A Short Introduction to Robotics and AI

David Vernon

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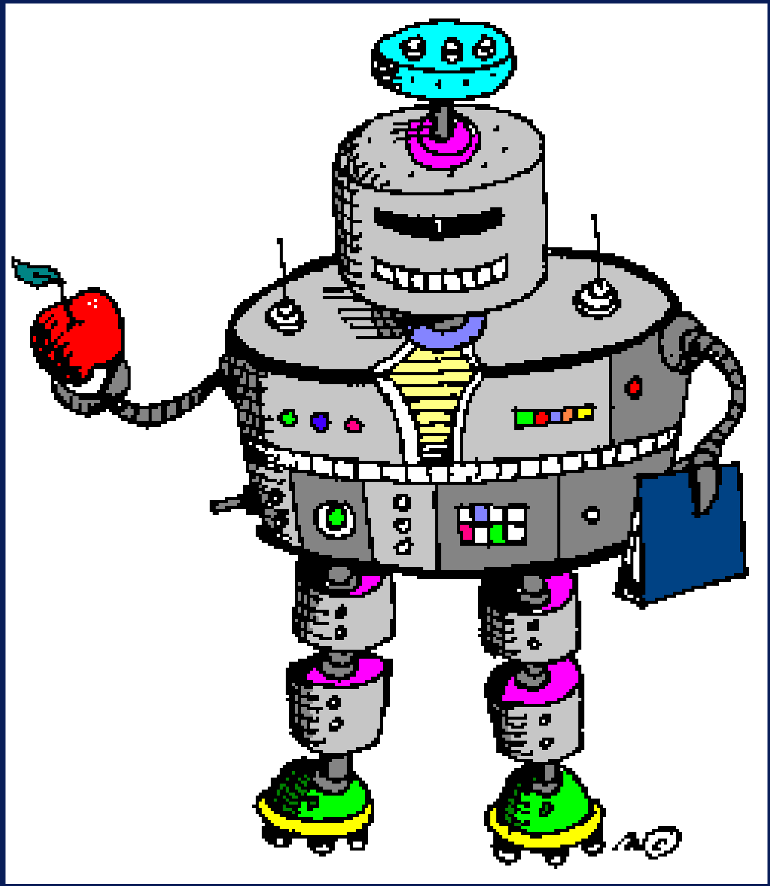


Learning Objectives

- Nature of robotics
- Robotic applications
- Principal engineering issues
- Principal AI issues
- The future of robotics

The Word "Robot"

- "Robot" is derived from a Czech word meaning "forced labor"
- First appeared in a 1920 play R.U.R. (Rossum's Universal Robots)

  by Czech playwright Karel Capek.

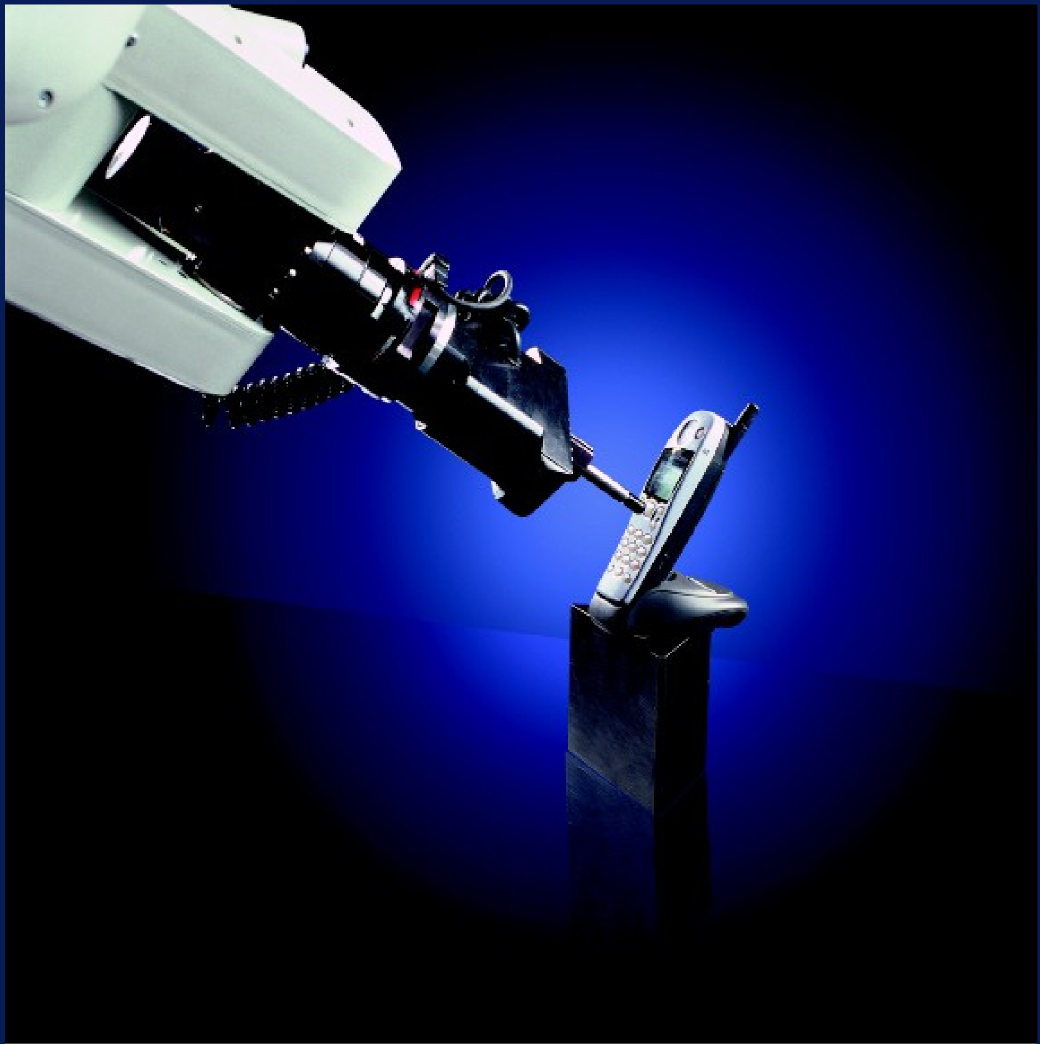
Definitions

- "A reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks“

  Robot Institute of America

Types of Robot

- Manipulators

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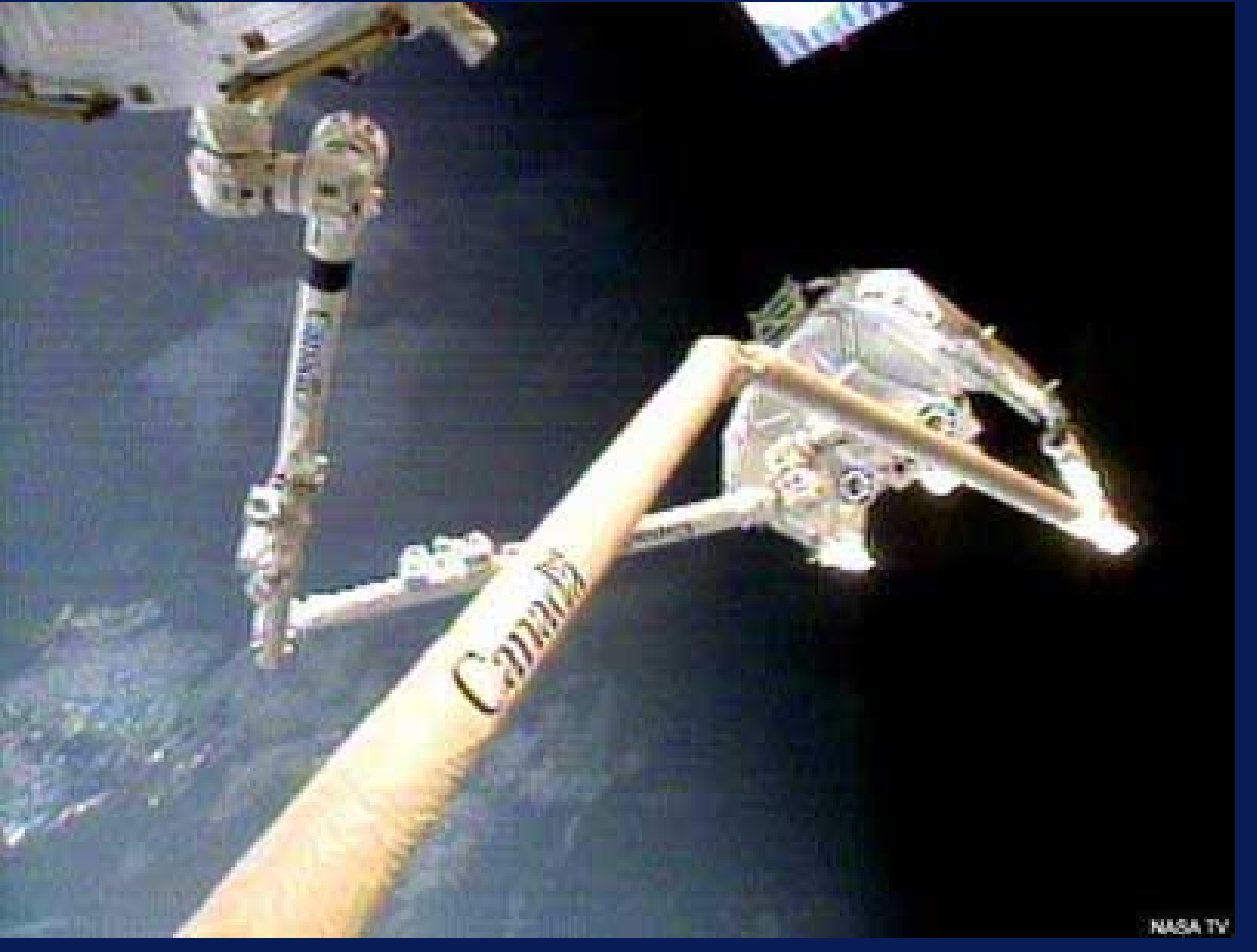
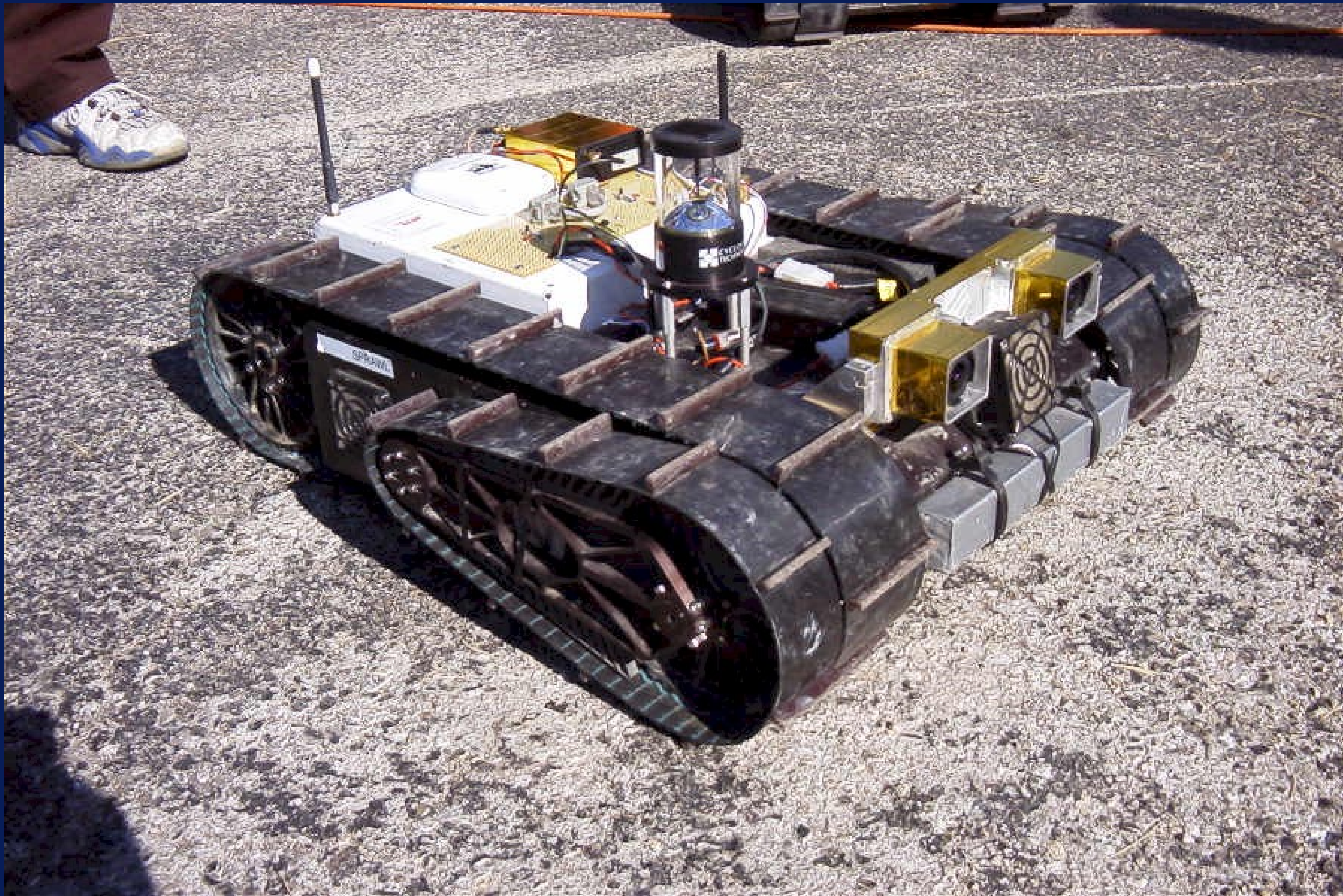


