Lecture 01
Robotics

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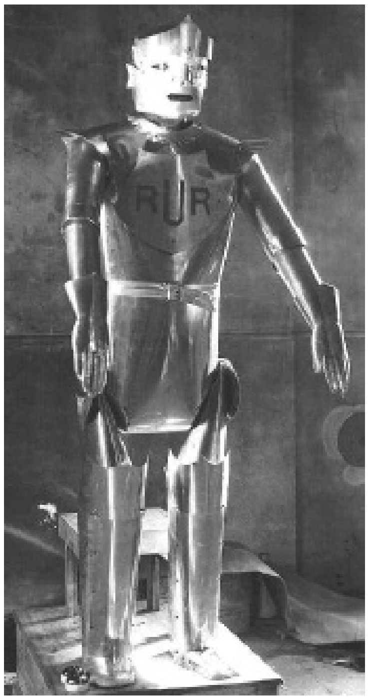
Course Details

- 70% (WE) - 30% (CA)
- Contents : Overview of Robotics, Robot Manipulator Modeling (kinematics), Robot Control (position and force), obstacle avoidance (mobile robots)
- MatLab based assignments
  - Mobile robot obstacle avoidance
  - MatLab Robotics Toolbox, Simulink
- Robot Control Lab Exercises
  - Robot manipulator control
  - Robot manipulator trajectory planning

Brief History of Robotics

- Definition:
  A piece of machinery that could perform tasks which are generally ascribed to humans, such as Voice recognition, speech synthesis, obstacle avoidance, face recognition, etc..



- The word **robot** first appeared in a Czeck stage play "**Rossum's Universal Robots**" by Karel Capek in 1921. In Czeck, "robot" means "**forced labor**"

- The word **robotics** first appeared in the science fiction "Runaround" by Issac Asimov in 1938. Robotics is the science and engineering of using robots.

Robotics is Interdisciplinary

Robotics →

- **Mechanical Engineering**
  Study of mechanics in static and dynamic situations
- **Mathematics**
  Spatial motions and their attributes of manipulaors
- **Control theory**
  Designing algorithms to realize desired motion/force
- **Electrical/Electronic Engineering**
  Integration of sensors, actuators through interfaces
- **Computer science**
  Programming the entire system to perform desired task

Fundamental Ideas

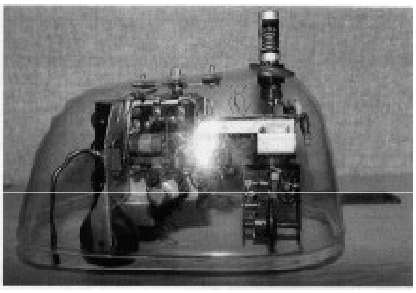
- The study of robotics concerns with the desire of synthesizing some aspects of human function by use of mechanisms, sensors, actuators, and computers. This is a huge undertaking, which require a multitude of ideas and expertise from various technical fields

Robotics Partitions

- The field of robotics has widened, and clearly partitioned recently. Currently, there are four partitions that can be clearly identified: mechanical manipulation, locomotion, computer vision, and artificial intelligence

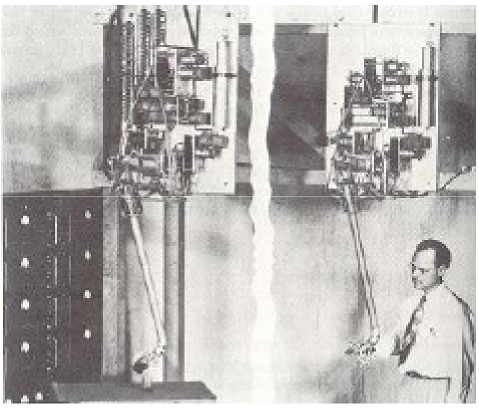
Very Early Robots

1940s



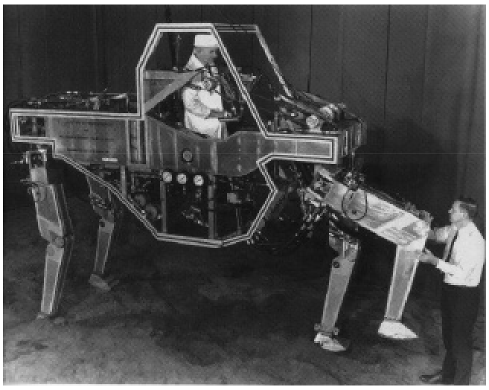
Gray Walter's "tortoise"

1945



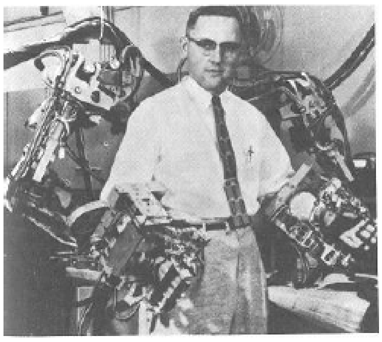
First modern master-slave teleoperator (Argonne National Lab, USA) for handling radioactive materials in a hot-cell

1960s



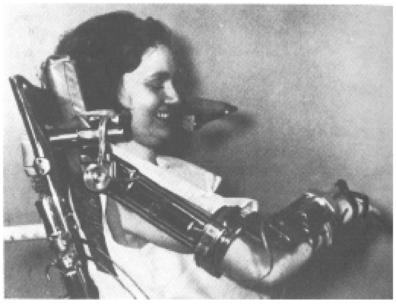
General Electric's "walking truck". First legged robot, walks 4miles/h

1960s



"Handyman" Masterslave electro-hydraulic manipulator, General Electric, 2 hands, 10dof

1960s

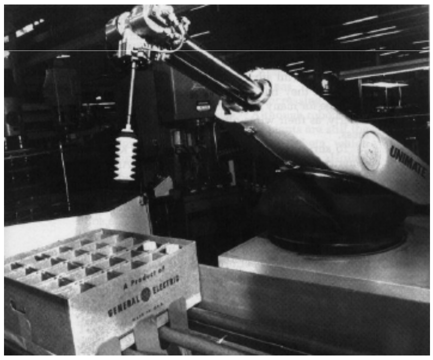


Teleoperators for welfare. Commands are taken from the tongue, or other remaining motor signals to actuate wheelchairs, prosthetic arms, etc.

