COMPUTER SCIENCE & ENGINEERING
UNIVERSITY of WASHINGTON

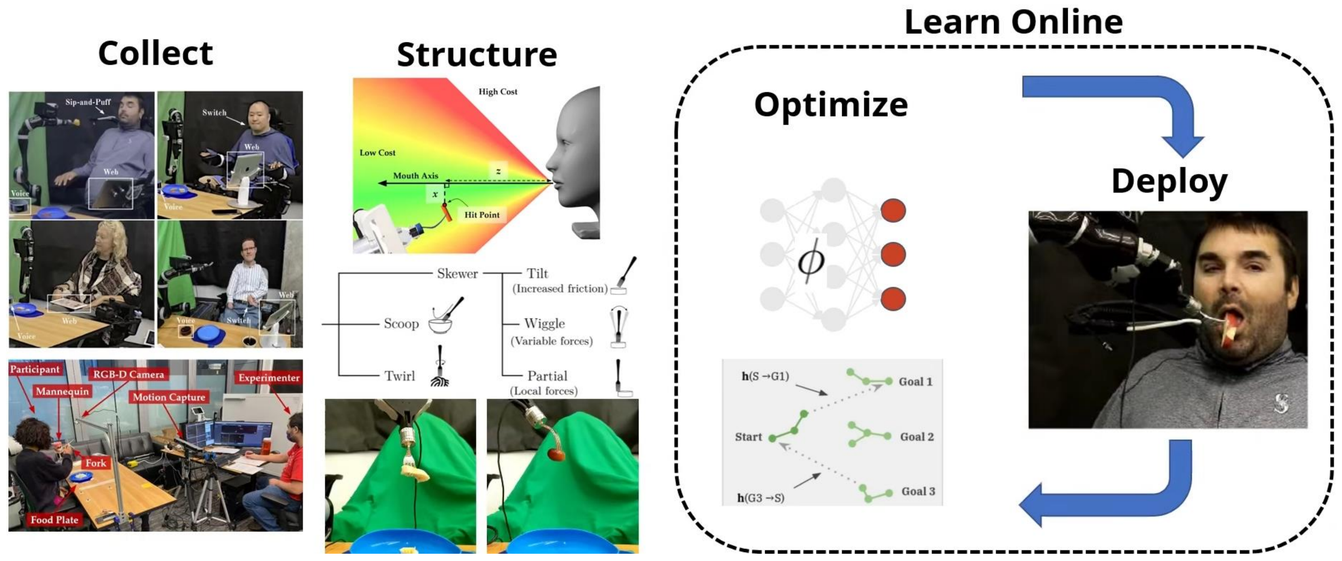
Ethan K. Gordon
HRI Pioneers 2023, Stockholm, SE

# Balancing Flexibility and Precision in Robot-Assisted Feeding

**In HRI, some task dimensions require precision, while others allow for flexible optimization.**
e.g., Bite Transfer: The food needs to get close to the user's mouth without injuring them. But the user's preferred speed and orientation can vary from food-to-food or throughout the meal.

**Key Insight: We can manage this trade-off with a hierarchical framework.**

- Create a User-Informed Relatively Small Set of **Models, Controllers, and Heuristics**
- Optimize Online with Relatively Simple Learning: **Contextual Bandit or Heuristic-Guided Planning**