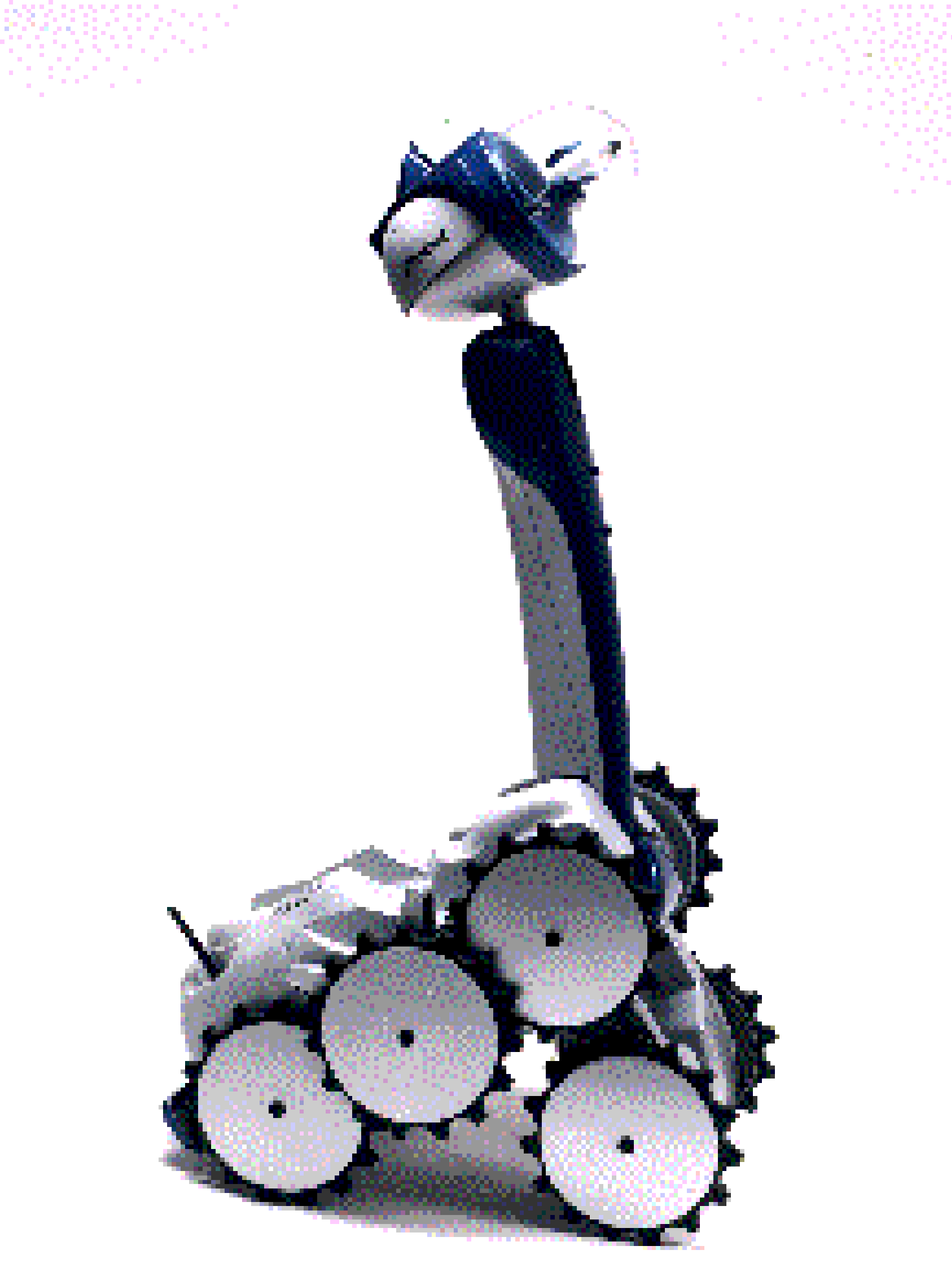
SSRMS

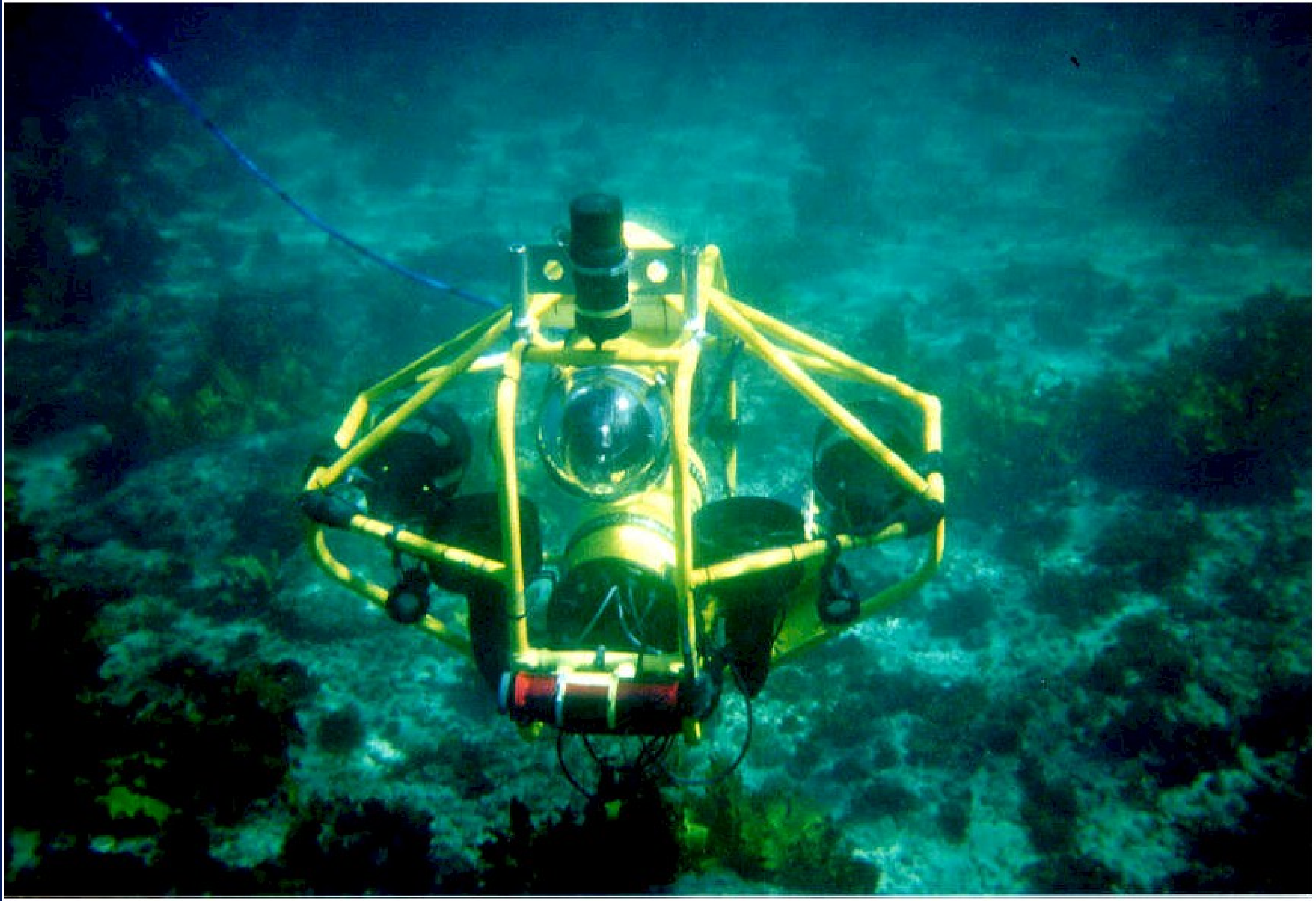

Canada

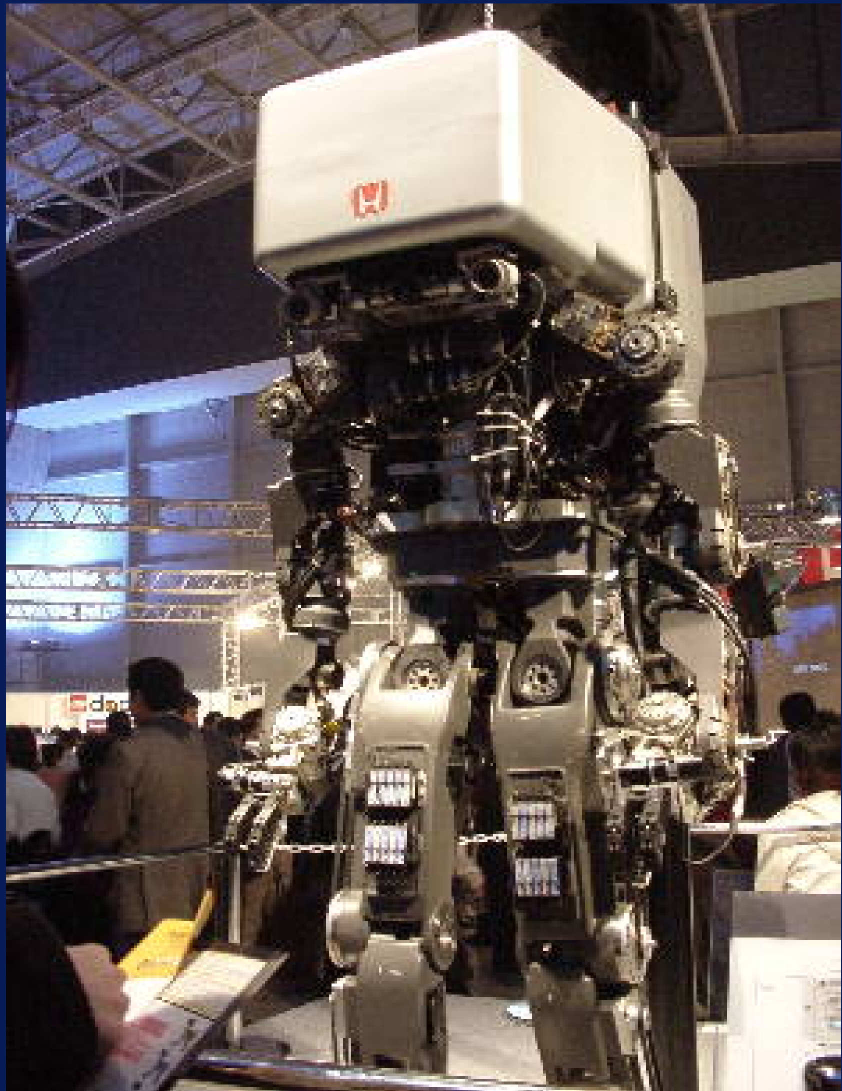
Types of Robot

- Manipulators
- Mobile robots







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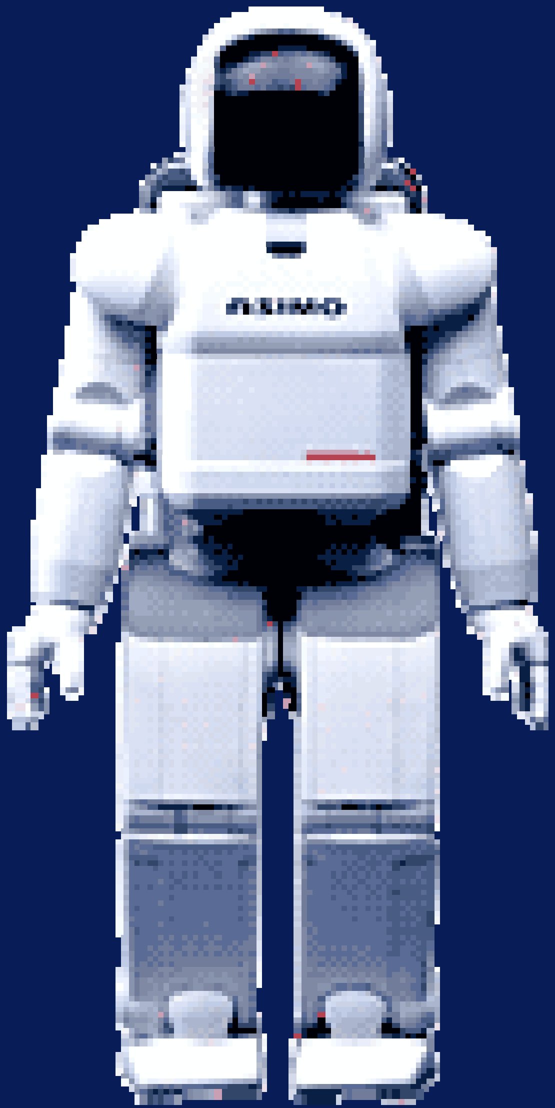
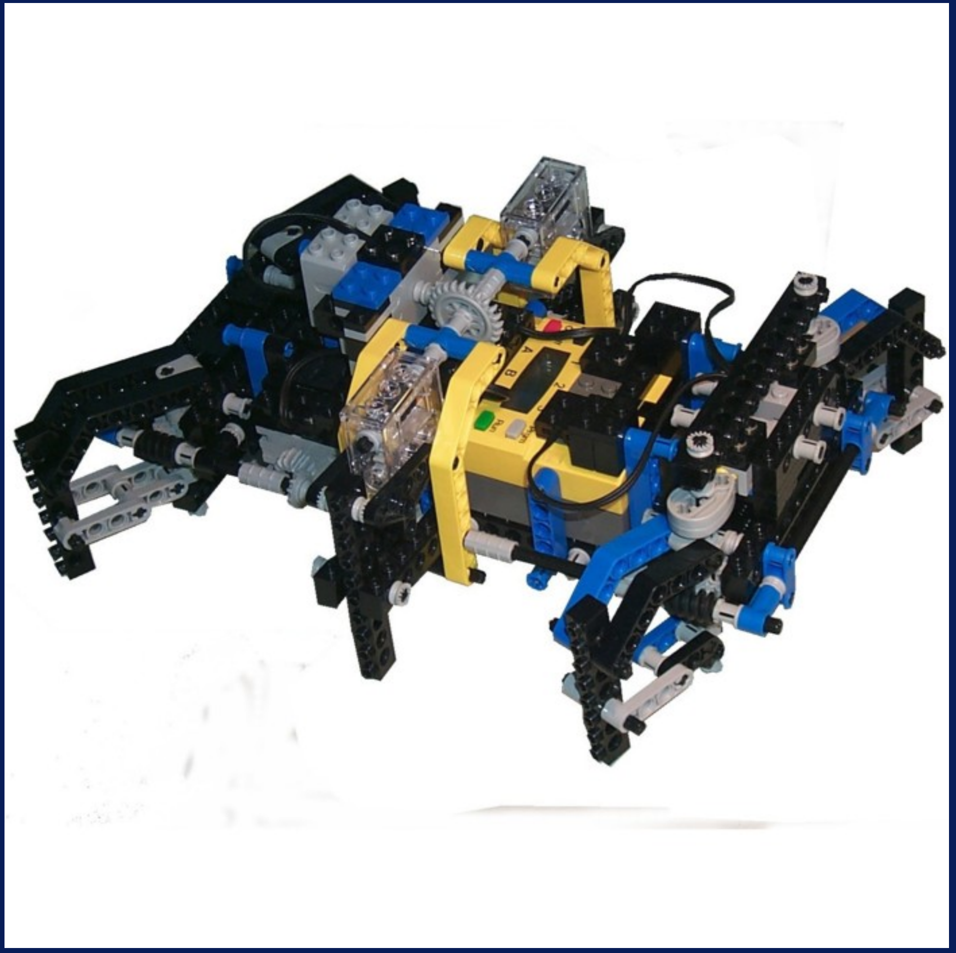

ASIMO

