

PLANNING AND MANUFACTURING ROBOTS

Jennifer Barry

Rethink Robotics

NSF Workshop on Robot Planning in the Real World

October 28, 2013





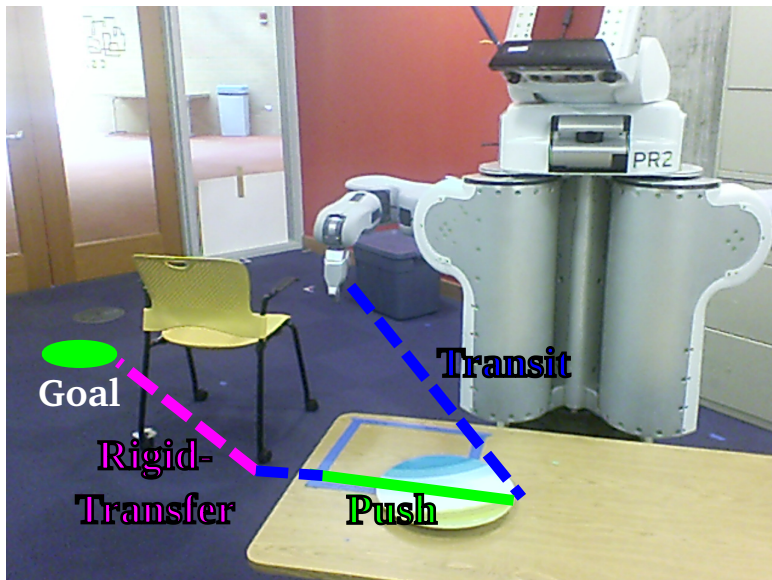
Plate

Barrier

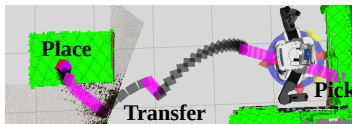


Video of the PR2 executing a plan to push a plate to the edge of the table and pick it up.

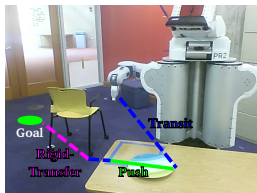
PROBLEM CHARACTERISTICS



PROBLEM CHARACTERISTICS



Diverse Actions

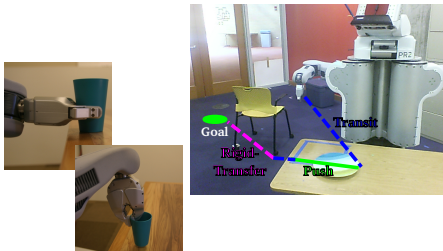


VAN DEN BERG08, OKADA04, STILMAN04,07,08: Multiple objects

PROBLEM CHARACTERISTICS



Diverse Actions



Multiple actions per object

SIMÉON04: Transit/rigid-transfer roadmap for re-grasping

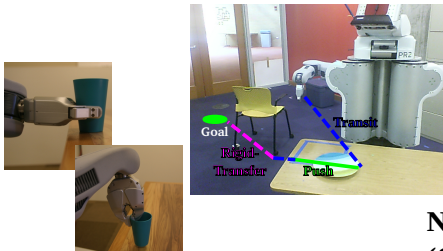
STILMAN07,BERENSON10,11: Holonomic end-effector constraints

