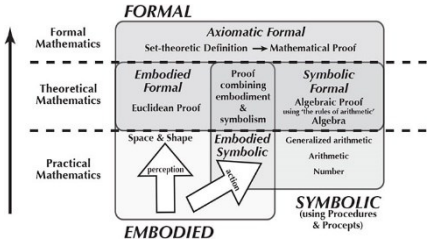
# Lecture 1 : History of AI and ML

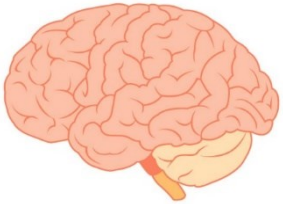
# Topics of this lecture

- History of AI and machine learning
  - Period for preparation
    - From “chaos” to “shape”
    - From “heart” to “brain”
    - From “analog” to “digital”
  - One wave after another
    - First wave: Inference with given knowledge
    - Second wave: Learning with given data
    - Third wave: Environment for learning
    - Fourth wave: Beyond human

# History of AI and ML

- AI was "prepared" a long time ago
  - From "chaos" to "shape"
    - Meta-mathematics: mathematics of mathematics.
  - From "heart" to "brain"
    - Cybernetics: Brain map, general system theory, neuron models.
  - From "analog" to "digital"
    - Boolean algebra
    - Computing machine
- Around 1960:
  - First wave of AI
  - Inference: **Given knowledge, "I" (AI) can make decisions like a "MAN".**



ZHAO's Law: A new wave comes
in about 1.5 generations (About 30 years)!

# History of AI and ML

- Around 1990:
  - Second wave of AI
  - Learning: **Given data, "I" can learn like a "MAN".**
- Around 2020:
  - Third wave of AI
  - Cyber-space: **Given the internet, "I" can collect data and learn in a way different from "MAN".**
- Around 2050:
  - Fourth wave of AI
  - Super AI: **Nothing needed from MAN. "I" can do everything myself.**

# From “chaos” to “shape”

- Formal mathematics is the theoretic foundation of digital computer and AI.
- Mathematics originated from Euclid around 300 BC.
- In the 19 century, mathematicians began to question about the “safety” of mathematics, and as a result, meta-mathematics was proposed around 1900 (e.g. The Principia Mathematica written by Alfred North Whitehead and Bertrand Russell).

Assumption: For any mathematics system, there exists an axiom system (not necessarily the smallest), so that all statements can be proved based on the axioms.

-> Impossible from Gödel's incompleteness theorem.

# Gauss and Bolyai: pioneers of pure mathematics

- Johann Carl Friedrich Gauss (1777-1855), a German mathematician, is ranked among history's most influential mathematicians. Gauss claimed to have discovered the possibility of **non-Euclidean geometries**. This discovery was a major paradigm shift in mathematics.
- János Bolyai (1802-1860), a Hungarian mathematician, discovered a consistent alternative geometry that might correspond to the structure of the universe. This discovery helped **to free mathematicians to study abstract concepts without considering the physical world**.

*(refer to Wikipedia)*

# Whitehead and Russell: pioneers of formal logic

- The **Principia Mathematica** (often abbreviated PM) is a three-volume work on the foundations of mathematics written by Alfred North Whitehead and Bertrand Russell and published in 1910, 1912, and 1913.
- PM was **an attempt to describe a set of axioms and inference rules in symbolic logic from which all mathematical truths could in principle be proven**. As such, this ambitious project is of great importance in the history of mathematics and philosophy.

*(from Wikipedia)*

# From “heart” to “brain”

- On the other hand, it was believed by Hippocrates (460–370 BC) that brain was the origin of intelligence or wisdom (that enables human to understand even mathematics).
- Unfortunately, this idea was not accepted by Aristotle (384–322 BC), and for this reason it was only from 17 and 18 centuries people began to understand that brain was the main controller of the whole body.
- Around 1900s, neuroscientists began to know more about brain through a lot experimental studies.

Around 1930s, scientists in Europe and America began to study relation between brain and intelligence, and a new field called “cybernetics” emerged.

