IEC-03
Artificial Intelligence Techniques

Autumn 2024

(credits: All AI researchers)

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Course Outlines:

S.No.	Contents	Contact hours
1.	**Introduction to AI:** Overview of the AI, History of AI, Categorization of AI, Mathematics of AI (Linear Algebra fundamentals, Probability theory fundamentals, optimization fundamentals)	8
2	**Computational Learning Theory:** Regression, Classification, AI algorithms (Decision Tree, Random Forest, PCA (SVD, EVD), SVM), Supervised learning, unsupervised learning, reinforcement learning, Artificial Neural Network; Introduction to Deep Learning.	26
3	**Applications of AI.:-** Time series analysis, Health Informatics, NLP (Large Language Models)	6

Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication
1.	Artificial Intelligence : A Modern Approach (Paperpack). Stuart Russell and Peter Norvig. Pearson; 3 edition.	2010
2.	Deep Learning, Goodfellow and Bengio, Courville, MIT Press	2016
3.	Pattern Recognition and Machine Learning. Christopher Bishop. Springer.	2006
4.	Deep Learning with Python, Chollet, Manning publications	2017
5.	Reinforcement Learning: An Introduction. Richard S. Sutton Andrew G. Barto . MIT Press,	2017

Weightage & Policies

- MTE - 20%
- ETE - 45%
- CWS - 35% (includes attendance, Quizzes, project and HW assignments)
  (subject to further review :-) !!)
- Attendance (95% and above – 5/5, 90% and above – 3.75/5 , 80% and above – 2.5/5, 75% and above – 1.25/5, Below 75% -- zero)

Goals of this course

- A brief intro to the philosophy of AI
- A brief intro to the breadth of ideas in AI
- More Application Oriented and broad !!!

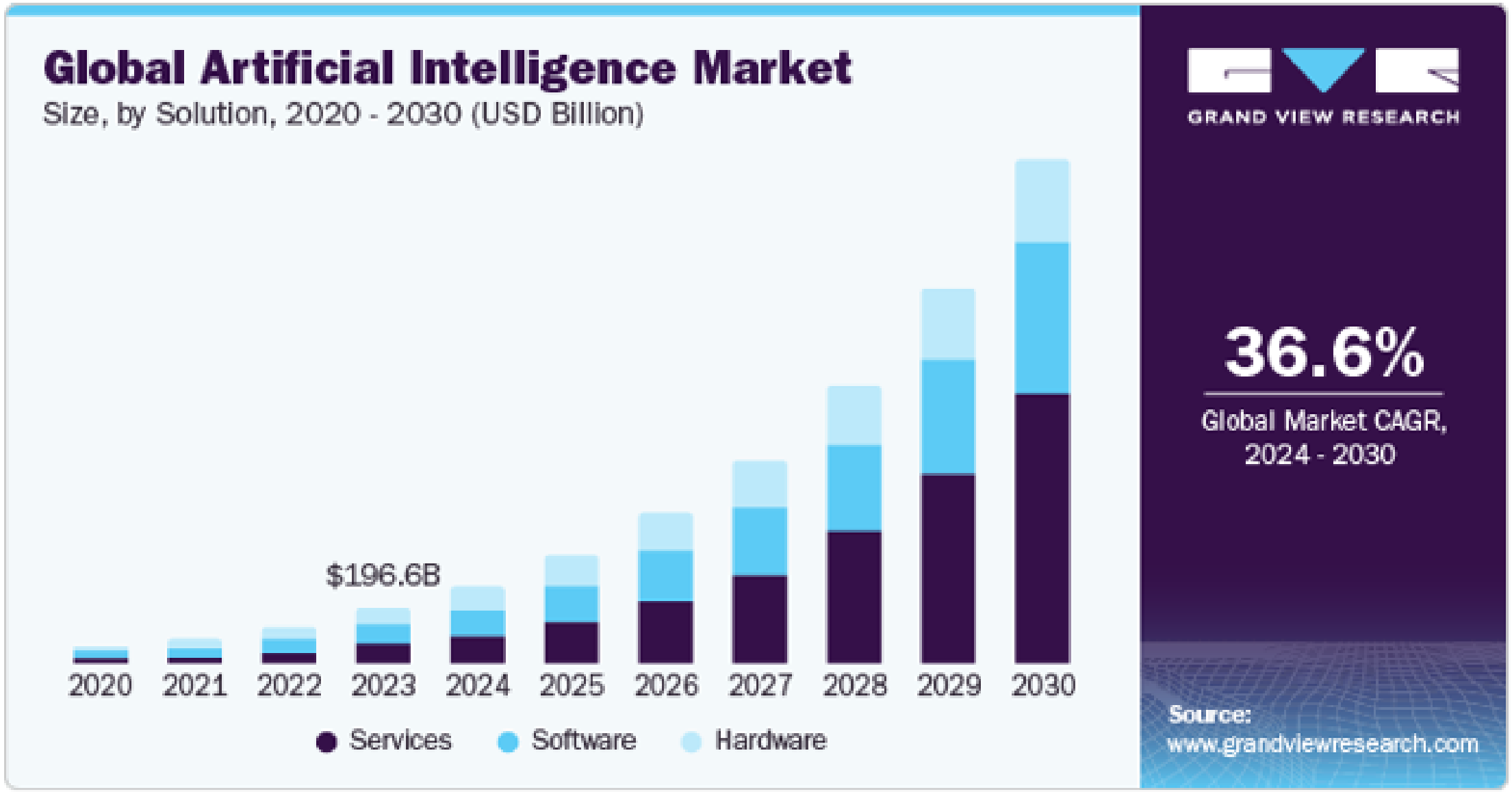
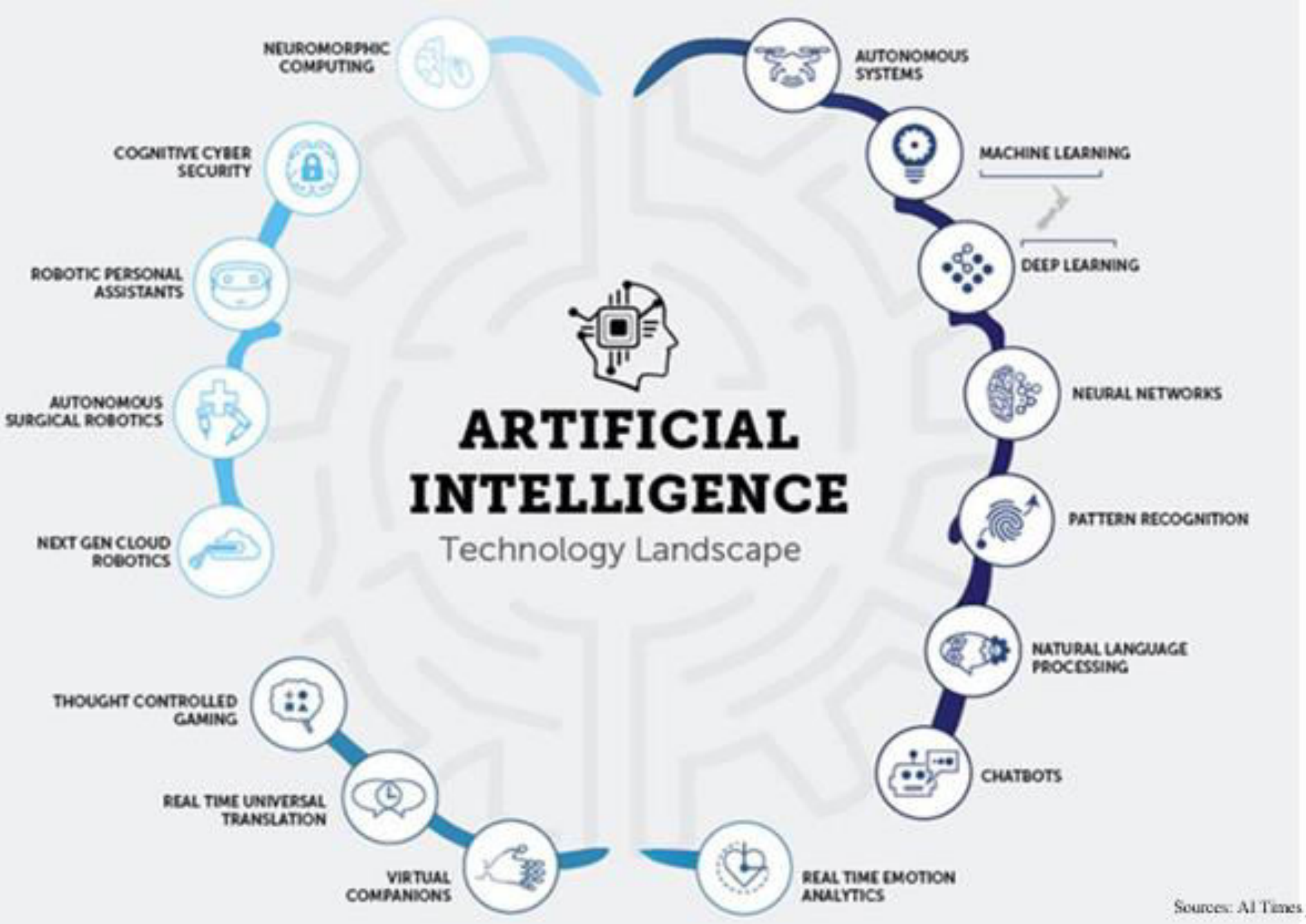


