CMPE 489/COGS 500: Intro. to Cognitive Science

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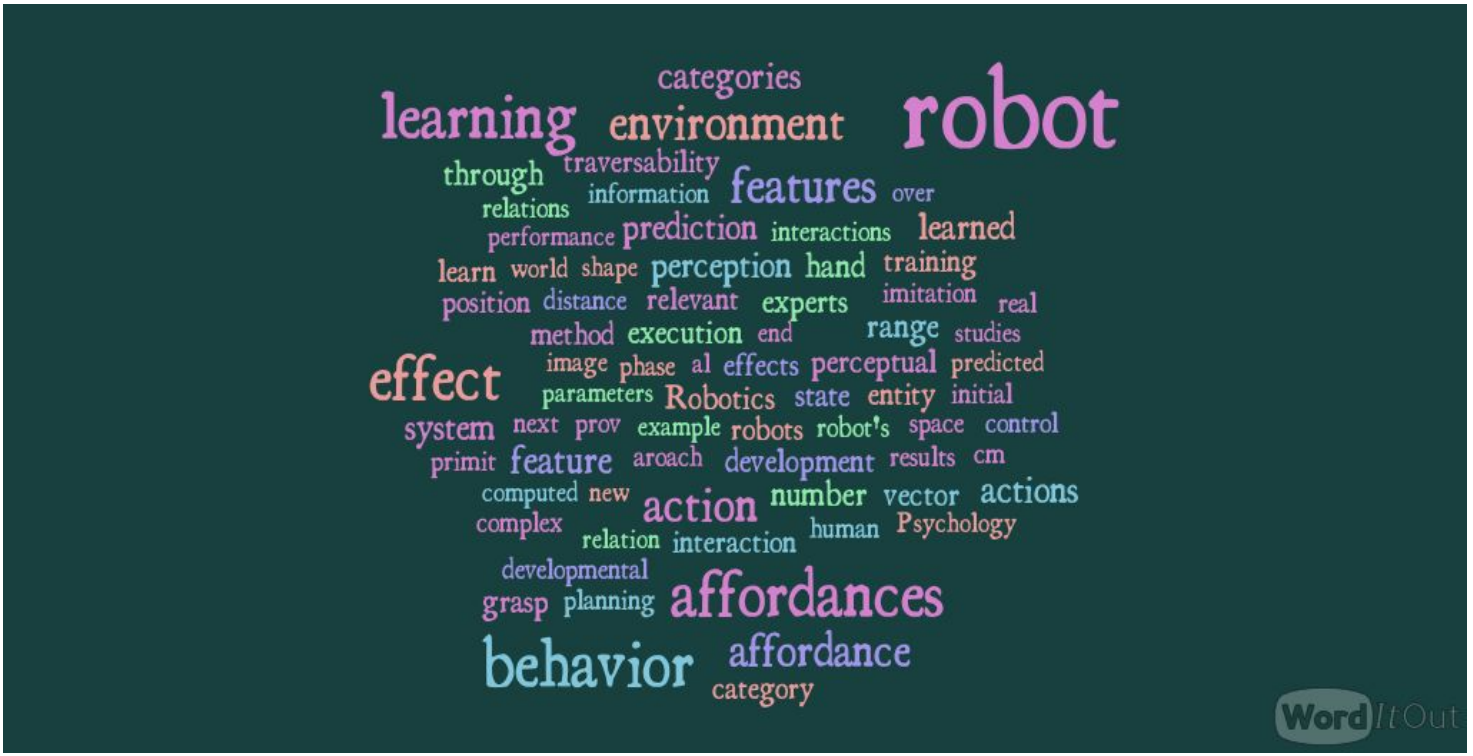
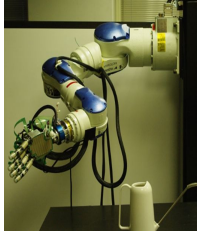
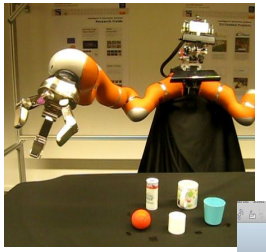
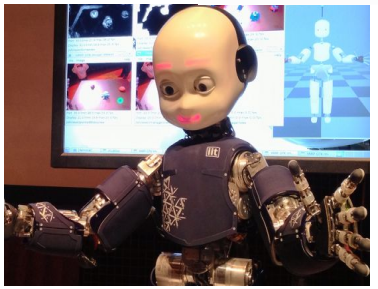
Slides adapted from
Albert Ali Salah