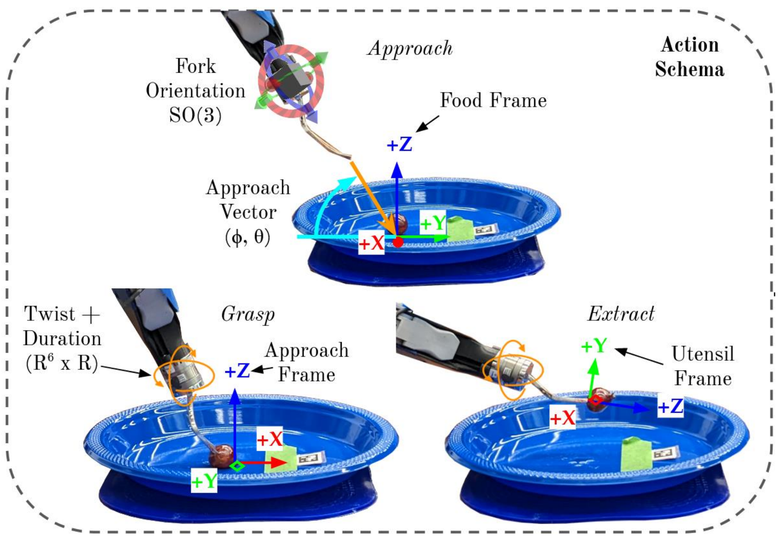



(1) Collect human food acquisition and transfer motions.
(2) Distill into a space of precise acquisition actions and transfer heuristics.
(3) Optimize in this space online based on acquisition success and user feedback.

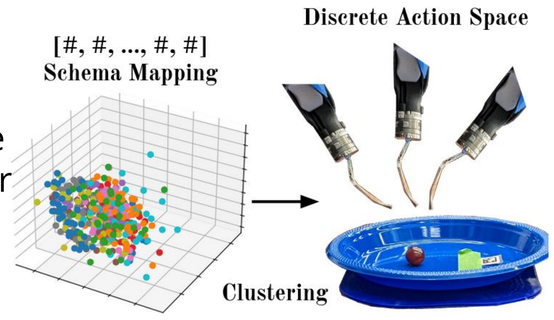
## Bite Acquisition: Building the Action Space

**Key Idea:** a very small subset of the space of possible acquisition actions is sufficient to acquire almost all food items that a human can pick up with a fork.

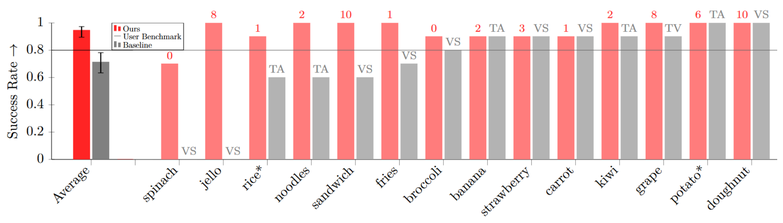
**Method:** Capture human acquisition motions and map them into an interpretable robot-based action space.


Cluster into a representative discrete set for easy online learning.