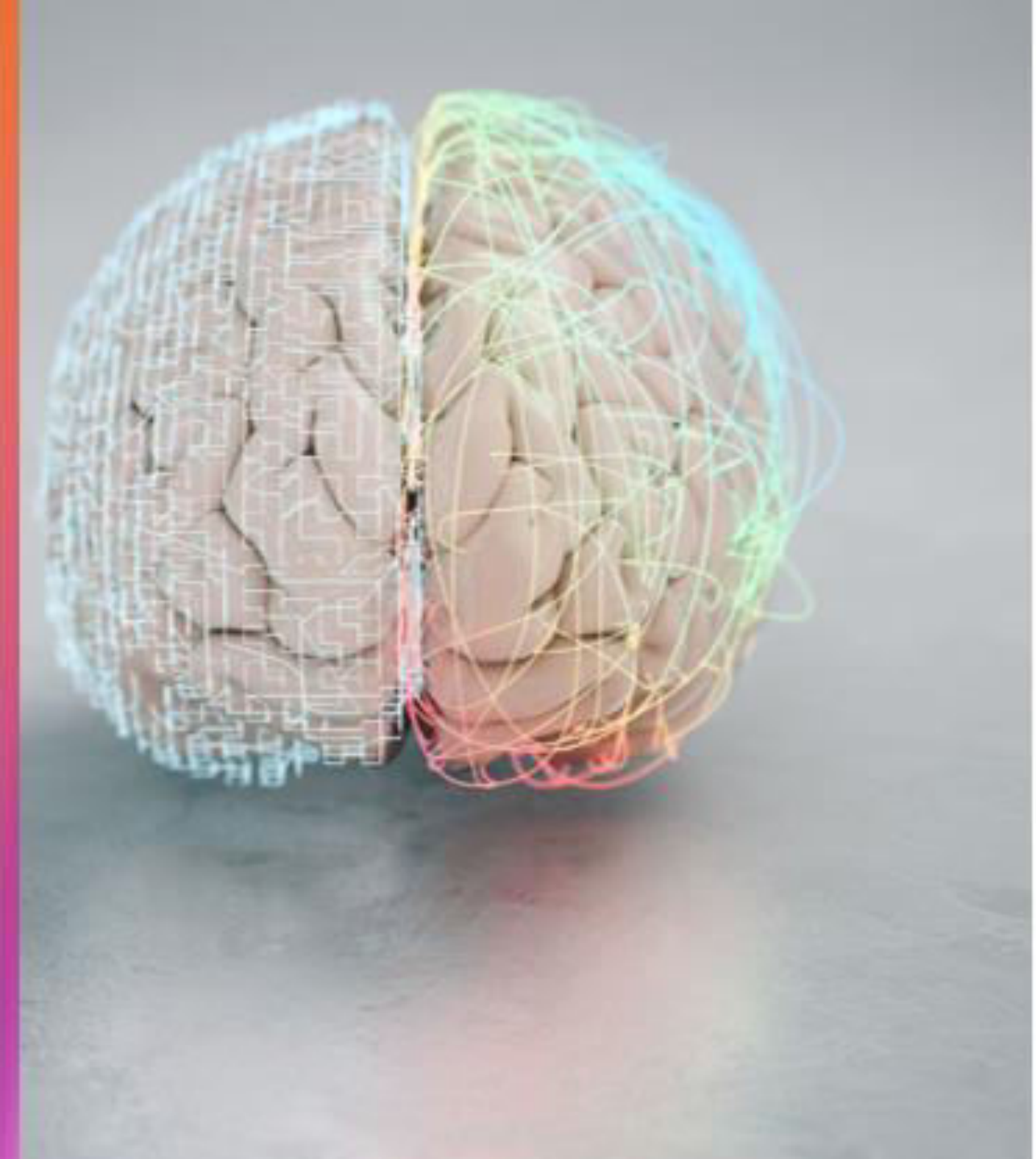
Fig 1. Global Artificial Intelligence market and size



Sources: AI Times journal

Digital Soldiers (Robot)

AI in Agriculture



Artificial Intelligence (from a western perspective)

- For thousands of years, we have tried to understand how we think and act—that is, how our brain, a mere handful of matter, can perceive, understand, predict, and manipulate a world far larger and more complicated than itself.

- Artificial intelligence is obsessed with not just understanding but also building intelligent entities—machines that can compute how to act effectively and safely in a wide kind of novel situations.

- Ranging from the general (learning, reasoning, perception, and so on) to the specific, such as playing chess, proving mathematical theorems, writing poetry, driving a car, or diagnosing diseases. AI is relevant to any intellectual task; it is truly a universal field

How AI works

Fig 2. AI Workflow Diagram

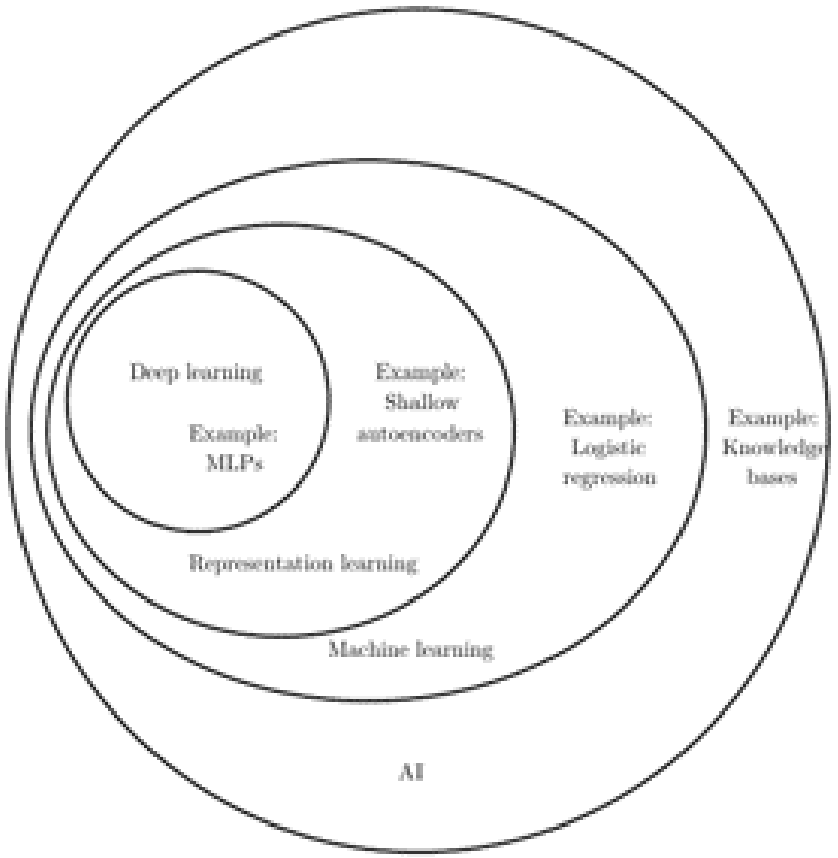


Figure 1.4: A Venn diagram showing how deep learning is a kind of representation learning, which is in turn a kind of machine learning, which is used for many but not all approaches to AI. Each section of the Venn diagram includes an example of an AI technology.

