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History and Background

What is old is new again (that doesn't mean it isn't true)

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Today

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

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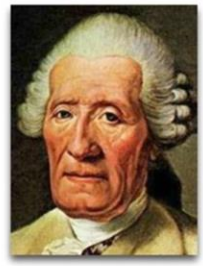
Jacques de Vaucanson (1709-1782)

- 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 parent's hall
- Soon he was making his own clock movements.



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Canard Digérateur

- Mechanical duck invented by Jacques de Vaucanson,1739
- Not a robot but an "automaton"
- Appeared to eat kernels of grain, metabolize them and defecate.
- Actually grain was collected in a hidden pocket
- no actual digestion took place
  - Feces was pre-stored and "produced"
- Vaucanson hoped that a truly digesting automaton could one day be designed.
- Voltaire wrote "without...the duck of Vaucanson, you would have nothing to remind you of the glory of France."

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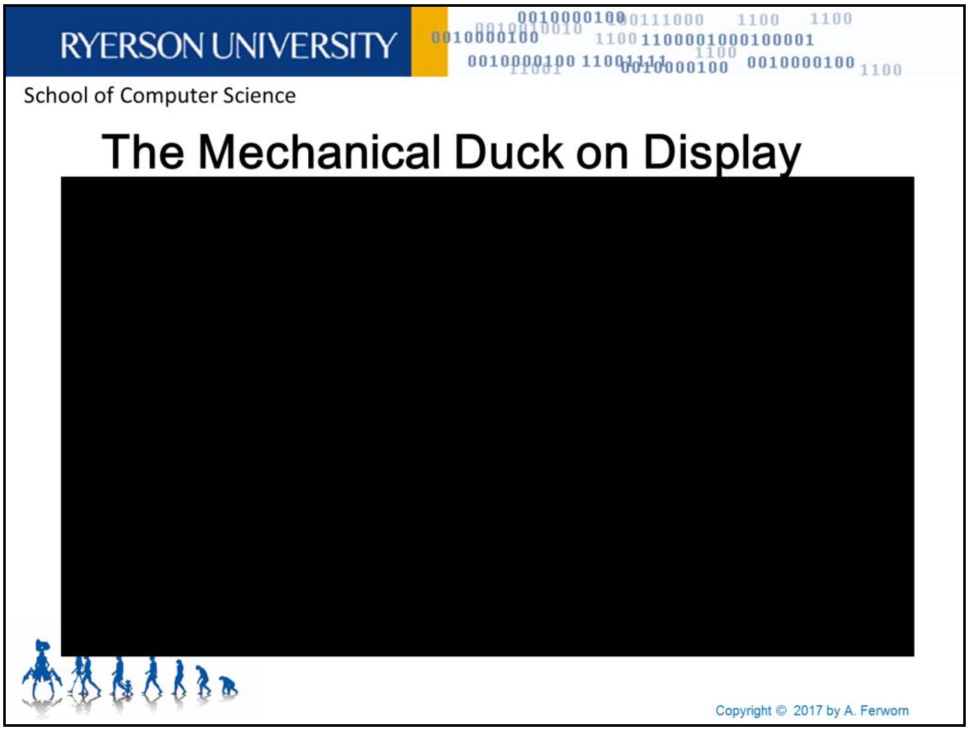
The Mechanical Duck

