INTRODUCTION TO MACHINE LEARNING

Bùi Tiến Lên

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TRƯỜNG ĐẠI HỌC KHOA HỌC TỰ NHIÊN

Contents

Machine Learning

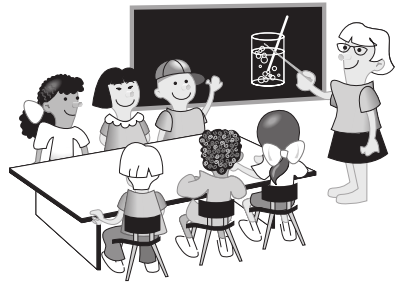
- Machine Learning
- Interpretable Machine Learning

What is the Learning Problem?

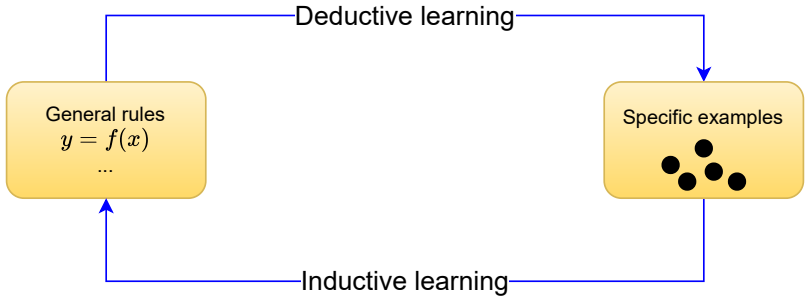
Concept 1 (Mitchell (1997))

Learning $\equiv$ Improving with experience at some task

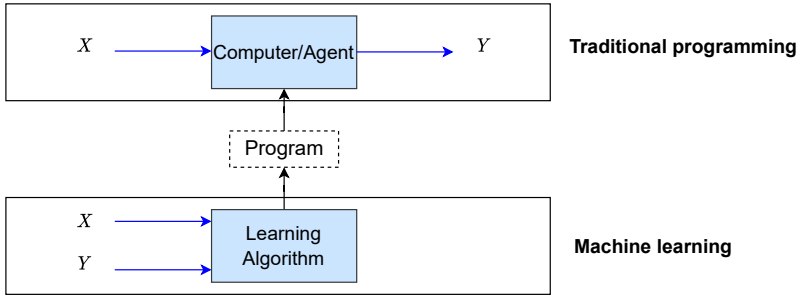
- Improve over task T,
- with respect to performance measure P,
- based on experience E.



