ROBOTICS

What are Robots?

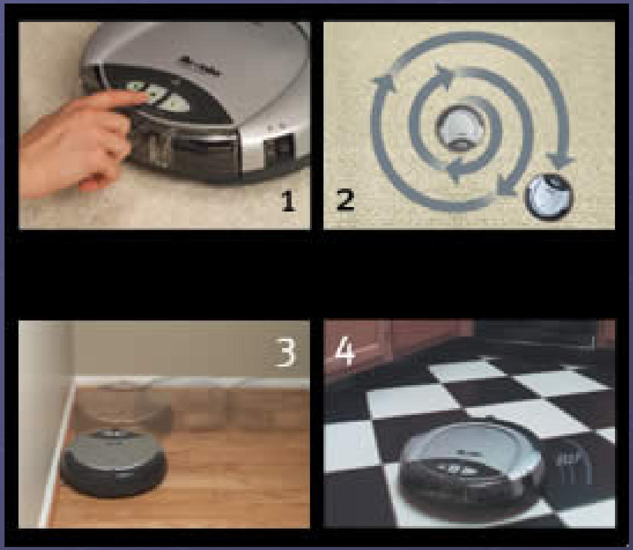
- Objectives
  - Define Intelligent Robot
  - Be able to list the four modalities of autonomous (unmanned) vehicles and the five components common to all autonomous systems
  - Be able to describe at least two differences between AI and Engineering approaches to robotics
  - Define and describe the difference between automation and autonomy
  - List the seven areas of Artificial Intelligence
  - List the three primitives of robot paradigms and express the three paradigms of robotics in terms of these primitives

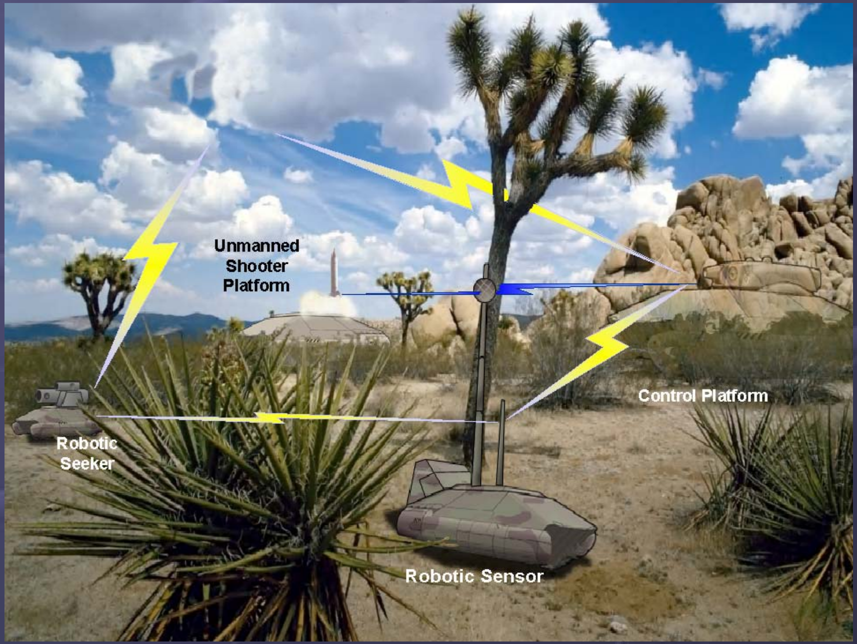
Intelligent Robot

- Mechanical creature which can function autonomously
- *Mechanical*= built, constructed
  - *Creature*= think of it as an entity with its own motivation, decision making processes
  - *Function autonomously*= can sense, act, maybe even reason; doesn’t just do the same thing over and over like *automation*

Why Robots?
Dirty, Dangerous, Dull Tasks

- JV2010, TRADOC, JFCOM, all branches even down to the organic level
  - Reconnaissance, MOUT, denial of area, consequence management, logistics, demining





Replace Humans with Robots

Why Robots?
Better Than Bio

- Robots at WTC…
  - voids smaller than person could enter
  - voids on fire or oxygen depleted

- NBC Response
  - Lose ½ cognitive attention with each level of protection
    - L
      normal ability

Do Things that Living Things Can’t

4 Major Robot Modalities

- Unmanned Ground Vehicles
  - since 1967
- Unmanned Aerial Vehicles
  - drones since Vietnam: Global Hawk, UCAV
- Unmanned Underwater Vehicles or Autonomous Underwater Vehicles
  - ROVs since 1960s
- Unmanned Surface Vehicles

All Have 5 Common Components

- **Mobility: *legs, arms, neck, wrists***
  - Platform, also called "effectors"
- **Perception: *eyes, ears, nose, smell, touch***
  - Sensors and sensing
- **Control: *central nervous system***
  - Inner loop and outer loop; layers of the brain
- **Power: *food and digestive system***
- **Communications: *voice, gestures, hearing***
  - How does it communicate (I/O, wireless, expressions)
  - What does it say?

CLASSIFICATION OF ROBOTS

LEVEL OF TECHNOLOGY

LOW TECH : NON SERVO
SIMPLE CONTROLS
PICK & PLACE OPERATIONS

MEDIUM TECH : MICROPROCESSOR CONTROL
SOPHISTICATED FEEDBACK
MOST WIDELY USED

HIGH TECH : STATE OF ART TECH
COMPLEX FEEDBACK
EXTREMELY FLEXIBLE

DESIRED FEATURES

SENSE

COMMUNICATION

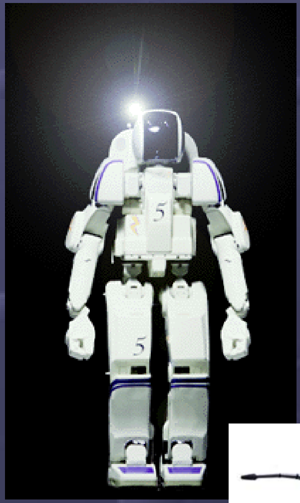
PARALLELISM

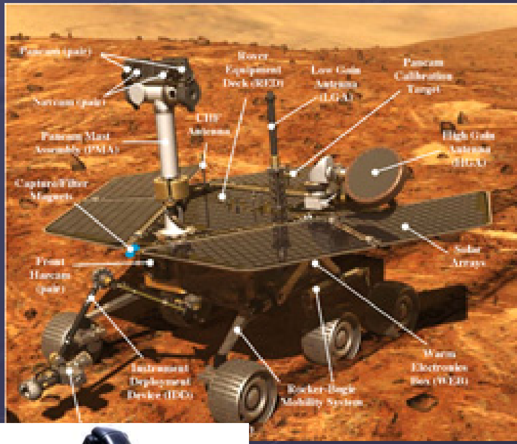
COLLISION AVOIDANCE

CONDITION MONITORS

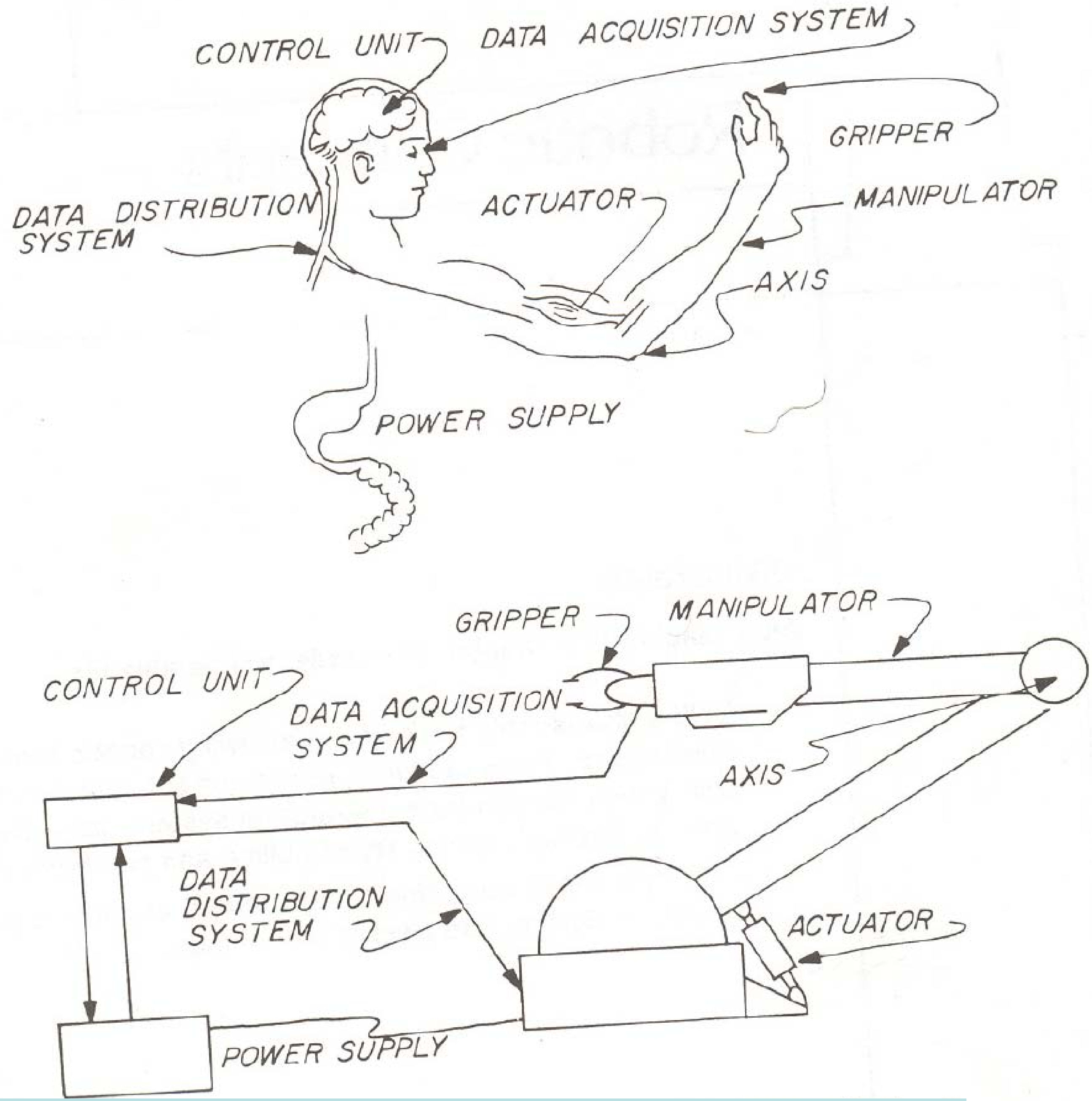
Unmanned Ground Vehicles

- Three categories:
  - Mobile
  - Humanoid/animal
  - Motes





- Famous examples
  - DARPA Grand Challenge
  - NASA MER
  - Roomba
  - Honda P3, Sony Asimo
  - Sony Aibo

