Robot Paradigms

Slide credits: Wolfram Burgard, Dieter Fox, Cyrill Stachniss, Giorgio Grisetti, Maren Bennewitz, Christian Plagemann, Dirk Haehnel, Mike Montemerlo, Nick Roy, Kai Arras, Patrick Pfaff and others

Robotics: General Background

- Autonomous, automaton
  - self-willed (Greek, auto+matos)

- Robot
  - Karel Capek in 1923 play R.U.R. (Rossum's Universal Robots)
    - labor (Czech or Polish, robota)
    - workman (Czech or Polish, robotnik)

The Robot


KAREL ČAPEK

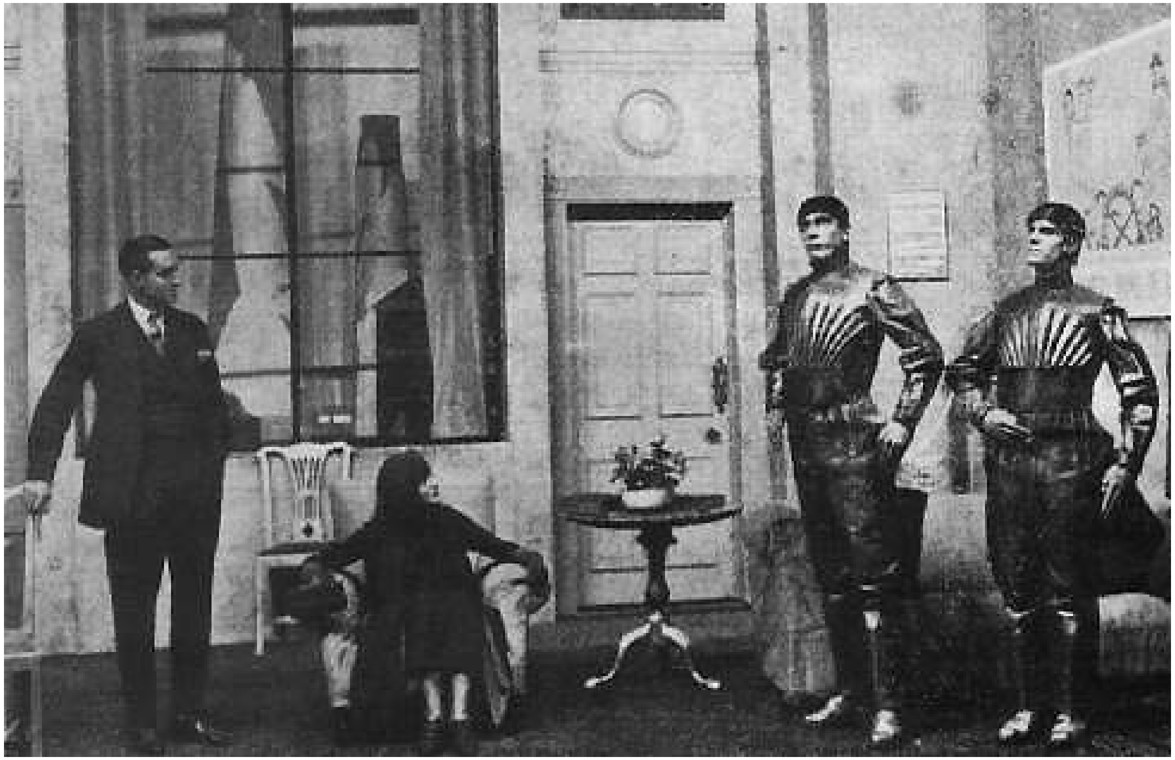
R.U.R

ROSSUM'S UNIVERSAL ROBOTS

KOLEKTIVNÍ DRAMA

O VSTUPNÍ KOMEDII A TŘECH AKTECH

VYDALO AVENTINUM V PRAZE 1920



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

Asimov's Three Laws of Robotics

1. A robot may not injure a human being, or, through inaction, allow a human being to come to harm.

2. A robot must obey the orders given it by human beings except when such orders would conflict with the first law.

3. A robot must protect its own existence as long as such protection does not conflict with the first or second law.

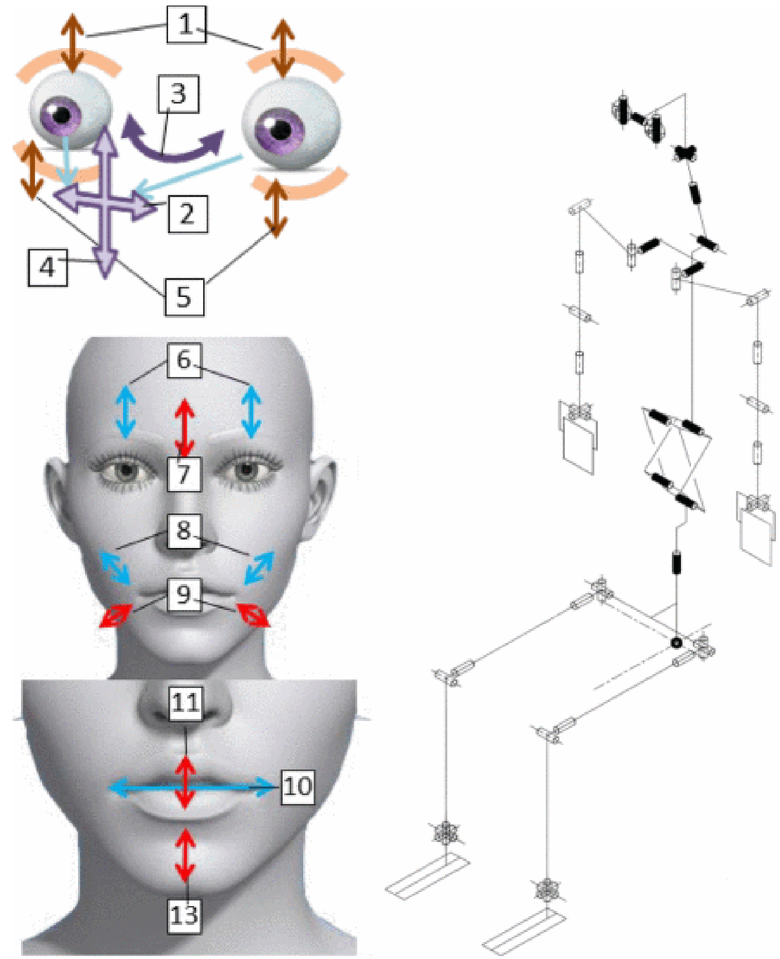
[Runaround, 1942]

Electro

Westinghouse Motor Man, 1939

[youtube]

