Electromechanical Systems: Robotics, Mechatronics, MEMS, Bioengineering

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ME 101 : Introduction to Mechanical Engineering

`http://zahurul.buet.ac.bd/ME101/`

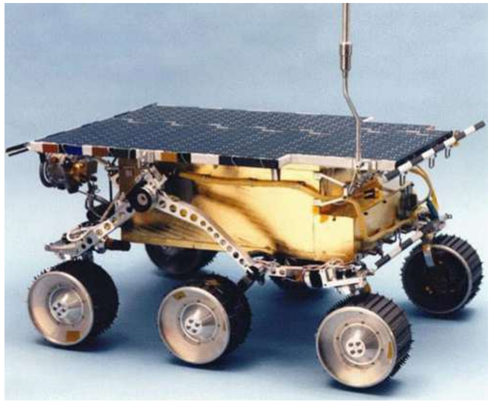
Introduction

- A **robot** is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks.
- **Robotics** is the art, knowledgebase, and the know-how of designing, applying, and using robots in human endeavours.
- Situations to promote the use of robots:
  - Hazardous environment for humans
  - Repetitive work cycle
  - Difficult handling for humans
  - Multi-shift operations
  - Infrequent changeovers

Robot Applications

- **Industrial Applications**:
  - Material handling
  - Processing operations
  - Assembly and inspection
- **Field Applications**: Robots are deployed in areas where human being could not survive or be exposed to unsustainable risks.
- **Service Applications**: Robots are used in civil applications such as intelligent transportations, patient rehabilitation system, medical applications, domestic aid, entertainments etc.

Field Robot Applications



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Sojourner rover, deployed by Pathfinder in 1997 by NASA

Service Robot Applications

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Autonomous car Stanley completed a path of 132 miles in record time of 6 h and 53 min in DARPA Grand Challenge 2005

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The EndoAssistant manipulates a laparoscopic camera at the command of the surgeon

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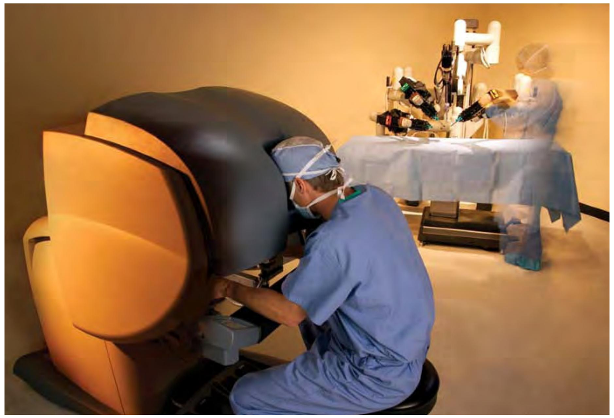

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The da Vinci robotic surgical system comprising of a surgeon's console and a patient side cart

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Asimo by Honda

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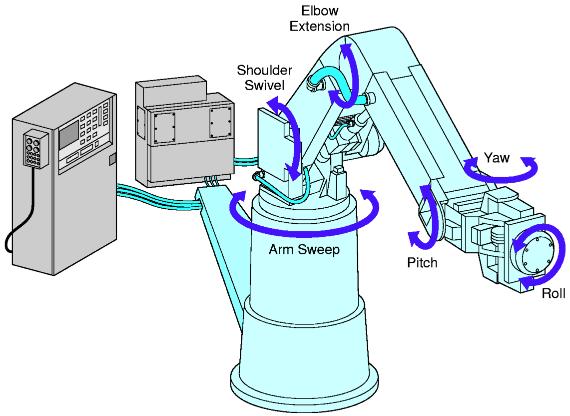
AIBO by Sony Corp

Robot Structure & Classifacations

- Robots can be classified as:
  1. robot manipulators (robots with fixed base)
  2. mobile robots (robots with mobile base)
- Robot manipulators are classified as:
  1. Cartesian (3P): 20% of industrial robots
  2. Cylindrical (R2P): 12%
  3. Spherical / Polar (2RP)
  4. Articulated / Anthropomorphic (3R): 59%
  5. Selective Compliance Assembly Robot Arm (SCARA): 8%
- Mobile robots are classified as:
  1. Wheeled mobile robots
  2. Legged mobile robots

