



FACULTY OF INFORMATION TECHNOLOGY

Artificial Intelligence Fundamentals (NM TTNT)

Semester 1, 2023/2024

Chapter 1. Introduction to AI



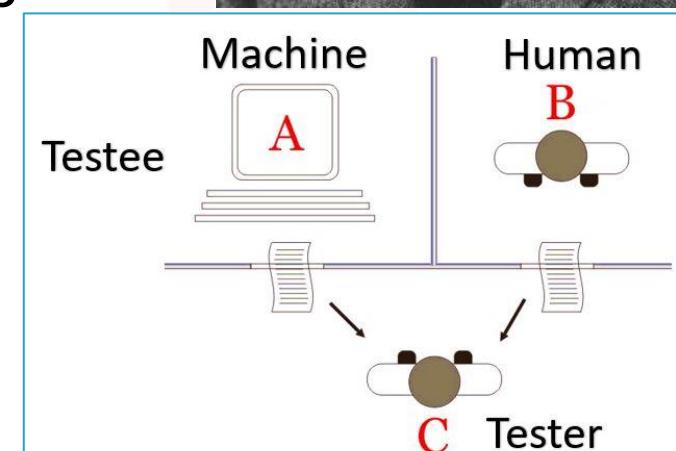
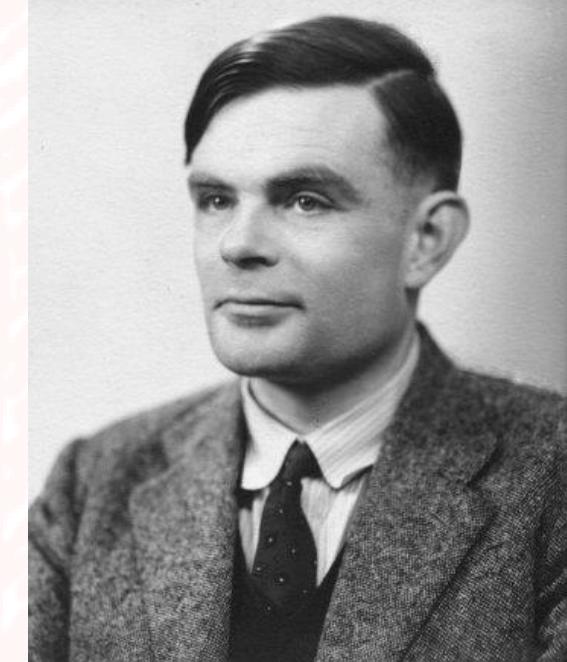
Content

- ▶ What is AI?
- ▶ AI application areas
- ▶ The history of AI
- ▶ The state of the art
- ▶ Fundamental issues for AI problems

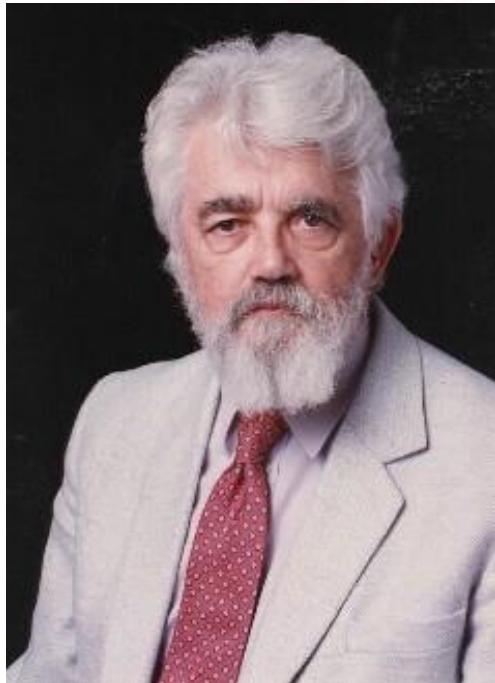
Turing Test

- ▶ In 1950, Alan Turing defined a test of whether a machine could “think”
- ▶ “A human judge engages in a natural language conversation with one human and one machine, each of which tries to appear human. If judge can't tell, machine passes the Turing test”

en.wikipedia.org/wiki/Turing_test



What is AI?



“It is the science and engineering of ***making intelligent machines***, especially intelligent computer programs. It is related to the similar task of ***using computers to understand human intelligence***, but AI does not have to confine itself to methods that are biologically observable.”

“Intelligence is the computational part of the ability to achieve goals in the world.”

John McCarthy

What is AI?



“AI is
the design, study and
construction
of computer programs
that behave
intelligently.”

Tom Dean

What is AI?

“AI is the study of **complex information processing problems** that often have their roots in some aspect of biological information processing.

The goal of the subject is to **identify solvable and interesting information processing problems**, and solve them.”

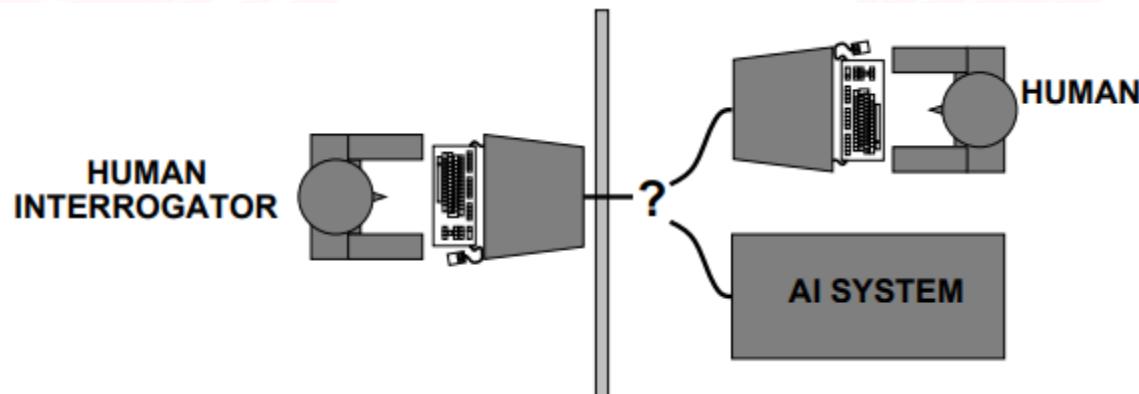
David Marr (1945–1980)

What is AI? (Approaches)

Thinking Humanly <p>“The exciting new effort to make computers think . . . <i>machines with minds</i>, in the full and literal sense.” (Haugeland, 1985)</p> <p>“[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . .” (Bellman, 1978)</p>	Thinking Rationally <p>“The study of mental faculties through the use of computational models.” (Charniak and McDermott, 1985)</p> <p>“The study of the computations that make it possible to perceive, reason, and act.” (Winston, 1992)</p>
Acting Humanly <p>“The art of creating machines that perform functions that require intelligence when performed by people.” (Kurzweil, 1990)</p> <p>“The study of how to make computers do things at which, at the moment, people are better.” (Rich and Knight, 1991)</p>	Acting Rationally <p>“Computational Intelligence is the study of the design of intelligent agents.” (Poole <i>et al.</i>, 1998)</p> <p>“AI . . . is concerned with intelligent behavior in artifacts.” (Nilsson, 1998)</p>

Acting Humanly: The Turing Test approach

- ▶ Turing (1950) “Computing machinery and intelligence”:
 - “Can machines think?” → “Can machines behave intelligently?”
 - Operational test for intelligent behavior: the **Imitation Game**



- Suggested major components of AI: knowledge, reasoning, language understanding, learning
- **Problem:** Turing test is not **reproducible, constructive, or amenable to mathematical analysis**

Thinking humanly: The cognitive modeling approach

- ▶ 1960s “cognitive revolution”: information – processing psychology replaced prevailing orthodoxy of behaviorism
- ▶ Requires scientific theories of internal activities of the brain
 - What level of abstraction? “Knowledge” or “circuits”?
 - How to validate? Requires
 - 1) Predicting and testing behavior of human subjects (top-down) or
 - 2) Direct identification from neurological data (bottom-up)
- ▶ Both approaches (roughly, Cognitive Science and Cognitive Neuroscience) are now distinct from AI

Thinking rationally: The “laws of thought” approach

- ▶ Normative (or prescriptive) rather than descriptive
- ▶ Example: “Socrates is a man; all men are mortal; therefore, Socrates is mortal.”
- ▶ Several Greek schools developed various forms of *logic notation* and *rules of derivation* for thoughts; may or may not have proceeded to the idea of mechanization
- ▶ Direct line through mathematics and philosophy to modern AI
- ▶ Problems:
 - Not all intelligent behavior is mediated by logical deliberation
 - What is the purpose of thinking? What thoughts should I have out of all the thoughts (logical or otherwise) that I could have?

Acting rationally: The rational agent approach

- ▶ Rational behavior: doing the right thing
- ▶ The right thing: that which is expected to **maximize goal achievement**, given the available information
- ▶ Doesn't necessarily involve thinking—e.g., blinking reflex—but thinking should be in the service of rational action
- ▶ Aristotle (Nicomachean Ethics):
Every art and every inquiry, and similarly every action and pursuit, is thought to aim at some good

Rational Agents

- ▶ An agent is an entity that *perceives* and *acts*
- ▶ This course is about designing rational agents
- ▶ Abstractly, an agent is a function from percept histories to actions:

$$f: P^* \rightarrow A$$

- ▶ For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance
- ▶ **Caveat:** computational limitations make perfect rationality unachievable
- ➔ design best program for given machine resources

What is intelligent behavior?

- ▶ Perceiving one's environment
- ▶ Acting in complex environments
- ▶ Learning and understanding from experience
- ▶ Using reasoning to solve problems and to discover “hidden” knowledge
- ▶ Applying knowledge successfully in new situations
- ▶ Thinking abstractly, using analogies
- ▶ Communicating with others

AI prehistory

Philosophy	
Mathematics	
Economics	
Neuroscience	
Psychology	
Computer engineering	
Control theory	
Linguistics	

AI prehistory (cont.)

Philosophy	Logic, methods of reasoning, mind as physical system foundations of learning, language, rationality
Mathematics	Formal representation and proof algorithms, computation, (un)decidability, (in)tractability, probability
Economics	utility, decision theory
Neuroscience	physical substrate for mental activity
Psychology	phenomena of perception and motor control, experimental techniques
Computer engineering	building fast computers
Control theory	design systems that maximize an objective function over time
Linguistics	knowledge representation, grammar

