Definitions

A robot is …

A programmable, multifunction manipulator designed to move material, parts, tools, or specific devices through variable programmed motions for the performance of a variety of tasks.

A [non-living] physical agent that performs tasks by manipulating the physical world.

Categories of robots

Manipulators
- Physically anchored to workplace
- For example, industrial robotic arms

Mobile robots
- Move about their environment using wheels, legs, or similar mechanisms
- For example, autonomous vehicles

Hybrids
- Mobile robots with manipulators
- For example, humanoids

What are robots good for?

Manufacturing
- Repetitive tasks on a production line are natural tasks for automation.
- 1961 – Unimate developed by Joseph Engelberger and George Devol
  - Sold to GM and used to manufacture TV picture tubes.
  - Devol earlier obtained first US patent on a robot.
- 1972 – Nissan among the first to automate entire assembly line with robots.

Transportation
- Self-steering vehicles (see notes from last lecture).
- Autonomous helicopters and planes that deliver objects to locations that would be dangerous or hard to access by other means.
- Gofers – for example, Helpmate
  - Used in dozens of hospitals.
  - Transports food and other items.

Hazardous environments
- Applications include
  - Toxic waste cleanup
  - Deep sea recovery
  - Exploration

    - Mining
    - Manipulation of biologically hazardous materials
  - Examples include
    - Robots to clean up and explore after Chernobyl disaster
    - Robots for clearing minefields
    - Robotic fly

Exploration

  - Mars rover.
  - Dextre – 2-armed robot; part of the Mobile Servicing System on the International Space Station.

Health care

  - Nursebot – intended to help guide individuals in assisted living communities.
  - Assist with instrument placement when operating on organs as intricate/sensitive as brain, eye, heart. Recent application to prostate surgery.
  - Hip replacement.

Personal services

  - Vacuum cleaners
  - Swimming pool cleaners
  - Lawn mowers

Human augmentation

  - Devices that make it easier for people to walk or move their arms.
  - Some involve teleoperation – i.e., robot manipulator emulates motion of human operator (Dextre, for example)
  - Brain-Computer Interfaces (robotic wheelchair, for example)

Robot parts

- Effectors
- Sensors

Effectors

An effector is any device that affects the environment, under the control of the robot.

  - Will make use of an actuator
    - Converts software commands into physical motion
    - Motor or hydraulic cylinder, for example

Used in two main ways

  - Locomotion
  - Manipulation

Locomotion

Various types, including snake-like slithering, but most commonly….

Legged locomotion [Videos]

- Useful for motion in rough terrain with large obstacles.
- Include hopping robots
  - Dynamically stable
    - Will crash if forced to pause
    - Do well as long as they keep moving
  - Use rhythmic motion of four legs, two legs, or even a single leg to control locomotion

Wheel, tread robots

- Most practical for most environments
- Simpler to build, more efficient, and provide better static support
- But with issues of their own:

Example. Car

- Three **degrees of freedom** – two for its (x,y) position and one for direction it's pointing.
- Only two actuators (driving and steering) – for small motions, car has two degrees of freedom (can't move sideways).

Nonholonomic robot – has fewer controllable degrees of freedom than total degrees of freedom.

A general rule – the larger the gap between controllable and total degrees of freedom, the harder it is to control the robot.

Possible to build truly **holonomic** robots, but at the cost of mechanical complexity.

Manipulation

Rotary motion – rotation around a fixed hub.
Prismatic motion – linear movement, as with a piston inside a cylinder.

A free body in space has six degrees of freedom
So manipulator needs six degrees of freedom => six joints.

We count one degree of freedom for each independent direction in which a robot (or one of its effectors) can move.

[How many degrees of freedom in the human hand?]

End effector interacts directly with the world

- Screwdriver or other tool
- Welding gun

- Paint sprayer
- Gripper (manufacturing applications typically make use of two- or three-fingered grippers)
- Anthropomorphic hand

Sensors: Tools for Perception

One way to categorize sensors based on how they gather information:

- Passive sensors
  - True observers of the environment
  - e.g., cameras

- Active Sensors
  - Send energy into the environment
  - e.g., sonar

Passive vs Active Sensors

- Active sensors tend to provide more focused information, but at the cost of increased power consumption
- Danger of interference when multiple active sensors are used

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Another way to categorize sensors

Based on what they record:

- Sensors that record distances
- Sensors that record entire images
- Sensors that record information about the robot itself

Range Finders

Sonar

- Sound Navigation and Ranging
- Emits sound waves which are reflected by objects; reflected sound gets back to the sensor; time and intensity of signal carry information about distance
- Alternatives include radar and laser
- Provides useful information about objects fairly close to the robot
- Very effective for obstacle avoidance and tracking a nearby object
- Generally won't provide precise data for mapping
  - Not a narrow beam of sound – conical spread
  - Sound only received back from patches of surface that are at right angles to the beam

GPS

- Measures the distance to satellites that emit pulsed signals
- Can determine absolute location on earth to within a few meters
- Does not work indoors or under water

Close range sensors

Include whiskers, bump panels, and

Touch sensitive skin

- Consider the task of picking up a paper cup
- Robotic version of the human sense of touch
- Uses an elastic material and a sensing scheme that measures the distortion of the material under contact
- Sensor may give data at an array of points on the elastic surface
- Like an image of “deformation”
- Can also sense vibration

Image sensors

For example, cameras. While the general problem of computer vision is hard, techniques exist for making visual interpretation more practical

- If the robot’s set of tasks is limited, vision need only supply information relevant to those tasks
- Can modify the environment to make the robot’s task easier
- Can include bar-code stickers in various locations to get exact position fix (for example, in environment of a robotic wheelchair)

Proprioceptive sensors

- Give a robot a sense of itself – i.e., its own position, orientation, etc.
- Encoders fitted to the joints can provide very accurate data about joint angle or extension
  - If the output of an encoder is fed back to the control mechanism during motion, the robot can have much greater positioning accuracy than humans
  - Typically a few thousandths of an inch of accuracy in its end-effector position
  - Humans can manage only a centimeter or two

- Change in position can be measured using **odometry**
  - Based on sensors that measure wheel rotation, for example
  - Position error an issue – due to slippage of wheels

- Magnetic compass or gyroscope system often used to measure orientation reliably

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Why is it so hard to build robots?

The real world is:

- Inaccessible – sensors are imperfect and can only perceive stimuli that are near the agent.
- Nondeterministic – you never know if an action is going to work; wheels slip, batteries run down, etc.
- Nonepisodic – the effects of an action may change over time.
- Dynamic – robot needs to know when it's worth deliberating and when it's better to act immediately.
- Continuous – states and actions are drawn from a continuum of physical configurations and motions.

[DARPA Grand Challenge video]
