

# Embodied Cognition

## International Lecture Serie

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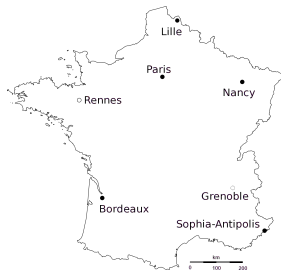
INRIA  
National Institute for Research  
in Computer Science and Control

国立情報学研究所  
National Institute of Informatics  
Tokyo, December 2, 2010

INRIA (French National Institute for Research in Computer Science and Control) is a public research establishment entirely dedicated to information and communication sciences.

## Organization

- 8 research centers
- 174 team-projects
- 3150 scientists



## Research themes

- Life Sciences & Environment
- Algorithmic, Programing, Software & Architectures
- Applied Mathematics, Computation & Simulation
- Perception, Cognition & Interaction
- Computational Sciences for Biology, Medicine & the Environment

# Cortex project

<http://cortex.loria.fr>

Cortex is a project whose goals are to design numerical and adaptive models in interaction with biology and medical science.

## Current organization

- 10 permanent scientists
- 3 post-docs
- 10 PhD students
- 2 assistants
- 2 engineers

## Research themes

- Microscopic level: spiking neurons and networks
- Mesoscopic level: dynamic neural fields
- Brain Signal Processing
- Connectionist parallelism
- The embodiment of cognition

# Outlook

## Lecture 1: Embodied Cognition

This lecture proposes to look back at (almost) 60 years of Artificial Intelligence researches in order to address the question of what has been accomplished so far towards our understanding of intelligence and cognition

## Lecture 2: Visual Attention

This lecture proposes to review current psychological and physiological data related to visual attention as well as anatomical and physiological data related to the oculomotor control.

## Lecture 3: Dynamic Neural Fields

This lecture introduces main concepts related to computational neuroscience and introduced dynamic neural field theory.

## Lecture 4: Models of Visual Attention

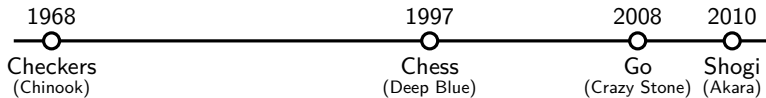
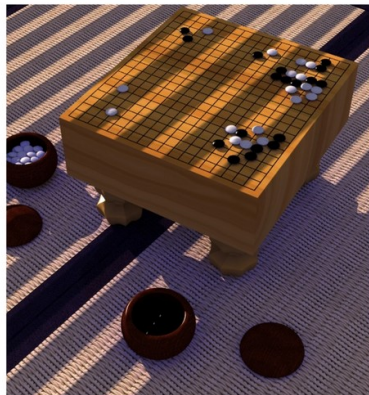
This lecture will introduce models relying on dynamic neural fields and show how covert and overt attention can emerge from such a substratum.

# Outlook

- ① Introduction
- ② A Short History of Artificial Intelligence
- ③ The Action Perception Loop
- ④ Embodied Cognition

# A Short History of Artificial Intelligence

# An Old Dream Comes True ?



# An Old Dream Comes True ?



In 1997, Deep Blue super computer (IBM) beat world chess champion Gary Kasparov. Today (2010), Nao (Aldebaran) would not even be able to compete with a one-year old baby.



# What is Artificial Intelligence ?

The science of making machines do things that would require intelligence if done by humans.

Marvin Minsky, *Semantic Information Processing*, 1968.

- What is machine ?
- What is intelligence ?
- What tasks require some form of intelligence ?
- What kind of humans do we consider ?

# What is Artificial Intelligence ?

## Weak A.I. hypothesis

According to weak AI, the principal value of the computer in the study of the mind is that it gives us a very powerful tool.

J. Searle, "Minds, Brains and Programs", 1980.

## Strong A.I. hypothesis

According to strong AI, the computer is not merely a tool in the study of the mind; rather, the appropriately programmed computer really is a mind.

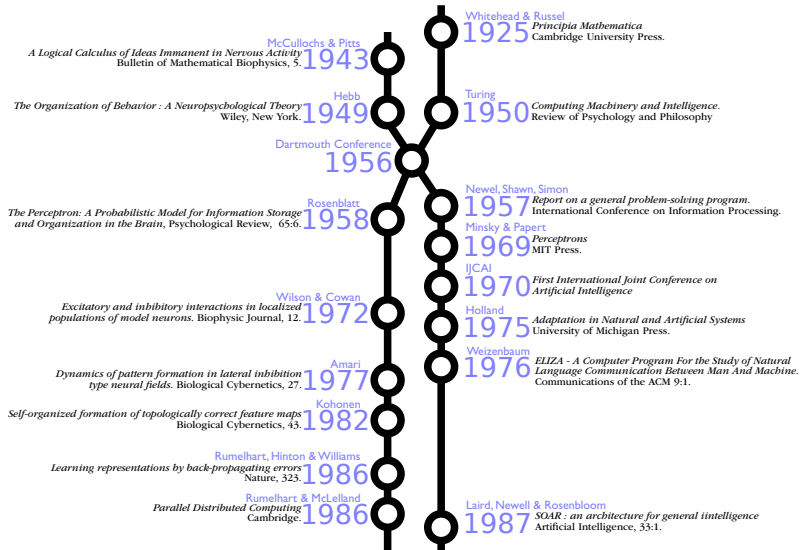
J. Searle, "Minds, Brains and Programs", 1980.

