

Artificial Intelligence and the Singularity

piero scaruffi

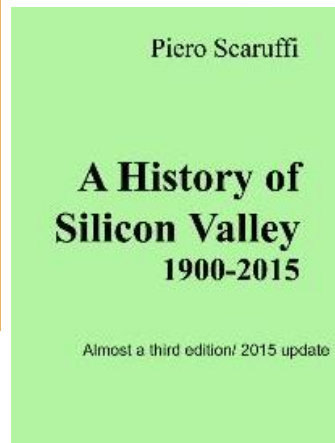
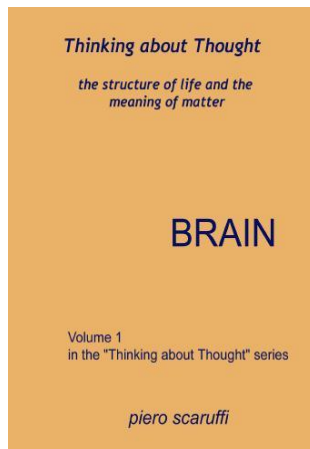
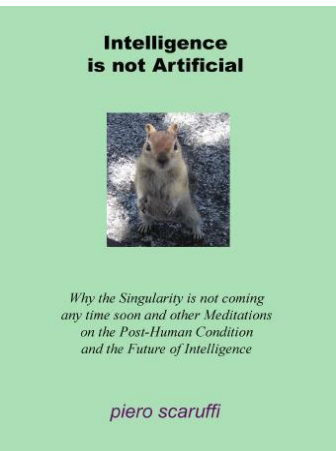
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*"The person who says it cannot be done should not
interrupt the person doing it" (Chinese proverb)*

Piero Scaruffi

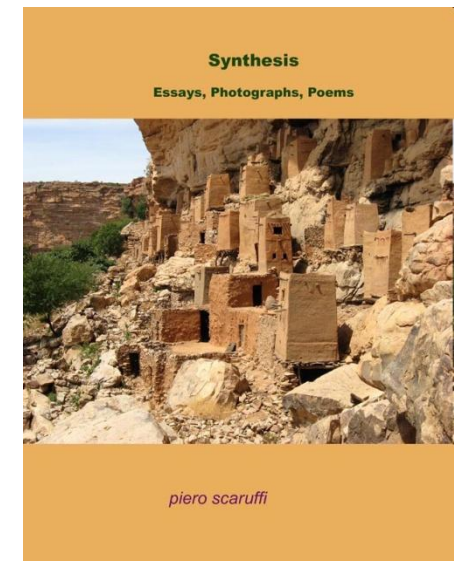
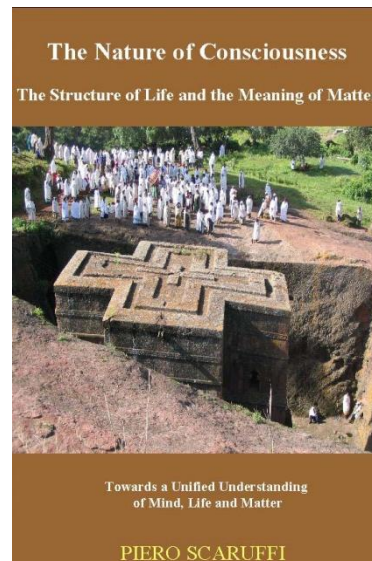
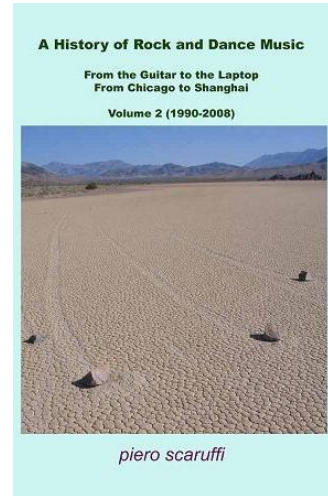
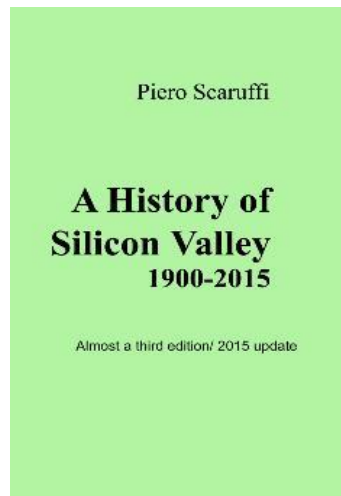
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Olivetti AI Center, 1987

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This is Part 3

- See <http://www.scaruffi.com/singular> for the index of this Powerpoint presentation and links to the other parts
 1. Classic A.I. - The Age of Expert Systems
 2. The A.I. Winter and the Return of Connectionism
 3. Theory: Knowledge-based Systems and Neural Networks
 4. Robots
 5. Bionics
 6. Singularity
 7. Critique
 8. The Future
 9. Applications
 10. Machine Art
 11. The Age of Deep Learning
 12. Natural Language Processing

Definition of A.I.?

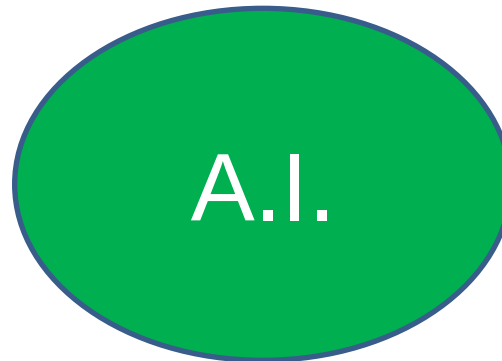
- A.I. = All the technologies needed for a machine to pass the Turing Test that could not de facto be implemented on a Von Neumann architecture: speech recognition, computer vision, natural language processing, reasoning, learning, common sense...

What is A.I.?

What does A.I. do that automation doesn't already do?



Automation



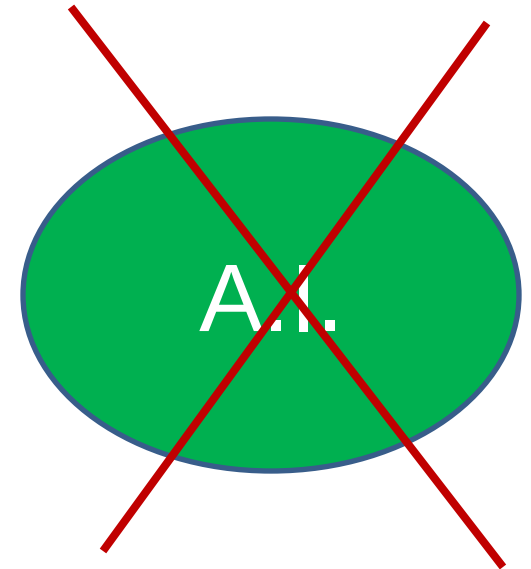
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What is A.I.?

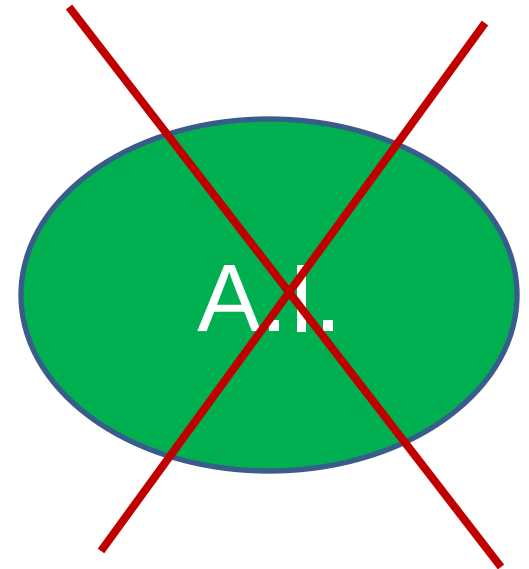
Automation: repetitive tasks

Automation: information-based processing

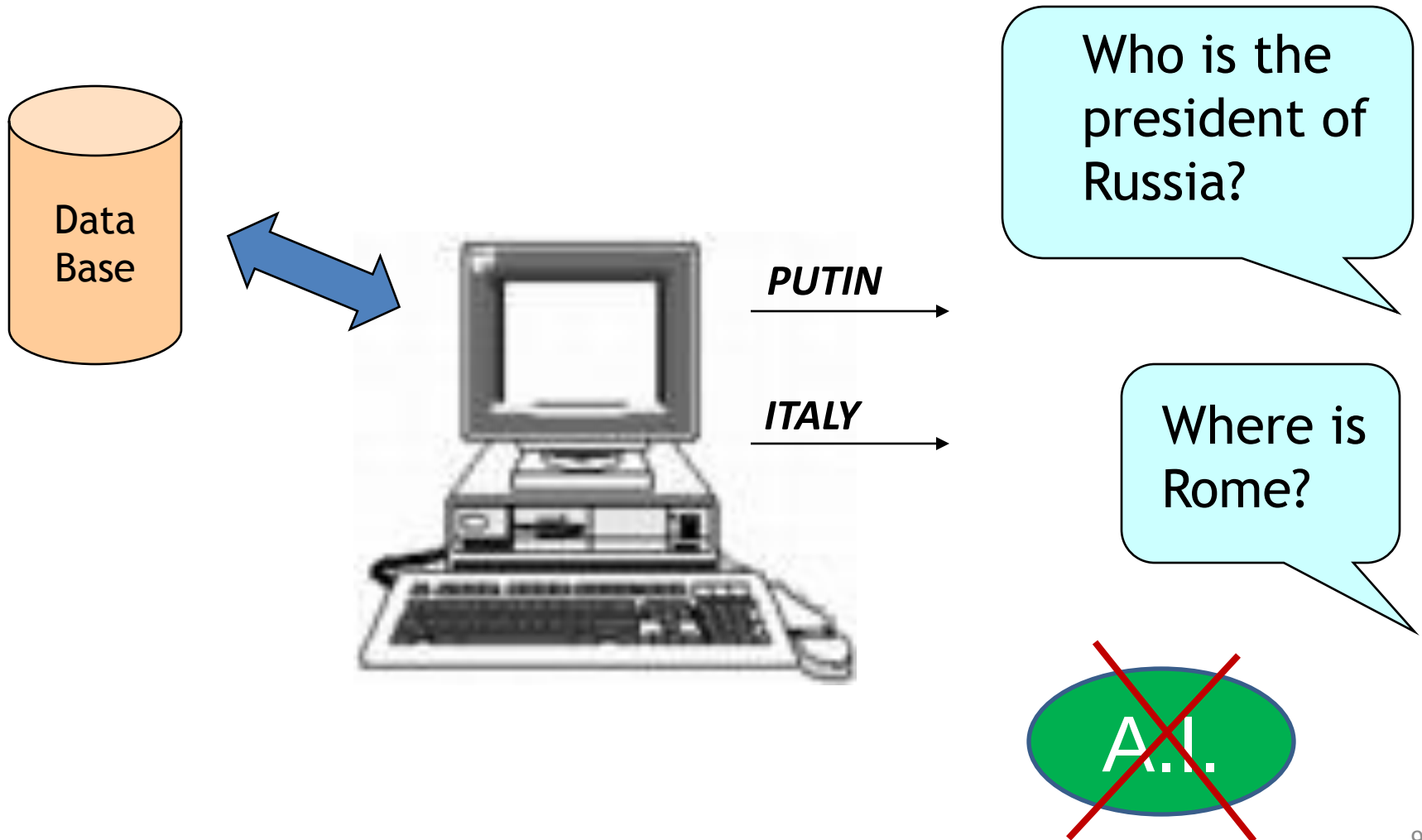


What is A.I.?