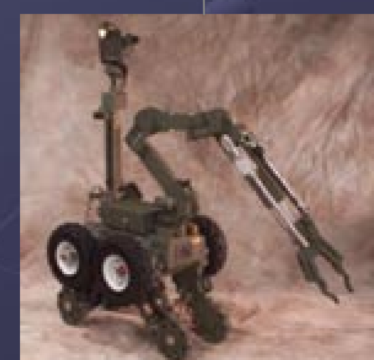


ANATOMY OF A ROBOT

Taxonomy of Mobile Robots

Ground

- Humanoid, Animals
- Mobile
  - Man-packable
  - Man-portable
  - Maxi
- Motes

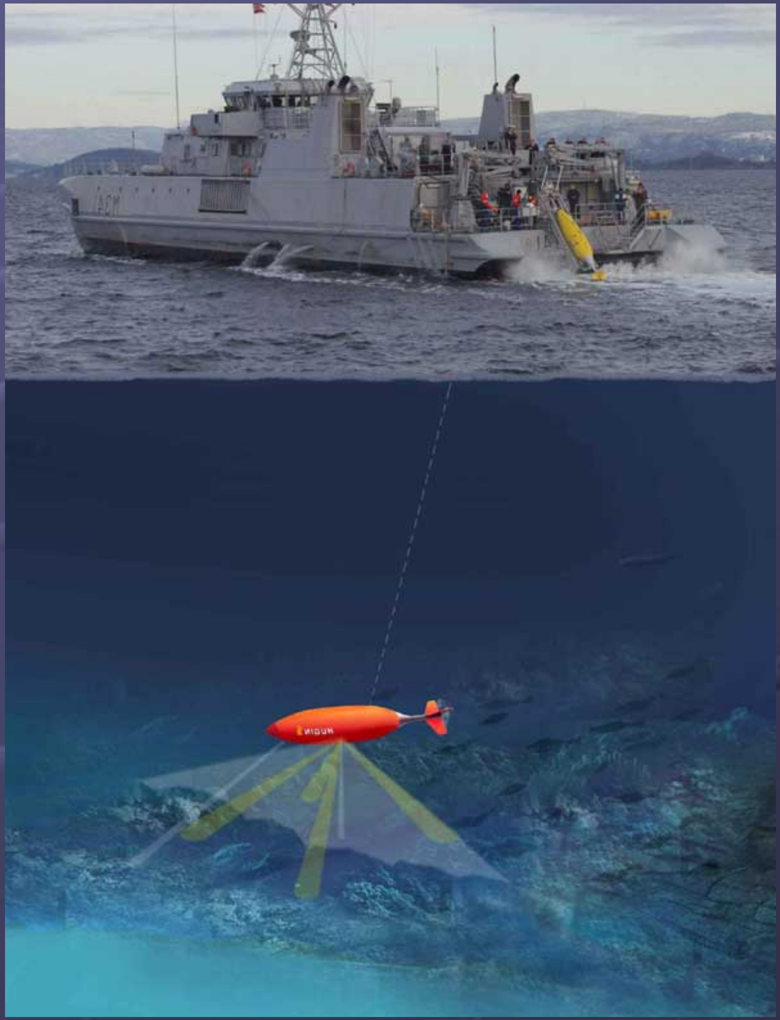


Unmanned Aerial Vehicles

- Three categories:
  - Fixed wing
  - VTOL
  - Micro aerial vehicle (MAV), which can be either fixed wing or VTOL
- Famous examples
  - Global Hawk
  - Predator
  - UCAV

Autonomous Underwater Vehicles

- Categories
  - Remotely operated vehicles (ROVs), which are tethered
  - Autonomous underwater vehicles, which are free swimming
- Examples
  - Persephone
  - Jason (Titanic)
  - Hugin



Unmanned Surface Vehicles

- Categories
  - Air-breathing submersible
  - Jet-ski based
  - Rigid Inflatable Boat based
- Examples
  - USV-S
  - OWL

Why UVs Need AI

- Sensor *interpretation*
  - Bush or Big Rock?, Symbol-ground problem, Terrain interpretation
- Situation awareness/ Big Picture
- Human-robot interaction
- “Open world” and multiple fault diagnosis and recovery
- Localization in sparse areas when GPS goes out
- Handling uncertainty
- Manipulators
- Learning

7 Major Areas of AI

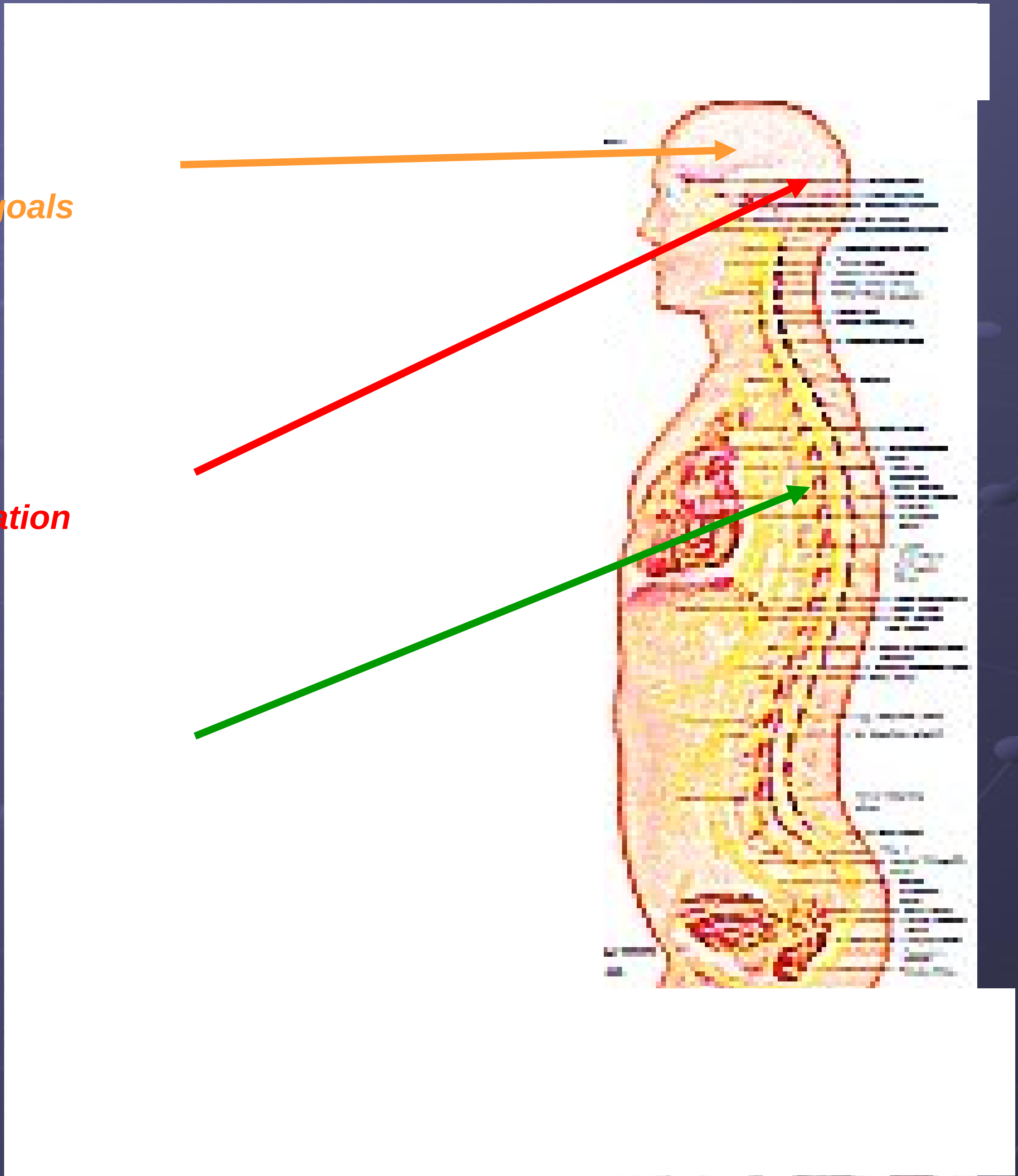
1. Knowledge representation
   - how should the robot represent itself, its task, and the world
2. Understanding natural language
3. Learning
4. Planning and problem solving
   - Mission, task, path planning
5. Inference
   - Generating an answer when there isn't complete information
6. Search
   - Finding answers in a knowledge base, finding objects in the world
7. Vision

Intelligence and the CNS

“Upper brain” or cortex
Reasoning over information about goals

“Middle brain”
Converting sensor data into information

Spinal Cord and “lower brain”
Skills and responses



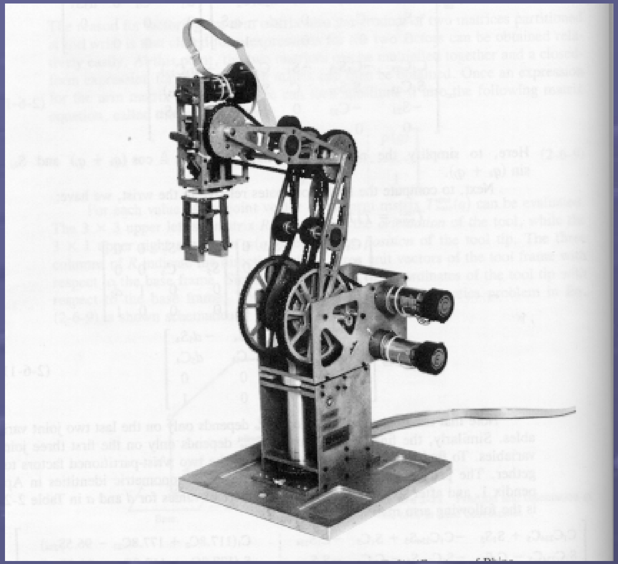
Engineering Approach

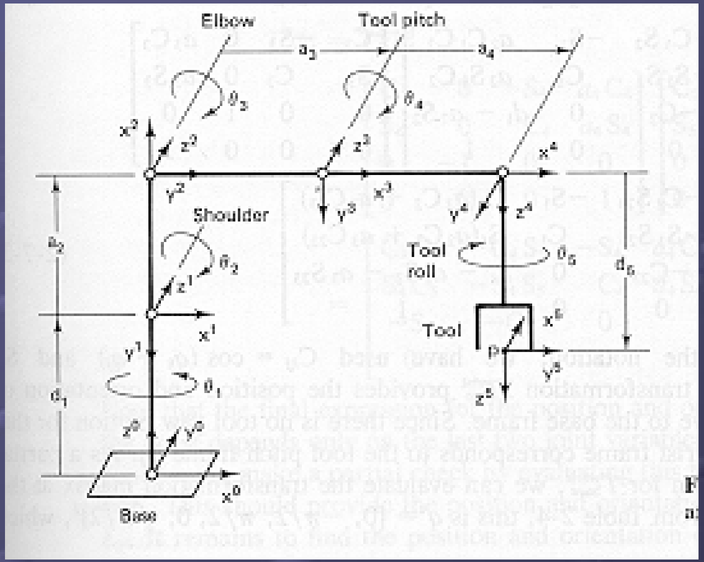
- Comes out of manipulator, control-theoretic tradition
- Focus on platform, inner loop control laws
  - Nerves, spinal cord, proprioceptive feedback
  - Accurate model of physics of the situation
  - *How* to perform an action versus *why* to do it
- Examples
  - Robot arms, factory automation
  - Auto-pilot, drones
  - Humanoid robots

Industrial Robots

- Industrial robots (manipulators) aren't physically situated *agents*
  - high repetition in a world where everything is fixtured to be in the right place at the right time
  - focus on control theory, joint movement to get fastest, repeatable trajectory
  - only recently begun adding sensors to reduce need for fixturing
    - fixed lighting
    - many cases cheaper just to shake the parts and sort them into the right position for a standard manipulator

Engineering Approach
Industrial Manipulators





- "Tommy" type of robots: deaf, dumb, and blind
- High precision, fast repetition
- Usually no sensing of the environment
  - Welding can be off by an inch…
- AUTOMATION

Automation? Autonomy?

- Automation
  - Execution of precise, repetitious actions or sequence in controlled or well-understood environment
  - Pre-programmed
  - *Fly-by-wire is a type of automation*
    - *Detailed models of physics and environment*

