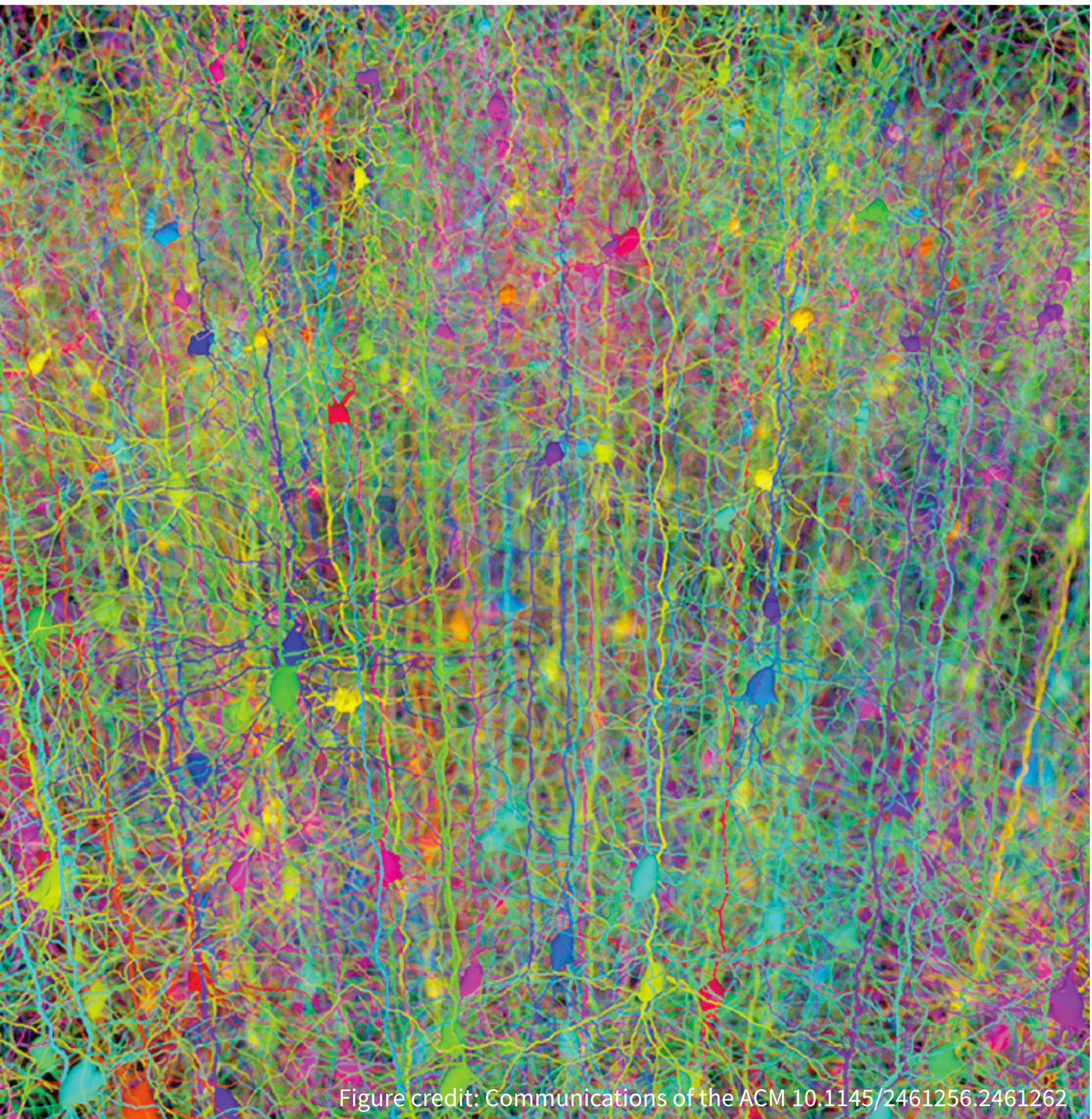


Introduction to Machine Learning

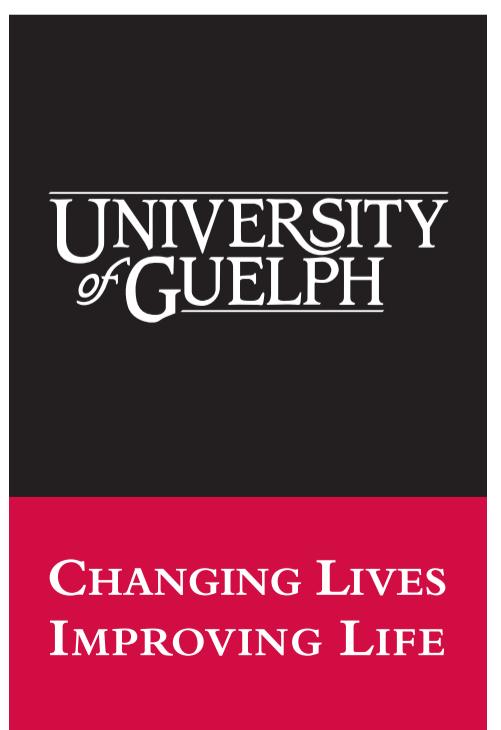


GRAHAM TAYLOR

VECTOR INSTITUTE

SCHOOL OF ENGINEERING
UNIVERSITY OF GUELPH

CANADIAN INSTITUTE
FOR ADVANCED RESEARCH

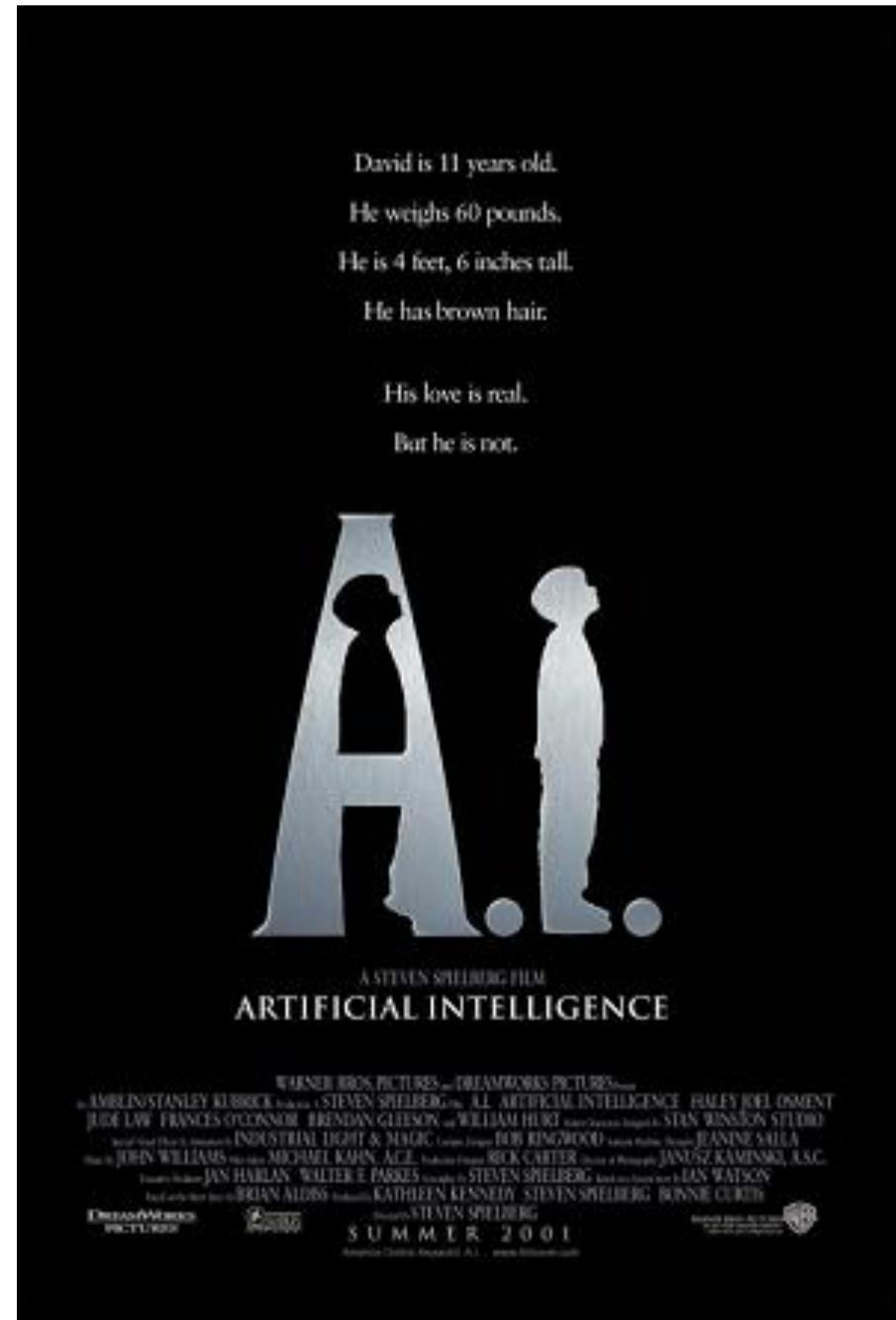


CIFAR
CANADIAN
INSTITUTE
FOR
ADVANCED
RESEARCH

What is Artificial Intelligence?

What is Artificial Intelligence?