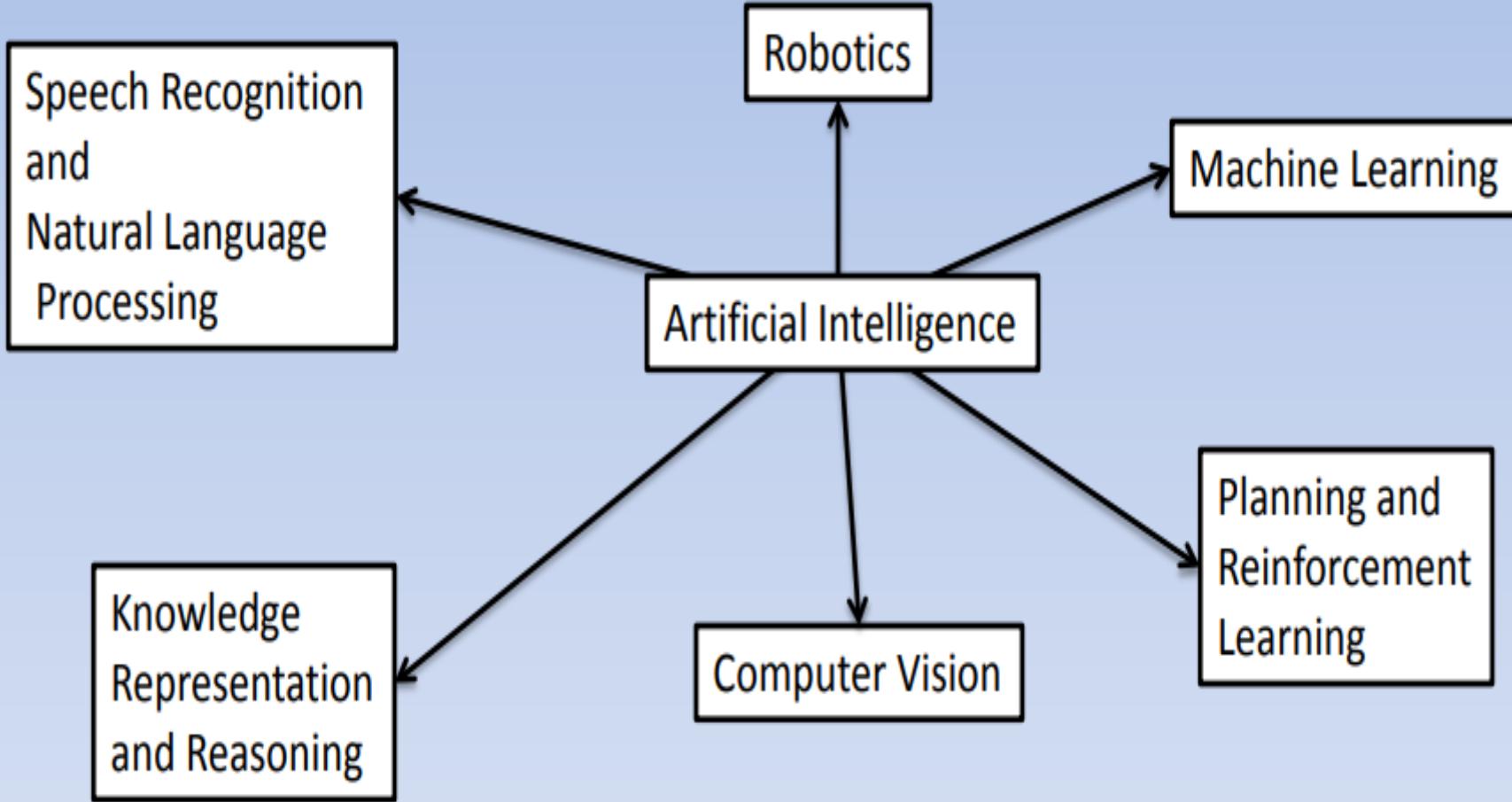
A Brief History of AI

- ▶ 1943: McCulloch & Pitts: Boolean circuit model of brain
- ▶ 1950: Turing's "Computing Machinery and Intelligence"
- ▶ 1952–69: Look, Ma, no hands!
- ▶ 1950s: Early AI programs, including Samuel's checkers program, Newell & Simon's Logic Theorist, Gelernter's Geometry Engine
- ▶ 1956: Dartmouth meeting: “Artificial Intelligence” adopted
- ▶ 1965: Robinson's complete algorithm for logical reasoning
- ▶ 1966– 74: AI discovers computational complexity; Neural network research almost disappears
- ▶ 1969 – 79: Early development of knowledge-based systems

A Brief History of AI (cont.)

- ▶ 1980 – 88: Expert systems industry booms (the Japanese government aggressively funded AI with its fifth generation computer project)
- ▶ 1988 – 93: Expert systems industry busts: “AI Winter”
- ▶ 1985 – 95: Neural networks return to popularity
- ▶ 1988 – present: Resurgence of probability; general increase in technical depth; “Nouvelle AI”: ALife, GAs, soft computing
- ▶ 1995 – present: Agents, agents, everywhere . . .
- ▶ 2003 – present: Human-level AI back on the agenda
- ▶ 2011– present: Deep learning, big data and artificial general intelligence (**strong AI**)

AI Subfields



AI Applications

1. Language translation services (Google)
2. News aggregation and summarization (Google)
3. Speech recognition (Nuance)
4. Song recognition (Shazam)
5. Face recognition (Recognizer)
6. Image recognition (Google Goggles)
7. Question answering (Apple Siri, IBM Watson)
8. Chess playing (IBM Deep Blue)
9. 3D scene modeling from images (Microsoft Photosynth)
10. Driverless cars (Google)
11. IBM Watson for oncology (applied in Vietnam)
12. ...



AI Applications (cont.)

- ▶ Most recent success of AI based on *machine learning*



AI-based on Machine Learning

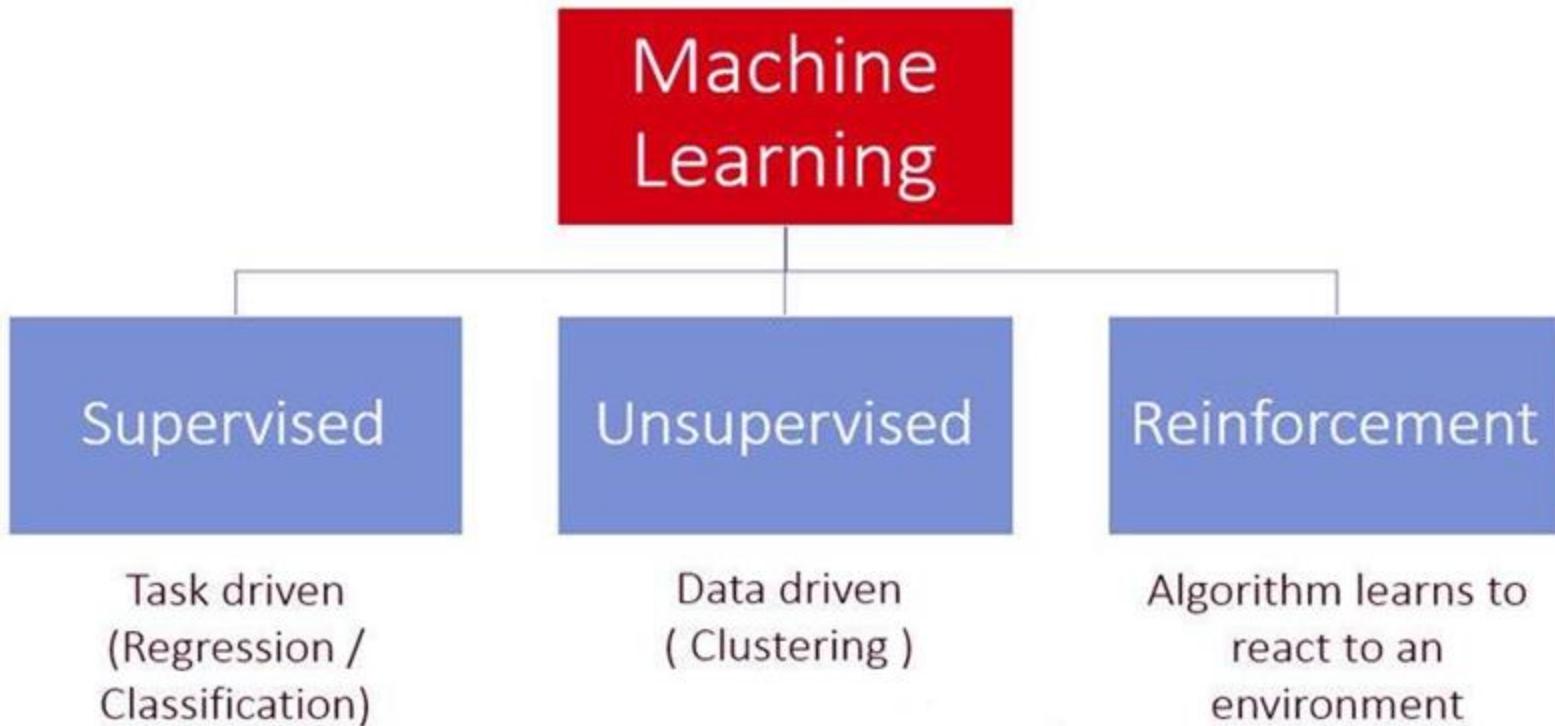
“Many developers of AI systems now recognize that, for many applications, it can be far easier to **train a system by showing it examples of desired input–output behavior than to program it manually by anticipating the desired response for all possible inputs.**”

M.I. Jordan, T. Mitchell. Machine Learning: Trends, perspectives, and prospects. Science, 349 (6245), 255–260, 2015.

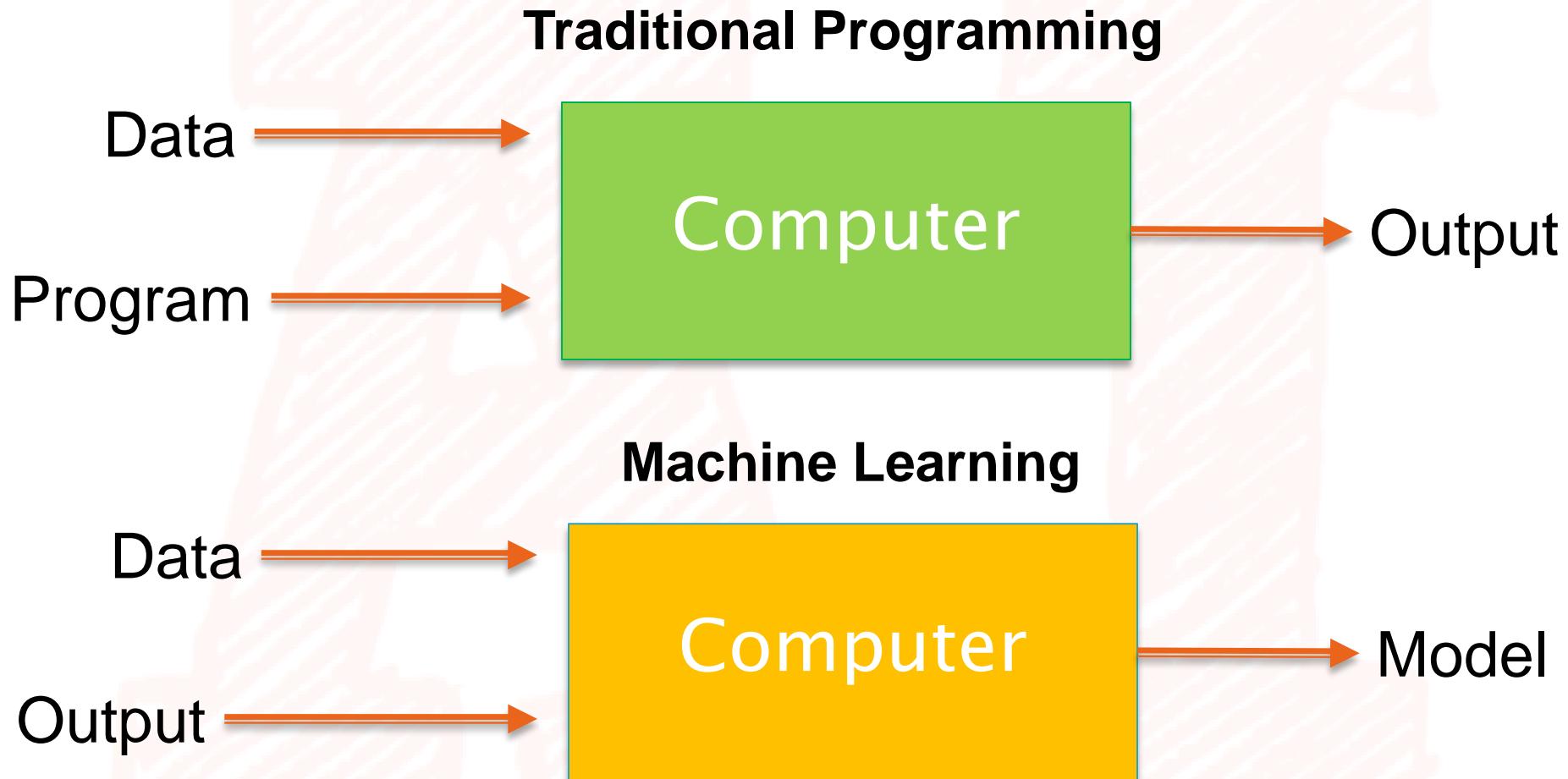
What is Machine Learning?

- ▶ Wikipedia: (ML introduced in 1980's)
 - *Machine learning is the subfield of computer science that “gives computers the ability to learn without being explicitly programmed”*
- ▶ Ability of computers to “learn” from “data” or “past experience”
 - **learn**: Make intelligent predictions or decisions based on data by optimizing a **model**
 - **data**: Comes from various sources such as sensors, domain knowledge, experimental runs, etc.

Types of Machine Learning



Machine Learning vs Traditional Programming

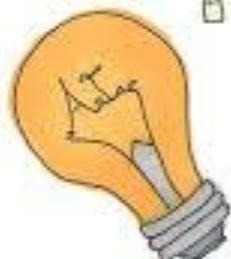


Artificial Intelligence vs Machine Learning vs Deep Learning



Artificial Intelligence

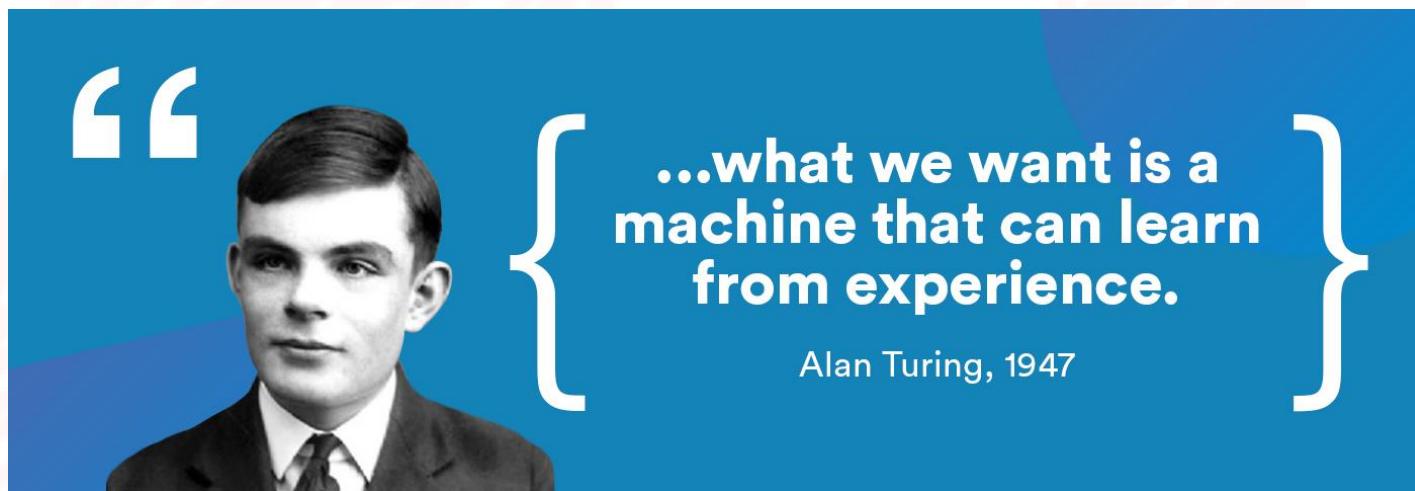
- ▶ Human intelligence exhibited by machines
 - empowers computers to mimic human intelligence such as decision making, text processing, and visual perception.

