What Is a Robot?

- “An autonomous system which exists in the physical world, can sense its environment, and can act on it to achieve some goals”

—Maja Matarić

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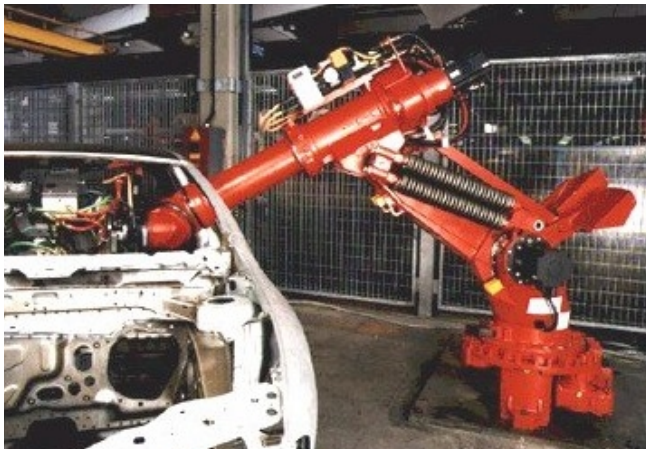
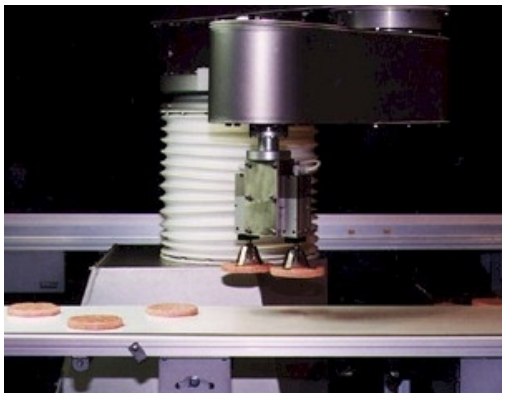
Robots Have Many Uses

