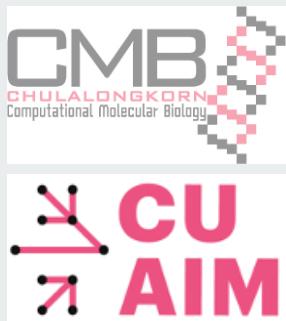

Computational Thinking, Machine Learning, and AI

300105 Medical Physics

October 10th, 2023



Sira Sriswasdi, PhD

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

Sira Sriswasdi (สิระ ศรีสวัสดิ์)

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ภูมิสิริ ชั้น 8 โซน C
ฝ่ายวิจัย งานน้ำฯ ชั้น 3



Hiking Mode

Work Mode

Education

BS **Mathematics** (2008)

Massachusetts Institute of Technology

PhD **Computational Biology** (2013)

University of Pennsylvania

JSPS Postdoctoral Fellow (2013-2017)

The University of Tokyo

Current Position

Center for AI in Medicine

Center for Computational Molecular Biology

Faculty of Medicine, Chulalongkorn University

Hobby

Hiking, Japanese

Toward the summit of Fuji-san, 2008



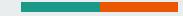
Research Keywords

Omics data analysis

Machine learning

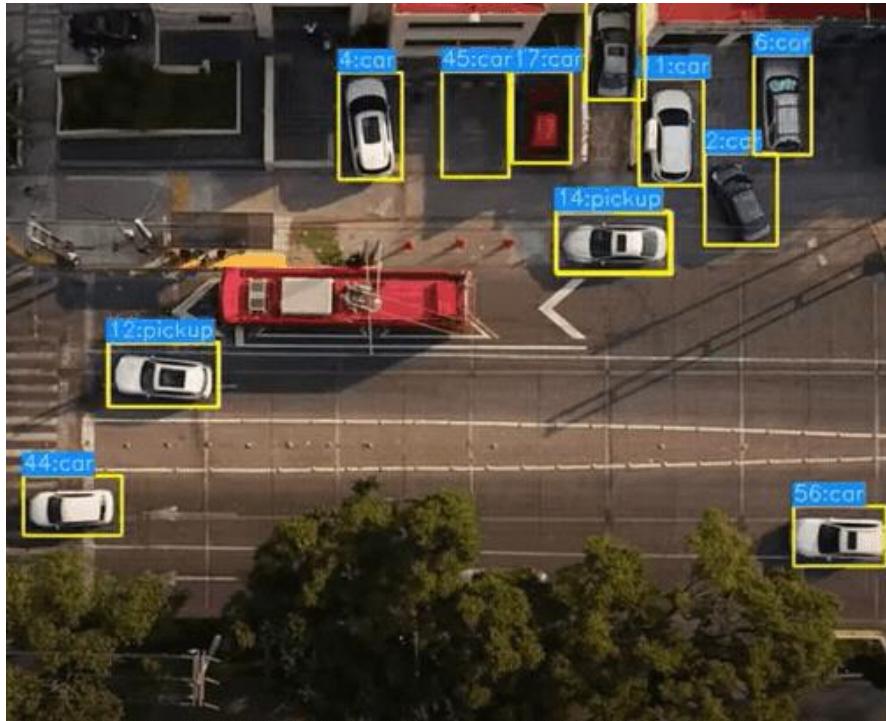
Evolution of microorganisms

Mathematical modeling

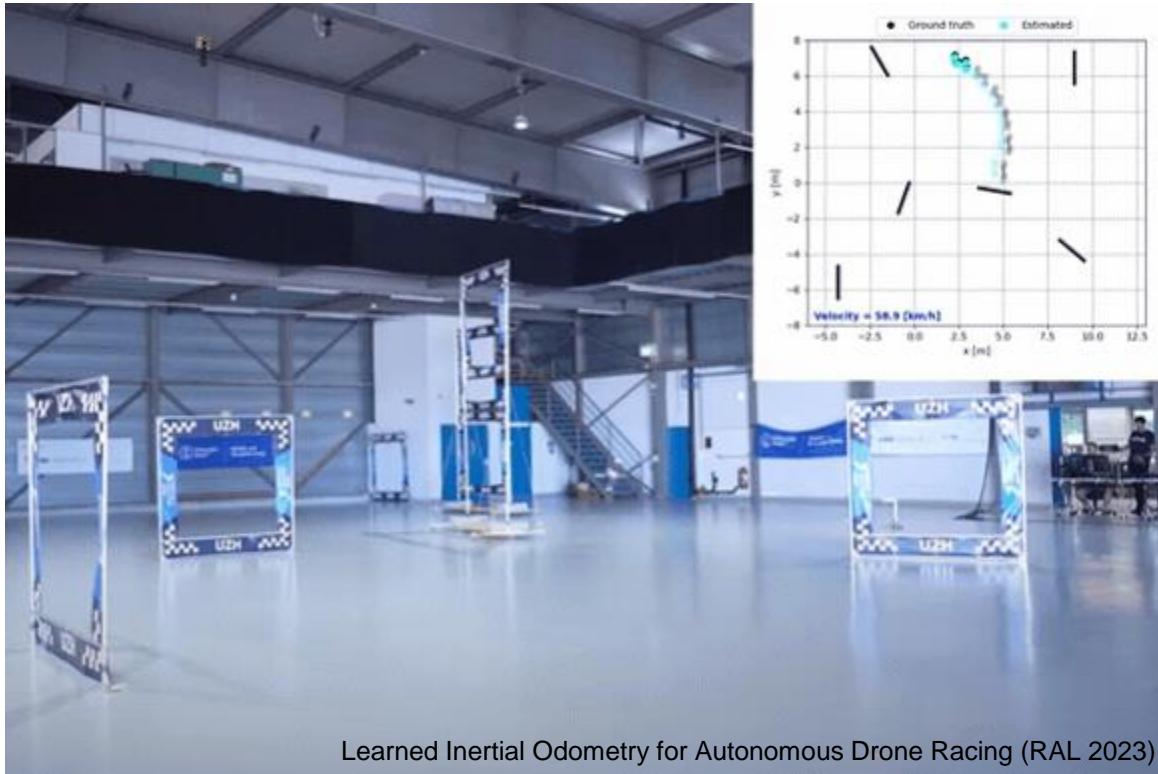


Today's Artificial intelligence

Real-time object recognition



Interaction with real-world environment



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



Language understanding: ChatGPT



I'm teaching a large group of first-year medical students. The session will be 1 hour. The broad topic is computational thinking, machine learning, and AI. Which particular topics should I pick to go into greater details given the limited time and limited background knowledge of the students?

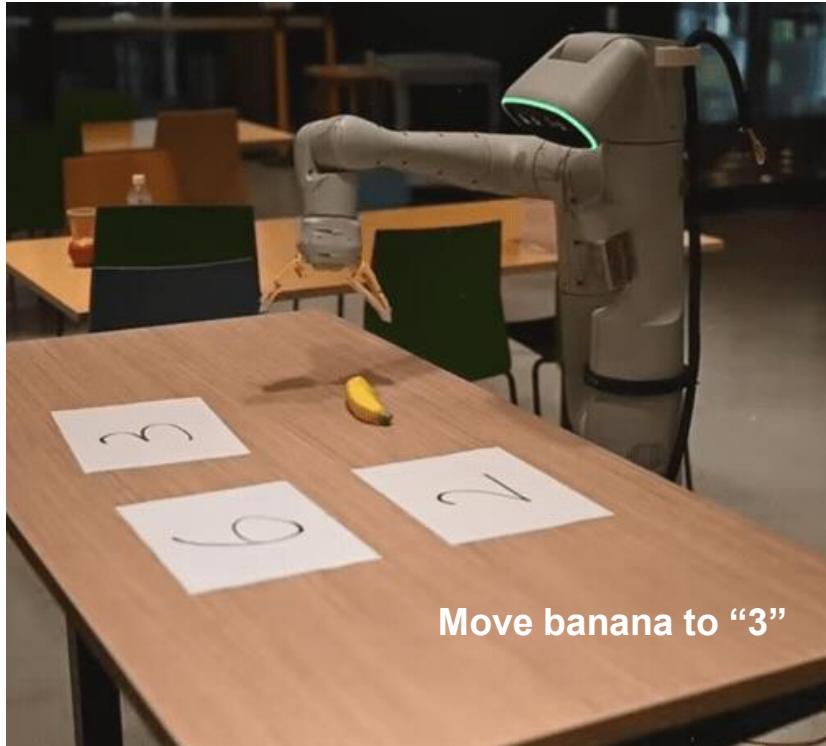


Teaching first-year medical students about computational thinking, machine learning, and AI in a one-hour session can be challenging, but you can provide them with a foundational understanding of these topics. Given the limited time and background knowledge, here are some specific topics you can cover in greater detail:

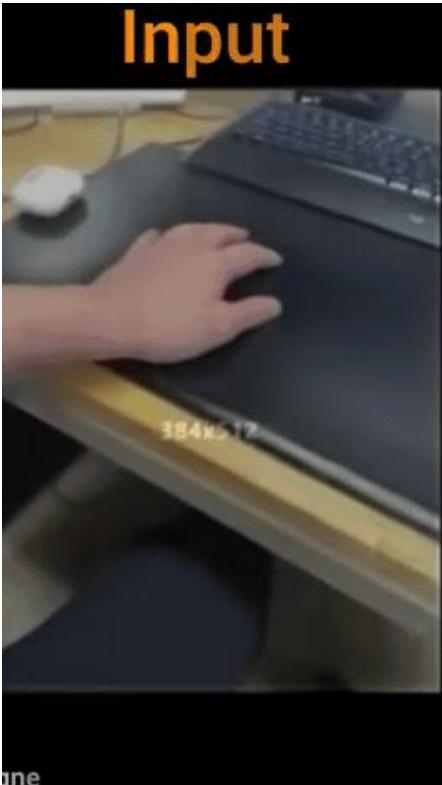
- 1. Introduction to Computational Thinking (15 minutes):**

- Define computational thinking and its importance in healthcare.

Text to action: Google RT-2



Art and deepfake



Talking head anime: <https://github.com/pkhungurn>



Stable Diffusion: 8

Generative AI: Stable Diffusion

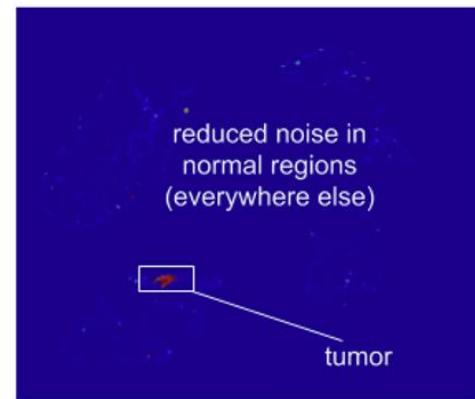
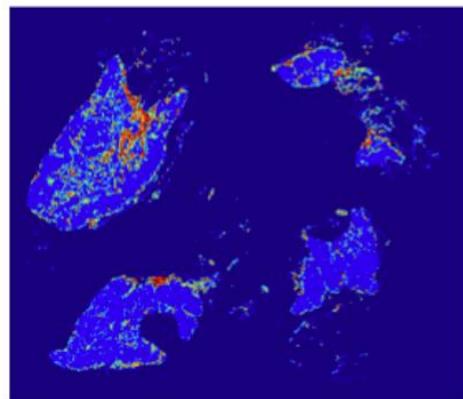
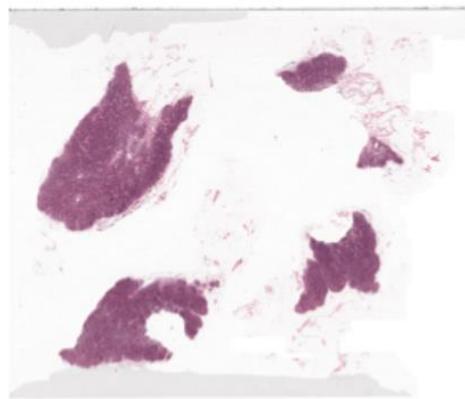
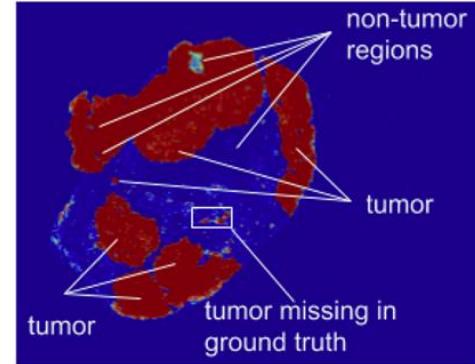
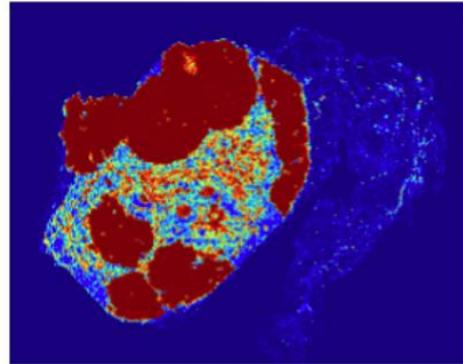
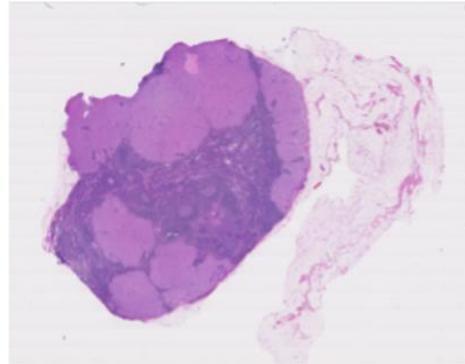
"A lecturer in front of a classroom of 300 medical students"





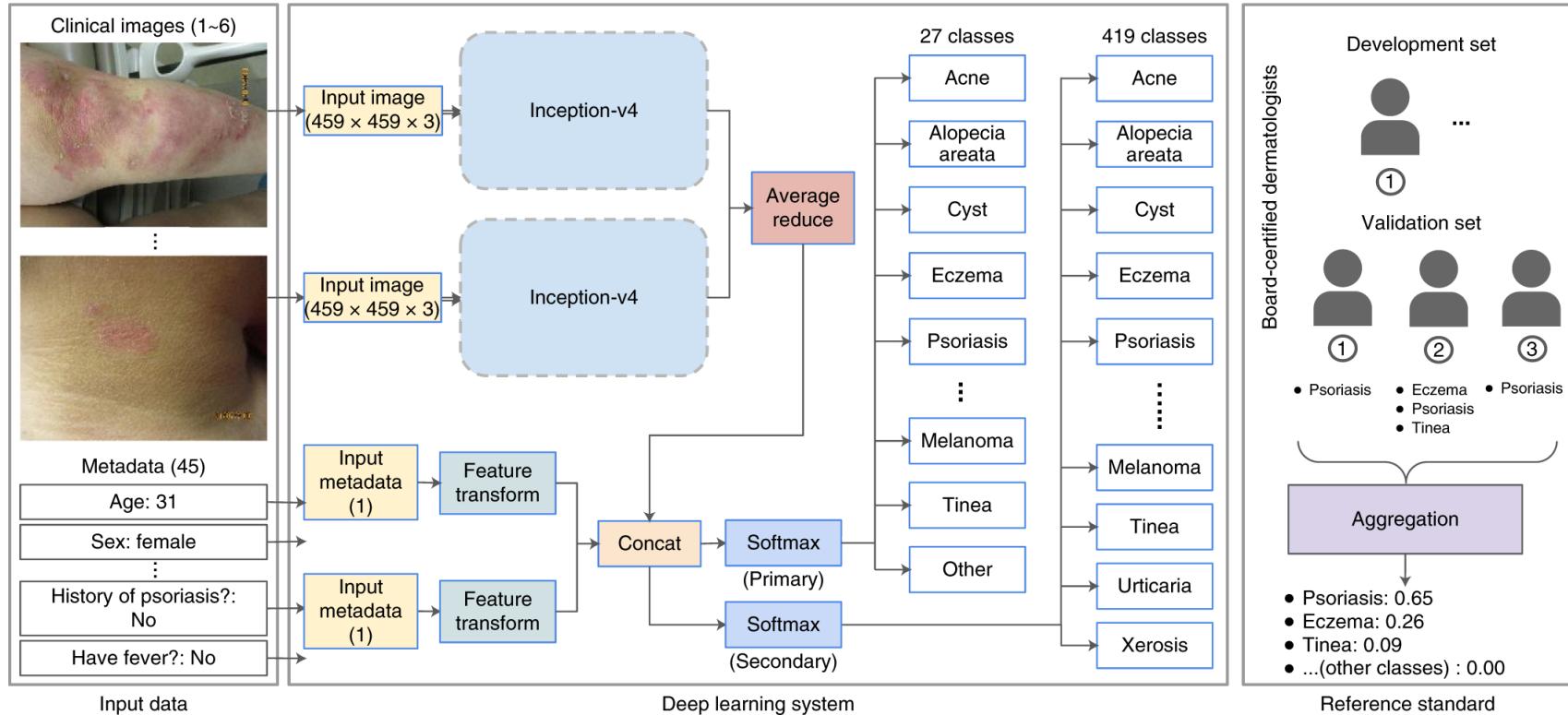
AI in medicine and healthcare

Tumor segmentation



Skin lesion assessment

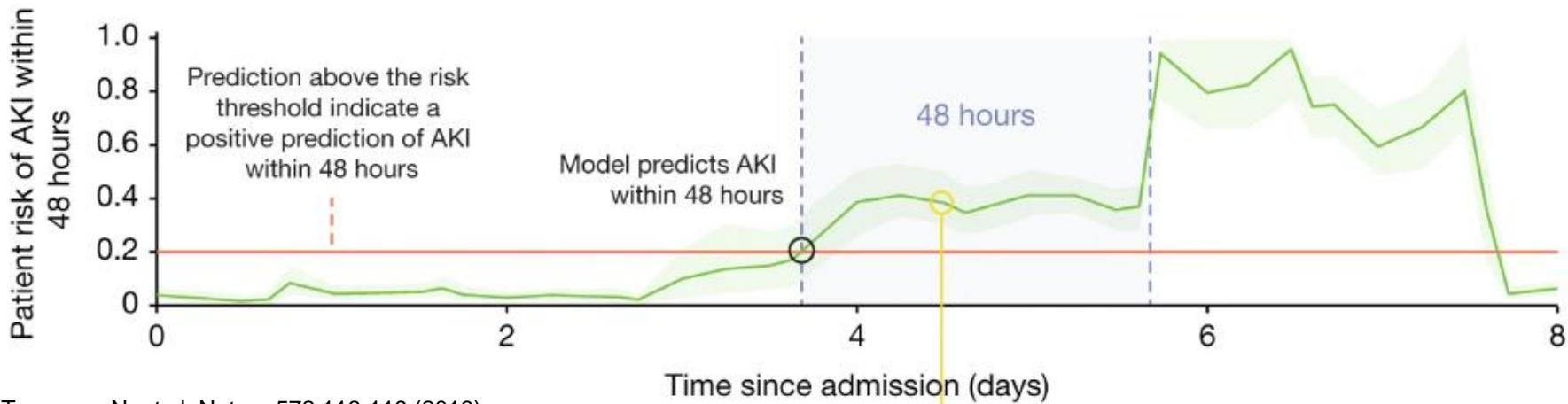
Liu, Y. et al. Nature Medicine 26:900-908 (2020)



