Introduction to AI and Its Applications

Hrachya Asatryan

Presentation Outline

- What is AI?
- What is Machine Learning?
- Practical examples in different fields
- Machine Learning directions

What is AI?

A question to answer before moving on: what is intelligence?

intelligence
/ɪnˈtɛlɪdʒ(ə)ns/

noun

The ability to acquire and apply knowledge and skills.

"an eminent man of great intelligence"

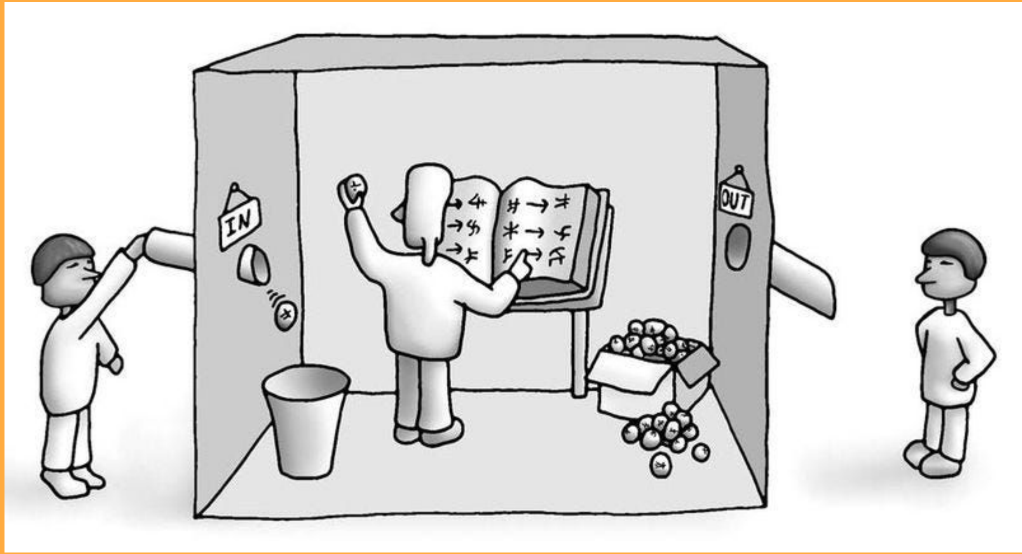
What makes a being intelligent?

Is an ape asking for an orange intelligent?

What makes a being intelligent?

How about a parrot looking into a mirror and asking what color?

Chinese Room Experiment

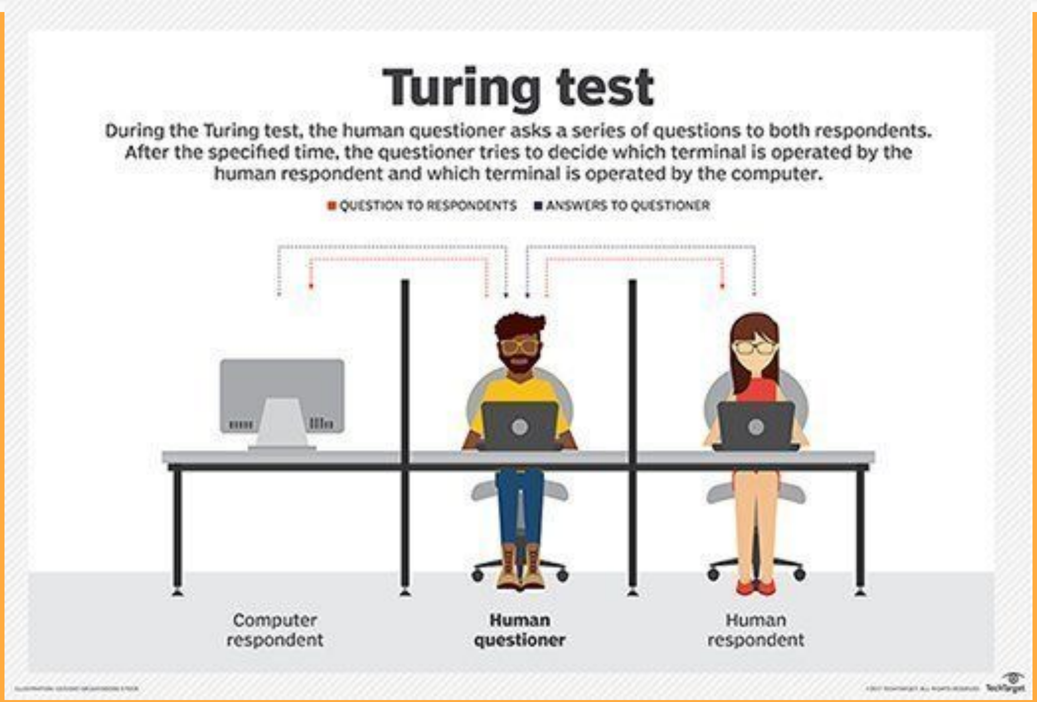


- The thought experiment was proposed by John Searle.
- It challenges the idea of strong AI and understanding.
- A person inside the room manipulates Chinese characters.
- The output seems intelligent without genuine comprehension.
- The experiment suggests AI might only simulate understanding.

What counts as intelligence?

Would a program that solves a quadratic equation count as intelligent? What about a chatbot like ChatGPT? Where do we draw the line?

One answer is the Turing test



3 Types of Artificial Intelligence

Artificial Narrow Intelligence (ANI)

Stage-1

Machine Learning

- Specialises in one area and solves one problem

Siri Alexa Cortana

Artificial General Intelligence (AGI)

Stage-2

Machine Intelligence

- Refers to a computer that is as smart as a human across the board

Artificial Super Intelligence (ASI)

Stage-3

Machine Consciousness

- An intellect that is much smarter than the best human brains in practically every field

Why Now ?

- Ability to collect and store large datasets

- Improved computational power

When to use Machine Learning ?

- Human expertise does not exist (navigating on Mars)
- Human are unable to explain their expertise (speech recognition)
- Solution changes in time (routing on a computer network)
- Solution needs to be adapted to particular cases (user biometrics)

Why to use Machine Learning?

- Understand and improve efficiency of human learning
- Reproduce an important aspect of intelligent behavior
- Ability to mimic human and replace certain monotonous tasks which require some intelligence
- Develop systems that are too difficult/expensive to construct manually
- Develop systems that can automatically adapt and customize themselves to individual users
- Discover new things or structure that were previously unknown to humans
- Discover new knowledge from large databases

Examples

Image taken from:
https://towardsdatascience.com/prototyping-a-recommender-system-step-by-step-part-1-knn-item-based-collaborative-filtering-637969614ea