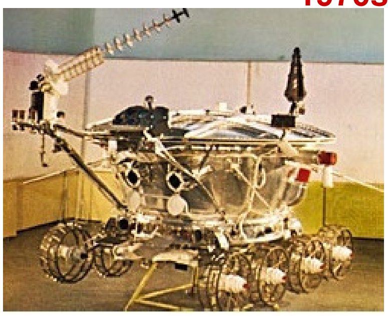
1970

Teleoperation in undersea applications. A cheaper and safer substitution for divers in searching offshore oil using small unmanned remote-controlled submarines with video.

“Unimate”, the first industrial robot developed by George Devol and Joe Engleberger, the father of robotics.
- picks and place parts
- CAD/CAM systems



1970s

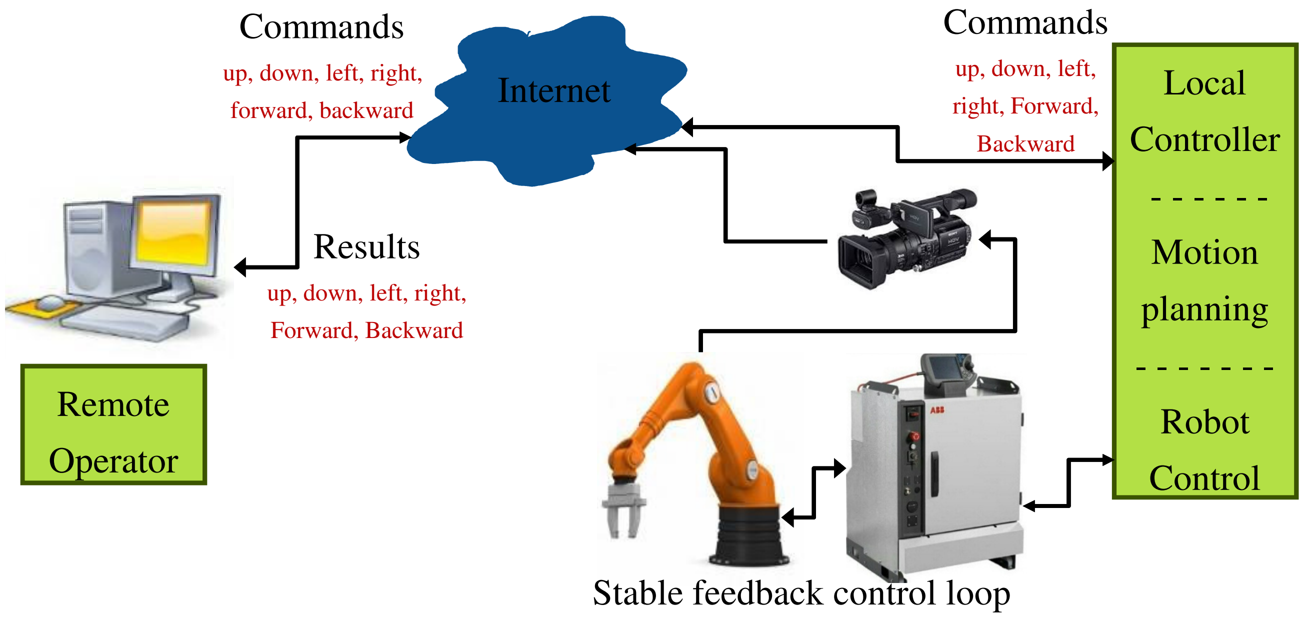


Race to the moon.
- First remotely controlled moon rover Lunakhod (USSR).
- Travelled 11km in 11months
- Time delay and stability problem.

Robotics Research Areas

- Telerobotics
- Medical robotics (telesurgery), Micromanipulation
- Flying robots / space robots, Climbing robots
- Milibots, millibot teams, Polybots (modular reconfigurable Robots)
- All terrain robots, Planetary exploration robots, Mobile robots, Self-driving cars, Telepresence Robots
- Humanoids, Service and care-giving robots
- Robotic prosthetic limbs, Grasping
- Exploration and mapping robots
- Biomimetic robots, Expressive Robotic creatures, Entertainment robots
- Surveillance robots, Demining robots, Aerial robots
- Industrial robots (welding, assembly, etc.)

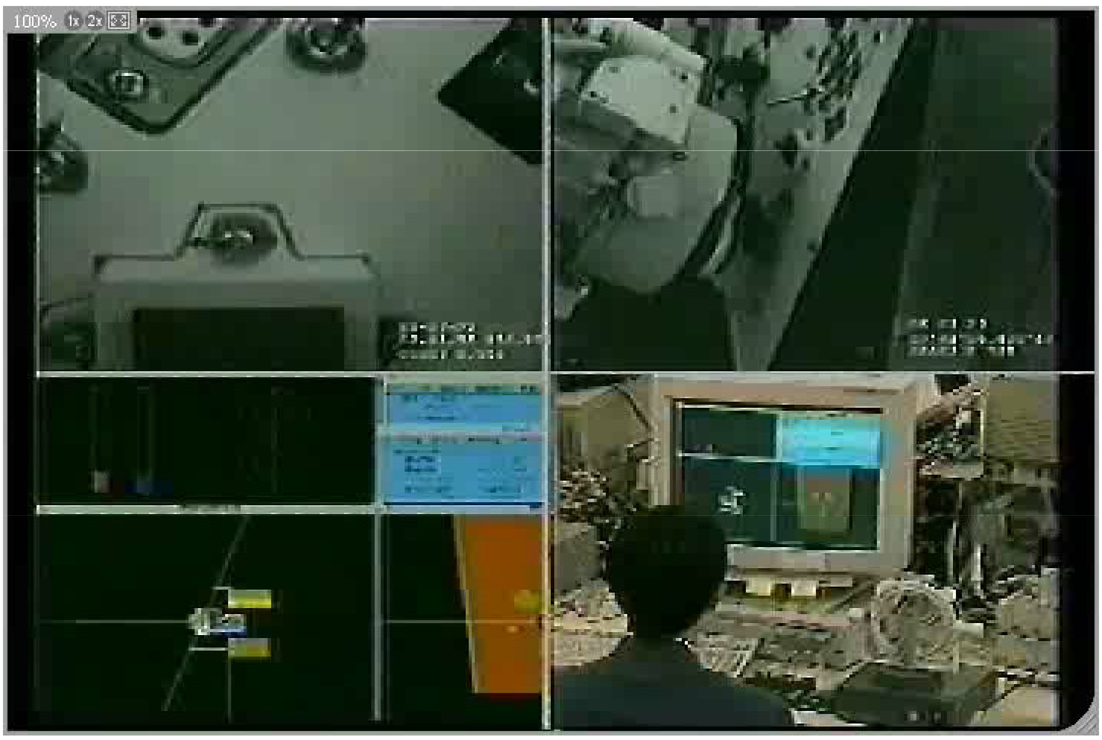
Telerobotics over the Internet



- Remote user issues only high-level commands, for which low level motion planning is carried out by the local controller. Feedback control loop is locally implemented, thus, stable operation is assured.
- Long range teleoperation is not continuous, but a stepped control process due to time delay ("move-and wait")