Early warning for acute kidney injury

- Inputs
 - Medical record
 - Blood tests
- Outputs
 - Risk of AKI in the next 48h

Using AI to give doctors a 48-hour head start on life-threatening illness



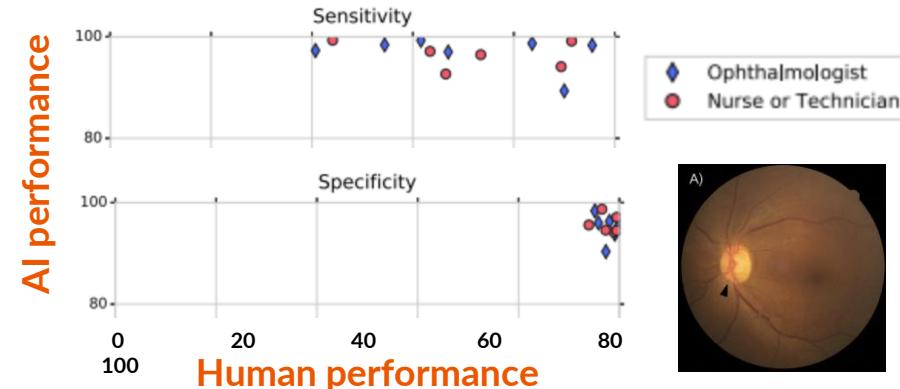
National diabetic retinopathy screening



ARTICLE

OPEN

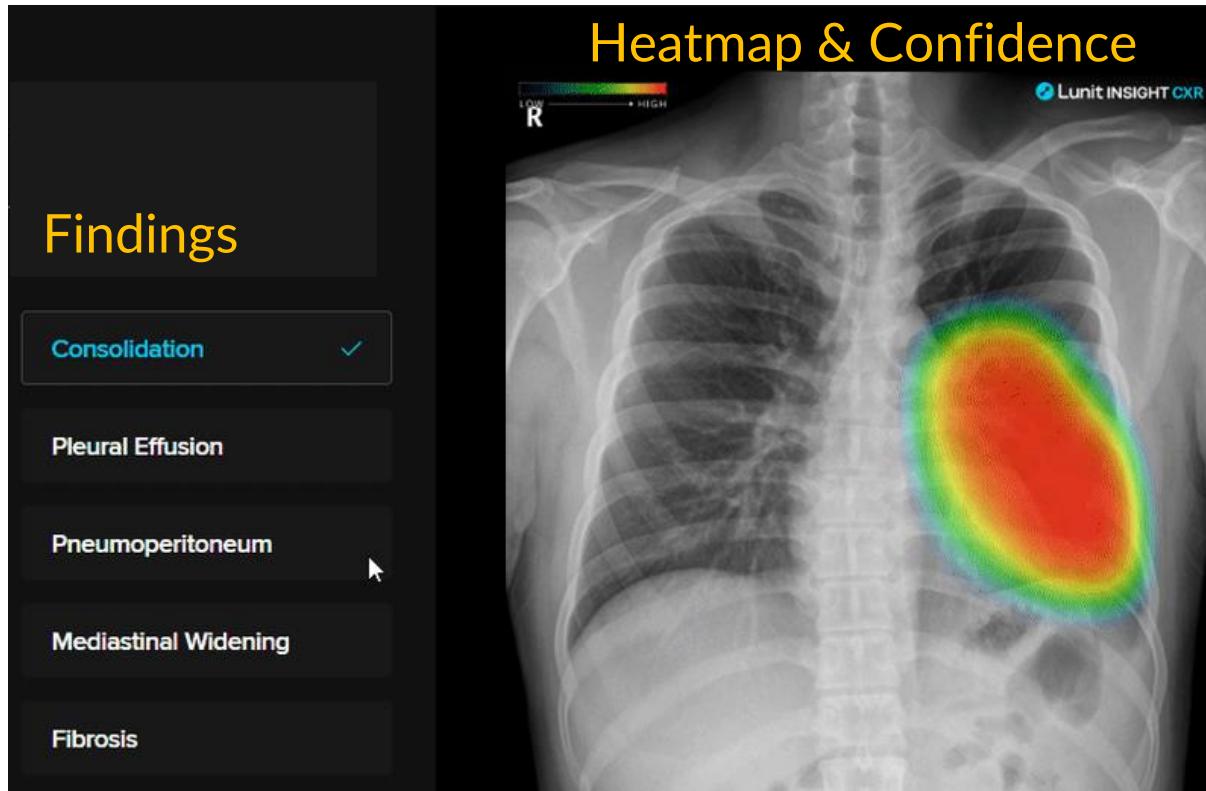
Deep learning versus human graders for classifying diabetic retinopathy severity in a nationwide screening program



- 25k fundus images from 7,517 patients in Thailand

Chest x-ray reader: Lunit

Ju Gang Nam et al. - European Respiratory Journal (2020)



Question answering service via ChatGPT



Domain-specific information

A screenshot of a web-based application showing a list of questions and answers. The interface includes a search bar, a 'Add Question' button, and a table with columns for Primary Question, Labels, Variations, Answer, and Last Updated.

Primary Question	Labels	Variations	Answer	Last Updated
What is an Endoscopy procedure	endoscopy	2	17 days ago Orbita Health	...
Can I exercise after my colonoscopy?	exercise gym	18	5 months ago Orbita Health	...

Interpreting question and formulating answer using ChatGPT

GPT-3.5, Prompt, Context, Question

Answer the question based on the context below.
If the question cannot be answered using the information provided answer with 'I don't know'

Context:

TEXT of Article from Vector DB



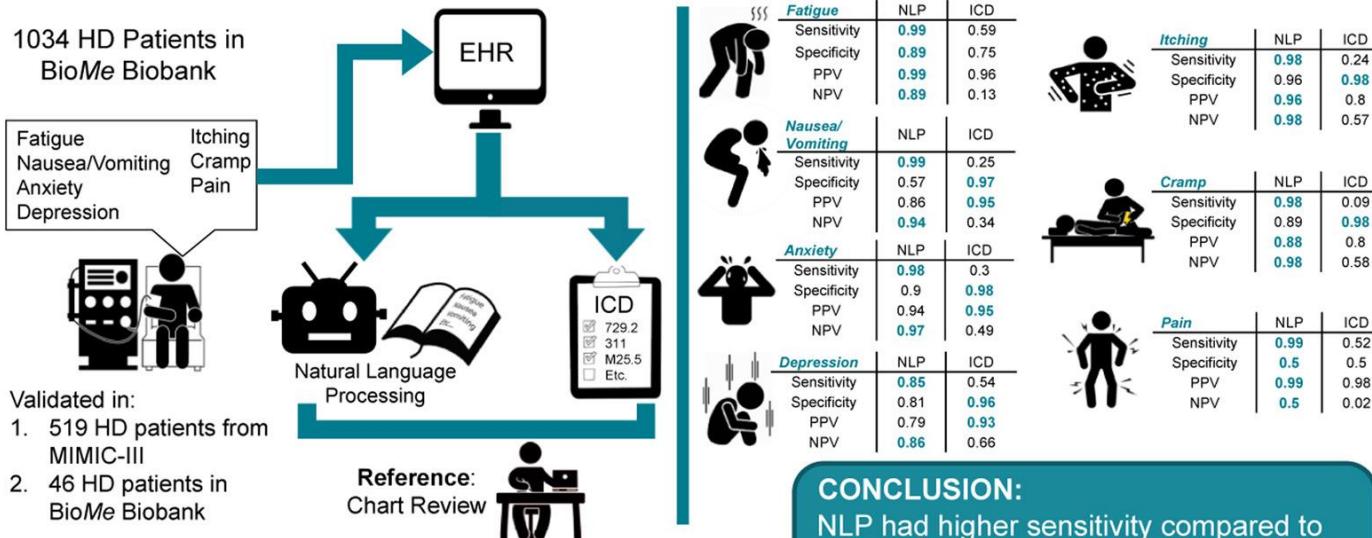
Where is your office

Our headquarters are located at 77 Sleeper St, Boston, MA 02210

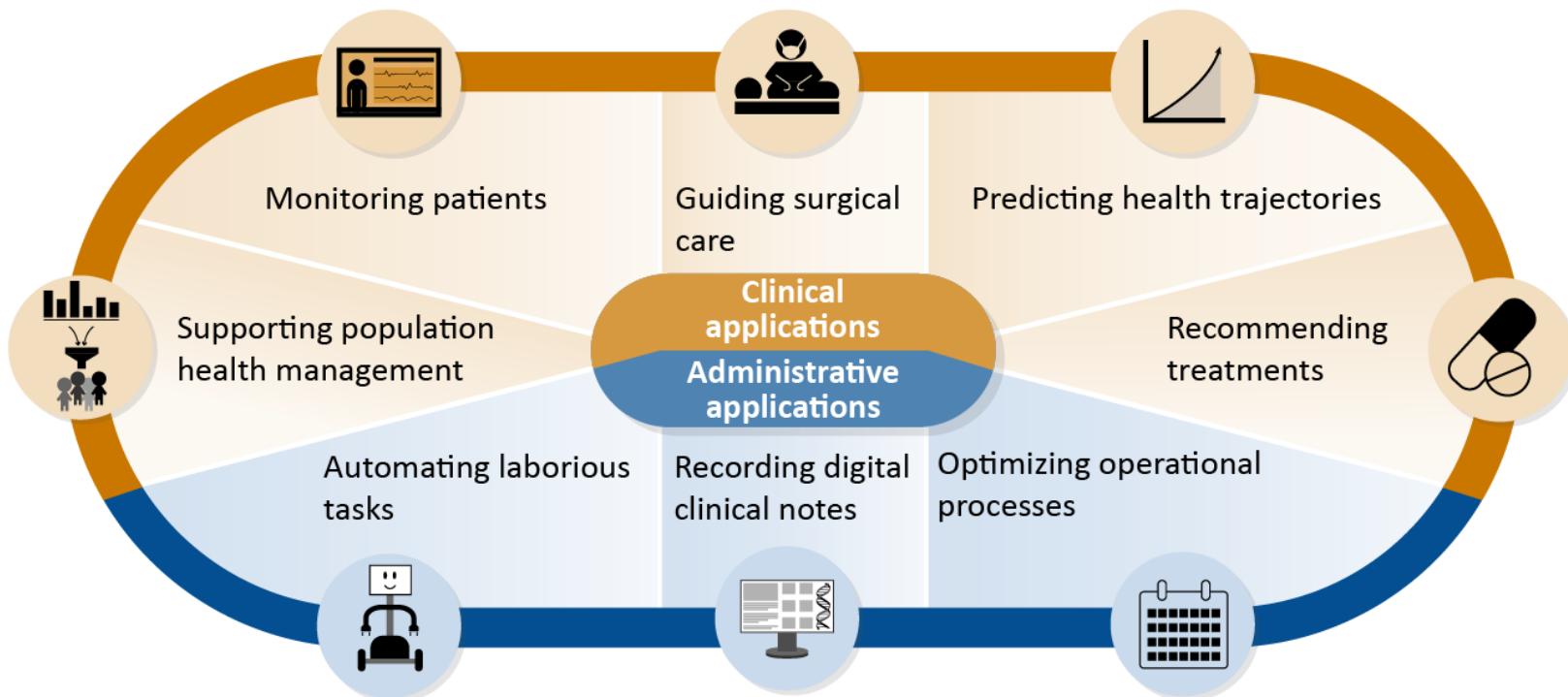
Information extraction from electronic health record

Chan, L. et al. Kidney International 97:383-392 (2020)

Natural language processing of electronic health records is superior to billing codes to identify symptom burden in hemodialysis patients.



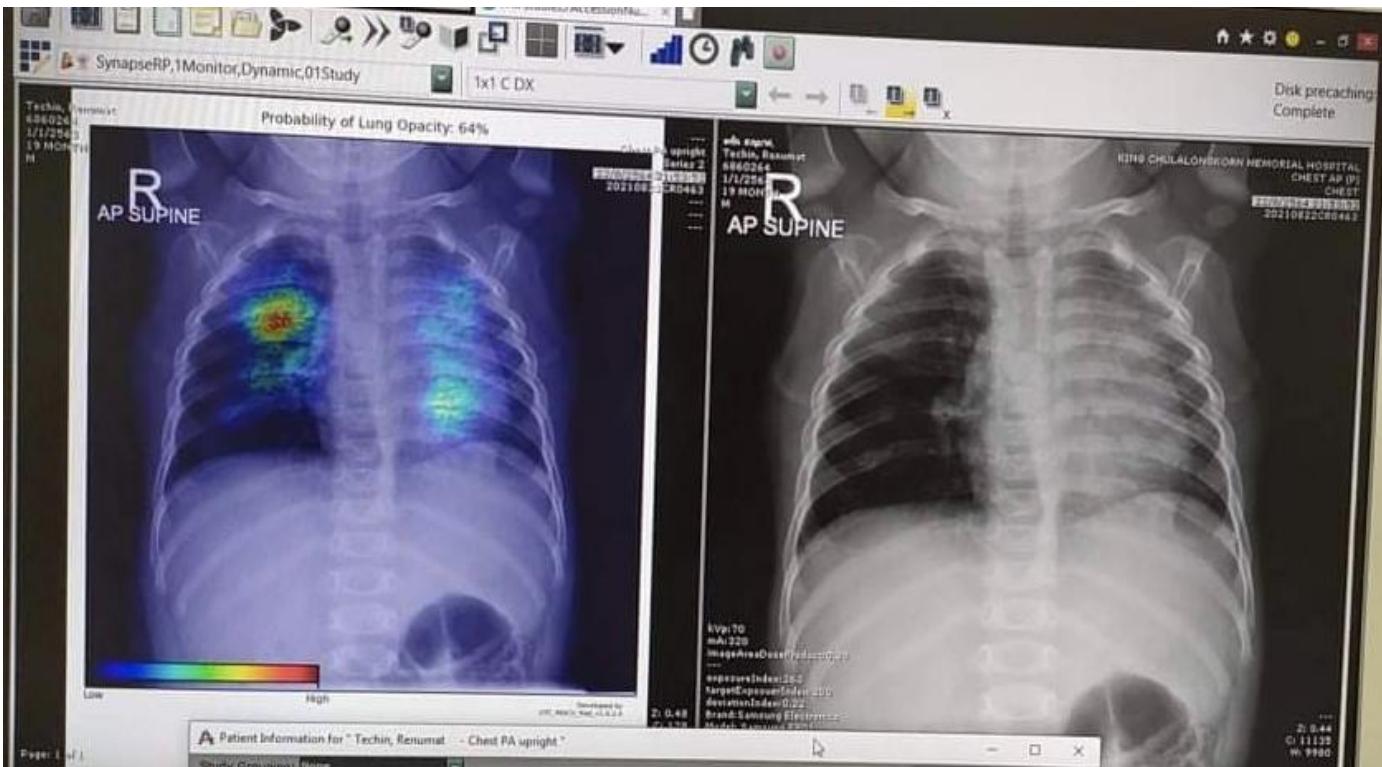
Use cases for AI in healthcare



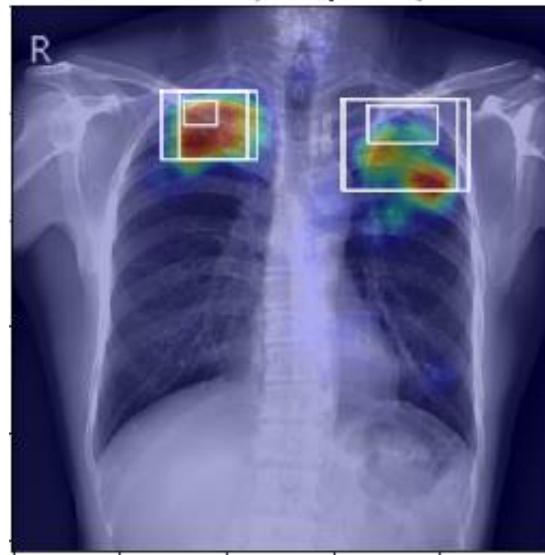
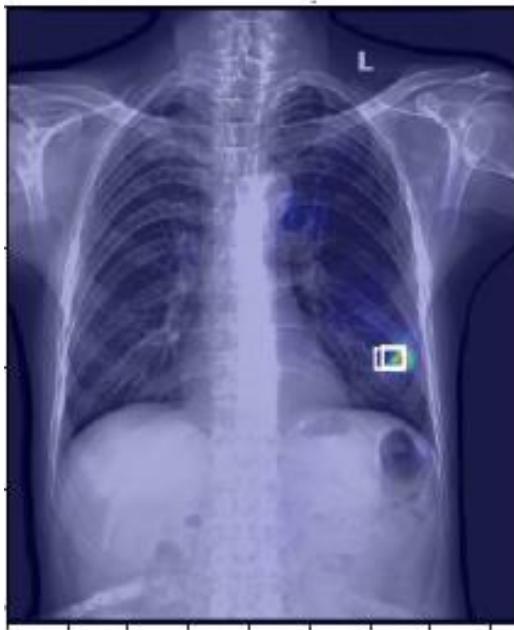
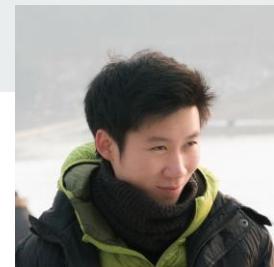


