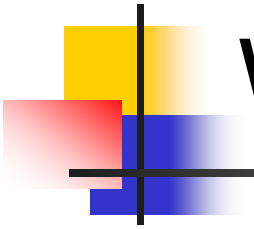
The History of Robotics



What we will cover

- Robot History
- Industrial Robotics
- Conventional Robotics and Failure
- Mobile Robots

Jacques de Vaucanson (1709-1782)

- Master toy maker who won the heart of Europe.
- Flair for inventing the mechanical revealed itself
  early in life. He was impressed by the uniform motion of the pendulum of the clock in his parents hall.
- Soon he was making his own clock movements.

Jacques de Vaucanson

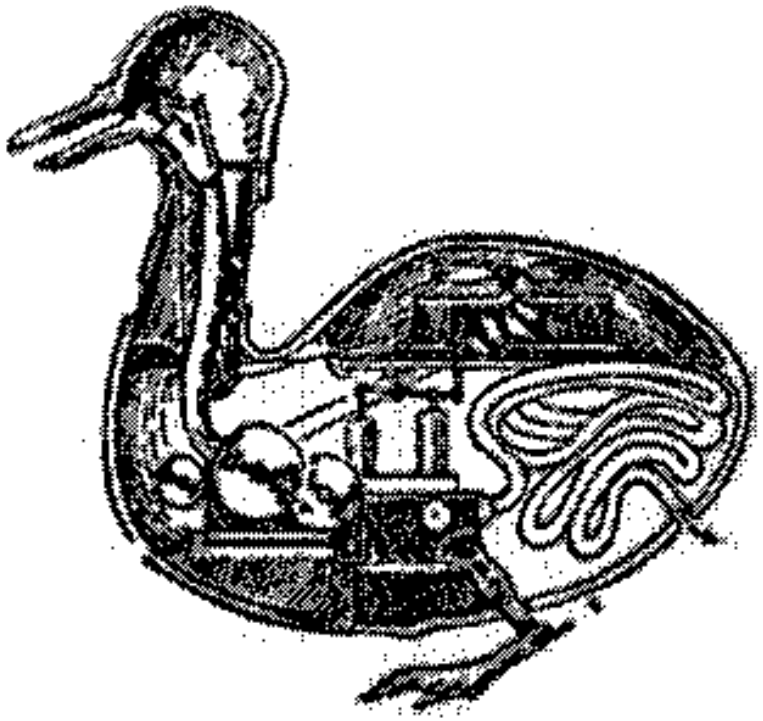
Jacques de Vaucanson (1709–1782)

The Mechanical Duck

- His aim was, he tells us, to represent the viscera, and to simulate the functions of eating, drinking and digesting. The duck stretched its neck to take grain from a hand and then swallowed and digested it. It drank, paddled and quacked, and imitated the gestures which a normal duck makes when swallowing precipitately. The food was digested by dissolution, not by trituration, 'the matter digested in the stomach being conducted by tubes, as in an animal by its bowels, into the anus, where there is a sphincter which permits it to be released.' Vaucanson disclaimed any attempt to make a perfect copy of the process of digestion, although he doubted whether the anatomists would feel that anything was left to be desired in the construction of the wings, 'which had been imitated bone by bone'. Since his intention was to demonstrate, rather than simply to exhibit a machine, the internal mechanisms were fully exposed to view, though some ladies preferred to see them decently covered.