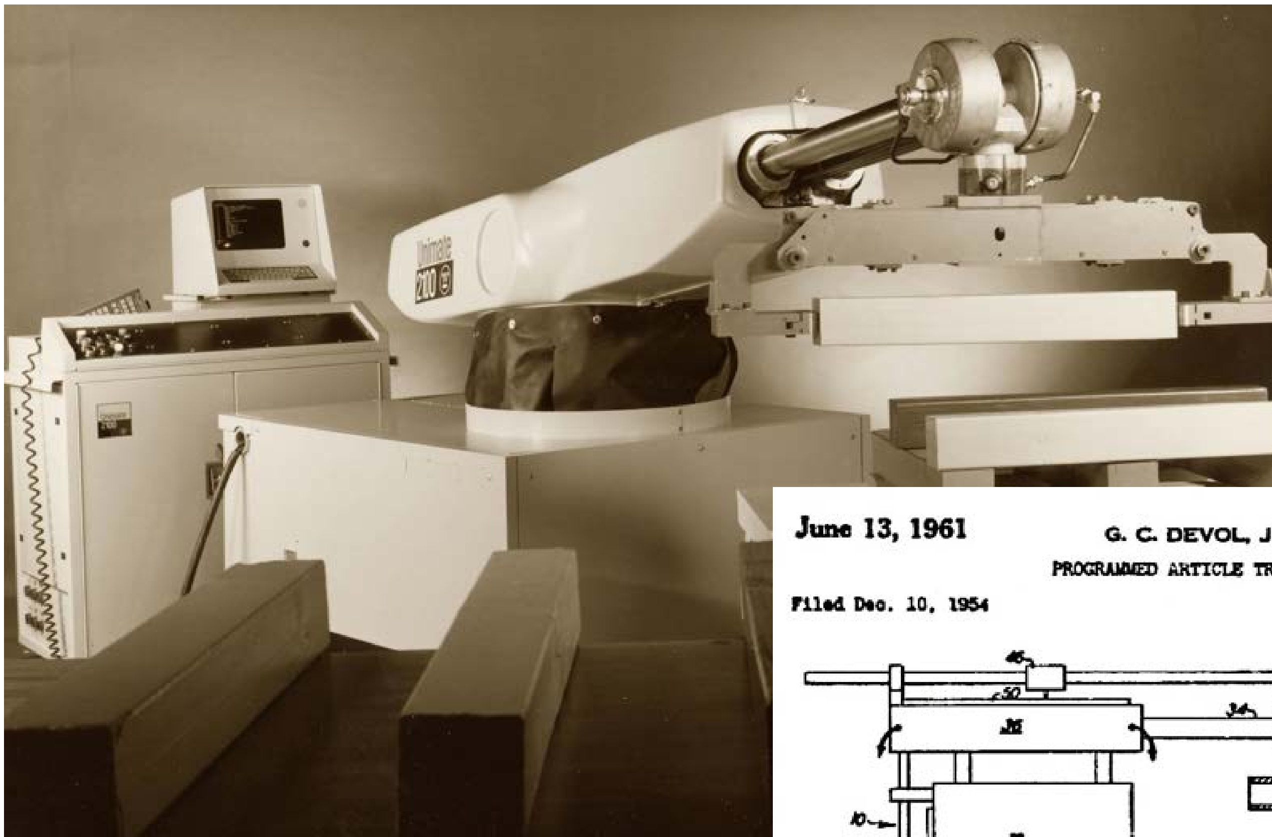
Erica

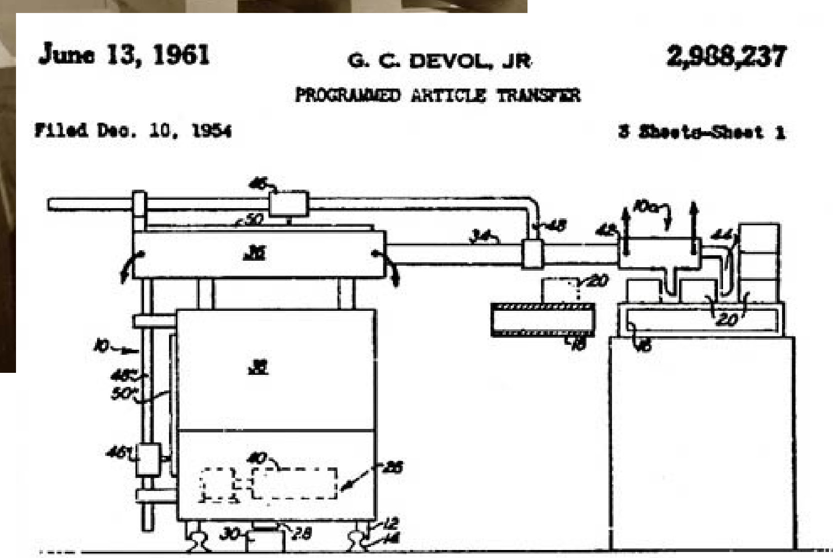


English Conversation

Intelligent Conversational Android 2016

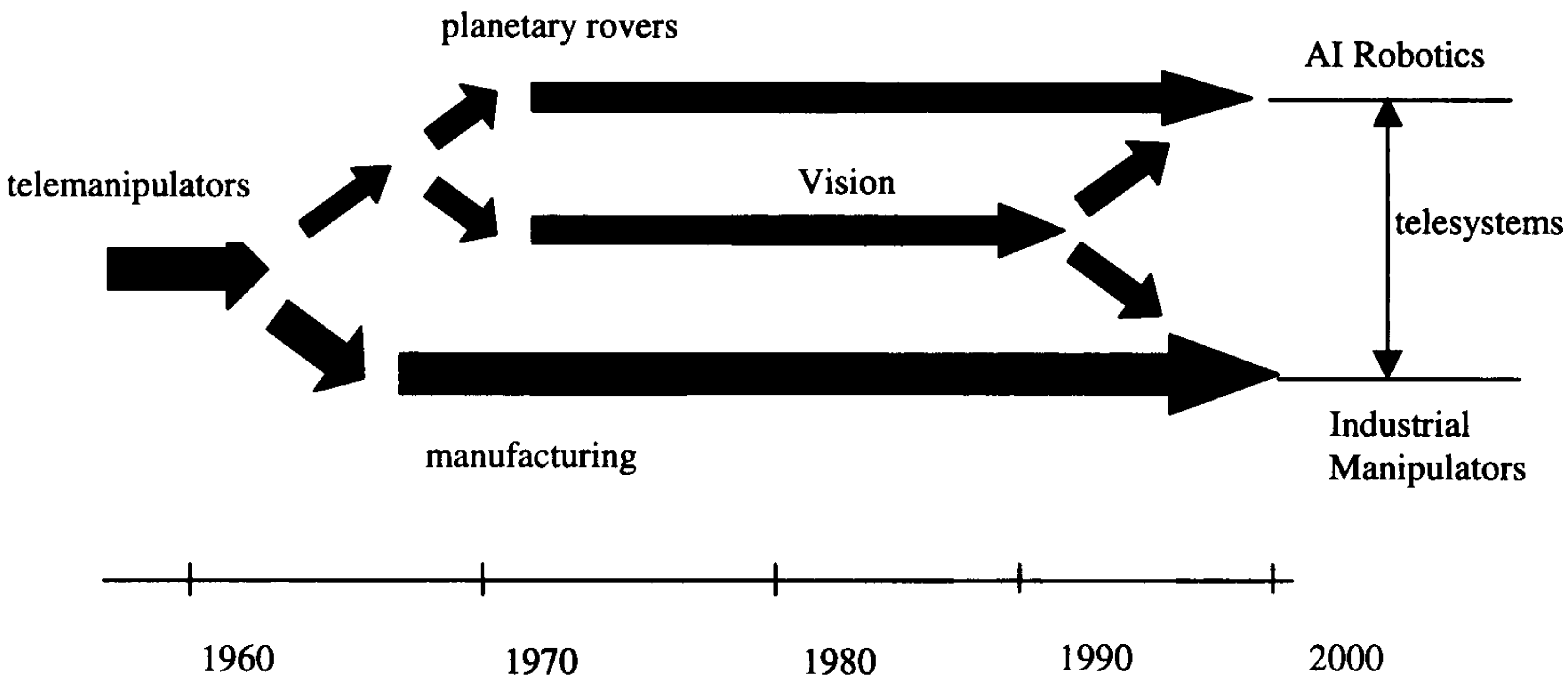
Unimate robot arm - 1961





Tesla assembly line, 2012

Robotic Evolution



AIMA p. 901

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).

