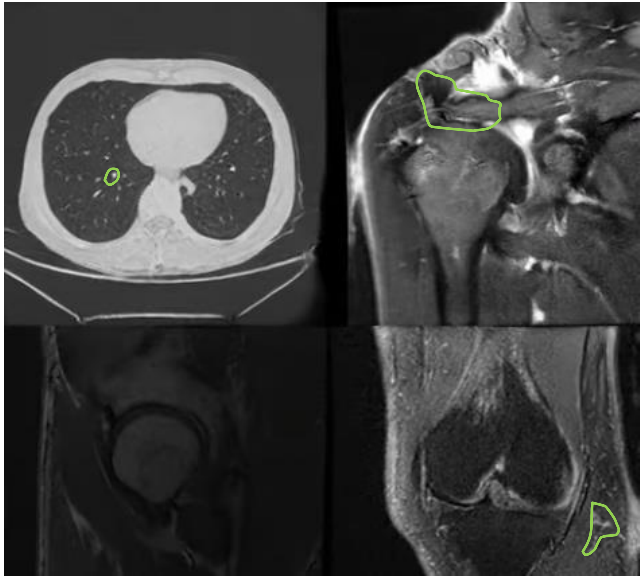
- Train a generative model with data from small-scale experiment
- Simulate time-course patient data
- Analyze simulated data to gain insights

Using synthetic data to train models

- Reduce data requirement for new hospital

- Resolve data privacy issue
  - Untraceable to the original patient

- Controlled data distribution
  - Specify disease and clinical characteristics when generated



Do AI really understand?

Maybe yes?

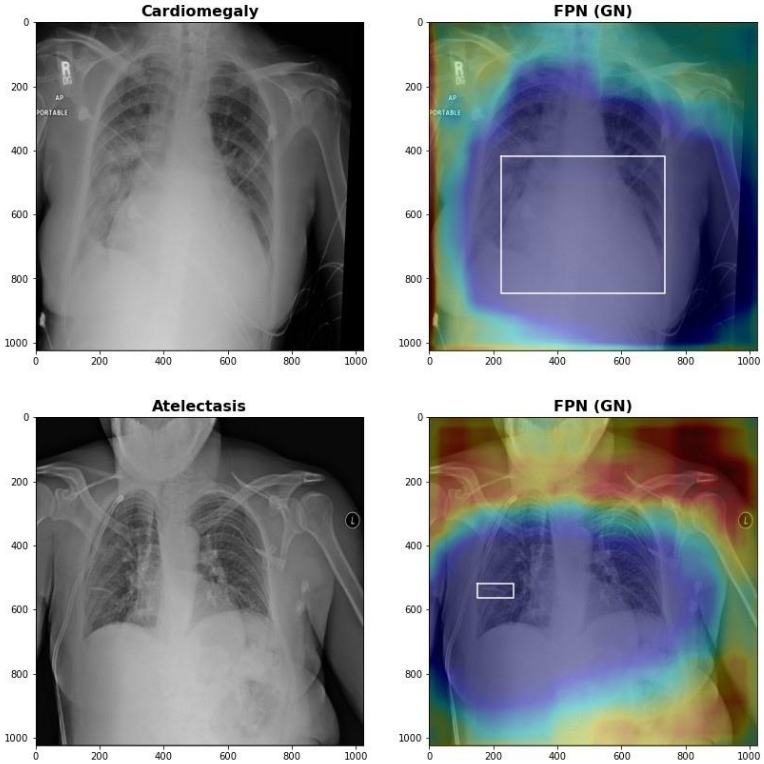
Maybe yes?