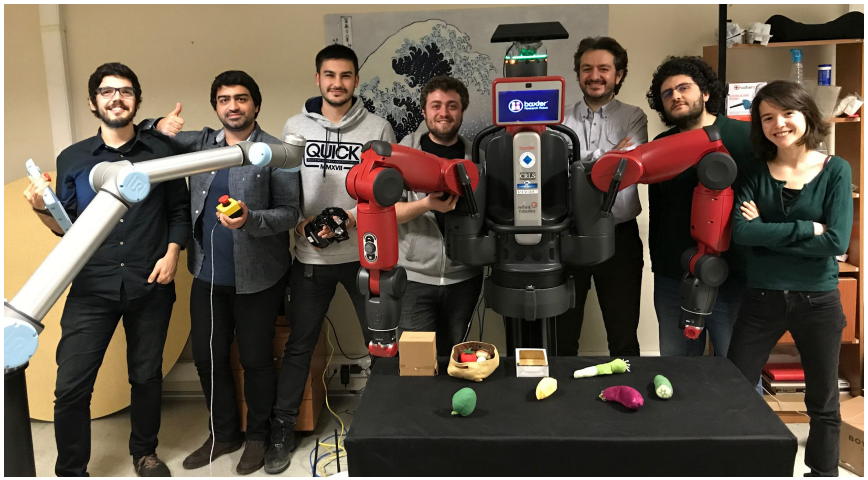


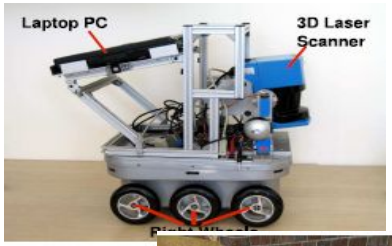






CoLoRs Lab: Cognition, Learning and Robotics





Basic information

- Time & Place:
  - Monday 13:00-14:00 – BM A3
  - Tuesday 09:00-11:00 – BM A3
- Staff:
  - Instructor: Emre Ugur
    - E-mail: emre.ugur@boun.edu.tr
    - Office: BM33
    - Office hours: Fridays 9:00-10:00
- Mailing list: cogs500-cmpe489@listeci.cmpe.boun.edu.tr

Basic information

- Format:
  - In-class discussions, no ‘main’ textbook
  - Quiz in a random time
  - Assignments every week
  - A lot of readings

- Grading:
  - Quizzes: 10
  - 10 homeworks: 30
  - midterm: 20
  - final: 20
  - project: 20

Basic information

- Course materials:
  - Will be (mostly) available in the library?
  - Will be available in course webpage:

https://www.cmpe.boun.edu.tr/~emre/courses/cogs500-cmpe489/

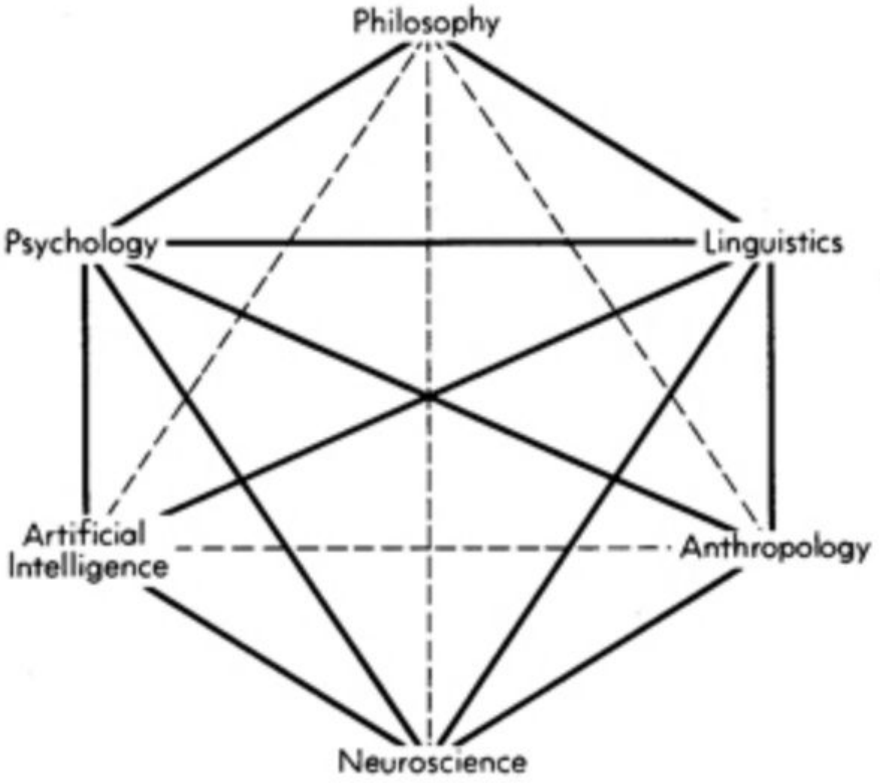
- cogs500-cmpe489@listeci.cmpe.boun.edu.tr

What is cognitive science?

- “The science of the mind” Bermudez
- Cognitive: «perceiving and knowing»
- What does it involve?

- “a contemporary, empirically based effort to answer long-standing epistemological questions – particularly those concerned with the nature of knowledge, its components, its sources, its development and its deployment” Gardner

Scope of cognitive science



Connections among the Cognitive Sciences

KEY: Unbroken lines = strong interdisciplinary ties
Broken lines = weak interdisciplinary ties

Sloan Initiative
SOAP unpublished report, 1978

Scope of cognitive science

Syllabus, course syllabus pdf

Guest lecturers:

- Week 2, on AI: Prof. Cem Say
- Week 3, on mirror neurons: Dr. Erhan Oztop
- Week 5, on cybernetics: Dr. Yagmur Denizhan
- Week 6, on language: Dr. Mine Nakipoglu
- Week 7, on embodiment: Dr. Lucas Thorpe
- Week 9, on cogn. development: Dr. Junko Kanero
- Week 10, on attention: Dr. Inci Ayhan