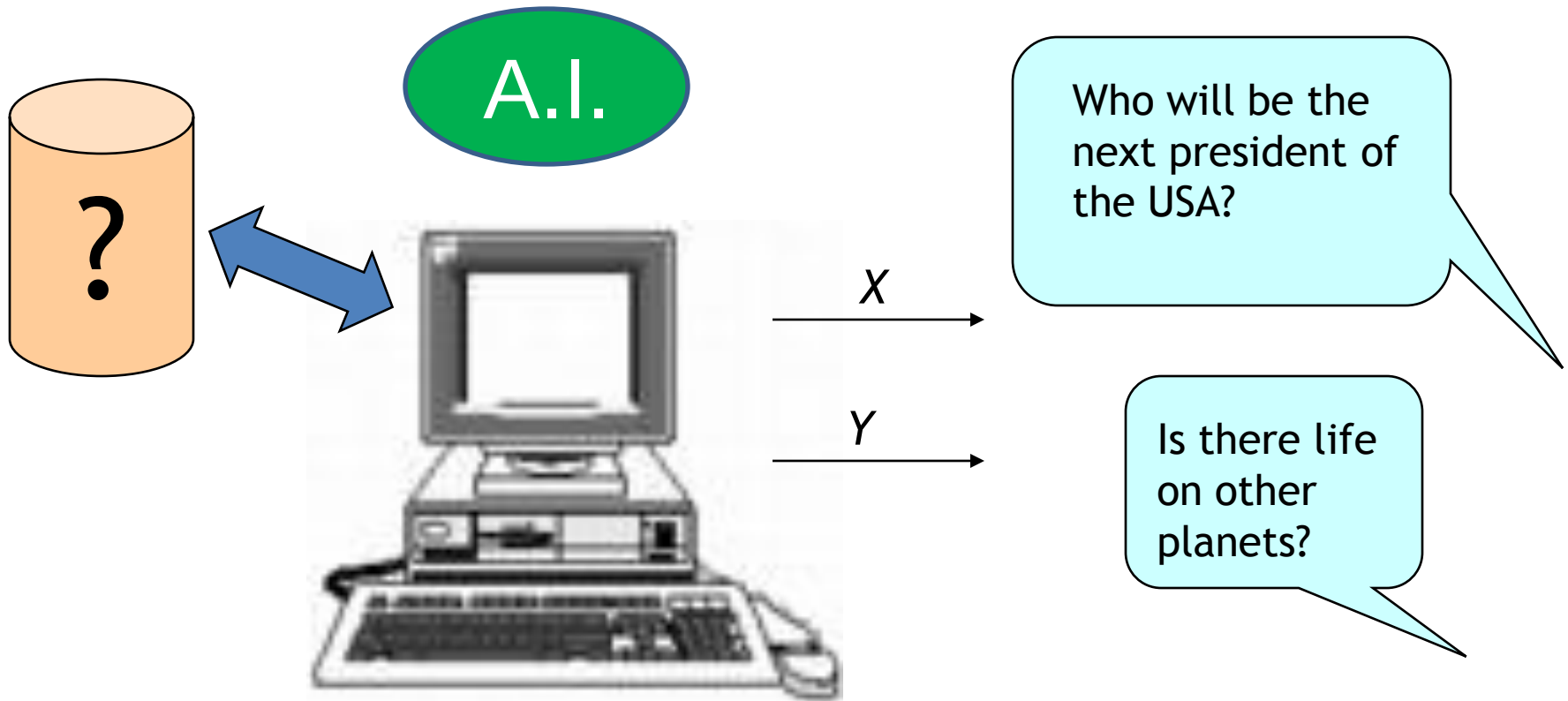
Warning: Today many companies claim that they are A.I. companies but they are simply doing traditional automation and information-based processing



Information-based Inference



Knowledge, not just Information

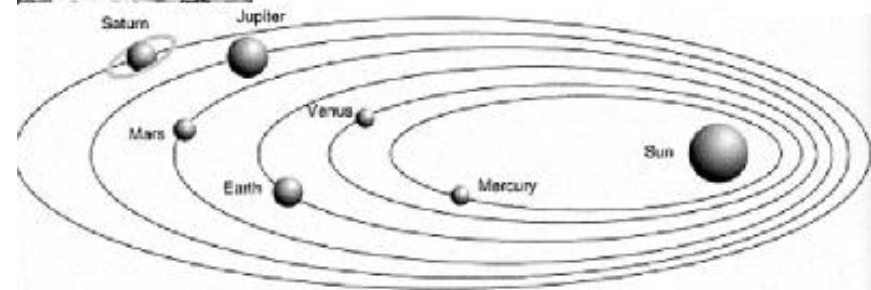


How can we turn Information into Knowledge?

1. Get knowledge from a human brain (e.g. from a domain's expert)
2. Do what the human brain does: discover patterns in the data and create new knowledge



KEPLER'S LAW



All animals are genetically programmed to detect patterns and assign meanings to them



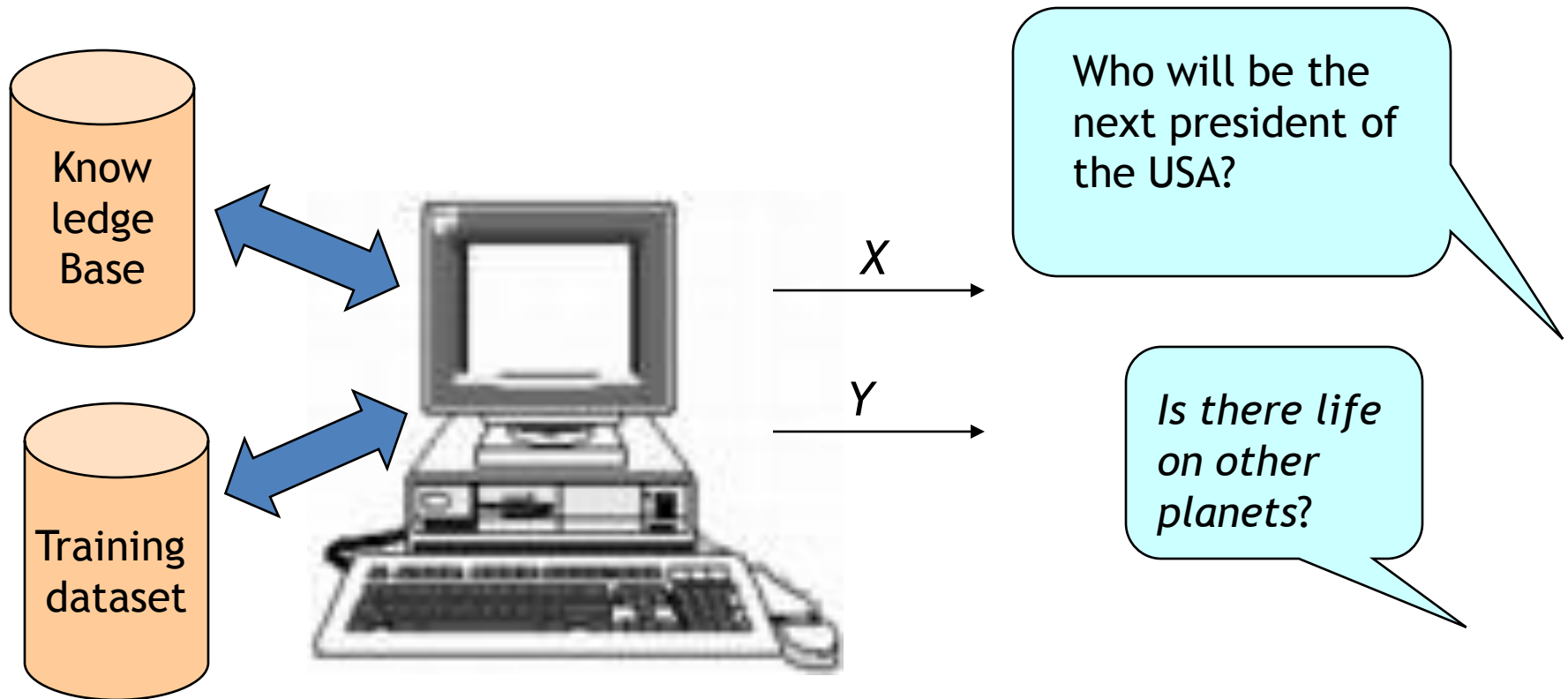
Front Neurosci. 2014; 8: 265.

Published online 2014 Aug 22. doi: [10.3389/fnins.2014.00265](https://doi.org/10.3389/fnins.2014.00265)

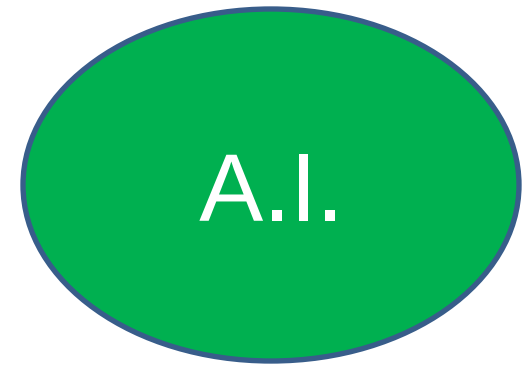
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Superior pattern processing is the essence of the evolved human brain

Knowledge-based or Pattern-based Inference



What is A.I.?



