INDIAN INSTITUTE OF INFORMATION TECHNOLOGY

# Basic Artificial Intelligence


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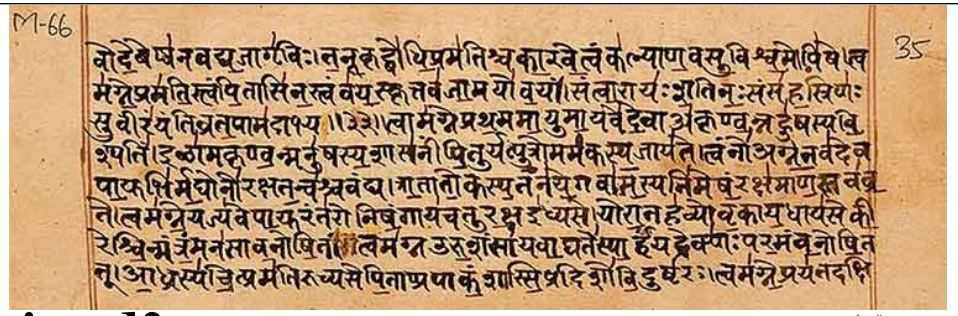
PDPM
Indian Institute of Information Technology, Design and Manufacturing, Jabalpur

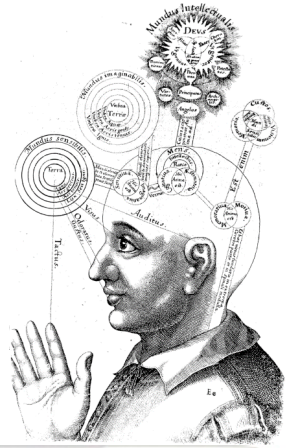
The Alan Turing Institute

# History and Definitions of AI

# Vedas on AI

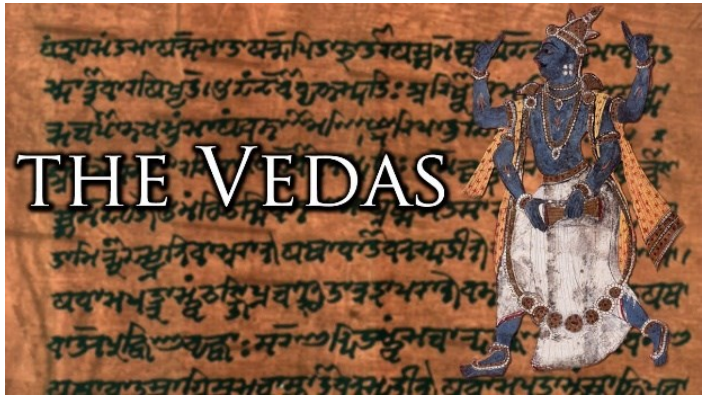


**How Ancient Human's Neural Network got trained?**



- Its origin in Vedas, Multi-Layers of Intelligence is following Sanskrit words
- **Dhi** (धी) meaning 'understanding', 'reflection', 'religious thought', 'mind', 'design', 'intelligence', 'opinion', 'meditation', 'imagination', 'notion', and 'intellect'
- **Dhṛti** or **Dhriti** or **Dhruti** (धृति) one of the Yamas (right living and ethical rules),
  - 'act with determination' (Bhagavad Gita Sl. XVIII.26),
  - 'patience' (Srimad Bhagavatam Sl. V.v.10-13),
  - 'firmness', 'perseverance', and 'wearing regularly' (Caitanyacaritamrita Madhya Sl. XXIV.11, Madhya Sl. XXIV.174, Madhya XXIV.333).
  - 'to bear', 'fortitude' and 'determination'
- **Smriti** (Remembered Knowledge), & **Shruti** (Heard Knowledge)
- **Vac** (वाच) Speech

# Vedas on Speech and Language

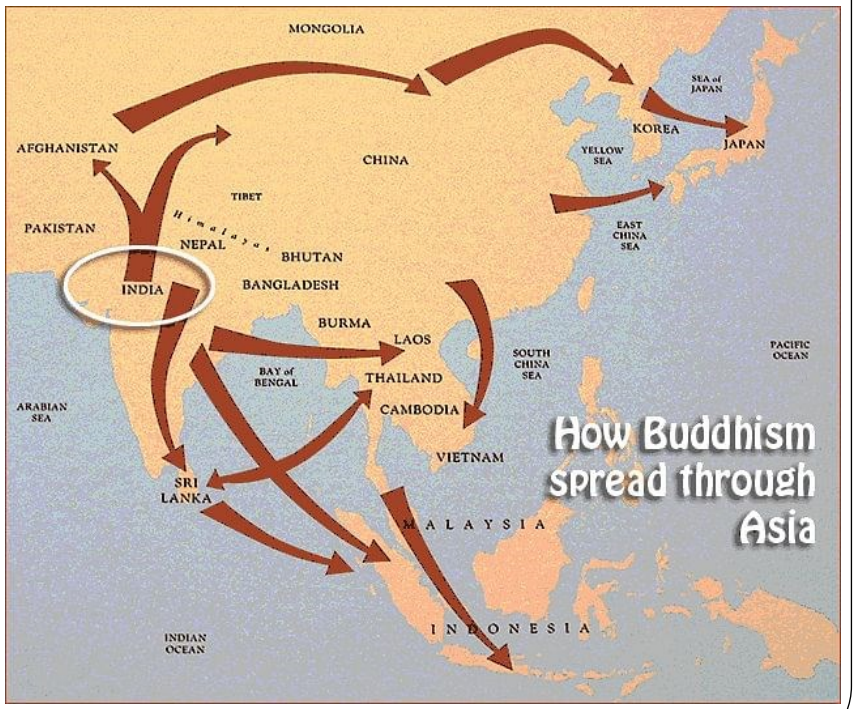



**How Ancient Human's Neural Network got trained?**

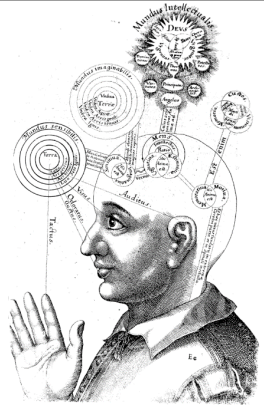
- *Patha:* means Path (English) and Marg (Hindi)
- *Samhita-patha*: continuous recitation of Sanskrit words bound by the phonetic rules of euphonic combination;
- *Pada-patha*: a recitation marked by a conscious pause after every word, and after any special grammatical codes embedded inside the text;
- *Krama-patha*: a step-by-step recitation where euphonically-combined words are paired successively and sequentially and then recited;
  - For example: a hymn would be recited as "word1word2 word2word3 word3word4 ….";
  - This method to verify accuracy is credited to Vedic sages Gargya and Sakalya in the Sanatan tradition and mentioned by the ancient Sanskrit grammarian Panini (dated to pre-Buddhism period);

# Vedas on Speech and Language

- *Krama-patha* modified: the same step-by-step recitation as above, but without euphonic-combinations (or free form of each word);
  - this method verifies accuracy by Vedic sages Babhravya and Galava in the Hindu tradition, and mentioned by the ancient Sanskrit grammarian Panini;
- *Jata-pāṭha*, *dhvaja-pāṭha* and *ghana-pāṭha* are methods of recitation of a text and its oral transmission
  - developed after 5th century BCE, that is after the start of Buddhism and Jainism;
  - these methods use more complicated rules of combination and were less used.



# Sat-Cit-Ananda

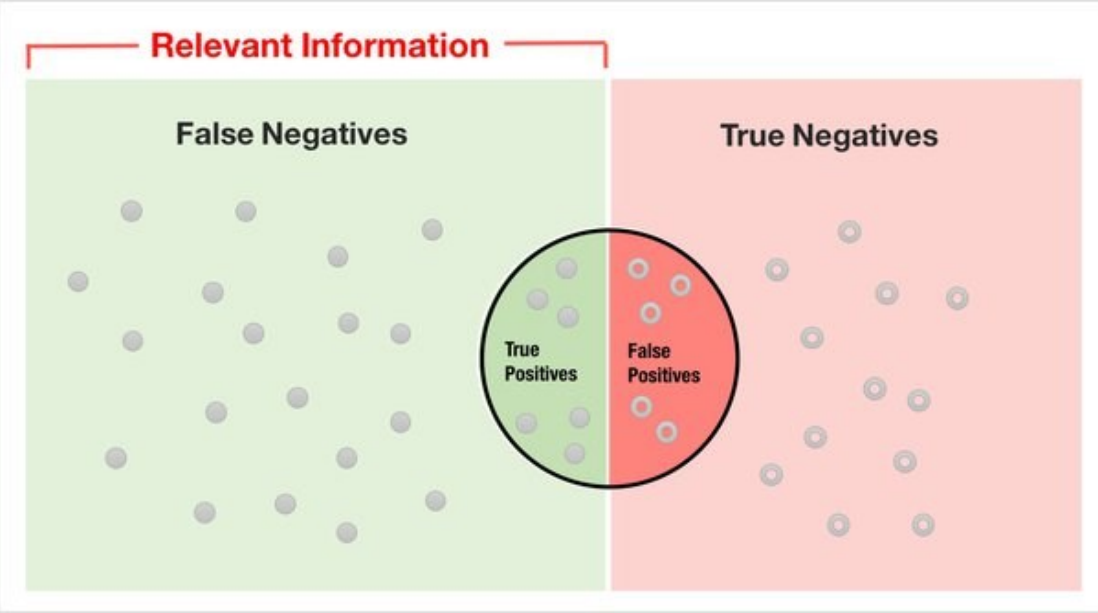


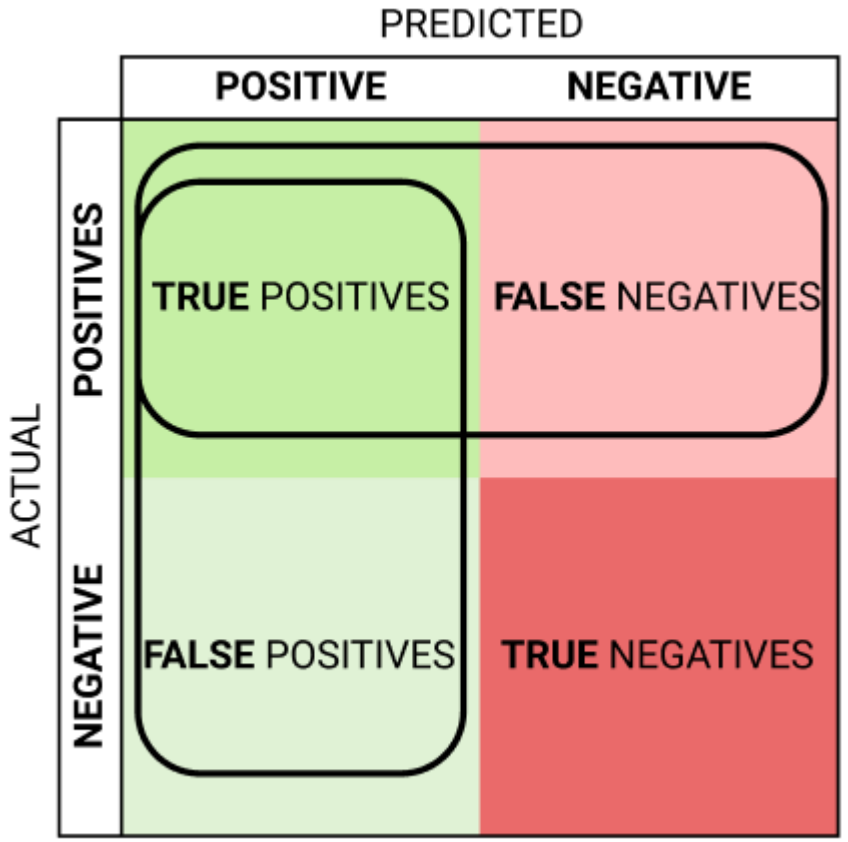
**How Ancient Human's Neural Network got trained?**

- An epithet and description for the subjective experience of the ultimate unchanging reality, called Brahman, especially Vedanta.
- It represents "existence, consciousness, and bliss" or "truth, consciousness, bliss".
- **sat** (सत्): In Sanskrit, *sat* means "being, existence", "real, actual", "true, good, right", or "that which really is, existence, essence, true being, really existent, good, true".
  - In AI, ground truth (True Positive and True Negative)
- **cit** (चित्): means "consciousness" or "spirit"
  - In AI, it is analogous to "intelligence"
- **ānanda** (आनन्द): means "happiness, joy, bliss", "pure happiness, one of three attributes of Atman or Brahman in the Vedanta philosophy".
  - In AI, it is finding, results, and objectives

# Brahma ब्रह्म "Intelligence of Cosmos"

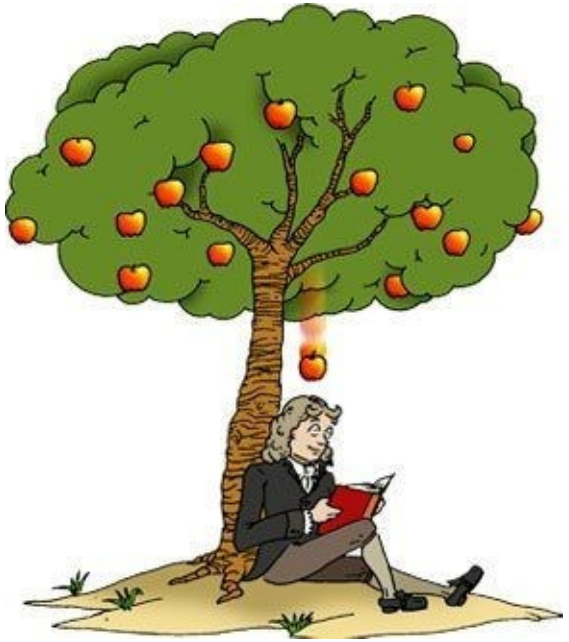
- Analogous to Neural Network of Cosmic Intelligence
- AI Algorithms: consider ancient two terms are Satyam सत्यम & Ṛtam ऋतम्
- Rigveda ऋग्वेद & Atharvaveda अथर्ववेद
- Satyam is Eternal Truth
  - Analogous to True Positive and True Negative
- Ṛtam is the law that governs the working of that Truth



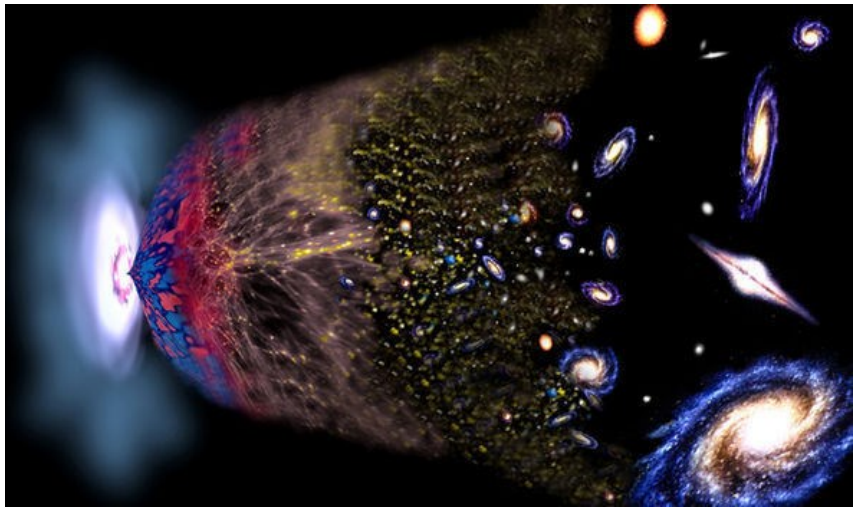
# Universal Ṛtam ऋतम्

- Universal Ṛtam in Vaiśeṣika Sutra वैशेषिक documented around 500 BC
  - Objects stay in hand due to their conjunction with the hand. When the conjunction is lost, the object falls down due to its own weight
  - Later attributed to Sir Isaac Newton in the late 16th century with the apple falling from the tree.
  - The **Apple** is remaining conjoint to the tree **Satyam**. **Experience falling down** is also Satyam.
  - Why it **stays conjoint** to the tree is **Ṛtam**, "Intertia"
  - How it **falls down** is also its **Ṛtam**, "Law of Gravity"



# Darśana दर्शन of Ṛtam ऋतम् and Satyam सत्यम

- Each manifestation in the cosmos, we experience as Truth or Satyam themselves reveal their Ṛtam
- The order of Created, Destroyed or Interreact with each other.
- These Universal Ṛtams of all cosmic interconnectedness from micro to macro and zero to infinity have already been available in the Vedas.




# Vāda वाद - Theorems, Postulates, or Hypothesis

- Vāda वाद which are challenged, refined refuted or accepted over time. For example
- In relation to Advaita अद्वैत means "nondualism"
- Vivartavāda विवर्तवाद & Parniāmvāda परिणिमवाद
  - Theory of causation, postulated by post-Shankara Advaita
- Vivarta (विवर्त) means alteration, modification, change of form, altered condition or state.
- Theory of Satkāryavāda, which means that the effect is pre-existent in the cause
- Parinamavada means the world is a real transformation (parinama means results) of Bramha

# Siddhant सिध्दांत means Algorithm

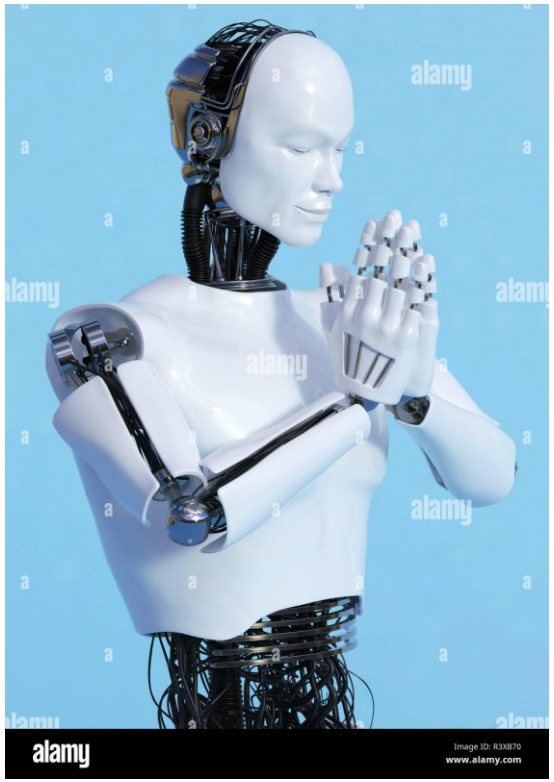
- Conjoint of 2 words सिध्द + अंत = सिध्दांत
- Siddha सिध्द which mean Perfection, Established, or an Indisputable result.
- Anta अंत which means End or nothing more beyond.
- Siddhant means Cosmic algorithms or Laws which are perfect and will never be challenged or refuted in Past, Present or Future.
- Tridośa त्रिदोष Sidhanta says
  - आयुर्वेद के सन्दर्भ में वात, पित्त, कफ इन तीनों को दोष कहते हैं।
  - In the context of Ayurveda, the Vata, Pitta and Kapha are all three doshas.
- There are different layers to Siddhānta in conjunction

# Darśana दर्शन of Ṛtam ऋतम्  and Satyam सत्यम

- Neural Networks based on algorithms of their philosophy called Darśana दर्शन
- Darśana are exponential algorithms, which explains the immense possibilities of cosmic creations
- Algorithm in Chāndogya upāniṣat छान्दोग्य उपनिषत
  - To convert input Clay to an output Pot
  - 1: We know the clay and we can know all things shaped out of it.
  - 2: Clay is empirically real or Satyam and the pot which is a modification of clay is also empirically real or Satyam
  - 3: As we can see and experience clay and pot, the manner in which the clay was shaped to pot is its Ṛtam “the universal law” which when understood can project innate possibilities.
  - 4: We know nature of creation, Past, Present & Future. This help to compare the creation.