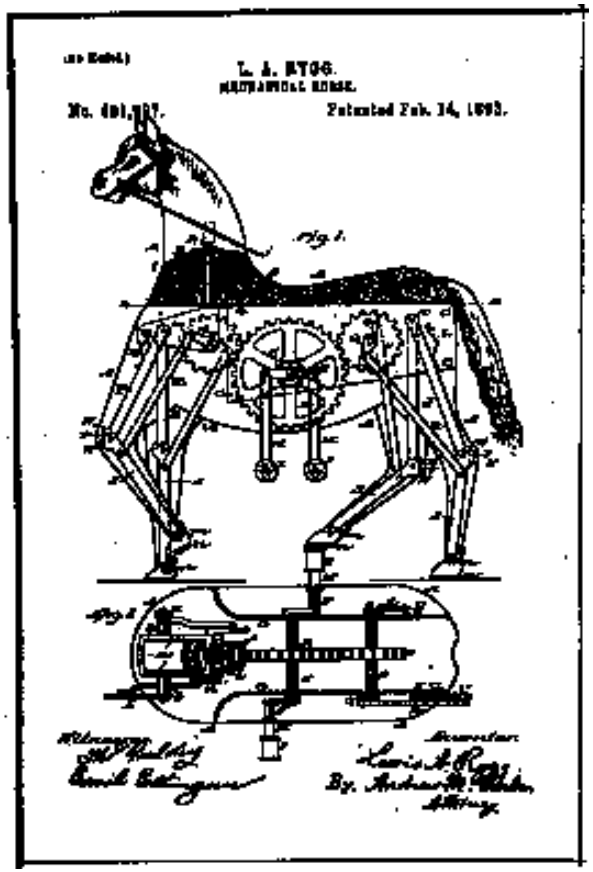
From "Human Robots in Myth and Science", John Cohen

The Mechanical Duck Displayed



Vaucanson's duck

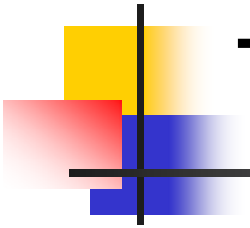
The Mechanical Horse



R.U.R.

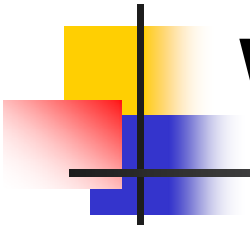
- The word "robot" was coined in 1921 by Czechoslovakian playwright Karel Capek in his play R.U.R. (Rossum's Universal Robots).
- Robot derives from the Czeck word for "worker"
- The brilliant scientist Rossum manufactures a line of robots designed to save mankind from work.
- The plot turns sinister when robots are used in a war to kill humans.
- After the robots are given emotions they no longer tolerate humans and eventually wipe them out...neat thought eh?

R.U.R. (more)



The Advent of Industrial Robots

- There is a lot of motivation to use robots to perform task which would otherwise be performed by humans.
  - Safety
  - Efficiency
  - Reliability
  - Worker Redeployment
  - Cheaper

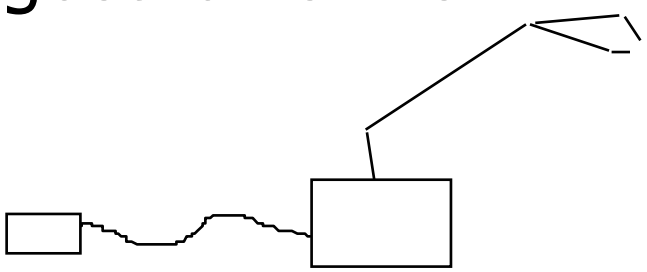


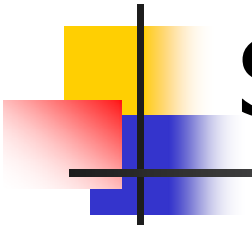
What are they?

- Most of the industrial robots used in factories throughout the world exhibit few of the characteristics that the average person would associate with the term "robot"
- Many are simple "pick and place" machines
- Lets have a working definition for an industrial robot
  - These machines are programmable, are automatic and can perform a wide variety of tasks

Pick and Place

- Simplest kind of industrial robot
- Still some on production lines but are being phased out
- Perform simple pickup and drop functions
- Cannot sense environment
- The limits of motion of each joint of the machine are fixed by electric or pneumatic impulse originating at a plugboard control panel