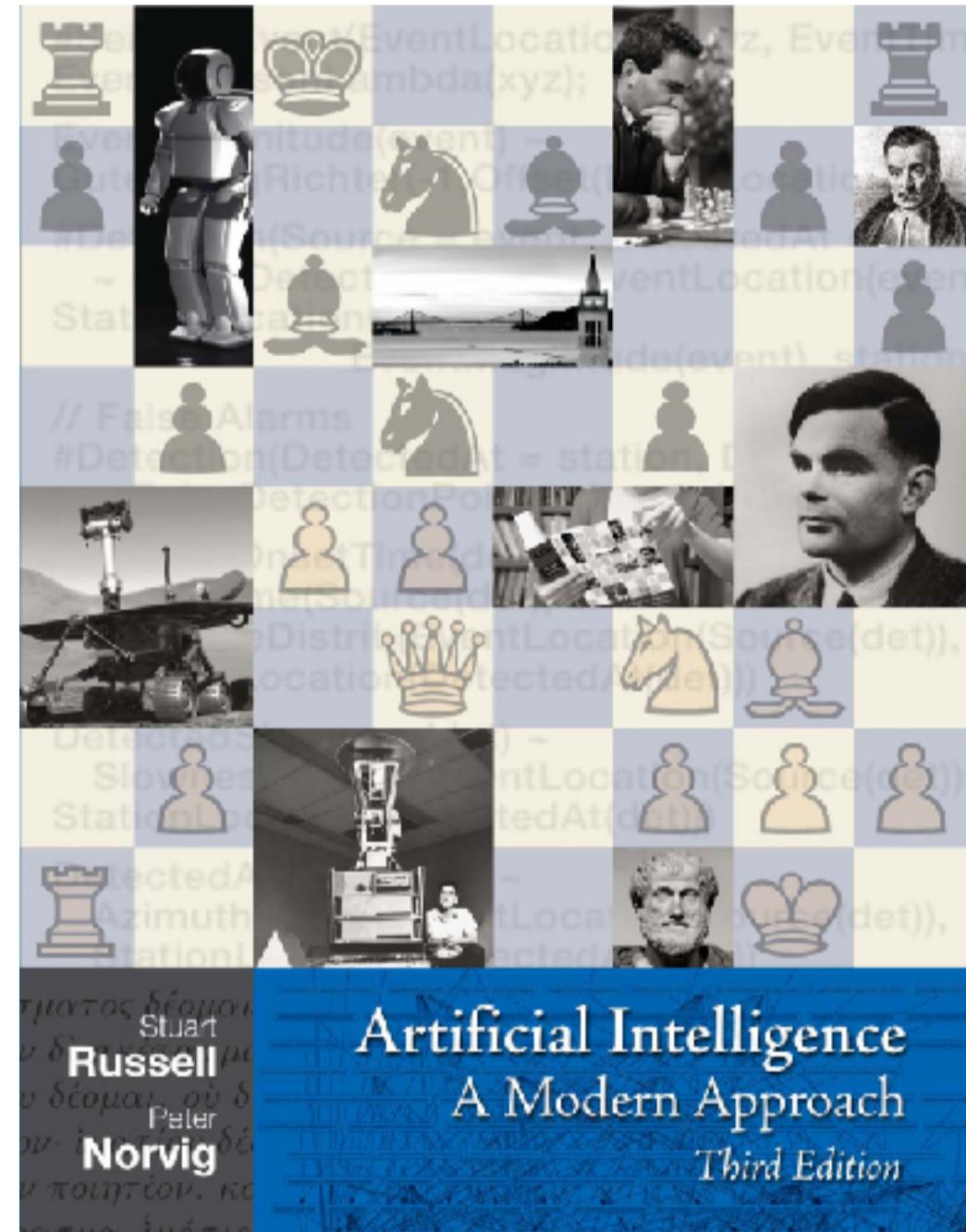
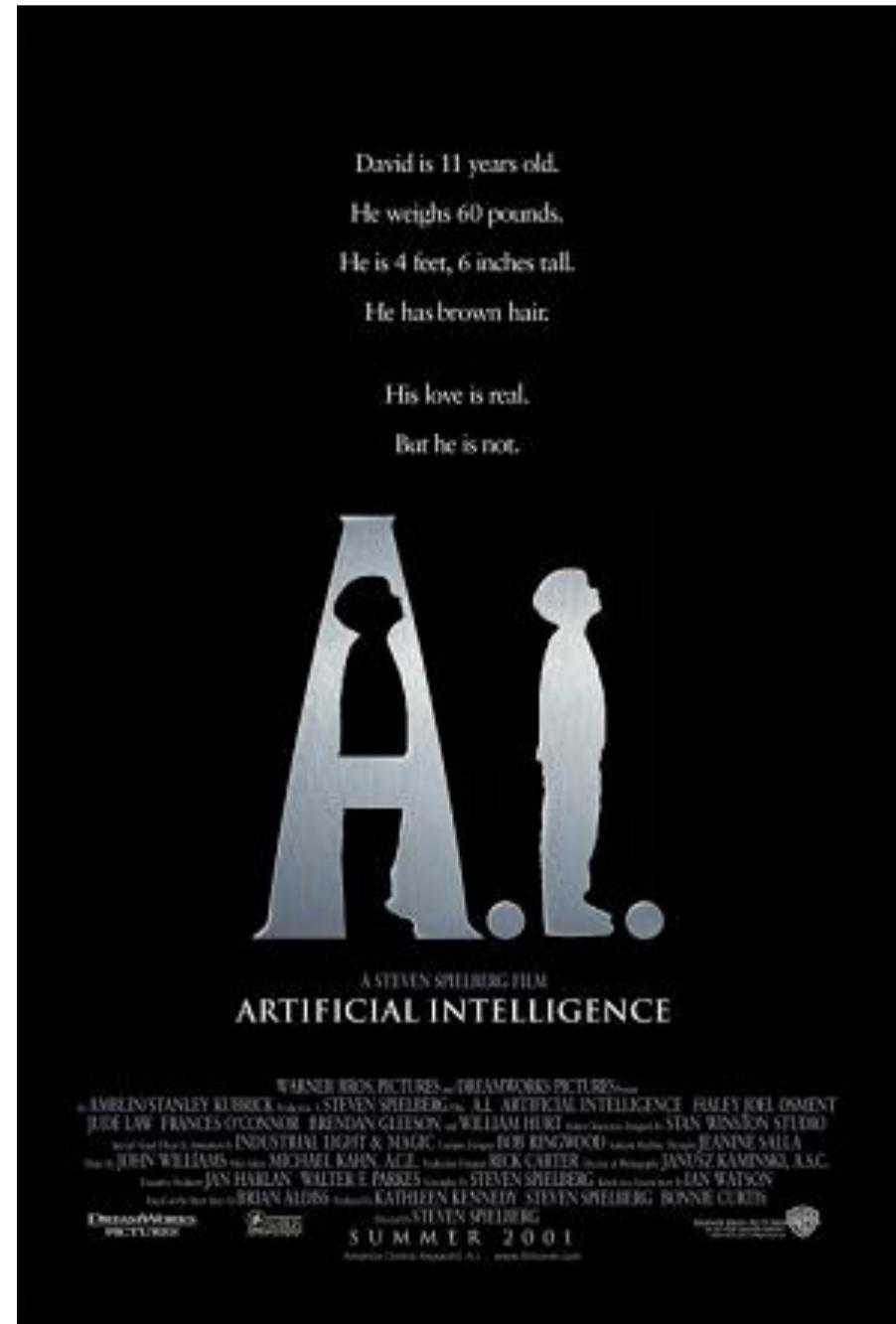
An Ideal



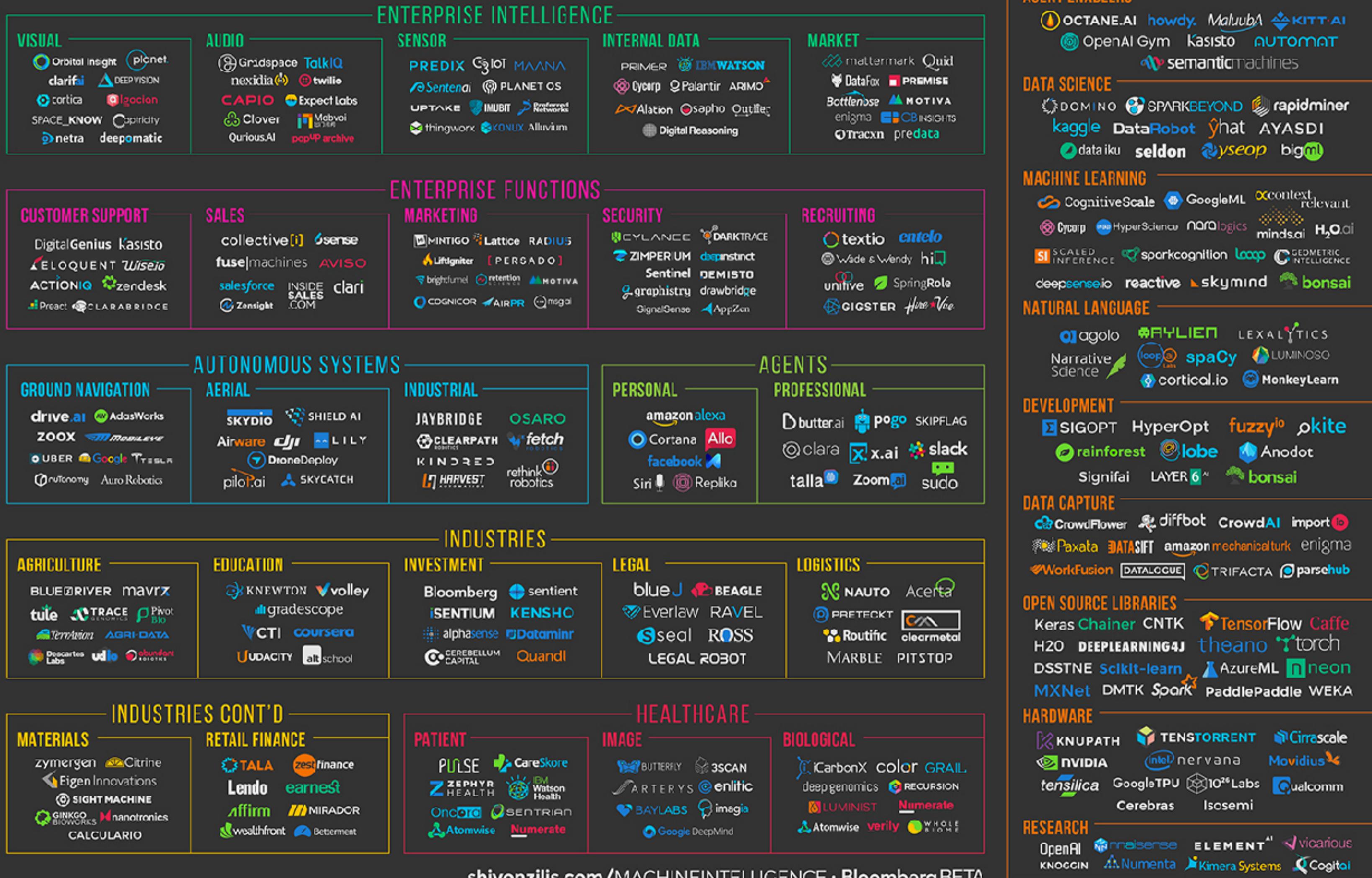
What is Artificial Intelligence?

An Ideal

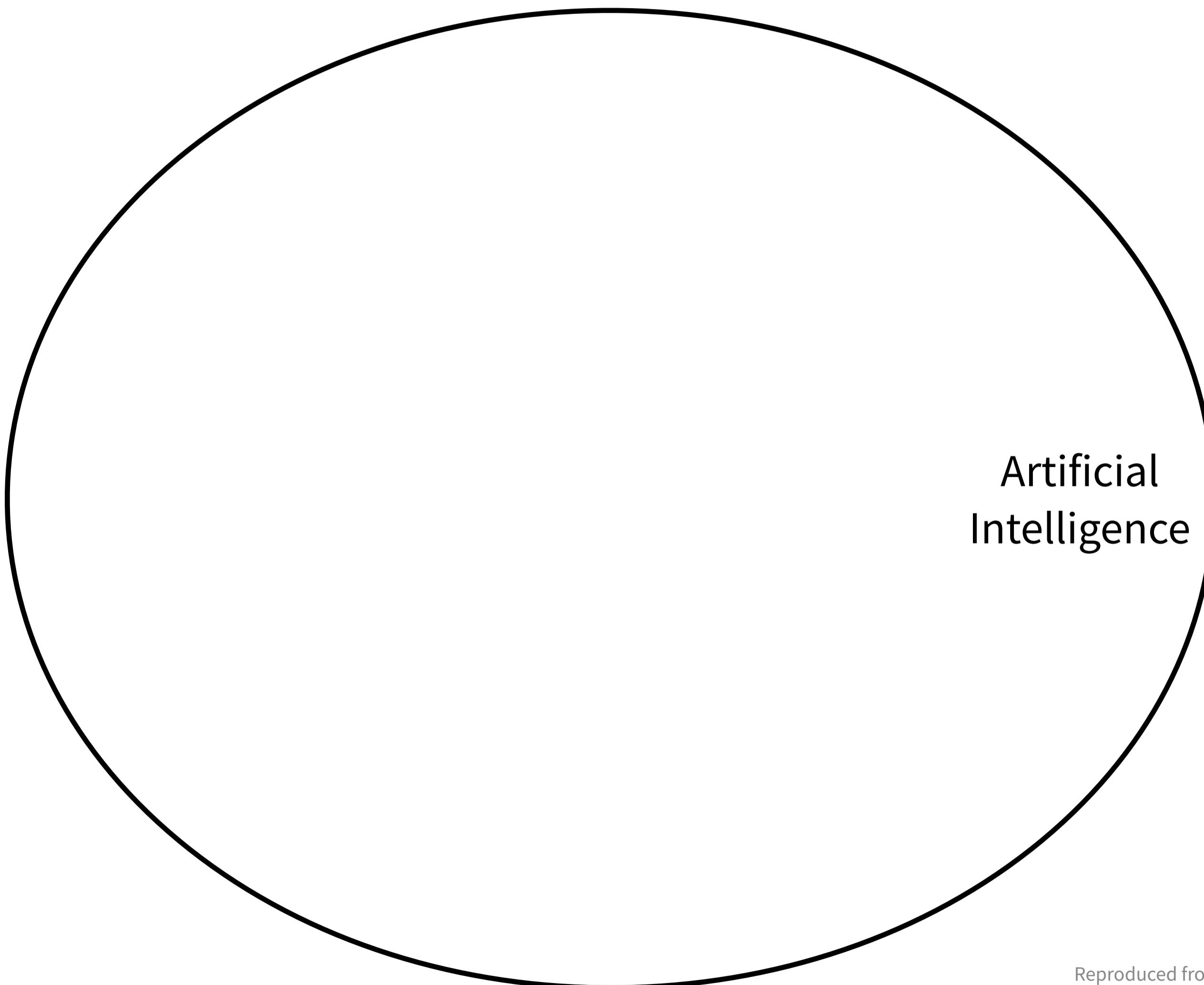
A Scientific Discipline/
Class of Technology