# What is Artificial Intelligence ?

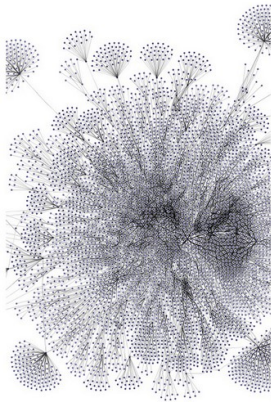
What were the main problems to be solved ?

- Deduction, reasoning, problem solving
- Knowledge representation
- Planning
- Learning
- Natural language processing
- Motion and manipulation
- Perception

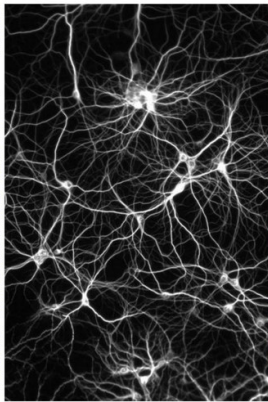
# A Brief History of A.I.



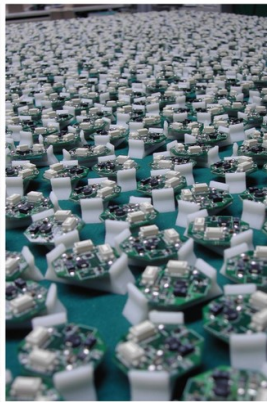
# Different Philosophies



Symbolic



Sub-Symbolic



Statistical

# Different Approaches

## The Physical Symbol System Hypothesis

A physical symbol system has the necessary and sufficient means for general intelligent action. By “necessary”, we mean that any system that exhibits general intelligence will prove upon analysis to be a physical symbol system. By “sufficient” we mean that any physical system of sufficient size can be organized further to exhibit general intelligence.

Newell & Simon, 1976

## The Connectionist hypothesis

The implicit assumption [of the symbol manipulating research program] is that it is relatively easy to specify the behavior that we want the system to perform, and that the challenge is then to design a device or mechanism which will effectively carry out this behavior... [I]t is both easier and more profitable to axiomatize the *physical system* and then investigate this system analytically to determine its behavior, than to axiomatize the *behavior* and then design a physical system by techniques of logical synthesis.

Rosenblatt, 1962

## Eliza, the computer therapist (Weizenbaum, 1966)

Eliza: How do you do. Please state your problem.

*I need a definition of A.I.*

Eliza: What would it mean to you if you got a definition of A.I. ?

*It would help me to finish my lecture.*

Eliza: Your lecture ?

*Yes, I'm a researcher.*

Eliza: Is it because you are a researcher that you came to me ?

*Yes, because I need this definition.*

Eliza: You seem to be quite positive.

*Not so much, because I still don't have the definition of A.I.*

Eliza: Is that the real reason ?

*Of course it is !*

# The Symbol Grounding Problem



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“La Trahison des images”,  
Magritte, 1929.

“La Trahison des images”,  
Magritte, 1929.

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?

S.Harnad, *The Symbol Grounding Problem*, 1990.



# The Frame Problem

Once upon a time there was a robot, named R1 by its creators. Its only task was to fend for itself. One day its designers arranged for it to learn that its spare battery, its precious energy supply, was locked in a room with a time bomb set to go off soon. R1 located the room, and the key to the door, and formulated a plan to rescue its battery. There was a wagon in the room, and the battery was on the wagon, and R1 hypothesized that a certain action which it called PULLOUT (Wagon, Room, t) would result in the battery being removed from the room. Straightaway it acted, and did succeed in getting the battery out of the room before the bomb went off. Unfortunately, however, the bomb was also on the wagon. R1 knew that the bomb was on the wagon in the room, but didn't realize that pulling the wagon would bring the bomb out along with the battery. Poor R1 had missed that obvious implication of its planned act.

Daniel C. Dennet, *Cognitive Wheels: The Frame Problem of AI*, 1987.

# The Action Perception Loop

## Acting on the world



The agent perceives the external world through perceptions (camera, sensors, etc.) and may act onto it using a set of actions (actuators, motors, etc.).