 "AI is the new electricity
- Andrew Ng"



Machine Learning

- ▶ An approach to achieve Artificial Intelligence.
 - a subfield of Artificial Intelligence that **enables machines to improve at a given task with experience**

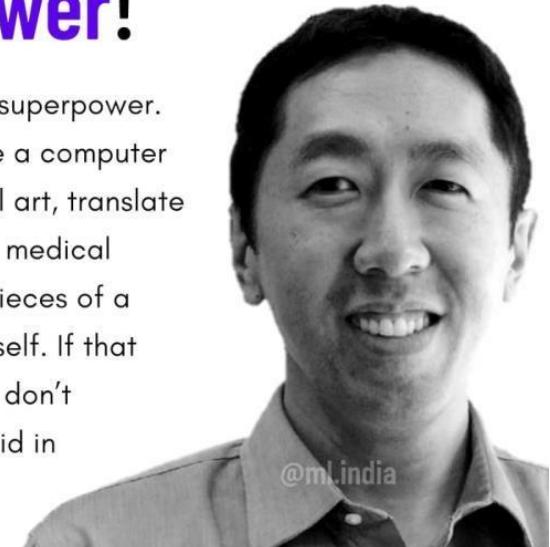


Deep Learning

- ▶ A technique for implementing machine learning
 - a specialized field of Machine Learning that relies on training of Deep Artificial Neural Networks (ANNs) using a large dataset such as images or texts

Andrew Ng compares deep learning to a superpower!

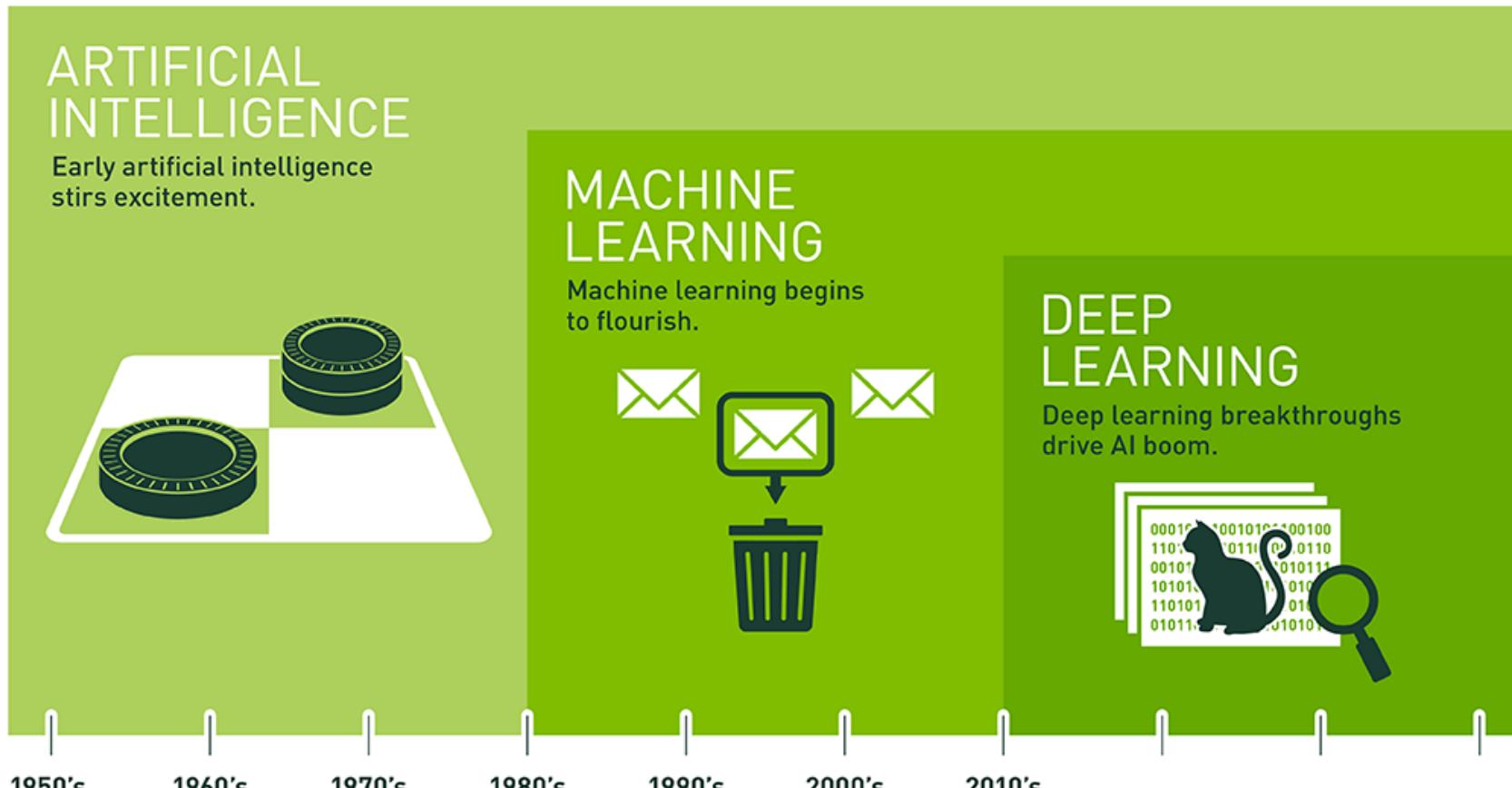
"Deep Learning is a superpower. With it you can make a computer see, synthesize novel art, translate languages, render a medical diagnosis, or build pieces of a car that can drive itself. If that isn't a superpower, I don't know what is", he said in an interview.



AI vs ML vs DL

- ▶ AI: Human intelligence exhibited by machines
 - **empowers computers to mimic human intelligence** such as decision making, text processing, and visual perception.
 - ▶ ML: An approach to achieve Artificial Intelligence.
 - a subfield of Artificial Intelligence that **enables machines to improve at a given task with experience**
 - ▶ DL: A technique for implementing machine learning
 - **a specialized field of Machine Learning** that relies on training of **Deep Artificial Neural Networks (ANNs)** using a large dataset such as images or texts
- Thanks to **Deep Learning**, AI has a bright future

AI vs ML vs DL (cont.)



Since an early flush of optimism in the 1950s, smaller subsets of artificial intelligence – first machine learning, then deep learning, a subset of machine learning – have created ever larger disruptions.

State of the Art (STOA)



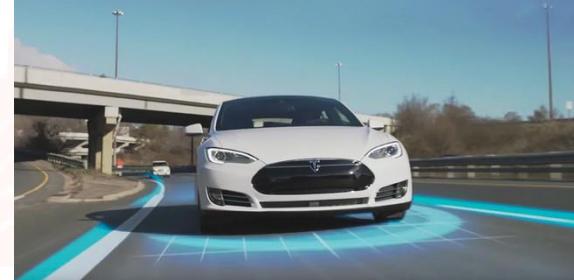
▶ AI Applications:

- Robotic vehicles
- Speech recognition
- Autonomous planning and scheduling
- Game playing
- Spamfighting
- Logistics planning
- Robotics
- Machine Translation
- ...



STOA: Robotic Vehicles

- ▶ 2006, a driverless robotic car – STANLEY won in DARPA Grand Challenge (desert)
- ▶ 2007, a driverless robotic car – CMU's BOSS won in Urban Challenge
- ▶ Tesla Autopilot



STOA: Speech Recognition

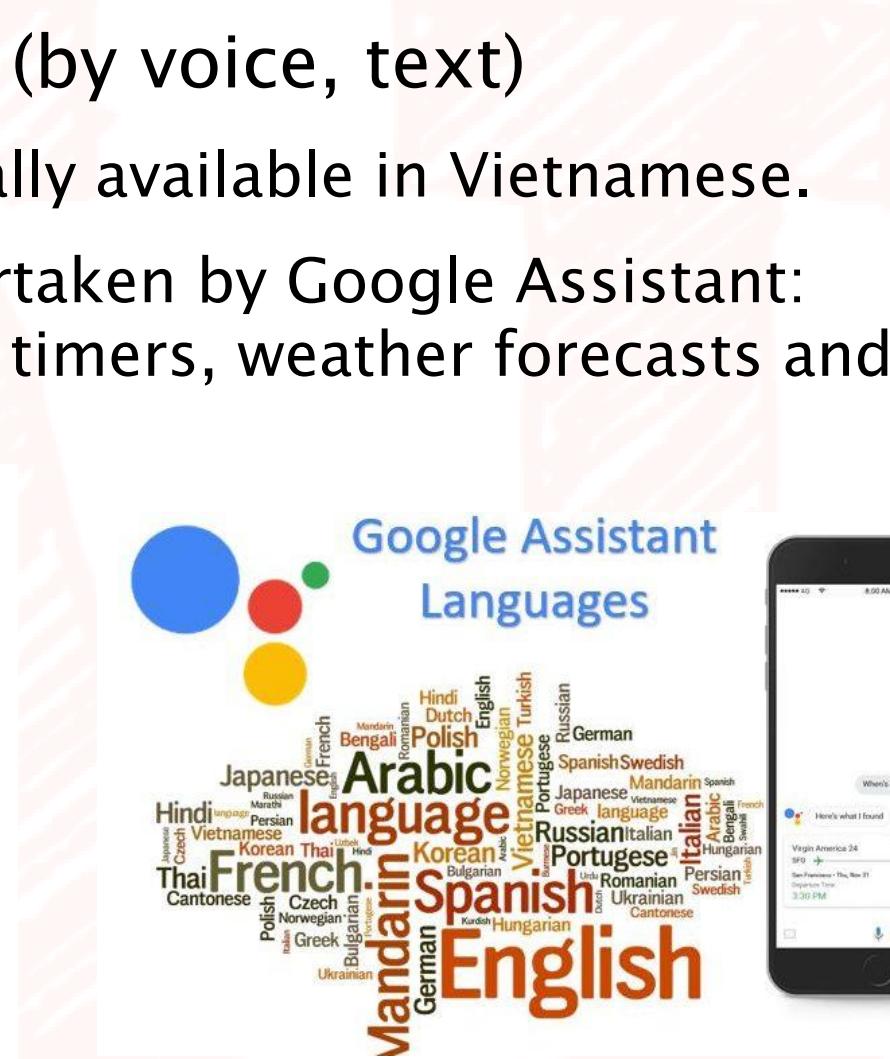
- ▶ PEGASUS allows users to obtain flight info and make reservations by speaking over the phone



STOA: Speech Recognition (cont.)

