Unit II

Drives and sensor

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DC servo motors

Analysis

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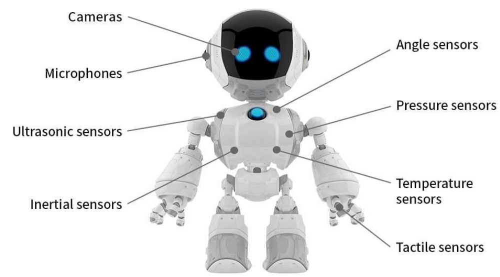
Sensor

- A sensor is a transducer that is used to make a measurement of physical variable
- Transducer is a device that convert one type of physical variable (pressure, temperature, velocity etc.) into another form
- Sensor is a device to make a measurement of a physical variable of interest and convert it into electrical signal.



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Function of sensor in robot

Sensors are used for a variety of functions in robotic systems such as:

1. for detecting positions and orientation of parts.
2. to ensure consistent product quality.
3. to discover variations of shape and dimensions of parts.
4. To identify unknown obstacles and
5. To determine system malfunctions and to analyze it.

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Desirable features of Sensor

- High accuracy.
- High precision.
- Linear response.
- Large operating range.
- Low response time.
- Easy to calibrate.
- Reliable and rugged.
- Low cost
- Ease of operation

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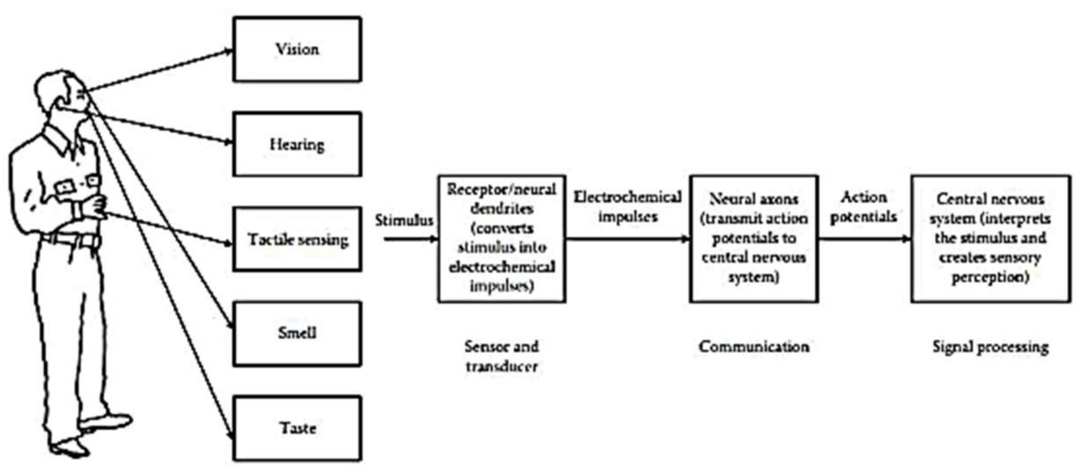
Human sensory system



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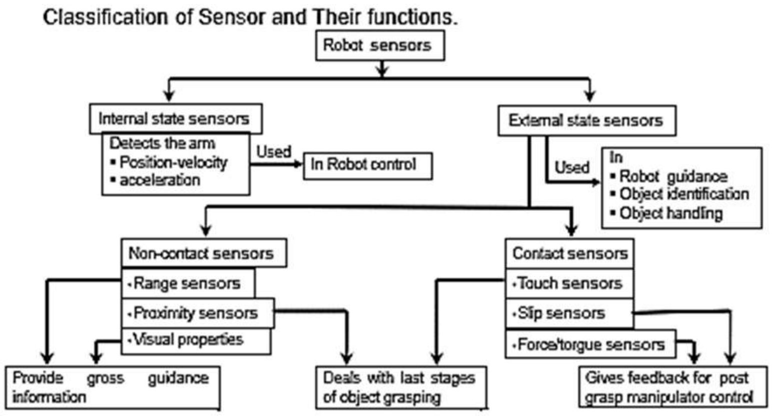
Classification



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Internal Sensor

- **Internal sensors measure variables** for control

✓Joint position.
✓Joint velocity.
✓Joint torque/force.

- **Joint position sensors (angular or linear)**

✓Incremental & absolute encoders — Optical, magnetic or capacitive.
✓Potentiometers.
✓Linear analog resistive or digital encoders.