Inductive Learning

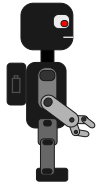


Machine Learning vs. Traditional Programming



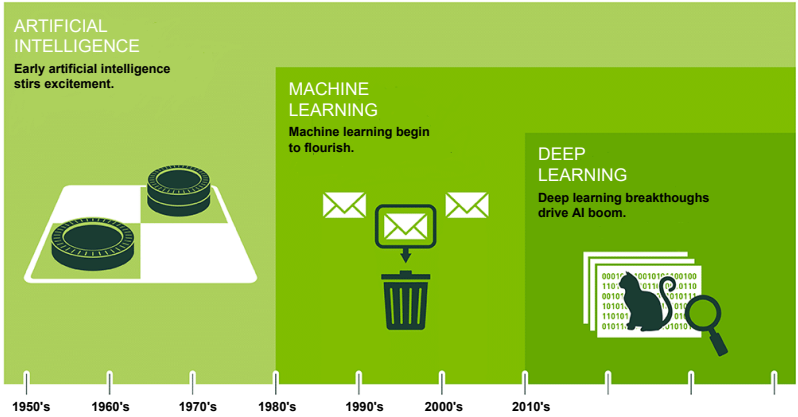
Machine Learning vs. Agents

hardware



software

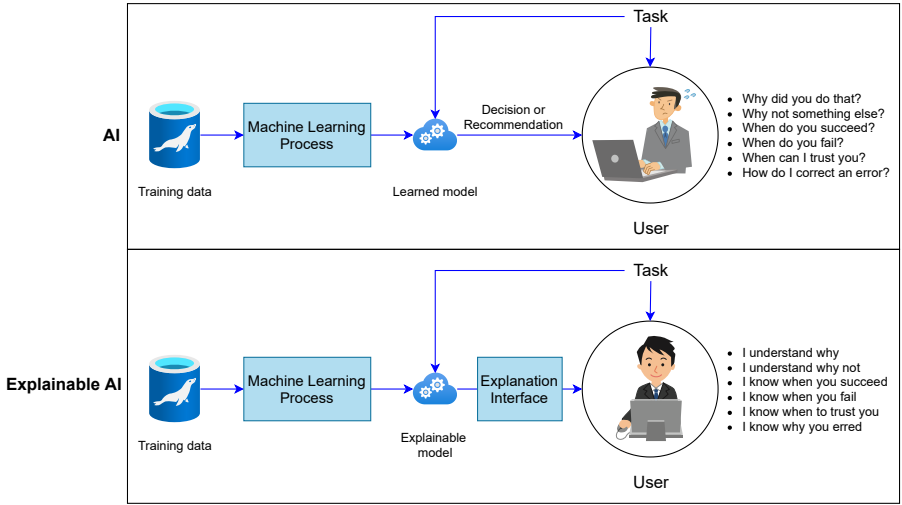
Machine Learning vs. Artificial Intelligence



Interpretable Machine Learning - Explainable Artificial Intelligence

- **Explainable** could mean **interpretable**
- **Abstraction**: how much of an explanation do we need?
- The **Explainable AI** (XAI) program aims to create a suite of machine learning techniques that:
  - Produce more explainable models, while maintaining a high level of learning performance (prediction accuracy)
  - Enable human users to understand, appropriately trust, and effectively manage the emerging generation of artificially intelligent partners.

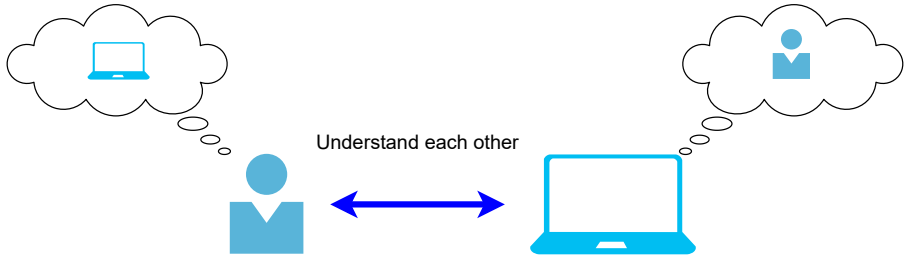
The Explainable Artificial Intelligence (cont.)



Human vs. Model

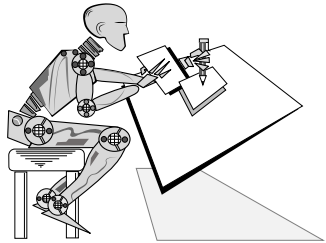
The challenge is people don't understand the system and the system doesn't understand the people.

- We need models for the system to use to understand and explain things to the human.
- We also need models in the human's head about what the system does.



Learning Agent

Agents Need Learning

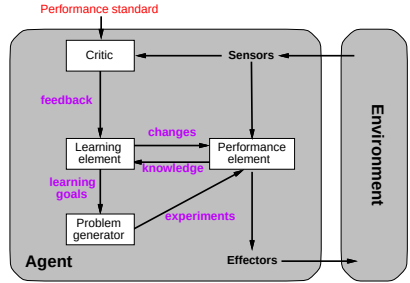


- Learning is essential for unknown environments, i.e., when designer lacks omniscience
- Learning is useful as a system construction method, i.e., expose the agent to reality rather than trying to write it down
- Learning modifies the agent's decision mechanisms to improve performance

Forms of Learning

Any component of an agent can be improved by learning from data. The improvements, and the techniques used to make them, depend on four major factors:

- Which *component* is to be improved.
- What *prior knowledge* the agent already has.
- What *representation* is used for the data and the component.
- What *feedback* is available to learn from.



