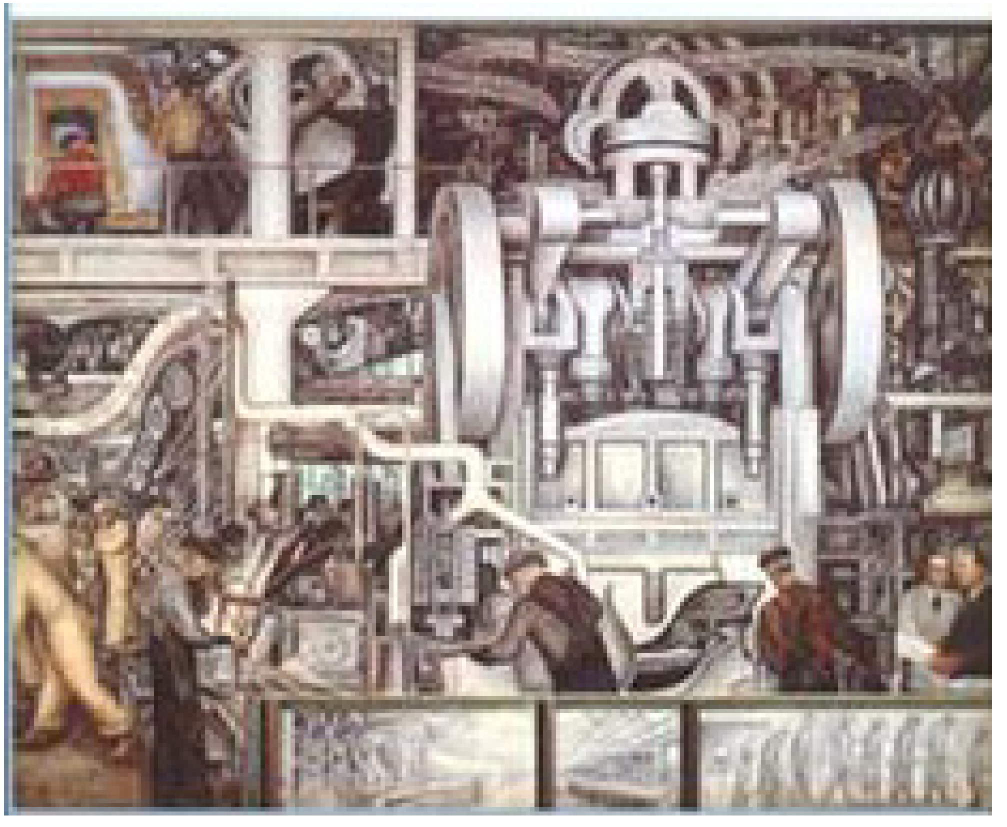
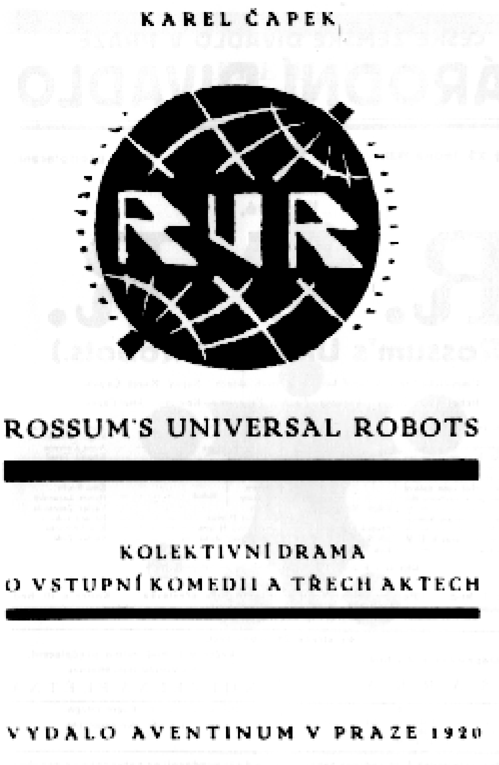
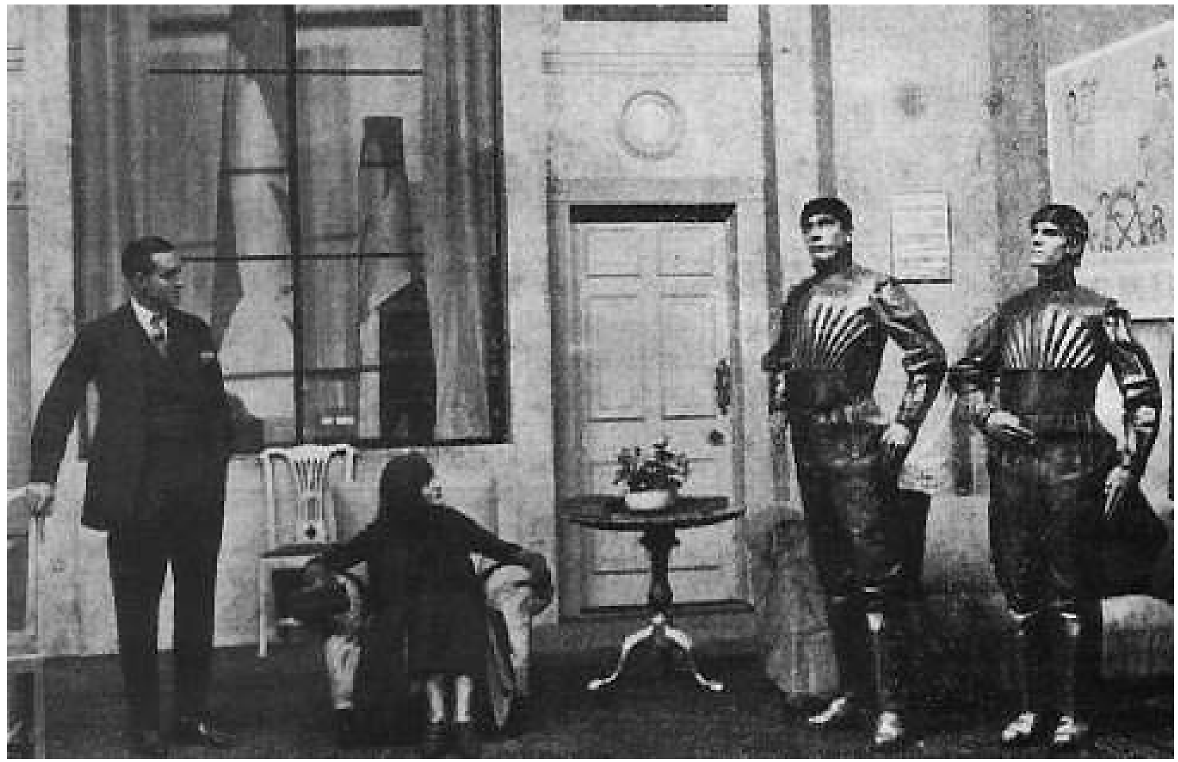
Introduction to
AI Robotics



Arnoud Visser

The Robot

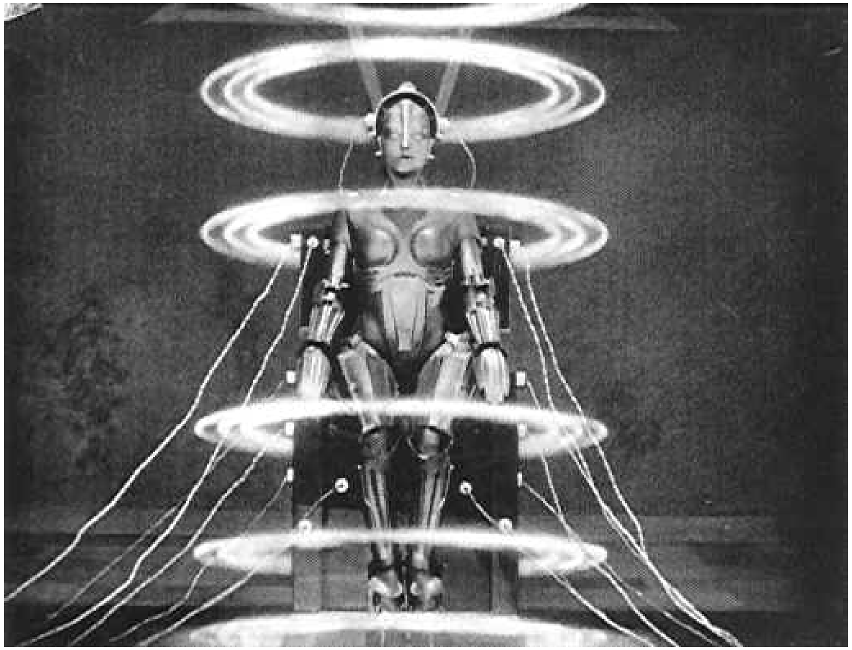




The word *robot* was introduced in 1920 in a play by Karel Capek called R.U.R

The Robot

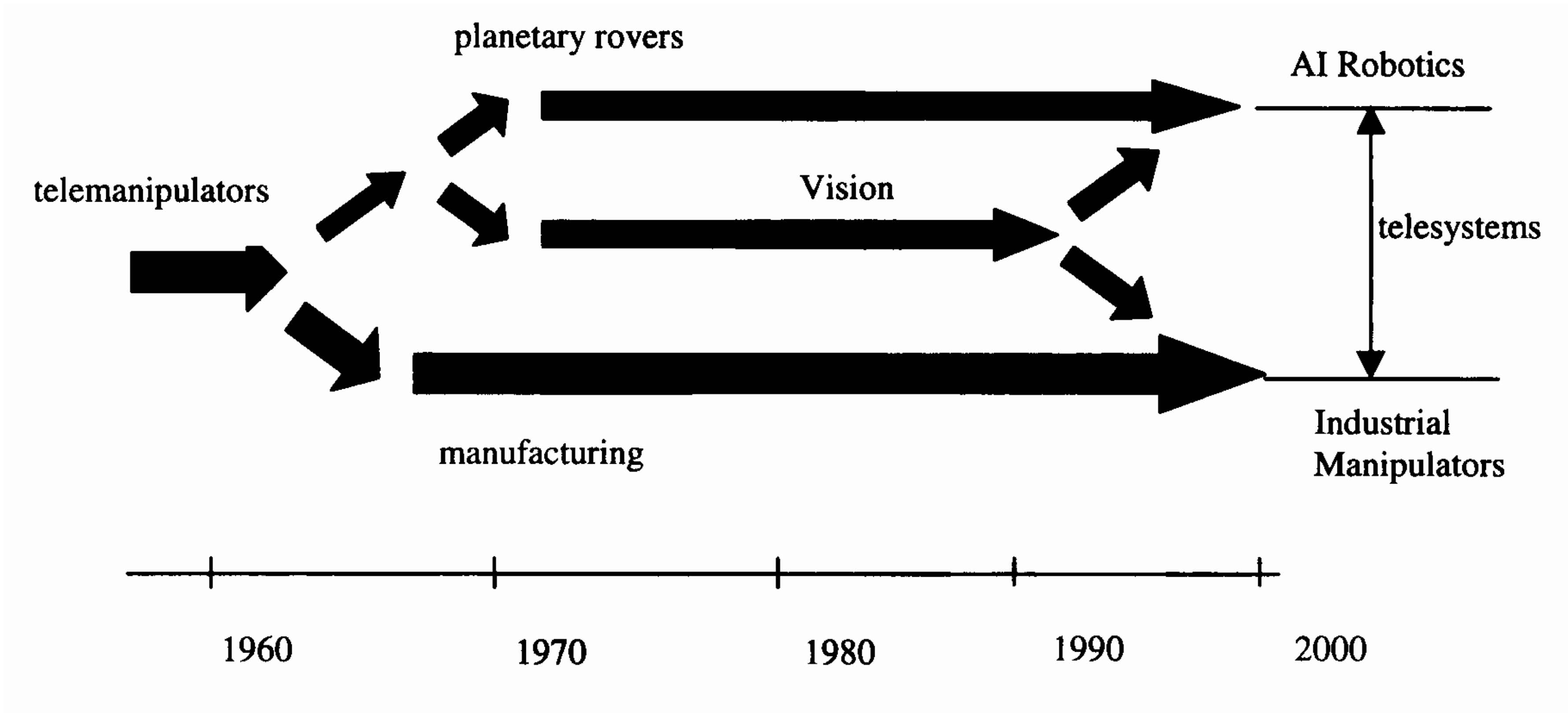
A robot is an artificial worker, which can replace a human worker.