# The Symbolic Approach

## Action/Perception loop

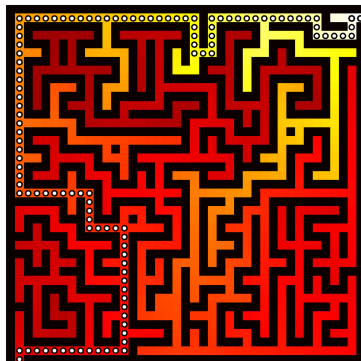
- World model
- Initial state
- Set of actions
- Goal state

## Agent/Action

- Dynamic
- Uncertain
- Noisy

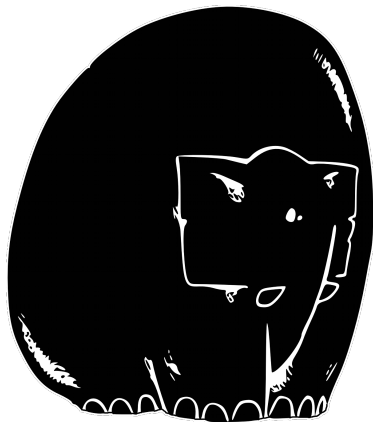
## World/Perception

- Noisy
- Continuous
- Unknown



# The subsumption architecture

(Rodney Brooks, 1986)



## Elephants Don't Play Chess

- The world is its own best representation
- A set of simple of independent behaviors
- Behaviors layered on top of each other

# Braitenberg vehicles



## Simple architecture

- Two sensors (light detectors)
- Two actuators (wheel motors)

→ 4 different behaviors (aggression, love, foresight and optimism)

# Embodied Cognition

# What is cognition ?

## What are the questions ?

- What are the minimal mechanisms that lead to some form of cognition ?
- What is/are the right biological level(s) of description ?
  - Molecule ? (→ neurotransmitters)
  - Organelle ? (→ axons, dendrites, synapses)
  - Cell ? (→ neurons, glial cells)
  - Tissue ? (→ nervous tissue)
  - Organ ? (→ brain)
- How do we identify a satisfactory answer ?



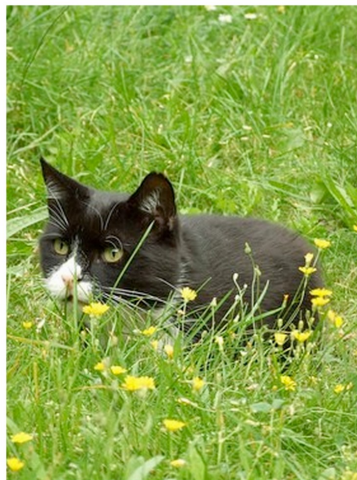
# What is cognition ?

To sit still and  
think or...



# What is cognition ?

Learning  
Attention  
Strategy  
Attack  
Localization  
Reflexes  
Emotions  
Control  
Decision  
Feedback  
Update  
Learning  
Regulation  
Acquisition  
Alert  
Action  
Motivation  
Learning



# Embodied cognition

## Many fields

Neurology, psychology, philosophy, linguistics, computer science, etc.

## Many forms

Abstraction, generalization, specialization, knowledge, decision, etc.

## Many expressions

Perception, action, emotions, memory, language, etc.

# Reclaiming the body



We ignored the fact that the biological mind is, first and foremost, an organ for controlling the biological body. Minds make motions, and they must make them fast — before the predator catches you, or before your prey gets away from you. Minds are *not* disembodied logical reasoning devices.

A.Clark, *Being there: putting brain, body, and world together again*, 1997.

# Reclaiming the body



- Embodiment of an organism simultaneously limits and prescribes the types of cognitive processes that are available to it.
- Cognition is deeply rooted in the body's interaction with the world
- Behavior is goal-directed or motivated

# Affordance theory

(Gibson, 1977)

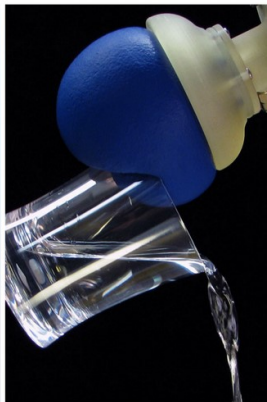
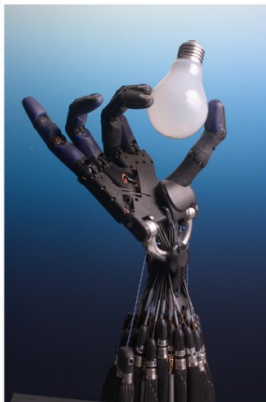
## Considering a lift

- For a human being, it is a way to go from one floor to the other
- For a wheeled robot, it is also a way to go from one floor to the other

## Considering a stair

- For a human being, it is a way to go from one floor to the other
- For a wheeled robot, it is quick and certain death

# Body helps cognition



The very nature of the body can simplify most control systems

# Conclusion

## Philosophy

What is cognition ?

## Neuroscience

What are the mechanisms and cerebral structures that cause cognition ?

## Computer science

How to build a computational cognitive model ?



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