What is AI (Continued.....)

- Intelligence (what it comprises??)
    - Loyal to Humane
    - Rationality (doing the right thing)
    - Property of thought processes and reasoning
    - Intelligent behavior

- Acting humanly: Turing test approach
- Thinking humanly: Cognitive modeling version
- Thinking rationally: Laws of thought approach
- Acting rationally: Rational Agent approach

What is intelligence?

- Dictionary.com: *capacity for learning, reasoning, understanding, and similar forms of mental activity*

- 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

What is *artificial* intelligence?

human-like *vs.* rational

thought *vs.* behavior

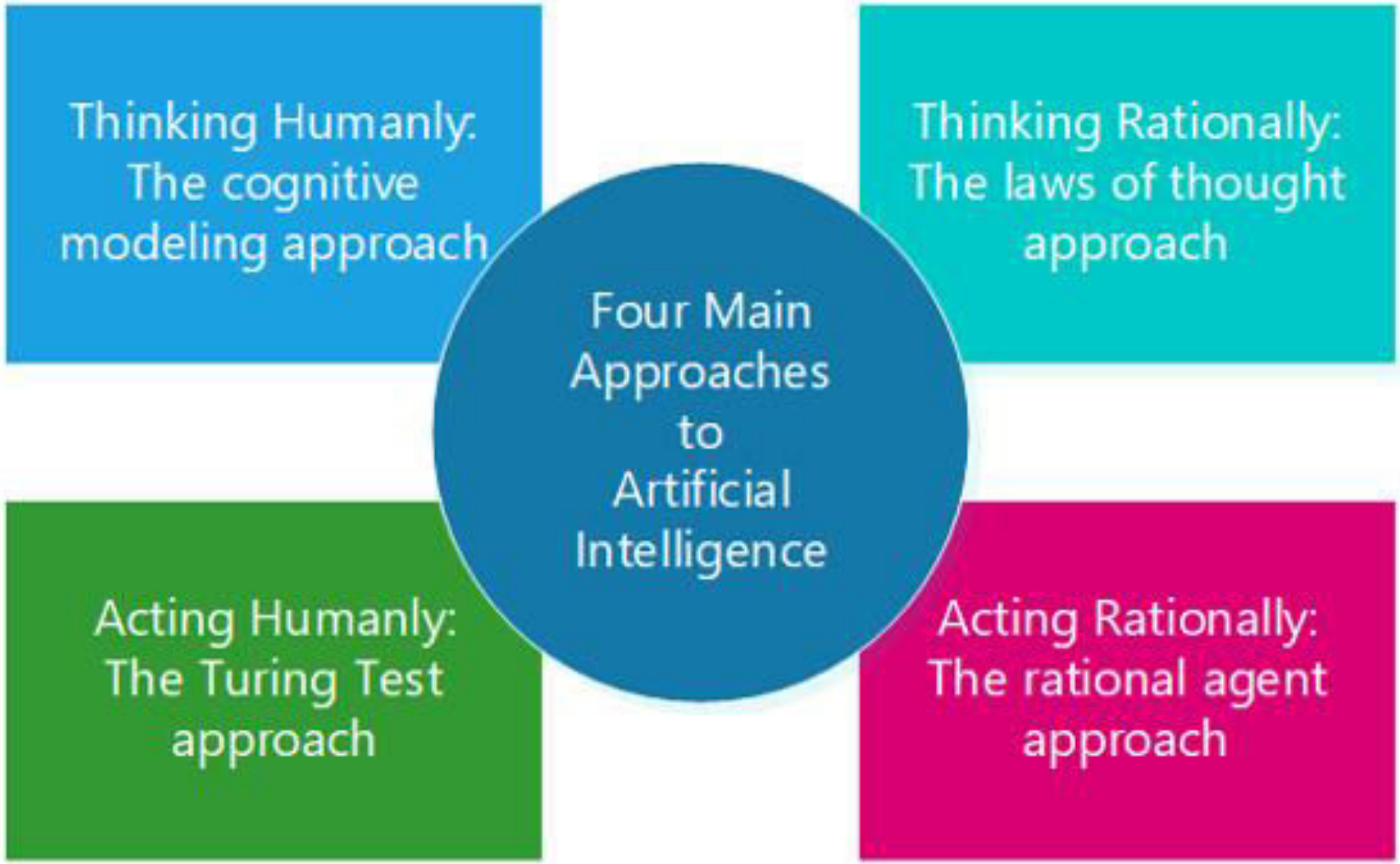
"[automation of] activities that we associate with human thinking, activities such as decision making, problem solving, learning..." (Bellman 1978)	"The study of mental faculties through the use of computational models" (Charniak & McDertmott 1985)
"The study of how to make computers do things at which, at the moment, people are better" (Rich & Knight 1991)	"The branch of computer science that is concerned with the automation of intelligent behavior" (Luger & Stubblefield 1993)

What is *artificial* intelligence?

thought *vs.* behavior \ human-like *vs.* rational	
Systems that think like humans	Systems that think rationally
Systems that act like humans	Systems that act rationally

Acting → Thinking?

- Weak AI Hypothesis vs. Strong AI hypothesis
  - Weak Hyp: machines could act as if they are intelligent
  - Strong Hyp: machines that act intelligent have to think intelligently too


Thinking Humanly: The cognitive modeling approach
Thinking Rationally: The laws of thought approach
Four Main Approaches to Artificial Intelligence
Acting Humanly: The Turing Test approach
Acting Rationally: The rational agent approach

Sources : GC

1950: Turing asks the question….

I propose to consider the question:

"Can machines think?"

