Introduction to Robotics

Robotics, Lecture 1

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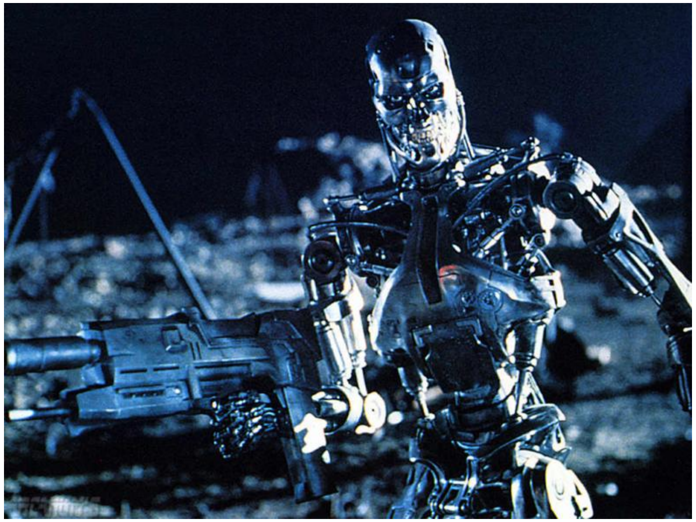
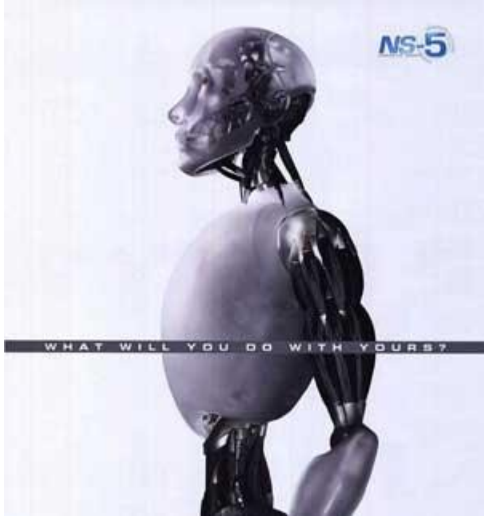
Agenda

- Scope
- Kinematics and Kinetics
- Sensors and Actuators
- Robot Vision
- Path Planning
- Control
- Discussion

