Chapter 1 Robotics History

Lecture Notes for

A Geometrical Introduction to Robotics and Manipulation

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CRC Press

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Robots and Robotics

Definition: Robot

"A *mechanical device* that sometimes resembles a human and is capable of performing a variety of often complex human tasks on command or being programmed in advance."

"A *machine* or *device* that operates automatically or by remote control."

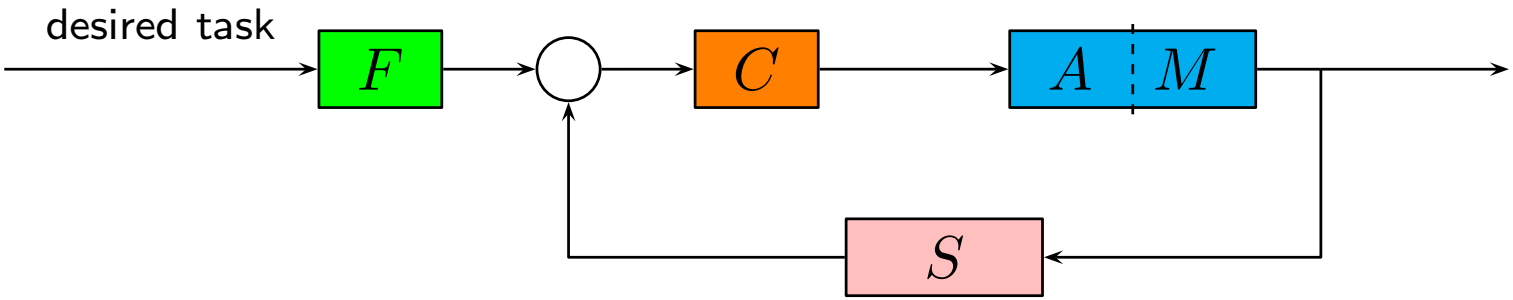
American Heritage Dictionary

Definition: Robotics

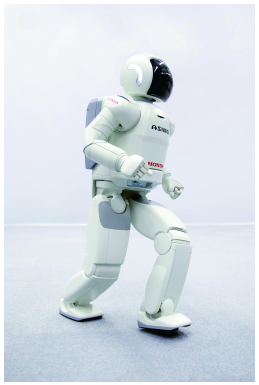
Science and technology of robots.

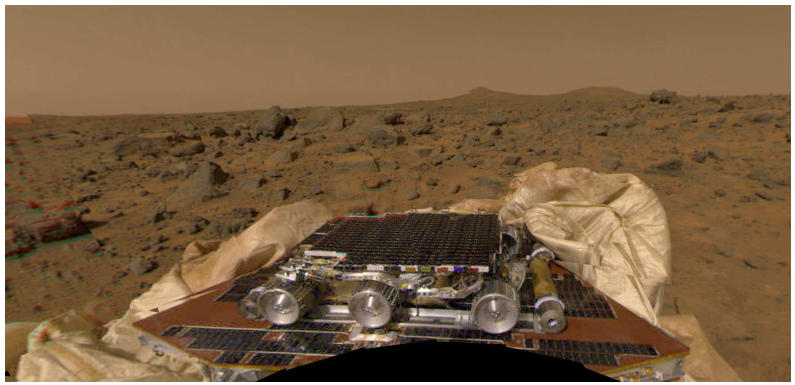
Robots and Robotics

◇ Function block description:



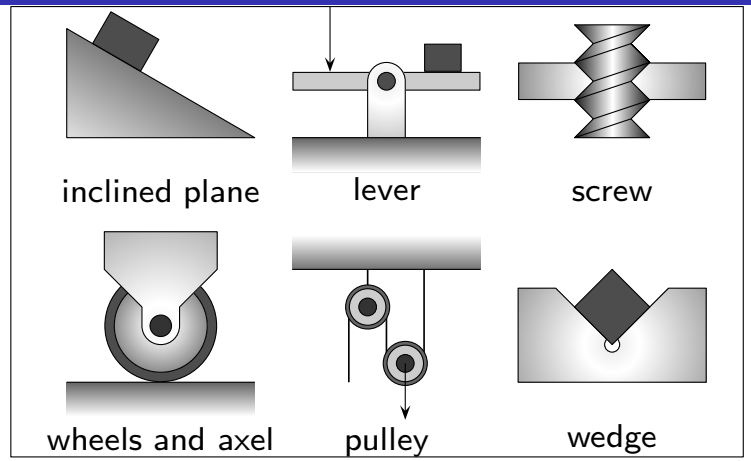
C: Control (Kinematics, dynamics, control)
A: Actuators (Motors, drives, servos, and transmissions)
M: Mechanisms (Synthesis and design)
S: Sensors (Signal processing, estimation, data fusion)
F: Feedforward (Motion planning and generation)





1.2 Ancient History (3000 B.C.-1450 A.D.)

Figure 1.1: Egyptian statues (3000 B.C.)



"If every tool, when ordered, or even of its own accord, could do the work that befits it... then there would be no need either of apprentices for the master workers or of slaves for the lords."

Figure 1.2: Aristotle (384-322 B.C.): Six basic machine elements and description of a robot

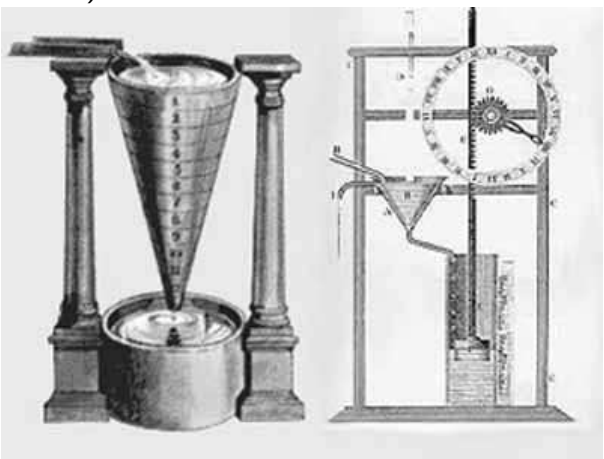
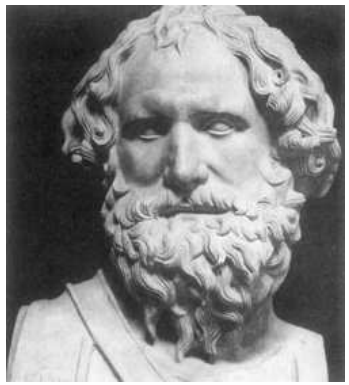


Figure 1.3: Ctesibius (Greek engineer, 270 B.C.): Water clock



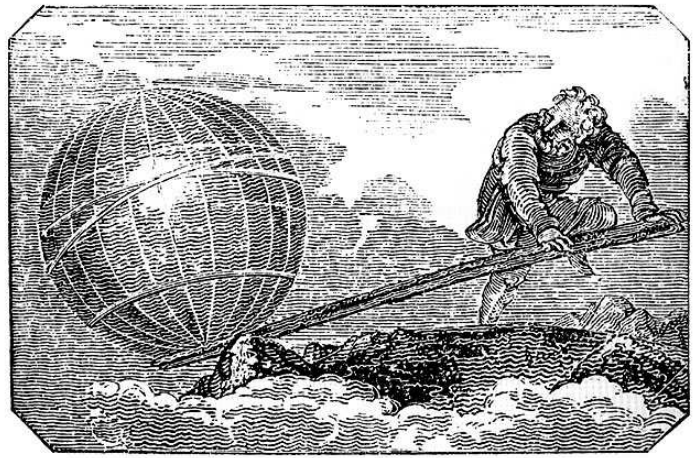


Figure 1.4: Archimedes (287 - 212 B.C.): Using six machine elements for machine design

Ancient History (3000 B.C.-1450 A.D.)