Upon examination of the chest X-ray image:

- The lungs are predominantly clear without any obvious consolidations, masses, or pneumothoraces.
- The cardiac silhouette appears within normal size limits.
- The bony thorax, including the ribs and clavicles, appears intact without any visible fractures.
- The diaphragm and costophrenic angles are well visualized and appear normal.
- There is no visible mediastinal widening or significant lymphadenopathy.

https://xrayinterpreter.com/resource/how-to-use-chatgpt-to-interpret-xrays

AI finds mathematical approximation



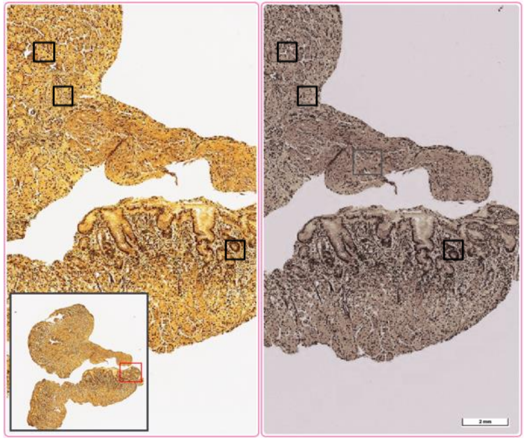
- AI are trained to optimize a narrow set of objects
- AI may or may not find a solution that matches true knowledge
- Cannot distinguish causation from correlation

So, should we use AI and what for?

Second opinions

- Boost confidence in decision made
- Suggest missed details
- Aid junior staff

Improve workflows



- User interaction and experience
- Automatic detection and QC
- Propose where to look
- Enable data-driven operation

Cautions when using AI

AI makes mistakes and biases SILENTLY

Some can be very difficult to tell

Alkaissi, H. et al. Cureus 15:e35179 (2023)

> Late onset Pompe disease (LOPD) is a rare genetic disorder characterized by the deficiency of acid alpha-glucosidase (GAA), an enzyme responsible for the breakdown of glycogen in lysosomes. The accumulation of glycogen in various tissues leads to progressive muscle weakness, primarily affecting the skeletal and respiratory muscles. However, recent studies have also reported liver involvement in LOPD, which is thought to occur as a result of the accumulation of glycogen in liver cells.

- There was no prior publication about liver involvement with LOPD
- However, the authors of this paper have an unpublished manuscript showing a link between liver disease and LOPD
    - *Did ChatGPT just synthesized new knowledge? Or simply hallucinated?*

Huge gap between development and actual use

Healthcare, Law, Regulation, and Policy, Machine Learning

"Flying in the Dark": Hospital AI Tools Aren't Well Documented

MODEL REPORTING GUIDELINES	EPIC MODEL BRIEFS											
	Deterioration Index	Early Detection of Sepsis	Risk of Unplanned Readmission	Risk of Patient No-Show	Pediatric Risk of Hospital Admission or ED Visit	Risk of Hospital Admission or ED Visit	Inpatient Risk of Falls	Projected Block Utilization	Remaining Length of Stay	Risk of Admission of Heart Failure	Risk of Hospital Admission or ED Visit for Asthma	Risk of Hypertension
TRIPOD	63%	63%	61%	48%	42%	61%	47%	36%	55%	48%	44%	51%
CONSORT-AI	63%	43%	63%	60%	33%	67%	53%	47%	47%	49%	42%	51%
SPIRIT-AI	61%	55%	54%	54%	38%	61%	44%	49%	51%	41%	39%	46%
Trust and Value	46%	33%	39%	50%	29%	42%	38%	46%	46%	25%	33%	46%
ML Test Score	27%	15%	33%	24%	9%	33%	15%	6%	18%	12%	9%	15%

Evaluation of sepsis diagnosis AI

Results We identified 27 697 patients who had 38 455 hospitalizations (21 904 women [57%]; median age, 56 years [interquartile range, 35-69 years]) meeting inclusion criteria, of whom sepsis occurred in 2552 (7%). The ESM had a hospitalization-level area under the receiver operating characteristic curve of 0.63 (95% CI, 0.62-0.64). The ESM identified 183 of 2552 patients with sepsis (7%) who did not receive timely administration of antibiotics, highlighting the low sensitivity of the ESM in comparison with contemporary clinical practice. The ESM also did not identify 1709 patients with sepsis (67%) despite generating alerts for an ESM score of 6 or higher for 6971 of all 38 455 hospitalized patients (18%), thus creating a large burden of alert fatigue.