Ground-Space Teleoperation

move-and-wait



Telerobotics

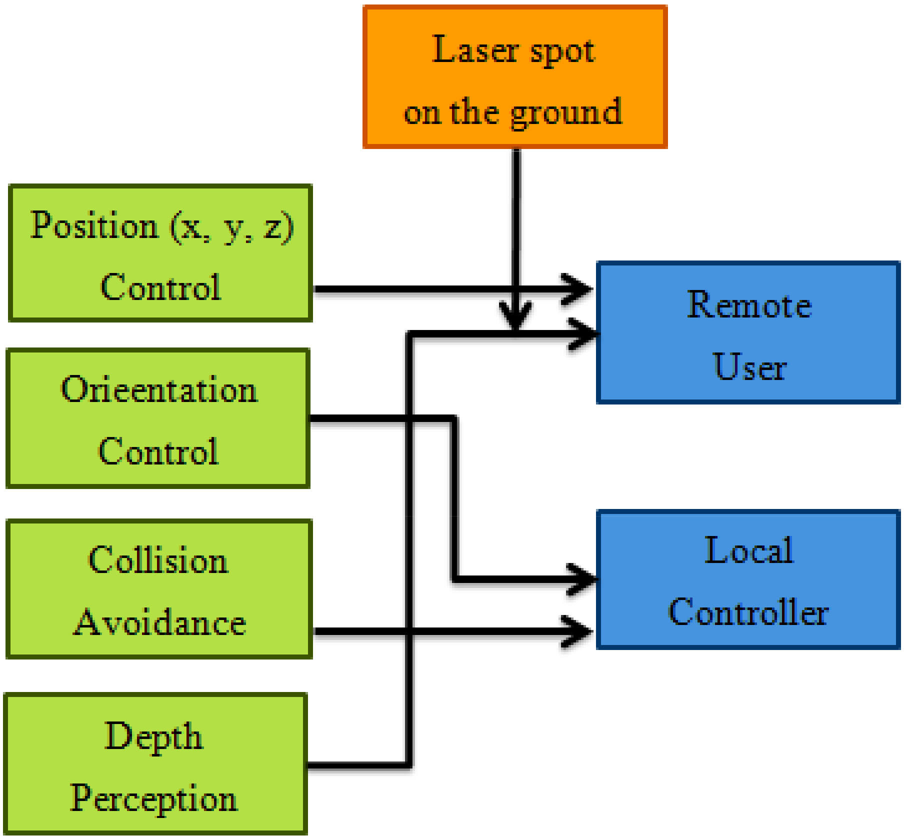
Test bed : Playing mini-golf on the Internet 2003-2004

Local Controller (Japan)

Remote Supervisor (Korea)

Task Resolved Motion Planning for Telerobotics

- High level commands for which higher cognitive function is required are assigned for the remote user
- Simple, low level tasks that can be carried out by a computer autonmusly are assigned to the local controller



Polybots: Modular Reconfigurable Robots

Modular self-reconfigurable robots
- modules can be connected to form a variety of shapes that enable a variety of functionalities
- self-reconfigurability

CrocRobot.dat

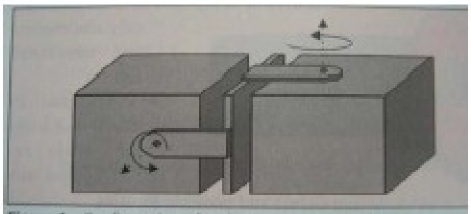


Figure 1. Configuration of each segment.

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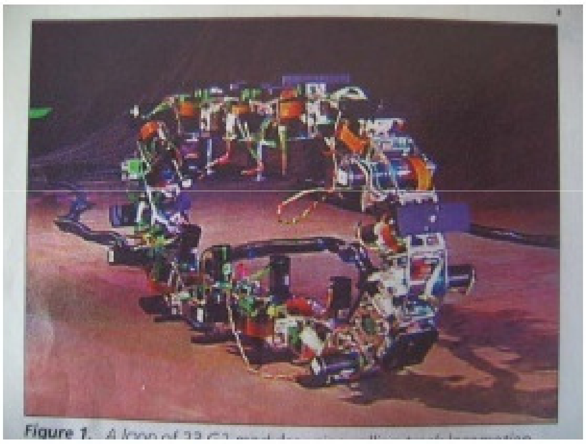
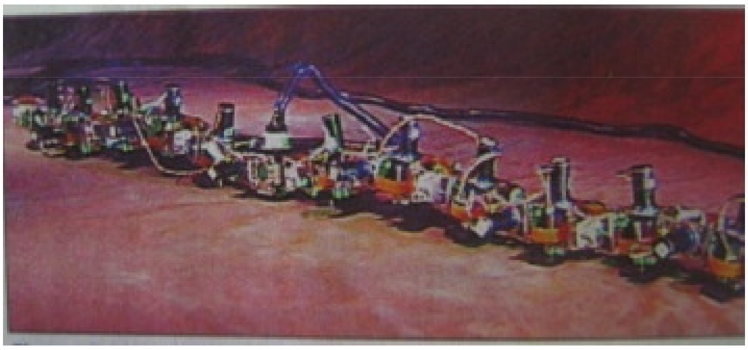
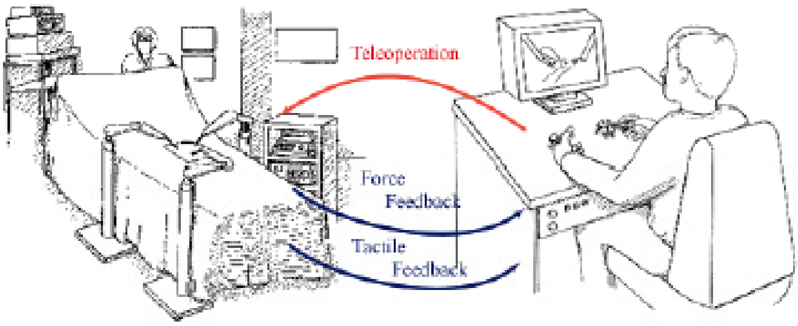
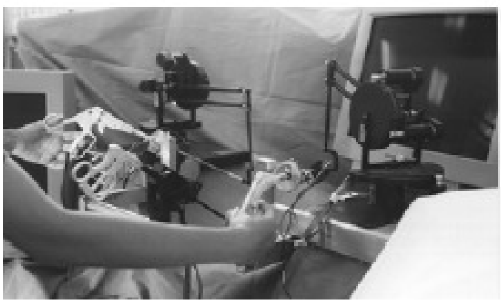