Introduction

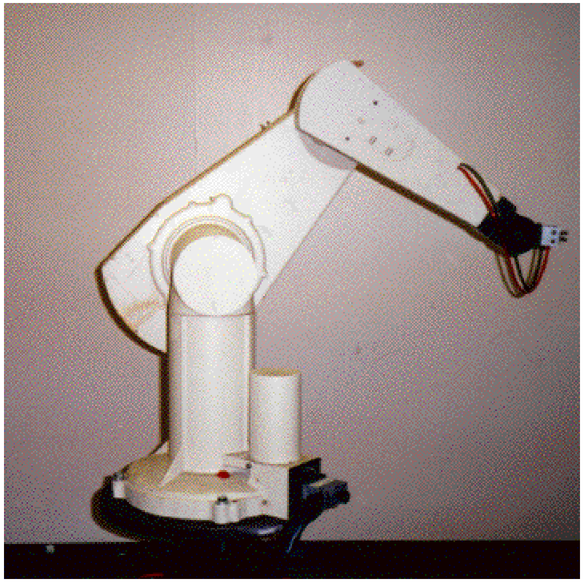
- Robots in movie

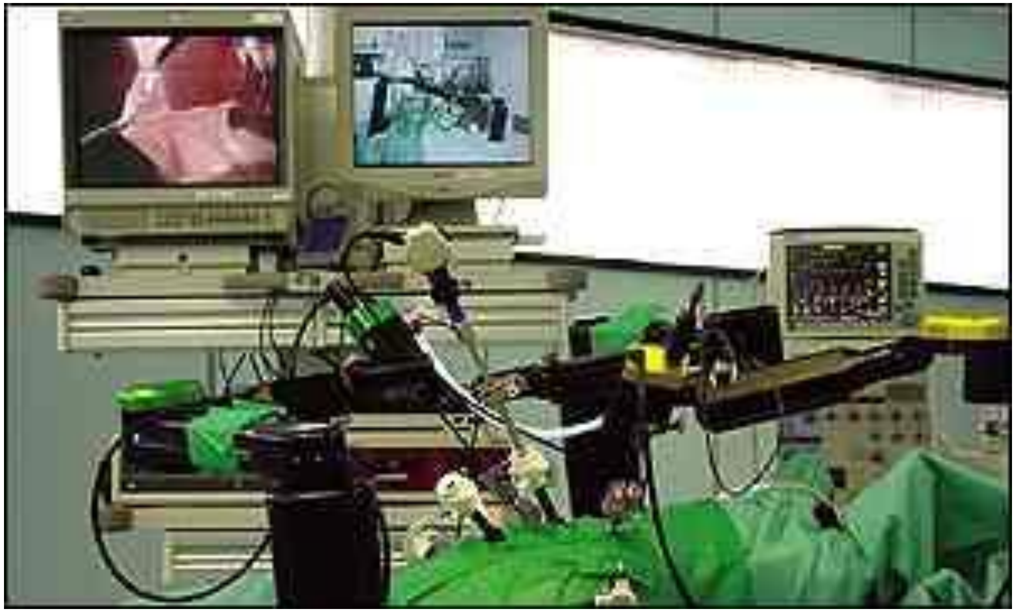




Modern Robots

- Robot in life
  - Industry
  - Medical

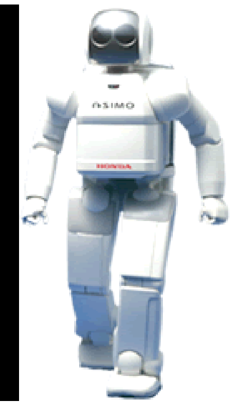




Robotics

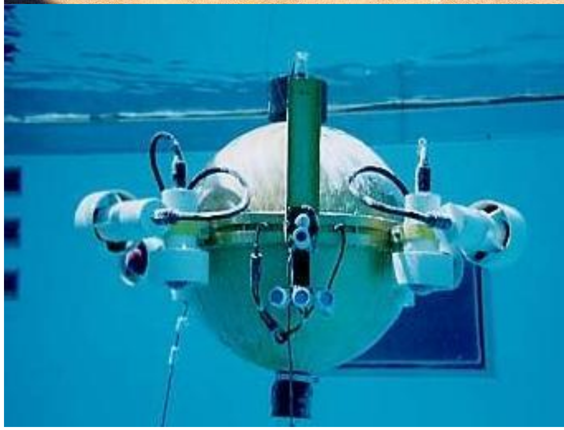
Modern Robots

- Robot in life
  - Home/Entertainment



Modern Robots

- Robots in life
  - Military/Unmanned Vehicle



Robotics

What is a Robot?

- The term **robot** was first introduced by Czech writer Karel Čapek in his play **Rossum's Universal Robots**, published in 1920. The word is coined from the Slavic word "robota" literally *meaning work* or labor.
- **DEFINITION: Robot**
  - "A **robot** is a reprogrammable multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks"
  - by Robot Institute of America

Agents

- An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators

- **Human agent**:
  - eyes, ears, and other organs for sensors;
  - hands, legs, mouth, and other body parts for actuators
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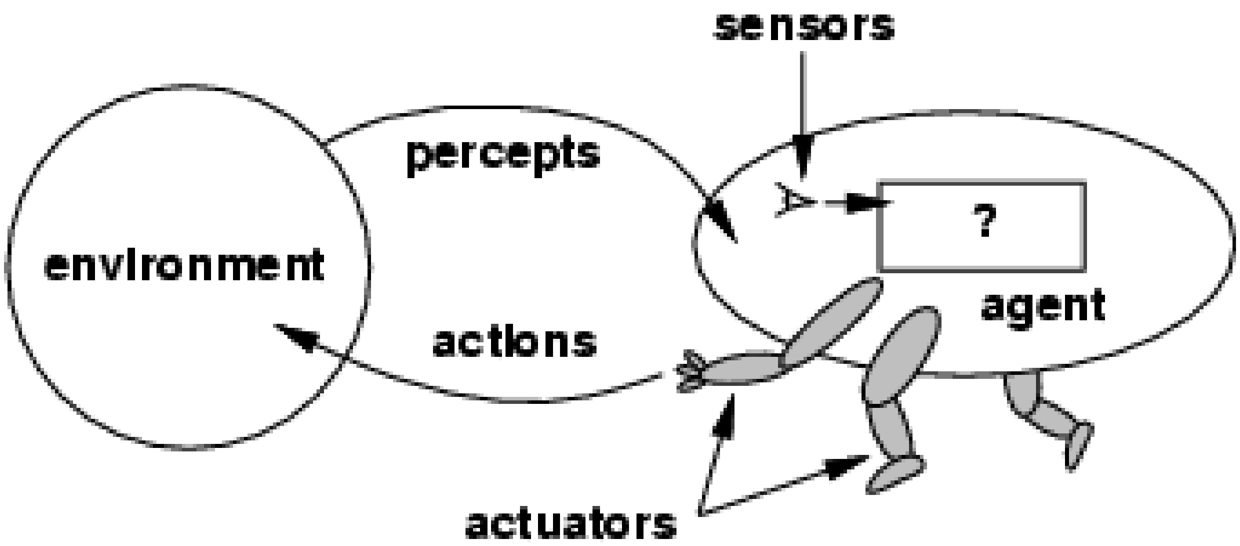
- **Robotic agent:**
  - cameras and infrared range finders for sensors;
  - various motors for actuators