MACHINE INTELLIGENCE 3.0



Relationship to Other Disciplines



Relationship to Other Disciplines

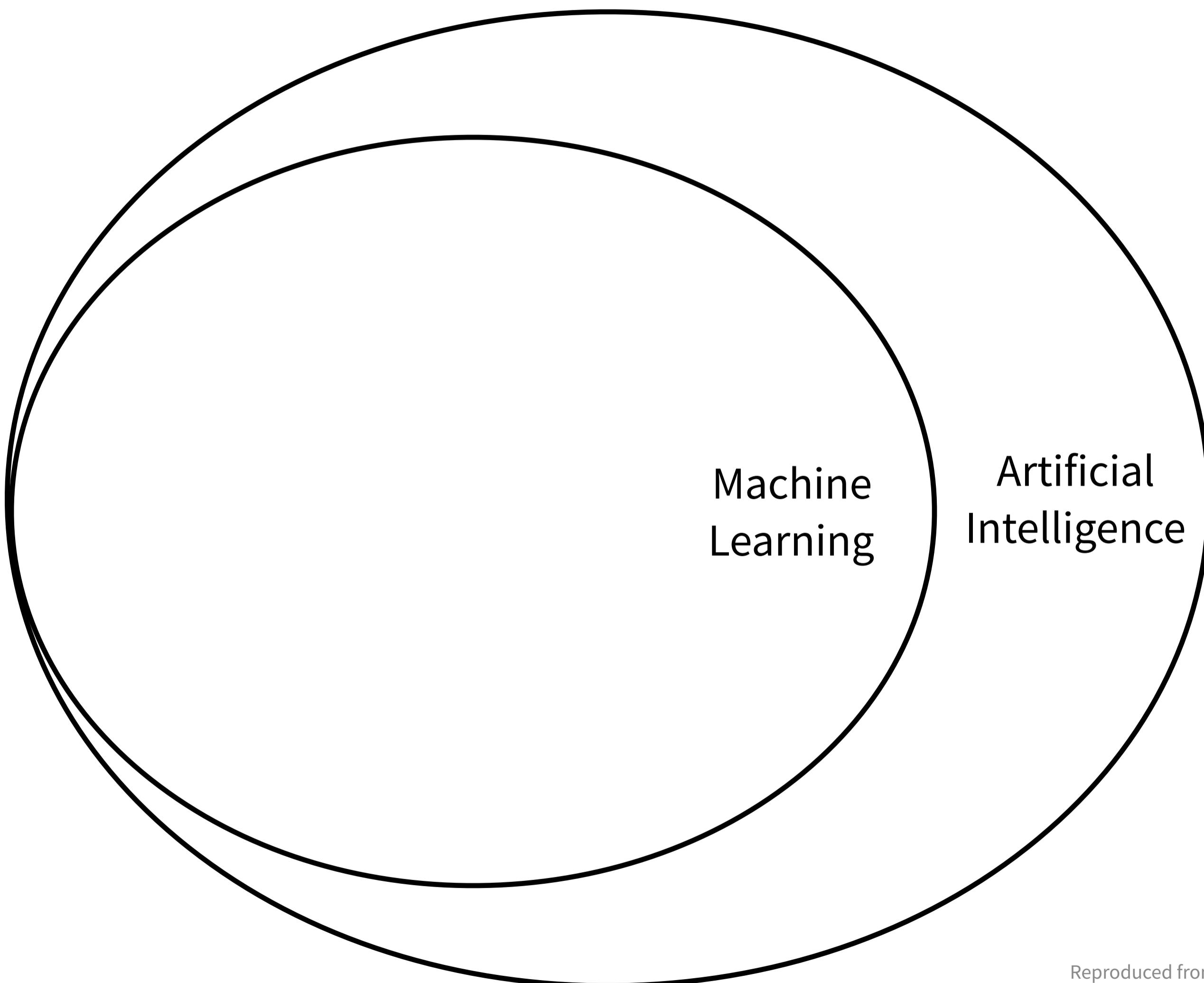




Image credit: Google

What is Machine Learning?

What is Machine Learning?

- There are many tasks that computers can do much more efficiently than humans
 - e.g. computing π to high precision, sorting a huge list



What is Machine Learning?

- There are many tasks that **computers** can do much more efficiently than humans
 - e.g. computing π to high precision, sorting a huge list
- There are tasks which come **very naturally to humans** but are very challenging to automate
 - e.g. recognizing a face or a song, understanding speech



What is Machine Learning?

Machine learning is about enabling computers to do these tasks, not by programming them with rules, but by learning from data.

Basic ML Framework

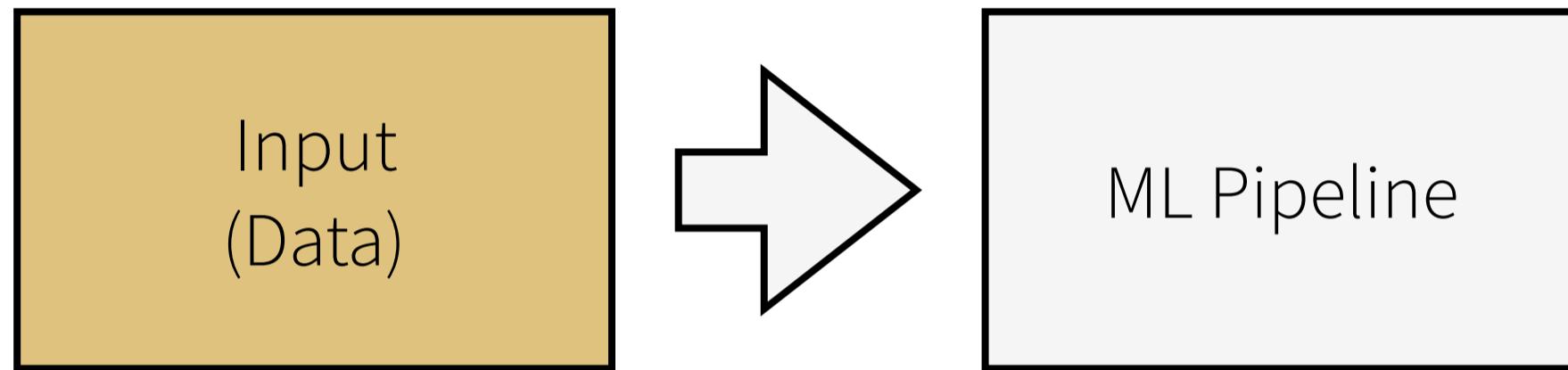
Basic ML Framework

Input
(Data)

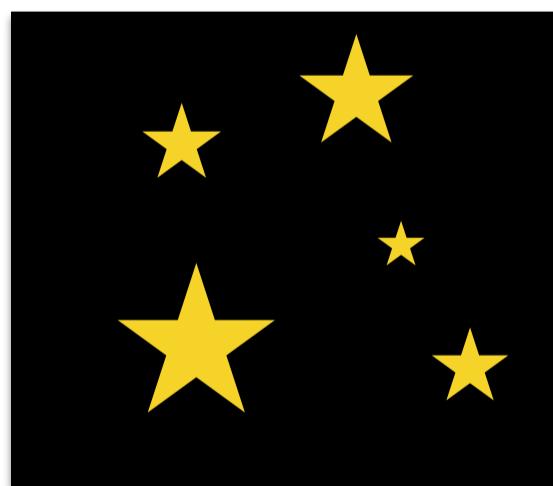


e.g. Image

Basic ML Framework



e.g. Image

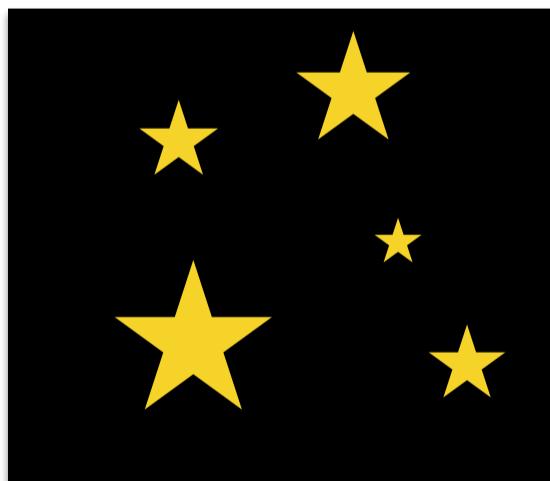


e.g. Feature Extraction
+ Support Vector Machine

Basic ML Framework



e.g. Image



e.g. Feature Extraction
+ Support Vector Machine



Detection
(Specified by labeled bounding box)

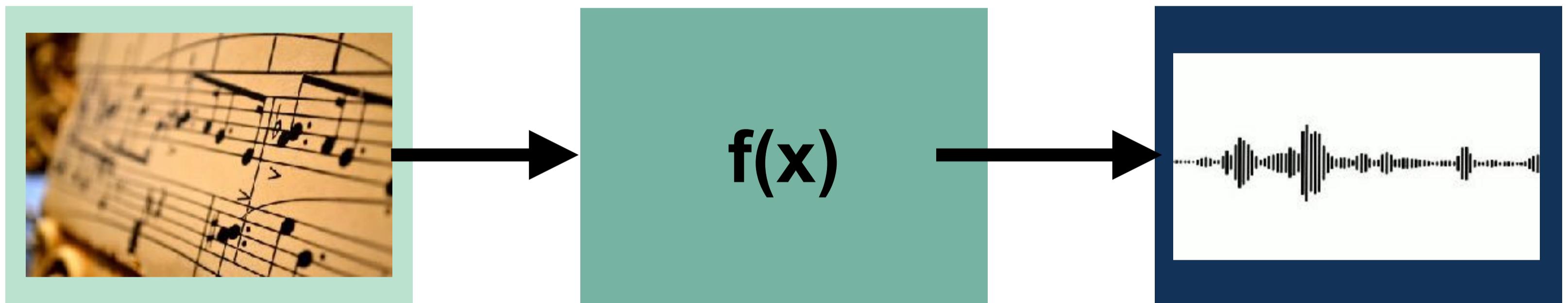
```
def square(x):  
    return x * x
```

square(1) = 1

square(2) = 4

square(3) = 9

...