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Internal Sensor

- **Joint velocity sensors**

✓DC tacho-generator & resolvers

✓Optical encoders.

- **Force/torque sensors.**

✓At joint actuators for control.

✓At wrist to measure components of force/moment being applied on environment.

✓At end-effector to measure applied force on gripped object

- Internal sensors use feedback information internally to ascertain their present condition.

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External sensor

- Detection of environment variables for robot guidance, object identification and material handling.
- Two main types –

❑Contacting and

❑Non-contacting sensors.

- The four most common external sensors are the microswitches, the simple touch or tactile sensors, the photoelectric devices, and the proximity sensors.

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Contact and non contact type sensor

Contacting sensors

Contacting sensors respond to a physical contact

- **Touch**: switches, Photo-diode/LED combination.
- Slip
- Tactile: resistive/capacitive arrays

Non-contacting sensors

- Non-contacting sensors detect variations in optical, acoustic or electromagnetic radiations or change in position/orientation.
- Proximity: Inductive, Capacitive, Optical and Ultrasonic
- Range: Capacitive and Magnetic, Camera, Sonar, Laser range finder, Structured light.
- Colour sensors.
- Speed/Motion: Doppler radar/sound, Camera, Accelerometer, Gyroscope.
- Identification: Camera, RFID, Laser ranging, Ultrasound.
- Localisation: Compass, Odometer, GPS.

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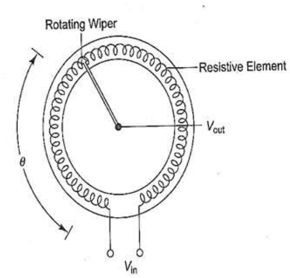
Position and velocity(displacement) sensor

Potentiometer

- Voltage ∝ resistance and resistance ∝ rotation at joint
- Not very accurate but very inexpensive.
- Types:-Linear and Angular
- More suitable for slow rotations.
- Adds to joint friction
- Inexpensive and easy to apply
- Temperature sensitive
- The wiper contact is subjected to wear and produce electrical noise



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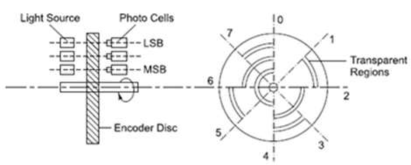
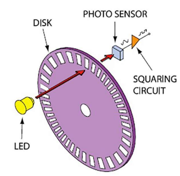
Position and velocity(displacement) sensor

Encoder

1. A simple incremental encoder uses a rotating disc with alternating transparent and opaque stripes.
2. A photo transmitter and receiver detect light changes to generate a pulse train proportional to rotation speed.
3. Two sets of transmitters and receivers, aligned 90° apart, provide direction information.
4. Pulse counting with direction allows position determination relative to a starting point.
5. Absolute encoders with which position can be known in absolute terms (i.e., not with respect to a starting position) employ the same basic construction as incremental encoders except that there are more tracks of stripes and a corresponding number of transmitters and receivers

Figure 5.4 An encoder





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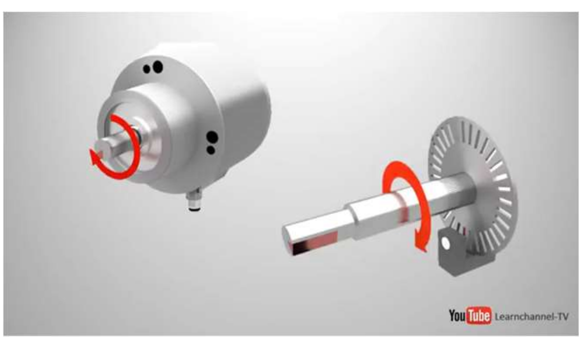
Incremental and absolute Encoder



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Position and velocity(displacement) sensor

Resolvers

- Rotary electrical transformer to measure joint rotation
- Analog output, need ADC for digital control.
- Electromagnetic device — Stator + Rotor (connected to motor shaft).
- Voltage (at stator) ∝ sin(θ), θ = rotor angl**e.**

Tachometer :-

- **Function**: Measures rotational speed of a shaft or disk.
- **Types**: Available in mechanical (analog) and electronic (digital) forms.
- **Output Signal**: Generates a voltage or frequency proportional to RPM.
- **Applications**: Used in engines, machinery, and aircraft for speed monitoring and control

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Resolver and a Tachometer

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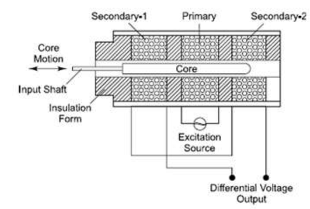
Position and velocity(displacement) sensor