Turing Test

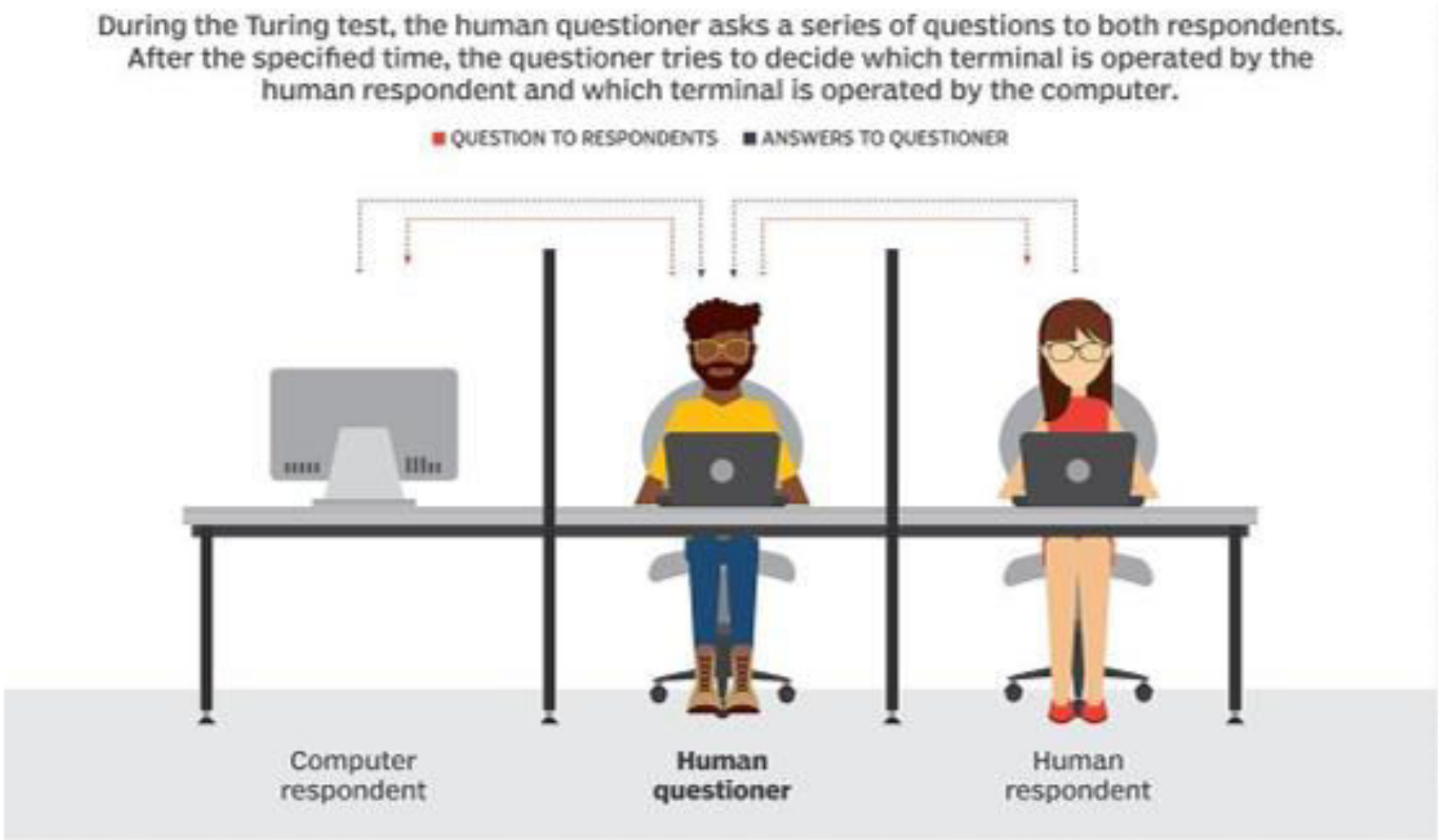


Fig 3. Turing Test Approach

Sources : Techtarget

Turing Test

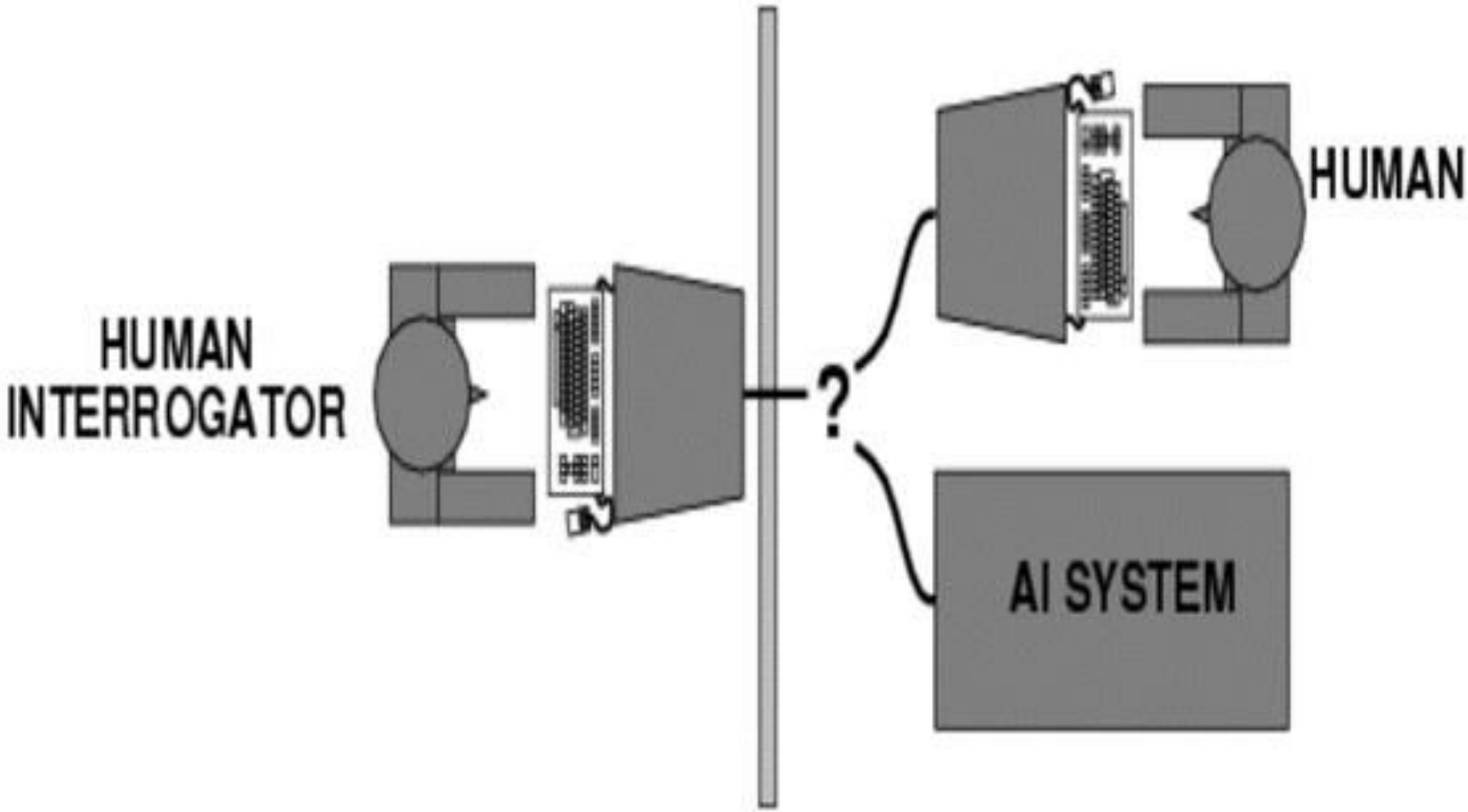


Fig 4. Turing Test approach

Turing Test

- Concept understood by a thought experiment !!
- Turing (1950) proposed a test based on a thought experiment answers the question "Can a machine think?"

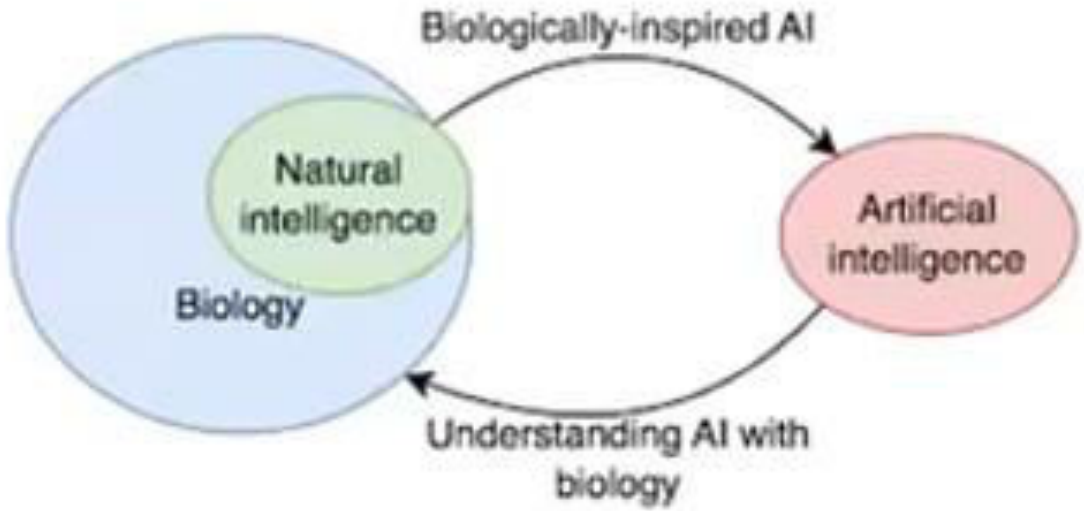
- Natural Language Processing to communicate successfully in a human language
- Knowledge Representation to store what it knows or hears
- Automated Reasoning to answer questions and to draw new conclusions
- Machine Learning to adapt to new circumstances and to detect and extrapolate patterns.