Trends in Robotics Research

Classical Robotics (mid-70's)

- exact models
- no sensing necessary

Reactive Paradigm (mid-80's)

- no models
- relies heavily on good sensing

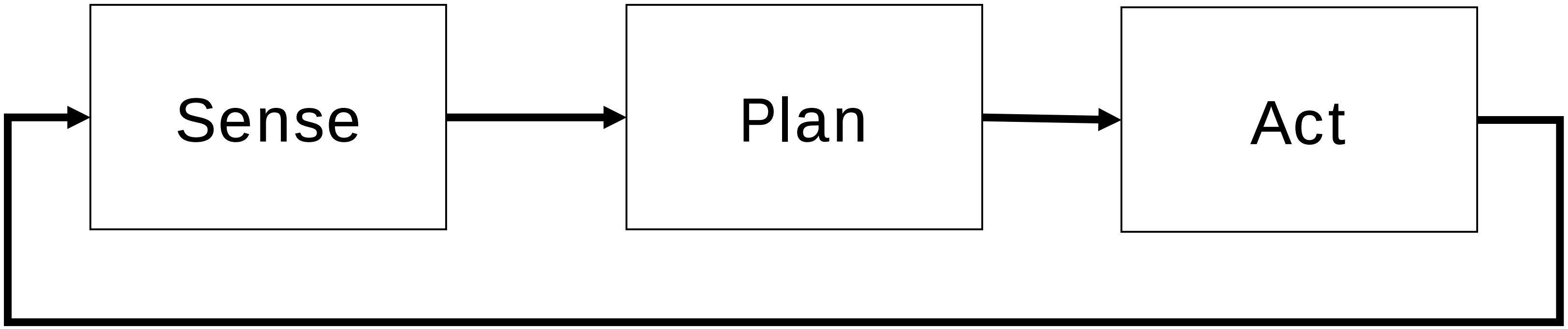
Hybrids (since 90's)

- model-based at higher levels
- reactive at lower levels

Probabilistic Robotics (since mid-90's)

- seamless integration of models and sensing
- inaccurate models, inaccurate sensors

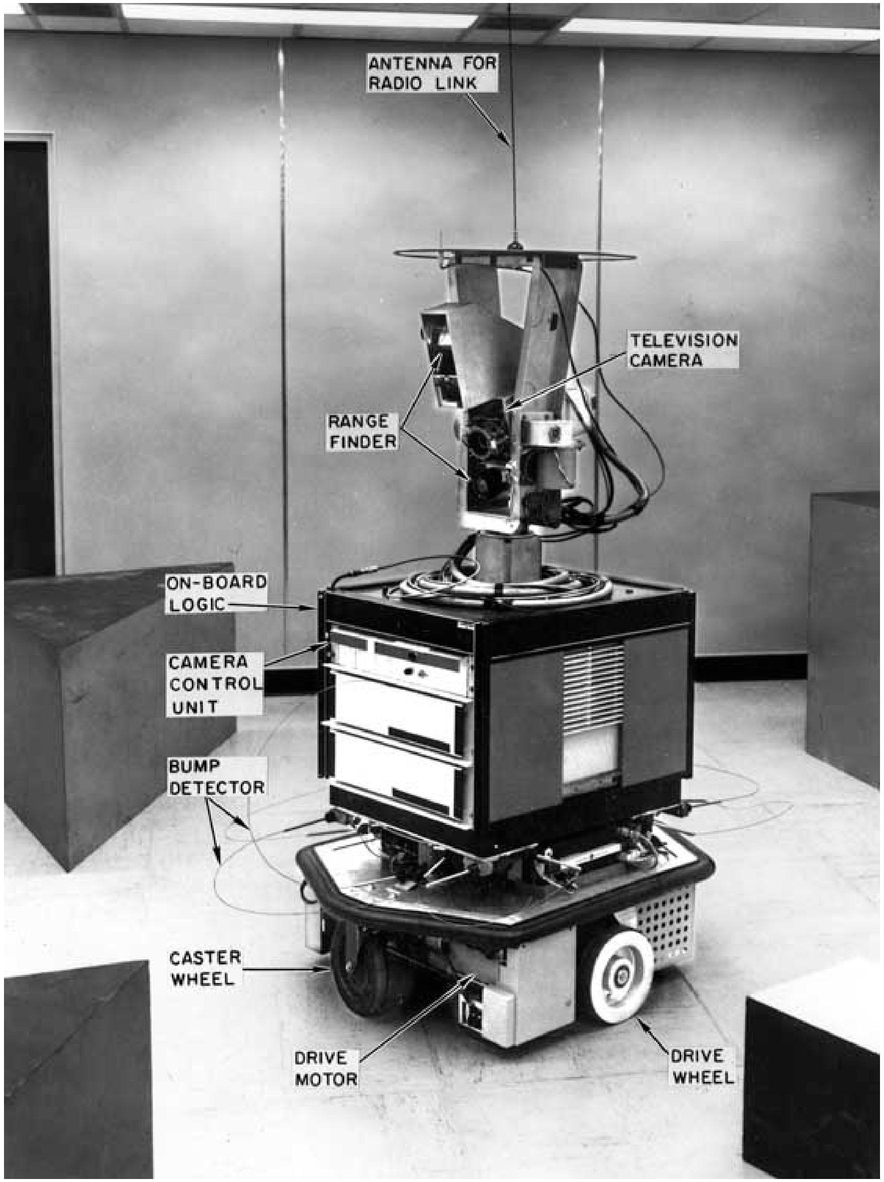
Classical / Hierarchical Paradigm



- 70's
- Focus on automated reasoning and knowledge representation
- STRIPS (Stanford Research Institute Problem Solver): Perfect world model, closed world assumption
- Find boxes and move them to designated position

Shakey '69

Stanford Research Institute



Stanford CART '73

Stanford AI Laboratory / CMU (Moravec)

Classical Paradigm
Stanford Cart

1. Take nine images of the environment, identify interesting points in one image, and use other images to obtain depth estimates.
2. Integrate information into global world model.
3. Correlate images with previous image set to estimate robot motion.
4. On basis of desired motion, estimated motion, and current estimate of environment, determine direction in which to move.
5. Execute the motion.