LVDT

1. **LVDT Basics:** An LVDT (Linear Variable Differential Transformer) measures linear displacement using a transformer with a primary coil and two secondary coils wound around a movable core.
2. **Operation:** As the core moves, it alters the magnetic coupling between the primary and secondary coils, producing a differential voltage that varies with the core's position.
3. **Output Signal:** The output is an AC voltage signal, where the amplitude is proportional to the displacement and the phase indicates the direction of movement.
4. **Advantages:** LVDTs offer high accuracy, resolution, and repeatability with no physical contact between the core and coils, reducing wear and maintaining performance over time.

Figure 5.5 LVDT construction



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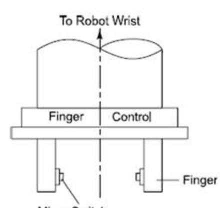
Touch sensor

- Touch Sensors: Used to detect contact between objects without measuring the force of contact.
- Types of Devices: Includes limit switches, microswitches, and other binary touch sensors.
- Multiple Sensors: Can be placed on the surfaces of each finger to provide additional tactile information.
- Application: These sensors help guide the hand through workspaces, similar to how humans feel their way in the dark

Figure 5.2 Robot hand with microswitches



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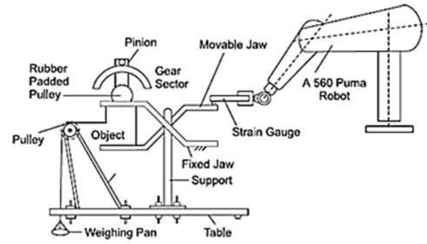
Slip Sensor for robot gripper

1. **Gripping Mechanism:** Fingers close on the object via a lever actuated by the robot's wrist to secure gripping.
2. **Force Measurement:** A full bridge with electrical strain gauges on the lever measures strain to determine the gripping force with proper calibration.
3. **Slip Detection:** A rubber-padded, spring-loaded wheel and a potentiometer measure slip by detecting positional rotation.
4. **Signal Processing:** Slip-induced changes in the potentiometer's analog voltage are digitized and processed by a microprocessor, which sends a high-value signal to the robot controller's I/O module upon detecting slip.

Figure 5.11 Slip sensor-based robot gripper



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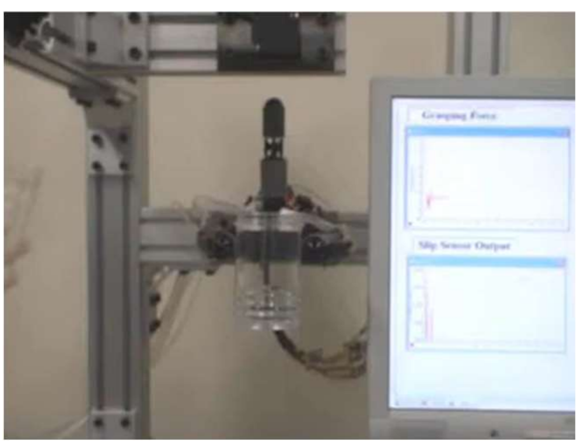
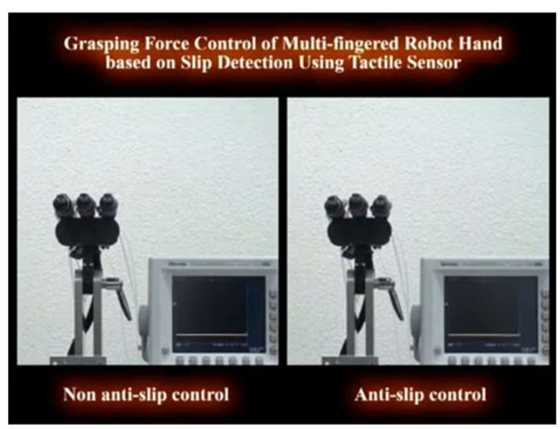
Slip Sensor for robot gripper





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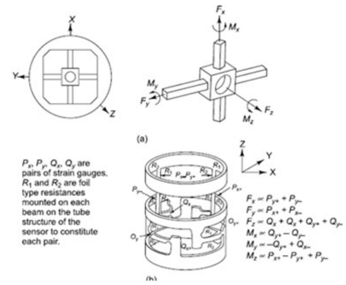
Force and Torque sensor

Force Measurement Capability: Allows robots to handle tasks such as grasping parts, material handling, machine loading, and assembly by applying the appropriate force.