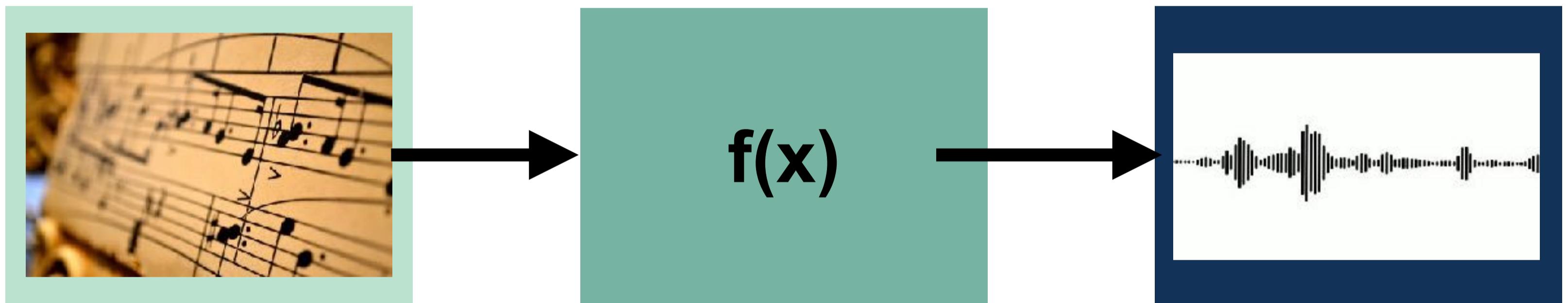


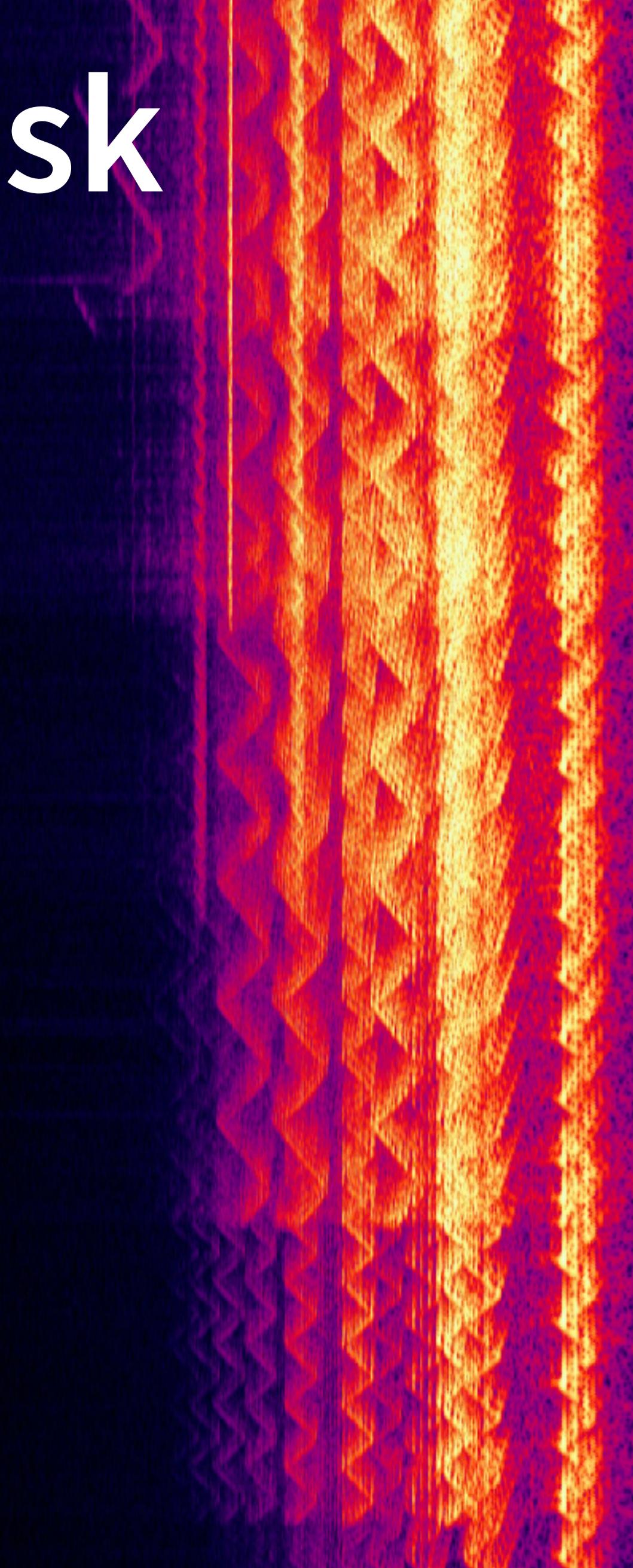


Image credit: Bloomberg

Task, Performance, Experience

- Originally formulated by Mitchell (1997)
- Expanded by Goodfellow et al. (2016)

1. The Task



Tasks as processing examples



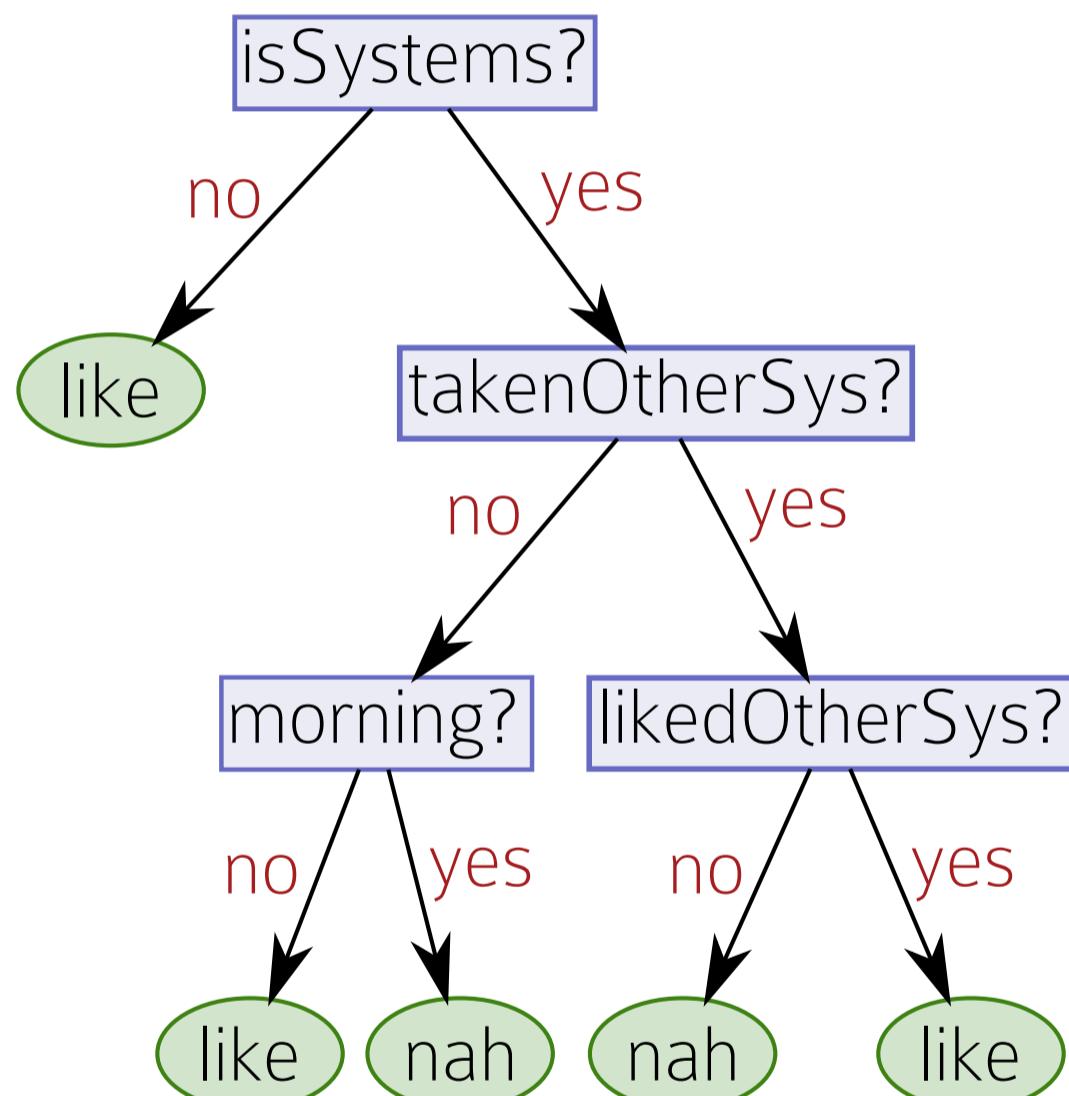
Examples/Dataset

Rating	Easy?	AI?	Sys?	Thy?	Morning?
2	y	y	n	y	n
2	y	y	n	y	n
2	n	y	n	n	n
2	n	n	n	y	n
2	n	y	y	n	y
1	y	y	n	n	n
1	y	y	n	y	n
1	n	y	n	y	n
0	n	n	n	n	y
0	y	n	n	y	y
0	n	y	n	y	n
0	y	y	y	y	y
-1	y	y	y	n	y
-1	n	n	y	y	n
-1	n	n	y	n	y
-1	y	n	y	n	y
-2	n	n	y	y	n
-2	n	y	y	n	y
-2	y	n	y	n	n
-2	y	n	y	n	y

Examples/Dataset

Rating	Easy?	AI?	Sys?	Thy?	Morning?
2	y	y	n	y	n
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2	n	n	n	y	n
2	n	y	y	n	y
1	y	y	n	n	n
1	y	y	n	y	n
1	n	y	n	y	n
0	n	n	n	n	y
0	y	n	n	y	y
0	n	y	n	y	n
0	y	y	y	y	y
-1	y	y	y	n	y
-1	n	n	y	y	n
-1	n	n	y	n	y
-1	y	n	y	n	y
-2	n	n	y	y	n
-2	n	y	y	n	y
-2	y	n	y	n	n
-2	y	n	y	n	y