Industrial Robots

- Industrial robots have replaced many human workers for tasks which are:
  - high repetitive
  - well structured
  - i.e. factory jobs

Robotic Evolution

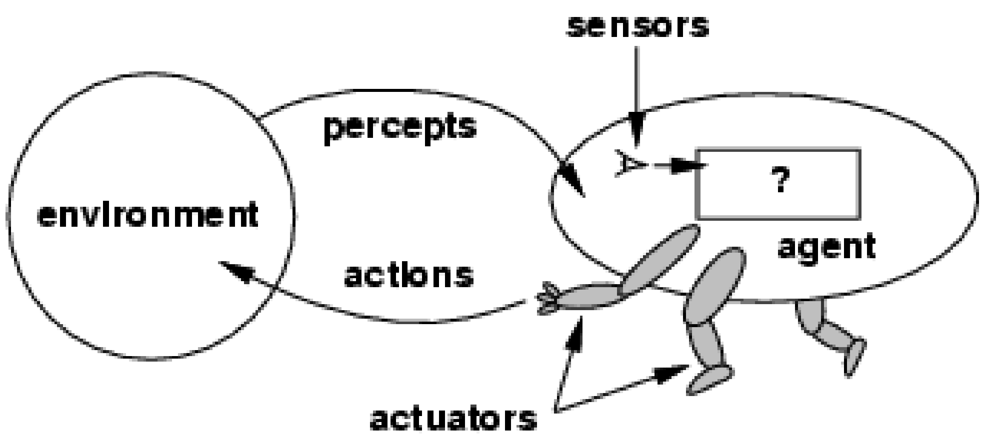


AI Robots

AI Robots are physically situated *agents* with:

- Knowledge representation
- Learning
- Planning and problem solving
- Search and Inference
- Vision
- Understanding natural language

Physical situated agent



An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators†

† Russell & Norvig, 'Artificial Intelligence – A modern approach', Prentice Hall, 2003

The physical grounding hypothesis

‘To build an intelligent system it is necessary to have its representations grounded in the physical world.’

i.e.:

‘The world is its own best model;
its always exactly up to date and
contains always every detail there is to know.’ †

† Rodney A. Brooks, ‘Elephants Don’t Play Chess’, Robotics and Autonomous System *6* (1990).

Theory of multiple intelligences

- linguistic,
- logical-mathematical,
- spatial,
- bodily-kinesthetic,
- naturalistic,
- musical,
- Interpersonal,
- intrapersonal. †

† Howard Gardner, 'Multiple Intelligences', BasicBooks, New York (2006).

Anthropic principle

To replace a human worker,
a robot needs the equivalent of:

- Human knowledge
- Human rational
- Human perception
- Human actuators
- Human communication

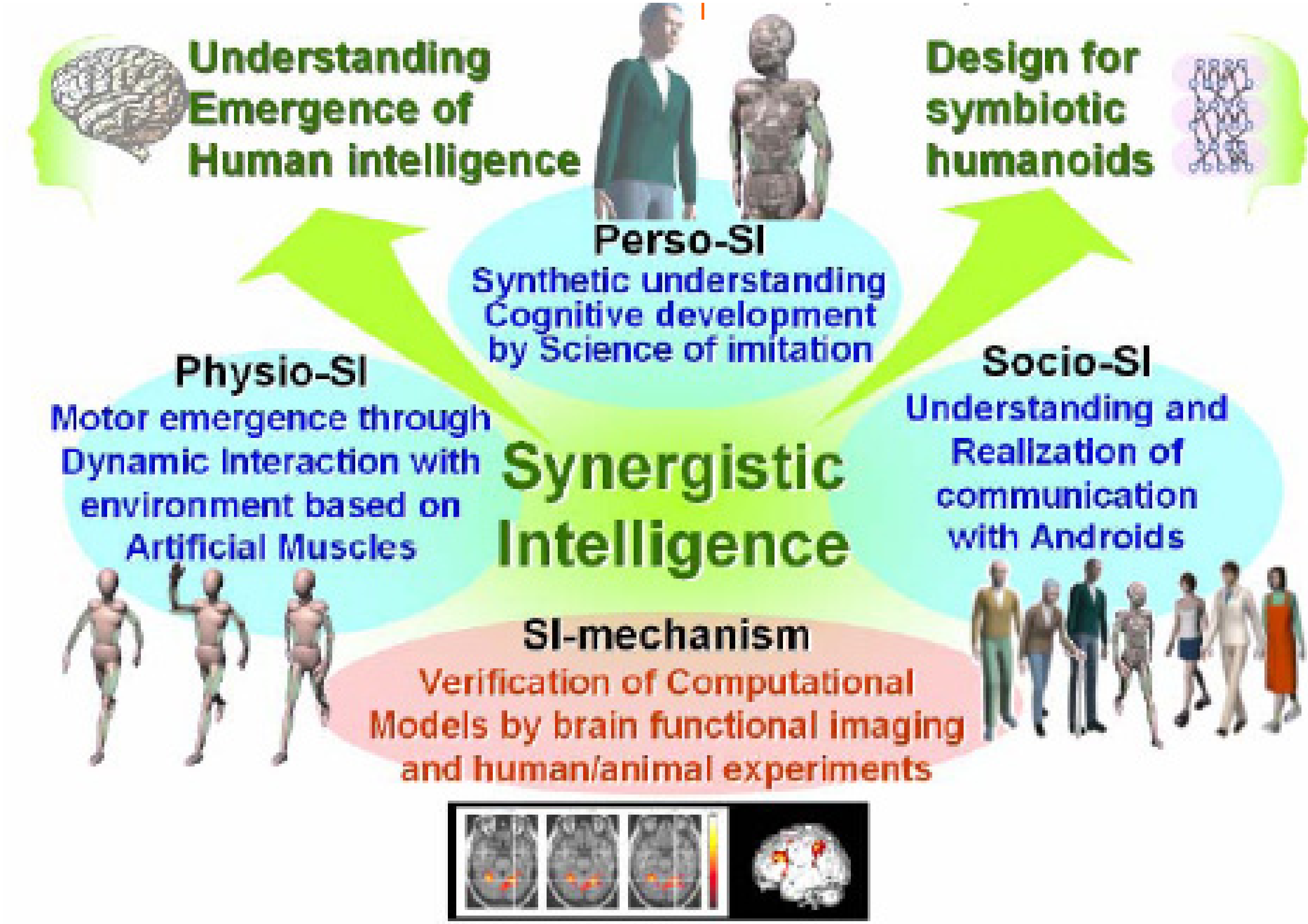
Human actuators

† Asimo, Honda's Humanoid robot, Commercial 2006

Robotics plays a central role in AI

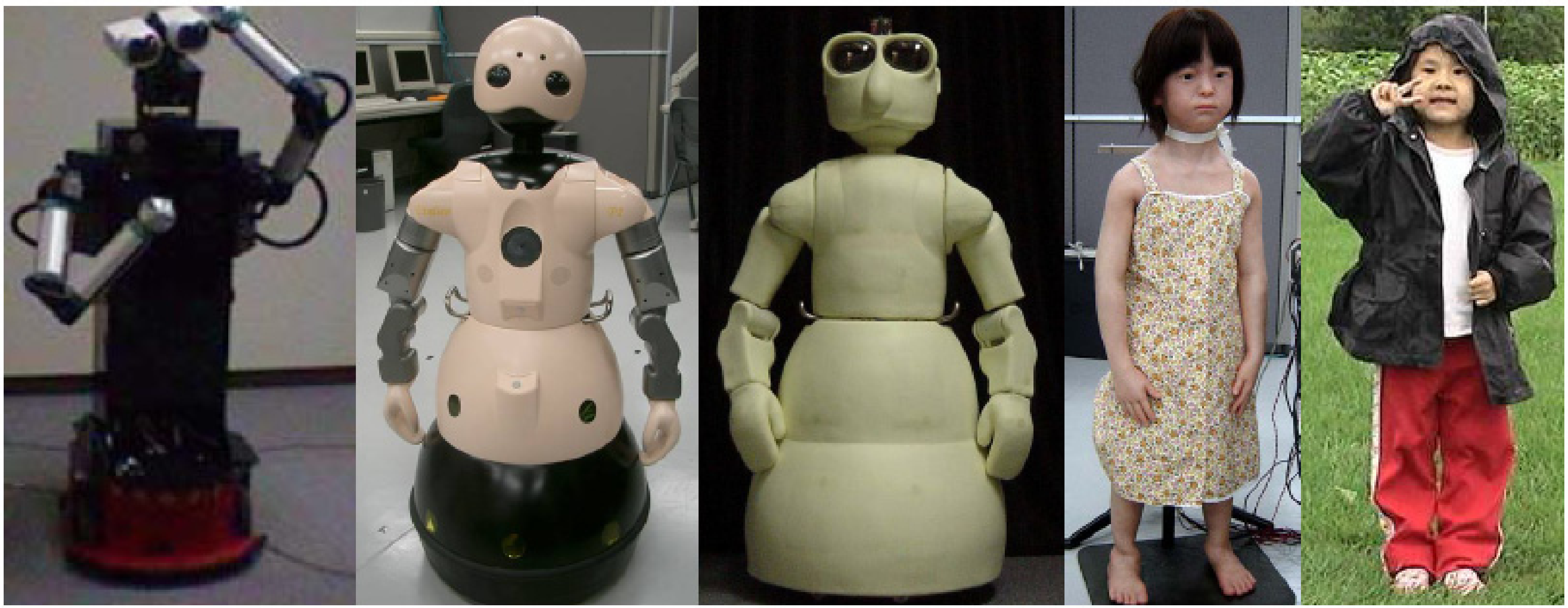
- Integration platform for many areas of AI
- Benchmark platform for progress in AI
- Embodiment is a prerequisite for intelligence
- Future of AI is projected on robotics