Types of Robot

- Manipulators
- Mobile robots
- Entertainment

Types of Robot

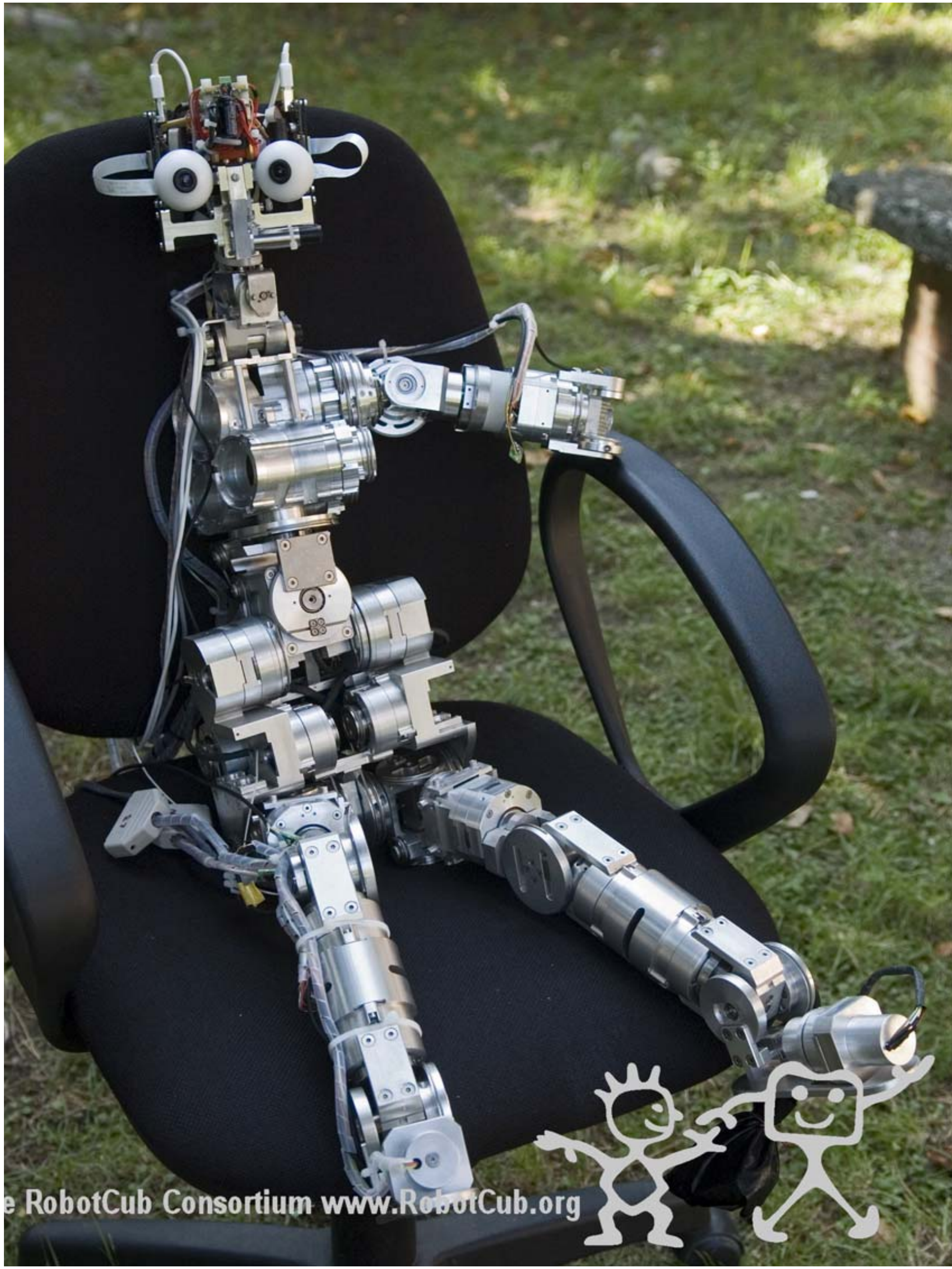
- Manipulators
- Mobile robots
- Entertainment
- Education



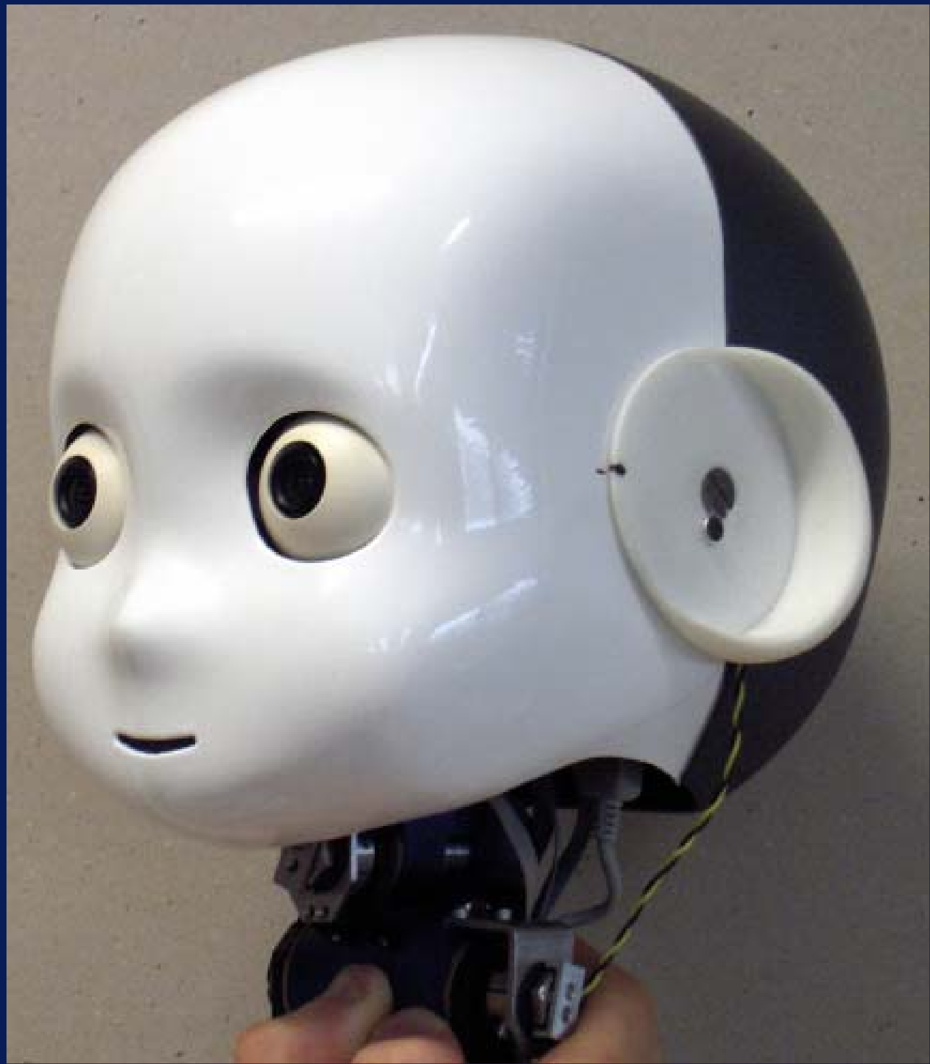
Types of Robot

- Manipulators
- Mobile robots
- Entertainment
- Education
- AI robots

COG



iCub
(www.iCub.org)