Examples/Dataset



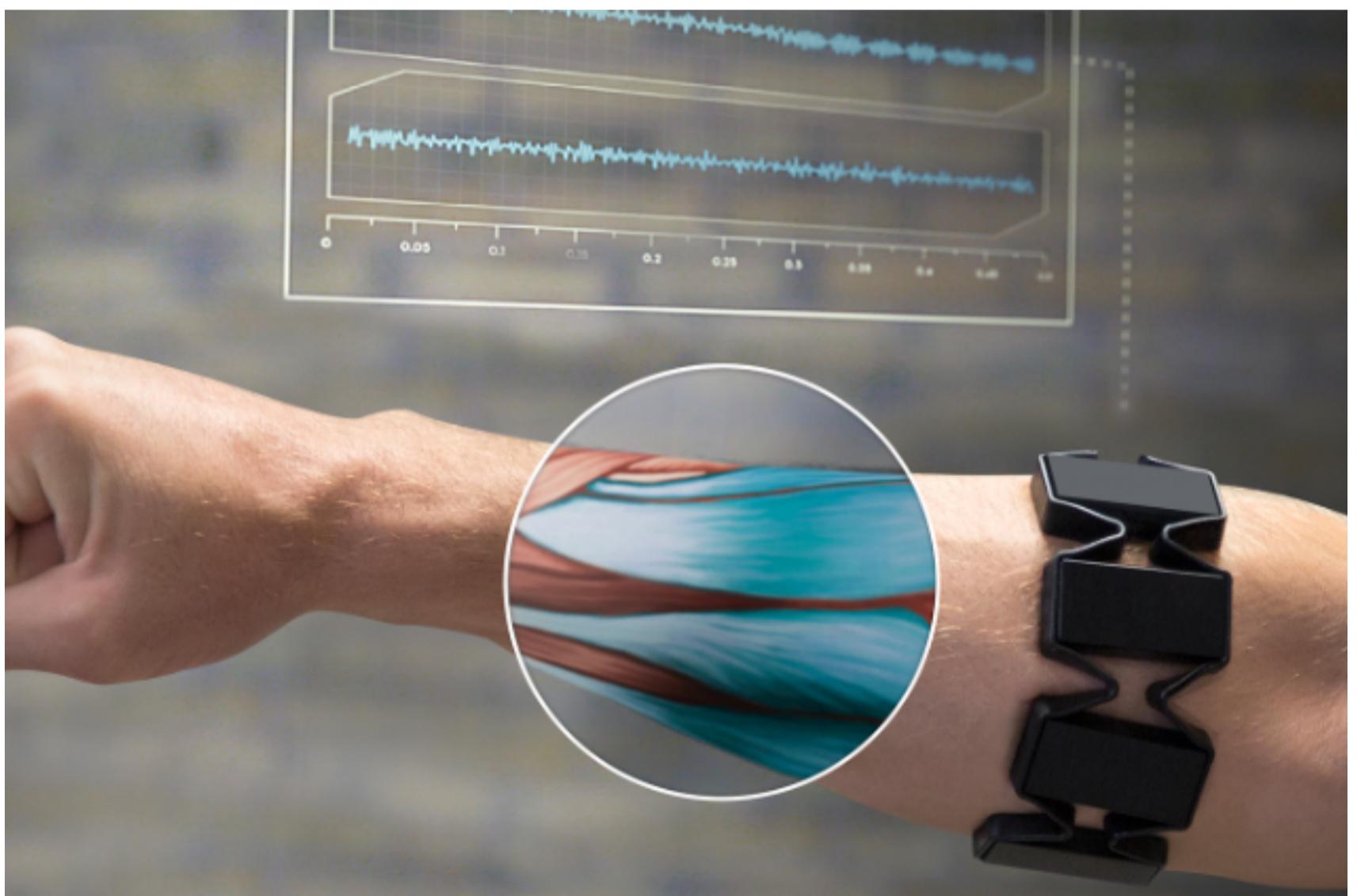
Rating	Easy?	AI?	Sys?	Thy?	Morning?
2	y	y	n	y	n
2	y	y	n	y	n
2	n	y	n	n	n
2	n	n	n	y	n
2	n	y	y	n	y
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1	n	y	n	y	n
0	n	n	n	n	y
0	y	n	n	y	y
0	n	y	n	y	n
0	y	y	y	y	y
<hr/>					
-1	y	y	y	n	y
-1	n	n	y	y	n
-1	n	n	y	n	y
-1	y	n	y	n	y
-2	n	n	y	y	n
-2	n	y	y	n	y
-2	y	n	y	n	n
-2	y	n	y	n	y

Classification

Assignment of inputs to one or more known categories.

Examples:

- Object recognition
- Scene labeling
- Medical diagnosis
- Ad click-through prediction
- Text blocks in documents
- Spam filtering
- Gesture recognition

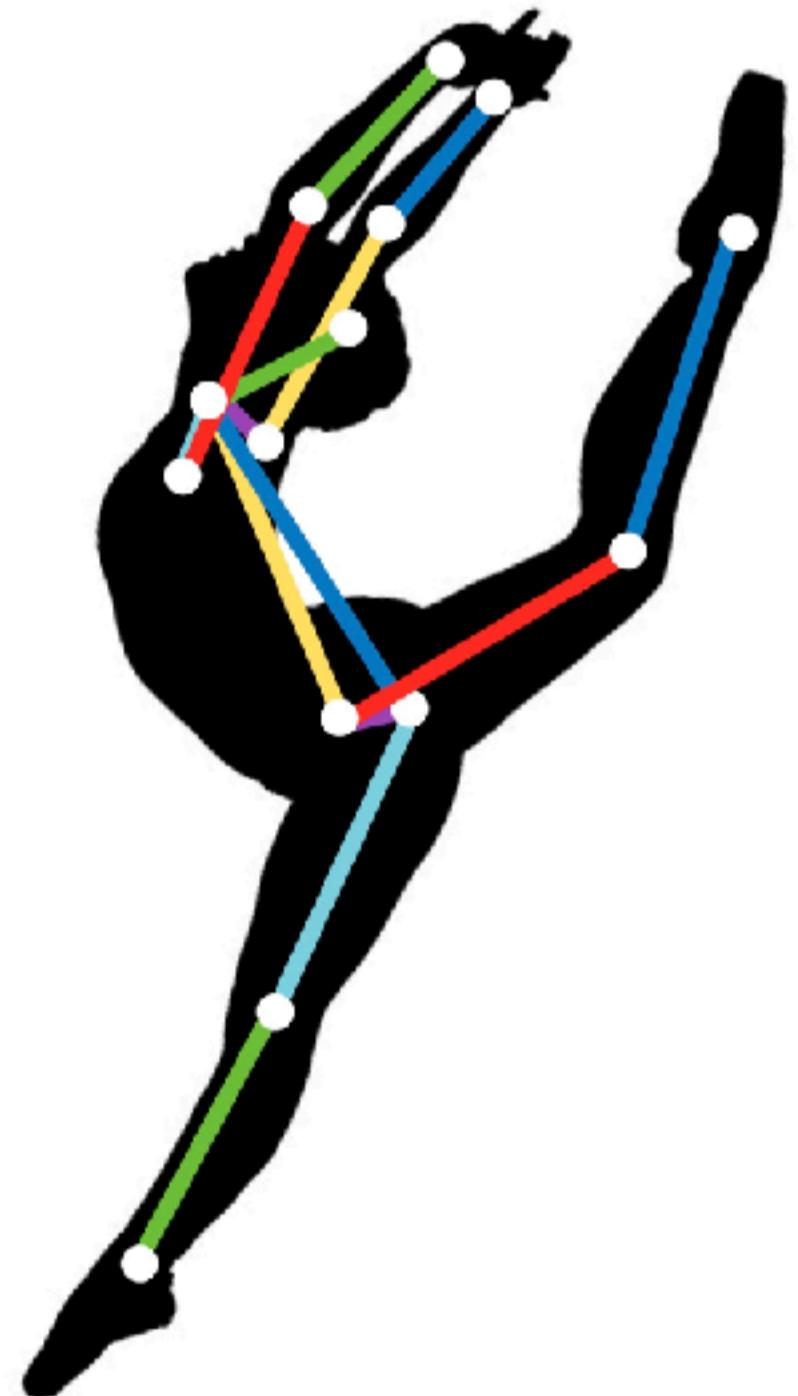
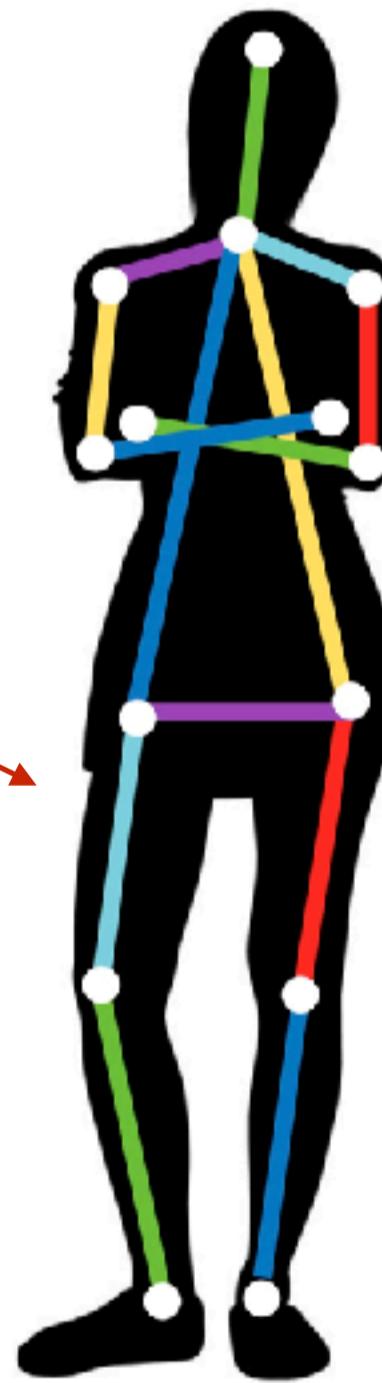
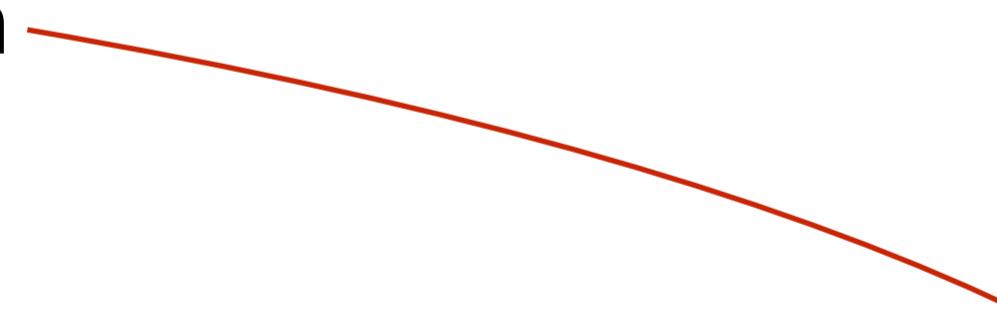


Regression

Prediction of one or more real-valued quantities.

Examples:

- Sentiment analysis
- Plant or soil health from aerial imagery
- Forecasting (e.g. weather, financial)
- Pose estimation



Transcription

Observe an unstructured representation and convert into a discrete textual form.

Examples:

- Speech recognition
- Optical character recognition
- Google Street View address numbers



[379] [61] [972] [101]

[26624] [98] [66] [175]

[2] [2503] [205] [100]

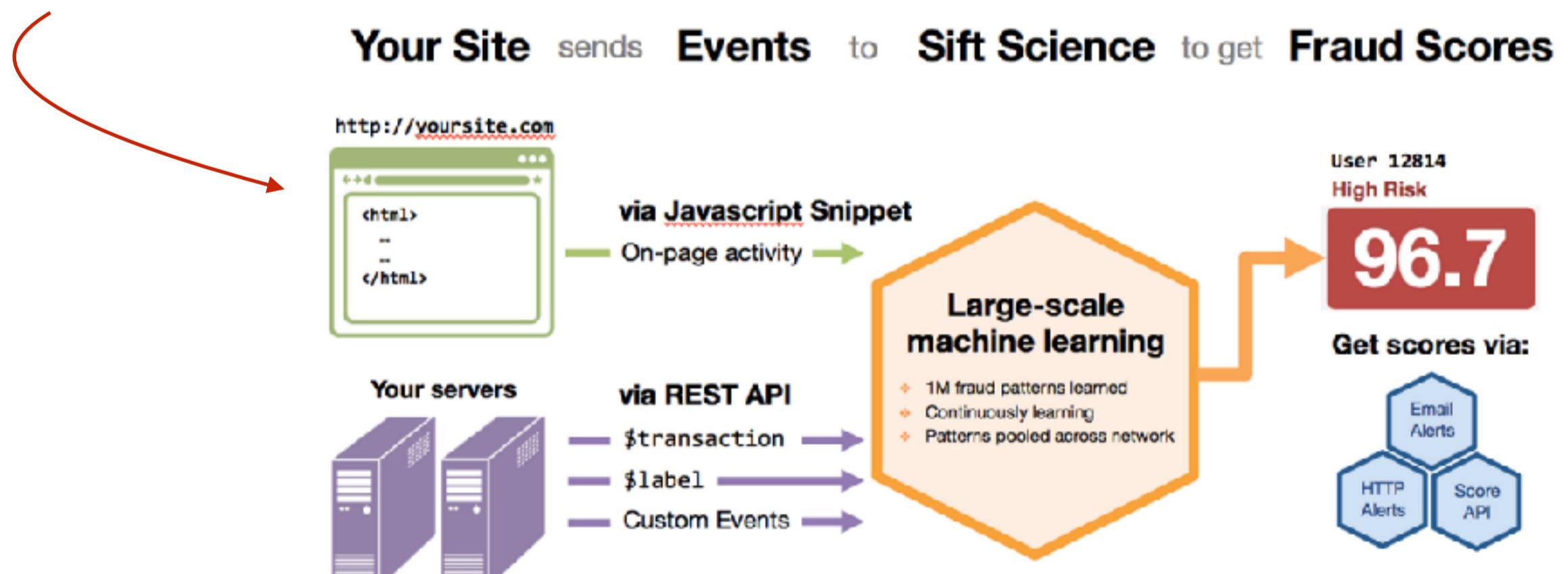


Anomaly detection

Sift through a set of events or objects and flag some as unusual or atypical.