Components to be learned

The components of these agents include:

1. A direct mapping from conditions on the current state to actions.
2. A means to infer relevant properties of the world from the percept sequence.
3. Information about the way the world evolves and about the results of possible actions the agent can take.
4. Utility information indicating the desirability of world states.
5. Action-value information indicating the desirability of actions.
6. Goals that describe classes of states whose achievement maximizes the agent's utility.

Each of these components can be learned.

Representation and prior knowledge

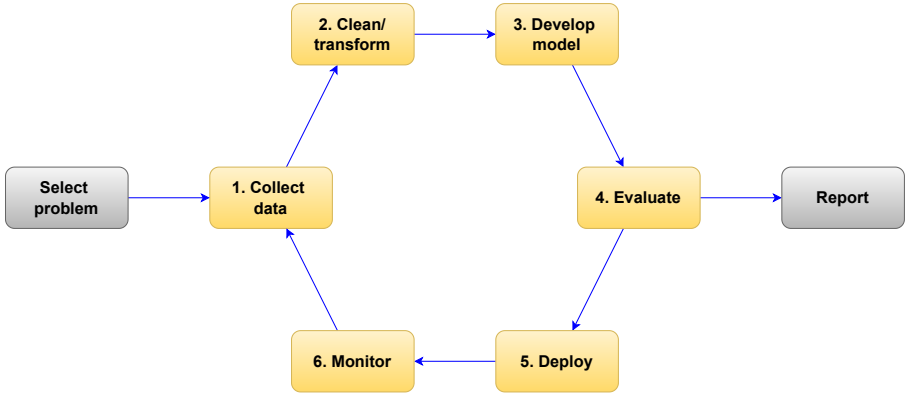
- Representations can be
  - Functions with inputs, a vector of attribute values, and outputs, either a continuous numerical value or a discrete value
  - Functions and prior knowledge composed of first-order logic sentences
  - Bayesian networks

Feedback to learn from

There are three *types of feedback* that determine the three main types of learning:

- In **unsupervised learning** the agent learns patterns in the input even though no explicit feedback is supplied.
- In **reinforcement learning** the agent learns from a series of reinforcements—rewards or punishments.
- In **supervised learning** the agent observes some example input–output pairs and learns a function that maps from input to output.
  - In **semi-supervised learning** we are given a few labeled examples and must make what we can of a large collection of unlabeled examples.

Machine Learning Workflow



Machine Learning Workflow (cont.)

1. Collect available data.
2. Clean and transform that data. If you're collecting data that is missing values, then you need to clean and transform that data until it's in the form machine learning requires.
3. Explore and visualize the data to make sure it is encoding what you expect it to encode. Build a model on training data.
4. Evaluate the model test data.
5. Deploy the model on un-seen data.
6. Monitor the model

Data

Types of Data

- **Record**
  - Relational records
  - Data matrix: numerical matrix
  - Document data: text documents
  - Transaction data
- **Graph and network**
  - World Wide Web
  - Social or information networks
  - Molecular Structures

Types of Data (cont.)

- **Ordered**
  - Video data: sequence of images
  - Temporal data: time-series
  - Sequential Data: transaction sequences
  - Genetic sequence data
- **Spatial, image and multimedia**
  - Spatial data: maps
  - Image data
  - Video data

Data Sets

Concept 2

- **Data sets** are made up of data objects.
- **A data object** represents an **entity** (also called samples, examples, instances, data points, objects, tuples).
- Data objects are described by **attributes**.

Attributes

Concept 3

An attribute (also called dimension, feature, variable) is a data field, representing a characteristic or feature of a data object.

