CHAPTER 1. INTRODUCTION

Background

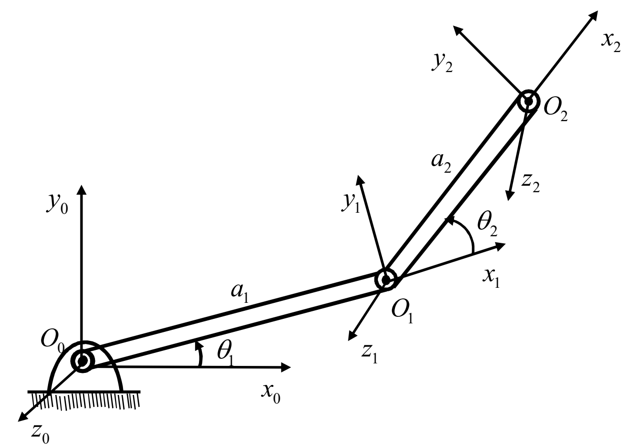
- Definition from Robot Institute of America (RIA)
  "A *Robot* is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks."

  - Advantage: reduces human labor, increases accuracy, productivity, and flexibility

- The term "robota (= labor)" is originated from Czech play "Rossum's Universal Robots."

- History of robots
  1954: one degree-of-freedom robot patented in U.S. by G.C. Devol.
  1961: first practical industrial robot developed by Unimation.
  1968: first Japanese industrial robot from Kawasaki.
  1970s: specialized industrial robots.
  1980s and 1990s: ↓
  21C and future: various applications – service, medical, military, etc.

- Robotics as a multidisciplinary field
  Statics
  Kinematics and dynamics
  Machine/mechanism design
  Control
  Sensing
  Vision
  Artificial intelligence
  Mechatronics
  Computer algorithm and programming



Terminologies and Overview

- Position and orientation
  - Step 1: Attach a coordinate system ("local frame") rigidly to each single rigid body.
  - Step 2: Describe the position and orientation of each local frame with respect to a reference coordinate system ("global frame" or "base frame").

- Mechanical manipulator (or manipulator): rigid links connected with joints → allows relative motion of neighboring links
  → Joint displacement or joint variable – relative (position sensor)
  Revolute joint (model) – joint angle
  Prismatic joint (model) – translation or joint offset
  (vs. physical joint)

- Degrees of freedom (DOFs): number of independent coordinates required to describe the configuration of a system
  - Particle unconstrained in 3D → 3 DOF (3 translations)
  - Rigid body unconstrained in 3D → 6 DOF (3 translations + 3 rotations)

- End-effector: free end of the chain of links which make up the manipulator

- Forward kinematics: given a set of joint variables, compute the position and orientation of the end-effector's local frame (i.e., tool frame) relative to the global frame
  → Description mapping: joint space → Cartesian space (= operational space, task space)

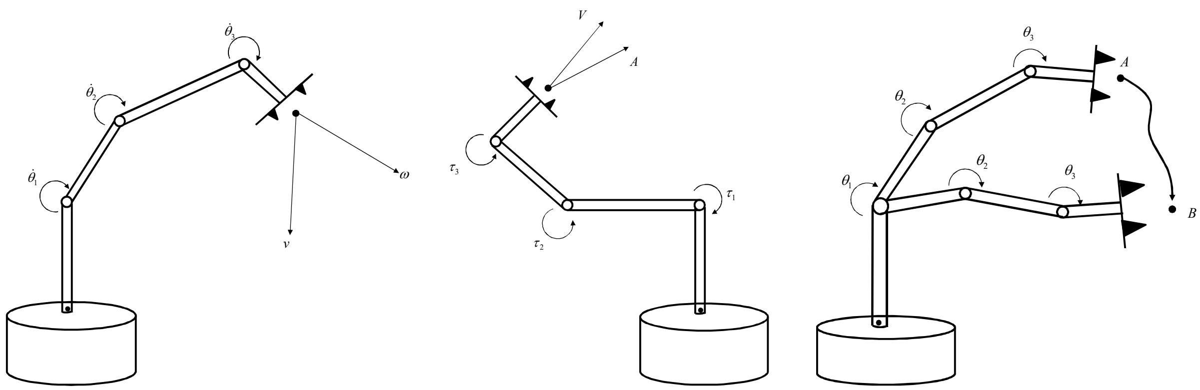
- Inverse kinematics: given the position and orientation of the end-effector, calculate the joint variables

- Workspace → existence/nonexistence of a kinematic solution

- Jacobian matrix → mapping from joint space velocities to Cartesian space velocities
  - Singularity point → mapping is not invertible

- Joint actuator; actuator torques → manipulator statics (equilibrium) and dynamics (equations of motion)

- Trajectory generation
  - Trajectory: spatial and temporal (function of time)
  - Path: spatial, but not temporal



- Position control system: automatically compensate for errors in knowledge of the parameters of a system, and suppress disturbances which tend to perturb the system from the desired trajectory
  - Position/velocity sensors → control algorithm → actuator torque computation

- Nonlinear position control: nonlinear dynamics of the manipulator

- Force control: addresses the interaction (e.g., contact force) with the environment (e.g., parts, tools, surfaces, etc.)
  - Complementary to position control → hybrid position/force control

<u>Steps of Solving Mechanics Problems</u>

Step 1: Identify and isolate system of interest.
Step 2: Draw free-body diagram (FBD) of the system of interest, its interactions (i.e., external forces and moments) with the environment, and coordinate frame(s).
Step 3: Formulate governing equations.

- Note: In general, a FBD should include all forces/moments exerted "on" the <u>system of interest</u> "by" the <u>environment</u>.