What is a Robot?

Robot can be defined as a machine that can automatically do tasks normally controlled by humans and mostly is used to perform repetitive tasks on an assembly line.
A **robot** is a mechanical or virtual, artificial agent. It is usually called as an electromechanical system.The word *robot* can refer to both physical and virtual software agents, but the latter are usually referred to as *bots* to differentiate.

Robot: a reprogrammable, multifunctional, mechanical manipulator that typically employs one or more means of power. For Example, Industrial robots have been used chiefly for spray painting, spot-welding, and transfer and assembly tasks.

What is Robotics?

The development of reprogrammable, multi formation manipulators that can be programmed to do several differing tasks without human assistance is called as Robotics

The Robotics Institute of America (RIA) officially recognizes four classes of robot:

A: Handling devices with manual control
B: Automated handling devices with predetermined cycles
C: Programmable, servo-controlled robots with continuous of point-to-point trajectories
D: Capable of Type C specifications, and also acquires information from the environment for intelligent motion

In contrast, the Japanese Industrial Robot Association (JIRA) recognizes as many as six classes:

1: Manual - Handling Devices actuated by an operator
2: Fixed Sequence Robot
3: Variable-Sequence Robot with easily modified sequence of control
4: Playback Robot, which can record a motion for later playback
5: Numerical Control Robots with a movement program to teach it tasks manually
6: Intelligent robot: that can understand its environment and able to complete the task despite changes in the operation conditions

Application of Robots

Robots can be placed into roughly two categories based on the type of job they do:

A: Jobs which a robot can do better than a human. Here, robots can increase productivity, accuracy, and endurance.
B: Jobs which a human could do better than a robot, but it is desirable to remove the human for some reason. Here, robots free us from dirty, dangerous and dull tasks.

Various area of applications are:

Car production: This is the primary example of factory automation. Over the last three decades automobile factories have become dominated by robots. A typical factory contains hundreds of industrial robots working on fully automated production lines - one robot for every ten human workers. On an automated production line a vehicle chassis is taken along a conveyor to be welded, glued, painted and finally assembled by a sequence of robot stations.

Packaging: Industrial robots are also used extensively for palletizing and packaging of manufactured goods, for example taking drink cartons from the end of a conveyor belt and placing them rapidly into boxes, or the loading and unloading of machining centers.

Electronics: Mass produced printed circuit boards (PCBs) are almost exclusively manufactured by pick and place robots, typically with "SCARA" manipulators, which remove tiny electronic components from strips or trays, and place them on to PCBs with great accuracy. Such robots can place several components per second (tens of thousands per hour), far out-performing a human in terms of speed, accuracy, and reliability.

Automated Guided Vehicles: Large mobile robots, following markers or wires in the floor, or using vision or lasers, are used to transport goods around large facilities, such as warehouses, container ports, or hospitals.

Dirty, dangerous, dull or inaccessible tasks: There are many jobs which a human could perform better than a robot but for one reason or another the human either does not want to do it or cannot be present to do the job. The job may be too boring to bother with, for example domestic cleaning; or be too dangerous, for example exploring inside a volcano. These jobs are known as the "dull, dirty, and dangerous" jobs. Other jobs are physically inaccessible. For example, exploring another planet, cleaning the inside of a long pipe or performing laparoscopic surgery

Military robots: Teleoperated robot aircraft, like the Predator Unmanned Aerial Vehicle, are increasingly being used by the military. These robots can be controlled from anywhere in the world allowing an army to search terrain , and even fire on targets, without endangering those in control. Currently, these robots are all teleoperated, but others are being developed which can make decisions automatically; choosing where to fly or selecting and engaging enemy targets.

Telerobots: When a human cannot be present on site to perform a job because it is dangerous, far away, or inaccessible, teleoperated robots, or telerobots are used. Rather than following a predetermined sequence of movements a telerobot is controlled from a distance by a human operator. The robot may be in another room or another country, or may be on a very different scale to the operator. A laparoscopic surgery robot such as da Vinci allows the surgeon to work inside a human patient on a relatively small scale compared to open surgery, significantly shortening recovery time. An interesting use of a telerobot is by the author Margaret Atwood, who has recently started using a robot pen (the Longpen) to sign books remotely. This saves the financial cost and physical inconvenience of traveling to book signings around the world. Such telerobots may be little more advanced than radio controlled cars. Some people do not consider them to be true robots because they show little or no agency of their own.

