



Cognitive Robotics:
The Return of the Body in the Sciences
of Mind

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Take home messages

- Embodied cognition is alternative to computationalism as approach to studying cognition
- Brains act in the context and in coordination with bodies
- Robots are natural tool of choice in the attempt to study embodied cognition
- In principle one can simulate the body/mind complex situated in the environment but that may prove to be complex/expensive
- Bodies have “minds” of their own; they’re not only interfaces to the outer world for the plans drawn by the brain
- Robot metaphor provided context unimaginable in the classical paradigm: sensory-motor learning, imitation, group behavior, mirror neurons, testing long standing paradigms in their natural niche

Overview of the tutorial

(as planned at least)

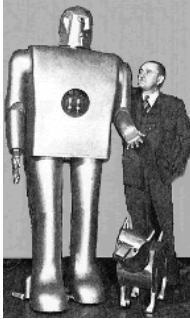
Day 1:	<i>The return of the body in the sciences of mind</i>
Day 2:	<i>So, what is Cognitive Robotics?</i>
Day 3:	<i>Social Robot(ic)s</i>
Day 4:	<i>Physical-model-based understanding of cognitive phenomena.</i>
Day 5:	<i>Present and the Future</i>

Today: The return of the body in the sciences of mind

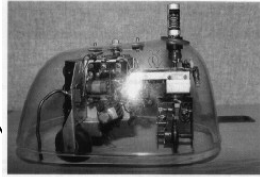
- AI and robotics in the popular culture and entertainment
- Robots and cognition
- Cognition as computation/symbolic representation
- The story of Shakey
- Problems with symbolic representation
- The story of William Grey Walter
- Anti-representation approach
- The body has a mind of its own
- Alternative approaches to computationalism

Robotics evolution timeline

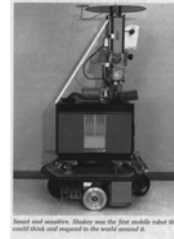
Westinghouse
ELEKTRO



Grey
Walters
tortoises



SRI's
SHAKY



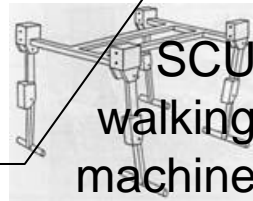
SONY's
AIBO



[more](#)

1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020

UNIMATE



Stanford
Arm

PUMA

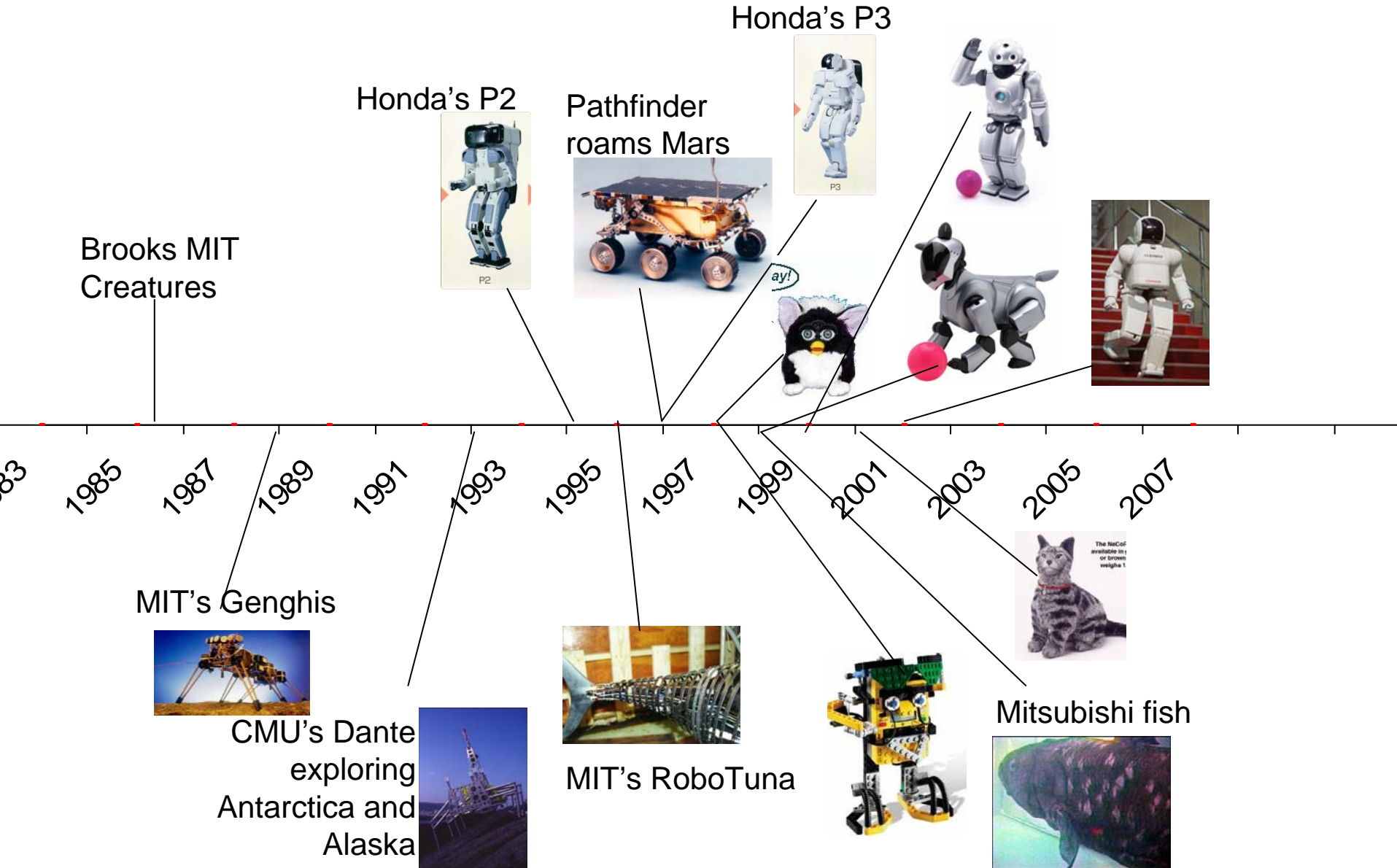


Lomonosov
walking bot

BiPed U
Tokyo



Things go wild in the 90s



AI and robotics in the popular culture and entertainment

What is a robot?

What makes something a robot?

When can we say that something is a robot?

What are the characteristics of a robot?

“... [A] robot is **a machine that senses, thinks, and acts**. Thus, a robot **must have sensors, processing ability that emulates some aspects of cognition, and actuators**. **Sensors are needed to obtain information from the environment**. Reactive behaviors (like the stretch reflex in humans) do not require any deep cognitive ability, but on-board intelligence is necessary if the robot is to perform significant tasks autonomously, and **actuation is needed to enable the robot to exert forces upon the environment**. Generally, **these forces will result in motion of the entire robot or one of its elements** (such as an arm, a leg, or a wheel).”

COGNITION

- A broad (...) term which has been traditionally used to refer to such activities as **thinking, conceiving, reasoning**, etc.

The Penguin Dictionary of Psychology

- The act or **process of knowing in the broadest sense**, including both awareness and judgment.

Merriam Webster's

- Cognition refers to all the processes by which the **sensory input is transformed, reduced, elaborated, stored, recovered, and used** (including) terms as sensation, **perception, imagery, retention, recall, problem solving, and thinking**.