# Raja Bhoja 11th Century

- **Robotics**




खड्गहस्तमथ मुद्गरहस्तं कुन्तहस्तमथवा यदि तत् स्यात् ।
तन्निहन्ति विशतो निशि चौरान् द्वारि संवृतमुखं प्रसभेन ॥ १०७

107

*khadga hastham* - hand equiped with a sword
*mudgara hastham* - gadha with spikes
*kuntha hastham* - lance
*yadi tatsyath* - whatever available
*tan nihanti* - automatically on his own
*vishatho* - trying to enter
*nishi* - at night
*chouran* - *chor* - thief
*prasabha* - outright
*sounvrita mukha* - covered face, masked face
disguised / hidden

# Raja Bhoja 11th Century

- **Robotics**

**Female Models Welcoming guests**

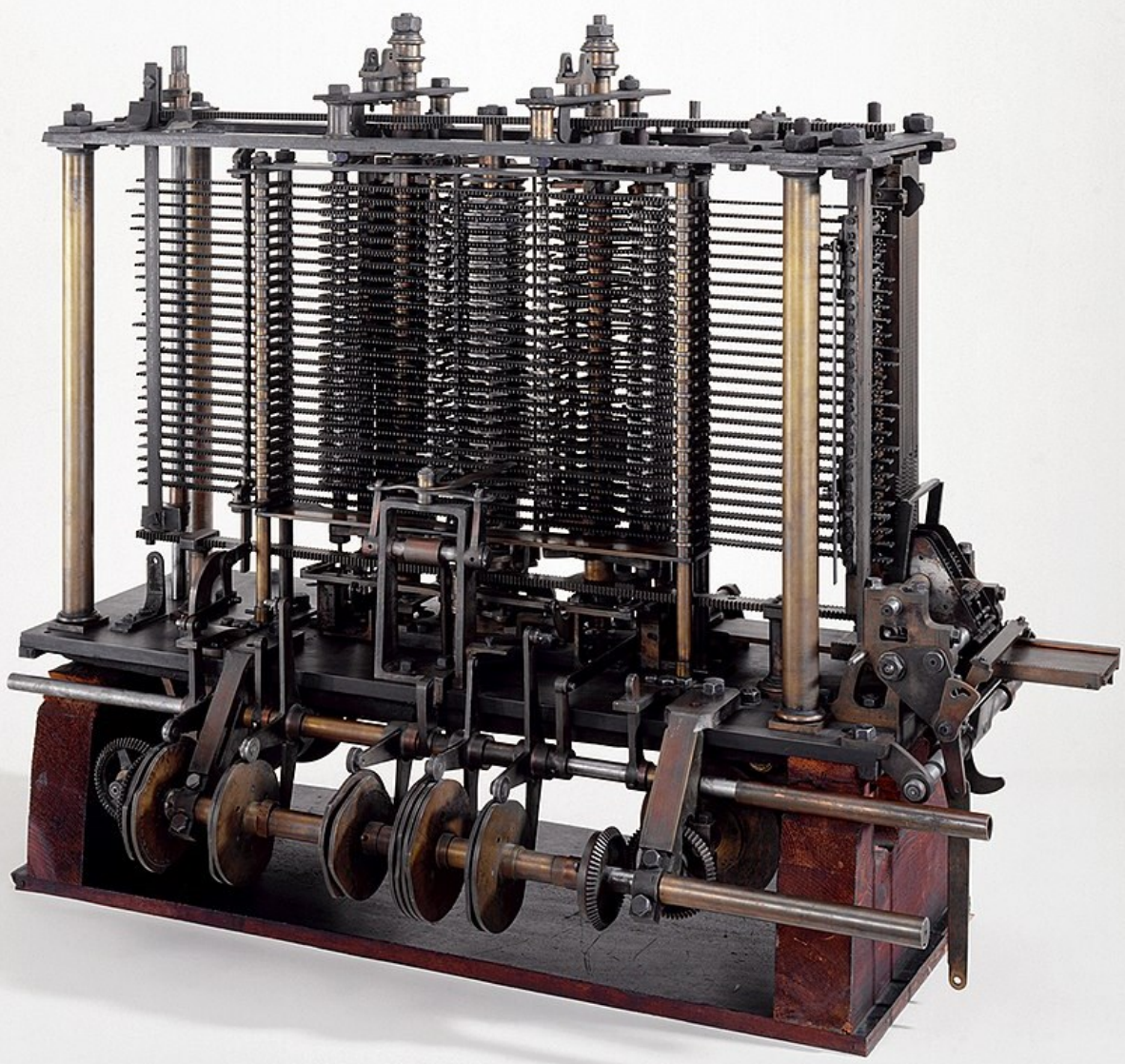
करग्रहणताम्बूलप्रदानजलसेचनप्रमाणा(णामा)दि ।
आदर्शप्रतिलोकनवीणावाद्यादि च करोति ॥ १०४ ॥

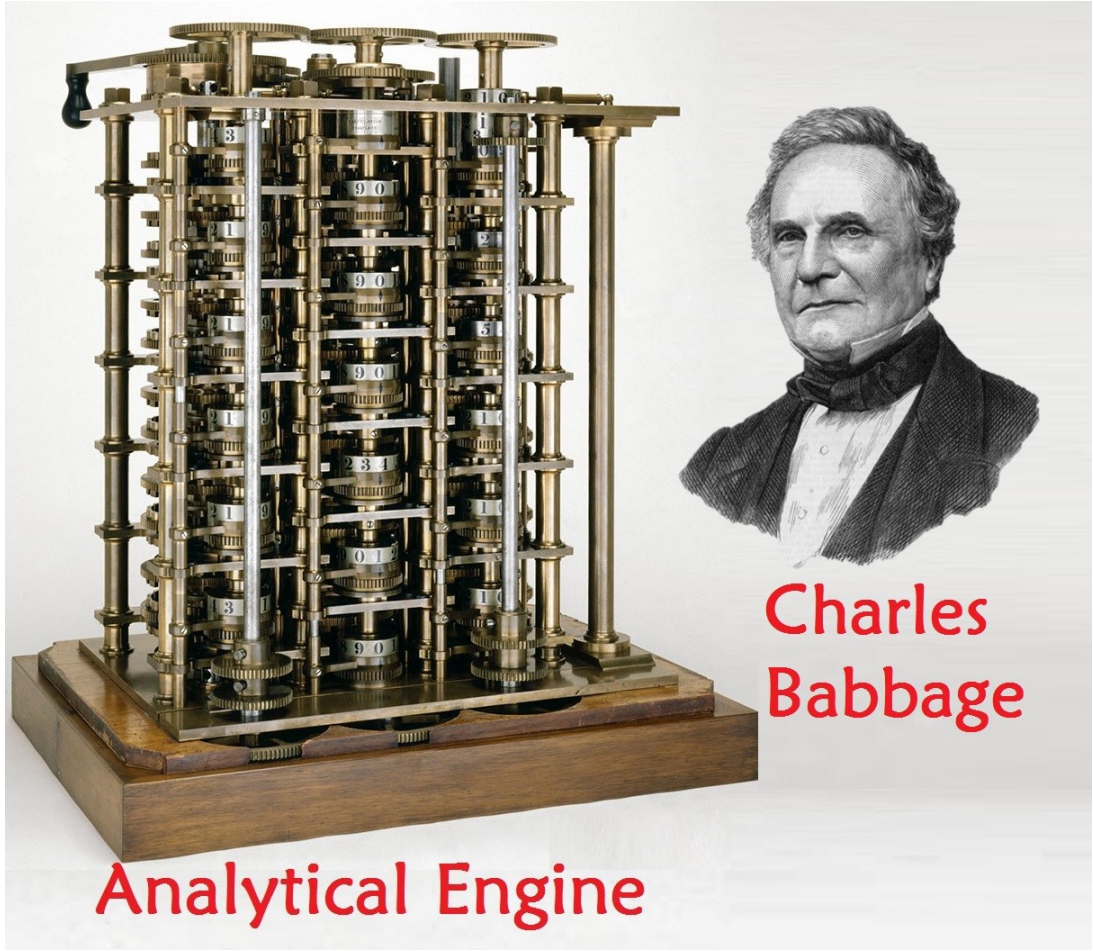
Sloka 104

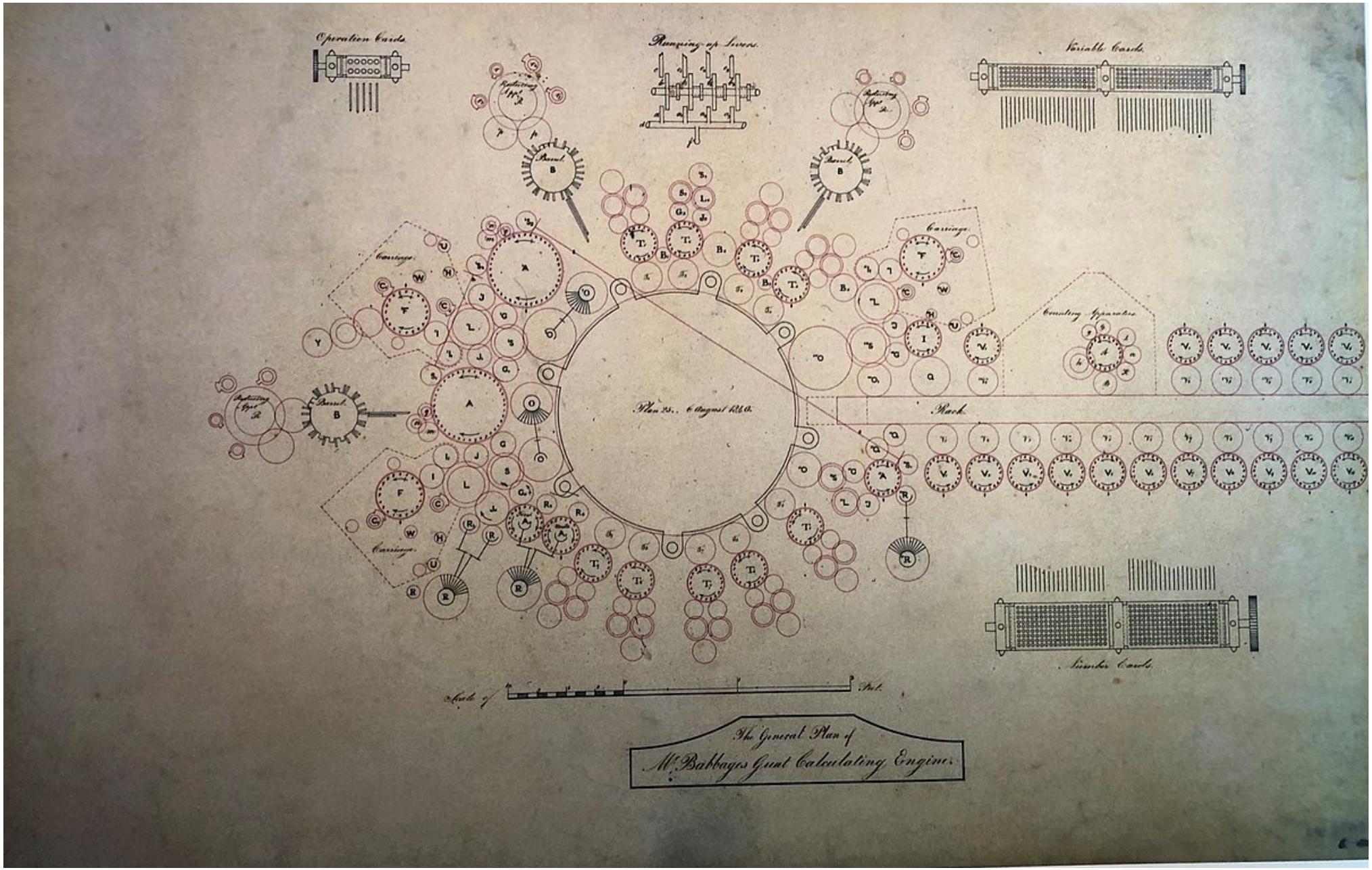
**Novelty**

- *Karnagrahana* - handshake
- *Pranama* - namasthe
- *Thamboola Pradhana* - give betal leaf, betal nut
- *Veena Vadya* - play veena
- ..... - sprinkle scented water

# Analytical Engine 1837

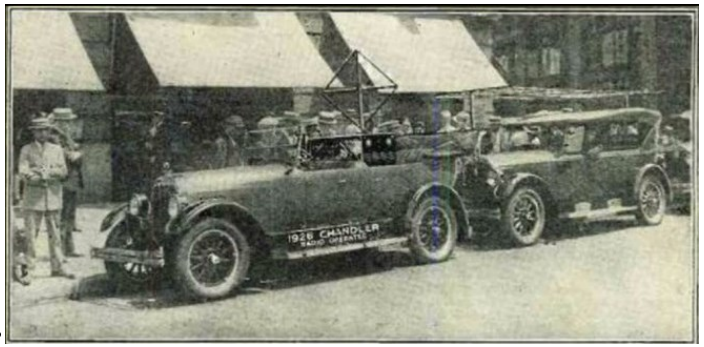




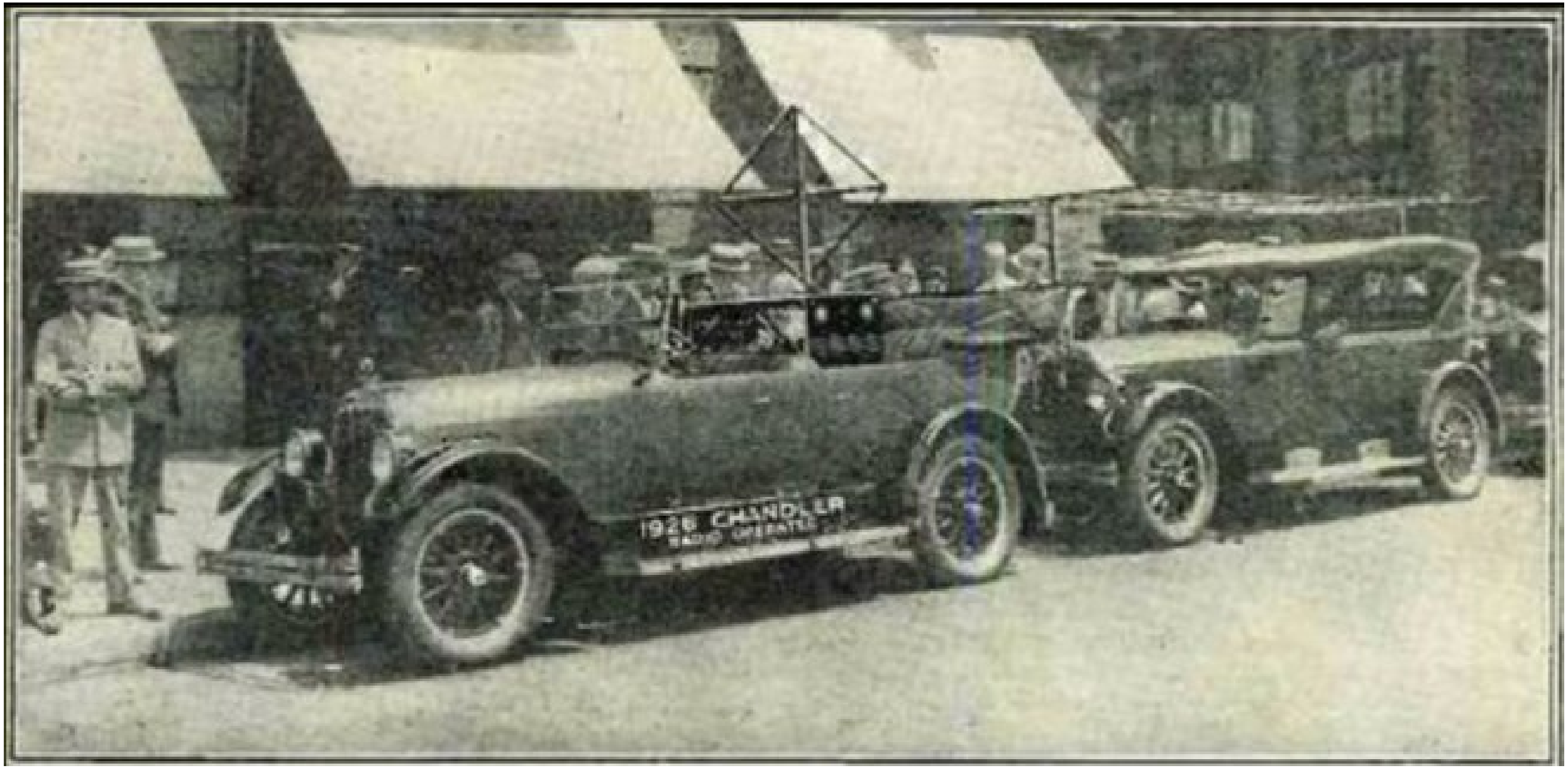



Plan diagram of the Analytical Engine from 1840

# Houdina Radio Control 1925



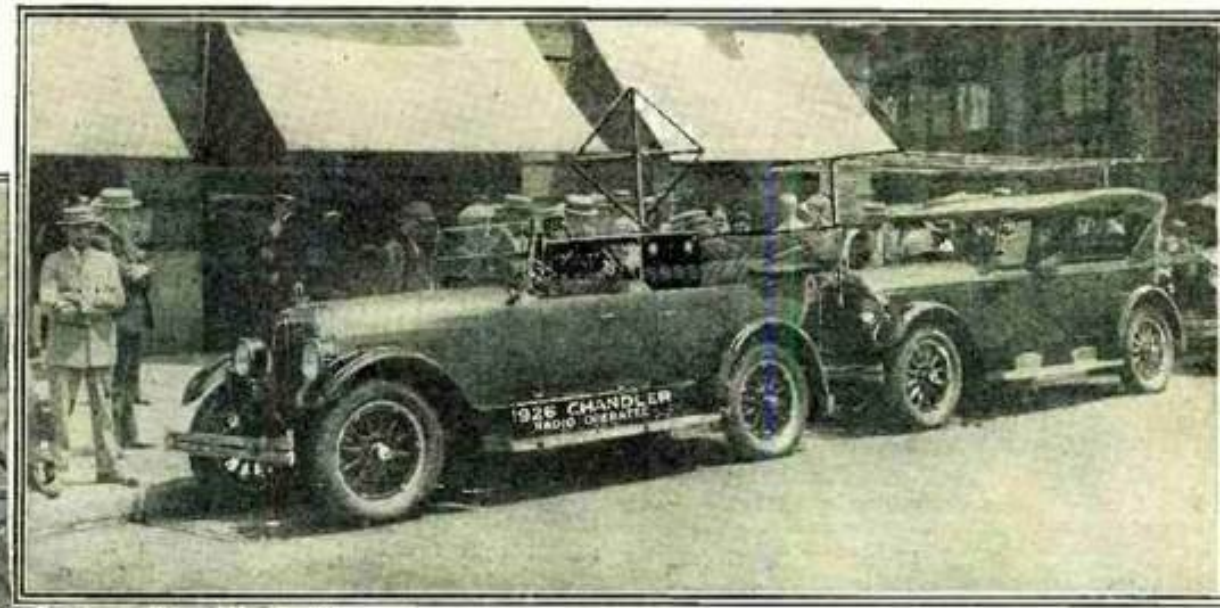

- Francis P Houdina developed a radio-operated automobile.
- He equipped a 1926 Chandler with a transmitting antenna on the tonneau and operated from a second car that followed it with a transmitter.
- The radio signals operated small electric motors that directed every movement of the car.
- In 1925, he publicly demonstrated his radio-controlled driver-less car American Wonder in New York City streets, traveling up Broadway and down Fifth Avenue through thick traffic

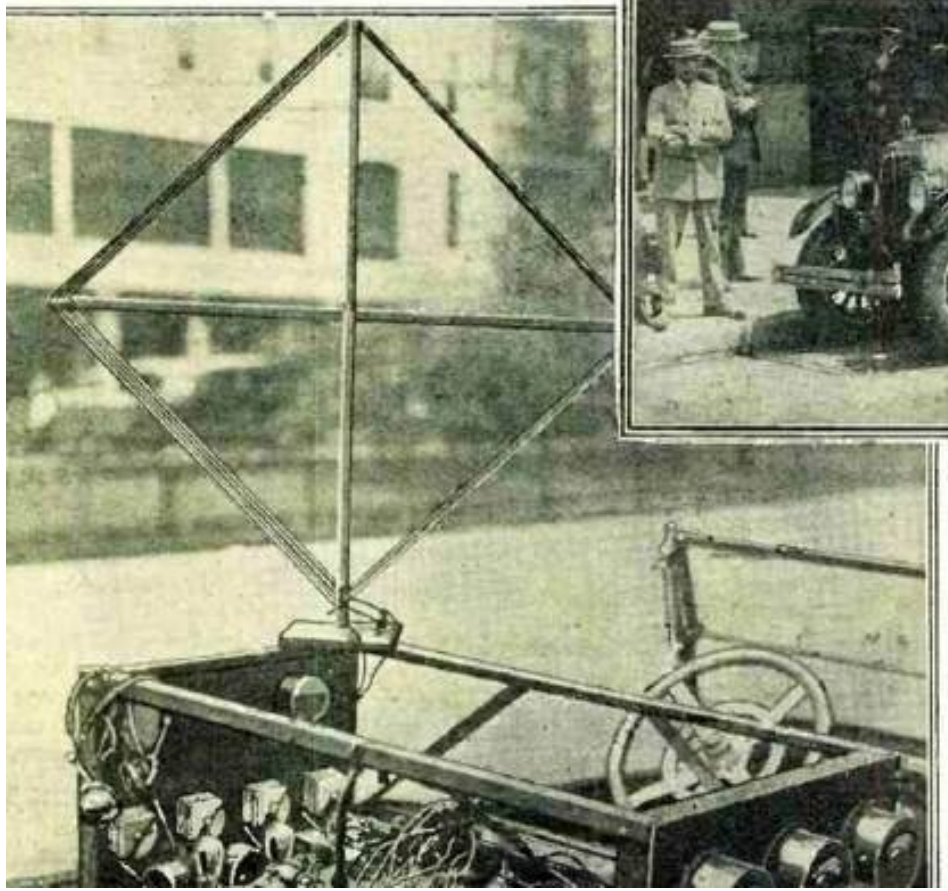

1928 CHANDLER

# Radio-Controlled Automobile

## By HERNDON GREEN

*Radio is to control a car in transcontinental tour. The system, which is extremely simple and effective, is fully described here.*



Above is shown the two cars used in the transcontinental tour by Mr. Francis P. Houdina. The front car has no driver but is controlled by radio from the second car. Note the transmitting antenna and the receiving loop.