Non-repetitive tasks

Uncertain situations

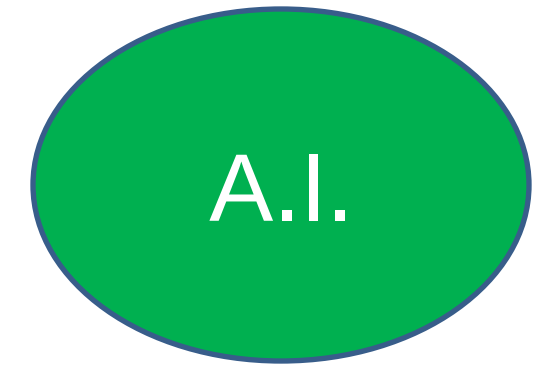
Knowledge, not just Information

Perception (vision, speech)

Reasoning/ planning

Multitask, not just one task

What is A.I.?



A.I. disciplines

- Computer vision
 - Object detection
 - Face recognition
 - Scene analysis
 - ...

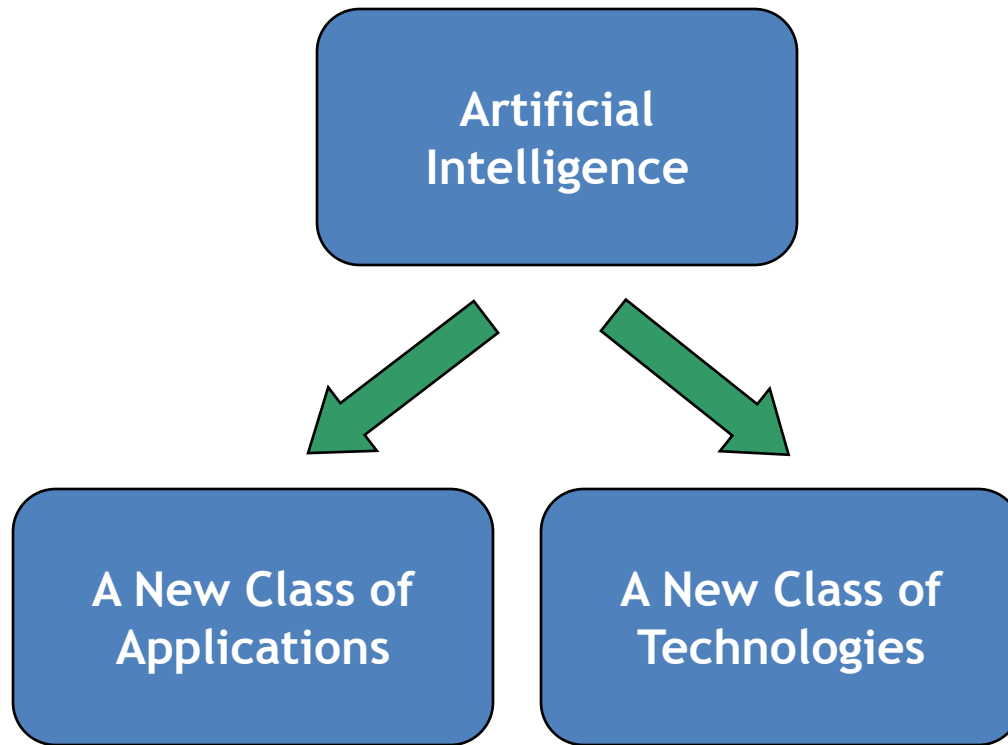
A.I. disciplines

- Reasoning/ planning
- Learning
- Discovery/ Theory formation

A.I. disciplines

- Natural language
 - Speech recognition
 - Automatic translation
 - Discourse analysis
 - Sentiment analysis
 - ...

What is A.I.



What is A.I.

A New Class of
Applications

Expert
Tasks

The algorithm
does not exist

A medical
encyclopedia
is not
equivalent to a
physician

Heuristics

There is an
algorithm
but it is
“useless”

Don't touch
boiling water

Uncertainty

The algorithm is
not possible

Brazil will win
the next
world cup of
soccer

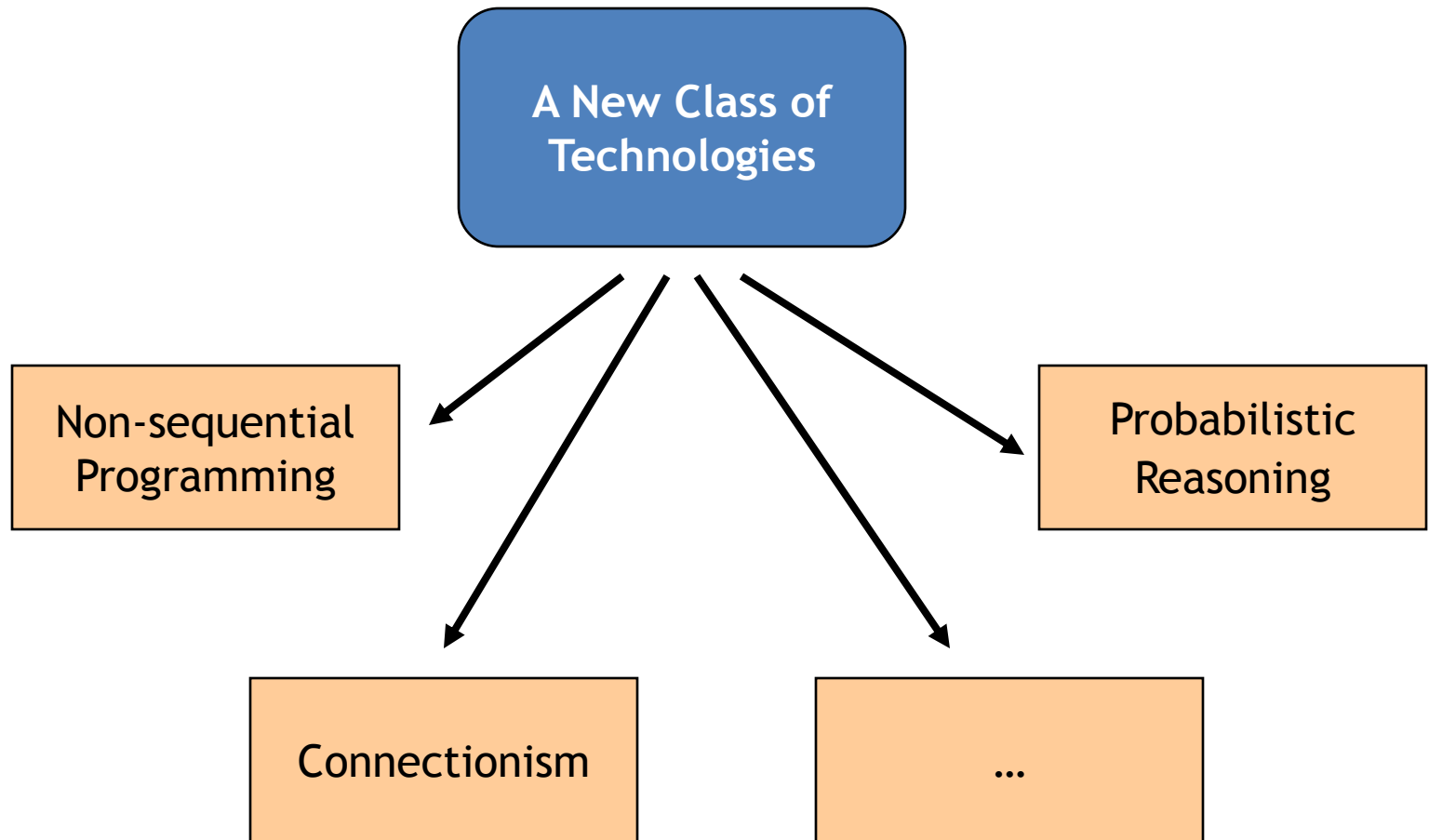
“Complex”
Problem Solving

The algorithm is
too
complicated

Design a cruise
ship

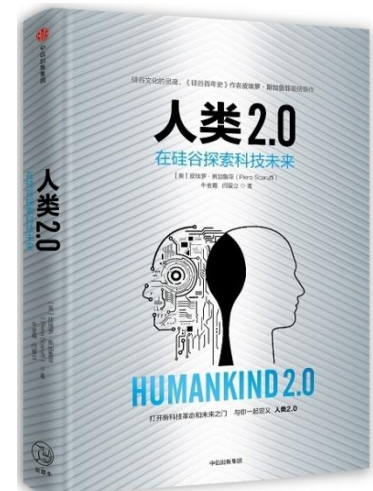
Discovery/
Theory Formation

What is A.I.