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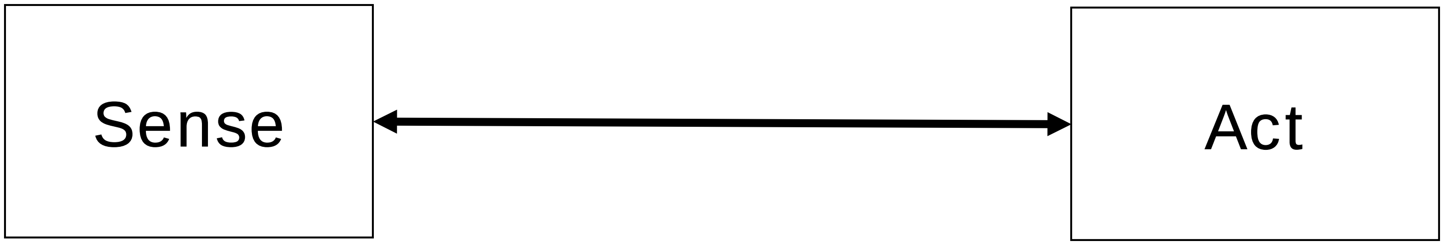
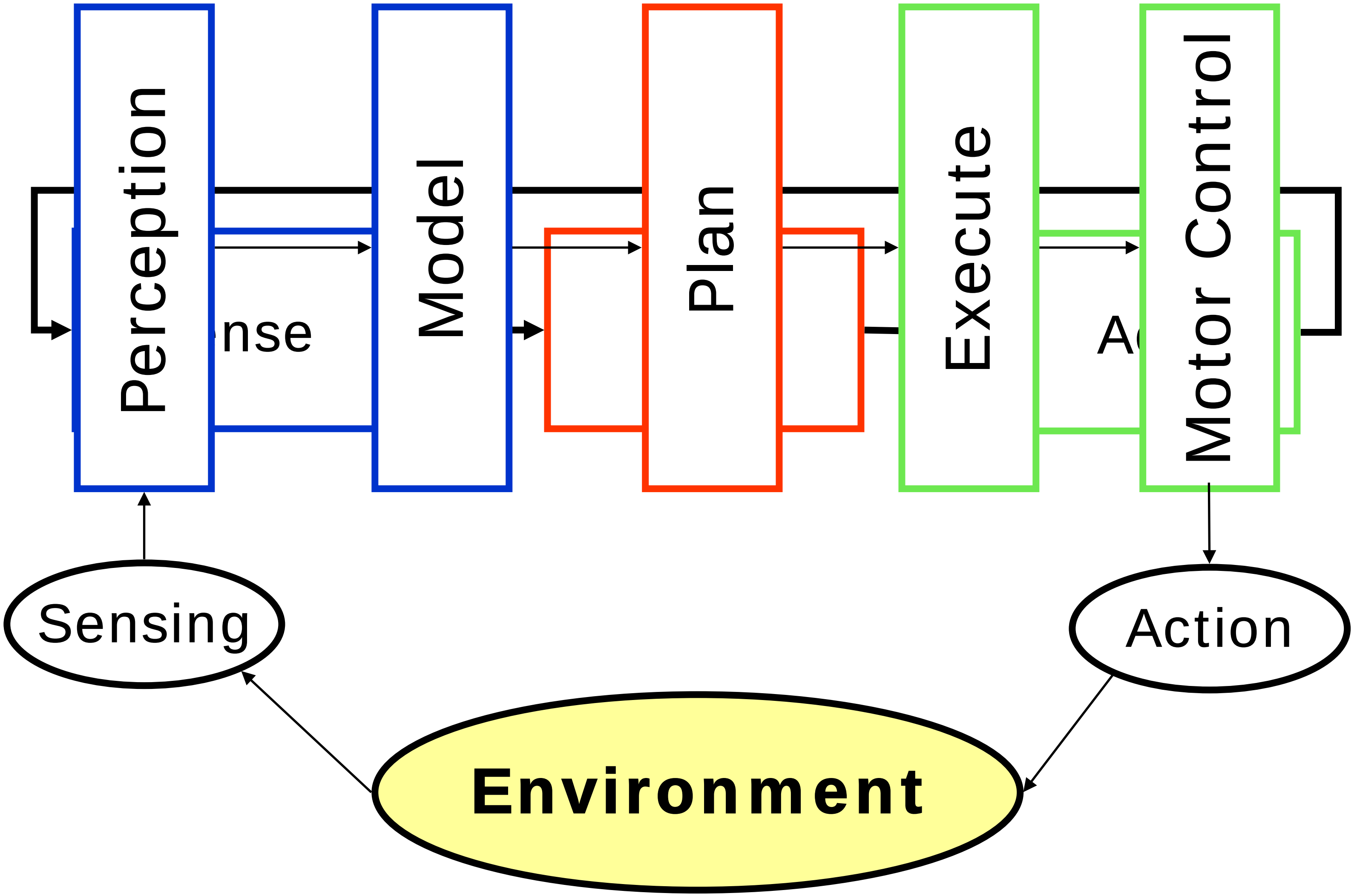
Reactive / Behavior-based Paradigm



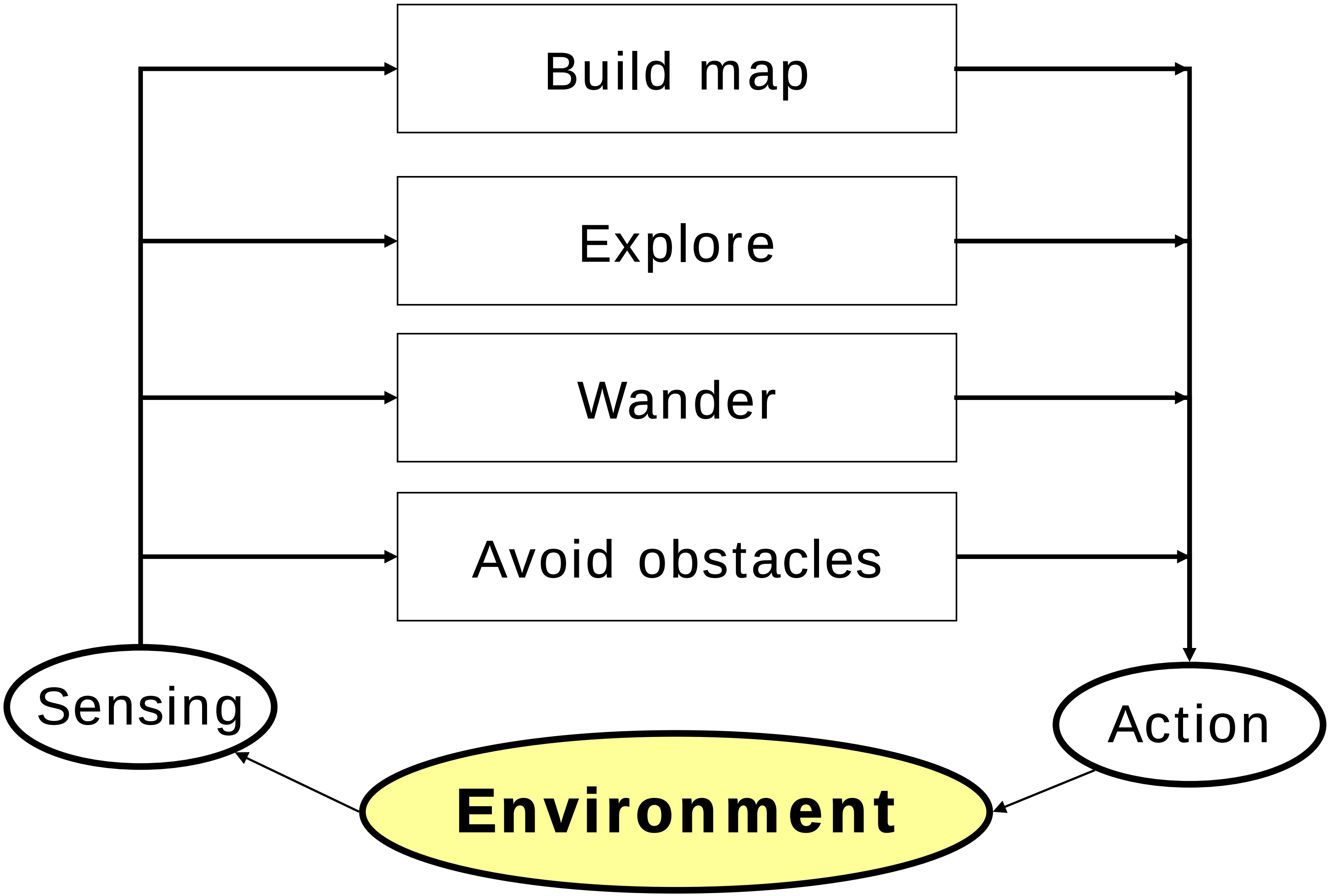
- No models: The world is its own, best model
- Easy successes, but also limitations
- Investigate biological systems