++ talks by phd students







Turing Machine: The idea of algorithm and computation

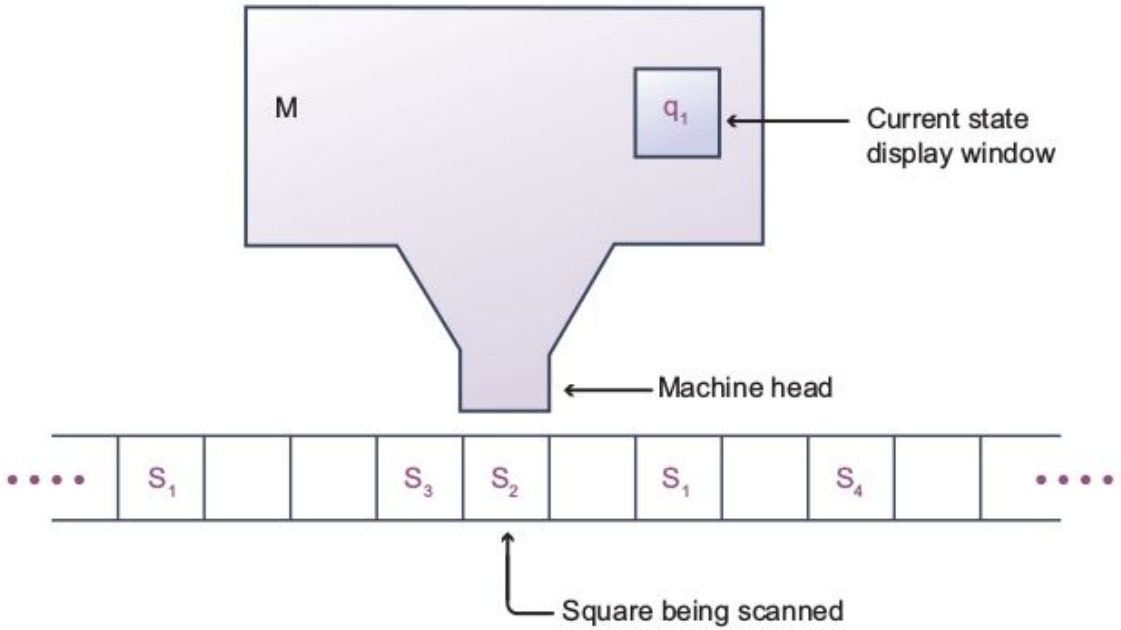


Figure 1.4 Schematic representation of a Turing machine. (Adapted from Cutland 1980)

- delete the symbol in the cell
- write a new symbol in the cell
- move the tape one cell to the left
- move the tape one cell to the right

Cognitive Science in 1950's

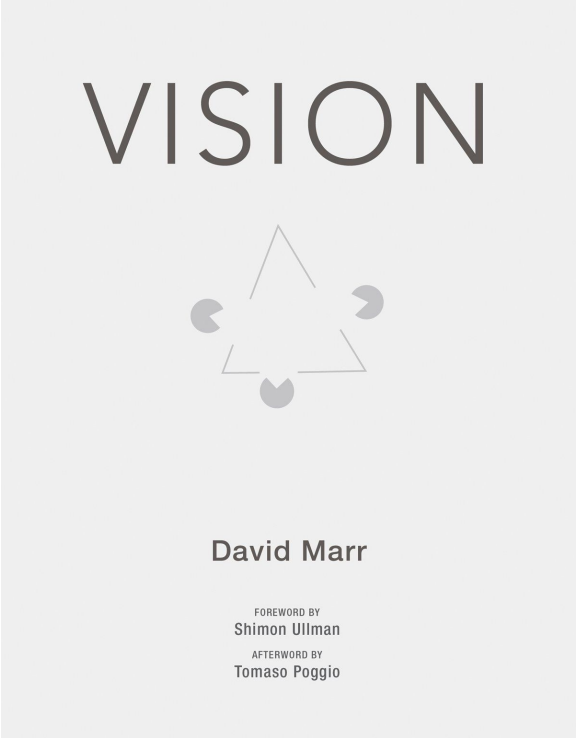
- Turing, Alan M. "On computable numbers, with an application to the Entscheidungsproblem." Proceedings of the London mathematical society 2.1 (**1937**): 230-265.
- McCulloch, W. S., & Pitts, W. (**1943**). A logical calculus of the ideas immanent in nervous activity. The bulletin of mathematical biophysics, 5(4), 115-133.
- Lettvin, J. Y., Maturana, H. R., McCulloch, W. S., & Pitts, W. H. (**1959**). What the frog's eye tells the frog's brain. Proceedings of the IRE, 47(11), 1940-1951.
- Hubel, David H., and Torsten N. Wiesel. "Receptive fields of single neurones in the cat's striate cortex." The Journal of physiology 148.3 (**1959**): 574-591.
- Miller, G. A. (**1956**). The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological review, 63(2), 81.
- Newell, Allen, and Herbert Simon. "The logic theory machine--A complex information processing system." IRE Transactions on information theory 2.3 (**1956**): 61-79.
- Chomsky, Noam. "Three models for the description of language." IRE Transactions on information theory 2.3 (**1956**): 113-124.
- Von Neumann, John. **1958** The computer and the brain. Yale University Press,.
- Putnam, H. **1960**. "Minds and Machines." InS. Hook, ed., Dimensions of Mind. New York: New York University Press.
- Marr, D. (**1982**) Vision: A Computational Investigation info the Human Representation and Processing of Visual Information. San Francisco: W. H. Freeman.