RECOMMENDED
SYSTEMS
INSTAGRAM REEL
10:30
Instagram

Face recognition

Self Driving Cars


Voice assistant

Generative AI

Machine Learning

Supervised Learning

Unsupervised Learning

Reinforcement Learning

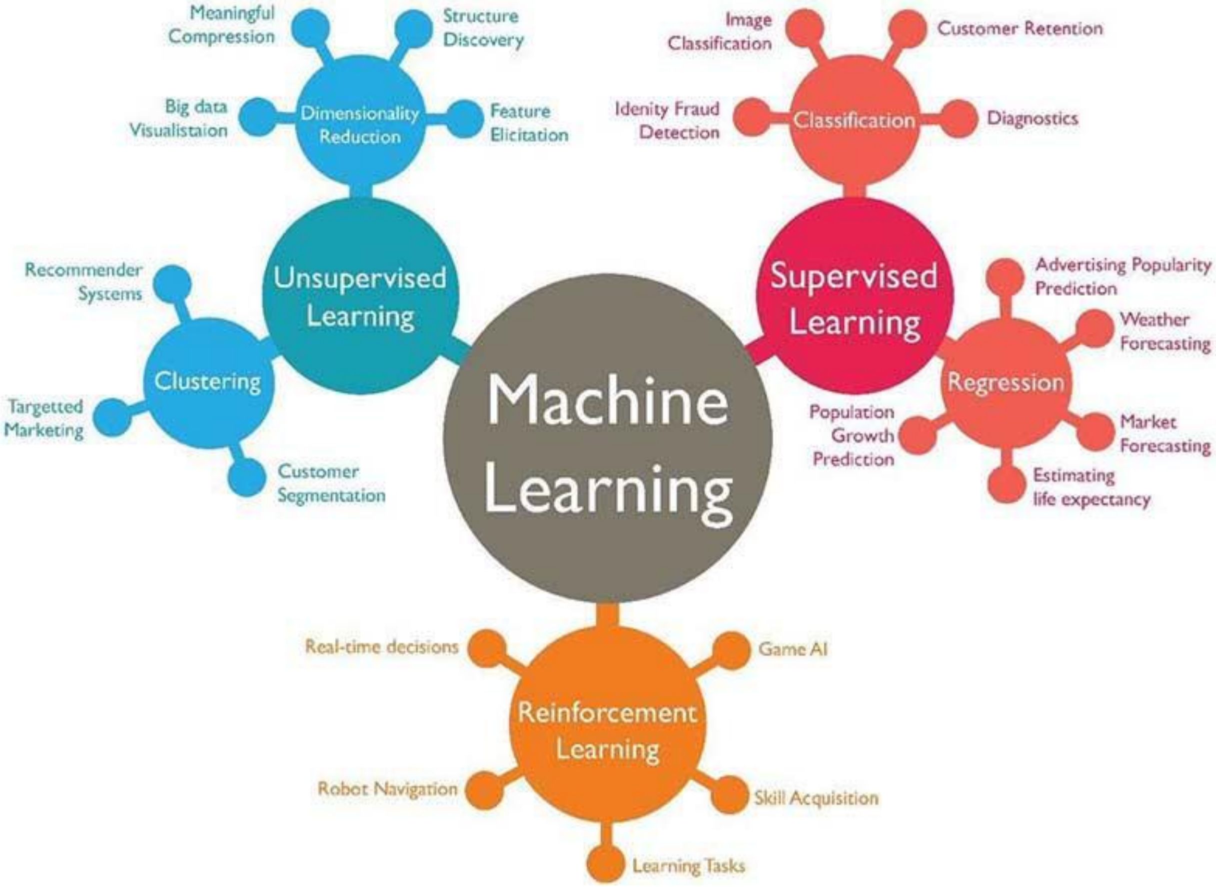
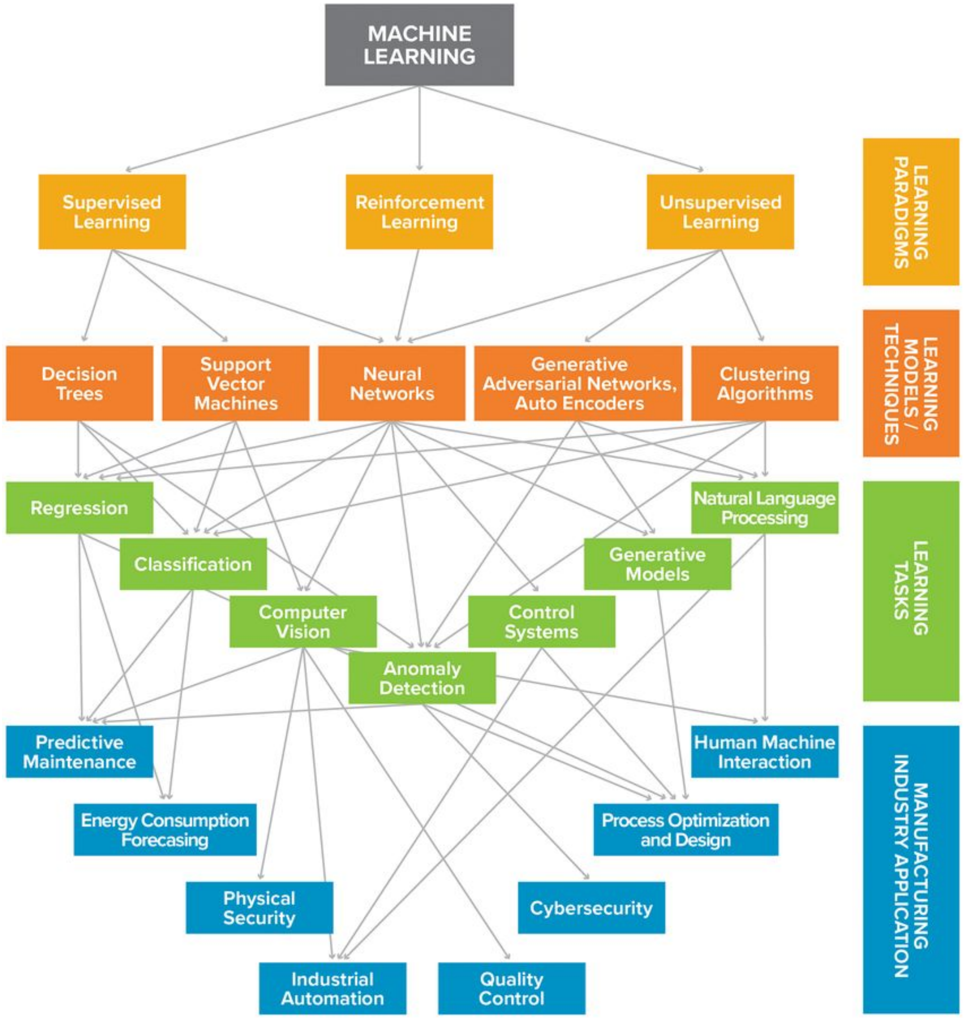
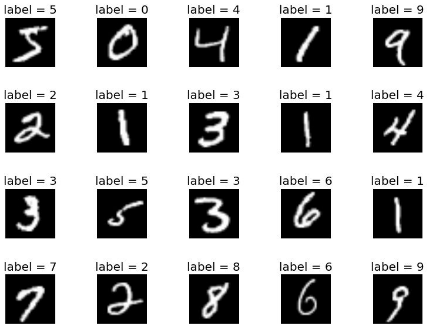


Figure taken from:
https://towardsdatascience.com/introduction-to-machine-learning-for-beginners-eed6024fdb08


MACHINE LEARNING
Supervised Learning
Reinforcement Learning
Unsupervised Learning
LEARNING PARADIGMS
Decision Trees
Support Vector Machines
Neural Networks
Generative Adversarial Networks, Auto Encoders
Clustering Algorithms
LEARNING MODELS / TECHNIQUES
Regression
Natural Language Processing
Classification
Generative Models
Computer Vision
Control Systems
Anomaly Detection
LEARNING TASKS
Predictive Maintenance
Human Machine Interaction
Energy Consumption Forecasing
Process Optimization and Design
Physical Security
Cybersecurity
Industrial Automation
Quality Control
MANUFACTURING INDUSTRY APPLICATION

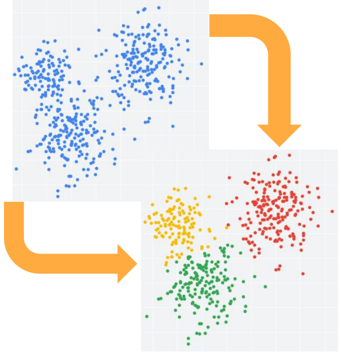
Supervised Learning



- **Regression**: A regression problem is when the output variable is continuous, such as “weight”, “height” or “dollars”.

- **Classification**: A classification problem is when the output variable is discrete (or a category), such as 0-1, “red” or “blue”, “disease” or “no disease”.