Welding



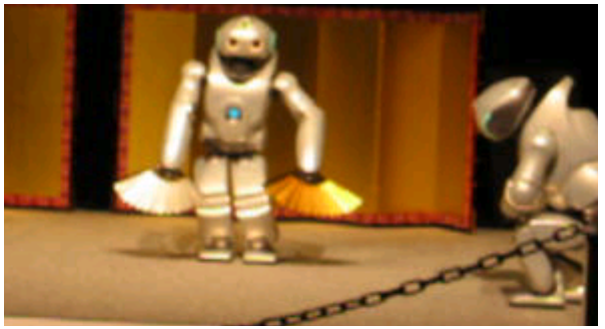
Assembly

Pumping gas



Packaging

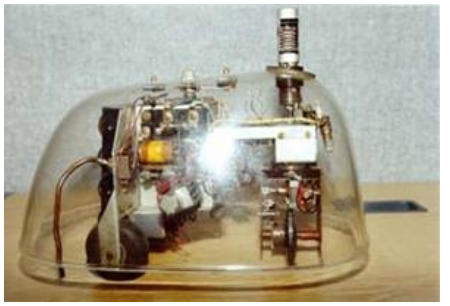
Eating cars

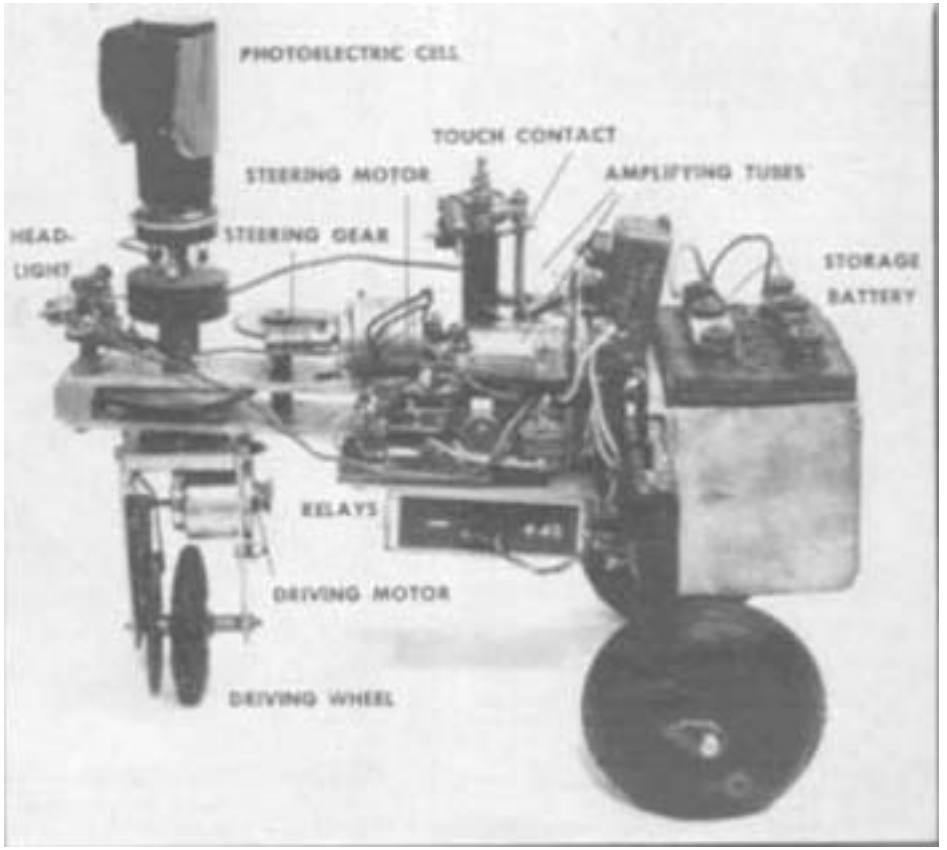


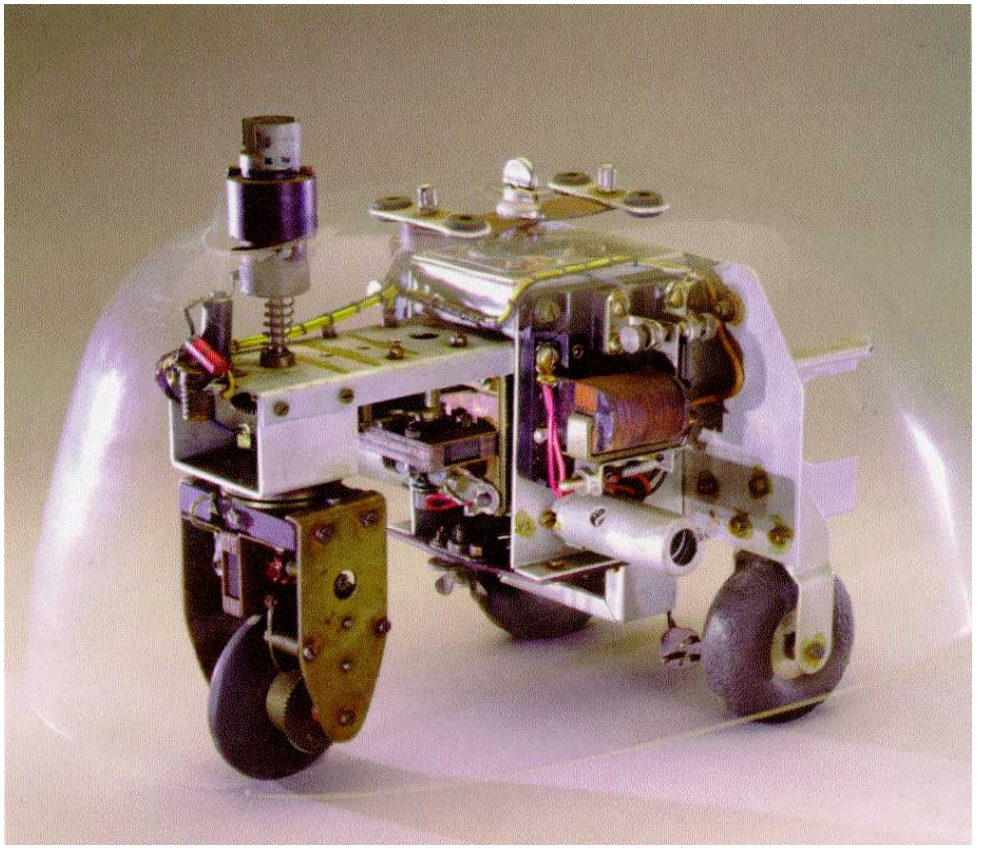
Dancing