Cognitive Models

- What do we model?
  - A cognitive phenomenon (system output)
  - Dynamics (representation and processing)
  - Physical structure (architecture)
- Descriptive model: To explain a cognitive phenomenon (cognitive science proper)
- Prescriptive model: To use some of the principles of cognitive phenomenon to realize other goals (AI proper)

Model of vision

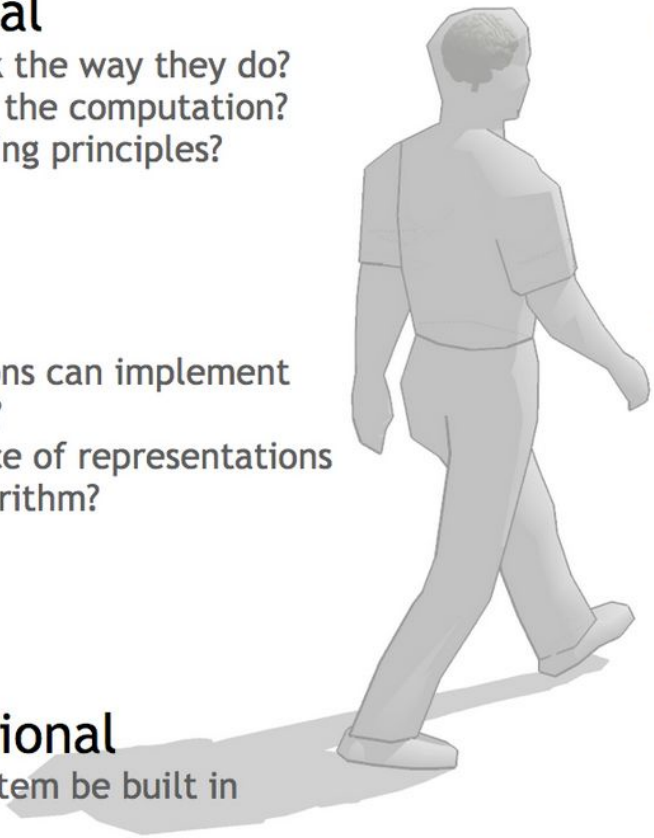
- Mind can be studied in different levels:
  - Bottom-up
  - Top-down
- Earliest systematic approach: David Marr's model of human visual system (1982)
- Integrated results from psychology, artificial intelligence, and neurophysiology into new models of visual processing.
- His work was very influential in computational neuroscience



Three levels of description *(David Marr, 1982)*

Computational

Why do things work the way they do?
What is the goal of the computation?
What are the unifying principles?

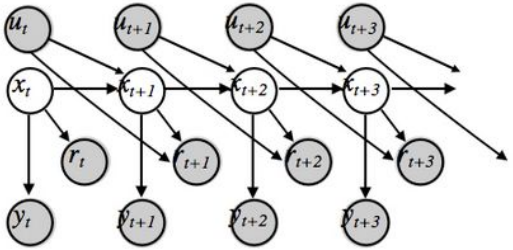


maximize:

$$R_t = r_{t+1} + r_{t+2} + \cdots + r_T$$

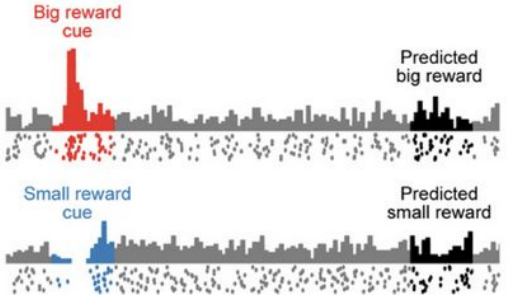
Algorthmic

What representations can implement such computations?
How does the choice of representations determine the algorithm?