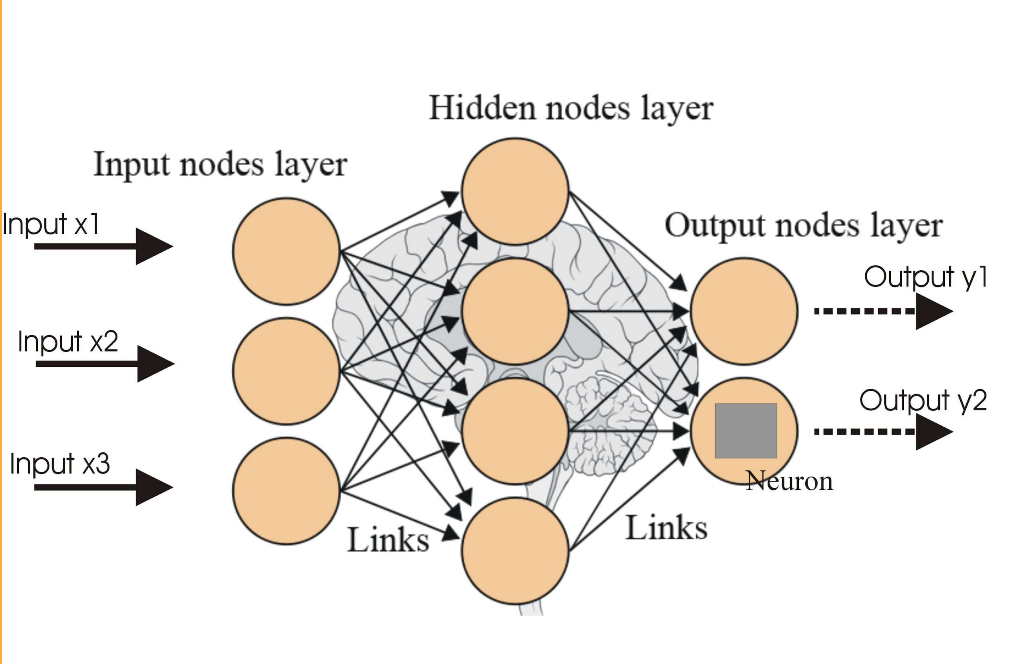
Unsupervised Learning



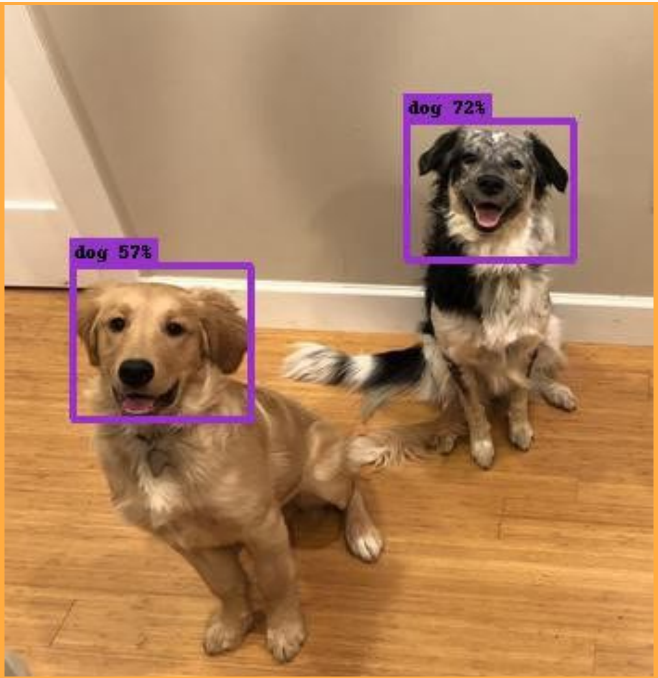
- **Clustering**: The goal is to group a set of objects in such a way that objects in the same group (called a cluster) are more similar (in some sense) to each other than to those in other groups (clusters).

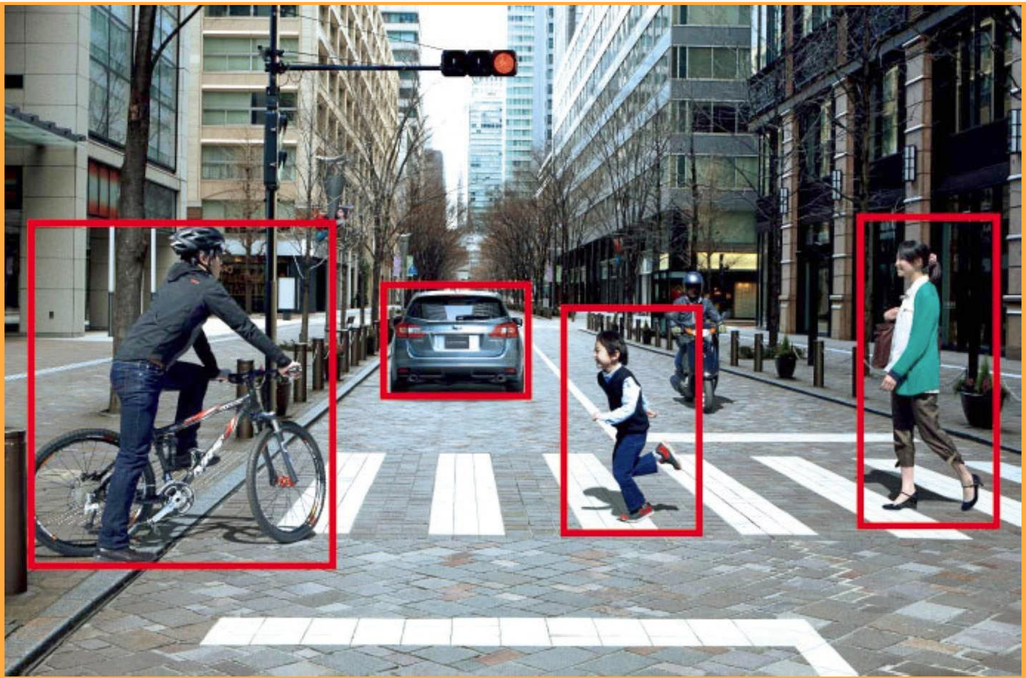
- **Dimensionality reduction**: The goal is to transform the data from a high-dimensional space into a low-dimensional space so that the low-dimensional representation retains some meaningful properties of the original data