Examples:

- Manufacturing process inspection
- Cybersecurity (e.g. network attacks)
- Credit card fraud detection

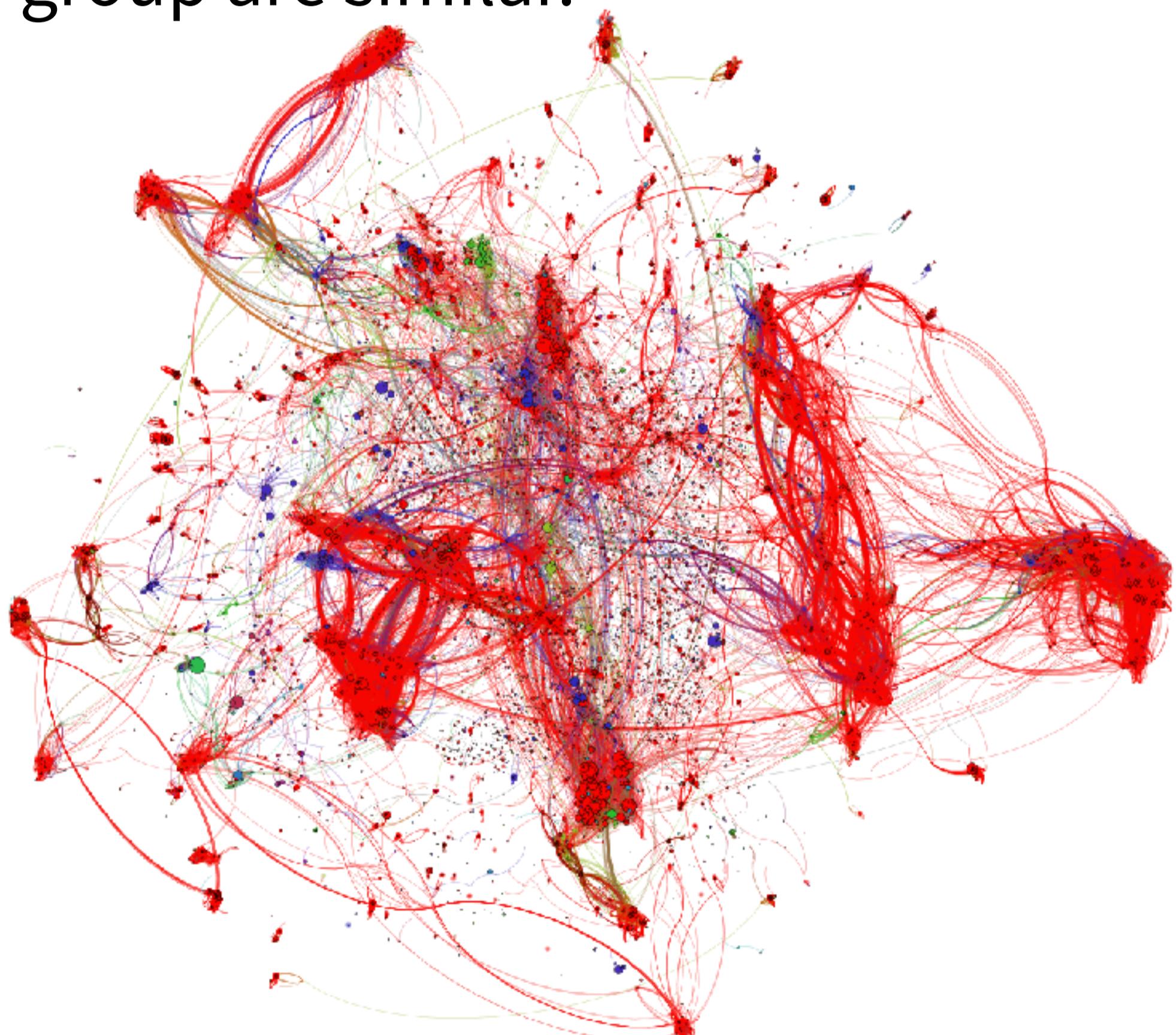


Clustering

Assignment of inputs to unnamed groups (“clusters”) such that objects in the same group are similar.

Examples:

- Exploratory data mining
- Plant and animal ecology
- Human genetic clustering
- Grouping of shopping items
- Market research
- Semi-automated grading

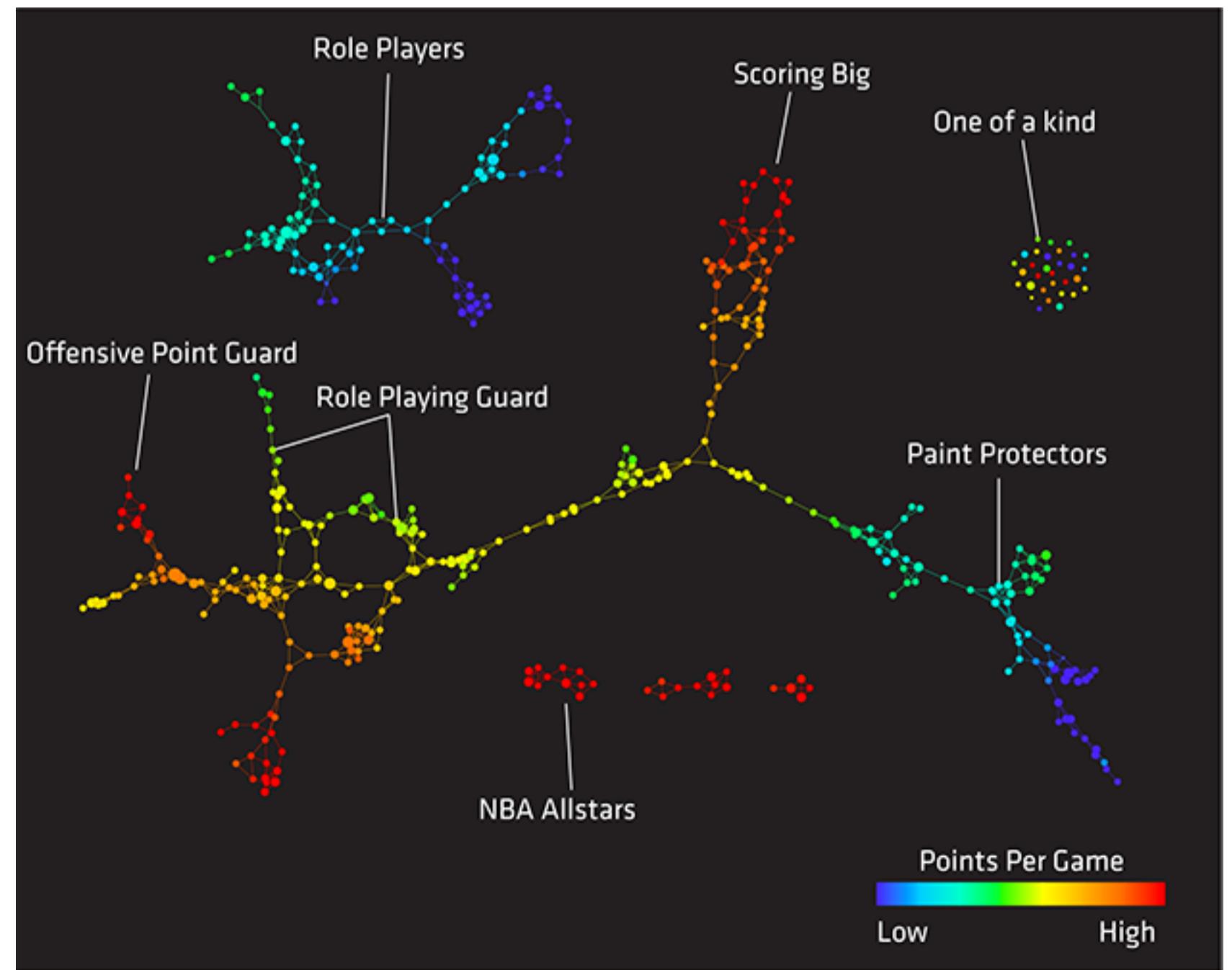
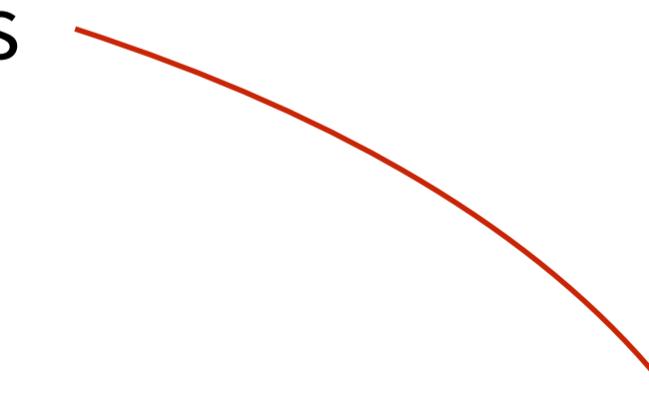


Dimensionality Reduction

Reducing the number of inputs under consideration.