Some Early Robots

- W. Grey Walter's **Tortoises** (1950's)







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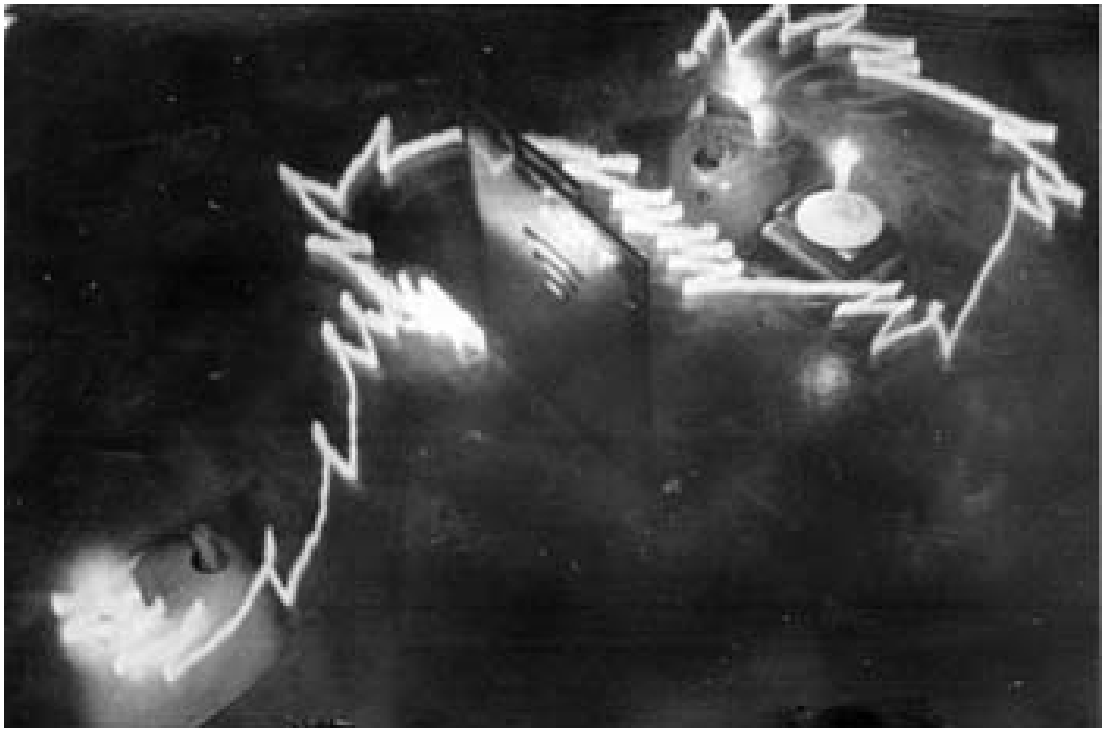
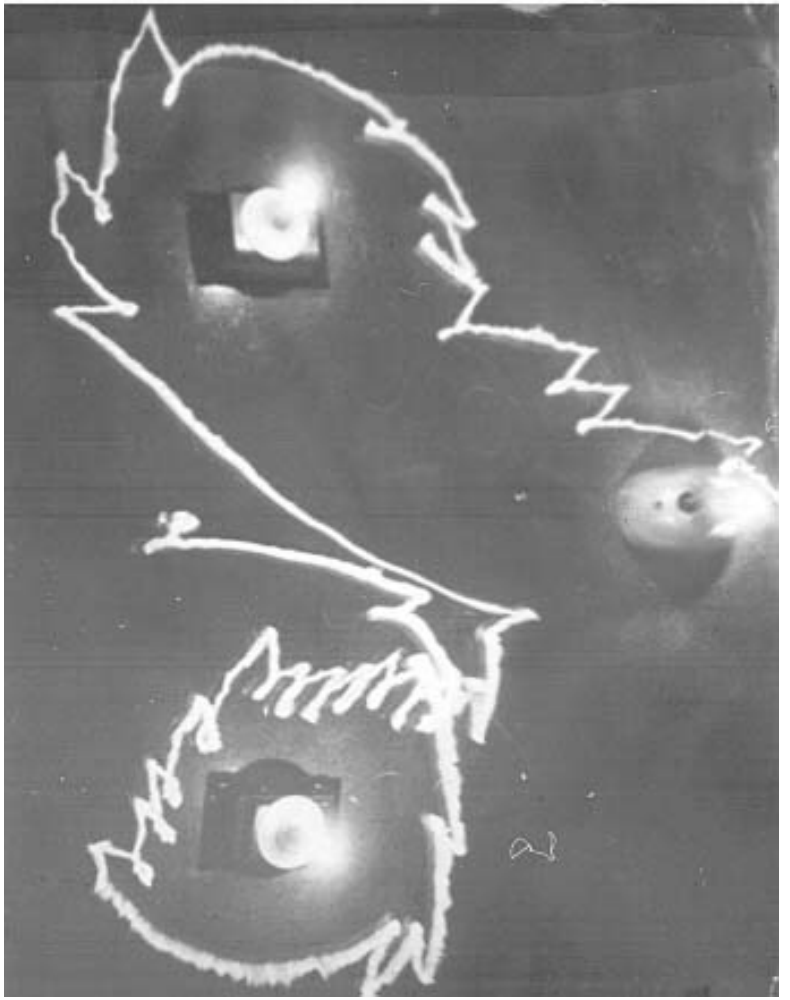
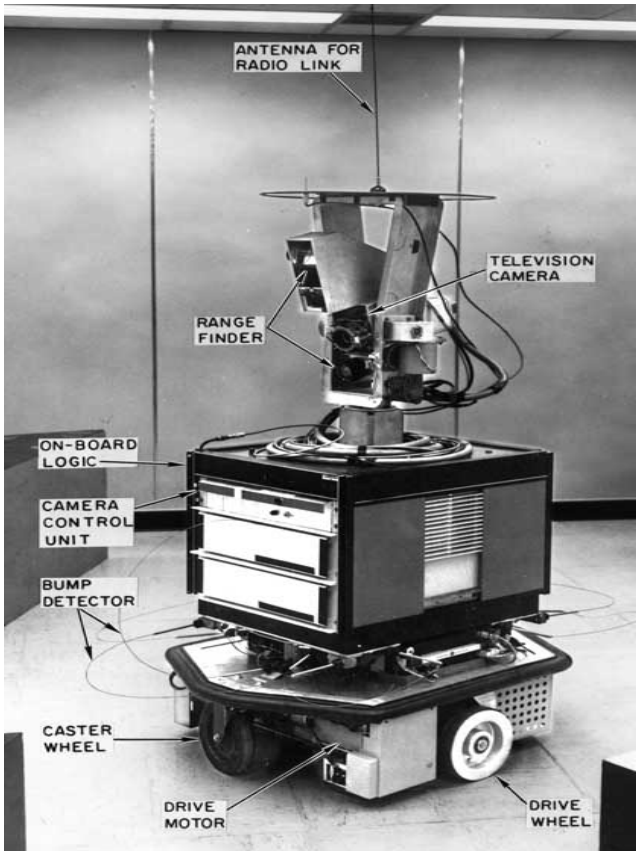