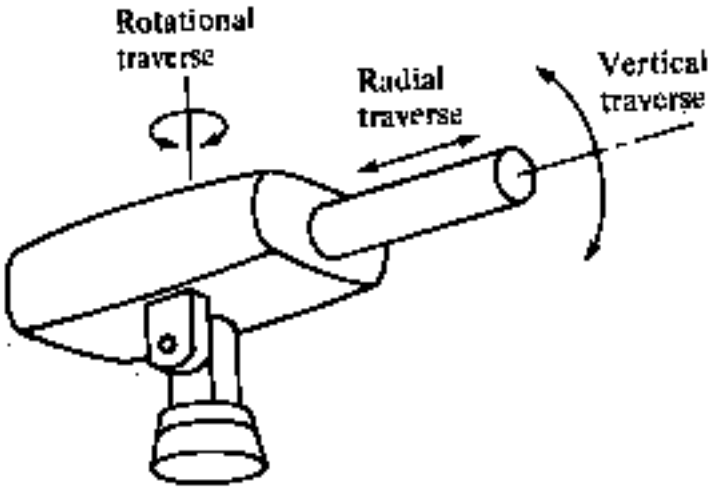


Servo Robots

- A more sophisticated level of control can be achieved by adding servomechanisms that can command the position of each joint.
- The measured positions are compared with commanded positions, and any differences are corrected by signals sent to the appropriate joint actuators.
- This can be quite complicated

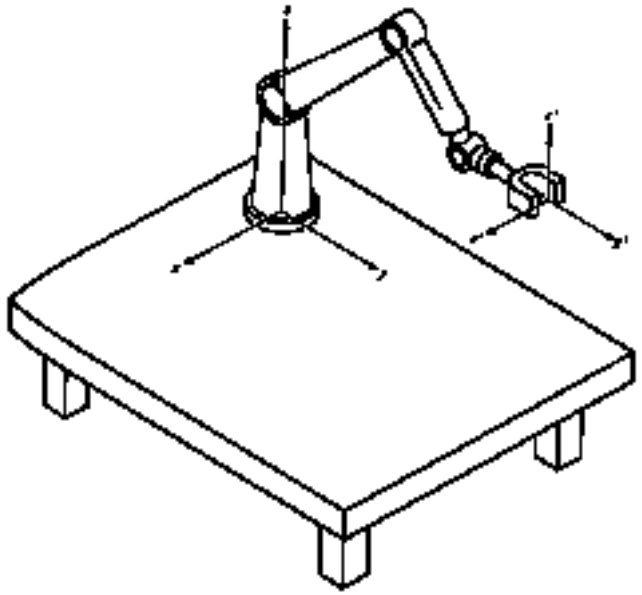
Degrees of Freedom

- For the robot arms to become more flexible, more "degrees of freedom" or planes of free movement had to be added.
- Many industrial arms have 6 or more planes of motion



