Industrial Robotics

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Quiz (10 pts)

• (6 pts) List at least two applications for industrial robots

• (4 pts) Why is industrial robotics important?
Statistics of Worldwide Industrial Robot Use

- Estimated worldwide annual shipments of industrial robots in main application areas (2014)
Latest Technology Industrial Robots
Industrial robots

• The largest commercial application of robotics technology

• Year of 2014
  • Estimated installation = 1.5 million units
  • 171,000 new installations
  • Estimated annual turnover of the robotics industry = $32 billion
Industrial robots

• Foundations for robot motion planning and control

• The origin of robotics science

• Many unsolved problems
Robot Geometry
Geometric Characteristics of Robots

- Degrees of freedom
  - Mechanisms, joints, kinematic pairs

- Robot configuration
  - Combination of mechanisms, joints, kinematic pairs

- Robot motion limits
  - Payload, reach, precision/accuracy, repeatability, workspace
Degrees of freedom
Degrees of Freedom (DOF)

- The minimum number of required independent coordinates to completely specify robot motions
  - # of required actuators?
  - # of joints?
Degrees of Freedom (DOF)

Rigid body planar motion:
2 Translational + 1 Rotational = 3-DOF

Rigid body spatial motion:
3 Translational + 3 Rotational = 6-DOF

Constrained motion - bead on a wire:
1 Translational + 1 Rotational = 2-DOF
Degrees of Freedom (DOF)

Four Bar Linkage Mechanism
Closed-Loop Kinematic Chain

Industrial Robot
Open-Loop Kinematic Chain
More than 6-DOF

- Kinematics redundancy
  - No unique solution \((\text{No. of solutions} = \infty)\)
- Need another parameter to determine configuration
  - Typically choose one DOF – then solve for the other six
- Less often used in industry
  - Too computationally intensive
More than 6-DOF

JPL 7-DOF Robotic Manipulator
(http://www-robotics.jpl.nasa.gov/tasks/showBrowseImage.cfm?TaskID=137&tdaiD=800004)

Motoman 7-DOF VS50
Spot Welding Robot
Kinematic Pairs
Kinematic pairs

- **Revolute**: 1 Degree of Freedom
- **Prismatic**: 1 Degree of Freedom
- **Screw**: 1 Degree of Freedom
- **Cylindrical**: 2 Degrees of Freedom
- **Spherical**: 3 Degrees of Freedom
- **Planar**: 3 Degrees of Freedom
Serial and parallel robots

Antennae Research
Parallel Kinematics

• Parallel Kinematic Machines (PKMs)
  • Closed kinematic loops
  • Stewart Platform / hexapods

• Pros:
  • Greater rigidity – parallel links
  • Higher speed – less mass to move
  • Higher accuracy – averaged error

• Cons:
  • Limited work envelope
  • Requires a large space for large motion
  • Inability to avoid objects
Stewart Platform
Serial Kinematics

- Serial Linkage Manipulators
  - Open kinematic loops

- First three joints
  - Combination of prismatic and revolute joints
  - Determines position of the end effector

- Last three joints
  - Generally comprised of a spherical system – RRR
  - Determines orientation of the tool
Robot motion limits
Robot motion limits

- Payload
- Reach
- Accuracy/repeatability
- Workspace
Robot motion limits

• Payload
  • The weight a robot can carry and still remain within its other specifications
  
  • A robot’s maximum load capacity may be much larger than its specified payload, but at the maximum level, it may become less accurate, may not follow its intended path accurately, or may have excessive deflections.
Reach

The maximum distance a robot can achieve within its work envelope.

For a robot, many points within the work envelope of the robot may be reached with any desired orientation, while for other points, close to the limit of a robot’s reach capability, orientation cannot be specified as desired.

Reach is a function of the robot’s joint lengths and its configuration.
Robot motion limits

• Accuracy
  • How accurately a specified point can be reached.

• Repeatability
  • How accurately the same position can be reached if the motion is repeated many times

• Accuracy/ repeatability depend on
  • Resolution of the actuators
  • Robot feedback devices
Robot motion limits

Repeatability and Accuracy over 10 measurements

- Bad repeatability and bad accuracy
- Bad repeatability and good accuracy
- Good repeatability and bad accuracy
- Good repeatability and good accuracy
Robot motion limits

- Workspace
  - Collection of points that a robot can reach
Five Basic Serial Robot Configurations

- Cartesian/rectangular/gantry (PPP)
- Cylindrical (RPP)
- Spherical (RRP)
- SCARA (RRP)
- Articulated (RRR)
Cartesian/rectangular/gantry (PPP)
Work Envelope of Cartesian Robot
Cylindrical (RPP)
Work Envelope of Cylindrical Robot
Spherical - RRP
Work Envelope of a Spherical Robot

- Axis 1
- Axis 2
- Axis 3

(a) Plan
(b) Elevation
SCARA (RRP)  
(Selective Compliance Assembly Robot Arm)
Compliant robot

Gravity compensation and external force following
Work Envelope of a SCARA Robot
Articulated (RRR)
Work Envelop of an articulated robot
Robot classification by work envelope

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Work envelope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cartesian</td>
<td>Rectangular</td>
</tr>
<tr>
<td>Cylindrical</td>
<td>Cylindrical</td>
</tr>
<tr>
<td>Polar</td>
<td>Spherical</td>
</tr>
<tr>
<td>Jointed-arm horizontal-axes</td>
<td></td>
</tr>
<tr>
<td>Jointed-arm vertical-axes</td>
<td></td>
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<tr>
<td>Pendulum arm</td>
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<tr>
<td>Multiple-joint arm</td>
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Consideration for choosing robot

- **Design:**
  - Desire large work envelope
  - Good performance:
    - Payload, speed, precision/accuracy, workspace, reach, repeatability

- **Usage:**
  - Need to know the design layout / configuration
  - Interface with other machines / robots

- **Purchasing:**
  - Need to consider complete cost
  - Necessary space
  - Tooling / end effectors
  - Maintenance

Next
Analysis of robot kinematics
Robot kinematics

- Kinematics analysis
  - Study robot motion (position, velocity, acceleration) without considering the force/torque that cause the motions
- Forward/inverse kinematics
Robot dynamics

• Study robot motion caused by force/torque

Applied torques

Joint motions

Forward Dynamics

Inverse Dynamics
Assignment

• Refresh your linear algebra
  • Vector and matrix operations

• Practice with Matlab

http://www.cyclismo.org/tutorial/matlab/matrix.html
End