2.7 Robot Sensors

Sensors are devices for sensing and measuring geometric and physical properties of robots and the surrounding environment

– Position, orientation, velocity, acceleration

– Distance, size

– Force, moment

– Temperature, luminance, weight

2.7.1 Desirable features of Sensors:

1. **Accuracy**
   Accuracy should be high. How close output to the true value is the accuracy of the device.
2. **Precision**
   There should not be any variations in the sensed output over a period of time precisionof the sensor should be high.
3. **Operating Range**
   Sensor should have wide range of operation and should be accurate and precise over this entire range.
4. **Speed of Response**
   Should be capable of responding to the changes in the sensed variable in minimum time.
5. **Calibration**
   Sensor should be easy to calibrate time and trouble required to calibrate should be minimum. It should not require frequent recalibration.
6. **Reliability**
   It should have high reliability. Frequent failure should not happen.
7. **Cost and Ease of operation**
   Cost should be as low as possible, installation, operation and maintenance should be easy and should not required skilled or highly trained persons.

Examples of Sensors:

Potentiometers

Thermocouples, thermistors.

Strain gauge

Load cell

Infrared sensors

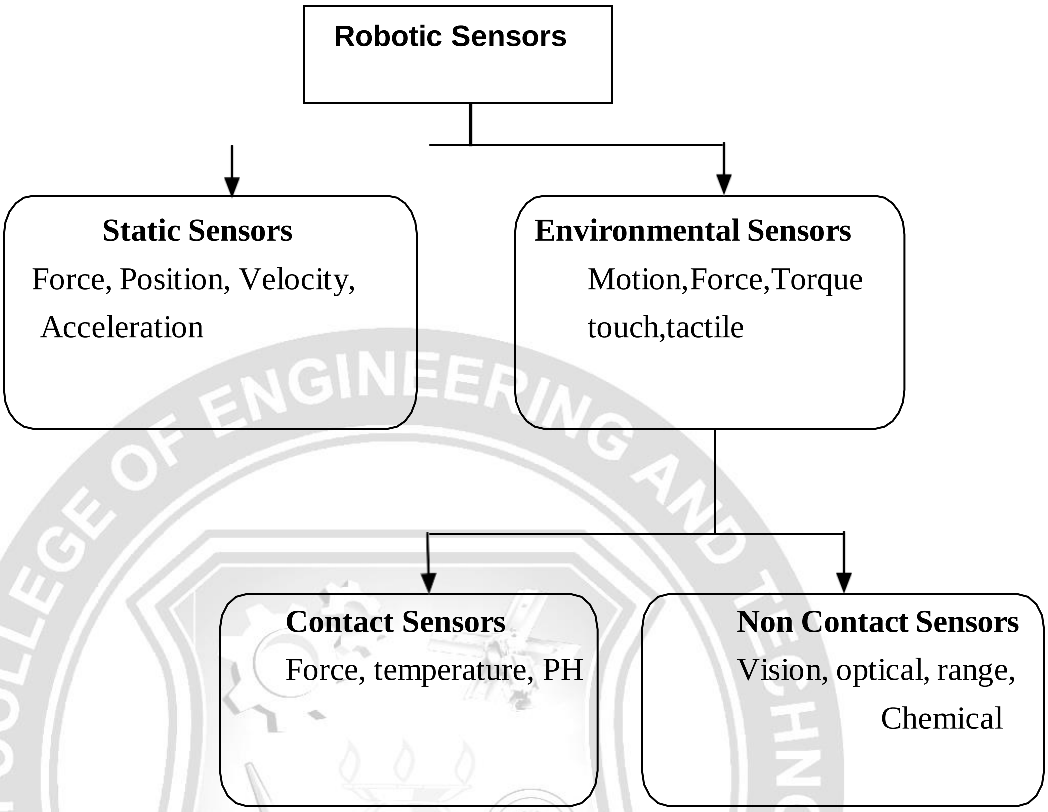
LVDT

Pyrometers

Pizeo electric devices

Pressure Transducers

Vision and voice sensors.



There are generally two categories of sensors used in robotics; these are for internal purposes, and those for external purposes. **Internal sensors** are used to monitor and control the various joints of the robot; they form a feedback control loop with the robot controller. Examples of internal sensors include potentiometers and optical encoders, while tachometers of various types can be deployed to control the speed of the robot arm. **External sensors** are external to the robot itself, and are used when we wish to controlthe operations of the robotwith other pieces of equipment in the robotic work cell. External sensors can be relatively simple devices, such as limit switches that determine whether a part has been positioned properly, or whether a part is ready to be picked up from an unloading bay.

ROBOTIC SENSORS For certain robot application, the type of workstation control using interlocks is not adequate the robot must take on more human like senses and capabilities in order to perform the task in a satisfactory way these senses and capability includes vision and hand eye coordination, touch, hearing accordingly we will dived the types of sensors used in robotics into the following three categories.