Neural Networks



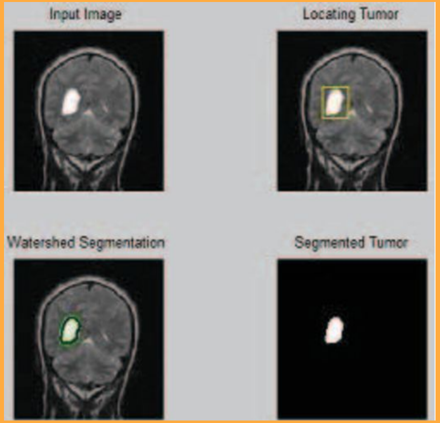
Convolutional Neural Networks





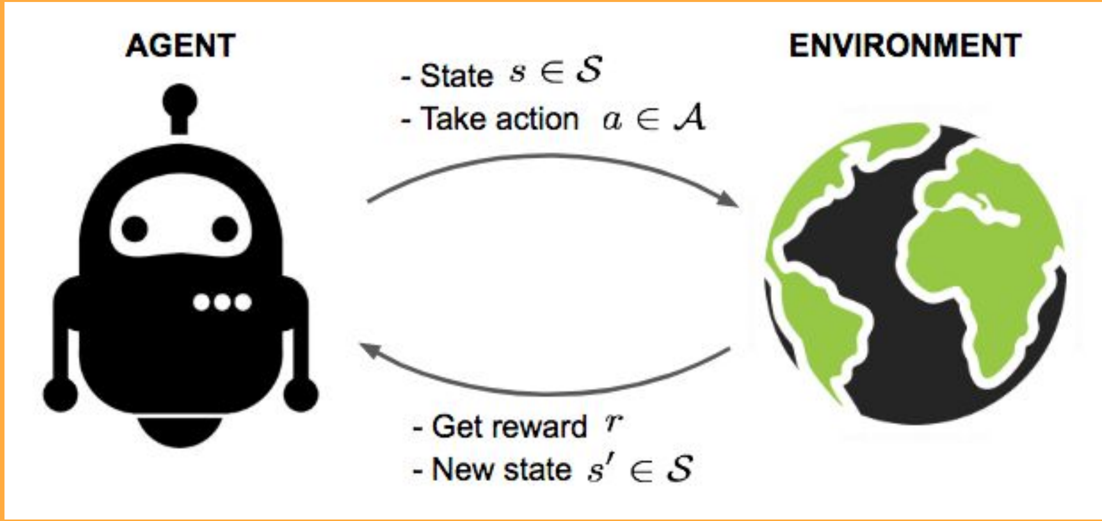
More examples

- Visual search
- Recommender engines
- Tumor identification

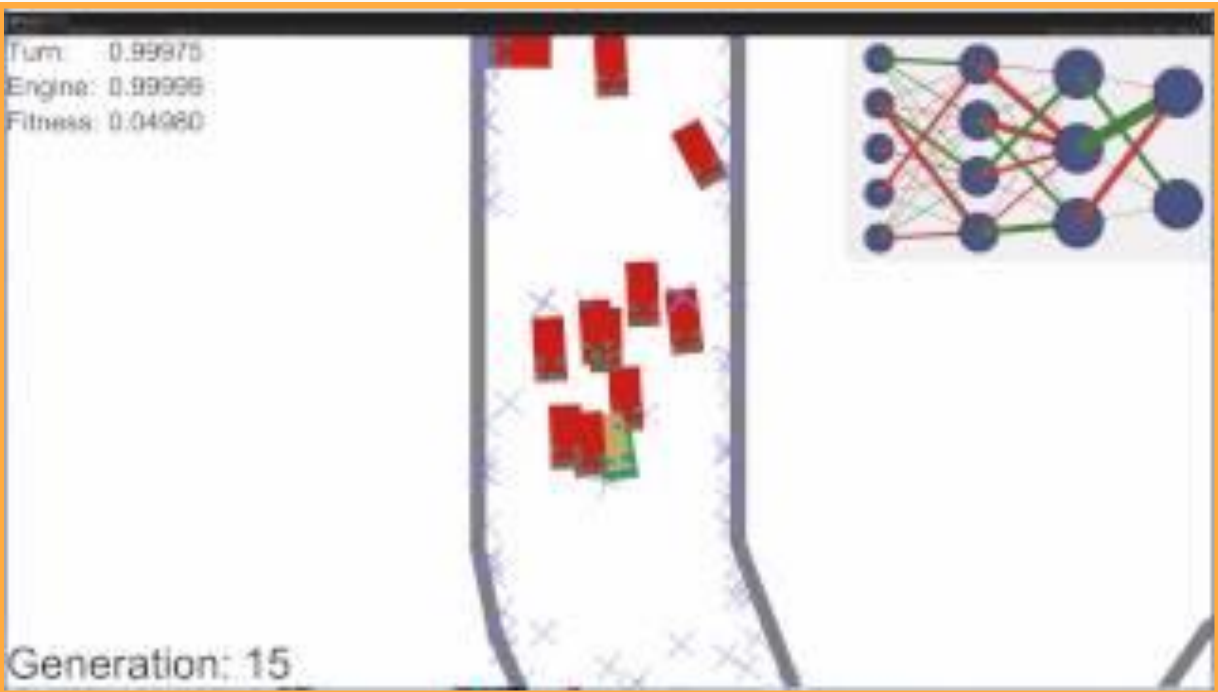


Reinforcement Learning

Train a machine learning model to generate a sequence of decisions



Reinforcement learning showcase



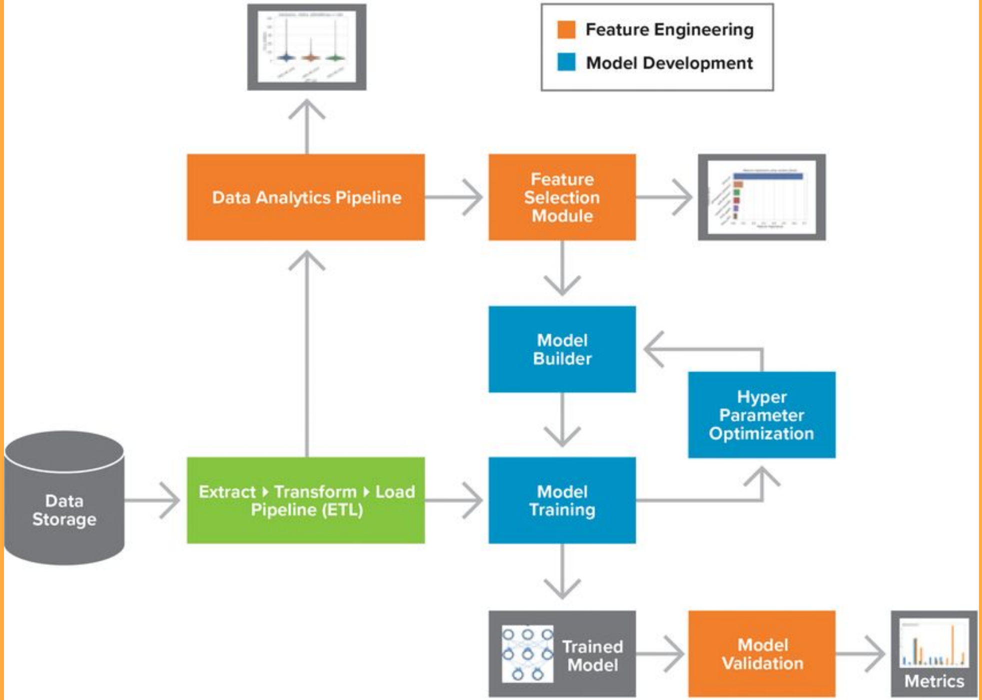
Autonomous car navigation

Environment: street model

Set of actions: 

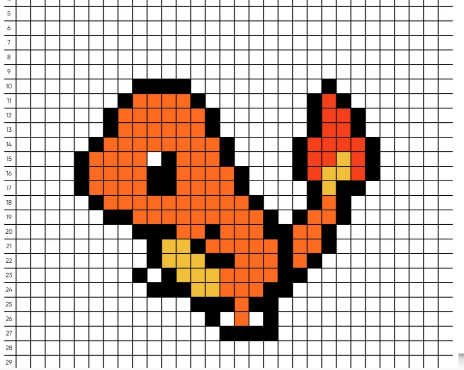
Scoring: penalty/reward

What does the ML Workflow look like?

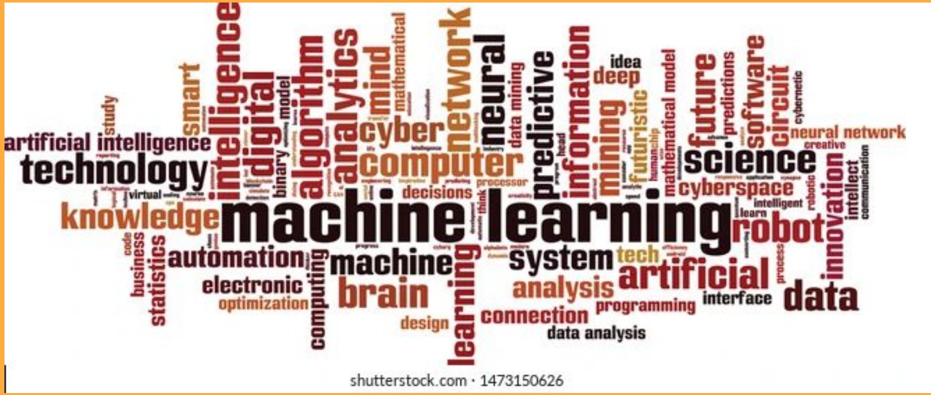


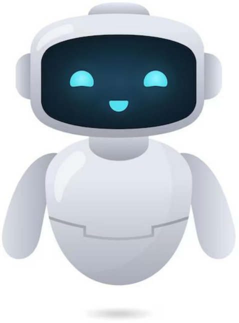
Applications

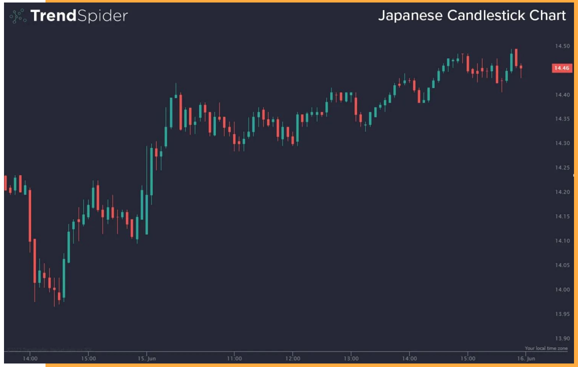
Applied AI - From Data to Decisions



- **Computer Vision:** Seeing matrix grids.
- **NLP:** Turning language into vectors.
- **Recommender Systems:** Filling in the NaNs.
- **Time Series & RL:** Predicting the future and learning from mistakes.