### THE DIAGRAM

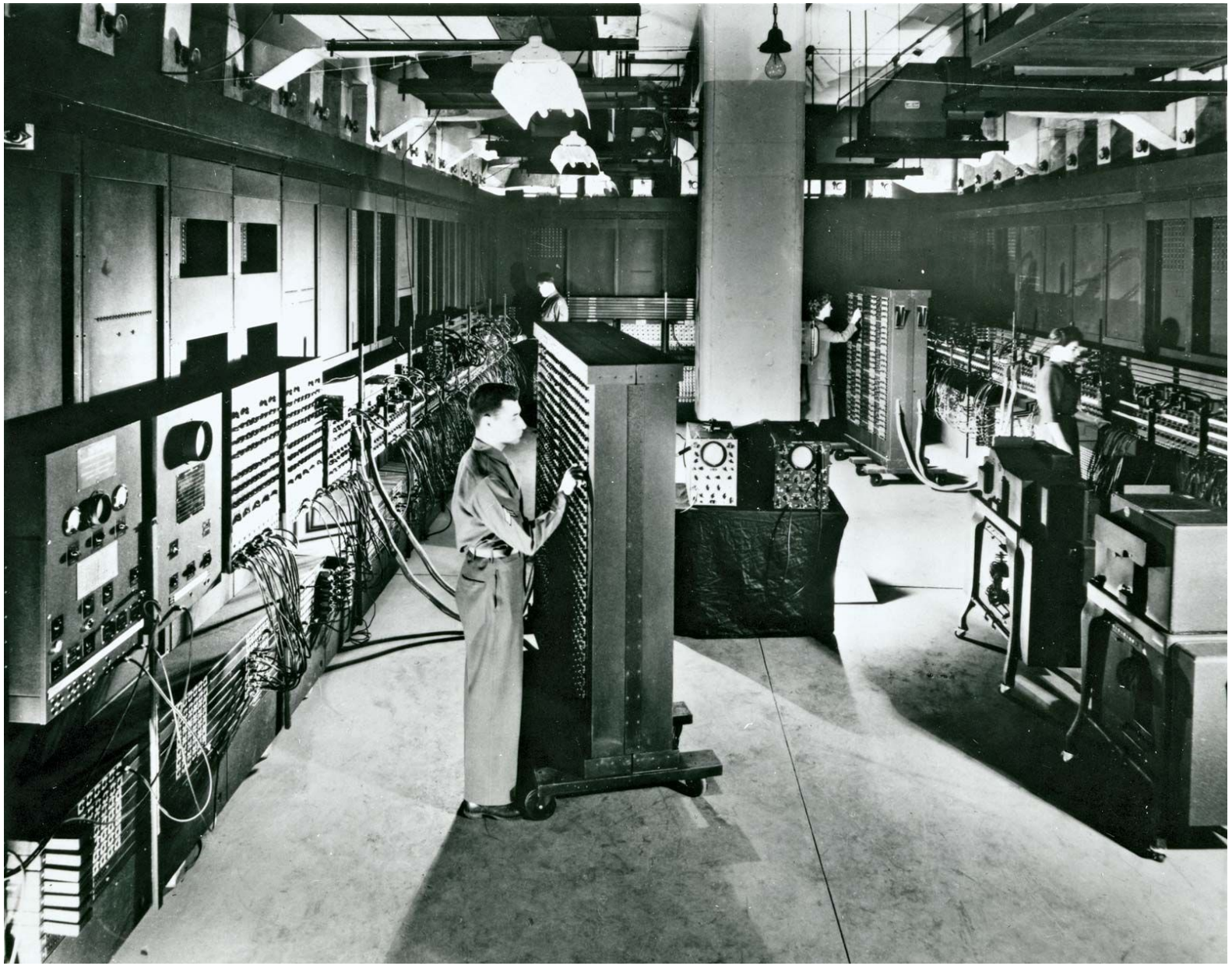
A glance at the wiring diagram given i an accompanying illustration will show th circuit in its simplest form. Some of th amplifying relays are left out in order t simplify the circuits.

The two transmitters are of the usua 10-watt type, using storage battery suppl for the filaments and plates. They ar housed in the tonneau of the control car to gether with the power units. The keys con trolling them are placed on a small shel at the right side of the dash.

The receivers are the usual type, employ

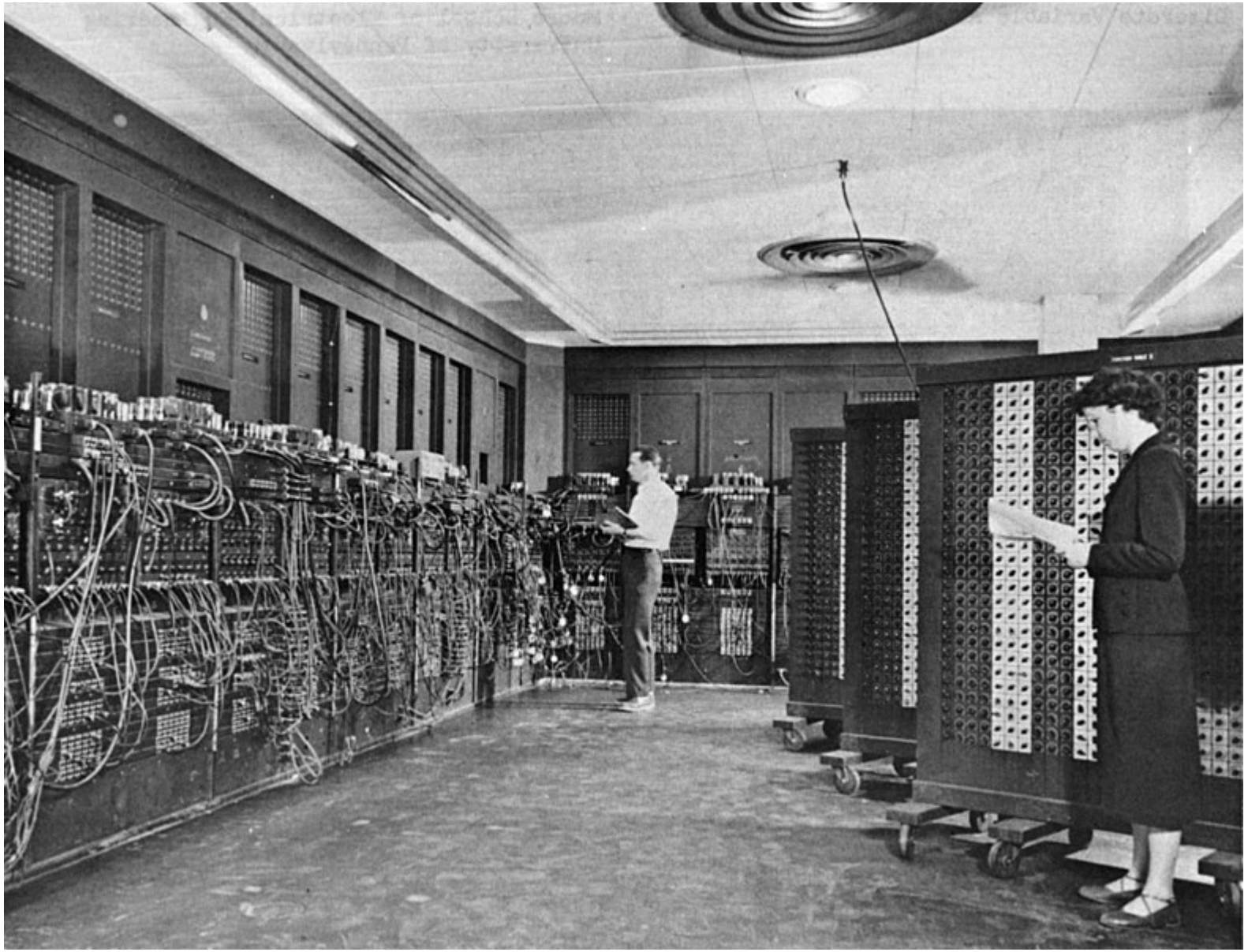
# 1946-1960

- 1946: ENIAC heralds the dawn of Computing

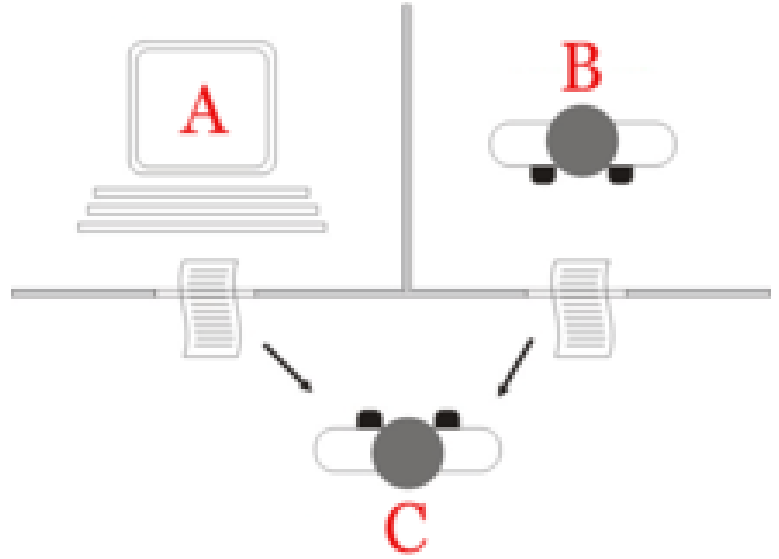


# 1946-1960

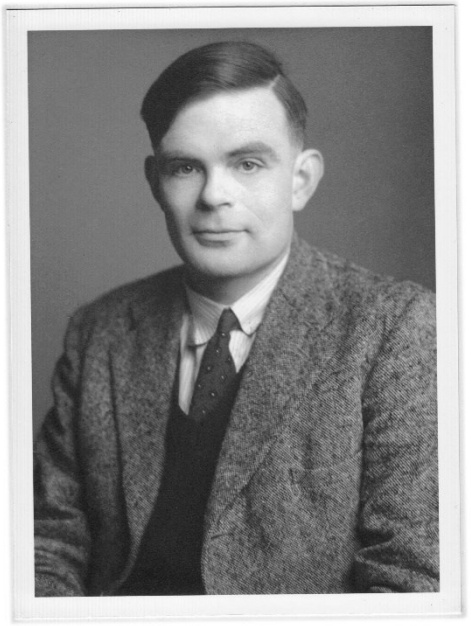
- 1946: ENIAC heralds the dawn of Computing



# 1946-1960 Turing Test




- 1950: Turing asks the question **"Can machines think?"**
- 'imitation game' is played with three people,
  - a man (A),
  - a woman (B), and
  - an interrogator (C)
- 'What will happen when a machine takes the part of A in this game?' Will the interrogator decide wrongly as often when the game is played like a man and a woman?
- Player C, the interrogator, is given the task to determine which player – A or B – is a computer and which is a human.
- The interrogator is limited to using the responses to written questions to make the determination.



# 1946-1960 Turing Test

- Turing defined "intelligent behavior as the ability to achieve human-level performance in all cognitive tasks, sufficient to fool an interrogator."
- Intelligent computer
  - interrogated by a human via invisible communication channel,
  - pass the test
    - "if the interrogator fails to guess there is a computer or a human at the other end"
- Popular Science Fictions
  - Small Wonders
  - Karishma ka Karishma



# DARTMOUTH RESEARCH PROJECT ON ARTIFICIAL INTELLIGENCE 1956

## A PROPOSAL FOR THE DARTMOUTH SUMMER RESEARCH PROJECT ON ARTIFICIAL INTELLIGENCE

**J. McCarthy, Dartmouth College**
**M. L. Minsky, Harvard University**
**N. Rochester, I.B.M. Corporation**
**C.E. Shannon, Bell Telephone Laboratories**

**August 31, 1955**

We propose that a 2 month, 10 man study of artificial intelligence be carried out during the summer of 1956 at Dartmouth College in Hanover, New Hampshire. The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it. An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves. We think that a significant advance can be made in one or more of these problems if a carefully selected group of scientists work on it together for a summer.

# DARTMOUTH RESEARCH PROJECT ON ARTIFICIAL INTELLIGENCE 1956

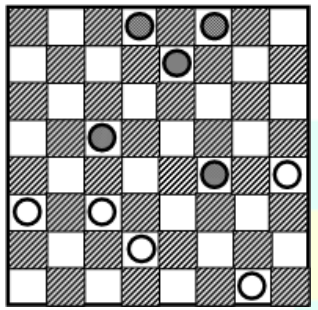
- The following are some aspects of the artificial intelligence problem:
  1. Automatic Computers
  2. How Can a Computer be Programmed to Use a Language
  3. Neuron Nets
  4. Theory of the Size of a Calculation
  5. Self-lmprovement
  6. Abstractions
  7. Randomness and Creativity
- Application of information theory concepts to computing machines and brain models.
- The matched environment - brain model approach to automata.

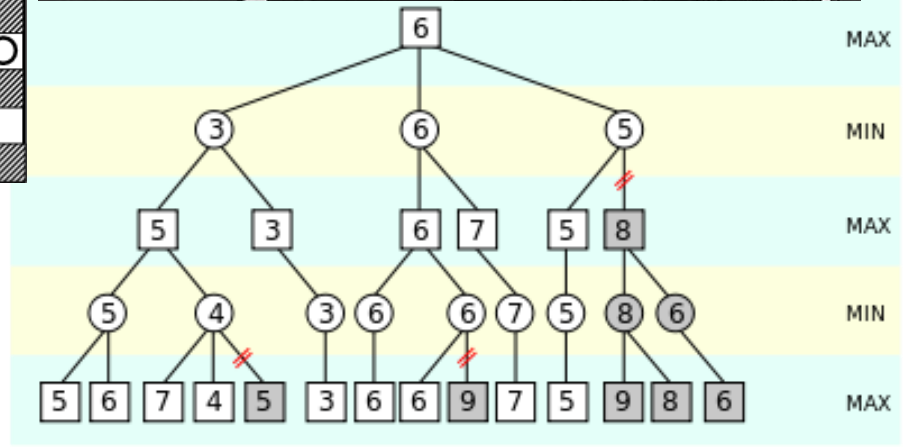
# DARTMOUTH RESEARCH PROJECT ON ARTIFICIAL INTELLIGENCE 1956

- The stage of programming in a computer.
- Originality in Machine Performance
- The Process of Invention or Discovery
  1. The environment provides data from which certain abstractions are formed.
  2. The abstractions together with certain internal habits or drives provide:
     1. A definition of a problem in terms of desired condition to be achieved in the future, a goal.
     2. A suggested action to solve the problem.
     3. Stimulation to arouse in the brain the engine which corresponds to this situation.
  3. Then the engine operates to predict what this environmental situation and the proposed reaction will lead to.
  4. If the prediction corresponds to the goal the individual proceeds to act as indicated.
- The Machine With Randomness

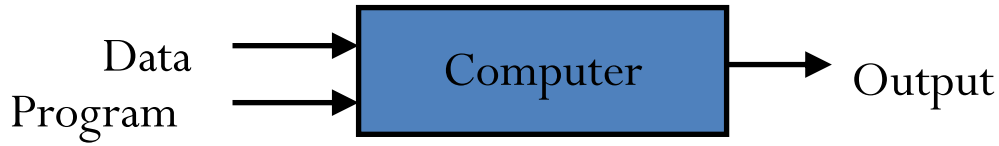
# 1959 Machine Learning

- Arthur Samuel: Automated Game for "Computer checkers" development
- Ability to learn without explicit programming.
  - Samuel implemented alpha-beta pruning
  - Grayed-out subtrees don't need to be explored (when moves are evaluated from left to right),
  - the group of subtrees yields the value of an equivalent subtree or worse, and
  - as such cannot influence the final result.

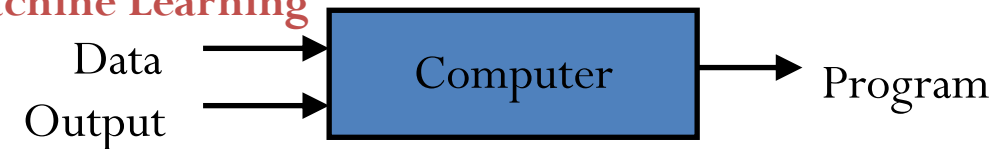





**Traditional Programming**




**Machine Learning**



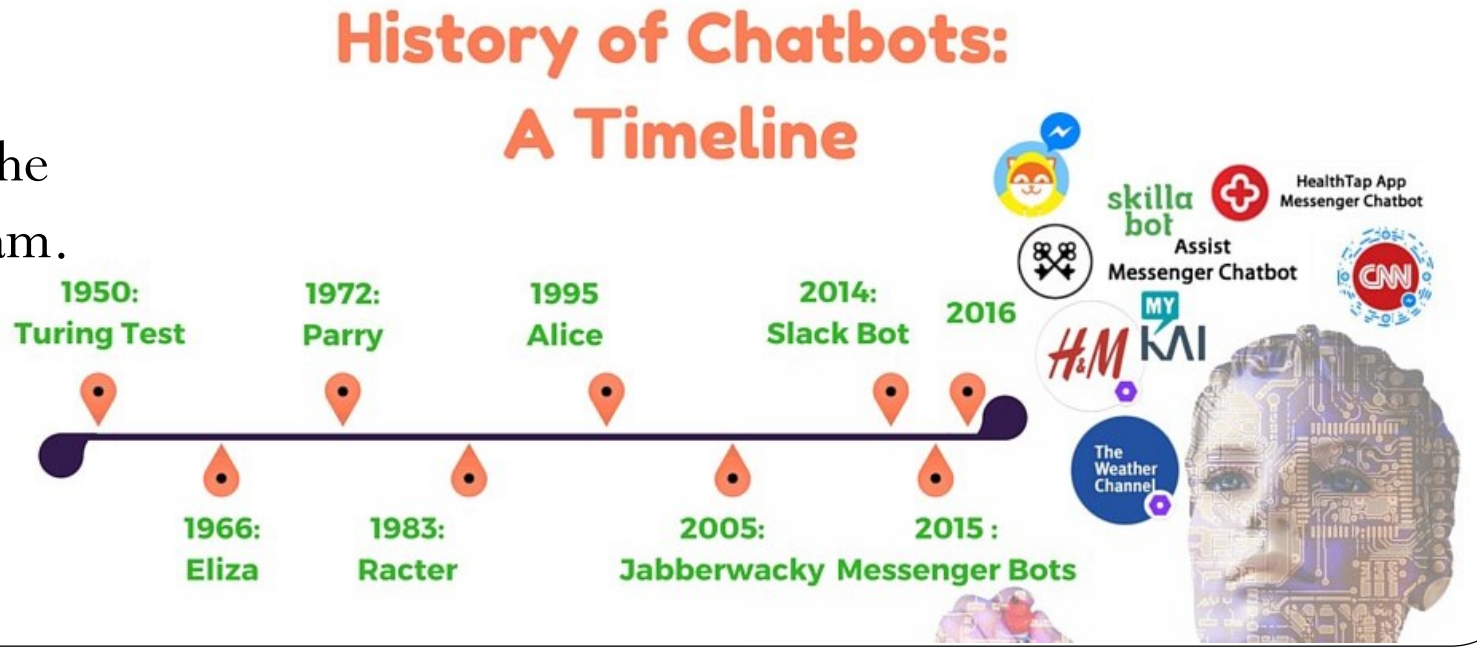
# 1964: Eliza Chatbot

- The chatbot psychotherapist
- Using "pattern matching" and substitution methodology, the program gives canned responses.
- It made early users feel they were talking to someone who understood their input.
- The program was limited by the scripts that were in the program.