A number of advanced sensor technologies may also be used; these are outlined in Table 1.

Table 1: Advanced sensor technologies for robotics

Sensor Type	Description
Tactile sensors	Used to determine whether contact is made between sensor and another object. Two types: touch sensors—which indicate when contact is made, and no more; and force sensors—which indicate the magnitude of the forcewith the object.
Proximity sensors	Used to determine how close an object is to the sensor. Also called a range sensor.
Optical sensors	Photocells and other photometric devices that are used to detect the presence or absence of objects. Often used in conjunction to proximity sensors.
Machine vision	Used in robotics for inspection, parts identification, guidance, and other uses.
Others	Miscellaneous category of sensors may also be used; including devices for measuring: temperature, fluid pressure, fluid flow, electrical voltage, current, and other physical properties.

2.7.2 Range sensor:

Ranging sensors include sensors that require no physical contact with the object being detected. They allow a robot to see an obstacle without actually having to come into contact with it. This can prevent possible entanglement, allow for better obstacle avoidance (over touch- feedback methods), and possibly allow software to distinguish between obstacles of different shapes and sizes. There are several methods used to allow a sensor to detect obstacles from a distance.

Light-based ranging sensors use multiple methods for detecting obstacles and determining range. The simplest method uses the intensity of the reflected light from an obstacle to estimate distance. However, this can be significantly affected by the color/reflectivity of the obstacle and external light sources. A more common method is touse a beam of light projectedat an angle and a strip of detectors spaced away from the emitter as in the animation to the right. The pictured Sharp sensor uses this method. This method is less affected by the color/reflectivity of the object and ambient light.

LIDAR, a more advanced method of range detection, uses a laser that is swept across the sensor's field of view. The reflected laser light is usually analyzed one of two ways. Units with longer ranges sometimes actually determine distance by measuring the time it takes for the laser pulse to return to the sensor. This requires extremely fast timing circuitry. Another method uses phase shift detection to determine range by analyzing the incoming light and comparing it toa reference signal.

Working principle

– ***Triangulation:*** Use the triangle formed by the travelling path of the signal to calculate the distance

Time-of-flight: Use the time of flight of the signals to measure the distance

Typical range sensors

– Infra-red range sensor (triangulation)

– Ultrasonic sensors (time-of-flight)

– Laser range sensor (triangulation)

Ultrasonic Sensors

Emit a quick burst of ultrasound (50kHz), (human hearing: 20Hz to 20kHz)

– Measure the elapsed time until the receiver indicates that an echo is detected.

– Determine how far away the nearest object is from the sensor

$D = v * t$

D = round-trip distance

v = speed of propagation (340 m/s)

t = elapsed time

Applications:

– Distance Measurement

– Mapping: Rotating proximity scans (maps the proximity of objects surrounding the robot)

Limitations of Ultrasonic Sensors

• Background noises: If there are other ultrasonic sources, the sensor may detect signals emitted by another source.

• The speed of sound varies with air temperature and pressure – a 16 degree centigrade temperature change can cause a 30cm error at 10m!

• Cross-talk problem: If a robot has more than one ultrasonic sensor, measurement ranges intersect, a sensor may receive signals emitted by others.

• Poor surface reflection: Surface materials absorb ultrasonic waves.

• Surface orientation affects the reflection of ultrasonic signals.

2.7.3 Tactile sensor

Tactile sensors provide the robot with the capability to respond to contact forces between itself and other objects within its work volume. Tactile sensors can be divided into twotypes:

1. Touch sensors
2. Stress sensors

Touch sensors are used simply to indicate whether contact has been made with an object. A simple micro switch can serve the purpose of a touch sensor. Stress sensors are used to measure the magnitude of the contact force. Strain gauge devices are typically employed in force measuring sensors. Potential use of robots with tactile sensing capabilities would be in assembly and inspection operations. In assembly, the robot could perform delicate part alignment and joining operations. In inspection, touch sensing would be used in gaugingoperations and dimensional measuring activities.

2.7.4 Proximity sensor

Proximity sensors are used to sense when one object is close to another object. On a robot, the proximity sensors would be located n or near the end effectors. This sensing capability can be engineered by means of optical proximity devices, eddy-current proximity detectors, magnetic field sensors, or other devices. In robotics, proximity sensorsmight be used to indicate the presence or absence of a work part or other object. They could also be helpful in preventing injury to the robots human coworkers in the factory.