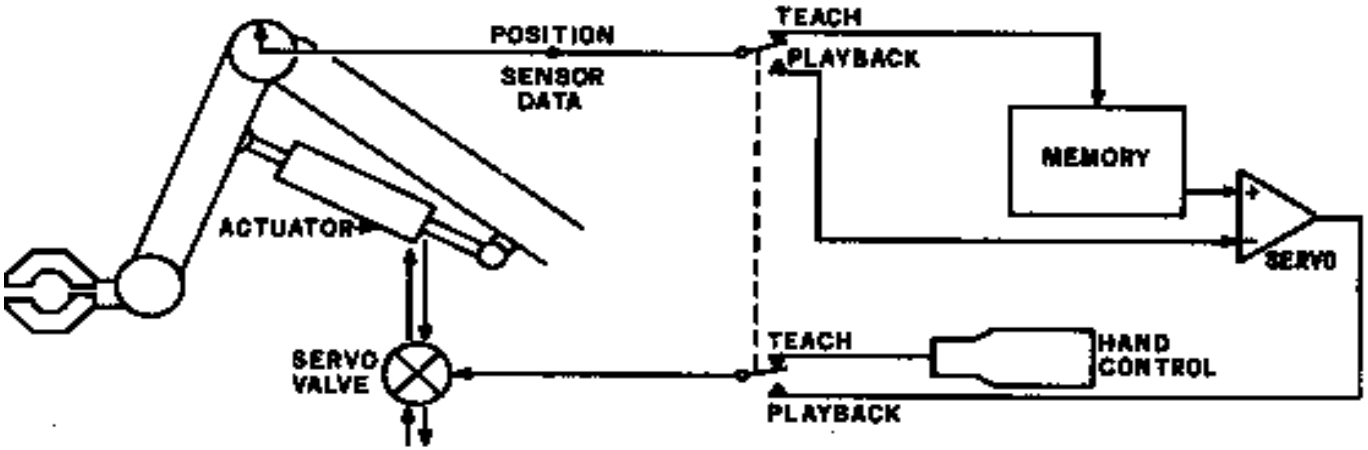
An Arm's Simple World

- Life is simpler for a robot arm which can always expect objects to be oriented in the same way.
- It only has to worry about its own coordinate system.
- The math gets complex but is manageable



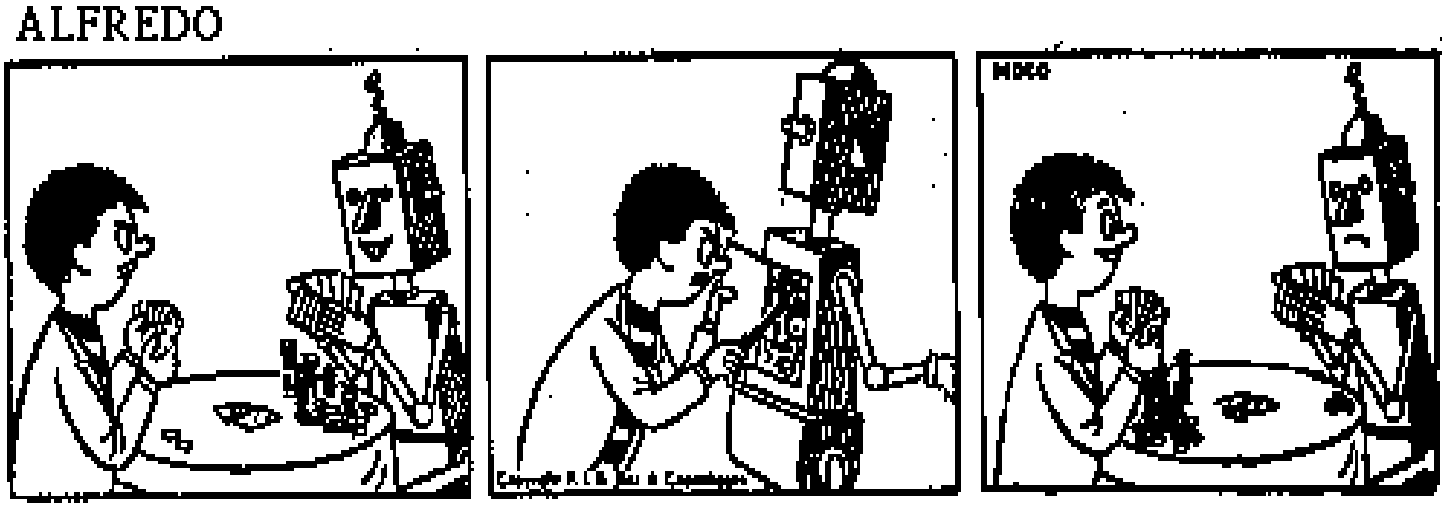
Teach and Play-back Robots

- Once the math is solved it is a relatively simple matter to teach a robot how to pick something up and what to do with it.
- Teaching involves moving the arm through the motions it is expected to perform
- During Recall mode the arm repeats, verbatim, what it has been taught



Over Confidence

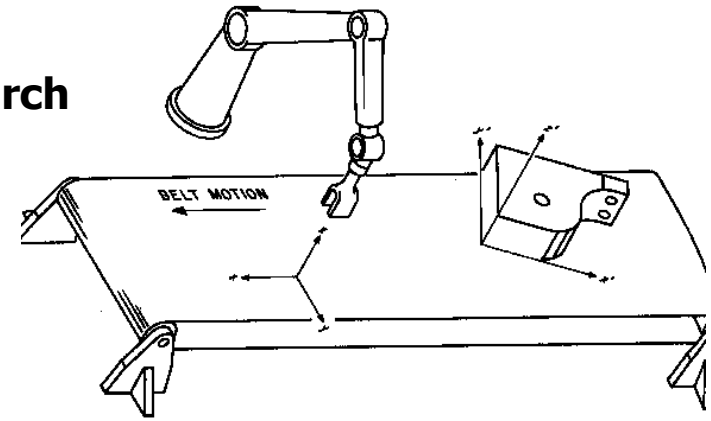
- Soon people had faith in their own ability to solve what turned out to be extremely complex control problems