# David Ferrier and Eduard Hitzig pioneers of neuroscience

- Eduard Hitzig (1838–1907) was a German neurologist and neuropsychiatrist. In 1870, Hitzig published a landmark paper entitled “On the Electrical Excitability of the Cerebrum” (with Gustav Fritsch), demonstrating that electrical stimulation of the cerebral cortex could produce limb movements contralateral to the hemisphere of stimulation. Their work provided hints for Richard Caton and later for Hans Berger to discover the Electro-Encephalogram (EEG).
- Sir David Ferrier FRS (1843–1928) was a pioneering Scottish neurologist and psychologist. He published “The Functions of the Brain” in 1876. His work provided hints for other scientists to build the brain map.

*(from Wikipedia)*

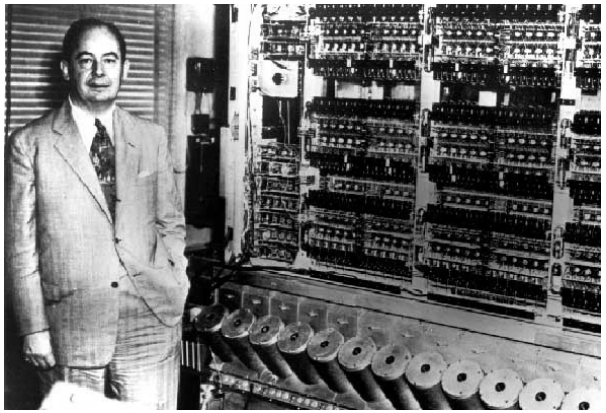
# Sherrington: knowing the brain further

- Sir Charles Scott Sherrington (1857–1952) was an English neurophysiologist. He received the Nobel Prize in Physiology or Medicine with Edgar Adrian, in 1932 for their work on the functions of neurons.
- Through his seminal 1906 publication, "The Integrative Action of the Nervous System", he had effectively laid to rest the theory that the nervous system, including the brain, can be understood as a single interlinking network. His explanation of synaptic communication between neurons helped shape our understanding of the central nervous system. -> neural network

*(from Wikipedia)*

# From analog to digital

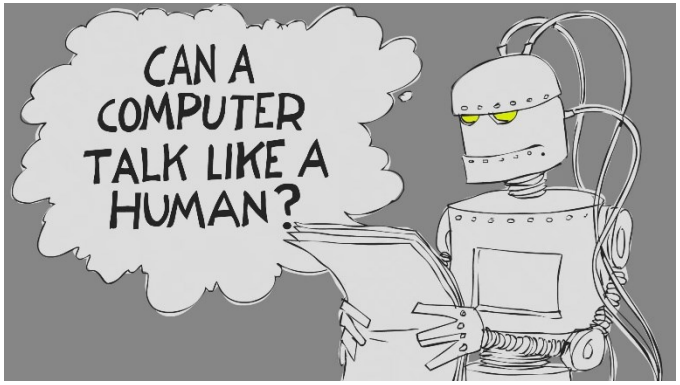
- Around 1900s, researchers began to think about “digital” technologies and theories.
- The movement from analog thinking to digital thinking started from then.
- **Digital thinking, or thinking like a machine, enables us to build simple but quick computing machines, which became digital computers later**.



http://dailynewsagency.com/2013/06/23/absurdly-massive-early-computers-ovb/

# George Boole and Alan Turing : pioneers of digital computing

- George Boole (1815-1864) was not a computer scientist. He developed the **Boolean algebra, and this has become** one of the mathematic foundations of computer science.
- Turing (1912-1954) is often considered to be the father of modern computer science. He provided an influential formalization of the concept of the algorithm and computation with the **Turing machine**.
- He also proposed the well-known **Turing test** to evaluate the "intelligence" degree of a machine.



# John von Neumann and Claude Shannon: fathers of computer & information theory

- Von Neumann (1903-1957) was a Hungarian-American mathematician who made major contributions to a vast range of fields including set theory, functional analysis, and computer science.
- The so called conventional CPU based computer was proposed by him, and he is generally regarded as one of the foremost mathematicians of the 20th century.
- Shannon (1916-2001) was an American electrical engineer and mathematician, and was "the father of information theory“.
- He is also credited with founding both digital computer and digital circuit design theory in 1937, when, as a 21-year-old master's student at MIT, he wrote a thesis demonstrating that electrical application of Boolean algebra could construct and resolve any logical, numerical relationship.