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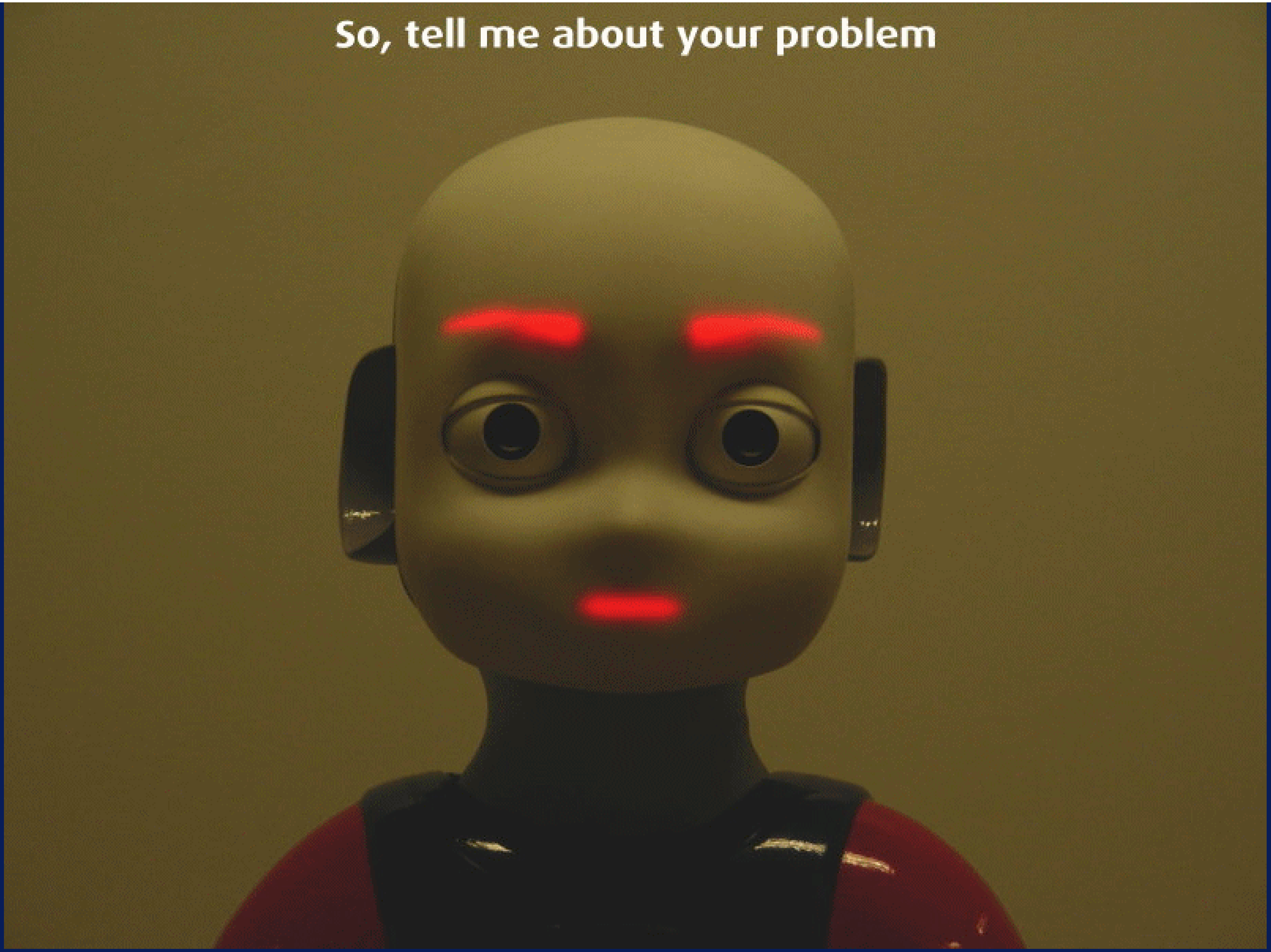
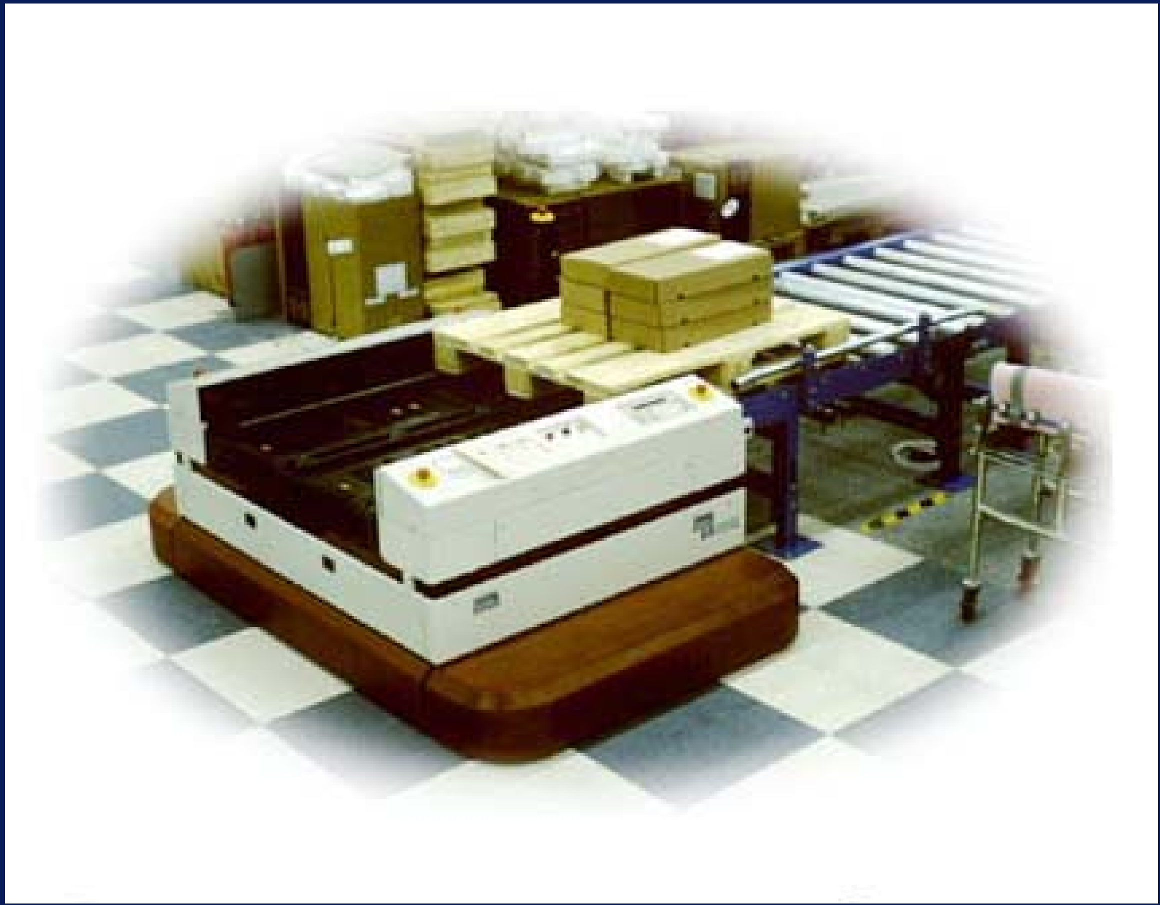


iCub
(www.iCub.org)

Robotic Applications

- Parts handling
- Assembly
- Painting
- Surveillance
- Security (bomb disposal … really telecherics rather than robotics)
- Home help (grass cutting, nursing)



LET YOUR ROBOT DO THE MOWING...

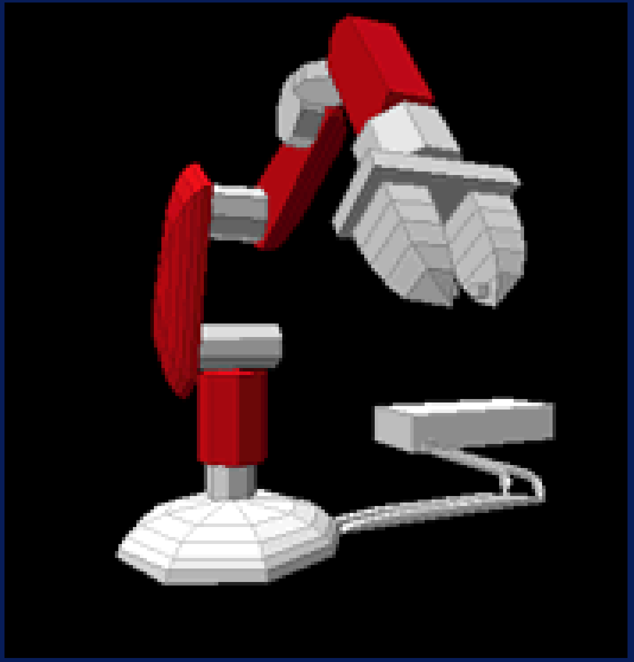

You worry that your grandmother lives alone. She reassures you she is doing fine, thanks to her new personal assistant,
Flo.

Vernon (www.vernon.eu)

Engineering Issues

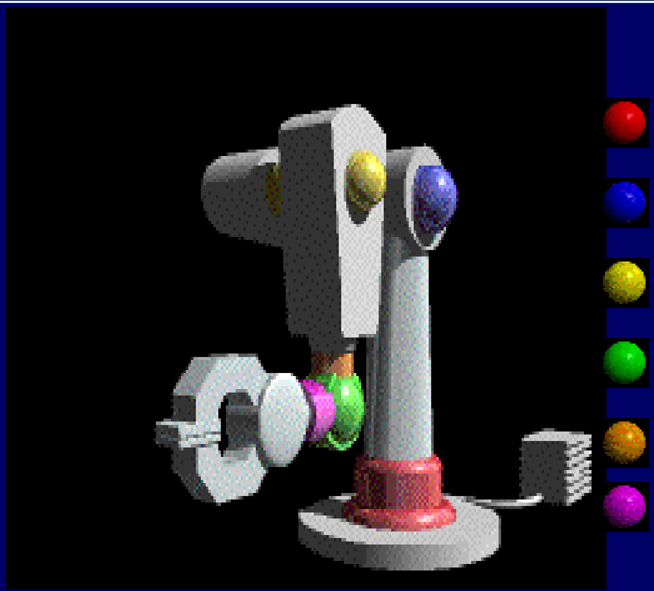
- Mechanical Construction
- Control
- Manipulation
- Task Specification
- Sensing
- Path planning
- Interaction
- Reasoning
- Autonomy and Adaptive Behaviour

Mechanical Construction



- Controller
- Arm
- Drive
- End Effectors
- Sensor

Degrees of Freedom



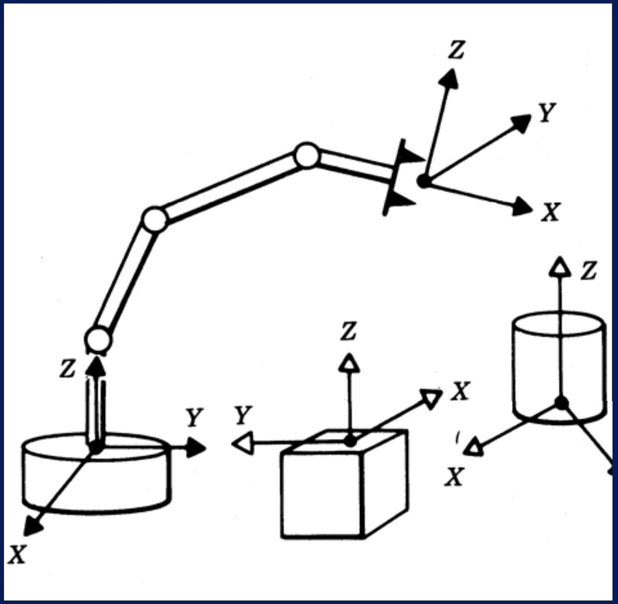
- ROTATE BASE OF ARM
- PIVOT BASE OF ARM
- BEND ELBOW
- WRIST UP AND DOWN
- WRIST LEFT AND RIGHT
- ROTATE WRIST

•Please click over the picture

Task Specification & World Modelling

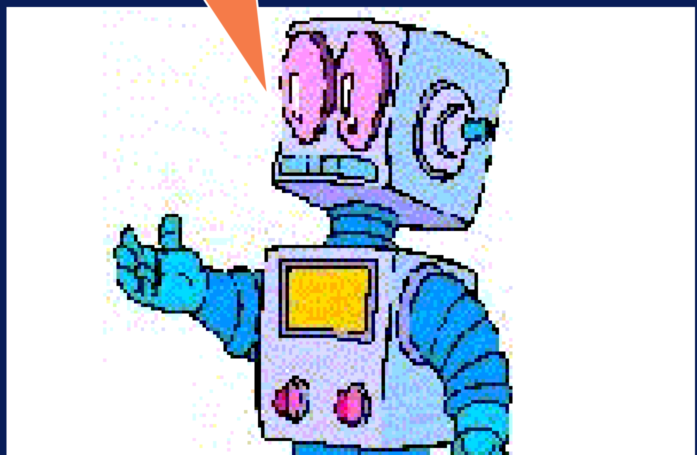
Location of objects:
-Links of manipulator, parts, tools