Robotics

Agents and environments



- The agent program runs on the physical architecture to implement the agent function

- **agent = architecture + program**

Robotics

autonomy

- If the agent's actions are based completely on built-in knowledge, we say that the agent lacks **autonomy.**
- A system is **autonomous** to the extent that its behavior is determined its own **experience**.

Specifying the agent PEAS

- **PEAS**:
  - Performance measure,
  - Environment,
  - Actuators,
  - Sensors
- Must first specify the setting for intelligent agent design
-

Robotics

PEAS

- **Agent**: **automated taxi driver robot**
- **Performance measure**:
  - Safe, fast, legal, comfortable trip, maximize profits
- **Environment**:
  - Roads, other traffic, pedestrians, customers
- **Actuators**:
  - Steering wheel, accelerator, brake, signal, horn
- **Sensors**:
  - Cameras, sonar, speedometer, GPS, odometer, engine sensors, keyboard
  -

Robotics

PEAS

- **Agent: Part-picking robot**
- **Performance measure:**
  - Percentage of parts in correct bins
- **Environment:**
  - Conveyor belt with parts, bins
- **Actuators:**
  - Jointed arm and hand
- **Sensors:**
  - Camera, joint angle sensors

Robotics

Environment types (ODESA)

- Fully observable (vs. partially observable): An agent's sensors give it access to the complete state of the environment at each point in time.
- Deterministic (vs. stochastic): The next state of the environment is completely determined by the current state and the action executed by the agent. (If the environment is deterministic except for the actions of other agents, then the environment is strategic)
-
- Episodic (vs. sequential): The agent's experience is divided into atomic "episodes" (each episode consists of the agent perceiving and then performing a single action), and the choice of action in each episode depends only on the episode itself.

Environment types (ODESA)

- Static (vs. dynamic): The environment is unchanged while an agent is deliberating. (The environment is semidynamic if the environment itself does not change with the passage of time but the agent's performance score does)

- Single agent (vs. multiagent): An agent operating by itself in an environment.
  - In **competitive** multi-agent environment, trying to maximize the performance measure of the opponent entity B, will minimize the agent A's performance measure, else it is **cooperative** environment.

Robotics

Environment types

	Chess with a clock	Chess without a clock	Taxi driving
Fully observable	Yes	Yes	No
Deterministic	Strategic	Strategic	No
Episodic	No	No	No
Static	Semi	Yes	No
Single agent	No	No	No