AI Focuses on Autonomy

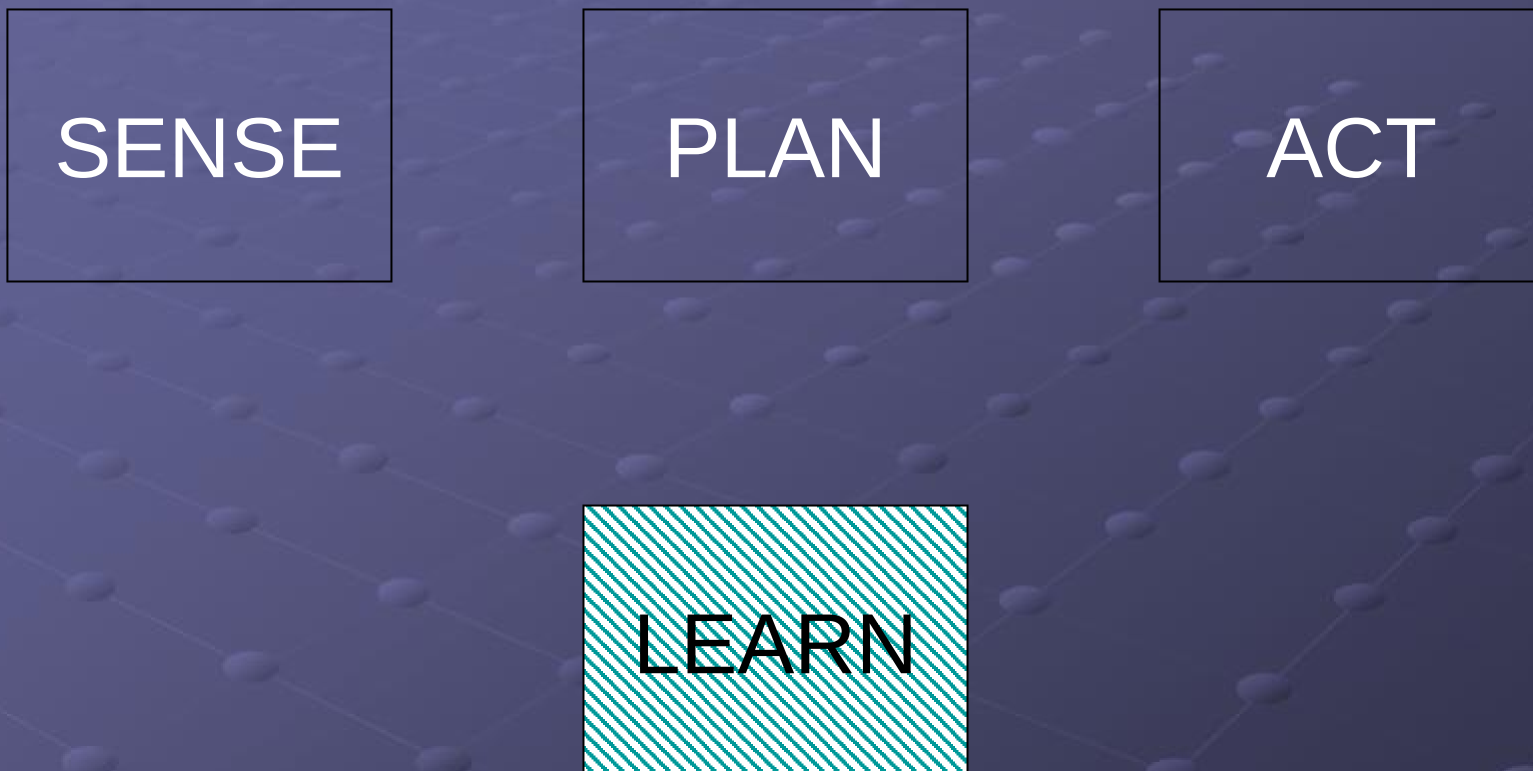
- Automation
  - Execution of precise, repetitious actions or sequence in controlled or well-understood environment
  - Pre-programmed
- Autonomy
  - Generation and execution of actions to meet a goal or carry out a mission, execution may be confounded by the occurrence of **unmodeled events or environments**, requiring the system to dynamically adapt and replan.
  - Adaptive

So How Does Autonomy Work?

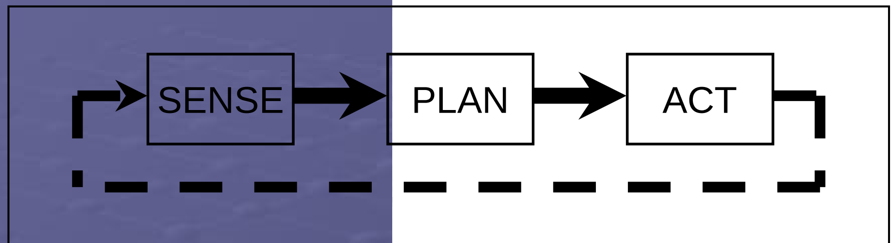
- In two layers
  - Reactive
  - Deliberative

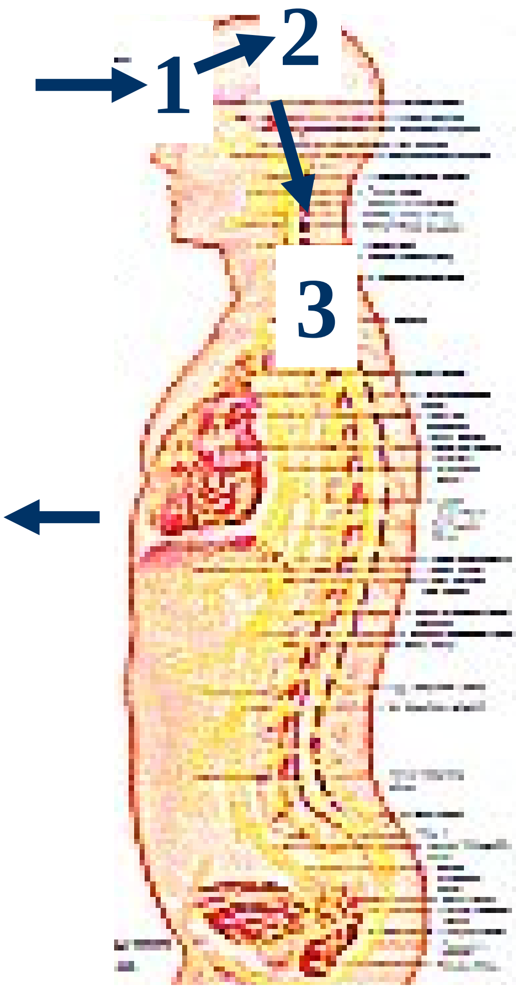
- 3 paradigms which specify what goes in what layer
  - Paradigms are based on 3 robot primitives: sense, plan, act

AI Primitives within an Agent



Hierarchical (1967)



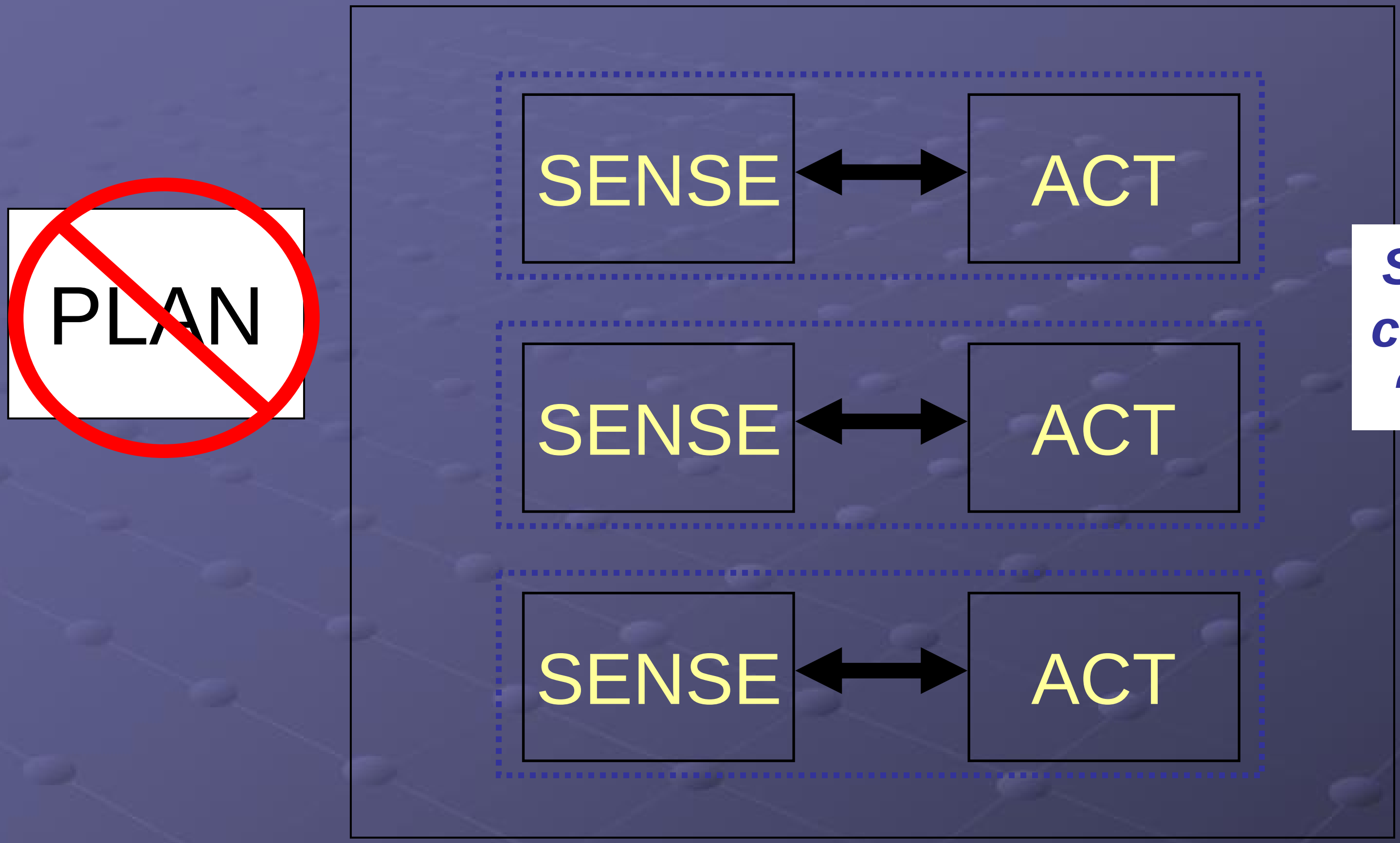


Control people hated because didn't "close the loop"

AI people hated because monolithic

Users hated because very slow

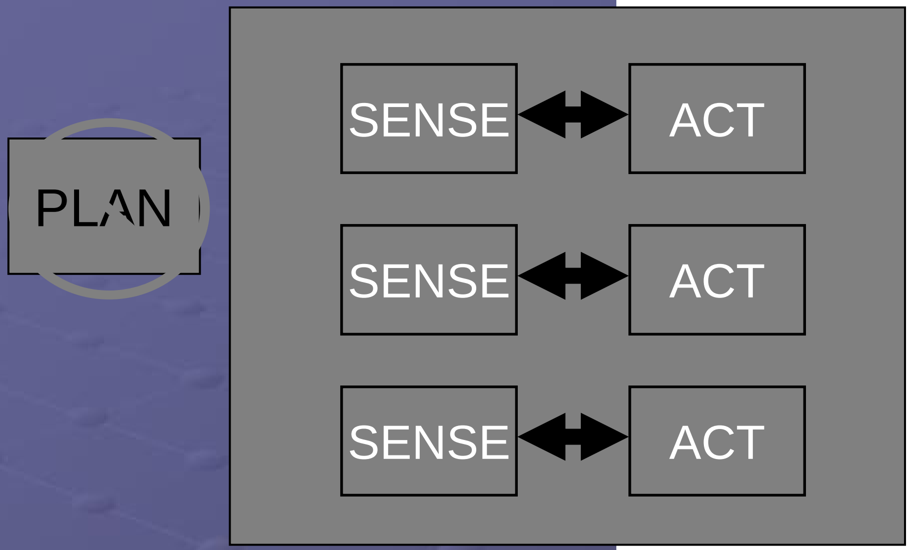
Reactive aka Behavioral (1986)

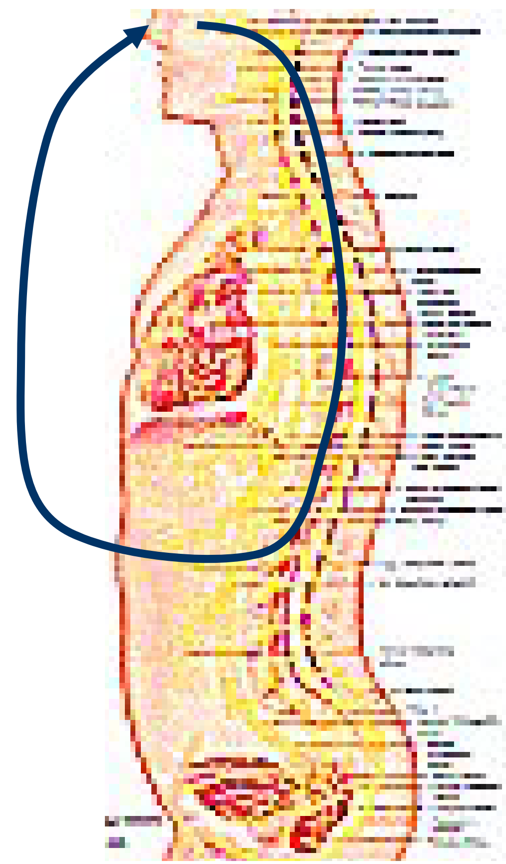


SENSE-ACT couplings are "behaviors"