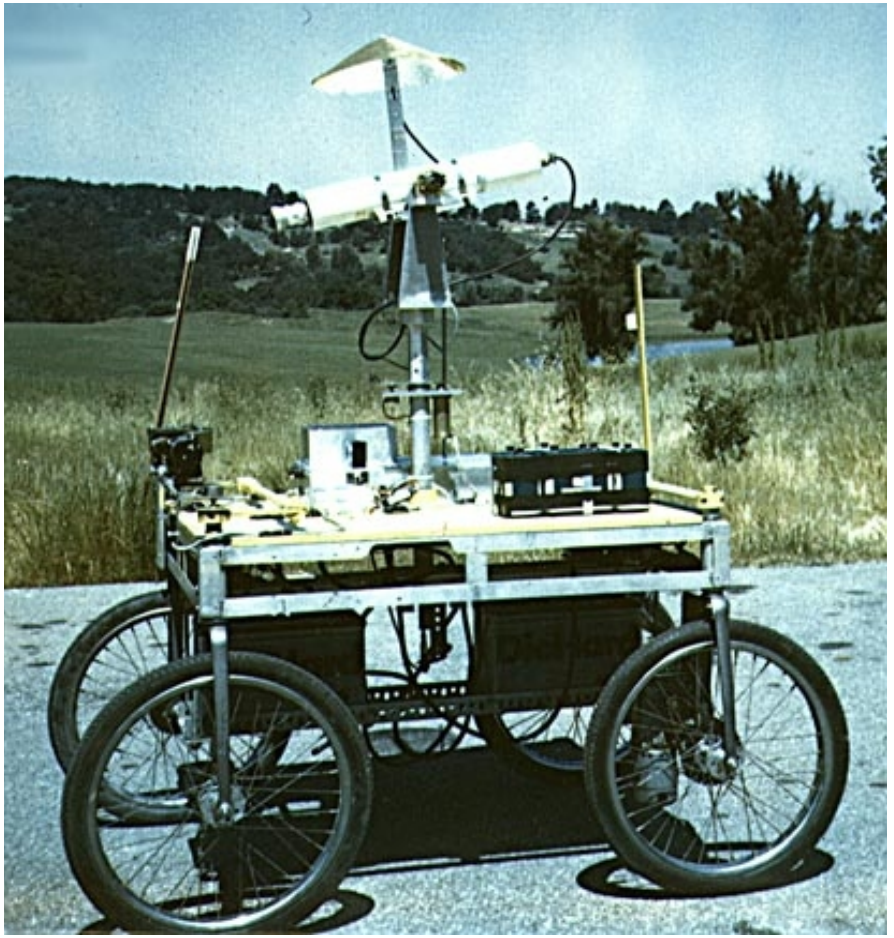
Some Early Robots

- **Shakey**
- Developed at Stanford (1969)
- Bump sensors
- Camera
- Lived in a special indoor world with a white floor and black objects (balls, pyramids, etc.)



Some Early Robots

- **Stanford Cart** (1977)
- Developed by Hans Moravec
- Vision-based navigation
- Path planning
- Operated in “Cartland”