**Talk to Eliza by typing your questions and answers in the input box.**

```
> Hello, I am Eliza. I'll be your therapist today.
* What is your name?
> Does that question interest you?
* Are you intelligent?
> Why are you interested in whether or not I am intelligent?
* To do Turing Test.
> I'm not sure I understand you fully.
* Do you know Turing Test?
> Oh... Let's move on to something else for a bit.  know Turing Test?
```

TYPE HERE




https://web.njit.edu/~ronkowit/eliza.html

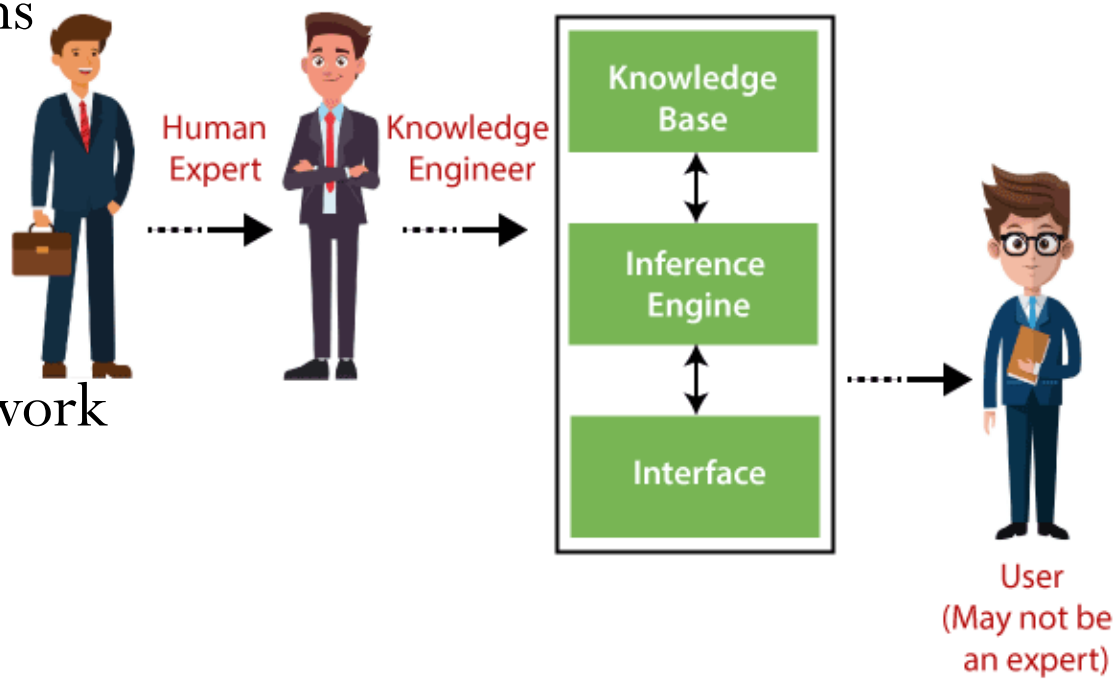
# 1966: Shakey general purpose mobile robot

- First mobile robot with the ability to perceive and reason about its surroundings
- Tasks required planning, route-finding, and the rearranging of simple objects.

https://www.sri.com/hoi/shakey-the-robot/

# 1960-74 Expert Systems

- Explicit, rules, programs
- Playing Chess
- Organic models, Biology recommendations
- Solving word problem in Algebra
- Natural Language processing
- Mobile Robot
- 1969: Backpropagation based Neural Network



# AI Winter (1974-80)

- Abandonment of AI: There were two major winters in 1974–1980 and 1987–1993
- 1966: failure of machine translation
- 1970: abandonment of connectionism
- Period of overlapping trends:
  - 1971–75: DARPA's frustration with the Speech Understanding Research program at Carnegie Mellon University
  - 1973: large decrease in AI research in the United Kingdom in response to the Lighthill report
  - 1973–74: DARPA's cutbacks to academic AI research in general
- 1974 – 1980: AI Winter #1
  - Failure of machine translation
  - Negative results in Neural nets
  - Poor speech understanding

# AI Winter (1974-80)

- Problem with A.I.
- Applications were primarily for toy problems
- Low computational power
- Combinatorial explosion too many exhaustive Rules
- Common-sense is nearly impossible to program
- Minsky's book = Perceptron showed limitations of simile neural network
- Loss of government funding in A.I.

# AI Winter (1987-93)

- 1987 – 1993: AI Winter #2
- 1987: collapse of the LISP machine market
  - Decline of LISP
- 1988: cancellation of new spending on AI by the Strategic Computing Initiative
- 1990s: end of the Fifth Generation computer project's original goals
- 1993: resistance to new expert systems deployment and maintenance
  - Decline of specialized hardware for expert systems

# AI Winter (1987-93)

- Popularity of the P.C.
- Lack of attractive results
- Funding cuts
- Lasting effects
  - "Artificial Intelligence is associated with systems that have all too often failed to live up to their promises."
  - "Some believe the word 'robotics' actually carries a stigma that hurts a company's chances at funding."

# AI Spring and Summer

**AI Spring (1980-87)**

- Expert systems used in several real-world applications
- Driverless car
- Hopfield network popularization of backpropogation
- Minsky (1984) – "Winter is coming!"

**AI Summer (1994-2000)**

- Apriori algorithm: Association Rule Mining by Rakesh Agarwal in 1993 and 1995
- 1997 Deep Bule beats Kasparov in chess
- Theory – Including probability, information theory, optimization etc.
- Moore's Lay – Rapid growth of processing power.
  - "Number of transistor doubles every two years"

# Apriori algorithm: Association Rule Mining (1993)

- Let $I = \{i_1, i_2, \ldots . i_m\}$ be a set of literals, called items.
- *Support* of a rule $X \rightarrow Y$ is the percentage of transactions that contain both X and Y.
- *Confidence* of a rule is percentage the if-then statements ($X \rightarrow Y$) are found true
- Find all rules that satisfy a user-specified *minimum support* and *minimum confidence*

| TID | Transaction Items |
|---|---|
| 1 | Bread, Jelly, PeanutButter |
| 2 | Bread, PeanutButter |
| 3 | Bread, Milk, PeanutButter |
| 4 | Beer, Bread |
| 5 | Beer, Milk |

{Bread} → {PeanutButter} (Sup = 60%, Conf = 75%)

{PeanutButter} → {Bread} (Sup = 60%, Conf = 100%)

{Beer} → {Bread} (Sup = 20%, Conf = 50%)

{PeanutButter} → {Jelly} (Sup = 20%, Conf = 33.33%)

{Jelly} → {PeanutButter} (Sup = 20%, Conf = 100%)

{Jelly} → {Milk} (Sup = 0%, Conf = 0%)

Rakesh Agrawal, Tomasz Imieliński, and Arun Swami. "Mining association rules between sets of items in large databases." SIGMOD. 1993.

Ramakrishnan Srikant, and Rakesh Agrawal. "Mining Generalized Association Rules." VLDB 1995.

# Apriori algorithm: Association Rule Mining (1993)

- Let $I = \{i_1, i_2, \ldots . i_m\}$ be a set of literals, called items.
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- *Confidence* of a rule is percentage the if-then statements ($X \rightarrow Y$) are found true
- Find all rules that satisfy a user-specified *minimum support* and *minimum confidence*
  - 90% of transactions that purchase *Bread* and *Butter* (antecedent) also purchase *Milk* (consequent). The number 90% is the confidence factor of the rule
    - [*Bread*], [*Butter*] → [Milk] 90%
  - 98% of customers who purchase *Tires* and *Auto accessories* also buy some *Automotive services*; here 98% is called the confidence of the rule.
    - [*Auto Accessories*], [*Tires*] → [*Automotive Services*] 98%

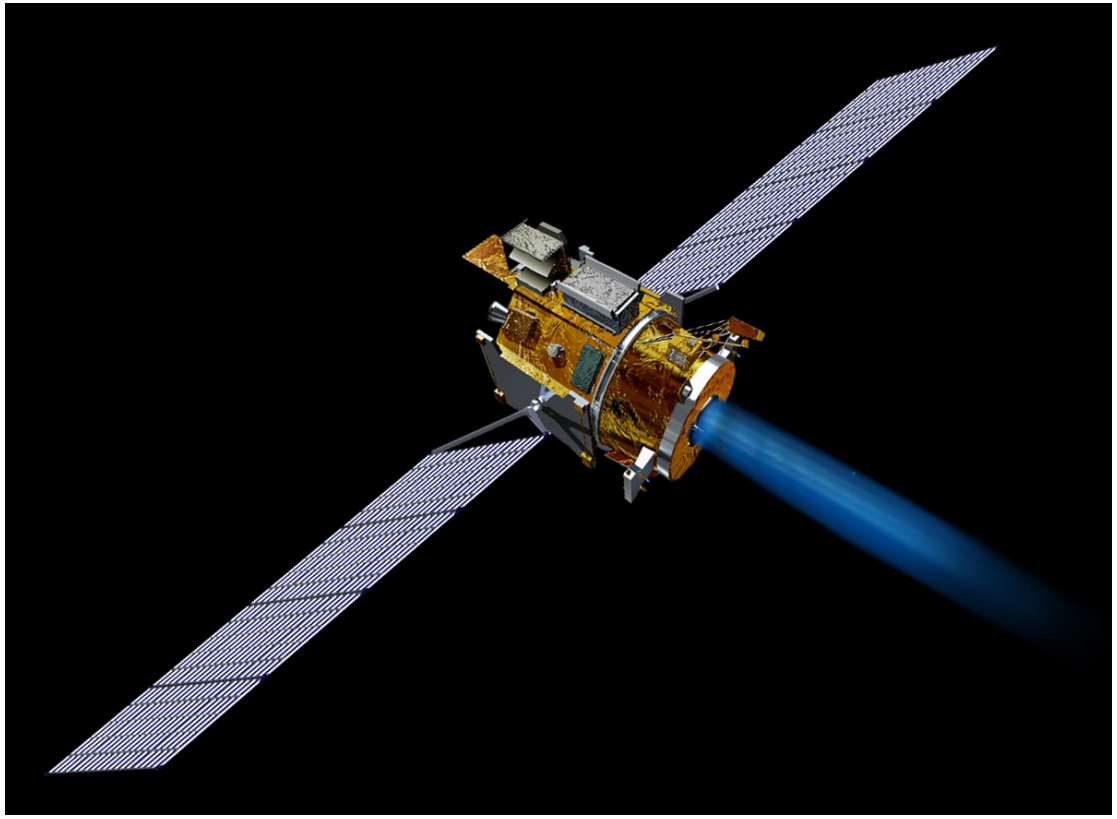
Rakesh Agrawal, Tomasz Imieliński, and Arun Swami. "Mining association rules between sets of items in large databases." SIGMOD. 1993.
Ramakrishnan Srikant, and Rakesh Agrawal. "Mining Generalized Association Rules." VLDB 1995.

# 1997: Deep Blue ends Human Supremacy in Chess

- I could feel human-level intelligence across the room -Gary Kasparov, World Chess Champion (human)
- In a few years, even a single victory in a long series of games would be the triumph of human genius.
- Does Deep Blue use AI? "If it works, its not AI!"
- "Saying Deep Blue doesn't really think about chess is like saying an airplane doesn't really fly because it doesn't flap its wings". – Drew McDermott


# 1998: Deep Space 1

- 1998: Deep Space 1
- For two days in May 1999, an AI program called "Remote Agent" autonomously ran Deep Space 1 (some 60,000,000 miles from earth)
- The spacecraft's main goal was to test 12 high-risk technologies including
  - ion propulsion,
  - autonomous optical navigation,
  - a solar power concentration array, and
  - a combination miniature camera-imaging spectrometer.



**Key Dates**

**Oct. 24, 1998:** Launch
**July 29, 1999:** DS1 passed by asteroid 9660 Braille
**Sept. 18, 1999:** Primary mission ended
**Sept. 22, 2001:** DS1 entered the coma of Comet Borrelly
**Dec. 18, 2001:** DS1's ion engine is finally turned off

https://solarsystem.nasa.gov/missions/deep-space-1/in-depth/

# AI (2000-12)

- Google is popular (Big File, Google File Systems, Page Rank Algorithm)
- Internet boom
- Shifted emphasis to big data – statistical techniques
- Graphical Processing Units (GPUs) inventions
- Spectacular results in Deep Neural Networks
- Specific goal oriented research expectations (Speech, Text, Image, Video etc)
- 2005 Autonomous driving for 135 miles in desert
- IBM's Watson beat the Jeopardy champions. Due to Advance NLP and Q&A.

# 2005: Driverless Cars

- DARPA Grand Challenge
- Stanley and three other cars drive themselves over a 132 mile mountain road


# Space AI progress

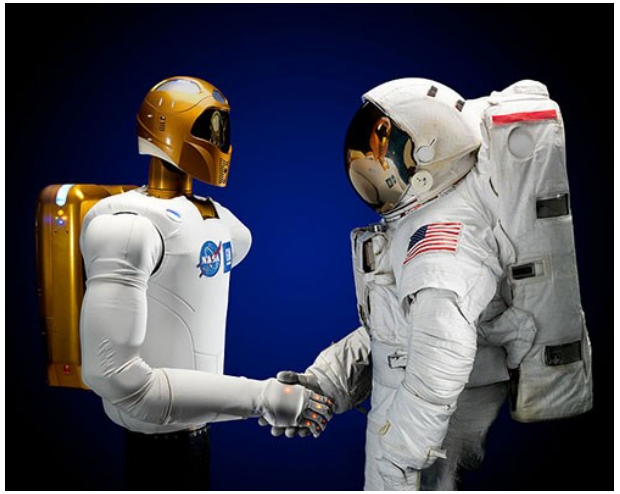
- IMAGE ANALYSIS AUTOMATION for galaxy, planet or star classification



https://www.wiley.com/edge/media/artificial-intelligence-for-space-exploration/

# Space AI progress

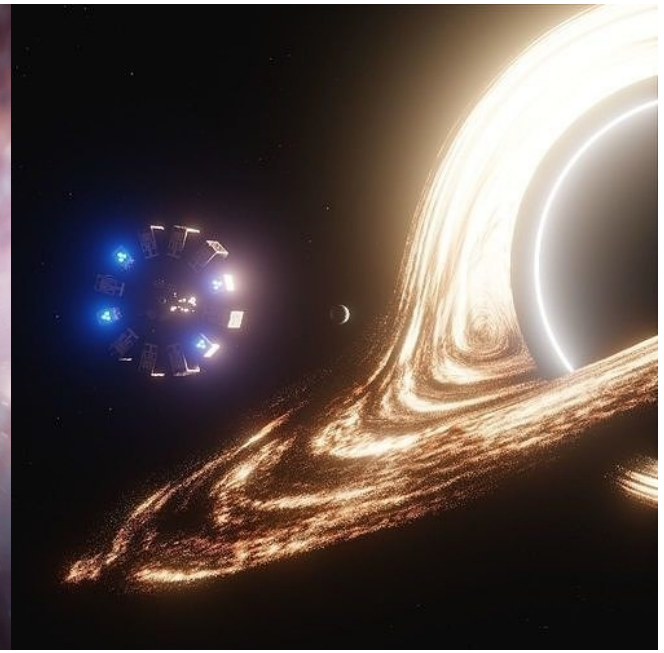
- INTELLIGENT NAVIGATION SYSTEM to help astronauts find their way on the planets
- AI-BASED ASSISTANTS AND ROBOTS to help astronomers in their long space travel
- AUTONOMOUS ROVERS that roam the surface of other planets (currently the surface of Mars).



https://www.wiley.com/edge/media/artificial-intelligence-for-space-exploration/

# Space AI progress

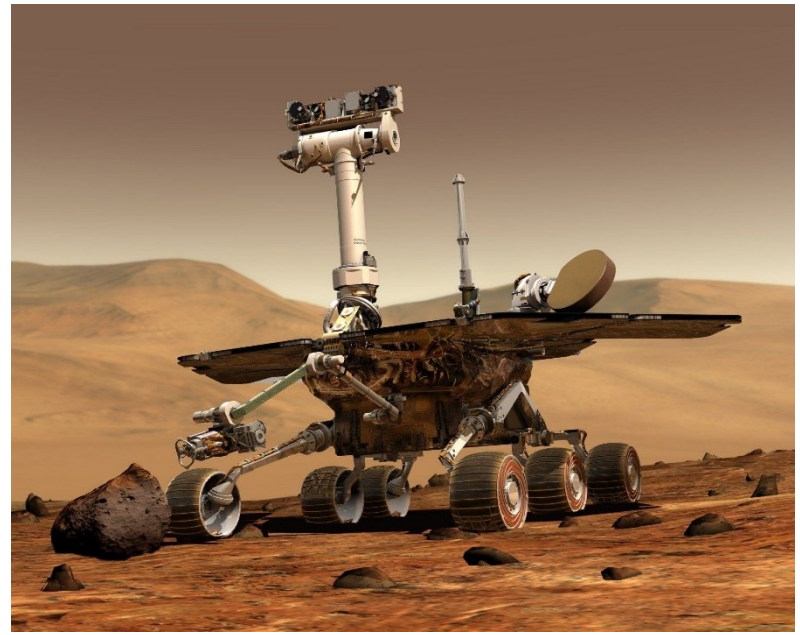
- AI'S ROLE IN SPACE EXPLORATION such as charting unnoted galaxies, stars, black holes, and studying cosmic events, as well as communication, autonomous StarCraft navigation, monitoring and system control.



https://www.wiley.com/edge/media/artificial-intelligence-for-space-exploration/

# Space AI progress

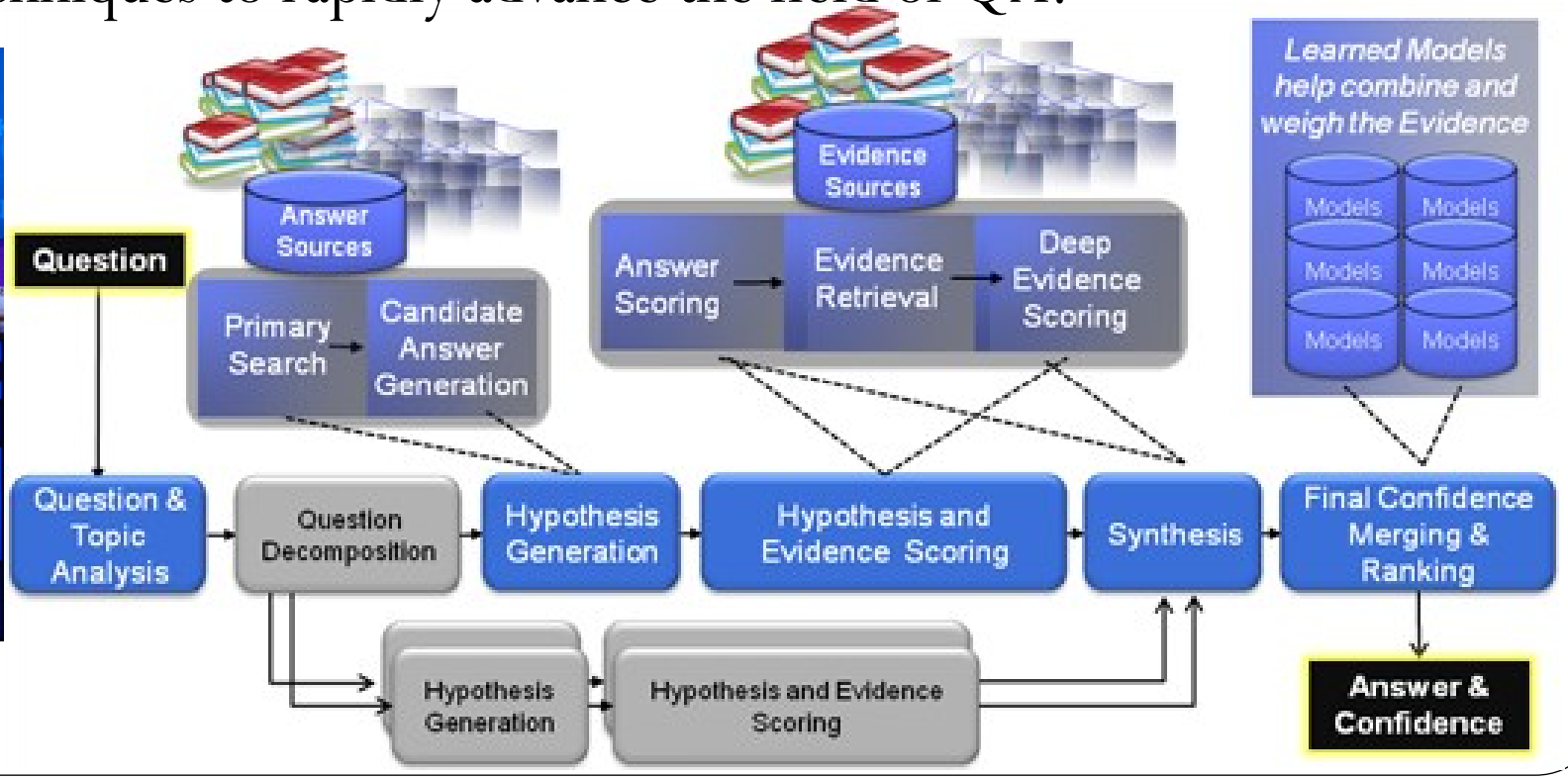
- Other Use Cases: Astronaut assistants, Mission design and planning, Satellite data processing, Space debris, Navigation systems
- To make decisions and avoid obstacles on the rough surface.
- Determining the best route without specific commands from the mission control.
- AI4Mars project to outline and identify different rock and landscape features.