Data set	Attributes
Sales database	customers, store items, sales
Medical database	patients, treatments
University database	students, professors, courses

Attribute Types

- **Nominal**: categories, states, or "names of things"
  - hair color = {auburn, black, blond, brown, grey, red, white}
  - marital status, occupation, ID numbers, zip codes
- **Binary**: nominal attribute with only two states
  - gender (symmetric: both outcomes equally important)
  - medical test (positive vs. negative) (asymmetric: outcomes not equally important)
- **Ordinal**: values have a meaningful order but magnitude between successive values is not known.
  - size = {small, medium, large}
  - grades, rankings

Numeric Attribute Types

- Quantity (integer or real-valued)
- **Interval scale**: Measured on a scale of equal-sized units. No true zero-point. Values have order
  - temperature in Celsius or Fahrenheit
  - calendar dates
- **Ratio scale**: Inherent zero-point
  - temperature in Kelvin
  - length
  - counts
  - monetary quantities

Discrete vs. Continuous Attributes

- **Discrete Attribute**: Has only a finite or countably infinite set of values
  - zip codes
  - profession

  Note: Sometimes, represented as integer variables; binary attributes are a special case of discrete attributes
- **Continuous Attribute**: Has real numbers as attribute values
  - temperature
  - height, or weight

Sample datasets

- Housing data for 506 census tracts of Boston from the 1970 census

	crim	zn	indus	chas	nox	rm	age	dis	rad	tax	ptratio	b	lstat	medv
1	0.00632	18	2.31	0	0.538	6.575	65.2	4.0900	1	296	15.3	396.90	4.98	24.0
2	0.02731	0	7.07	0	0.469	6.421	78.9	4.9671	2	242	17.8	396.90	9.14	21.6
3	0.02729	0	7.07	0	0.469	7.185	61.1	4.9671	2	242	17.8	392.83	4.03	34.7
4	0.03237	0	2.18	0	0.458	6.998	45.8	6.0622	3	222	18.7	394.63	2.94	33.4
5	0.06905	0	2.18	0	0.458	7.147	54.2	6.0622	3	222	18.7	396.90	5.33	36.2
6	0.02985	0	2.18	0	0.458	6.430	58.7	6.0622	3	222	18.7	394.12	5.21	28.7

- Iris data set gives the measurements in centimeters of the variables sepal length and width and petal length and width, respectively, for 50 flowers from each of 3 species of iris.

	Sepal.Length	Sepal.Width	Petal.Length	Petal.Width	Species
1	5.1	3.5	1.4	0.2	setosa
2	4.9	3.0	1.4	0.2	setosa
3	4.7	3.2	1.3	0.2	setosa
4	4.6	3.1	1.5	0.2	setosa
5	5.0	3.6	1.4	0.2	setosa
6	5.4	3.9	1.7	0.4	setosa

Sample datasets (cont.)

- BBC news dataset

#	sentences	class
0	Labour plans maternity pay rise\n\nMaternity p...	politics
1	Watchdog probes e-mail deletions\n\nThe inform...	politics
2	Hewitt decries 'career sexism'\n\nPlans to ext...	politics
3	Labour chooses Manchester\n\nThe Labour Party ...	politics
4	Brown ally rejects Budget spree\n\nChancellor ...	politics
...	...	...
2220	Trial begins of Spain's top banker\n\nThe tria...	business
2221	UK economy ends year with spurt\n\nThe UK econ...	business
2222	HealthSouth ex-boss goes on trial\n\nThe forme...	business
2223	Euro firms miss out on optimism\n\nMore than 9...	business
2224	Lacroix label bought by US firm\n\nLuxury good...	business

Large Language Models

Year	Model	# parameters	dataset size
2018	ELMo	$9.36 * 10^7$	$\approx$ 6GB *
2019	BERT	$3.4 * 10^8$	16 GB
2019	Megatron-LM	$8.3 * 10^9$	174 GB
2020	**GPT-3**	$1.75 * 10^{11}$	570 GB
2020	GShard	$6.00 * 10^{11}$	†
2021	Switch-C	$1.57 * 10^{12}$	745 GB
2021	Gopher	$2.8 * 10^{11}$	$\approx$ 1800 GB ‡
2022	PaLM	$5.4 * 10^{11}$	$\approx$ 4680 GB $

* 1 billion words

† 25 billion training examples (100 languages)

‡ 300 billion tokens

$ 780 billion tokens

How Much Data is that?

Someone who reads a 400 page book each day will take how long to read the same amount of information as GPT-3 was trained on?