▶ Google Assistant: (by voice, text)

- 06/05/2019 officially available in Vietnamese.
- Tasks can be undertaken by Google Assistant: reminders, alarms, timers, weather forecasts and directions

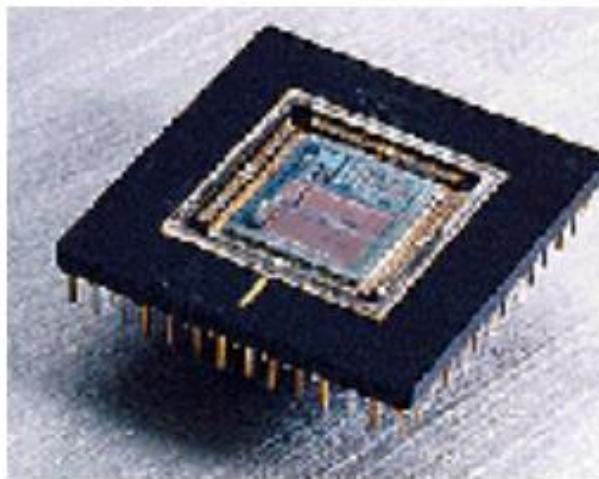


STOA: Autonomous Planning and Scheduling

- ▶ **NASA's Remote Agent program (2000):** controls the scheduling of operations for a spacecraft.
- ▶ **MAPGEN (2004):** plans the daily operations for NASA's Mars Exploration Rovers
- ▶ **MEXAR2 (2007):** logistics and science planning—for the European Space Agency's Mars Express

STOA: Game Playing – Chess

- ▶ 1997, Deep Blue (IBM) has defeated Garry Kasparov
 - won 3 games,
 - lost 2,
 - tied 1



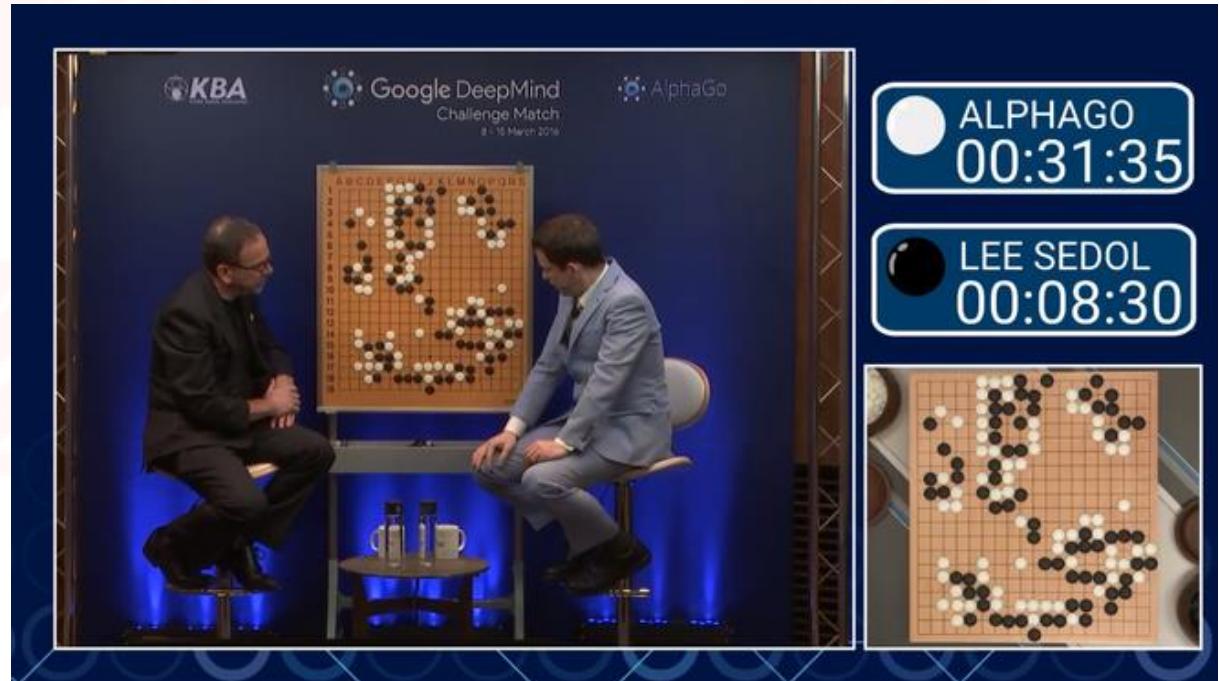
Deep Blue chip



STOA: Game Playing – Go

- ▶ 2016, AlphaGo (Deepmind, Google) has defeated Lee Sedol.

won 4 games,
lost 1



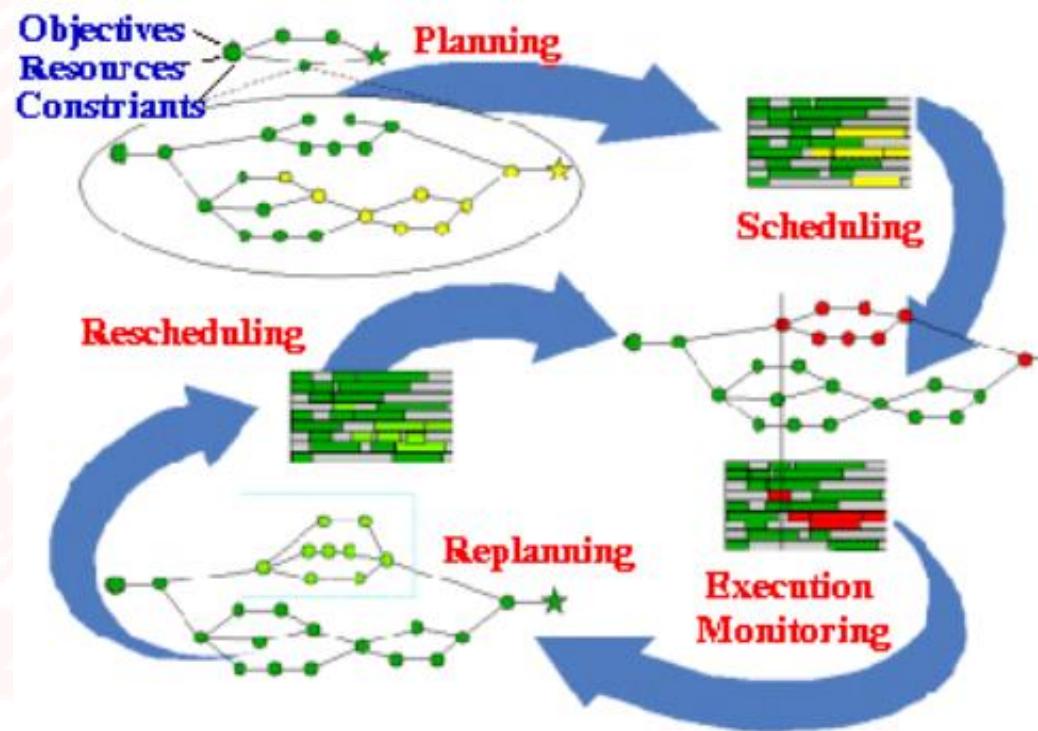
STOA: SpamFighting

- ▶ Learning algorithms classify over a billion messages as spam



STOA: Logistics Planning

- In 1991, U.S. forces deployed a **Dynamic Analysis and Replanning Tool, DART** to do:
 - automated logistics planning and scheduling for transportation.



STOA: Robotics

- ▶ iRobot Corporation: has sold millions of **Roomba** robotic vacuum cleaners



- ▶ iRobot: also deployed **PackBot** to Iraq and Afghanistan for handling:
 - hazardous materials,
 - clear explosives, and
 - identify the location of snipers.



STOA: Robotics (cont.)

- ▶ **Sophia**: a social humanoid robot
 - developed by Hong Kong based company **Hanson Robotics**.
 - activated on February 14, 2016
 - 10/2017, became a Saudi Arabian citizen – the first robot to receive citizenship of any country



STOA: **Robotics** (cont.)

▶ Industrial robots

- Robots are used in manufacturing to take on repetitive tasks, which streamlines the overall assembly workflow



STOA: Robotics (cont.)

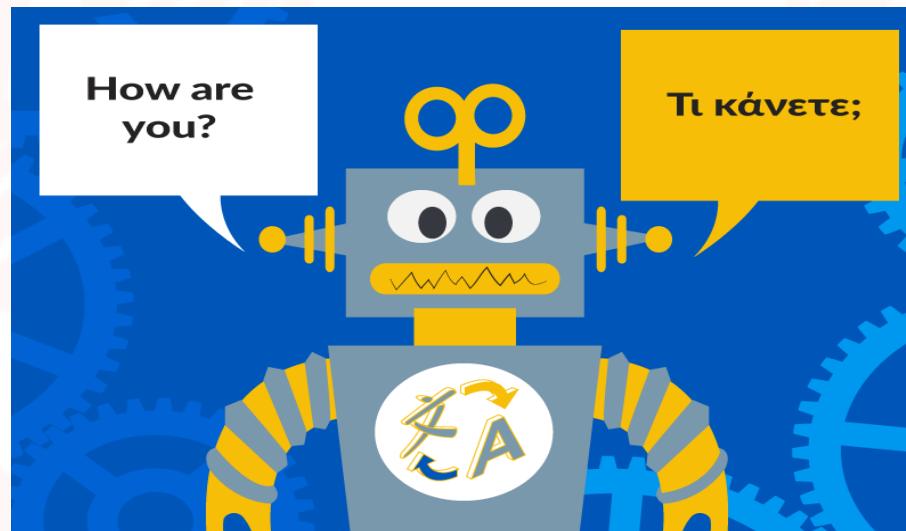
- ▶ Japanese robot OriHime: can work in the home and hospital
- ▶ OriHime is not an AI-robot.
 - This little machine's job is to connect people who are apart from each other, creating the feeling that the person is right there with you.



Kentaro Yoshifiji

STOA: Machine Translation

- ▶ Brants et al., 2007: developed a computer program automatically translates from Arabic to English



STOA: Computer Vision



- ▶ Face recognition programs:

- banks, casinos, police



- ▶ CMU's ALVINN:

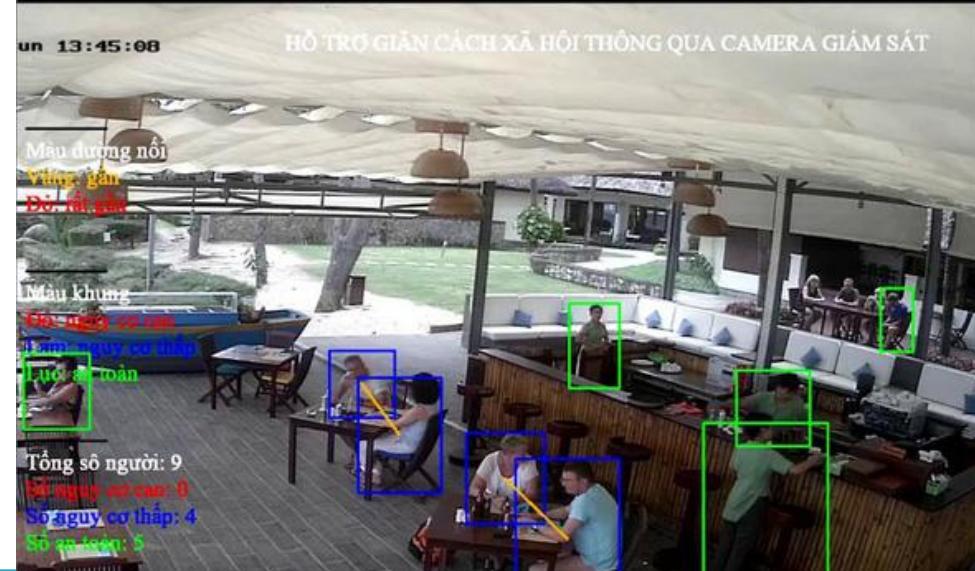
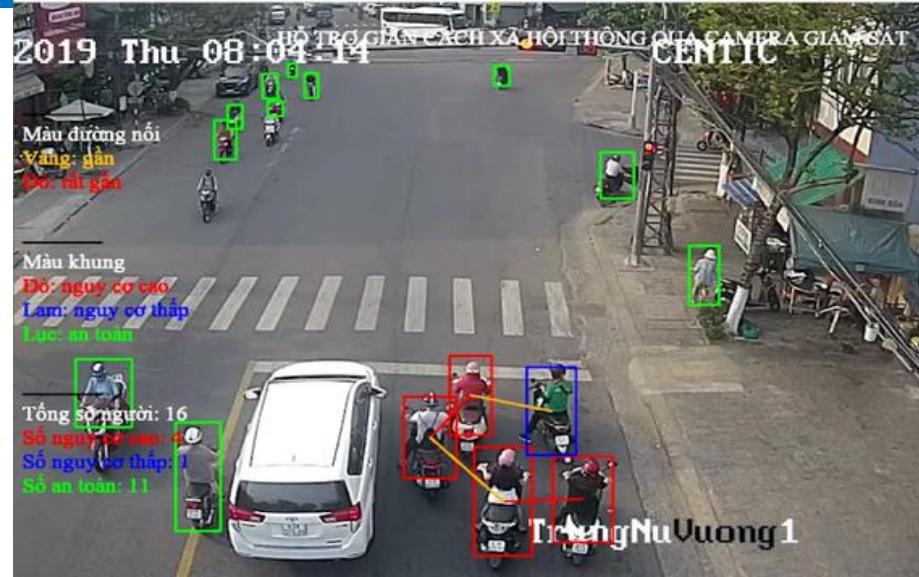
- autonomously drove a van from Washington, D.C. to San Diego, averaging 63 mph day and night, in all weather conditions



- ▶ Handwriting recognition, electronics and manufacturing inspection, photo–interpretation, baggage inspection, etc.

STOA: Computer Vision (cont.)

- ▶ A monitoring system for ensuring safe distance in COVID-19 pandemic (by MMLab, VNU-HCM)



<http://mmlab.uit.edu.vn/>

STOA: Computer Vision (cont.)