HAUSER08,11: Multi-modal planning

PROBLEM CHARACTERISTICS



Diverse Actions



Multiple actions per object

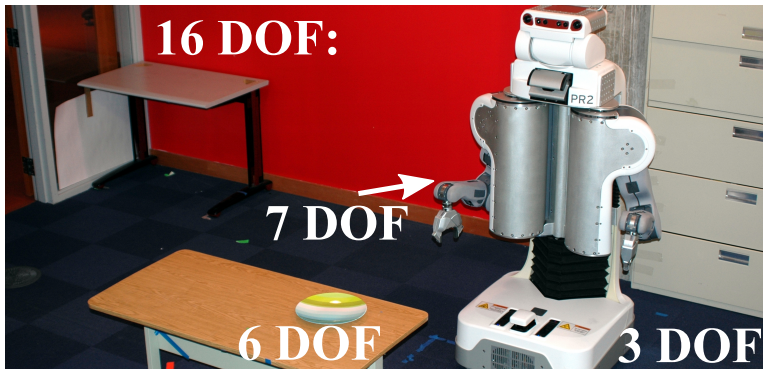


**Non-prehensile actions
(Object and robot not rigidly attached)**

BROST88, DOGAR10, HUANG98, MASON01: Control

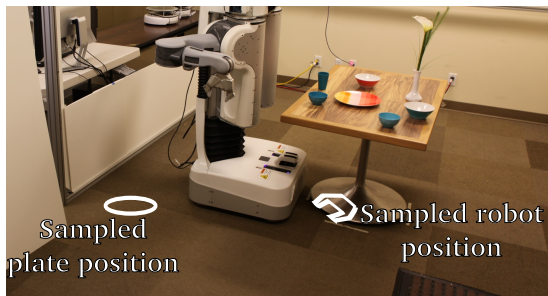
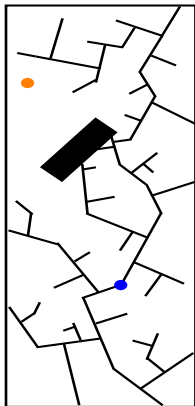
COSGUN11, DOGAR11: One non-prehensile action per object

DIVERSE ACTION RAPIDLY EXPLORING RANDOM TREE (DARRT)



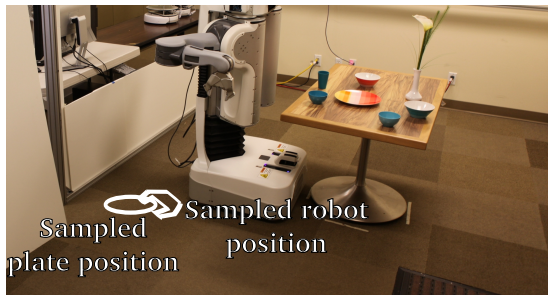
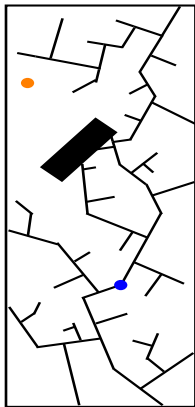
- **CONFIGURATION SPACE:** Joint space of robot and objects

DIVERSE ACTION RAPIDLY EXPLORING RANDOM TREE (DARRT)



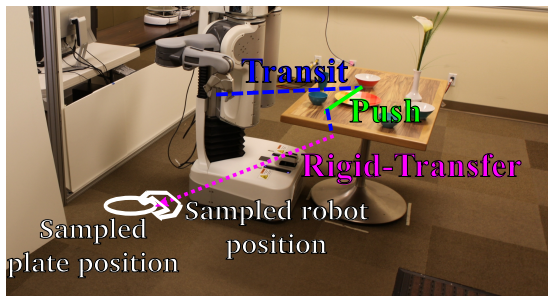
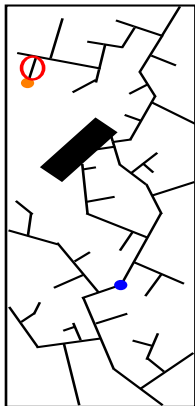
- **CONFIGURATION SPACE:** Joint space of robot and objects
- Extension of Rapidly exploring Random Tree (RRT) algorithm
- Modifies **SAMPLING** and **EXTENSION** routines

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

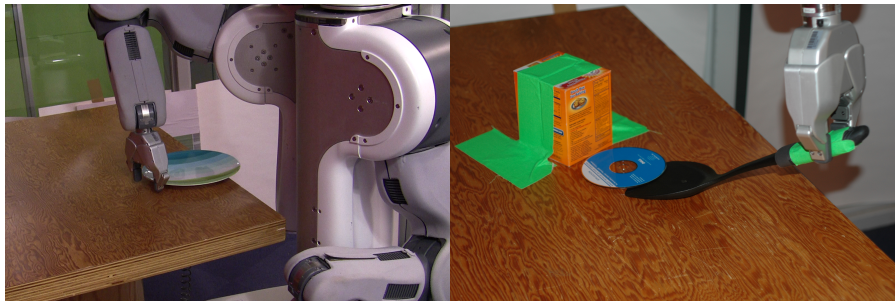
DIVERSE ACTION RAPIDLY EXPLORING RANDOM TREE (DARRT)



- **CONFIGURATION SPACE:** Joint space of robot and objects
- Extension of Rapidly exploring Random Tree (RRT) algorithm
- Modifies **SAMPLING** and **EXTENSION** routines

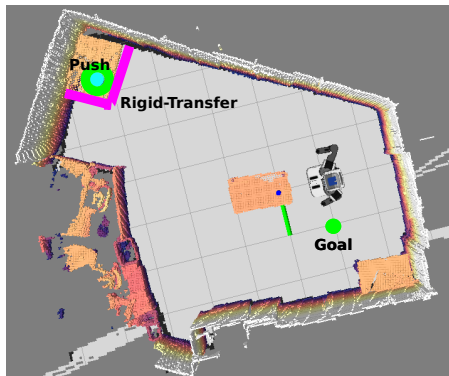
DIVERSE ACTION RAPIDLY EXPLORING RANDOM TREE (DARRT)