Specified by:
-frame, coordinate systems

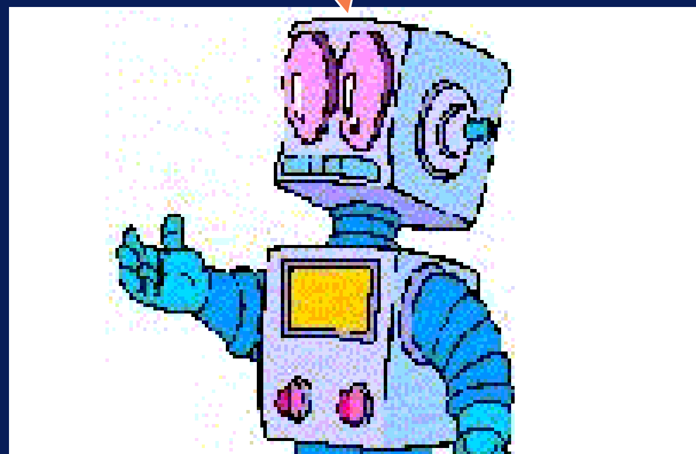


Trajectory Generation

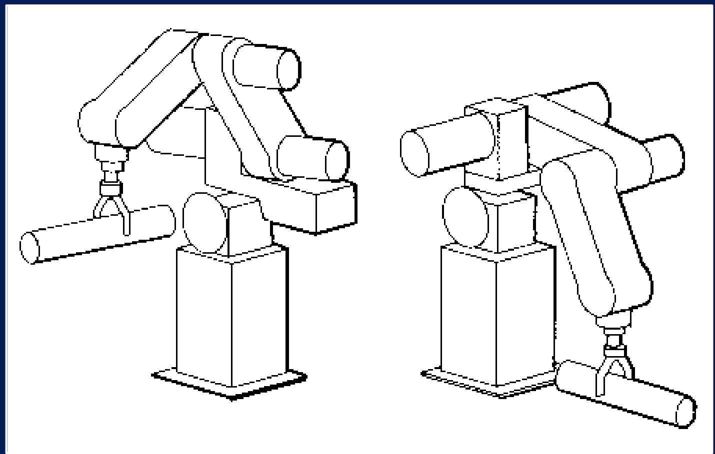
How do I move
from this location



To this location



Trajectory Generation

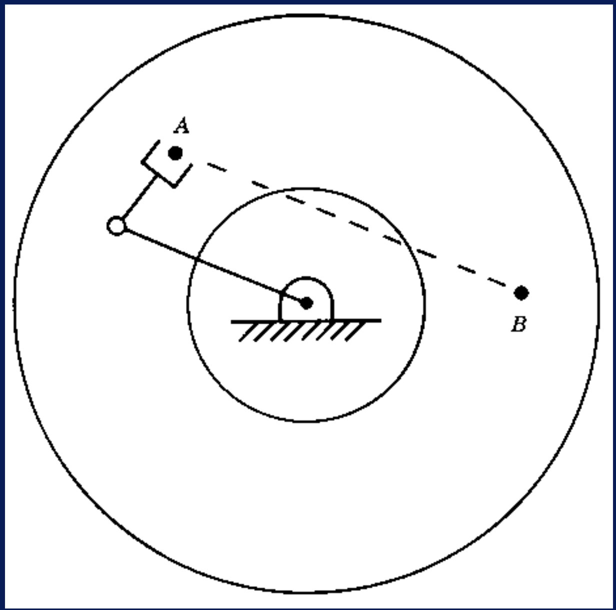


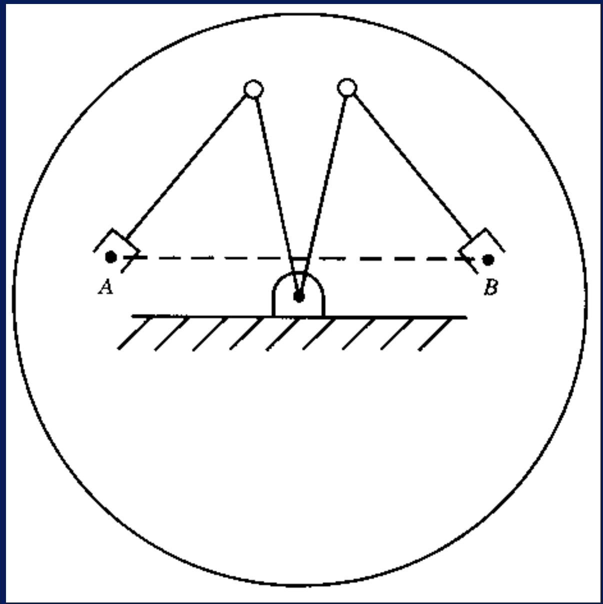
- Cartesian space vs. Joint Space
- Manipulator kinematics (given joint angles, find position and orientation of end effector)
- Inverse kinematics (given position and orientation of end effector, find joint angles)
- Dynamics

Trajectory Generation

- Location:
  - Start location
  - End location
  - Intermediate location
- Interpolation
  - PTP-motion
  - Linear motion
  - Circular motion
- Dynamics
  - Velocity
  - Acceleration
  - Tool Functions and Settings

Trajectory Generation





- Problems with Cartesian space interpolation
- Unreachable configurations
- Multiple solutions

Task Specification & World Modelling

Specification of orientation:

Use transformation matrices and Euler angles or Roll-Pitch-Yaw convention

$$
{}^{A}_{B}R_{XYZ}(\alpha,\beta,\gamma)=\begin{bmatrix} c\alpha & -s\alpha & 0 \\ s\alpha & c\alpha & 0 \\ 0 & 0 & 1 \end{bmatrix}\cdot\begin{bmatrix} c\beta & 0 & s\beta \\ 0 & 1 & 0 \\ -s\beta & 0 & c\beta \end{bmatrix}\cdot\begin{bmatrix} 1 & 0 & 0 \\ 0 & c\gamma & -s\gamma \\ 0 & s\gamma & c\gamma \end{bmatrix}
$$

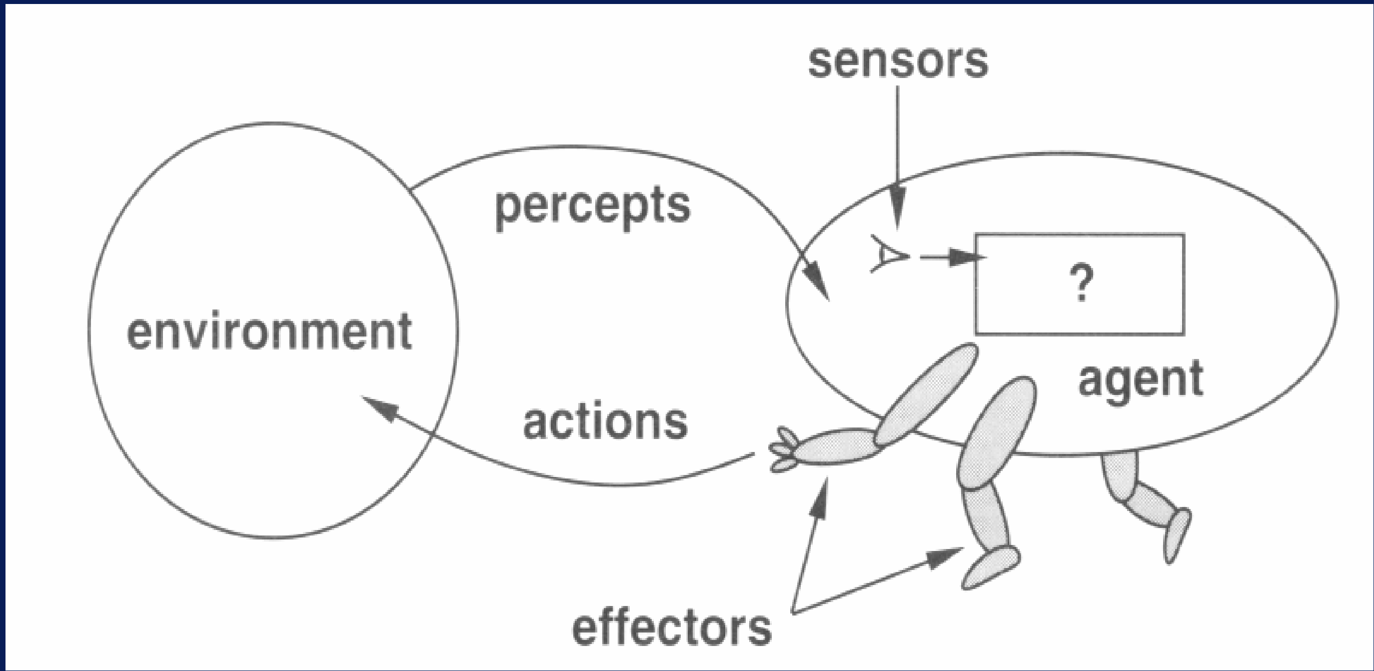
$$
=\begin{bmatrix} c\alpha c\beta & c\alpha s\beta s\gamma - s\alpha c\gamma & c\alpha s\beta c\gamma + s\alpha s\gamma \\ s\alpha c\beta & s\alpha s\beta s\gamma + c\alpha c\gamma & s\alpha s\beta c\gamma - c\alpha s\gamma \\ -s\beta & c\beta s\gamma & c\beta c\gamma \end{bmatrix}
$$

Sensors

Visual	Video cameras range sensors
Auditory	Microwave
Olfactory	Gas sensor
Taste	(Under study)
Tactual	Pressure,temperature, humidity,touch