6 DOF Industrial Robot Example



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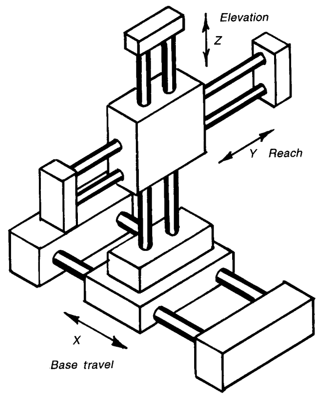
In most general case of arbitrarily positioning and orienting an object in 3D space 6 DOFs are required

Carteisan (3P) Robot



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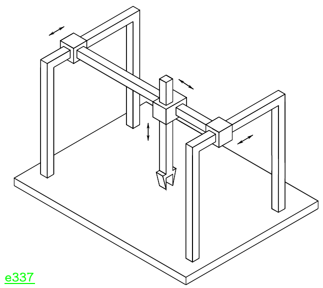
- *Cartesian roots have 3 prismatic joints whose axes typically are mutually orthogonal and thus it is natural to perform straight motions in space.*
- *The Cartesian structure offers very good mechanical stiffness.*

Gantry Robot



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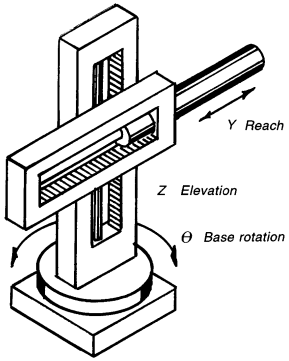
Ganty robots can approach an object from the top. Such a structure offers large volume workspace and enables the manipulation of objects of large dimensions and heavy weight.

Cylindrical (R2P) Robot



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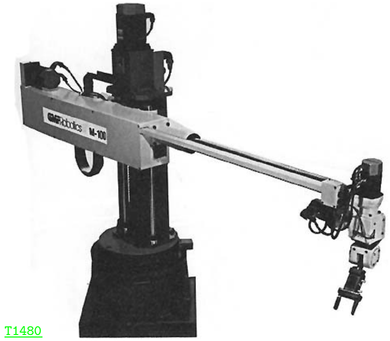

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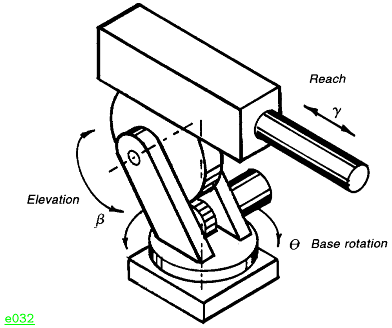
- *Cylindrical geometry differs from Cartesian in that the first prismatic joint is replaced with a revolute joint.*
- *Cylindrical manipulators are mainly employed for carrying objects of large dimensions.*

Spherical (2RP) Robot



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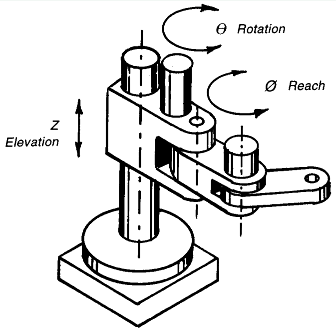
- *Spherical geometry differs from cylindrical in that the second prismatic joint is replaced with a revolute joint.*
- *Spherical manipulators are mainly employed for machining. Electric motors are typically used to actuate the joints.*

SCARA Robot



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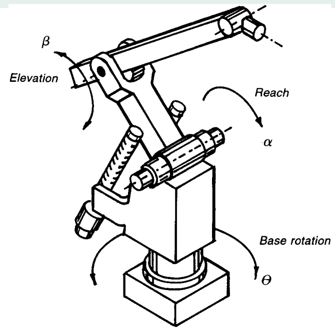
- *Selective Compliance Assembly Robot Arm (SCARA) has two revolute joints and one prismatic joint in such a way that all the axes of motion are parallel.*
- *SCARA manipulator is suitable for manipulation of small objects; joints are actuated by electric motors.*

Articulated (3R) Robot



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- *Articulated robots have three revolute joints; by virtue of its similarity with the human arm, the second joint is called the shoulder joint and the third joint the elbow joint since it connects the 'arm' with the 'forearm'.*
- *Joints are typically actuated by electric motors. The range of industrial applications is wide.*