Behaviors are independent, run in parallel

Reactive



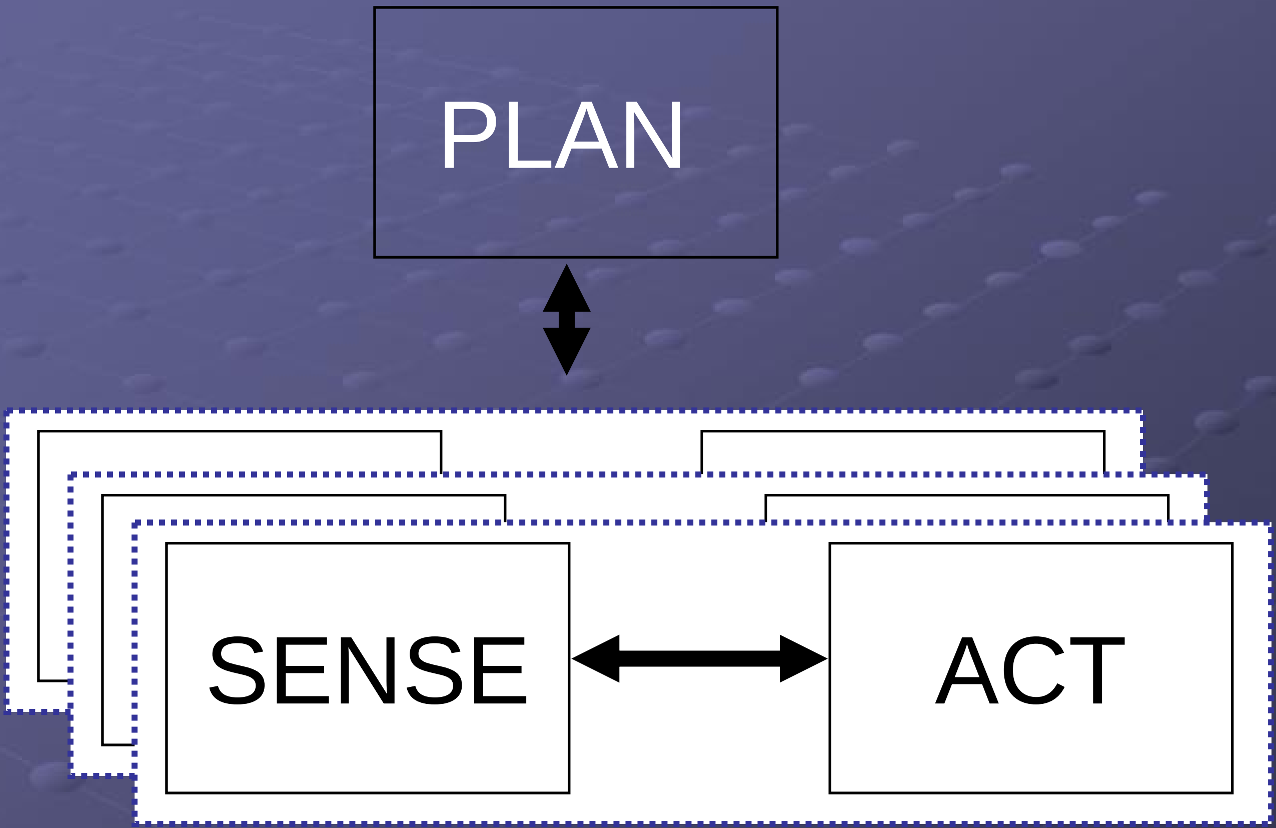


Users loved it because it worked

AI people loved it, but wanted to put PLAN back in

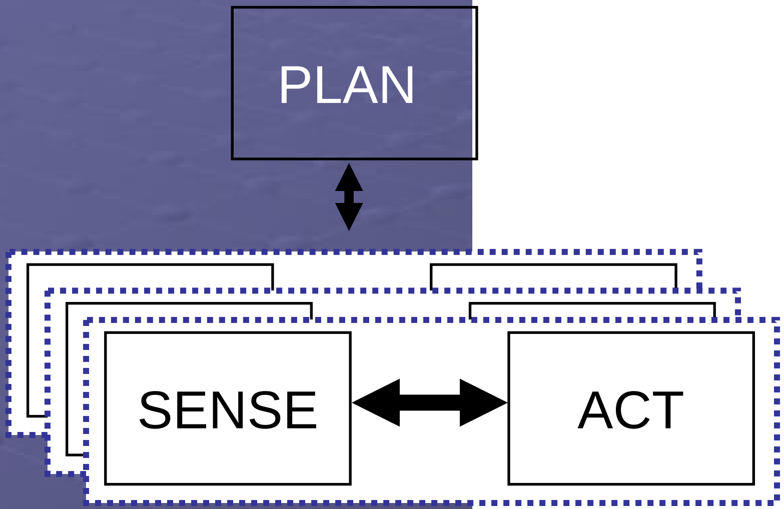
Control people hated it because couldn't rigorously prove it worked

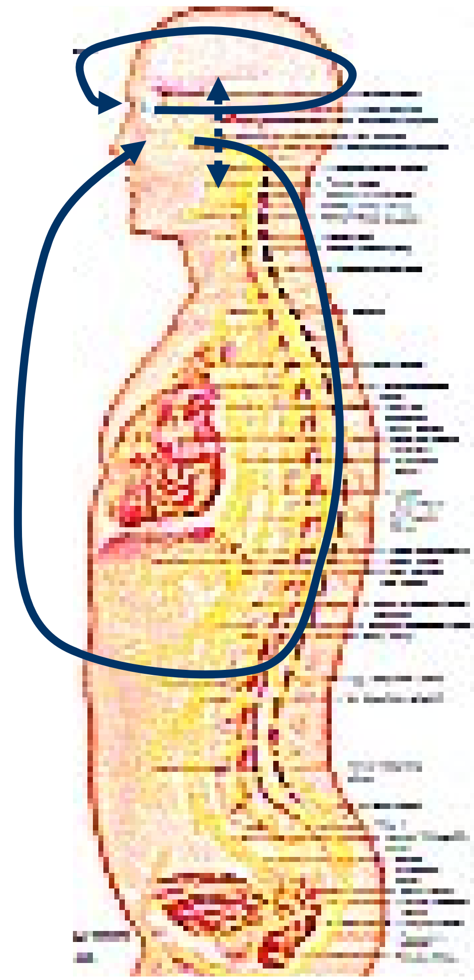
Hybrid Deliberative/Reactive (1990)



Plan, then sense-act until task is complete or need to change;
Note movement towards event-driven planning rather than continuous

Hybrid



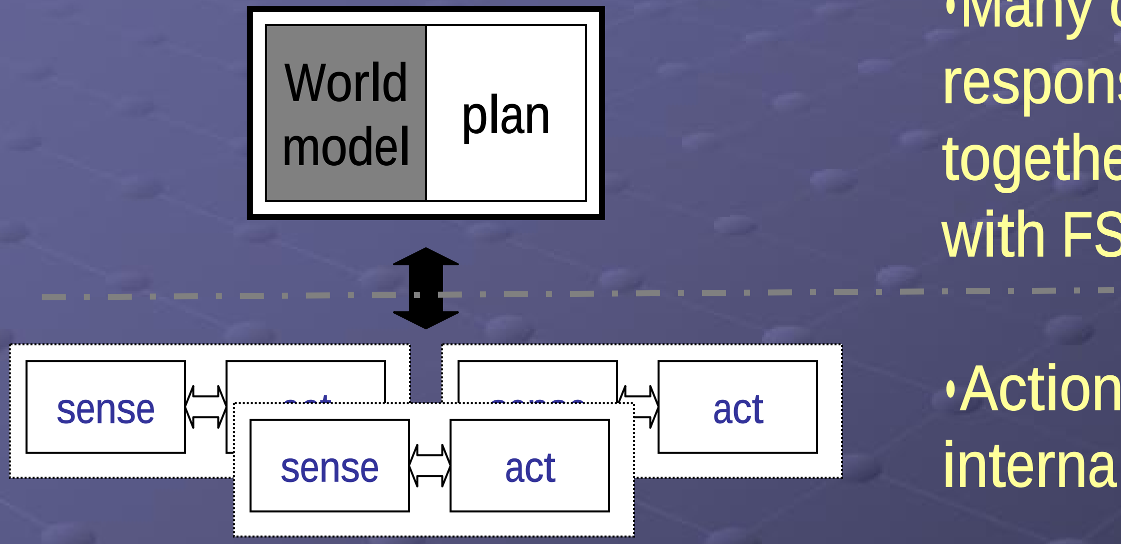


Control people hated it because AI, but are getting over it

AI people loved it

Users loved it

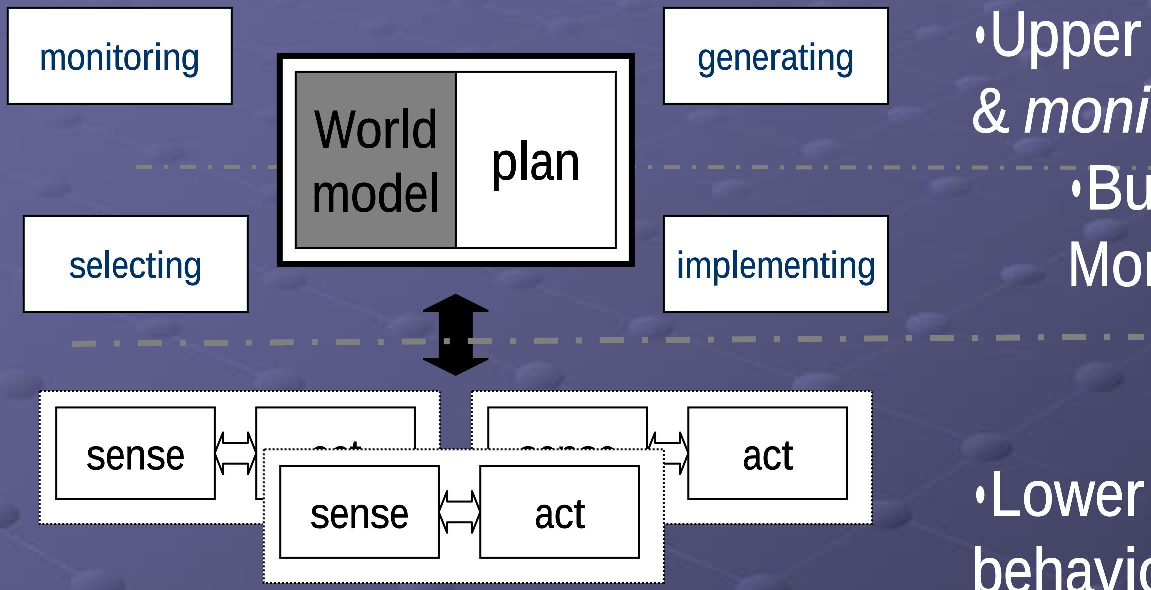
How AI Relates to Control Theory



Reactive (fly by wire, inner loop control):

- Many concurrent stimulus-response behaviors, strung together with simple scripting with FSA
- Action is generated by sensed or internal stimulus
- No awareness, no monitoring
- Models are of the vehicle, not the “larger” world

How AI Relates to Factory Automation



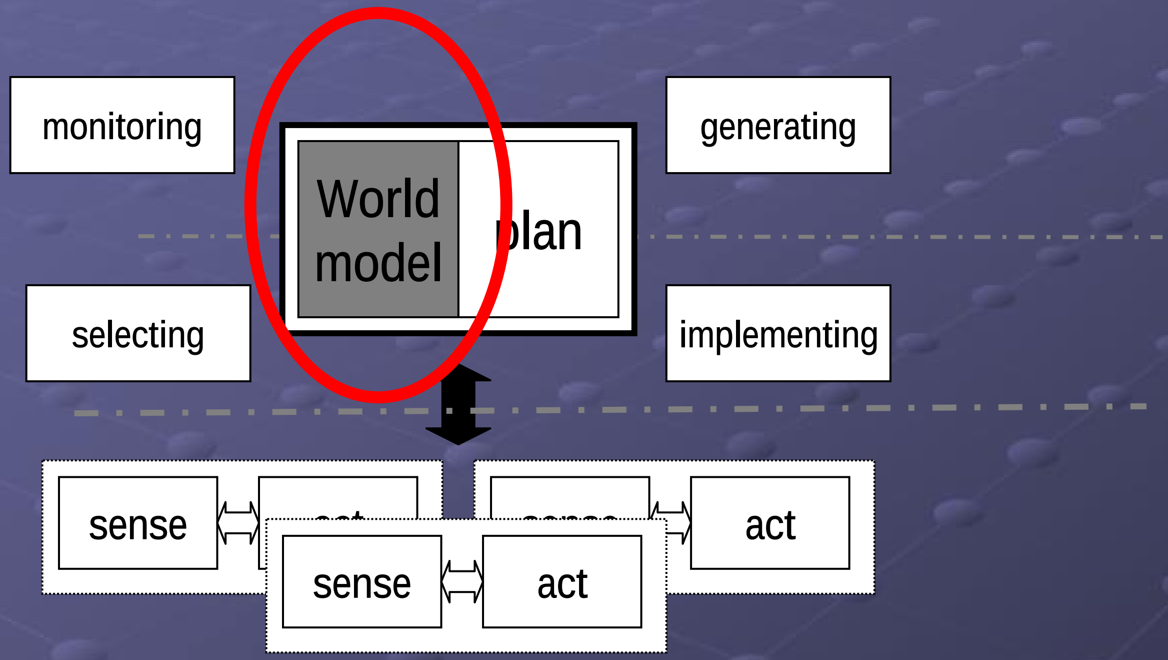
Deliberative:

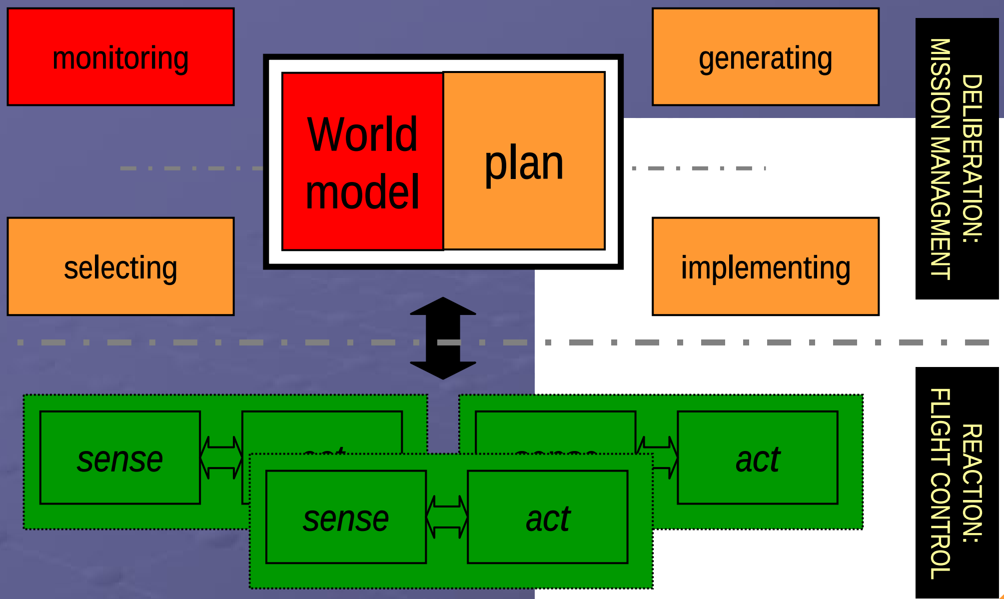
- Upper level is *mission generation & monitoring*
  - But World Modeling & Monitoring is hard (SA)

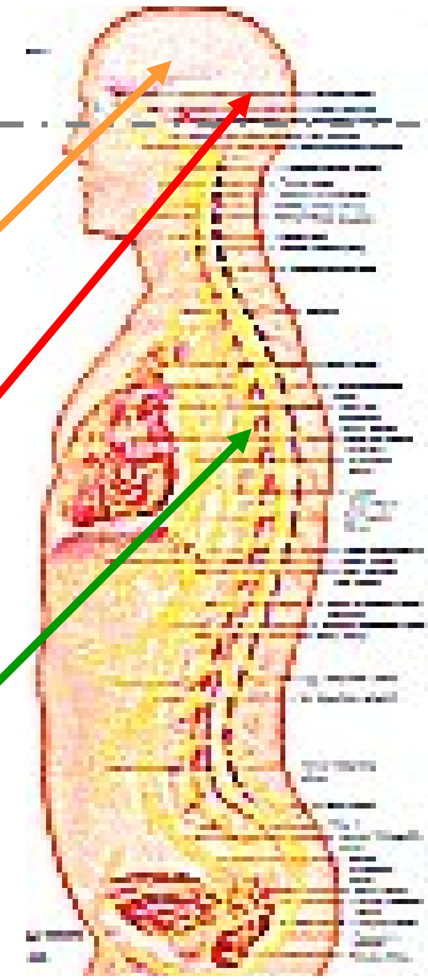
- Lower level is *selection* of behaviors to accomplish task (*implementation*) & local monitoring

But…Theory-Practice Gap

We don't know how to do this…







Reasoning over information about goals:

- Promising results: Navigation, payload planning, contingency replanning
- Open issues: Multi-agent replanning, fault recovery & reconfiguration, reasoning over multiple failures

Converting sensor data into information:

- Promising results: ATR, single failure health monitoring
- Open issues: creation of world models & situation awareness, monitoring & detection of new threats, exceptions, opportunities

Skills and responses

MILITARY ROBOTICS

Military robots must have accurate sensing of their environment.

PLATFORM

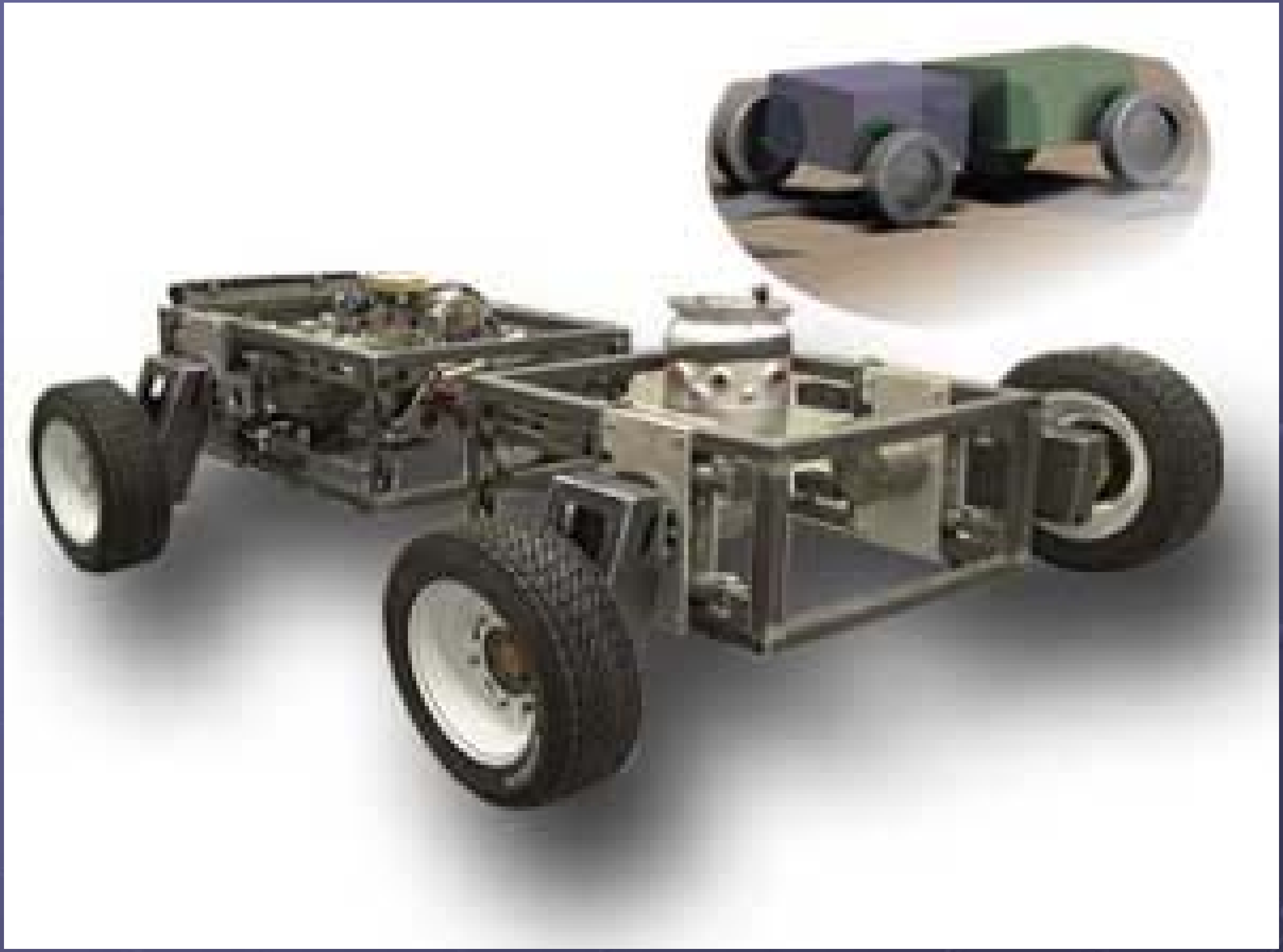
Provides locomotion, utility infrastructure and power for the robotic systems.

Provide the robot with the capability to act within its environment.