Synergistic Intelligence

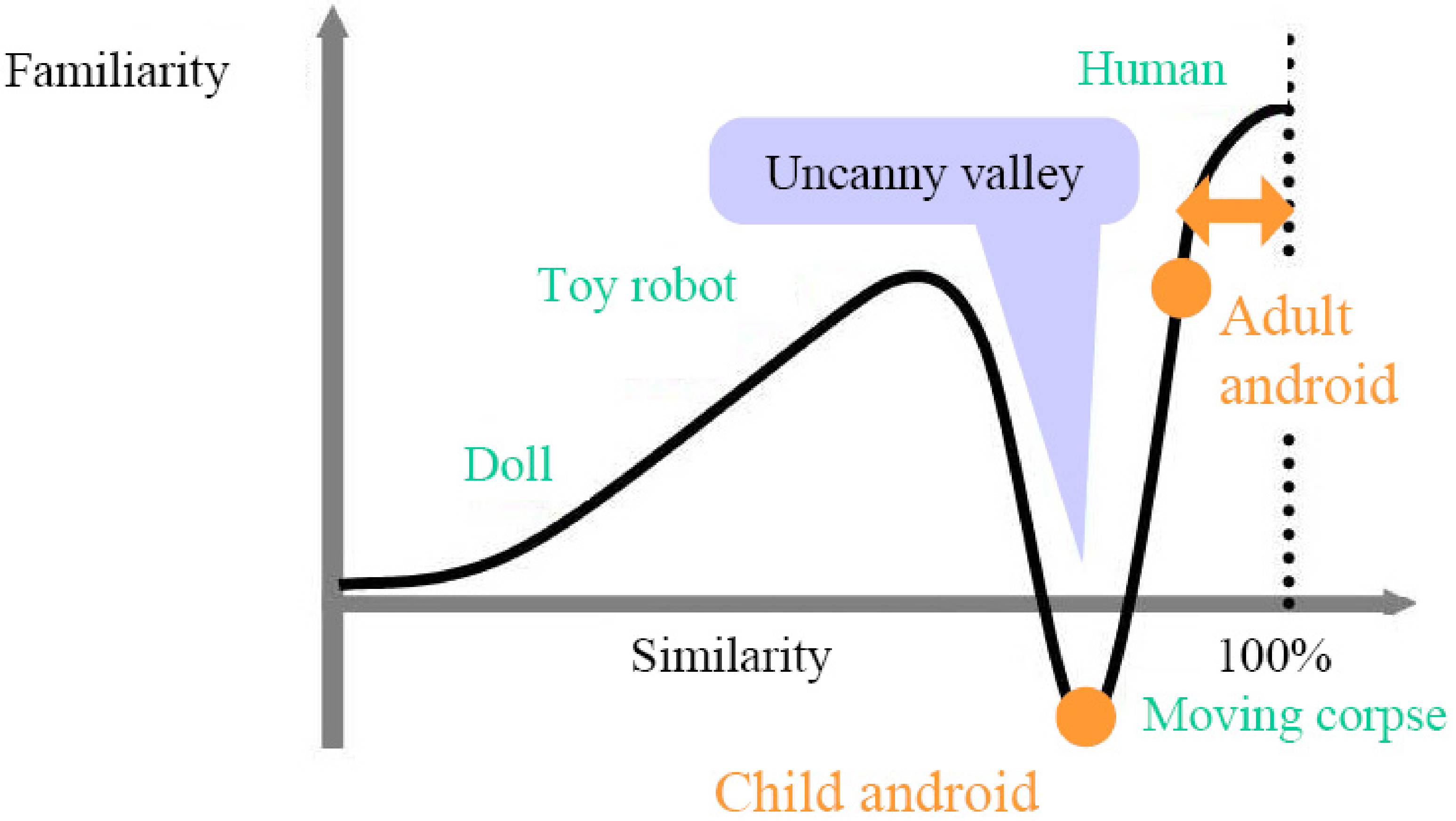


† Hiroshi Ishiguro '2006-2056 Projects and Vision in Robotics', 50 years Artificial Intelligence Symposium, Bremen.

Developments humanoids go fast

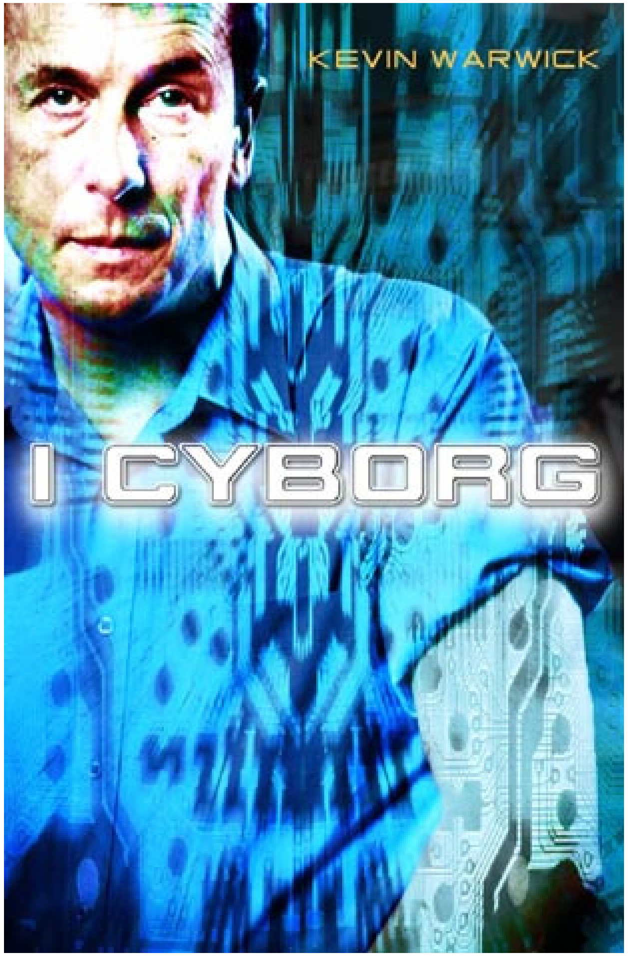


Uncanny valley [Mori et al. '97]



Cybernetics

- Can we use technology to upgrade humans?
- Can we use organic brains in robots?



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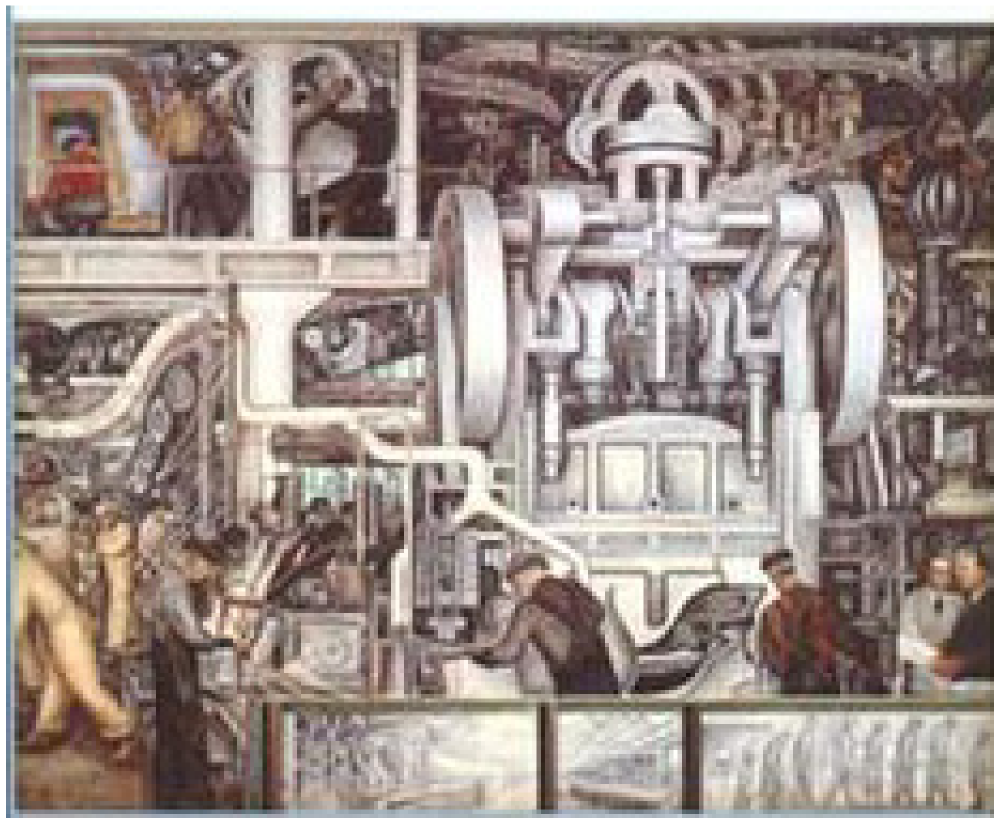
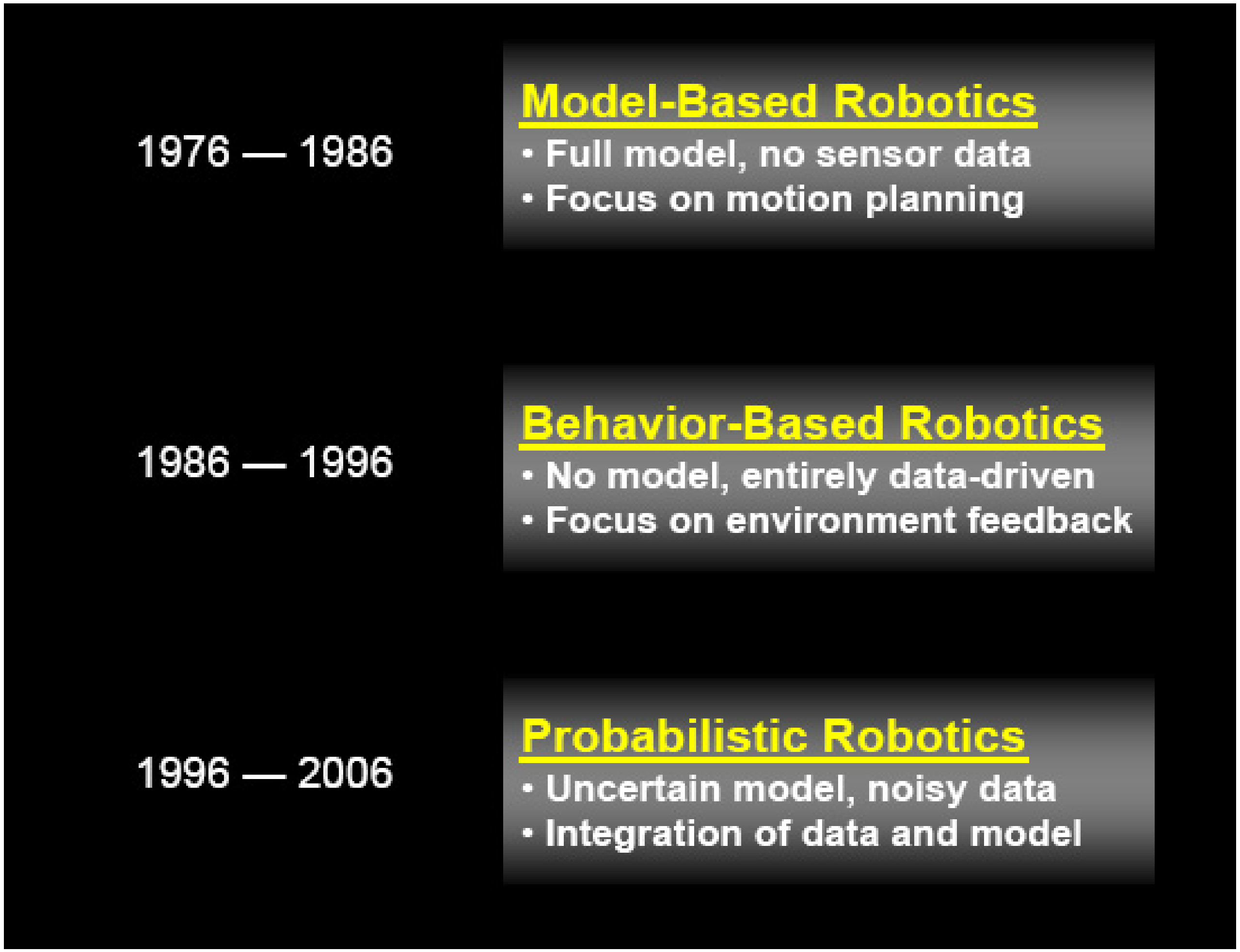