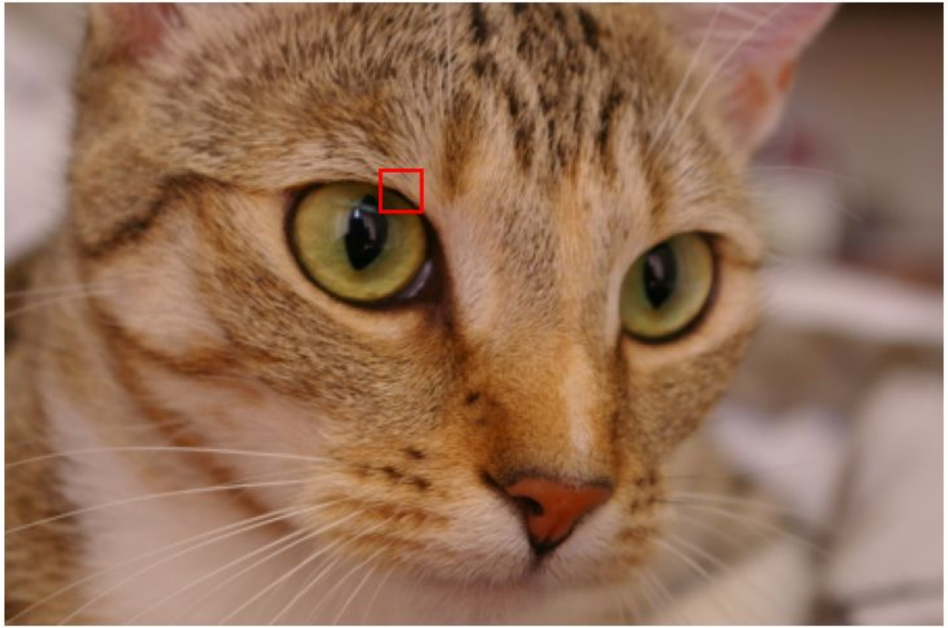




Computer Vision: The "Semantic Gap"

- **The Input:** A tensor of shape `(Height, Width, Channels)`.
  - Values: 0-255 (Intensity).
- **The Problem:** The computer sees a grid of numbers. We see a "Cat."
- **The Semantic Gap:** Small changes in the image (lighting, rotation, crop) drastically change the pixel grid, but not the *meaning*.
- **Why is this hard?**
  - Occlusion (Cat behind a sofa).
  - Illumination (Cat in the dark).
  - Deformation (Cat stretching).

Input Image (H, W, 3)



Pixel Values (Slice [80:100, 180:200])

132	129	136	139	134	124	138	145	139	122	122	105	121	138	142	155	132	130	148	147
143	137	127	137	150	144	132	133	151	123	108	126	116	117	137	137	147	128	144	150
114	138	153	153	139	143	154	146	137	144	119	98	137	124	128	130	134	143	138	146
109	121	140	147	156	145	132	133	129	115	134	111	99	140	140	130	137	144	140	137
127	113	104	107	127	145	143	130	139	130	113	131	117	109	137	132	137	141	143	135
122	110	109	106	104	109	127	137	142	145	127	127	137	125	120	145	140	146	141	134
111	119	115	114	102	104	113	128	129	136	141	132	133	142	127	131	144	143	138	130
57	69	87	99	107	98	98	110	124	128	129	132	129	137	145	137	139	142	144	141
39	38	48	69	72	87	98	93	104	128	130	127	128	125	141	146	144	141	139	147
26	22	16	19	30	41	55	67	86	98	111	117	121	127	129	144	143	144	142	141
34	32	29	21	15	13	13	18	35	66	100	109	112	117	128	136	144	138	144	141
35	35	33	31	25	25	15	9	8	19	51	97	106	102	99	126	143	144	135	142
33	33	32	34	33	35	28	21	12	9	13	38	80	100	97	97	125	138	137	134
30	30	33	33	33	37	34	32	30	19	9	12	33	66	99	102	101	119	134	138
29	31	29	30	28	35	35	33	36	34	28	14	15	37	62	99	107	110	119	132
29	26	29	31	31	32	36	36	36	38	38	34	21	13	29	52	90	103	114	119
26	29	30	30	31	32	33	38	39	41	40	40	33	22	14	17	47	78	96	114
18	28	32	33	32	30	32	40	43	45	44	42	43	38	25	15	24	50	69	96
16	23	30	34	31	30	30	36	41	45	46	44	42	47	39	26	18	23	37	65
19	22	28	35	35	34	34	37	40	45	51	47	43	48	47	42	29	16	20	37

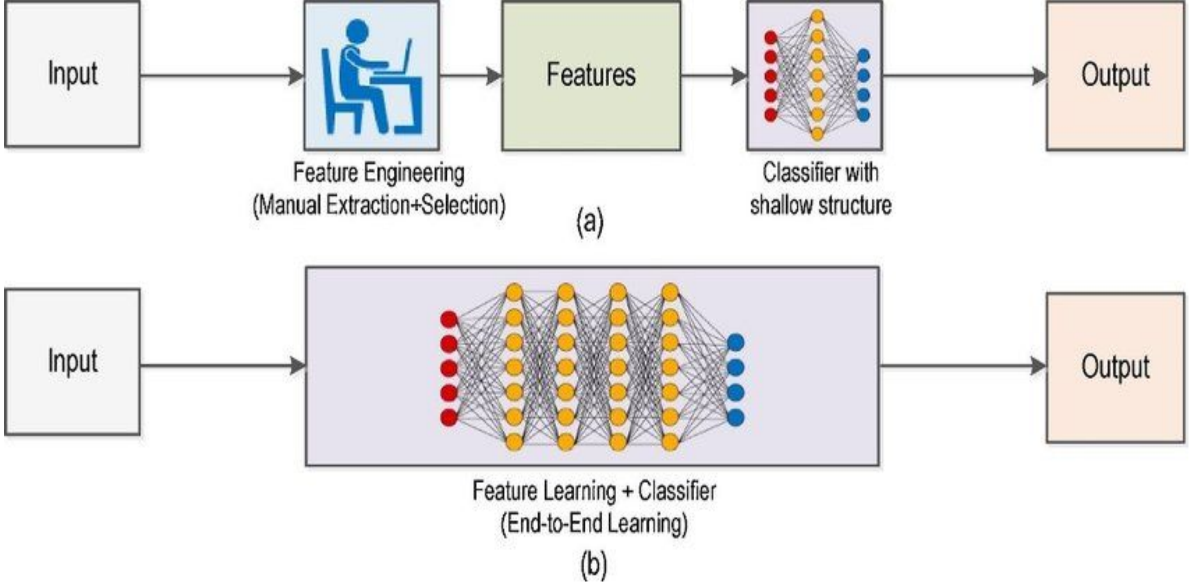
A Brief History of Vision

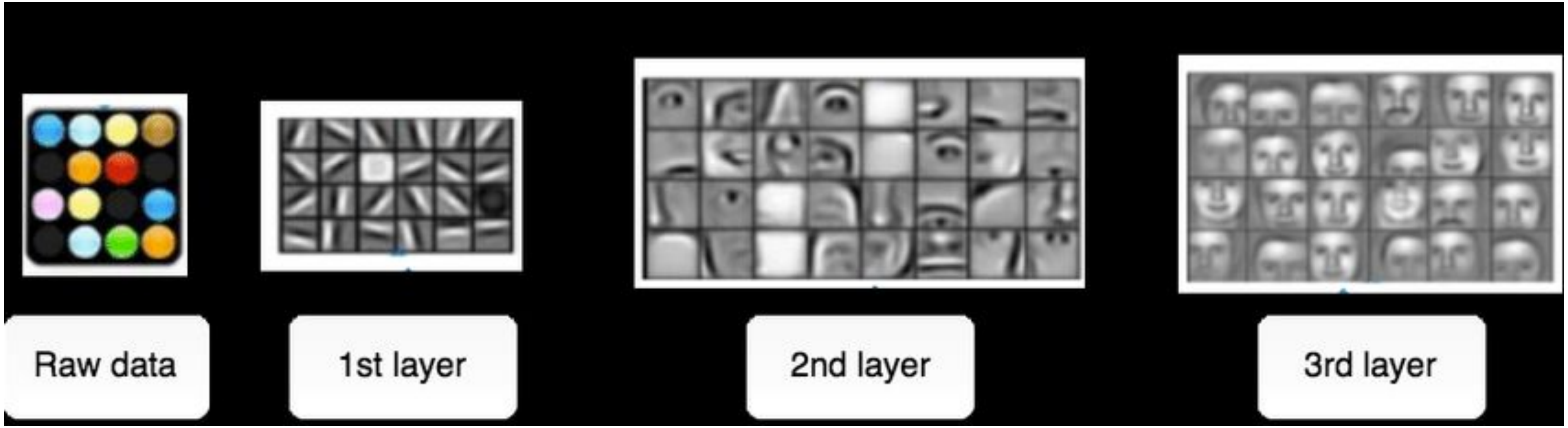
Pre-2012 (Classical CV):