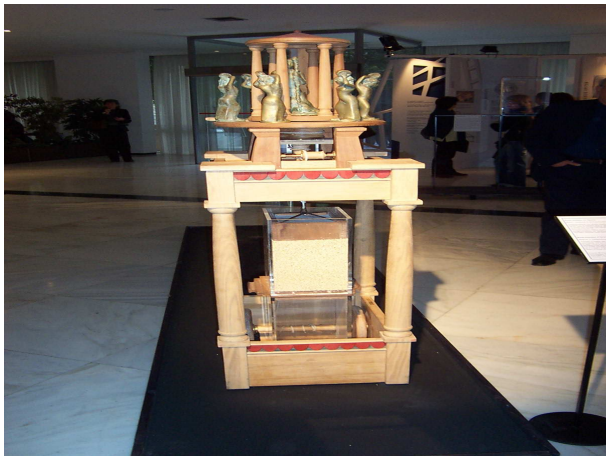


Figure 1.5: Heron of Alexandria (85 A.D.): Automatic theater and a steam engine

Figure 1.6: Zhang Heng (100 A.D.): South-pointing Chariot (non-magnetic differential mechanism)

Figure 1.7: Al-Jazari (1200 A.D.): Automata and first use of crank

Early History (1451 A.D.-1960)

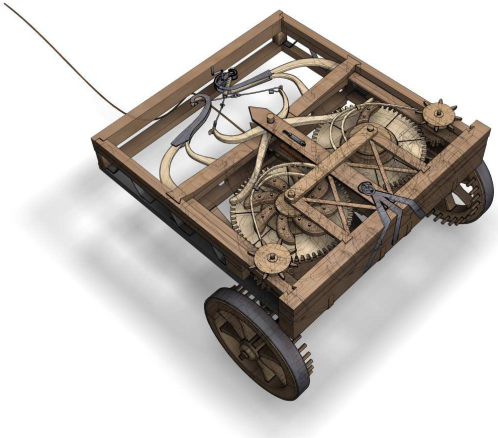
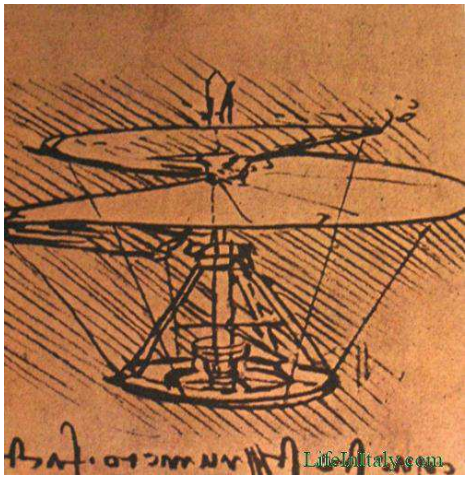




Figure 1.8: Leonardo da Vinci (1452-1519): Numerous machine designs recorded in Codex Atlanticus, Manuscript B and Codex Madrid (watch the da Vinci movie).

Figure 1.9: P. Ambroise (Paris 1564): Design of a mechanical hand.

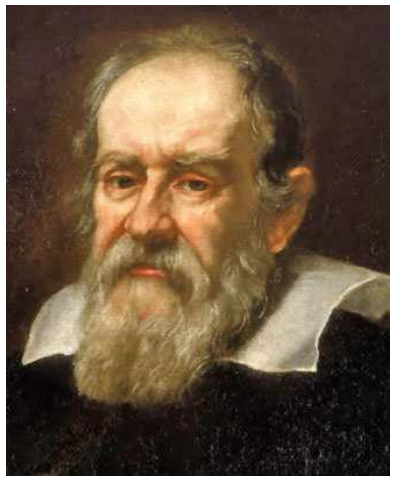
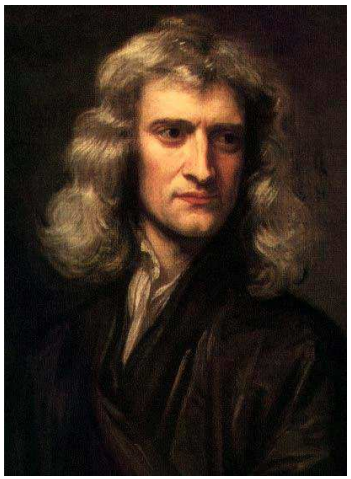


Figure 1.10: Galileo Galilei (1564-1642): Mechanics of motion

Early History (1451 A.D.-1960)



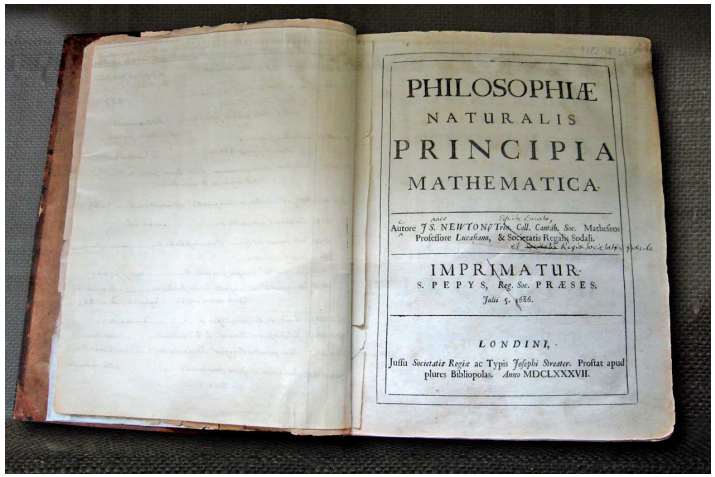


Figure 1.11: Isaac Newton (1642-1727): Calculus and Laws of Motion

Figure 1.12: L. Euler(1707-1783): Rigid dynamics and Euler's equations

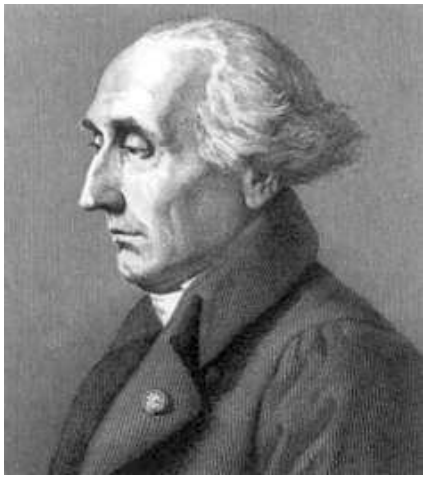


Figure 1.13: J. Lagrange (1736-1813): Calculus of variation and Principles of least action.

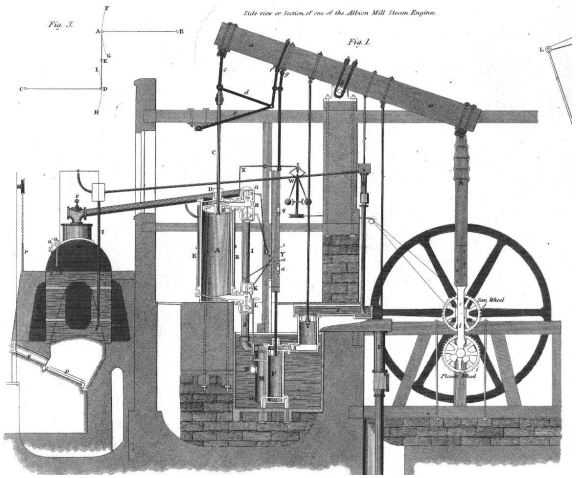


Figure 1.14: J. Watt(1736-1819): Sun and planet gear, centrifugal governor, parallel motion linkage, and double acting engine.

