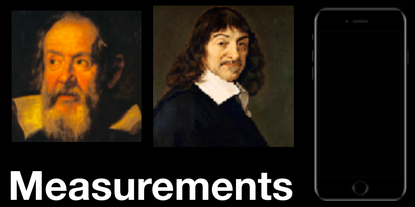
From Data to Learning

Compression



Measurements

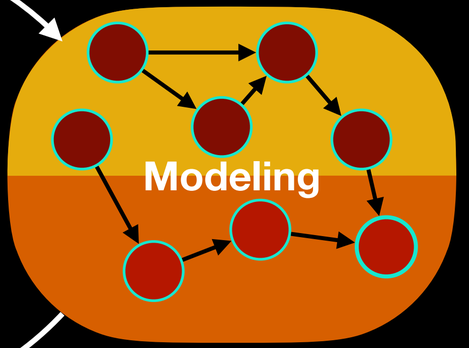
Learning

Seen

Unseen

World

Data



Modeling

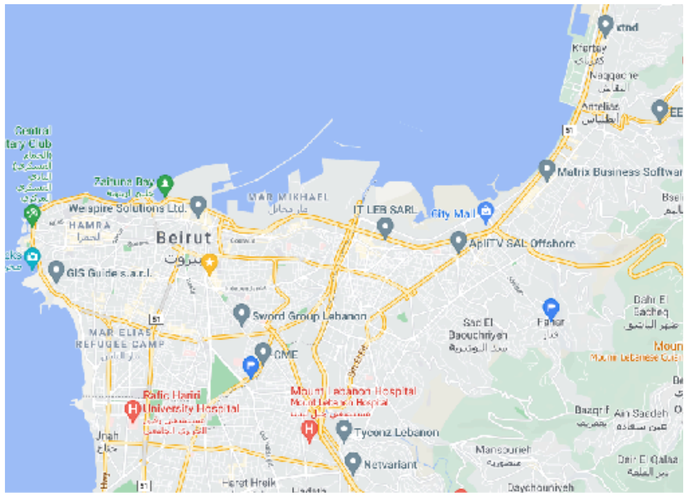
Inference

Projection

Reconstruction

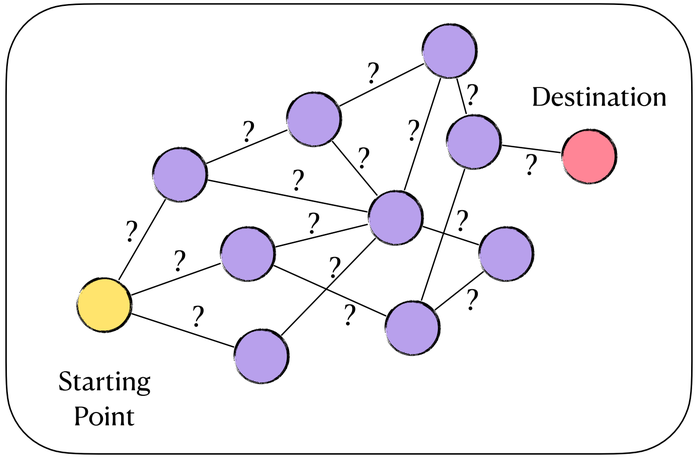
The 3 pillars of Artificial Intelligence

Real world

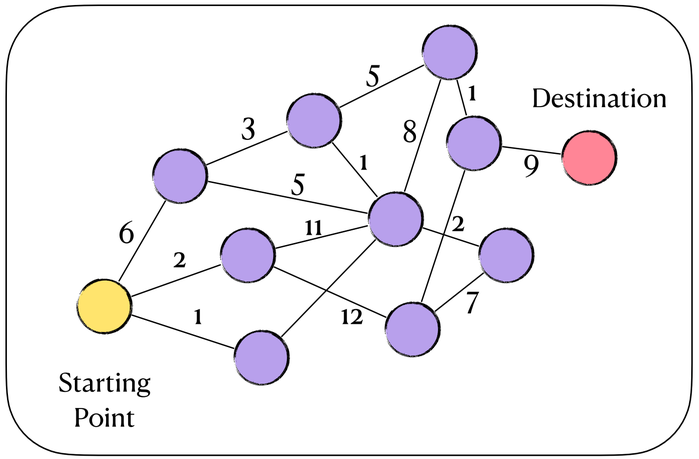


What's the shortest path from AUB to my home?

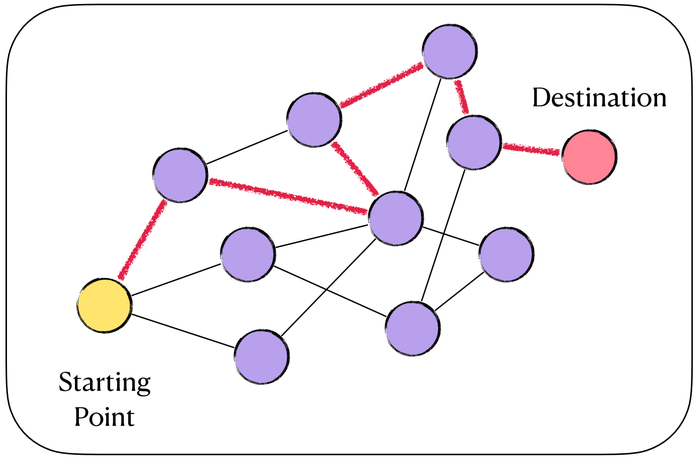
Learning



Modeling



Inference



Machine Learning

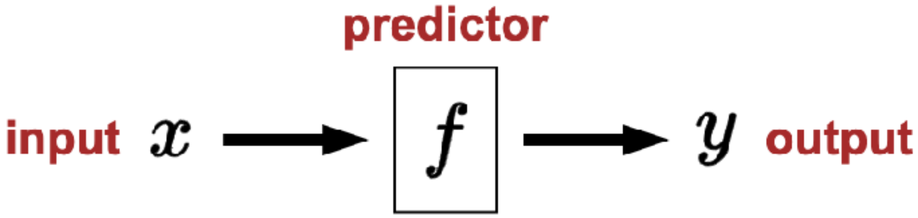
$$f(x) = 2^x$$

x `0, 1, 2, 3, 4, 5`

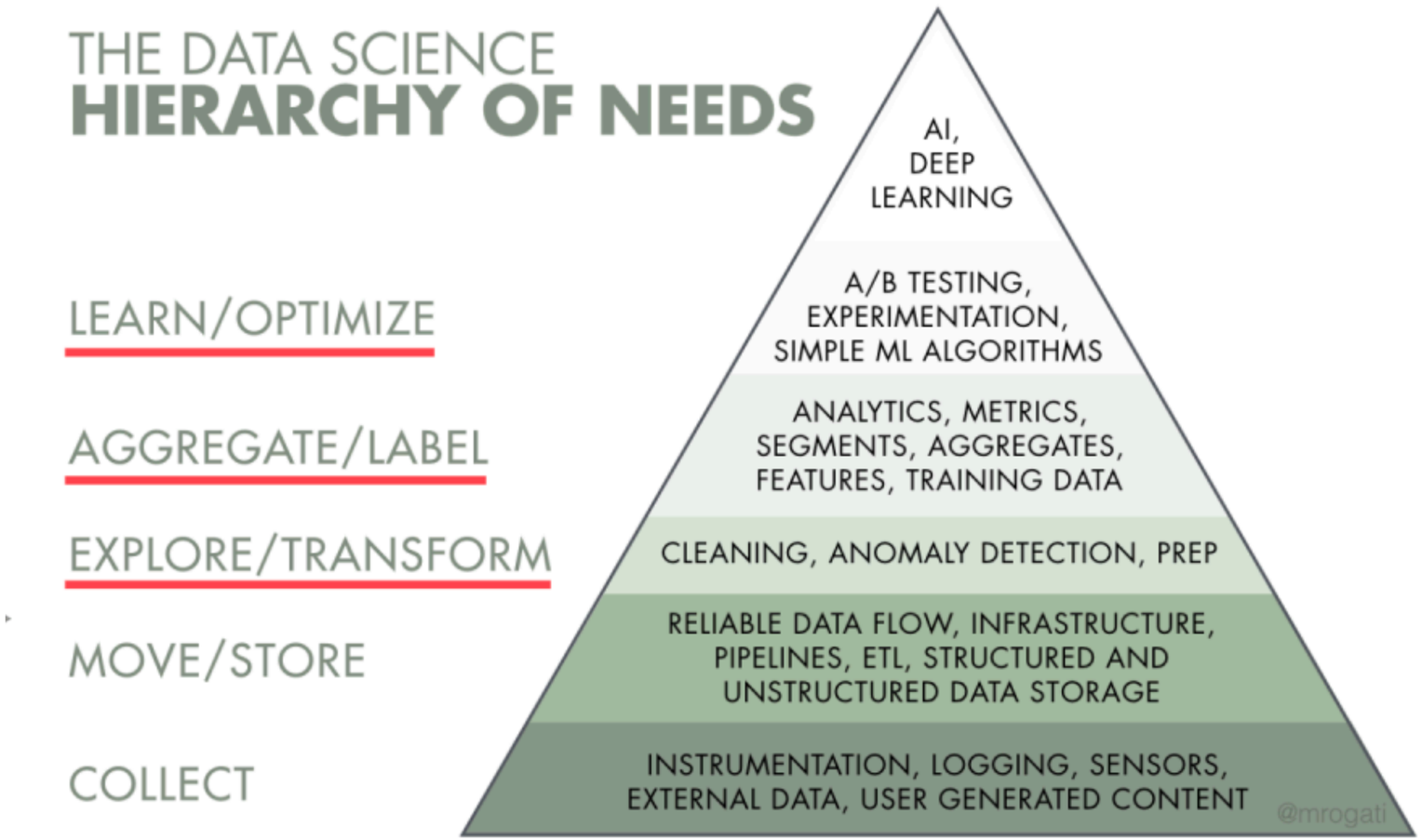
y `1, 2, 4, 8, 16, ?`

$x \quad y$

$$f(x) = 2x$$



The data science hierarchy of needs



Data needs as illustrated by Monica Rogati

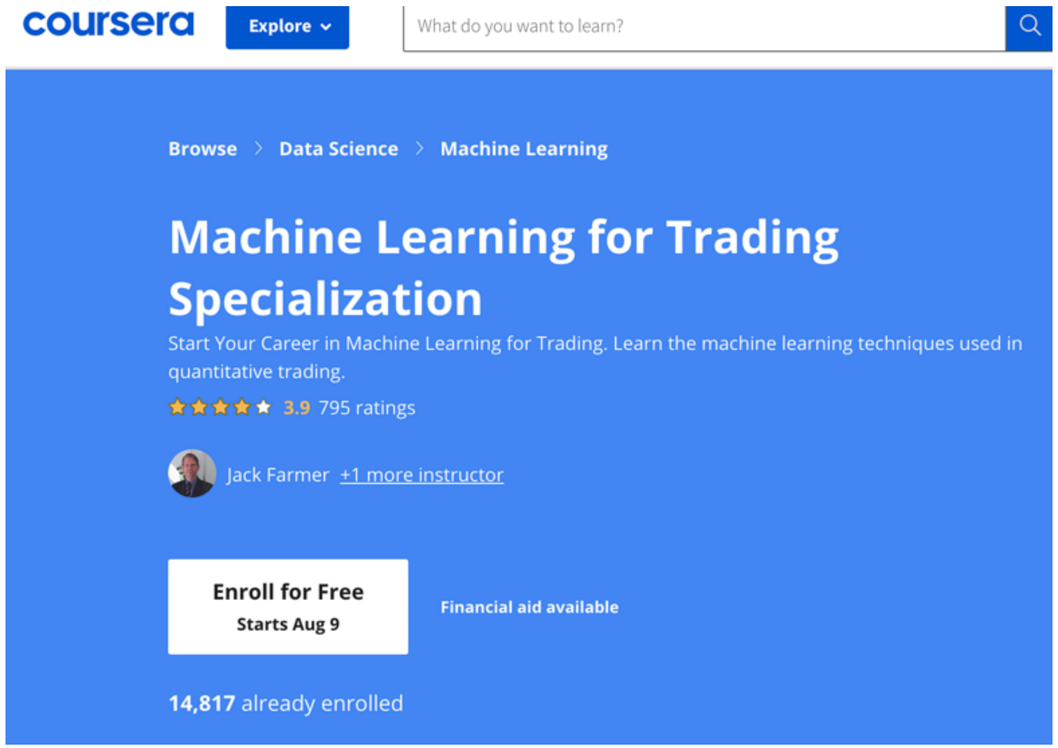
What **are*** Data?