2.7.5 Optical or Infrared Light-Based sensors

This is one of the areas that is receiving a lot of attention in robotics research computerized visions systems will be an important technology in future automated factories. Robot vision is made possible by means of video camera a sufficient light source and acomputer programmed to process image data. The camera is mounted either on the robot or in a fixed position above the robot so that its field of vision includes the robots work volume. The computer software enables the vision system to sense the presence of an object and its position and orientation. Vision capability would enable the robot to carry out the following kinds of operations. Retrieve parts which are randomly oriented on a conveyor Recognize particular parts which are intermixed with other objects Perform assembly operations which requirealignment.

Another very popular method uses projected light waves, usually infrared, to detect obstacles. This system projects a pulse of light and looks for the reflection. Properties of the reflected light are analyzed to determine characteristics about the object detected. Light has the advantages of traveling extremely fast, allowing for fast sensor response time, high resolution, and less error to account for. Light from this type of sensor is often formed into a narrow beam or many times a laser is used. This provides good resolution over large distances.

2.7.6 Proximity sensors

The simplest light-based obstacle sensor projects a light and looks for a reflection of certain strength. If the reflection is strong enough, it can be inferred that an obstacle lies within a certain range of the sensor. Multiple light sources can be pulsed on in sequence to give some resolution to the sensor as in the figures.

2.7.7 Voice sensors

Another area of robotics research is voice sensing or voice programming. Voice programming can be defined as the oral communication of commands to the robot or other machine. The robot controller is equipped with a speech recognition system which analyzes the voice input and compares it with a set of stored word patterns when a match isfound between the input and the stored vocabulary word the robot performs some actions which corresponds to the word. Voice sensors could be useful in robot programming to speed up the programming procedure just as it does in NC programming. It would also be beneficial in especially in hazardous working environments for performing unique operations such as maintenance and repair work. The robot could be placed in hazardous environment and remotely commanded to perform the repair chores by means of step by step instructions.

Internal sensor

Internal sensors measure the robot's internal state. They are used to measure its position, velocityand acceleration.

2.7.8 Position sensor

Position sensors measure the position of a joint (the degree to which the joint is extended). Theyinclude:

- Encoder: a digital optical device that converts motion into a sequence of digital pulses.
- Potentiometer: a variable resistance device that expresses linear or angular displacements in terms of voltage.
- Linear variable differential transformer: a displacement transducer that provides high accuracy. It generates an AC signal whose magnitude is a function of the displacement ofa moving core.
- Synchronous and Resolvers

2.7.9 Velocity Sensor

A velocity or speed sensor measures consecutive position measurements at known intervals andcomputes the time rate of change in the position values.

2.7.10 Acceleration Sensors:

Accelerometer

An accelerometer measures acceleration (change in speed) of anything that it's mounted on. How does it work? Inside an accelerator MEMS device are tiny micro- structures that bend due to momentum and gravity. When it experiences any form of acceleration, these tiny structures bend by an equivalent amount which can be electrically detected. Today, accelerometers are easily and cheaply available, making it a very viable sensor for cheap roboticshobbyists like you and me

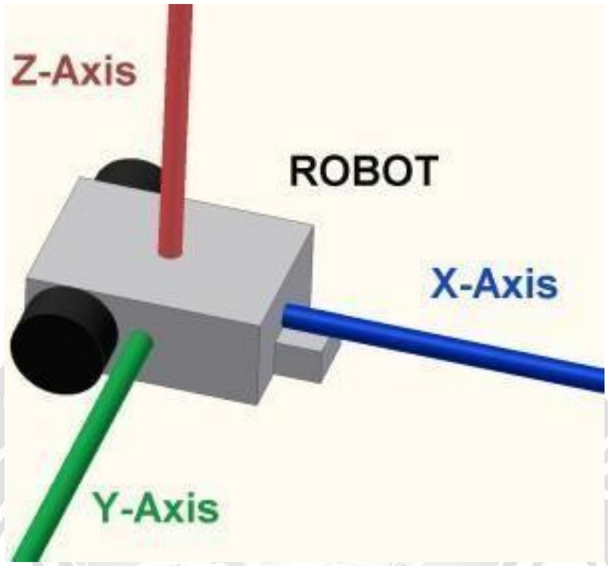
Applications for Accelerometers are very important in the sensor world because they can sense such a wide range of motion. They're used in the latest Apple Power books (and other laptops) to detect when the computer's suddenly moved or tipped, so the hard drive can be lockedup during movement. They're used in cameras, to control image stabilization functions. They're used in pedometers, gait meters, and other exercise and physical therapy devices. They're used ingaming controls to generate tilt data. They're used in automobiles, to control airbag release when there's a sudden stop. There are countless other applications for them.