- ▶ Information Extraction from ID Cards by FPT.AI (accuracy up to 99%)



STOA: Computer Vision (cont.)

- ▶ **PhotoSolver** developed by GotIt (2018, Tran Viet Hung , VN)

The screenshot shows the PhotoSolver app interface. On the left, there is a camera viewfinder with a yellow shutter button at the bottom. Below it is a button labeled "Tap here to view a demo". The main area displays handwritten mathematical steps:

- $\int_0^1 2x^2 - x \, dx$
- $\sin x - \cos 2x = 0$
- $\lim_{n \rightarrow 0} \frac{1}{n+1}$
- $\int_1^2 \frac{x^4 + x^3 + 3x^2 + 2x - 2}{x^2 + x} \, dx$

On the right, the app provides a step-by-step solution with AI interactions:

- Step 2:** Integrate the sum term by term and
 $= \int \frac{1}{x+1} \, dx + \int x^2 \, dx - 2 \int \frac{1}{x} \, dx + 3 \int 1 \, dx$
Does this make sense?
Yes No
- Step 3:** For the integrand $\frac{1}{x+1}$, substitute $u = x+1$:
 $= \int u^{-1} \, du + \int x^2 \, dx - 2 \int \frac{1}{x} \, dx + 3 \int 1 \, dx$
Does this make sense?
Yes No
- Last Step:** Substitute back for $u = x+1$
Answer: $\frac{x^3}{3} + 3x - 2\log(x) + \log(2)$
Does this make sense?
Yes No

Text boxes on the right provide additional context:
The integral of 1 is x
 $= \log(u) + \frac{x^3}{3} + 3x - 2\log(x) + \text{constant}$
Does this make sense?
Yes No

Feedback at the bottom right:
Awesome. Step by step explanations are the best.
Did you find this helpful?
Yes No

STOA: Computer Vision (cont.)

▶ NLUMath



A screenshot of the NLUMath app showing handwritten mathematical equations:
$$\begin{cases} 2x - 3y = 5 + 6x \\ 8y + 6 = -x + 9y \end{cases}$$

2x-3y=5+6x;8y+6=-x+9y

Giải

GIẢI

Giải hệ phương trình:

$$\begin{cases} 2x - 3y = 5 + 6x \\ 8y + 6 = -x + 9y \end{cases}$$

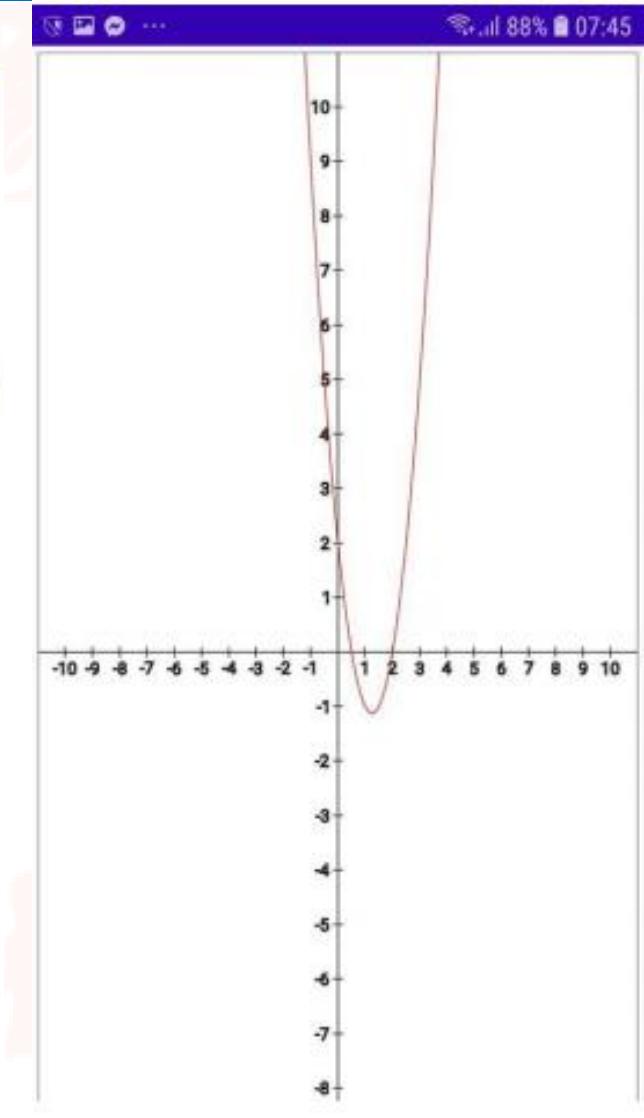
Sắp xếp lại hệ phương trình, ta được như sau:

$$\begin{cases} 2x - 3y = 6x + 5 \\ 8y + 6 = -x + 9y \end{cases}$$

Thu gọn hệ phương trình, ta được:

$$\begin{cases} 2x - 3y = 6x + 5 \\ 8y + 6 = -x + 9y \end{cases}$$

Chuyển biến sang trái, chuyển số tự do sang phải, kết hợp đổi dấu ta được:



STOA: Natural Language Chatbots

▶ Auditory:

- Siri (Apple)
- Google Assistant (Google)
- Cortana (Microsoft)
- **Kiki (Zalo , VN)**

▶ Textual:

- personal stylist (Sephora)
- order pizza (Dominos Pizza)
- Fashion- ecommerce- chatbots (H&M)

▶ ALICE: 2004 Loebner Prize winner

- Loebner Prize gold medal, awarded annually to best AI program

▶ ELIZA: psychotherapist

▶ Valerie: CMU (Carnegie Mellon University) Robot Receptionist



(ALICE) Pandorabots

Jerry: my name is jerry.

ALICE: Hey jerry.

Jerry: Do you know Turing?

ALICE: A brilliant and tragic figure in the history of computer science.

Jerry: Who else do you know?

ALICE: Hugh Loebner, Robby Garner, and Steven Spielberg

Jerry: Which film do you like?

ALICE: My favorite movie is Teknolust. Have you seen it?

Jerry: No.

ALICE: I would recommend you check it out.

Jerry: What is it about?

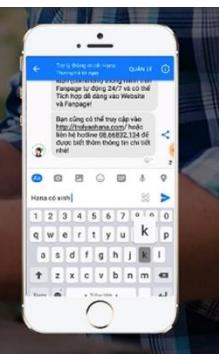
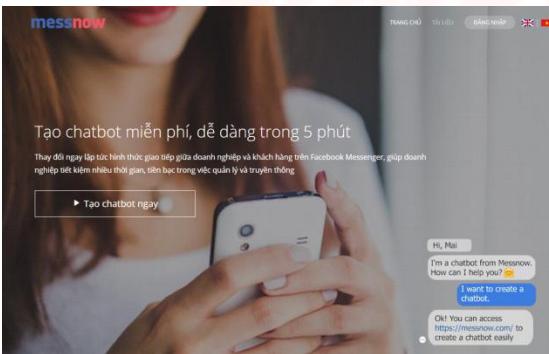
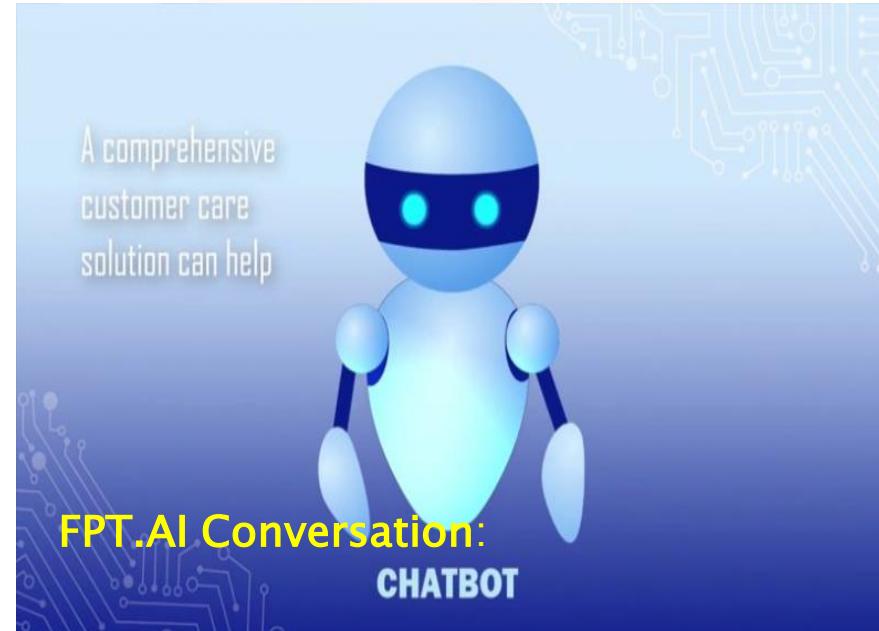
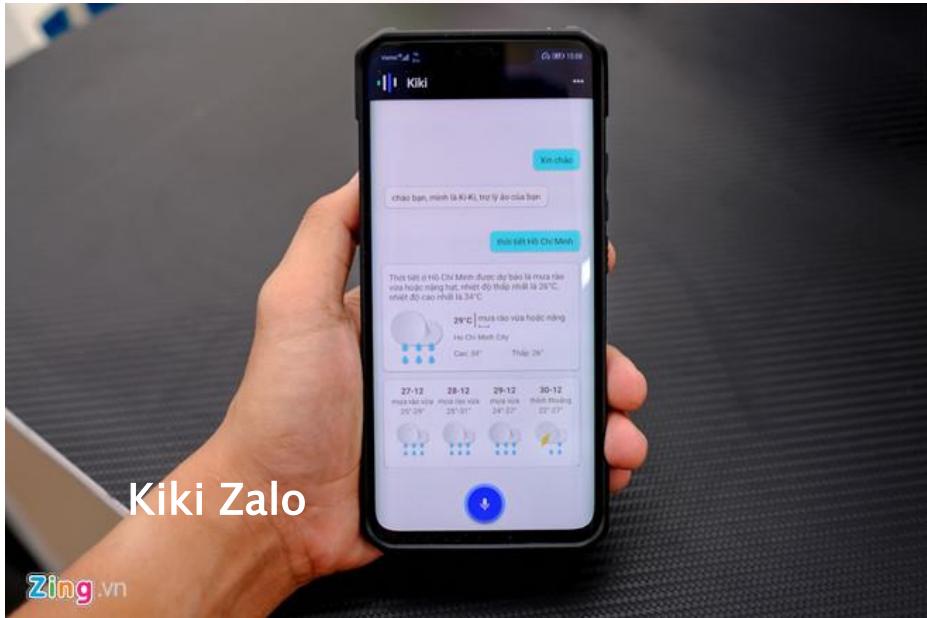
ALICE: Science fiction.

Jerry: Do you remember my name?

ALICE: Your name is jerry, seeker.

<https://home.pandorabots.com>

Chatbots



Chatbot (cont.)

H&M Chatbot



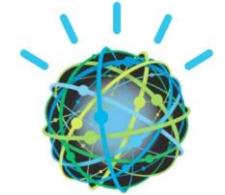
“Smart virtual lawyer”
in the legal industry



Lĩnh vực chăm sóc sức khỏe

▶ IBM Watson:

- Responses to natural language questions
- Cho phép bệnh nhân có thể tra cứu tình hình khỏe
- Có thể duyệt cùng lúc hàng triệu hồ sơ bệnh án (trong vài giây) → cung cấp cho bác sĩ những lựa chọn điều trị



IBM WATSON

▶ Chatbot:

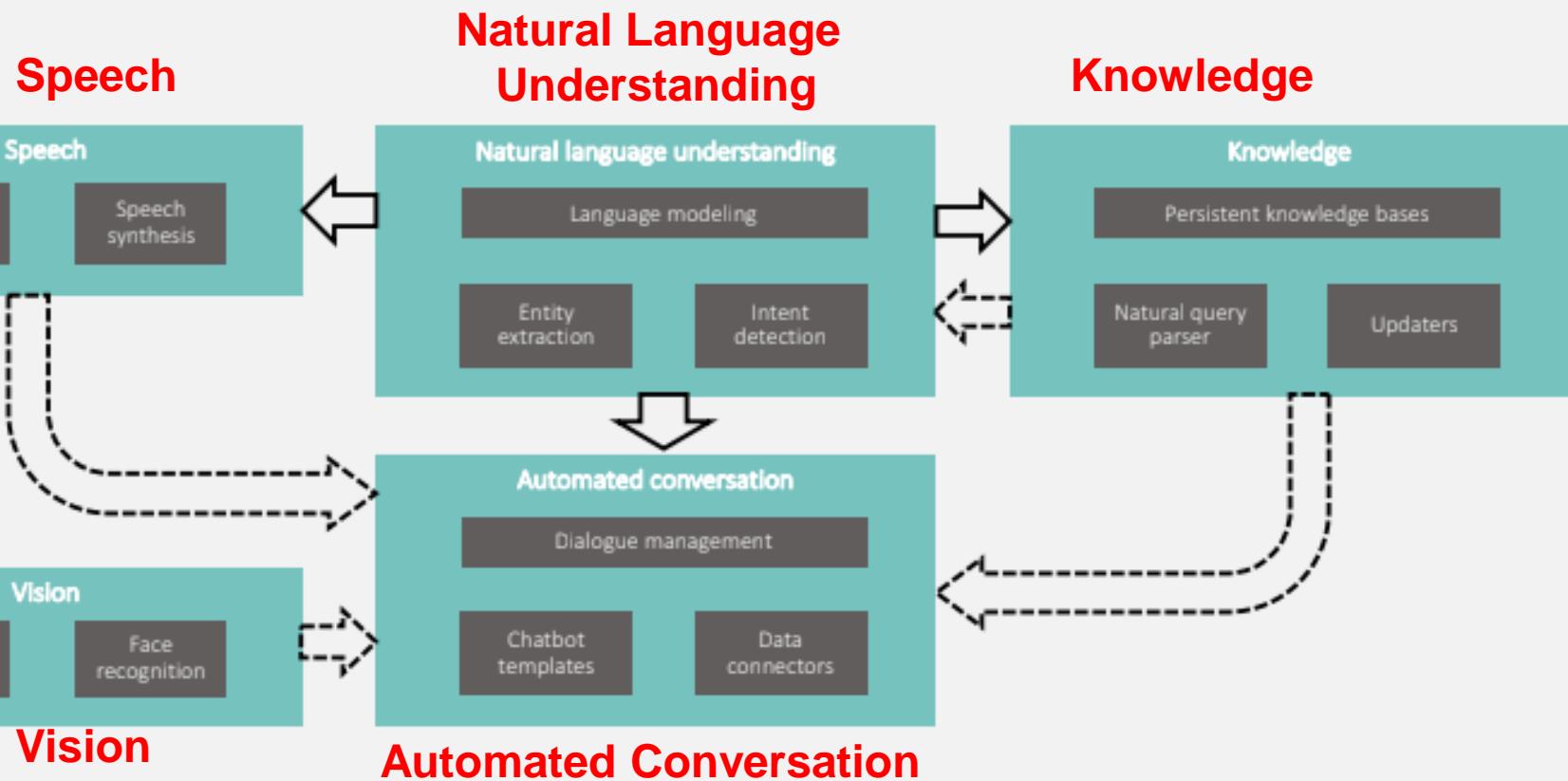
- Trả lời câu hỏi trực tuyến và hỗ trợ khách hàng
- Sắp xếp cuộc hẹn



<https://genk.vn/viet-nam-thi-diem-cong-nghe-tri-tue-nhan-tao-cua-ibm-trong-dieu-tri-ung-thu-2017121215292938.chn>

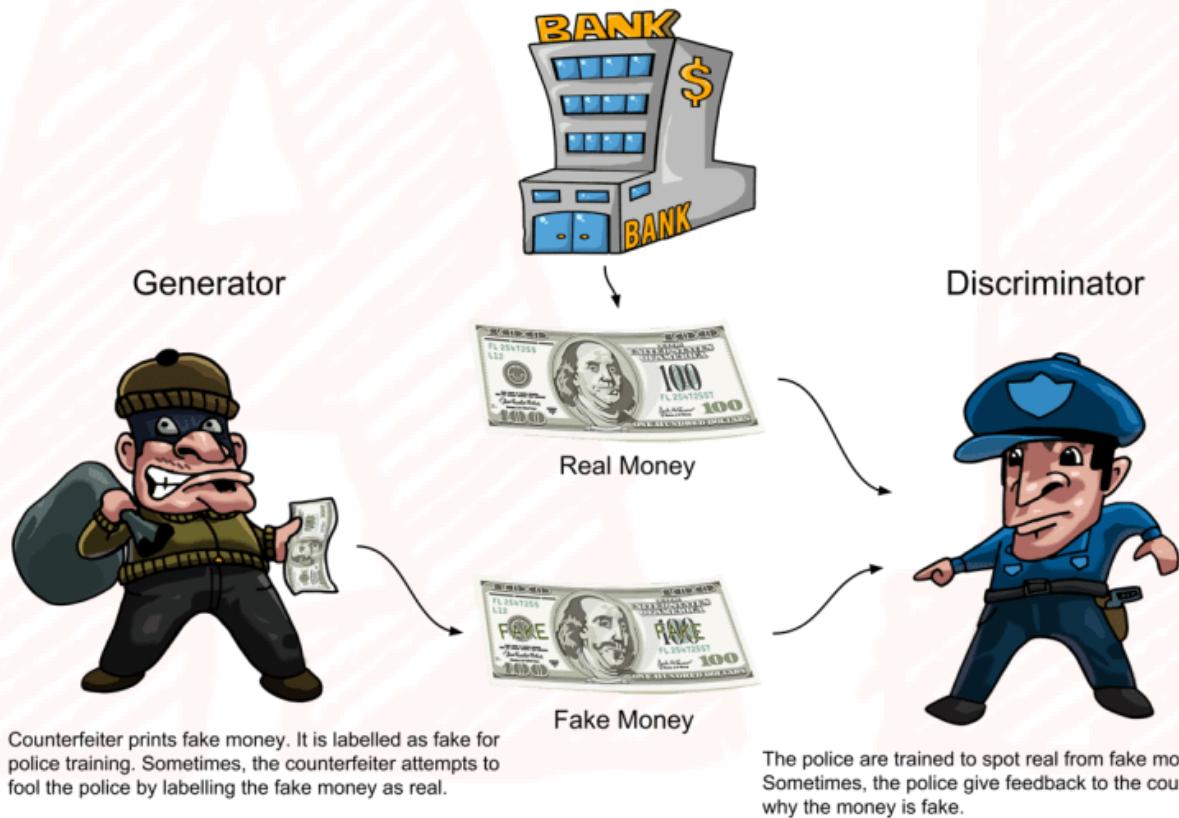
FPT.AI Architecture

FPT.AI

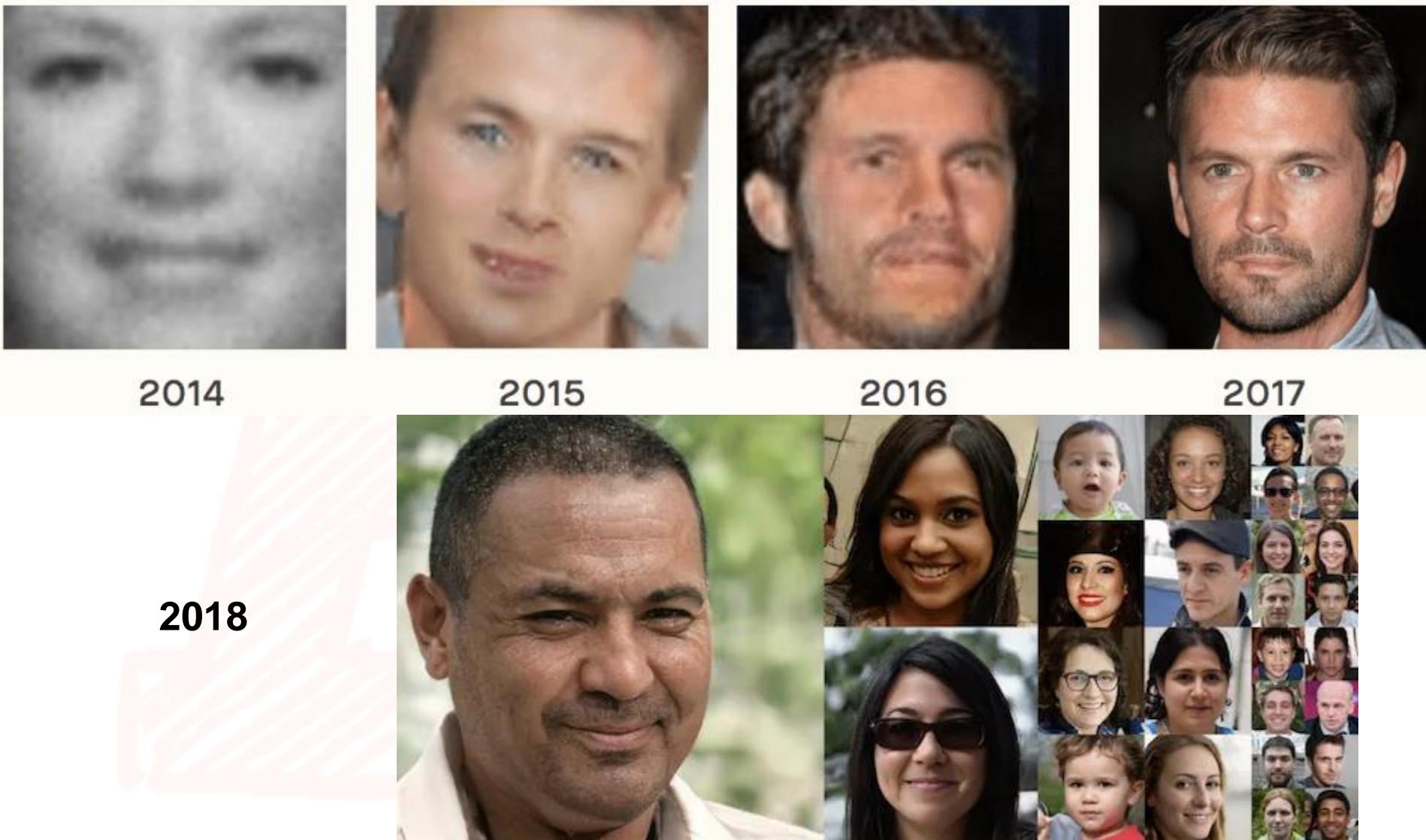


GAN: Generative Adversarial Networks

- ▶ GAN: learn to model the input distribution by training two competing (and cooperating) networks called **generator** and **discriminator**



GAN (cont.)



GAN (cont.)

- ▶ Generate Anime characters



GAN (cont.)

► Text to image

(a) Stage-I
images

This bird has a yellow belly and tarsus, grey back, wings, and brown throat, nape with a black face



This bird is white with some black on its head and wings, and has a long orange beak



This flower has overlapping pink pointed petals surrounding a ring of short yellow filaments



(b) Stage-II
images



GAN (cont.)

► Music generation



(a) MidiNet model 1



(b) MidiNet model 2



(c) MidiNet model 3

Figure 3. Example result of the melodies (of 8 bars) generated by different implementations of MidiNet.

MidiNet: A Convolutional Generative Adversarial Network for Symbolic-domain Music Generation

Large Language Model

- ▶ **Large Language Model (LLM):**
 - a type of **artificial intelligence algorithm**
 - applies **neural network techniques with lots of parameters** to process and understand human languages or text using self-supervised learning techniques
 - uses **deep learning-based Models** like **transformers** that include lakhs of parameters in their architecture which help **to create better results on the NLP tasks**

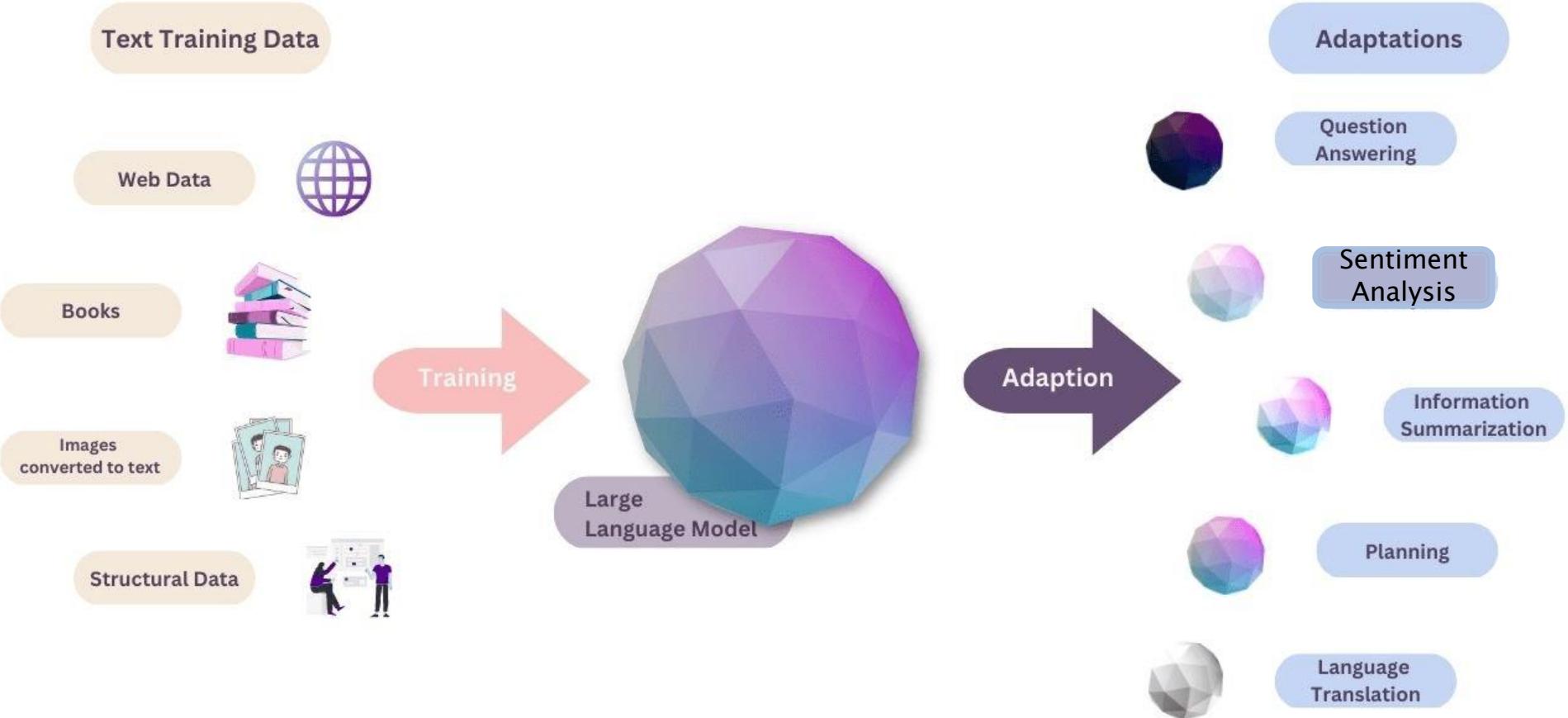
Large Language Model (cont.)