- Best-known advocate: Rodney Brooks (MIT)

Classical Paradigm as Horizontal/Functional Decomposition



Reactive Paradigm as Vertical Decomposition



Characteristics of Reactive Paradigm

- Situated agent, robot is integral part of the world.
- No memory, controlled by what is happening in the world.
- Tight coupling between perception and action via behaviors.
- Only local, behavior-specific sensing is permitted (ego-centric representation).

Behaviors

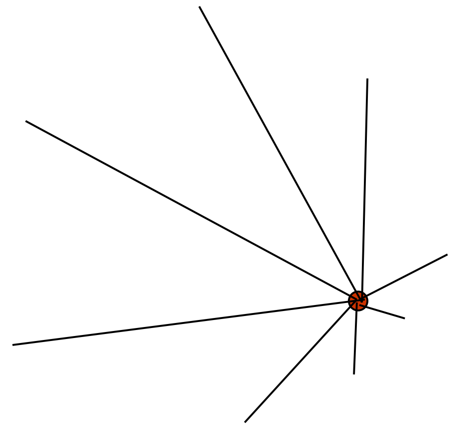
- ... are a direct mapping of sensory inputs to a pattern of motor actions that are then used to achieve a task.
- ... serve as the basic building block for robotics actions, and the overall behavior of the robot is emergent.
- ... support good software design principles due to modularity.

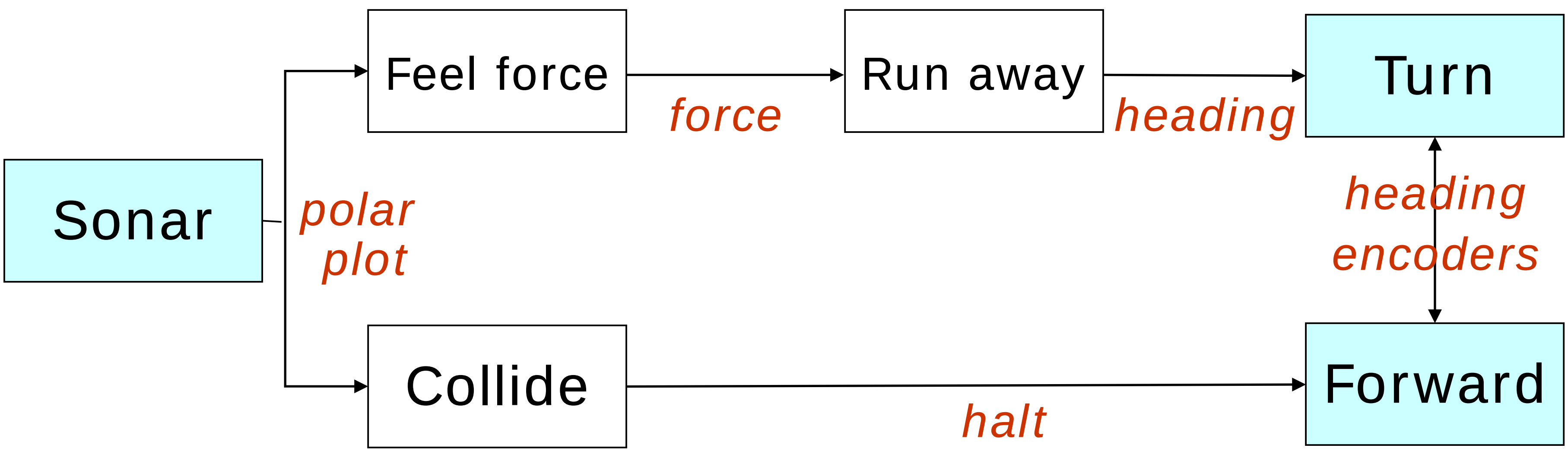
Subsumption Architecture

- Introduced by Rodney Brooks '86.
- Behaviors are networks of sensing and acting modules (augmented finite state machines AFSM).
- Modules are grouped into layers of competence.
- Layers can subsume lower layers.
- No internal state!