https://www.wiley.com/edge/media/artificial-intelligence-for-space-exploration/

# IBM Watson beaten Human in Jeopardy

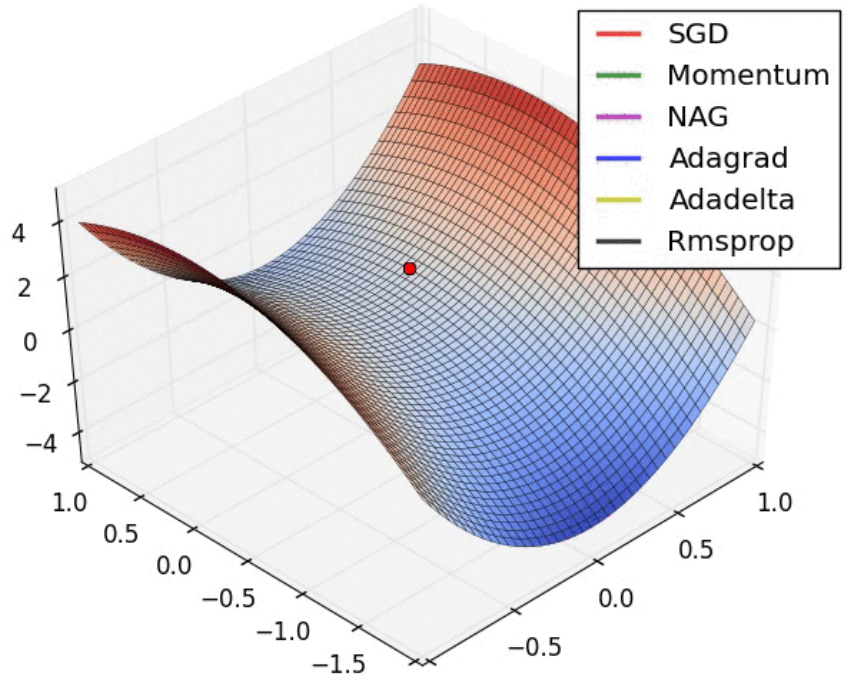
- Watson is performing at human expert levels in terms of precision, confidence, and speed at the Jeopardy quiz show.
- DeepQA architecture for combining, deploying, evaluating, and advancing a wide range of algorithmic techniques to rapidly advance the field of QA.

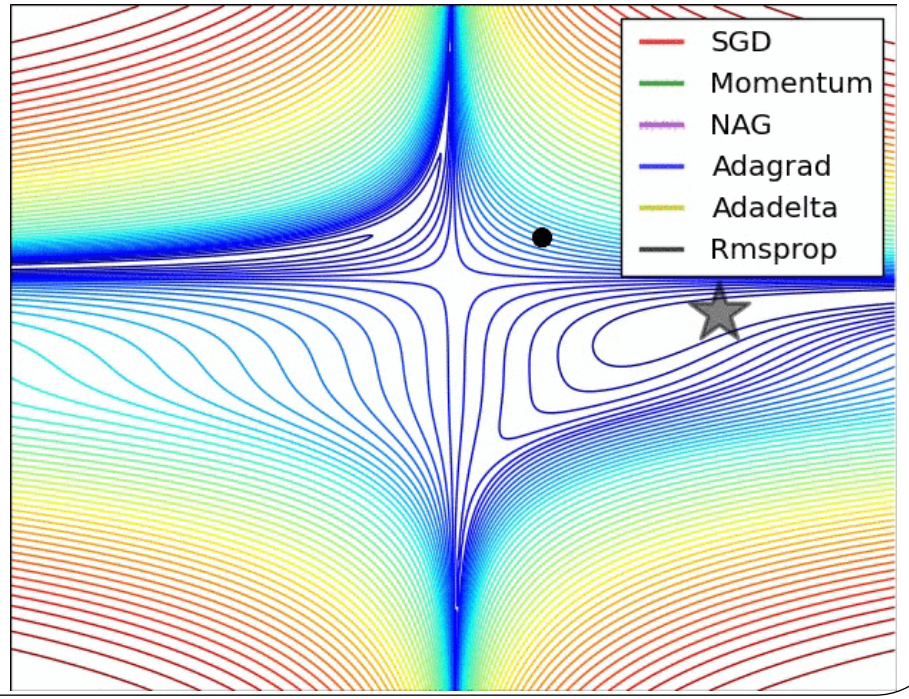



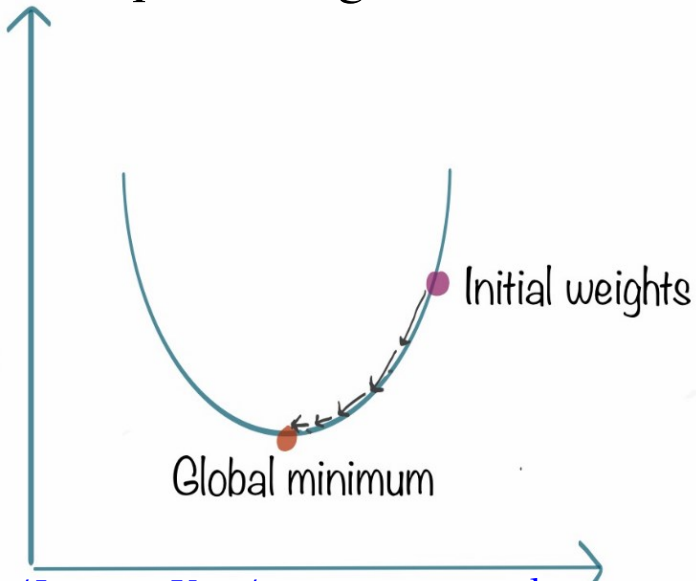

https://researcher.watson.ibm.com/researcher/view_group_subpage.php?id=2159

# Deep Learning

- For the Probabilities and Expectation equations
  - an optimization algorithm finds the value of the parameters (weights) that minimize the error when mapping inputs to outputs.
  - Optimization algorithms affect the accuracy and the speed of the training a deep learning model.



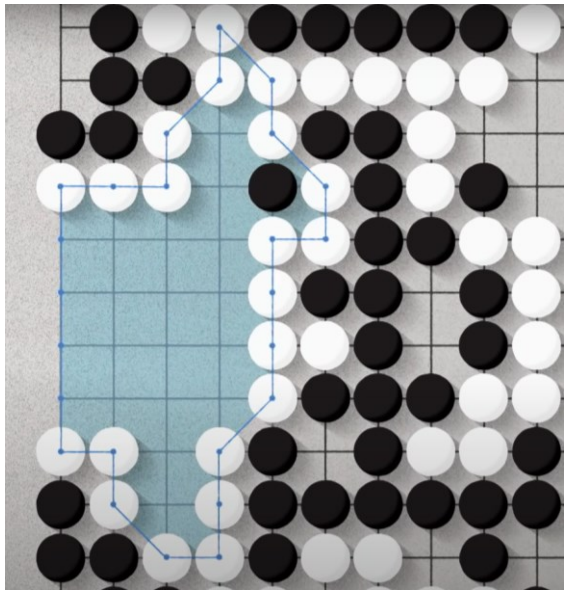

https://awesomeopensource.com/project/Jaewan-Yun/optimizer-visualization

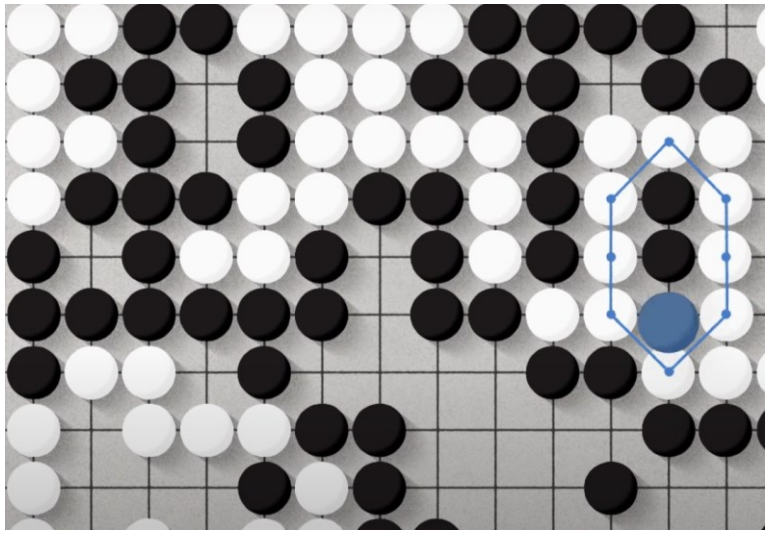
# AI Spring (2012 - till now)

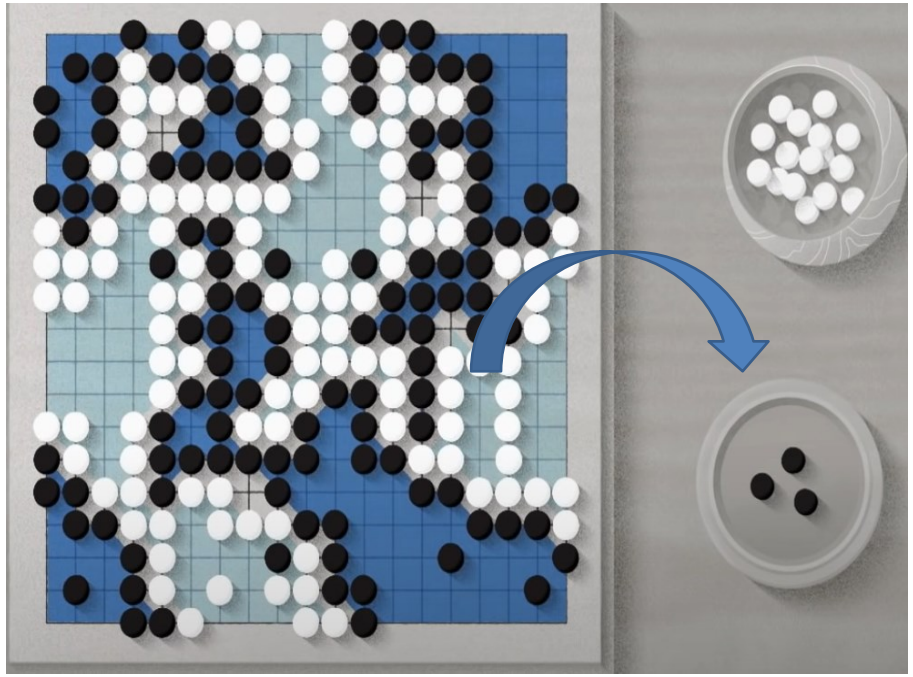
- Private funding companies
- Microsoft, Google, Facebook, IBM, AWS etc
- Fast development of computational power
- Availability of Big data: Growth of data
- Better data mining and machine learning
- Large volume of data generation
- Better automated gaming due to Reinforcement Learning
- Better technology and huge computational power
- Cloud based Shared resources (Software and Hardware)
- Better algorithms, Open source software development

# 2016: Alpha Go

- Make territories
- Capture opponent pieces
- Largest territory

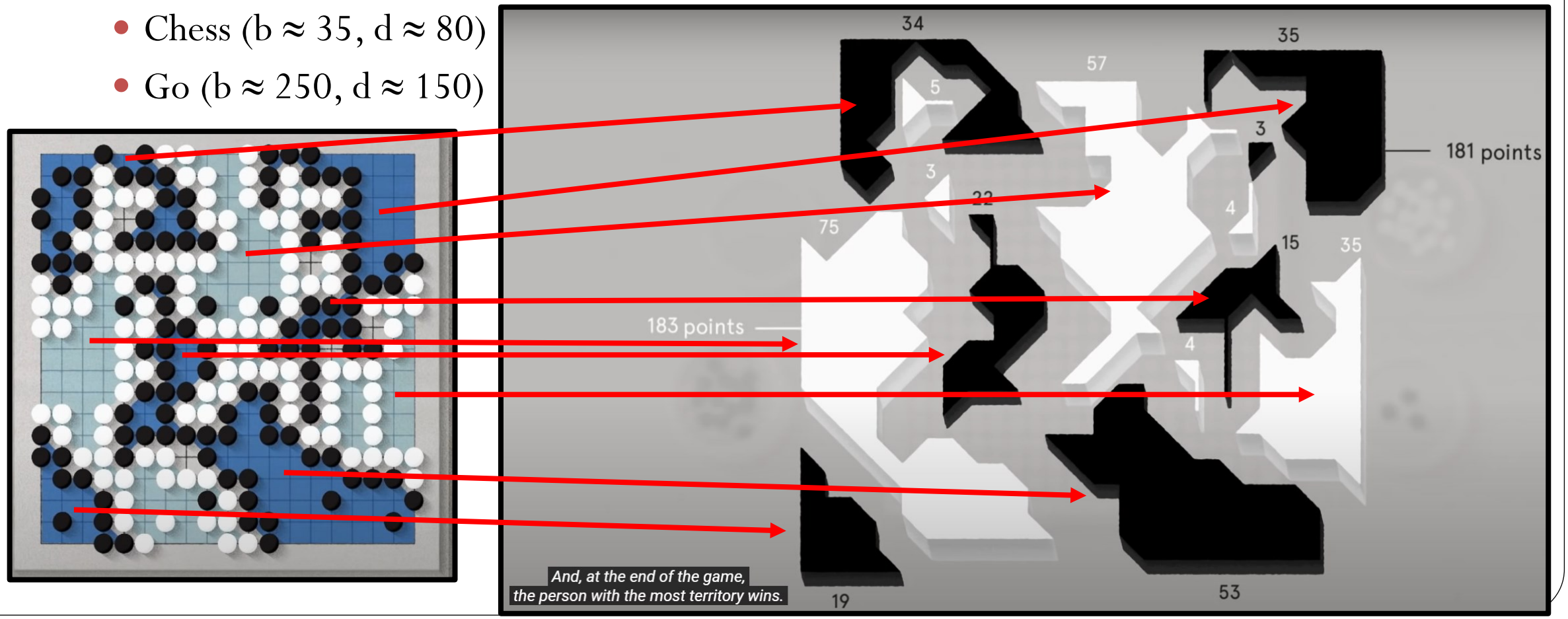






# 2016: Alpha Go

- Large games, search tree containing approximately $b^d$ possible sequences of moves
  - exhaustive search is infeasible because
  - Chess (b ≈ 35, d ≈ 80)
  - Go (b ≈ 250, d ≈ 150)



# 2016: Alpha Go

- AlphaGo achieved a 99.8% winning rate against other Go programs, and defeated the human European Go champion by 5 games to 0.
- This is the first time that a computer program has defeated a human professional player in the full-sized game of Go.

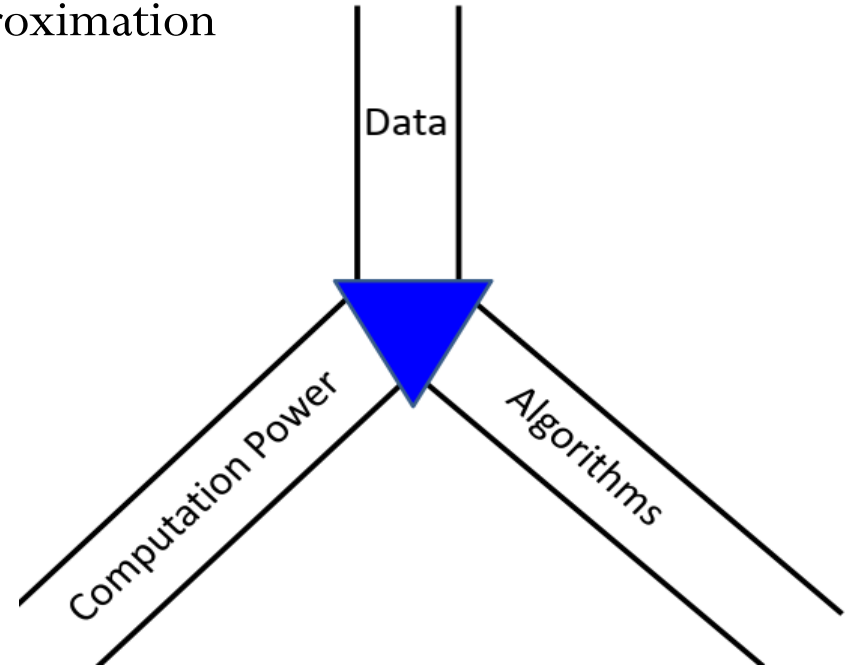

# Improvement resulted better AI

Despite these problem

- sharp minima (leading to overfitting), non-robustness
  - Analysis corresponds too closely or exactly to a particular set of data, and may therefore fail to fit to additional data or predict future observations reliably
- numerical instability (vanishing/exploding gradients)
  - numerical stability is a generally desirable property of numerical algorithms for solving ordinary and partial differential equations by discrete approximation

Why does AI work so well because

- high capacity (susceptible to overfitting)
- Better and more training Data
- Better, large, scalable, parallel Computational Power
- Better, parallel and distributed Algorithms
- Slowly but steadily increasing emphasis on
  - Explainability and Interpretability
  - theoretical justifications

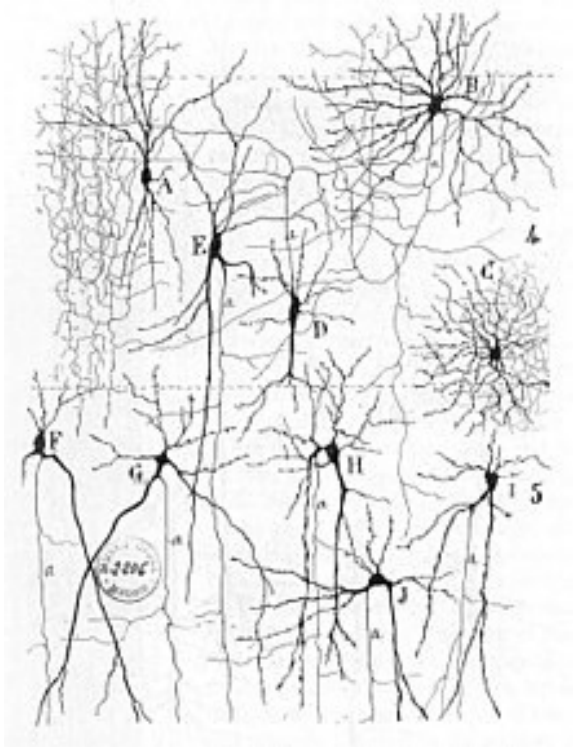


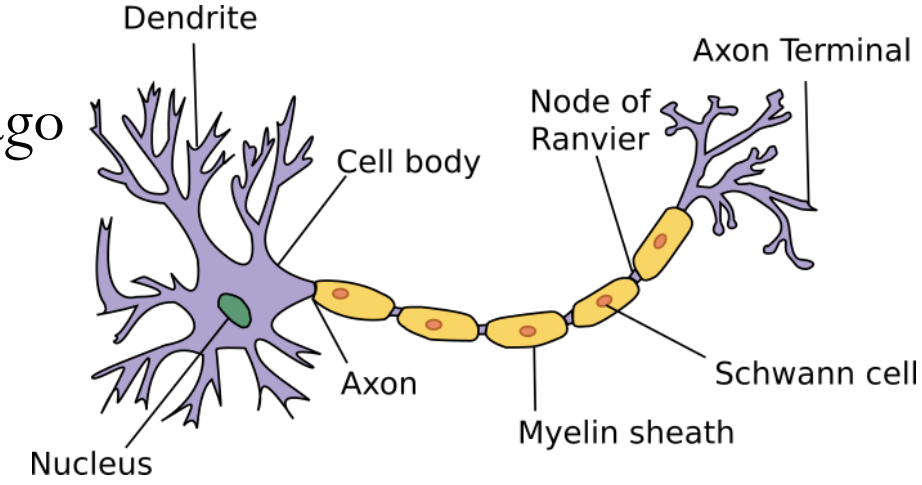

https://whataftercollege.com/robotics-embedded-system/chronological-history-of-mobile-robotics/

# History of Artificial Neural Network

# Neural Network (Anatomy)

- **1870s:** Reticular Theory "nervous system and brain is a single continuous network, all nerve cells in the nervous system constituted a continuous, interconnected network"
- **1888:** Neurons "fundamental units of the brain and nervous system, each nerve cell is an independent entity and nerve synapses transfer nerve impulses from one cell to another"
- **1906:** Novel price to both Camillo Golgi and Santiago Ramón y Cajal "in recognition of their work on the structure of the nervous system."