Possible uses for accelerometers in robotics:

- Self balancing robots
- Tilt-mode game controllers
- Model airplane auto pilot
- Alarm systems
- Collision detection
- Human motion monitoring
- Leveling sensor, inclinometer
- Vibration Detectors for Vibration Isolators
- G-Force Detectors

Axis of acceleration

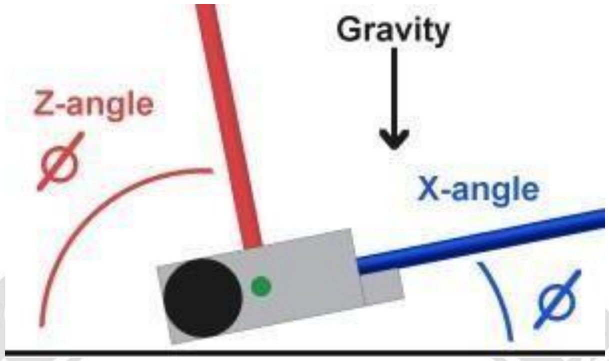
The tiny micro-structures can only measure force in a single direction, or axis of acceleration. This means with a single axis measured, you can only know the force in either the X, Y, or Z directions, but not all. So if say your X-axis accelerometer endowed robot was running around and ran into a wall (in the X direction). Your robot could detect this collision.But if say another robot rammed into it from the side (the Y direction), your robot would be oblivious to it. There are many other situations where a single axis would not be enough. It is always a good idea to have at least 2 axes (more than one axis).



Gravity

Gravity is acceleration. Your accelerometer will always be subject to a -9.81 m/s^2 acceleration (negative means towards the ground). Because of this, your robot can detect what angle it is in respect to gravity. If your robot is a biped, and you want it to always remain balanced and standing up, just simply use a 2-axis accelerometer. As long as the X and Y axes detect zero acceleration, this means your robot device is perfectly level and balanced.

Accelerometers, Rated G When you buy your accelerometer, you will notice it saying something like 'rated at 2g' or '3g accelerometer.' This is the maximum g force your sensor can report. Gravity accelerates objects at 1g, or 9.81 m/s^2. For example, if your robot is moving at 1g upwards, then that means you sensor will detect 2g. For most robotics applications a 2g rating will be fine. So why not just get the highest rating possible? The lower the rating, the more sensitive it will be to changes in motion. You will always have a finer tuned sensor the lower the rating. But then again, more sensitive sensors are more affected by vibration interference.



Chances are you would have no need to measure the force, but if you reverse the equation youcan calculate the angle by knowing the angleAvailability and cost.

The MEMS IC's are easily available and very affordable. However they all require support circuitry and come as surface mounts. I highly discourage buying an IC and doing your own wiring. However there are many already setup accelerometer packages you can buy. For example, Dimension Engineering has a great plug and play dual axis accelerometerwhich requires no additional support circuitry. There are several other great sensors out there, some as a3-axis, and now some even with built in rotation sensor.

Wiring Requirements Any accelerometer package will have a power and ground line, anda single output analog pin for each axis of acceleration. Some of the sensors come with additional features/pins, read their datasheets. Additional Tips and Uses Placing an accelerometer on a mobile robot that experiences bumps can trigger the accelerometer unintentionally. Use a capacitor to smooth out output over several hundred milliseconds (testing required) to prevent this. Also, read the interpret sensor data tutorial to enhance your accelerator sensor accuracy.

2.7.11 Touch, Force, Torque:

A tactile sensor is a device that measures information arising from physical interaction with its environment. Tactile sensors are generally modeled after the biological sense of coetaneous touch which is capable of detecting stimuli resulting from mechanical stimulation, temperature, and pain (although pain sensing is not common in artificial tactile sensors). Tactile sensors are used in robotics, computer hardware and security systems. A common application of tactile sensors is in touch screen devices on mobile phones and computing.

Tactile sensors may be of different types including piezoresistive, piezoelectric, capacitive and elasto-resistive sensors

Force Sensors (Force Transducers) There are many types of force sensors, usually referred to as torque cells (to measure torque) and load cells (to measure force).

Force transducers are devices useful in directly measuring torques and forces within your mechanical system. In order to get the most benefit from a force transducer, you must have a basic understanding of the technology, construction, and operation of this unique device. Forces can be measured by measuring the deflection of an elastic element.

Strain gauges: Most common sensing elements of force. It converts the deformation to the change of its resistance. Gauge resistance varies from 30 to 3K, corresponding to deformation from 30µm to 100 µm. Shaft torque is measured with strain gauges mounted on a shaft with specially designed cross-section.

2.7.12 Position Measurement

• An optical encoder is to measure the rotational angle of a motor shaft.

• It consists of a light beam, a light detector, and a rotating disc with a radial grating on its surface.

• The grating consists of black lines separated by clear spaces. The widths of the lines and spaces are the same.

– Line: cut the beam and hence a low signal output

– Space: allow the beam to pass and hence a high signal output

• A train of pulses is generated with rotation of the disc.

By counting the pulses, it is possible to know the rotational angle.