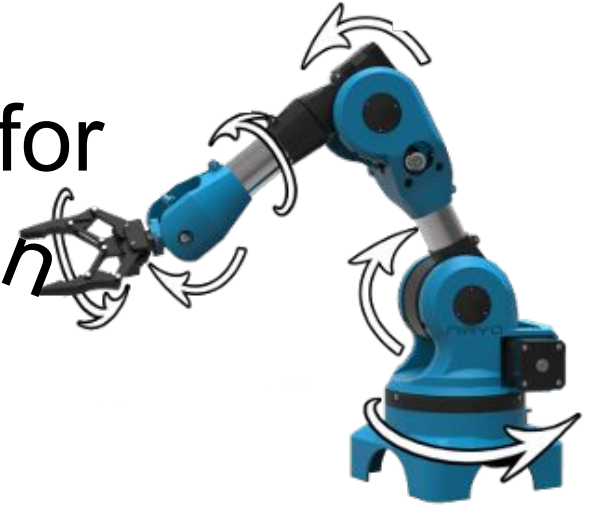# Task and Motion Planning for Robotic Food Preparation

Montiel Abello
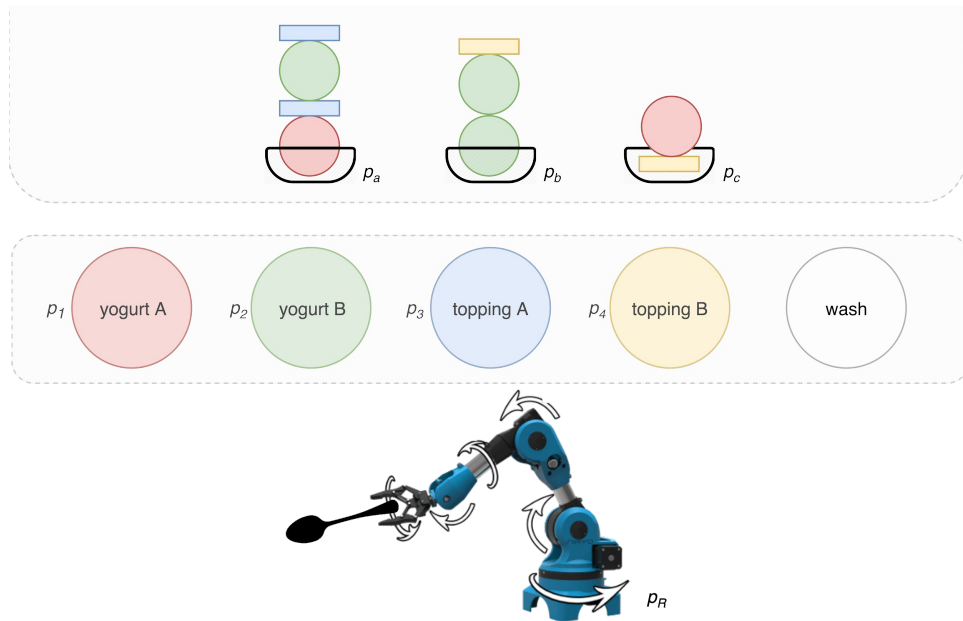Travers Rhodes
Sudharshan Suresh
Himanshi Yadav

16-782 project presentation

Problem

- Robots in real-world scenarios need to plan both **tasks** and **motions.**

- In the food preparation setting, orders define tasks and we plan serving motions.

- We aim to apply these to prepare multiple yogurt parfaits.

Mathematical Definition: Task and Motion Planning

- Initial/Goal states: set of grounded conditions
- Search infinite domain of arm trajectories
  - For arm with n joints $T : [0, t_0] \mapsto SO(3)^n$
- Trajectory has `Preconditions, Effects, Costs`
- Trajectories constrained by kinematics, dynamics, environment.
- Find optimum plan

$$\pi^* = \langle T_0, \ldots, T_i, \ldots, T_k \rangle$$

- Cost function
 - Assuming constant velocity, it is integral of trajectory

$$c(\pi) = \sum_i \text{arclength} \ (T_i)$$

Planning Algorithm

- Planning Domain Definition Language (`PDDL`) - like `STRIPS`, but better.
- There are efficient, complete methods for symbolic planning, we use ***Fastdownward[2]***.
- **RRT-connect** for motion planning - probabilistically complete

Streams[1]:

- Modified `PDDL/STRIPS` planning representation
- Generate candidate actions from *streams* of possible actions.
- Try to solve the `STRIPS` problem
  - if unsolvable draw new actions and repeat.
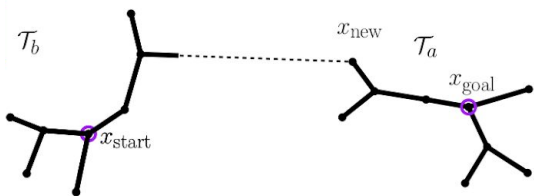
```
(define (problem pb2)
    (:domain sorbet)
    (:objects vanilla strawberry nuts cup1 cup2)
    (:init
      (is-cup cup1)
      (is-cup cup2)
      (clear cup1)
      (clear cup2)
      (is-vanilla vanilla)
      (is-straw strawberry)
      (is-nuts nuts)
    )
    (:goal ( and (Order cup1 vanilla nuts strawberry)
              (Order cup2 vanilla vanilla nuts)
    )
    )
)
```


$\mathcal{T}_b$ x_{new} $\mathcal{T}_a$ x_{goal} x_{start}

[1] Garrett, Caelan Reed, Tomás Lozano-Pérez, and Leslie Pack Kaelbling. "STRIPStream: Integrating Symbolic Planners and Blackbox Samplers." *arXiv preprint arXiv:1802.08705* (2018).
[2] Helmert, Malte. "The fast downward planning system." Journal of Artificial Intelligence Research 26 (2006): 191-246.

Case A: **Only Task** Planning ([video](#))

Example action : **wash**

```
(:action wash
  :parameters ()
  :precondition (or (DirtyVanilla) (DirtyNuts) (DirtyStraw))
  :effect (and (not (DirtyVanilla)) (not (DirtyNuts)) (not(DirtyStraw)))
)
```

"Make 2 sorbets: one with vanilla at the bottom, nuts in the middle, topped off with strawberry; the other with two scoops of vanilla topped with nuts."
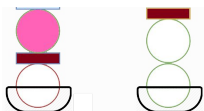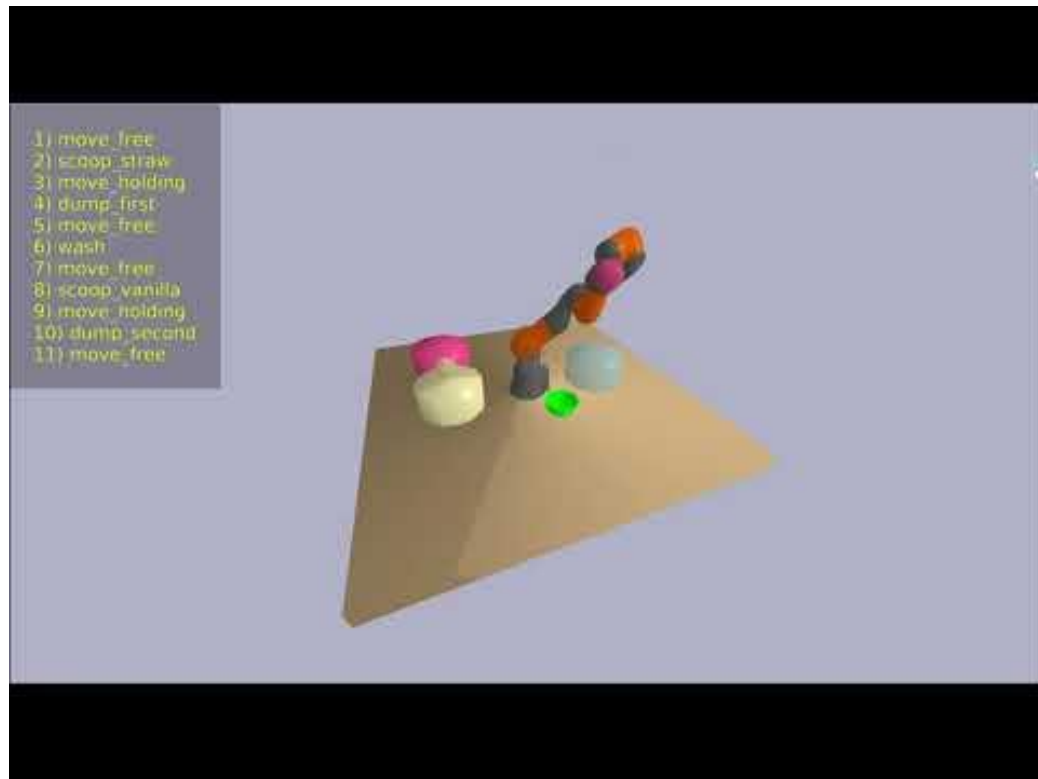

*Custom local gradient-based planner used for point-to-point motion. Scooping from human imitation.

Case B: **Task** and **Motion** Planning (+demo) ([video](#))

"Make 1 sorbet: strawberry at the bottom with vanilla on top"

- We use KUKA arm here.
- Sampling grip poses in the simulator sometimes takes arbitrary amount of time (bug!?).

Case B: **Task** and **Motion** Planning (video)

"Make 2 sorbets: one with vanilla at the bottom, nuts in the middle, topped off with strawberry; the other with two scoops of vanilla topped with nuts."