State of the Art

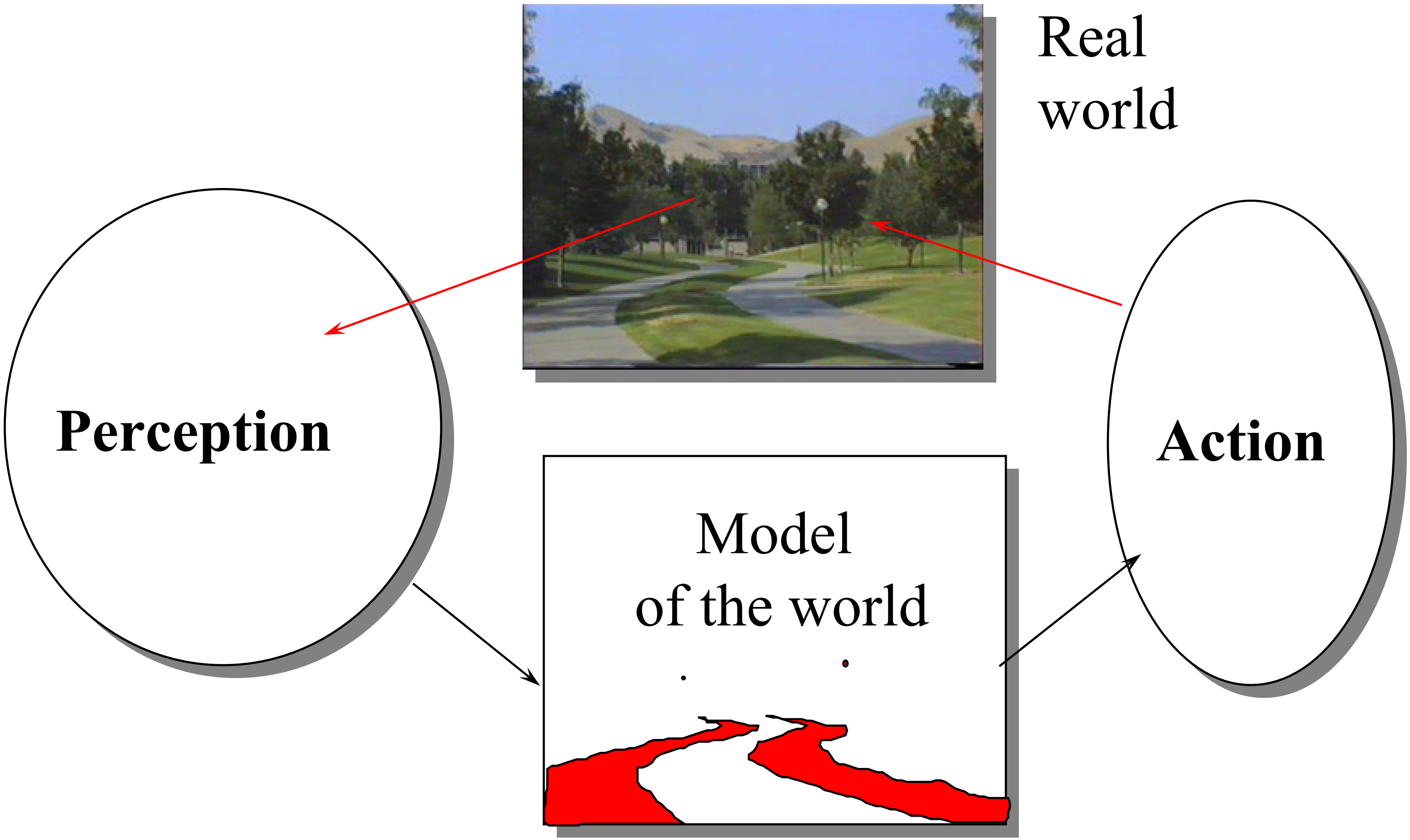
† Summary of Leo Dorst's course material belonging to Robin Murphy's book 'Introduction to AI Robotics', MIT Press, 2000.

Robotic Paradigms



† Sebastian Thrun '1996-2006 Autonomous Robots', 50 years Artificial Intelligence Symposium, Bremen.

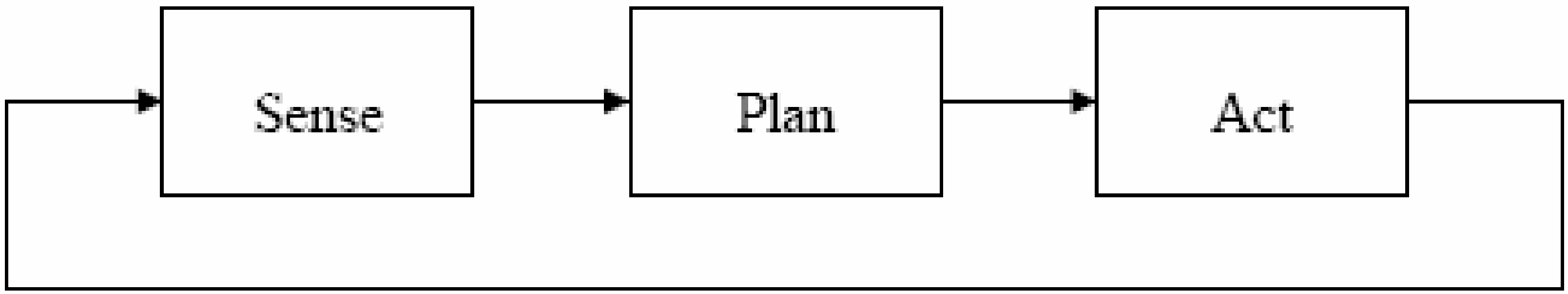
Perception - Action Cycle



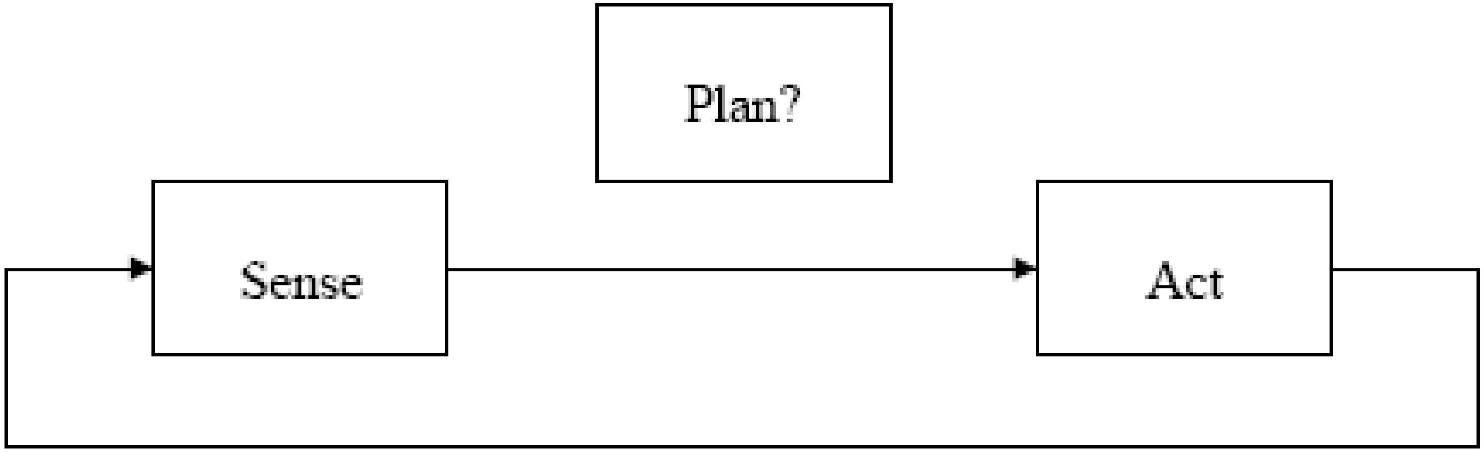
Sense-Plan-Act

- Sense
  - "Translate" physical properties to electrical (digital) signals.
  - Sensor: Input of the system
- Plan
  - Attempt to solve a problem (with a purpose)
  - Needs (complete) model of the world
- Act
  - "Translate" electrical (digital) signals to other physical properties.
  - Actuator: Output of the system

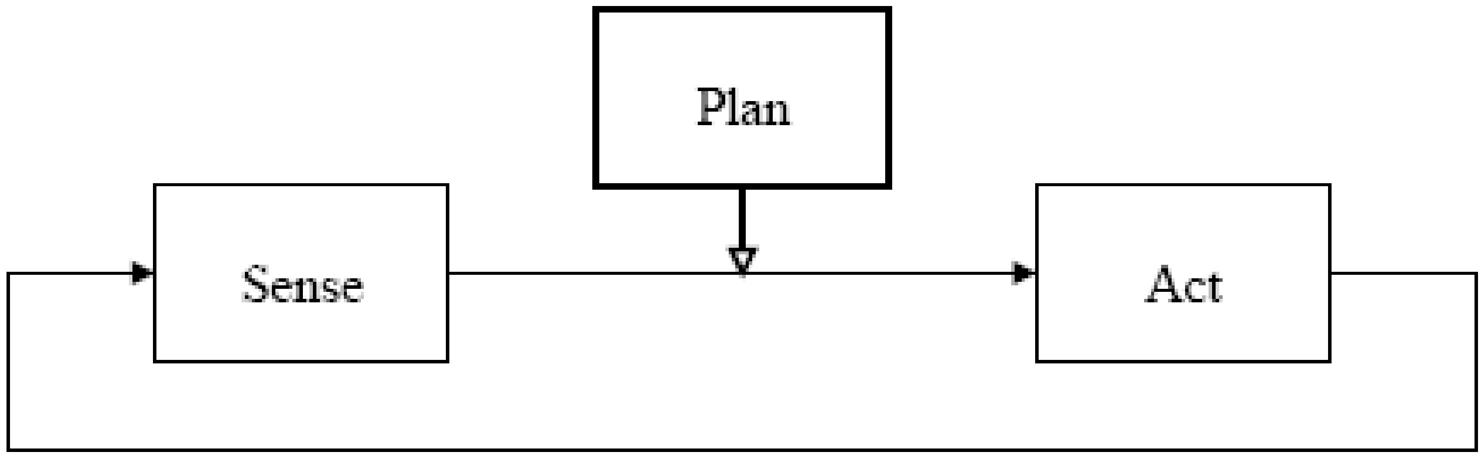
Hierarchical approach



Reactive Approach



Hybrid / deliberative approach



- Planning is making decisions autonomously!

Typical use of robots

'3D' Tasks

- Dirty
- Dull
- Dangerous

Unreachable by humans

- Surgery
- Underwater
- Mars

Do Things that Living Things Can't

Unmanned Vehicles

Unmanned Aerial Vehicles

- drones since Vietnam: Global Hawk, UCAV
- easy: nothing to hit
- hard: mission sensing, human-in-the-loop control

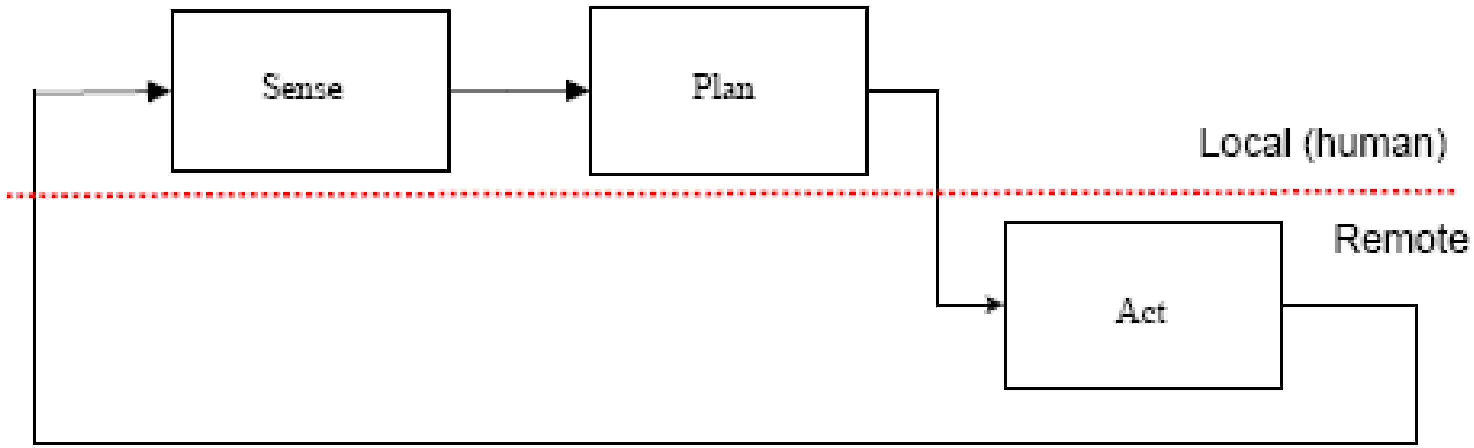
Unmanned Ground Vehicles

- since 1967
- easy: can always stop and think, a priori maps
- hard: perceiving, e.g., light vegetation vs. wall