Implementational

How can such a system be built in hardware?
How can neurons carry out the computations?



https://fias.uni-frankfurt.de/~rothkopf/docs/david_marr_3_levels.jpg

Turing machine example

- Computational
  - Characterization of multiplication function
- Algorithmic
  - Turing machine table
- Implementational
  - Construction of a physical Turing machine

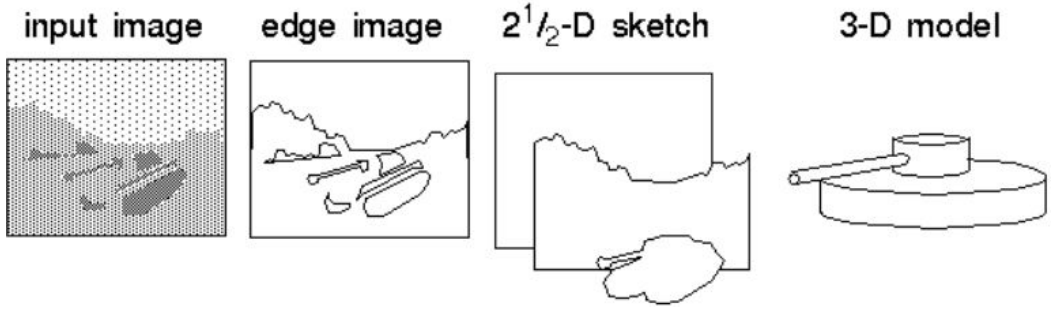
Visual perception model of Marr

- Computational
  - Derive a representation of the 3-d shape and spatial arrangement of an object in a form that allow that object to be recognized.
  - Object centric view.

- Algorithmic
  - How exactly input/output encoded. Representational primitives, what sort of operations on those primitives
  - Intensity of light reaching retina,

- Implementation level

  Actual implementation



The computer

- Use of computer models
  - Confirm that a particular algorithm works
  - Predict behaviour
  - Simulate and analyse different conditions
  - Gain useful insight
  - Support empirical evidence

The computer

- Unsuccessful computer model
  - Bad programming? Insufficient training data?
  - Does not prove that computers cannot do it.
  - Cannot show “the limits of (*connectionist)* models”
- Successful computer model
  - Does not prove that the brain does it that way.
  - Overuse of simplifying assumptions?
  - Proves(?) that computers can do it.

Methodology of philosophy

- Deductive reasoning:
  - Socrates is a man
  - All man are mortal
  - Therefore, Socrates is mortal
- Inductive reasoning:
  - Socrates is a man
  - Socrates is mortal
  - All man are mortal

Methodology of philosophy

- Deductive reasoning
  - Conclusions are certain
  - They are derived from syntax/forms, via logic
  - Objective reasoning
- Inductive reasoning
  - Conclusions are probabilistic/intuitive
  - Evaluation is subjective
  - Depending on prior knowledge, we can sometimes perform huge inductive leaps!

Methodology of philosophy

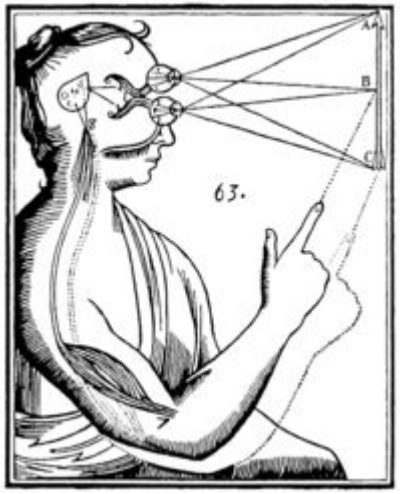
- Abductive reasoning
  - a form of logical inference which goes from an observation to a theory which accounts for the observation, ideally seeking to find the simplest and most likely explanation.
  - Charles Sanders Pierce introduced it.
  - It is reasoning from incomplete evidence (guessing), and has a probabilistic nature
  - Example: The lawn is wet -> It might have rained last night.