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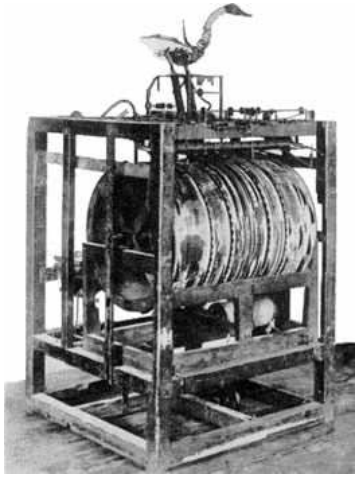

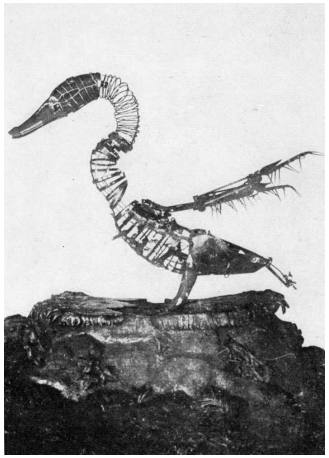

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Figure 1.16: P. Jaquet-Droz (1770): The writer and piano player.

Figure 1.17: A.M. Ampere (1175-1836): Kinematics.

Figure 1.18: J. Jaquard (1801): Automated loom controlled by punched cards.

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Figure 1.19: F. Kaufmann (1810): Mechanical Trumpeter.

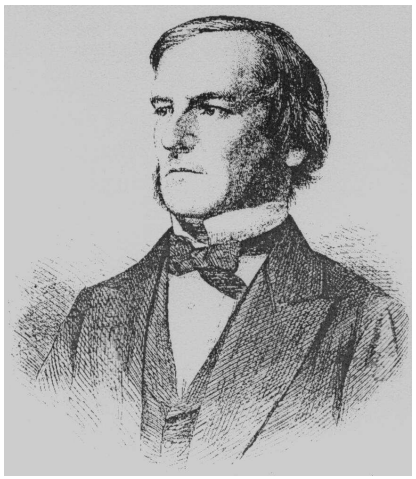
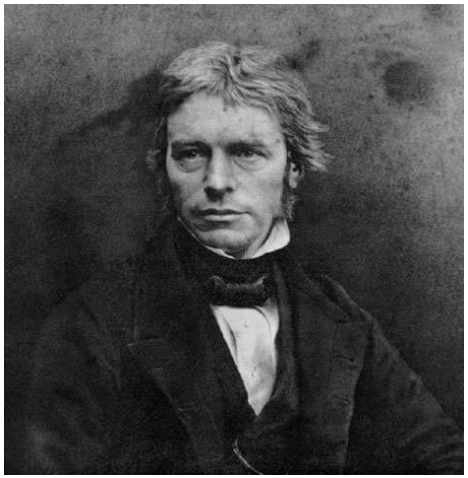


Figure 1.20: G. Boole (1815-1864): Theory of binary logic.



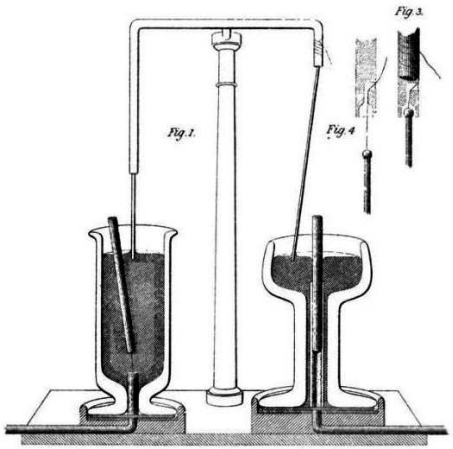


Figure 1.21: M. Farady (1821): electromagnetic rotation and motors.

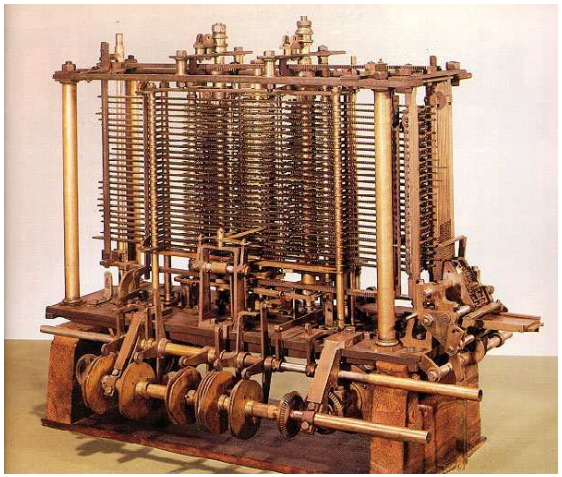


Figure 1.22: C. Babbage (1822): Difference and analytic engines.

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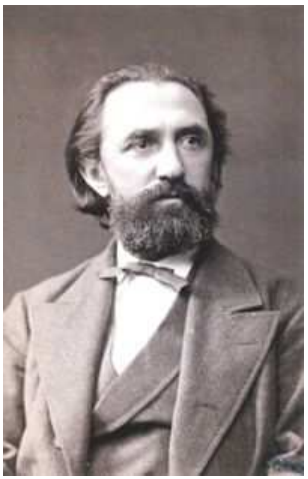

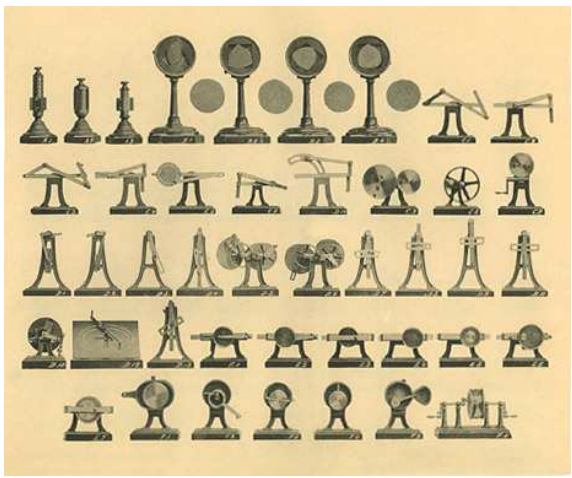

Figure 1.23: F. Reuleaux (1829-1905): Lower pairs and modern kinematics.

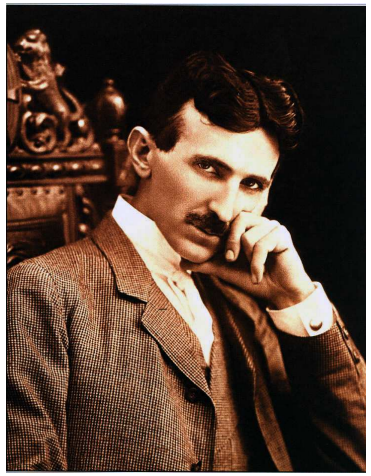

Figure 1.24: Nikola Tesla (1898): Remote controlled robot boat.