Classification of Robots

Aerial Vehicle

An **unmanned aerial vehicle (UAV)** is an aircraft with no onboard pilot. UAVs can be remote controlled or fly autonomously based on pre-programmed flight plans or more complex dynamic automation systems. UAVs are currently used in a number of military roles, including reconnaissance and attack. They are also used in a small but growing number of civil applications such as firefighting where a human observer would be at risk, police observation of civil disturbances and scenes of crimes, and reconnaissance support in natural disasters.
There are a wide variety UAV shapes, sizes, configurations, and characteristics.

Terrestrial Vehicles

A autonomous or remotely controlled vehicle which is designed to maneuver on different types of terrain.

Underwater Vehicles

An **Autonomous Underwater Vehicle (AUV)** is a robot which travels underwater. Sometimes called Unmanned Underwater Vehicles, these devices are powered by batteries or fuel cells and can operate in water as deep as 6000 meters. Advances in propulsion systems and power source technology give these robotic submarines extended endurance in both time and distance.

The oil and gas industry uses AUVs to make detailed maps of the seafloor before they start building subsea infrastructure. The detailed maps from the AUVs allows the Oil Companies to install pipelines and sub sea completions in the most cost effective manner with the minimum disruption to the environment. A typical military mission for an AUV is to map an area to determine if there are any mines. Scientists use AUVs to study the ocean and the ocean floor.

Most AUVs in use today are powered by rechargeable batteries (lithium ion, lithium polymer, nickel metal hydride etc). Some vehicles use primary batteries which provide perhaps twice the endurance -- at a substantial extra cost per mission. A few of the larger vehicles are powered by aluminum based semi-fuel cells.

Remotely Operated and Autonomous Robots

Remotely Operated Robots

Any vehicle which is controlled either by any human being or a machine via a wired or wireless remote control.

Autonomous Robots

Autonomous robots are robots which can perform desired tasks in unstructured environments without continuous human guidance. Many kinds of robots have some degree of autonomy. Different robots can be autonomous in different ways. A high degree of autonomy is particularly desirable in fields such as space exploration, where communication delays and interruptions are unavoidable. Other more mundane uses benefit from having some level of autonomy, like cleaning floors, mowing lawns, and waste water treatment.

Some modern factory robots are "autonomous" within the strict confines of their direct environment. Maybe not every degree of freedom exists in their surrounding environment but the work place of the factory robot is challenging and can often be unpredictable or even chaotic. The exact orientation and position of the next object of work and (in the more advanced factories) even the type of object and the required task must be determined.

A fully autonomous robot has the ability to

- Gain information about the environment.
- Work for an extended period without human intervention.
- Move either all or part of itself throughout its operating environment without human assistance.
- Avoid situations that are harmful to people, property, or itself.

Locomotion

A mobile robot needs locomotion mechanisms to make it enable to move through its environment. There are several mechanisms to accomplish this aim; for example one, four, and six legged locomotion and many configurations of wheeled locomotion.
The focus of this elaboration is legged and wheeled locomotion.

Legged Locomotion

Legged robot locomotion mechanisms are often inspired by biological systems, which are very successful in moving through a wide area of harsh environments, for example the six legged walking of a stick insect, which is often a paradigm for six legged robots

A legged robot is well suited for rough terrain; it is able to climb steps, to cross gaps which are as large as its stride and to walk on extremely rough terrain where, due to ground irregularities, the use of wheels would not be feasible.

To make a legged robot mobile each leg must have at least two degrees of freedom (DOF). For each DOF one joint is needed, which is usually powered by one servo. The main problems are the mechanical complexity of legs, stability and power consumption.

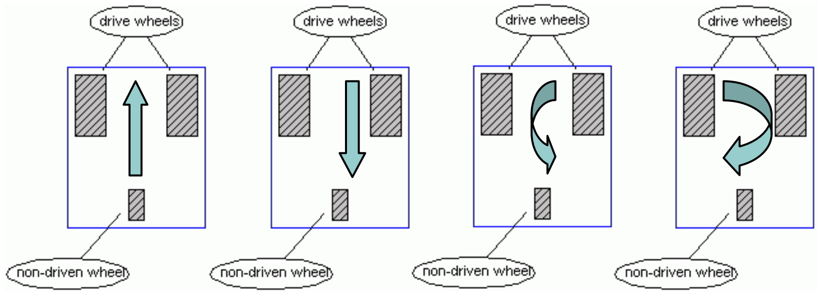
Wheeled Locomotion System

Three types of drives are defined under it:

- Differential drive
- Car type drive
- Pivot drive

Differential Drive

This is the most commonly used form of locomotion system used in mobile robots as it's the simplest and easiest to implement. It has a free moving wheel in the front accompanied with a left and right wheel. The two wheels are separately powered.
When the wheels move in the same direction the machine moves in that direction. Turning is achieved by making the wheels oppose each other's motion, thus generating a couple



Black arrows denote the direction of wheel. The green ones show robot movement.