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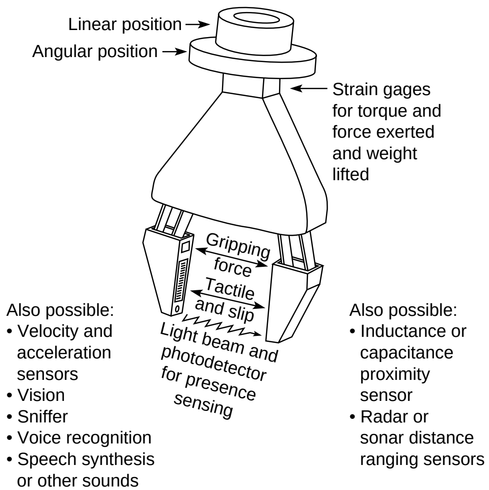
Robot Gripper



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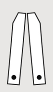
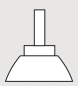
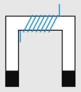
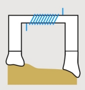
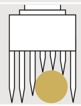
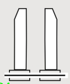
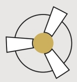
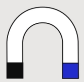
mechanical grippers		suction grippers	magnetic grippers	adhesive grippers	mold grippers	nail grippers
scissors gripper	fork gripper		electromagnet	adhesive foil		
						
parallel jaw gripper	three-point gripper		permanent magnet			
						

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- **Mechanical grippers:-** consisting of two or more fingers that can be actuated by the robot controller to open and close to grasp the work-piece.
- **Vacuum grippers:-** such cups are used to hold flat objects.
- **Magnetized devices:-** for holding ferrous work-pieces.
- **Adhesive devices:-** where adhesive substances are used to hold flexible materials like fabric.
- **Simple mechanical devices:-** such as hooks and scoops.

Robot Drives

	pneumatic	hydraulic	electric
translatory drive movement with limited travel	pneumatic cylinder	hydraulic czylinder	electromotor
translatory drive movement with unlimited travel			linear motor
rotary drive movement with limited rotary angle	swivel/rotary cylinder	swivel/rotary cylinder	
rotary drive movement with unlimited rotary angle	air-pressure motor	hydromotor	stepping motor DC motor AC motor

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1. **Pneumatic drive:-** pressurized air is supplied through lines to cylinders, causing air pressure to be transformed into mechanical work.
2. **Hydraulic drive:** pressurized fluid entering into cylinders causes the cylinder to extend or retract.
3. **Electric drive:-** electric drive systems either use AC or DC electric motors. Motors are connected to the manipulator's axes through gear reduction mechanisms to develop necessary torque for the robot to lift heavy payloads.

Robot Sensors

tactile	non-tactile		
force/torque	**video-visual**	**ultrasonic**	**other**
• multicomponent force/ torque sensor • gripping force measure • active wing/blade gripper • RCC • IRCC	• linear sensor • image processing (binary, gray scale value) • 3 D stereo imageprocessing • image processing with active illumination	• proximity switch • sonic barrier • distance measuring • scanner • acoustic correlation sensor	• microwave • pneumatic • radioactive • chemical
tactile	**visual**	**inductive, capacitive, magnetic and piezoelectric**	
• switch • distance measuring • touch line • touch matrix • flat-top switch • slip sensor	• light barriers • reflection light master • distance measuring • 2 D scanner • 3 D scanner • light stripe sensor • visual correlation sensor	• proximity switch • distance measuring • welding seam tracking • vibration analysis	

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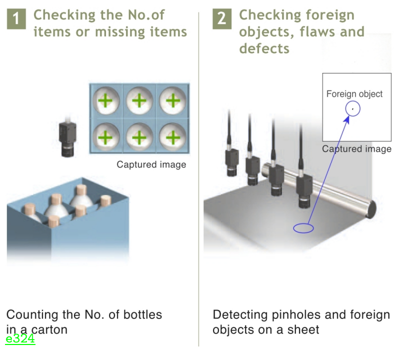
Robot Programming Modes

1. **Physical setup:-** an operator sets up switches and hard stops that control the motion.
2. **Lead through or teach mode:-** the robot's joints are moved with a teach pendant.
3. **Continuous walk-through mode:-** all robot joints are moved simultaneously, while the motion is continuously sampled and recored by the controller.During playback, the recorded motion is executed.
4. **Software mode:-** a program is written off-line/on-line and is executed by the controller to control the motion.