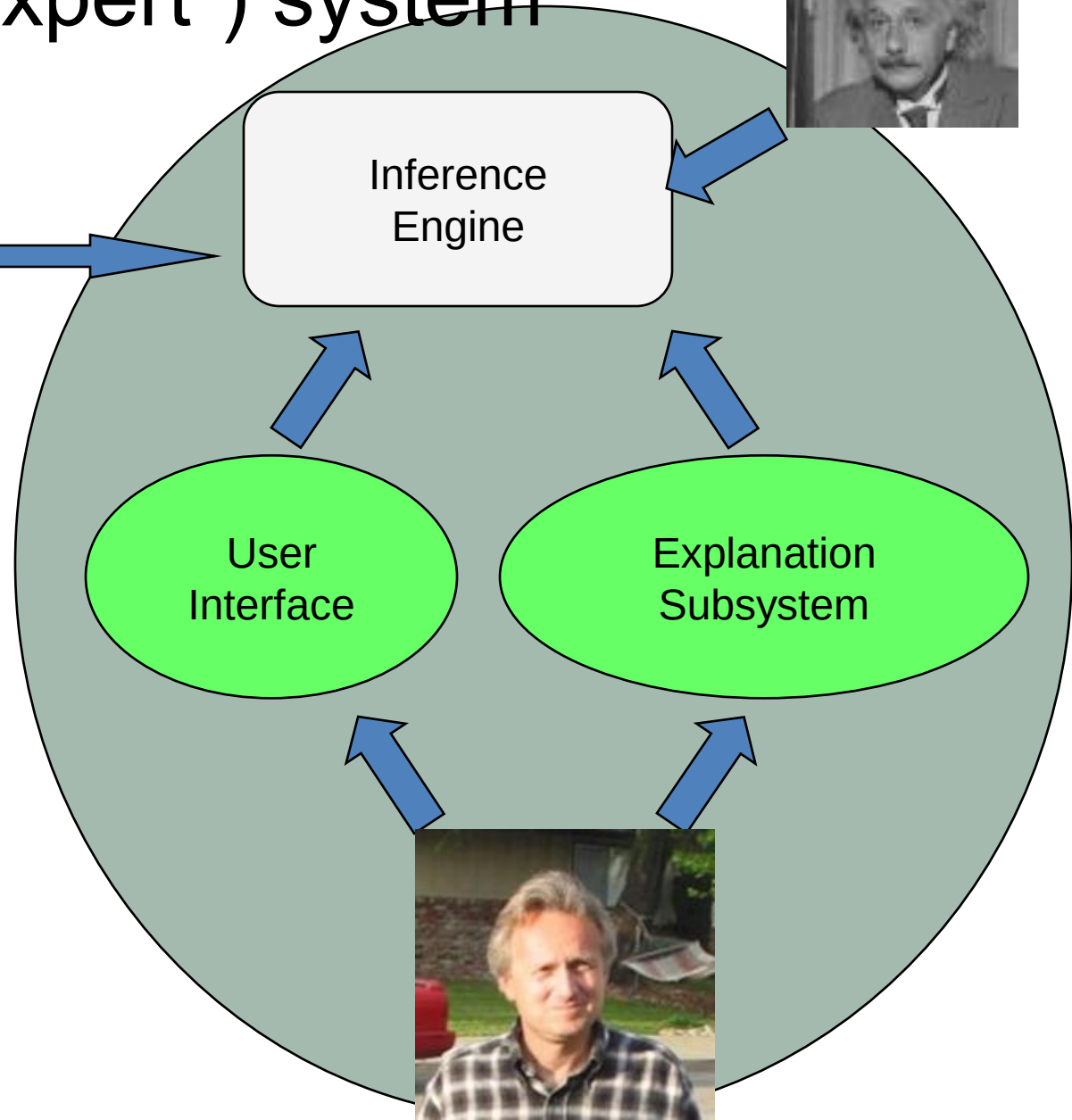
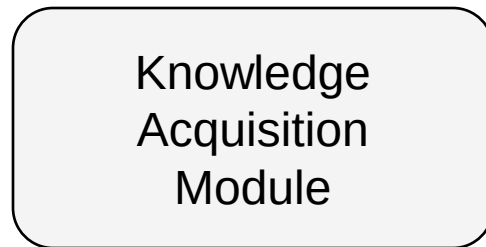
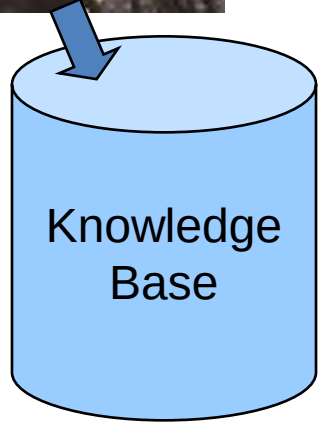
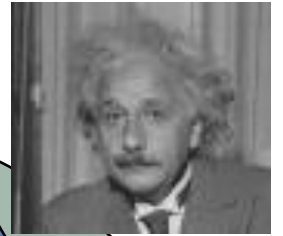
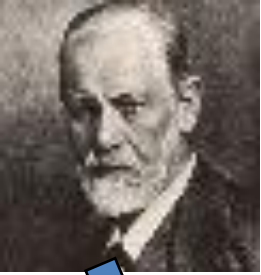


What is A.I.

- A.I. is a **tool**
- IoT, VR/AR, Blockchain, A.I., Cloud, 3D Printing, Wearables, etc are **“Human 1.5” tools**
- What is **“Human 2.0”**? Solutions to problems that today cannot be solved:
 - Longevity
 - Smart City
 - Human-machine interaction
 - Drug discovery
 - ...



Knowledge-based ("Expert") system



Mediation

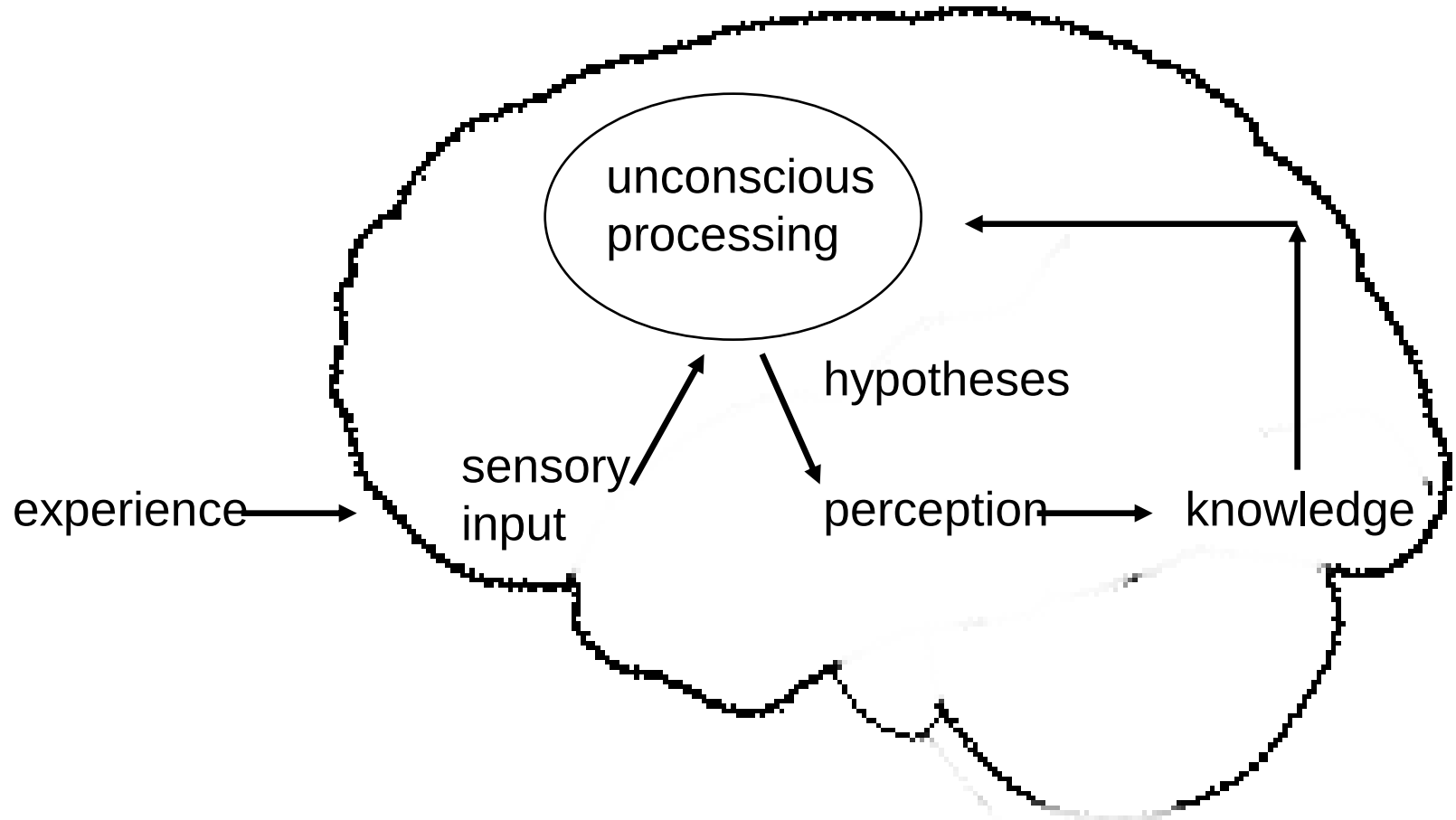


- Hermann Helmholtz (19th c)
 - Perception and action are mediated by a process in the brain
 - The "reaction time" of a human being is high because this brain process is slow
 - Perceptions are derived from unconscious inference on sense data
 - The brain turns perceptions into knowledge
 - All knowledge comes from experience, there is no innate knowledge
 - Perceptions are mere hypotheses about the world and can be wrong (optical illusions)
 - Perceptions are hypotheses based on our knowledge

Mediation



- Hermann Helmholtz (19th c)