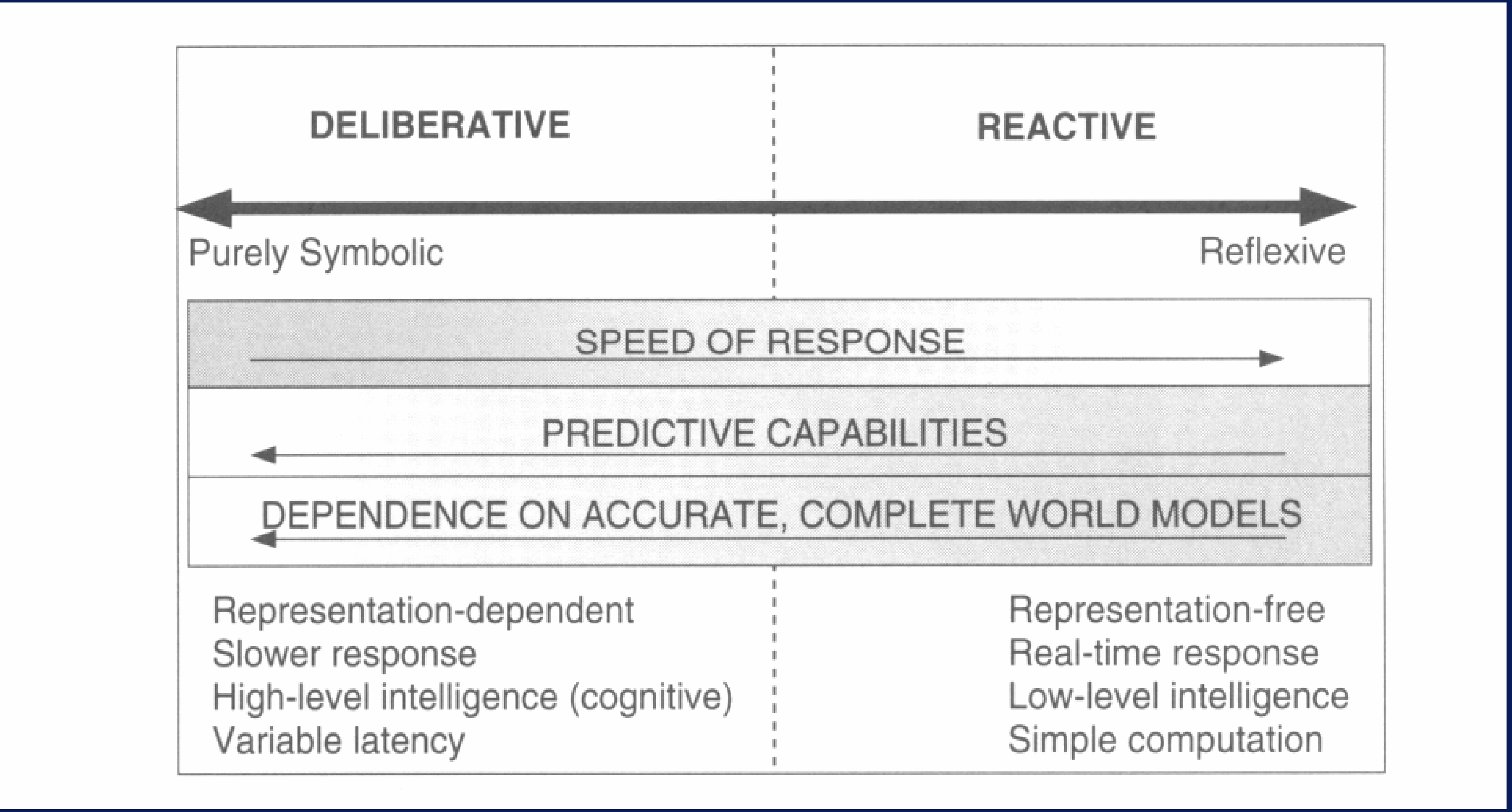
AI & Robotics

Interaction with the environment

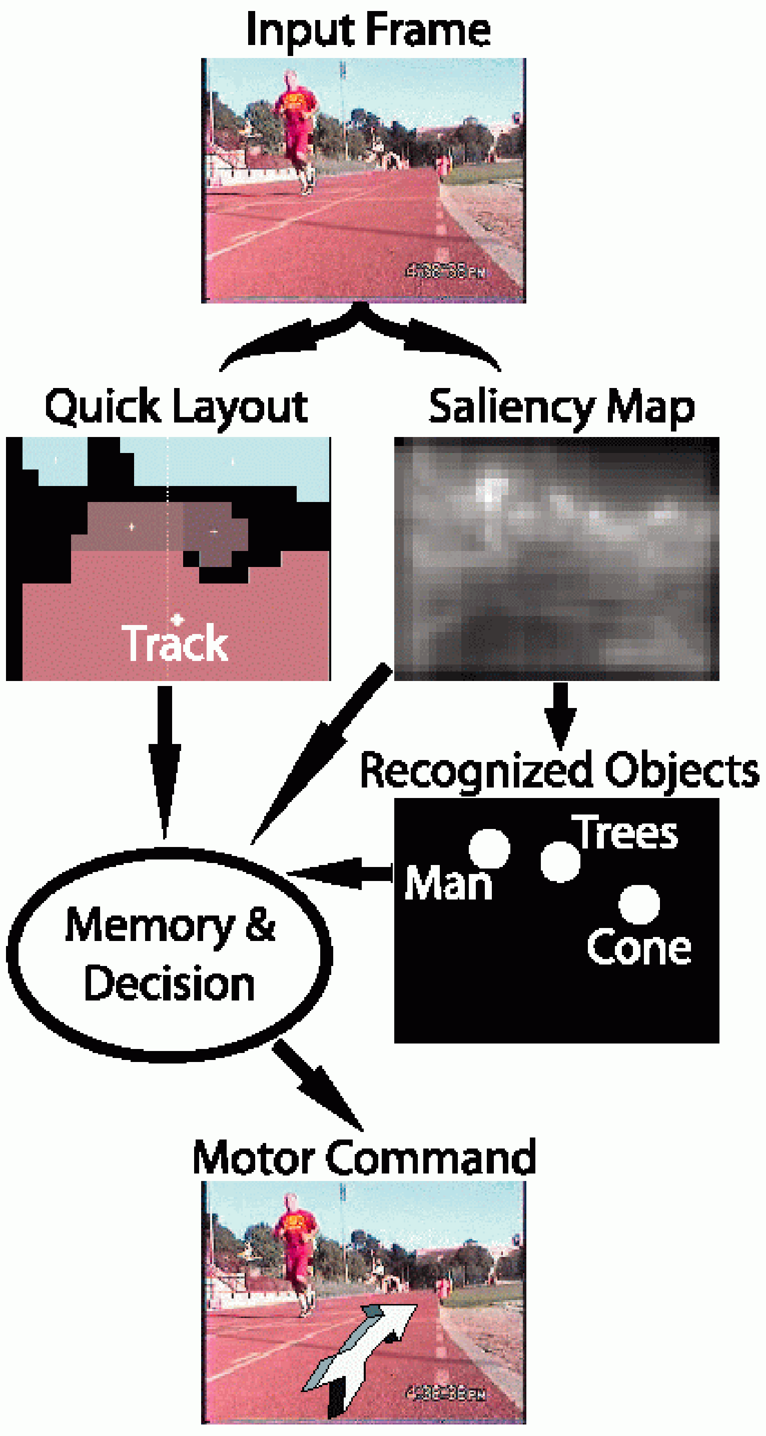


The Real World

- Uncertain, Incomplete, Time-varying



From Introduction to AI Robotics, Robin Murphy



AI & Robotics

Agent based examples taken from:
Q. Tipu, University of Southern California

AI & Robotics

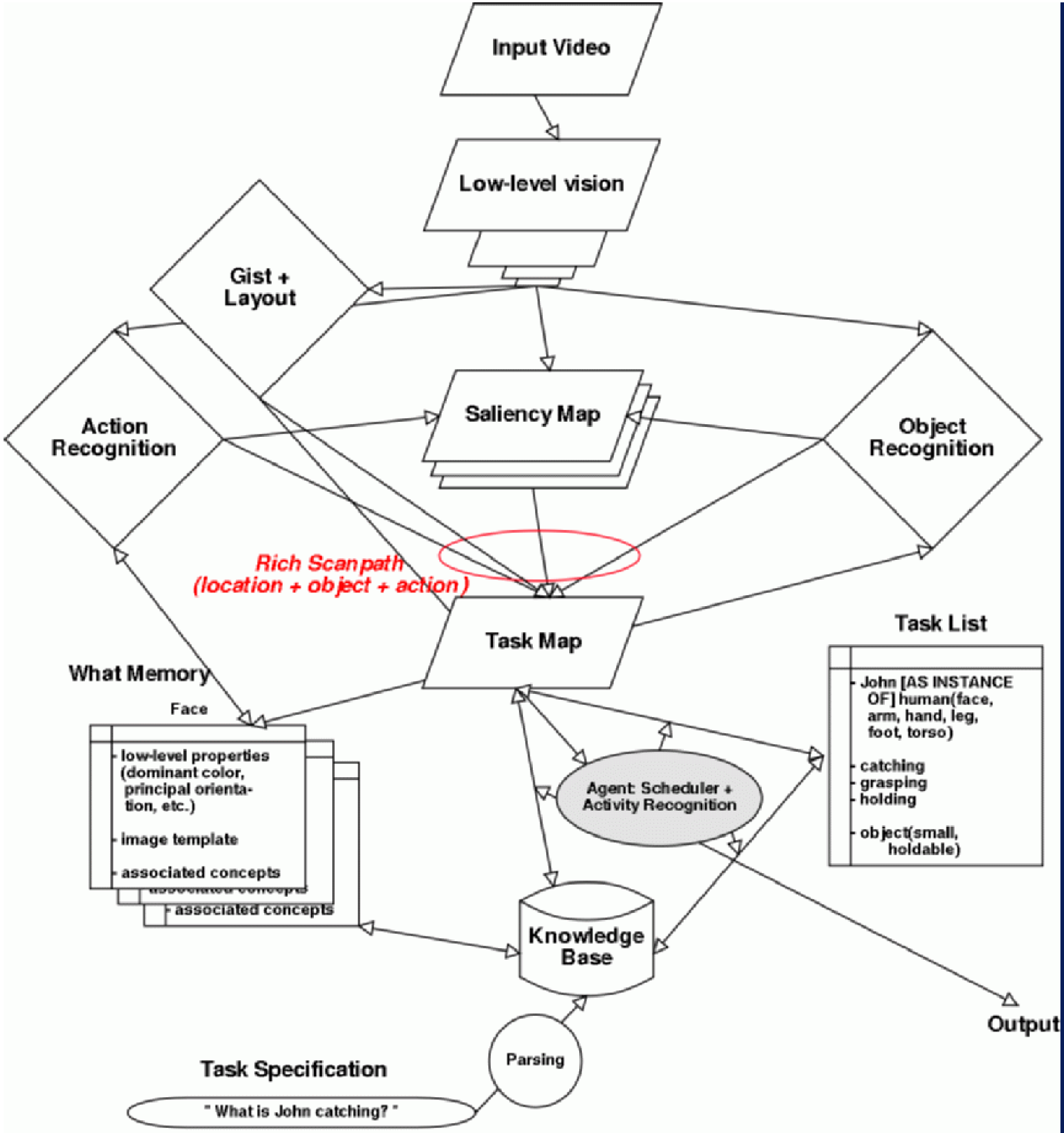
- How to represent knowledge about the world?

- How to react to new perceived events?
- How to integrate new percepts to past experience?

- How to understand the user?
- How to optimize balance between user goals & environment constraints?
- How to use reasoning to decide on the best course of action?
- How to communicate back with the user?

- How to plan ahead?
- How to learn from experience?

General Architecture



AI & Robotics

- Three ways to make controllers (Brain=computer=AI)

1. Most robots with rule-based controllers
2. Neural networks
3. Stimulus-Response Mechanism
   - Subsumption Architecture (Brooks at MIT)
   - no memory and logical decision
   - hard-wired response to stimulation
   - COG
4. Intelligent Agents

What is an (Intelligent) Agent?

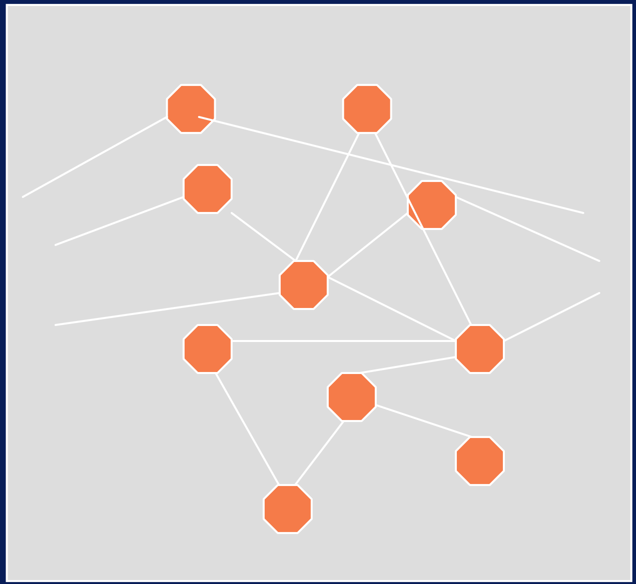
- An over-used, over-loaded, and misused term.
- Anything that can be *as* **perceiving** its **environment** through **sensors** and **acting** upon that environment through its **effectors** to maximize progress towards its **goals**.
- PAGE (Percepts, Actions, Goals, Environment)
- Task-specific & specialized: well-defined goals and environment
- The notion of an agent is meant to be a tool for analyzing systems, not an absolute characterization that divides the world into agents and non-agents. Much like, e.g., object-oriented vs. imperative program design approaches.

Intelligent Agents and Artificial Intelligence

- Human mind as network of thousands or millions of agents all working in parallel. To produce real artificial intelligence, this school holds, we should build computer systems that also contain many agents and systems for arbitrating among the agents' competing results.

- Distributed decision-making and control

- Challenges:
  - Action selection: What next action to choose
  - Conflict resolution



Agent Types

We can split agent research into two main strands:

- Distributed Artificial Intelligence (DAI) – Multi-Agent Systems (MAS) (1980 – 1990)
- Much broader notion of "agent" (1990's – present)
  - interface, reactive, mobile, information

Towards Autonomous Vehicles

http://iLab.usc.edu

http://beobots.org

Interacting Agents

Lane Keeping Agent (LKA)

- Goals: Stay in current lane
- Percepts: Lane center, lane boundaries
- Sensors: Vision
- Effectors: Steering Wheel, Accelerator, Brakes
- Actions: Steer, speed up, brake
- Environment: Freeway

Interacting Agents

Collision Avoidance Agent (CAA)

- Goals: Avoid running into obstacles
- Percepts: Obstacle distance, velocity, trajectory
- Sensors: Vision, proximity sensing
- Effectors: Steering Wheel, Accelerator, Brakes, Horn, Headlights
- Actions: Steer, speed up, brake, blow horn, signal (headlights)
- Environment: Freeway

Conflict Resolution by Action Selection Agents

- **Override:** CAA overrides LKA
- **Arbitrate:** if Obstacle is Close then CAA
  else LKA
- **Compromise:** Choose action that satisfies both agents
- Any combination of the above
- **Challenges:** Doing the right thing

The Right Thing = The Rational Action

- **Rational Action:** The action that maximizes the expected value of the performance measure given the percept sequence to date
  - Rational = Best ?
  - Rational = Optimal ?
  - Rational = Omniscience ?
  - Rational = Clairvoyant ?
  - Rational = Successful ?

The Right Thing = The Rational Action

- **Rational Action:** The action that maximizes the expected value of the performance measure given the percept sequence to date
  - Rational = Best Yes, to the best of its knowledge
  - Rational = Optimal Yes, to the best of its abilities (incl. its constraints)
  - Rational ≠ Omniscience
  - Rational ≠ Clairvoyant
  - Rational ≠ Successful

Behavior and performance of IAs

- **Perception** (sequence) to **Action Mapping:** $f : \mathcal{P}^* \rightarrow \mathcal{A}$
  - **Ideal mapping:** specifies which actions an agent ought to take at any point in time
  - **Description:** Look-Up-Table vs. Closed Form

- **Performance measure:** a *subjective* measure to characterize how successful an agent is (e.g., speed, power usage, accuracy, money, etc.)

- (degree of) **Autonomy:** to what extent is the agent able to make decisions and actions on its own?