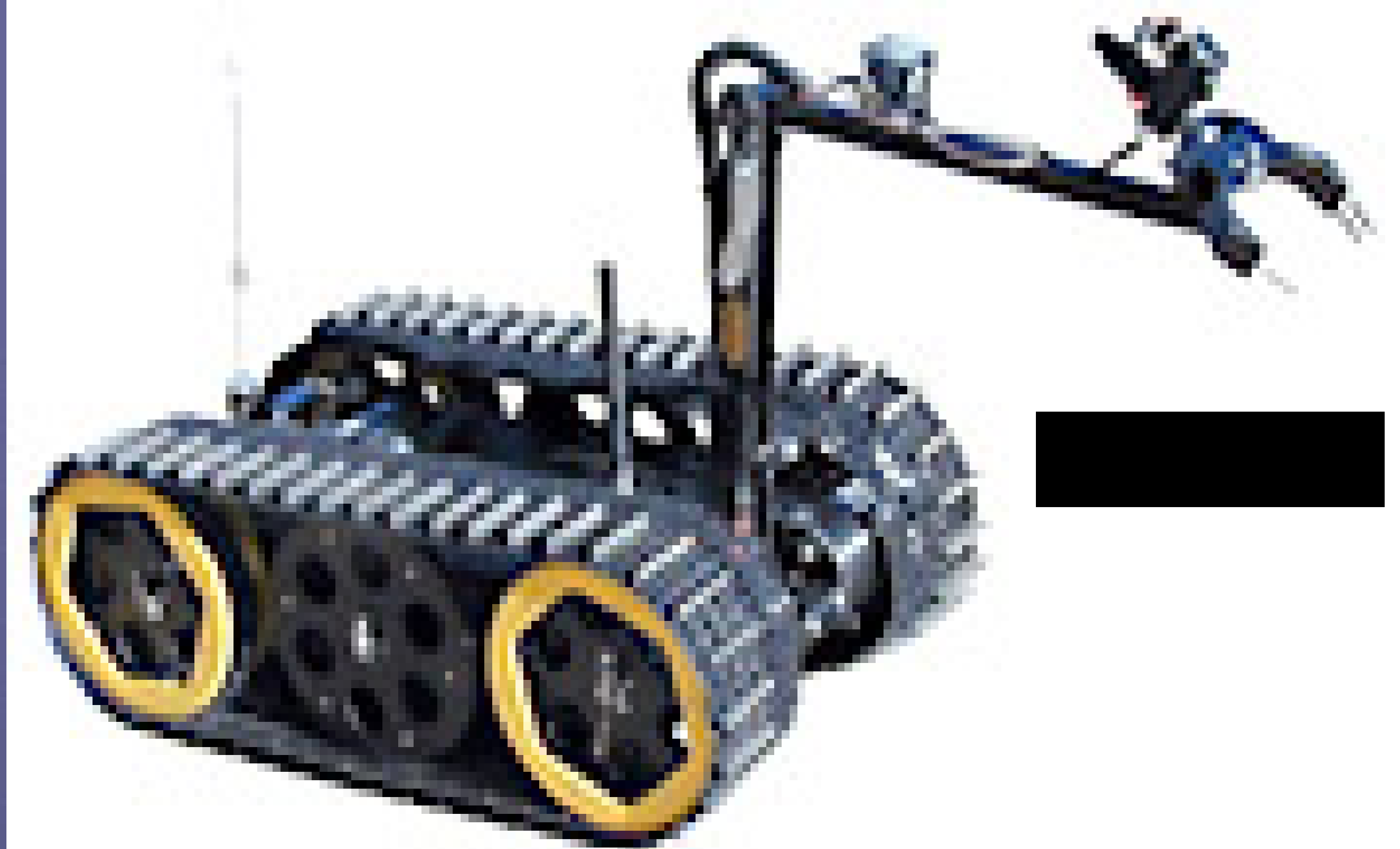
HUMAN MACHINE INTERFACE

COMMUNICATION

SYSTEM INTEGRATION



MILITARY ROBOTIC APPLICATIONS

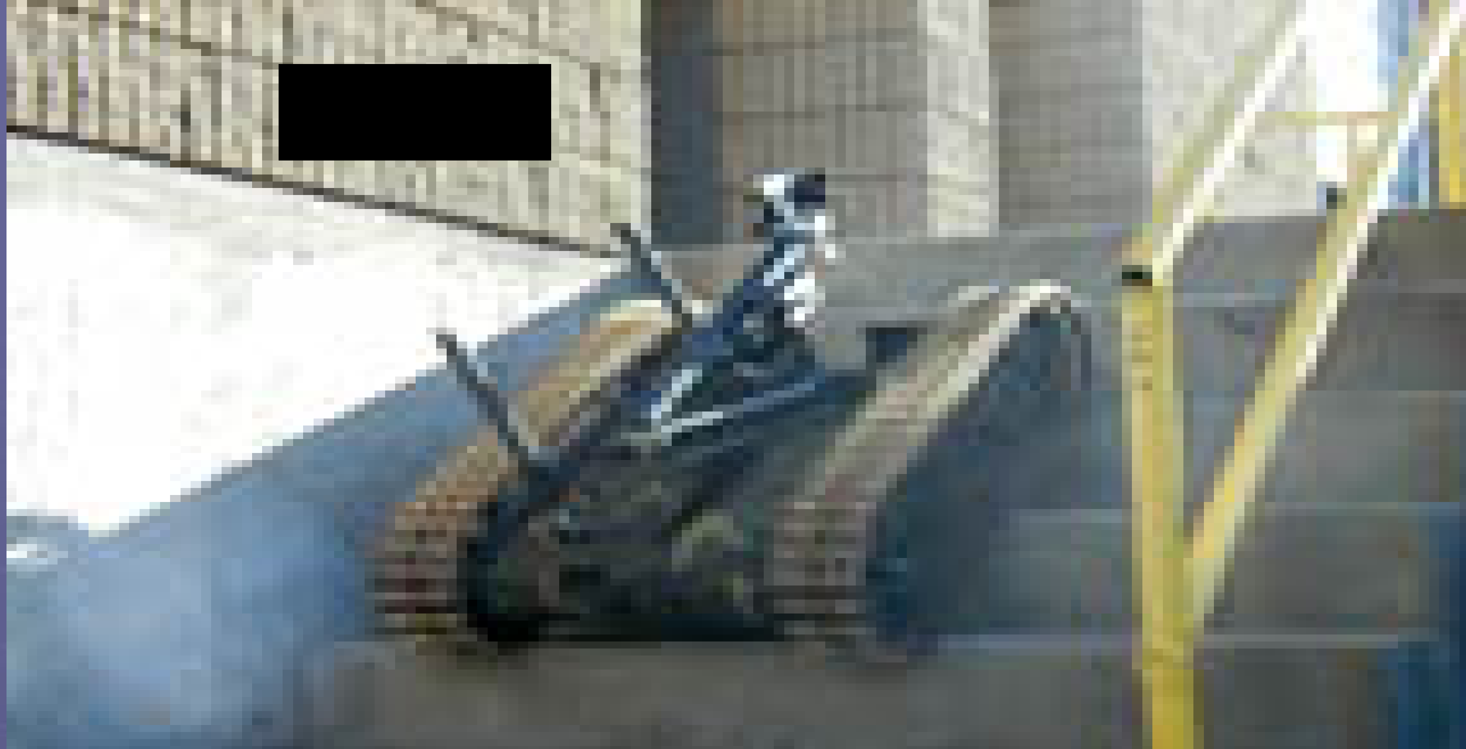


All terrain, all-weather platform with day/night capability. Controlled by two-way RF or fiber optic link from OCU. OCU displays video from up to seven cameras with audio and data feedback for precise vehicle positioning and control .

TALON FEATURES

TALON can carry more than 90 kg. It uses a two-stage arm that can reach a maximum length of 1.6 m and a gripper attachment to manipulate hazardous materials or ordnance.

Other attachments are available for deploying special sensors such as night vision, microphones and zoom cameras.



Can be adapted for ordnance removal, recce, communication, and security. Uses a removable, double-jointed, 64-inch pincer arm easily adaptable for other uses. It can climb stairs, traverse, negotiate rock piles, snow and sand, and overcome concertina wire.

Robot for recce in fd. Controlled through a two-way RF link from the OCU for video and data feedback at distances up to 1 mile. SOLEM's color camera can be elevated 15 inches above the vehicle to see above bushes and obstacles. Camera output can be seen on the OCU monitor.

Used to loc & dispose of bombs. Its movable arm can lift objects weighing up to 15 pounds & place them in bomb-proof boxes. Detachable accessories let it break windows, see in the dark, and to defuse or detonate bombs directly, either by blasting them with water, firing at them with a shotgun, or bombs nearby.

FUTURE

Focus on the perception and control of robotic vehicles in an effort to increase the level of autonomy and utility for Military applications.

ROBOTIC APPLICATIONS

Robots are ideal for jobs that require repetitive, precise movements.

Robots don’t need a safe working environment,salaries, breaks, food & sleep.

Robots don’t get bored.

<u>BENEFITS</u> : Improved quality

Reduced Costs

ROBOTICS : THE FUTURE

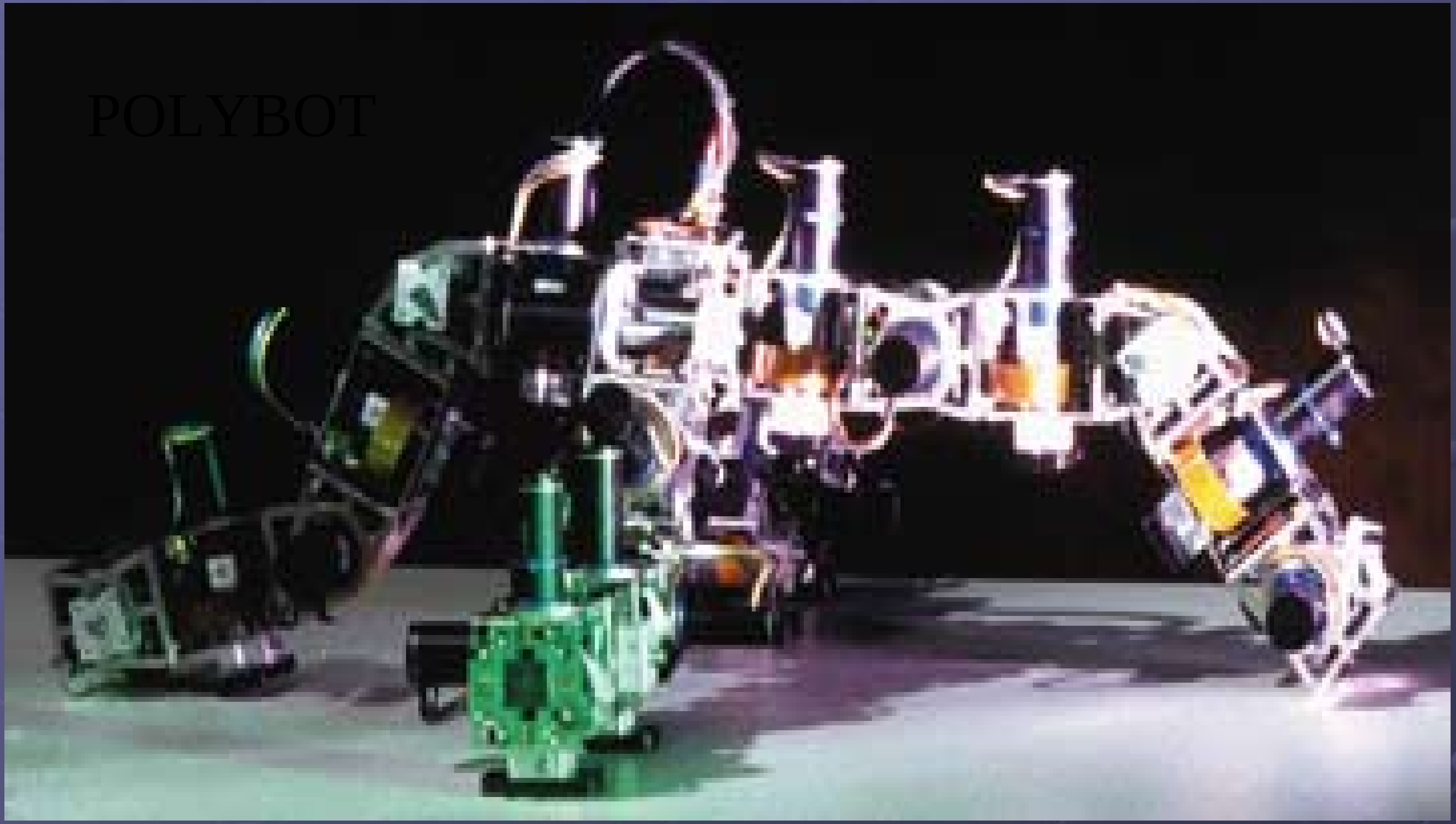
The coming Robotic Revolution.

Robot that can Sense Human Emotion.

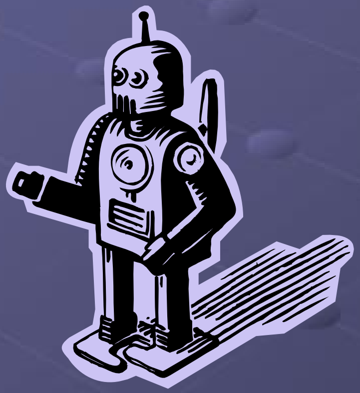
Robots for Safe Mining.

Robotic Heart Surgery.