Unmanned Underwater Vehicles

- ROVs since 1960s
- easy: run tethers
- hard: platform operation in unfriendly environment

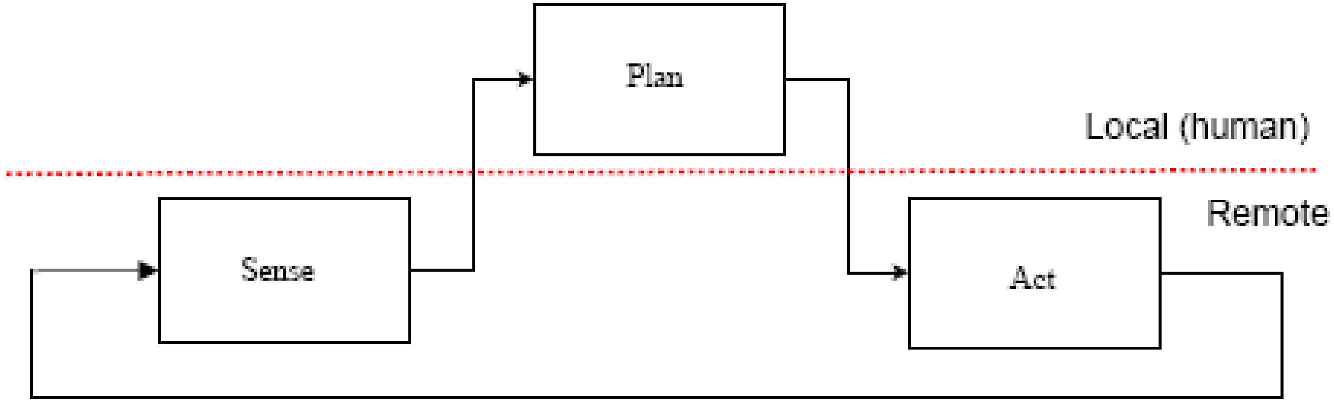
Remote Control



- you control the robot
- you can view the robot and its relationship to the environment
- *operator isn't removed from scene, not very safe*

Example: Bomb squad

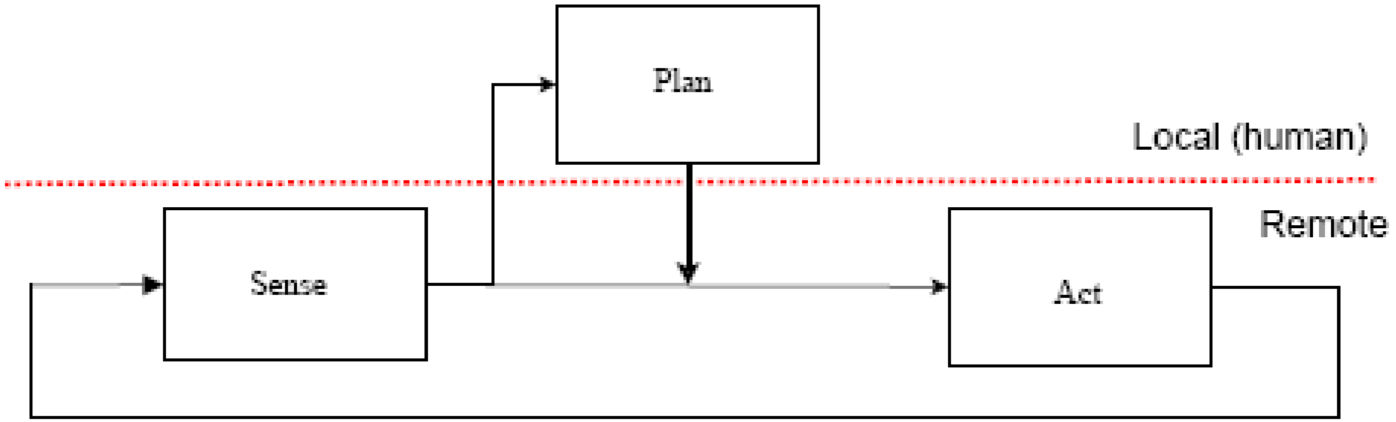
Teleoperation



- you control the robot
- you can only view the environment through the robot's eyes
- *don't have to figure out AI*
- Depending on display: Telepresence

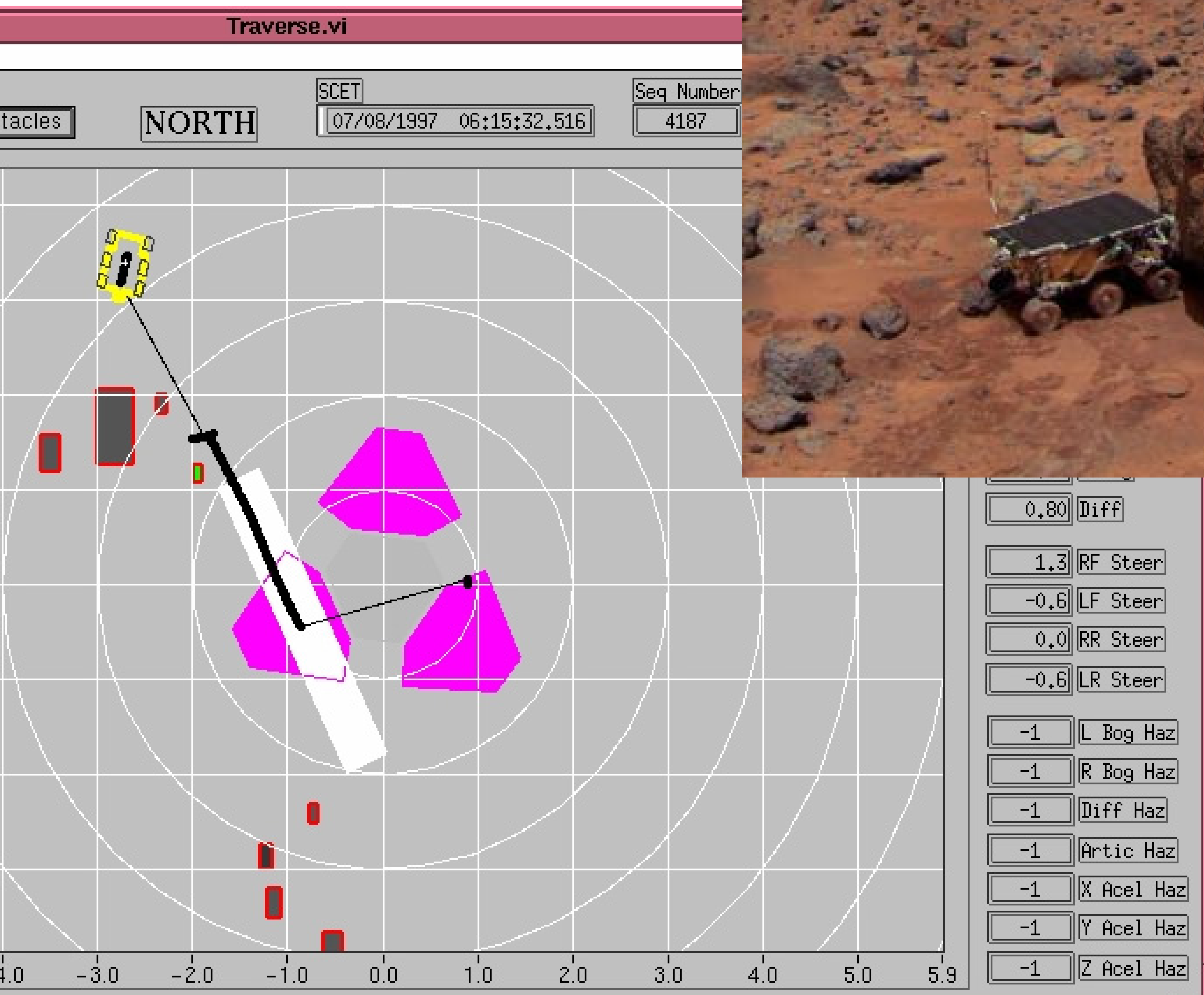
Example: Micro Aerial Vehicle

semi-autonomy



- human is involved, but routine or "safe" portions of the task are handled autonomously by the robot
- Shared Control/ Guarded Control
  - human initiates action, interacts with remote by adding perceptual inputs or feedback, and interrupts execution as needed
  - robot may "protect" itself by not bumping into things
- Traded Control
  - human initiates action, does not interact
- *human doesn't have to do everything*

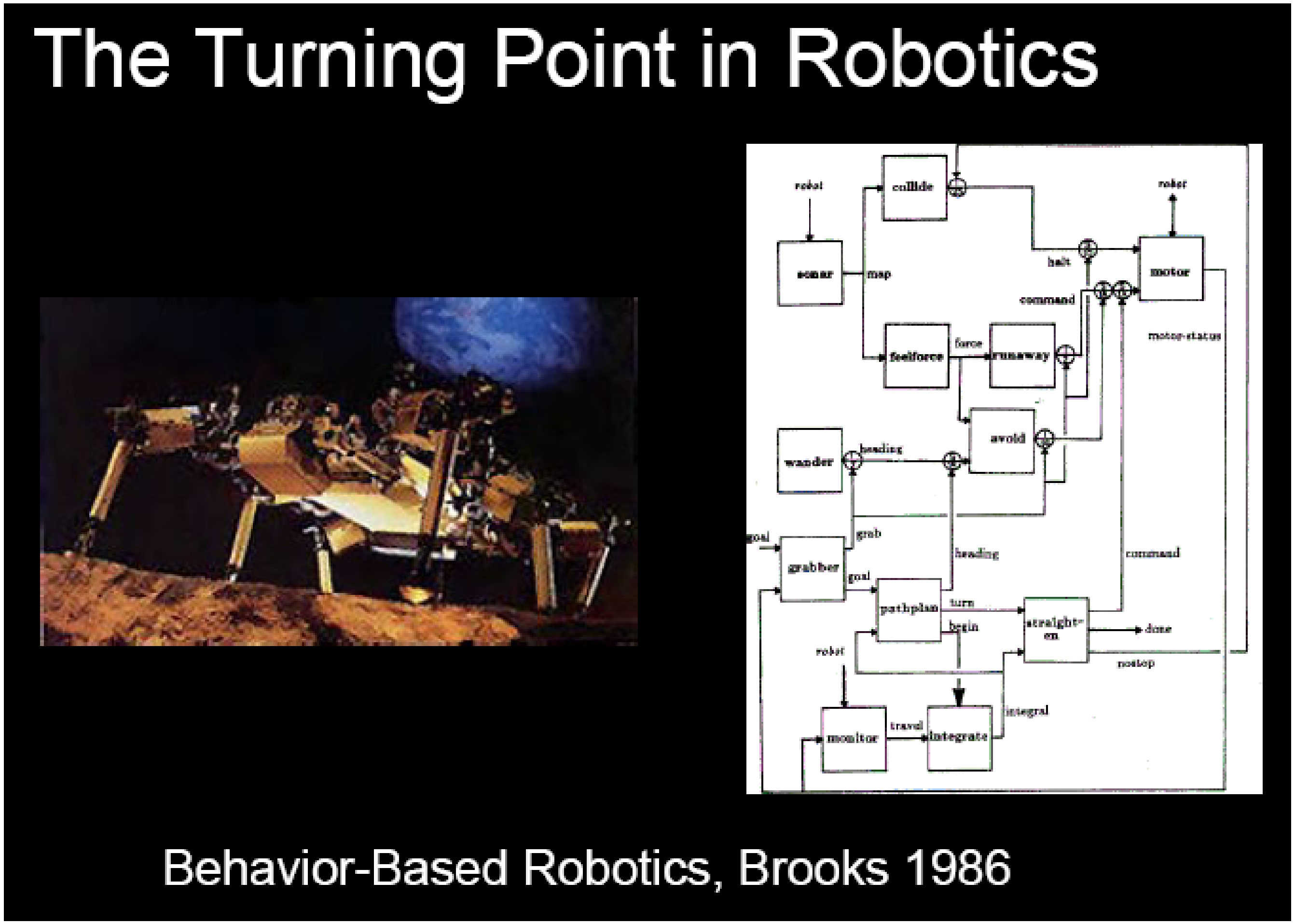
Example: semi-autonomy



Autonomy in Robotics

- Use Robots
  - when humans cannot or do not want do do it
- In Teleoperations
  - humans do not act, but are needed all the time
  - cognitive fatigue, high comms bandwidth, long delays, and many:one human to robot ratios
- Semi-autonomy
  - tries to reduce fatigue, bandwidth by delegating portions of the task to robot
  - human only acts when needed