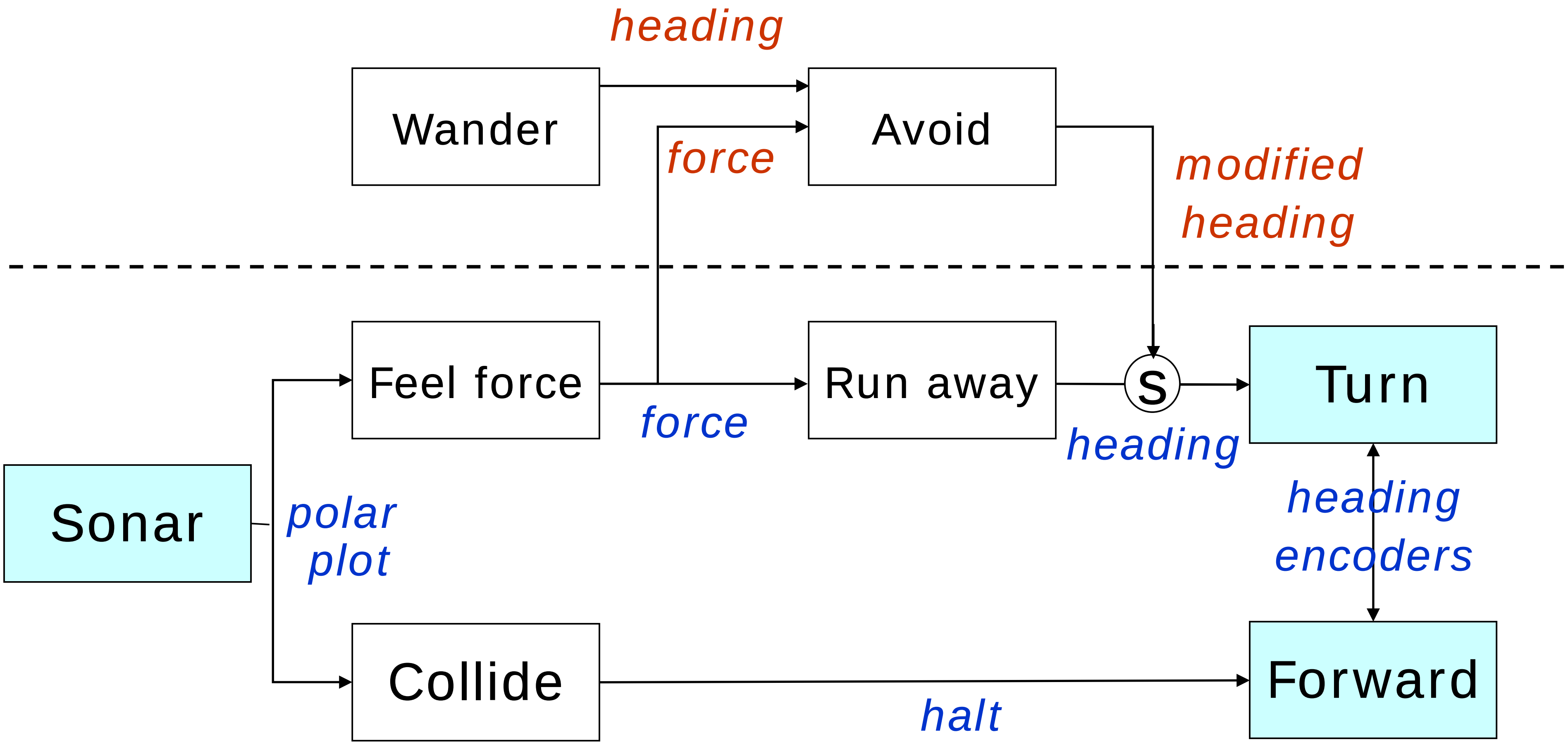
Level 0: Avoid

Polar plot of sonars

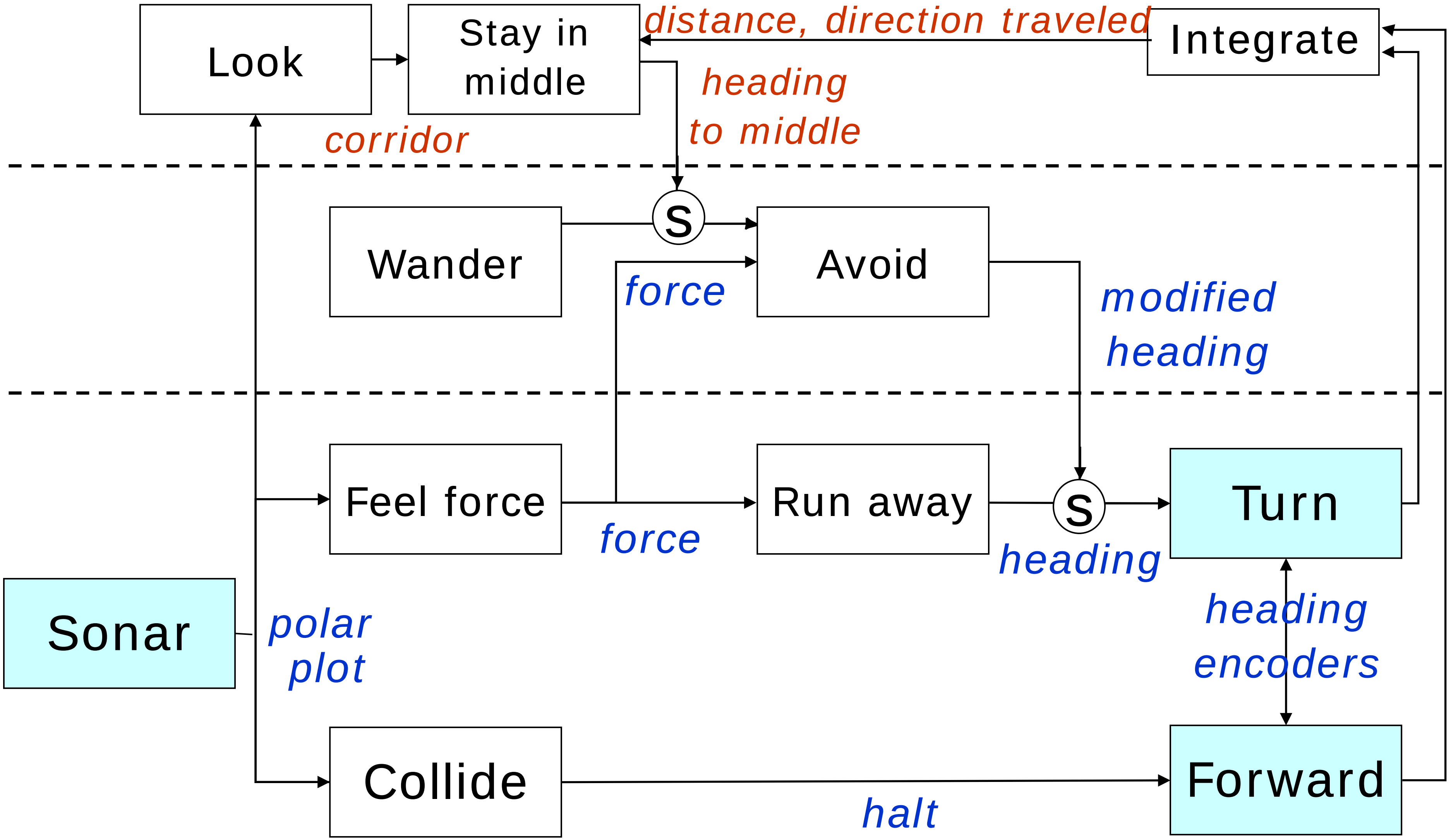




Level 1: Wander



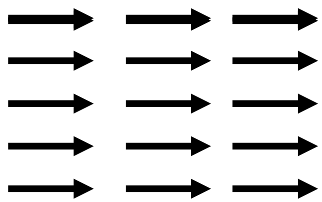
Level 2: Follow Corridor



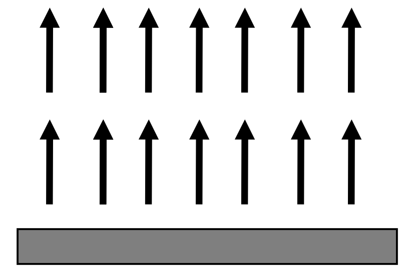
Potential Field Methodologies

- Treat robot as particle acting under the influence of a potential field
- Robot travels along the derivative of the potential
- Field depends on obstacles, desired travel directions and targets
- Resulting field (vector) is given by the summation of primitive fields
- Strength of field may change with distance to obstacle/target