Medical Robotics
Minimum Invasive Surgery (MIS)

- UCB, Robotics and Intelligent Machines Laboratory
- Minimum Invasive Surgery (MIS)
  - Small incisions in the body through which surgical instruments and camera are Inserted.
  - No surgical trauma, or severE tissue damage
  - There are limitations of manipulatability, and viewing





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Robotic Micromanipulation

- Biotechnology
- Microsurgery
- Microassembly
- Microchips

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Service and Care-giving Robots

My Spoon

Developed by Secom of Japan. The My Spoon is a robotic feeding device with an articulated arm for scooping chow and placing it where a hungry user can get at it. The device is usable with almost all types of everyday foods. No special food packets required. It can be tailored for specific types of disabilities with interchangeable controllers.

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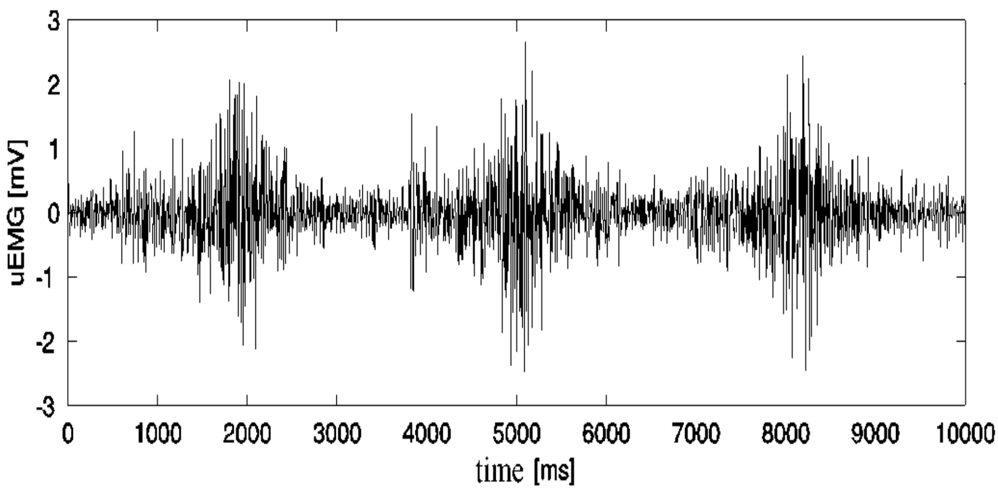
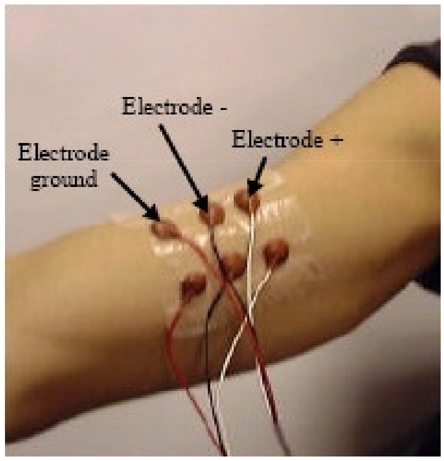
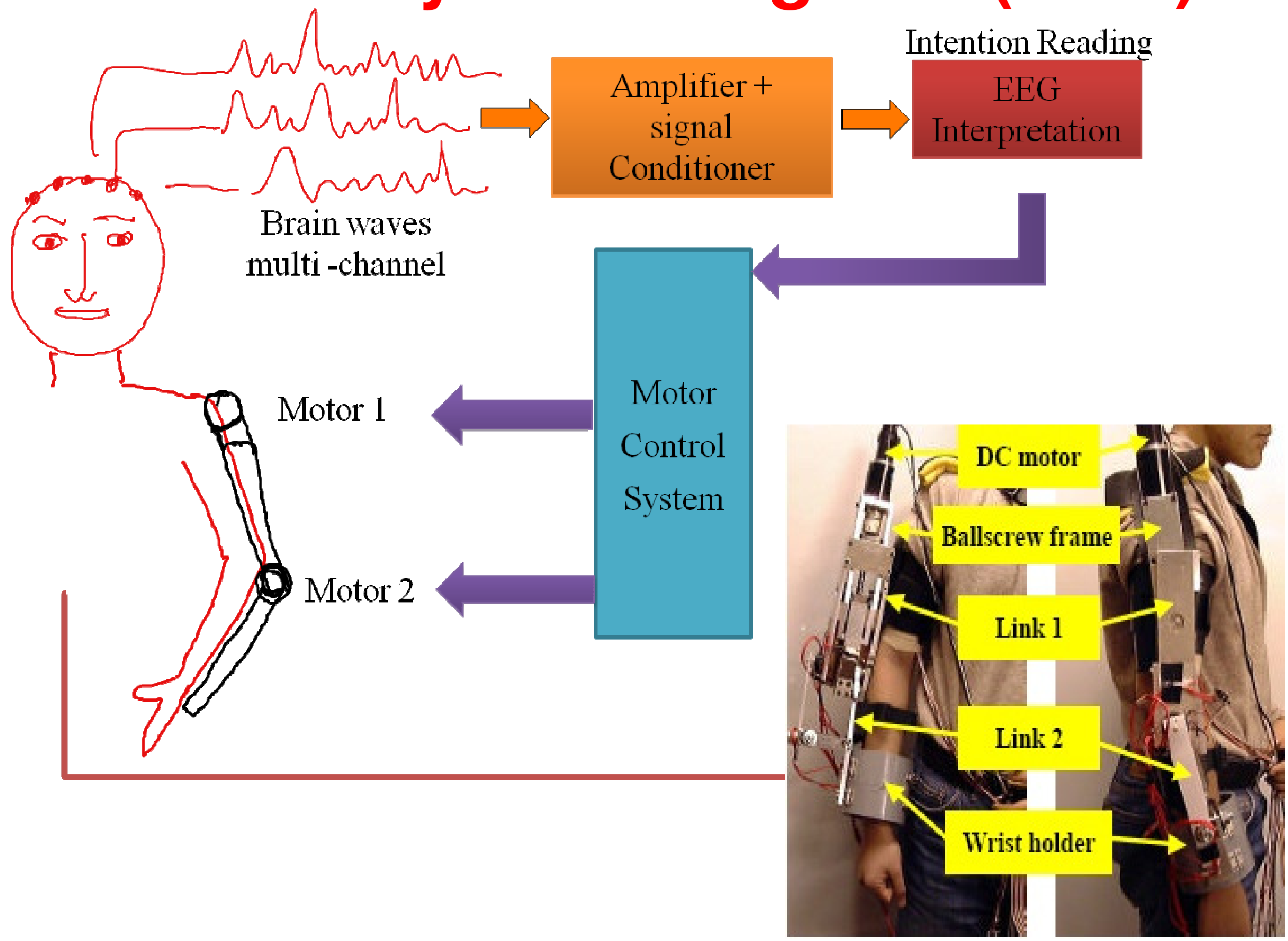
Actuation by Muscle Signals (EMG)