Time Series

Stocks

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Price 1	35	37	35	34	33	30	49	48	46	44	46	49	48	66	50	55
Price 2	4	3	5	6	7	7	7	5	6	9	9	22	21	23	21	22

Trading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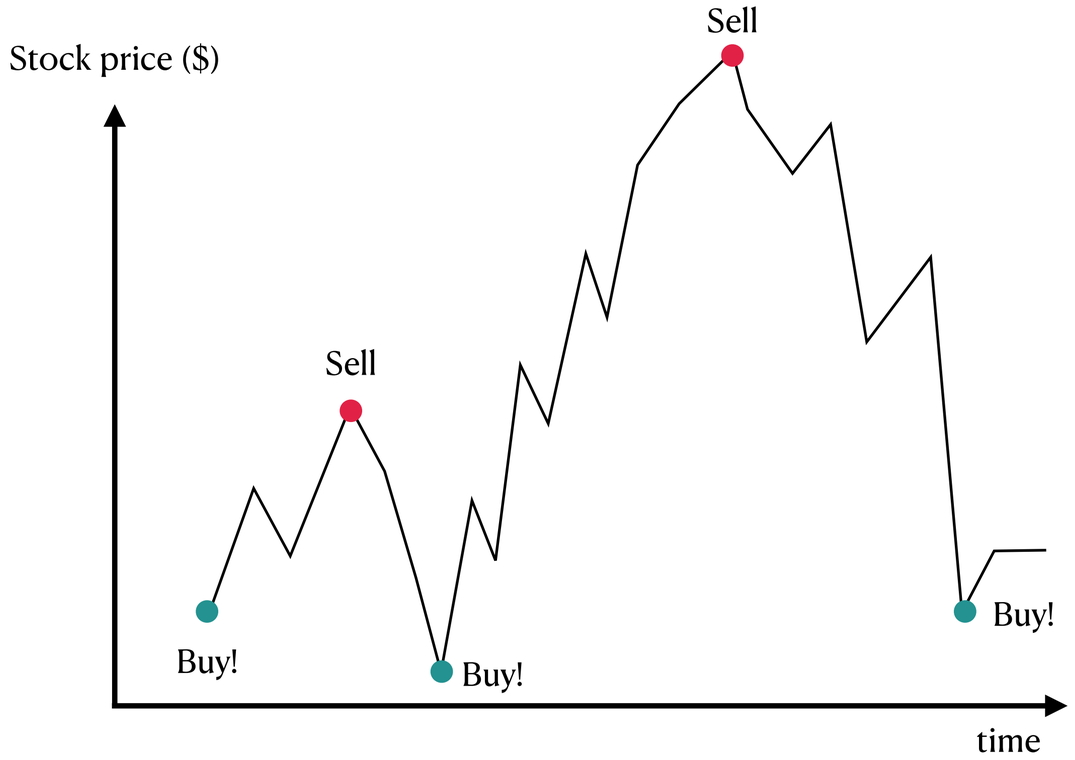
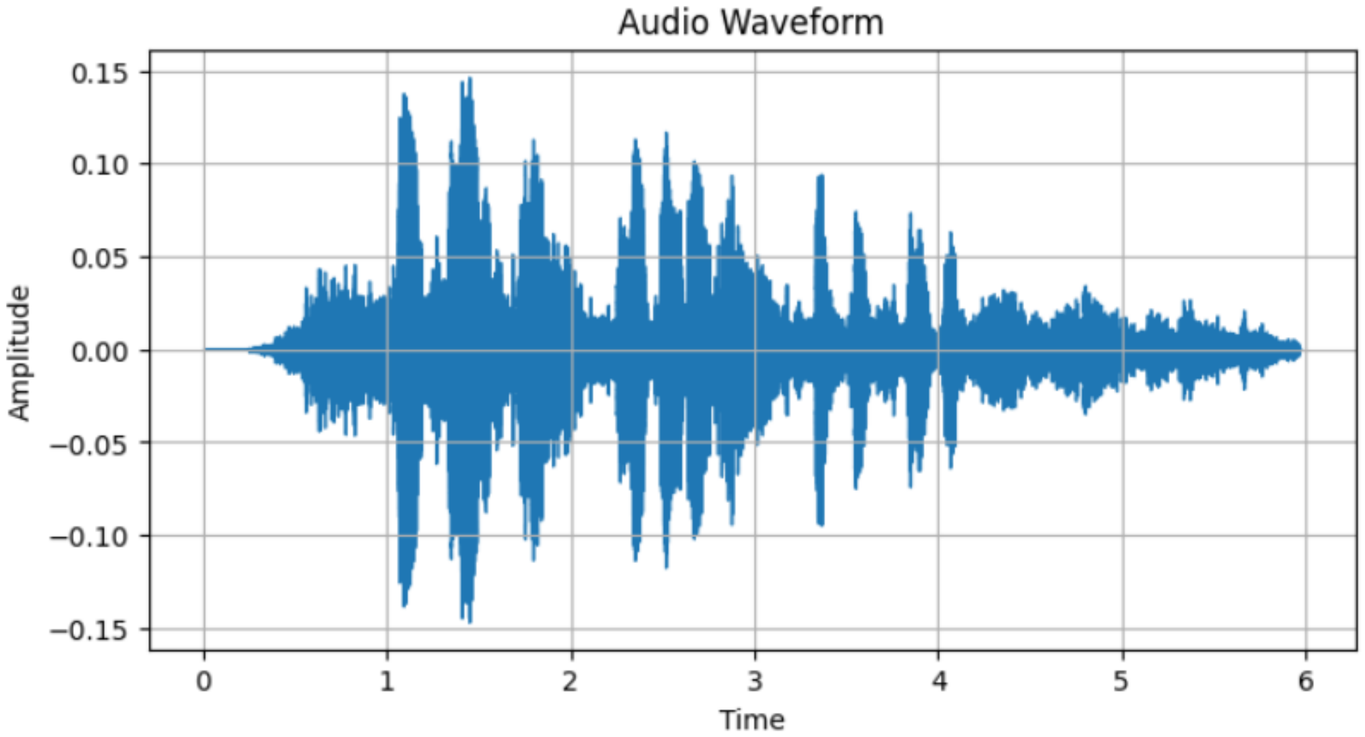
Start Your Career in Machine Learning for Trading. Learn the machine learning techniques used in quantitative trading.
3.9 795 ratings
Jack Farmer +1 more instructor
Enroll for Free
Starts Aug 9
Financial aid available
14,817 already enrolled


Stock price ($)
Sell
Sell
Buy!
Buy!
Buy!
time

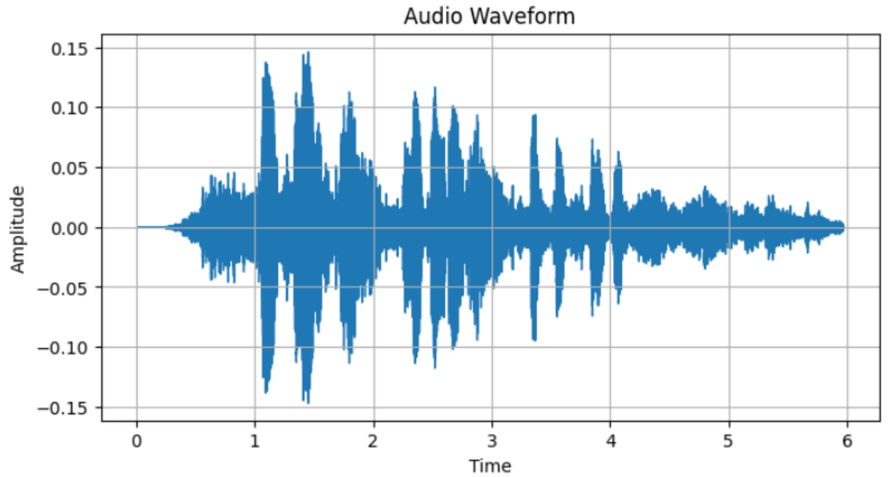
Audio



Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Amplitude	35	37	35	34	33	30	49	48	46	44	46	49	48	66	50	55

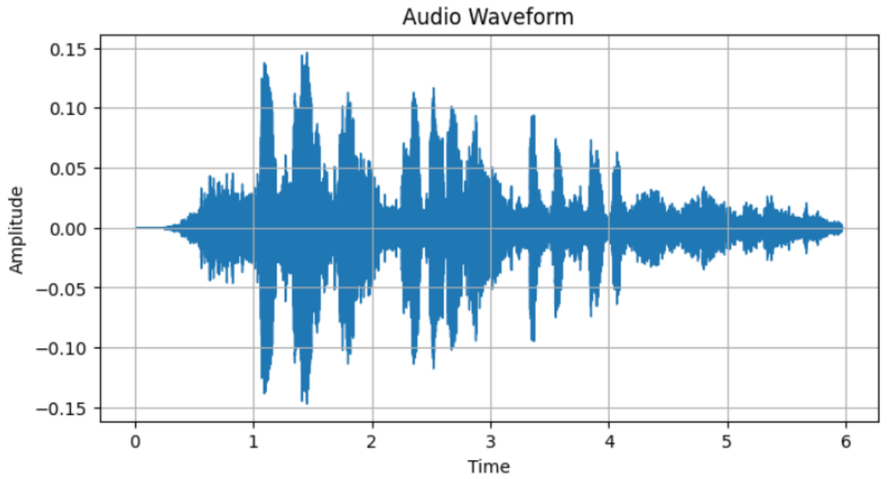
Audio

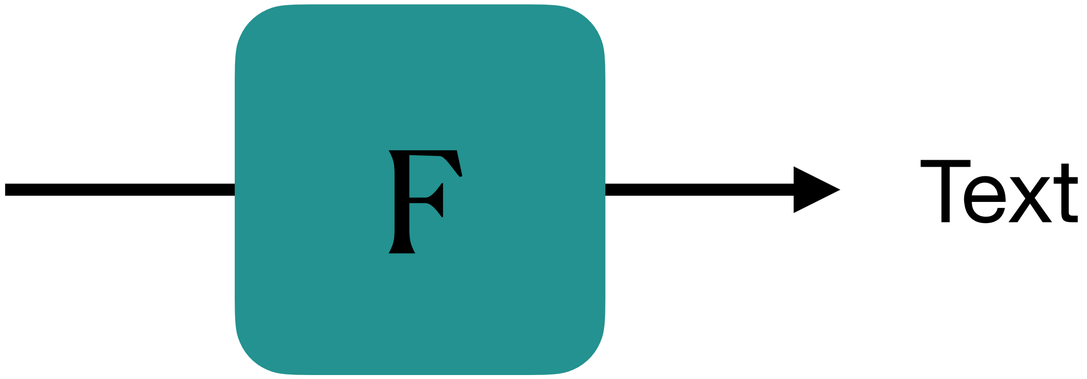
Text → F



Time	1.1	2.1	3.4	4.3	5	6	7	8	9	10	11	12	13	14	15	16
Amplitude	35	37	35	34	33	30	49	48	46	44	46	49	48	66	50	55

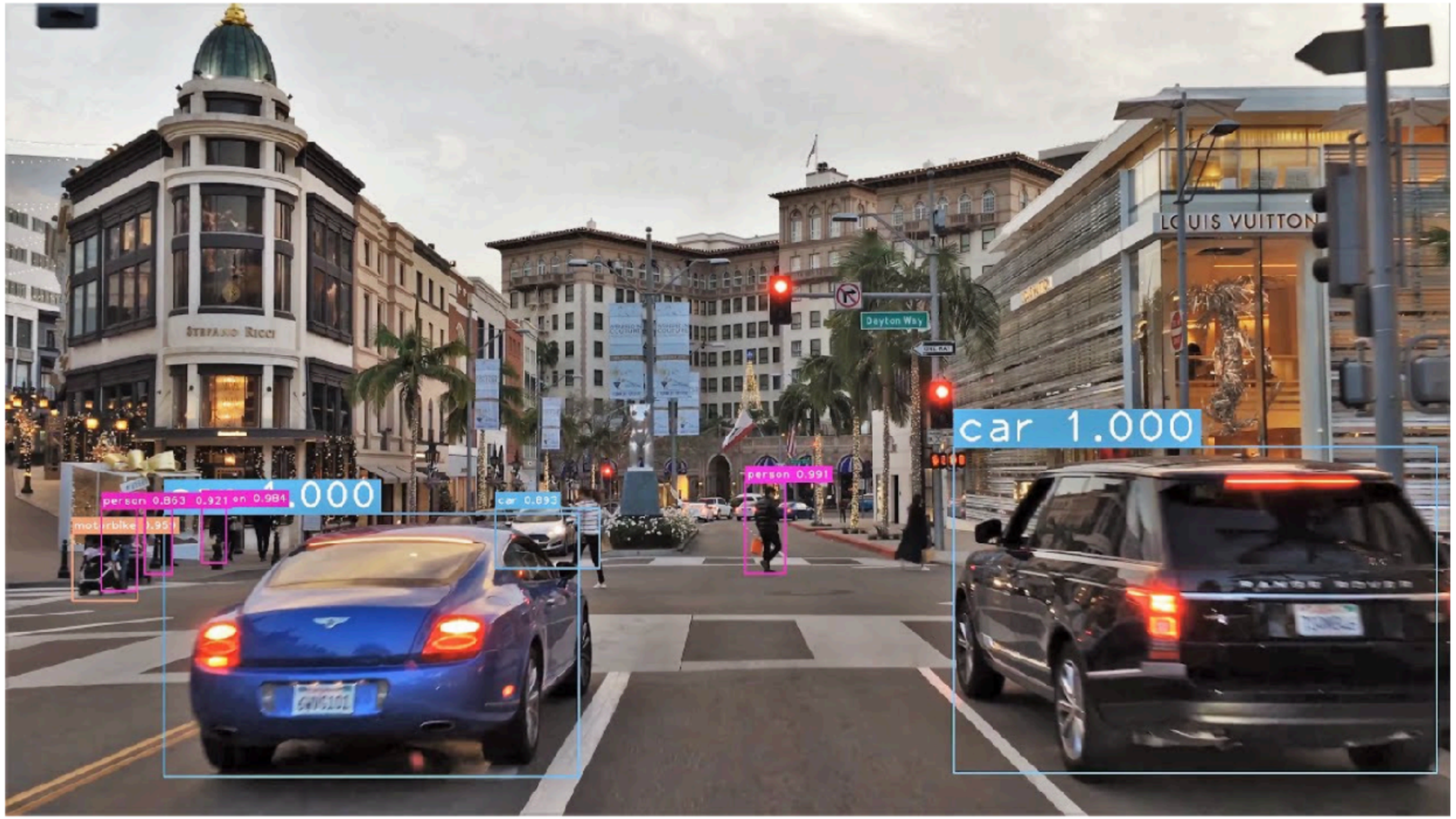
Audio





Time	1.1	2.1	3.4	4.3	5	6	7	8	9	10	11	12	13	14	15	16
Amplitude	35	37	35	34	33	30	49	48	46	44	46	49	48	66	50	55