Examples:

- Exploratory data mining
- Preprocessing
- Recommender systems
- Sports analytics

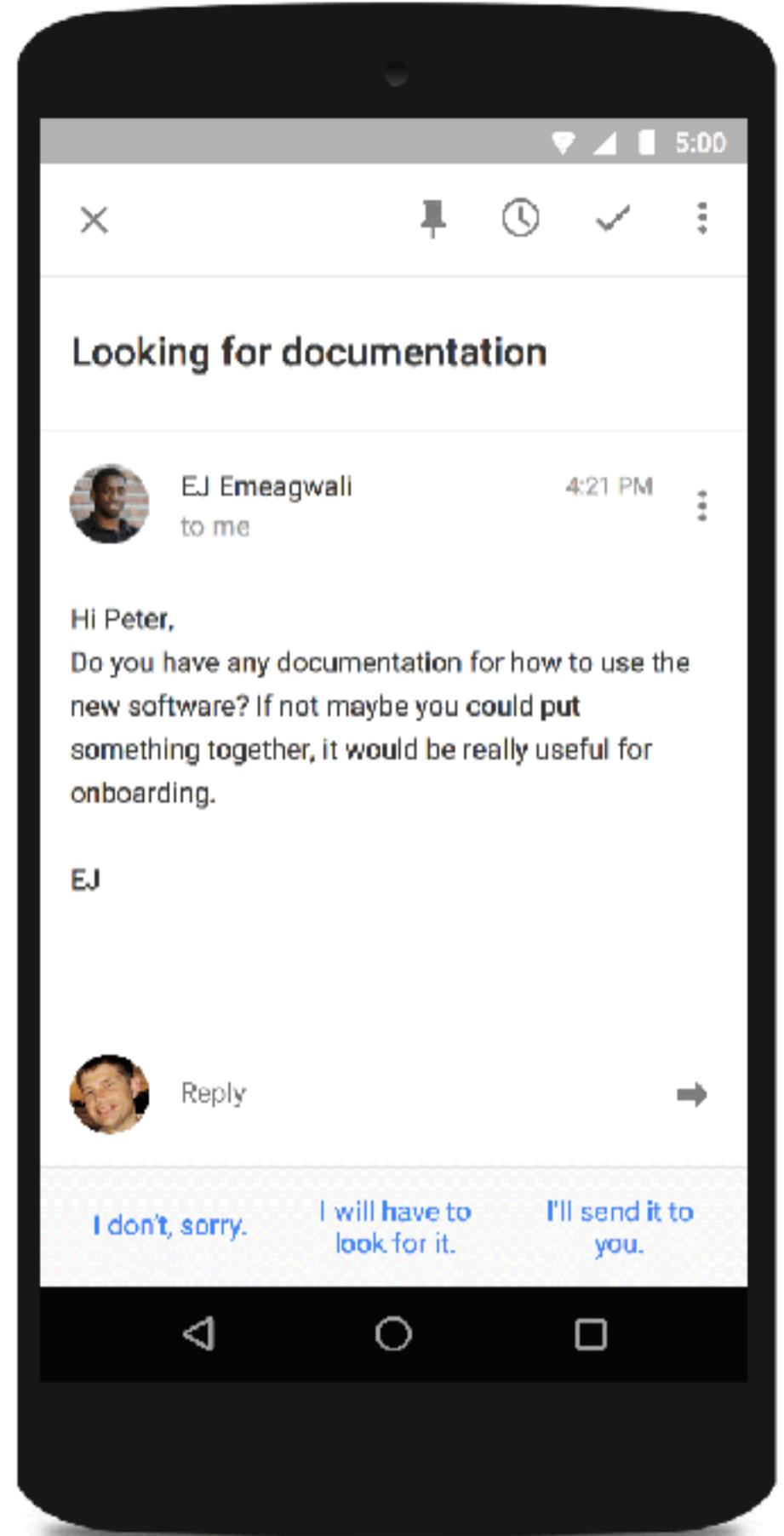


Generation

Creation of high-dimensional output, often conditional on input.

Examples:

- Image/Speech/Text Synthesis
- Image-to-Text (captioning)
- Text-to-Speech
- Text-to-Text (e.g. auto-reply)



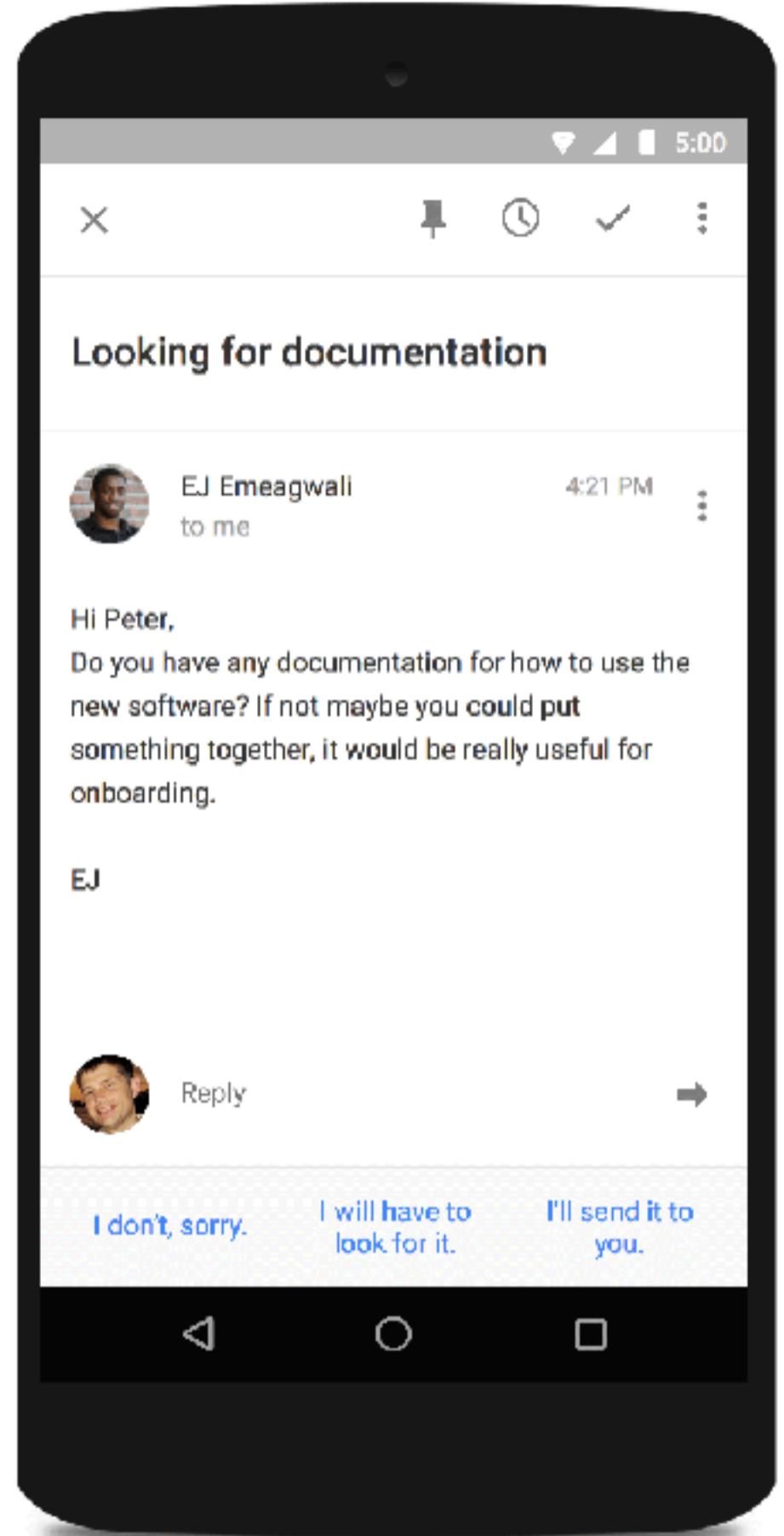
Still may require
human-in-the-loop (judgement)

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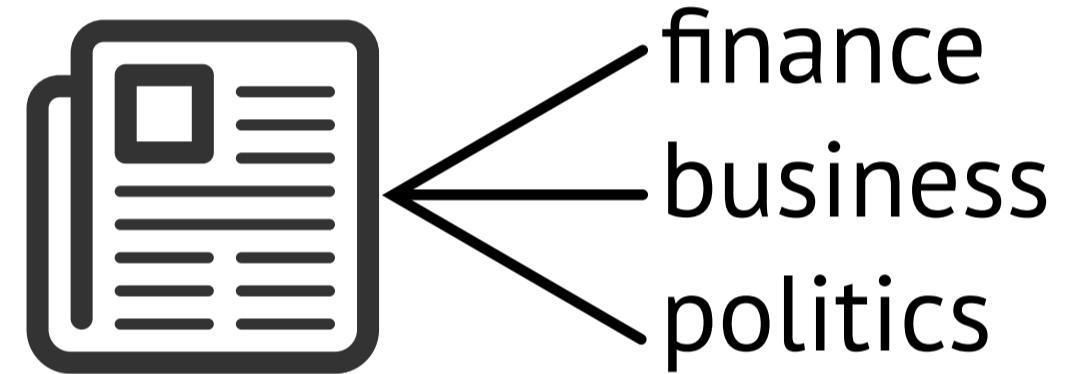
Still may require
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Structured Output

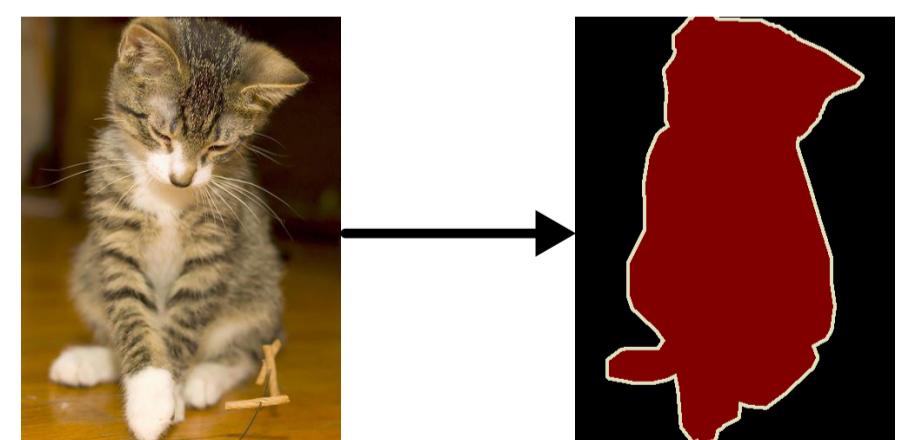
An important class of tasks where the high-dimensional output has important relationships among the elements.

Subsumes:

- Some classification tasks (e.g. multi-label)
- Some regression tasks (e.g. pose estimation)
- Transcription
- Translation
- Generation