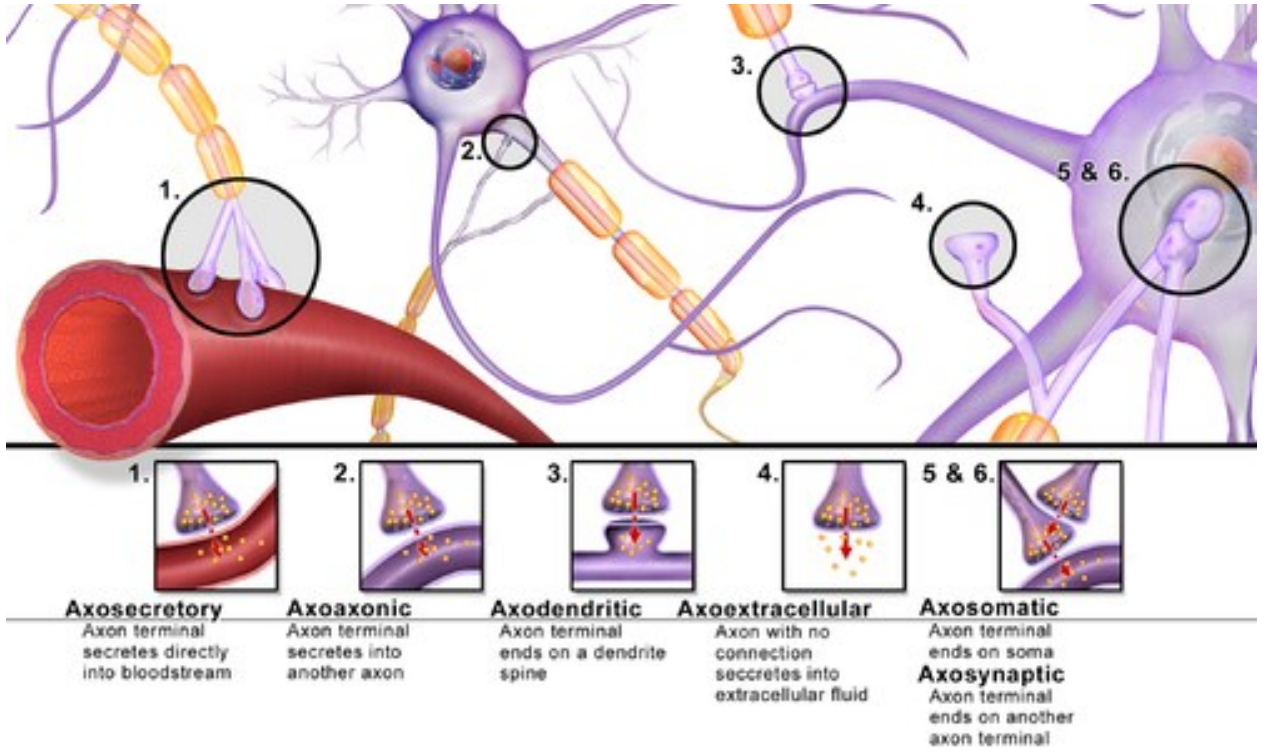





https://www.nobelprize.org/prizes/medicine/1906/summary/

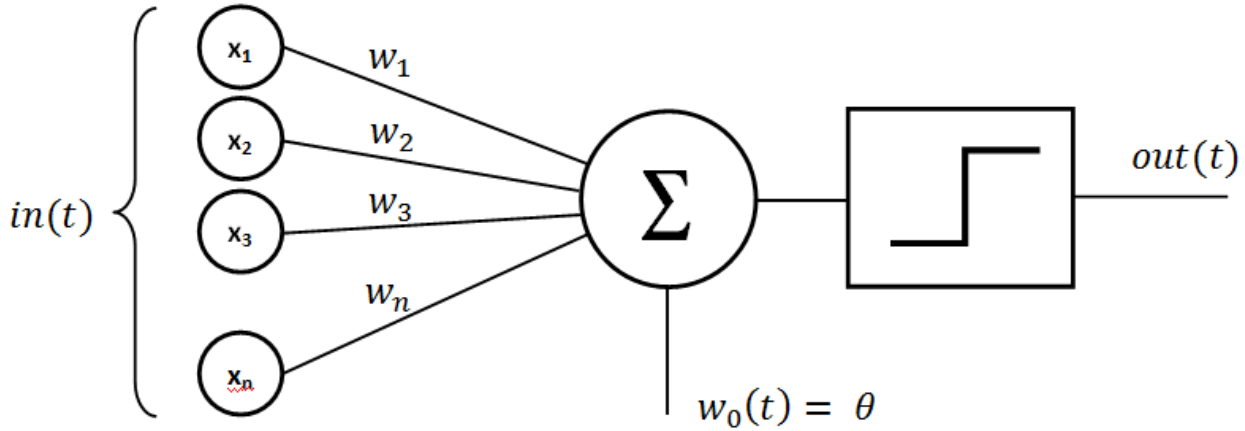
# Neural Network (Anatomy)

- Synapse is a structure that permits a neuron (or nerve cell) to pass an electrical or chemical signal to another neuron or to the target effector cell.
- Synapses are essential to the transmission of nervous impulses from one neuron to another.
- Different types of synapses



# Perceptron

- **1943 Perceptron** was invented by **McCulloch and Pitts**
- **1958 Mark I Perceptron** hardware developed and constructed by **Frank Rosenblatt**



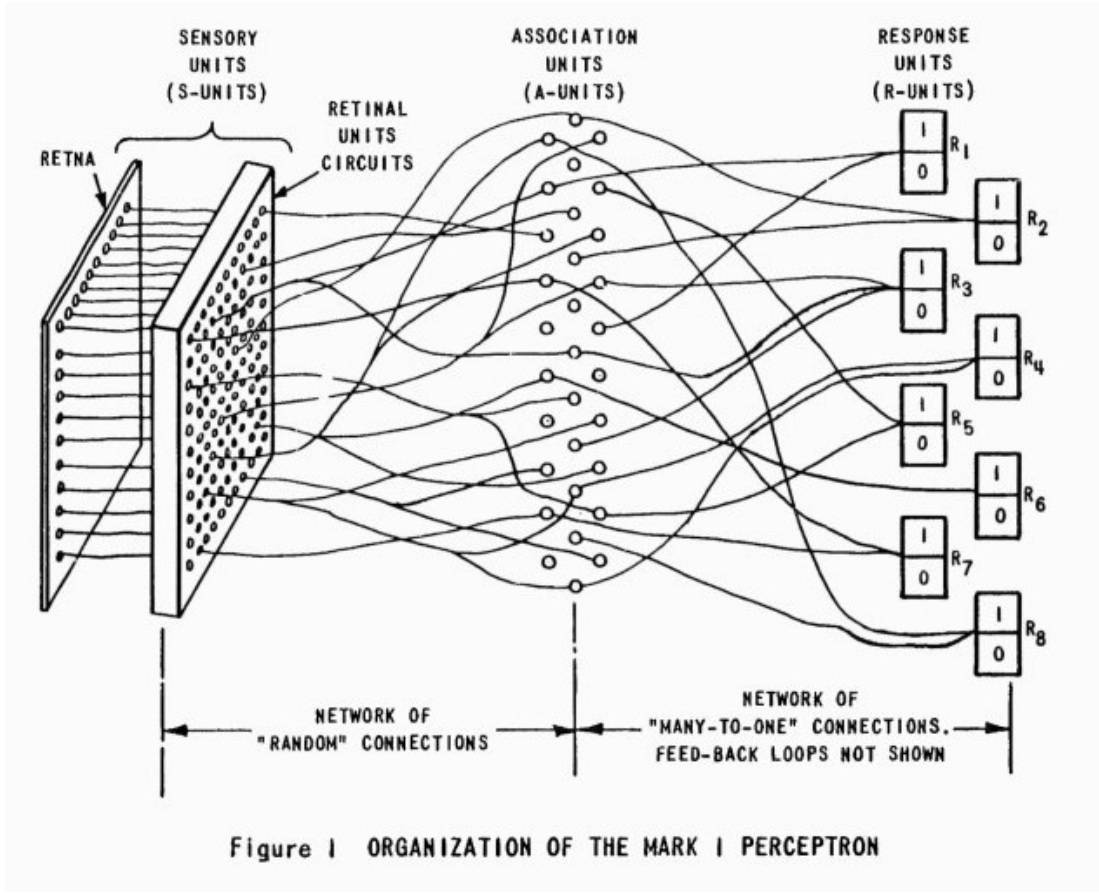
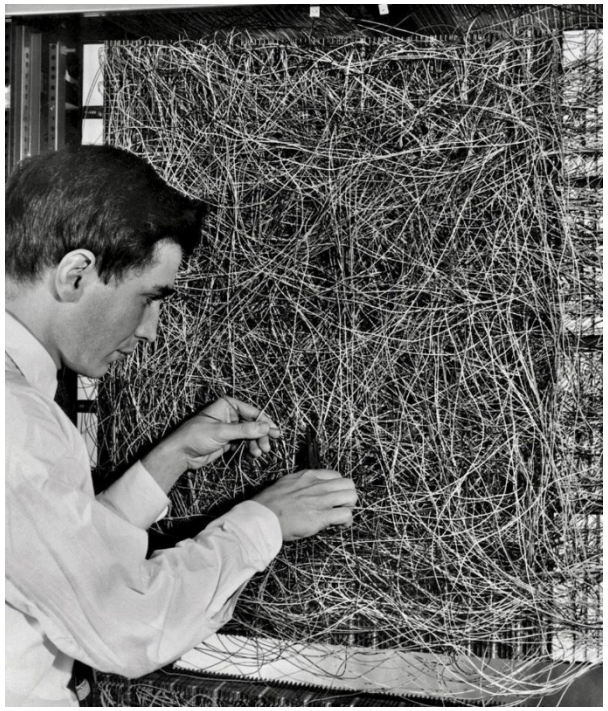
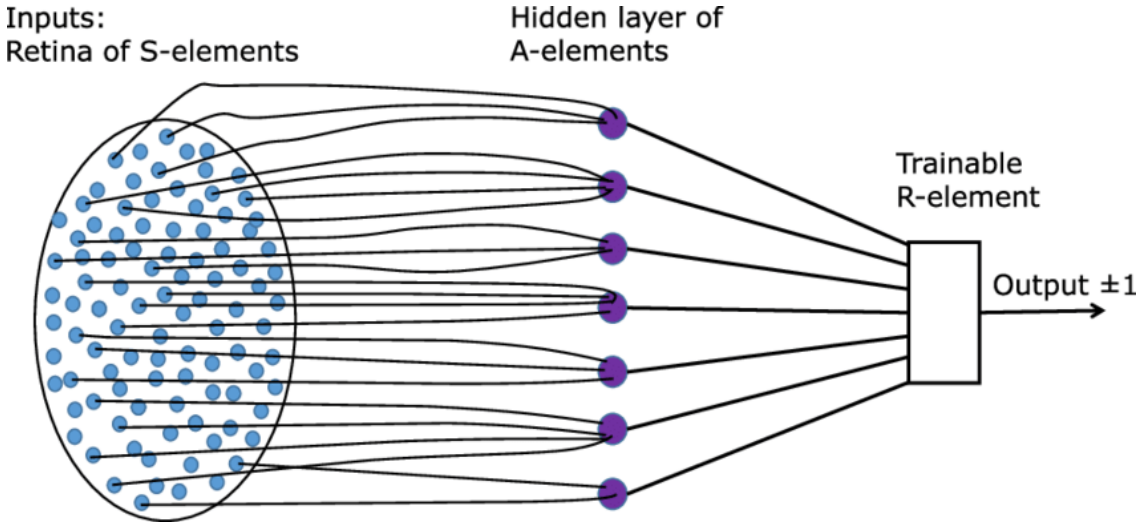




Figure I ORGANIZATION OF THE MARK I PERCEPTRON

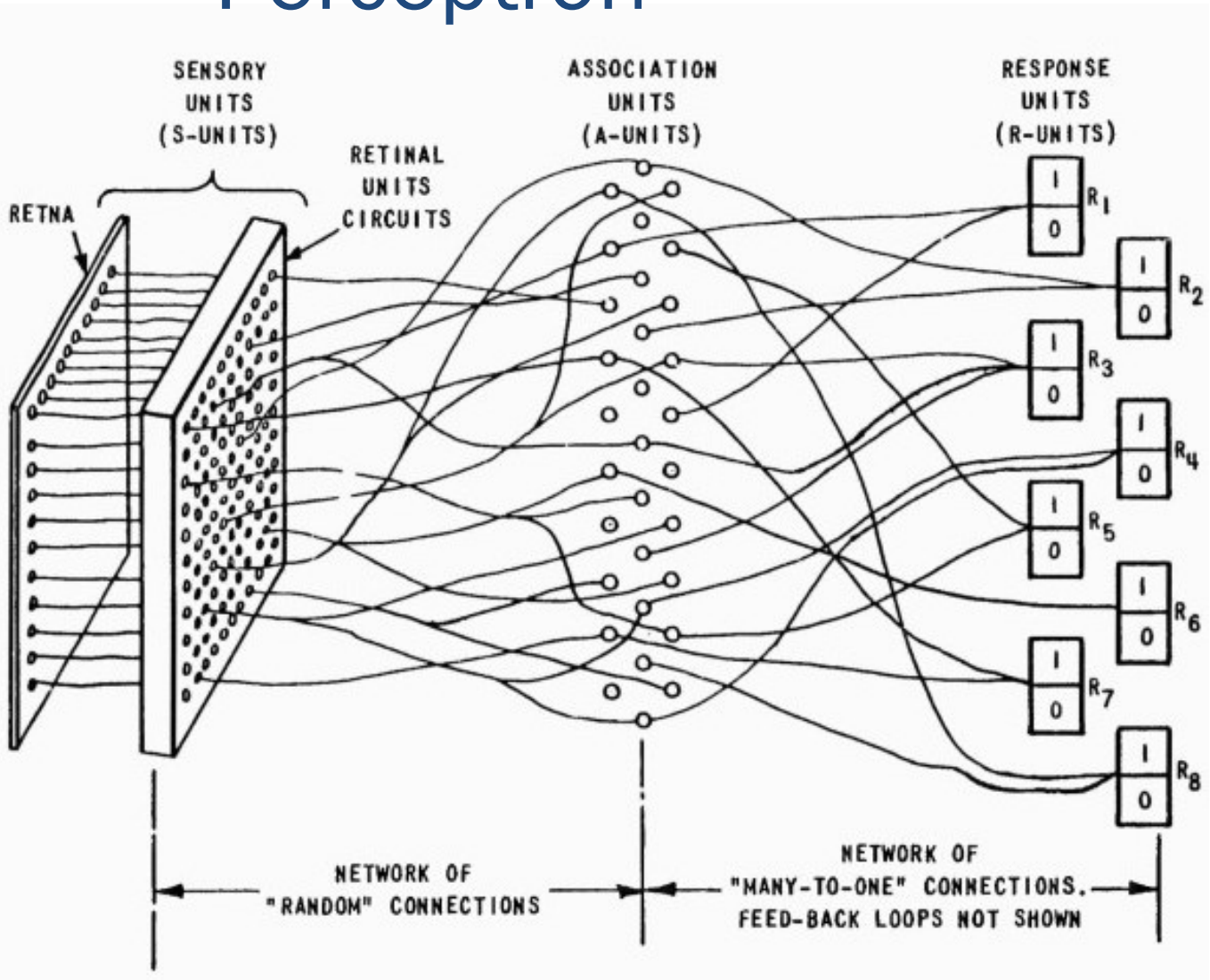
# Perceptron

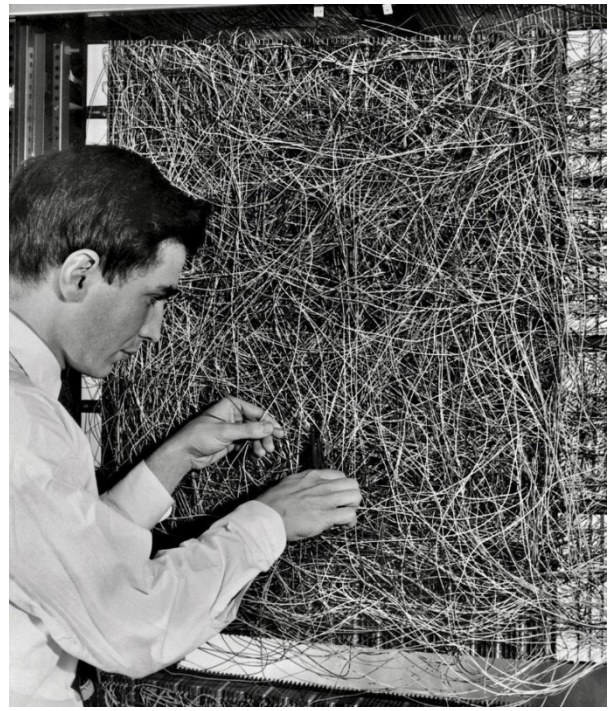
- **1958** Frank Rosenblatt development and hardware construction of the "**Mark I Perceptron**"
  - the first computer that could learn new skills by trial and error, using a type of neural network that simulates human thought processes.
  - at the Cornell Aeronautical Laboratory funded by the United States Office of Naval Research.