Ulrich Neisser

- The most widespread use is as a descriptive term for the **large class of so-called higher-level processes**, that is, **processes not directly driven by the sensory and motor systems.**

Rolf Pfeifer, Christian Scheier, 1999, Understanding Intelligence

- Cognition in humans is **exhibited through the characteristics of short- and long-term memory, categorizing and conceptualizing, reasoning, planning, problem solving, learning, and creativity.**

Stan Franklin, 1997, Autonomous Agents as Embodied AI, Cybernetics and Systems, Special Issue on Epistemological Aspects of Embodied AI

“Cognitive science is an intensely **interdisciplinary study of cognition, perception, and action**. It is based on the **assumption that cognition is information processing** [...], where information processing is **generally construed as the rule-governed manipulation of data structures that are stored in a memory**. As a result of this assumption, a basic aim of cognitive science is identifying the functional architecture of cognition – the primitive set of rules and representations that mediate thought [...]”.

M. R. W. Dawson, 2002/1998 *Understanding Cognitive Science*.
Oxford, UK: Blackwell

Five questions of the early sciences of mind

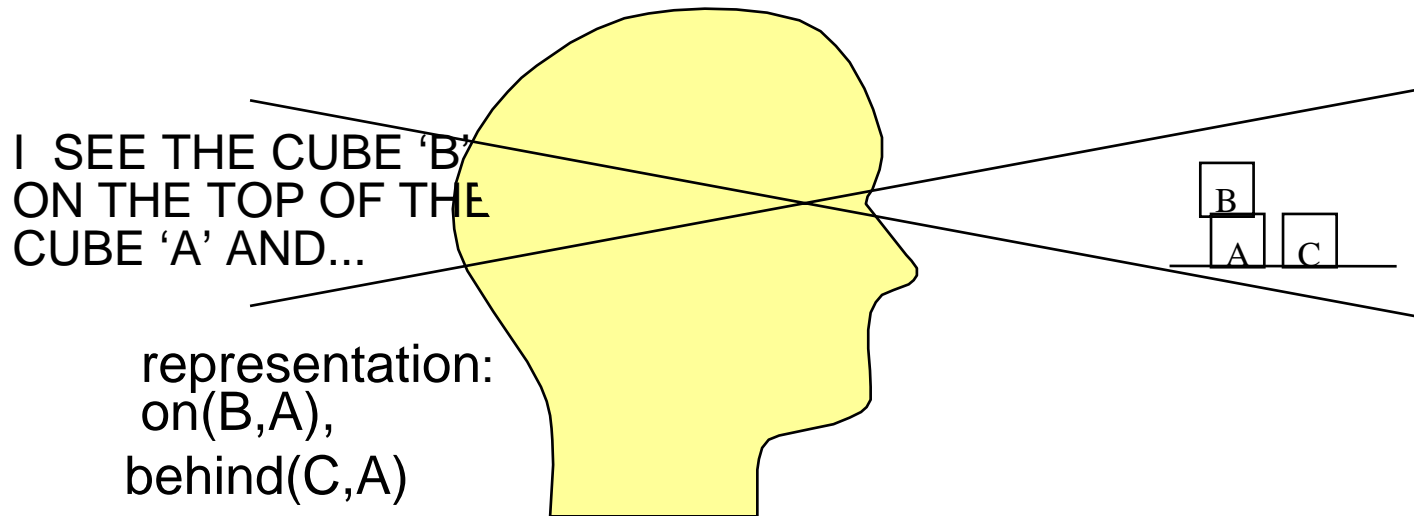
- How cognition operates? How it converts perceptions into action plans?
- How to talk about internal states without resorting to dualism or to a method of pure introspection?
- Explain how come mental phenomena are so qualitatively different from the physical brain phenomena which presumably make them happen?
- Bridging the conceptual gap between the knowledge within physiology and psychology?
- A great desire for a formalism (preferably a mathematical one) which could capture psychological phenomena.

The computer metaphor seemed to provide the answers

- Cognition operates like a digital computer program, by manipulating internal representations according to some set of rules.
- Inspiring metaphor for functionalism – mental entities are like software while physical mechanisms are like hardware. A plausible escape from dualism!
- Psychological phenomena are the software running upon the biological hardware.
- It provided a mathematical formalism that gave psychology some long-desired rigor – the language of predicate logic and information theory.

TRADITIONAL COGNITIVE SCIENCE and AI

(representationalism, encodingism...)



Isolationism

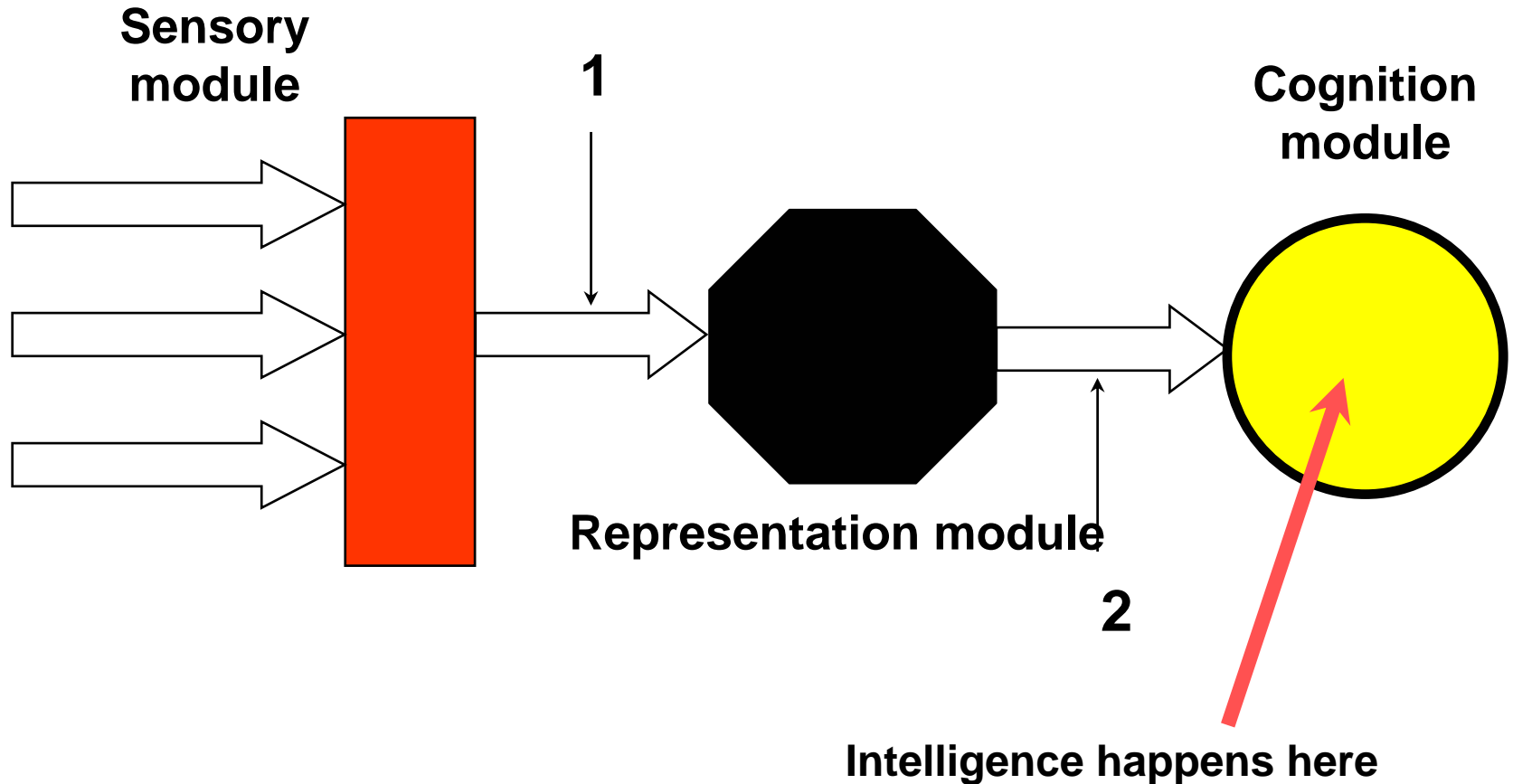
“The **world is (just) a source of inputs** and an **arena for outputs**. And **the body is just an organ for receiving inputs and effecting outputs (actions)**. The task of early processing is to render the inputs as an inner world-model of sufficient thickness to allow the bulk of problem-solving activity to be defined over the inner model alone.”