Multi-label Classification

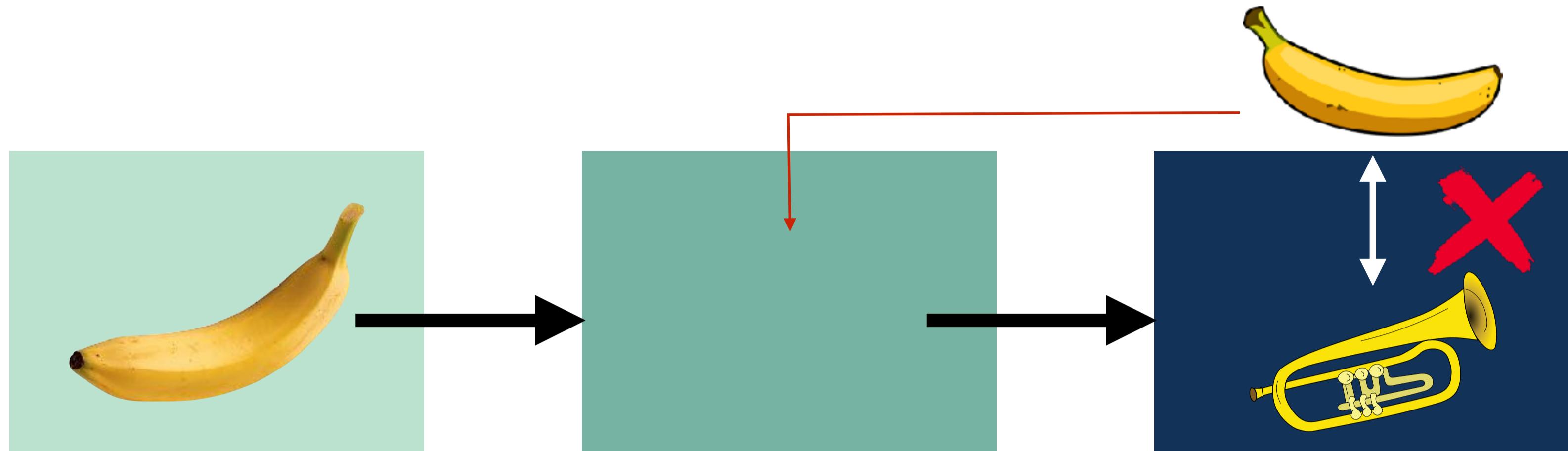


Segmentation

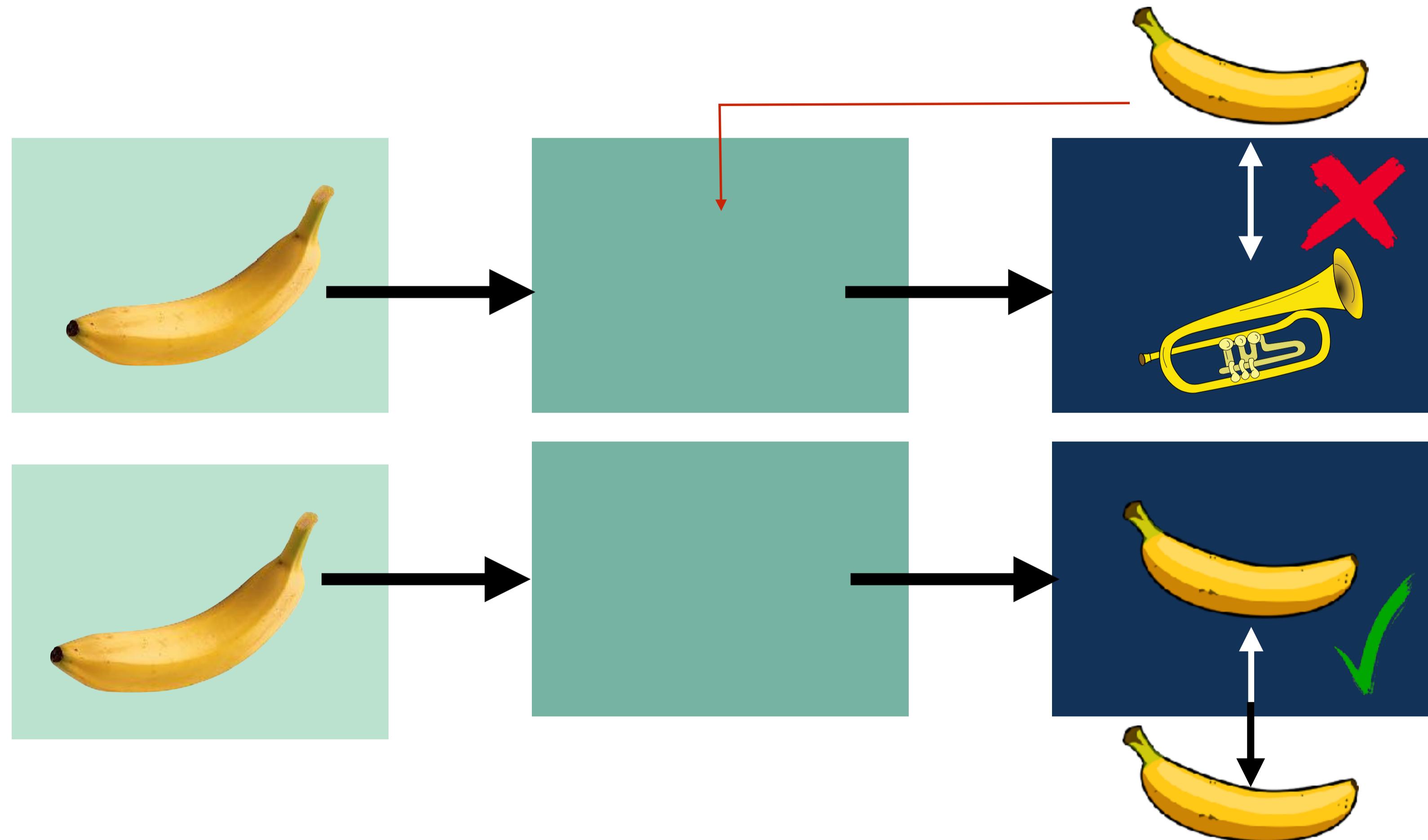
2. The Performance Measure



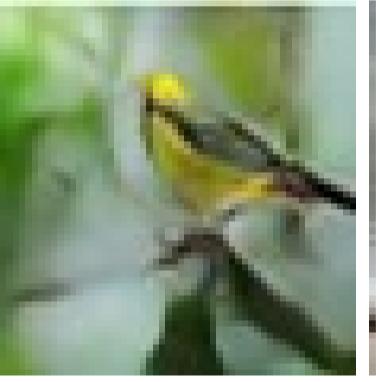
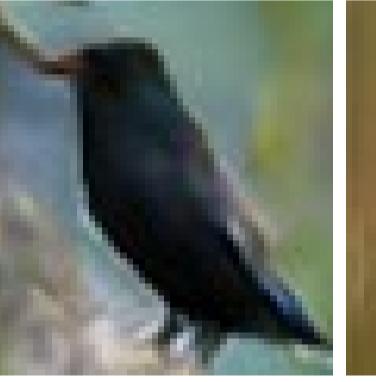
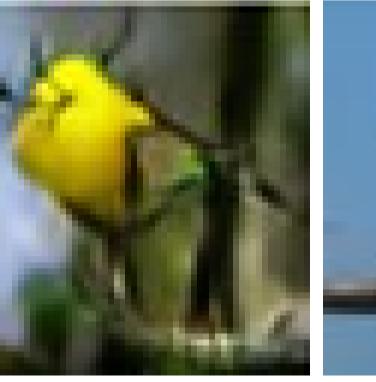
2. The Performance Measure



2. The Performance Measure



Evaluating Generative Performance

Text description	This bird is red and brown in color, with a stubby beak	The bird is short and stubby with yellow on its body	A bird with a medium orange bill white body gray wings and webbed feet	This small black bird has a short, slightly curved bill and long legs	A small bird with varying shades of brown with white under the eyes	A small yellow bird with a black crown and a short black pointed beak	This small bird has a white breast, light grey head, and black wings and tail
64x64 GAN-INT-CLS [22]							
128x128 GAWWN [20]							
256x256 StackGAN							

Zhang et al. "Stack GAN"
<https://arxiv.org/abs/1612.03242>

Training vs. Testing

Training vs. Testing

Training Stage (Learning)

Data is fed to model, parameters (degrees of freedom) are updated

Typically takes a long time



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Testing Stage (Deployment)

Parameters frozen, model consumes data, produces outputs

Typically very fast (e.g. real time!)



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Parameters frozen, model consumes data, produces outputs

Typically very fast (e.g. real time!)



*Note that systems may undergo additional learning
after deployment*

3. The Experience



via parentscafe.org



via thetimes.co.uk

Datasets

Most learning algorithms we discuss will be able to experience an entire dataset

Dataset as a “design matrix”

Rows represent “data points”
Or “examples”,

Columns represent features

Unsupervised Learning Algorithms

Experience a dataset containing many features, then learn **useful properties** of the structure of this dataset

Columns represent features

Rows represent “data points”
or “examples”

Supervised Learning Algorithms

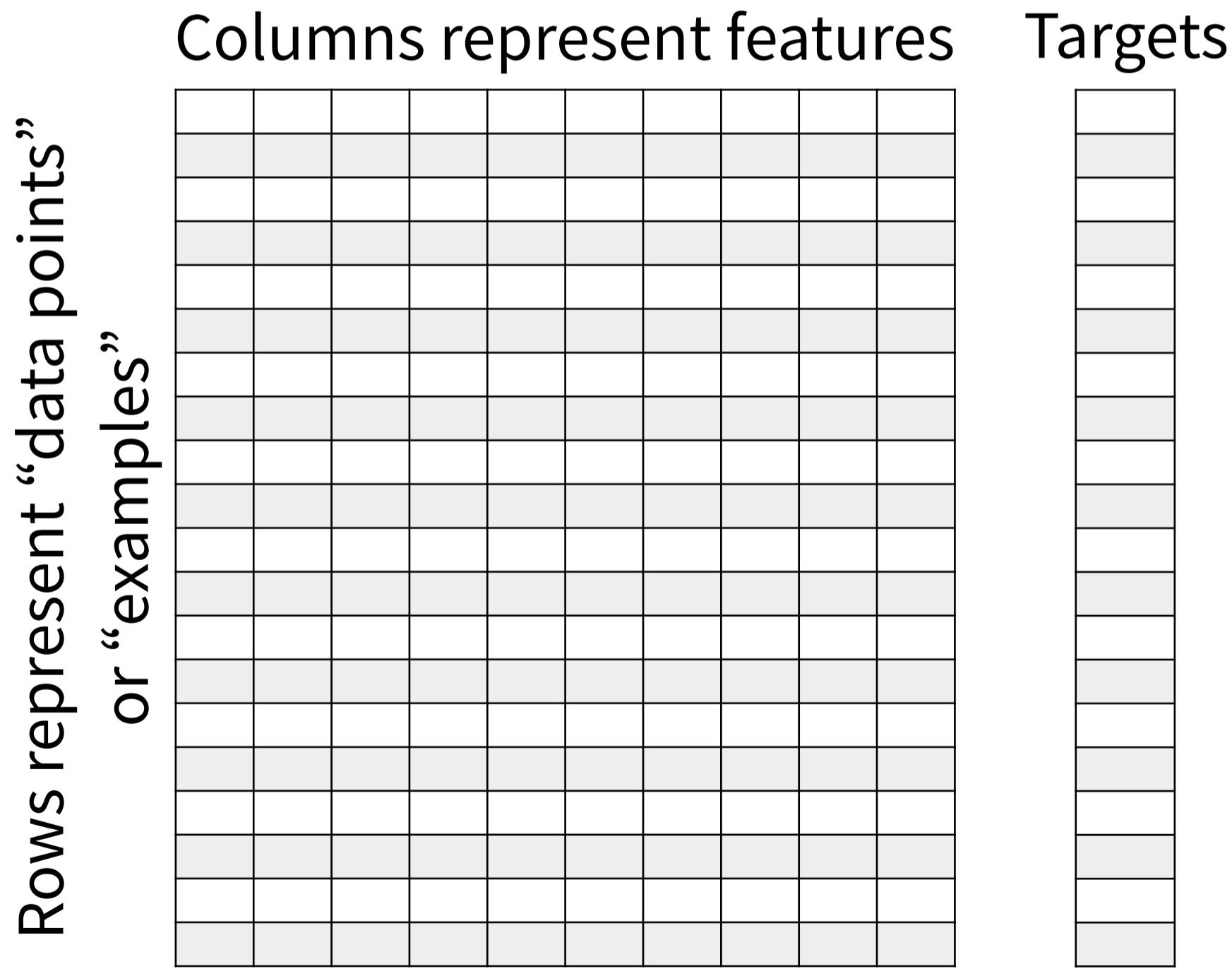
Experience a dataset containing features, but each example is also associated with a **label** or **target**

Columns represent features

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or “examples”

Supervised Learning Algorithms

Experience a dataset containing features, but each example is also associated with a **label** or **target**



Blurred Paradigms

Unsupervised and supervised learning are not completely distinct or formal concepts.

Other variants of the learning paradigm are possible.

Examples:

- Semi-supervised learning
- Multiple-instance learning
- Reinforcement learning



Google DeepMind's AlphaGo
A Hybrid of Several Learning Paradigms
+ Some “Brute Force”