- In-place (zero turning radius) rotation is done by turning the drive wheels at the same rate in the opposite direction.
- Arbitrary motion paths can be implemented by dynamically modifying the angular velocity and/or direction of the drive wheels.

Total of two motors are required, both of them are responsible for translation and rotational motion.

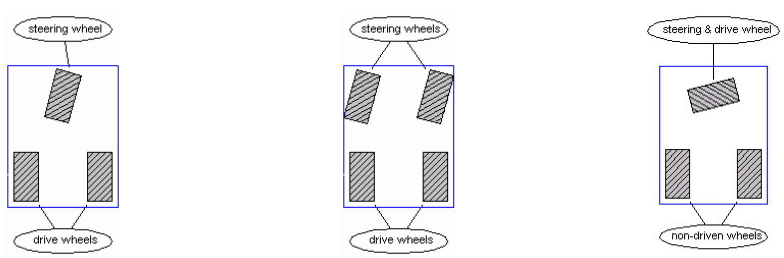
Differential Drive An Analysis

- Simplicity and ease of use makes it the most preferred system by beginners.
- Independent drives makes it difficult for straight line motion. The differences in motors and frictional profile of the two wheels cause them to move with slight turning effect
- The above drawback must be countered with appropriate feedback system. Suitable for human controlled remote robots.

Car Type Drive

This is the car type drive and the most common in real world but not in robot world

- It is characterized by a pair of driving wheels and a separate pair of steering wheels
- The translation and rotation are independent of each other. But translation and rotation are interlinked hence this system faces severe path planning problem



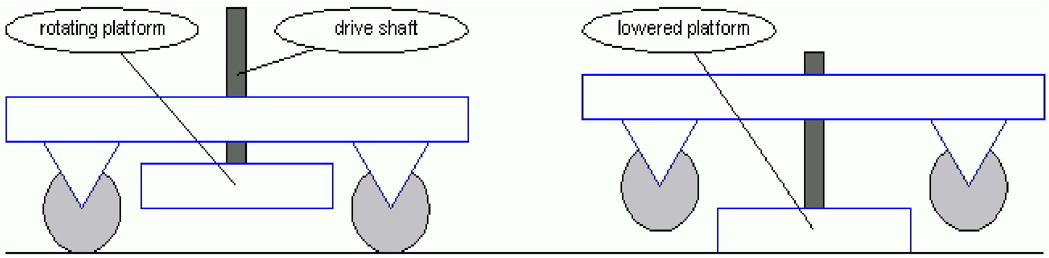
Disadvantages Of Car Type Drive

- The turning mechanism must be accurately controlled. A slight inaccuracy may cause large odometry errors
- There are no direct directional actuators.

Pivot type drive

The most unique type of Locomotion system

- It is composed of a four wheeled chassis and a platform that can be raised or lowered



- The wheels are driven by a motor for translation motion in a straight line
- For rotation one motor is needed to lower/raise the platform & another to rotate the chassis around the platform
- This system can guarantee perfect straight line motion as well as accurate in – place turns to a desired heading

Complexity of Pivot Drive

- The system is quite complex in design
- A still more complex design uses only two motors. The wheels and the platform rotation are coupled to a single motor. When in translation the platform has no effect as it is above ground. And when turning, the wheels are off the ground due to the lowered platform
- The machine is restricted to only in – place turns. This may be an hindrance in some cases

Mechanical and Actuation systems

Power, Torque and Speed

Power is the product of Torque and Angular Velocity

- $P = \zeta \times \omega$
- That implies that if we want more Torque from same motor, we have to sacrifice speed of the motor or vice versa.