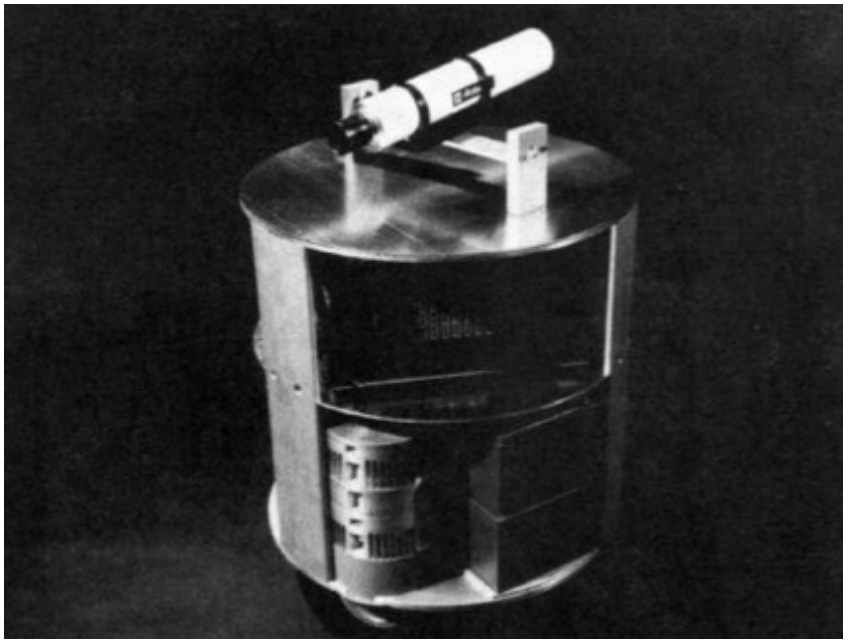


Cartland

Cartland

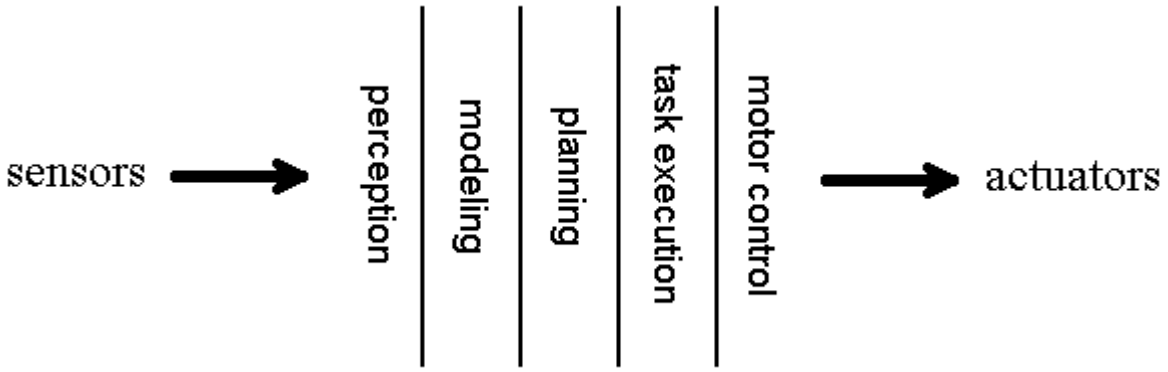
Some Early Robots

- **CMU Rover** (1983)
- Developed by Hans Moravec at CMU
- Camera and ultrasound sensors
- Navigation and path planning



Traditional Robotics

- Knowledge-based approach
- Maintain an accurate internal model of the world
- “Sense ⇒ model ⇒ plan ⇒ action” cycle
- Poor performance in real-time complex environments
- Complex behavior results from complex internal algorithms
- Traditional task decomposition:

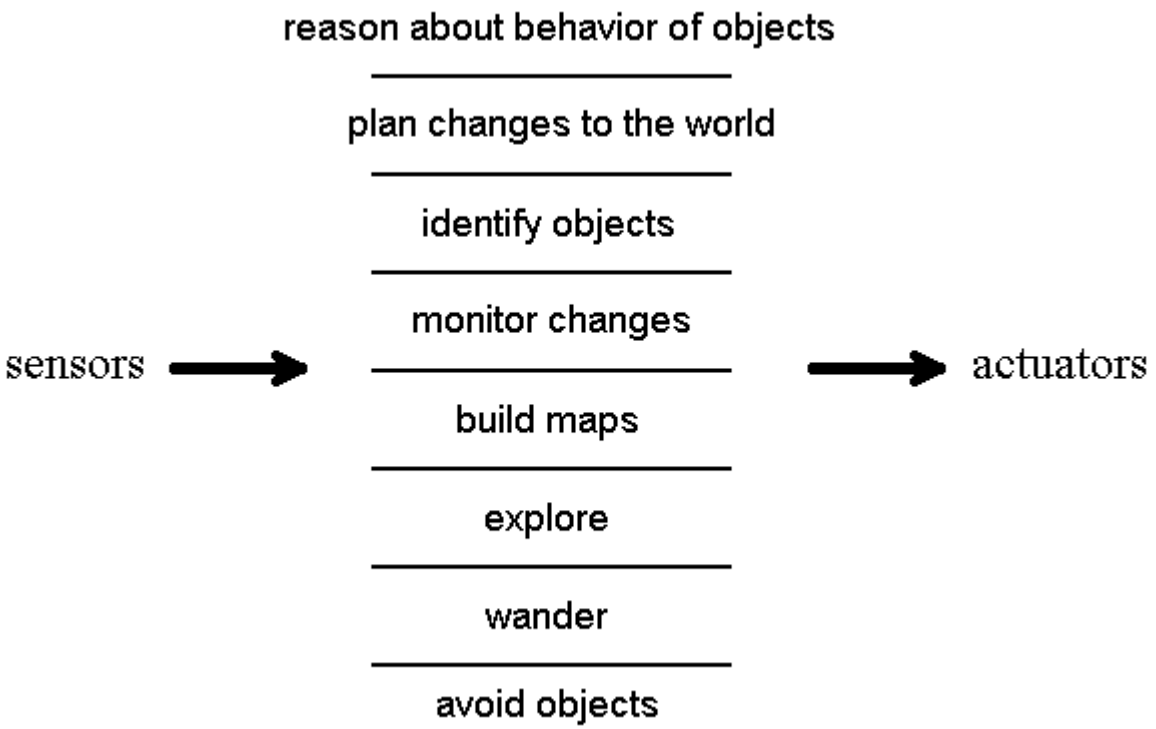


Behavior-Based Robotics

- No explicit internal representations
- “The world is its own model”
- Direct sensory-motor couplings
- Distributed, decentralized organization
- Good performance in real-time complex environments
- Complex behavior emerges from interactions between simple internal processes and the environment