Images



Google announces Waymo in 2010

Images

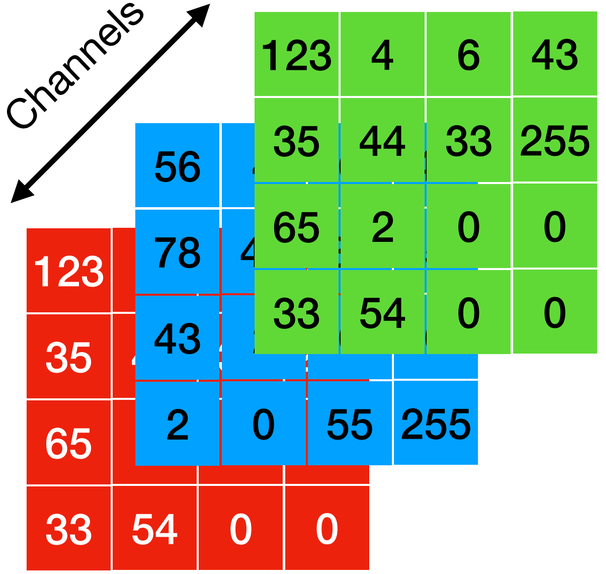
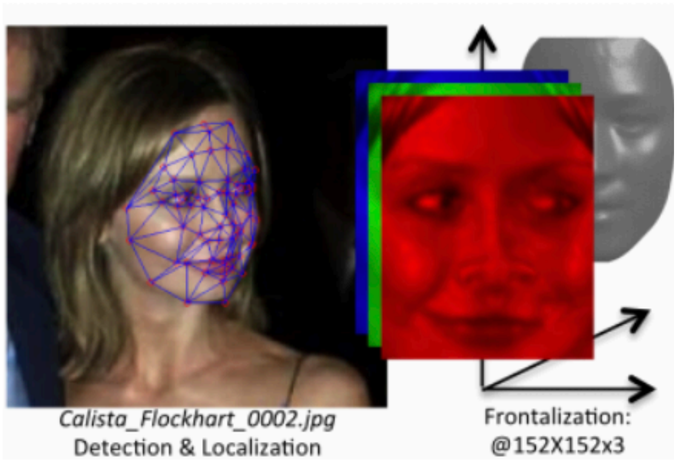
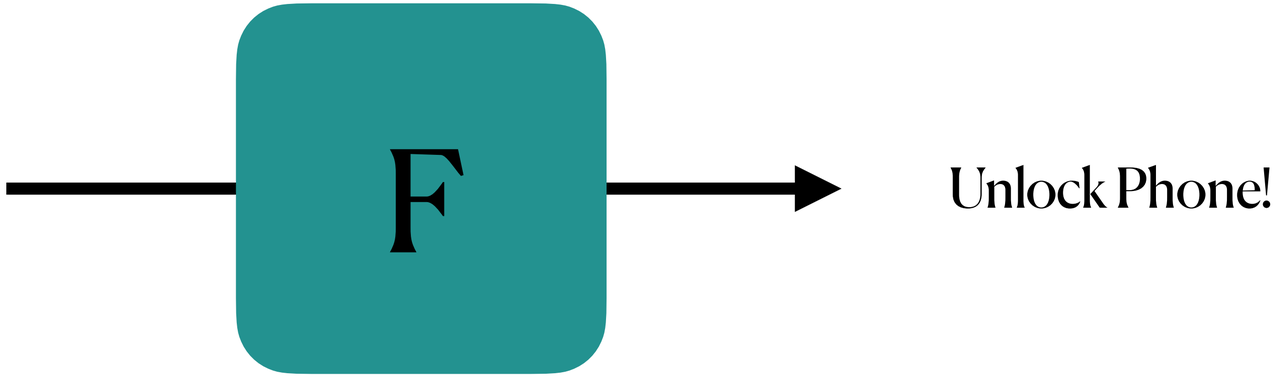


Image dimension: $h \times w \times 3$

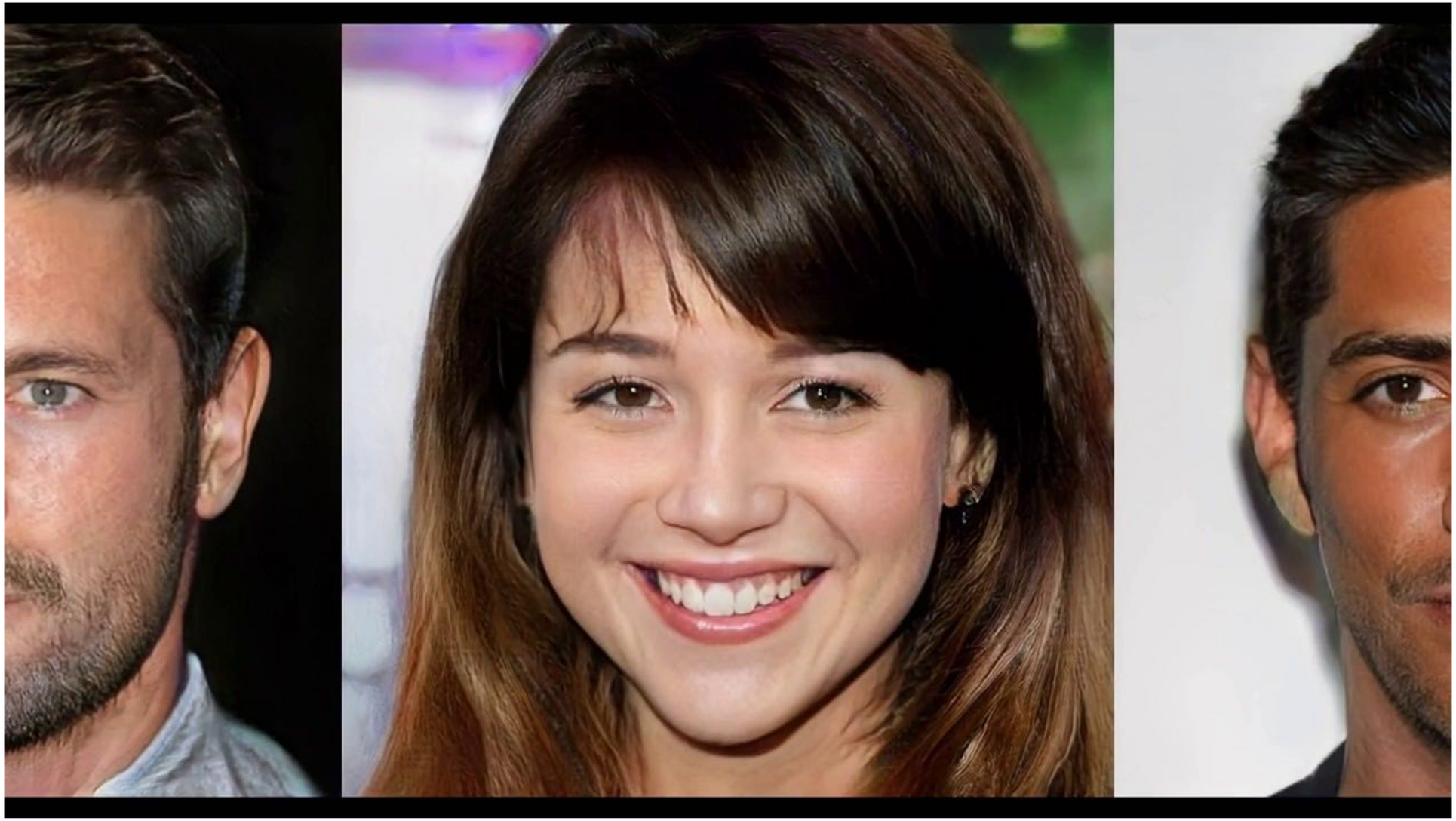
Image recognition





- Google Brain uses deep learning to recognize cats in images (2012)
- Facebook recognizes faces with 97% accuracy (2014)

Generative Adversarial Networks (2014)

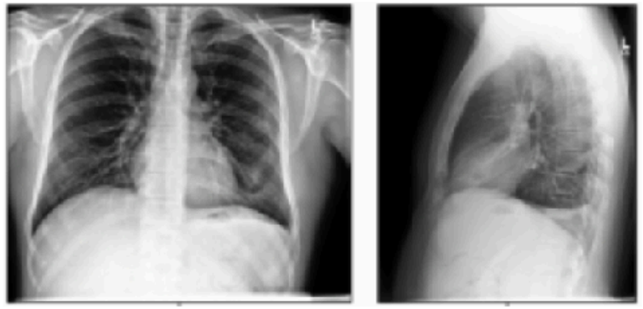


Progressive Growing of GANs for Improved Quality, Stability, and Variation

https://www.youtube.com/watch?v=G06dEcZ-QTg&t=36s&ab_channel=TeroKarrasFI

Image recognition

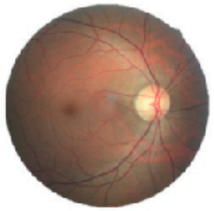
Chest radiology



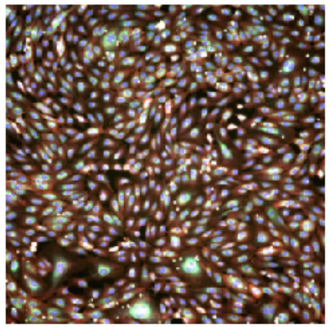
2019

Google AI outperforms radiologists at lung cancer detection

Diabetic retinopathy



Drug screening for COVID-19



Video

This is not Morgan Freeman - A look behind the Deepfake Singularity - https://youtube.com/watch?v=F4G6GNFzoO8

