COMPUTER SCIENCE & ENGINEERING
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Achieving Deployable Autonomy through Customizability and Human-in-the-Loop: A Case Study in Robot-assisted Feeding

Despite decades of research on personal physically assistive robots for people with motor impairments, deployments of such robots are few.

The key challenge is every user's needs, environments, and care routines are unique, making it difficult to develop a robot that's sufficiently customized and robust to deploy.

Goal: Develop a robot-assisted feeding system to feed **any user**, in **any environment**, a **meal of their choice**, **without researcher intervention**, while aligning with their **preferences**.

Key Insight: The robot and user form a joint system; we can achieve the desired robustness & customizability by **giving users intuitive and transparent controls**.

Method: Work with community researchers (Community-Based Participatory Research)

1. Needs Assessment

What are users' needs & wants?

Method: Interviews with *n=10* participants with motor impairments about their meal routines and reflections on robot-assisted feeding videos.

Key Results:
- Robots can alleviate some dining challenges.
- Users want to control & customize their robot.

A. "If I'm ready to eat and then someone starts talking to me suddenly, **I want [the robot] to wait** until that person finishes talking." (P1)

B. "With any kind of input, there are times the robot will misunderstand it, so **I'd want an option to stop it quickly**." (P10)

CONTROL

CUSTOMIZATION

C. "Since my chair is oversized, I don't fit going straight into tables. I have to sit sideways. So **the robot will have to pick bites from [a plate on] the side**, **not the front**." (P4)

D. "Before giving me food, **I'd prefer it rests off to the side**, so I don't face people not being able to look at me. But for the actual into-mouth motion, **I can't turn my head, so I'd need the food to come from the front**." (P8)

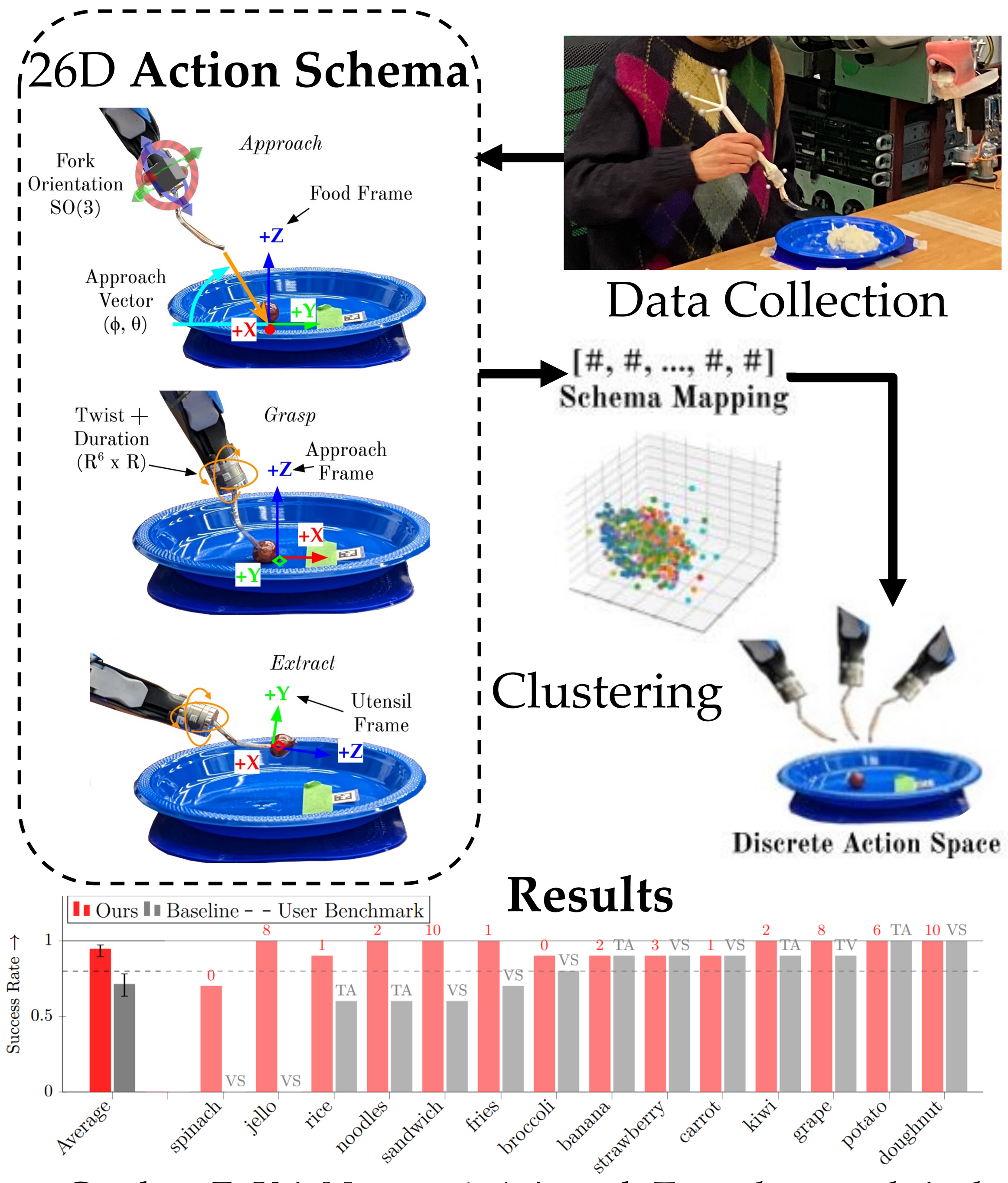
E. "Every person is different. **The way we sit, the way we eat**, we have our own positions and height. This robot, they'd have to customize it." (P3)