1. 2 years
2. 20 years
3. 200 years
4. 2000 years

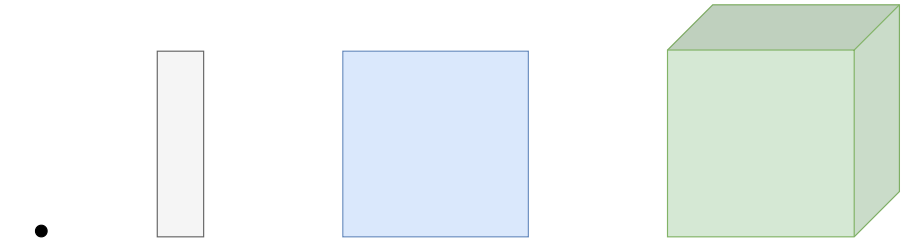
Tensor-based Attributes

Concept 4

A **tensor** is a generalized matrix, a finite table of numerical values indexed along several discrete dimensions.

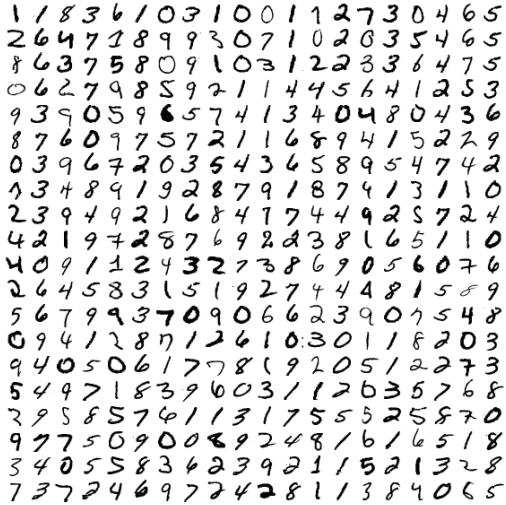
- A 0d tensor is a scalar
- A 1d tensor is a vector (e.g. a sound sample)
- A 2d tensor is a matrix (e.g. a grayscale image)
- A 3d tensor (e.g. a multi-channel image)
- A 4d tensor (e.g. a sequence of multi-channel images)

Tensor-based Attributes (cont.)



Sample dataset

- 28×28 grayscale images, 60k train samples, 10k test samples.



Exploration

Data Visualization

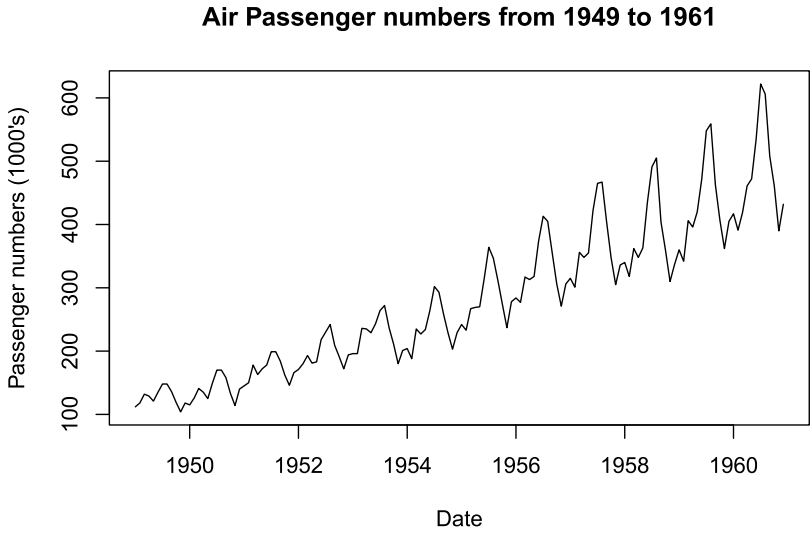
Concept 5

Visualization is the conversion of data into a **visual** or **tabular format** so that the characteristics of the data and the relationships among data items or attributes can be analyzed or reported.

Humans have a well developed ability to analyze large amounts of information that is presented visually

- Can detect general patterns and trends
- Can detect outliers and unusual patterns

Data Visualization (cont.)