Cartoon from the Manchester Evening News, *May 10, 1957*

A Robot's More Complex World

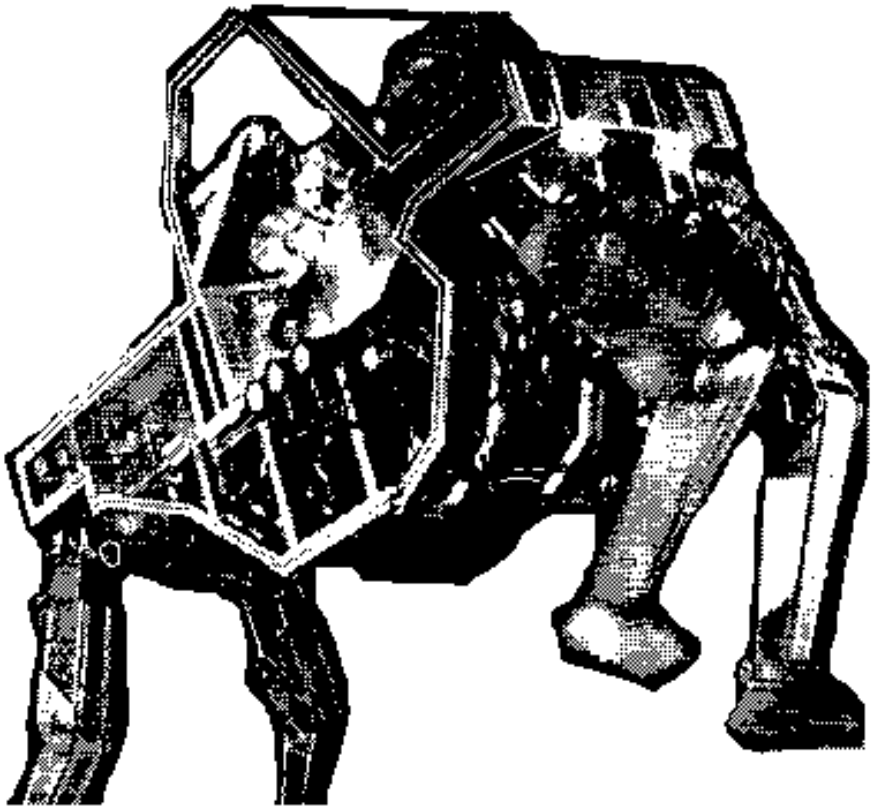
- **It gets more complex when you expect an arm to pick up objects which can be in any orientation.**
- **There are several problems**
  - **How do you pick it up?**
  - **How do you recognize it is there?**
  - **How do you know you are holding it firmly?**
  - **How do you have to change your grip to hold it the way you need to?**
- **This is still a subject of much research**

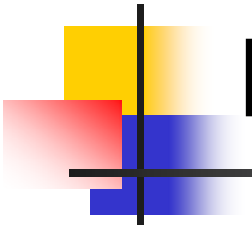


The Army and the Artificial Elephant

- **The U.S. military was "winning" the war in Vietnam…therefore it needed an elephant**
- **They contracted the "walking truck" to be built by the General Electric Company for the U.S. Army in 1969.**
- **Project failed because of the "unanticipated computational difficulty" of simultaneously controlling all of the degrees of freedom in the four legs.**
- **This failure dramatically demonstrated the sophistication that control systems must have to produce successful walking behaviour in legged mechanisms.**