Video

dimension: $T \times h \times w \times 3$

t_1

123	4	6	43
35	44	33	255
65	2	0	0
33	54	0	0

t_2

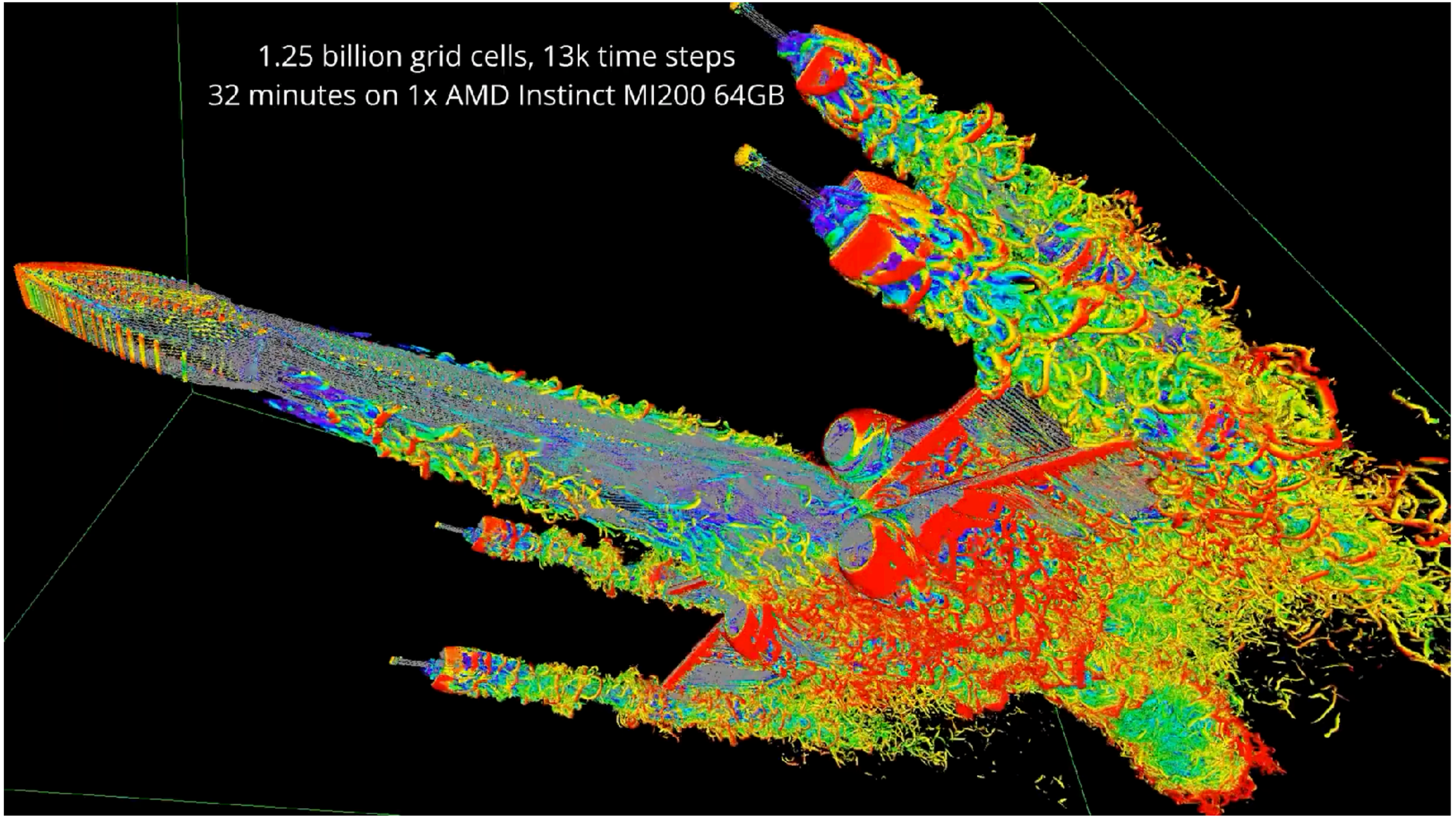
123	4	6	43
35	44	33	255
65	2	0	0
33	54	0	0

. . . . . .

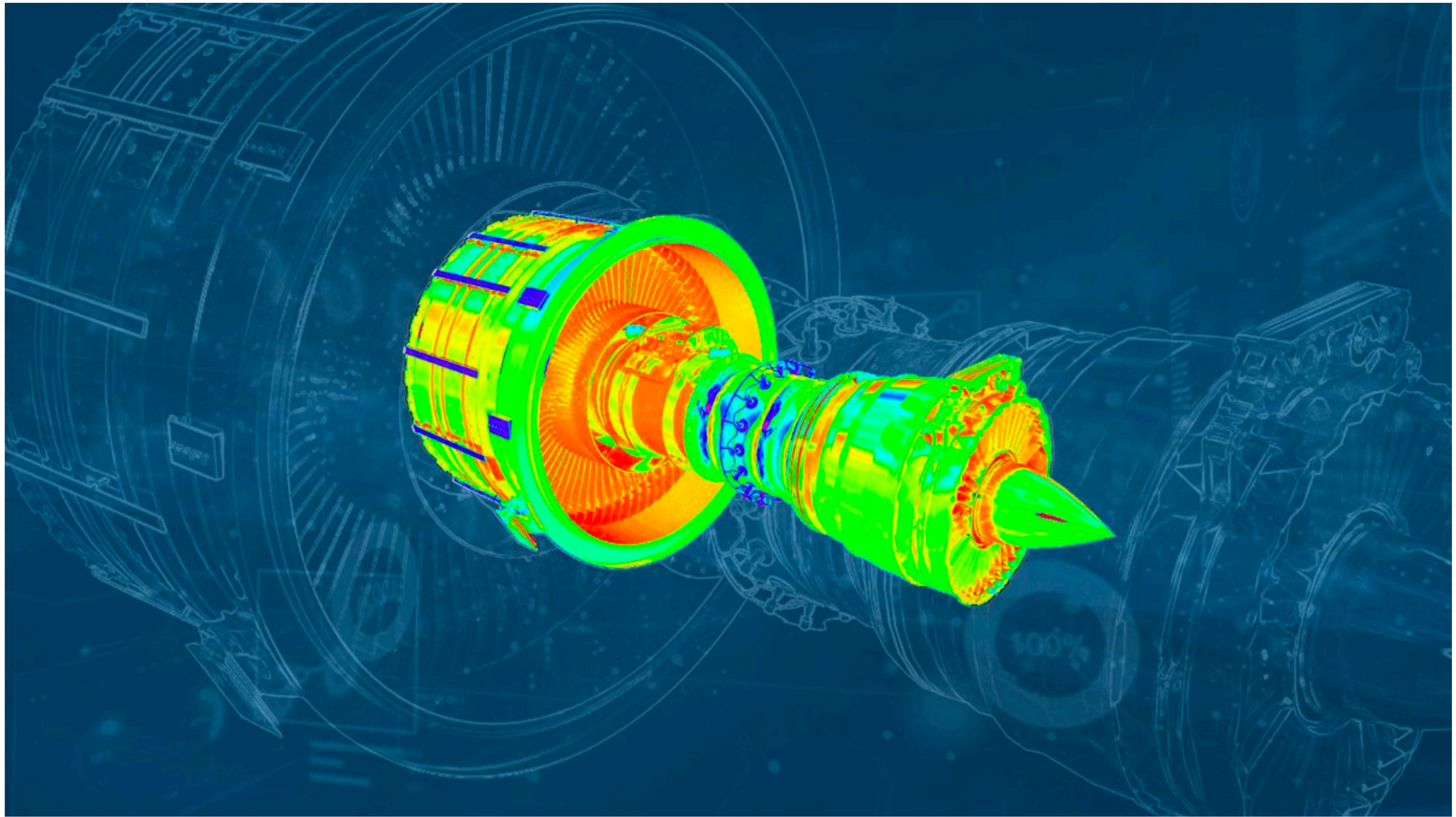
T

123	4	6	43
35	44	33	255
65	2	0	0
33	54	0	0

Fluid dynamics



Machine learning in materials research



Language

Deep learning surpasses traditional approaches in speech recognition in 2010

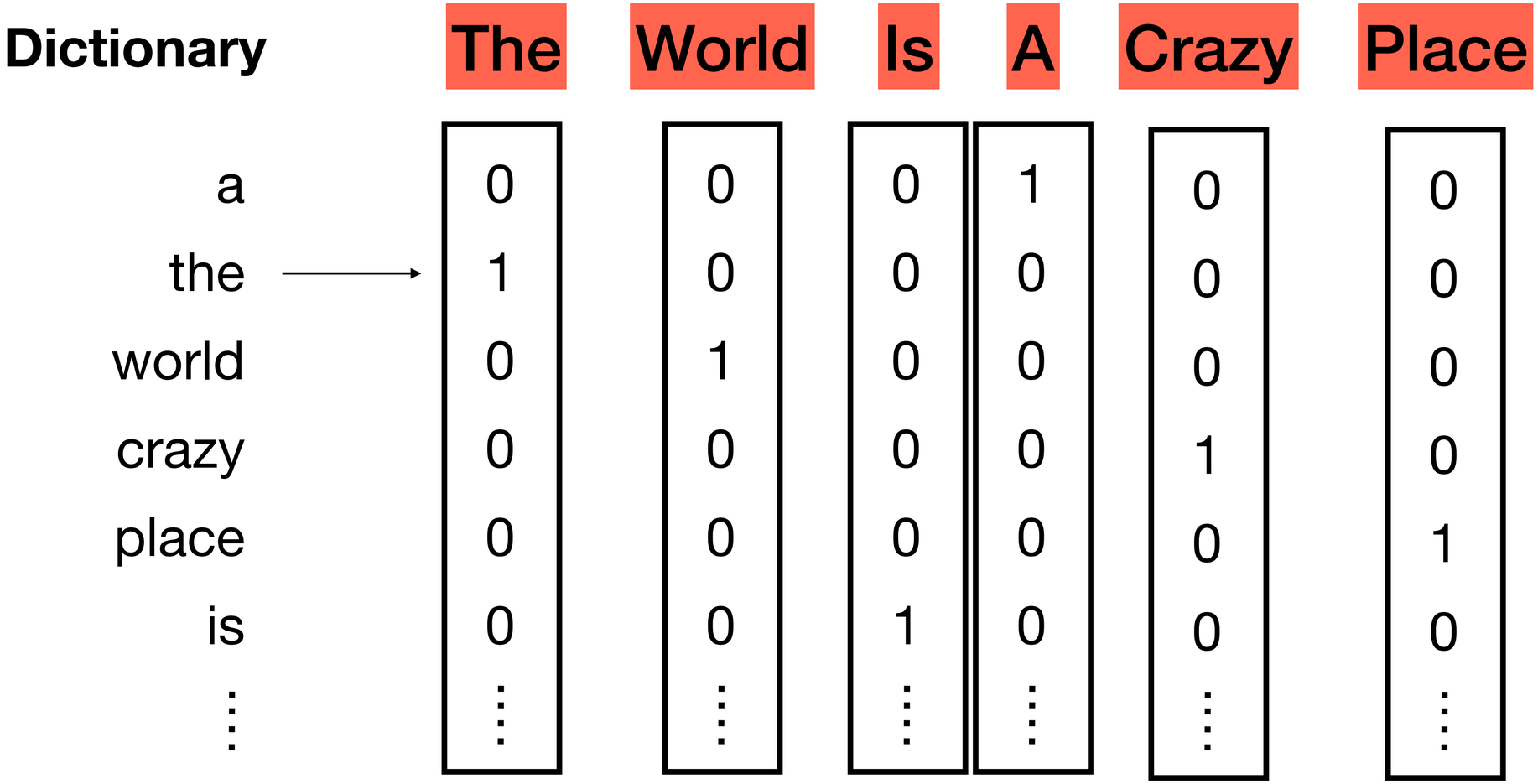
2016 2014 2011

IBM-Watson Defeats Humans in "Jeopardy!"

2011

Text

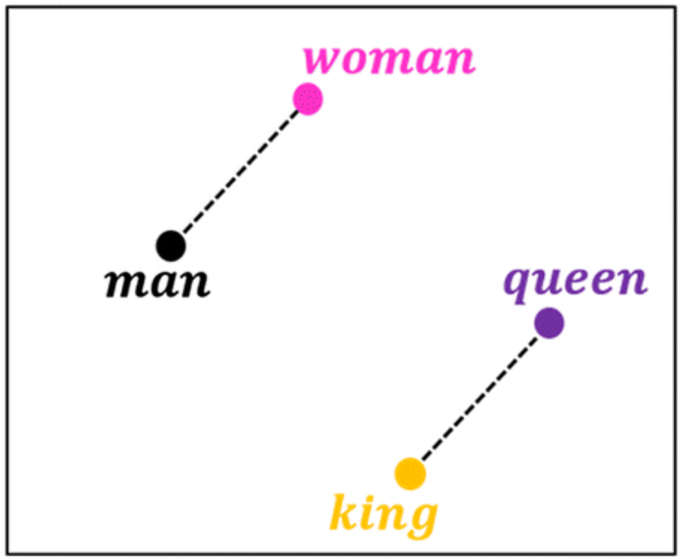
One-hot word representation



Text

Word Embedding Representation

man	→	0.6	−0.2	0.8	0.9	−0.1	−0.9	−0.7
woman	→	0.7	0.3	0.9	−0.7	0.1	−0.5	−0.4
king	→	0.5	−0.4	0.7	0.8	0.9	−0.7	−0.6
queen	→	0.8	−0.1	0.8	−0.9	0.8	−0.5	−0.9



Words

Embedding

Semantic Space

https://www.analyticsvidhya.com/blog/2021/07/feature-extraction-and-embeddings-in-nlp-a-beginners-guide-to-understand-natural-language-processing/

Text Generation

give me some project ideas on machine learning for music

Machine Learning Project Ideas for Music

Music Generation and Composition

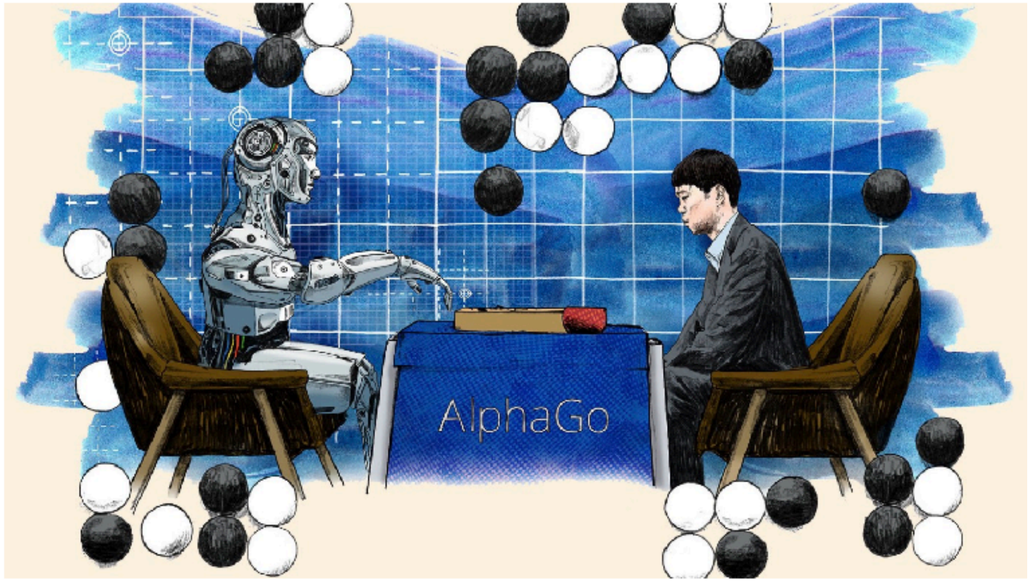
- **Style Transfer:** Train a model to transfer the style of one musical piece to another. For instance, create a Bach piece in the style of a Beatles song.
- **Generative Adversarial Networks (GANs):** Generate new, original music pieces using GANs. You can train the model on specific genres or composers to create music in those styles.
- **Melody Generation:** Develop a model to generate catchy and melodic sequences, which can be used for jingles, background music, or as a starting point for composing full pieces.
- **Chord Progression:** Create a model to predict chord progressions based on given musical contexts, aiding in songwriting and composition.