- Humans wrote the features.
- Edge detection, Corner detection, Color histograms.
- *Limitation:* If you didn't code a rule for "fluffy texture," the model couldn't see it.

Post-2012 (The Deep Learning Explosion):

- **ImageNet Competition:** The turning point.
- **Convolutional Neural Networks (CNNs):** The model *learns* the features.
- Instead of coding an "edge detector," the network learns filters that find edges, then shapes, then objects.


Input
Feature Engineering
(Manual Extraction+Selection)
Features
Classifier with
shallow structure
Output
(a)
Input
Feature Learning + Classifier
(End-to-End Learning)
Output
(b)

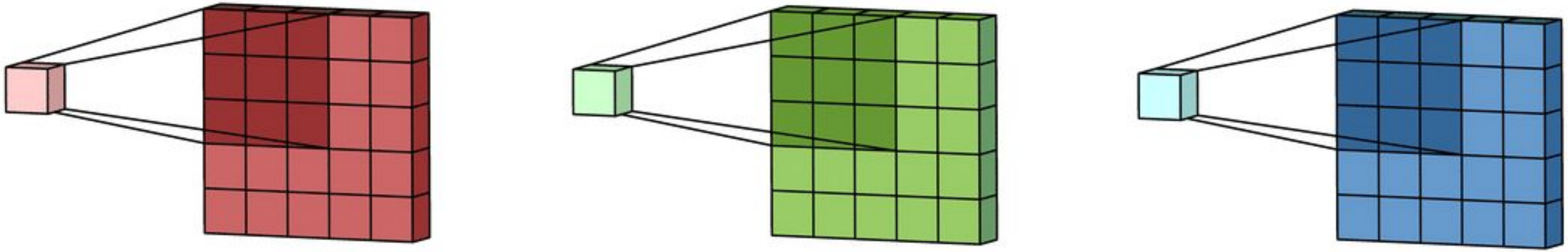

Raw data
1st layer
2nd layer
3rd layer

Deep Dive: Convolution as "Feature Matching"

The Operation: Sliding a small window (Kernel) over the image.
The Math: Element-wise multiplication and summation (Dot Product).
The Intuition:

- If the image patch matches the filter pattern -> High output number.
- If they don't match -> Low output number.

Result: A "Feature Map" that highlights where specific patterns exist in the image.



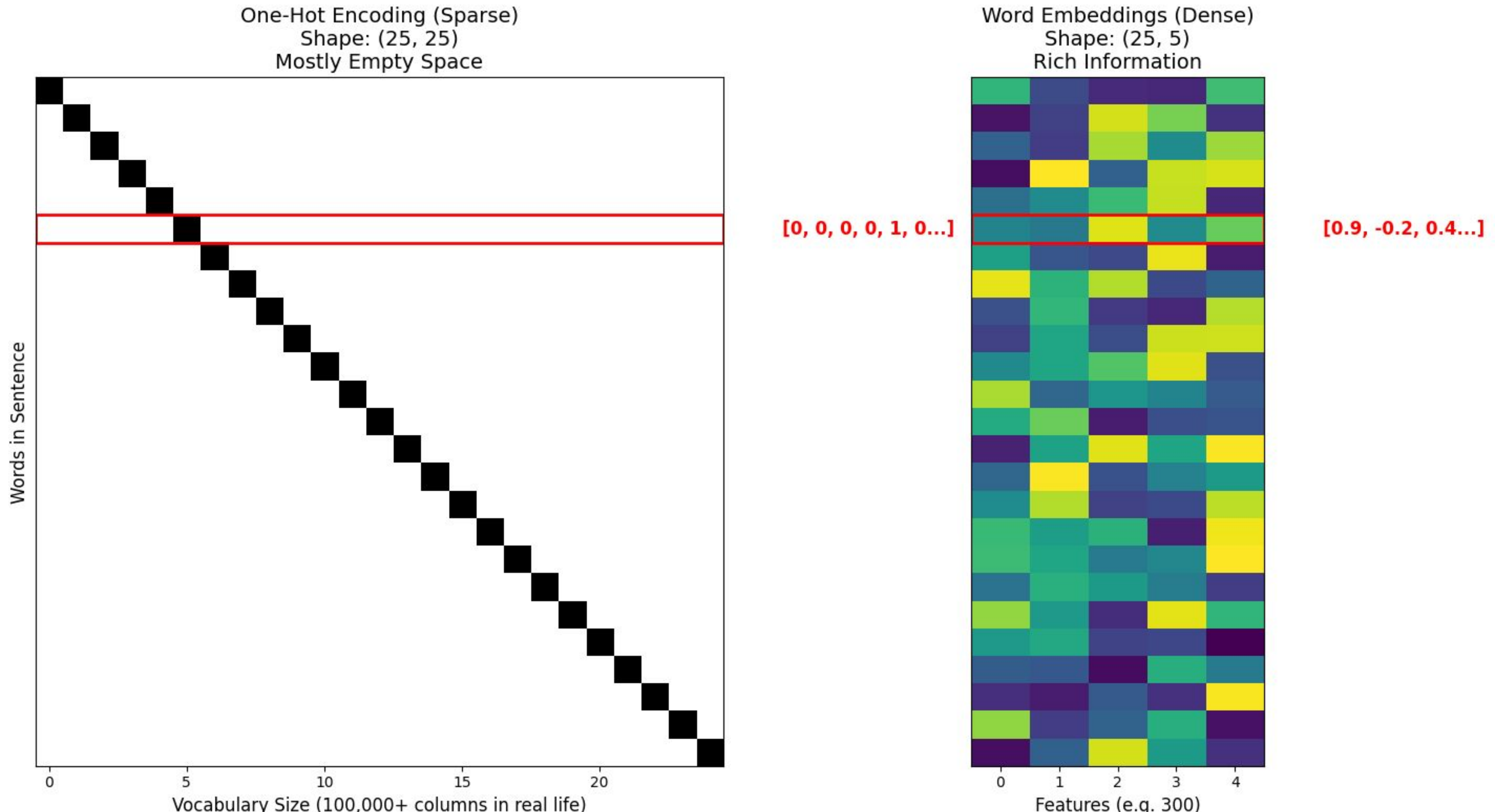
NLP: How do we calculate language?

The Challenge: Computers cannot read. They only process numbers.

Attempt 1: One-Hot Encoding

- A vector of zeros with a single `1`.
- Problem: "Huge" vector size (100,000+ words).
- Problem: No meaning. `[1, 0, 0]` (Apple) is equidistant from `[0, 1, 0]` (Pear) and `[0, 0, 1]` (Car).

The Solution: Word Embeddings (Vector Space).



One-Hot Encoding (Sparse)
Shape: (25, 25)
Mostly Empty Space
Words in Sentence
0
5
10
15
20
Vocabulary Size (100,000+ columns in real life)
[0, 0, 0, 0, 1, 0...]
Word Embeddings (Dense)
Shape: (25, 5)
Rich Information
0
1
2
3
4
Features (e.g. 300)
[0.9, -0.2, 0.4...]