The Elephant in Operation



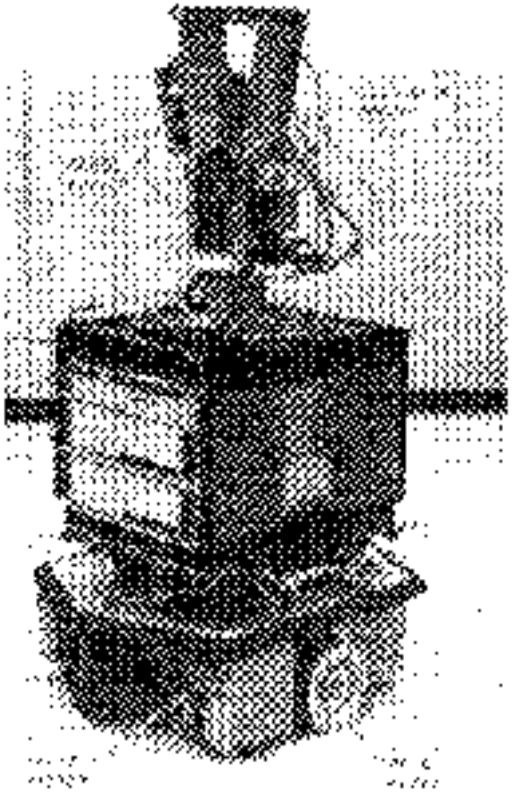


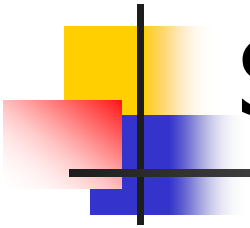
Expanding Horizons

- Undaunted by previous failures, robotocists continued research in the field
- People thought a good strategy would be to start from the state-of-the-art as practiced in industrial robotics and gradually expand the sensory and control capabilities until the more difficult tasks became tractable.
- This was the strategy adopted by the robotics group at S.R.I

Shakey

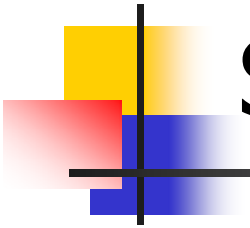
- Shakey was an early robot, conceived as a demonstration project for the Advanced Research Projects Agency (ARPA) artificial Intelligence program





Shakey (more)

- Shakey could be given a task such as finding a box of a given size, shape, and colour and told to move it to a designated position.
- Shakey was able to search for the box in various rooms, cope with obstacles, and plan a suitable course of action.
- It was controlled by an off-board PDP-10 computer through a radio link.
- It carried a TV camera, an optical range finder, and touch sensors so that it could know when it bumped into something.



Shakey (more more)

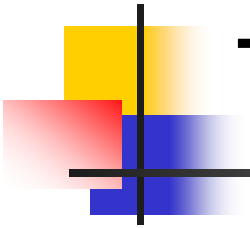
- While Shakey was a success in some respects it was a great failure as far as autonomy was concerned...
  - It was controlled by an off-board computer
  - It could only detect the baseboards of the special rooms it worked in
  - It could not deal with an unconstrained environement
  - It was really slow!

Rodney A. Brooks

- Born in Adelaide, Australia in 1954
- Received Ph.D in computer science from Stanford University
- Member of the M.I.T Artificial Intelligence Lab where he leads the mobile robot group.
- Well funded to do research in autonomous vehicles. ($$$$)

Rodney Brooks - Before Funding

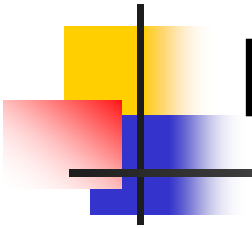
Rodney Brooks - After Funding



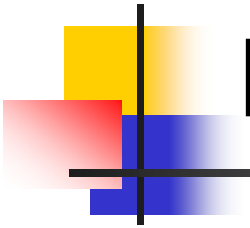
The early years

- Brooks was painfully aware of the failure of robotics to live up to its potential.
- Autonomous vehicles were not that autonomous and weren't even very good vehicles.
- He identified various aspects of mobile robotics which he considered to be important and obvious