- 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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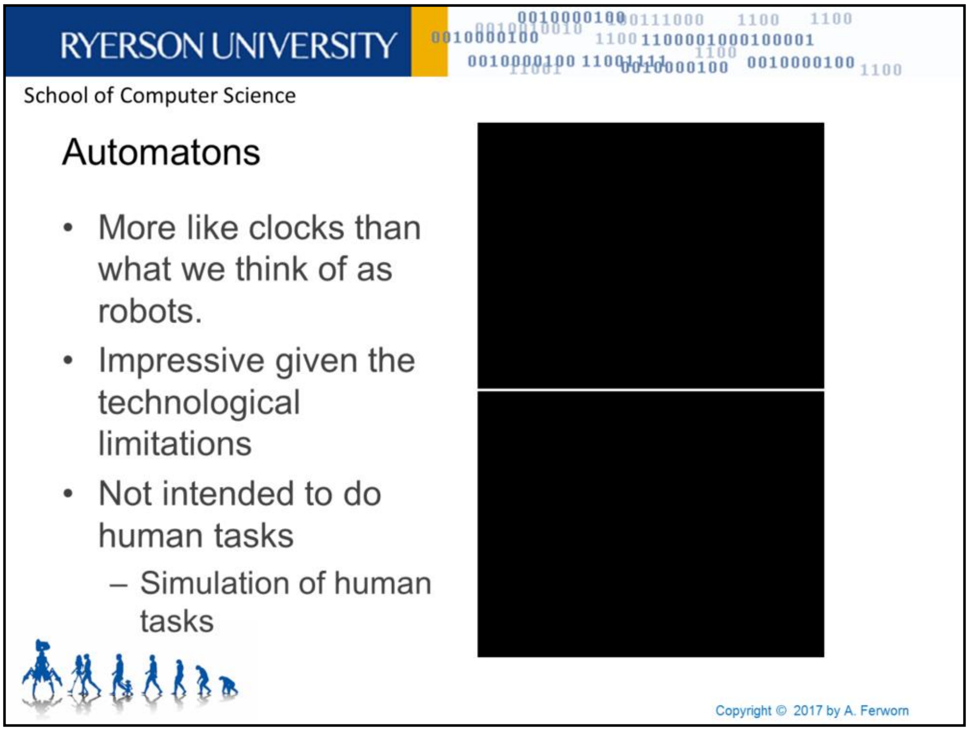
The Mechanical Duck on Display
Copyright © 2017 by A. Ferworn



French Musical Automaton "The Peasant and His Pig" by Gustave Vichy 1895

Smoking Buffalo Bill

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The basics: What is a robot?

- Term robot first used in "Rossumovi Univerzální Roboti" (R.U.R.) (1920) a science fiction play by the Czech writer Karel Čapek.
  - "Roboti"—compulsory laborers (slaves)

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R.U.R.

- 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.

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Radio Remote Control Aircraft System

- Early robots were teleoperated
- Edward M. Sorensen US Patent 2490844 (1940)
- invention communicated with ground terminal via radio signals
  - Rate of climb/descent,
  - altitude,
  - banking,
  - direction,
  - rpm and other
- Enabled tele-operations outside of visual range

US Patent 2,490,844 filed in May of 1940; Patent 2,408,819 filed May 16, 1940 and patent 2,482,804 filed May 16, 1940

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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

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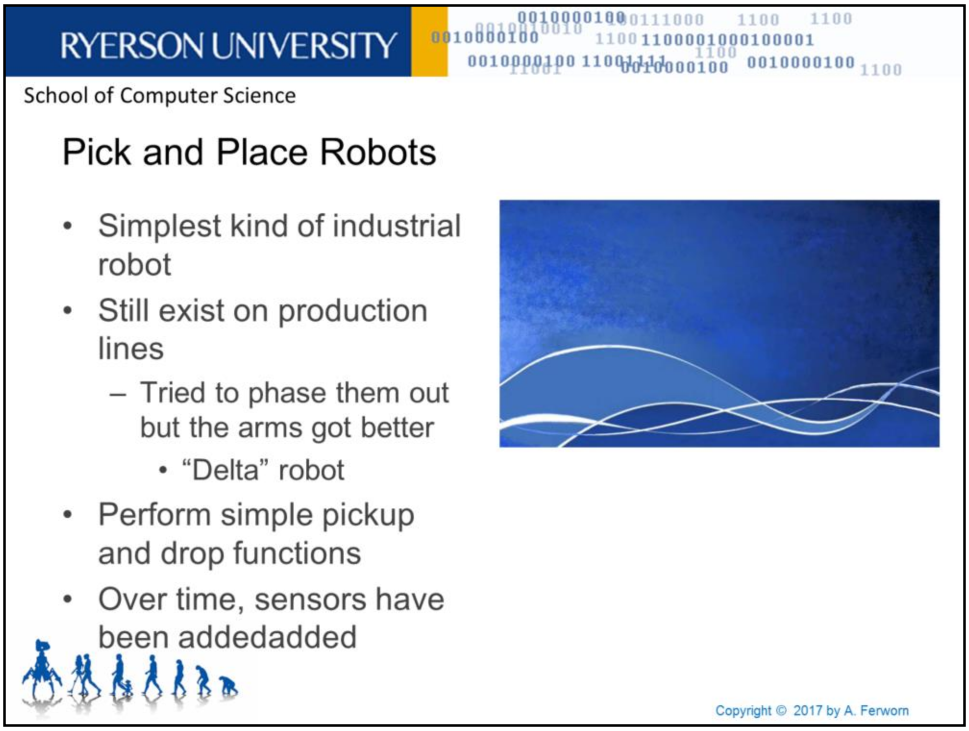
What are industrial robots?