# First wave of AI

- In 1956, the term AI was proposed by John McCarthy and his colleagues in the famous Dartmouth Conference.
- This was a natural result of studies related to meta-mathematics.
  - Logic representation of knowledge
  - Formal theorem proof via logic inference
- On the other hand, computer can be considered a natural result of both meta-mathematics and cybernetics (Alan Mathieson Turing and John von Neumann).
- **Automatic decision making** became possible, provided that "knowledge" is given.
  - General problem solver (GPS)
  - Expert systems
  - Semantic network -> frame -> ontology engineering (of today)

# Allen Newell and Herbert A. Simon: first attempt to general AI

- General Problem Solver is a computer program created in 1959 by Herbert A. Simon, J.C. Shaw, and Allen Newell.
- Any problem that can be expressed as a set of well-formed formulas (WFFs) or Horn clauses, and that constitute a directed graph with one or more sources (viz., axioms) and sinks (viz., desired conclusions), can be solved, in principle, by GPS.
- GPS was the first computer program which separated its knowledge of problems (rules represented as input data) from its strategy of how to solve problems (a generic solver engine).

*(from Wikipedia)*

# Marvin Minsky: From semantic net to frame

- Frames were proposed by Marvin Minsky in his 1974 article "A Framework for Representing Knowledge."
- A frame is an artificial intelligence data structure used to divide knowledge into substructures by representing "stereotyped situations."
- Frame has been extended to ontology engineering, and is now an important research filed in AI.

*(from Wikipedia)*

# Second wave of AI

- Knowing that the bottle-neck for building an AI system is "knowledge acquisition", various machine learning algorithms have been proposed around the 1990s.
- The most notable one is neural network-based learning, which enables a computer to learn various knowledge (like a human) from data or experiences.
- However, the importance of neural network-based learning was recognized only in the late 1980s after the well-known back-propagation algorithm was re-invented.
  - This also triggered a new field called "soft computing", which includes neuro-computing, fuzzy logic, evolutionary computation.
  - Evolutionary computation have evolved to meta-heuristics later.

# Revival of neural networks

- The second wave of AI was triggered by the revival of neural networks.
- In the 1950s, Minsky proved that the "perceptron" can only solve linearly separable problems, and this brought an "ice age" of NN.
- In 1987, an efficient learning algorithm was "re-invented" by a research group in the USA, and this algorithm can train NNs for solving "any given problems".

# Revival of evolutionary algorithms

- In the 1990s, evolutionary algorithms, such as “evolutional programing”, “Evolution strategies”, were re-considered useful for solving “complex problems” more wisely.
- These algorithms have been generalized to meta-heuristics and memetic algorithms (e.g. particle swarm optimization, ant colony optimization).

# Soft computing: Natural computing and human-like computing

- On the other hand, fuzzy logic also attracted great attention in the 1990s.
- Along with neural network and evolutionary algorithms, fuzzy logic was considered the 3rd component of soft computing.
- Later, soft computing has been extended to include many different algorithms that emulate the natural phenomena or human behavior.
- These algorithms, although lack theoretic background, are often useful to solving problems that cannot be described well using existing knowledge.

# Third wave of AI

- The question is, even if we have a good learning machine and a learning algorithm, an AI located in a laboratory cannot learn knowledge needed for solving various real problems.
- Fortunately, “internet” provides an efficient way for an AI to learn many things in a virtual world (or cyber-space).
- On the other hand, deep neural network model provides an efficient way for learning various knowledge.

General purpose AI becomes possible when DNN is used to learn, and internet is used to provide the learning environment.

# Modern AI was Supported by Many Technologies

- Internet and communication in general are the main supporters of AI.
- IoT along with sensor networks around the world provide a way to get data from the real world, automatically and autonomously.
- Cloud computing provides an infrastructure for managing a large scale databases.
- Data analytics (bid data technology) provides a way for using all sorts of data efficiently.

# Fourth wave of AI

- AI is living in the virtual world as a “soul”.
  - It can “see” the real world from data obtained from the sensors;
  - It can learn and know everything by just staying inside the virtual world; and
  - It can make decisions and control the real world through various actuators (including human operators).
- AI works in a similar way as the soul inside the brain.
  - It can become It can be good if we input “good” data, and it can be evil if we input “bad” data.
  - After all, what is good and evil? From human standard, or from a point of view of God?

# Homework

- Write a short (less than 500 words) report entitled “Without XXX, modern AI will not be possible”, where, XXX can be a “technology” or a “person”.
- You should cite all references you used in writing your report. This is a good habit for you in the future to write your thesis/papers.