- Total Turing test,
- Needs interaction with objects and people in the real world.
  To pass the total Turing test, a robot will need
- computer vision and speech recognition to perceive the world
- robotics to manipulate objects and move about.

- These six disciplines compose most of AI. Yet AI researchers have devoted little effort to passing the Turing test, believing that it is more important to study the underlying principles of intelligence.

What is AI (Continued.....)

- Thinking humanly: The cognitive modeling approach
  - Introspection, Psychological experiment & Brain imaging



Will It Ever Be Possible to Create a General AI with Sentience and Conscience and Consciousness?

  - Thinking rationally: The "laws of thought" approach & Acting rationally: The rational agent approach (Ignored)

Thinking Rationality : Laws of thought approach

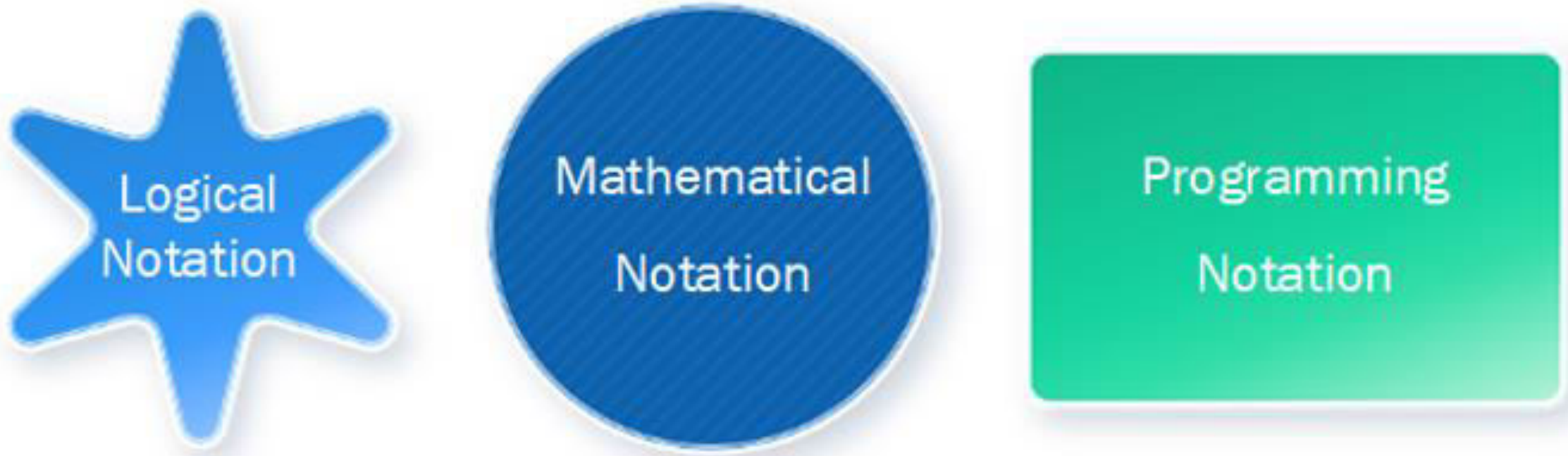
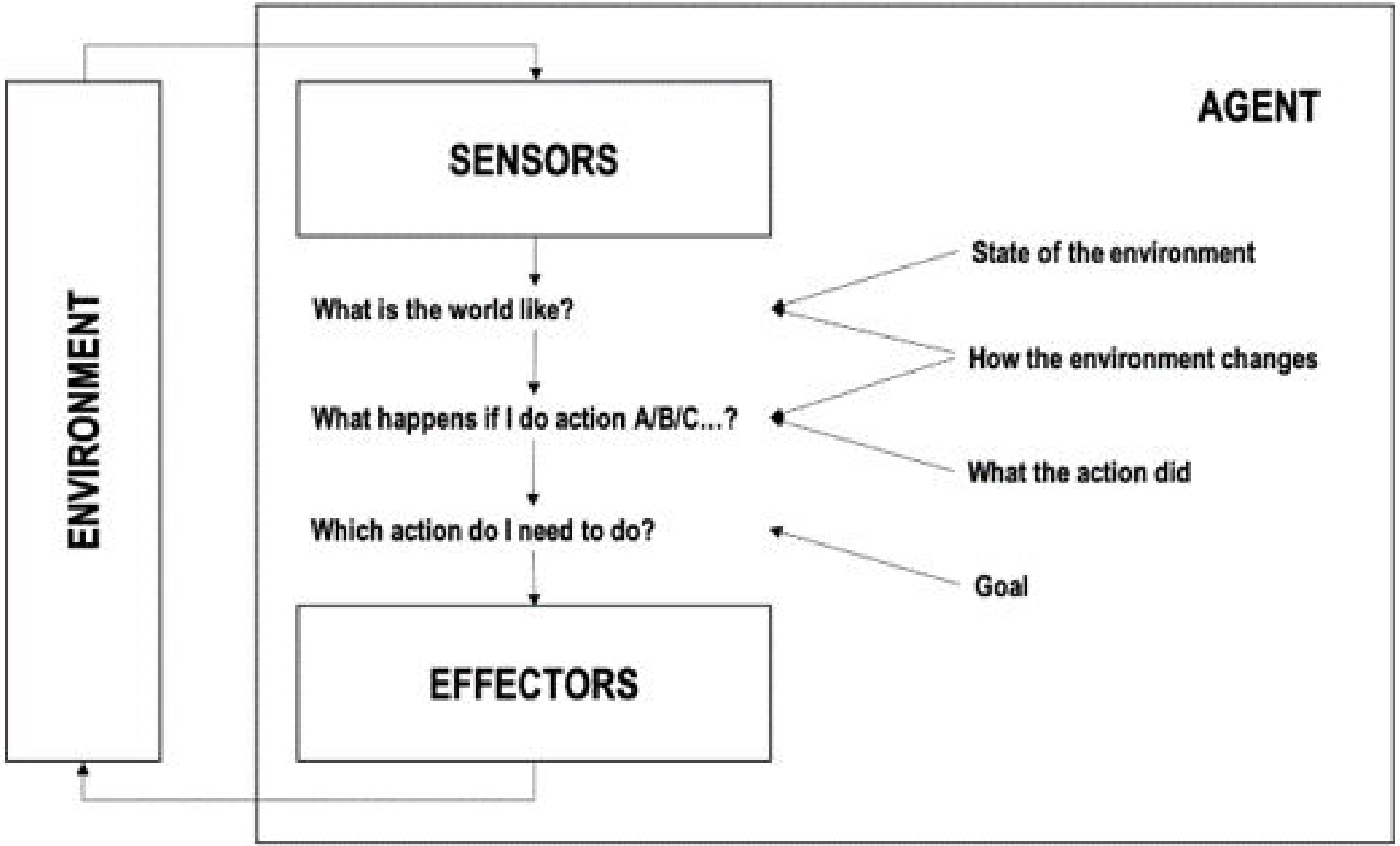