Andy Clark, 2003/1998, *EMBODIMENT AND THE PHILOSOPHY OF MIND*, O'Hear (ed) CURRENT ISSUES IN PHILOSOPHY OF MIND: ROYAL INSTITUTE OF PHILOSOPHY SUPPLEMENT 43,

Cambridge University Press

Traditional division of tasks

(Sense-Think-Act model)



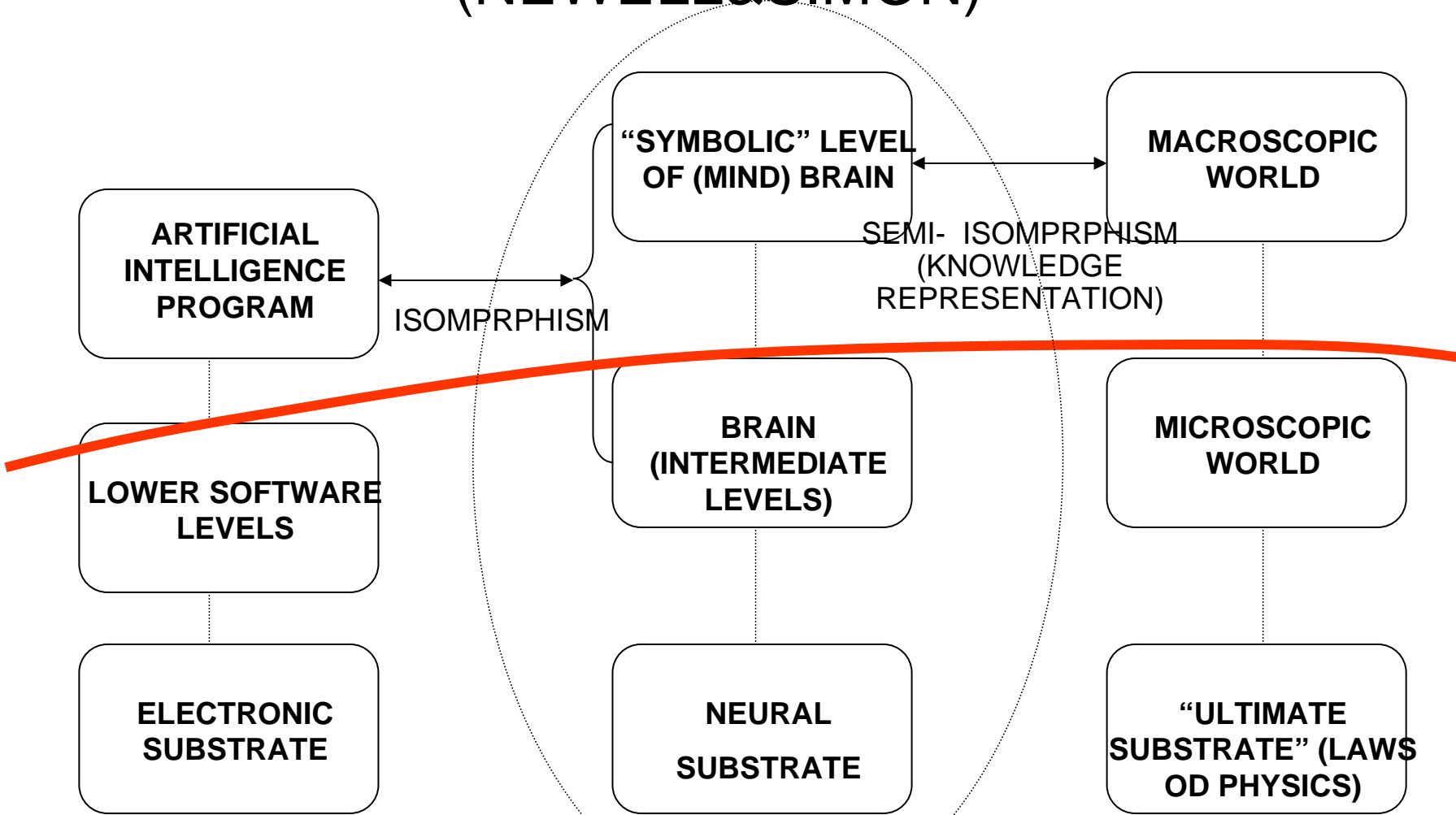
Consequences of the S-T-A model

Traditional disciplinary boundaries and the need for specialization in science **have divided the large problem of behavior into smaller sub-problems such as Perception, Cognition, and Action.**

These **disciplinary boundaries then spill over into large-scale brain theories**, yielding a **model of the brain with distinct modules separated by putative internal representations.**

The **Perceptual module** is separated from the **Cognitive module** by an **internal unified representation of the external world**, and the Cognitive module is separated from the Action module by a representation of the motor plan.

AI APPROACH TO COGNITION: PHYSICAL SYMBOL SYSTEM HYPOTHESIS (NEWELL&SIMON)