Torque

- Torque is a important point of concern in robot systems
- Torque can be thought as “Rotational Force” which can cause change in rotational motion
- In robotics Torque can be defined as pulling capacity of the robot.
- $\zeta = F \times r$ where F is the force and r is radius of the arrangement

Gears

Gears are used to

- Decrease RPM of the output shaft
- Increase the output torque
- Change the direction of the motion (Clockwise to anticlockwise or vice-versa)
- Change circular motion to linear motion or vice-versa

Gear Ratios/Reduction Ratios

- For optimum output gears must be in proper ratio
- Assume N1, N2 as RPMs of bigger and smaller gear respectively. D1, D2 as diameter of bigger and smaller gear respectively.

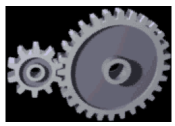
  Then $D1/D2 = N2/N1$
- Same can be determined using number of teeth on the gear. Lets say Z1 and Z2 are the number of teeth on above said gears

  Then $Z1/Z2 = N2/N1$

Types of Gears

Spur Gear

- Most commonly used gear set
- Mostly used for large reduction ratios

Helical Gears

- The teeth on helical gears are cut at an angle to the face of the gear
- Helical gears operates much more smoothly and quietly than spur gears

- Helical gears also can be used to transmit motion perpendicularly..

Bevel Gears

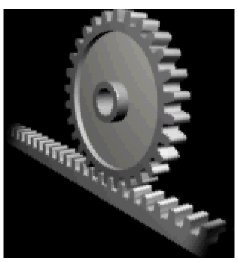
- Used when the direction of shaft's transmission needs to be changed
- Work well with angles other than 90 degree

Worm Gears

- Used when large reduction is required
- Can have reduction upto 300:1 in single step
- Only worm can turn the gear but gear cannot turn the worn
- This locking feature can act as a brake

Rack and Pinion

- Used to convert rotation into linear motion
- Mostly used for steering the wheels



Planetary Gear-sets

- Any Planetary gear set has three components
  - Sun Gear
  - Planet Gears with carrier
  - Ring Gear

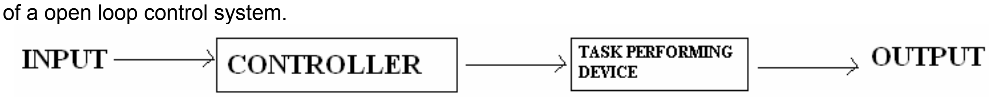
Control Systems

Control systems basically signify the mode of operation of various devices.
They are primarily of three types.

- Open loop control system.
- Closed loop control system.
- Proportional control system.

Open loop control system

Working of a open loop control system.



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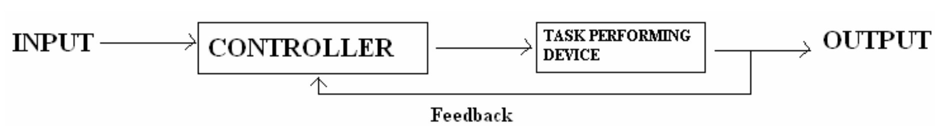
- No error correction can be done in this type of control system i.e. there is no way to check whether the action has been performed or not.
- System is simple to design but not reliable.
- Requires regular calibration of the system.

Closed Loop control system

Working of a closed loop control system:



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- Here we can check if the desired action has been performed or not by checking the feedback from the task performing device.
- System may become a little complex to design.
- System reliability increases.

Proportionality control system

In this type correction is made depending on the magnitude of the error.

- If desired o/p>actual o/p
  then new i/p>previous i/p

  If desired o/p< actual o/p
  then new i/p< previous i/p

- New input = Previous input+
  K(desired output-actual output).

Motors

Primarily motors that we use in robotics are of three types:

D C Motors

- DC motors are most widely used for hobby robotics and simple application.
- It can be rotated in either of the direction by reversing the direction of the current.
- It follows inverse speed torque relationship.
- The DC motors with gearbox can be used for high torque application.
- The metallic gears of gearbox can wear off due to load and can pose problem if they are not made of good quality metal.
- It's an example of open loop control system.
- It can be converted into closed loop control system by using shaft encoders.
- Shaft encoders are used to measure the speed as well as the direction of the rotation of the DC motor.

Stepper Motors

- It is used for measured rotation
- It can be held at a particular position of the shaft
- It is ideal for many autonomous robots requiring higher precision
- Open loop control type.