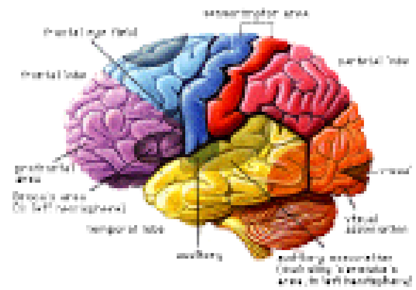
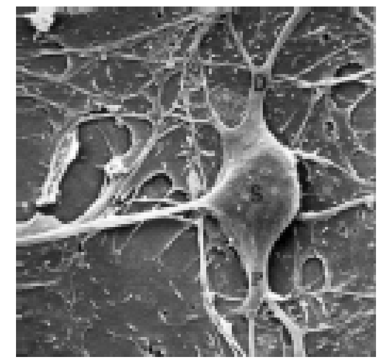
Behavior-based approach

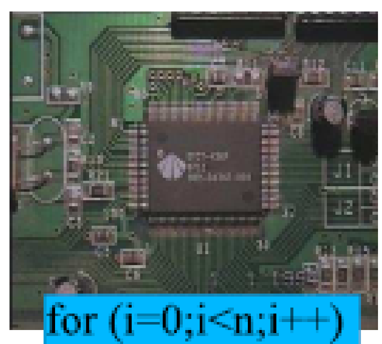


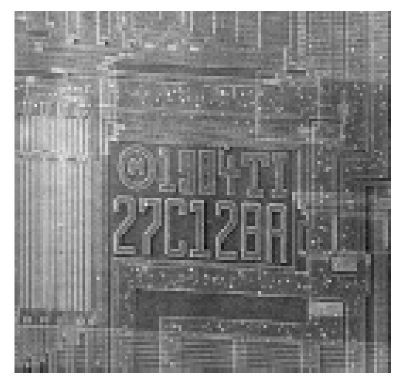
† Sebastian Thrun '1996-2006 Autonomous Robots', 50 years Artificial Intelligence Symposium, Bremen.

Bio-inspired

Level 1: What is the phenomena?	Level 2: How is it represented?	Level 3: How is it implemented?

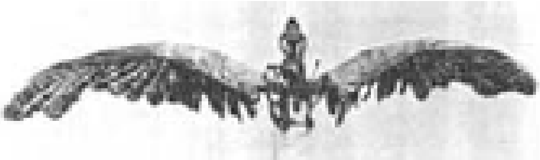






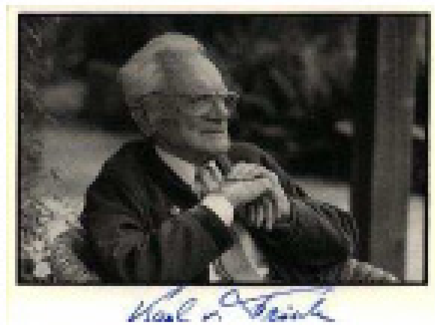


Why look at biology?

- No world model (so no frame problem)
  - "The world is its own best representation" [Gibson]
- Proof of principle
  - It is possible
- Copying the "organization"
  - Shows how it can be done



Ethology: Coordination and Control of Behaviors



1973 Nobel Prize for Physiology or Medicine:

- Karl Von Frisch, Konrad Lorenz and Nikolaas Tinbergen

Behaviors

Types of behaviors

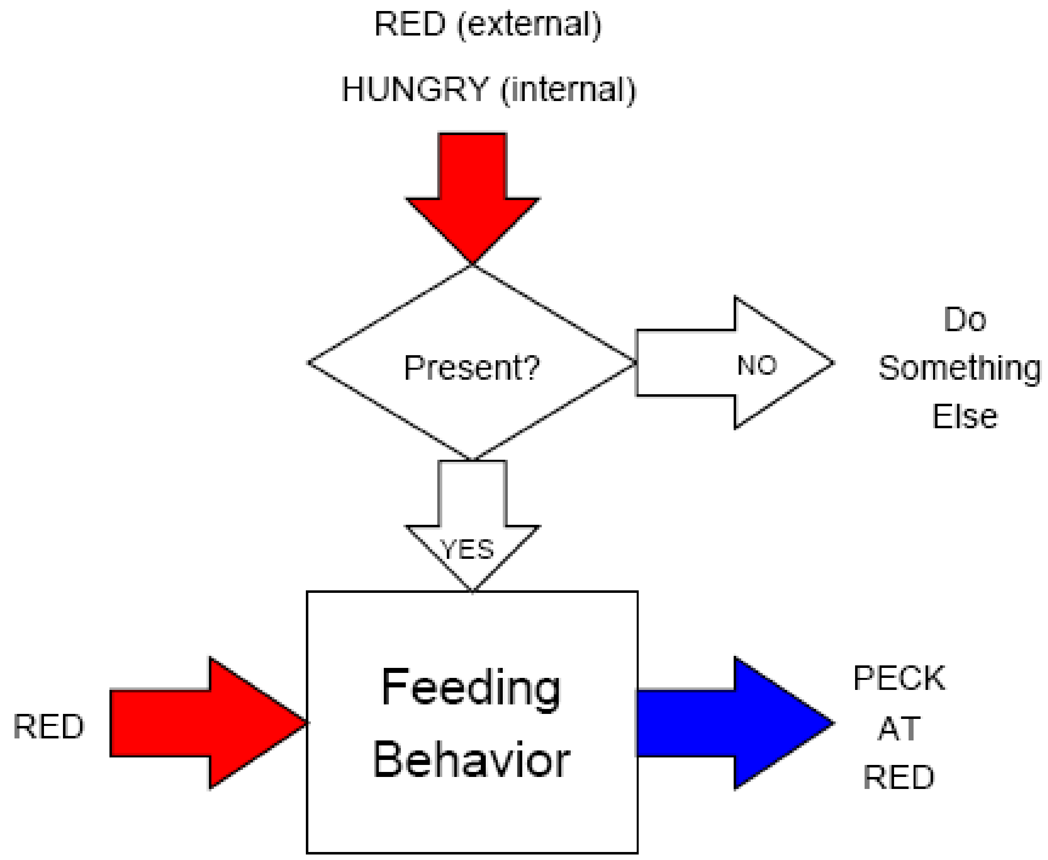
- Reflexive
  - stimulus-response, often abbreviated S-R
- Reactive
  - learned or "muscle memory"
- Conscious
  - deliberately stringing together

Warning: In robotics "reactive behavior" often means purely reflexive, and reactive behaviors are refered to as "skills".

Example of reflexive behavior

- Arctic terns live in the Arctic (black, white, gray environment, some grass) but adults have a red spot on beak
- When hungry, baby pecks at parent's beak, who regurgitates food for baby to eat
- How does it know its parent?
  - It doesn't! It just goes for the largest red spot in its field of view (e.g., ethology student)
  - Only red thing should be an adult tern
  - Closer = large red

Feeding behavior



General principles

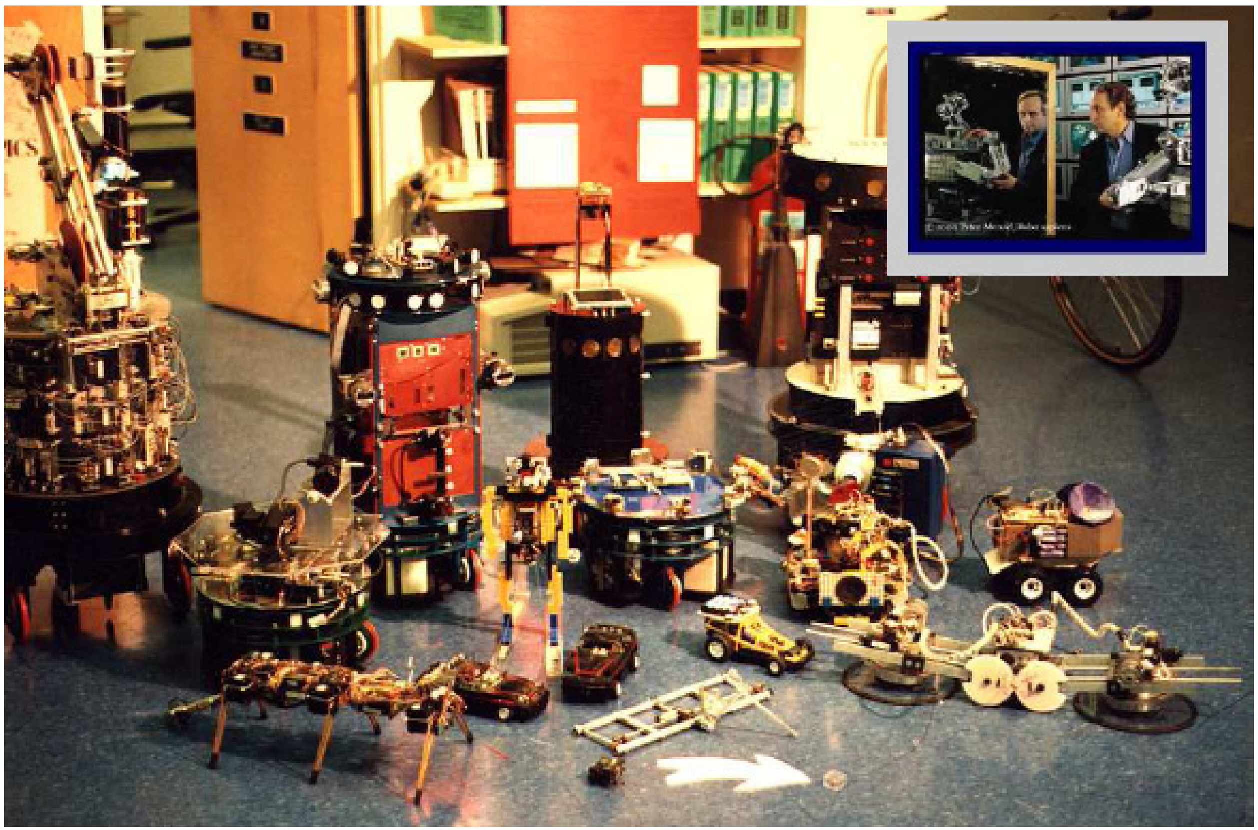
Ethology

- All animals possess a set of behaviors
- Releasers for these behaviors rely on both internal state and external stimulus
- Perception is filtered; perceive what is relevant to the task
- Some behaviors and associated perception do not require explicit knowledge representation

Robotics

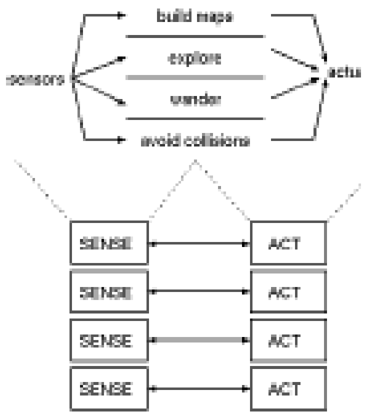
- Individual robots must survive, not species
- Must be able to predict emergent behaviors
- Not clear how to learn quickly
- Robots need more alternative perceptual schemas since poorer understanding of the environment

Subsumption architecture
(Brooks 1986)