Medical AI at MDCU

Our local CXR AI



Accurate lesion localization



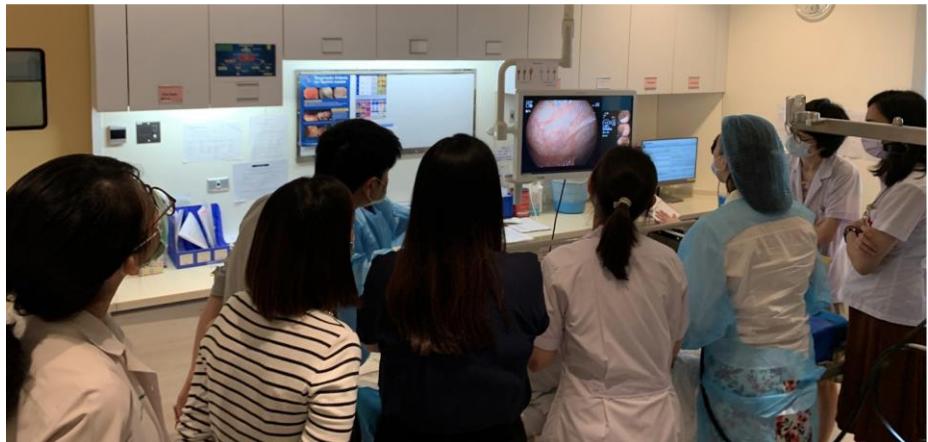
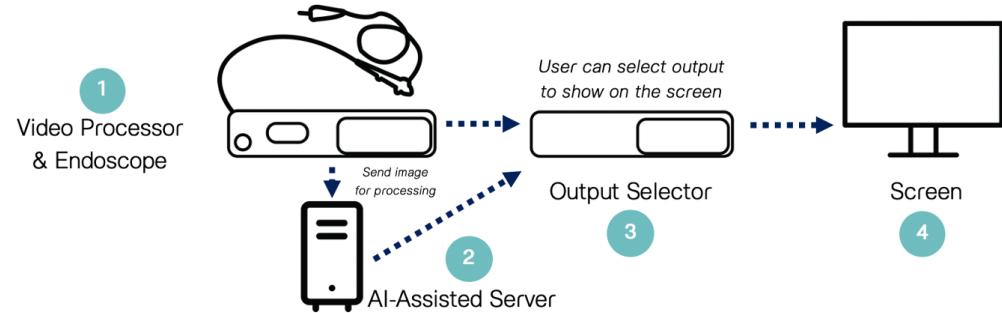
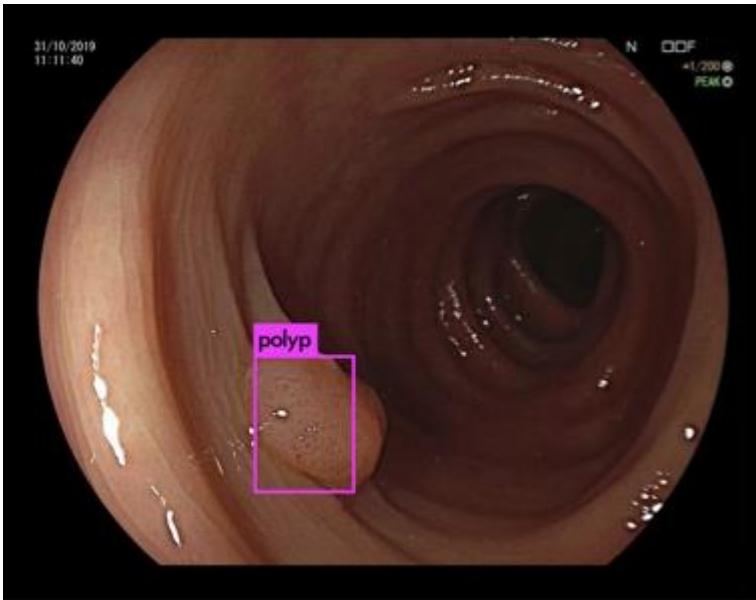
- Trustworthy AI must be able to provide evidence supporting prediction

Automatic radiologist report generation

X-ray	Ground truth	LSP
	<p>frontal and lateral views of the chest were obtained. there are streaky linear opacities at the lung bases which are likely due to atelectasis with chronic changes. no definite focal consolidation is seen. there is no pleural effusion or pneumothorax. no pneumothorax is seen. the aorta is calcified and tortuous. the cardiac silhouette is top normal to mildly enlarged. dual-lead left-sided pacemaker is seen with leads in the expected positions of the right atrium and right ventricle. chronic-appearing rib deformities on the right is again seen.</p>	<p>frontal and lateral views of the chest were obtained. there is a small left pleural effusion with overlying atelectasis. there is no focal consolidation, pleural effusion or pneumothorax. the aorta is calcified and tortuous. the heart is mildly enlarged. a left-sided pacemaker is seen with leads in the expected position of the right atrium and right ventricle. the patient is status post median sternotomy and cabg. the lungs are otherwise clear.</p>

AI-assisted endoscopy

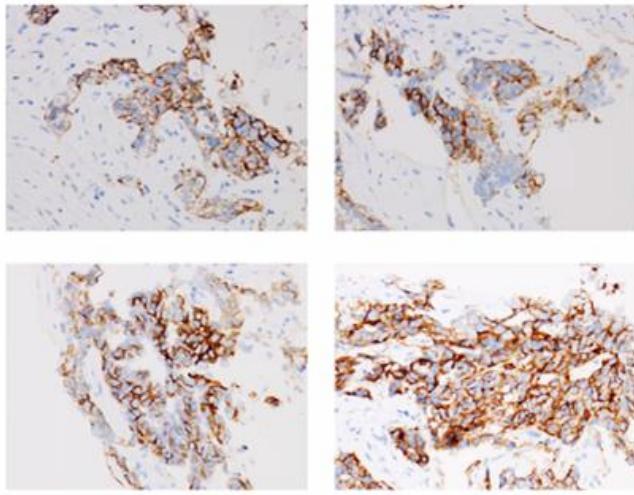
Real-time polyp detection



Digital pathology

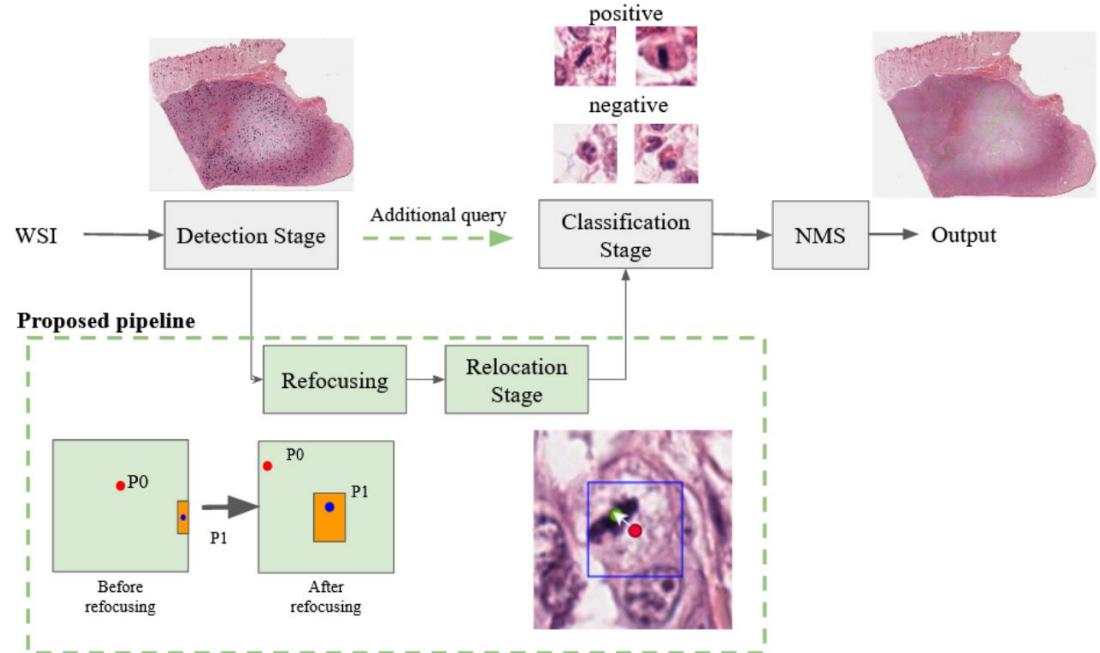


HER2 quantification & grading



- Speed up analysis and improve accuracy

Mitotic hotspot proposal

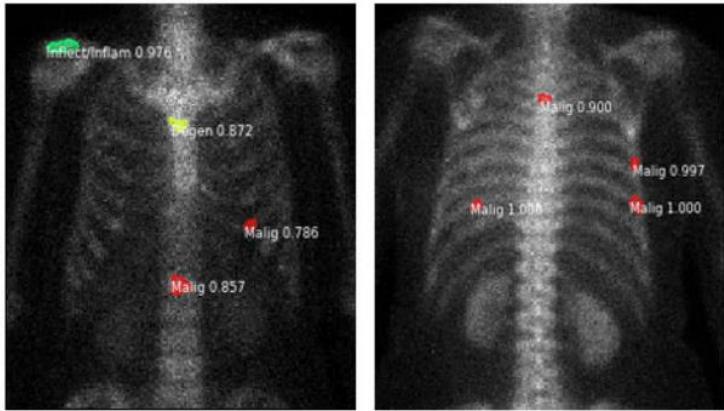


Piansaddhayanon, C. et al. AI in Medicine (2023)

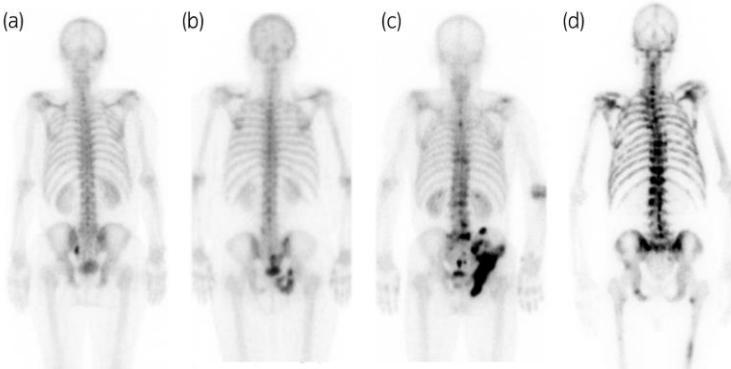


Bone scan analysis

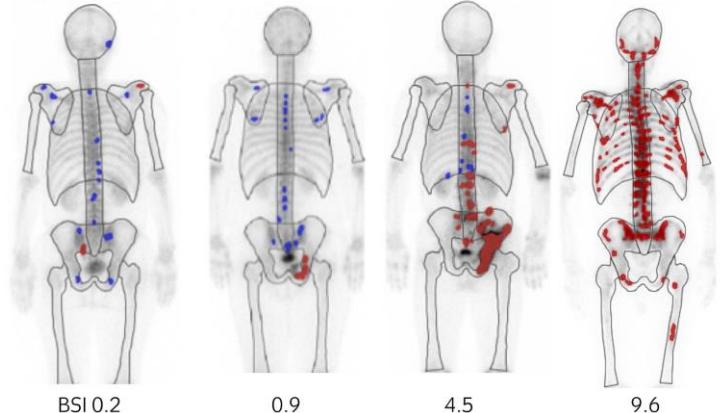
Predicted as metastasis



Whole-body
bone image:
posterior view



Artificial neural
network
analysis



- Increase junior radiologist's performance to the same level as senior radiologist's

D-Mind: Depression diagnosis and management



Natural Language
Processing (NLP)



Facial



Feature
Engineering (FE)



Speech Emotion
Recognition (SER)



หมอพร้อม Chatbot

สามารถเลือกจากเมนูหรือพิมพ์คำถาม
ด้านล่างได้เลยครับ

ตรวจสุขภาพใจ

ประเมินการใช้งาน



ผลการประเมิน
คุณมีความเสี่ยงซึ่งเป็น
ระดับสูง



หมอพร้อมคิดว่าคุณต้องการ
ความช่วยเหลือ ณ ขณะนี้
เรามีติดต่อกลับหากคุณโดยเร็วที่สุด

ติดต่อนักจิตวิทยา



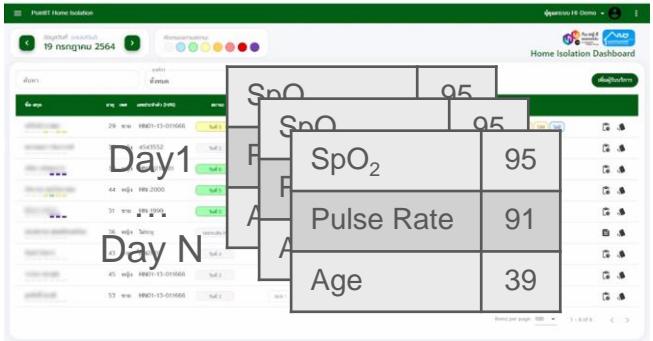


AI-assisted COVID-19 monitoring

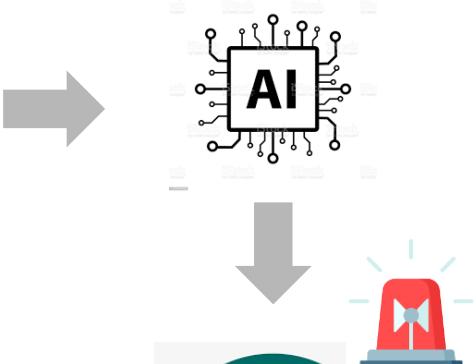
1. Patients send vital sign and symptom data from home



Monitoring dashboard (weSAFE)



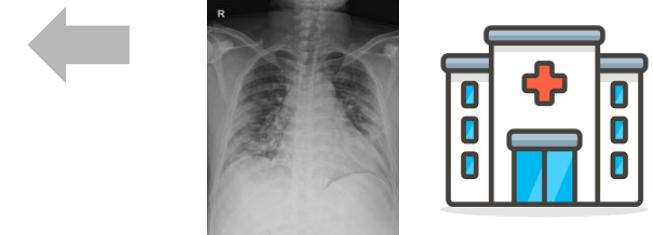
2. AI predicts risk of adverse event



5. Conventional healthcare decision making



4. Follow-up for high-risk patients



3. Alert doctors





Your roles in AI development and utilization

Hallucination problem

Prompt: When did The New York Times first report on “artificial intelligence”?



ChatGPT: It was July 10, 1956, in an article titled “Machines Will Be Capable of Learning, Solving Problems, Scientists Predict” about a seminal conference at Dartmouth College. This conference is now considered to be the birthplace of artificial intelligence as a field of study.

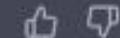
- Made up information written eloquently can fool non-experts

But is it hallucination?

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?*

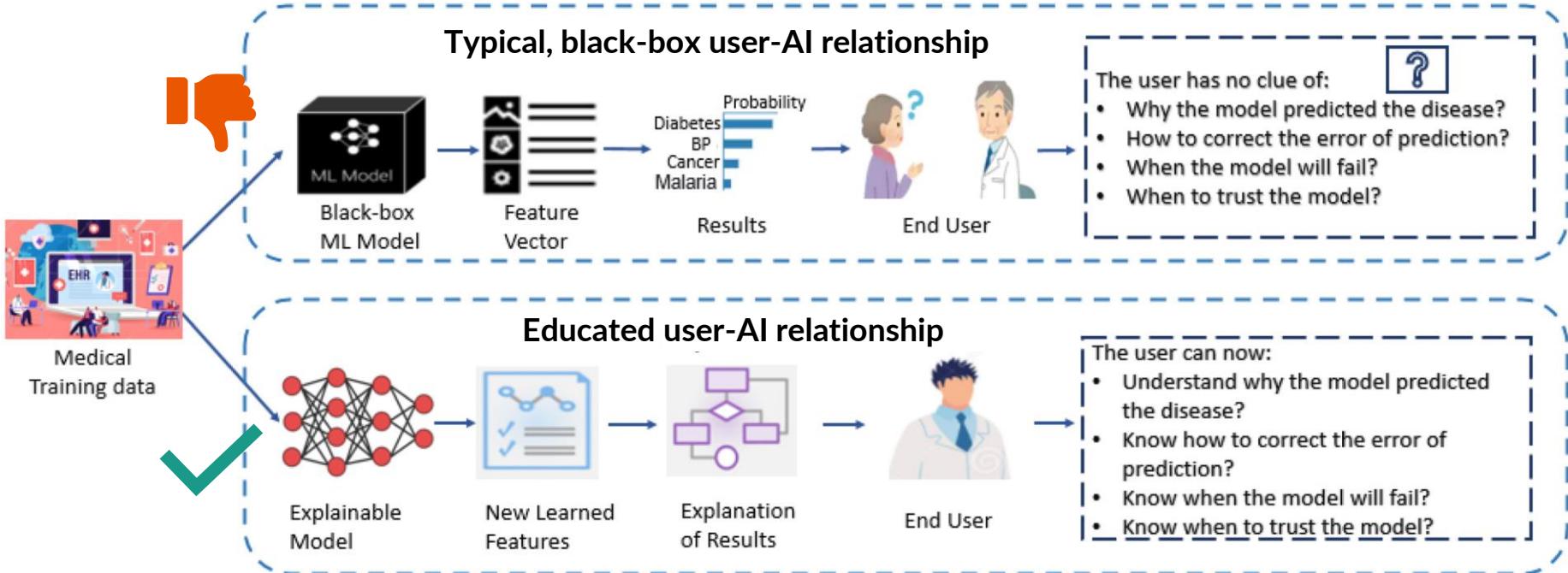
AI-assisted, not AI-driven, healthcare



AI provides quantitative assessment and real-time monitoring of clinical data

Clinicians **combine personal expertise with AI's outputs** to make the final decision