- **Electromyography : Electrical activity of muscles**
- **Power assistance for physically weak people**
- **Biological signals**
  - Skin surface electromyogram (EMG) signals ⇒ intention
- **Control**
  - Joint servos ⇒ arm configuration



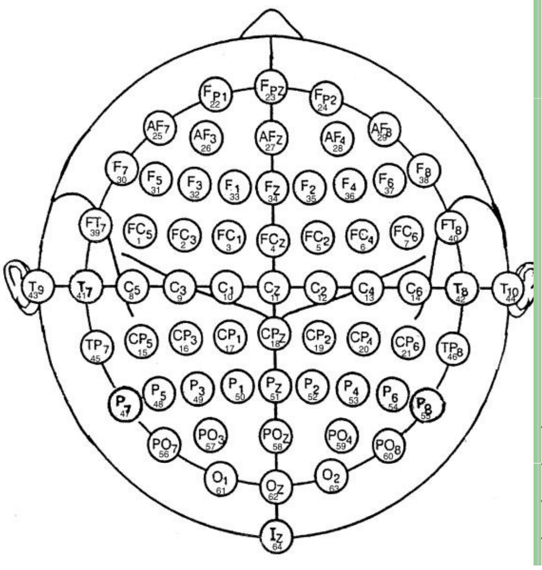


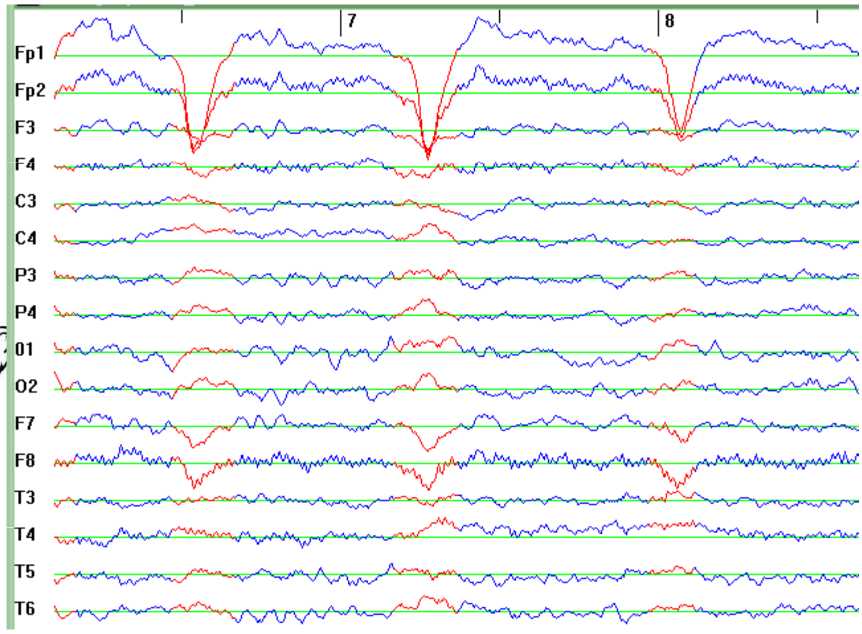
Actuation by Brain Signals (EEG)

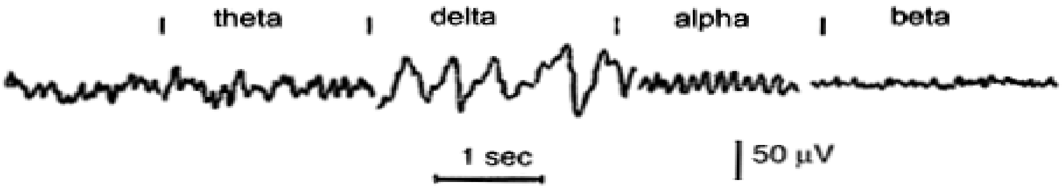


EEG : Electroencephalogram

- Many electrodes attached to scalp (multi channel EEG)







Robotic Prosthetic Limbs/Arms

- The bionic hand, manufactured by the German prosthetics company Otto Bock, is equipped with six sensors that overly the skin and detect neuronal signals in the forearm. The signals passing through the forearm are sent from the brain to control movement. The prosthetic translates those signals into mechanical movements.