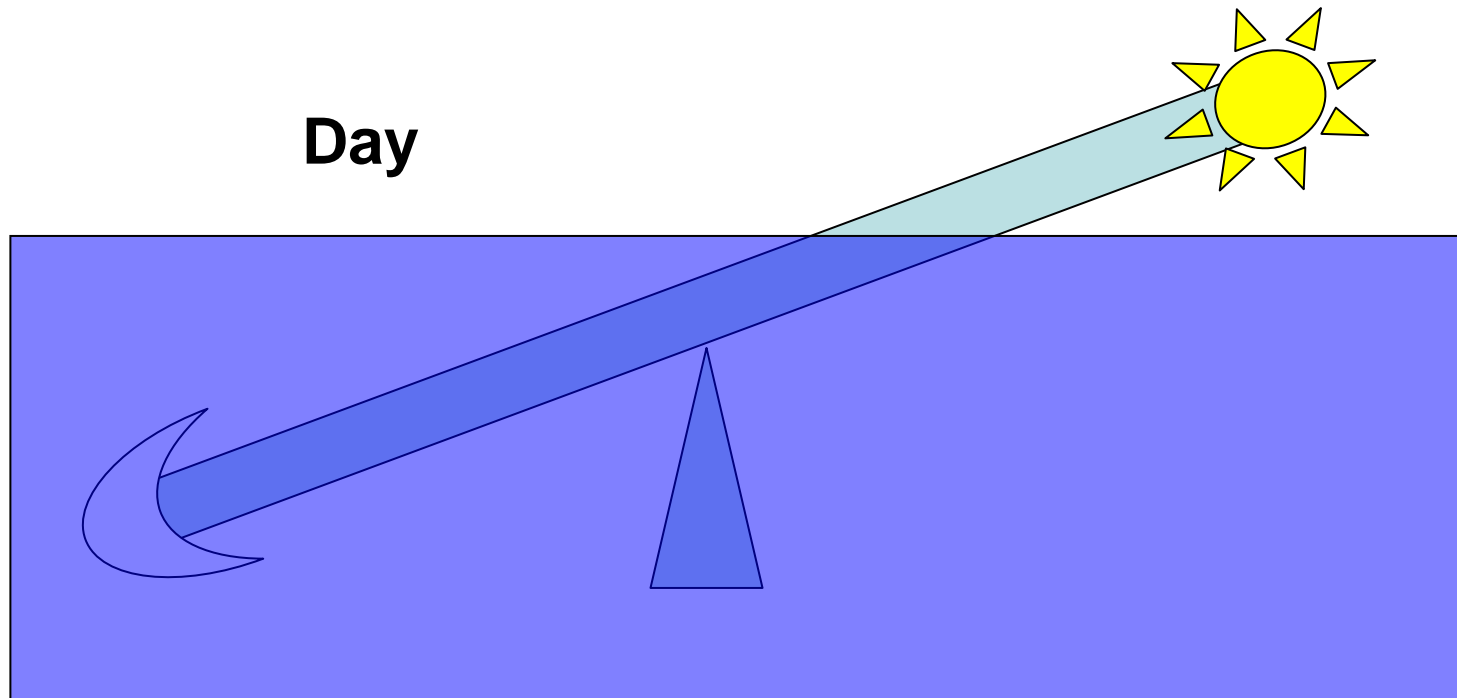


(Adapted from Hofstadter, 1979)

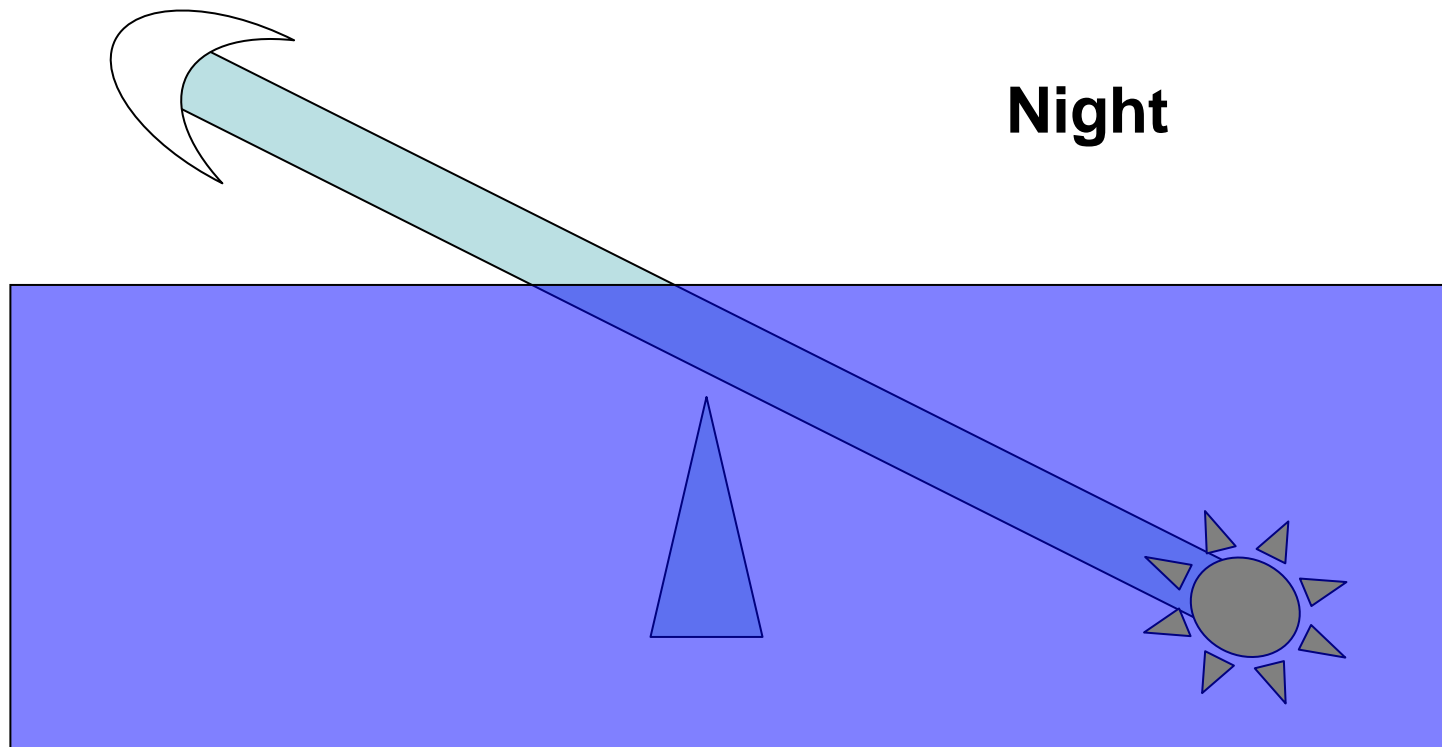
PHYSICAL SYMBOL SYSTEM HYPOTHESIS (NEWELL&SIMON)

A PHYSICAL SYMBOL SYSTEM IS ANY SYSTEM IN WHICH SUITABLY MANIPULABLE TOKENS ARE ASSIGNED ARBITRARY MEANINGS AND BY WAY OF PROGRAMMING CAN BE EXPECTED TO BEHAVE IN WAYS, TO A SPECIFIED DEGREE, CONGRUENT WITH THAT PROJECTED SEMANTIC CONTENT.

PSS representing the tautology:
"It is either night or day"



PSS representing the tautology:
"It is either night or day"