Machine Vision Applications



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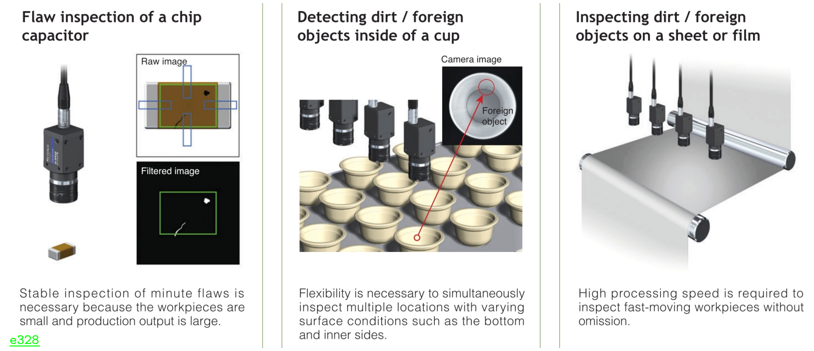
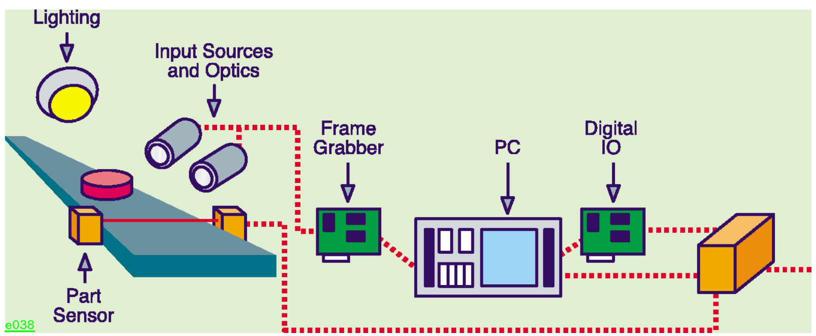


Machine Vision: Key Components



Machine Vision: Key Components

1. **Front-end optics:-** includes the camera, lens and the lighting.
2. **Frame grabber:-** or video capture card, interfaces the imaging units to the host computer. It takes the image data provided by the camera(s) in either analog or digital form and convert it for use by the host computer.
3. **Computer and software:-** A computer forms a necessary part of the machine vision system. Softwares processes the incoming image data and makes decisions such as pass or fail.

Machine Vision: Process steps

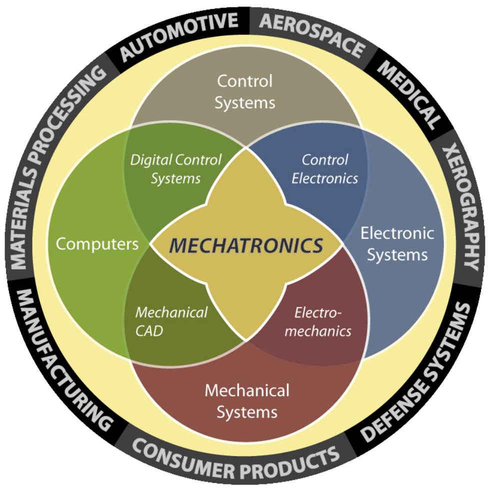
1. **Image acquisition:-** system gathers images to be converted into digital format and placed into computer memory.
2. **Image processing:-** various algorithms are used to enhance elements of the image that are of specific importance to the process.
3. **Feature extraction:-** processor identifies and quantifies critical features in the image and sends data to control programs.
4. **Decision and control:-** control program make decision based upon the data. Are the holes within specifications? Is a pin missing? How must a robot move to pick up the component?

Mechatronics

- The portmanteau **Mechatronics** was first coined by Mr. Tetsuro Mori, a senior engineer of the Japanese company Yaskawa, in 1969.
- Mechatronics is the synergistic combination of precision mechanical engineering, electronic control and systems thinking in the design of products and manufacturing processes [1].
- Mechatronics is a *methodology* used for the optimal design of electromechanical products.

