

# CS26N: Motion Planning for Robots, Digital Actors, and Other Moving Objects

<http://ai.stanford.edu/~latombe/cs26n/2012/home.htm>

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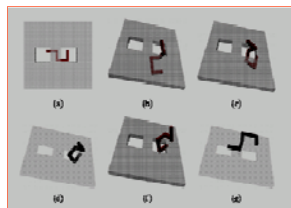
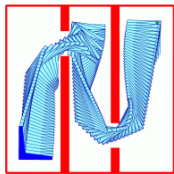
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Motion planning is the ability for an agent to compute its own motions in order to achieve certain goals. All **autonomous** robots and digital actors should eventually have this ability



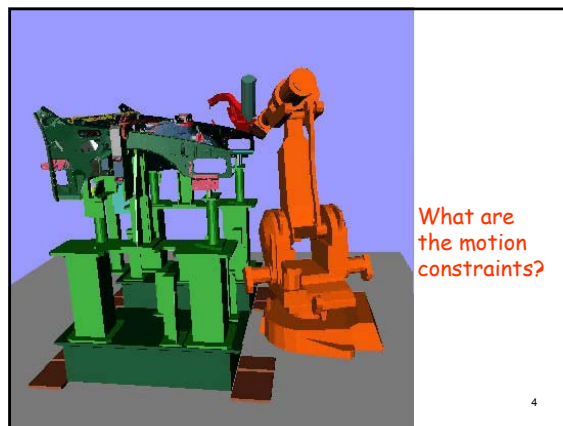
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## Piano Mover's Problem



What is a path? a trajectory?  
What are the constraints?

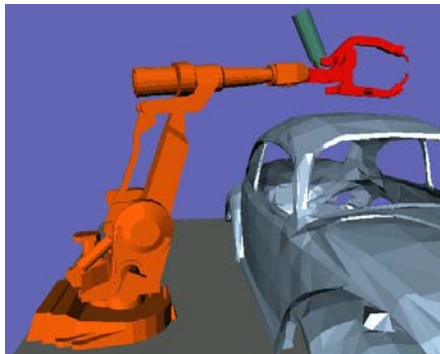
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What are the motion constraints?

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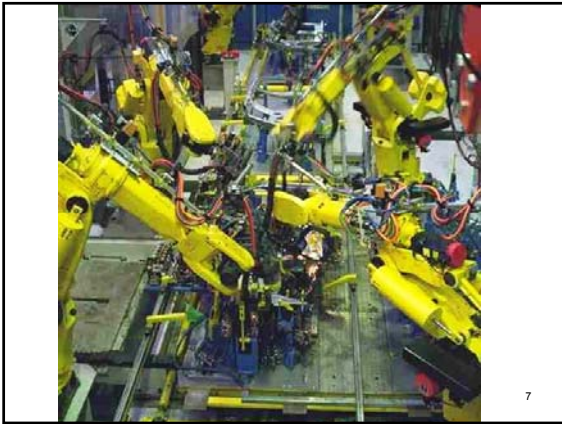
Why is this example difficult?