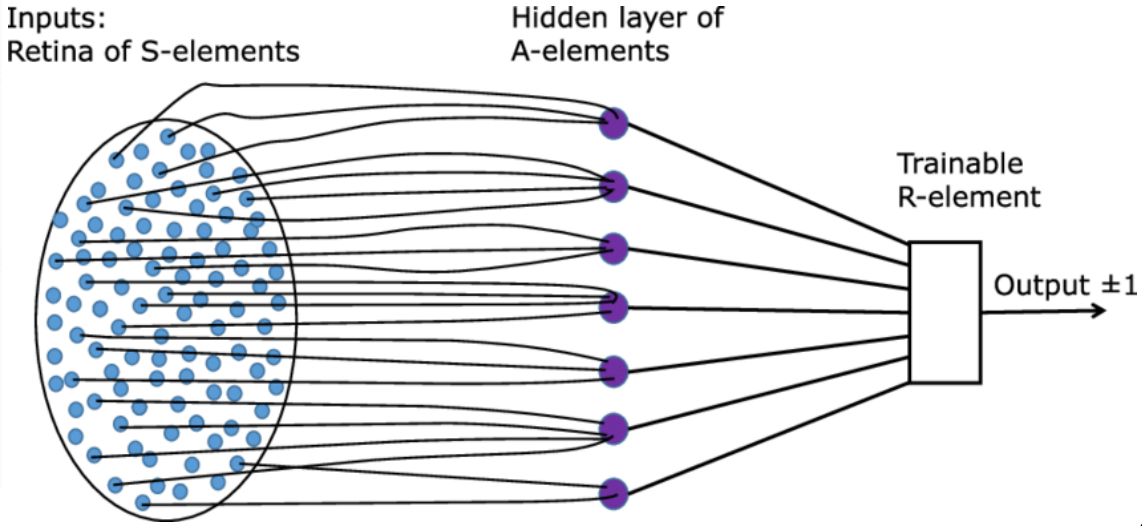




# Perceptron

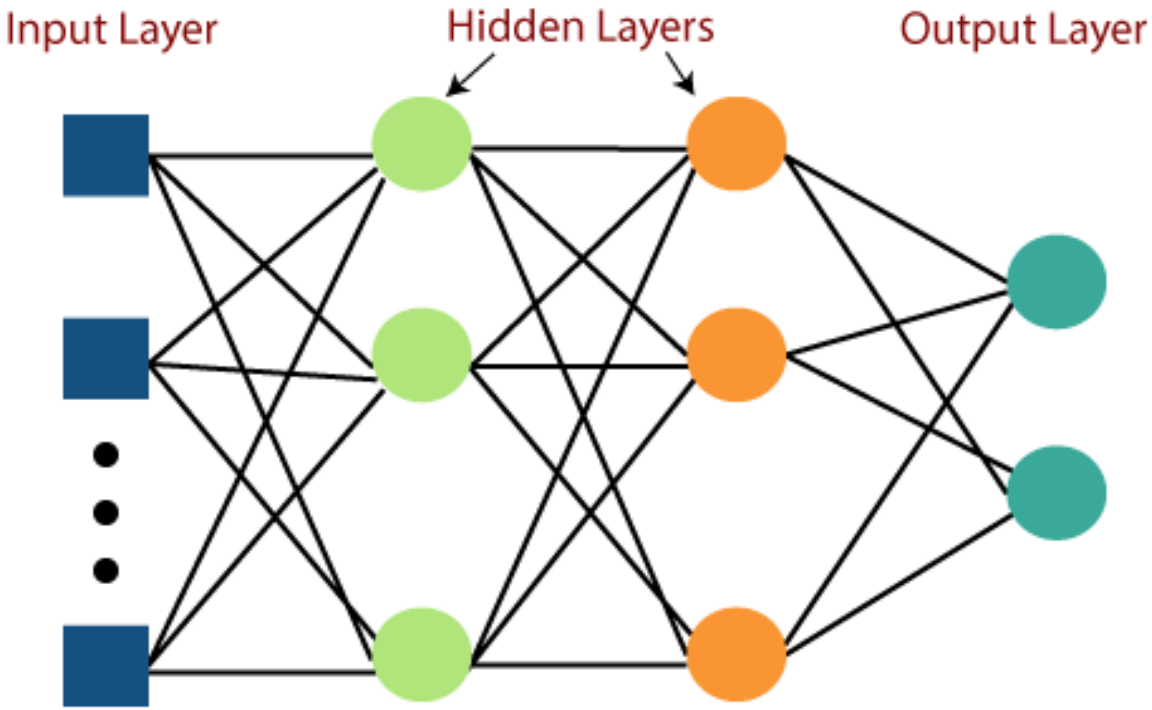

SENSORY UNITS (S-UNITS)
ASSOCIATION UNITS (A-UNITS)
RESPONSE UNITS (R-UNITS)
RETINAL UNITS CIRCUITS
RETNA
R1
R2
R3
R4
R5
R6
R7
R8
NETWORK OF "RANDOM" CONNECTIONS
NETWORK OF "MANY-TO-ONE" CONNECTIONS. FEED-BACK LOOPS NOT SHOWN

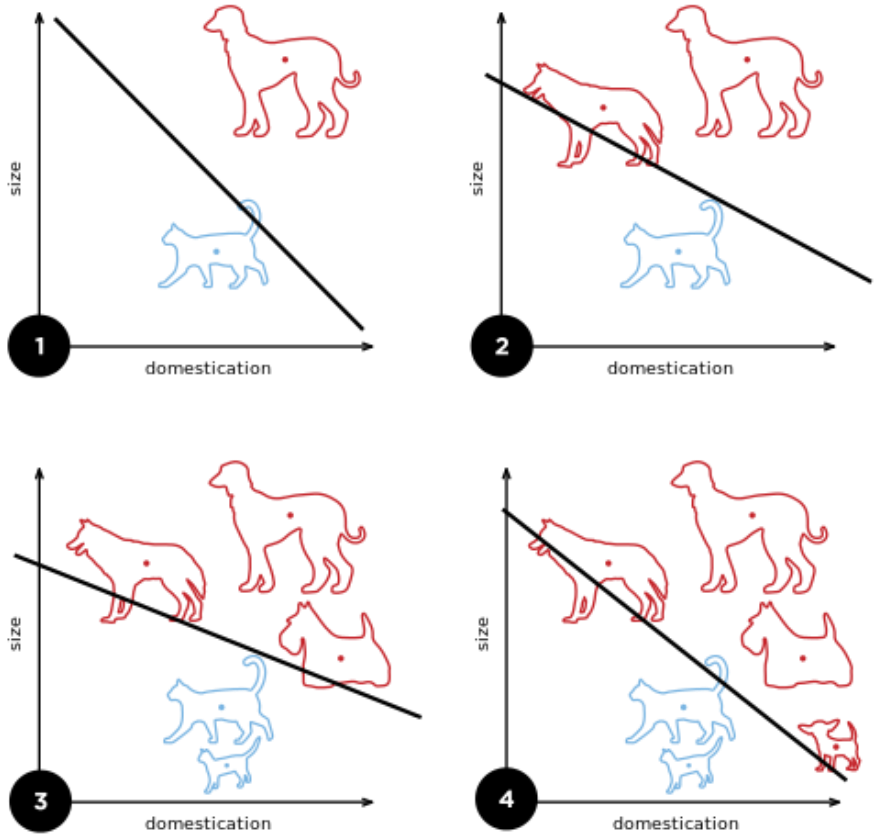



Inputs:
Retina of S-elements
Hidden layer of
A-elements
Trainable
R-element
Output ±1

# Multi-layer Perceptron

- **1960s** Limitation of Perceptron: Failed to classify basic problems
- Ivakhnenko et. al. introduced Multilayer Perceptrons

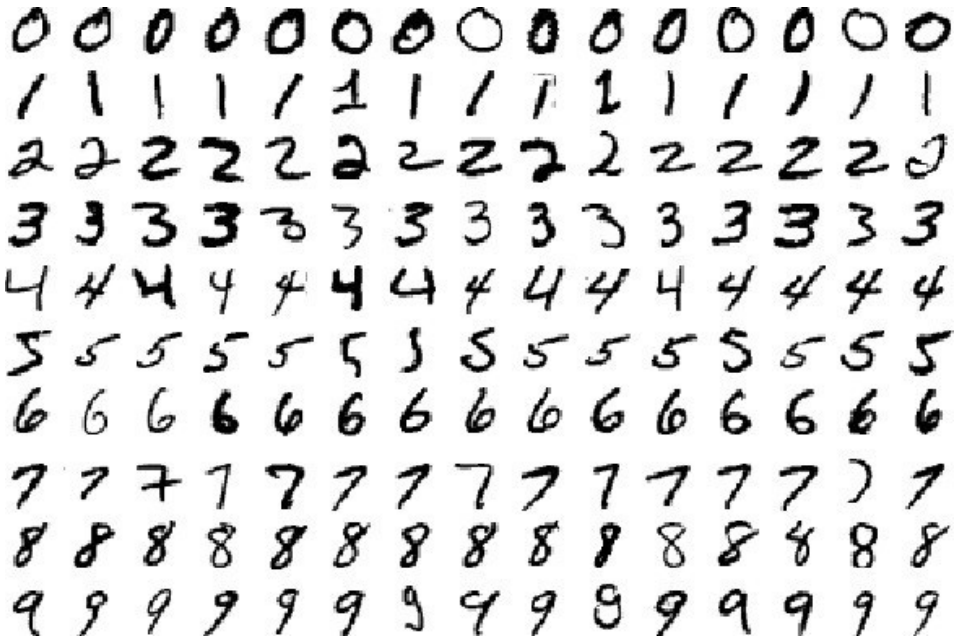


# Artificial Neural Network and Backpropagation

- 1982: Werbos introduced Backpropagation first used it in the context of Artificial Neural Networks
- 1986: Rumelhart et. al. popularized the Backpropagation
- Use of Cauchy discovered theories of Gradient Descent on Convex function for Optimization
- 1989: Universal Approximation Theorem "A multilayered network of neurons with a single hidden layer can be used to approximate any continuous function to any desired precision"

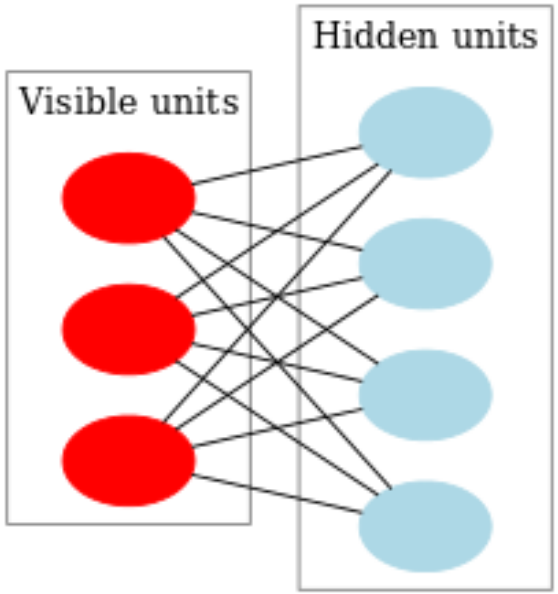
# Deep Learning



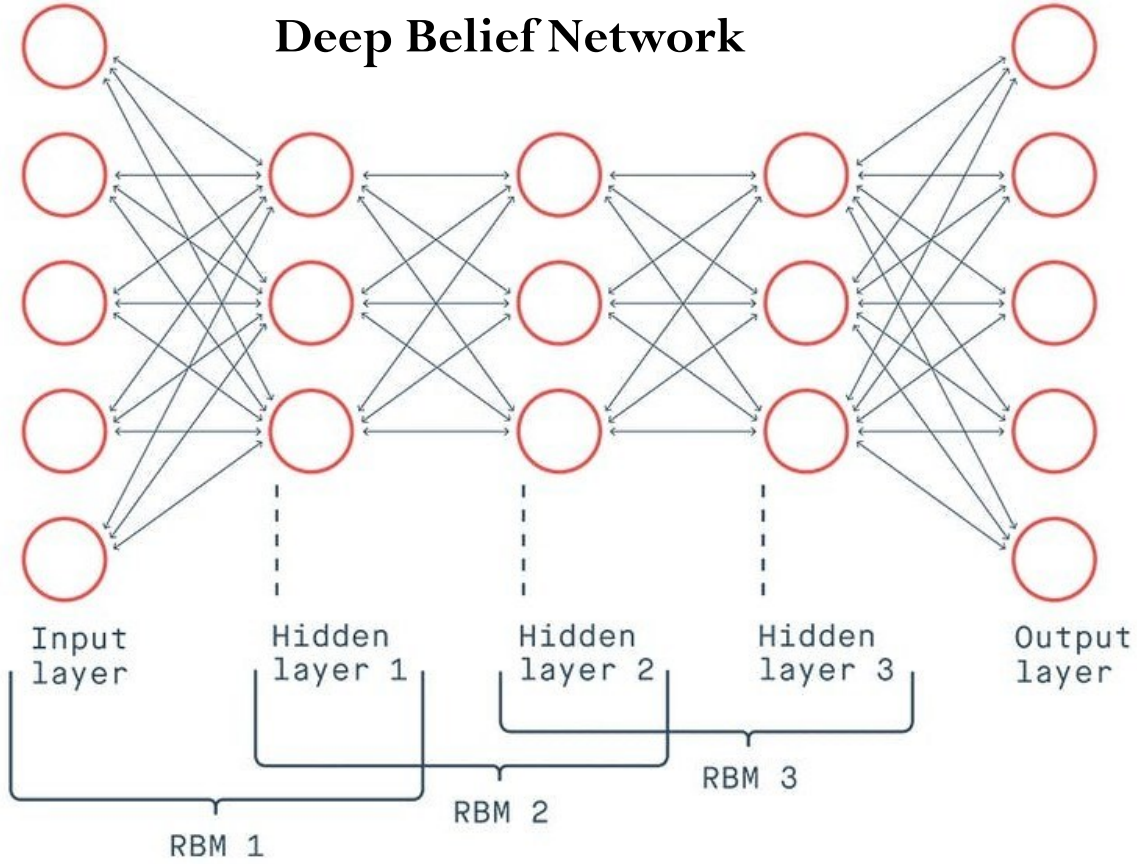
- Unsupervised Pre-Training
  - 1991-1993: J. Schmidhuber "Very Deep Learner"
  - 2006: Hinton and Salakhutdinov
- 2009: Handwriting Recognition
  - MNIST dataset
- 2010: Speech Recognition
  - Dahl et. al. achieved error reduction of 16.0% to 23.2% over previous works
- Traffic Sign Recognition Competition
  - D. C. Ciresan et. al. got only 0.56% error rate

# Restricted Boltzmann Machine and Deep Belief Network

**Restricted Boltzmann Machine**



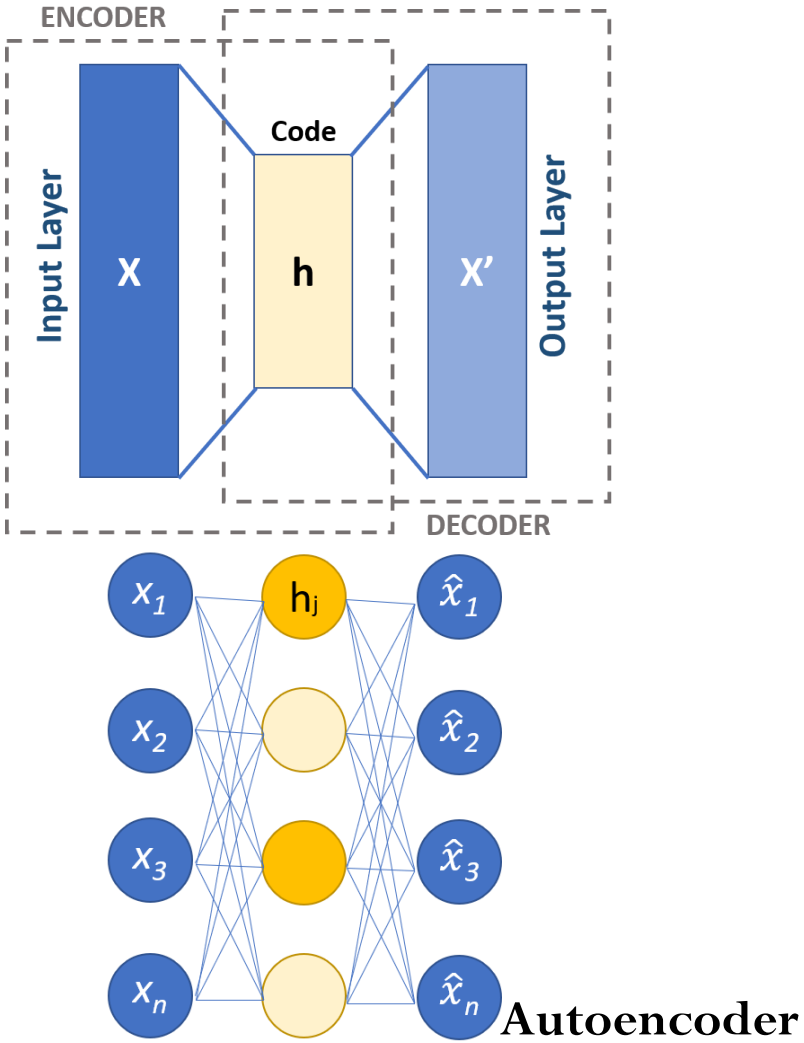

**Deep Belief Network**



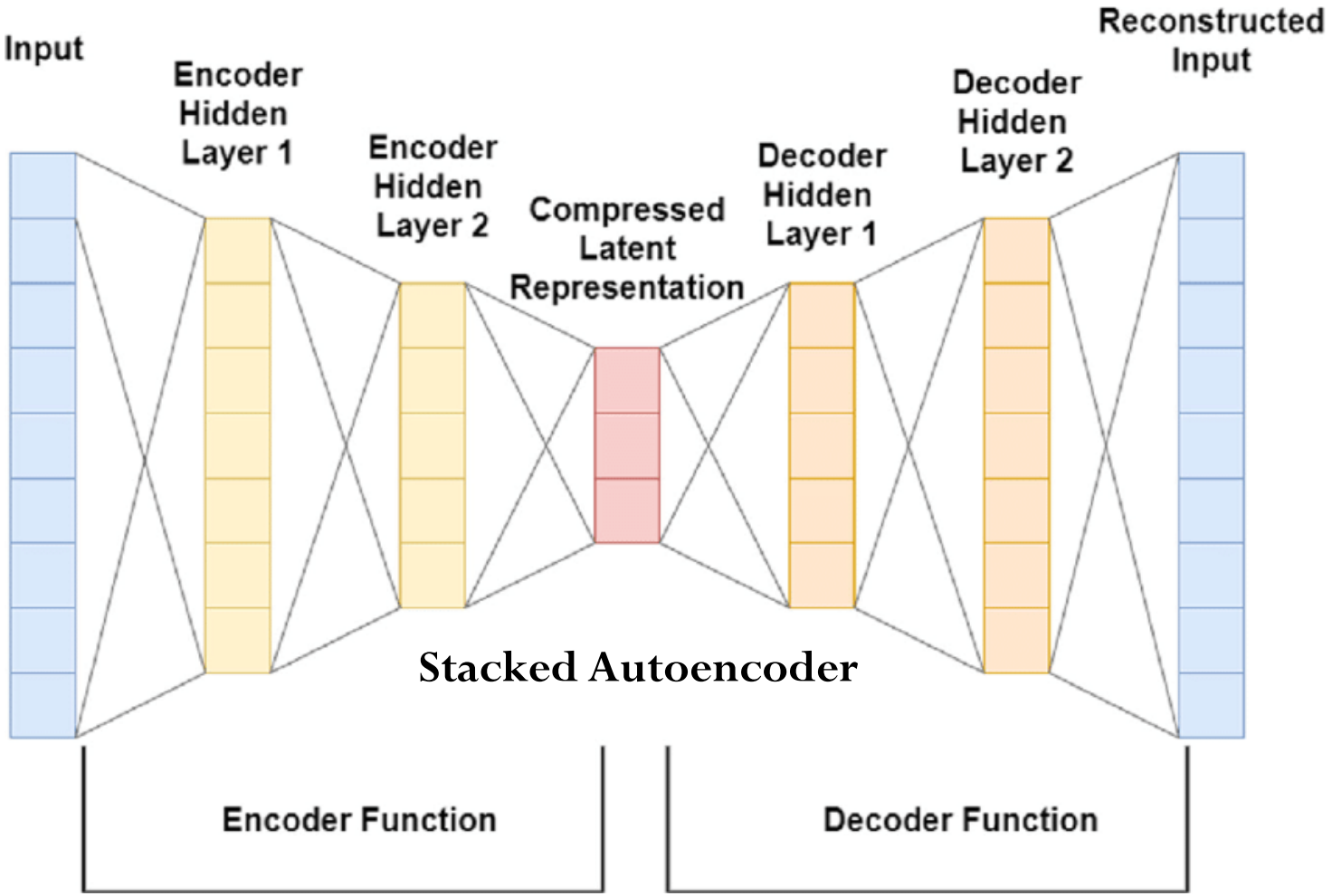

Ruslan Salakhutdinov, Andriy Mnih, and Geoffrey Hinton. "Restricted Boltzmann machines for collaborative filtering." Proceedings of the 24th International Conference on Machine learning. 2007.

Geoffrey E. Hinton, Simon Osindero, and Yee-Whye Teh. "A fast learning algorithm for deep belief nets." Neural computation 18.7 (2006): 1527-1554.

# Autoencoder and Stacked Autoencoder




**Autoencoder**



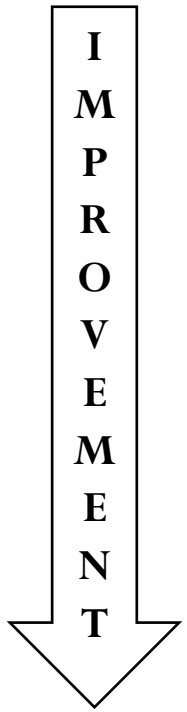

**Stacked Autoencoder**

Pascal Vincent, et al. "Stacked denoising autoencoders: Learning useful representations in a deep network with a local denoising criterion." Journal of Machine Learning Research 11.12 (2010).