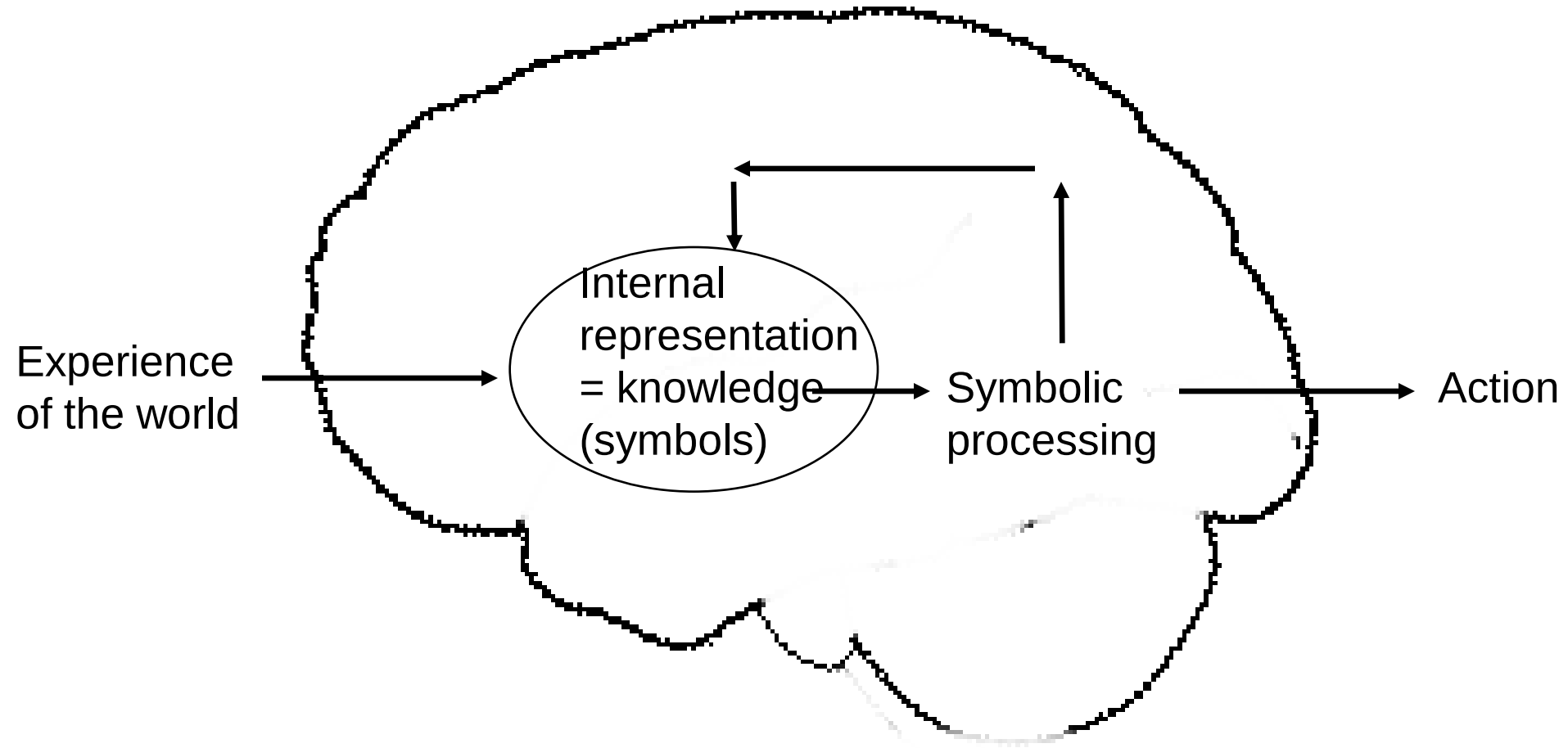
Representation



- Kenneth Craik (1943)
 - Mind may be a particular type of machine which is capable of building internal models of the world and processing them to produce action
 - Internal representation
 - Symbolic processing of such representation
 - Intelligence = inferential processing of knowledge
 - Descartes' automaton: mechanical reactions to external stimuli - no knowledge and inference
 - Craik's automaton: action based on knowledge and inference

Representation

- Kenneth Craik (1943)



Symbolic Processing

- The computer architecture is able to achieve cognitive faculties
- Computers consist of interacting modules each processing symbols
- Maybe the human mind too can be

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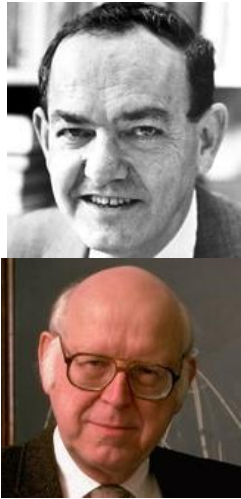


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Symbolic Processing



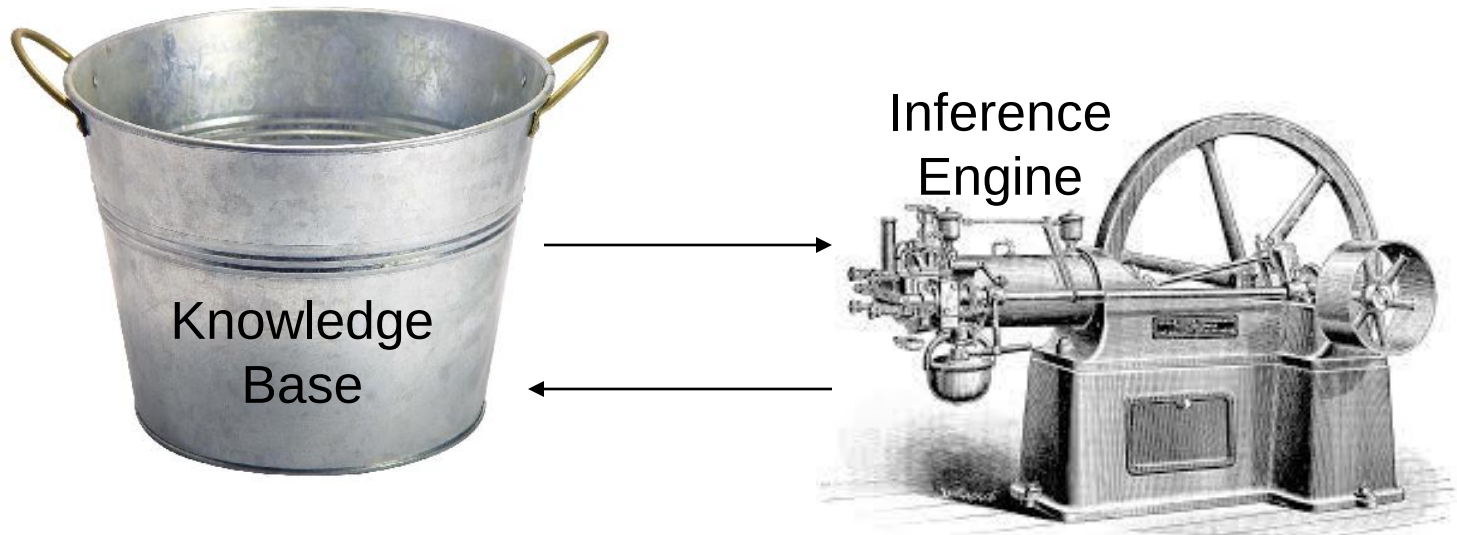
- Herbert Simon & Allen Newell: Physical Symbol Systems (1976)
 - Systems that process symbols to achieve a goal
 - "A physical symbol system has the necessary and sufficient means for intelligent action"
 - A physical symbol system is quite simple: the complexity of its behavior is due to the complexity of the environment it has to cope with
 - Physical symbol processors are Turing machines
 - No complex system can survive unless it is organized as a hierarchy of subsystems

Symbolic Processing

- Physical Symbol Processor/ predecessors
 - Thomas Hobbes: reasoning is "nothing more than reckoning"
 - Gottfried Leibniz: a logical calculus of human thought
 - David Hume: perceptions can be reduced to "atomic impressions"
 - Hilary Putnam, Jerry Fodor: the computational theory of mind

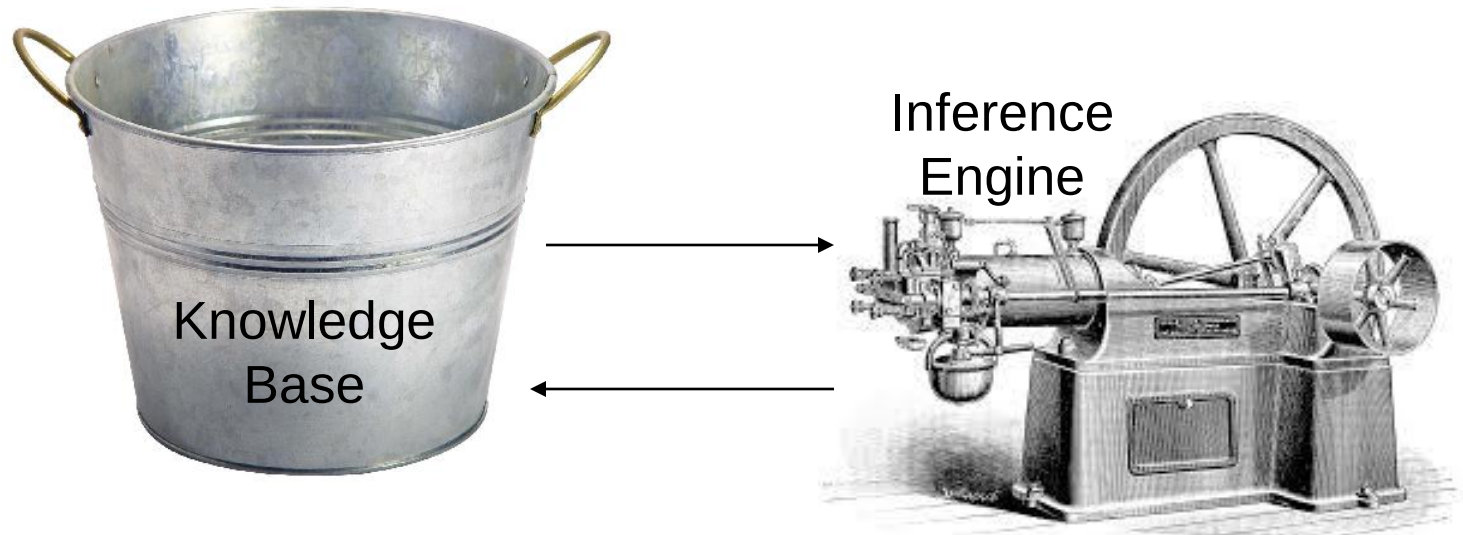
Symbolic Processing

- Physical Symbol Systems
 - A memory containing knowledge is operated upon by an inference engine; the results are added to the knowledge base; inference engine operates on the knowledge base;...