Games

IBM creates a checker playing program

1959

AlphaGo beats world's best Go player

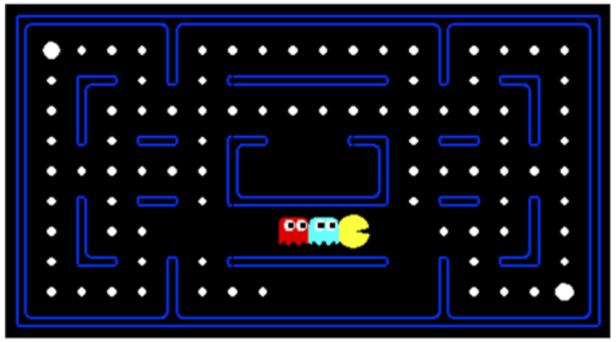


2016

IBM Deep Blue beats Kasparov

1997

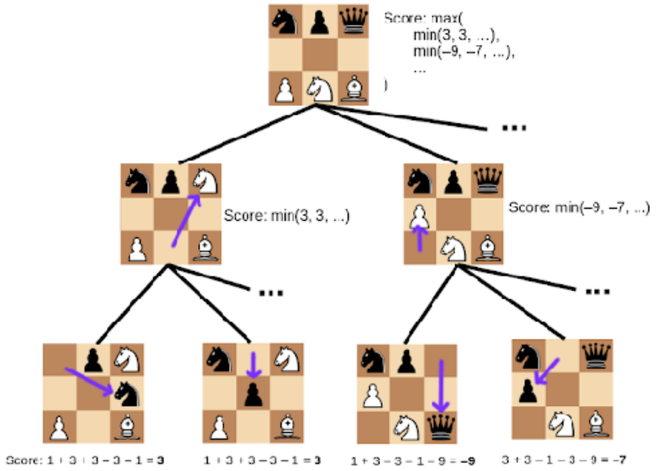
Solving puzzles



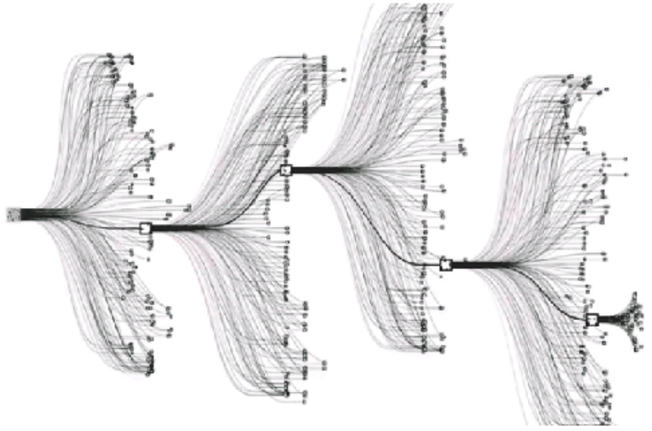
5	3			7				
6			1	9	5			
	9	8					6	
8				6				3
4			8		3			1
7				2				6
	6					2	8	
			4	1	9			5
				8			7	9

→

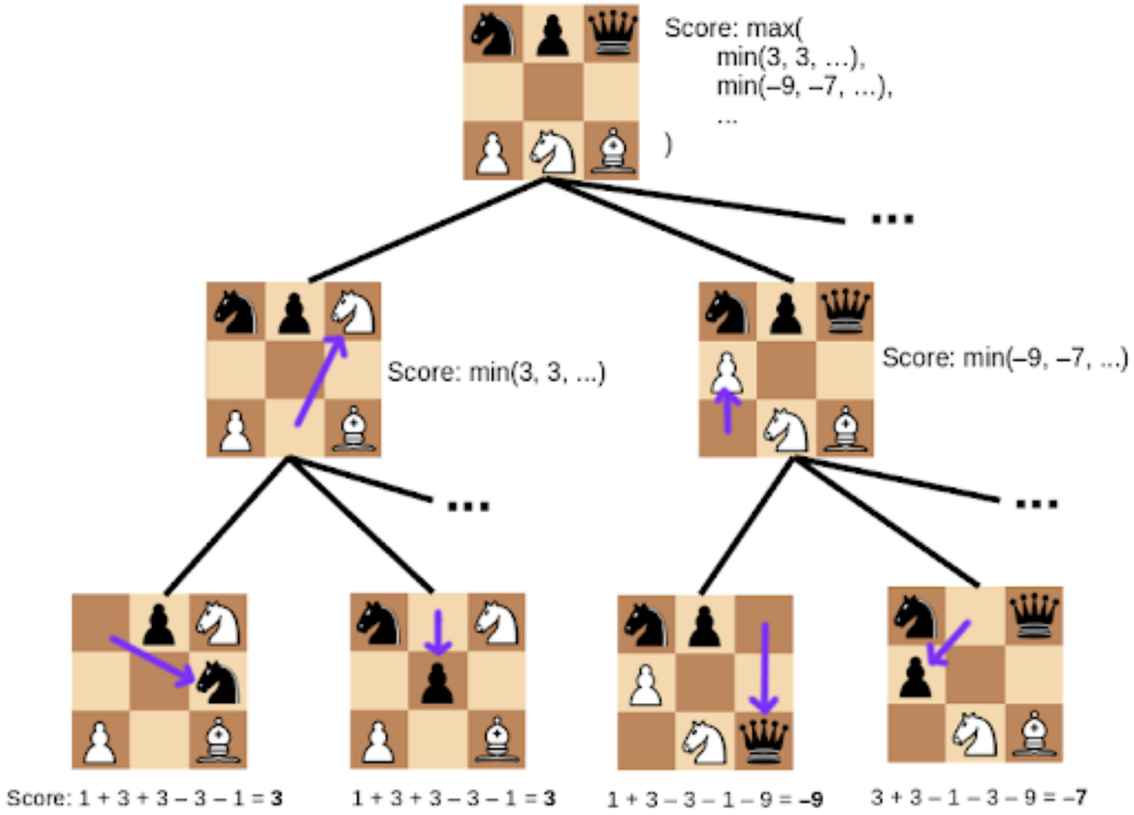
5	3	4	6	7	8	9	1	2
6	7	2	1	9	5	3	4	8
1	9	8	3	4	2	5	6	7
8	5	9	7	6	1	4	2	3
4	2	6	8	5	3	7	9	1
7	1	3	9	2	4	8	5	6
9	6	1	5	3	7	2	8	4
2	8	7	4	1	9	6	3	5
3	4	5	2	8	6	1	7	9



