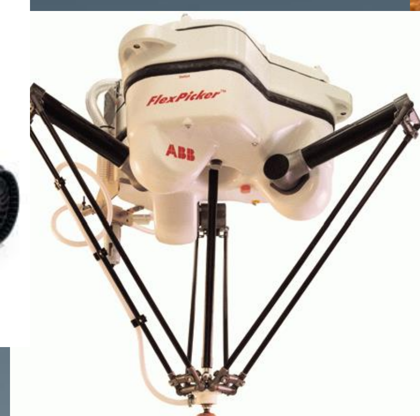
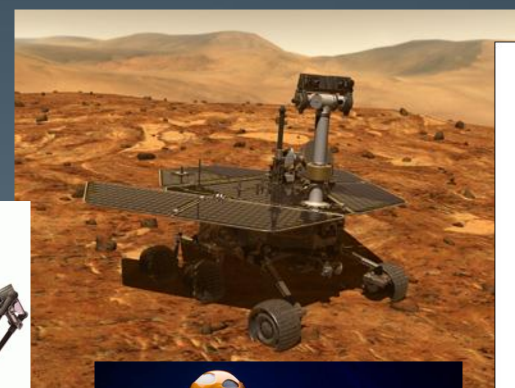
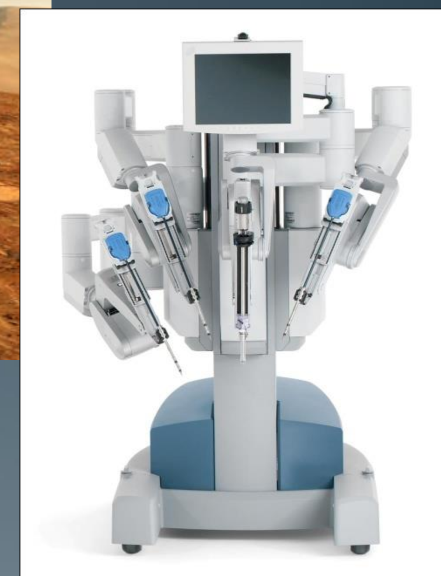
Introduction to Robotics







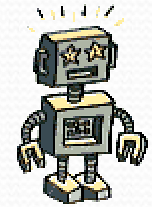
WIA1004/WAES 1102

Topics

- Why are robots important?
- Types of robots
- Future growth areas
- Technologies used in robotics
- Technical disciplines needed in robotics
- Sensing and Sensors

What do you think of when you hear the word "robot"?

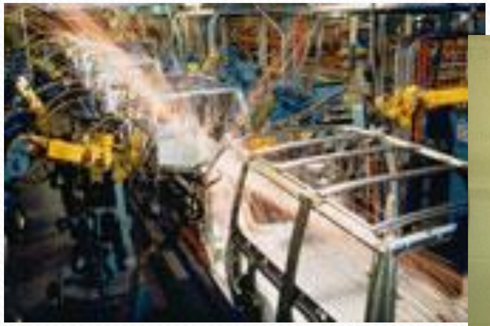
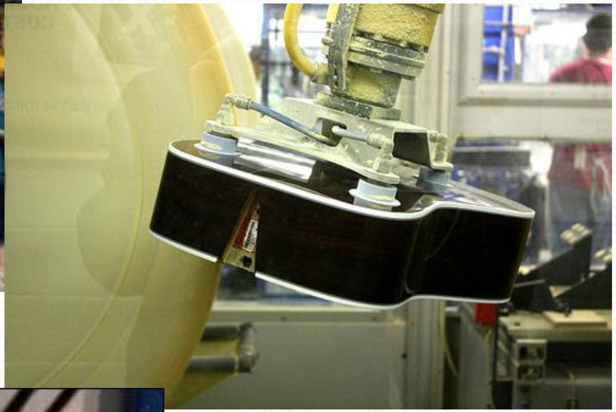
Why Robotics?



- Areas that robots are used:
  - Industrial robots
  - Military, government and space robots
  - Service robots for home, healthcare, laboratory
- Why are robots used?
  - Dangerous tasks or in hazardous environments
  - Repetitive tasks
  - High precision tasks or those requiring high quality
  - Labor savings
- Control technologies:
  - Autonomous (self-controlled), tele-operated (remote control)

Industrial Robots

- Uses for robots in manufacturing:
  - Welding
  - Painting
  - Cutting
  - Dispensing
  - Assembly
  - Polishing/Finishing
  - Material Handling
    - Packaging, Palletizing
    - Machine loading

Industrial Robots - Automotive

Industrial Robots - Packaging

Military/Government Robots

- iRobot PackBot

- Remotec Andros

Military/Government Robots

Soldiers in Afghanistan being trained how to defuse a landmine using a PackBot.