Fig 7. Thinking Rationality : Laws of thought

Acting rationally: Rational Agent approach



Sources: Techslang

Fig 8. Acting rationality : Rational Agent approach

Acting rationally: Rational Agent approach

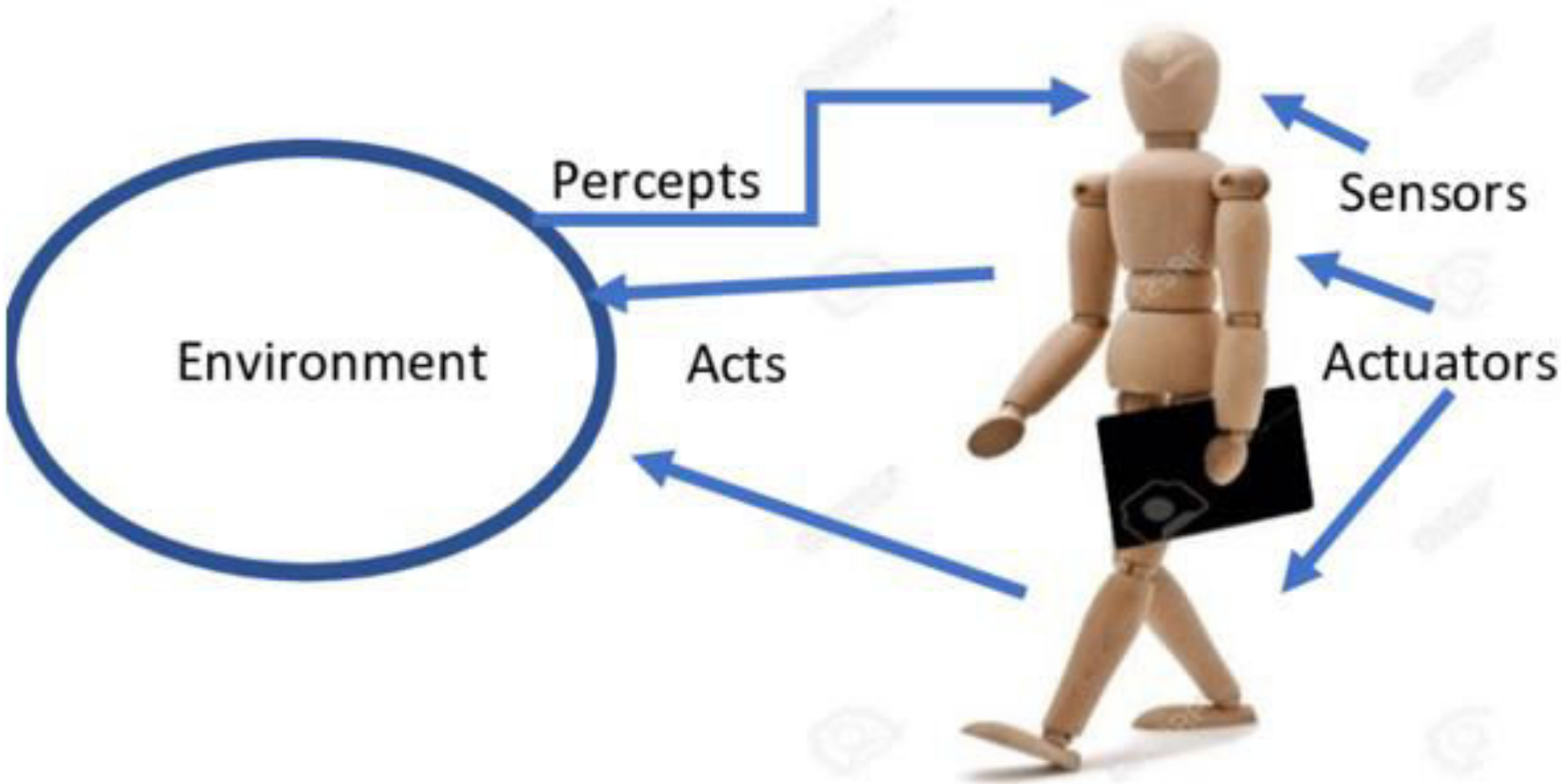


Fig 9. Acting rationality: Rational Agent approach

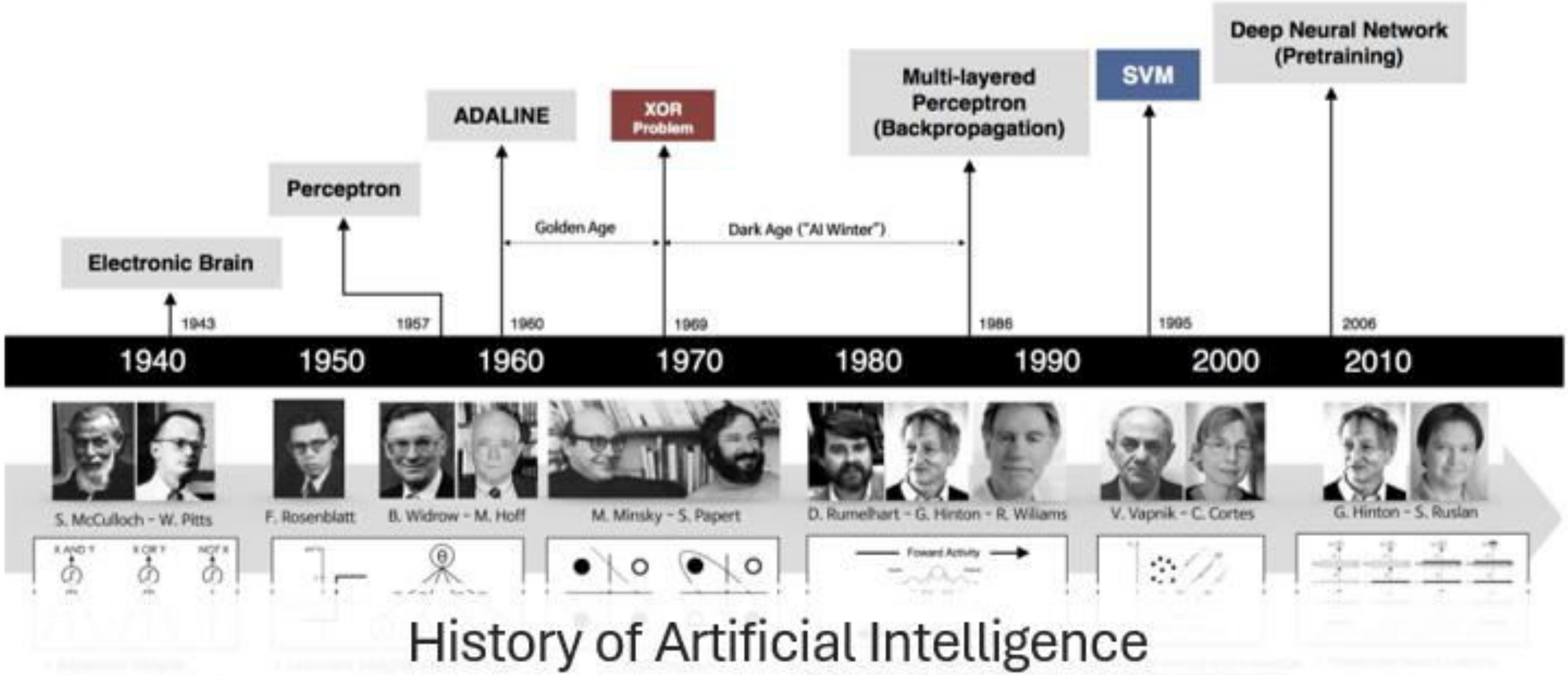
https://www.researchgate.net/figure/A-rationally-acting-agent-C-123RF_fig3_357618741

Foundations of AI

- Philosophy
- Mathematics
- Economics
- Neuroscience
- Psychology
- Computer Engineering
- Control theory and cybernetics
- Linguistics

History of Artificial Intelligence

- Marvin Minsky (1969) and John McCarthy (1971) for defining the foundations of the field based on representation and reasoning (Turing Award winners)
- Ed Feigenbaum and Raj Reddy (1994) for developing expert systems that encode human knowledge to solve real-world problems
- Judea Pearl (2011) for developing probabilistic reasoning techniques that deal with uncertainty in a principled manner
- Yoshua Bengio, Geoffrey Hinton, and Yann LeCun (2019) for making “deep learning” (multilayer neural networks) a critical part of modern computing