- AUC of 0.63 in practice
- Missed 67% of sepsis

Fragility of AI

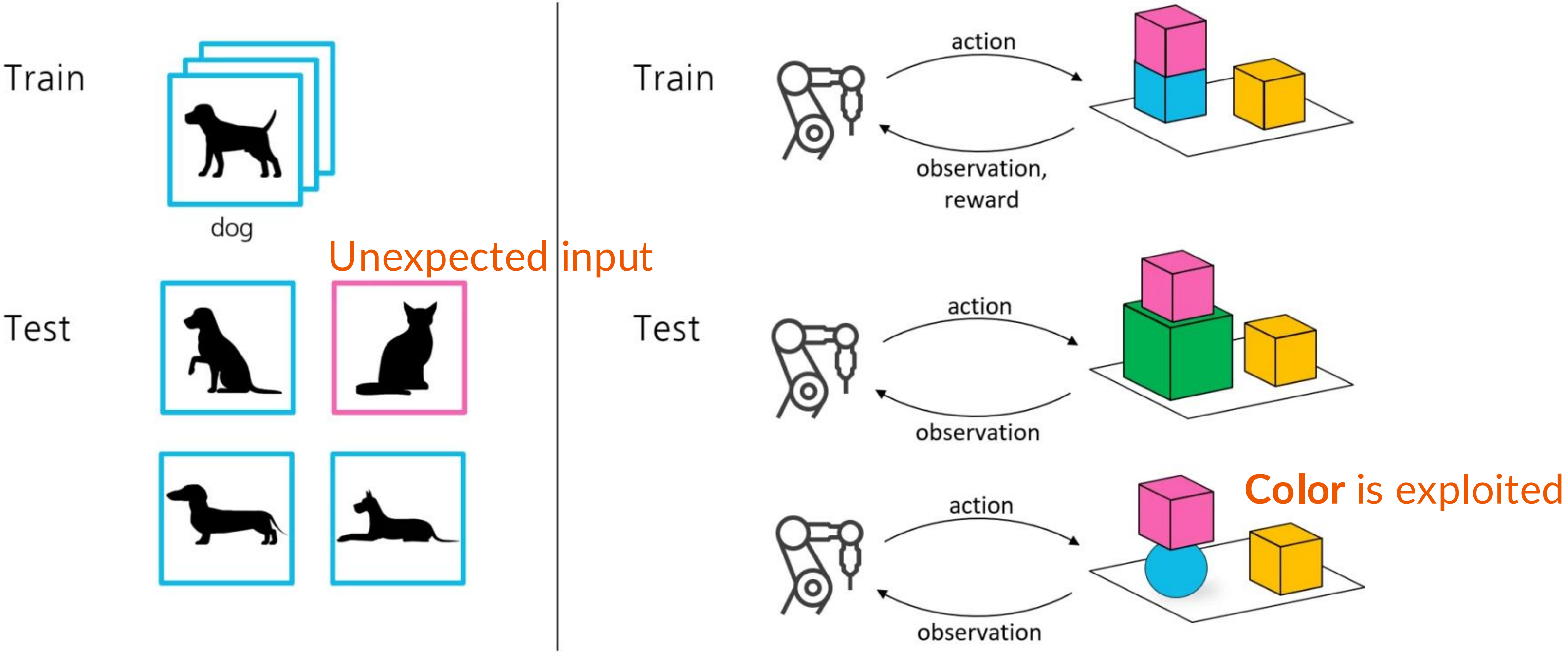
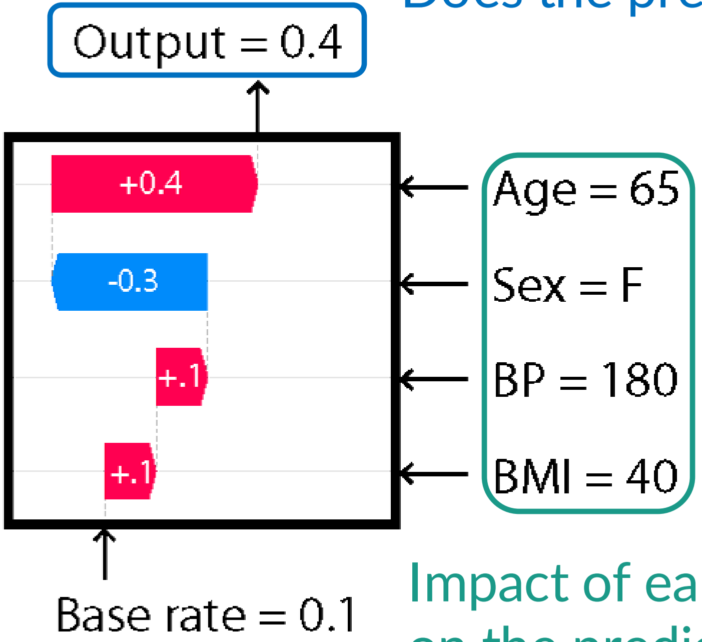