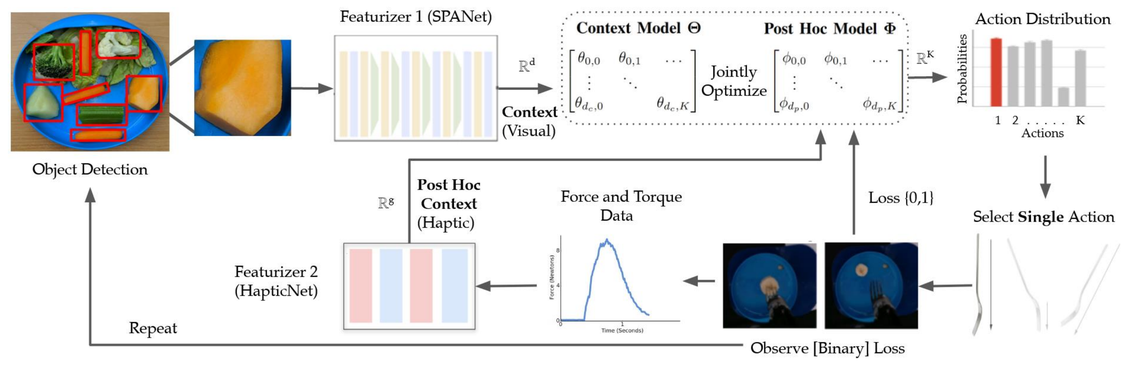

**Result:** A space of 10 actions that can pick up a diverse set of foods with a user-acceptable success rate.

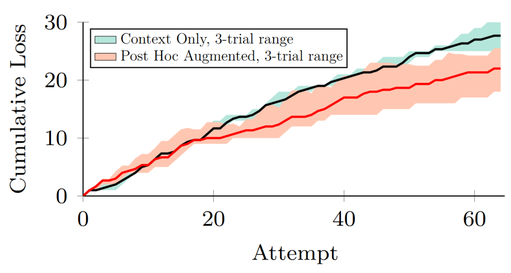



## Learning the Optimal Action

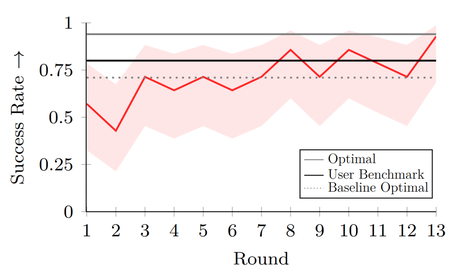
**Method**: Model as a Linear Contextual Bandit with binary loss (success/failure), augmented with linear post hoc context. Optimize and balance exploration/exploitation using LinUCB.

**Key Ideas:** (1) We can model Bite Acquisition as a Contextual Bandit, choosing the best of a set of good actions. (2) Haptic data can be used for faster learning without necessitating the use of probing actions.



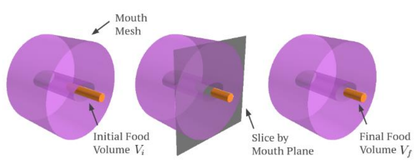



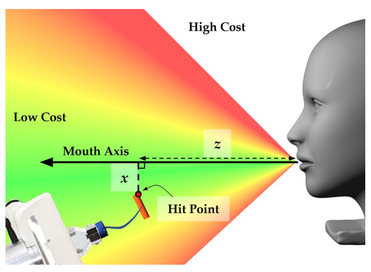

**Results**: *(Left)* Adding the haptic post hoc context leads to faster learning and fewer failures. *(Right)* With the 10-action space, we reach user-acceptable performance within 10 trials per food item.



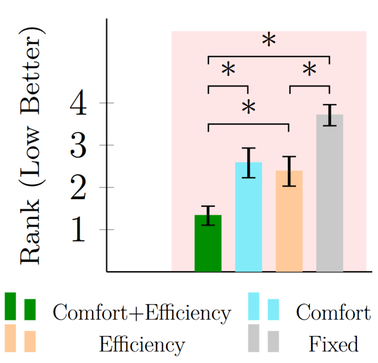

## Bite Transfer: Human-Informed Heuristics

**Key Idea:** Create a space of precise transfer trajectories optimized with different heuristic weights, allowing optimization based on user preference without jeopardizing efficacy.




**Method:** Optimize trajectories with h-RRT based on efficiency *(top)* and comfort *(right)*.




**Preliminary Results:** Users preferred trajectories optimized with these heuristics over baselines.

**Future Work:** Update heuristics with further user study. Allow users to select heuristic weights based on personal preference.

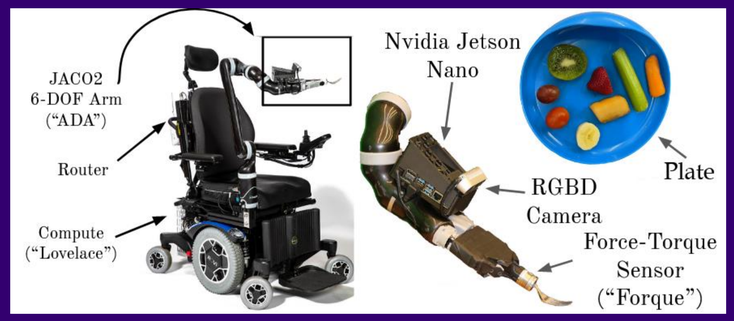
## Shooting for the Home

**Goal:** Install a complete system in a user's home for a whole week of meals. Identify what works and what more needs to be done.

**Meet our Co-Designer and Participant:**

Tyler Schrenk
www.thetsf.org

**Open Hardware**: Completely portable and self-contained on the user's wheelchair.




**Open Software**: Made public for use by anybody. See: www.robotfeeding.io

**Target Deployment: Summer 2023**

Personal Robotics Lab

This work was (partially) funded by the National Science Foundation NRI (#2132848) and CHS (#2007011), DARPA RACER (#HR0011-21-C-0171), the Office of Naval Research (#N00014-17-1-2617-P00004 and #2022-016-01 UW), and Amazon.

HRI 2023 PIONEERS