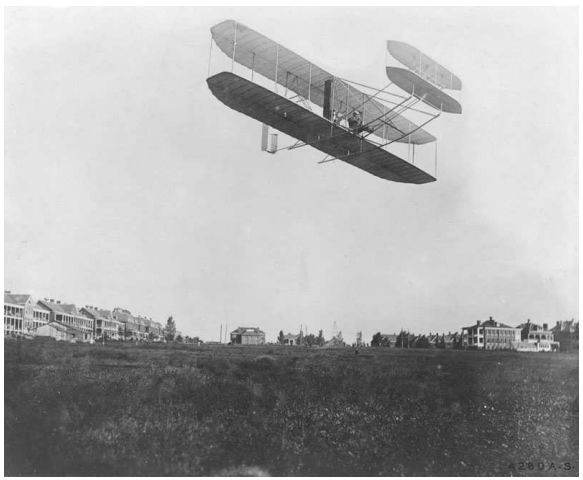

Figure 1.25: O. Wright (1908): First powered flight.

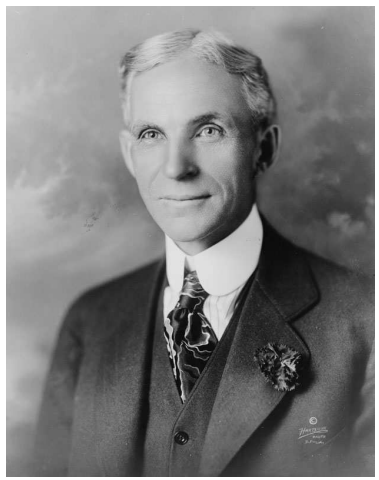

Figure 1.26: Henry Ford (1903): Assembly-line method of automated production.

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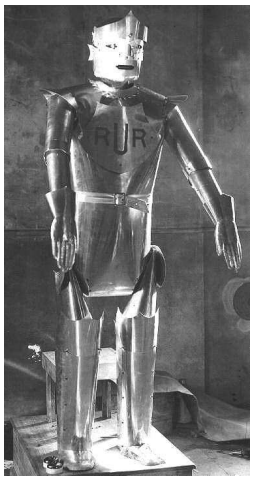

Figure 1.27: Karel Capek (1921): Coined the word "ROBOT" in a play called "RUR" (Rossum's Universal Robots)

Figure 1.28: V. Bush (1927): Analog computer.

Figure 1.29: Nyquist and Bode (1932, 1938): Classic control.

Figure 1.30: A. Turing (1936): Machine Intelligence

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Figure 1.31: H. black (1898-1983): Negative feedback

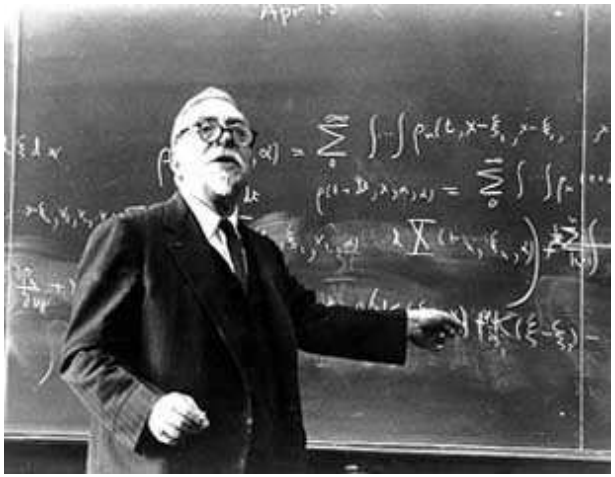

Figure 1.32: N. Wiener (1894-1964): Cybernetics

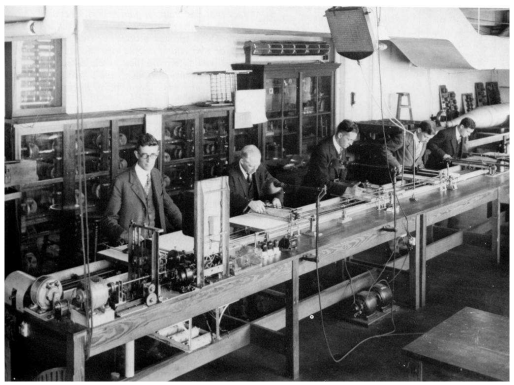

Figure 1.33: Hazen (1934): Theory of servomechanism.

Figure 1.34: R. Kalman (1930-): Modern control and Kalman filter

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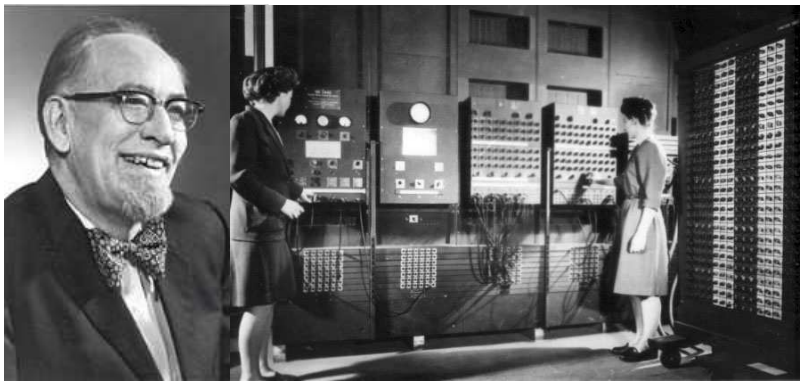
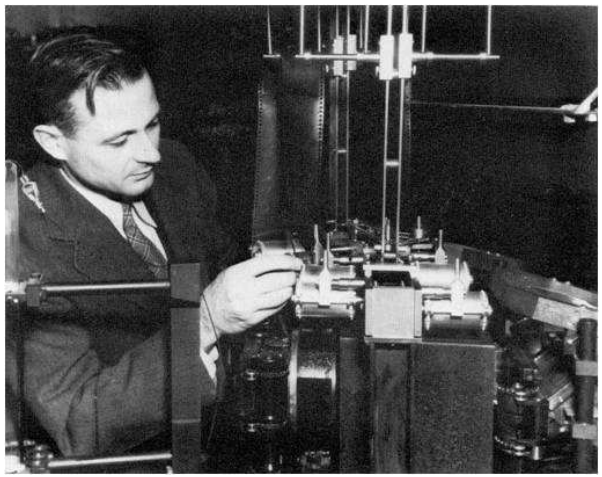
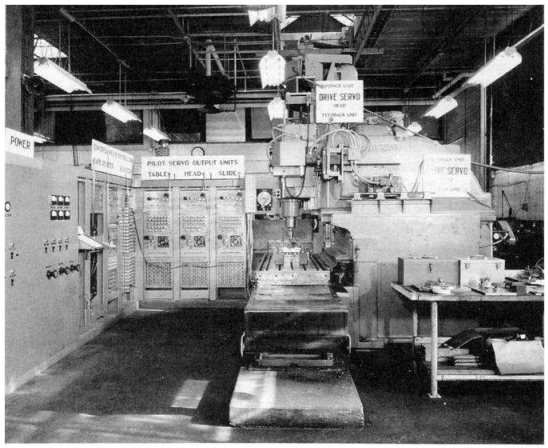


Figure 1.35: J. Eckert and J. Mauchley (1946): developed ENIAC, electronic digital computer

Figure 1.36: J. Von Neumann (1903-1957): Game theory and Von Neumann architecture.

Figure 1.37: Goertz at Argonne & Oakridge National Lab (1948): Telemanipulator.





The MIT numerically controlled milling machine.

Figure 1.38: G. Brown (1952): First CNC machine and APT

Early History (1451 A.D.-1960)

"1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey any orders given to it by human beings, except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law."