Brook's Robot Requirements

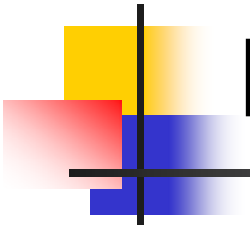


- He identified a number of requirements of a control system for an intelligent autonomous mobile robot.
  - Multiple Goals: Some conflict, context dependent
  - Multiple Sensors: All have errors, inconsistencies and contradiction.
  - Robustness: The robot must by fault-tolerant.
  - Extensible: You have to be able to build on whatever you built



Dogma

- Brooks also introduced, what he called, "9 dogmatic principles",
  1. Complex (and useful) behaviour need not necessarily be a product of an extremely complex control system.
  2. Things should be simple: Interfaces to subsystems etc.
  3. Build cheap robots that work in human environments
  4. The world is three-dimensional therefore a robot must model the world in 3 dimensions.

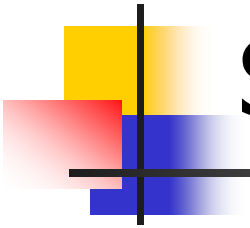


Dogma (more)

5. Absolute coordinate systems for a robot are the source of large cumulative errors.
6. The worlds where mobile robots will do useful work are not constructed of exact simple polyhedra.
7. Visual data is useful for high level tasks. Sonar may only be good for low level tasks where rich environmental descriptions are unnecessary.
8. The robot must be able to perform when one or more of its sensors fails or starts giving erroneous readings.

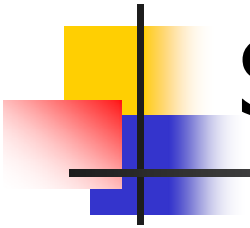
Dogma (more more)

9. "We are interested in building "artificial beings" --robots that survive for days, weeks and months, without human assistance, in a dynamic complex environment. Such robots must be self-sustaining



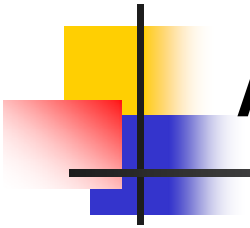
Subsumption

- Brooks and his group eventually came up with a computational architecture.
- Model arrived at by continually refining attempts to program a robot to reactively avoid collisions in a people-populated environment.
- Not intended as a realistic model of how neurological systems work.
- The model is called "subsumption architecture" and its purpose is to program intelligent, situated, embodied agents.



Subsumption Priciples

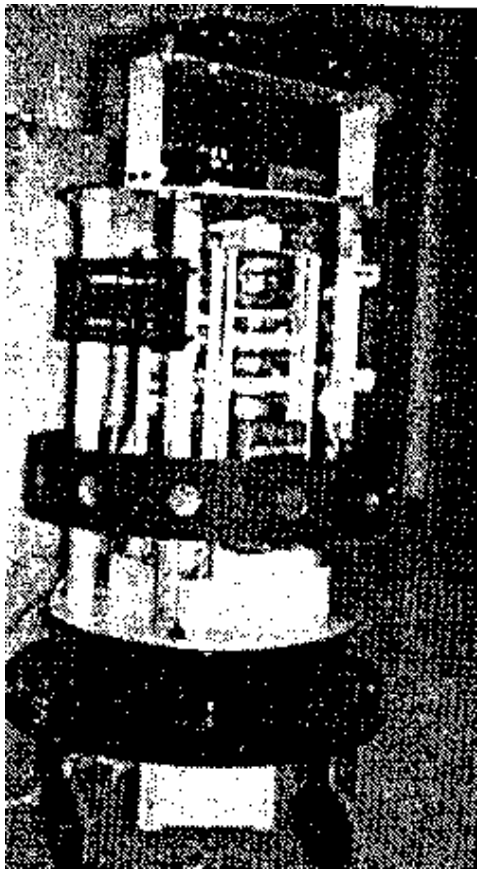
1. Computation is organized as an asynchronous network of active computational elements (they are augmented finite state machines (FSAs)), with a fixed topology of unidirectional connections.
2. Messages sent over connections have no implicit semantics-they are small numbers (typically 8 or 16 bits, but on some robots just 1 bit) and their meanings are dependent on the dynamics designed into both the sender and receiver
3. Sensors and actuators are connected to this network, usually through asynchronous two-sided buffers.