- 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
- Working definition for an industrial robot:
  - Programmable machines that can perform a wide variety of physical tasks



A **delta robot** is a type of parallel **robot**. It consists of three arms connected to universal joints at the base. The key design feature is the use of parallelograms in the arms, which maintains the orientation of the end effector.

Pick and Place example

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Degree of Freedom

- a direction in which independent motion can occur.
- 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
- All of this requires
  - Lots of motors
  - Some way to figure out where motor shaft is
  - Math

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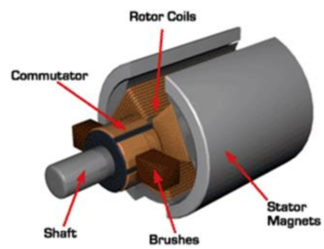
Parts of a Motor

- Motors enable robotics



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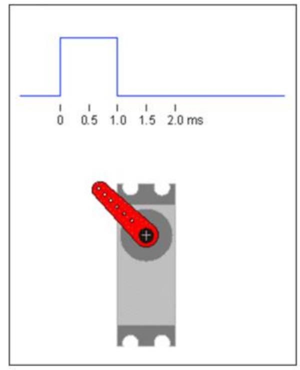
Servo Mechanism

- Shortened to “servo”
- an automatic device that uses error-sensing negative feedback to correct the action of a mechanism.
- Usually includes a built-in encoder or other position feedback mechanism to ensure the output is achieving the desired effect.



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Teaching robot arms

- If you have lots of servos in an arm, you can tell where all the motor shafts are
- 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.
  - You measure where a shaft is or you tell a shaft how much to turn
- 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

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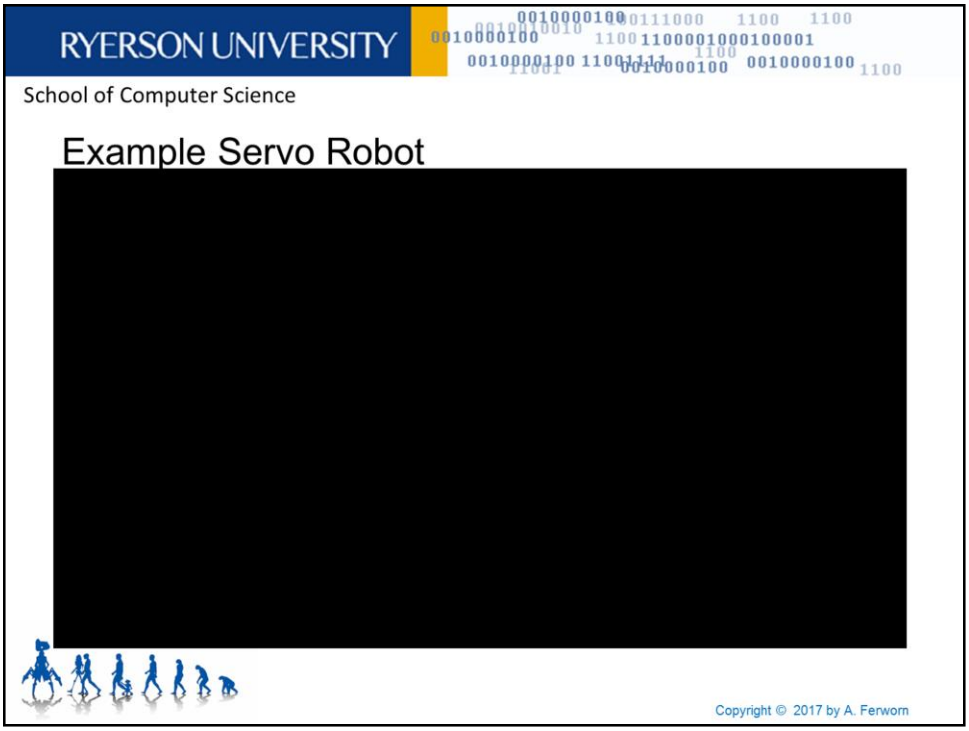
Servo Robots

- 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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Example Servo Robot
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Over Confidence