- Extension of RRT
- ✓ Experimentally validated
- ✓ Exponentially convergent



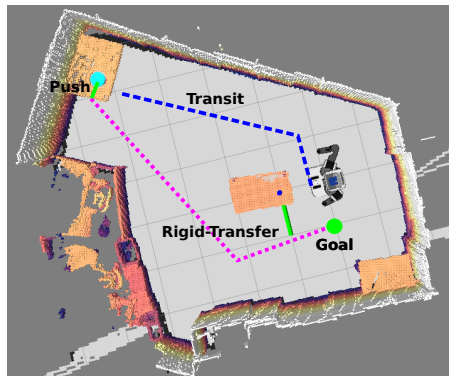
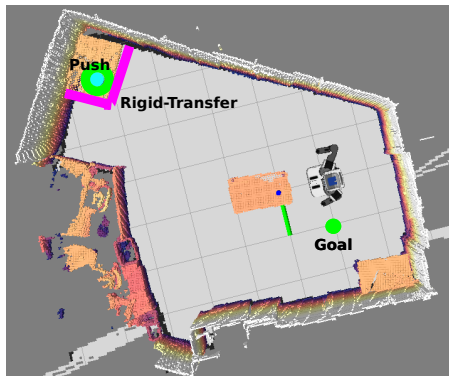
DARRTH: HIERARCHICAL APPROACH

- 1 Automatically identify sub-goals in regions in which manipulation actions can change



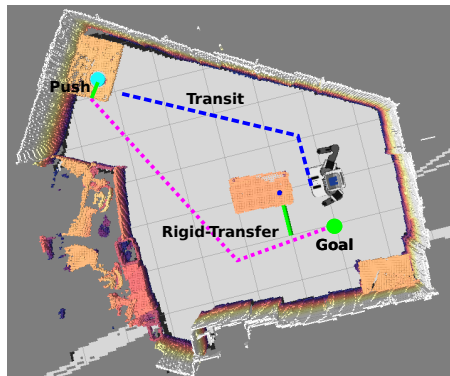
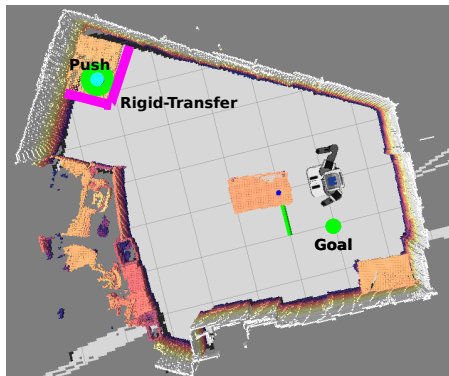
DARRTH: HIERARCHICAL APPROACH

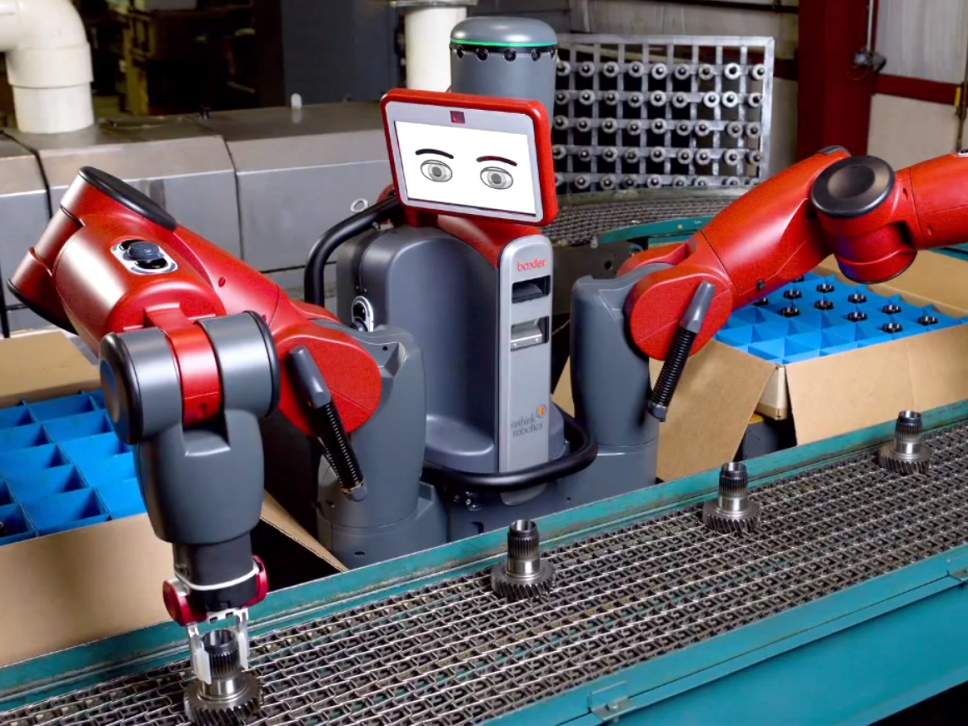
- 1 Automatically identify sub-goals in regions in which manipulation actions can change
- 2 Use DARRT to plan for each sub-goal