Type of Learnings

Basic Premise of Learning

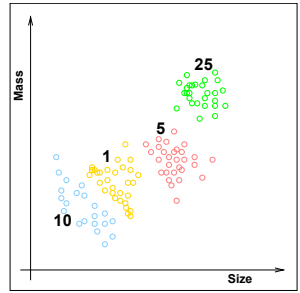
"**Using a set of observations to uncover an underlying process or rule**"

broad premise $\Longrightarrow$ many variations

- Supervised learning
- Unsupervised learning
- Reinforcement learning

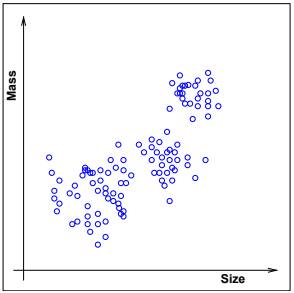
Supervised Learning

- We get data $\mathcal{D}$: (**input**, **correct ouput**)
  - When the **output** is one of *a finite set of values*, the learning problem is called **classification**
  - When the **output** is a *number*, the learning problem is called **regression**
- Example from vending machine - **coin classification**



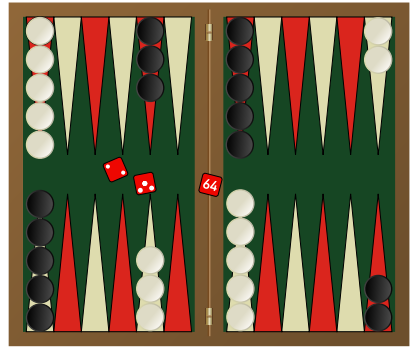
Unsupervised Learning

- Instead of (**input**, **correct output**), we get (**input**, ?)



Reinforcement Learning

- We get data $\mathcal{D}$: (**observation**, **action**, and **reward**)



Successes of Machine Learning

- Vision
- Language
- Games
- Robotics
- Other

Detection and Segmentation

P. O. Pinheiro, T. Y. Lin, R. Collobert, and P. Dollar. Learning to refine object segments, ECCV, 2016

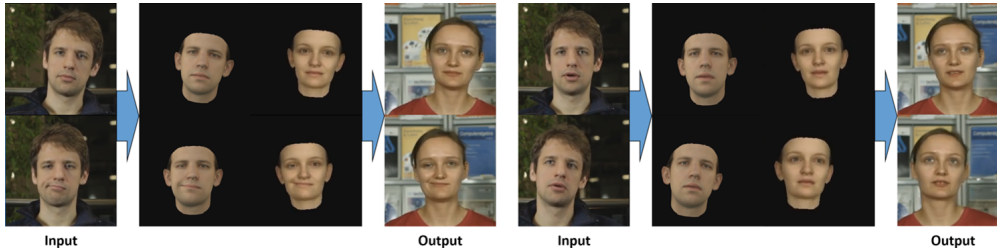
Face recognition

Image generation

- Faces: 1024x1024 resolution, CelebA-HQ dataset

T. Karras, T. Aila, S. Laine, and J. Lehtinen, Progressive Growing of GANs for Improved Quality, Stability, and Variation, ICLR 2018

DeepFakes



H. Kim et al., Deep video portraits, SIGGRAPH, 2018

Translation

- "The reason Boeing are doing this is to cram more seats in to make their plane more competitive with our products," said Kevin Keniston, head of passenger comfort at Europe's Airbus.

↓

- Kevin Keniston, người đứng đầu bộ phận thoải mái của hành khách tại Europe's Airbus, cho biết: "Lý do Boeing làm điều này là để nhồi nhét thêm ghế để máy bay của họ cạnh tranh hơn với các sản phẩm của chúng tôi."

Text Generation

- Language model: GPT3

MIT Technology Review

Artificial intelligence / Machine learning

OpenAI's new language generator GPT-3 is shockingly good—and completely mindless

The AI is the largest language model ever created and can generate amazing human-like text on demand but won't bring us closer to true intelligence.