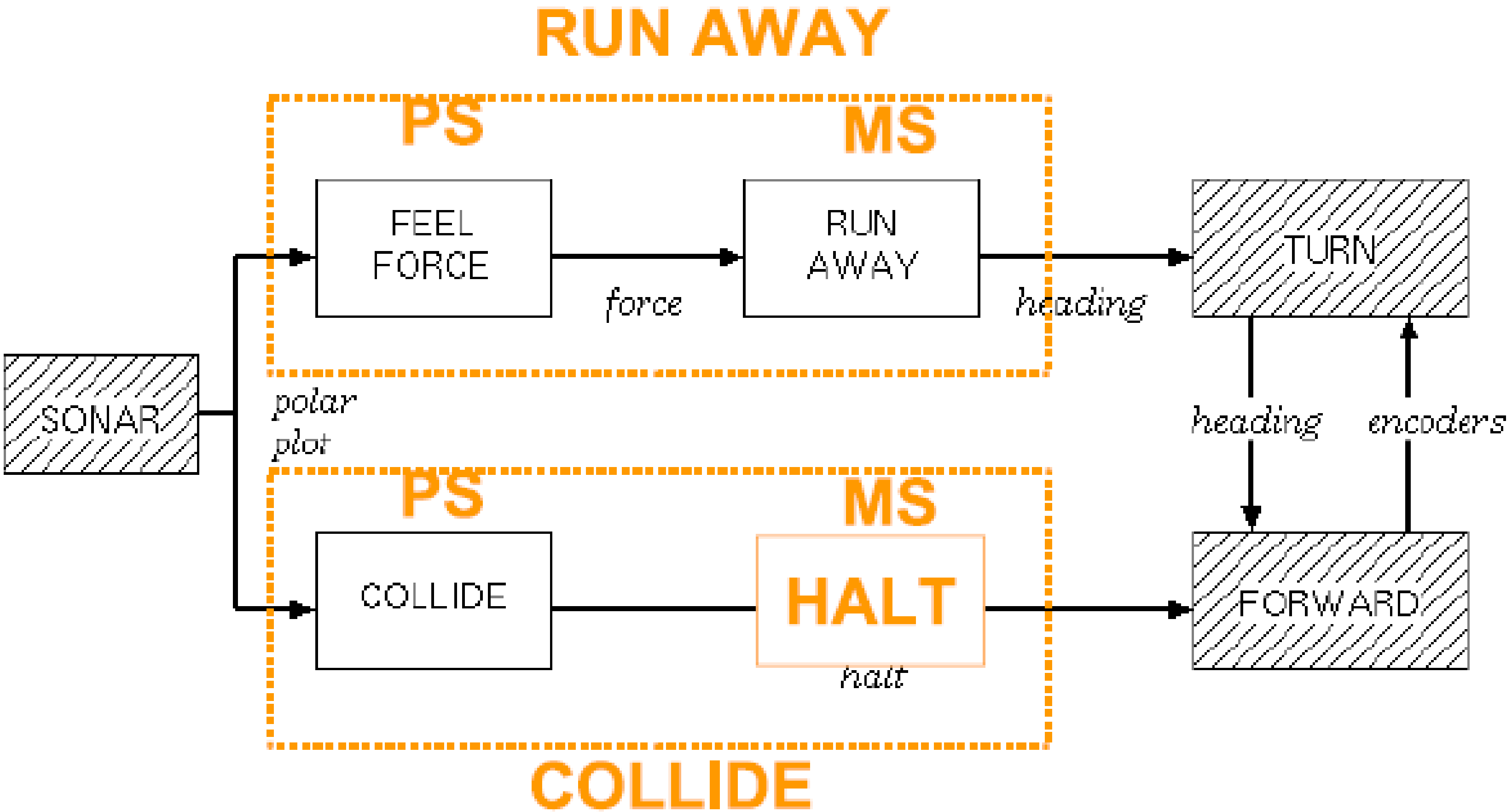


Subsumption philosophy

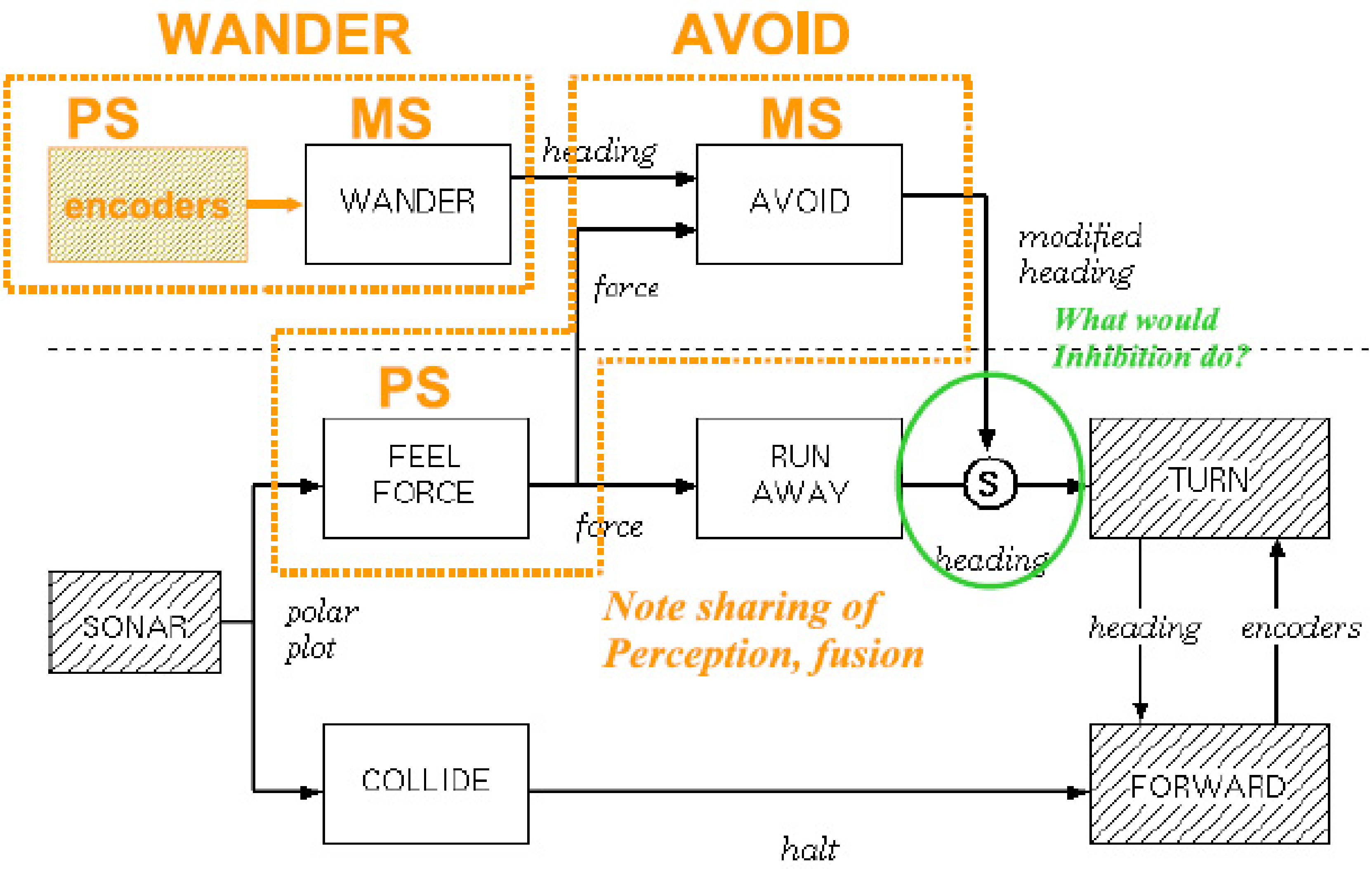
- Modules should be grouped into layers of competence
- Modules in a higher lever can override or subsume behaviors in the next lower level
  - Suppression: substitute input going to a module
  - Inhibit: turn off output from a module
- No internal state in the sense of a local, persistent representation similar to a world model.
- Architecture should be taskable: accomplished by a higher level turning on/off lower layers