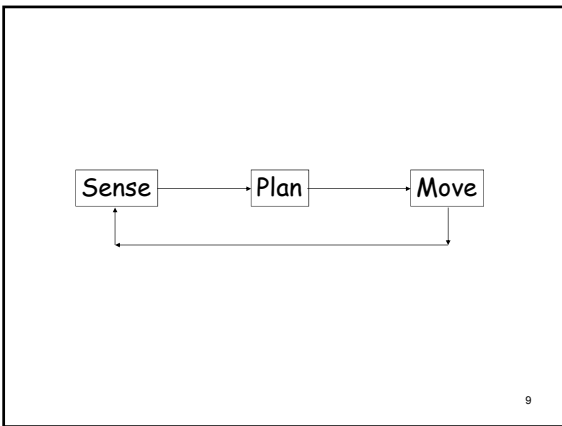
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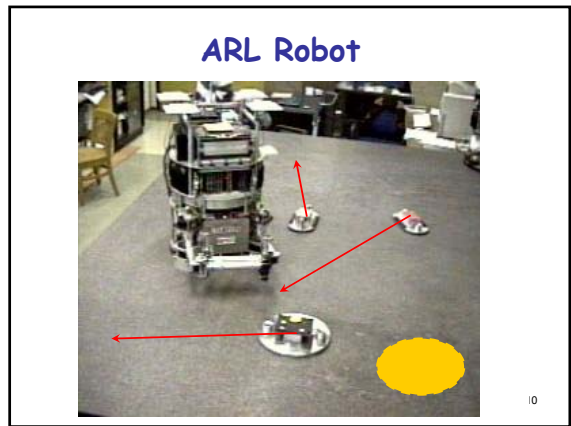
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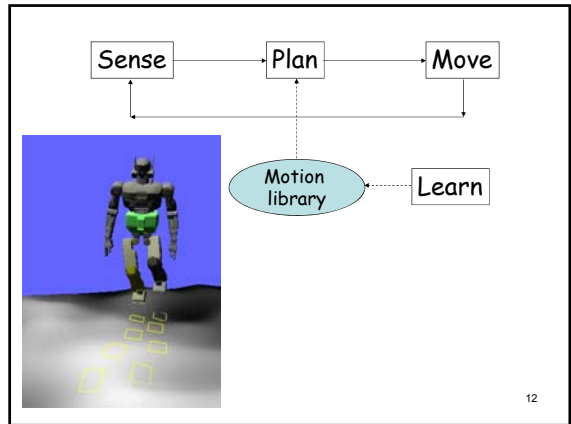
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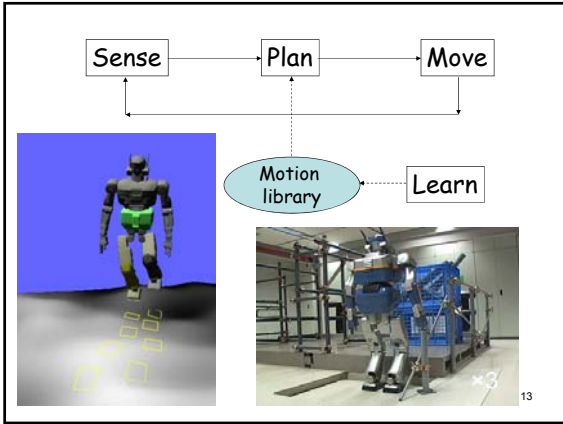
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### Goal of Motion Planning

- Compute **motion strategies**, e.g.:
  - geometric paths
  - time-parameterized trajectories
  - sequence of sensor-based motion commands
- To achieve **high-level goals**, e.g.:
  - go to A without colliding with obstacles
  - assemble product P
  - build map of environment E
  - find object O

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### Fundamental Question

Are two given points connected by a path?

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Are two given points connected by a path?

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### Is It Easy?

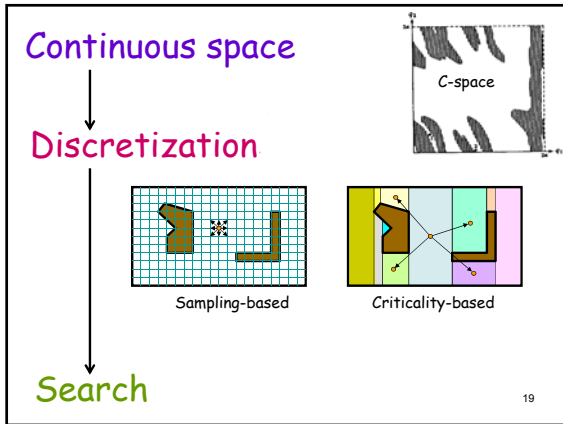
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### Tool: Configuration Space

Problems:

- Geometric complexity
- Space dimensionality

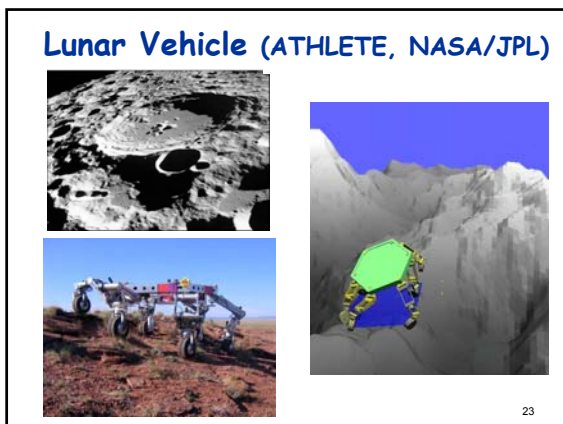
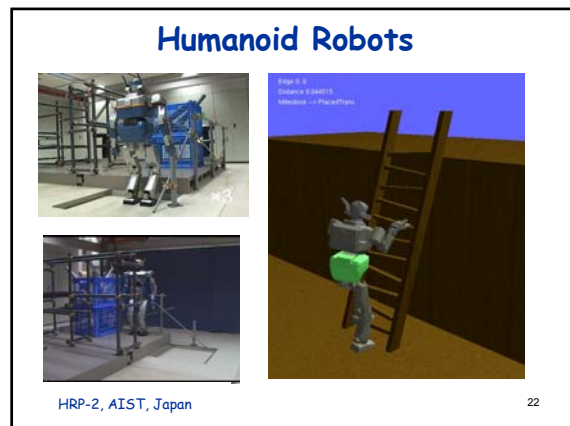
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- ### Many Variants
- Moving obstacles
  - Multiple robots
  - Movable objects
  - Assembly planning
  - Goal is to acquire information by sensing
    - Model building
    - Object finding/tracking
    - Inspection
  - Nonholonomic constraints
  - Dynamic constraints
  - Stability constraints
  - Optimal planning
  - Uncertainty in model, control and sensing
  - Exploiting task mechanics (sensorless motions, under-actuated systems)
  - Physical models and deformable objects
  - Integration of planning and control
  - Integration with higher-level planning
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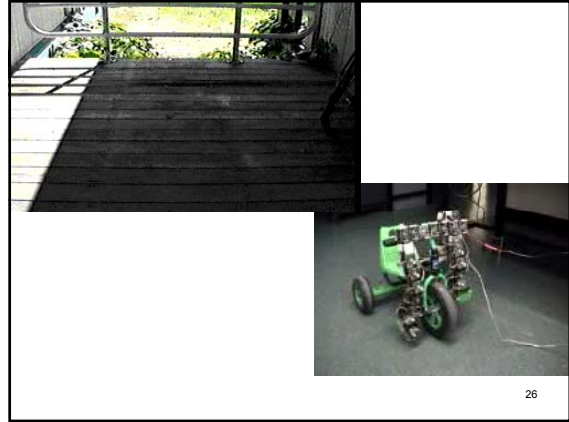
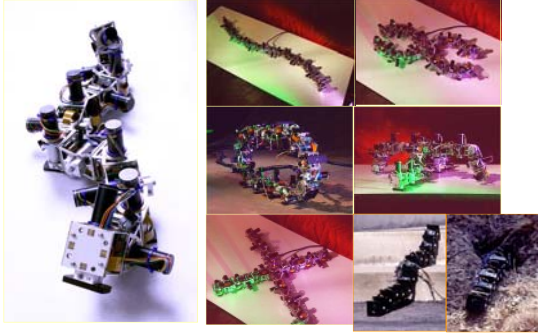
### Some Applications

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## Modular Reconfigurable Robots



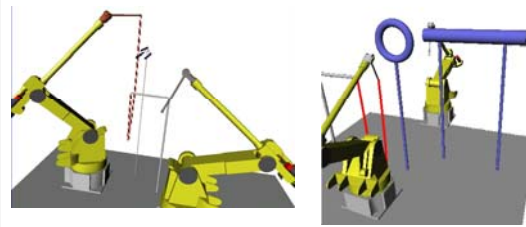
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## Dexterous Manipulation



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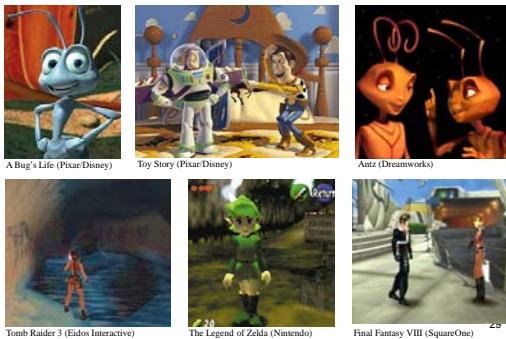
## Manipulation of Deformable Objects



Topologically defined goals

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## Digital Characters



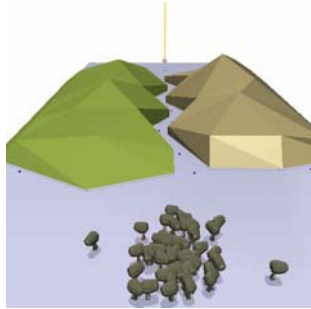
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## Digital Characters



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### Animation of Crowds

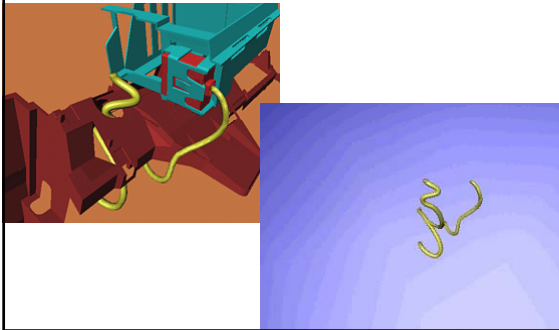


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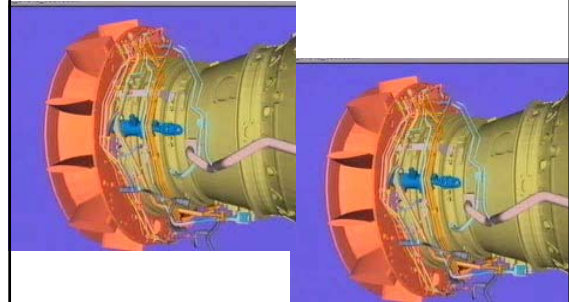