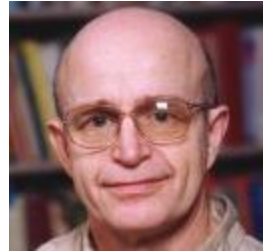


Symbolic Processing

- Physical Symbol Systems
 - Knowledge is continuously created, whether acquired from the external world or inferred from the existing knowledge



Symbolic Processing



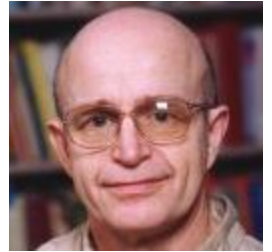
- Production Systems
 - John Anderson's Act (1976)
 - Knowledge is expressed in “production rules” (“If it is raining, take the umbrella”)
 - Declarative knowledge ("knowing that") that can be consulted vs procedural knowledge ("knowing how") that must be enacted in order to be used

I know that a bicycle
has two wheels

I know how to ride a
bicycle



Symbolic Processing



- Production Systems
 - ACT (1976)
 - Knowledge is continuously compiled into more and more complex procedural chunks through an incremental process of transformation of declarative knowledge into procedural knowledge
 - Two kinds of memory: a declarative memory (that remembers experience) and a procedural memory (that remembers rules learned from experience)

Symbolic Processing

- Production Systems

- John Laird and Paul Rosenbloom's SOAR (1987)
 - “Universal weak method”: the kind of knowledge determines the kind of reasoning that can be applied
 - “Universal sub-goaling”: break down a problem (top-down reasoning)
 - When a goal is successfully completed, a chunk that represents the results of the task is created
 - “Chunking”: create new production rules (bottom-up reasoning)



Symbolic Processing



- Production Systems
 - SOAR (1987)
 - A task is implemented as a goal hierarchy
 - Final goal: a chunk for the top-level goal
 - “Power law of practice”: the more you practice, the better you get at it



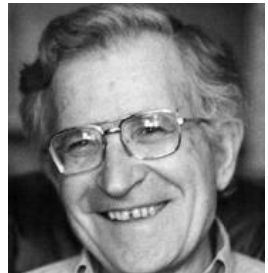
MENTAL MODULES



- Mental Modules (David Marr, 1982)
 - The vision system must employ innate information to make sense of the ambiguous signals that it perceives from the world
 - Innate and universal knowledge coexist and collaborate
 - Processing of perceptual data must be performed by specialized "modules" which are controlled by a central module

MENTAL MODULES

- Mental Modules
 - Marr, Chomsky and Fodor:
 - 1. the mind can be decomposed in modules, and
 - 2. syntactic processing can account for what the mind does



MENTAL MODULES



- Vision (David Marr, 1979)
 - Three levels of abstraction created by the modules of the vision system:
 - the "primal sketch": a symbolic representation drawn from the meaningful features of the image (boundaries, contours, shading, textures)
 - a two-and-a-half dimensional sketch, which is a representation centered on the visual system of the observer (distances and orientation)
 - the tri-dimensional representation, which is centered on the object
 - Memory: not what the retina picked up, but what the brain computed

MENTAL MODELS



- Mental Models (Philip Johnson-Laird, . . .)
 - Production rules implausible
 - Minds construct mental models
 - Minds solve problems by building mental models
 - A sentence is a procedure to build, modify, extend a mental model
 - Mental models allow the mind to find "adequate" solutions

MENTAL SPACES

- Mental Spaces (Gilles Fauconnier, 1994)
 - Mental spaces proliferate as we think or talk
 - "Conceptual blending"
 - "creative" thinking
- Cognitive Models (George Lakoff):
embodied, i.e. they are linked with
bodily experience.



Knowledge Representation

- Otto Selz's Schema (1913)
 - To solve a problem entails to recognize the situation and to fill the gaps
 - Information in excess contains the solution



Knowledge Representation



- Otto Selz's Schema (1920s)
 - Representation of past experience is a complete schema. Representation of present experience is a partially complete schema
 - Schema's anticipatory nature: to solve a problem is equivalent to comprehending it, and comprehending ultimately means reducing the current situation to a past situation

Knowledge Representation



- Otto Selz's Schema (1920s)
 - Infer = anticipate
 - To solve a problem = to comprehend it
 - Comprehending = reducing the current situation to a past situation

Knowledge Representation

- Otto Selz's Schema
 - Both a mental representation of the world and a process that determines action in the world

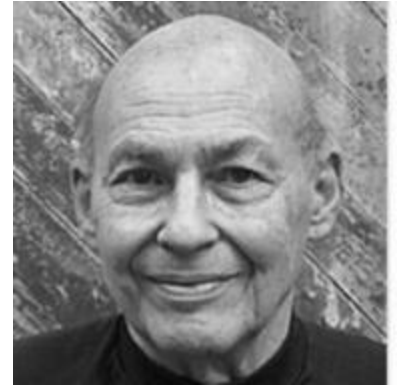
Knowledge Representation



- Edward Tolmans' cognitive map (1932)
 - Learning involves acquisition of knowledge about the world (a "cognitive map")
 - A cognitive map encodes "expectations" about the world
 - We don't act in the world, we respond to the world

Knowledge Representation

- Marvin Minsky's “Frame” (1974)
 - A packet of information that helps recognize and understand a scene
 - Stereotypical situations
 - A category by means of a prototypical member (default properties) and a list of actions that can be performed on any member of the category
 - Memory is a network of frames



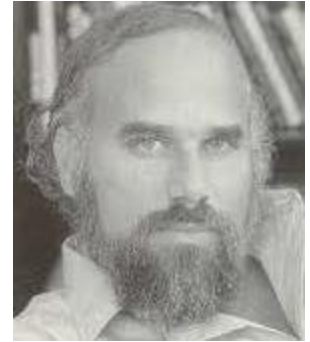
Knowledge Representation

- Marvin Minsky's “Frame”
 - Each perception selects a frame, i.e., classifies the current situation in a schema
 - This is equivalent to interpreting the situation and deciding which action must be performed
 - Reasoning is adapting a frame to a situation.
 - Knowledge imposes coherence on experience
 - Unity of perception, recognition, reasoning, understanding and memory

Knowledge Representation

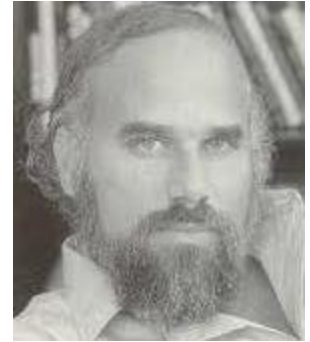
- Marvin Minsky's “Frame”
 - Perception, recognition, reasoning, understanding and memory cannot be separated

Knowledge Representation



- Roger Schank's Script (1975)
 - Case-based reasoning
 - analogical reasoning
 - the elementary unit is the “case”, or situation
 - Episodic memory archives generalizations of cases
 - Whenever a new case occurs, similar cases are retrieved from episodic memory.
 - the new case is interpreted based on any similar cases that were found in the episodic memory
 - the new case is used, in turn, to further refine the generalizations

Knowledge Representation



- Roger Schank's Script (1975)
 - A dynamic memory that grows from experience
 - Expectation-driven
 - Script = stereotypical knowledge of situations as a sequence of actions and a set of roles
 - Script = helps understand the situation and predicts what will happen
 - New memories = expectation failures

Knowledge Representation

- Roger Schank's Script
 - Anticipatory reasoning
 - Remembering is closely related to understanding and learning.
 - Memory has the passive function of remembering and the active function of predicting.
 - The comprehension of the world and its categorization proceed together.
 - Knowledge is stories
 - Conversation is reminding and storytelling is understanding

Knowledge Representation

- Self-organizing behavior
 - Charles Peirce (1906): "Habit", a set of operational rules that, by exhibiting both stability and adaptability, lends itself to an evolutionary process
 - Jean Piaget (1930s): Schemas are compounded as they are built to yield successive levels of a cognitive hierarchy
 - Categories are not innate, they are constructed through the individual's experience. What is innate is the process that underlies the construction of categories.

Knowledge Representation

- Jeff Hawkins (2005)
 - Memory is a reservoir of possible solutions to problems.
 - Memory constantly predicts what will happen next.
 - That's how it can keep track of situations that would require almost infinite computational capabilities



A BRIEF DETOUR/1

- Vernon Mountcastle (1978)
 - The neocortex is uniform
 - There is no indication that any region of the neocortex operates differently from the other regions
 - What makes the difference between seeing and hearing if the cortex that process them is the same?
 - The difference in "output", though, must be due almost entirely to the different inputs
 - What is different is the pattern: spatial patterns versus temporal patterns.



A BRIEF DETOUR/1

- Vernon Mountcastle (1978)
 - The vision of something and the hearing of something are created in the brain
 - It is the brain that sees, not the eye. It is the brain that hears, not the ear.



A BRIEF DETOUR/2

- Maurice Merleau-Ponty (1960s)
 - Cognitive scientists tend to focus on the input (perception) and neglect the output (action).
 - Most models of the mind have been built by concentrating on perception: how the world is perceived by the mind. Very little is usually said on how the mind acts on the world
 - Maxine Sheets-Johnstone (1999): thinking is modeled on the body and grounded in animate form
 - All our cognitive life is grounded in movement.

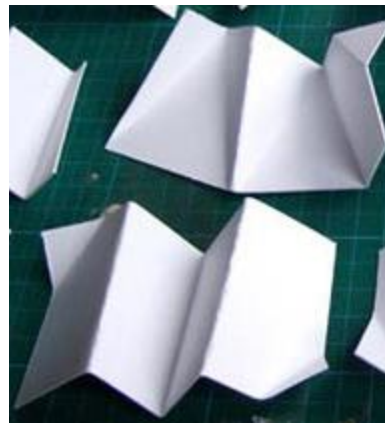


The Unity of COGNITION

- Perception, memory, learning, reasoning, understanding and action are simply different aspects of the same process.
- All mental faculties are different descriptions of the same process
- Cognition does not seem to require consciousness

The Unity of COGNITION

- Cognition = algorithm, refined by natural selection, that operates on structures that reflect our experience
- Various levels of cognition can be identified in other systems
- Everything in nature can be said to remember and to learn something
- Cognition: a general property of matter?