Military Robots

- Aerial drones (UAV)

- Military suit

Space Robots

- Mars Rovers – Spirit and Opportunity
  - Autonomous navigation features with human remote control and oversight

Service Robots

- Many uses…
  - Cleaning & Housekeeping
  - Rehabilitation
  - Inspection
  - Agriculture & Harvesting
  - Lawn Mowers
  - Surveillance
  - Mining Applications
  - Construction
  - Automatic Refilling
  - Fire Fighters
  - Search & Rescue

iRobot Roomba vacuum cleaner robot

Medical/Healthcare Applications

DaVinci surgical robot by Intuitive Surgical.

St. Elizabeth Hospital is one of the local hospitals using this robot. You can see this robot in person during an open house (http://www.youtube.com/watch?v=EiVY-htgRUY)

Japanese health care assistant suit (HAL - Hybrid Assistive Limb)

Also… Mind-controlled wheelchair using NI LabVIEW

Laboratory Applications

Drug discovery

Test tube sorting

Technologies Used in Robotics

- Drivetrain – servomotors, gear reducers
- Hydraulics (oil), pneumatics (air)
- Electrical controls – motor drives, computers
- Lightweight materials – aluminum, carbon fiber, titanium
- Sensors
  - Photoeyes
  - Encoders/position measurement sensors
  - Proximity switches
  - Laser scanners
  - Vision systems
  - Navigation systems/GPS

Disciplines Used in Robotics

- Robotics merges many technical disciplines:
  - Bio-Medical Engineering
  - Ethics and Legal Issues
  - Mechanical Engineering
  - Electrical Engineering
  - Computer Science
- Latest advancement:
  - Artificial Intelligence

Mechatronics

Intelligent Agents

Sensing and Sensors

Human Sensing

Sense:	Sensed what?	Sensor?
Vision	EM waves	Eyes
Audition	Pressure waves	Ears
Gustation	Chemicals - flavor	Tongue
Olfaction	Chemicals - odor	Nose
Tactile	Contact pressure	Skin
Thermoception	Heat	Skin
Nociception	Pain	Skin, organs, joints
Equilibrioception	Sense of balance	Ears
Proprioception	Body awareness	Muscles, joints

Robot Sensors

Sense:

- Vision
- Audition
- Gustation
- Olfaction
- Tactitions
- Thermoception

Sensor:

- Camera
- Microphone
- Chemical sensors
- Chemical sensors
- Contact sensors
- Thermocouple

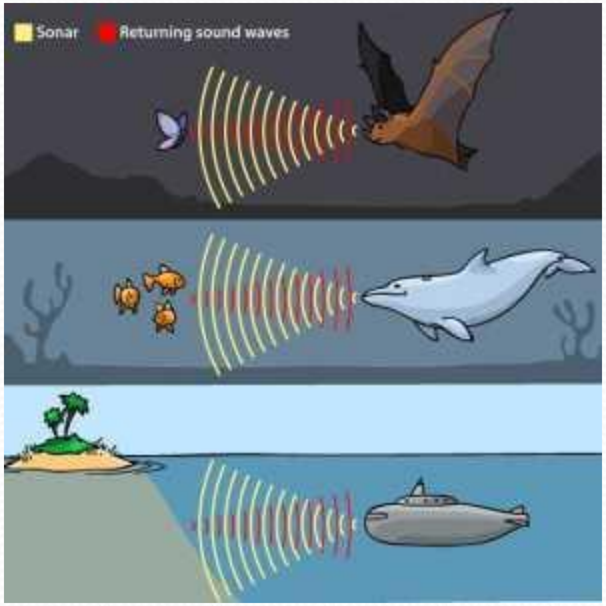
Robot Sensors

Sense:

- Equilibrioception
- Proprioception
- Magnetoception
- Electroception
- Echolocation

Sensor:

- Accelerometer
- Encoders
- Magnetometer
- Voltage sensor
- Sonar



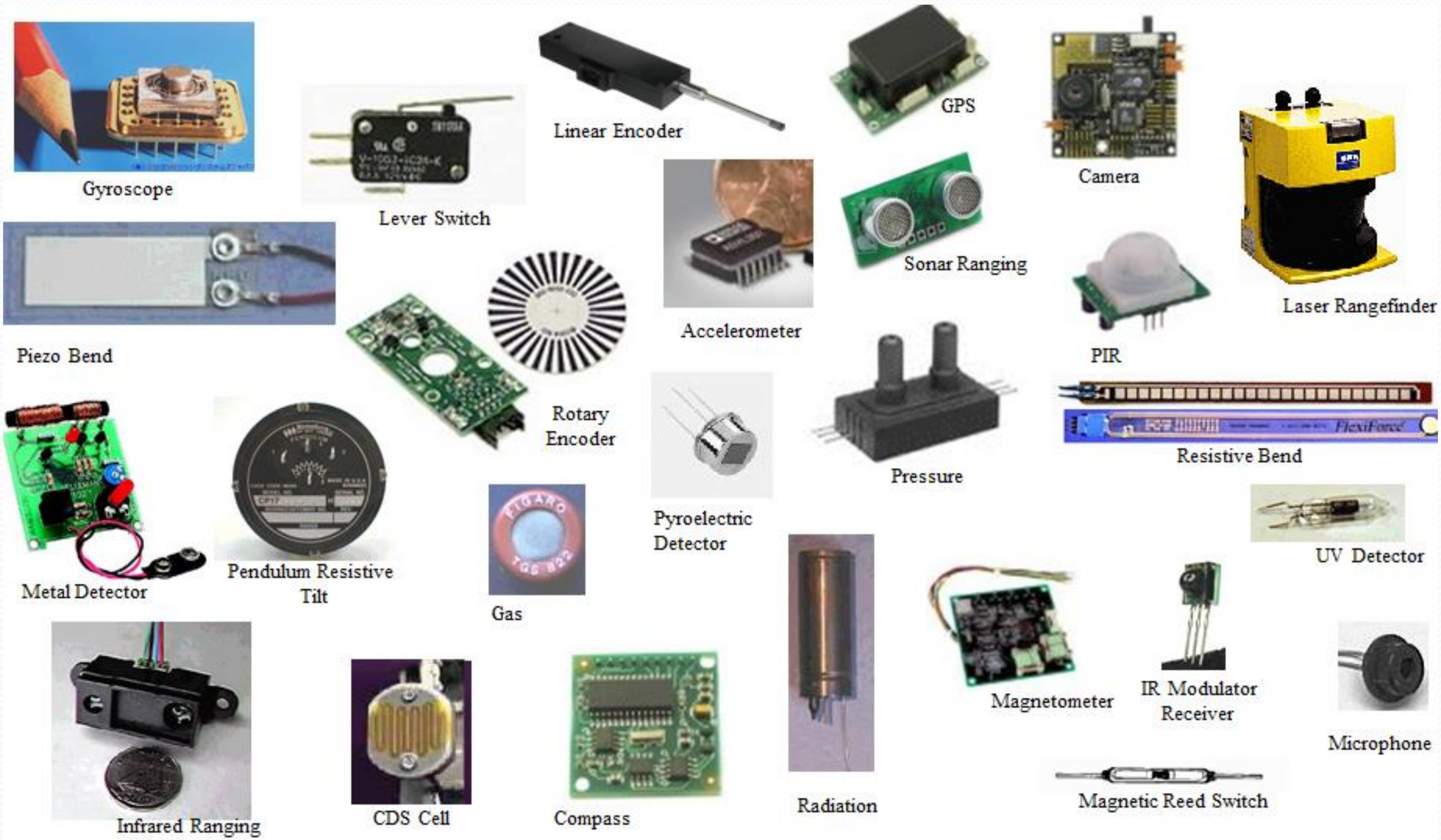
Sonar Sensor

- How does it detect distance?
  - The sensor send out a high-frequency sound pulse and times how long it takes for the echo of the sound to be reflected back.
  - The speed of sound is known, 341 m/s in air, the sensor uses rate and time to calculate distance
  - $Distance\ to\ object = \frac{t \times speed\ of\ sound}{2}$
  - Reference:
  - http://learn.cs2n.org/solt/lessons/nvt2.0/content/resources/helpers/nxt_sensors/ultrasonic.html