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### Design for Manufacturing and Servicing

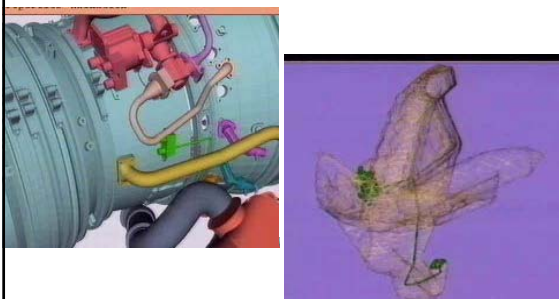


### Design for Manufacturing and Servicing



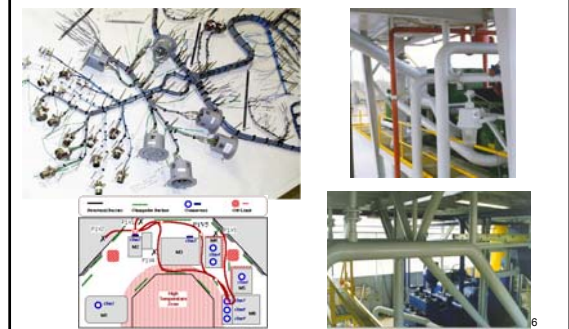
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### Design for Manufacturing and Servicing



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### Cable Harness/ Pipe design



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## Map Building

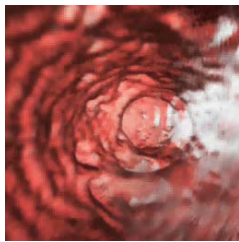
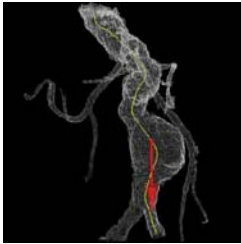
Where to move next?



## Navigation Through Virtual Environments

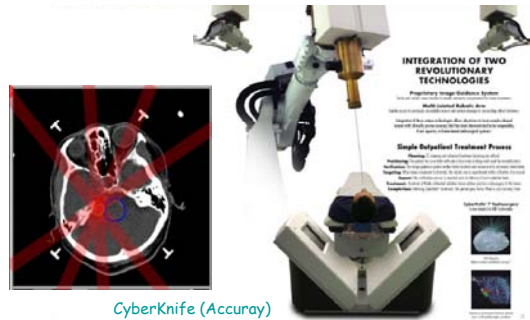


## Virtual Angiography / Bronchoscopy / Colonoscopy



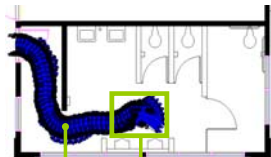
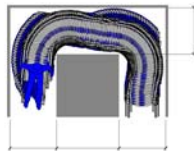
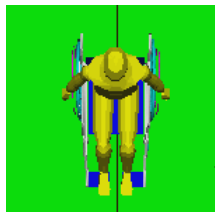
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## Radiosurgical Planning



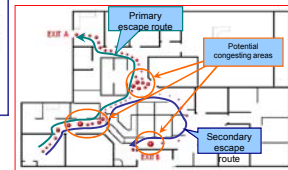
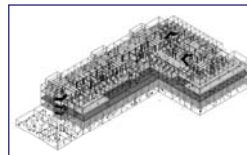
CyberKnife (Accuray)

## Building Code Verification



24-inch turning radius 18-inch turning radius

## Egress Simulation



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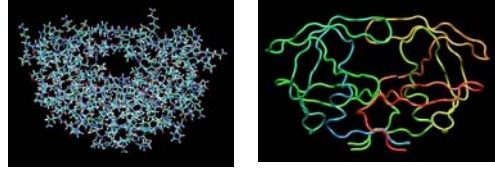
## Transportation of A380 Fuselage through Small Villages



Kineo

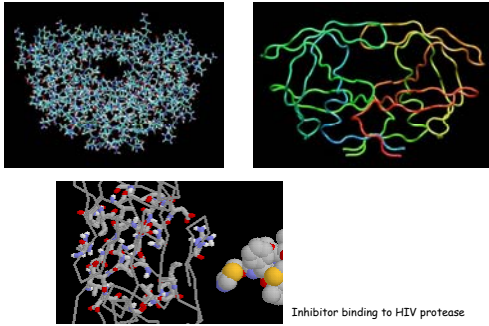
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## Study of Motion of Bio-Molecules



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## Study of Motion of Bio-Molecules



Inhibitor binding to HIV protease

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