- The environment type largely determines the agent design
-
- The real world is (of course) partially observable, stochastic, sequential, dynamic, continuous, multi-agent
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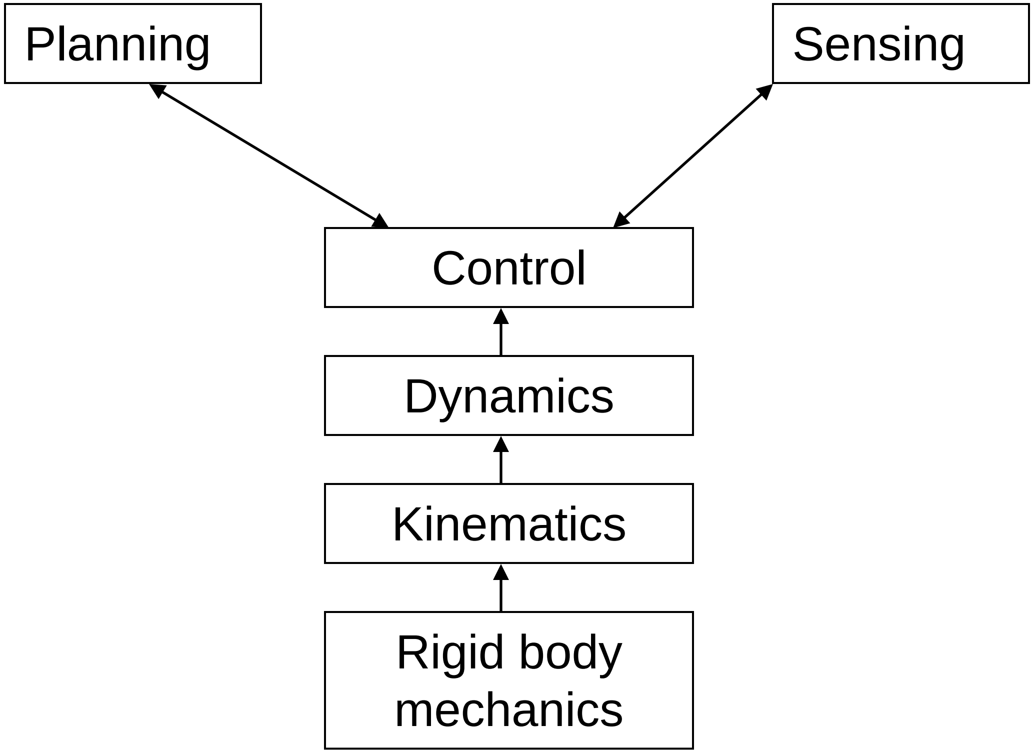
Robotics

Scope



Planning
Sensing
Control
Dynamics
Kinematics
Rigid body mechanics

Example Problem Statement

- To build a mobile robot with a manipulator arm.
- Add position sensing and environment sensing capabilities.
- Enable position control through a microcontroller and sensors.
- Plan a path and execute the same.

Question

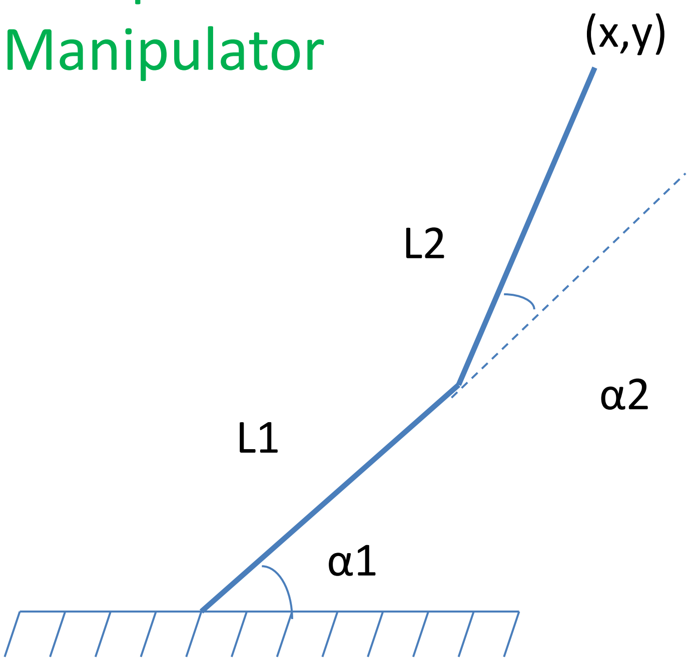
What is Kinematics and Kinetics ?

Robot Kinematics

- Robots will usually have manipulator links or will be mobile themselves, hence understanding motion of links/bot is primal.
- Manipulator joints can be either Rotary or Prismatic.
- Motion of all links is ‘seen’ from a base frame attached to the robot.

Forward and Inverse Kinematics

Simple 2R Manipulator



$X = L1\cos(\alpha1) + L2\cos(\alpha1+\alpha2)$
$Y = L1\sin(\alpha1) + L2\sin(\alpha1+\alpha2)$

Or

$X = f(\theta)$

Where 'X' is the position vector of the end effector and 'θ' is the joint vector.

Kinetics

- Study of forces on the robot body, divided into Statics and Dynamics.
- Consider the statics problem on the arm. By principal of virtual work, $F.\delta x = \tau.\delta\theta$, or $F = \tau J$, where 'J' is the Jacobian Matrix.
- Problem of Dynamics is not easy to solve. Most practical applications avoid direct solving of equations.