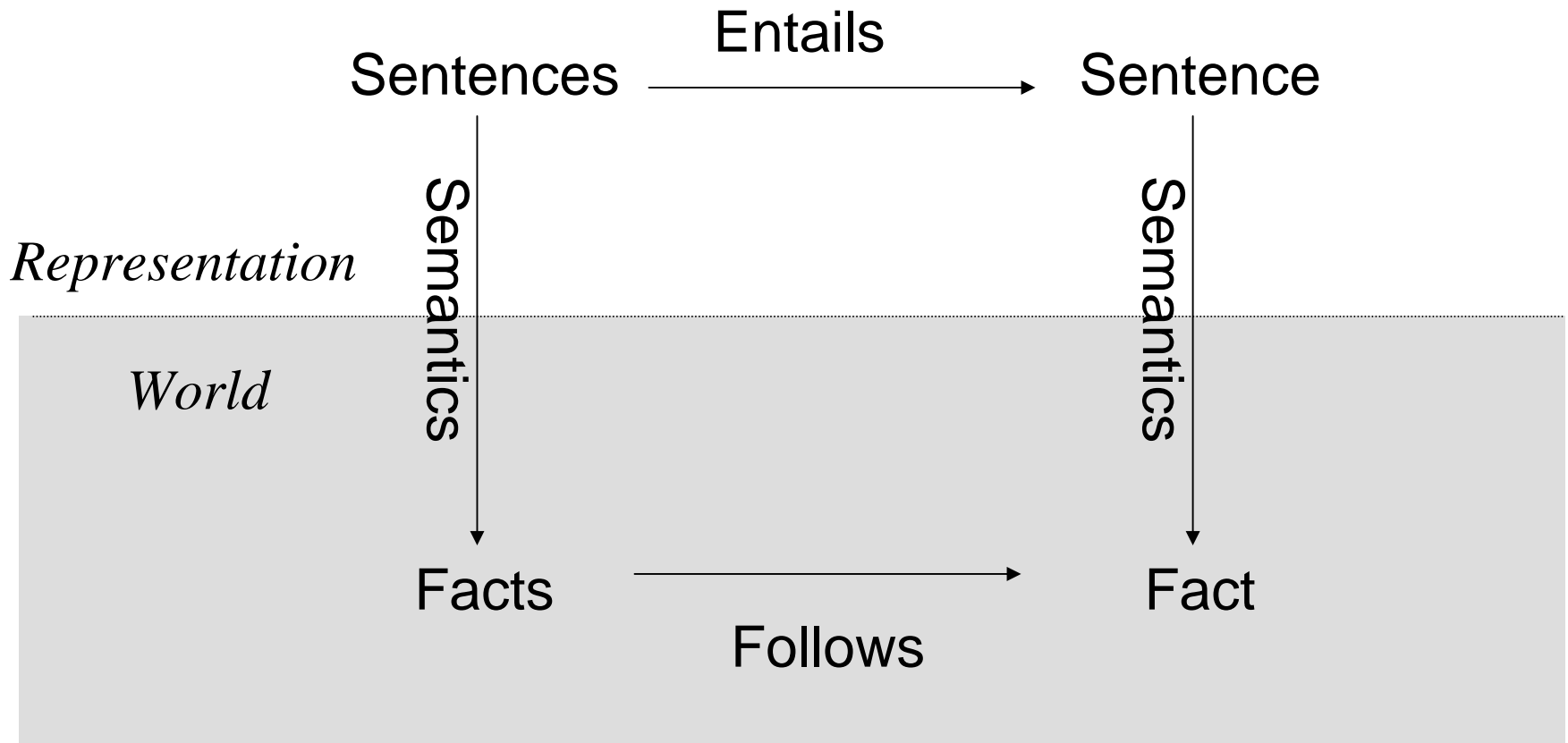
Symbolic representations

- Knowledge is represented in **amodal symbolic form**.
- **Meaning is referential**, in that it derives from a posited correspondence between the system of abstract symbols and their corresponding extensions, the objects and events in the world.
- Concepts are symbolic representations by nature, and as **thinking**, they **can be reduced to symbolic (not necessarily neural) computation**.

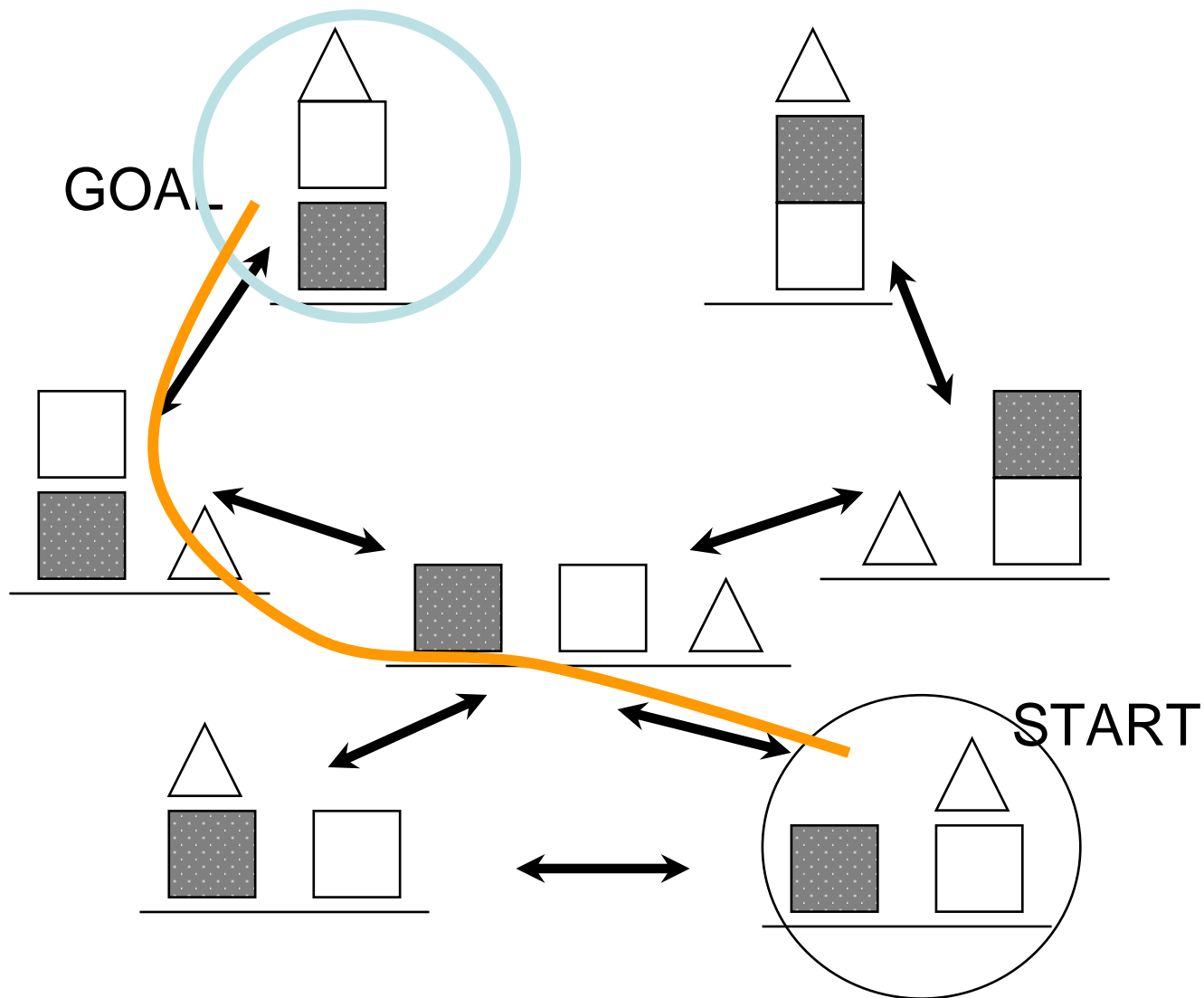
Classical representations

- Atomic concepts directly interpretable for humans (like: **wants(X,Y)** meaning that “**X wants Y**”)
- **Compositional semantics**, that is, the meaning of a **complex concept is a function of the meaning of the elementary concepts** that it contains

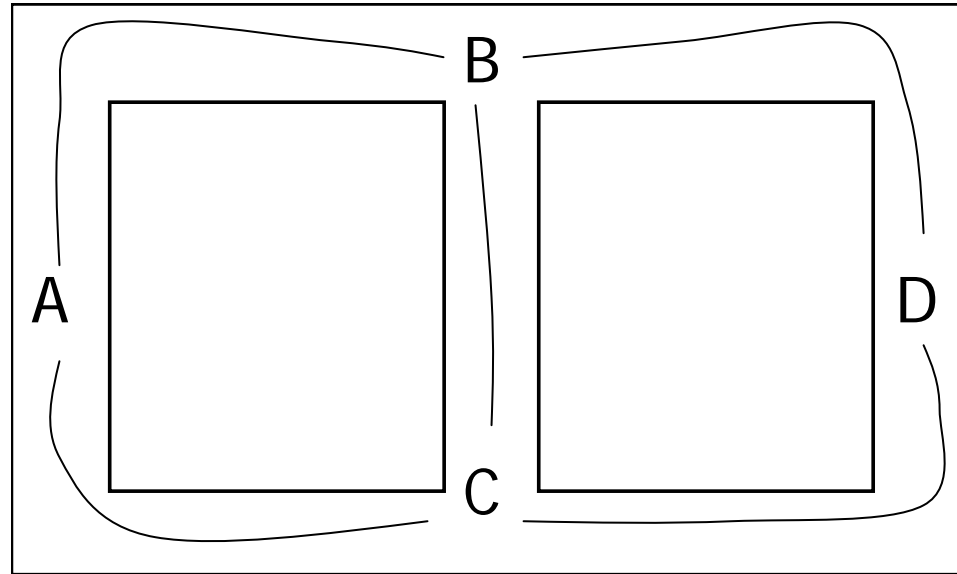
Semantics of the representation language provides the connection between sentences and facts