DARRTH: HIERARCHICAL APPROACH

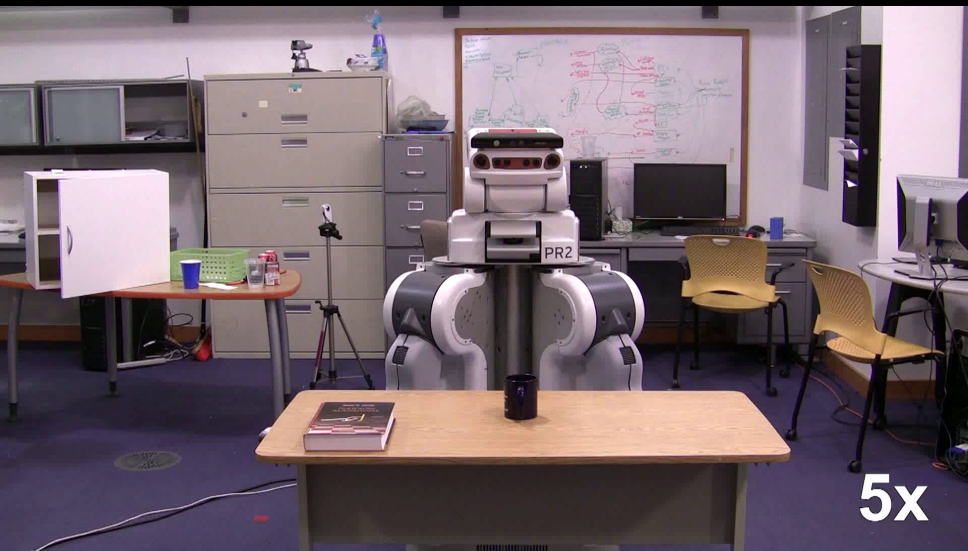
- 1 Automatically identify sub-goals in regions in which manipulation actions can change
 - 2 Use DARRT to plan for each sub-goal
- ✓ Significantly faster than DARRT







Video of Baxter loading buckets onto a conveyor at Elgen Robotics



5x

Video of an overly-complicated RRT plan.

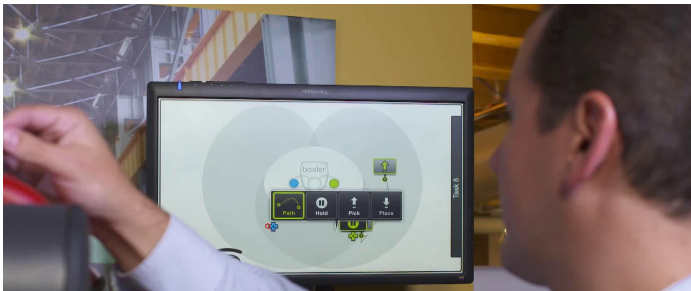


Video of the PR2 arm hitting the camera.



Video of Baxter moving its right hand through the shelf.

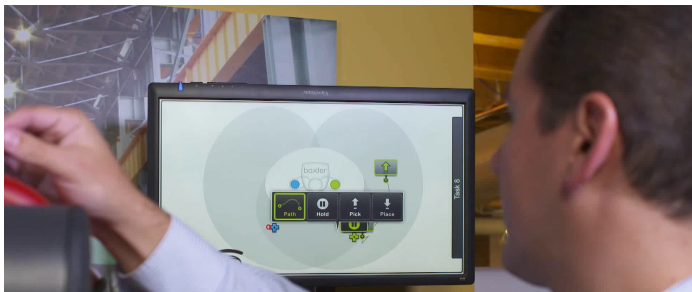
PLANNING FOR MANUFACTURING



UNDERSTANDING ENVIRONMENT

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

PLANNING FOR MANUFACTURING



UNDERSTANDING ENVIRONMENT

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

PLANNED PATHS

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