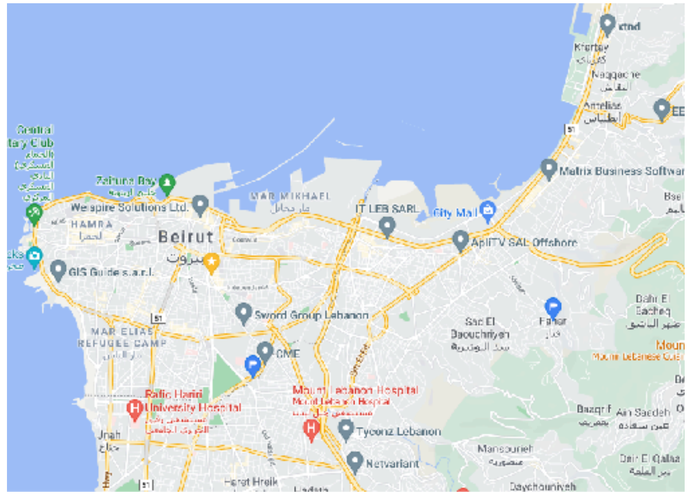
10^{120} possibilities

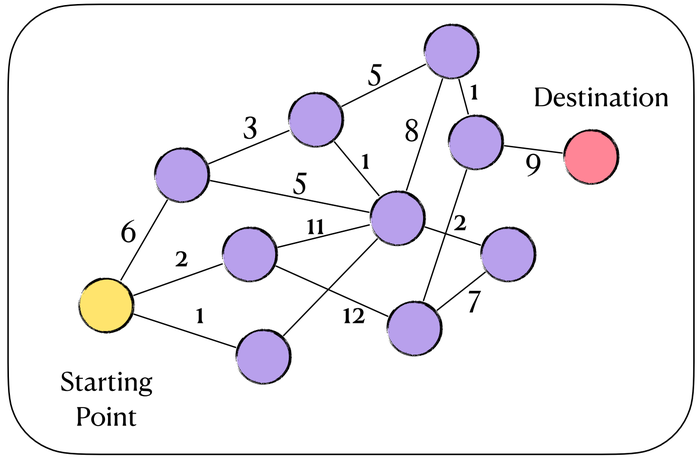


Graph Representation



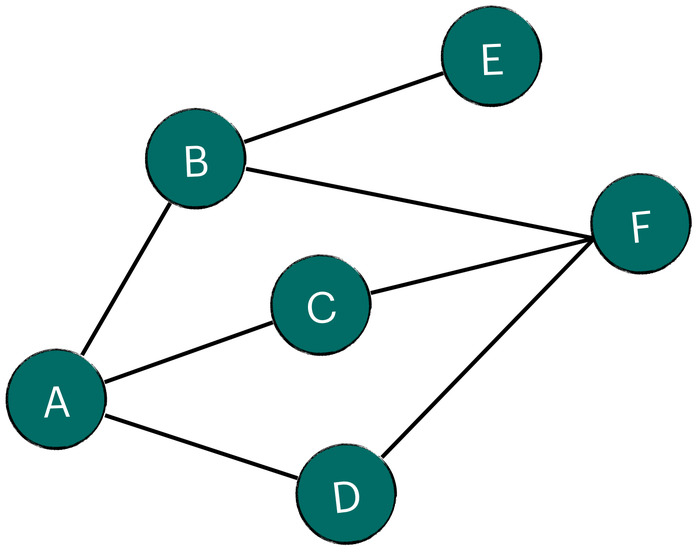
Real world





Graph Representation

Graph with Vertices and Edges



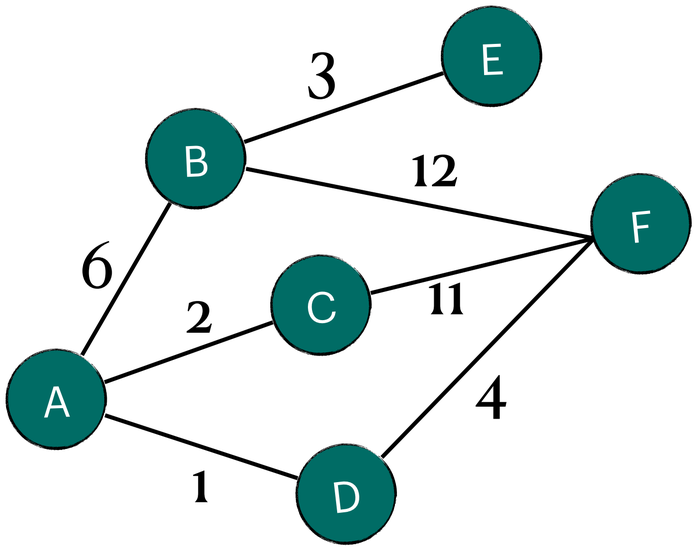
Adjacency Matrix

	A	B	C	D	E	F
A	0	1	1	1	0	0
B	1	0	0	0	1	1
C	1	0	0	0	0	1
D	1	0	0	0	0	1
E	0	1	0	0	0	0
F	0	1	1	1	0	0

https://www.cs.mtsu.edu/~xyang/3080/adjacencyMatrix.html

Graph Representation

Weighted Graph



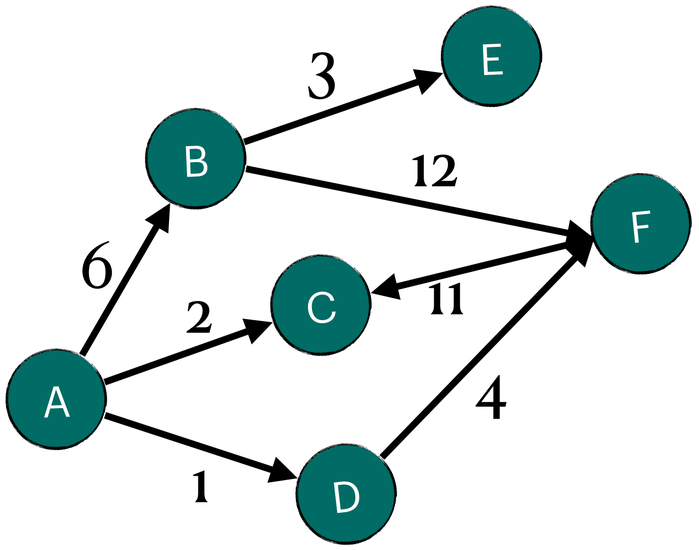
Adjacency Matrix

	A	B	C	D	E	F
A	0	6	2	1	0	0
B	6	0	0	0	3	12
C	2	0	0	0	0	11
D	1	0	0	0	0	4
E	0	3	0	0	0	0
F	0	12	11	4	0	0

https://www.cs.mtsu.edu/~xyang/3080/adjacencyMatrix.html

Graph Representation

Weighted Directed Graph

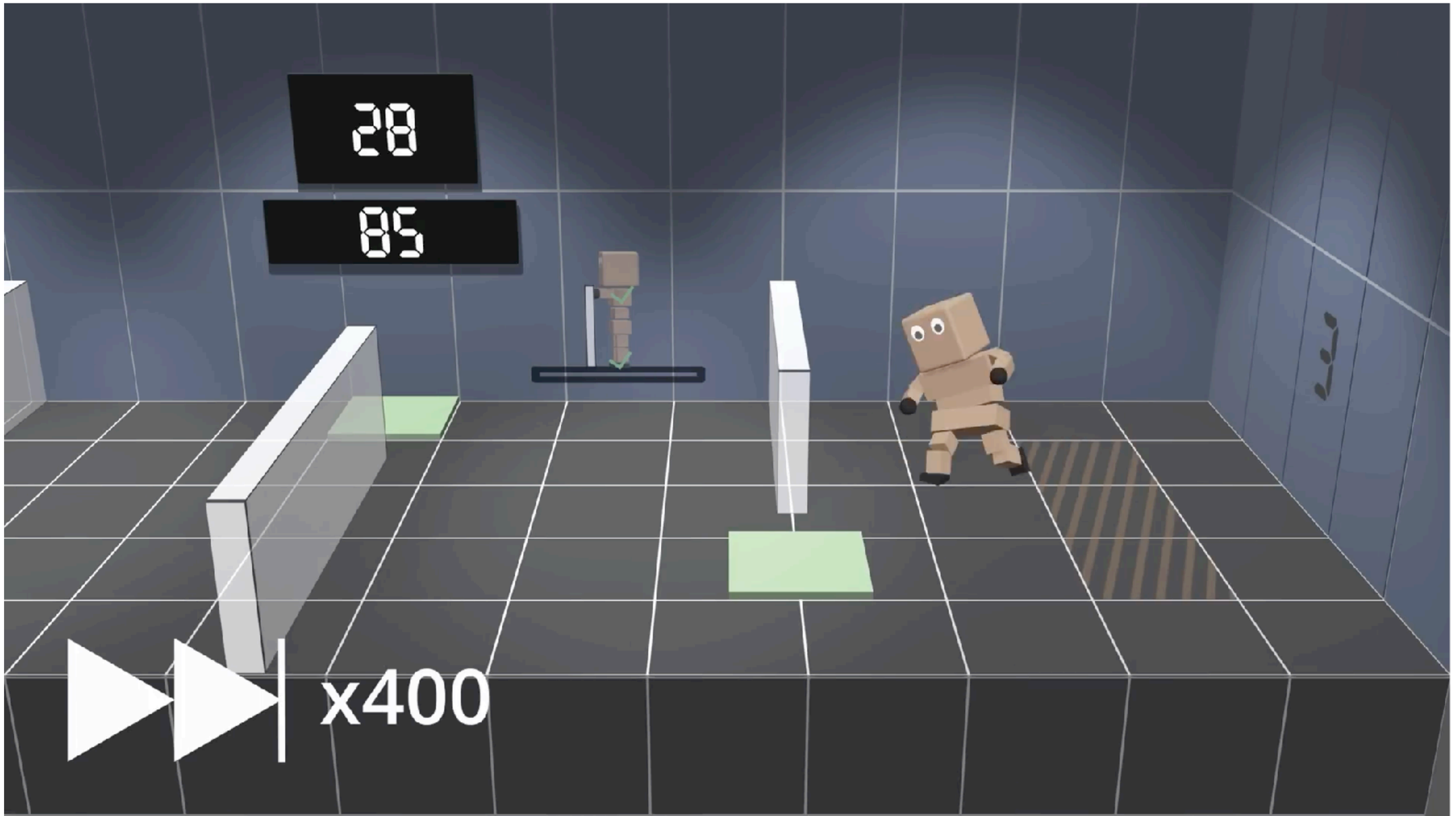


Adjacency Matrix

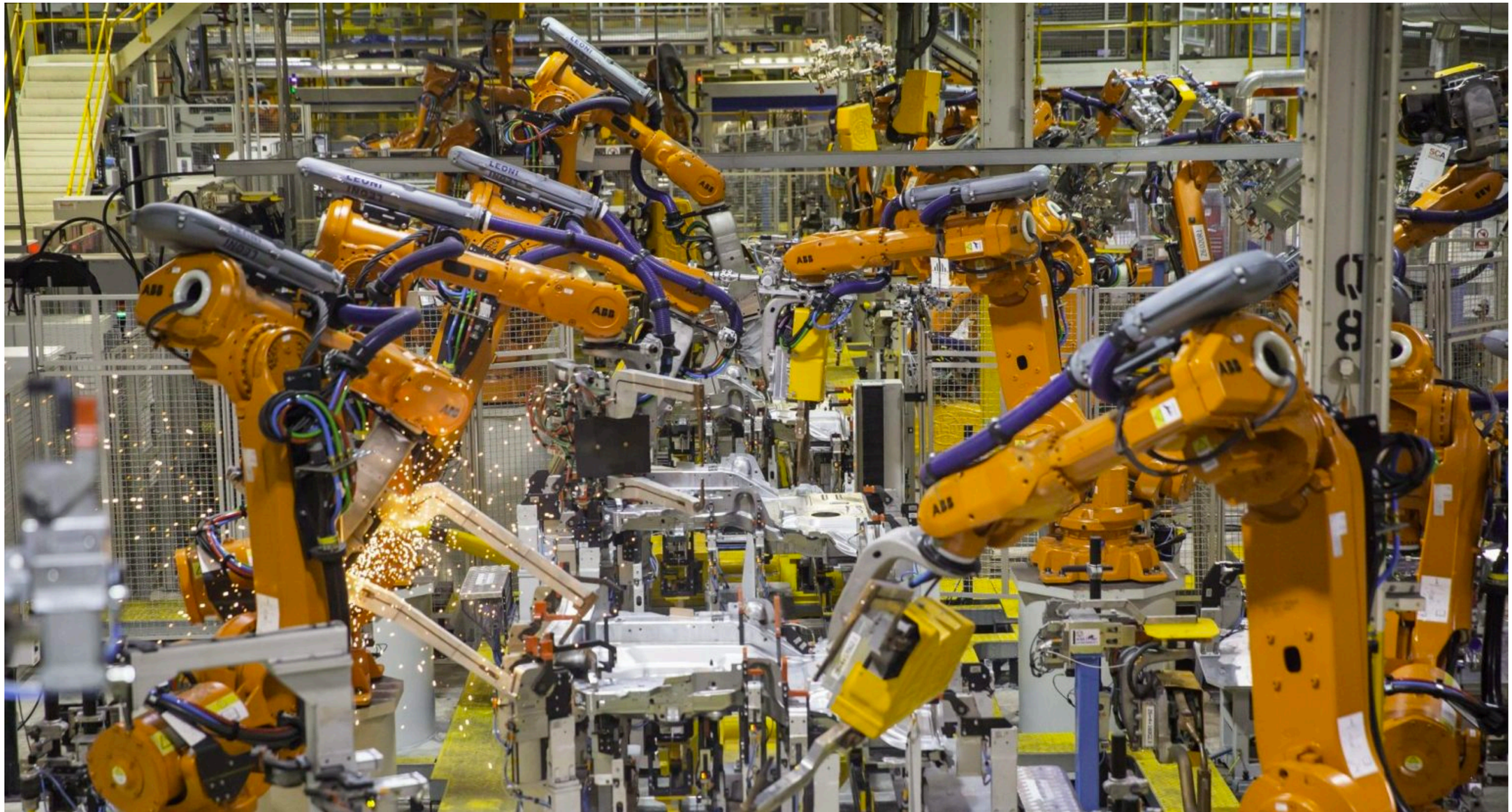
	A	B	C	D	E	F
A	0	6	2	1	0	0
B	0	0	0	0	3	12
C	0	0	0	0	0	0
D	0	0	0	0	0	4
E	0	0	0	0	0	0
F	0	0	11	0	0	0

https://www.cs.mtsu.edu/~xyang/3080/adjacencyMatrix.html

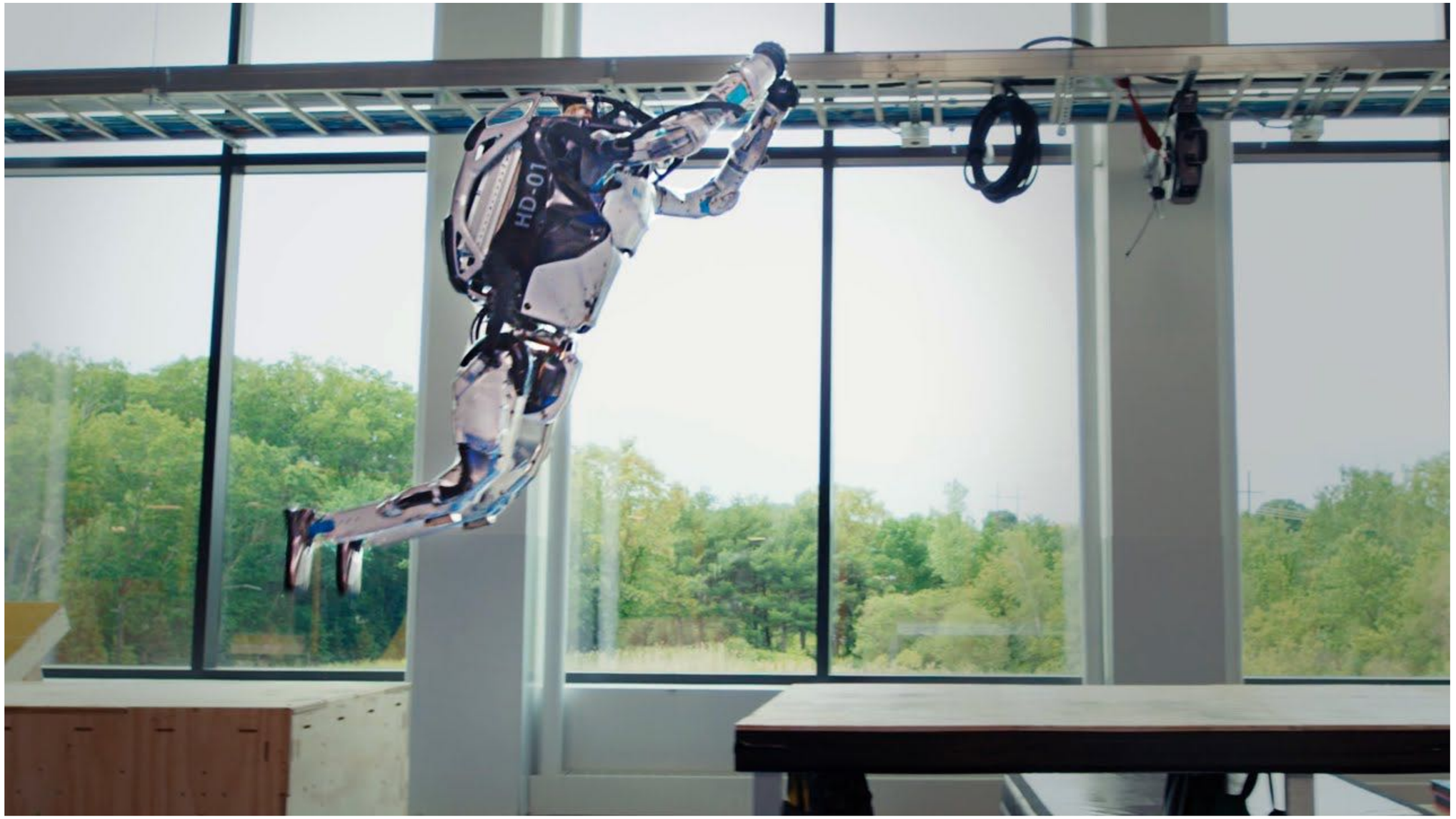
Robotics and games: Reinforcement Learning