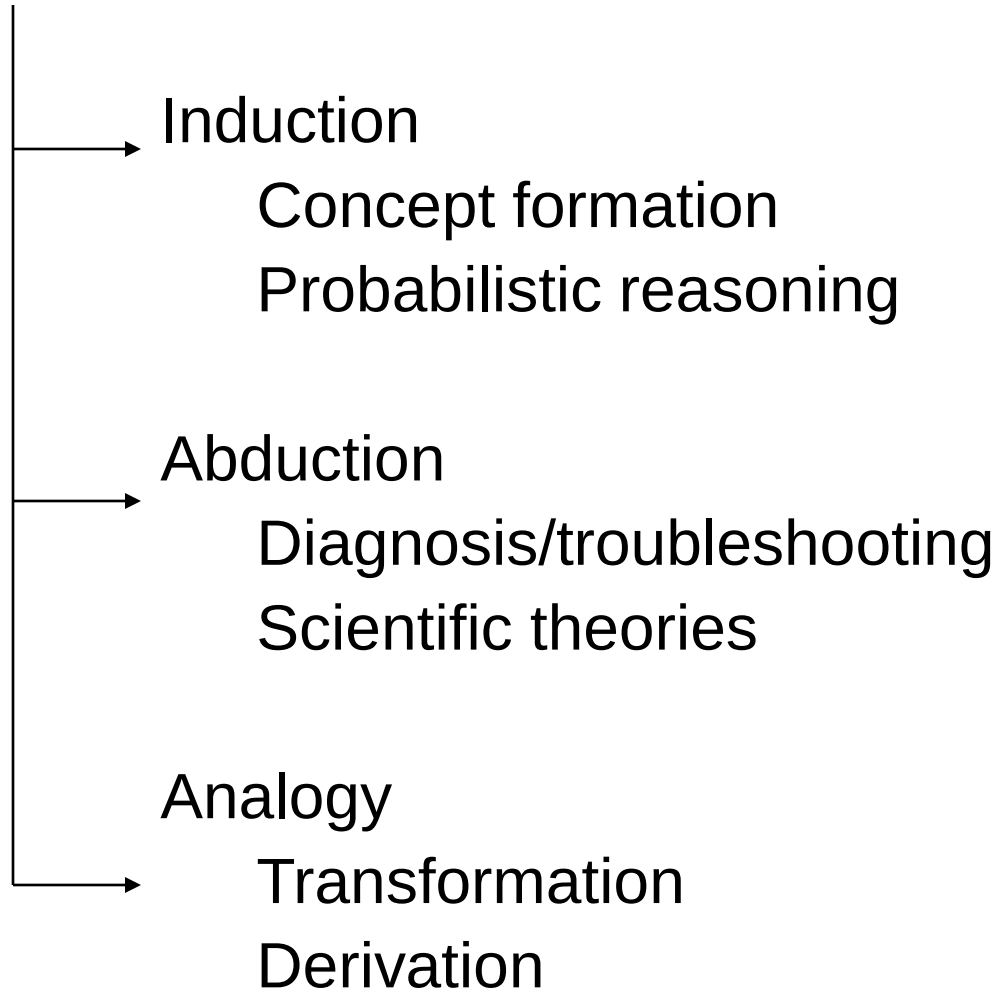
Paper that has “learned”
a position after being
repeatedly bent

Common Sense

*Small minds are concerned with the
extraordinary, great minds with the ordinary"*
(Blaise Pascal)

Common Sense

Types of inference



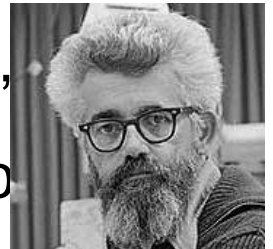
Common Sense

- Plausible reasoning
 - Quick, efficient response to problems when an exact solution is not necessary
- Non- monotonic Logic
 - Second thoughts: inferences are made provisionally and can be withdrawn at any time

Common Sense

The Frame Problem

- Classical logic deducts all that is possible from all that is available
- In the real world the amount of information that is available is infinite
- It is not possible to represent what does “not” change in the universe as a result of an action (“ramification problem”)
- Infinite things change, because one can go into greater and greater detail of description
- The number of preconditions to the execution of any action is also infinite (“qualification problem”)



Common Sense

Uncertainty

“Maybe i will go shopping”

“I almost won the game”

“This cherry is red”

“Piero is an idiot”

Probability

Probability measures "how often" an event occurs

But we interpret probability as “belief”

Common Sense



Principle of Incompatibility (Pierre Duhem)

The certainty that a proposition is true
decreases with any increase of its
precision

The power of a vague assertion rests in its
being vague (*"I am not tall"*)

A very precise assertion is almost never
certain (*"I am 1.71cm tall"*)

Common Sense

Heuristics

- Knowledge that humans tend to share in a natural way: rain is wet, lions are dangerous, most politicians are crooks, carpets get stained...
- Rules of thumbs

György Polya (1940s): “Heuretics” - the nature, power and behavior of heuristics: where it comes from, how it becomes so convincing, how it changes



Common Sense

Qualitative Reasoning

- Pat Hayes: "Naive Physics Manifesto" (1978)
- Johan DeKleer (1979)
- Kenneth Forbus (1981)

Common Sense

- Progress in fundamental A.I.
 - Common sense - knowledge-based reasoning
 - Doug Lenat's Cyc (1984)
 - Catherine Havasi's Open Mind Common Sense (1999)
 - Google's Knowledge Graph (2012)
 - Microsoft's Satori



conceptnet5.media.mit.edu

ConceptNet 5



- World's largest knowledge base
- Billion-triple RDF Graph

- Horizontally scalable
- Memory-based graph database
- Specific index and query optimization for RDF data
- Efficient query processing

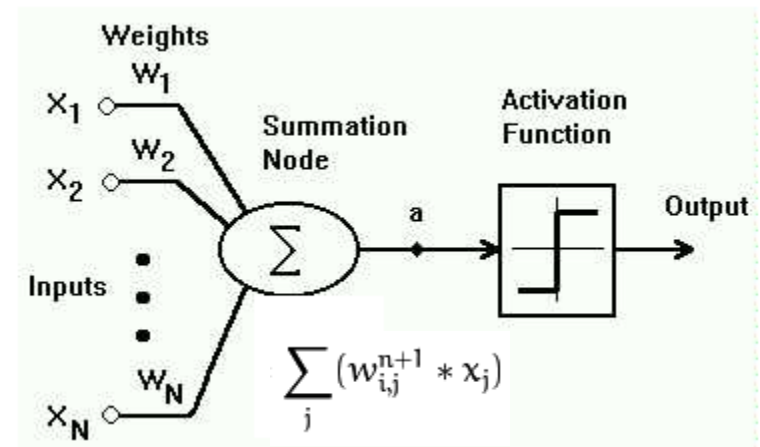
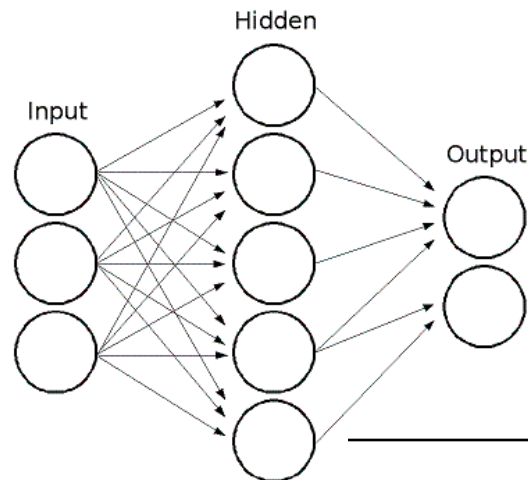


Connectionism

A neural network is a set of interconnected neurons (simple processing units)

Each neuron receives signals from other neurons and sends an output to other neurons

The signals are “amplified” by the “strength” of the connection



Connectionism

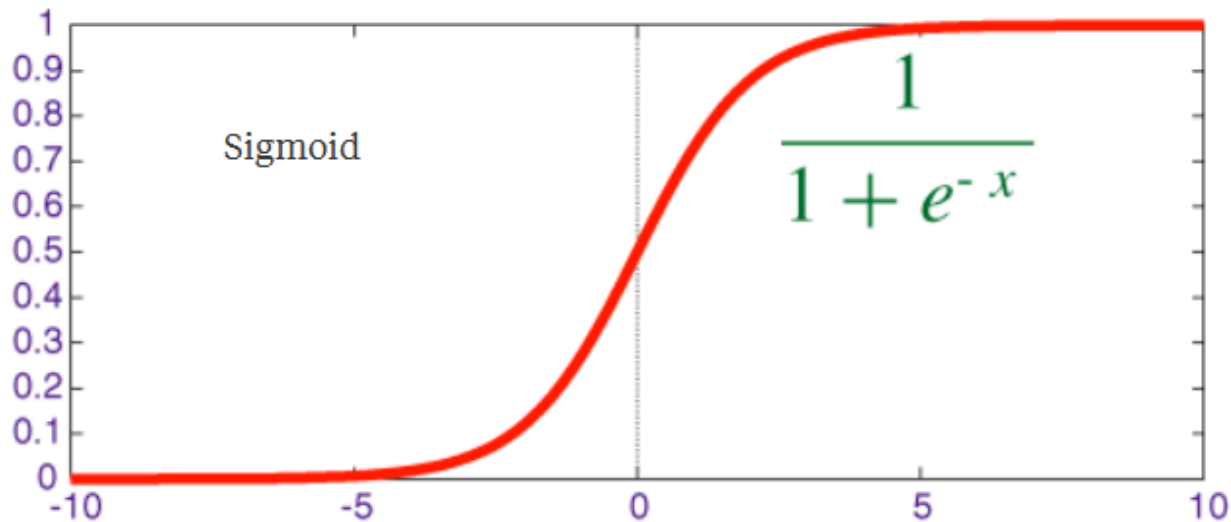
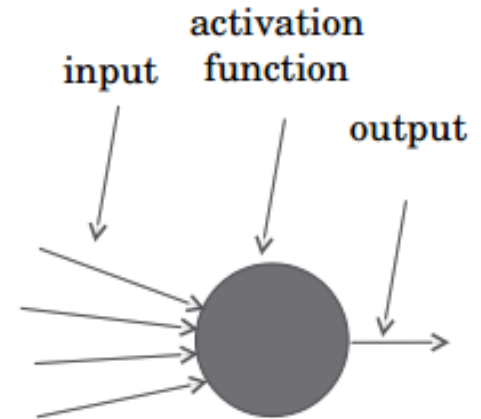
Sigmoid

Activation function

$$h_{(w,b)} = f(w^T \cdot x + b)$$

where

$$f(z) = \frac{1}{1 + e^{-z}}$$

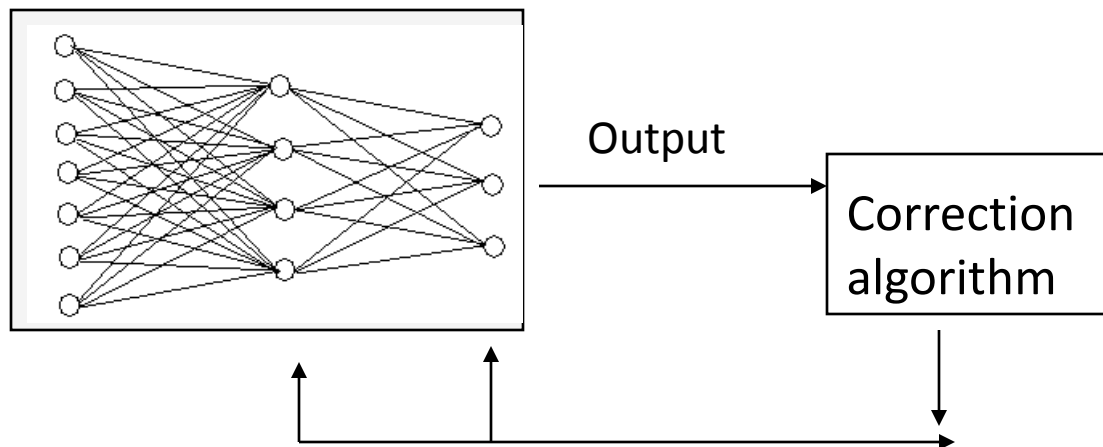


acceptable mathematical representation of a biological neuron

Connectionism

The strength of the connection changes over time according to a feedback mechanism (output desired minus actual output)

The net can be “trained”



Connectionism

- Distributed memory
- Non-sequential programming
- Fault-tolerance
- Recognition
- Learning

Connectionism

Where are we?