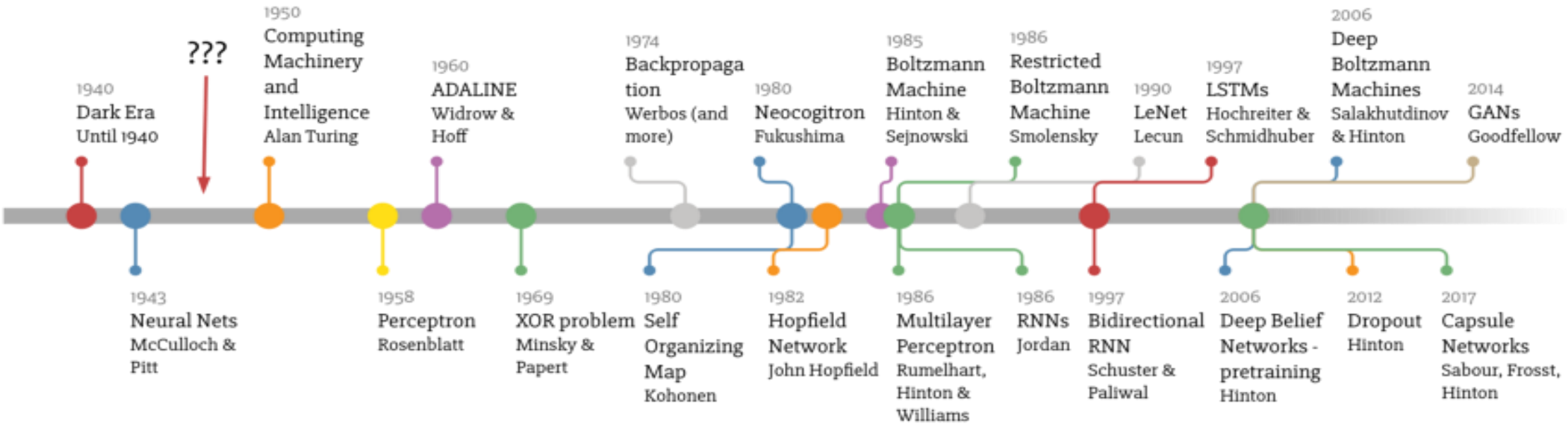
# Visual Recognition Challenges

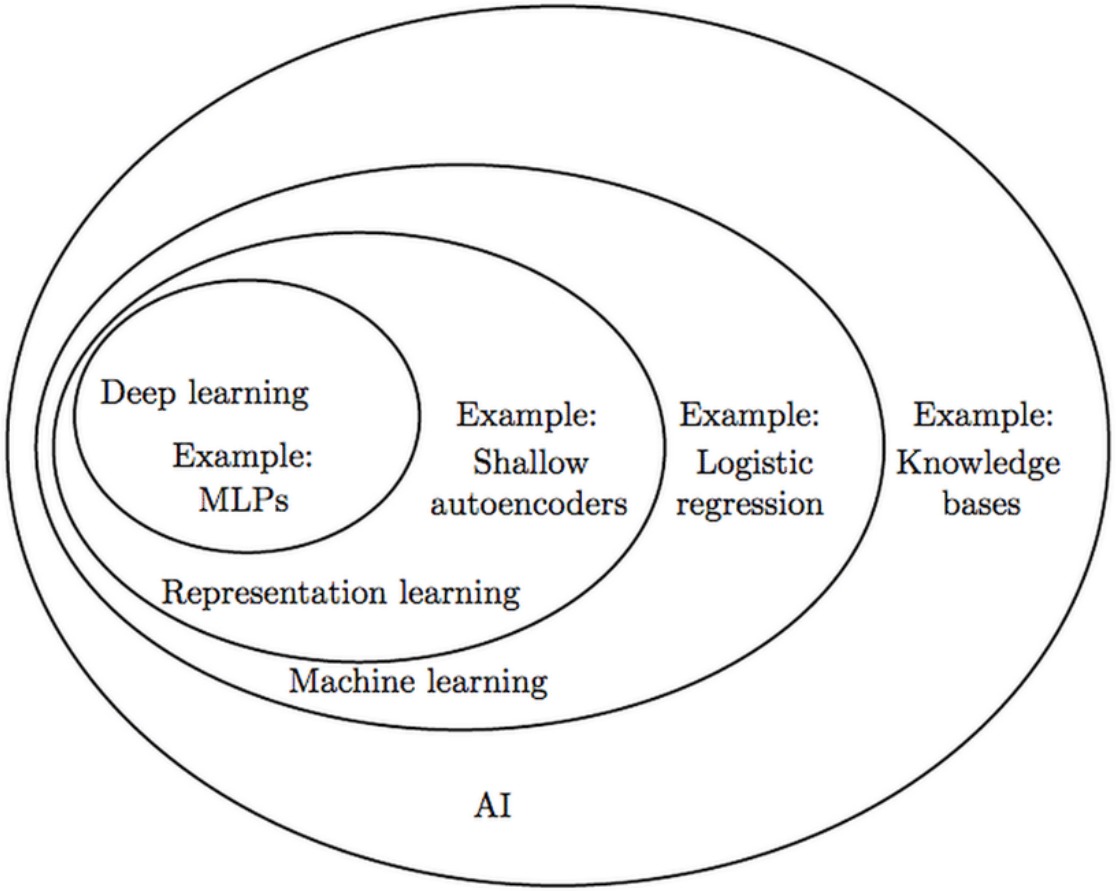
- ImageNet challenge successful 2012-2016

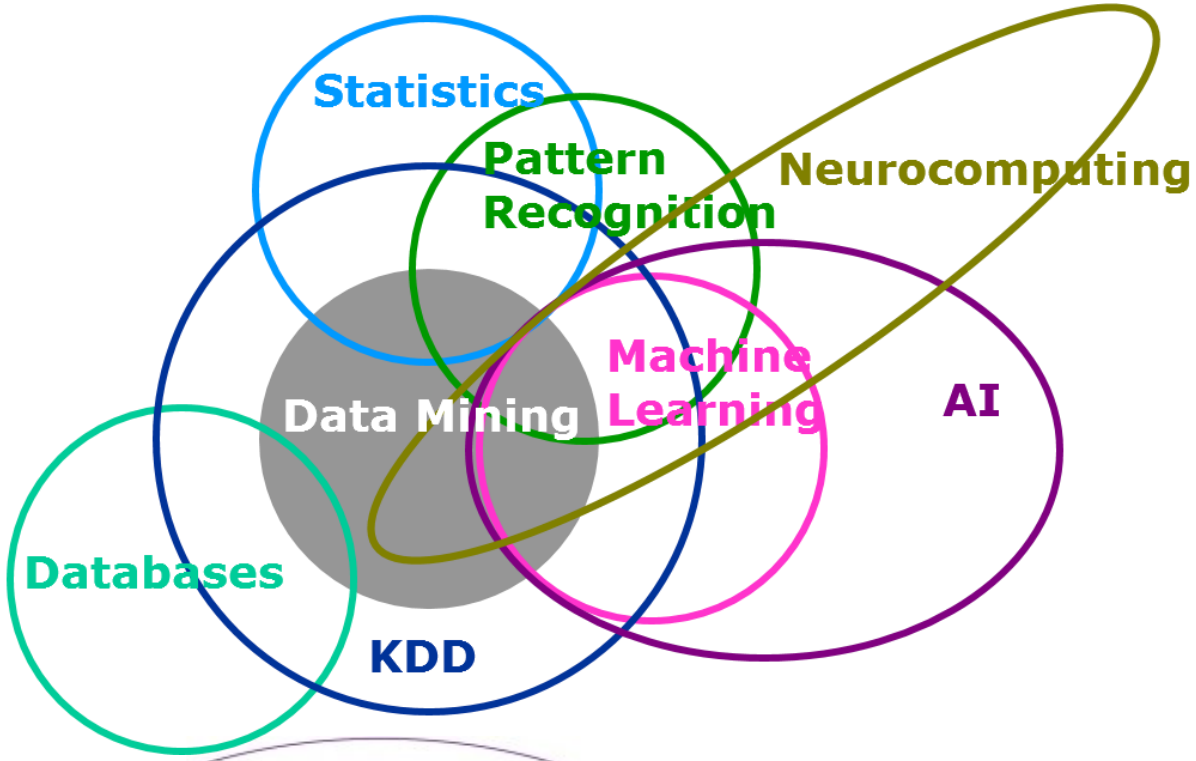
| Network | Error | Layers |
|---|---|---|
| AlexNet | 16.0% | 8 |
| ZFNet | 11.2% | 8 |
| VGGNet | 7.3% | 19 |
| GoogLeNet | 6.7% | 22 |
| MS ResNet | 3.6% | 152!! |

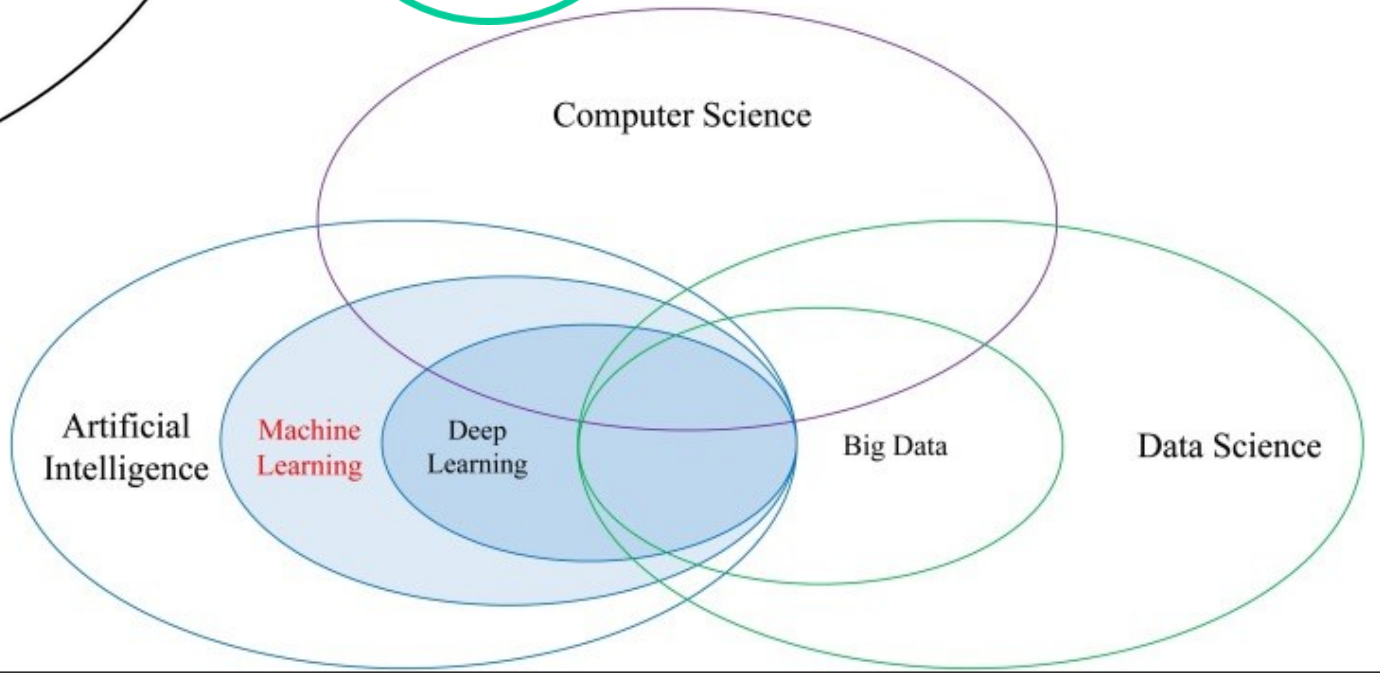


# Artificial Neural Network




Deep learning
Example:
MLPs
Example:
Shallow
autoencoders
Example:
Logistic
regression
Example:
Knowledge
bases
Representation learning
Machine learning
AI


Statistics
Pattern
Recognition
Neurocomputing
Machine
Learning
AI
Data Mining
Databases
KDD


Computer Science
Artificial
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# Humanly and Rationally (Thinking and Acting)

# Definition of AI

- Physics:
  - Where did the ***physical universe*** come from?
  - What are **physical laws**?
- Biology:
  - Does the ***biological life*** evolved?
  - How does organs in **living organisms** works together?
- AI:
  - What is ***intelligence*** *of a living being and non-living being?*
  - capacity for learning, reasoning, understanding, and similar forms of mental activity

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# What is Intelligence of Living being

- Ability to perceive and act in the world
- Reasoning: proving theorems, medical diagnosis
- Planning: take decisions
- Learning and Adaptation: recommend movies, learn traffic patterns
- Understanding: text, speech, visual scene

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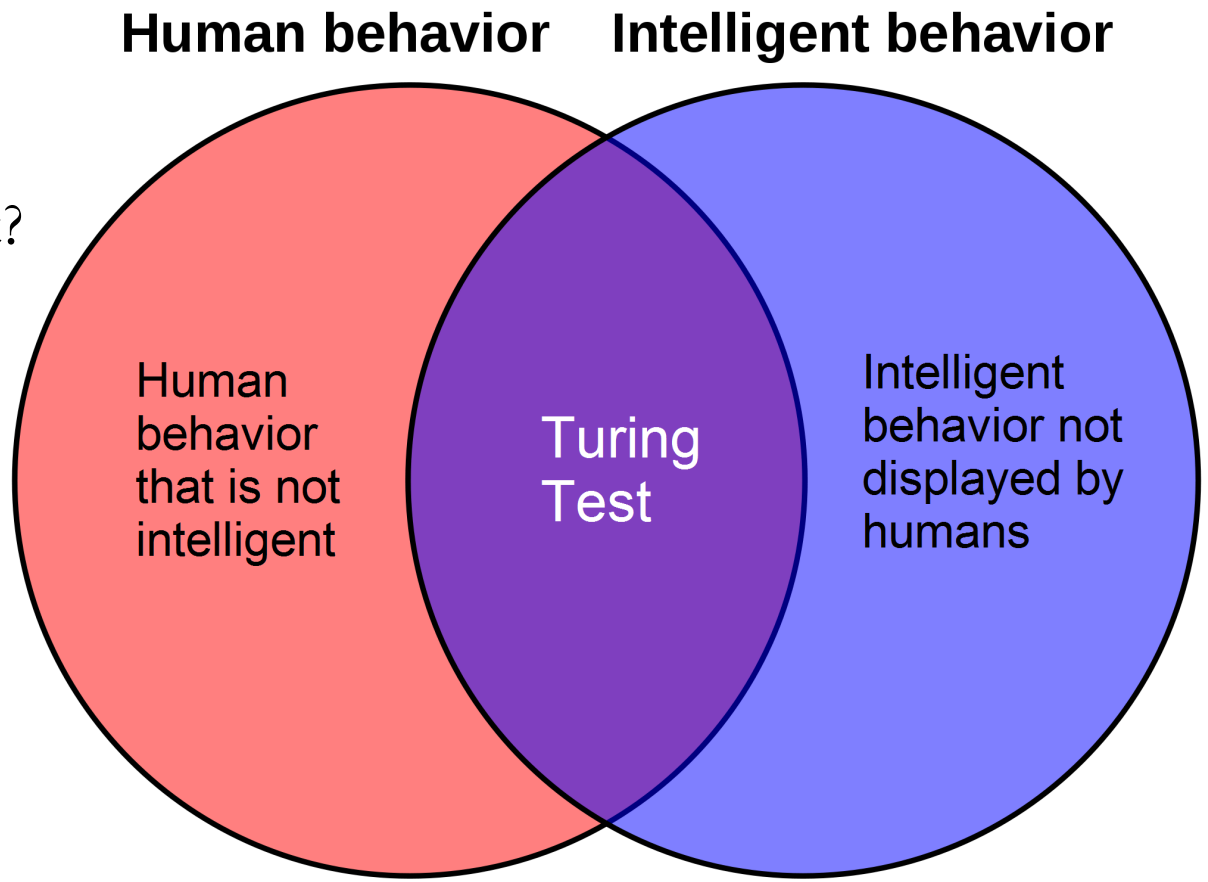
# Intelligence vs. humans

- Are humans intelligent?
  - replicating human behavior early hallmark of intelligence
- Are humans ~~always~~ intelligent?
  - not necessary ☺
- Can non-human behavior be intelligent?
  - possible ☺

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# Rationally vs Humanly

- **Artificial Intelligence is the study of how to make computers do things at the moment, and do better**
- **AI important elements:**

1. Systems that think like humans
2. Systems that act like humans
3. Systems that think rationally
4. Systems that act rationally

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# Human-like vs Rational
# Thought vs Behavior

## Human-like vs Rational

| Thought vs Behavior | Human-like | Rational |
|---|---|---|
| | ``The exciting new effort to make **computers think** … *machines with minds*, in the full and literal sense" (Haugeland, 1985)``The automation of activities that we associate with **human thinking**, activities such as decision-making, problem solving, learning …" (Bellman, 1978) | ``The study of **mental faculties** through the use of **computational models**" (Charniak and McDermott, 1985)``The study of the computations that make it possible to **perceive, reason, and act**" (Winston, 1992) |
| | ``The art of creating machines that perform functions that require **intelligence when performed by people**" (Kurzweil, 1990)``The study of how to make computers do things at which, at the moment, **people are better**" (Rich and Knight, 1991) | ``A field of study that seeks to **explain and emulate intelligent behavior** in terms of computational processes" (Schalkoff, 1990)``The branch of computer science that is concerned with the **automation of intelligent behavior**" (Luger and Stubblefield, 1993) |

| Thought vs Behavior | Human-like | Rational |
|---|---|---|
| Thought | Systems that think like humans. | Systems that think rationally. |
| Behavior | Systems that act like humans | Systems that act rationally |

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# Intelligent Computer

- Possess the following capabilities:
  - **Natural Language Processing** to enable it to communicate successfully in English (or some other human language);
  - **Knowledge Representation** to store information provided before or during the interrogation;
  - **Automated Reasoning** to use the stored information to answer questions and to draw new conclusions;
  - **Machine Learning** to adapt to new circumstances and to detect and extrapolate patterns.
  - **Computer vision** to perceive objects, and
  - **Robotics** to move them about.

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# Thinking and Acting

- Two thoughts
  - Humanly: concerned with reasoning steps of human subjects solving the same problems.
  - Rationally: concerned with getting the right answers regardless of how humans might do it.


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# Thinking humanly


- Cognitive Science and Modelling:
  - Determining how humans think and workings of human minds
  - Hard to understand how humans think
  - Two ways
    - Introspection --trying to catch our own thoughts
    - Psychological experiments
- Do we want a machine that beats humans in chess or a machine that thinks like humans while beating humans in chess?
    - Deep Blue supposedly DOESN'T think like humans..
  - Express the theory as a computer program behavior matches human behavior
- Thinking like humans important in Cognitive Science applications
  - Intelligent tutoring
  - Expressing emotions in interfaces… HCI

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# Thinking Rationally

- **Right Thinking:** "arguments structures that always gave correct conclusions given correct premises"
- **Syllogism:** "Socrates is a man; all men are mortal therefore Socrates is mortal."
- **Field of Logic:** Laws of thought were supposed to govern the operation of the mind.
  - Logical notation to find solution to a problem.
  - Finding solution to all kinds of things in the world and the relations between them.
- **Issue 1:** Not easy to take informal knowledge and state it in the formal terms required by Logical notation, particularly when the knowledge is less than 100% certain.
- **Issue 2:** There is a big difference between being able to solve a problem "in principle'" and doing so in practice. Means proposing algorithm and it's coding are different problems.
- Power of the representation and reasoning systems

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# Acting Humanly




- Loebner Prize
  - Every year in Boston
  - an annual contest based on the Turing Test
  - an annual competition in artificial intelligence that awards prizes to the computer programs considered by the judges to be the most human-like.
- Problems
  - Not reproducible, constructive, or mathematically analyzable
  - Make human-like errors

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# Acting Rationally


- Acting to achieve one's goals, given one's beliefs.
- Rational behavior: doing the right thing
- Need not always be deliberative
  - Reflexive
- Every art and every inquiry, and similarly every action and every pursuit is thought to aim at some good.
  - By Aristotle (Nicomachean ethics)


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