[1] *IEEE/ASME Transactions on Mechatronics*

Mechatronics Applications



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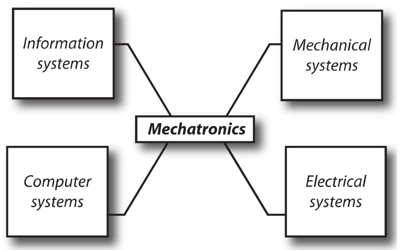
Mechatronics Constituents & Key Elements



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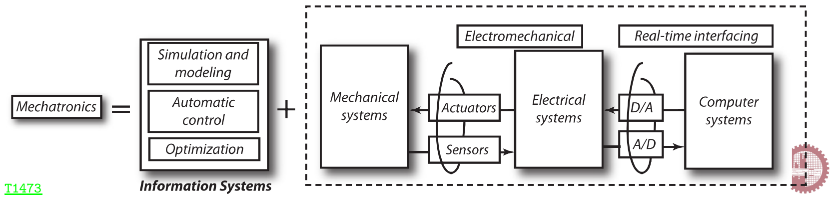

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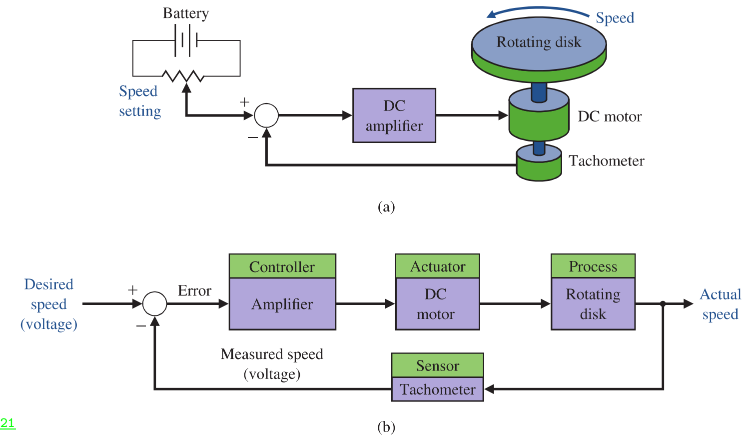
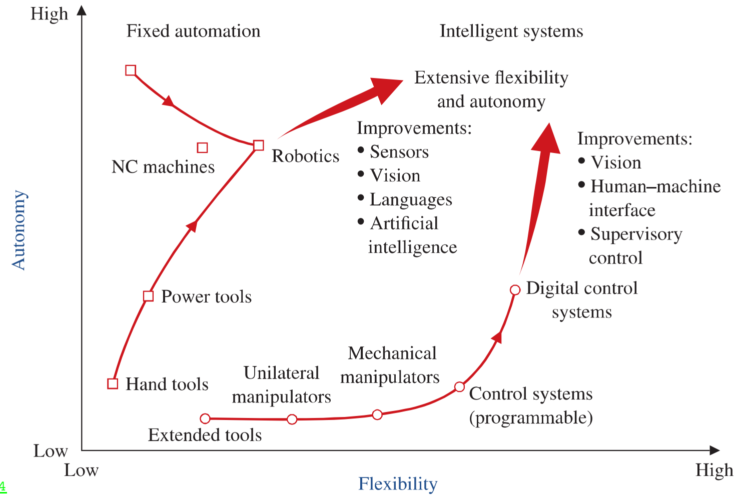
Simulation and Modelling

- **Modelling** is the process of representing the behaviour of a real system by a collection of mathematical equations and logic.
- **Simulation** is the process of solving the model and is performed on computer.
- Simulation process has the three basic steps:
  1. Initialisation
  2. Iteration
  3. Termination.

Control System



Feedback Control system



Evolution of control systems and autonomy.