Nanavati, A.*, Alves-Oliveira, P.*, et al. *Design principles for robot-assisted feeding in social contexts.* HRI '23 (Best Design Paper).

2. Bite Acquisition

"…a meal of their choice…"

Method: Collect a dataset of *people* acquiring diverse foods, learn representative motion primitives for a *robot arm* to acquire the foods.



Gordon, E. K.*, Nanavati, A.*, et al. *Towards general single-utensil food acquisition with human-informed actions.* CoRL '23.

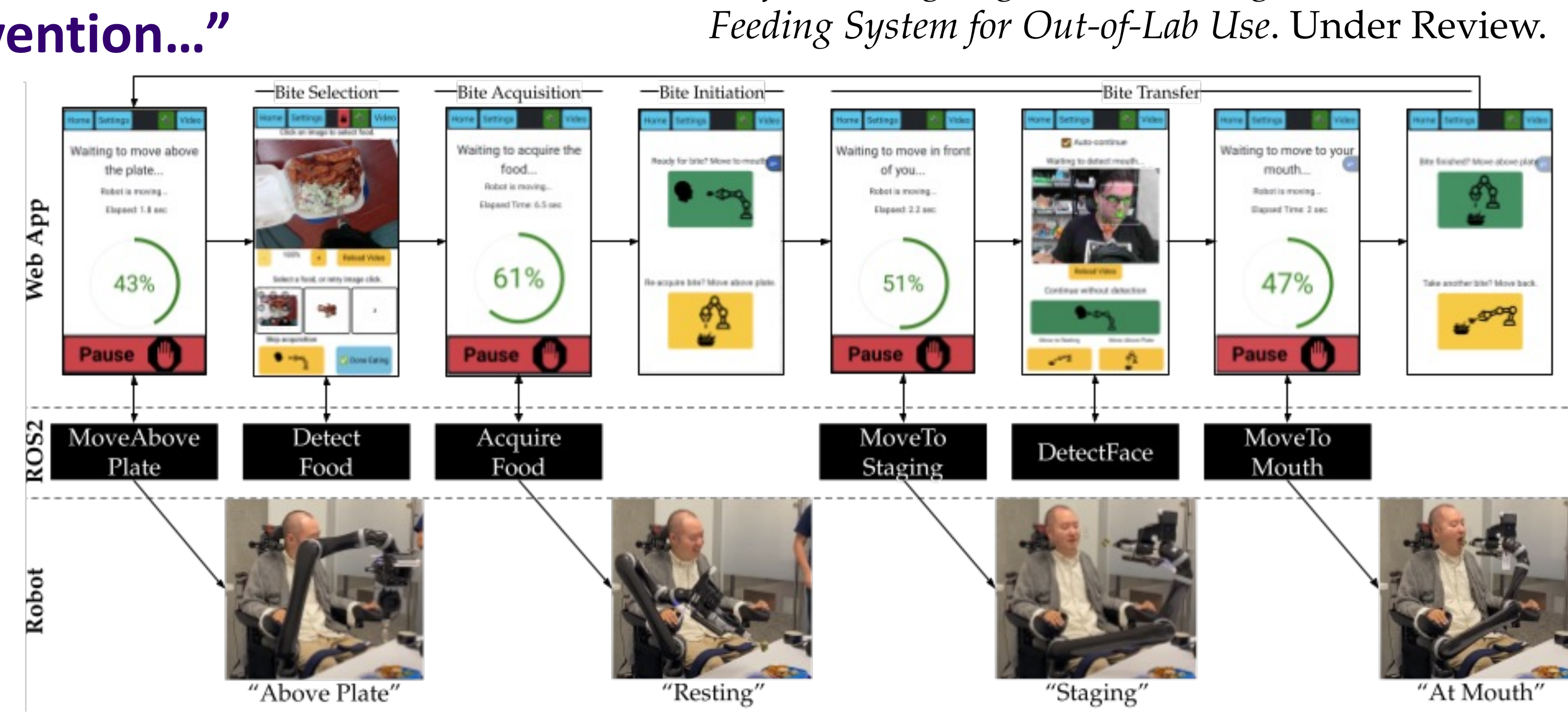
3. Robustness via Human-in-the-Loop

"…without researcher intervention…"

Nanavati, A.*, Gordon, E. K.*, et al. *Lessons Learned from Designing and Evaluating a Robot-Assisted Feeding System for Out-of-Lab Use.* Under Review.

Method: Co-design app & robot with community researchers, to ensure robustness to off-nominals.

Evaluation: *n=6* users, meals of their choice, realistic meal settings (top-right fig)



Key Results:
- 4/6 users rated it at-or-above-average usability (System Usability Score).
- Users had relatively low cognitive workload, despite multiple human-in-the-loop steps.