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

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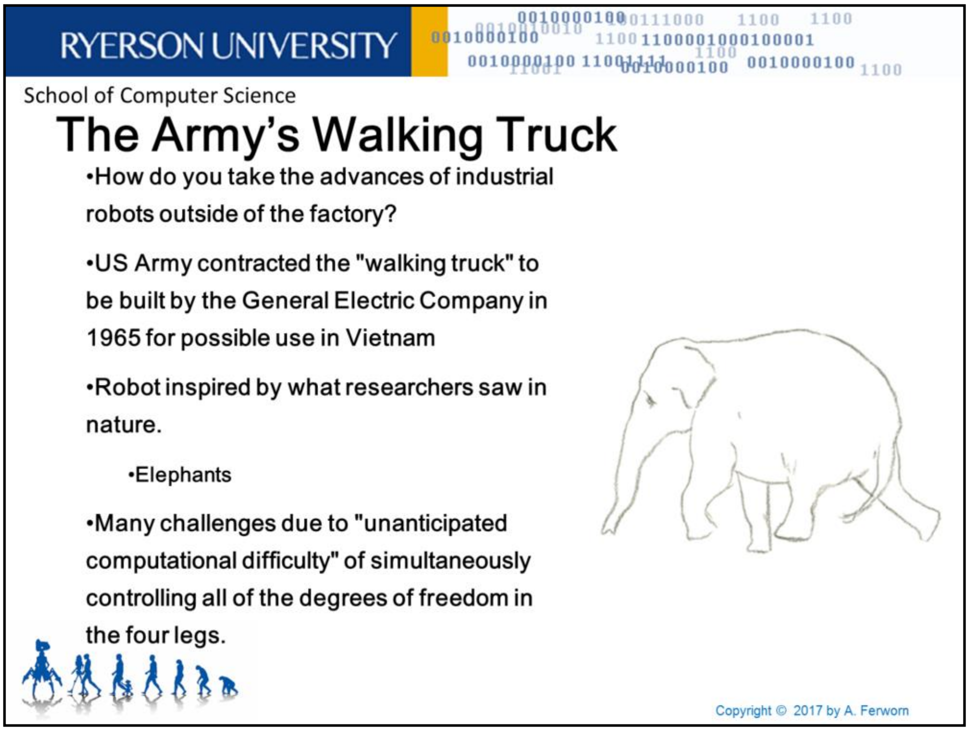
A Robot's More Complex World

- 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 Times Record – 24 July 1962 p13

From as early as 1962, the General Electric Ordinance Dept. in Pittsfield, Mass., undertook a study for the US Army which may lead to the building of a manned walking machine, with arms and legs, ….. where tractors might get stuck.

The mechanism for which the Boston Ordinance District has awarded a study contract, would be called a "pedipulator." It would be designed for rough or muddy terrain and its 12-foot legs would hike at 35-mile speed.

The human operator, who would be coupled directly to the mechanism, would walk inside the big machine and the 12-foot legs would take the same steps. The arms of the machine would follow the movements of the operator's arms.

Two or three machines might be lined up like men carrying a stretcher, or a litter, and thus transport equipment or men. The body of the pedipulator would be big enough to hold, besides the operator, electronic circuits, servo units and power drives.

An important element is making the human operator comfortable during extended periods and this will involve human-factor research.

By mid 1965, impressed by the results of the 'pedipulator", the Department of Defense and the Army Tank and Automotive Center asked GE to turn-out a semi-amphibious four-legged, cargo-carrying CAM (Cybernetic Anthropomorphous Machine). It was unveiled to the public in April 1969.

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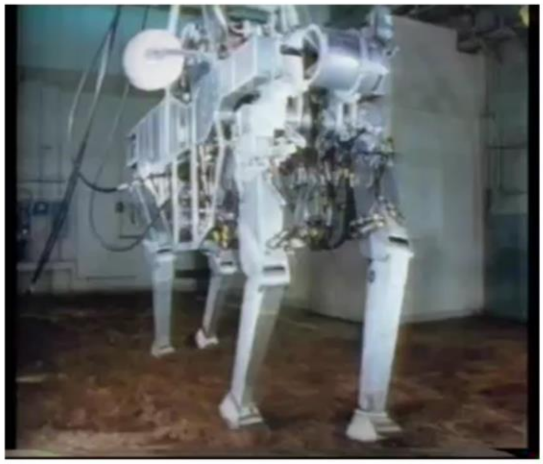
The Walking Truck in Operation