Greek philosophers

- “Where does human knowledge come from?”
- “What is the purest form of knowledge?”
- Plato: Idealized forms, innate in human soul
- “What is a form, an image, a concept, a word? How do these representations relate to each other?”
- “What is the influence of language over thoughts and beliefs?”

Schools of thought

- Descartes attributed all thought and creativity to mind, and devalued senses.
- He was a “rationalist”, as opposed to “empiricists” (like Locke) who were more interested in external sensory impressions.
- The British empiricists: Locke, Hume, Berkeley



René Descartes' illustration of mind/body dualism. Source: wikipedia

Wikipedia

Schools of thought

- Rationalist: Impose powers of reasoning upon the world of sensory experience
- Empiricist: Mental processes either reflect or are structured on the basis of external sensors

Locke and Empiricism

- John Locke:

Let us then suppose the mind to be, as we say, white Paper, void of all Characters, without any *Ideas:* How comes it to be furnished? Whence comes it by that vast store, which the busy and boundless Fancy of Man has painted on it, with an almost endless variety? Whence has it all the materials of Reason and Knowledge? To this I answer, in one word, From *Experience.* (Quoted in Herrnstein and Boring 1965, p. 584)

Logical empiricism

- George Berkeley: no material world
- David Hume: It is impossible to attribute causality reliably, and there is no observing or controlling soul behind the processes of thought

  - The nature of sensory experience
  - The classification of objects
  - The role of language
  - The status of individual conscious self

Kant and foundational philosophy

- Later (1781) Kant tried to bring these together.
- Kant: Some knowledge is a-priori, this is the ground on which everything else rests. The everything else, that is sensation. The a-priori part is the rationalist grounding.

Early 20th century

- Unmodifiable rules of logic, impossibility of psychology
- Dramatic advancements in mathematics and physics
- Alfred North Whitehead and Bertrand Russell
  - All mathematics from basic laws of logic
  - Make sense of external world through logical construction from sensory data
- Ludwig Wittgenstein
  - Logical structure implicit to language
  - Propositions of language, perceptual expressions of thoughts, logical pictures of facts
  - Objects in the world, thoughts in the mind, words in language

Fresh approaches to epistemology

- Hilary Putnam (1973): nature of computers and their implications for thinking.
  - Processes attributed part of “thinking” can now be performed by computers
  - İdea of functional organization
  - Shows the importance of abstraction
  - Mind-body problem:
    - Thought can indeed occur in a physical apparatus and can be correlated with certain behavior and yet not have to be identifies with the precise class of activities that happen to be produced.

PART II – ARTIFICIAL INTELLIGENCE

Cybernetics Perspective

- Thinking is a form of computation. The computation involved is not the mental operation of a human being who manipulates symbols in applying rules, such as those of addition or multiplication; instead it is what a particular class of machines do-machines technically referred to as “algorithms”
- Physical laws can explain why and how nature appears to us to contain meaning, finality, directionality, and intentionality

J.P. Dupuy, On the Origins of Cognitive Science

Artificial Intelligence

- Modest definition: “Making computers that outperform **humans** in tasks which humans currently excel.” (Rich & Knight)
- Ambitious definition: “Making computers that **think**.”
  - (strong AI?)
- Relation to cognitive science:
  - Human is the yardstick of AI
  - The human brain is an exceptional system
- The Turing test

“Artificial Intelligence is the ability to adapt to change in artificial agents”

Artificial Intelligence

- Problem solving
- Natural language processing
- Machine learning
- Pattern recognition
- Expert systems
- Reasoning
- Embodied systems and robotics
- ....

AI vs. Cognitive Science

- **CogSci** asks questions of cognitive psychology
  - Tries to explain an aspect of cognition
  - Works in a primarily reductionist mode
- Uses **computational techniques** from AI
  - Information processing is the prevalent metaphor for brain activity
- Uses **empirical data** in constructing and validating its hypotheses
  - Linked strongly to medical and biological sciences

Quiz