Users need to understand AI



Huge gap between development and deployment

Healthcare, Law, Regulation, and Policy, Machine Learning

“Flying in the Dark”: Hospital AI Tools Aren’t Well Documented

Evaluation of sepsis diagnosis AI

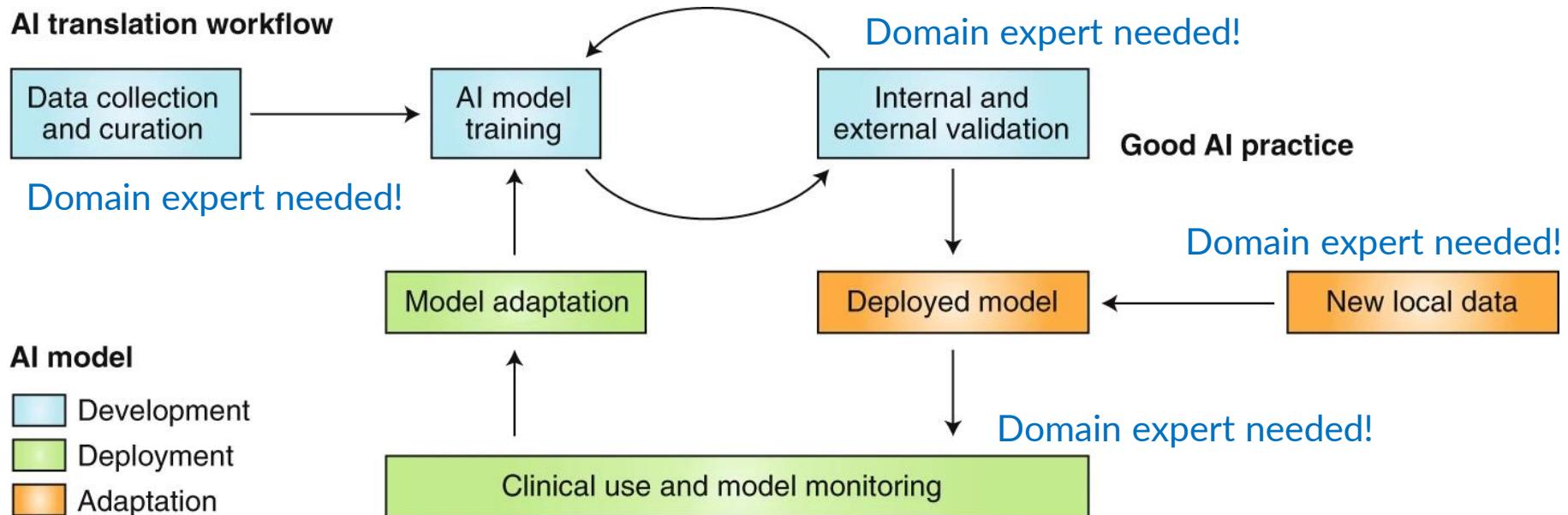
MODEL REPORTING GUIDELINES	EPIC MODEL BRIEFS												
	Deterioration Index	Risk of Early Detection	Risk of Unplanned Readmission	Pediatric Risk of Patient No-Show	Hospital Risk of ED Visit	Risk of Hospital Admission or ED Visit	Inpatient Risk of Falls	Projected Block Utilization	Remaining Length of Stay	Risk of Heart Failure	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%	

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

Sustainable AI requires domain experts

AI translation workflow



- Anyone can feed data through ML library
- Only domain experts can spot model weakness and find data to fix it



Foundation toward understanding AI

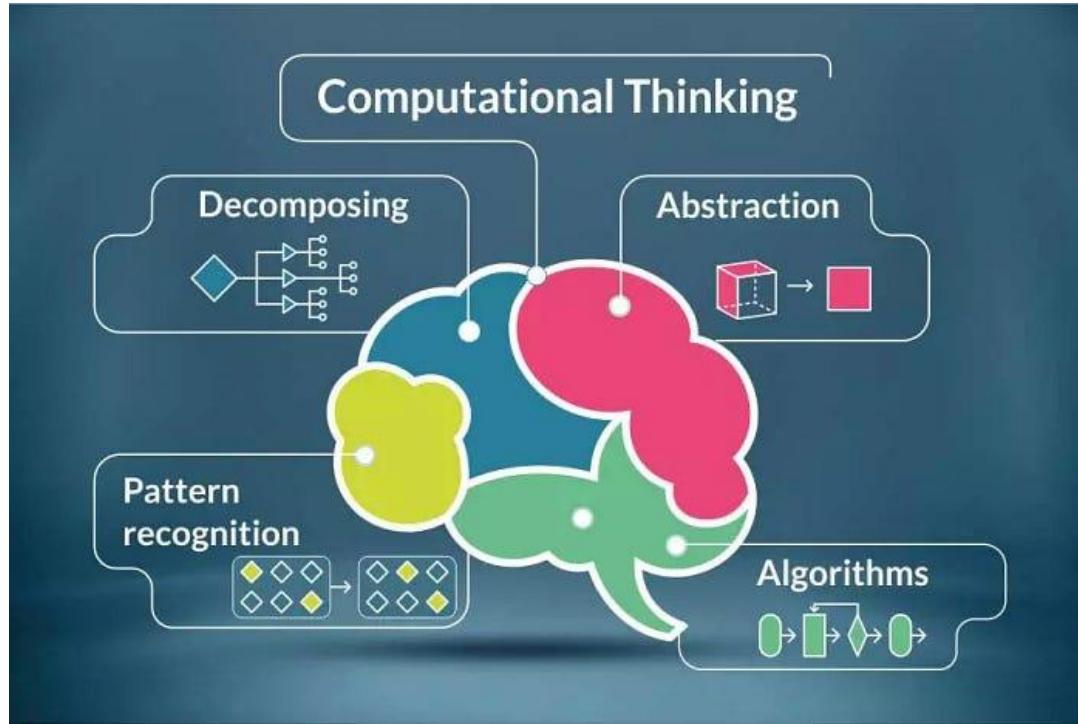


Computational thinking

What is computational thinking?

Breaking down a complex problem into smaller components and relationships

Identifying similarities or patterns in the data to utilize and learn from them



Simplifying the variables to focus on the most important factors

Formulating a well-defined step-by-step process to solve the problem

Decomposing

Breaking down a complex problem into smaller components and relationships

Cure Cancer!

Early Diagnosis

Can we detect tumor DNA in bloodstream?

Subtyping

Can we identify groups of patients with similar characteristics?

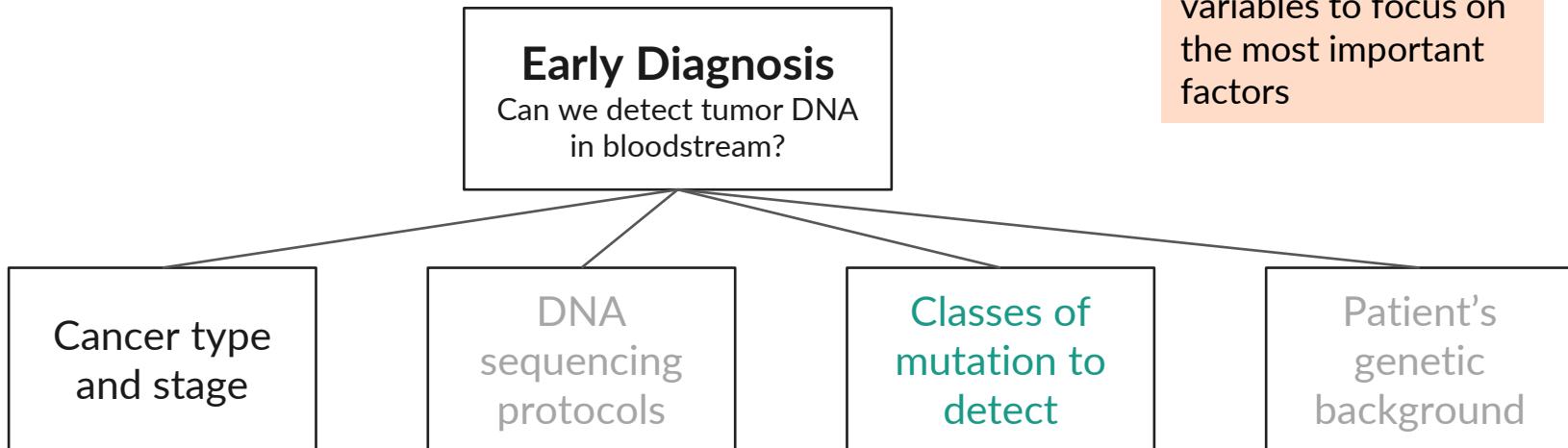
Prognosis

How severe is this case?
Should aggressive treatments be considered?

Treatment

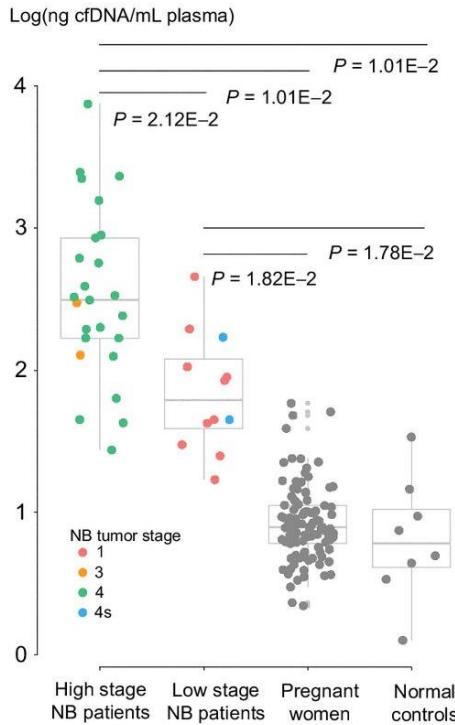
How to identify the best treatment for each patient?

Abstraction



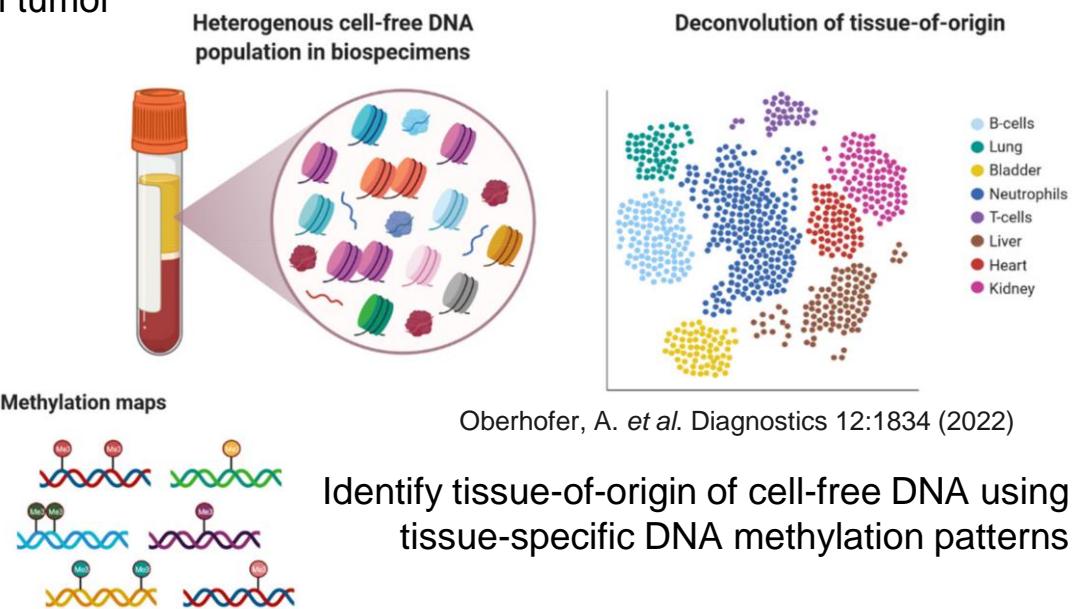
- **Single-nucleotide mutation**
 - Many **non-cancer-related** mutations
- **Copy number and structural variation**
 - **Easier to detect**
 - But **may not be present** at early stages

Pattern recognition



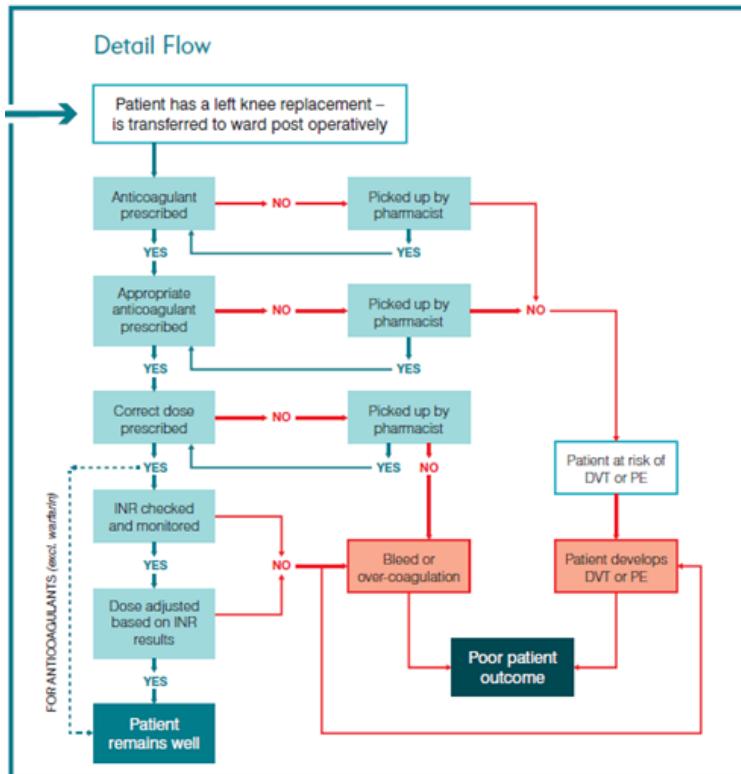
Abundance of cfDNA in bloodstream correlates with tumor stage

Identifying similarities or patterns in the data to utilize and learn from them



Algorithm

Formulating a step-by-step process to solve the problem



- Organized and systematic
- Easy to debug (find & solve errors)
- Provide a standard
 - Good inter-rater agreement
 - No batch effect
 - Replicable results

Data analysis and visualization

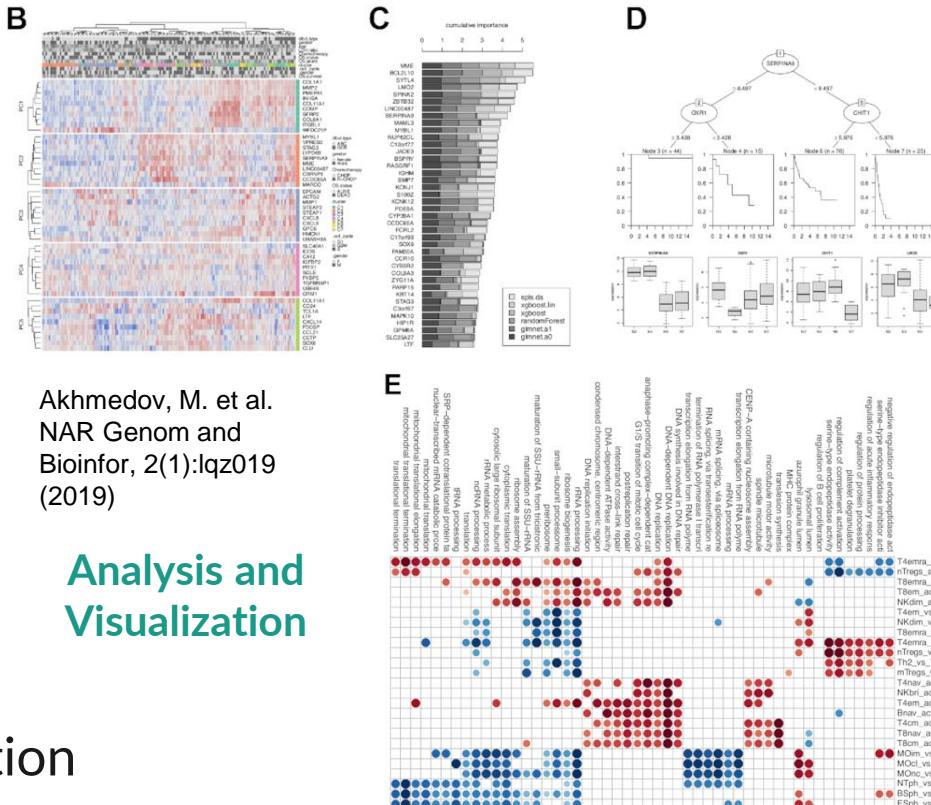


Data

Gene ID	P61_2_C	P62_2_C	P63_2_C	P64_2_C	P68_2_C
ENSG000000000003.14	4.637576	6.183992	5.237635	2.372719	5.665966
ENSG000000000005.5	0	0	0	0	0
ENSG00000000419.12	11.22781	4.813792	2.99782	10.99452	10.7482
ENSG00000000457.13	7.656414	5.082675	7.710682	9.014404	8.488388
ENSG00000000460.16	3.172546	2.245954	5.974815	3.501081	4.162024
ENSG00000000938.12	0	0	0	0.042488	0
ENSG00000000971.15	6.626259	8.19511	5.904925	11.7748	2.050394
ENSG000000001036.13	1.790445	0.76823	3.670635	0.68115	1.894823
ENSG000000001084.11	19.53907	25.08378	11.04872	5.815902	20.23763
ENSG000000001167.14	15.34717	20.00867	17.10001	25.31168	27.41216
ENSG000000001460.17	0.889852	3.090642	0.744581	3.439525	2.417934
ENSG000000001461.16	3.771195	3.12468	1.385353	2.767444	2.973217
ENSG000000001497.16	16.75059	9.662455	15.4965	14.34071	10.62035
ENSG000000001617.11	2.998366	3.712208	3.885852	17.50663	3.019686

Akhmedov, M. et al.
NAR Genom and
Bioinfor, 2(1):lqz019
(2019)