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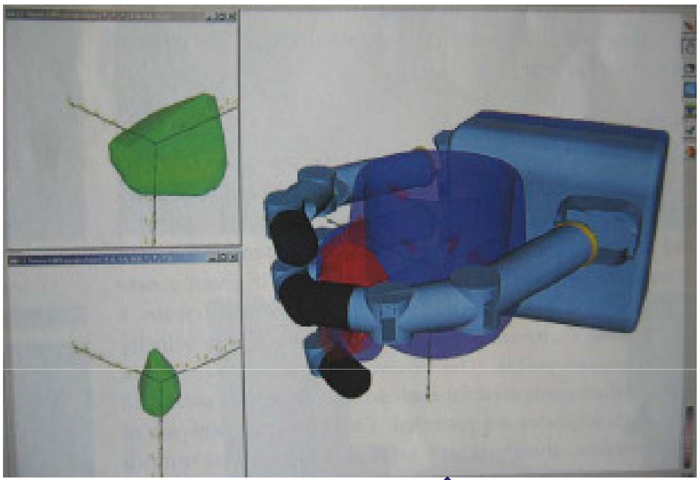
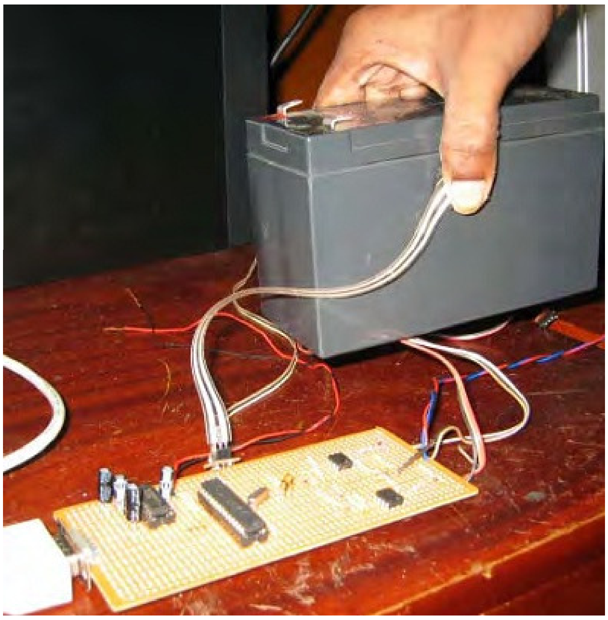
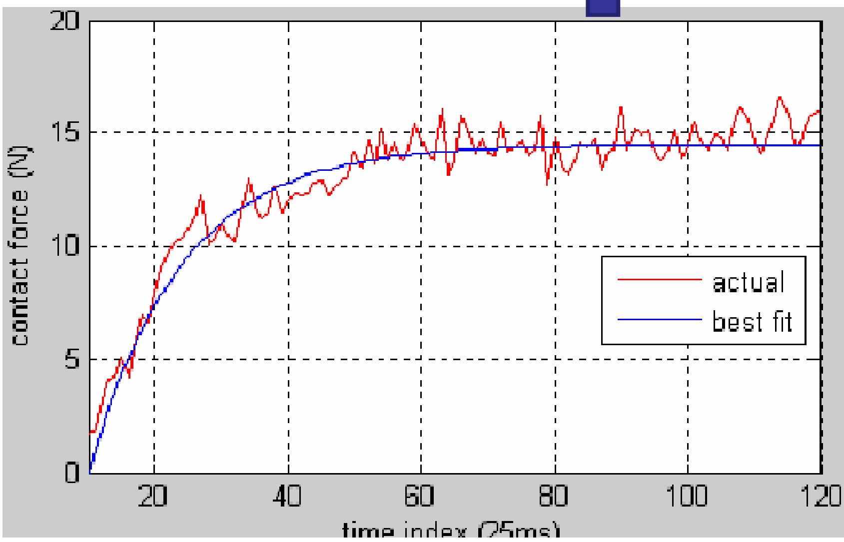
Robotic Grasping

- **Grasping force control**
  - **Too much force could damage the object/robot**
  - **Too little force could drop the object through fingers**
  - **What's human force control**

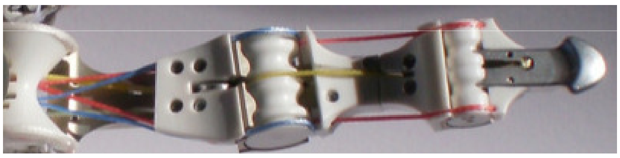




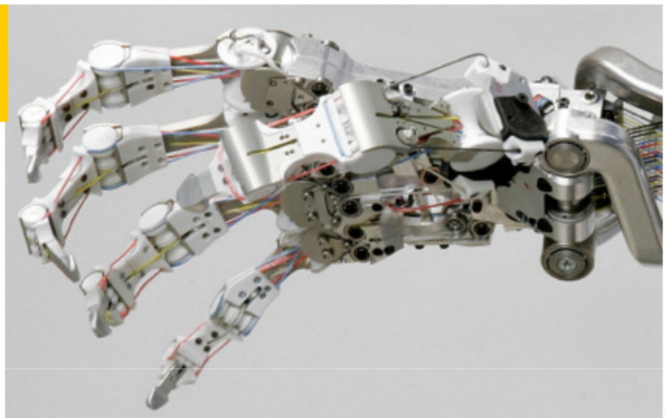


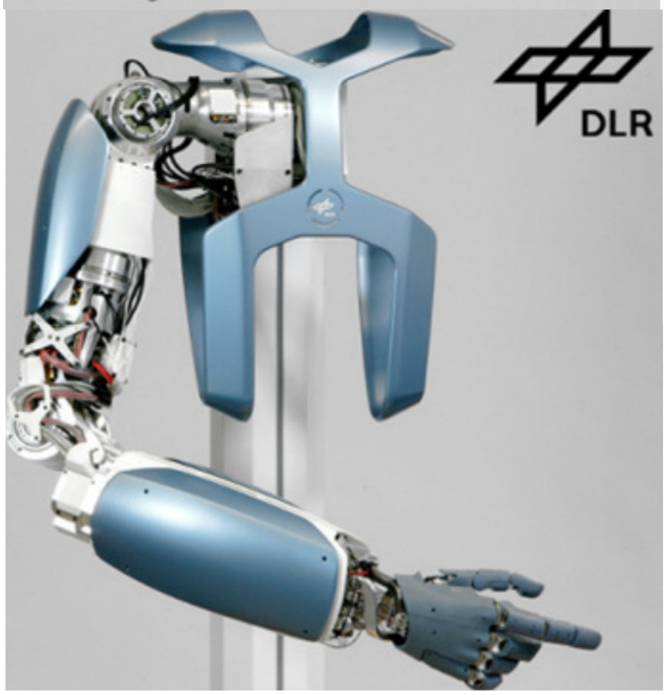
Strongest Robot Hand

- 38 tendons (two in each finger joint, and driven by two motors – antogonistic actuation).