Sensors

- Used to determine both internal state of the robot and the external state (environment).
- Will have a sensing element (transducer) and an appropriate interface.
- Encoders, GPS, accelerometers, Gyroscopes, etc. are examples of internal state sensors.
- Cameras, Laser scanners, SONAR, etc. are examples of external state sensors.

Question

What principle does a Gyroscope work on?

Sensor Example – Ultrasonic Sensor

- Gives PWM or Serial output.
- Range 4m approx.
- Noisy and prone to interference.
- Cheap and TTL compatible.

Alternative

- Accurate, fast but expensive.
- Needs complete Operating system.

Actuators

- Used to create motion of a particular link or entire robot. Like sensors we always prefer linear actuators.
- Motors – DC, AC, Servos, Steppers, etc.
- Prismatic actuators – Lead Screws, Hydraulic and Pneumatic pistons, etc.
- Always be careful of inductive loads of actuators!

Robot Vision

- 2D or 3D vision can be added to the robot by using a Color (RGB) camera or a Depth (XYZRGB) camera respectively.
- Various techniques for feature extraction, Color clustering, registration, etc. can be used.
- Requires higher processing systems usually with proper Operating System.

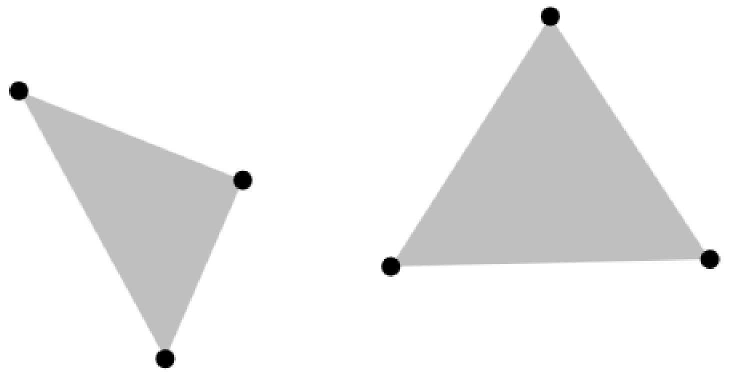
Question

Is human vision 2D or 3D?

Path Planning

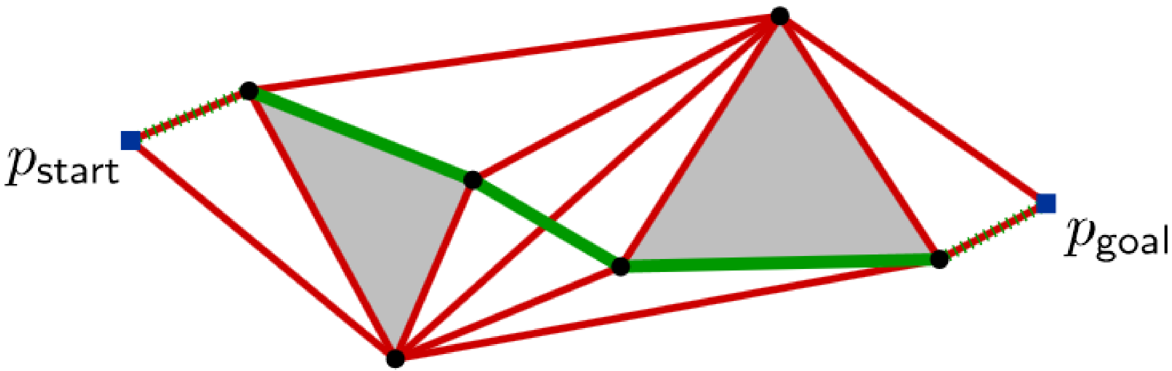
- Often you would want to move your robot or manipulator in its workspace from one configuration to other.
- The workspace may be filled with static or dynamic obstacles.
- The problem of deciding the sequence in which the joint variables must move to traverse a path is called path planning.

Visibility Graphs



Method valid for 2D configuration space only.

Gives shortest path.



Robot Control

- Once a trajectory of the joint variables is decided, a control law must be made which executes the joint actuators so that they move accordingly.
- Control can be Open Loop or Closed Loop.
- Most practical systems use closed loop control strategies because there are always modeling and computation errors preventing open loop.

Question

What is the most common closed loop strategy used in Control Systems?

Thank You

Please give us your feedback