Types: wrist, joint and Tactile array

Wrist Sensing: Sensors, like strain gauges, are mounted between the robot arm's tip and the end-effector to measure force.

- Purpose: Wrist sensors provide data on the three force components (F_x, F_y, F_z) and three moments (M_x, M_y, M_z) applied at the robot arm's end.
- Applications: This information helps ensure precise operations like avoiding side forces during insertion or guiding the end-effector along irregular surfaces.
- Sensor Design: Wrist sensors are compact, lightweight, and sensitive, converting forces and moments into measurable deflections or displacements.
- Example: A sensor with eight pairs of strain gauges on deflection bars measures forces and moments by calculating the output voltages along the X, Y, and Z axes.



Force and Torque sensor

Joint sensor

Joint sensors measure the cartesian components of force and torque acting on a robot joint and adds them vectorially. For joints driven by d.c. motor, sensing is done simply by measuring the armature current for each of the joint motors.

- **Torque Measurement:** For d.c. servo motors, joint torque can be measured indirectly by placing a resistor in the motor lead and measuring the voltage, which is proportional to the current and thus the torque.
- **Measurement Simplicity:** This method is straightforward and cost-effective for determining motor torque.
- **Accuracy Issues:** Measurements can be affected by friction in motor bearings, gears, and joint bearings, impacting the accuracy of the torque readings.
- **Additional Forces:** The measurements also account for forces and torques needed to accelerate the arm's links and overcome joint friction and transmission losses.

Torque sensor

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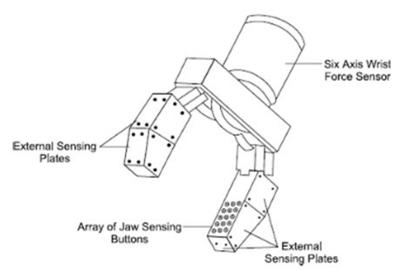
Tactile Array sensor

Tactile Array Sensor: A force sensor with a matrix of sensing elements that provides detailed force data and other information about the contact surface can be determined

- **Data Utilization:** The data can be combined with pattern recognition to determine characteristics such as object presence, contact area, shape, location, orientation, pressure, and pressure distribution.
- **Mounting Options:** These sensors can be mounted on robot gripper fingers or attached to work tables as flat touch surfaces.
- **Applications:** They enable precise tactile feedback and detailed analysis of objects in contact with the sensor surface.



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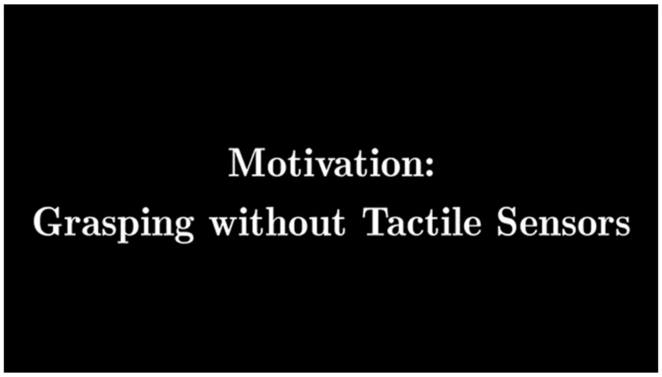
Tactile Sensor



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Proximity sensor

- The presence of an object can be sensed by a proximity sensor. Photoelectric proximity sensors may control the motion of a manipulator arm.
- Proximity and range sensors may be located on the end-effector or wrist
- There are various techniques that may be employed for designing proximity sensors. They include optical devices, acoustics, eddy currents, magnetic fields
- Types :- Inductive , capacity , optical(photoelectric), magnetic and acoustic(ultrasonic)

Figure 5.13 *Proximity sensor*

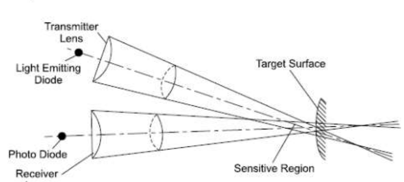
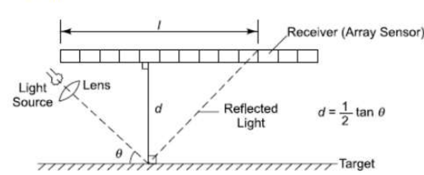


Figure 5.14 *Proximity array sensor*



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Proximity sensor

- https://www.youtube.com/watch?v=ghQI6rk4qDw

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Range sensor

- Range sensors are used to sense and measure the distance between the objects and the sensing device and they may be used even to locate the workpiece in the robot workcell.