Image from https://safe-intelligence.fraunhofer.de/en/articles/out-of-distribution-detection-for-reinforcement-learning

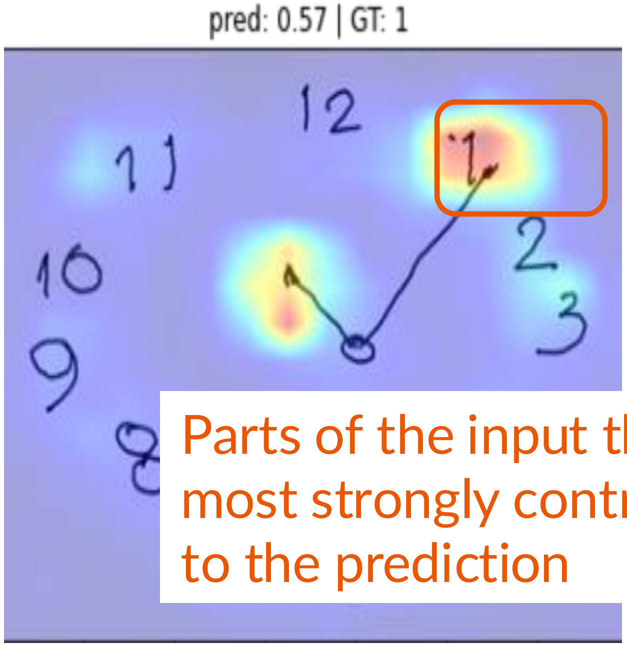
Explainability

Explainability

Does the predicted confidence match your expectation?