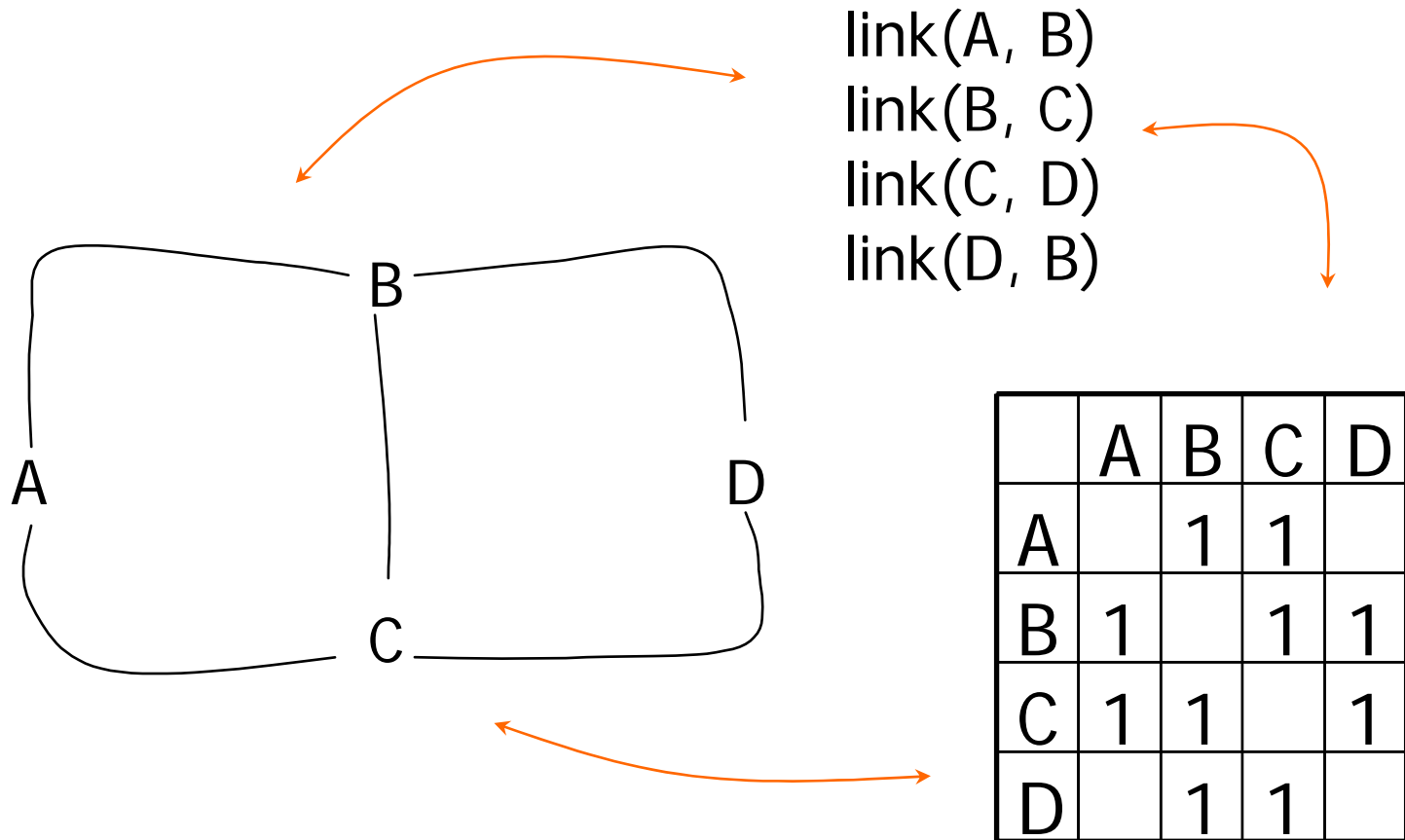
Intelligence as search of the state space



Or, how to represent the problem of negotiating a maze



Various symbolic structures representing the maze

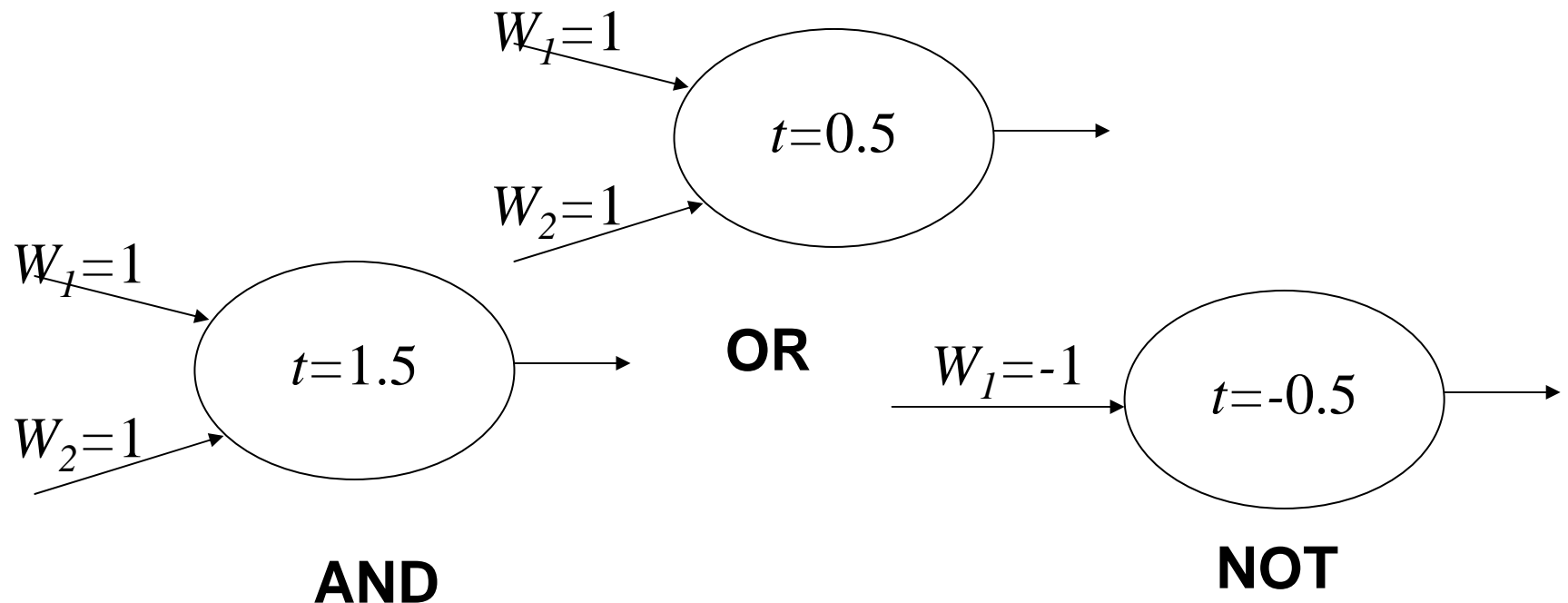


Typical first generation AI applications

- LOGIC THEORIST (SIMON & NEWELL)
- GENERAL PROBLEM SOLVER (SIMON & NEWELL)
- CHECKERS PLAYER (SAMUEL) and other games

The first artificial neural network: **McCulloch & Pitts 1943**

They wanted to demonstrate that with neuron like elements it was possible to implement any Boolean function