Figure 1.39: I. Asimov (1950): Three Laws of a robot

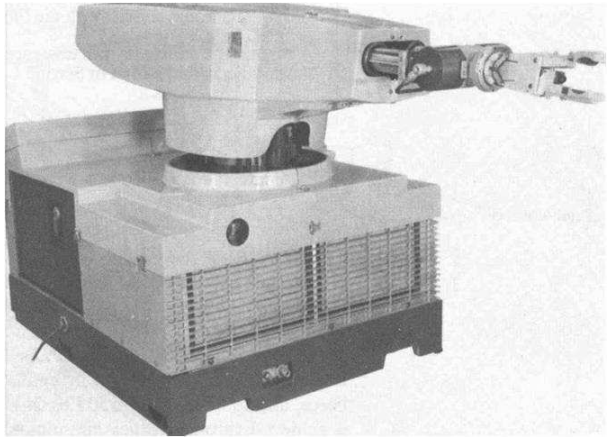


Figure 1.40: George Devol filed first robot patent (1954).

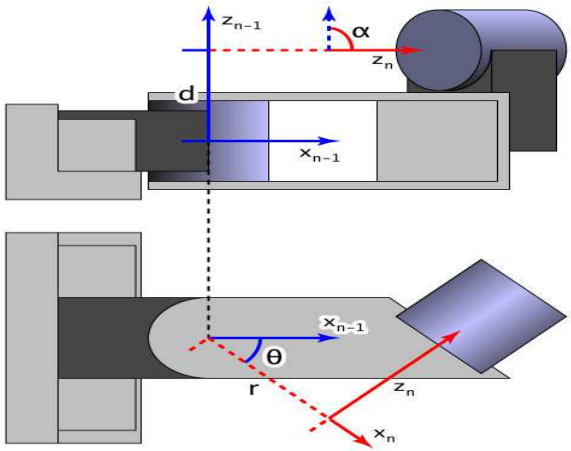


Figure 1.41: J. Denavit and R.S. Hartenberg (1956): Homogeneous transformations for Lower-pair mechanisms.

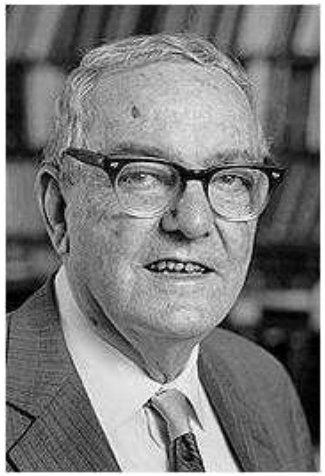


Figure 1.42: A. Newell and H. Simon (1956): Expert system

Early History (1451 A.D.-1960)

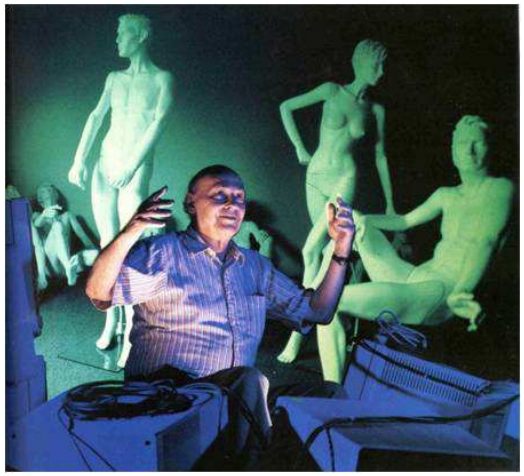


Figure 1.43: Marvin Minsky and John McCarthy (1956): AI lab at MIT

Figure 1.44: J. Kilby and R. Noyce (1958-1959): Integrated circuit

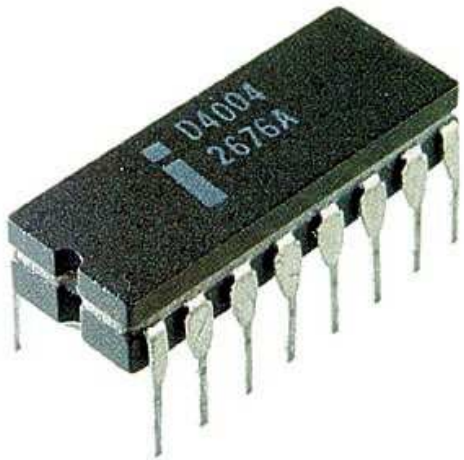


Figure 1.45: F. Faggin, T. Hoff and S. Mazor (1971): First microprocessor

Modern History (1961-)

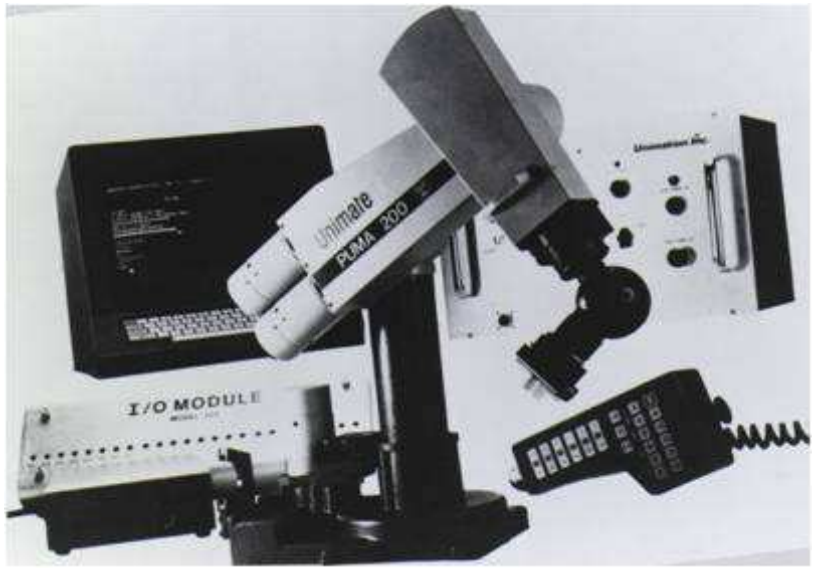


Figure 1.46: George Devol and Joseph Engelberger founded Unimation (1961), which installed the first industry robot at a GM plant in Trenton, New Jersy.

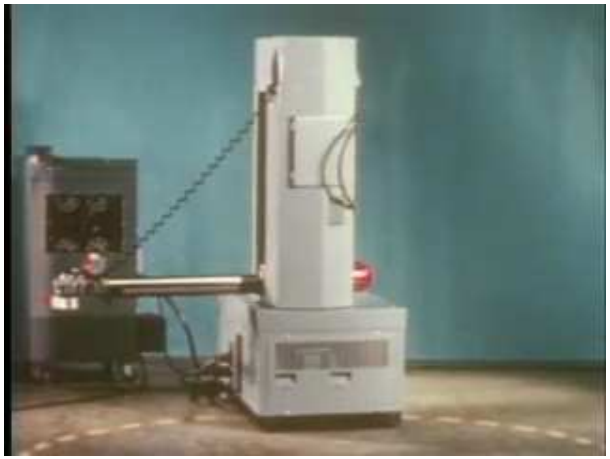


Figure 1.47: American Machine Foundry (AMF 1960) markets Versatran, a cylindrical robot.