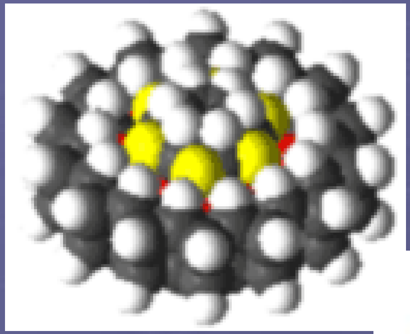
ROBOTS AND TERRORISM

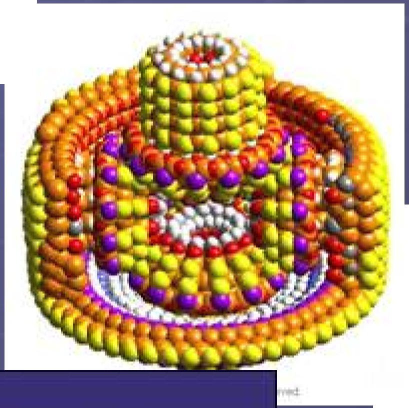


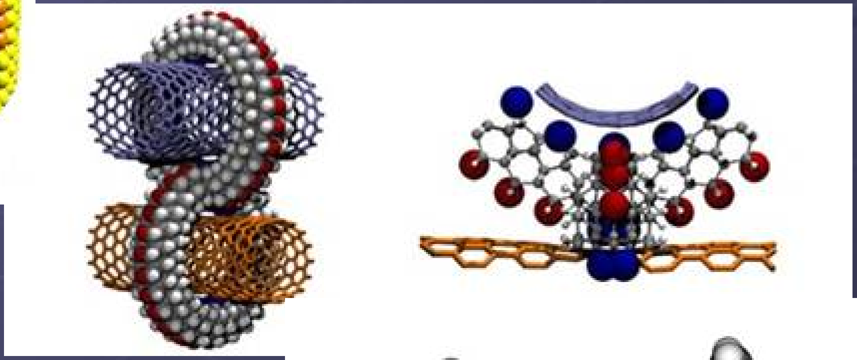
Micro/Nano Robotics

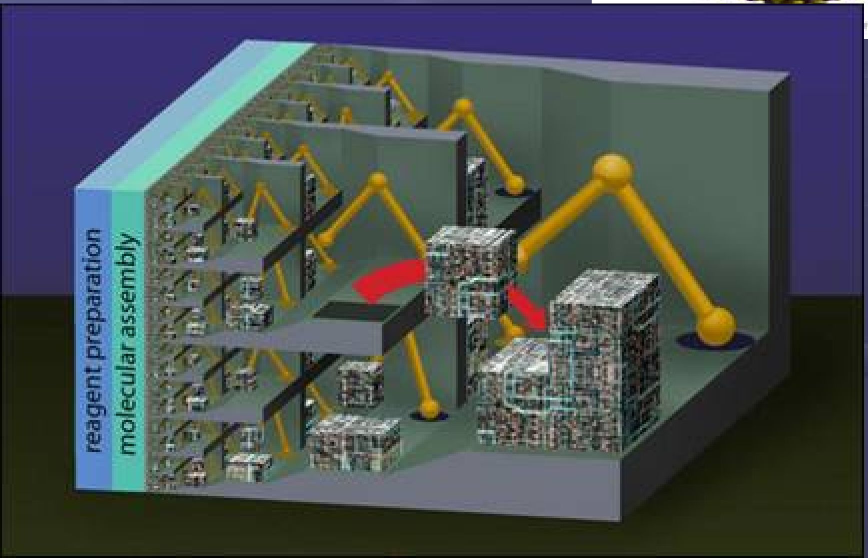


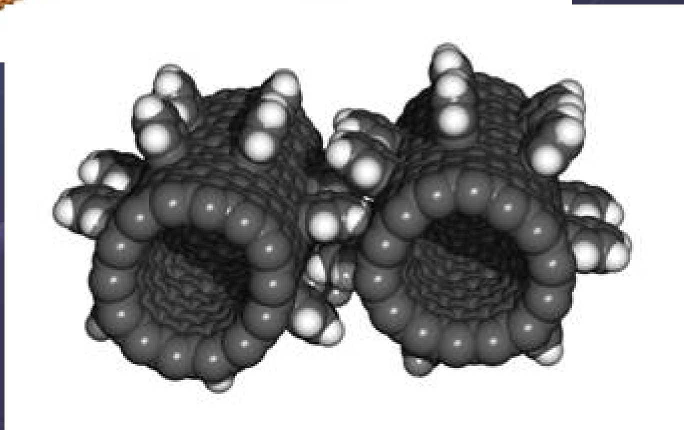
Drexler's dream of diamond based nanomachines-











NANOROBOT

DESIGNED TO PERFORM SPECIFIC TASK OR TASKS REPEATEDLY WITH PRECISION.

AUTONOMOUS NANOROBOT HAS ON BOARD NANO COMPUTER.

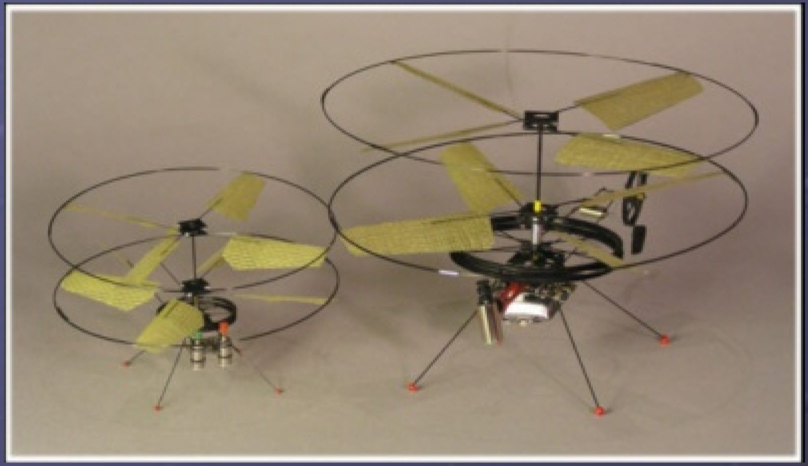
INSECT NANOROBOT ONE OF MANY CONTROLLED BY CENTRAL COMPUTER.

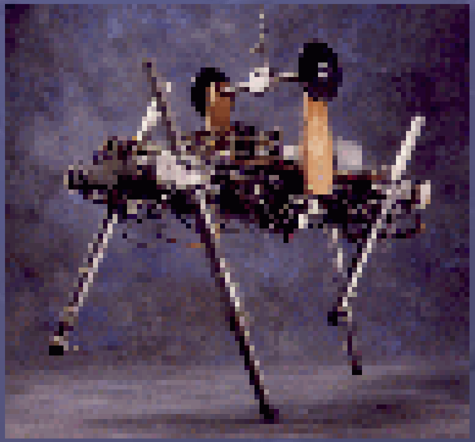
..

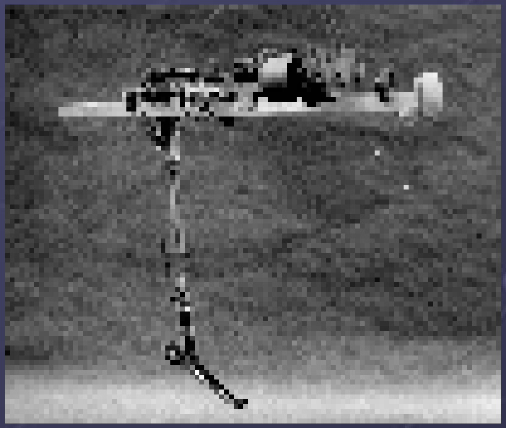
Nanorobots

Humans still have a lot to learn about the idea of constructing materials on such a small scale. Consumer goods that we buy are made by pushing piles of atoms together in a bulky, imprecise manner. Imagine if we could manipulate each individual atom of an object. That's the basic idea of nanotechnology, and many scientists believe that we are only a few decades away from achieving it.

Robots that fly, walk and hop.

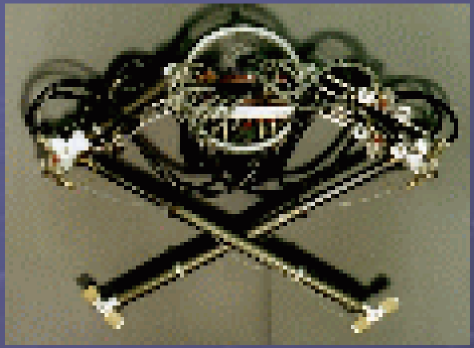






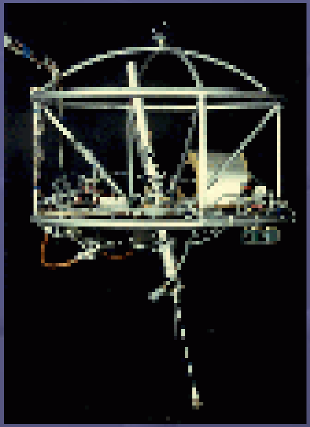
MIT group continued- LEGS program.

http://www.ai.mit.edu/projects/leglab/navigation.html



Crab

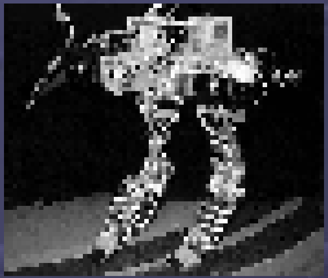
Uniroo



3D hopper, actively
Balanced dynamic
locomotion

Geekbot
Study transfer
Weight on feet

3D biped, Hops,
runs, Somersaults



Turkey

Flamingo; uses
-feet and ankles

Bug robotics

Case Western Reserve Univ.

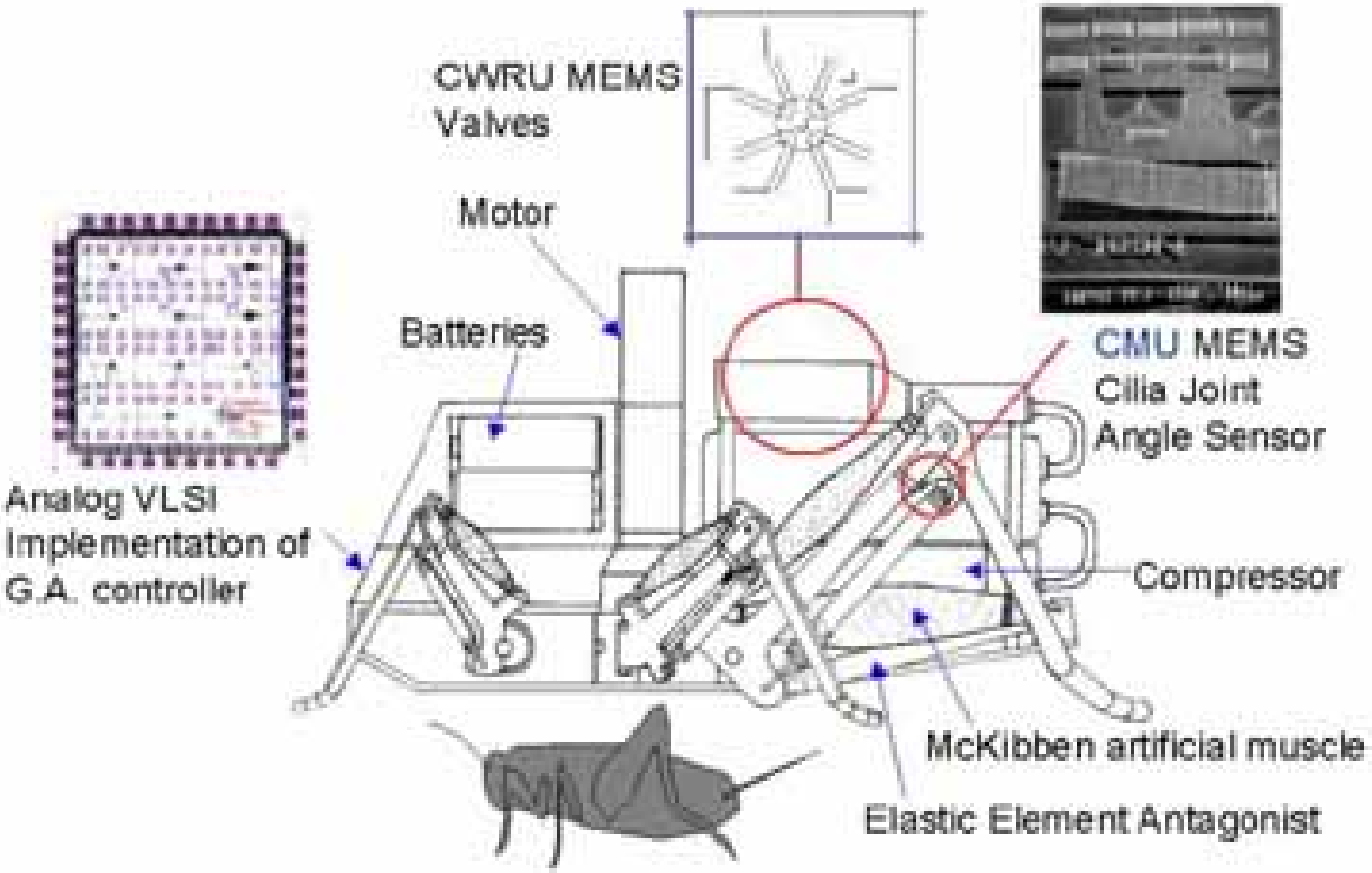
Biologically Inspired Robotics Lab.
Micro-Cricket Series of Robots
http://biorobots.cwru.edu/projects/c_mrobot/c_mrobot.htm

CASE WESTERN RESERVE UNIVERSITY

Cricket movie 5

Cricket movie 7

Anatomy of our cricket micro-robot



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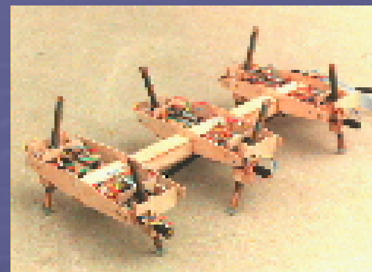
Robot I

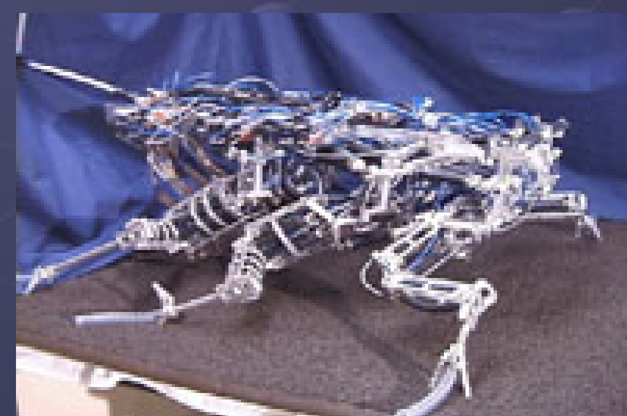


Robot II
Uses bug instincts

Slat; robot II walking over slats

Robot III

Robot IV



MINI-WHEGS Robots

CASE WESTERN RESERVE UNIVERSITY

Jumping mini-Whegs movie
Wings and legs = Whegs.