Robotist approach: ***just do it!***

The story of Shakey

Problems with symbolic representations

- ***The Frame problem (Pylyshyn, 1987)***, or the problem of determining what pieces of the vast amount of the stored knowledge are relevant for the current situation (or problem if you want);
- ***The Symbol Grounding problem (Harnad, 1990)***. The whole symbolic AI enterprise relies on the properties of transduction, that is the possibility to transform sensory states into symbolic representation. To use Harnad's words "**How can the semantic interpretation of a formal symbol system be made intrinsic to the system, rather than just parasitic on the meanings in our heads?**";
- ***The Frame-of-Reference problem (Clancey, 1989)***. This problem concerns the relations among the observer, the designer, the artifact, and the environment. For example (Verschure, 1993), when designing some classical expert system, the knowledge engineer is at the same time observer and designer who observes and describes in symbolic terms the problem-solving behavior of a human expert. The categories and symbols are those of the engineer and are grounded in his and not in the experience of the artifact.

The story of William Grey Walter

Anti-representational approach in AI and robotics

The importance of being embodied

- It is important being embodied! But what does it mean?
- In a trivial sense, even a computer program has a body (the computer it is being executed on)
- Moreover, Shakey had a body?

“THE BODY HAS A MIND OF
ITS OWN”

ALTERNATIVES TO THE COMPUTATIONALISM

Take home messages

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- In principle one can simulate the body/mind complex situated in the environment but that may prove to be complex/expensive
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**COGNITIVE ROBOTICS PUTS SOME
FLESH (OR METAL) ON THE THEORIES
OF EMBODIED COGNITION**

“Cognitive Robotics” what’s in a name?

- Cognitive Artificial Intelligence?
- Cognitive Physics?
- Cognitive Chemistry?
- Cognitive Mathematics?
- Cognitive Geography?
- Cognitive History?
- Cognitive Linguistics?
- ...

Classicist/Cognitivist View

1. Computer metaphor of mind; rule-based, logic driven.
2. Isolationist analysis - cognition can be understood by focusing primarily on an organism's internal processes.
3. Primacy of computation.
4. Cognition as passive retrieval.
5. Symbolic, encoded representations

Embodied Cognition View

1. Coupling metaphor of mind; form of embodiment + environment + action constrain cognitive processes.
2. Relational analysis-interplay among mind, body, and environment must be studied to understand cognition.
3. Primacy of goal-directed action unfolding in real time.
4. Cognition as active construction based upon an organism's embodied, goal-directed actions
5. Sensorimotor representations

Representation

- Is there one? What sort of things can one do without?
- How does it get there?
- How it is used to control robot behavior?
- How does it change over time?

Cognitive modeling using robots

- More constraints from physics
- More predictions in social environment
- Many more ways to break the body (probe the model) and see what happens

“Surprisingly as it may sound, the mind exists in and for an integrated organism; our minds would not be the way they are if there were not for the interplay of body and brain during evolution, during individual development, and at the current moment.

The mind had to be first about the body, or it could not have been. On the basis of the ground reference that the body continually provides, the mind can then be about many other things, real or imaginary.

This idea is anchored in the following statements:

(1) The human brain and the rest of the body constitute an indissociable organism, integrated by means of mutually interactive and neural regulatory circuits (including endocrine, immune, and autonomic neural components);

(2) The organism interacts with the environment as an ensemble: the interaction is neither of the body alone nor of the brain alone;

(3) The physiological operations that we call mind are derived from the structural and functional ensemble rather than from the brain alone: mental phenomena can be fully understood only in the context of an organism’s interacting in an environment. That the environment is, in part, a product of the organism’s activity itself, merely underscores the complexity of interactions we must take into account.”

Visceral reactions to faces



philosophie

philosophie

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N°10



ENQUÊTE

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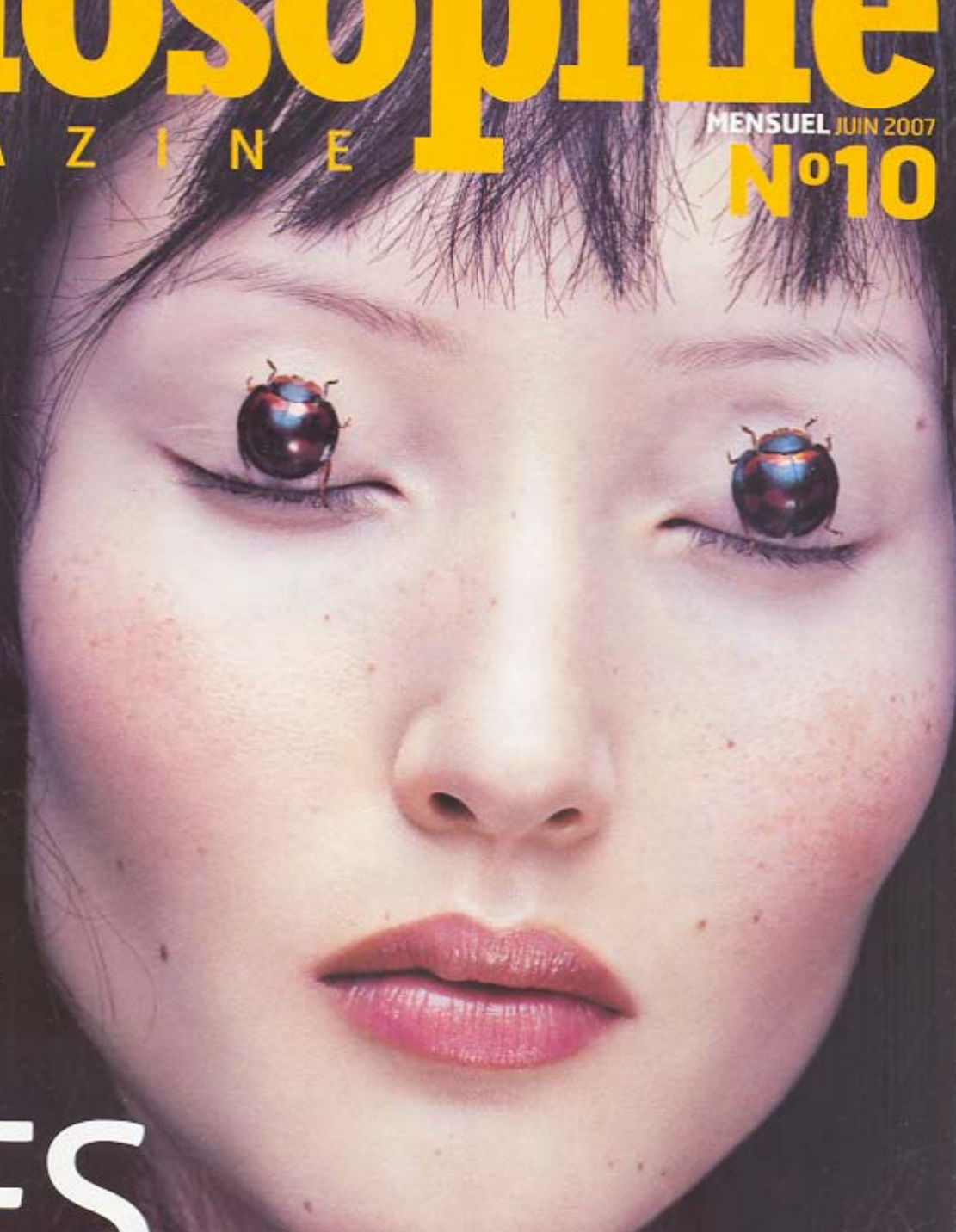
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DOSSIER