Optimisation

- In mechatronics, optimisation is primarily used to establish the optimal system configuration. It solves the problem of distributing limiting resources throughout a system such that the pre-specified aspects of its behaviour is satisfied.
- In general, resources are referred to as **design variables**, aspects of system behaviour as **objectives**, and system governing relationships (equations and logic) as **constrains**.
- Example - for a box-shaped luggage to maximise volume:

Design variables:	L (length), W (width), H (height)
Objective:	Maximise V = V(L,W,H)
Constraints:	System relationship V = LHW

Key Mechatronic Sensors

Measurement	Sensing Parameter	Principle
Distance measurement	• Edge detection; • Monitoring the distance between tool and work piece as in laser cutting machines; • Collision avoidance in robotics	• Potentiometric, inductive, capacitive principle • Non-contact sensors, such as optical or ultrasonic sensors • Laser interferometer • Laser digitizer
Contour measurement	• Detection of edges and surfaces • Robot guided tools in welding operation	• Inductive, capacitive • Non-contact sensors, such as optical, fiber optic, or ultrasonic sensors
Pattern recognition	• Shape information • Object classification	• Optical • Tactile • Ultrasonic
Machine diagnostics	• Cutting tool condition • Tool wear, breakage • Machine vibration • Power consumption	• Force, torque • Current, frequency • Amplitude, acceleration • Surface roughness, roundness

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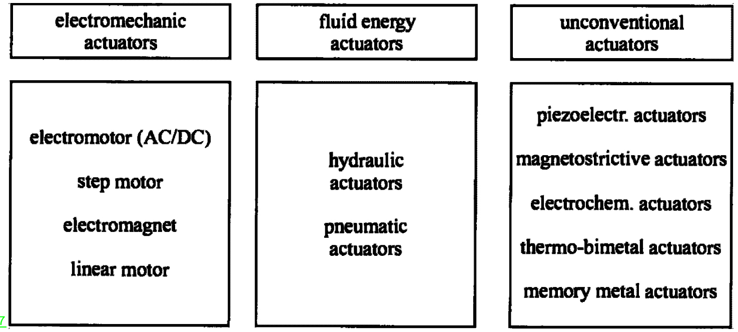
Key Mechatronic Actuators

Actuators can be classified into three general groups:

1. Electromagnetic actuators
2. Fluid power actuators
3. Unconventional actuators



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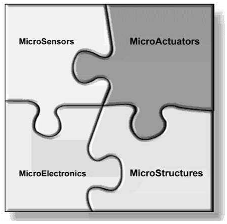
Micro-Electro-Mechanical-Systems (MEMS)



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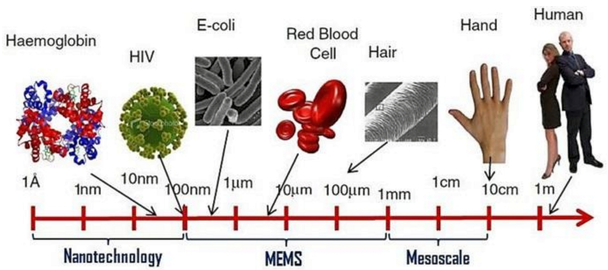

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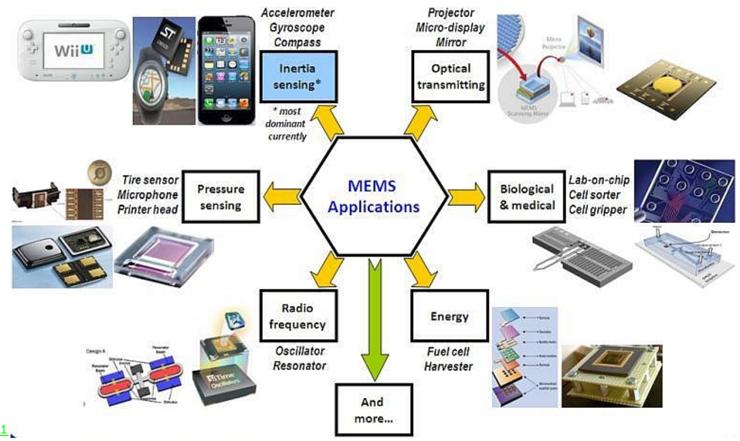
Applications of MEMS



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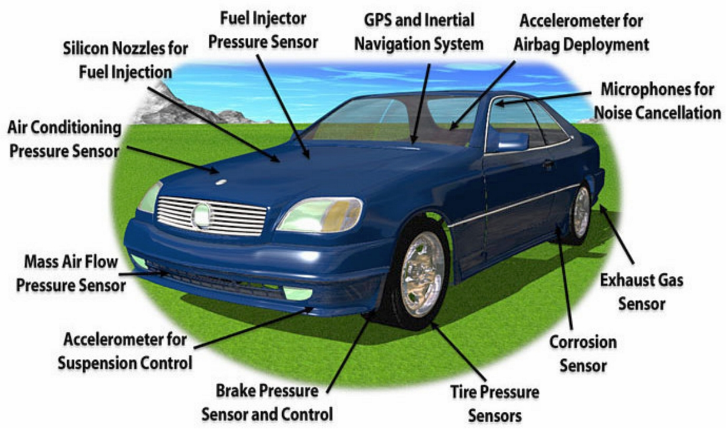