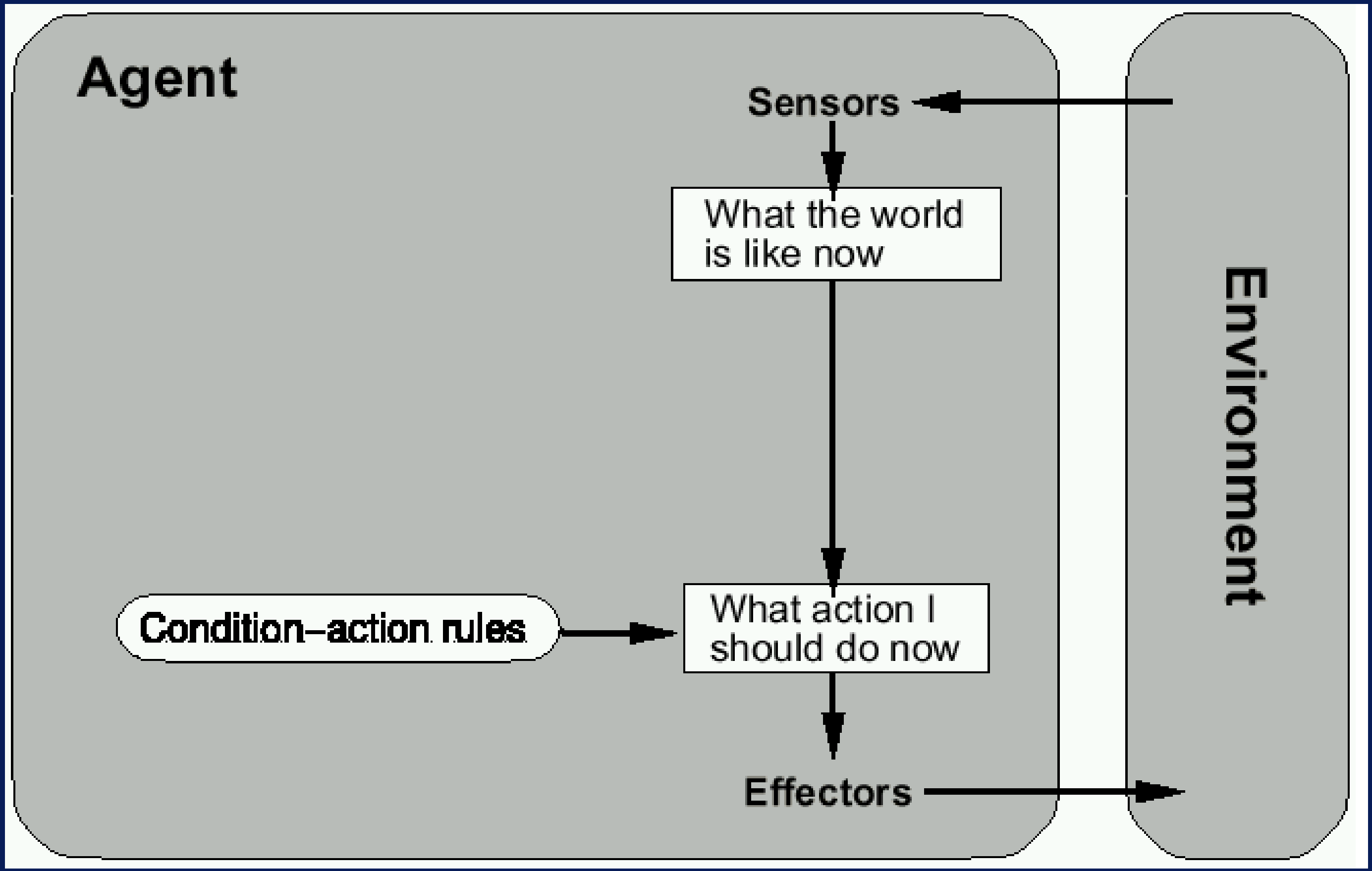
How is an Agent different from other software?

- Agents are **autonomous**, that is they act on behalf of the user
- Agents contain some level of **intelligence**, from fixed rules to learning engines that allow them to adapt to changes in the environment
- Agents don't only act **reactively**, but sometimes also **proactively**
- Agents have **social ability**, that is they communicate with the user, the system, and other agents as required
- Agents may also **cooperate** with other agents to carry out more complex tasks than they themselves can handle
- Agents may **migrate** from one system to another to access remote resources or even to meet other agents

Agent types

- Reflex agents
- Reflex agents with internal states
- Goal-based agents
- Utility-based agents

Reflex agents

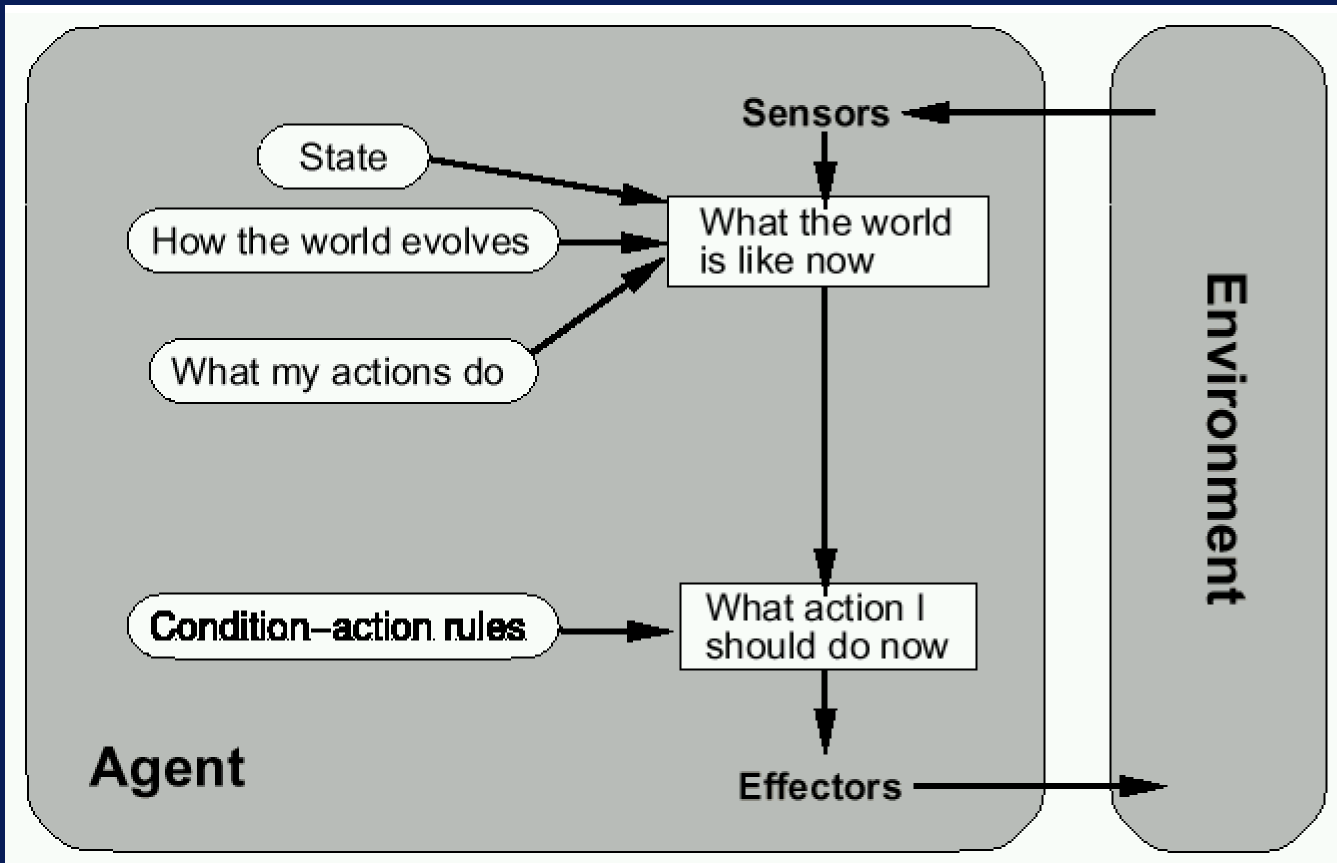


Reactive agents

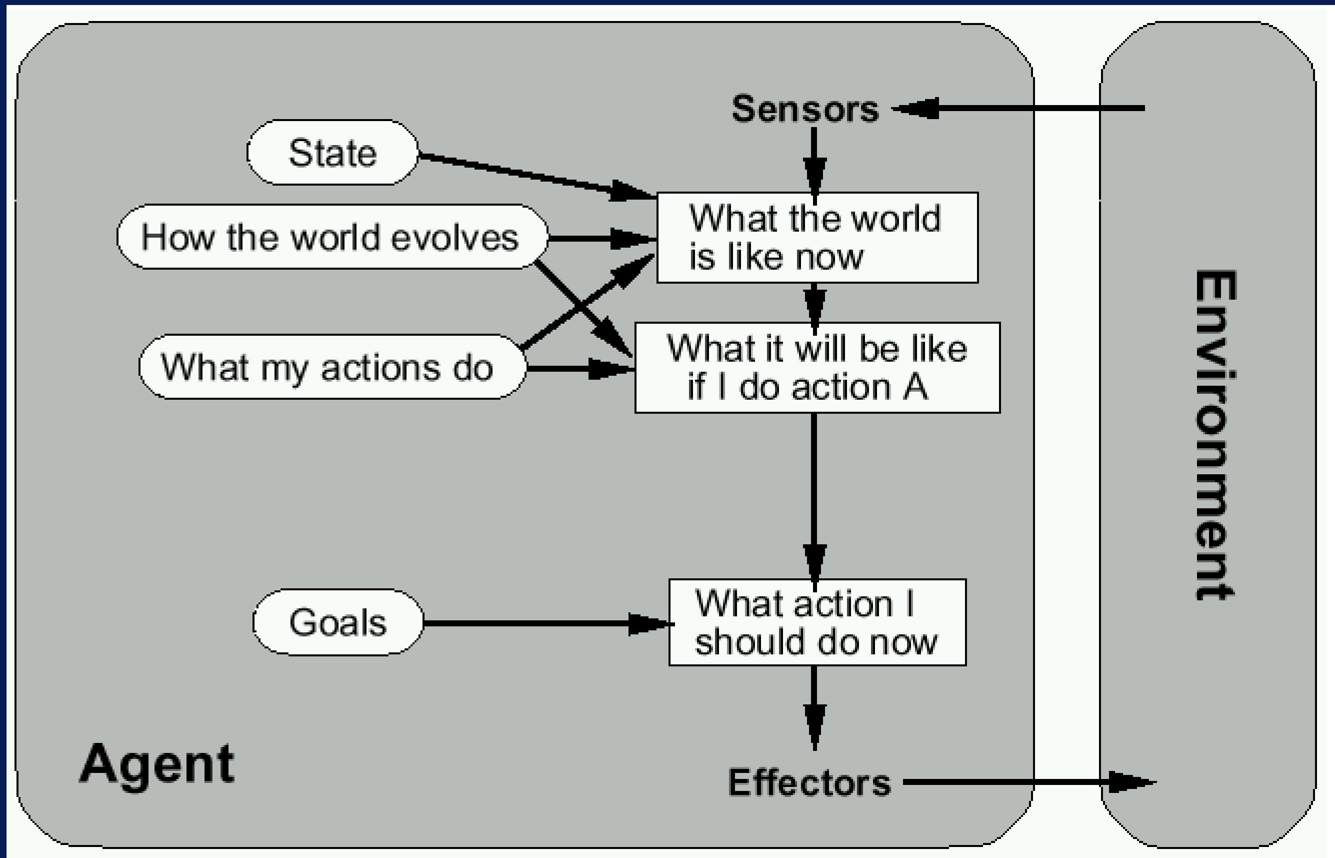
- Reactive agents do not have internal symbolic models.
- Act by stimulus-response to the current state of the environment.
- Each reactive agent is simple and interacts with others in a basic way.
- Complex patterns of behavior emerge from their interaction.

- **Benefits:** robustness, fast response time
- **Challenges:** scalability, how intelligent?
  and how do you debug them?

