Planning and Manufacturing Robots

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Video of the PR2 executing a plan to push a plate to the edge of the table and pick it up.
PROBLEM CHARACTERISTICS

Goal

Transit

Push

Rigid-Transfer

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PROBLEM CHARACTERISTICS

Diverse Actions

Transfer
Place
Pick
Goal
Transit
Push
Rigid-Transfer

VAN DEN BERG08, OKADA04, STILMAN04,07,08: Multiple objects
PROBLEM CHARACTERISTICS

Multiple actions per object

SIMÉON04: Transit/rigid-transfer roadmap for re-grasping
STILMAN07, BERENSON10,11: Holonomic end-effector constraints
HAUSER08,11: Multi-modal planning
**Problem Characteristics**

- Non-prehensile actions (Object and robot not rigidly attached)
- Multiple actions per object
- Diverse Actions
  - Transfer
  - Place
  - Pick
  - Goal Transit
  - Push
  - Rigid-Transfer

**Brost88, Dogar10, Huang98, Mason01:** Control

**Cosgun11, Dogar11:** One non-prehensile action per object
Diverse Action Rapidly Exploring Random Tree (DARRT)

16 DOF:

7 DOF

6 DOF

3 DOF

Configuration Space: Joint space of robot and objects
**Diverse Action Rapidly Exploring Random Tree (DARRT)**

- **Configuration Space:** Joint space of robot and objects
- Extension of Rapidly exploring Random Tree (RRT) algorithm
- Modifies **Sampling** and **Extension** routines
**DIVERSE ACTION RAPIDLY EXPLORING RANDOM TREE (DARRT)**

- **Configuration Space:** Joint space of robot and objects
- Extension of Rapidly exploring Random Tree (RRT) algorithm
- Modifies **SAMPLING** and **EXTENSION** routines
**Diverse Action Rapidly Exploring Random Tree (DARRT)**

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DIVERSE ACTION RAPIDLY EXPLORING RANDOM TREE (DARRT)

- Extension of RRT
- Experimentally validated
- Exponentially convergent
**DARRTH: Hierarchical Approach**

1. Automatically identify sub-goals in regions in which manipulation actions can change.
DARRTH: Hierarchical approach

1. Automatically identify sub-goals in regions in which manipulation actions can change
2. Use DARRT to plan for each sub-goal

Diagram 1: Example of sub-goals: Push, Rigid-Transfer, Goal

Diagram 2: Example of sub-goals: Push, Transit, Rigid-Transfer, Goal
DARRTH: HIERARCHICAL APPROACH

1. Automatically identify sub-goals in regions in which manipulation actions can change
2. Use DARRT to plan for each sub-goal
✓ Significantly faster than DARRT
Video of Baxter loading buckets onto a conveyor at Elgen Robotics
Video of an overly-complicated RRT plan.
Video of the PR2 arm hitting the camera.
Video of Baxter moving its right hand through the shelf.
PLANNING FOR MANUFACTURING

UNDERSTANDING ENVIRONMENT

- Humans demonstrate and modify paths
- Learn free space through human interaction
Understanding Environment
- Humans demonstrate and modify paths
- Learn free space through human interaction

Planned Paths
- Smooth, fast, natural-looking execution
- Cost functions for manufacturing