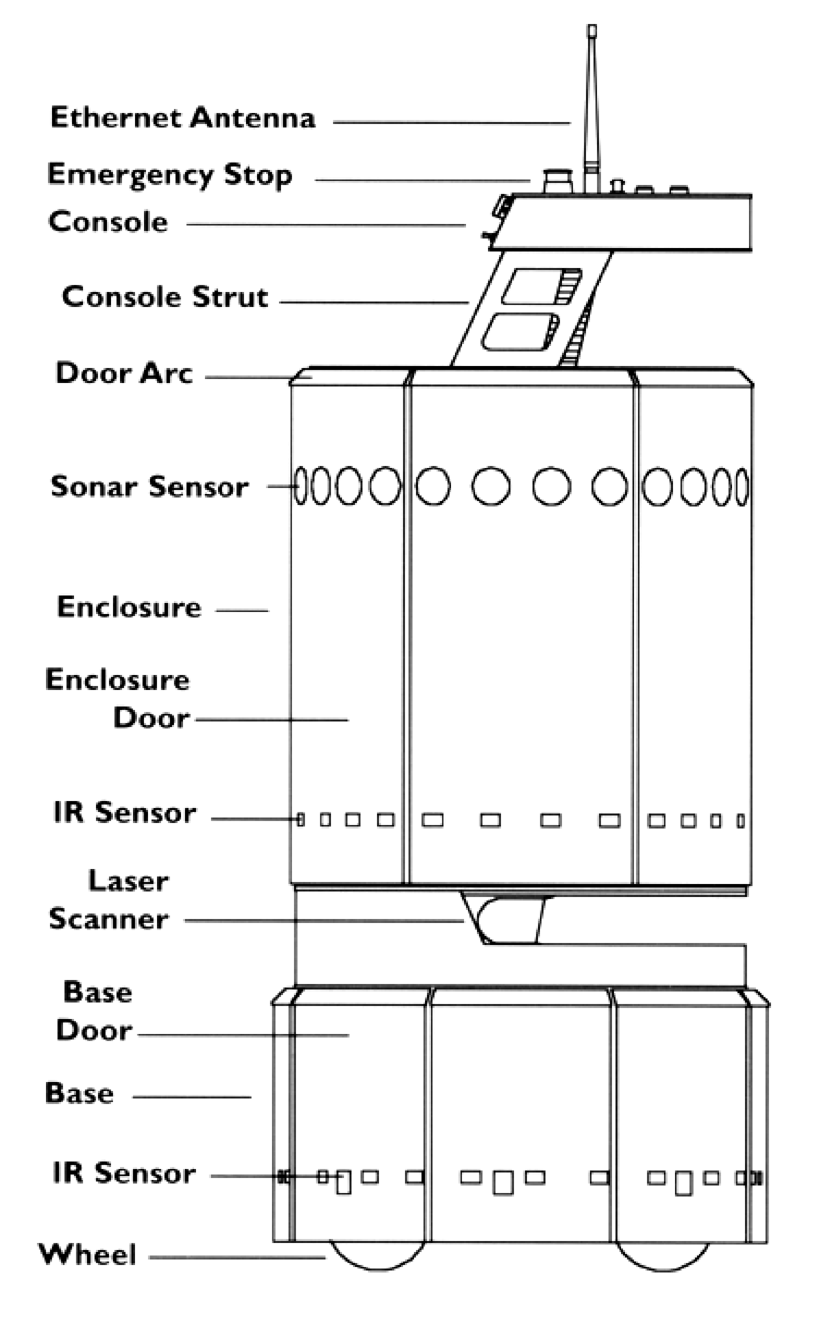
Sonar Sensor

- Factors that might limit the accuracy of sonar reading:
  - *Object too far away*
  - *Flat object is not facing sensor*
  - *Object is too small*
  - *Object is too soft*