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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

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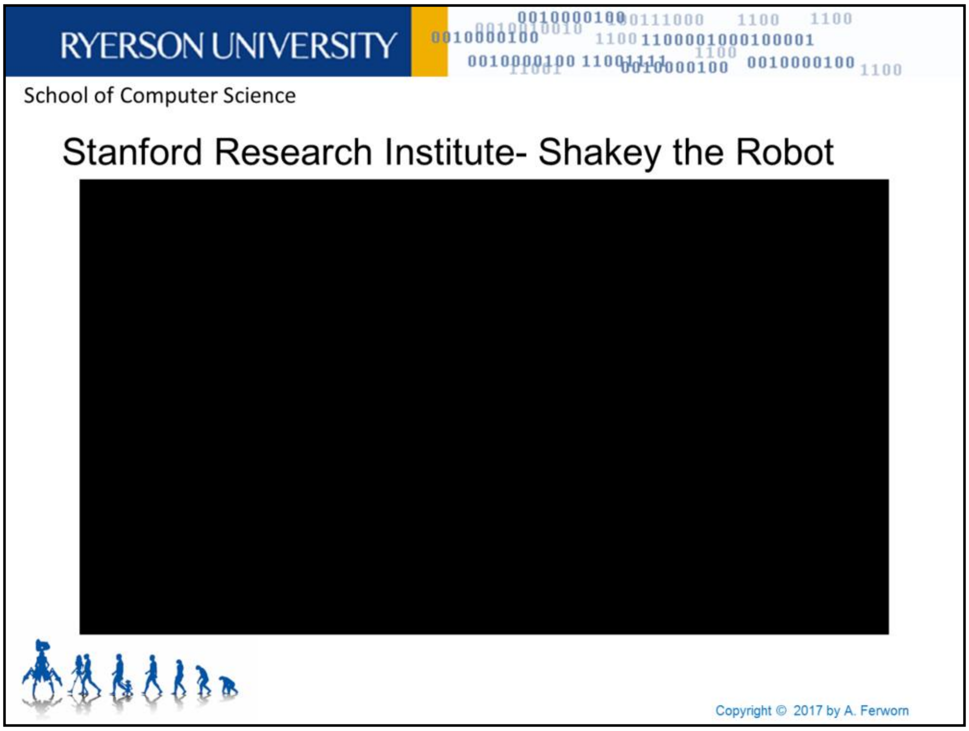
Shakey

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



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

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Shakey

- 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.

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The trouble with Shakey

- 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 environment
  - “Top down” thinking made it slow

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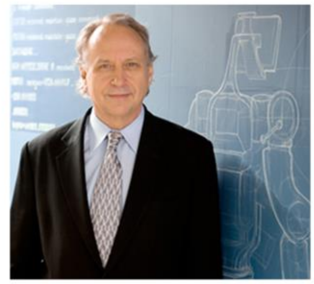
Rodney Brooks



- 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 lead the mobile robot group.
- Interested in Autonomous Robots that did real things

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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

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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, inconsisencies and contradiction.
  - Robustness: The robot must by fault-tolerant.
  - Extensible: You have to be able to build on whatever you built

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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.

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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.

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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

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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.
    - Larger behaviors are made up of smaller behaviors.

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Subsumption == bottom up robotics

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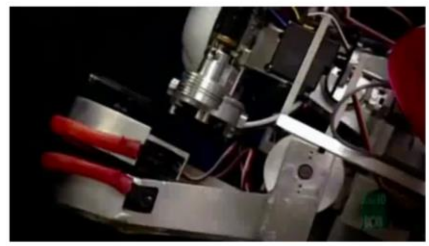
Kismet-Social Interaction Robot

- 1997 MIT AI Lab
- Creator: grad student Cynthia Breazeal (now Prof.)
- Kismet:
  - experiment in affective computing; a machine that can recognize and simulate emotions.
  - **Kismet** comes from a Turkish word meaning "fate" or sometimes "luck".



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Jibo the autonomous social interaction robot (2017)

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We've seen this before. Actimates (1998)

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Where do we go from here?

- There are many many problems that subsumption does not address, including,
  - Learning
  - Memory
- There is still much work to be done and it doesn't have to cost that much money.
  - Everything after lab 1 is essentially subsumption