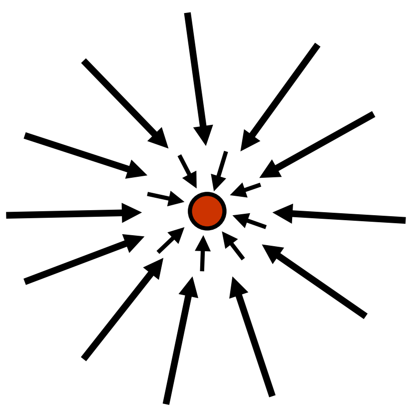
Primitive Potential Fields



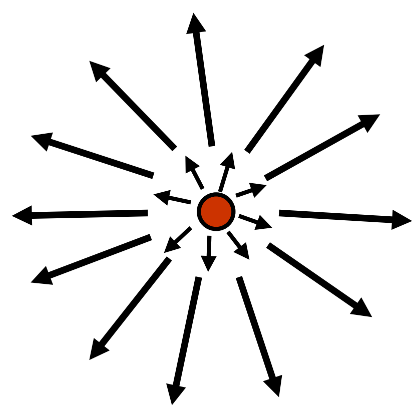
Uniform



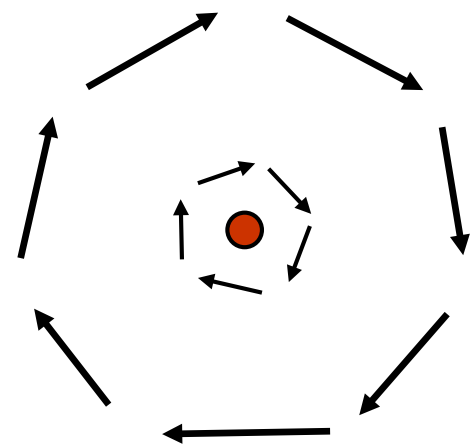
Perpendicular



Attractive



Repulsive



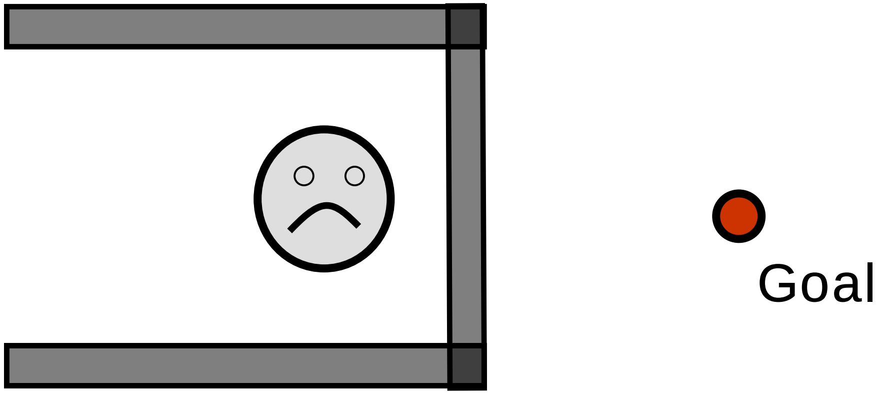
Tangential

Corridor following with Potential Fields

- Level 0 (collision avoidance)
  is done by the repulsive fields of detected obstacles.
- Level 1 (wander)
  adds a uniform field.
- Level 2 (corridor following)
  replaces the wander field by three fields (two perpendicular, one uniform).

Characteristics of Potential Fields

- Suffer from local minima



  - Backtracking
  - Random motion to escape local minimum
  - Procedural planner s.a. wall following
  - Increase potential of visited regions
  - Avoid local minima by harmonic functions

Characteristics of Potential Fields

- No preference among layers
- Easy to visualize
- Easy to combine different fields
- High update rates necessary
- Parameter tuning important

Reactive Paradigm

- Representations?
- Good software engineering principles?
- Easy to program?
- Robustness?
- Scalability?

Discussion

- Imagine you want your robot to perform navigation tasks, which approach would you choose?
- What are the benefits of the reactive (behavior-based) paradigm? How about the deliberate (planning) paradigm?
- Which approaches will win in the long run?

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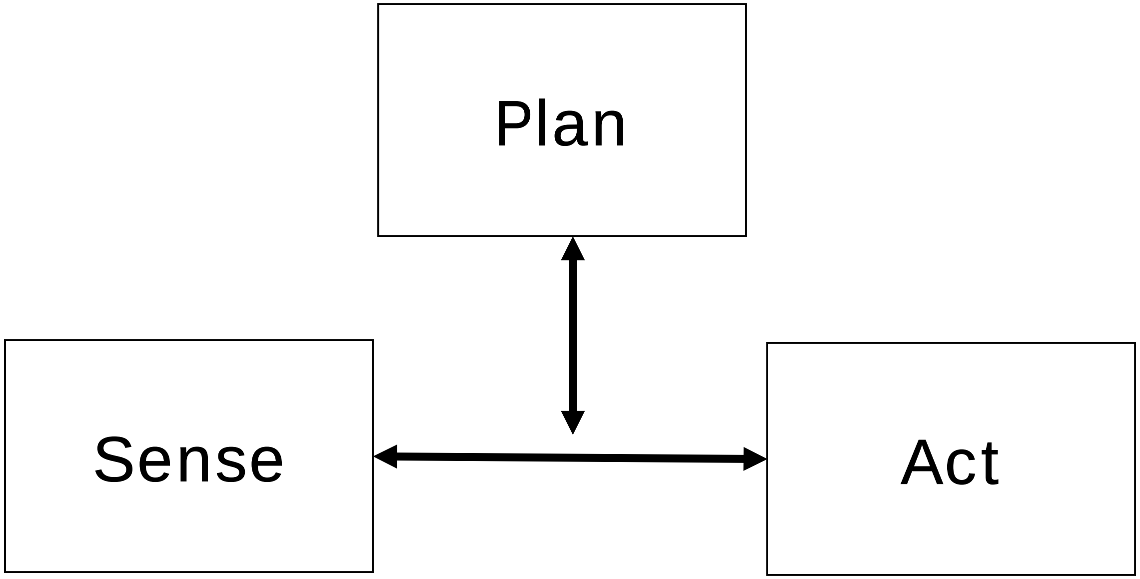
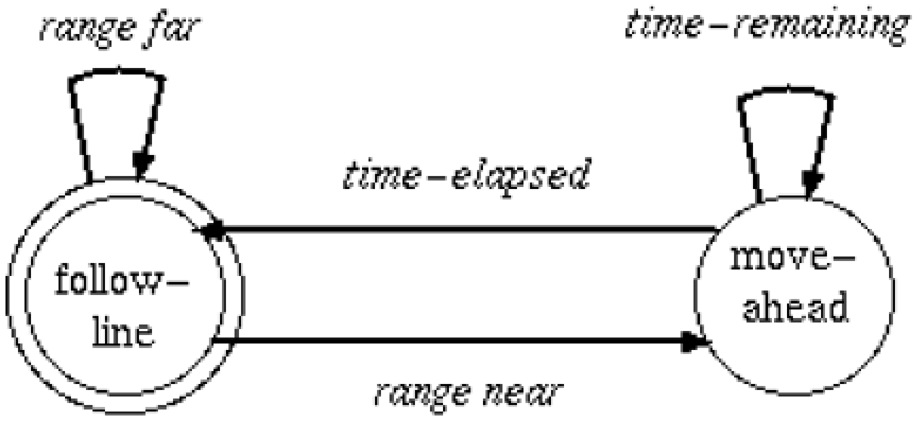
Hybrid Deliberative/reactive Paradigm