► Applications of LLM:

- text generation, machine translation, summary writing, image generation from texts, machine coding, chat-bots, Conversational AI
- Examples: **Chat GPT** by open AI, **BERT** (Bidirectional Encoder Representations from Transformers) by Google

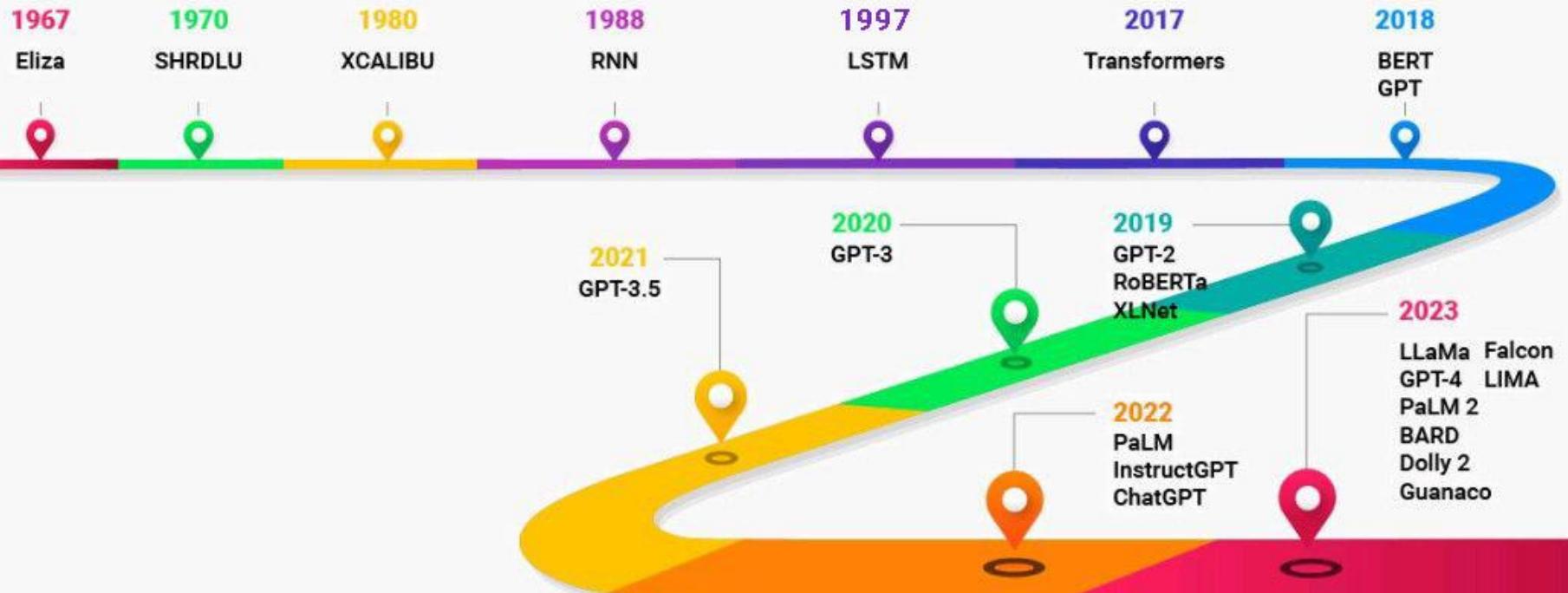


Large Language Model (cont.)

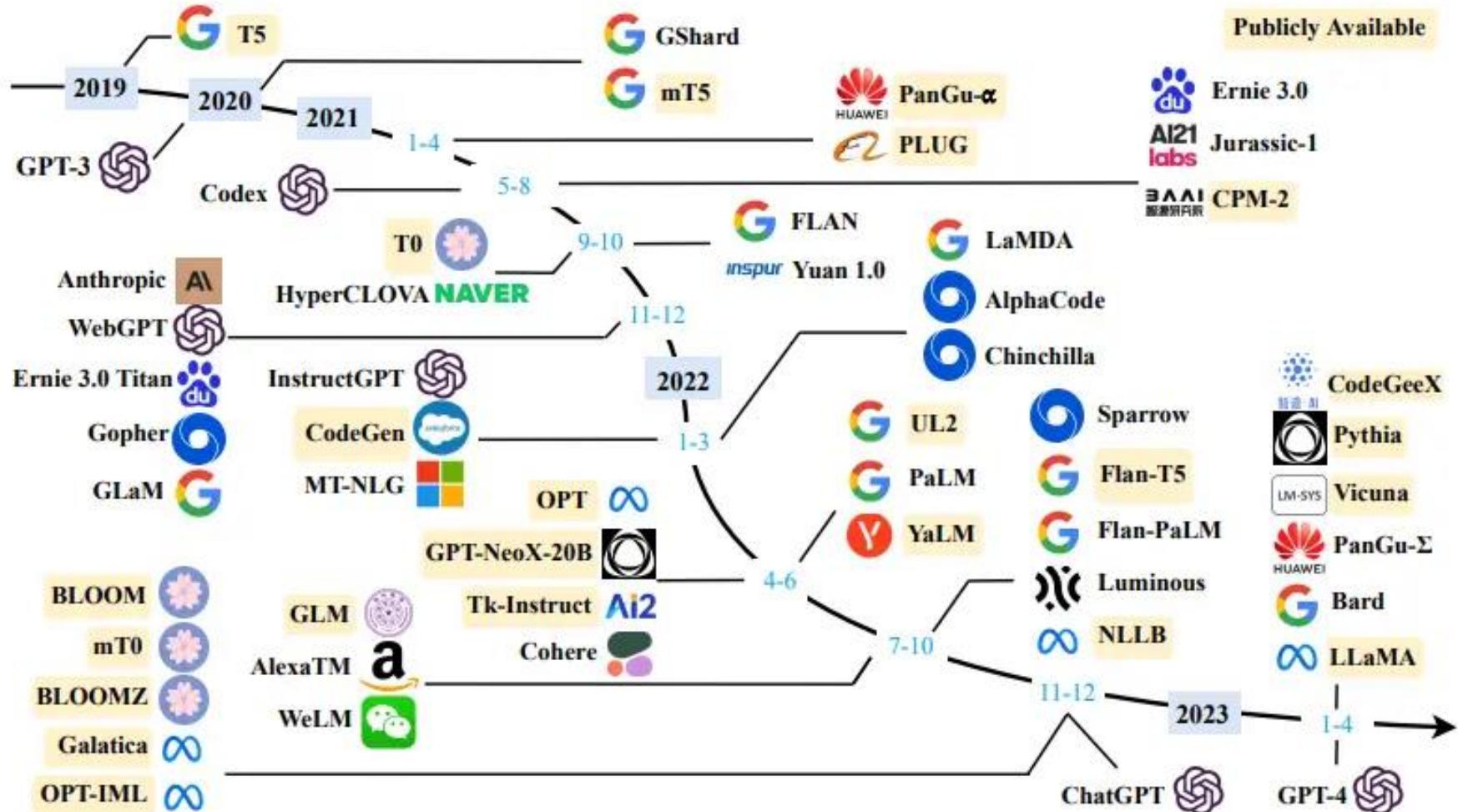


History of Large Language Models?

Evolution of Large Language Models



Timeline History of Large Language Models



Difference between NLP and LLM

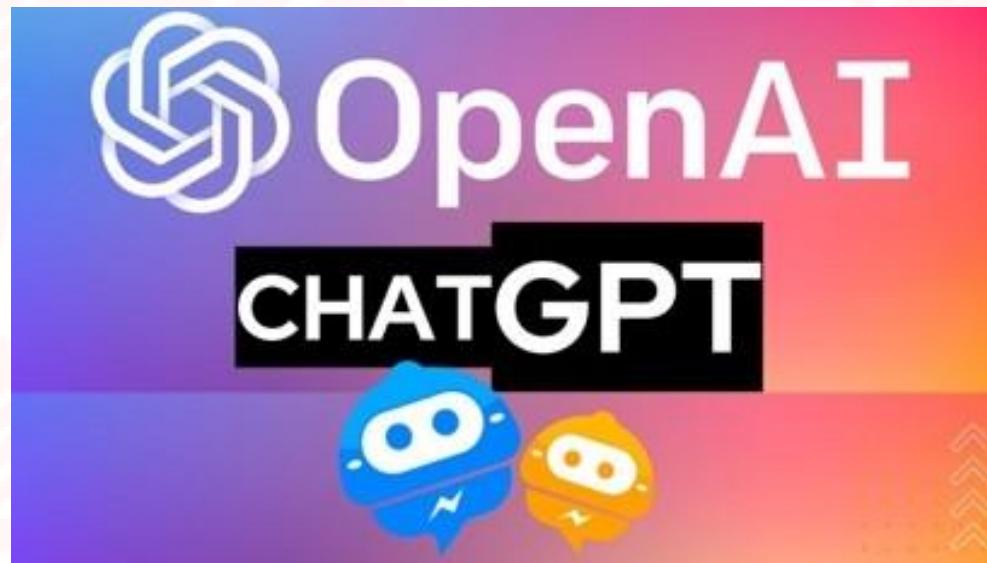
- ▶ NLP (Natural Language Processing):
 - a field of artificial intelligence (AI)
 - consists of the development of the algorithms, techniques
 - **NLP is a broader field than LLM**
- ▶ Applications of NLP:
 - Automotive routine task
 - Improve search, search engine optimization
 - Analyzing and organizing large documents
 - Social Media Analytics
- ▶ LLM (*remind*):
 - A Large Language Model, and
 - is more specific to human-like text, providing content generation, and personalized recommendations



ChatGPT

▶ ChatGPT:

- a **deep learning language model**
- developed by OpenAI,
- which is capable of **generating human-like text** based on the input provided