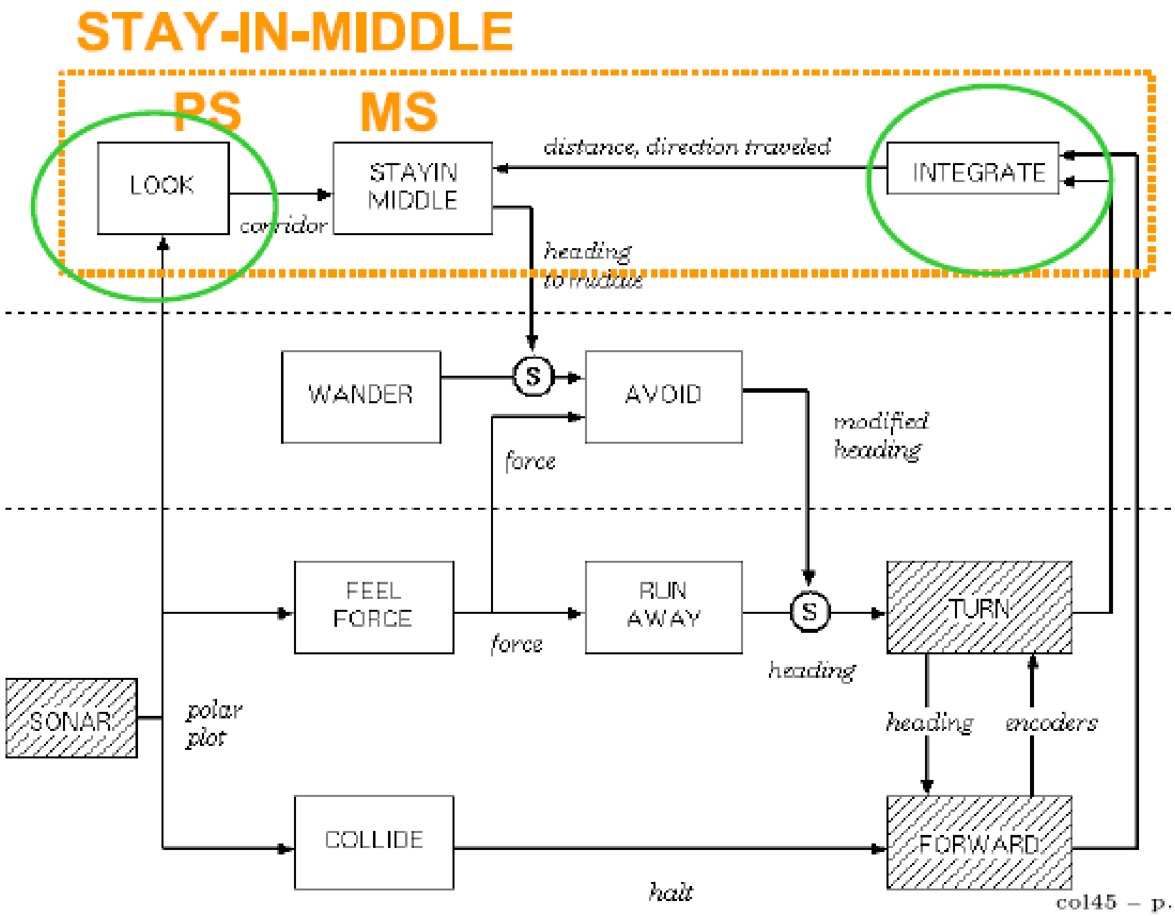
Level 0: avoid collision



Level 1: wander

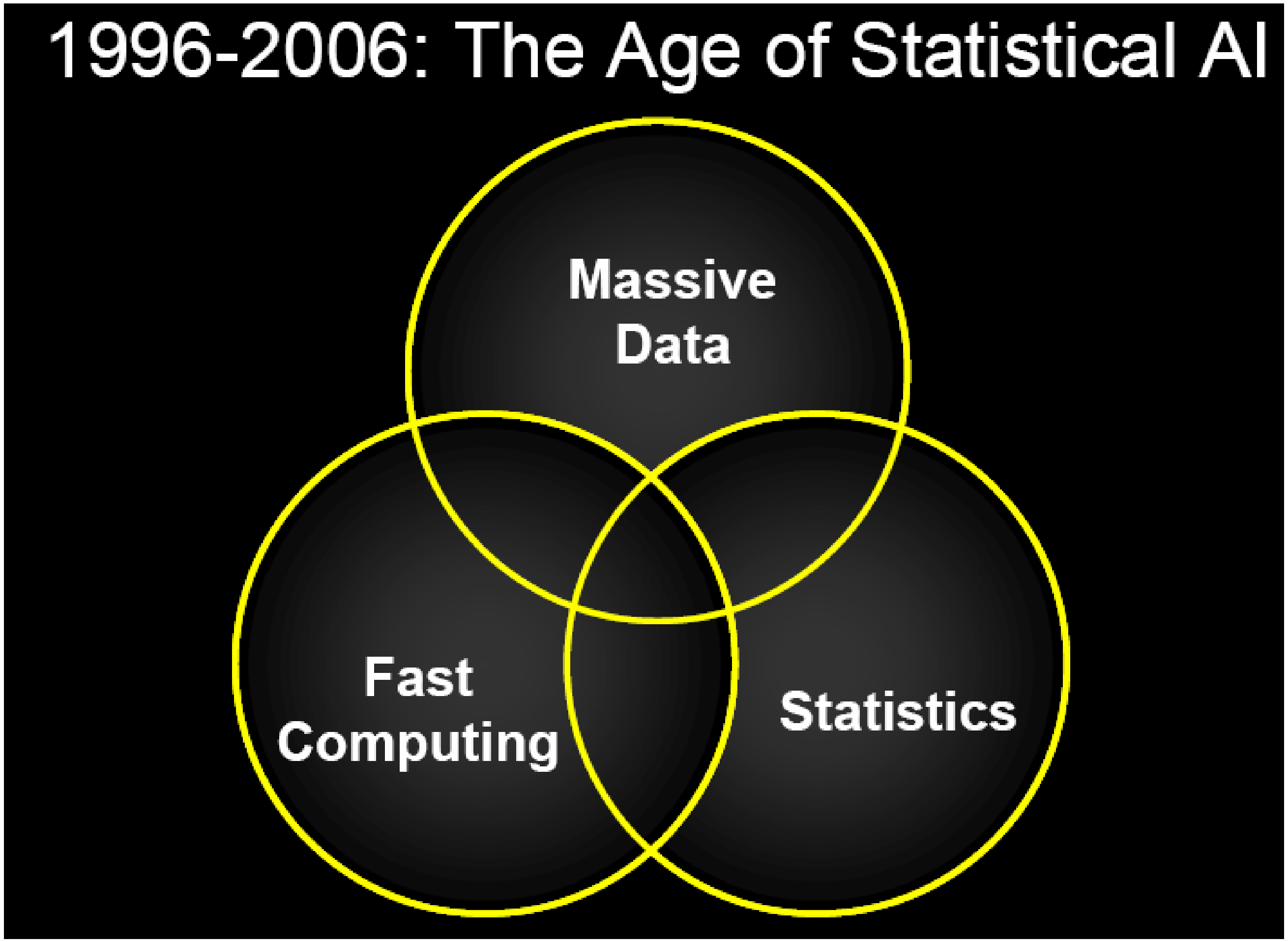


Level 2: follow corridor



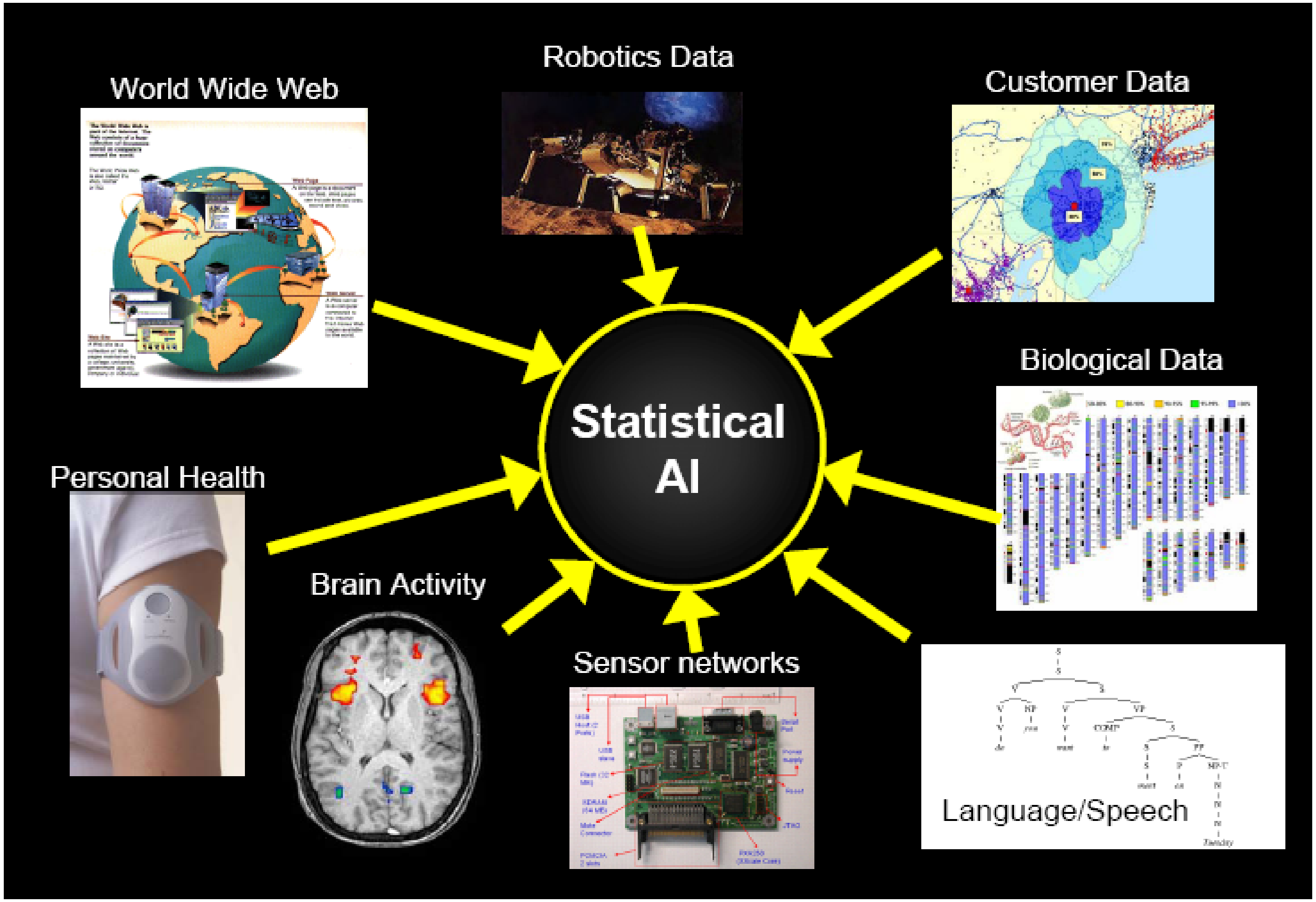
The result: Finite State Automata

FSM is a simplification of the world



† Sebastian Thrun '1996-2006 Autonomous Robots', 50 years Artificial Intelligence Symposium, Bremen.

Searching for correlations in data



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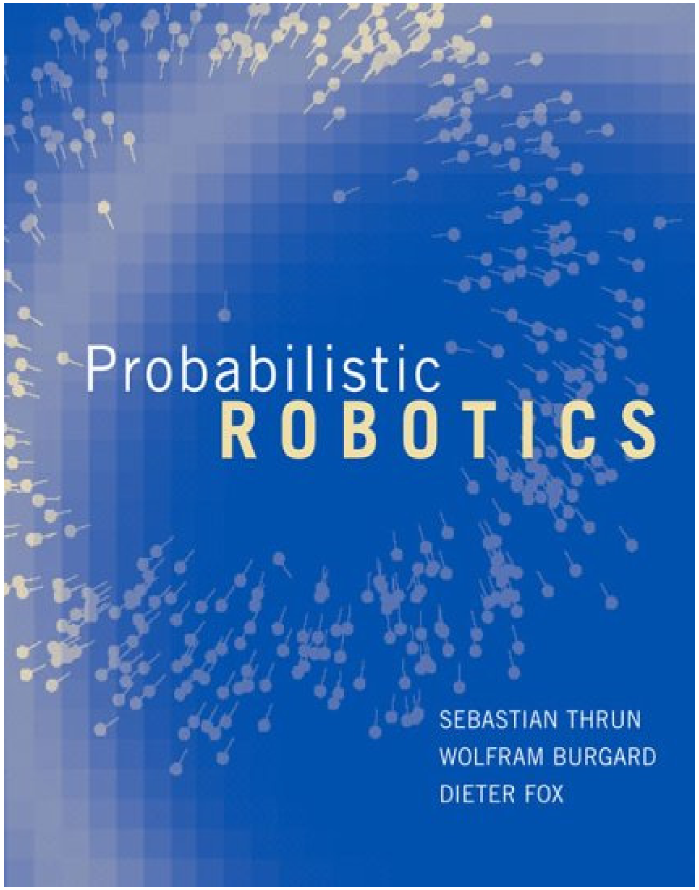
Spatial Knowledge in Robotics†

- Localization (current location)
  Where am I?
- Mapping (past locations)
  Where have I been?
- Exploration (future locations)
  Where am I going?

† Robin R. Murphy, 'Introduction to AI Robotics', MIT Press, 2000

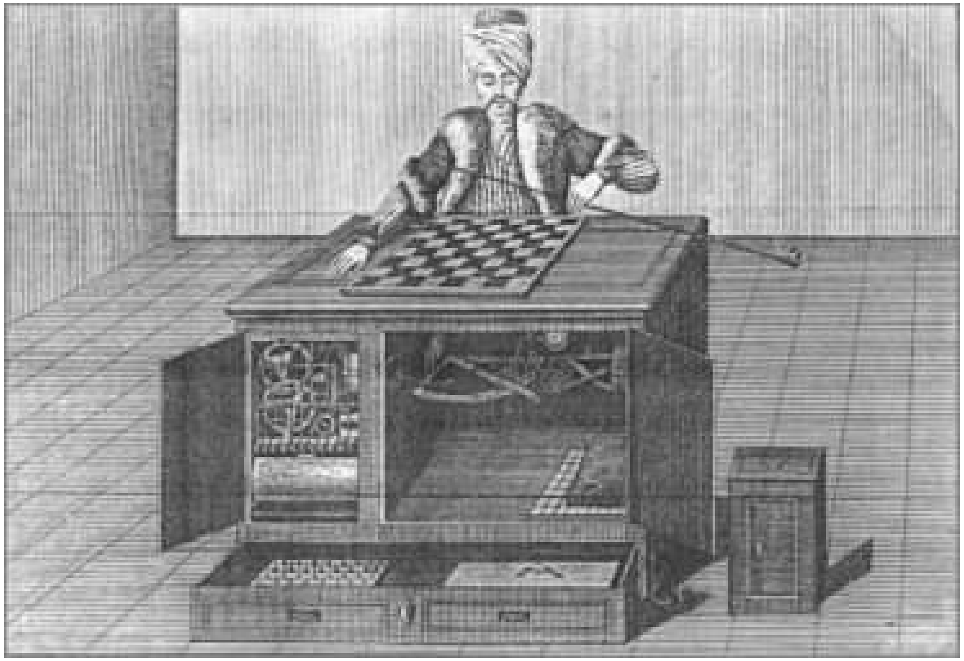
Probabilistic Robotics†



† S. Thrun, W. Burgard, D. Fox, ‘Probabilistic Robotics’, MIT Press, 2005

Conclusion

- Robotics plays a central role in AI



The chess-playing Turk defeated Napoleon in 1769