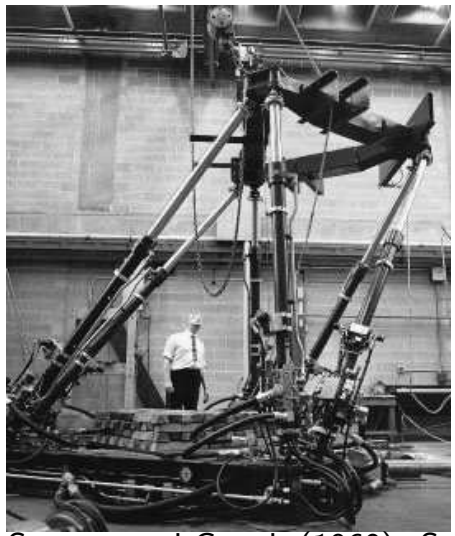


Figure 1.48: Stewart and Gough (1960): Stewart platform

Modern History (1961-)

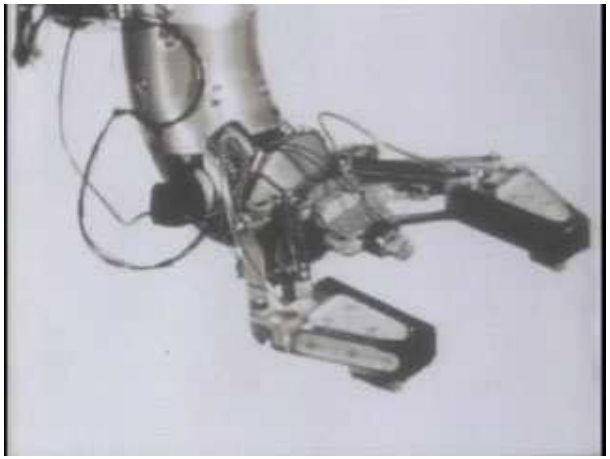


Figure 1.49: H. A. Ernst (MIT 1961): Computer control of mechanical arms using touch sensor.

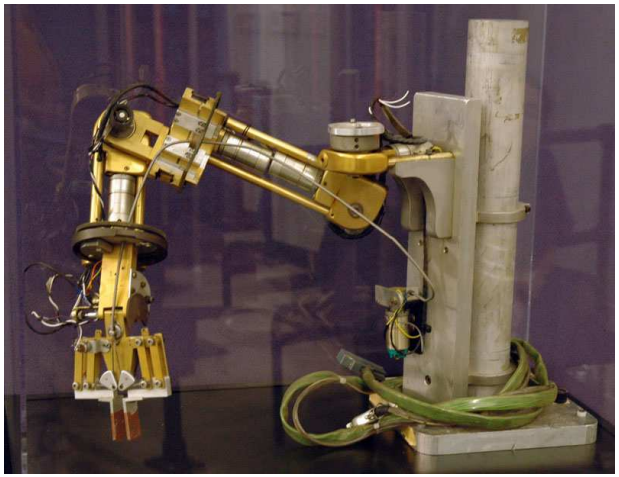


Figure 1.50: Stanford University(1963): Rancho Arm, the first artificial robotic arm to be controlled by a computer.

1.51: Research on robot kinematics and design initiated by B. Roth (1964), D. Pieper (1968), K. J. Waldron (1972), etc.

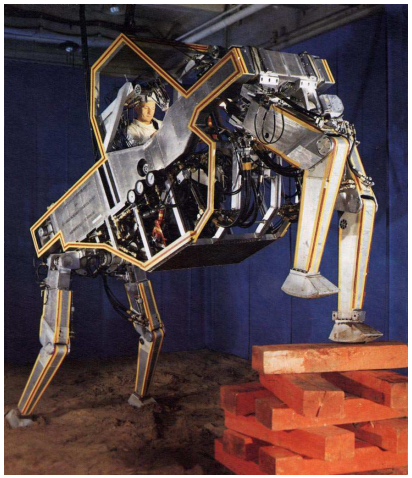


Figure 1.52: R. Mosher at General Electric (1968): quadrupled walking machine (11 ft tall, 3000lb)

Modern History (1961-)

Figure 1.53: Kawasaki robots in Japan with a patent from Unimation (1968)

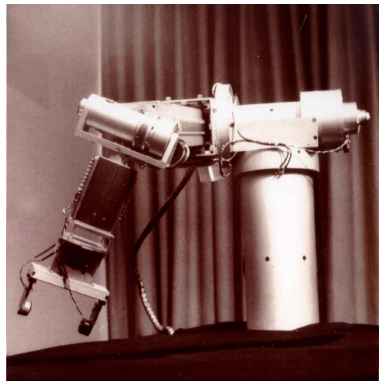


Figure 1.54: V. Scheinman (1969): The Stanford arm

Figure 1.55: Draper Lab (1970) (RCC Device), SCARA robots by H. Makino, Japan (1978), Adept Robotics (1982)

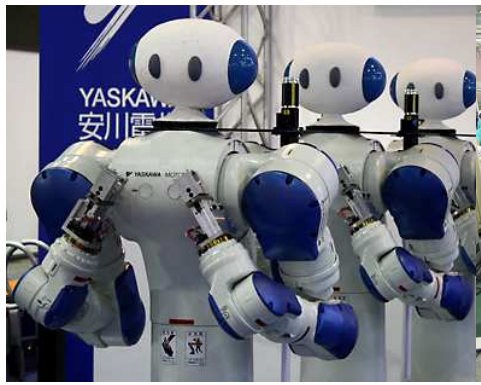


Figure 1.56: Yaskawa engineers coined the term "Mechatronics" (1971)

Modern History (1961-)

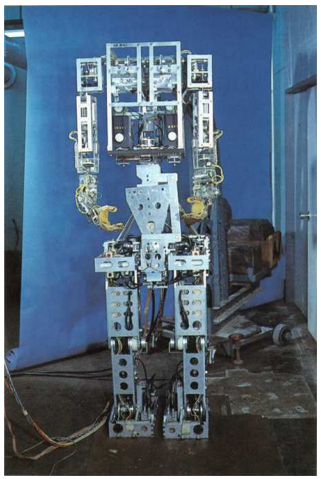
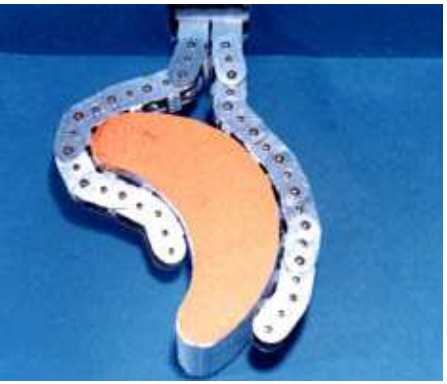


Figure 1.57: Waseda University develops Wabot-1 (1973) and Wabot-2 (1980)

Figure 1.58: Cincinnati Milacron (1974): (T3 Robots) Payload (100lb)



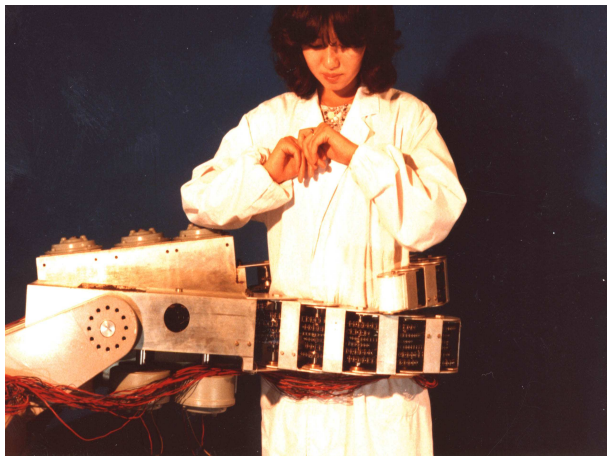


Figure 1.59: S. Hirose (1976): The soft gripper

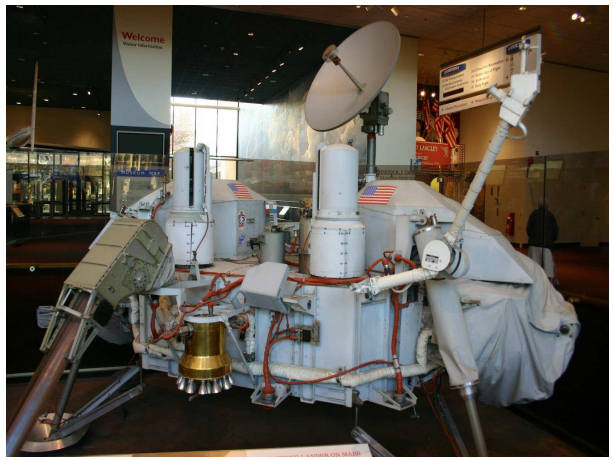


Figure 1.60: Viking 1 and 2 space probes, equipped with robot arms (1976)