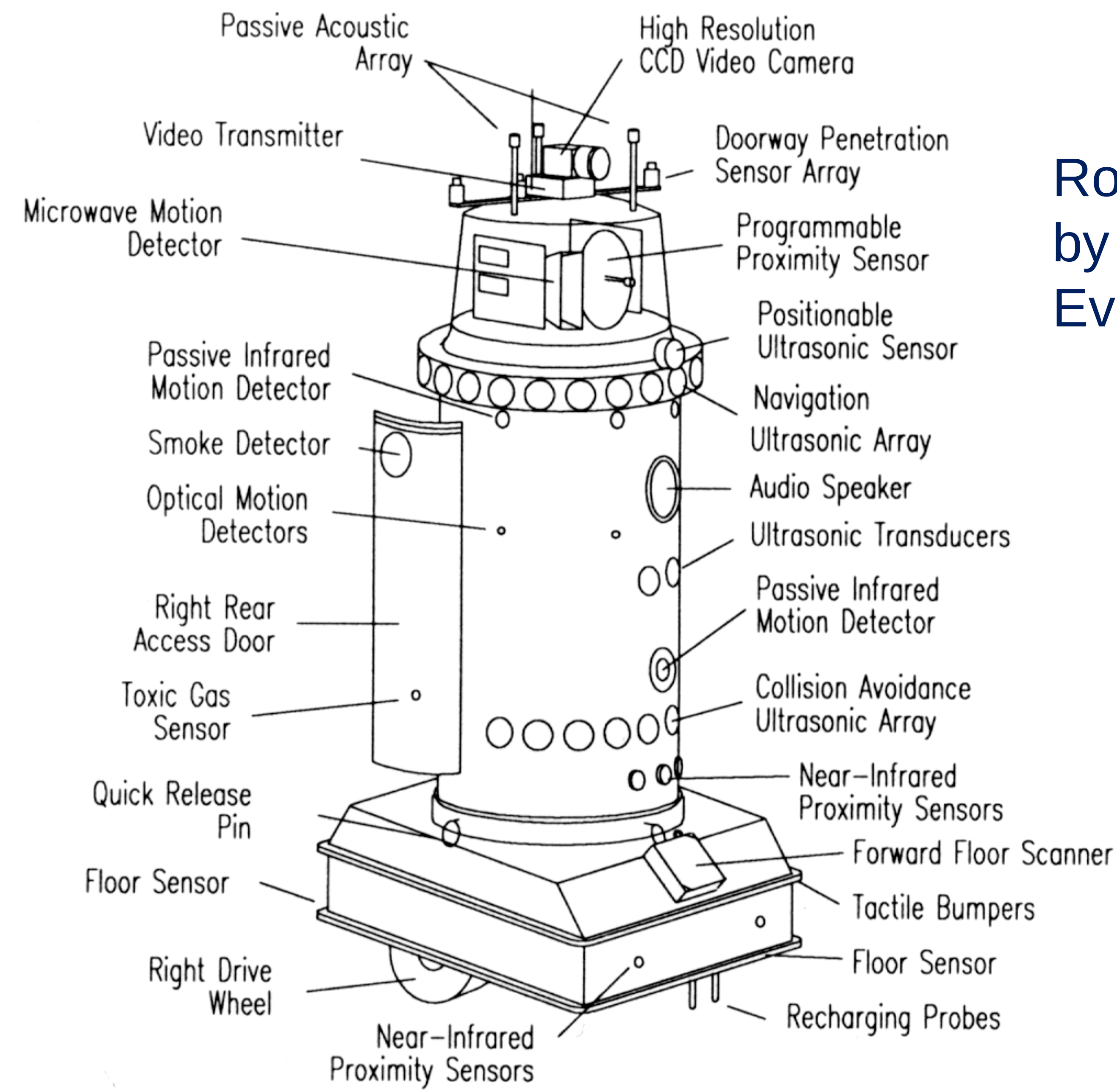
Sample of robot sensors



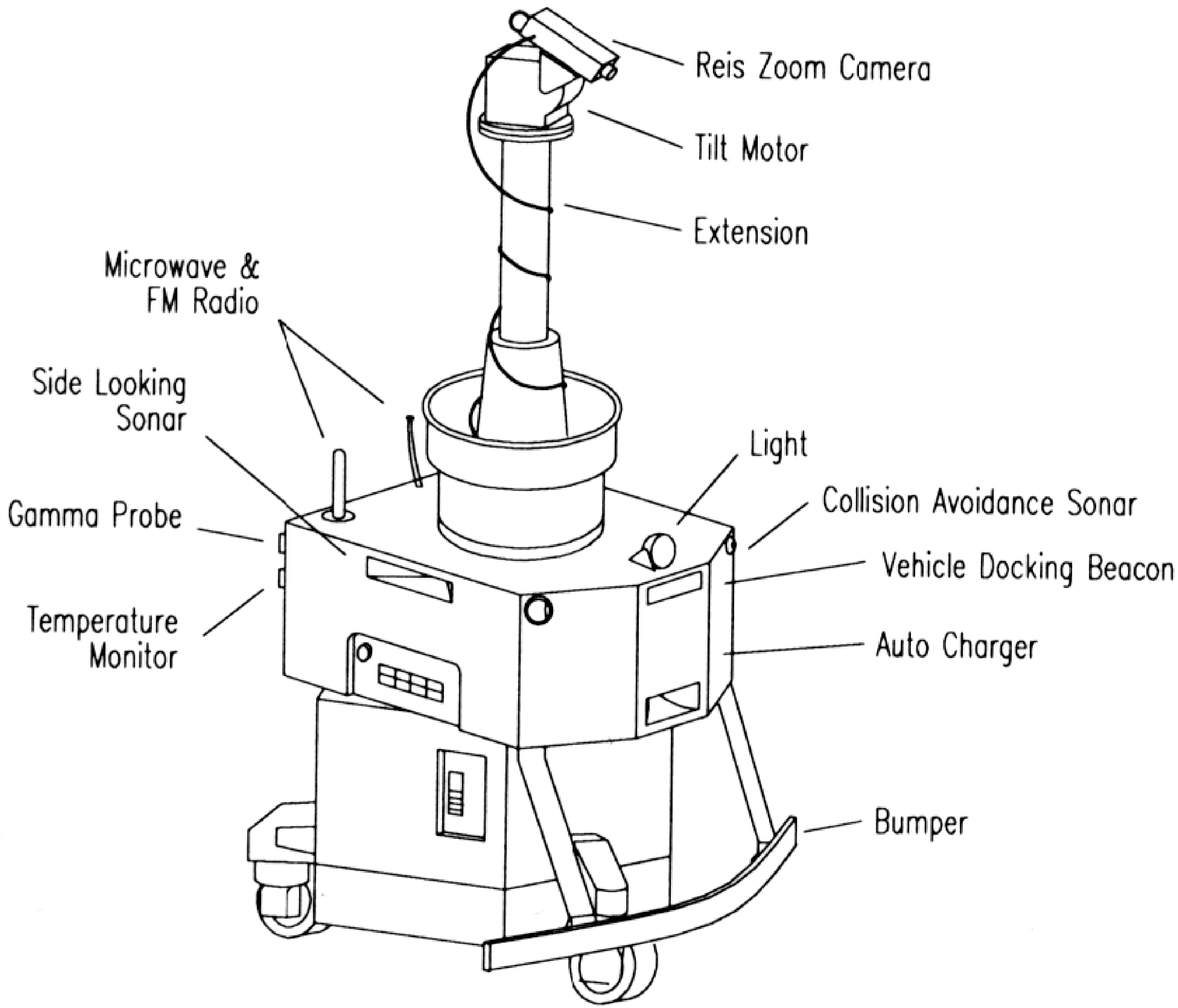
Robot Sensory Architecture



B21 robot's real world interface



Robart II, by H.R. Everett


Reis Zoom Camera
Tilt Motor
Extension
Microwave & FM Radio
Side Looking Sonar
Gamma Probe
Temperature Monitor
Light
Collision Avoidance Sonar
Vehicle Docking Beacon
Auto Charger
Bumper

BibaBot, BlueBotics SA, Switzerland

IMU
Inertial Measurement Unit

Emergency Stop Button

Wheel Encoders

Omnidirectional Camera

Pan-Tilt Camera

Sonar Sensors

Laser Range Scanner

Bumper

Evolution Robotics' Scorpion

- Logitech QuickCam Pro 3000
  - 640 X 480 video; 1.3 MP still mode
- Built-in microphone for sound/voice recognition applications
- IR Sensors
  - 4 ledge detection sensors
  - 3 up-facing sensors
  - 13 horizontal facing sensors
- Bump Sensor

Activmedia Robotics' PeopleBot

Classification of Sensors

- Proprioceptive (internal) sensors
  - Measure values internally to the system (robot)
  - E.g. motor speed, wheel load, heading of the robot, battery status
- Exteroceptive (external) sensors
  - Information from the robots environment
  - Distances to objects, intensity of the ambient light, unique features

Sensor Performance

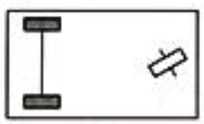
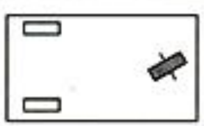
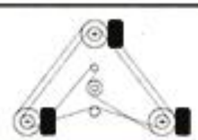
Measurement in real world environment is error prone