Robotics and Manufacturing



Robotics



Boston Dynamics - https://youtube.com/watch?v=tF4DML7FIWk

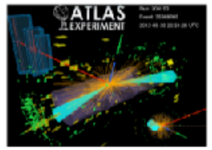
Classification

classifier

$$x \longrightarrow \boxed{f} \longrightarrow y \in \{+1, -1\}$$ label

Fraud detection: credit card transaction $\longrightarrow$ fraud or no fraud

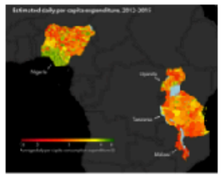
Toxic comments: online comment $\longrightarrow$ toxic or not toxic



Higgs boson: measurements of event $\longrightarrow$ decay event or background

Regression

$$x \longrightarrow \boxed{f} \longrightarrow y \in \mathbb{R} \text{ response}$$



Poverty mapping: satellite image $\longrightarrow$ asset wealth index

Housing: information about house $\longrightarrow$ price

Arrival times: destination, weather, time $\longrightarrow$ time of arrival

Structured Prediction

$x \longrightarrow \boxed{f} \longrightarrow y$ is a complex object

Machine translation: English sentence → Japanese sentence

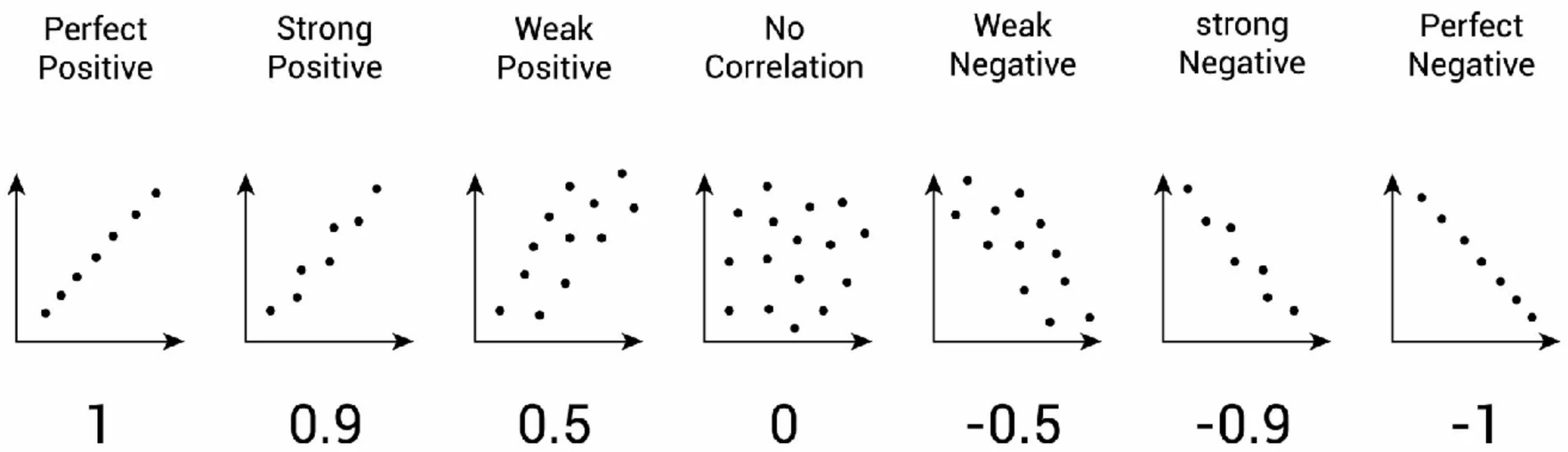
Dialogue: conversational history → next utterance

Image captioning: image → sentence describing image

Image segmentation: image → segmentation

Data Analysis

Correlation coefficient (2 variables)



$$r_{XY} = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}} = \frac{\mathrm{Cov}(X, Y)}{\sigma_X \sigma_Y}$$

https://sphweb.bumc.bu.edu/otlt/mph-modules/bs/bs704_summarizingdata/bs704_summarizingdata8.html

Correlation Matrix (multiple variables)

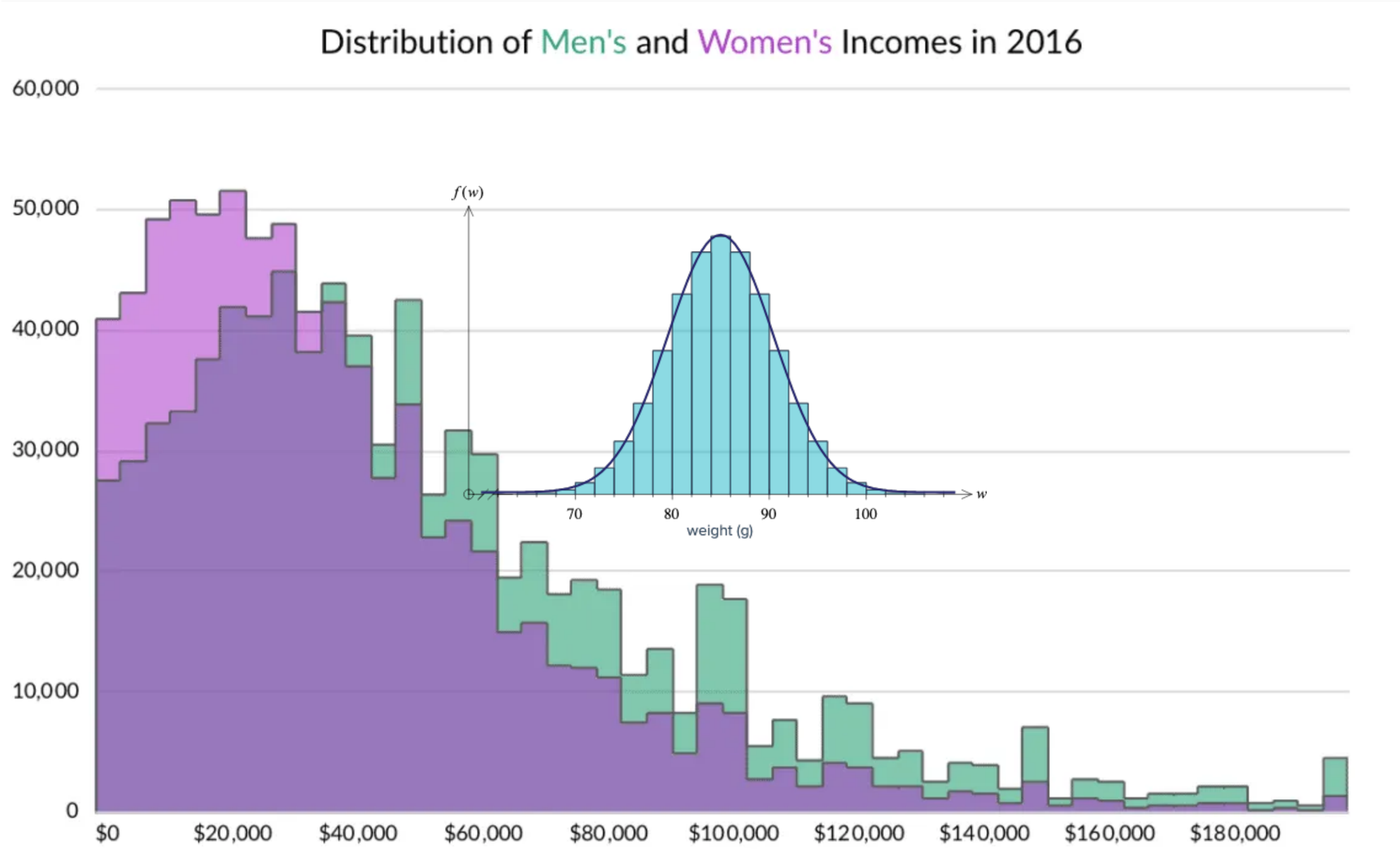
	Hours spent studying	Exam score	IQ score	Hours spent sleeping	School rating
Hours spent studying	1.00	0.82	0.48	-0.22	0.36
Exam score	0.82	1.00	0.33	-0.04	0.23
IQ score	0.08	0.33	1.00	0.06	0.02
Hours spent sleeping	-0.22	-0.04	0.06	1.00	0.12
School rating	0.36	0.23	0.02	0.12	1.00

$$r_{ij} = \frac{\mathrm{Cov}(X_i, X_j)}{\sigma_{X_i}\sigma_{X_j}}$$

$$\mathbf{R} = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{pmatrix}$$

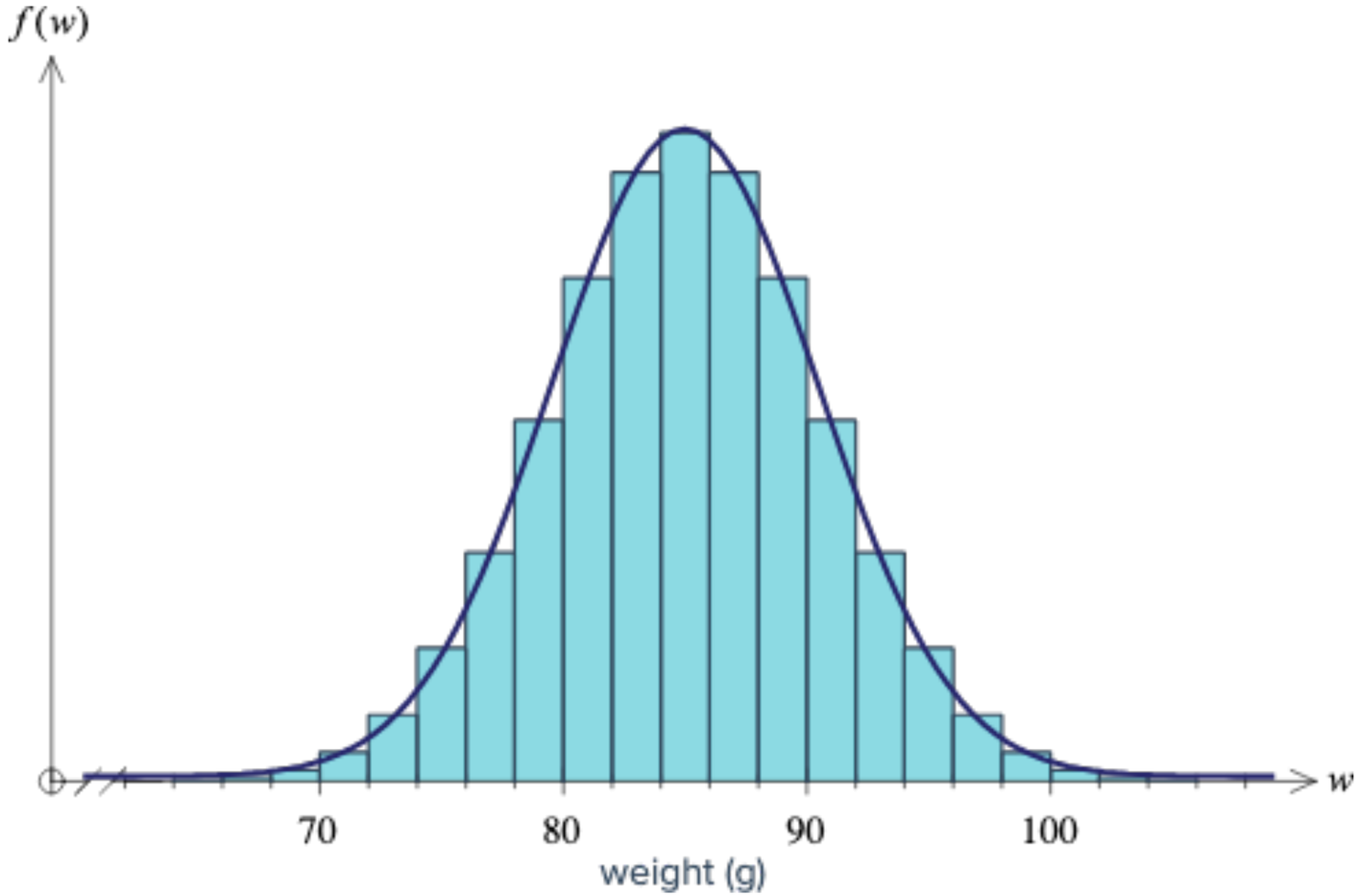
https://www.statology.org/how-to-read-a-correlation-matrix/