History of Artificial Intelligence

Figure: Evolution of artificial learning paradigm over the time

History I

- **1943** – The first mathematical model of a neural network was proposed by Walter Pitts, a logician and Warren McCulloch, a nuerologist in their seminal work "A Logical Calculus of Ideas Immanent in Nervous Activity"
- **1950** – Alan Turing, a British mathematician proposed "turing test" through his paper "Computing Machinery and Intelligence". The test requires a machine to carry on a conversation via text with a human being. If after five minutes the human is convinced that they're talking to another human, the machine is said to have passed.
- **1957** – Frank Rosenblatt, a psychologist, submitted a paper entitled "The Perceptron: A Perceiving and Recognizing Automaton" where he claimed to construct an electronic or electromechanical system which would learn to recognize similarities or identities between patterns of optical, electrical, or tonal information, in a manner which may be closely analogous to the perceptual processes of a biological brain. His idea did plant the seeds of bottom-up learning, and is widely recognized as the foundation of deep neural networks (DNN).
- **1959** – Neurophysiologists and Nobel Laureates David H. Hubel and Torsten Wiesel discovered two types of cells in the primary visual cortex: simple cells and complex cells which inspired and heavily influenced the field of artificial neural networks (ANNs).
- **1960** – Henry J. Kelley, a professor published "Gradient Theory of Optimal Flight Paths" where his ideas about control theory (i) the behavior of systems with inputs, and (ii) how that behavior is modified by feedback were used to develop the basics of a continuous error backpropagation model used in training neural networks.

History II

- **1965** – Mathematician Alexey Ivakhnenko, considered to be the father of modern deep learning and V.G. Lapa developed the Group Method of Data Handling (GMDH) applied it to neural networks to successfully create an 8-layer deep network.
- **1979-80** – Kunihiko Fukushima, a recognized innovator in neural networks, developed "Neocognitron", an ANN that learned to recognize visual patterns such as handwritten character, other pattern recognition tasks, recommender systems, and natural language processing. His work which was heavily influenced by Hubel and Wiesel, led to the development of the first convolutional neural networks (CNN), which are based on the visual cortex organization found in animals.
- **1982** – In 1982, John Hopfield created recurrent neural network (RNN) that serves as a content addressable memory system, and remain a popular implementation tool for deep learning in the 21st century.
- **1985** – Terry Sejnowski, Computational neuroscientist created a program NETtalk that learned to pronounce English words in much the same way a child does and was able to improve over time while converting text to speech.
- **1986** – David Rumelhart, Geoffrey Hinton, and Ronald J. Williams published a paper entitled "Learning Representations by Back-propagating Errors" which described in greater detail the process of backpropagation. They showed how it improved the existing neural networks for many tasks such as shape recognition, word prediction, and more. Despite some setbacks after that initial success, Hinton kept at his research to reach new levels of success which led him to be considered as godfather of deep learning.
- **1989** – Yann LeCun, another rock star in the AI and DL universe combined CNN with recent backpropagation theories to read handwritten digits. His system was eventually used to read handwritten checks and zip codes by NCR and other companies, processing anywhere from 10-20% of cashed checks in the United States in the late 90s and early 2000s.

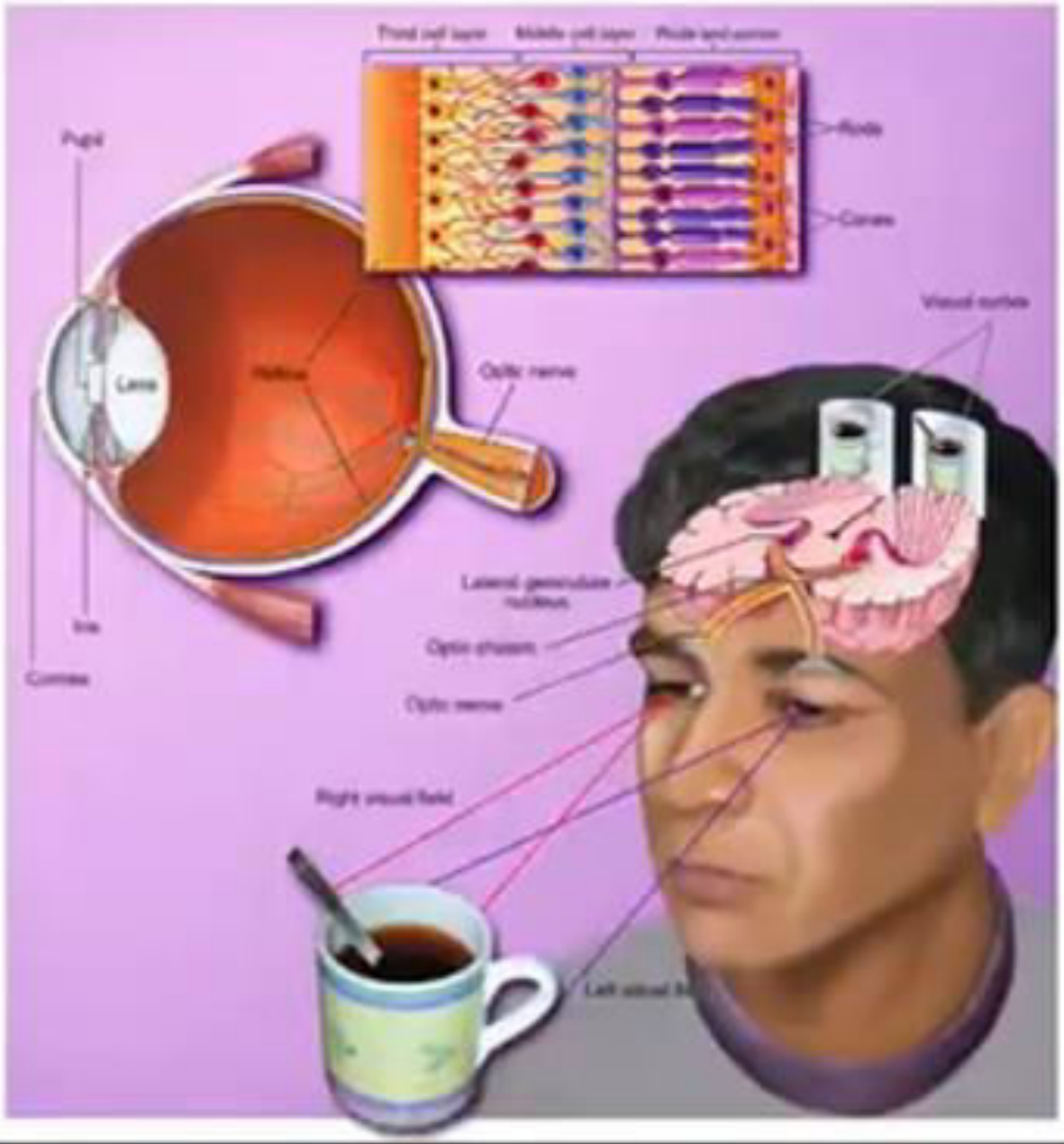
History III

- **1989** – Christopher Watkins published his PhD thesis "Learning from Delayed Rewards" in which he introduced the concept of Q-learning. This new algorithm suggested that it was possible to learn optimal control directly without modelling the transition probabilities or expected rewards of the Markov Decision Process (MDP).
- **1993** – Jürgen Schmidhuber,a German computer scientist solved a "very deep learning" task that required more than 1,000 layers in the RNN. It was a huge leap forward in the complexity and ability of neural networks.
- **1995** – Corinna Cortes and Vladimir Vapnik prsented Support vector machine (SVM) which can be used for recognizing and mapping similar data, text categorization, handwritten character recognition, and image classification.
- **1997** – Jürgen Schmidhuber and Sepp Hochreiter proposed a recurrent neural network framework, long short-term memory (LSTM). It eliminates the long-term dependency problem and can "remember" the past information for a longer period of time. Refined over time, LSTM networks are widely used in DL circles, and Google recently implemented it into its speech-recognition software for Android-powered smartphones.
- **1998** – Yann LeCun published his paper "Gradient-Based Learning Applied to Document Recognition". The Stochastic gradient descent algorithm (SGD) combined with the backpropagation algorithm is the preferred and increasingly successful approach to deep learning.
- **2009** – Fei-Fei Li, a professor and head of the Artificial Intelligence Lab at Stanford University, launched ImageNet. As of 2017, it's a very large and free database of more than 14 million (14,197,122 at last count) labeled images available to researchers, educators, and students for the purpose of training neural nets in supervised learning.