- Basic sensor response ratings
  - **Dynamic range:** Ratio between lower and upper limits, usually in decibels
  - **Range:** Difference between min and max
  - **Resolution:** Minimum difference between two values
  - **Linearity:** Variation of output signal as function of the input signal
  - **Bandwidth or frequency:** The speed with which a sensor can provide a stream of readings

Sensor Performance

- Mobile robots have to perceive, analyze and interpret the state of their surroundings
- Measurements in real world environments are dynamically changing and error prone
- Examples:
  - Changing illuminations
  - Specular reflections
  - Light or sound absorbing surfaces
  - Non adaptive to environment changes (climate (heat/damp), surface, texture, etc)

Wheel/Motor Encoders

# of wheels	arrangement	description	example
2		One steering wheel in the front, one traction wheel in the rear	Bicycle, motorcycle
		Two-wheel differential drive with the center of mass (COM) below the axle	Cye personal robot
3		Two-wheel centered differential drive with a third point of contact	Nomad Scout, smartRob EPFL
		Two independently driven wheels in the rear/front, 1 unpowered omnidirectional wheel in the front/rear	Many indoor robots, including the EPFL robots Pygmalion and Alice
		Two connected traction wheels (differential) in rear, 1 steered free wheel in front	Piaggio minitrucks
		Two free wheels in rear, 1 steered traction wheel in front	Neptune (Carnegie Mellon University), Hero-1
		Three motorized Swedish or spherical wheels arranged in a triangle; omnidirectional movement is possible	Stanford wheel Tribolo EPFL, Palm Pilot Robot Kit (CMU)
		Three synchronously motorized and steered wheels; the orientation is not controllable	"Synchro drive" Denning MRV-2, Georgia Institute of Technology, I-Robot B24, Nomad 200

Heading Sensors

- Heading sensors can be proprioceptive/internal (gyroscope, inclinometer) or exteroceptive/external (compass)
- Used to determine the robots orientation and inclination (slope/gradient descent)
- Allow, together with appropriate velocity information, to integrate movement to a position estimate
  - This procedure is called **dead reckoning** (ship navigation)

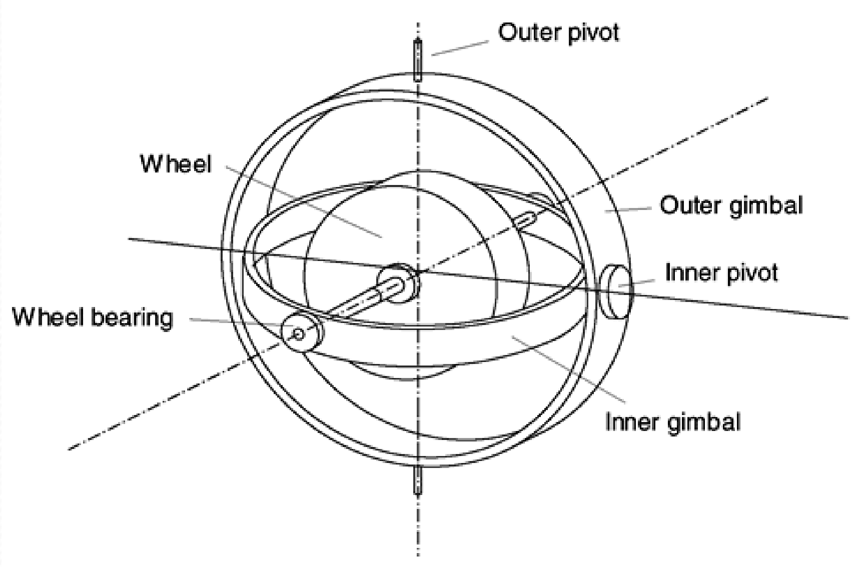
Gyroscope

- Heading sensors, that keep the orientation to a fixed frame
  - Absolute measure for the heading of a mobile system
- Gyroscopes are used in aeroplanes, Segways and the space shuttle and affect how yo-yos and bicycles work!
- Two categories of gyroscopes
  - Mechanical gyroscopes
  - Optical gyroscopes

  (not covered in this lecture)

Gyroscope

- Concept: inertial properties of a fast spinning rotor
  - Gyroscopic precession
- Angular momentum associated with a spinning wheel keeps the axis of the gyroscope inertial-ly stable
- Reactive torque t (tracking stability) is proportional to the spinning speed w, the precession speed W and the wheels inertia I