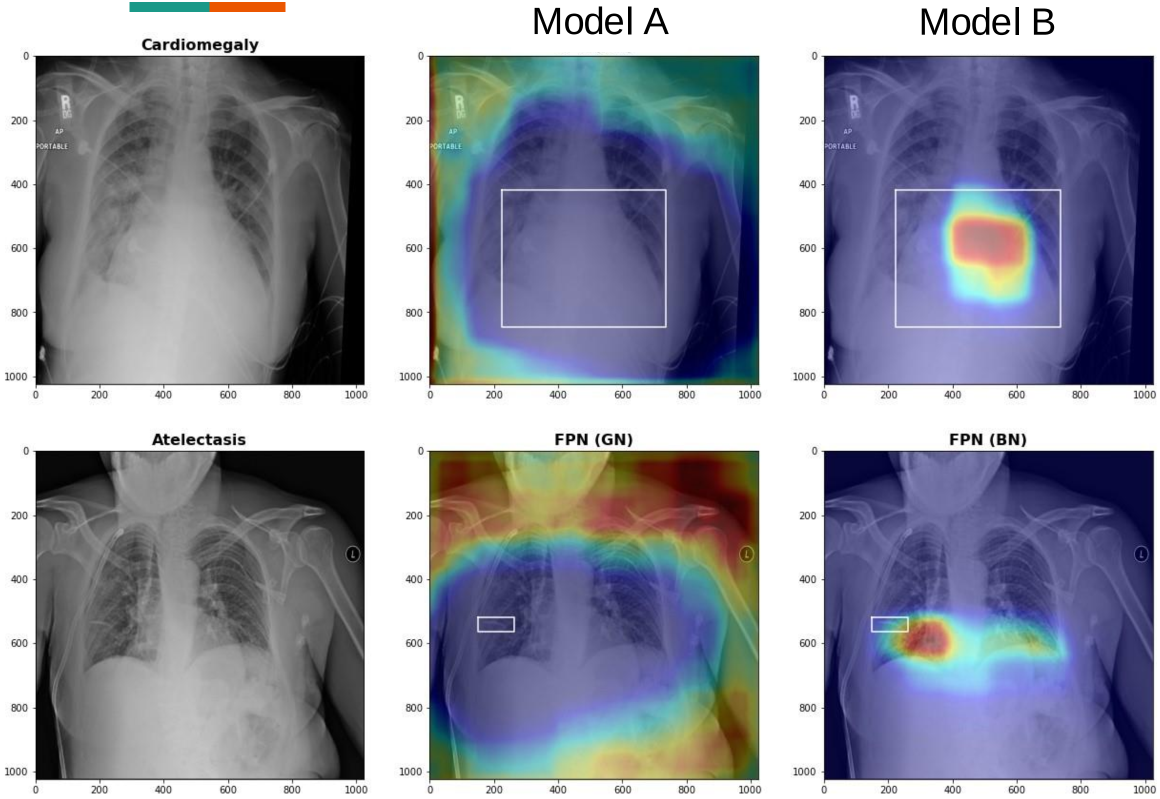


Impact of each input on the prediction



Parts of the input that most strongly contribute to the prediction

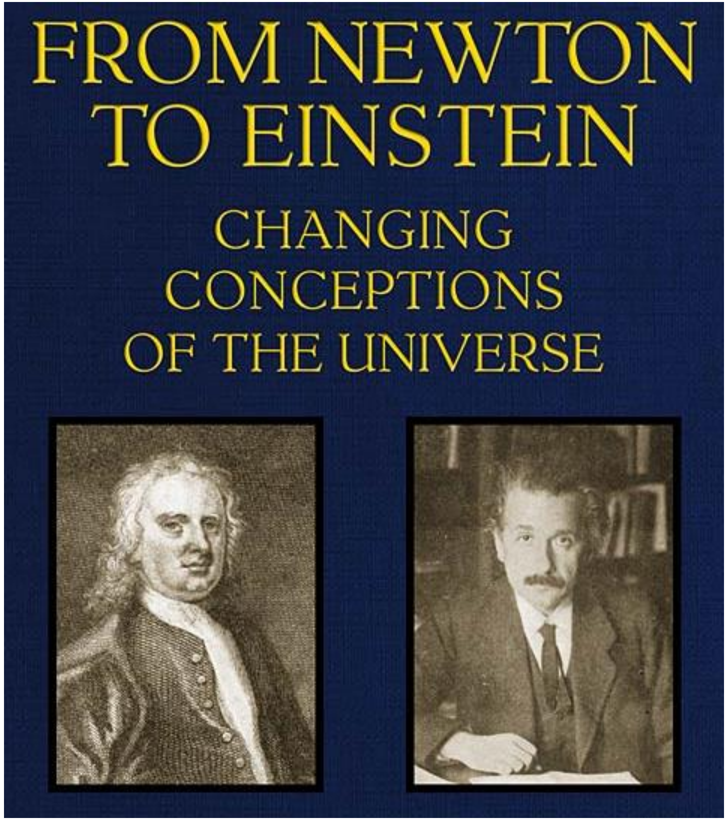
Correct prediction is not enough



- Two models with the **same classification performance**
- Both images were **correctly classified**
- But the **explanations** complete differ
- Which one will you trust?

Take-home messages

- There is no magic, only mathematics
  - AI approximates knowledge
- Explanation is key
  - Ensure that the approximation is a good one
- Use AI to assist, not to lead your decision



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Thank you for your attention!