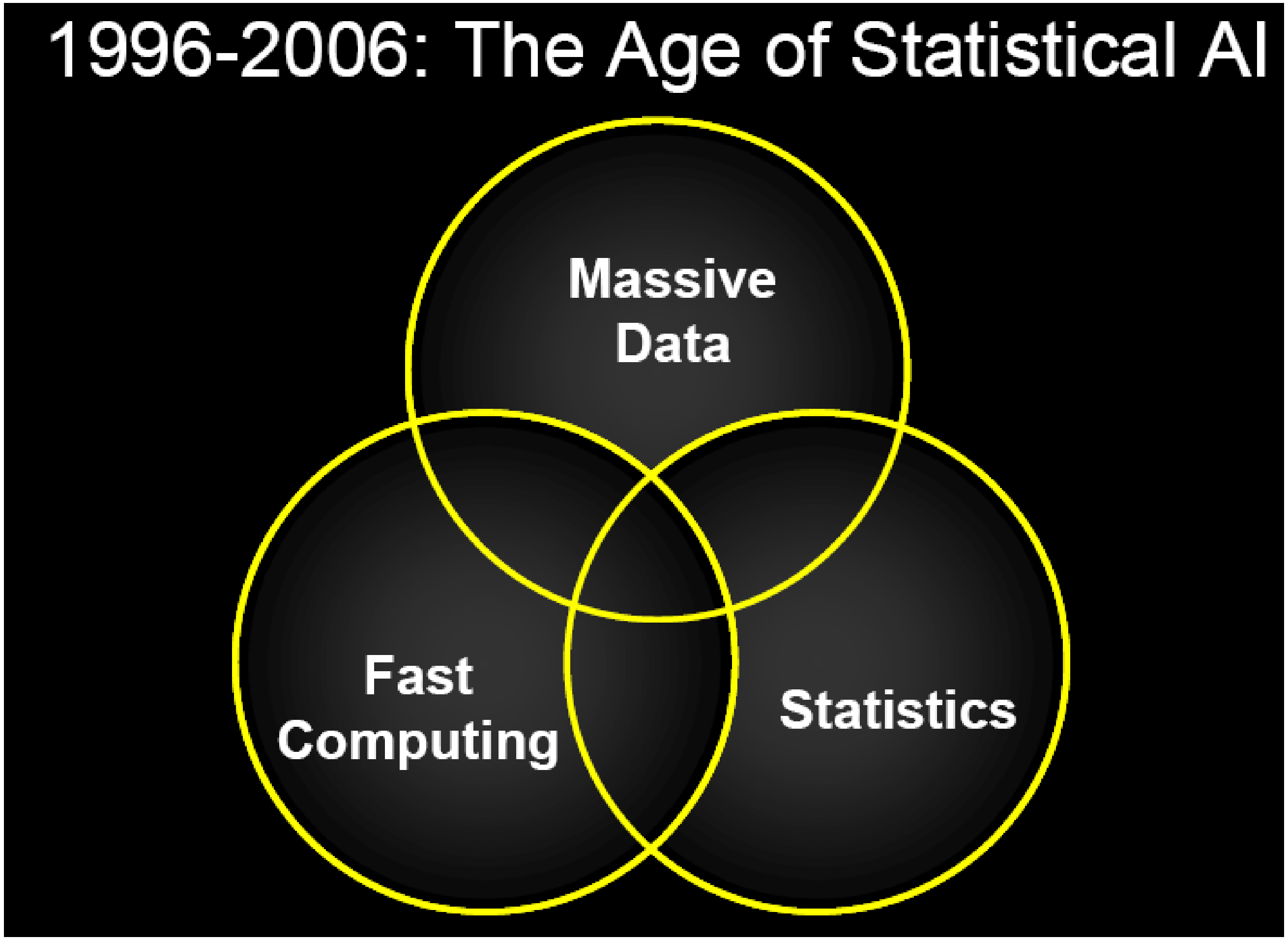


- Combines advantages of previous paradigms
  - World model used for planning
  - Closed loop, reactive control

The result: Finite State Automata

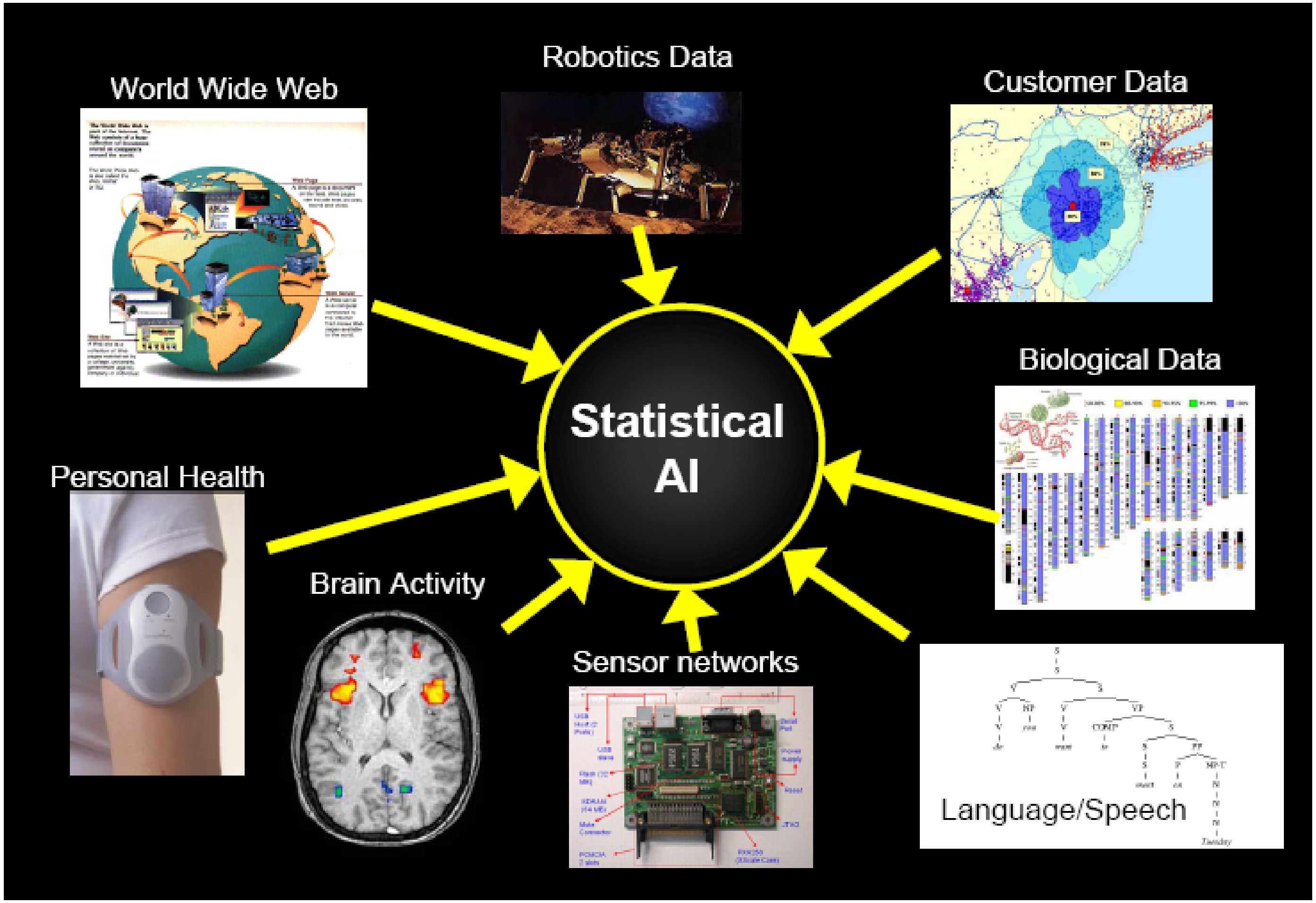


FSM is a simplification of the world



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

Searching for correlations in data



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Probabilistic Robotics