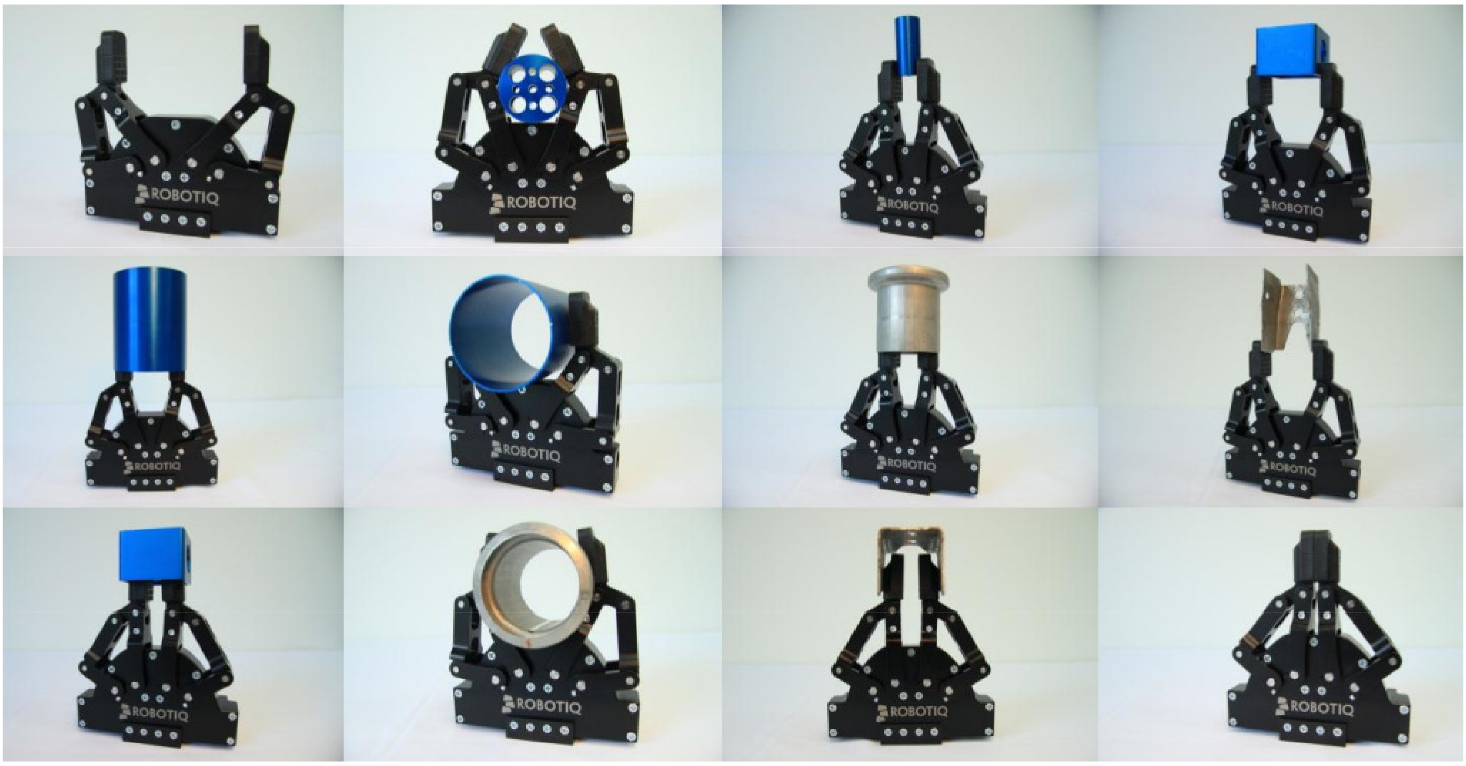


- Motors control tension of the tendons, thus stiffness of fingers. Can absorb kinetic energy without being damaged
- 500°/s finger speed, 2000°/s with spring action
- 70k-100k euros / hand





Robot Grippers



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Biomimetic Robots

- How birds fly, how fish swim, and how humans walk can best be discovered by trying to reproduce these activities on a robot. Extract principles from nature and use them to built advance robots.
  - cockroaches can run over obstacles without slowing down. Can a robot be build with that capability?
  - An alternative approach to algorithmic-intensive AI
- The knowledge gained might not be immediately useful. But it could some day lead to useful technologies

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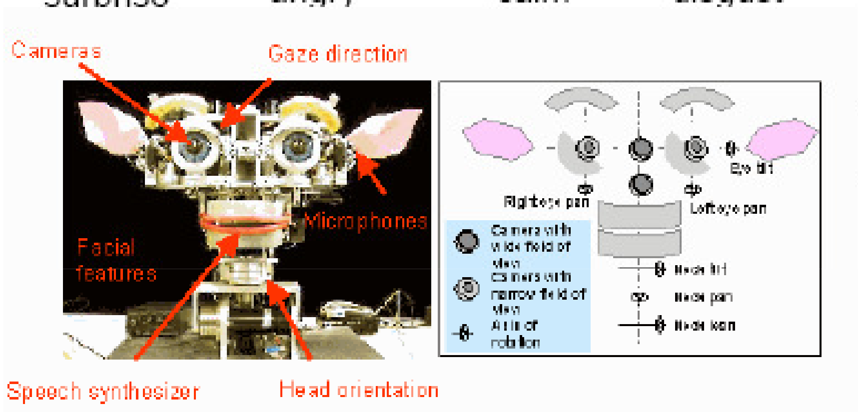
Expressive Robotic Creatures

- **Kismet, MIT AI Lab**
- **Emotion expression capability**
- **Perceptual and motor modalities similar to human communication**



- eye/neck control by nine networked 400 MHz PCs running QNX.
- expressive speech synthesis and vocal affective intent recognition runs on a dual 450 MHz PC running NT
- speech recognition system runs on a 500 MHz PC running Linux.

- **Vocalization: Steer the eyes, ears, and head towards the sound source**
- **Realtime processing of visual and auditory signals**

Humanoids and Legged Robots

Asimo (Honda), the world's most advanced Humanoid robot

Package

- Experimental robot on which algorithms can be tested

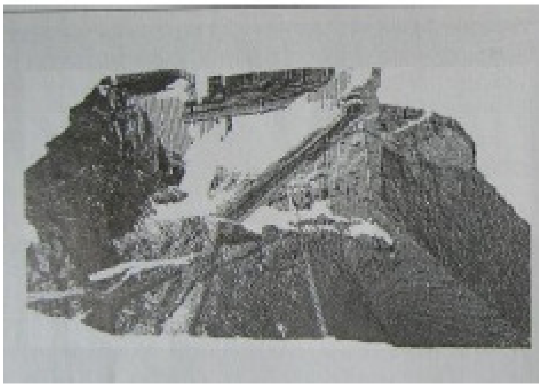
Big Dog (Boston Dynamics), the world's most advanced legged robot
- **Gasoline engine**
- **Climbing slopes upto 35°**
- **Carries 340lb**