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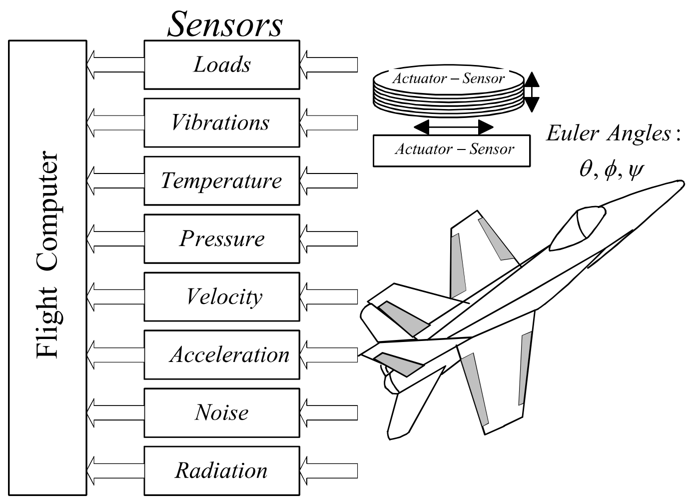

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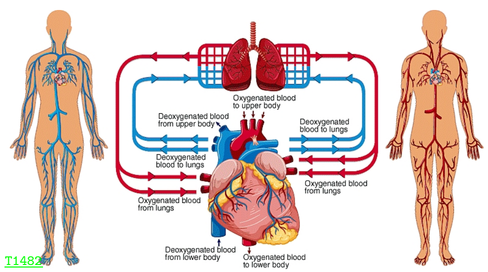
Human Heart-lung & Mechanical Heart-lung



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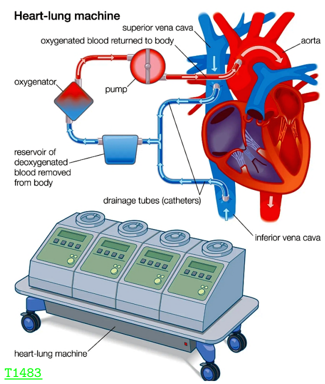

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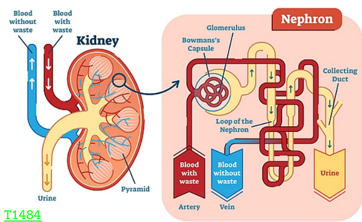
Human Kidneys & Artificial Kidney

A healthy kidney can filter 180 liters of blood a day and thus maintain a healthy balance of water, salts, and minerals – such as sodium, calcium, potassium, and phosphorus – in your blood stream.



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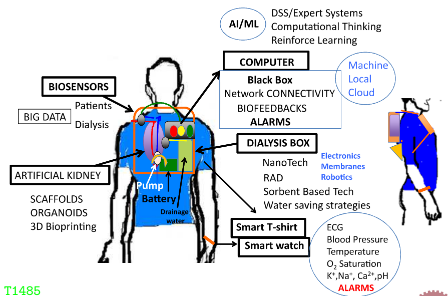

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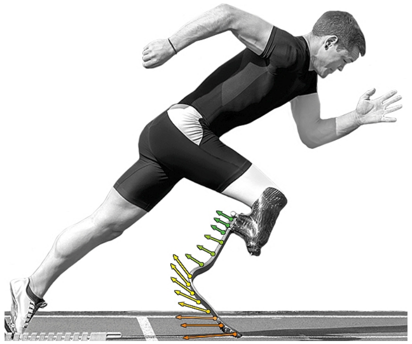
Biomechanics & Artificial Limb



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Famous South African Olympian Oscar Pistorius can run a quarter mile in 45.07 seconds - fast enough to compete in the 2012 Olympic using artificial limbs below knee.