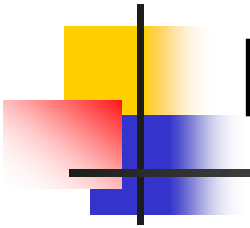


Allen

- First Subsumptive Robot
- Almost entirely reactive, using sonar readings to keep away from people and other moving obstacles, while not colliding with static obstacles.
- Also had a non-reactive higher level which attempted to head towards a goal.
- Used same type of architecture for both types of behaviours.

Allen (more)



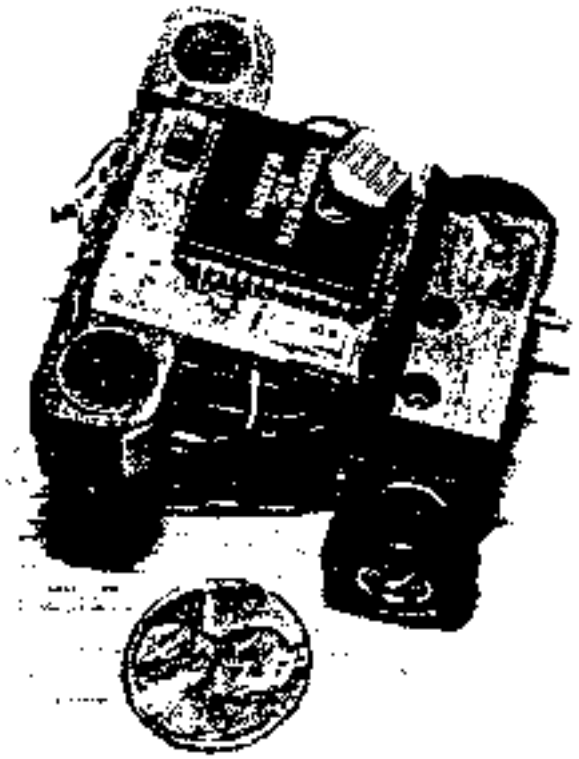


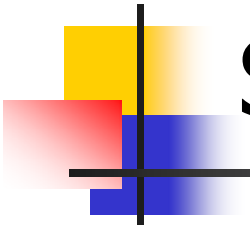
Herbert

- Used a laser scanner to find soda can-like objects visually, infrared proximity sensors to navigate by following walls and going through doors.
- A magnetic compass was used to maintain a global sense of orientation.
- A host of sensors on an arm were used to reliably pick up a soda can.
- Herbert's task was to wander around looking for soda cans, pick one up and bring it back to where Herbert had started from.

Squirt

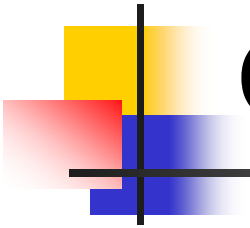
- Smallest robot they built
- Weighs 50 grams and is about 5/4 cubic inches in volume.





Squirt (more)

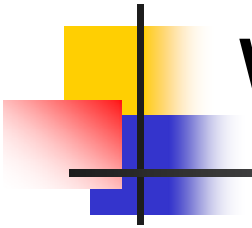
- Incorporates an 8-bit computer, an on-board power supply, three sensors and a propulsion system.
- Normal mode of operation is to act as a "bug", hiding in dark corners and venturing out in the direction of noises, only after the noises are long gone.
- The entire compiled control system for Squirt fits in 1300 bytes of code on an on-board computer.



Genghis

- Genghis is a 1Kg six legged robot which walks under subsumption control and has an extremely distributed control system
- It can walk over rough terrain using 12 motors, 12 force sensors, 6 pyroelectric sensors, one inclinometer and 2 whiskers.
- They built a follow-up, Attila--Stronger climber, and able to scramble at around 3 KPH.

Genghis (more)



Where do we go from here?

- There are many many problems that subsumption does not address, including adaptation through learning
- There is still much work to be done and it doesn't have to cost that much money.
- Try building one of these yourself.