MIT Technology Review

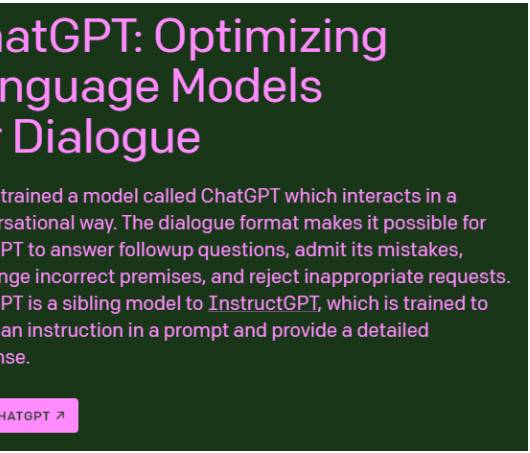
Opinion

GPT-3, Bloviator: OpenAI's language generator has no idea what it's talking about

Tests show that the popular AI still has a poor grasp of reality.

by **Gary Marcus** and **Ernest Davis** August 22, 2020

ChatBot

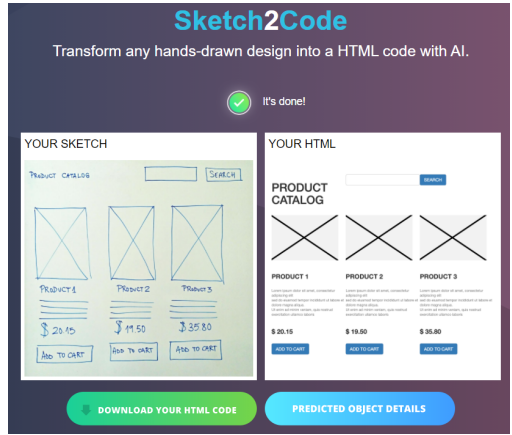


Speech Applications

- Siri
- Alexa
- Google Assitance

Sketch2Code

- Sketch2Code is a web-based solution which uses AI to transform a handwritten user interface design from a picture to a valid HTML markup code



Auto-captioning

Vinyals et al., 2015

Text-to-Image

OpenAI's DALL-E

- **TEXT PROMPT**:

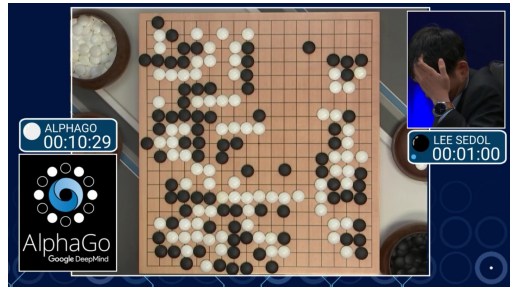
  an illustration of a baby daikon radish in a tutu walking a dog

- **AI-GENERATED IMAGES**:

Text-to-Image (cont.)

Games

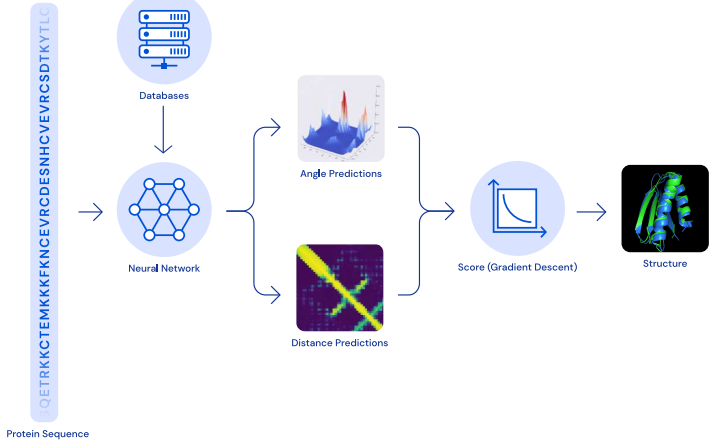
- **2013**: DeepMind uses deep reinforcement learning to beat humans at some Atari games
- **2016**: DeepMind's AlphaGo system beats Go grandmaster Lee Sedol 4-1
- **2017**: AlphaZero learns to play Go and chess from scratch
- **2019**: DeepMind's AlphaStar (StarCraft 2) AI is better than 99.8 percent of all human players



Self-driving cars

Solving scientific problems

- AlphaFold 2 (2020): Using AI for scientific discovery; a solution to a 50-year-old grand challenge in biology.



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