Compass

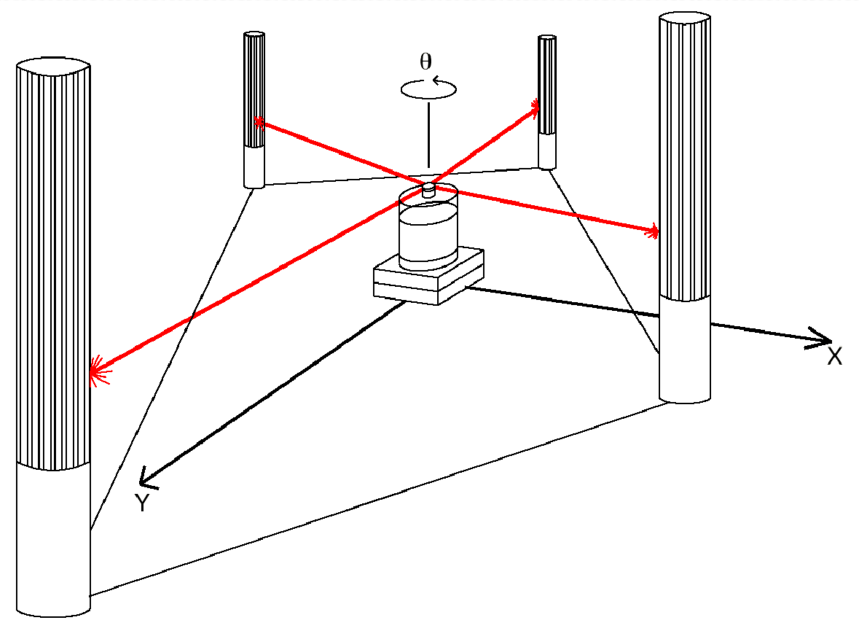
- The compass has been around since at least 2000 B.C.
  - The Chinese suspended a piece of natural magnetite from a silk thread and used it to guide a chariot over land
- Magnetic field on earth
  - Absolute measure for orientation

Compass

- There are a large variety of ways to measure the earth's magnetic field
  - Mechanical magnetic compass
  - Direct measure of the magnetic field (Hall-effect, magneto-resistive sensors)
- <u>Major drawback</u>
  - Weakness of the earth's magnetic field
  - Easily disturbed by magnetic objects or other sources
  - Not feasible for indoor environments

Beacons (ground based)

- Elegant way to solve the localization problem in mobile robotics
- Beacons are signaling guiding devices with a precisely known position
- Beacon base navigation has been used since humans started to travel
  - Natural beacons (landmarks) like stars, mountains or the sun
  - Artificial beacons like lighthouses



Beacons (ground based)

- The recently introduced Global Positioning System (GPS) has revolutionized modern navigation technology
  - Already one of the key sensors for outdoor mobile robotics
  - For indoor robots GPS is not applicable
- Major drawback with the use of beacons in indoor:
  - Beacons require changes in the environment -> costly
  - Limit flexibility and adaptability to changing environments

Range Sensors

- The traveled distance of a sound or electromagnetic wave is given by
- $$d = c \, . \, t$$
- Where
  - d = distance traveled (usually round-trip)
  - c = speed of wave propagation
  - t = time of flight.

Range Sensors

- It is important to point out:
  - Propagation speed of sound: ~0.3 m/ms
  - Propagation speed of of electromagnetic signals: ~0.3 m/ns
  - 3 meters
    - Takes 10ms for an ultrasonic system
    - Only 10ns for a laser range sensor
    - Measuring time of flight with electromagnetic signals is not an easy task
    - Laser range sensors are expensive and delicate

Range Sensors

- The quality of time of flight range sensors mainly depends on:
  - Uncertainties about the exact time of arrival of the reflected signal
  - Inaccuracies in the time of fight measure (laser range sensors)
  - Opening angle of transmitted beam (ultrasonic range sensors)
  - Interaction with the target (surface, specular reflections)
  - Variation of propagation speed
  - Speed of mobile robot and target (if not at rest)

Sensors Summary

- Robots use sensors to sense what is going on in the world around them
- Sensors can be broadly categorised as *proprioceptive* or *exteroceptive* and *active* or *passive*
- Sensor error can be a serious issue that we need to take care of
- There are many kinds of sensors that offer different levels of performance, error, price, etc