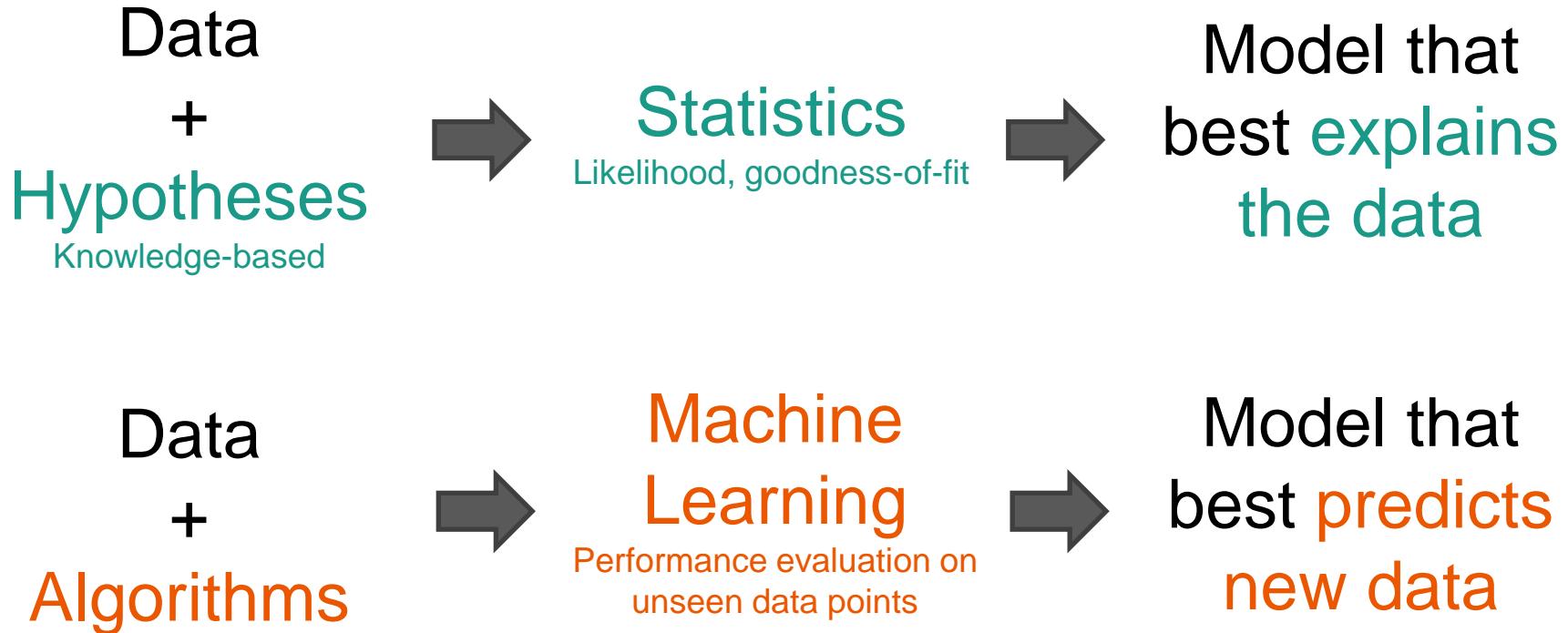
Analysis and Visualization



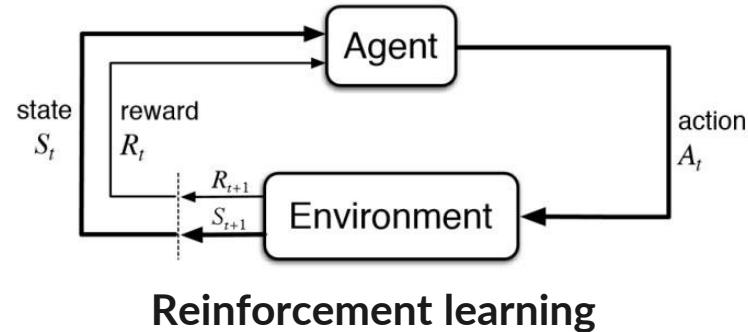
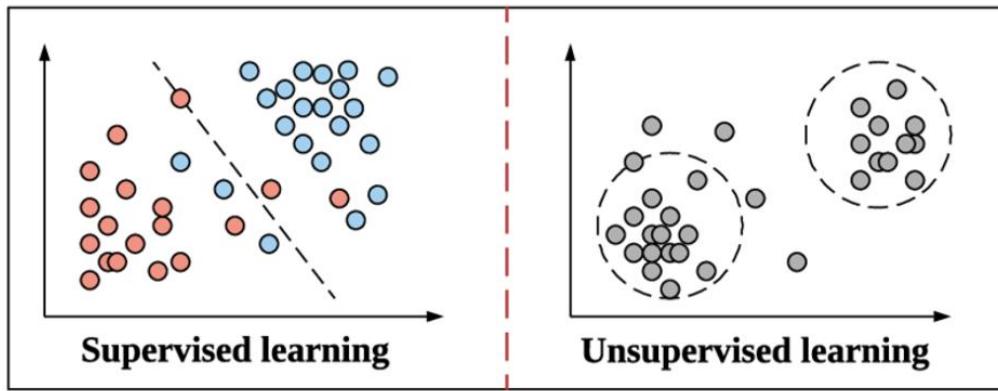


Machine learning (ML)

Machine learning versus human's way of thinking



Machine learning paradigms



Qian, B. et al. "Orchestrating the Development Lifecycle of Machine Learning-Based IoT Applications: A Taxonomy and Survey"

- **Supervised:** Model learns from a dataset (x, y) to predict y from x
- **Unsupervised:** Pattern recognition with no target output (only x)
- **Reinforcement:** Model learns by interacting and receiving feedbacks from the environment (dynamic data)

Supervised learning

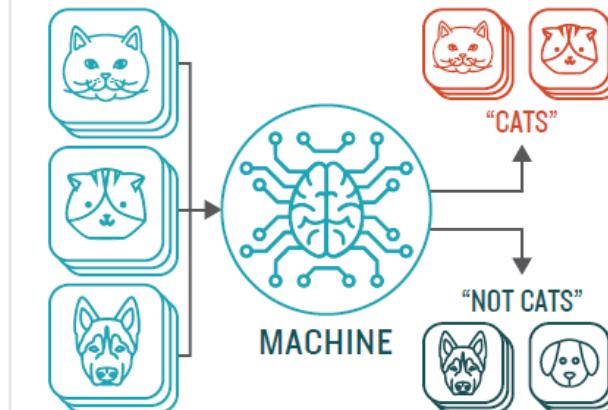
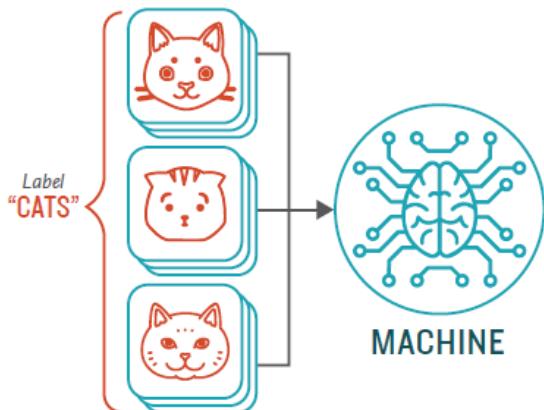
Source: towardsdatascience.com

STEP 1

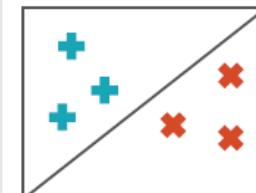
Provide the machine learning algorithm categorized or “labeled” input and output data from to learn

STEP 2

Feed the machine new, unlabeled information to see if it tags new data appropriately. If not, continue refining the algorithm

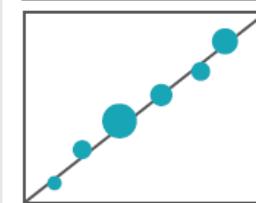


TYPES OF PROBLEMS TO WHICH IT'S SUITED



CLASSIFICATION

Sorting items into categories

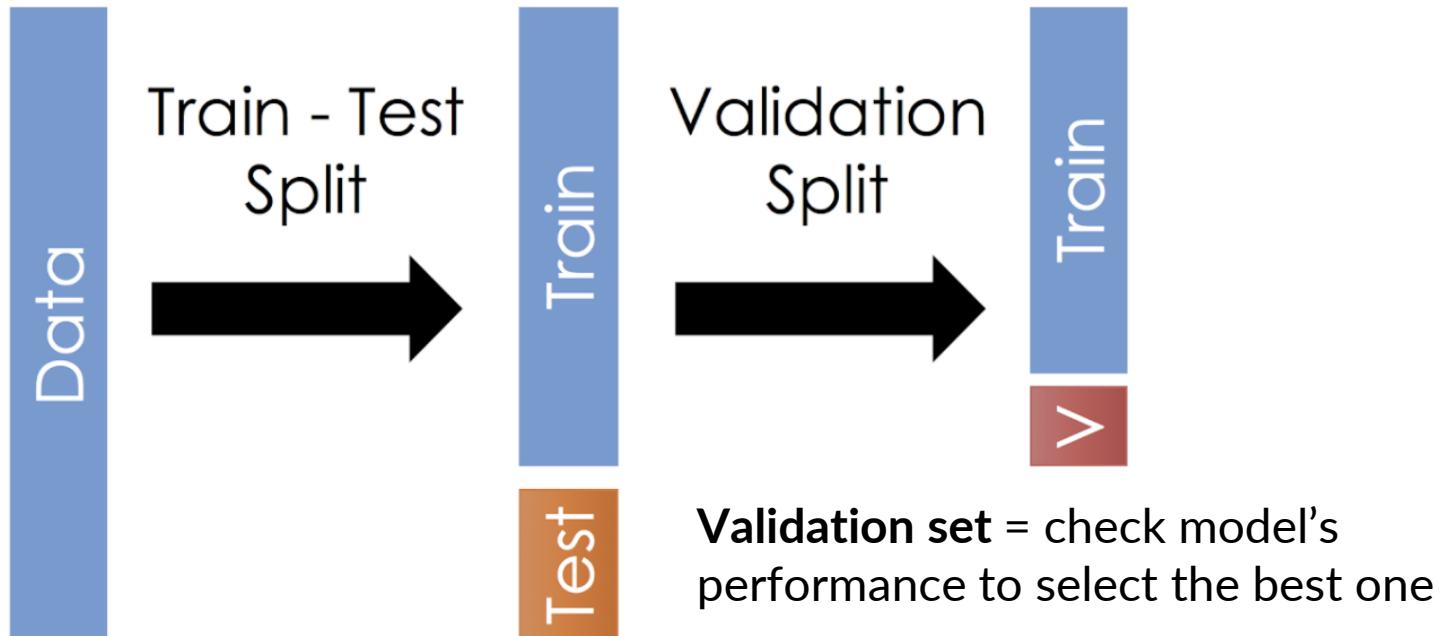


REGRESSION

Identifying real values (dollars, weight, etc.)

- **Training & Validation** = Feed a dataset (x, y) to fit the model and tune the model to maximize performance
- **Test** = Measure the performance of the model on unseen data

Data split



Source: medium.com

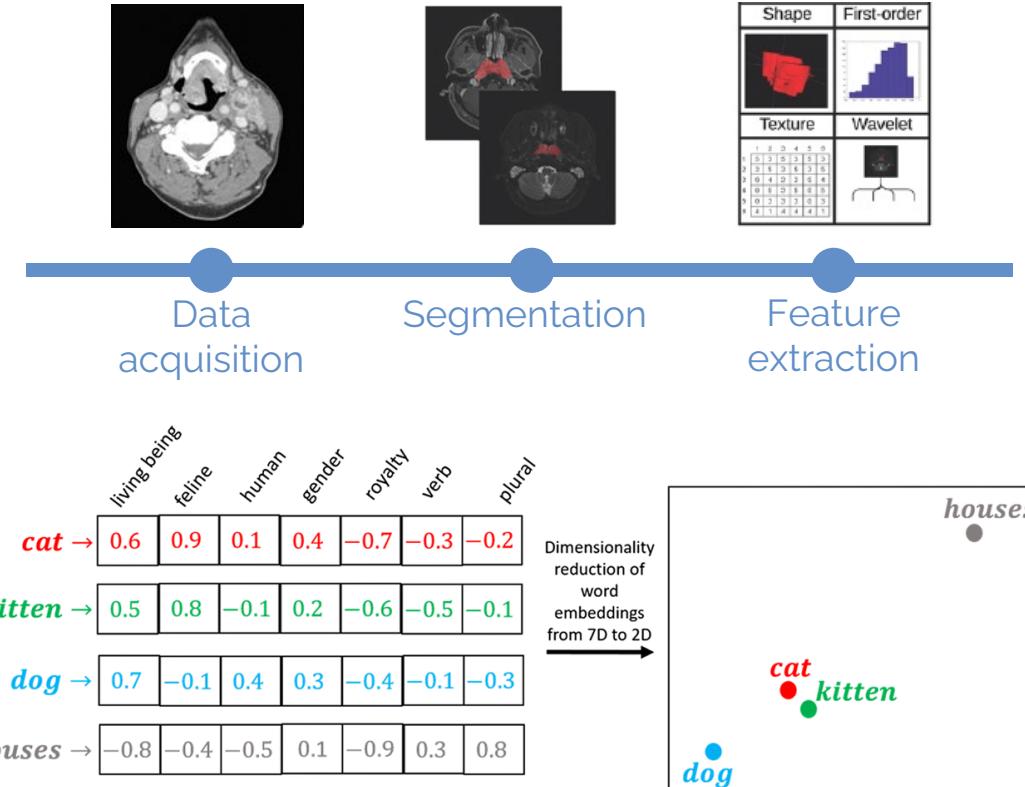
- Complex model can memorize everything → withhold data for evaluation

Features = Genes

Features

Gene ID	P61_2_C	P62_2_C
ENSG00000000003.14	4.637576	6.183992
ENSG00000000005.5	0	0
ENSG00000000419.12	11.22781	4.813792
ENSG00000000457.13	7.656414	5.082675
ENSG00000000460.16	3.172546	2.245954
ENSG00000000938.12	0	0
ENSG00000000971.15	6.626259	8.19511
ENSG000000001036.13	1.790445	0.76823
ENSG000000001084.11	19.53907	25.08378
ENSG000000001167.14	15.34717	20.00867
ENSG000000001460.17	0.889852	3.090642
ENSG000000001461.16	3.771195	3.12468
ENSG000000001497.16	16.75059	9.662455
ENSG000000001617.11	2.998366	3.712208

Samples

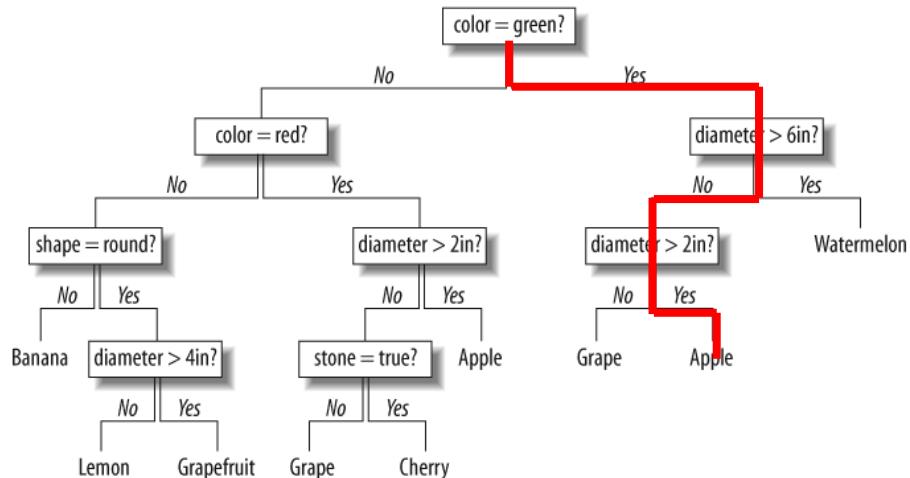


<https://swatimeena989.medium.com/training-word2vec-using-gensim-14433890e8e4>

- Features describe characteristics of the sample → used to make prediction

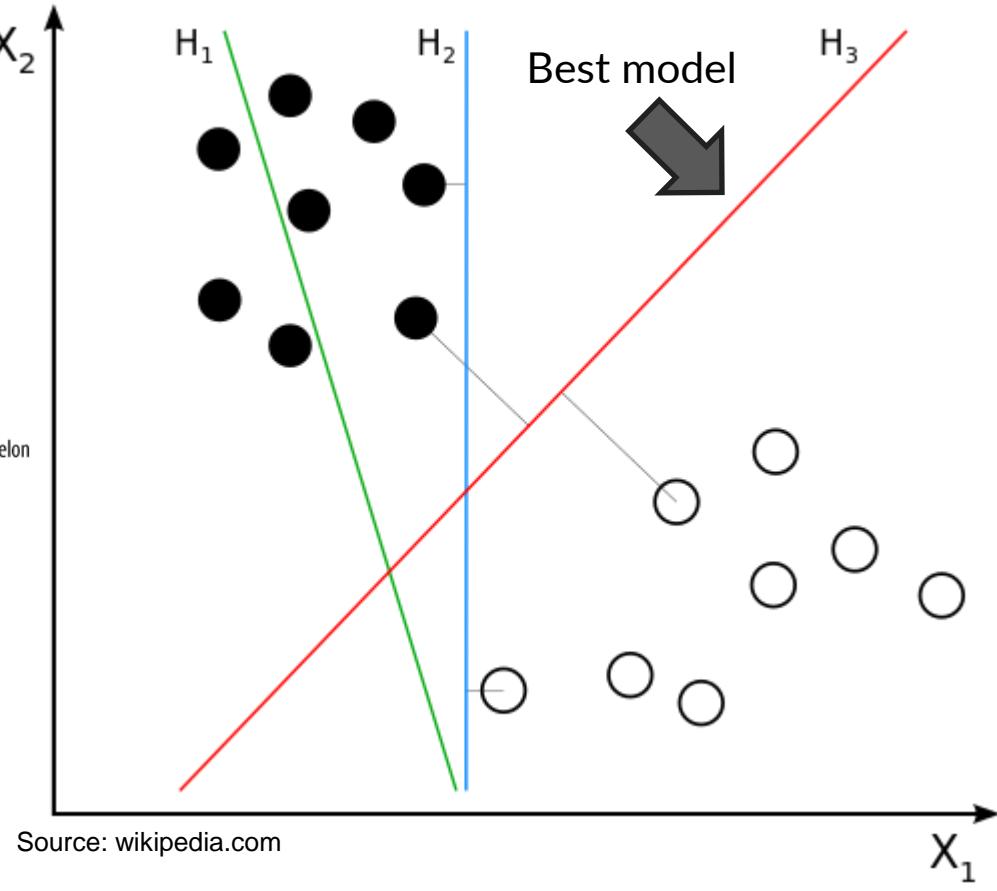
Classical ML

Decision tree



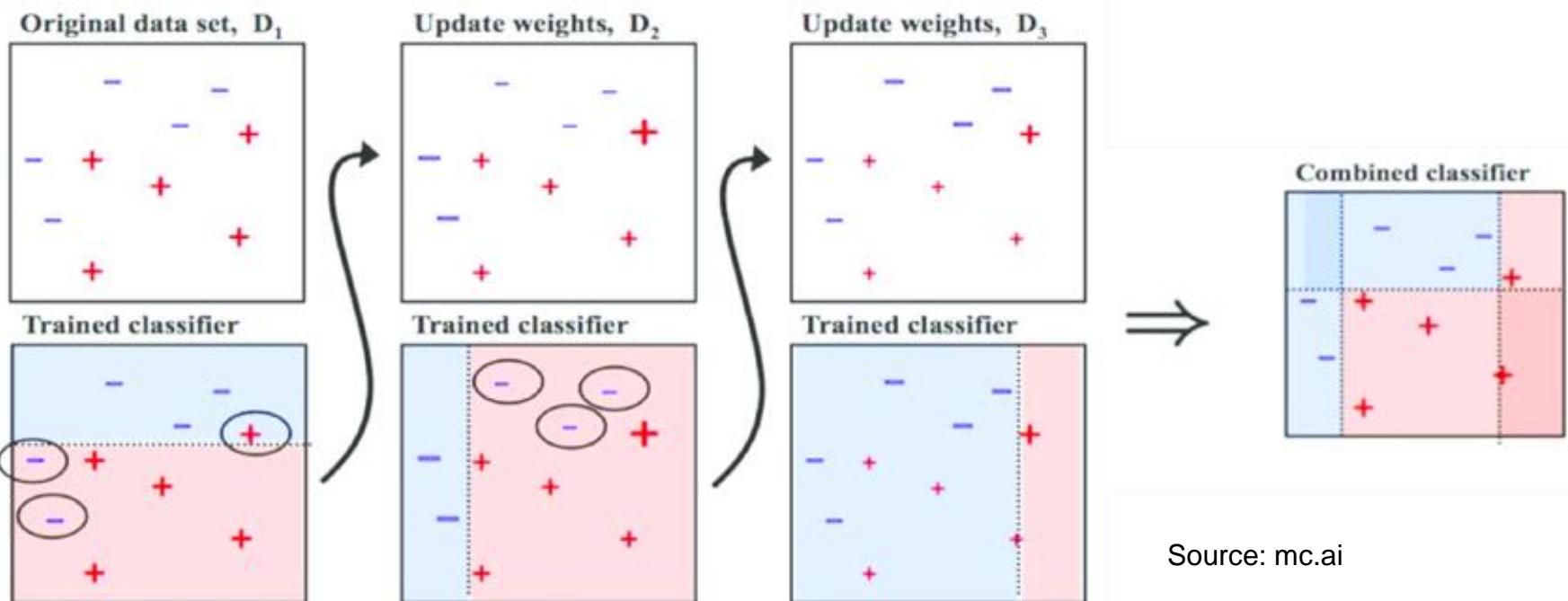
Source: Programming collective intelligence by Toby Segaran