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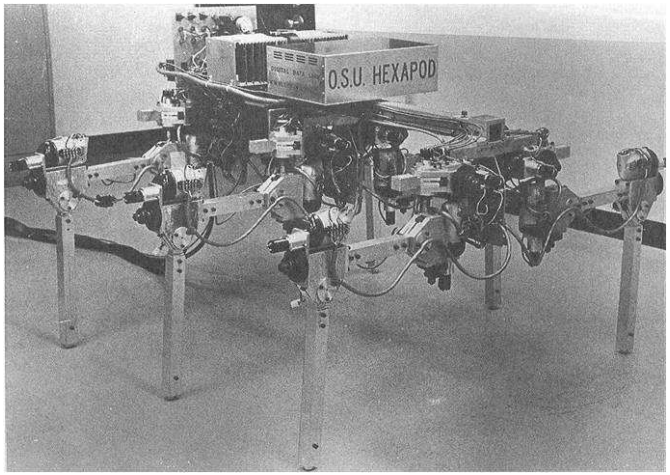

Figure 1.61: OSU Hexapod (1977)

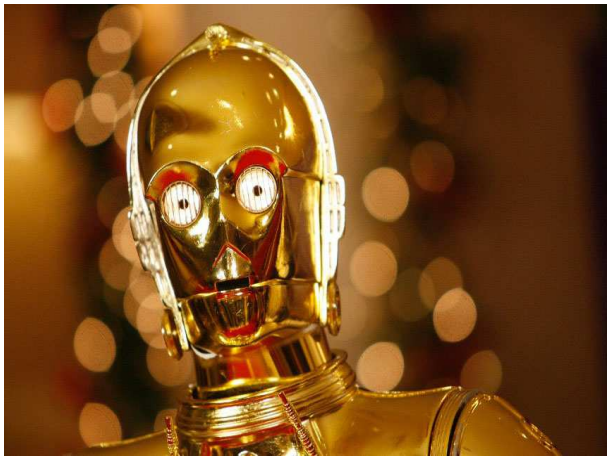

Figure 1.62: Star Wars (1977): R2-D2 and C-3PO

THE ROBOTICS INSTITUTE

Figure 1.63: Robotics Institute at CMU is established (1979), leading to first PhD program in Robotics.

1.64: Research on robot control initiated by J. Luh, M.W. Walker, R. Paul (1980), S. Arimoto (1984), D.E. Whitney (1977), J. Salisbury (1980), M. Raibert and J. Craig (1981), N. Hogan (1985), M. Mason (1981), O. Khatib (1987), etc.

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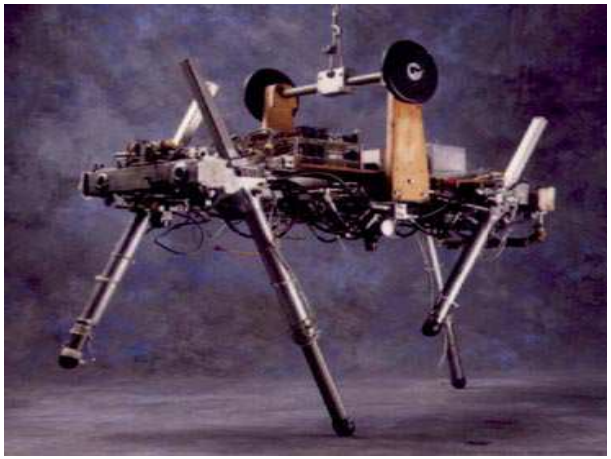
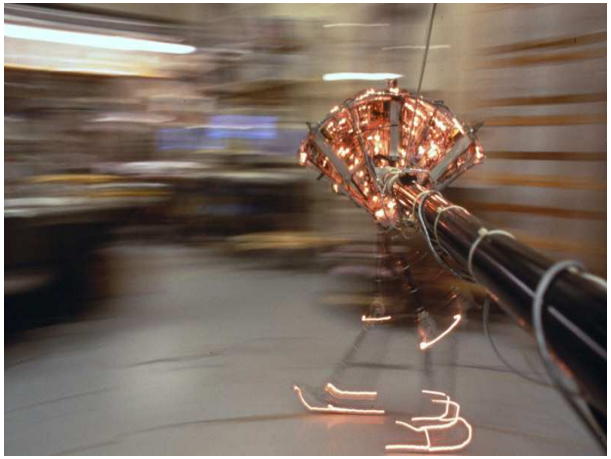
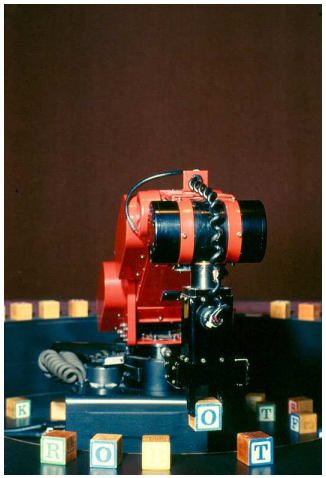




Figure 1.65: M. Raibert (1980) (RI, CMU & AI lab, MIT): Hopping, Robots, Monoped, biped and Quadpeds. Dynamically stable quadruped robot BigDog created by Boston Dynamics (founded by M. Raibert in 1992) with the NASA Jet Propulsion Laboratory, Caltech (2005).



1.66: Research on robot dynamics initiated by J. Luh (1980), T. Kane (1983), R. Featherstone (1983), etc.

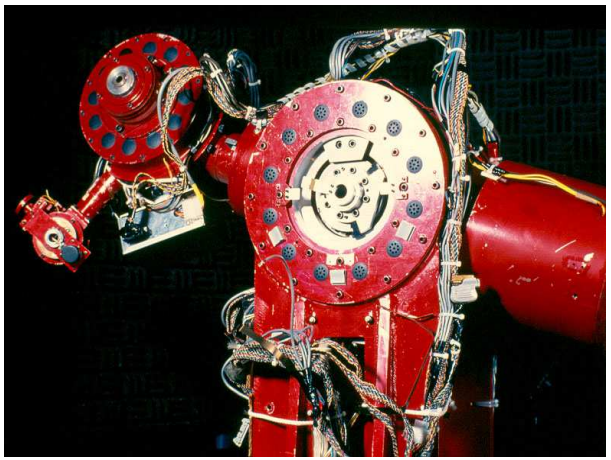


Figure 1.67: H. Asada and T. Kanade at CMU (1981): Direct drive robots

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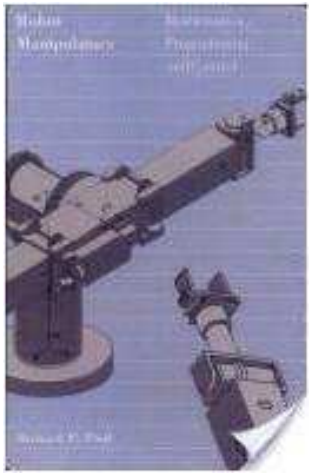

Figure 1.68: R. Paul (1981): **Robot Manipulators: Mathematics, Programming, and Control.** MIT Press.