Biggest neural computer:

- Stanford and NVIDIA (2013): 11.2 billion connections (three servers accelerated using 16 GPUs)
- Google (2012): 1.7 billion connections (on a 1,000-server network) learn to recognize cats in YouTube videos
- Worm's brain:
 - 1,000 neurons
 - But the worm's brain still outperforms neural nets

Human brain:

- 100 billion neurons
- 200,000 billion connections

Hence...

Artificial Intelligence

- Knowledge-based approach
- Neural-net approach

Meanwhile...

- 1947: The "transistor"
- 1949: The first stored-program computers
- 1951: The first commercial computers
- 1956: The hard-disk drive
- 1957: The first serious programming language
- 1961: The first database management system
- 1961: The first industrial robot
- 1963: The first computer graphics program
- 1964: The first online transaction processing
- 1965: The first serious mini-computer
- 1969: The Unix operating system
- 1969: The Arpanet (Internet)
- 1970: The first pocket calculators
- 1970: The first practical optical fiber
- 1971: The microprocessor
- 1972: The Global Positioning System (GPS)
- 1972: Email
- 1973: The first cellular telephone
- 1974: The first GUI
- 1975: The first personal computers
- 1982: The compact disc
- 1984: The first personal assistant
- 1984: The first virtual-reality
- 1984: Flash memory
- 1987: JPEG
- 1990: The first digital camera
- 1990: The World-Wide Web
- 1990: The first Internet search engine
- 1991: The first "browser"
- 1992: The first text message
- 1995: The first "wiki"
- 1996: The first "smartphone"
- 1997: The first social network
- 1998: The first MP3 player

The Decline of Knowledge-based Systems

- 1. Google it...
 - Artificial Intelligence was trying to develop “expert systems” capable of finding a solution to every problem in a given domain, just like a human expert in that domain
 - Overt assumption: Domain knowledge is the key to finding solutions
 - Hidden assumption: Logical inference is the key to finding the solution

The Decline of Knowledge-based Systems

- Google it...
 - Artificial Intelligence never delivered on the promises of “expert systems”...
 - ...but search engines did: there is at least one webpage somewhere that has the solution to a given problem, and it's just a matter of finding it
 - Crwdsourcing did it

The Decline of Knowledge-based Systems

- Google it...
 - Logical inference (intelligence) is irrelevant.
 - It's the quantity of information (not the quality of inference) that matters
 - All we needed is a (digital) library big enough and computers powerful enough to search it
 - What those computers don't need is: intelligence

The Decline of Knowledge-based Systems

- Google it...
 - A person can solve any problem as long as she is capable of searching the Web for the solution
 - No other skills required beyond reading skills
 - No large, expensive supercomputer required: just a (relatively dumb) smartphone
 - The Web plus the search engine does what AI wanted to do: it gives an answer to every possible question that a human can answer (in fact, many more than any one person can answer)

The Decline of Knowledge-based Systems

- 2. Big Data
 - Very soon Homo Sapiens will be producing more data every year than in the previous 200,000 years
 - Big Data shift the disadvantage to the knowledge-based approach: too much knowledge makes it unfeasible

The Decline of Knowledge-based Systems

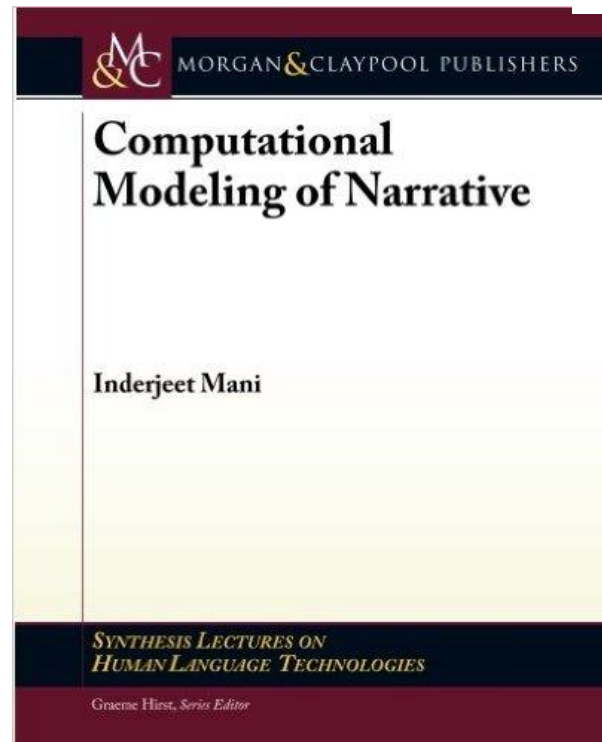
- 3. Cheap computing
 - Computational power per \$ increased dramatically
 - Neural nets and Bayesian nets became feasible (“deep learning”)
 - A.I. based on statistical analysis
 - “Best Guess AI”
 - Translation
 - Search
 - Voice recognition

Limits of Neural Nets

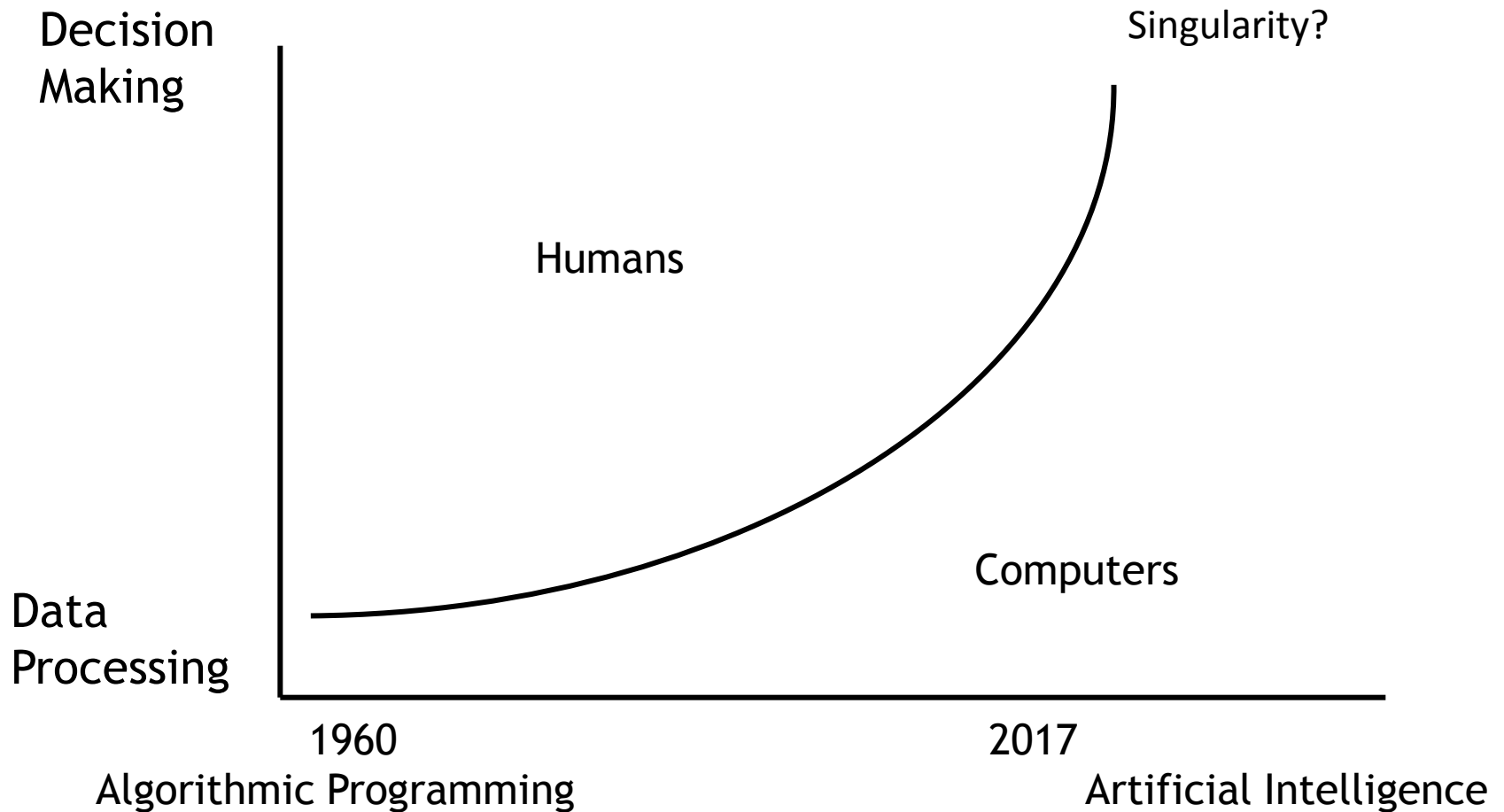
- Machine learning
 - Supervised learning is “learning by imitation”, which is only as good as the expert that you are learning from
 - Statistical method yields a plausible result but it has not learned why
 - The learned skills cannot be applied to other fields

Natural Language Processing

- Progress in “recognition”
- Very little progress in understanding stories
- Language generation



The Future of Mind



The Future of Body

Next...

- See <http://www.scaruffi.com/singular> for the index of this Powerpoint presentation and links to the other parts