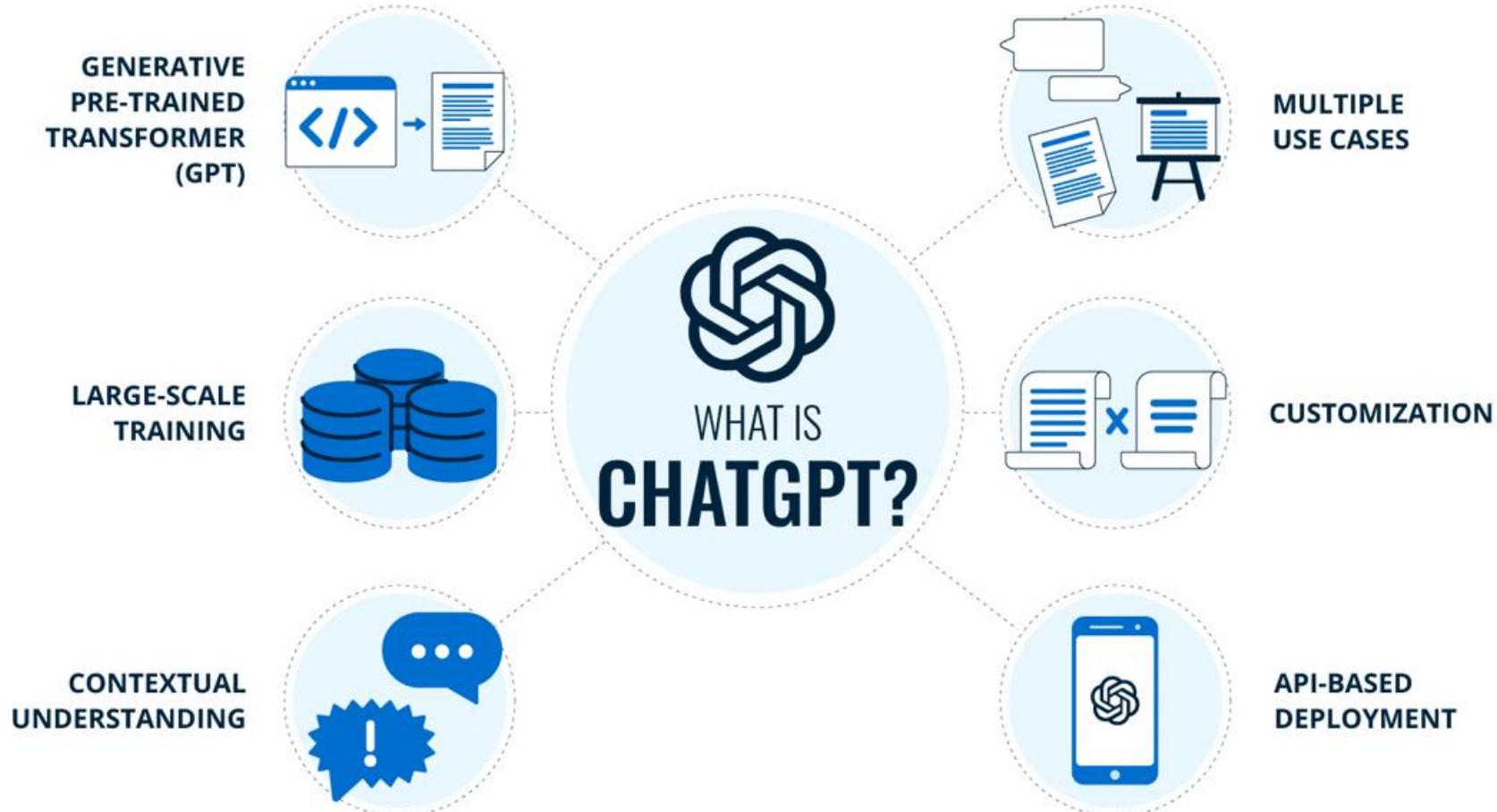
ChatGPT (cont.)

- ▶ The main features of ChatGPT include the following:
 - **Generative Pre-trained Transformer (GPT)**: a cutting-edge, AI-based text generation model that utilizes **transformer architecture** to create linguistically similar text to human writing
 - **Large-scale training**: was trained on a massive dataset consisting of over 45 terabytes of text data
 - **Contextual understanding**: can model various conversational scenarios using its powerful language modeling and natural language processing capabilities

ChatGPT (cont.)

- ▶ The main features of ChatGPT include the following:
 - **Multiple use cases:** used for various natural language processing tasks, including question answering, text generation, dialogue generation, and text classification, among others
 - **Customization:** can be customized and fine-tuned to the specific requirements of any user or domain
 - **API-based deployment:** can be easily integrated into applications through its API,
 - allowing developers to build custom applications that leverage the power of deep learning for text generation.

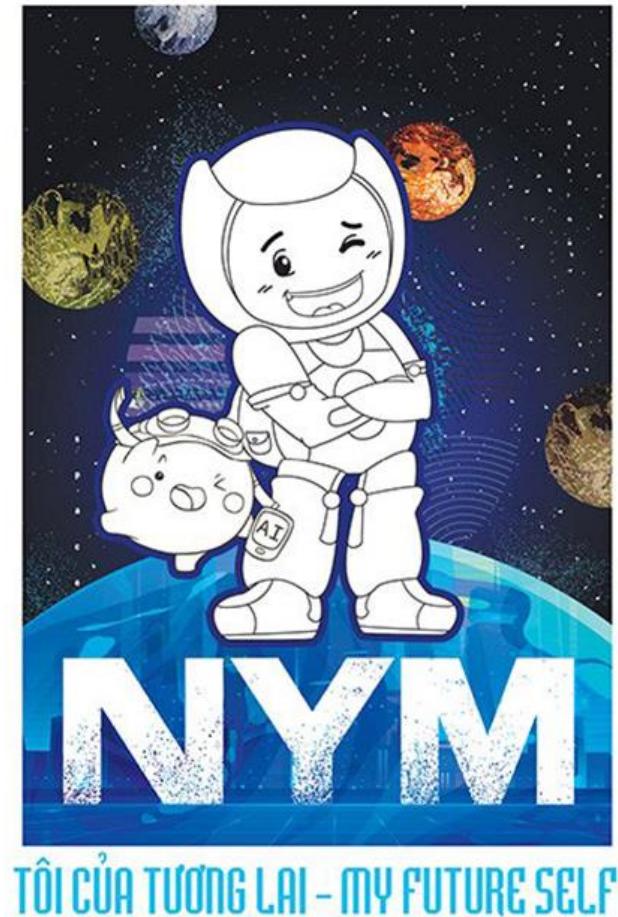
ChatGPT (cont.)



AI for Writing

- ▶ **Nym**: AI do Nguyễn Phi Vân xây dựng trong hơn ba năm, được nạp dữ liệu về ngôn ngữ, kiến thức đời sống.
 - AI đã nói chuyện trực tiếp, một – một với 11 triệu người trẻ Việt trên facebook để thu thập thông tin.
 - **Nym – Tôi của tương lai** – quyển sách con người và AI hợp tác viết.

Một cuốn sách của NGUYỄN PHI VÂN



AI news anchor

- ▶ 3 AI news anchors appeared on Indonesian television



AI singer

▶ Ann:

- developed by Bobo Đặng, 3/2023
- MV "Làm sao nói thương anh"



Some AI "Grand Challenge" Problems

- ▶ Intelligent Agents
- ▶ Smart Clothes
- ▶ Aids for the Disabled
- ▶ Tutors
- ▶ Accident-avoiding Vehicles
- ▶ Self-Organizing Systems
- ▶ Translating Telephone Conversations
- ▶ Extracting and representing information from lots of data
 - Neural networks, hidden Markov models,
 - Bayesian networks, heuristic search, logic, ...

Issues for AI Problems



Fundamental Issues for AI Problems

- ▶ Representation

- ▶ Search

- ▶ Inference

- ▶ Learning

- ▶ Planning



Representation

Facts about the world are remembered:

- ▶ How do we **represent facts**?
- ▶ What should we store?
- ▶ How do we structure this knowledge?
- ▶ What is explicit? What is inferred?
- ▶ How are **inference rules** encoded?
- ▶ How should **inconsistent, incomplete**, and **probabilistic knowledge** be dealt with?

Representation (cont.)

▶ Example:

“The fly buzzed irritatingly on the window pane”.

“Jill quickly picked up a newspaper”.

▶ What is the inference?

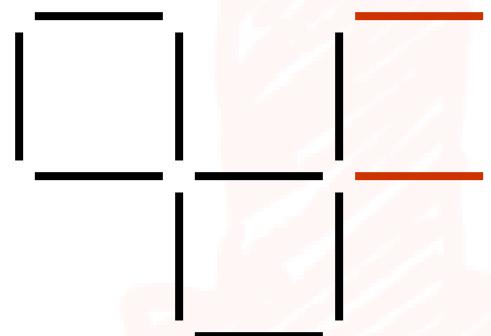
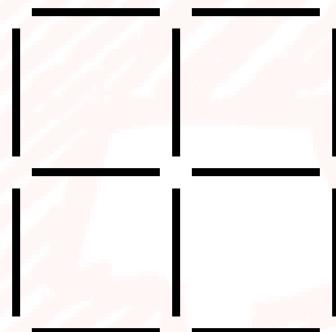
- Jill is going to start a fire?
- Jill is going to start a papier mache project?
- Jill is going to exterminate the fly?



Representation (cont.)

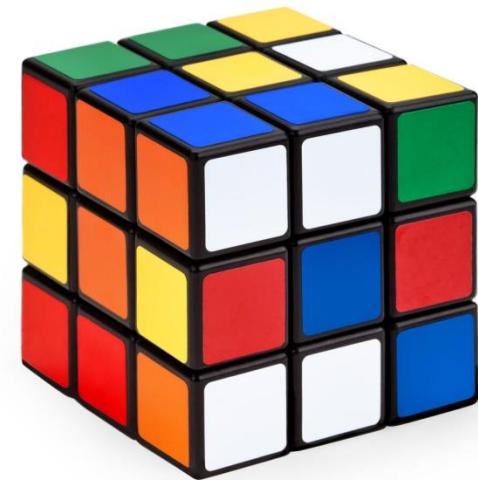
▶ Example:

"Given 12 sticks in a 2 by 2 grid, move 3 to leave exactly 3 boxes."



Search

- ▶ A problem space is searched for a solution
 - Checkers: 10^{40} states
 - Chess: 10^{120} states
 - Tic-Tac-Toe: 3^9 states
 - Rubik's Cube: 10^{19} states
- ▶ How do **limit the search space**?
- ▶ How do we find an **optimal solution**?
- ▶ How are **heuristics** and **constraints** used?



Inference

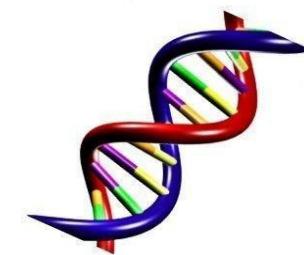
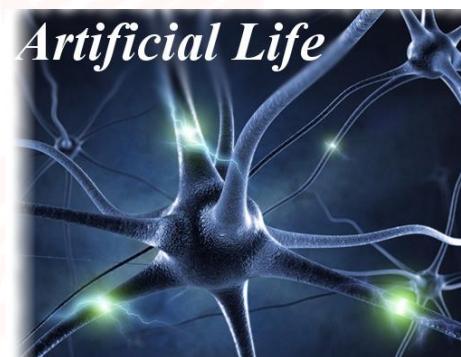
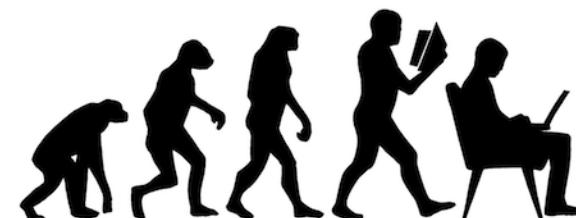
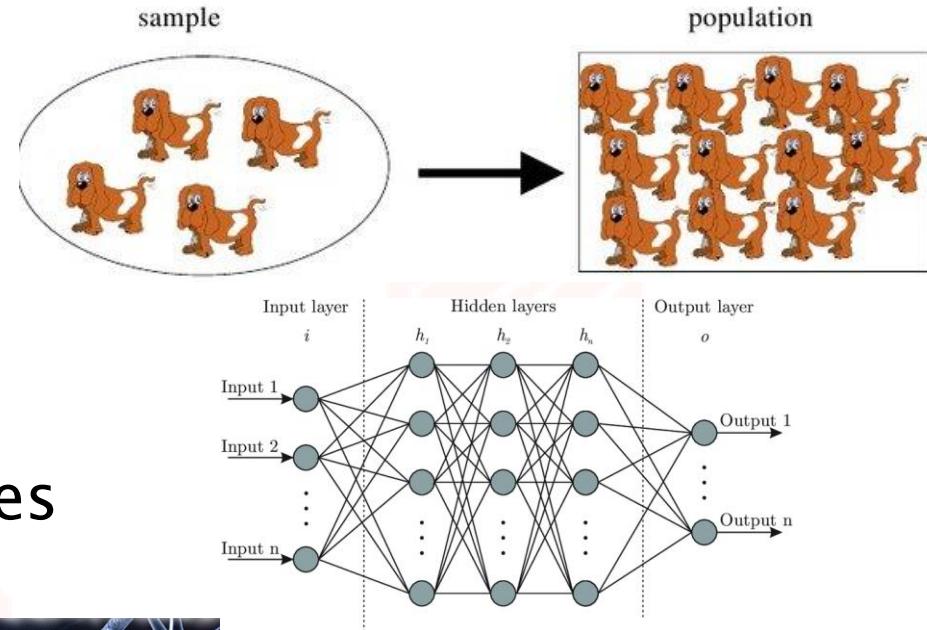
- ▶ New facts are determined from a set of existing facts
 - deduction
 - abduction non-monotonic reasoning
 - reasoning under uncertainty
- ▶ Example: All elephants have trunks. Clyde is an elephant.
 - 👉 Does Clyde have a trunk?
 - 👉 Willy has a trunk. Is Willy an elephant?



Learning

► New knowledge is acquired:

- inductive inference
- neural networks
- genetic algorithms
- artificial life
- evolutionary approaches



Planning

A strategy for achieving a goal in terms of a sequence of primitive actions is generated

- ▶ What general facts about the world are needed?
- ▶ What facts about the specific situation are needed?
- ▶ What facts are needed about the effects of actions?
- ▶ How do you state the goal?
- ▶ How do you know the goal has been reached?



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