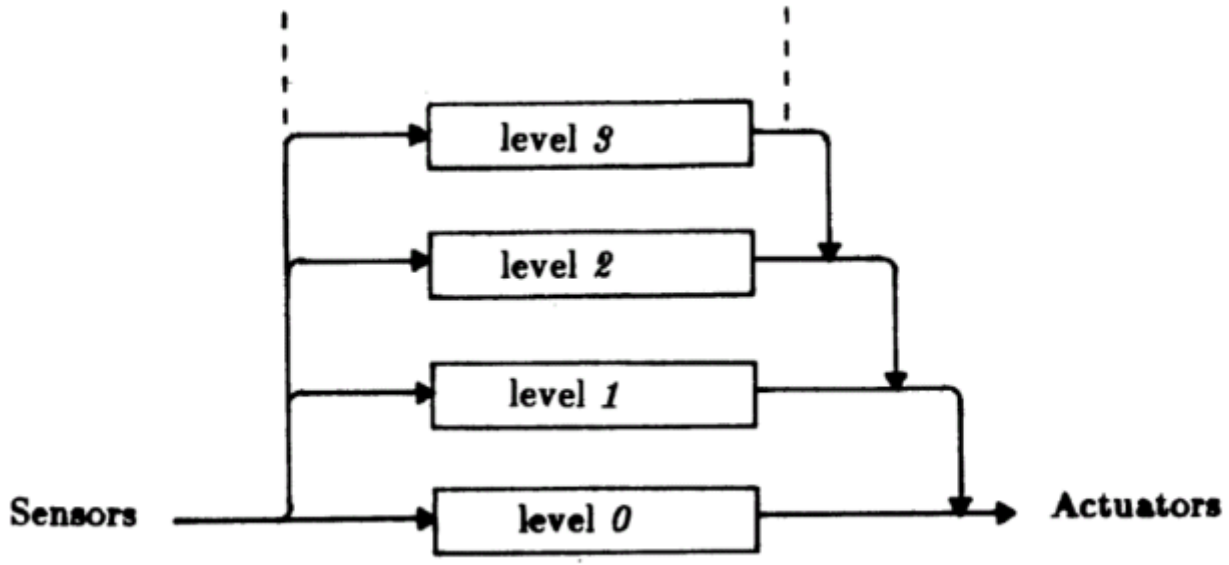
Behavior-Based Robotics

- Behavior-based task decomposition:



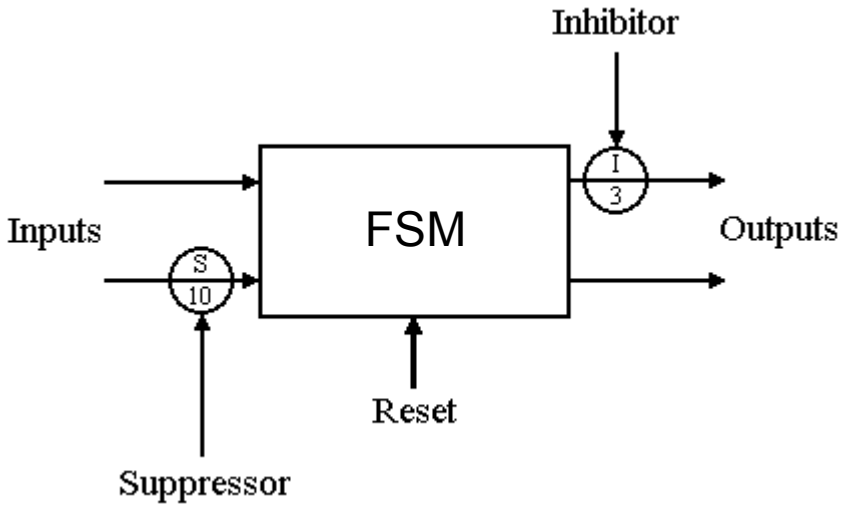
Subsumption Architecture

- Layers of control
- Incremental, evolutionary approach
- Suppression and inhibition of control signals between layers



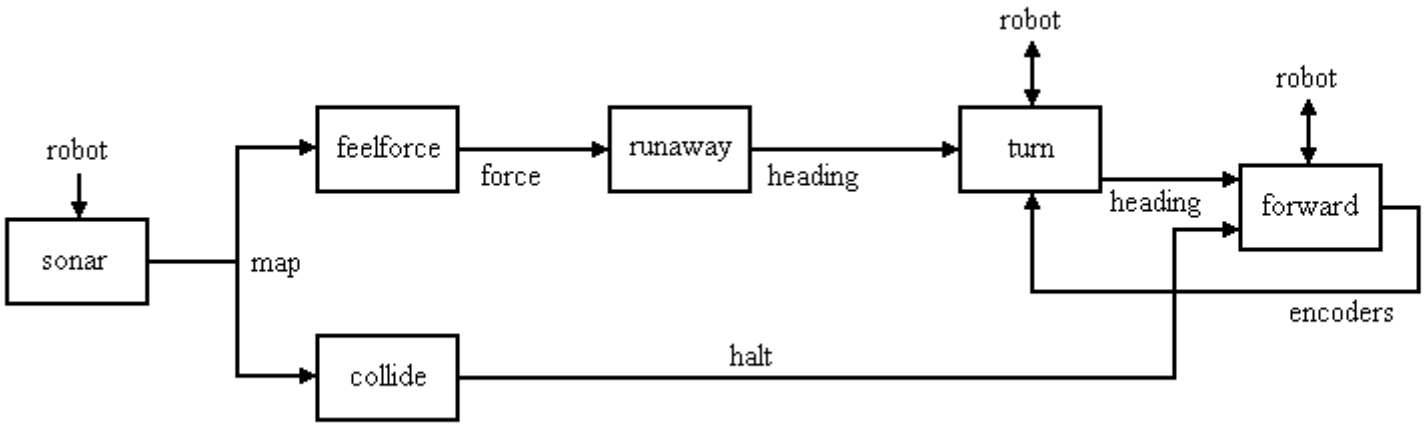
Subsumption Architecture

- Layers consist of collections of Finite State Machines

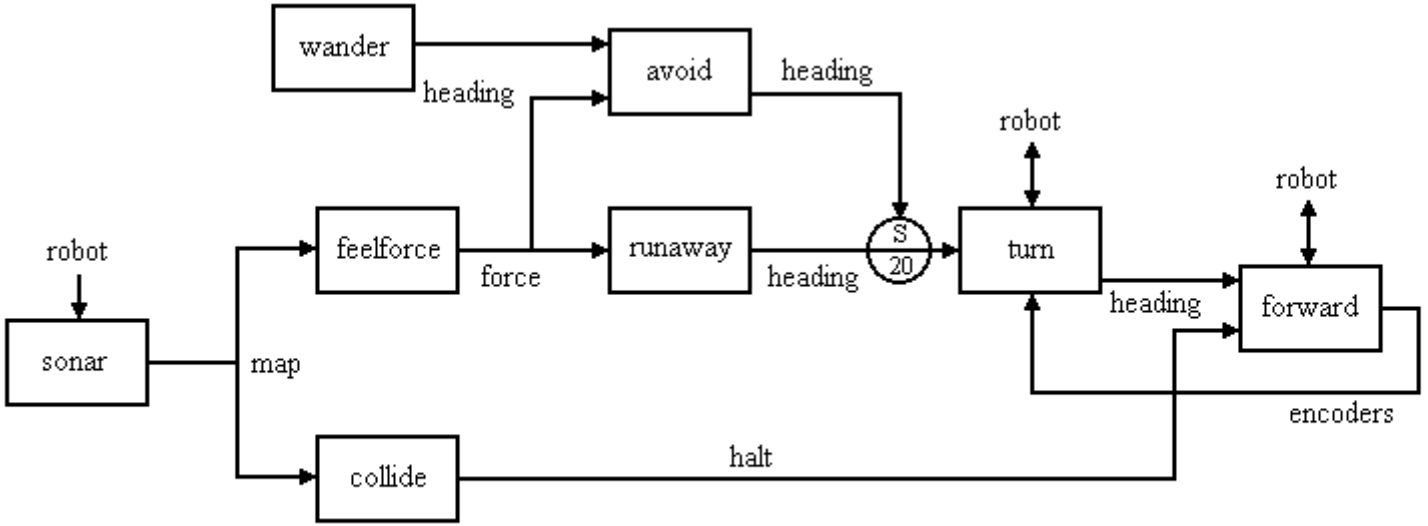


- Example: explore environment, seek out “interesting” places while avoiding obstacles
  - Layer 0: avoid obstacles
  - Layer 1: wander around aimlessly
  - Layer 2: seek out interesting places