History IV

- **2011** – Alex Krizhevsky, won several international machine and deep learning competitions with his creation AlexNet, a CNN. AlexNet built off and improved upon LeNet5 (built by Yann LeCun years earlier). It initially contained only eight layers i.e. five convolutional followed by three fully connected layers and strengthened the speed and dropout using rectified linear units (ReLU). Its success kicked off a CNN renaissance in the deep learning community.
- **2012** – "The Cat Experiment" was a major step forward in which a neural network spread over thousands of computers was presented 10,000,000 unlabeled images. After completion of this unsupervised learning, program had taught itself to identify and recognize cats, performing nearly 70% better than previous attempts at unsupervised learning. Though, the network recognized only about 15% of the presented objects, it was yet another baby step towards genuine AI.
- **2014** – Facebook developed and released the social media behemoth's deep learning system DeepFace which uses neural networks to identify faces with 97.35% accuracy. That's an improvement of 27% over previous efforts, and a figure that rivals that of humans which is reported to be 97.5%.
- **2014** – Goodfellow introduced Generative Adversarial Networks (GAN) that enable models to tackle unsupervised learning, which is more or less the end goal in the artificial intelligence community. Essentially, a GAN uses two competing networks: the first takes in data and attempts to create indistinguishable samples, while the second receives both the data and created samples, and must determine if each data point is genuine or generated. Learning simultaneously, the networks compete against one another and push each other to get "smarter" faster.
- **2016** – Powerful machine learning products such as Microsoft's neural-network software and its XC50 supercomputers with 1,000 NVIDIA Tesla P100 graphic processing units, deep learning tasks are performed in a fraction of the hours instead of days.

The Human Perception



Although the visual processing mechanisms are not yet completely understood, recent findings from anatomical and physiological studies in monkeys suggest that visual signals are fed into at least three separate processing systems. One system appears to process information mainly about shape; a second, mainly about color; and a third, movement, location, and spatial organization.

Perception

Information is picked by our senses

Information is sent by the sense to the brain

These information are electrical signals

What we experience is:
sound, touch, form, taste, smell

In actuality, we experience the image, sound, taste, smell & touch not just electrical data of things

Components of Conscious Experience

External World

Sensory Processing

Neural Processing

Mental States

Easy Problems

Hard Problem

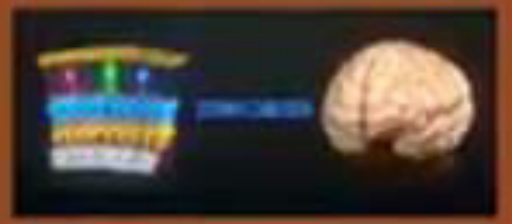
"The most difficult aspect of consciousness is the so-called hard problem of qualia... ...No one has produced any plausible explanation as to how the experience of the redness of red could arise from the actions of the brain." (1990s)

Francis Crick

ANOMALIES - VISUAL SPARSENESS

Light falls on the eye

Neuroreceptors are fired



The signal is send to the brain

The quantity of data received by the brain:

	Bits of data
Hitting the retina	100 Billion
Ready to go down optic nerve	6 Million
Arrives at visual processing area	10,000
Used to generate a single image	500

Equivalent of 20 pixels for a colour image

ANOMALIES - VISUAL SPARSENESS

What you experience

What you should see

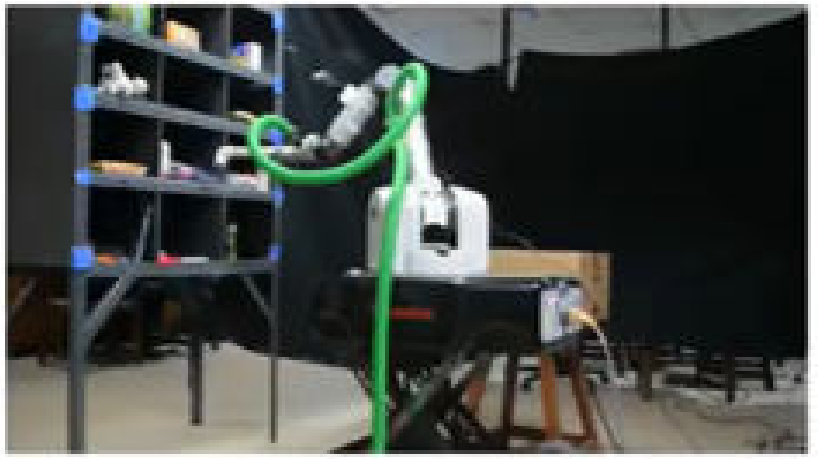
THE BINDING PROBLEM

How is a unitary perceptual experience generated that combines qualities such as colour, shape, location, orientation?

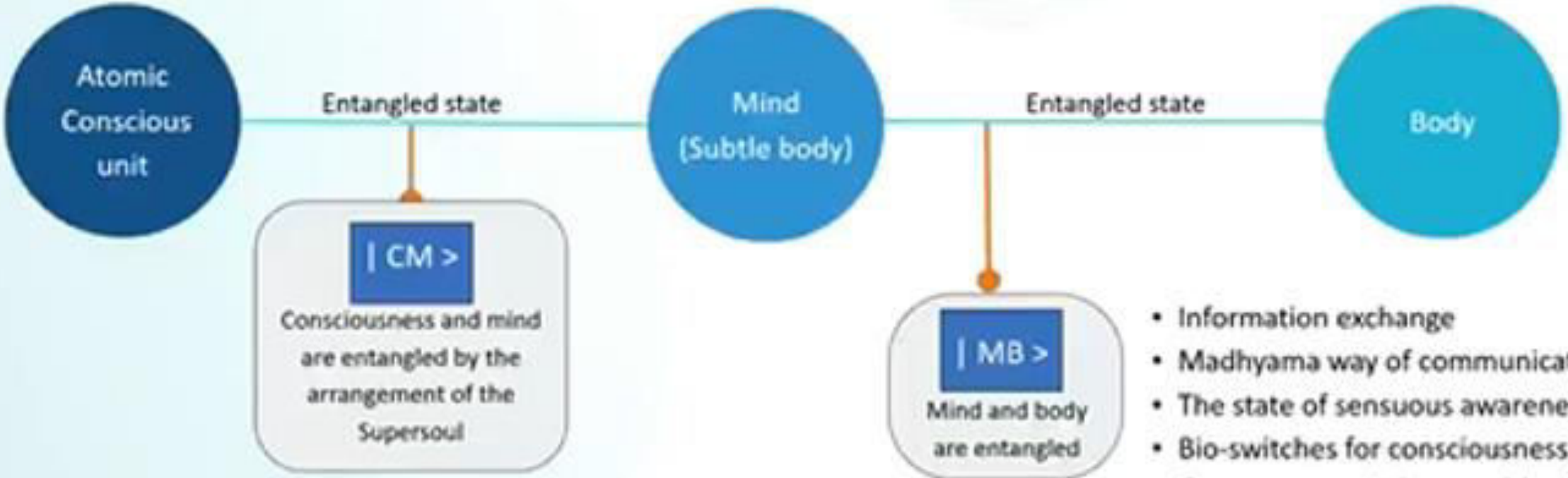
Eugen Goldste

How does current AI tackle Visual Processing?

- Huge Computational Architecture
- Huge Computational Power
- Huge Data



Individual Perception Model in IKS



- Information exchange
- Pashyanti way of communication
- The state of worldly awareness/desires

- Information exchange
- Madhyama way of communication
- The state of sensuous awareness
- Bio-switches for consciousness
- Gross energy attains cognitive features

Unentangled mind is like a spiritual mirror that reveals consciousness