Word Embeddings (Word2Vec)

The Concept: "A word is defined by the company it keeps."
The Data Structure: Dense vectors (e.g., length 300) representing semantic meaning.
The Magic (Vector Arithmetic):

- King - Man + Woman ≈ Queen
- Paris - France + Italy ≈ Rome

Visualization: Plotting words in 2D space shows that similar words cluster together (e.g., all fruits in one corner, all verbs in another). Demo.

Recommender Systems: The "Netflix" Problem

- **The Data:** Users vs. Items Matrix.
  - Rows = Users.
  - Columns = Movies.
  - Values = Ratings (1-5).
- **The Issue:** Sparsity.
  - Most users haven't watched most movies.
  - The matrix is 99% NaN (Missing Data).
- **The Goal:** Accurately predict the value of the NaN cells.

Collaborative Filtering: Predicting the Missing Value

	Star Wars	Titanic	Shrek	The Matrix	Godfather
User A	?	3	5	NaN	NaN
User B	5	NaN	1	NaN	5
User C	NaN	4	NaN	5	NaN
User D	4	NaN	NaN	5	4
User E	NaN	5	NaN	NaN	5

Scale: Why Netflix Logic fails on Instagram Reels

The Problem:

- **Volume:** Billions of items. The matrix is too big.
- **Velocity:** Content is "alive" for only 24 hours. We cannot re-train the model every minute.

The Solution: The Recommender Funnel

- **Step 1: Retrieval (Candidate Generation)**
  - *Fast & Cheap.*
  - "User liked 'Cats', so grab all 'Cat' videos uploaded in the last hour."
  - Input: 1 Billion videos -> Output: 500 Candidates.
- **Step 2: Ranking (The Heavy ML)**
  - *Slow & Precise.*
  - A Neural Network predicts: "Probability user watches > 3 seconds."
  - Input: 500 Candidates -> Output: Top 5 on your screen.

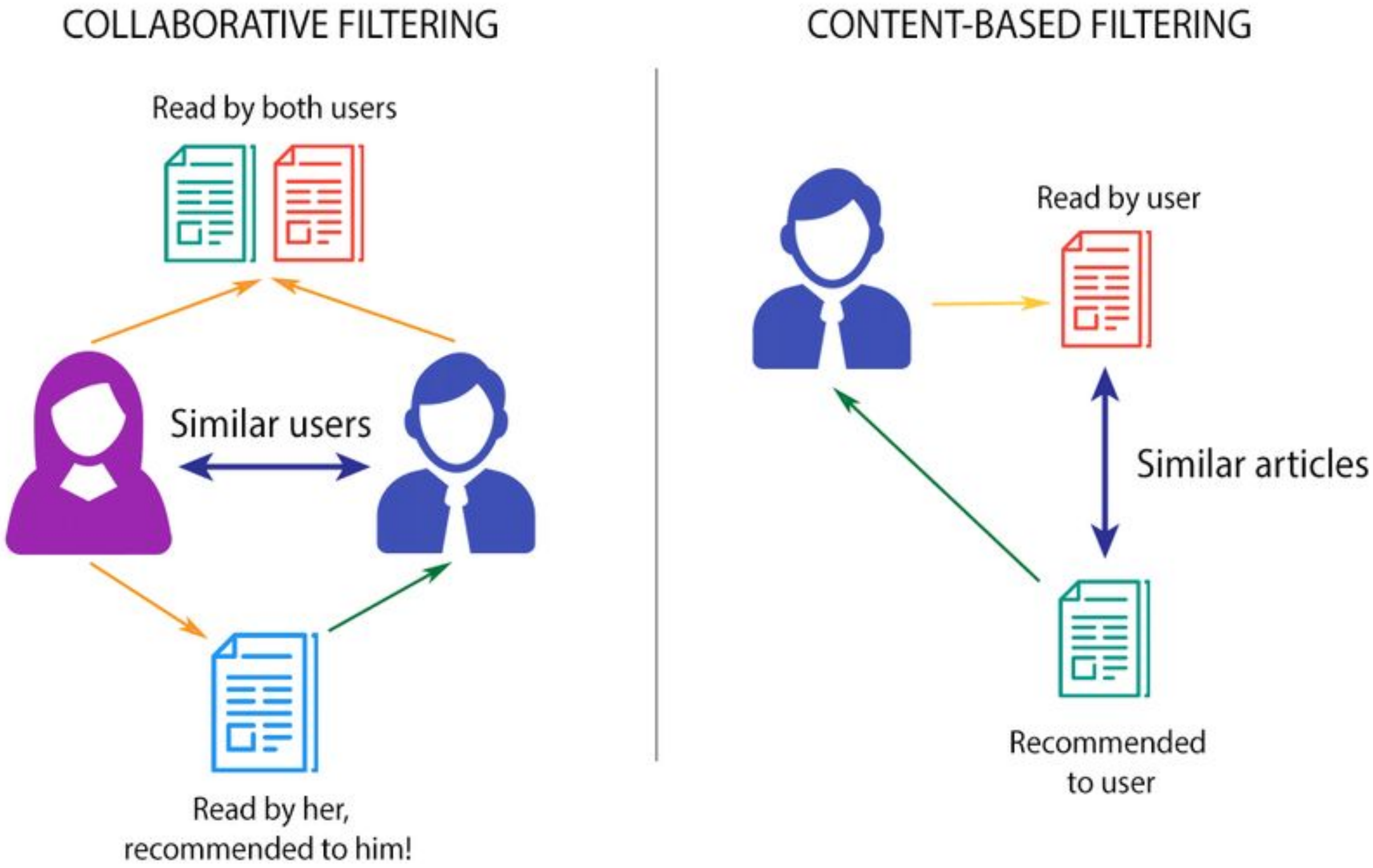
Filtering Strategies

Content-Based Filtering:

- "You liked 'Iron Man'? Here is 'Captain America'."
- Based on item metadata (Genre, Actor, Director).

Collaborative Filtering:

- "Users like you also liked..."
- Based on user behavior patterns, ignoring the content of the movie itself.
- *Mathematical Intuition:* Finding similar rows (Users) or similar columns (Items) in the matrix.


COLLABORATIVE FILTERING
Read by both users
Similar users
Read by her,
recommended to him!
CONTENT-BASED FILTERING
Read by user
Similar articles
Recommended
to user

