An Assistive Robot Feeding System

Personal Robotics Lab   Computer Science & Engineering   University of Washington

Problem and Motivation

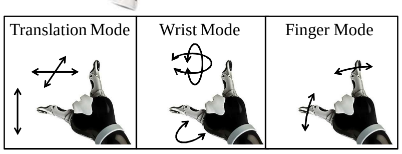


Fig. 1: The JACO robot arm uses control modes that the operator can switch between by pressing a button. Each control mode specifies which axis the wheelchair's joystick is controlling.

- People with upper extremity disabilities are gaining increased independence through the use of assistive devices such as robotic arms, but performing tasks that require many small precise movements remains difficult
- Also, controlling high-dimensional robot arms with a much lower dimensional interface like a joystick requires the use of control modes (Fig. 1) and more mental effort
- Eating / Feeding is a particularly **high impact task** because:
  - Eating is an activity of Daily Living (ADL)
  - 56.7 million people had disability in 2010 (Brault, 2012)
  - 12.3 million people needed assistance with ADLs and IADLs (Perry, 2008)
  - Time-consuming for caregiver (Perry, 2008)
  - Challenging for care recipient to accept socially (Perry, 2008)
- **Key Challenges:**
  - Many small, precise movements
  - **Bite Acquisition** : Food perception, Manipulating deformable objects
  - **Bite Timing :** Understanding the cadence of social dining

Fig.2:
Top Left: Pouring a pitcher of water with the MICO robot arm, a research version of the JACO assistive arm.

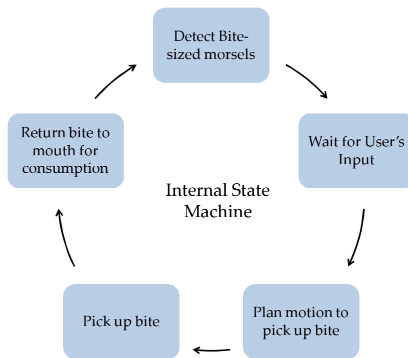
Top Right: The mealtime partner dining system. Existing automated systems require a lot of time-consuming setup, and manual triggering and bite selection.

Bottom: Feeding with the MICO robot arm

Solution : Automated Dining Capability

Our system, ADA (Assistive Dexterous Arm), is a combination of a MICO robot arm, a depth camera, and a computer running ROS and software developed in the Personal Robotics Lab.

- First, the camera detects individual bites which would be precut by the caregiver, and could be items such as fruit, sandwich bites, marshmallows, etc.
- Next, using planning libraries we developed on HERB, the robot autonomously picks up the bite with the fork
- Finally, the loaded fork is brought to the operator's mouth for consumption



Strengths:
- The robot automatically re-evaluates the status of the plate before each bite, so if food shifts, or more food is added, the program has no difficulty adapting
- The location for feeding the user can be personalized to the person's comfort zone
- Taking a bite is fairly fast and has a low cognitive load on the operator

But, what about bite acquisition in a plate with many different food items ?

And, what about bite-timing in a social dining setting ?

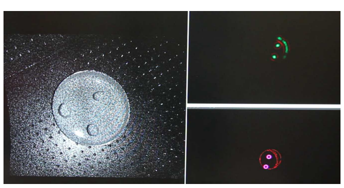


Fig. 3:
Left: RANSAC is used to remove the plane of the table. All contiguous shapes of reasonable bite size are then located. The edge of the plate is also filtered out. We are left with individual detected bite locations.

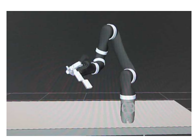


Fig. 4:
Left: Simulation of the robot in OpenRAVE for planning the robot's motion.

Right: Photo of ADA performing automated bite acquisition.

Insights : Bite Acquisition and Bite Timing

Bite Acquisition :

For food perception, we want to explore multiple sensing modalities (Haptics, Vision (RGBD), Motion, Thermal etc.)

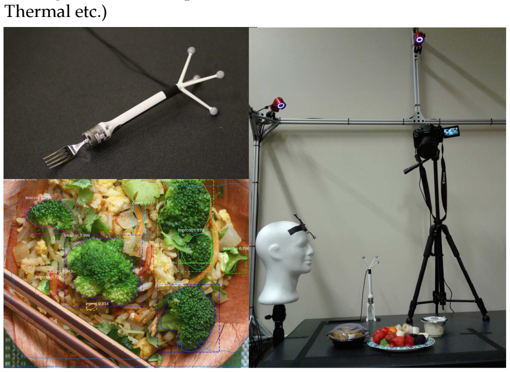


Fig. 5: Using multiple modalities for food perception

Bite Timing :

- Features such as gaze direction (speaker or plate), conversation, mouth (closed or open), time since last bite etc. are informative of bite-timing
- Represented as a state-transition model - More states than bite acquisition and eating : People wait with full fork and empty fork

Fig. 6: 3 participants in a social dining setting. Cameras placed in the middle of the table capture video of the faces of each participant, and an overhead camera (middle) shows the tabletop.

Scientific Impact :

- Understanding the cadence of social dining can shed light into models of human behavior in a group setting
- A unique opportunity to collect and share a dataset of multiple modalities for activity recognition, and perception with the community
- Results from this project can provide insights into a meaningful integration of multiple modalities such as speech, motion, haptics, vision, thermal, gaze etc. for recognition tasks

Broader Impact :

- Development of an automated assistive robot feeding system which can **impact the quality of life** for older adults with a wide range of upper extremity disabilities

Award # 1745561 - Learning Control Sharing Strategies for Assistive Cyber-Physical Systems : PI – Siddhartha Srinivasa, Award Date : October 1, 2015