Histogram



https://policyviz.com/2018/11/27/histogram-design-decisions/

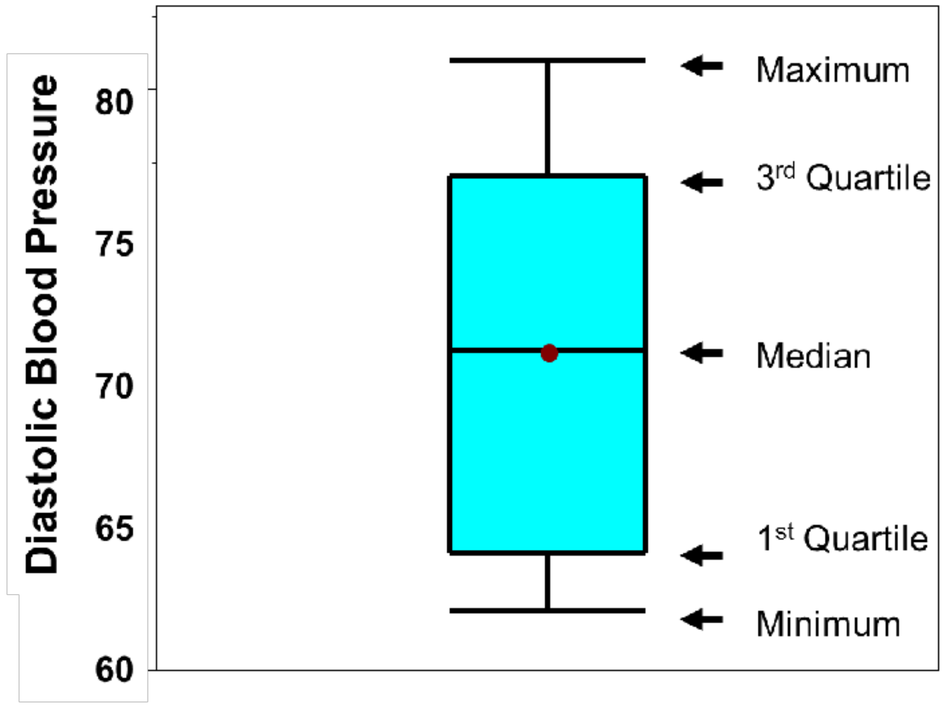
Probability Density Function

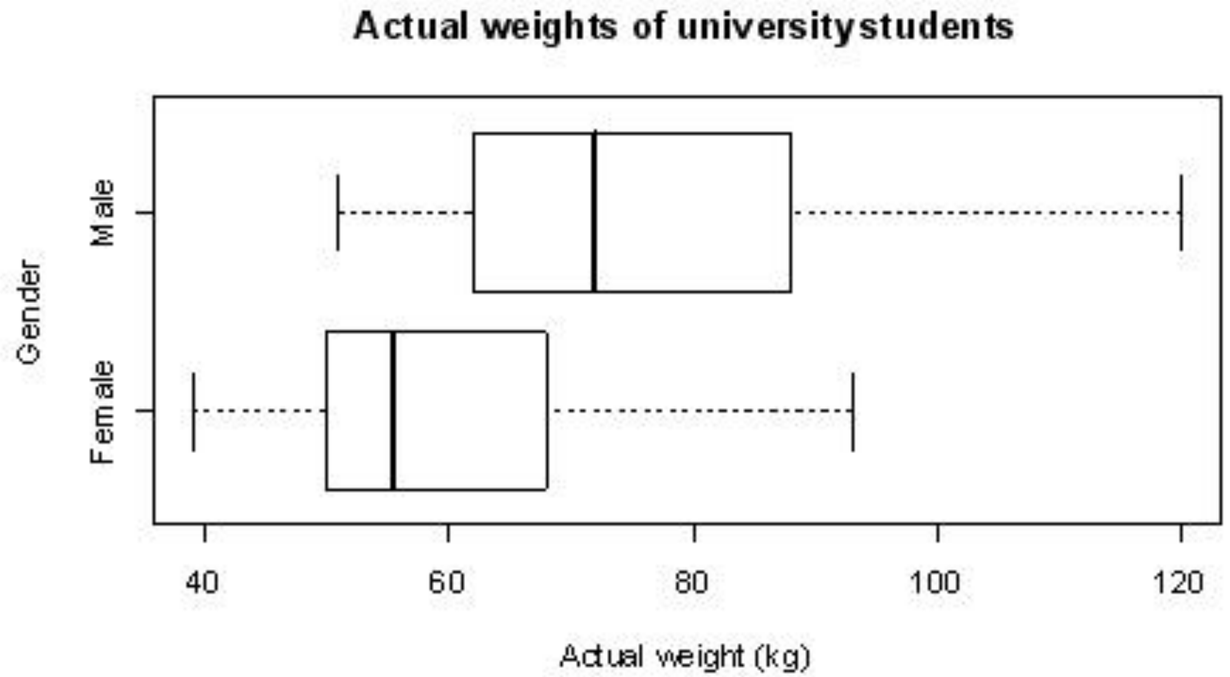


https://mathspace.co/textbooks/syllabuses/Syllabus-826/topics/Topic-18358/subtopics/Subtopic-279214/?activeTab=theory

Looking for data

Box and Whisker Plot

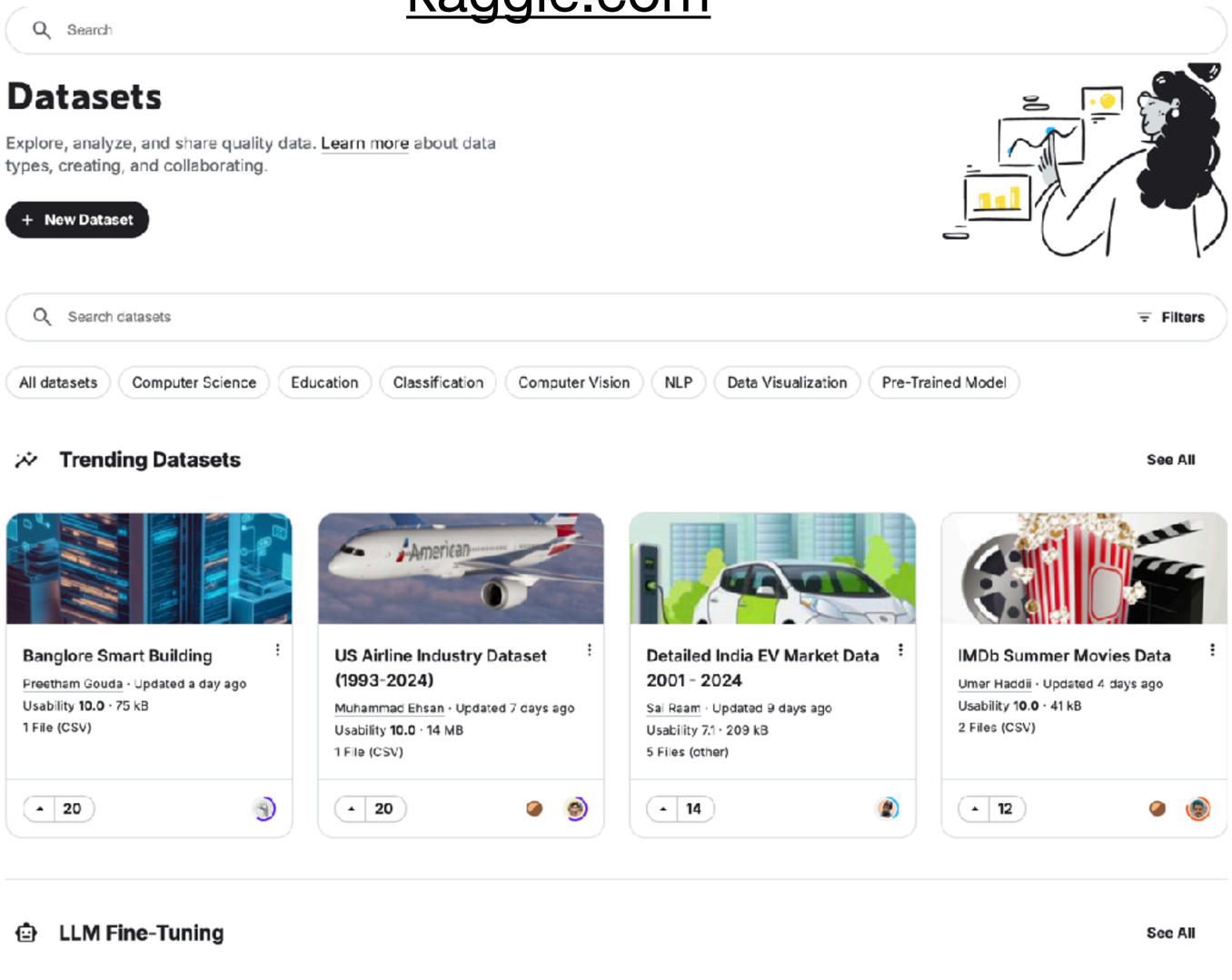




https://sphweb.bumc.bu.edu/otlt/mph-modules/bs/bs704_summarizingdata/bs704_summarizingdata8.html

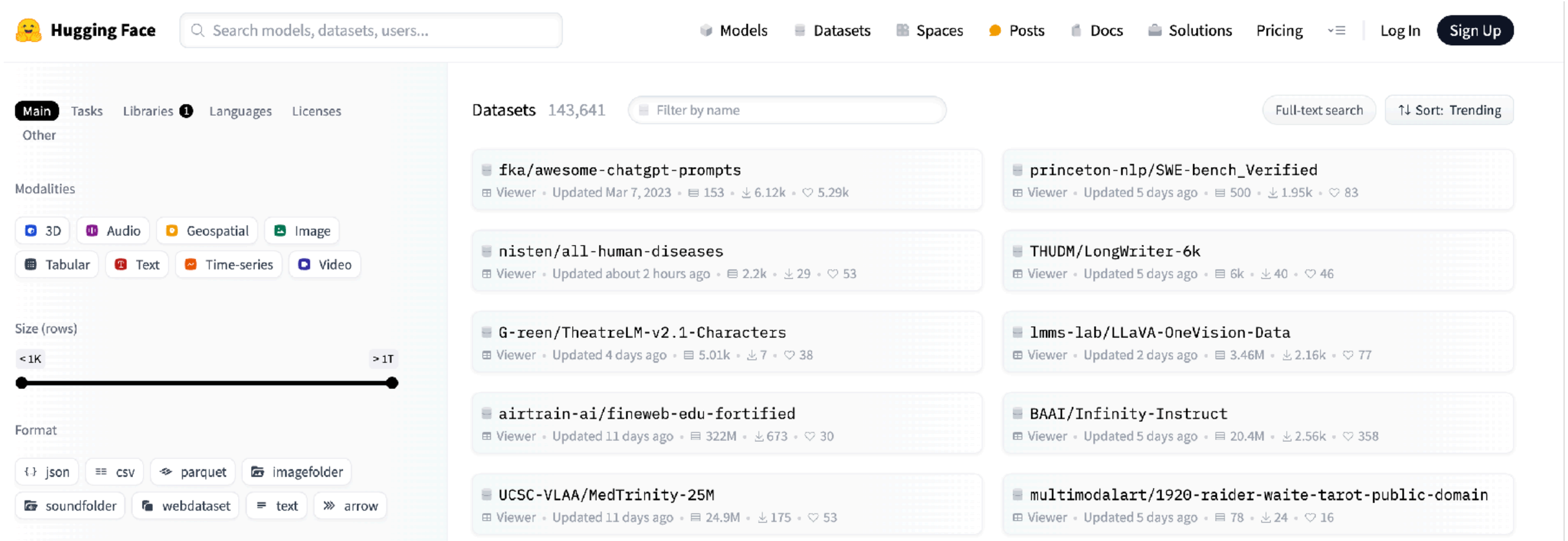
Where to look for data?

kaggle.com



Where to look for data?

huggingface.co



Where to look for data?

Ask GPT

I'm working on a machine learning project. Where do I look for data?

When you're starting a machine learning project, finding the right data is crucial. Here are some good places to look for data:

1. **Public Data Repositories:**
   - **Kaggle:** Offers a wide range of datasets across different domains, along with competitions that can help you refine your skills.
   - **UCI Machine Learning Repository:** A classic resource with numerous datasets often used in academic research.
   - **Google Dataset Search:** A search engine for datasets that pulls from various sources on the web.
   - **Data.gov:** For datasets related to U.S. government, health, and other sectors.
   - **AWS Public Datasets:** Datasets hosted on Amazon Web Services, spanning multiple fields.
2. **Specific Domain Databases:**
   - **ImageNet:** For image data, often used for training deep learning models.
   - **OpenStreetMap:** If you're working on geographic data or maps.
   - **National Centers for Environmental Information (NCEI):** If you're looking for climate and environmental data.
   - **Spotify API:** For music-related data.
3. **APIs:**
   - **Twitter API:** Great for text and sentiment analysis projects.
   - **Reddit API:** Another source for text data, particularly discussions and community interactions.
   - **OpenWeatherMap API:** For weather-related data.
4. **Web Scraping:**
   - If you have a specific niche in mind, web scraping could be your go-to. Tools like BeautifulSoup or Scrapy in Python can help you collect data from websites (just be sure to check the site's terms of service).
5. **Academic Journals and Research Papers:**
   - Sometimes datasets are shared as part of academic research. Sites like **arXiv** or **IEEE Xplore** might provide links to datasets used in published research.

How do you come up with project ideas?

google.com

gemini.google.com