Time Series Forecasting

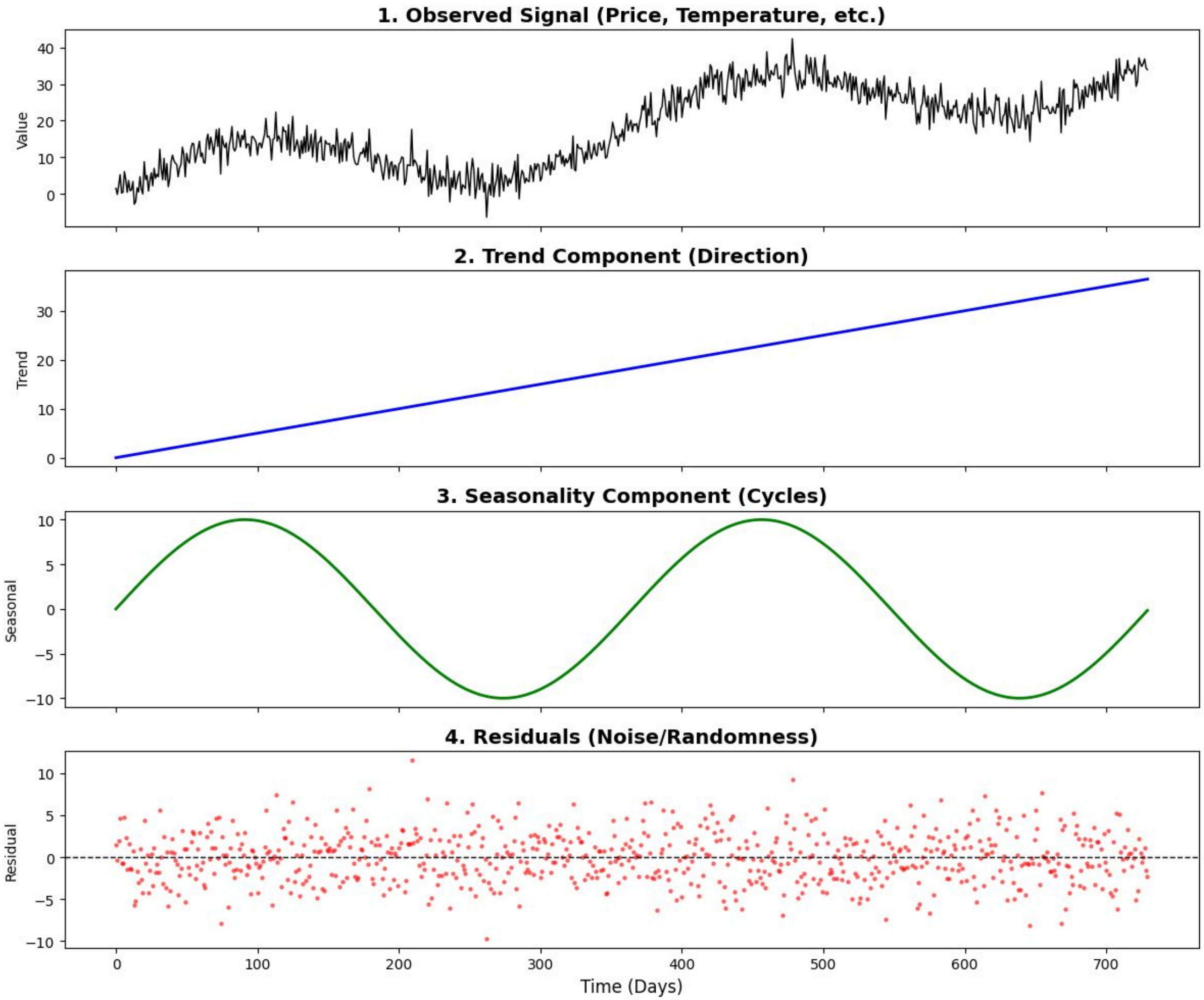
The Key Difference: Data is not independent (i.i.d.).

- The value at t is highly dependent on t-1.
- You cannot shuffle the rows of your DataFrame!

Components:

- **Trend:** Long-term direction (Stock going up).
- **Seasonality:** Repeating patterns (Ice cream sales in July).
- **Noise:** Random variation.

Applications: Stock prices, Weather, Inventory demand, Heart rate monitoring.


1. Observed Signal (Price, Temperature, etc.)
Value
40
30
20
10
0
2. Trend Component (Direction)
Trend
30
20
10
0
3. Seasonality Component (Cycles)
Seasonal
10
5
0
−5
−10
4. Residuals (Noise/Randomness)
Residual
10
5
0
−5
−10
0
100
200
300
400
500
600
700
Time (Days)

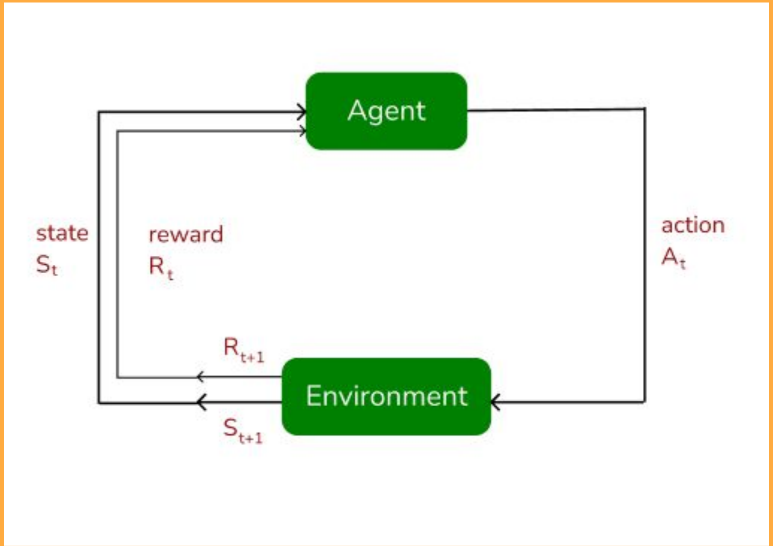
Reinforcement Learning (RL)

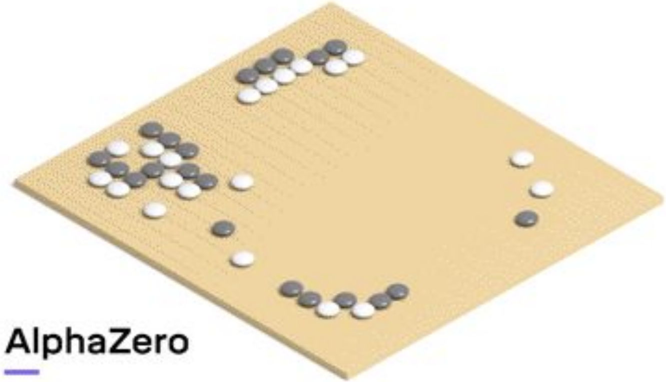
A Different Beast: No labeled dataset.

The Loop:

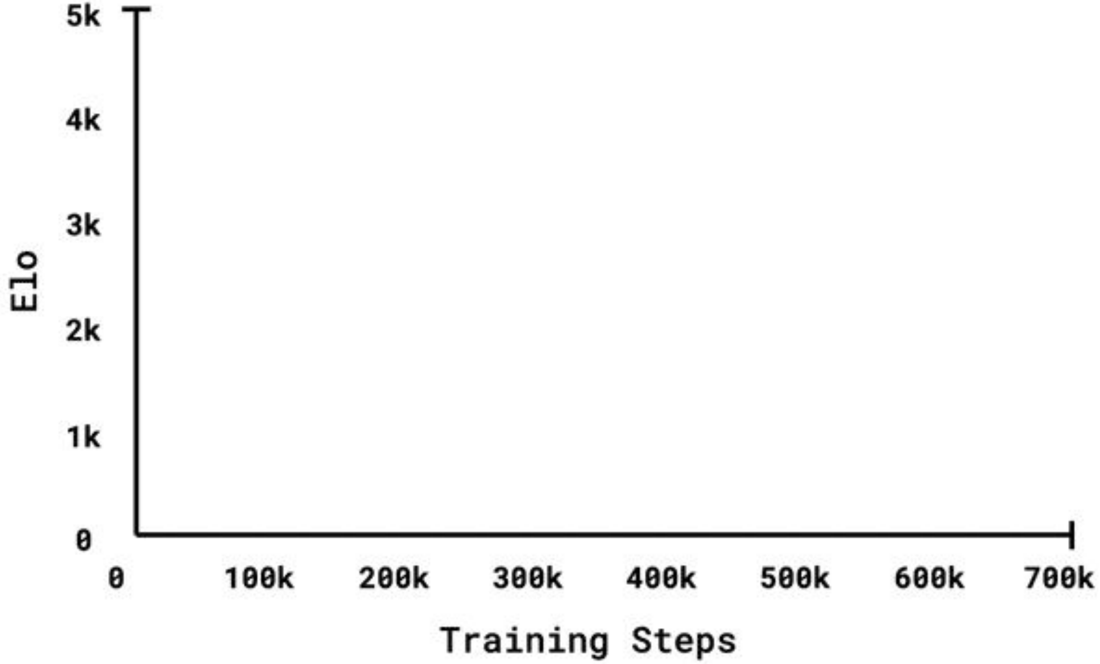
- **Agent:** The learner (e.g., Mario).
- **Environment:** The world (e.g., The Level).
- **Action:** What the agent does (Jump, Run).
- **Reward:** Feedback (+100 for coin, -100 for death).

The Goal: Maximize *cumulative* reward over time.
Example: AlphaGo, Self-Driving Cars, Robotics.





AlphaZero



5k
4k
3k
2k
1k
0
Elo
0
100k
200k
300k
400k
500k
600k
700k
Training Steps

Resources

- The Elements of Statistical Learning
- Pattern Recognition and Machine Learning

Thank you.