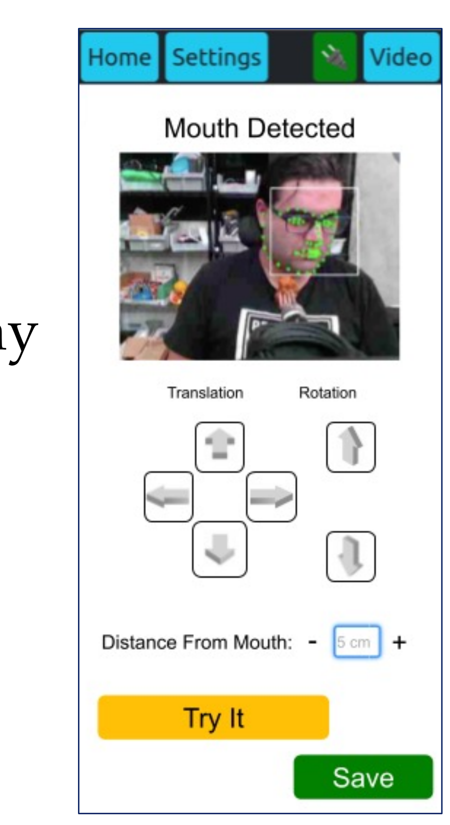
4. Customizability

"…any user…any environment…preferences…"

Method: Work with community researchers to identify desired realms of customization, co-design ways to provide that customization.

Key Insight: By allowing users to *change key robot arm configurations*, they can customize the robot to their *preferences* (e.g., don't block my view of my dining partner) and *environments* (e.g., bed-feeding vs. seated feeding).

Proposed Study: Evaluate user preferences across customization interfaces (manual vs. active learning).



Proposed Interface

5. Upcoming Home Deployment

Method: Week-long deployment in a user's home (*n=1*). Let them freely use the system to eat, identify directions for future work.

Community Researcher: Jonathan Ko

Metrics: meal length, stress levels, caregiver time, # researcher interventions, qualitative insights

Project Webpage

Personal Robotics Lab

Human-Centered Robotics Lab

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