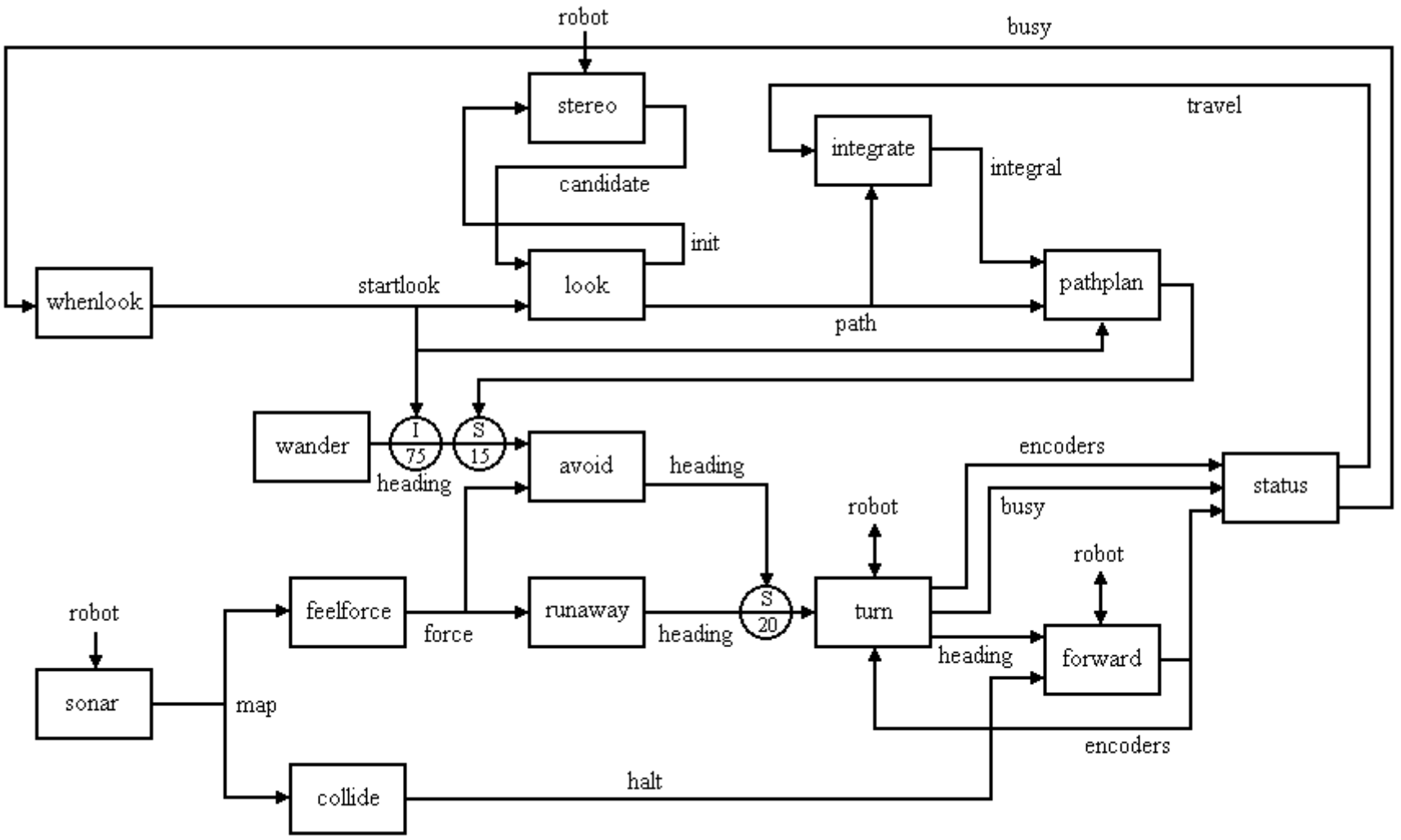
Layer 0: Avoid obstacles



Layer 1: Wander around aimlessly



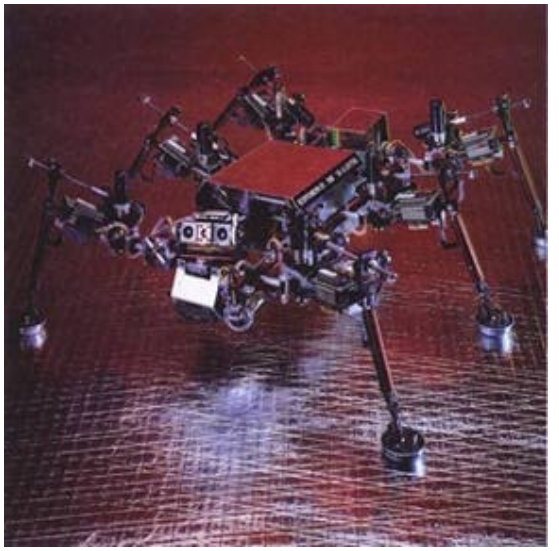
Layer 2: Seek out interesting places

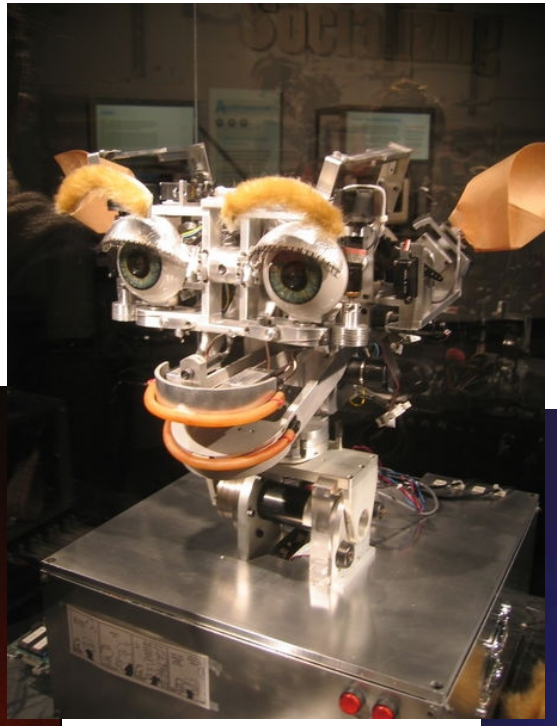


Some Famous Behavior-Based Robots

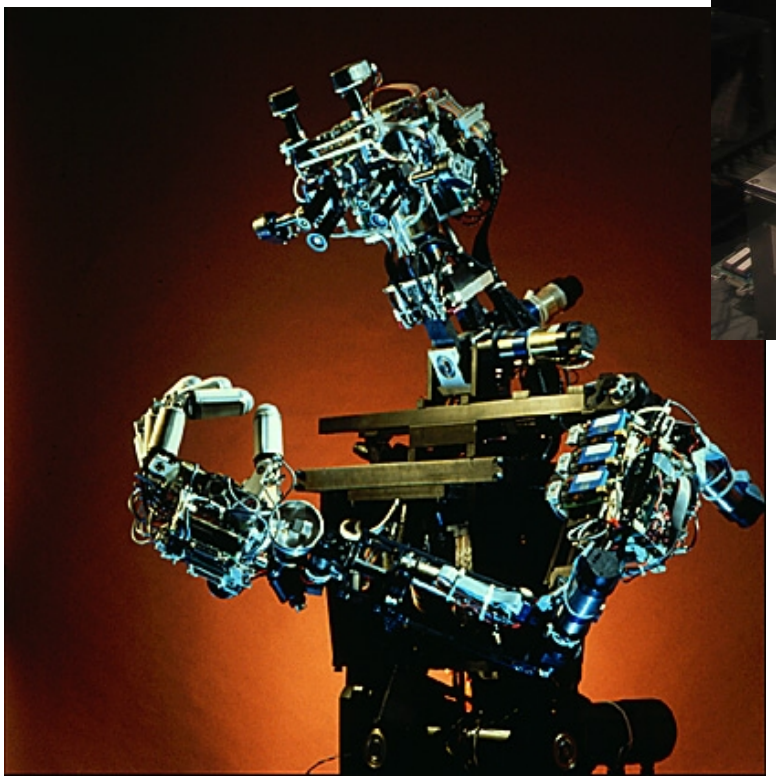
Genghis

Hannibal





Kismet



COG

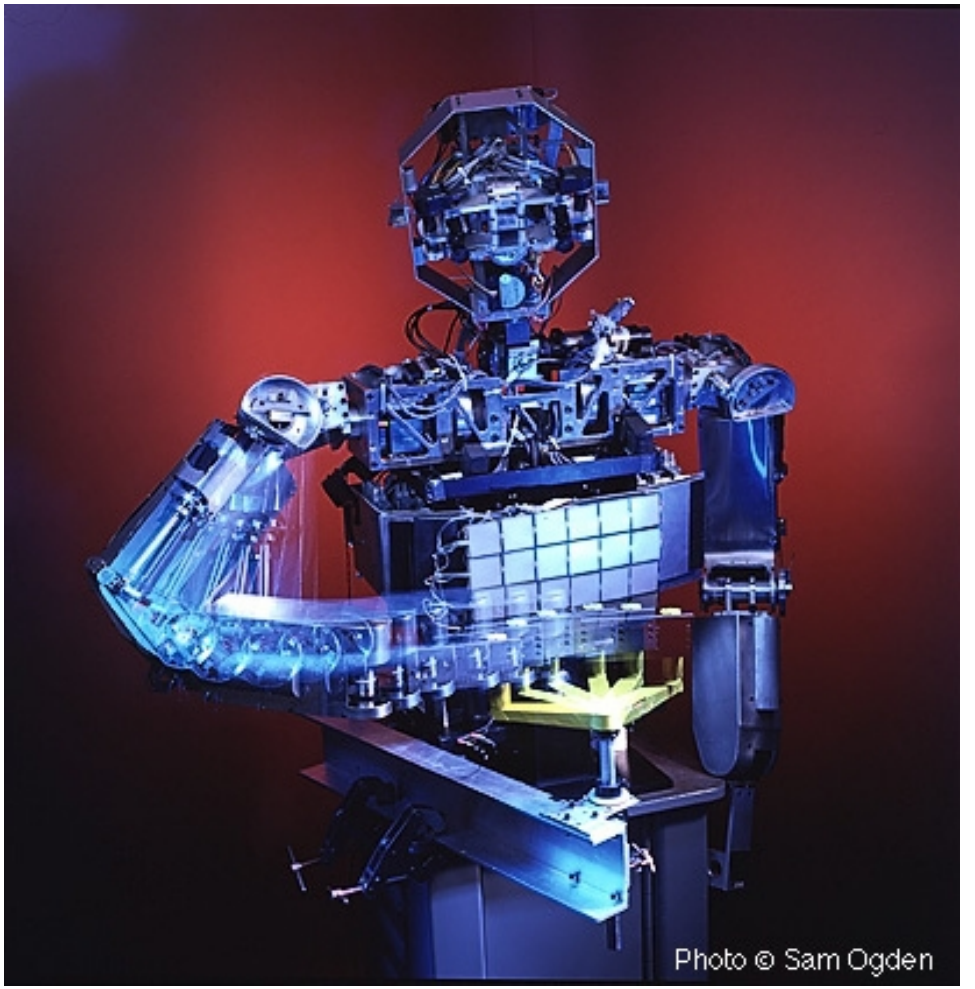
Behavior-Based Robotics

- Rodney Brooks and students, MIT (1980s)
- Distributed, parallel architecture
- Emergent behaviors