CRISES



Human See, Human Do

Brain Cells That
Mirror Actions We See
Are Key to Learning,
Empathy, Even Culture

page 22

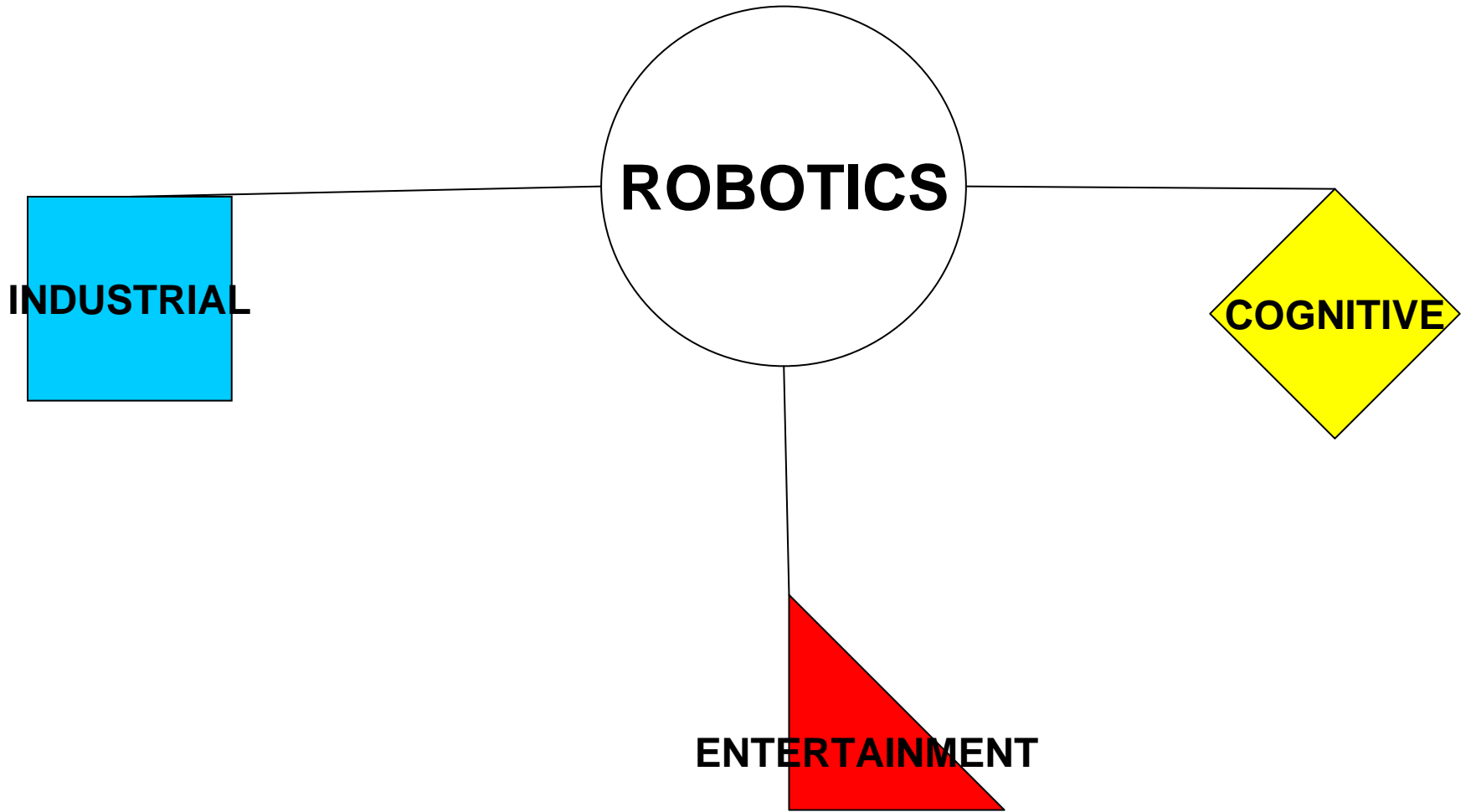
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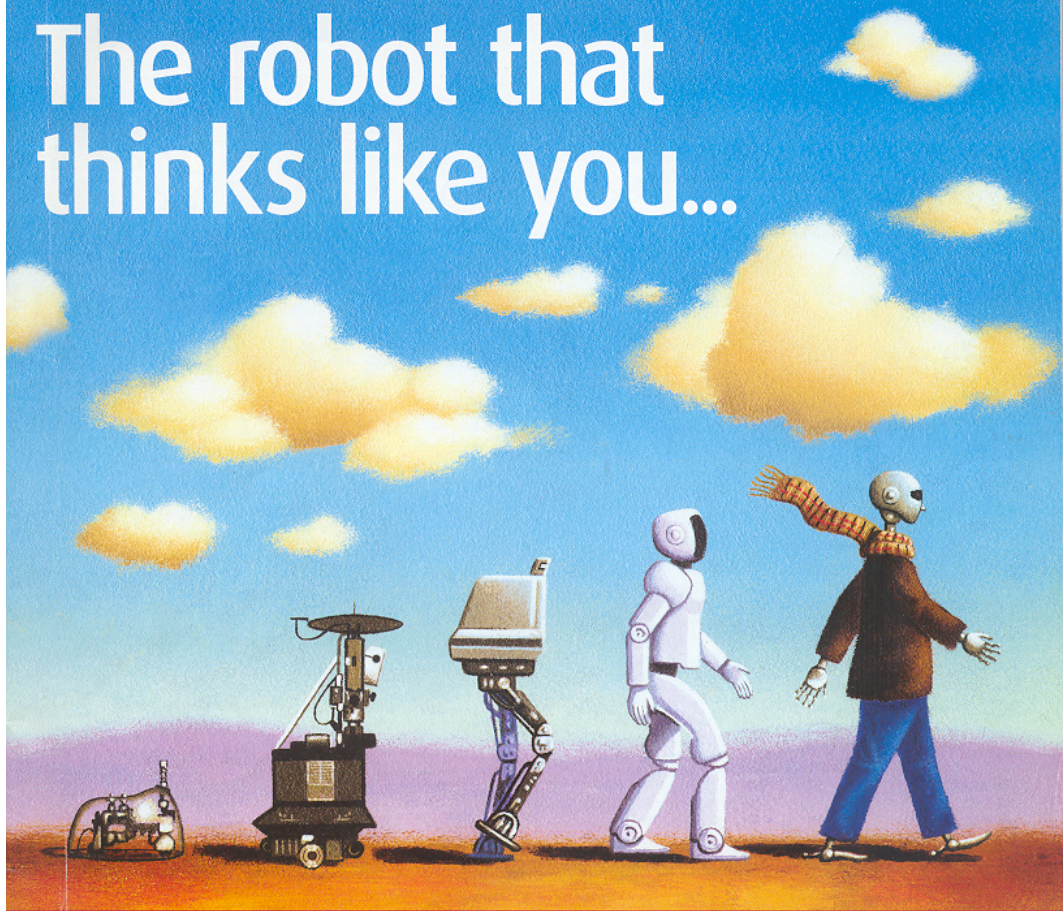
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The robot that thinks like you...



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DARWIN'S
TROUBLING
LEGACY**



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