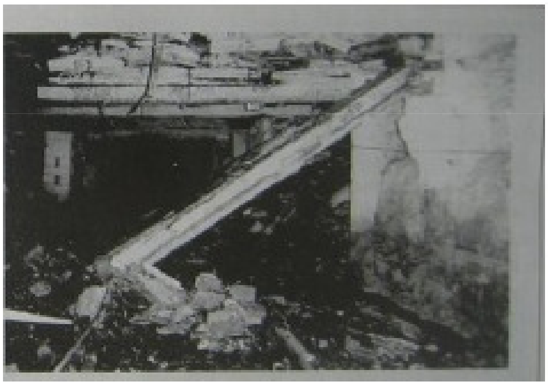
Package

Package

Exploration and Mapping Robots

- Groundhog by Sebastian Thurn
- Maps abandoned mines, unknown terrains
- Laser range sensors, gas and sinkage sensors





Planetary Exploration Robots

- Robot Geologists for Mars Exploration
  - *Spirit* and *Opportunity* : Two Mars Rovers (microwave oven size)
  - *Curiosity* : Mars Science Laboratory (mini cooper car size)
- Functions
  - Autonomous Navigation
  - Terrain identification (panoramic HD video)
  - Soli sample test
  - Drilling rocks

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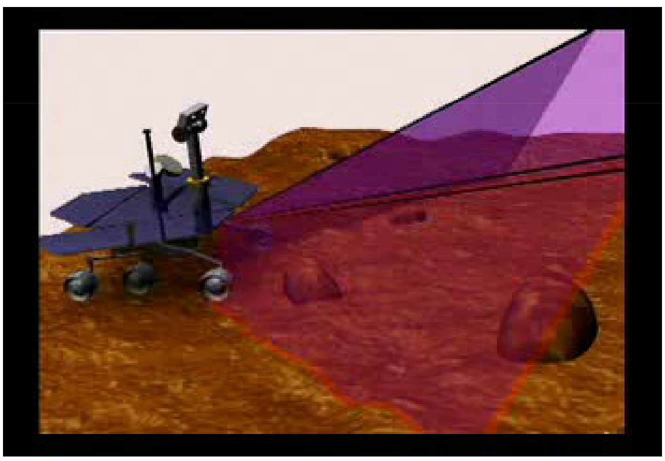

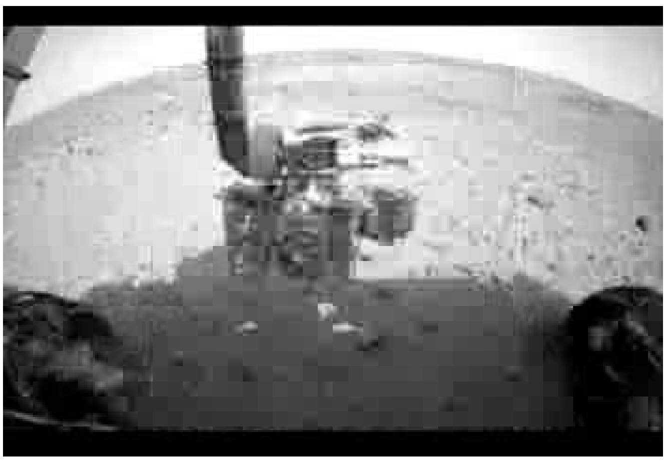

Holonomic Mobile Platforms

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- Can turn wheels at any direction
- Adaptive parking

All Terrain Mobile Robots

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- Wheels+legs design provides adaptive behavior to cope with rough terrains

Avoidance of Dynamic Obstacles

A much needed skill for future robots to be able to inhabit human-populated dynamic environments such as offices, hotels, hospitals, etc.

Classical Potential Field
O. Khatib, RI,
Stanford Univ., USA

Velocity Dipole Field
S. R. Munasinghe
Univ. of Moratuwa, SL

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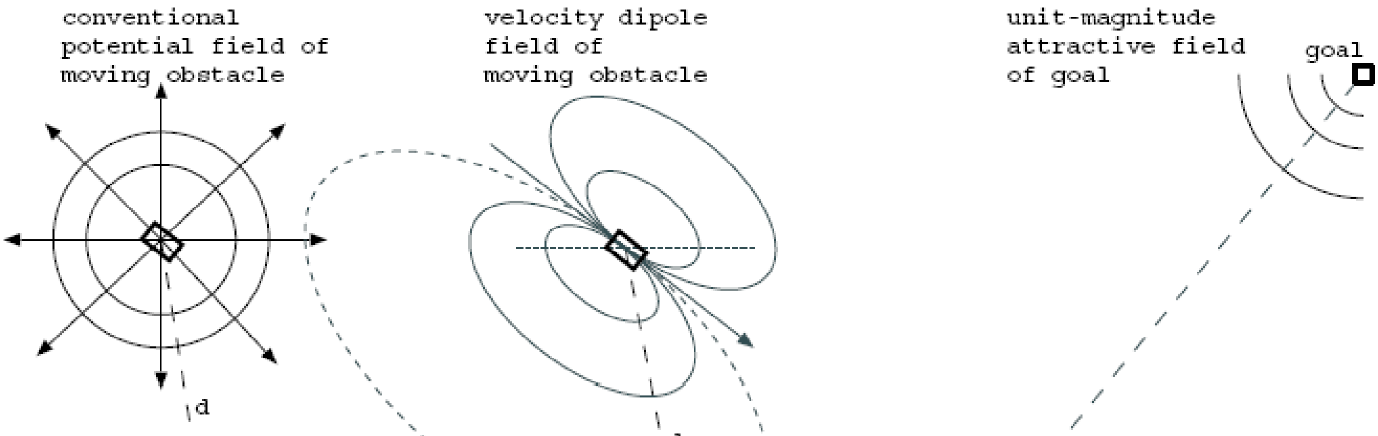

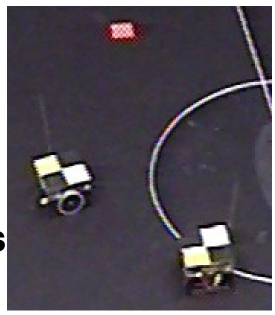

Deliberative Behavior and Reactive Behavior (imagine how humans walk to the destination avoiding obstacles getting on the way)

Robot Vehicles

- Robotics technology in vehicles
- Driver assistance, improved safety
- Adaptive mobility in rough terrains

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Telepresence Robots

- Remotely operable robot with real-time vision and voice connectivity, through which the operator can make his presence while being away. Robot knows its position and how to navigate safely to destinations within the residing building..

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