Genghis

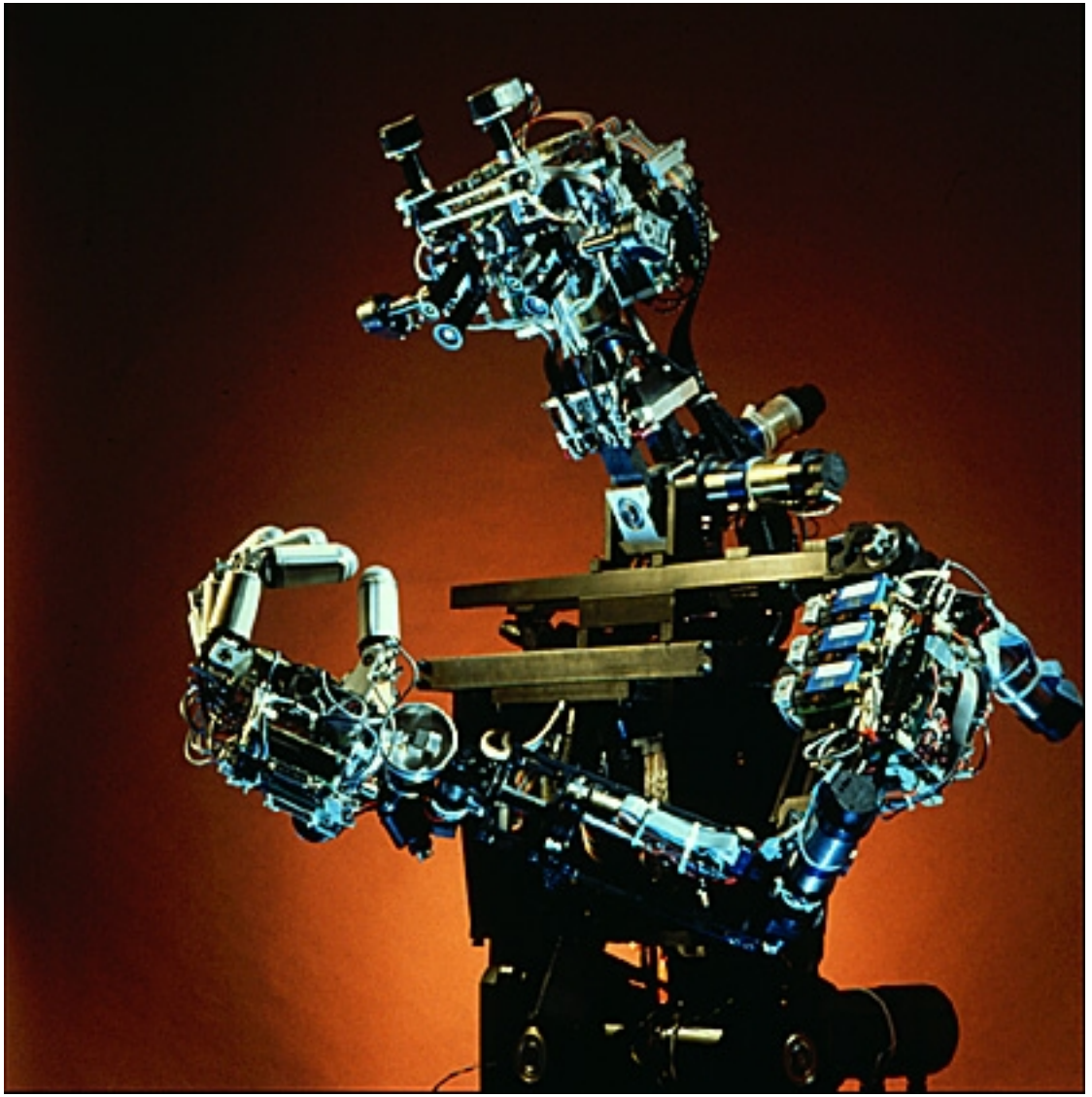
Hannibal

The Cog Project



(Rodney Brooks, MIT)

The Cog Project



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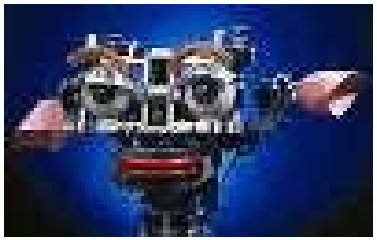

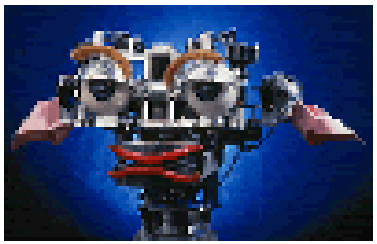

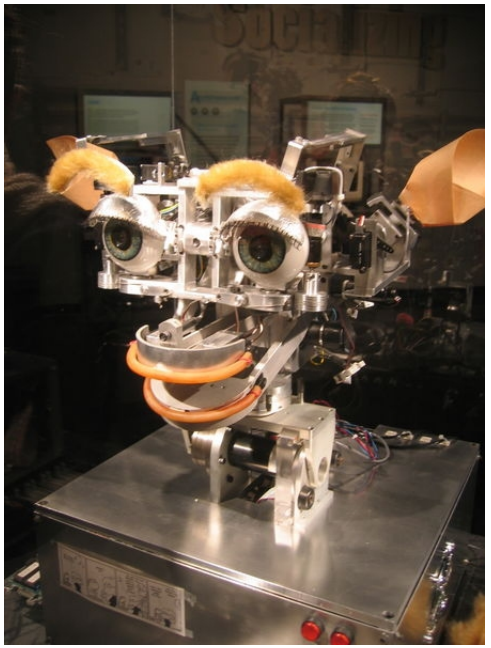

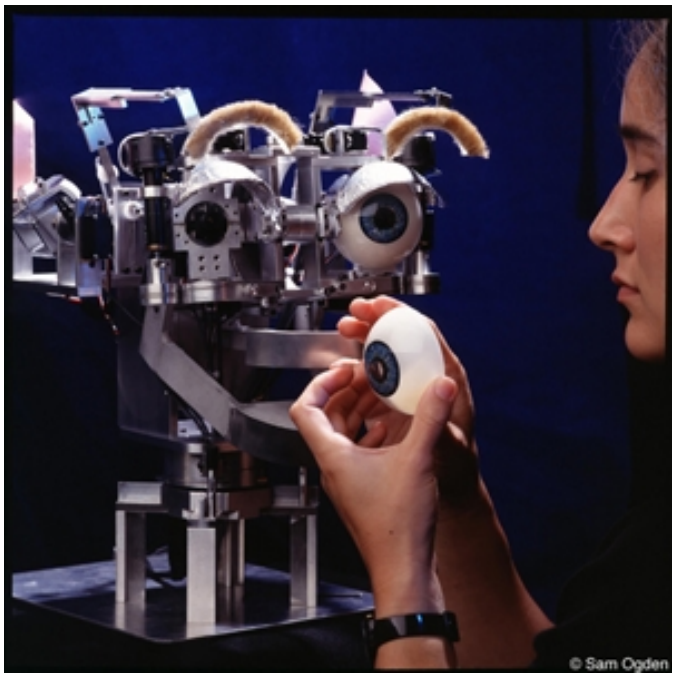

(Rodney Brooks, Cynthia Breazeal, MIT)

Roomba Vacuuming Robot

(Rodney Brooks, iRobot Corporation)