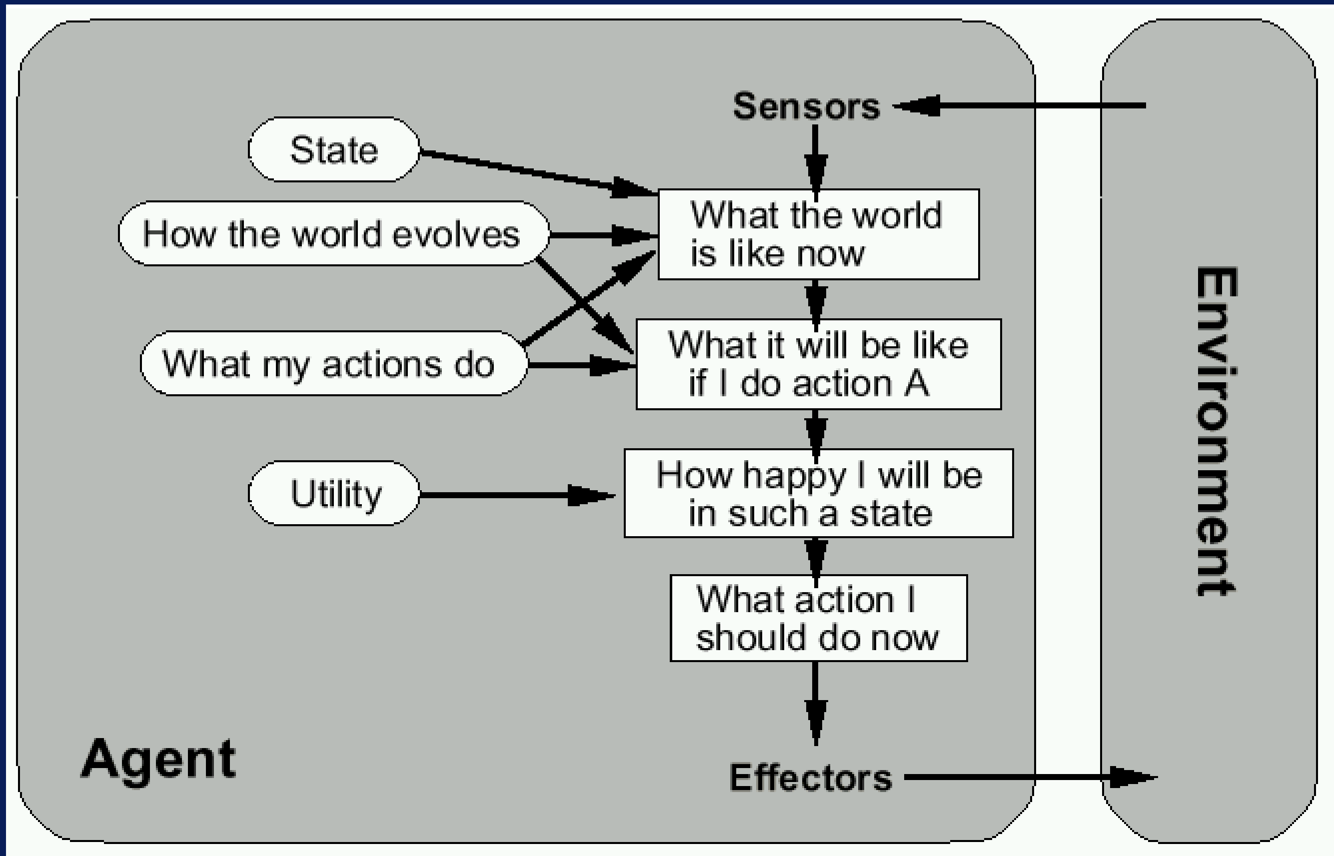
Reflex agents w/ state

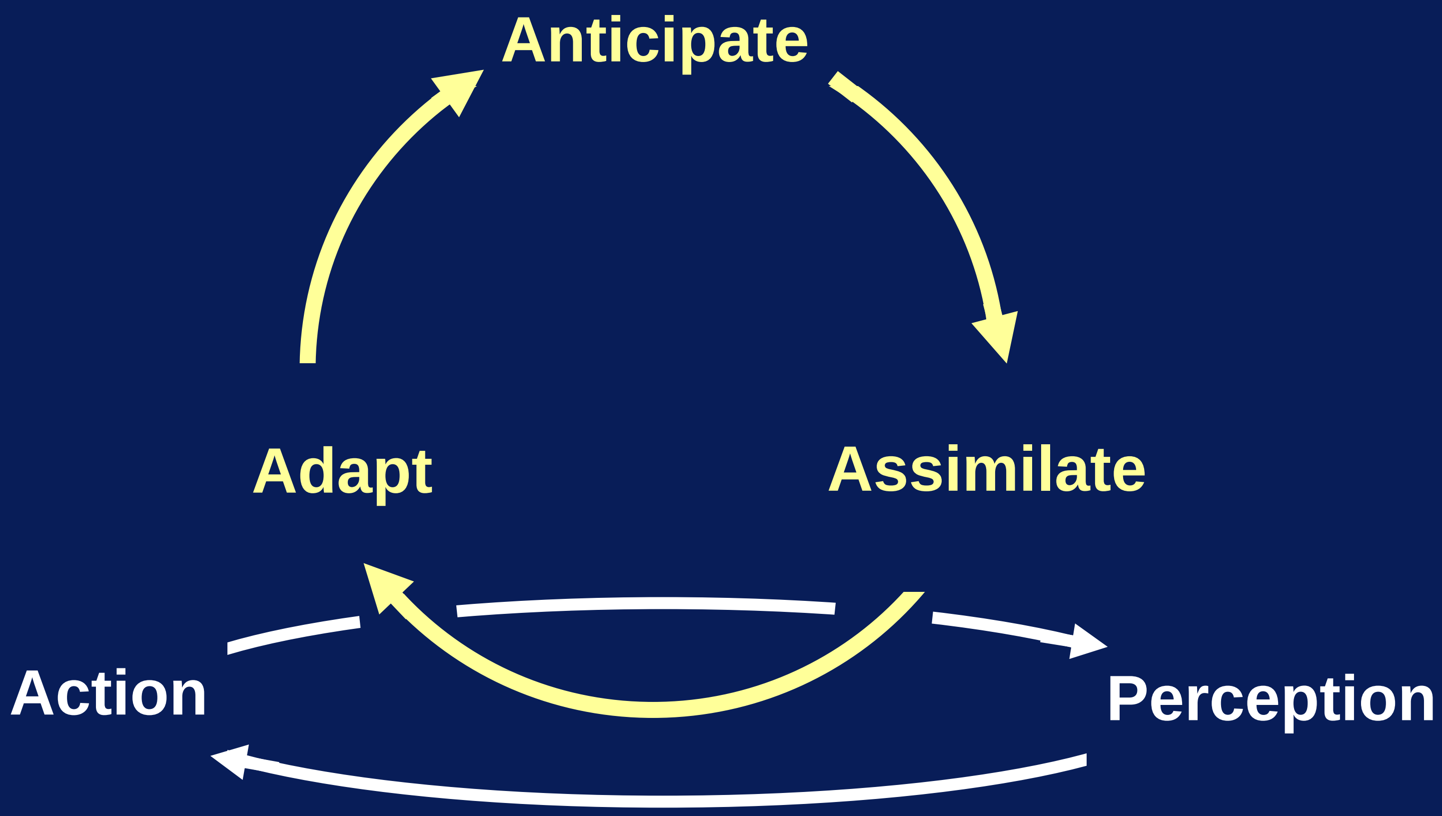


Goal-based agents



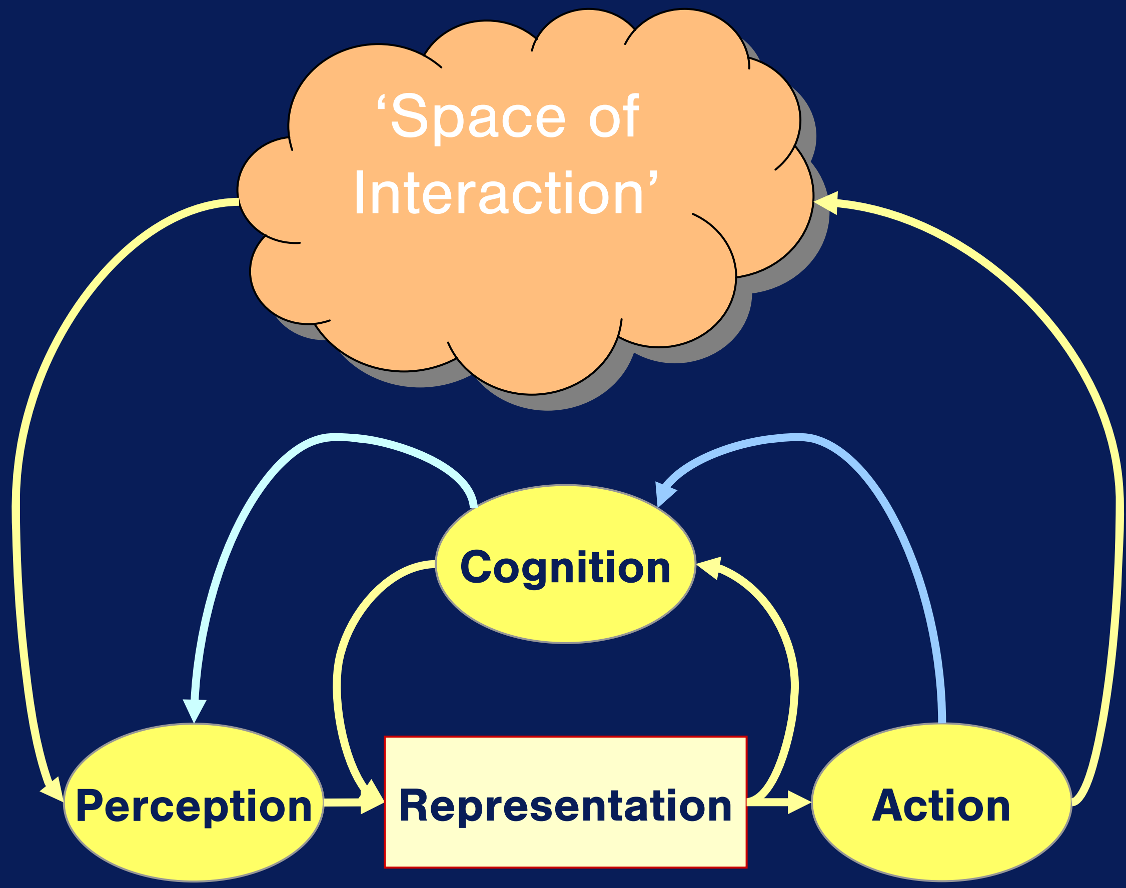
Utility-based agents

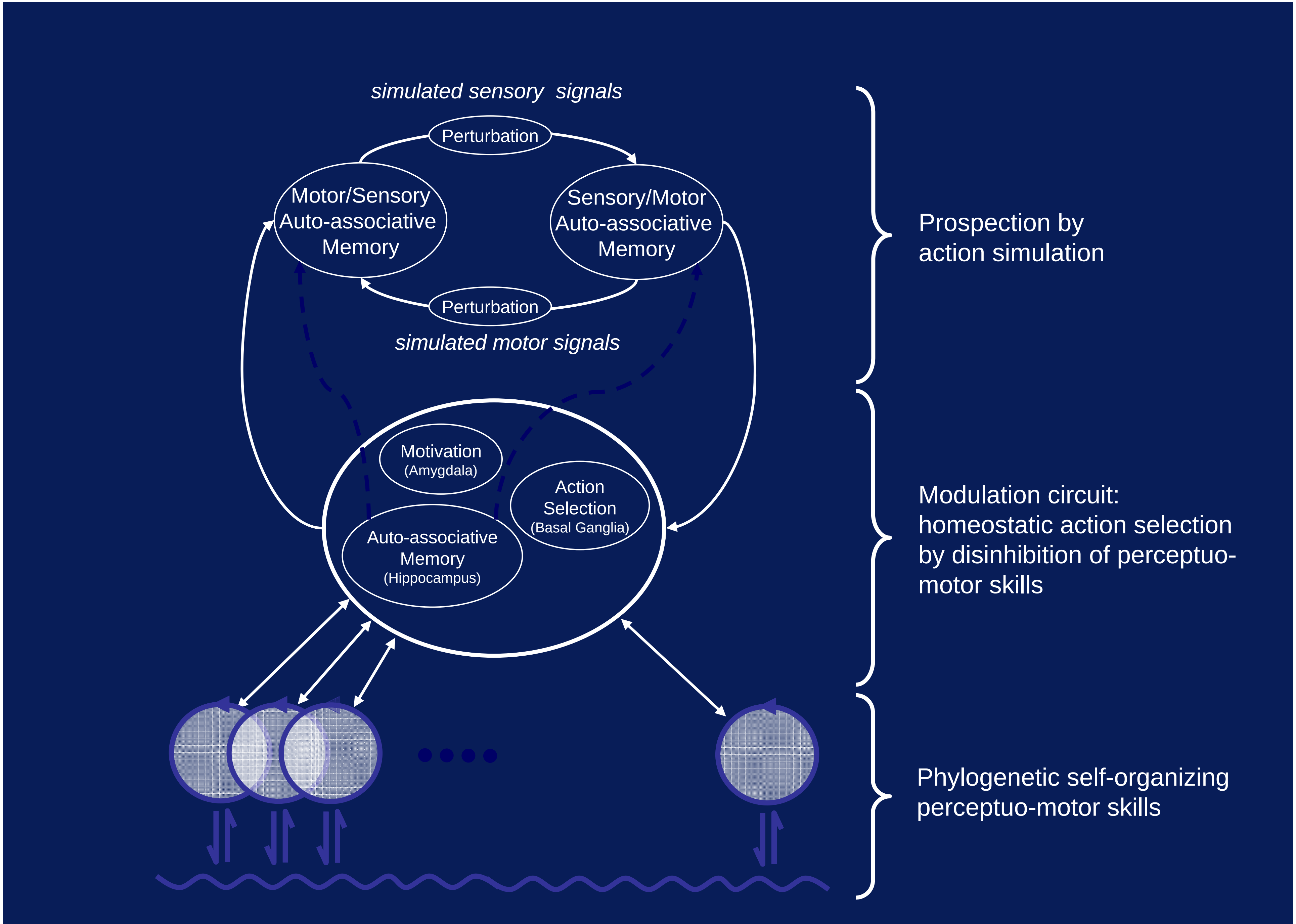




Cognition

But there is a long way to go yet …




simulated sensory signals
Perturbation
Motor/Sensory Auto-associative Memory
Sensory/Motor Auto-associative Memory
Perturbation
simulated motor signals
Motivation (Amygdala)
Action Selection (Basal Ganglia)
Auto-associative Memory (Hippocampus)
Prospection by action simulation
Modulation circuit: homeostatic action selection by disinhibition of perceptuo-motor skills
Phylogenetic self-organizing perceptuo-motor skills