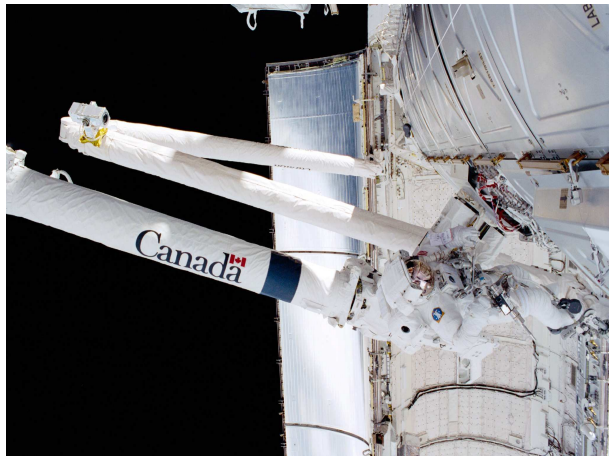

Figure 1.69: NASA (1981): Candarm

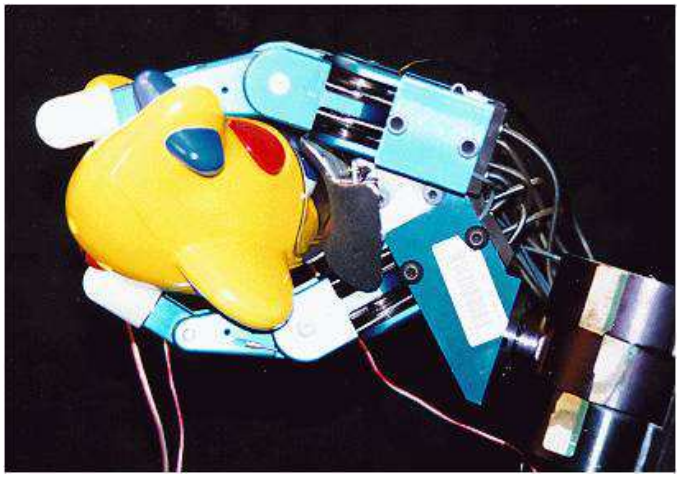

Figure 1.70: K. Salisbury (1981): Salisbury Hand

Figure 1.71: Fanuc of Japan and General Motors form a joint Venture (1982): Fanuc Robotics America.

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1.72: International Journal of Robotics Research (1982), IEEE International Conference on Robotics and Automation (ICRA , 1985), and IEEE Journal of Robotics and Automation (1985)

1.73: R. Brockett (1983): Product of exponential formula for robot kinematics, and D. Montana (1986): Kinematics of contact.

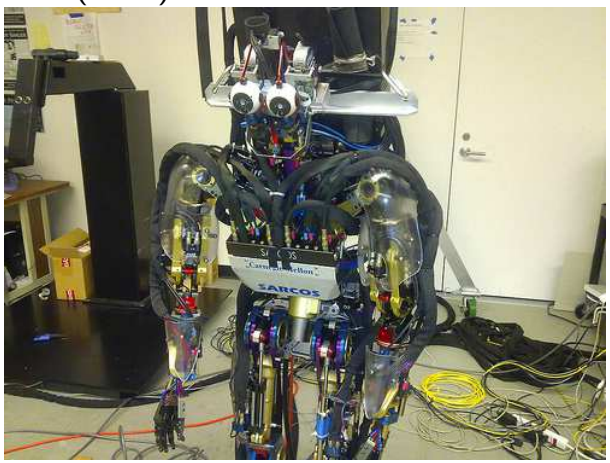

Figure 1.74: Sarcos, Utah (1983): Entertainment robot.

1.75: Motion planning research initiated by J. Schwartz and M. Sharir (1983), Lozano-Perez (1983), J. Canny (1988), and O. Khatib (1986).

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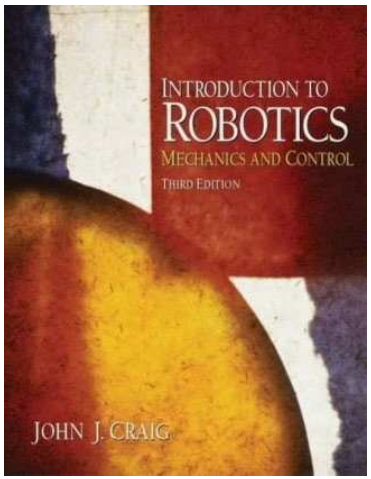

Figure 1.76: J. Craig (1986): **Introduction to Robotics: Mechanics and Control.** Addison-Wesly.

Figure 1.77: Odetics Walking robots (1988)

Figure 1.78: Utah/MIT (1989): Utah/MIT hand

Figure 1.79: R. Brooks and A.M. Flynn (MIT, 1989): **"Fast, cheap and Out of Control: A Robot Invasion of the Solar System"**

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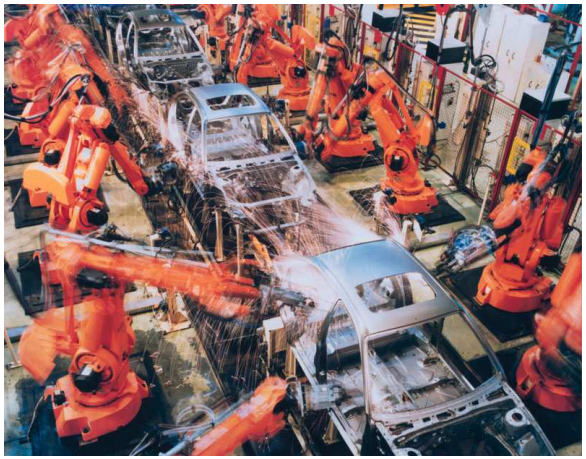

Figure 1.80: ABB of Switzerland acquires Cincinnati Milacron, creator of PUMA (1990)

Figure 1.81: iRobot was founded in 1990 by Rodney Brooks, Colin Angle and Helen Greiner after working in MIT's Artificial Intelligence Lab (1990)

Figure 1.82: R. Clavel (1991): Delta robot

Figure 1.83: Da Vinci robot by Intuitive surgical (1995)

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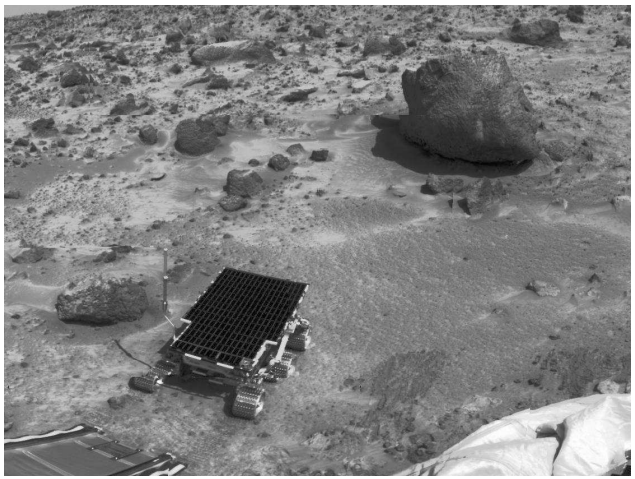

Figure 1.84: NASA (1996): Sojourner, NASA (First Manned Robot to land on Martian Surface)

Figure 1.85: DLR Hand (1998)

Figure 1.86: Sony (1999): AIBO robots

Figure 1.87: EPFL (1999): High Mobility Wheeled Rover, SHRIMP

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Figure 1.88: Honda (2000):Humanoid Robot, ASIMO

Figure 1.89: Defense Advanced Research Projects Agency (DARPA, 2004-): DARPA Grand/Urban Challenge

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