Support vector machine



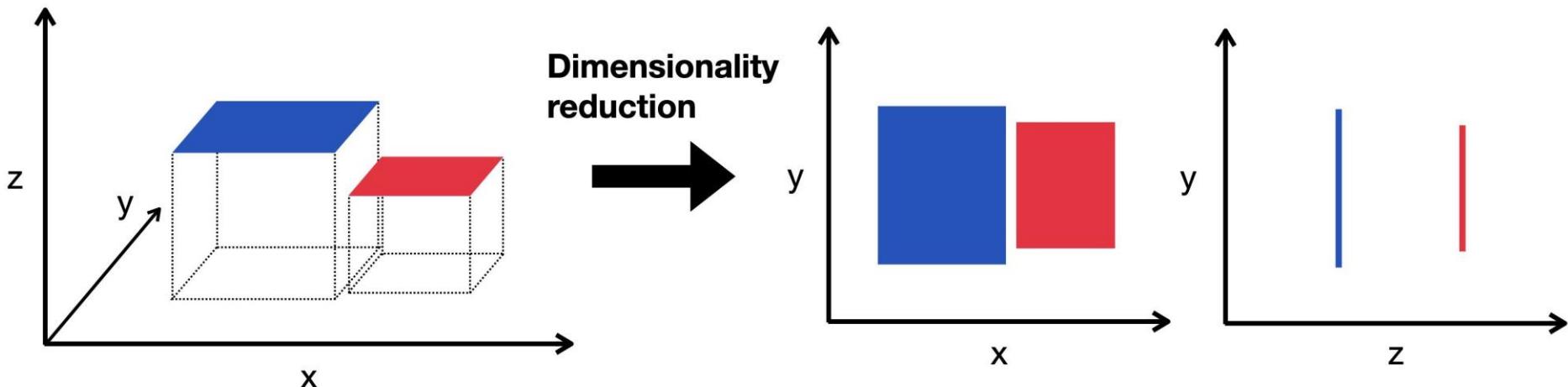
Source: wikipedia.com

Adaptive boosting (an ensemble approach)



- Multiple simple models work together to perform a complex task

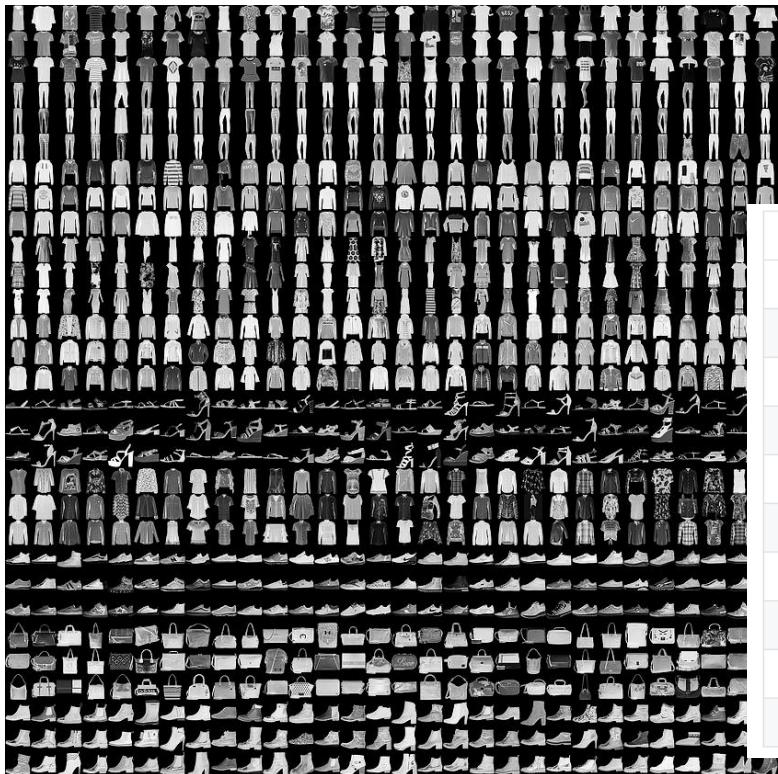
Dimensionality reduction



https://www.sc-best-practices.org/preprocessing_visualization/dimensionality_reduction.html

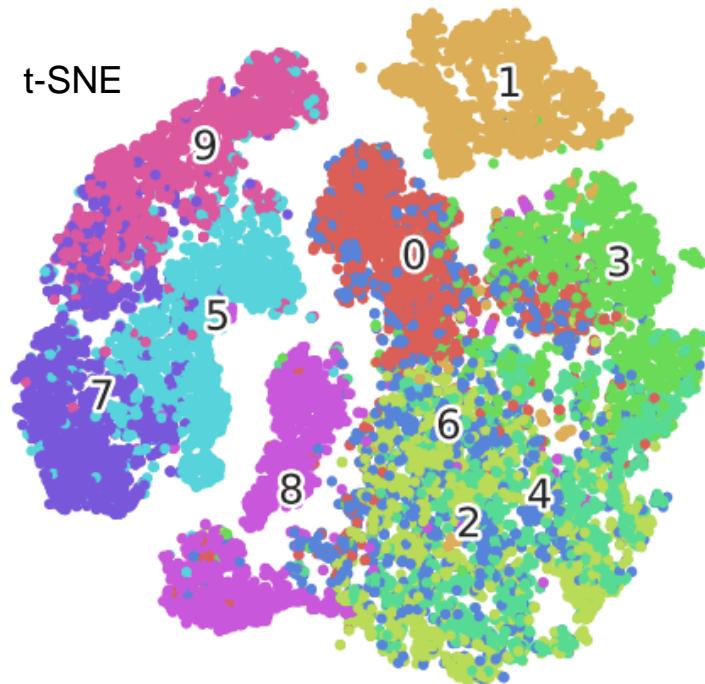
- Reduce dimension (number of features) while maintaining information
- Patient with similar symptoms also exhibit similar lab tests or have similar demographics or similar medical history

t-SNE and UMAP

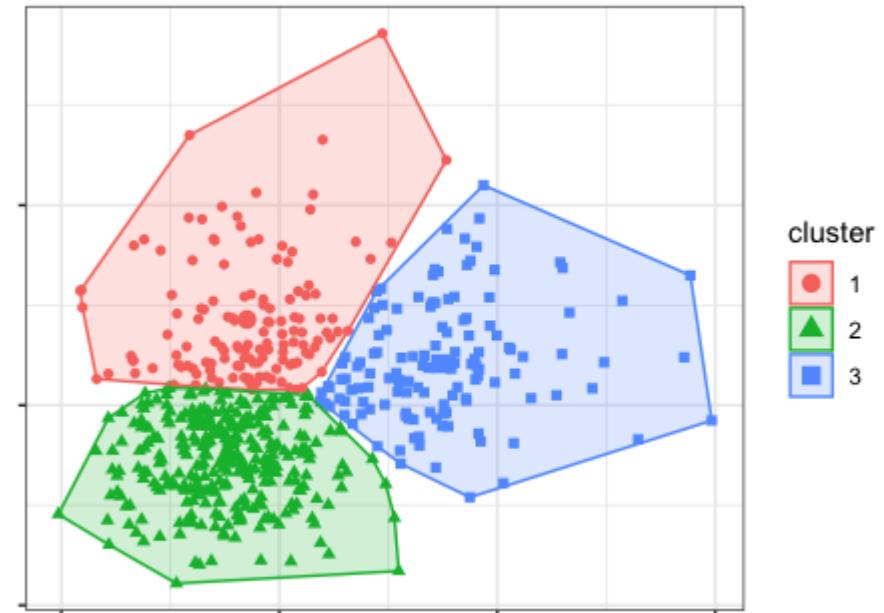
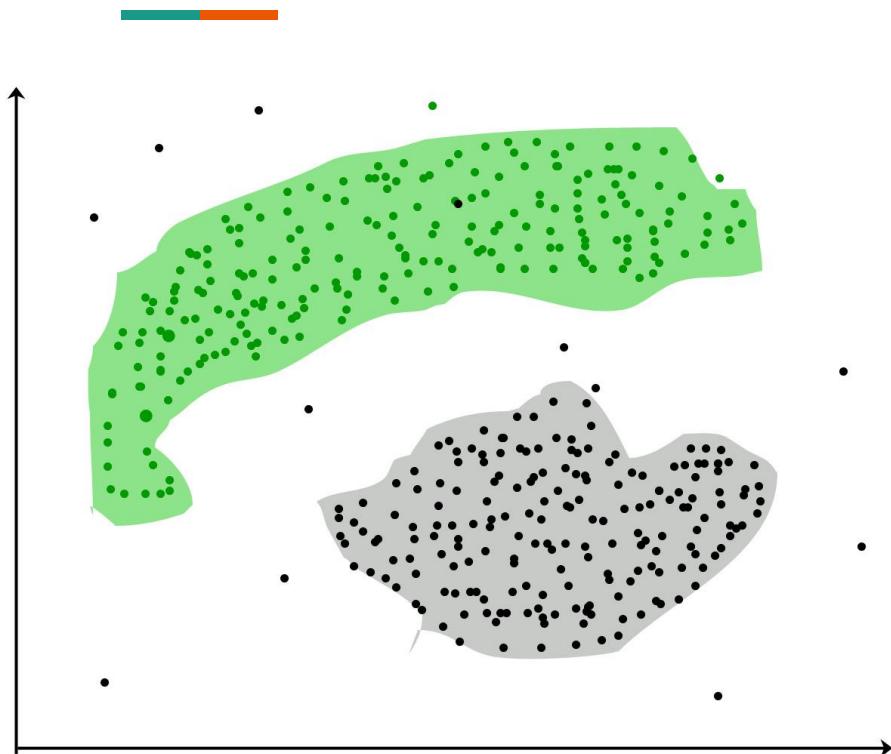


Label	Description
0	T-shirt/top
1	Trouser
2	Pullover
3	Dress
4	Coat
5	Sandal
6	Shirt
7	Sneaker
8	Bag
9	Ankle boot

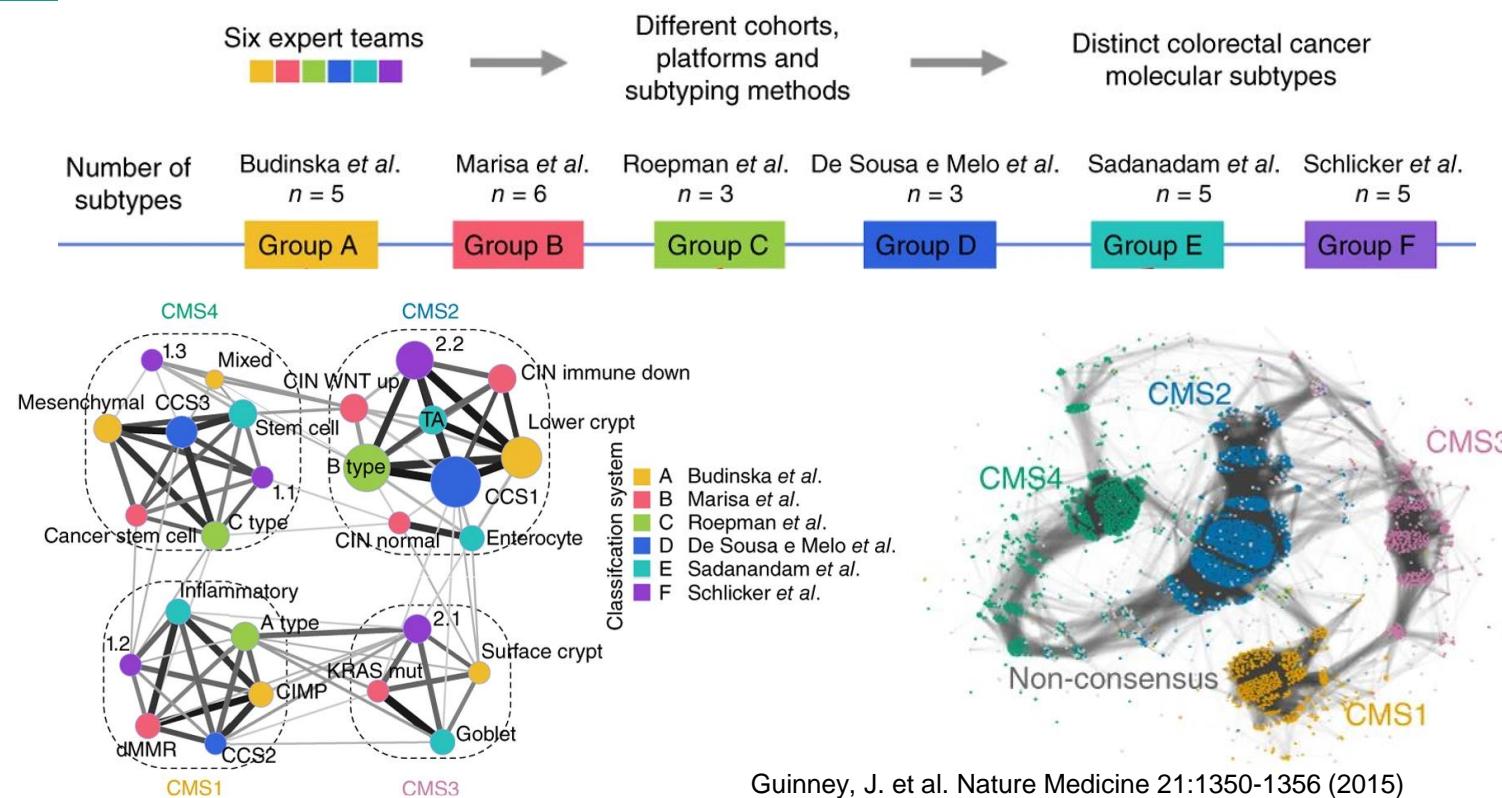
Fashion MNIST dataset
28x28 pixel images of clothing



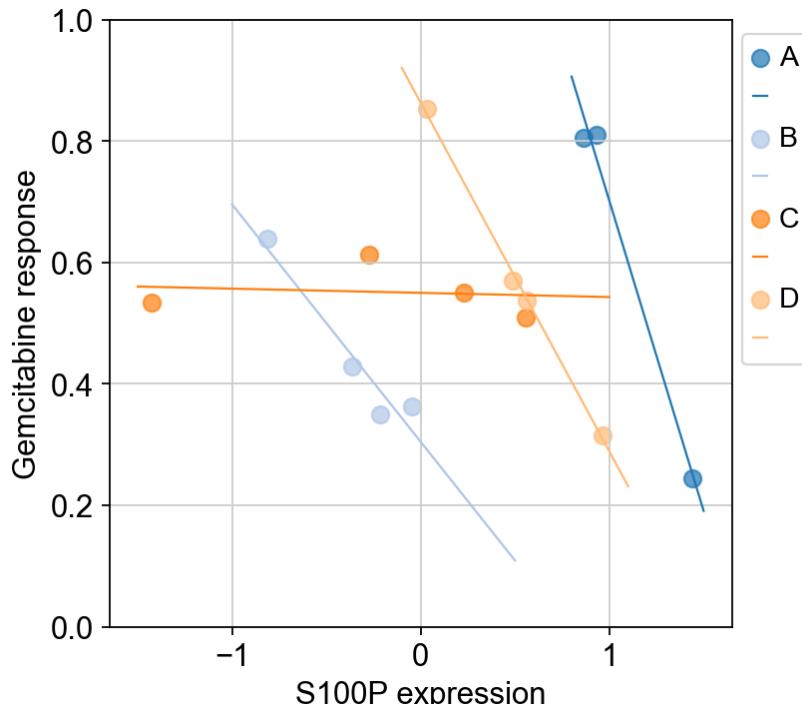
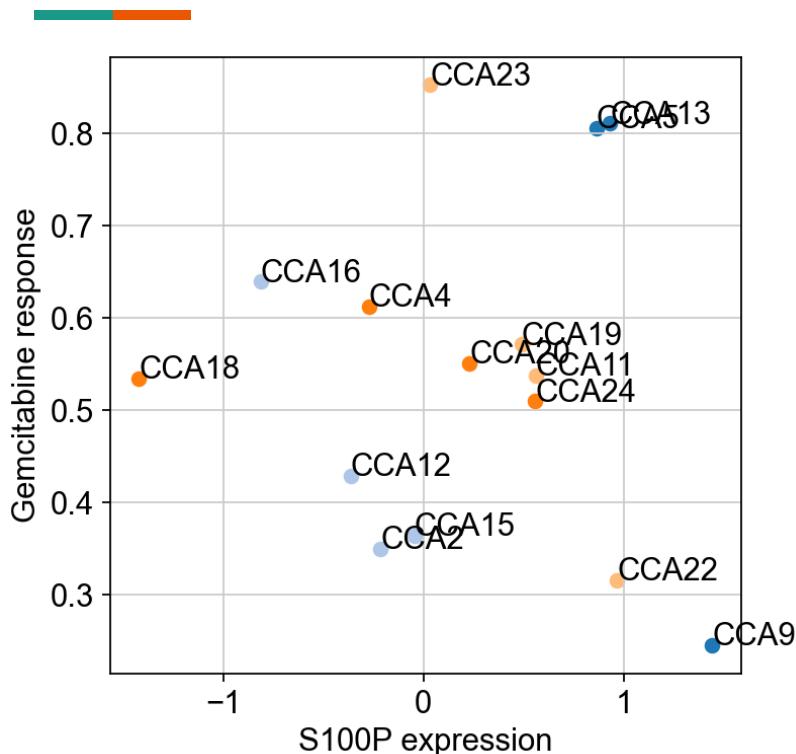
Clustering = grouping of similar data points