Camera on the mini-robot

Mini robots: KTH Microsystems Technology Group

Walking micro robot

Speed test micro robot

So now lets walk up walls and walk on Mars and fly too!!

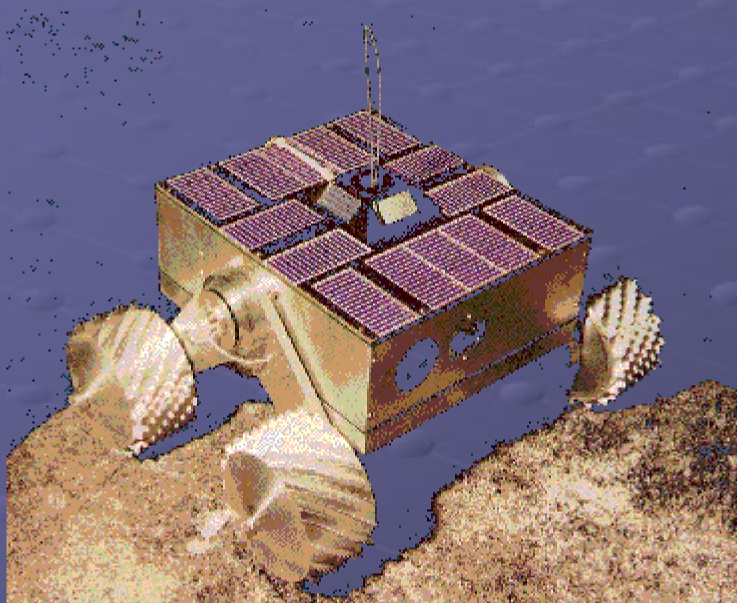
http://www.erg.msu.edu/microrobot/fr_main.html

Flipper; is able to flip Over and the suction cups allow it to literally walk up Walls.

Walk and fly over Mars

http://robotics.jpl.nasa.gov/tasks/nrover/nrt_main.html

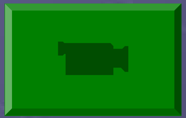
http://avdil.gtri.gatech.edu/RCM/RCM/Entomopter/EntomopterProject.html

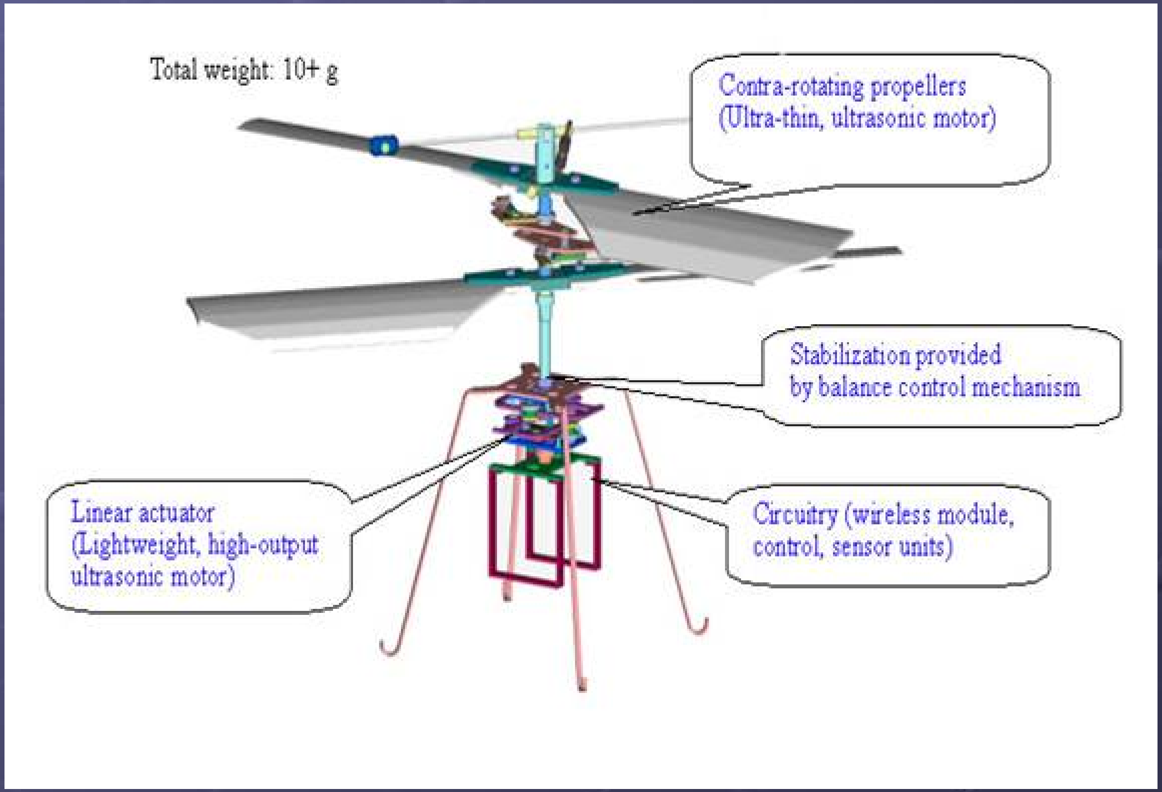


Entomopter movie
Flying over Mars
Biomimetrics

Nanorover Technology JPL: Miniature Rover
For small body and planetary surface exploration.

More flying machines worlds smallest flying beastie:





http://www.epson.co.jp/e/newsroom/news_2003_11_18_2.htm

Really tiny robots

Japanese Robot 1999 measure 1cm long.
US gov engineers are also working on
Robots that can hover around a room. NASA
Wants a “spacecraft on a chip”.
http://www.cnn.com/TECH/ptech/9907/13/japan.microrobot/

MINI-ROBOT RESEARCH — Sandia National Laboratories researcher Doug Adkins takes a close-up view of the mini-robots he and Ed Heller are developing. At 1/4 cubic inch and weighing less than an ounce, they are possibly the smallest autonomous untethered robots ever created. (Photo by Randy Montoya)
Download 300dpi JPEG image, 'micro_robots.jpg', 1.7MB (Media are welcome to download/publish this image with related news stories.)

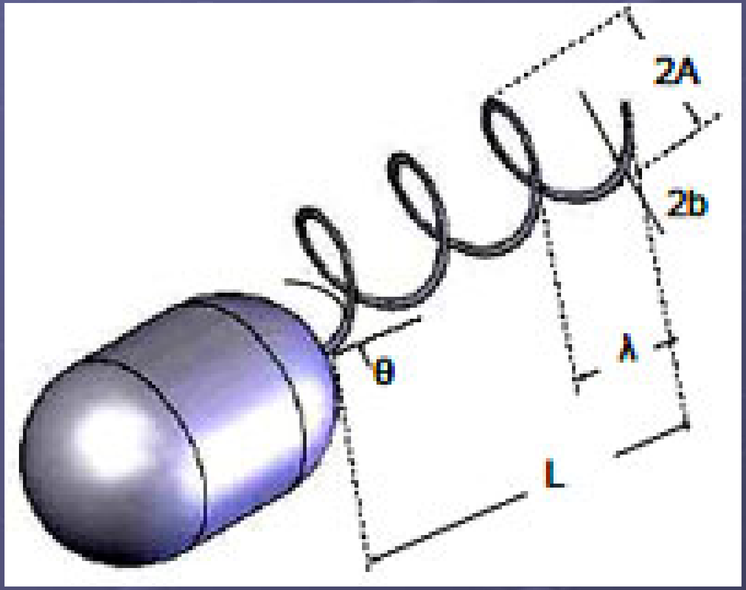
Movie of the microbot
In motion.

Sandia
National
Laboratories

Swimming robotics bugs

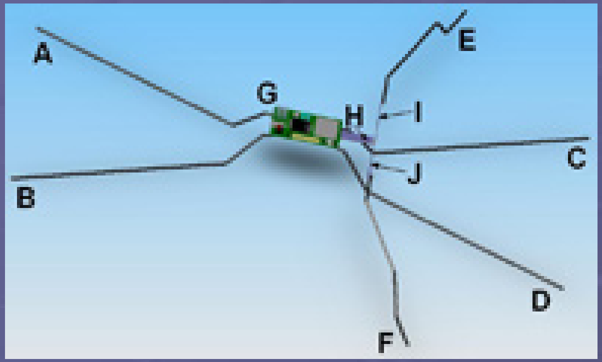
http://www.me.cmu.edu/faculty1/sitti/nano/projects/swimming/

NanoRobotics Lab
@ Carnegie Mellon



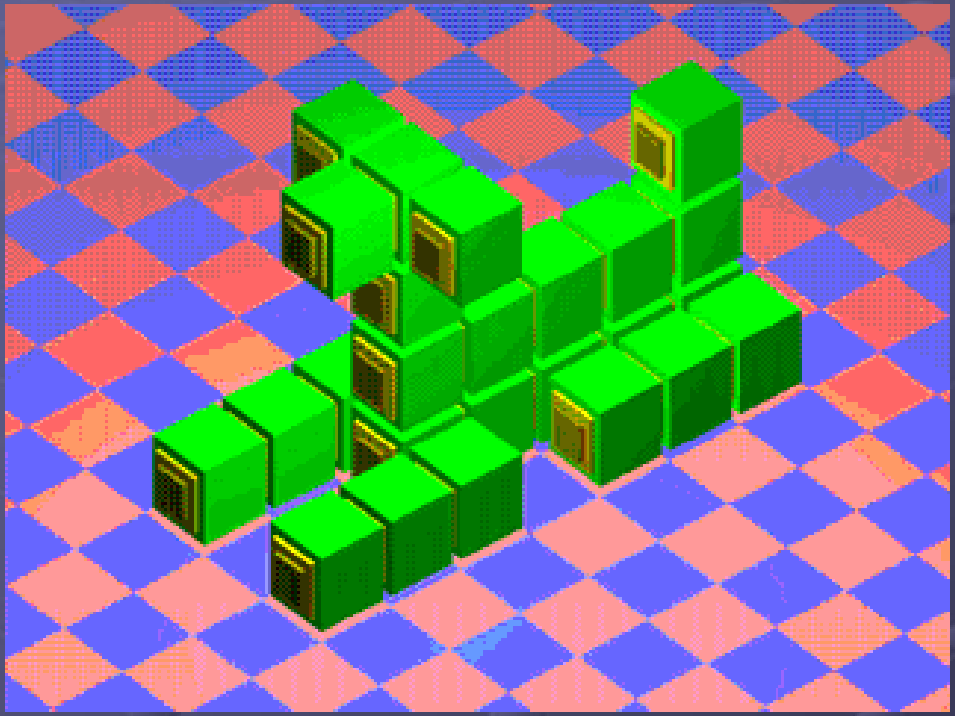
Remember high viscosity at
Small scales makes a corkscrew
Motion of propulsion far more
Effective.

and bugs that walk on water!!



Little mini robots that change shape.

http://www.mit.edu/~vona/xtal/xtal.html



Dog changes into a couch!

ADVANTAGES OF NANOROBOTS

(a) VERY LITTLE ENERGY TO OPERATE.

(b) DURABILITY.

(c) HIGH SPEED .

(d) WIDE RANGING MEDICAL APPLICATIONS.

BIOMETRIC ROBOT

HOME BUTLER.

MEDICAL ASSISTANT.

ETHICS & ROBOTICS

Summary

- Robots mean more than just Sony dogs and Mars Rovers: *land, air, sea, and underwater*
- Automation assumes a “closed world” while autonomy assumes a “open world” which can change unexpectedly
- Engineering approaches focus on *how* to execute an action, AI approaches focus on *why* to perform the action at that particular time.
- Control Theory and AI is currently pretty good with “low level” or “muscle” intelligence
- AI can outperform humans in planning, optimization, etc.
- AI isn’t good as converting sensing into information or incorporating learning

Review Questions

- What is an Intelligent Robot?
- What are two reasons to have robots?
- What are the four modalities of autonomous (unmanned) vehicles?
- What are the five components common to all autonomous systems?
- What are two differences between AI and Engineering approaches to robotics?
- What is the difference between automation and autonomy?

Review Questions

- What is the state of the practice?
- What are the seven areas of Artificial Intelligence?
- What are the three primitives of robot paradigms?
- What are the three paradigms of robotics in terms of these primitives?

CONCLUSION