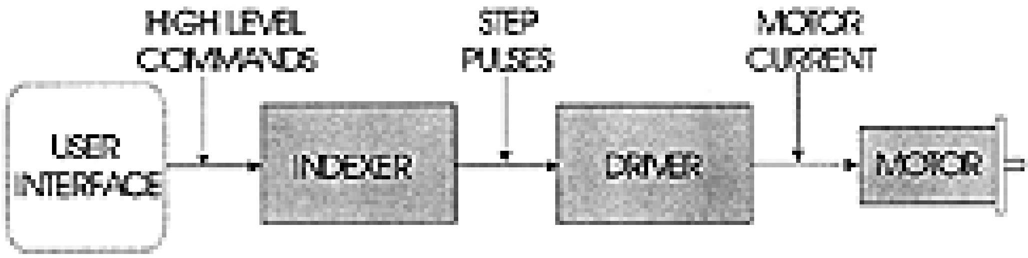
Terminology

Step angle:

- The amount of rotation achieved by shaft each time the winding Is energized.
- Can vary from as low as 0.9 to 90 degrees.

Pulse Rate:

- Heavy duty have a steps per revolution of 200-300
- Can be up to 1000 but with low torque and can't be used as driving motor.



- The Indexer (or Controller) is a microprocessor capable of generating step pulses and direction signals for the driver
- The Driver (or Amplifier) converts the indexer command signals into the power necessary to energize the motor windings

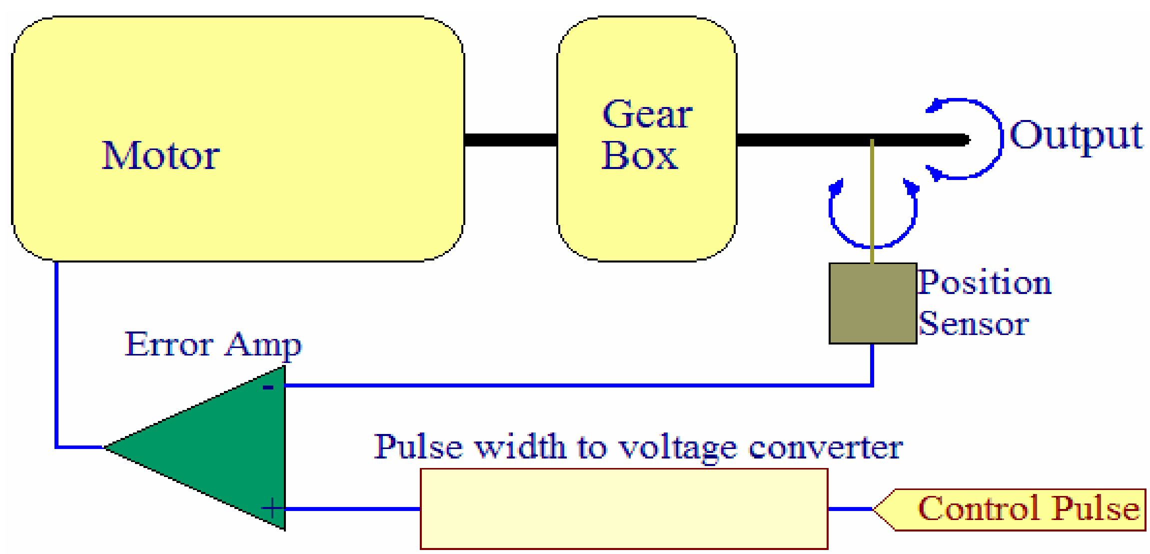
Step Modes

- Full step - Standard (hybrid) stepping motors 200 full steps per revolution of the motor shaft. Dividing the 200 steps into the 360º rotation equals a 1.8º full step angle
- Half step - simply means that the motor is rotating at 400 steps per revolution or 0.9 º
- Micro step - micro stepping is technology that controls the current in the motor winding to a degree that further subdivides the number of positions between poles

Servo Motors

- They provide the necessary feedback which tells the controller about the amount of rotation achieved upon the action being completed.
- The servo motors are deigned to be operated via Radio controlled link and so are referred to radio controlled or RC servo.
- Used for specific angular positioning.
- Built in gearing and feedback control loop circuitry
- Used for robot, RC plane, and RC boat builders

Inside the servo is a motor, a series of gears to reduce the speed of the motor, a control board, and a potentiometer. The motor and potentiometer are connected to the control board, all three of which form a closed feedback loop. Both control board and motor are powered by a constant DC voltage.