Colorectal cancer subtyping with transcriptomics

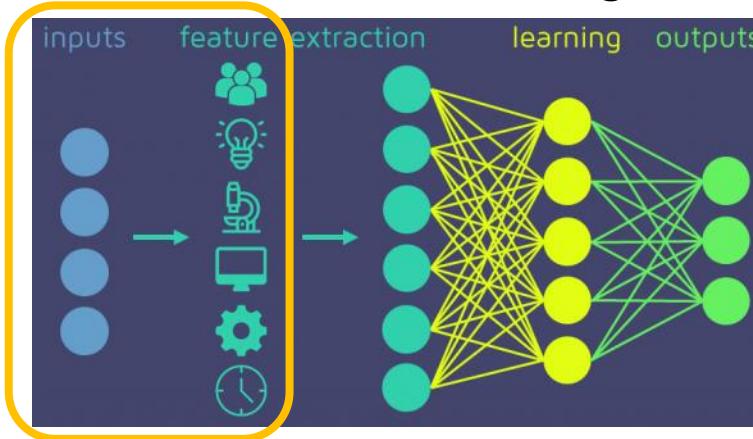


Cluster of patients with unique drug-gene responses

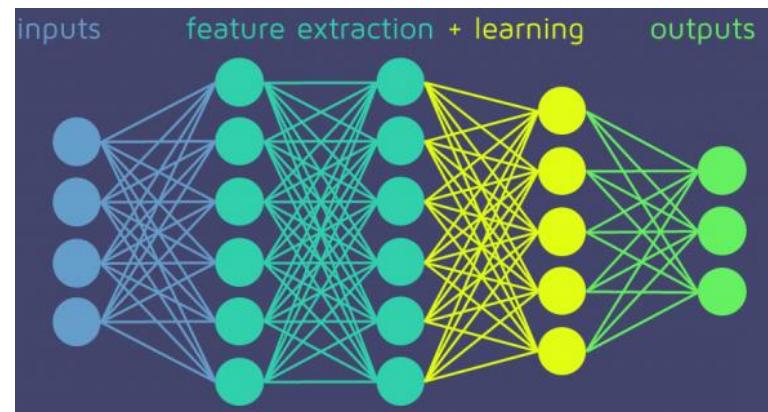


Limitation of classical (supervised) machine learning

Traditional learning



End-to-end learning

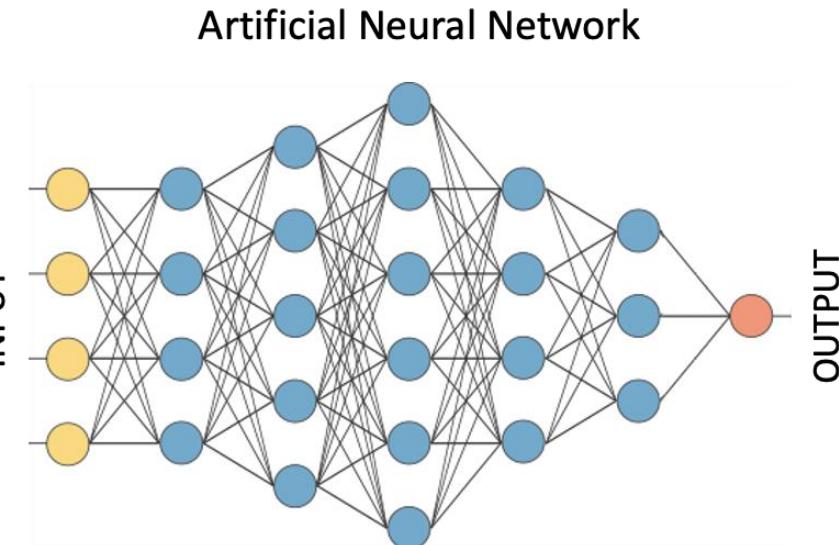
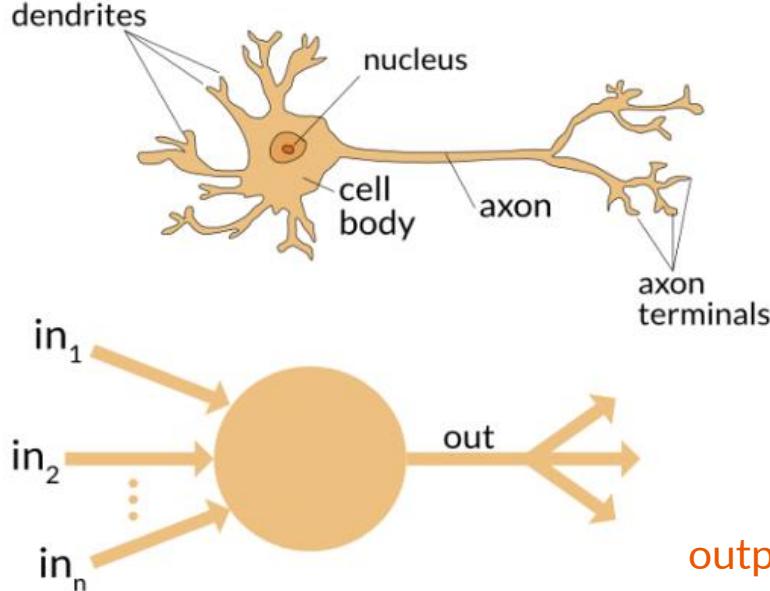


- Classical ML operates on pre-processed data (tabular data)
- Cannot handle raw data, such as image or text



Deep learning (DL)

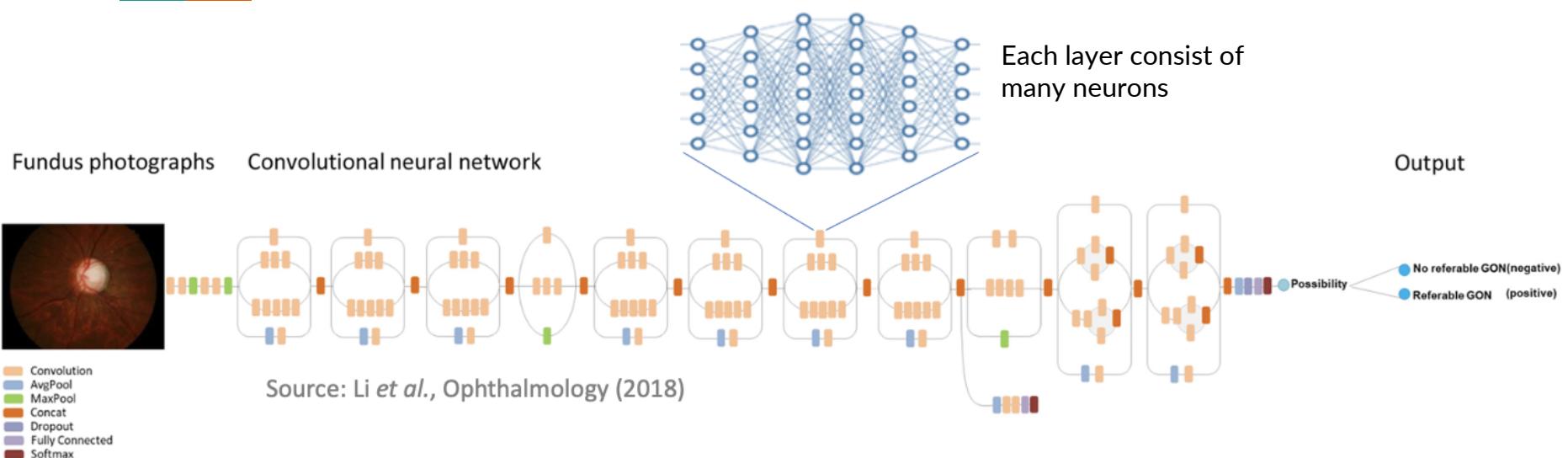
Artificial neural network (ANN)



$$\text{output} = \text{activation}(w_1 \times in_1 + w_2 \times in_2 + \dots + w_n \times in_n)$$

- Network of simple neurons (computing units)

Deep artificial neural network

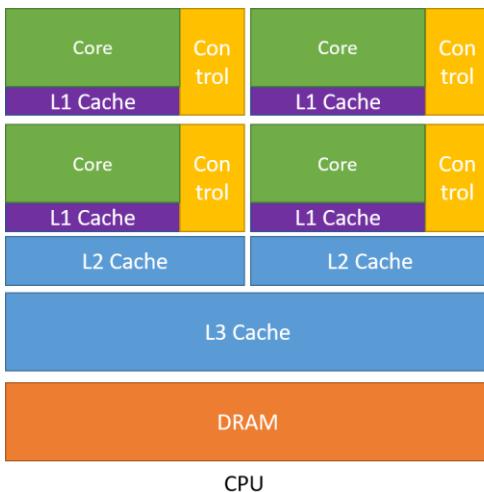


- 10 million parameters with 100k samples!!
- Deep learning is the technique for developing deep artificial neural network and theory on how such feat is possible

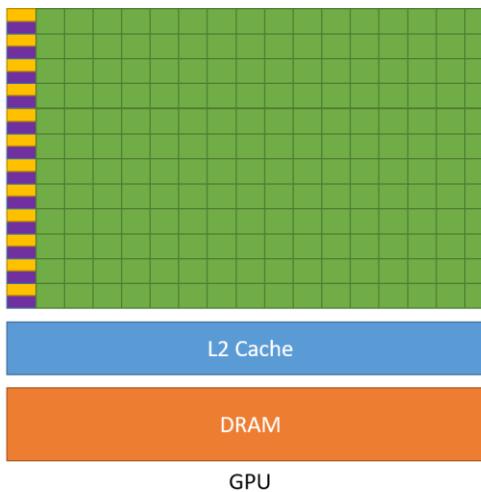
Deep learning



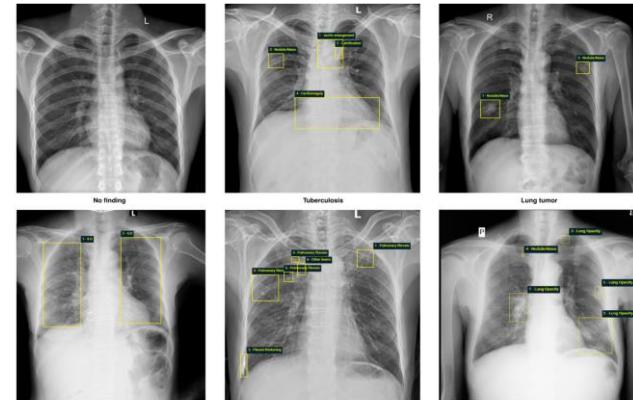
Key drivers of deep learning: GPU and data



Graphical Processing Unit



>500k public annotated CXR



THE CANCER GENOME ATLAS (TCGA) BY THE NUMBERS

TCGA produced over

2.5
PETABYTES
of data

TCGA data describes

...including

 **33**
 DIFFERENT
 TUMOR TYPES

10
RARE
CANCERS

~100k public omics data

ImageNet: The rise of deep artificial neural network

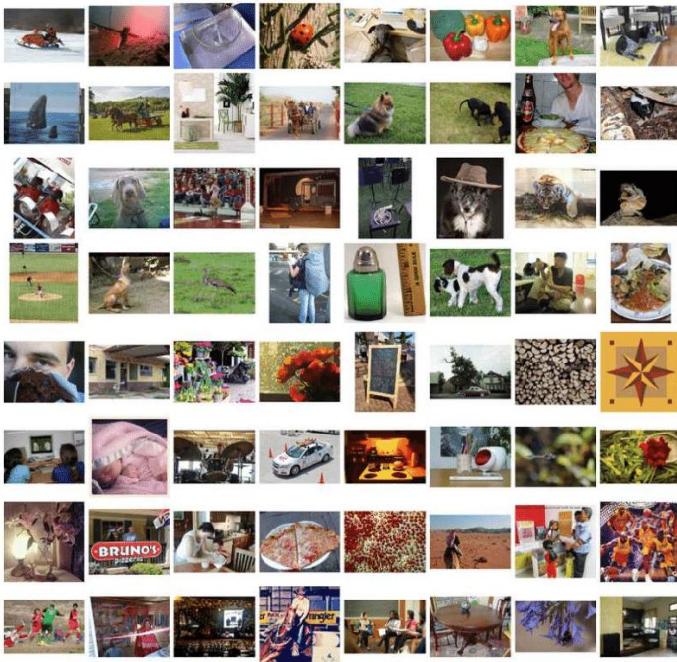
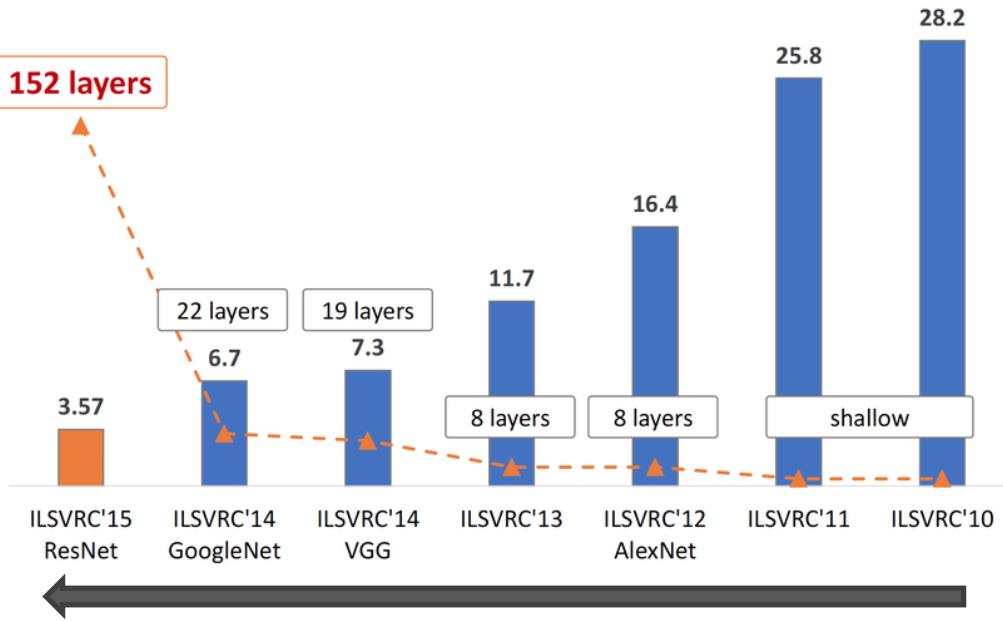


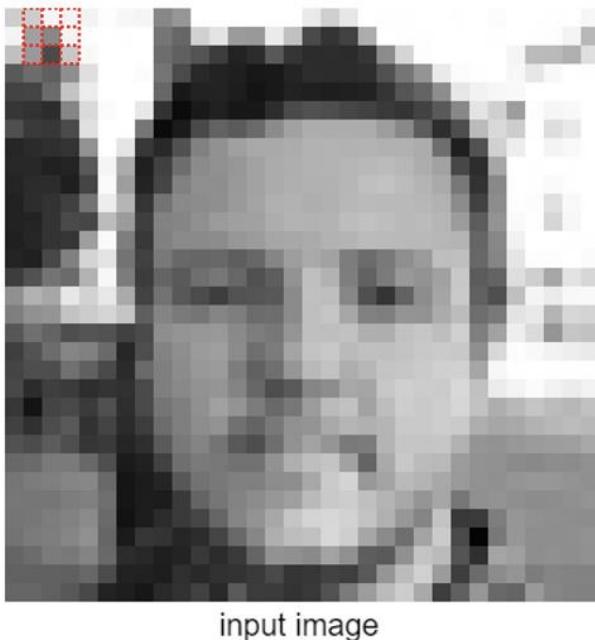
Image classification error





How did the magic happen? ANN's ability to extract meaningful features

Information extraction from image data

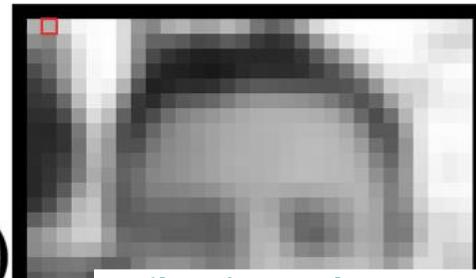


Filter/Kernel

$$\begin{pmatrix} 205 & + & 247 & + & 245 \\ \times 0.0625 & & \times 0.125 & & \times 0.0625 \\ + & 161 & + & 137 & + & 244 \\ \times 0.125 & & \times 0.25 & & \times 0.125 \\ + & 154 & + & 75 & + & 200 \\ \times 0.0625 & & \times 0.125 & & \times 0.0625 \end{pmatrix} = 175$$