Types:-

- One based on transmitting a laser pulse and measuring the time of arrival of the reflected signal
- Second based on transmitting an amplitude modulated laser beam and measuring the phase shift of the reflected signal.
- The transmitted beam and the received light are essentially coaxial

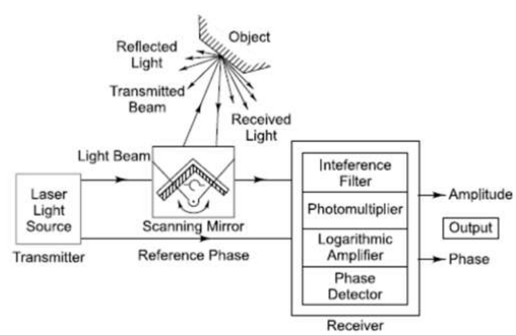

Figure 5.15 Range imaging sensor

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Range sensor

- https://www.youtube.com/watch?v=vTlrhhULVzk&pp=ygUTbGFzZXlgcmFuZ2Ugc2Vuc29yIA%3D%3D

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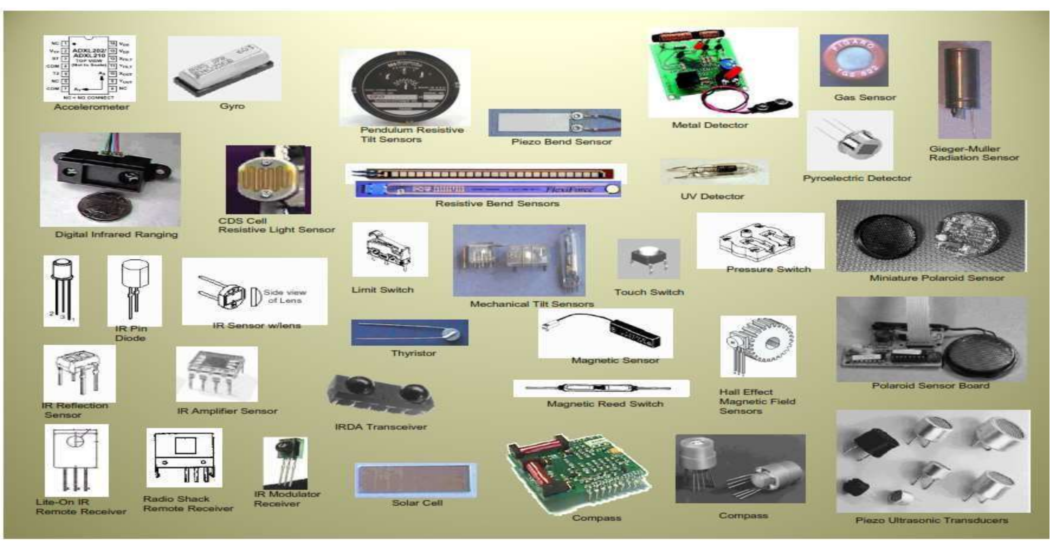
Various types of sensor



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MCQ

- Which sensor is commonly used for detecting obstacles in robotics?
  — A. Gyroscope
  — B. Accelerometer
  — C. Infrared Sensor
  — D. Sonar Sensor

Answer: C. Infrared Sensor

- Which type of sensor is commonly used for detecting distance in robotics?
  — A. Gyroscope
  — B. Accelerometer
  — C. Ultrasonic Sensor
  — D. Camera

Answer: C. Ultrasonic Sensor

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Selection of sensor

- You are tasked with designing a robotic work cell for a manufacturing process. The work cell will include a 6-axis robot arm, a conveyor belt for part delivery, and a fixture for holding parts during processing. What types of sensors would you recommend integrating into the work cell design and why? Consider the following factors in your sensor selection:
- Precise positioning and orientation of parts for the robot to grasp
- Detecting the presence and location of parts on the conveyor
- Monitoring forces and torques applied by the robot end effector
- Ensuring safe operation around human workers
- Flexibility to adapt to variations in part location and orientation

Provide a rationale for each sensor type selected and describe how it would enhance the capabilities and performance of the robotic work cell. Be specific in your recommendations and explain the purpose and benefits of each sensor.

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