- To turn the motor, a digital signal is sent to the control board. This activates the motor, which, through a series of gears, is connected to the potentiometer.
- The position of the potentiometer's shaft indicates the position of the output shaft of the servo.
- When the potentiometer has reached the desired position, the control board shuts down the motor.
- The motor shaft of an R/C servo is positioned by using a technique called pulse width modulation (PWM). In this system, the servo responds to the duration of a steady stream of digital pulses. Specifically, the control board

responds to a digital signal whose pulses vary from about 1 millisecond (one thousandth of a second, or ms) to about 2 ms.

- These pulses are sent some 50 times per second.
- The exact length of the pulse, in fractions of a mil- lisecond, determines the position of the servo.
- It is not the number of pulses per second that controls the servo, but the duration of the pulses that matters.
- The servo requires about 30 to 60 of these pulses per second. This is referred to as the refresh rate
- If the refresh rate is too low, the accuracy and holding power of the servo is reduced.

What are sensors?

A sensor is a type of transducer.

A Transducer is a device, usually, electrical, electronic, or electro-mechanical, that converts one type of energy to another for various purposes including measurement or information transfer.

A sensor need to obey some laws :

- Sensitive to measured property
- Insensitive to any other property
- Should not influence the measured property

To make effective sensor choices & to use the chosen sensor well, you must be cognizant of several things

- What does the sensor actually measure?
- The robot need to ask particular question during its operation ; the sensor you choose will answer those questions.

Sensors are used in everyday life such as touch-sensitive elevator buttons and lamps which dim or brighten by touching the base. There are also innumerable applications for sensors in field of automobiles, machines, aerospace, medicine, industry, and robotics.
A sensor's sensitivity indicates how much the sensor's output changes when the measured quantity changes. For instance, if the mercury in a thermometer moves 1cm when the temperature changes by 1°, the sensitivity is 1cm/1°. Sensors that measure very small changes must have very high sensitivities.

Types of sensors

Collision sensors

- It is used to avoid collision between robot & an obstacle in environment
- The robot/environment force is non-zero anytime a collision occurs between robot & an object in the environment

Types of Collision sensor

Bump sensors

- It can sense only what it touches
- It provides the most direct method for detecting force between robot and environment
- But, these sensors are incapable of providing full detection

Stall sensors

- It indicates that the robot has stopped moving while the motors are still running
- Small mobile robots most commonly use PMDC motors to power their drive wheels
- PMDC motors require current in proportion to the torque they produce.

- Maximum current flows for an instant, when the motors begin from a dead stop continuously, if an external force prevents the motor from turning

Stasis sensors

- It indicates whether robot is moving by looking for some type of change
- It's a kind of virtual sensor
- A stasis sensor triggers an escape maneuver by virtually creating a collision

Avoidance sensors

- It is used to detect obstacles while they are still some distance away
- Various light based & acoustic based sensor comes under this category

Types of Avoidance Sensor

Infrared proximity sensor

- It consist of IR emitter & a detector
- Utilizes wavelengths in the 880-980 nm range
- IR receiver give output of low signal when obstacle is present & high signal when obstacle is not present

Infrared range sensor

- It is more efficient than IR proximity sensor
- It is capable of returning a distance
- It is based on triangulation rather than reflected intensity
- Less sensitive to color

Sonar sensor

- It is effective at sensing large objects oriented perpendicular to the beam at a distance not too large and not too small
- Non sonar sensors can be used as back-ups

Homing sensors

- It provides the robot with a means to reach some destination
- A beacon, light or color can be used for this purpose

Types of Homing Sensor

Photocells, Phototransistors & Photodiodes

- These sensors measures intensity of light
- Output is analog voltage whose value is function of light intensity
- Intensity of light source reaching sensors is related to the distance to the source & the angle of incidence between source and detector

$$i \propto 1/r^2$$
$$i \propto \cos(\theta)$$

Coded Beacons

- It consist of an Omnidirectional IR source modulated in some particular way
- One or more receivers on robot look only for the modulation pattern of the transmitter
- Stray IR does not fool the system

Pyroelectric sensor

- These are transducer that convert radiant heat into an electric signal
- It is sensitive to the longer wavelength far IR radiations emitted by warm blooded animals
- Commonly found in motion-sensing burglar alarms

Magnetic sensor (hall effect sensor)

- It is transducer that varies its output voltage in response to change in magnetic field
- Used for switching, positioning, speed detection, and current sensing applications
- It is an analog transducer directly returning a voltage, with known magnetic field its distance from the hall plate can be determined
- Range is limited as magnetic sources produce a dipole field whose intensity falls off as the inverse cube of distance

Introduction to Microcontrollers

A Microcontroller can be defined as a "Computer-on-Chip".
Just as a Personal Computer has input devices like keyboards, mouse, etc, output devices like monitor, printer, etc and the Central Processing Unit, a Microcontroller also has :

- Input/Output ports and
- a Processor embedded into a single chip.