kernel:
blur

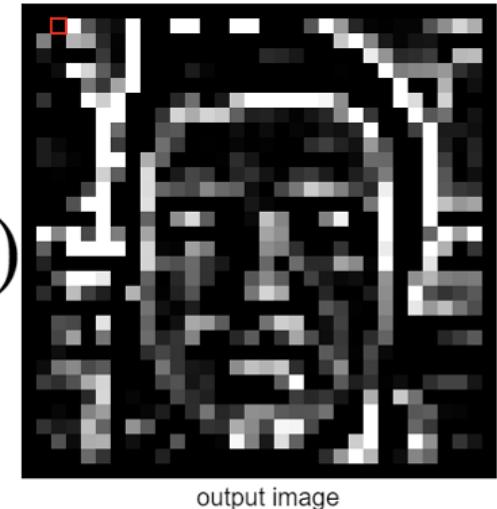
<https://setosa.io/ev/image-kernels/>



Filter/Kernel

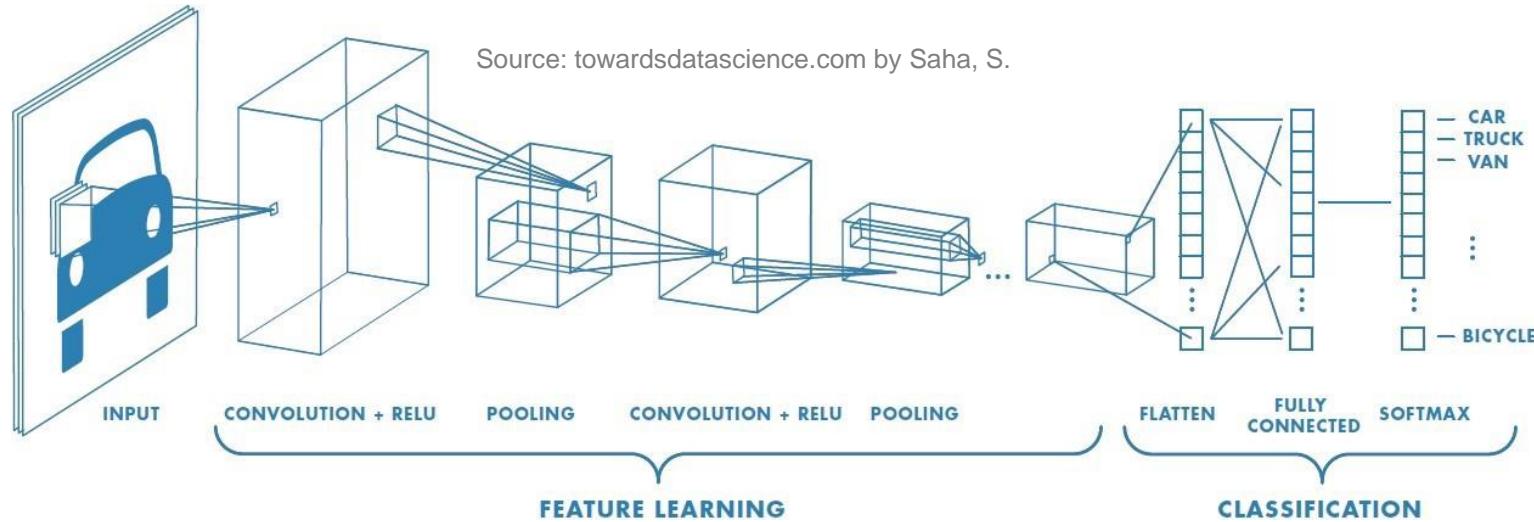
$$\begin{pmatrix} 205 & + & 247 & + & 245 \\ \times -1 & & \times -1 & & \times -1 \\ + & 161 & + & 137 & + & 244 \\ \times -1 & & \times 8 & & \times -1 \\ + & 154 & + & 75 & + & 200 \\ \times -1 & & \times -1 & & \times -1 \end{pmatrix} = -435$$

kernel:
outline



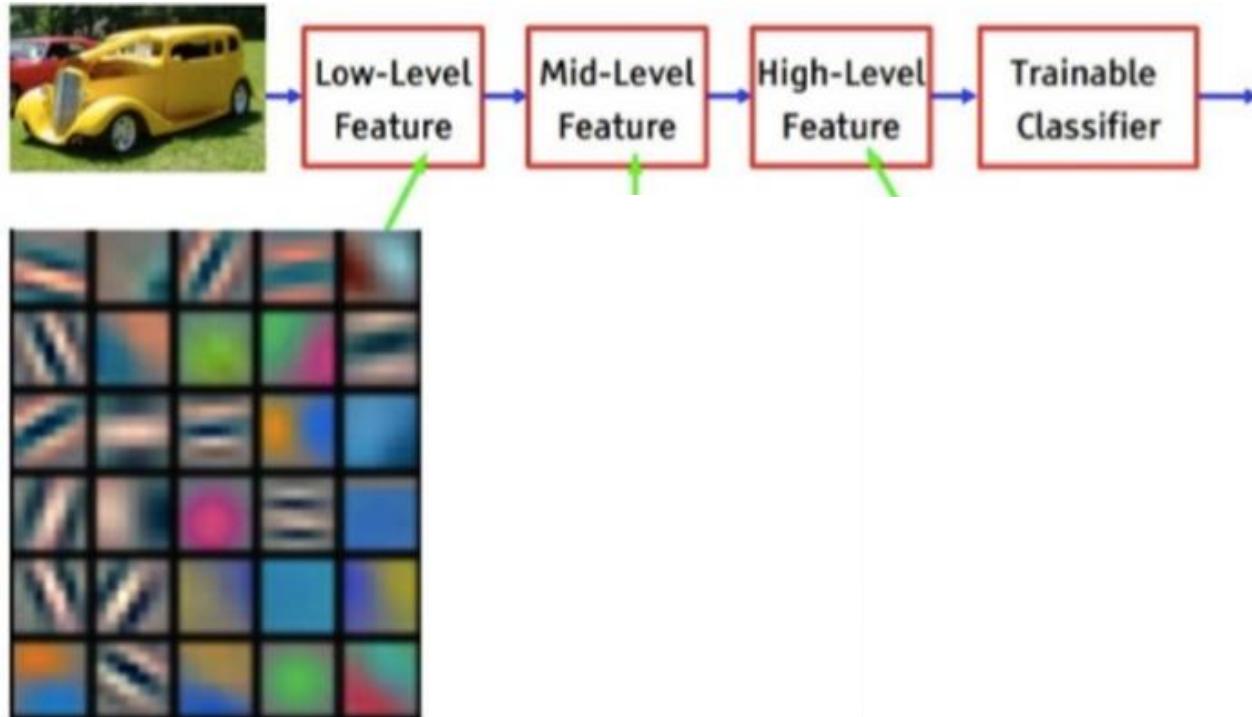
- Pixel value pattern → geometric information

Convolutional neural network (CNN)



- Instead of human-defined filter matrices, CNN optimizes them on-the-fly to achieve maximal prediction performance
- **Assumption:** Filters that are useful for prediction capture some meanings

Complex geometry emerges from deep CNN layers

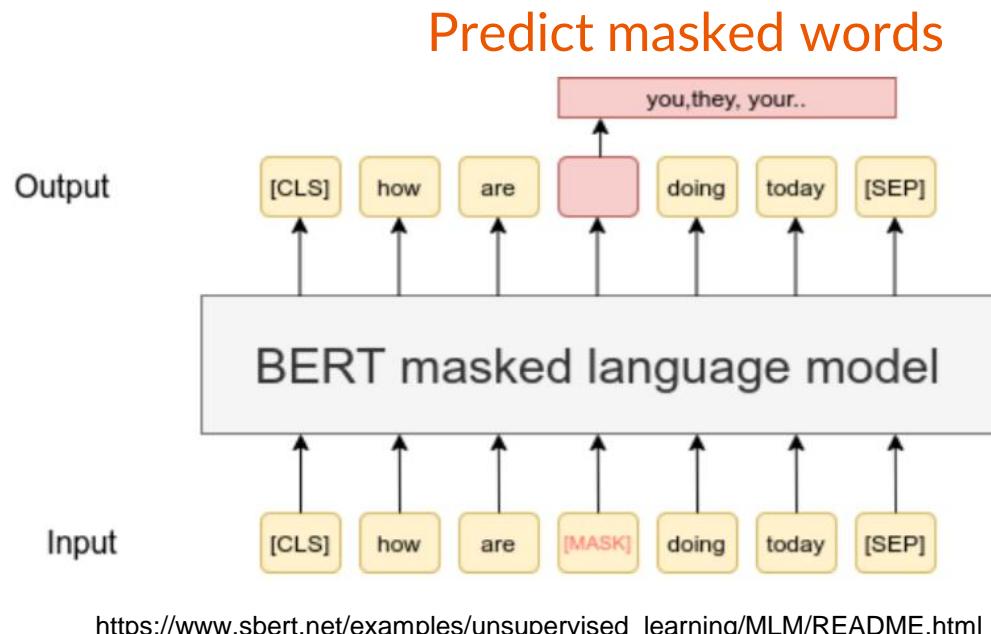


Deeper layers have broader field of view

Source: Zeiler and Fergus (2013)

Natural Language Processing (NLP)

- Phase 1: Transforming words to vectors (**embeddings**) that capture some meanings or characteristics
 - Abundant data on the web
- Phase 2: Utilizing learned **embeddings** to make predictions, such as emotion, topic, replies
 - Task-specific annotation



https://www.sbert.net/examples/unsupervised_learning/MLM/README.html

Meaningful word embedding



man →

woman →

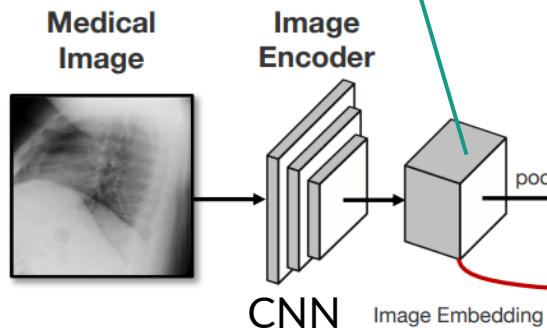
king →

queen →

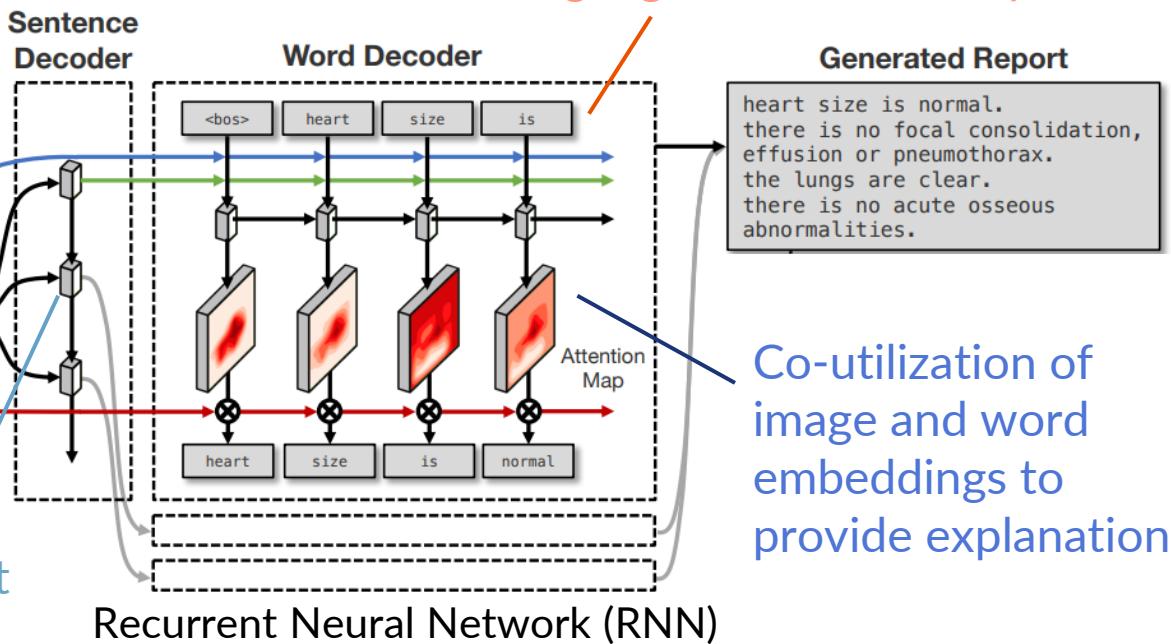


Putting everything together

Capture key characteristics about the image – lesions?



Generate embedding that define a sentence's topic





Last words

Overfitting and exploitation

Out of distribution

Train



dog

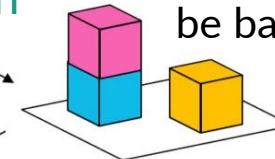
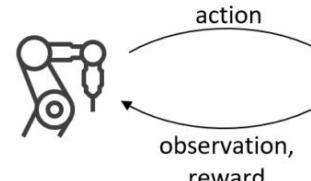
Test



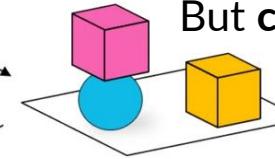
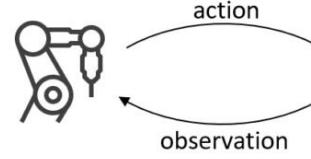
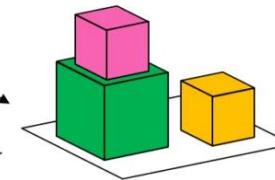
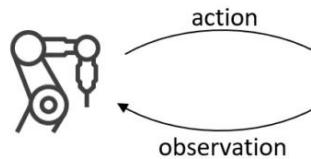
Model can easily break down on unexpected inputs

Pattern exploitation

Train



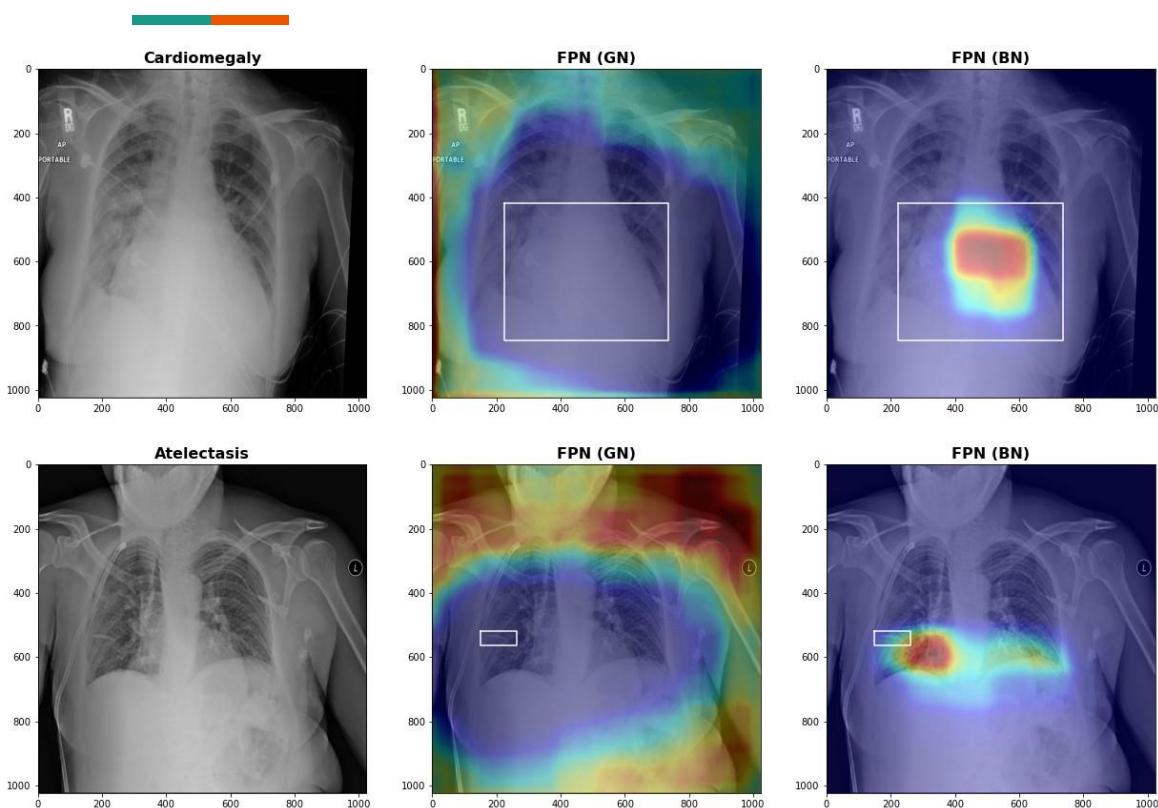
Test



Robot's action should be based on geometry

But color is exploited

Correct prediction doesn't imply correct reasoning



- The two models have the same classification performance
- Both images were correctly classified
- But the image areas that contributed to the prediction completely differ

Explainability & interpretability

Feature contribution to the prediction

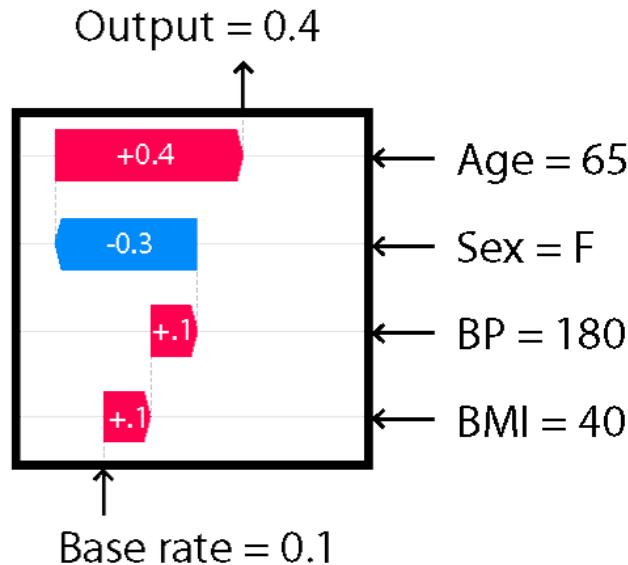
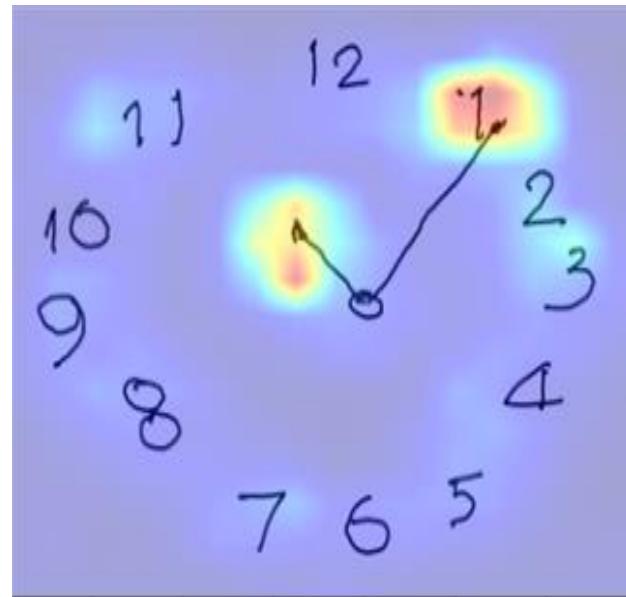


Image area that support the prediction



What's your next move?

- Accumulate domain (medical) knowledge
- Don't neglect other sciences and mathematics
 - Try several courses to find those whose ways of teaching resonate
- Pick up a computer program
 - Data analysis and visualization
- Start early on computational curriculum
 - Machine learning
 - Algorithm, numerical method, optimization, linear algebra, probability

Thank you for your attention

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อยากร่วมทำวิจัยสายค่านวน / แอบนั่งเรียนในรายวิชาโท-เอก / connect อ. วิศวะ
คอมที่ทำ Deep Learning / แนะนำเรียนต่อเมืองนอก