A Microcontroller is a complete self-sufficient system usually requiring no external components.

Microcontrollers Vs Microprocessors

Often people misuse the terms Microprocessor" and "Microcontroller", but both of them are different.

- A Microprocessor is just a processor similar to a CPU of a PC. Microprocessors is just a processor which can follow the instructions but doesn't have any input/output port and memory
- A Microcontroller is a complete self-sufficient system with on chip I/O ports, Memory and various other features. Microcontrollers have Flash RAM, RAM and EEPROM inbuilt on it.

Various types and families of Microcontrollers

- AVR Family
- 8051 Family
- PIC Family
- ARM Family
- OOPic Family
- And many more

The AVR Family and Atmega16

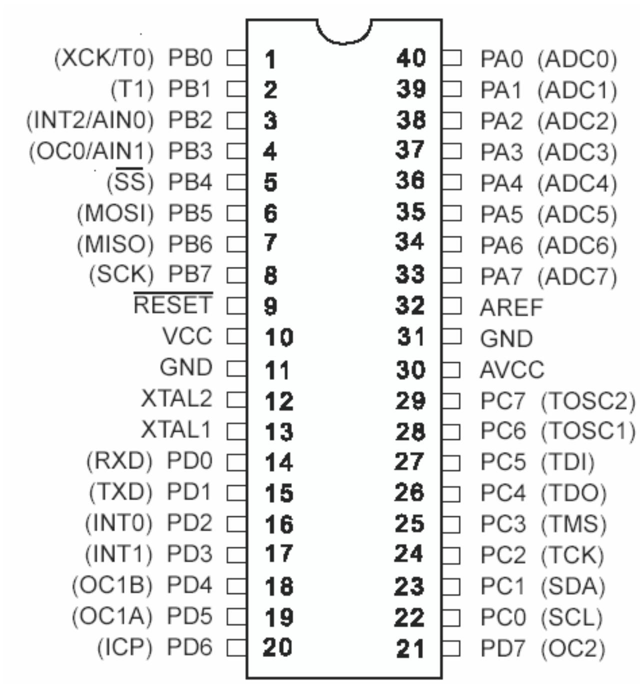
- AVR stands for Advanced Virtual RISC
- AVR family has 8-bit RISC architecture
- Amenability to C, Basic and Assembly programming

- In-System-Programmable (ISP) Flash
- Other features include Timers, PWM generation, built-in ADCs, UART and more.

ATmega16 Features

- Up to 16 MIPS Throughput
- 16 KB of ISP Flash
- 512 Bytes of EEPROM
- 1 KB of SRAM
- Two 8-bit timers with separate prescalers
- One 16-bit timers with separate prescalers
- Four PWM Channels
- 8-channel, 10-bit ADC
- 32 programmable Input/Output lines in 4 different port, 8 lines in each port.
- Programmable UART and SPI
- Available in 40 pin PDIP Package

ATmega16 Pin Configuration



Port and Pin details

- Port A (PA7 – PA0) – 8 I/O pins. This port also act as Analog to Digital Converter
- Port B (PB7 – PB0) – 8 I/O pins.
- Port C (PC7 – PC0) – 8 I/O pins.
- Port D (PD7 – PD0) – 8 I/O pins.
- Any single pin or entire port can be configured as input or output
- RESET – Low at this pin resets the counter and restarts the execution of the program

- Vcc – Power supply to the microcontroller
- AVcc – Separate power supply to the A/D converter
- AREF – Reference to the Analog Signals at ADC

In-System-Programmer

- No need of specialized programmer hardware
- No need to remove chip from circuit for programming
- Only six pins of microcontroller are need to be connected
- MISO, SCK, MOSI, RESET, GND and Vcc

A/D Converter

- ATmega16 has one 8-channel, 10-bit ADC
- It has resolution of 1024