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Learning control sharing strategies for assistive cyber-physical systems

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Challenge: Control space for assistive robot arms is unmanageably complex

- Assistive robots with 7 DOF are complex to control, because available interfaces, such as **joysticks**, **sip-n-puff**, and **head arrays**, only cover a portion of the control space

Kinova Joystick

Therafin Sip-n-Puff

ASL Head Array

- **Modal control** allows users to actuate a few DOF at a time, but it takes significant time and mental energy (Herlant et al., 2016)
- **Goal:** Ease the burden of modal control to enable assistive arm use with varied interfaces.

Courtesy of Kinova Robotics

Solution: Intelligent autonomous control mode switching

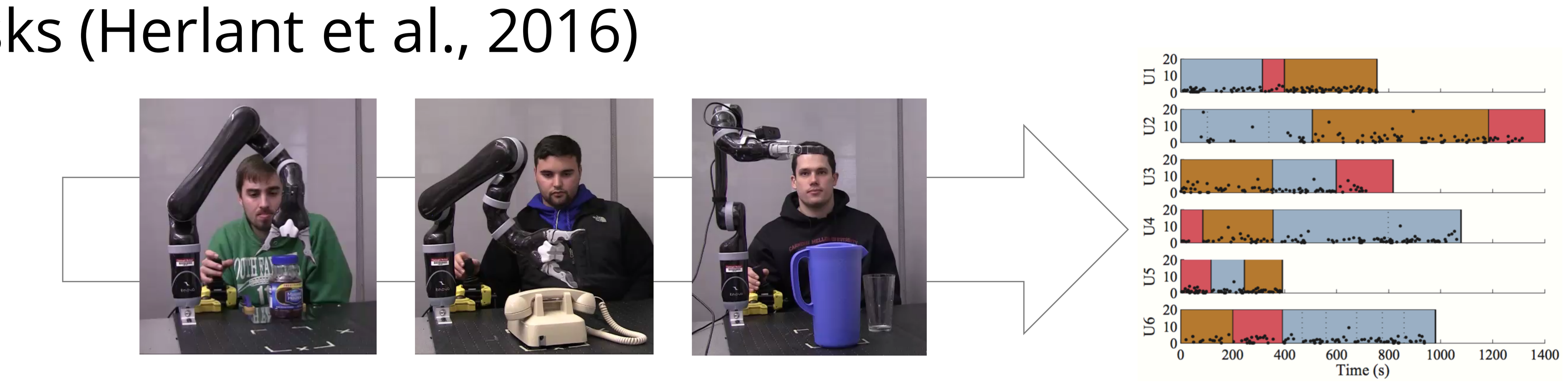
- **Key insight**: Represent control problem as a hybrid dynamical system, with control modes as the states.
- **Key insight**: Model assistance as an optimization over a desired cost function, with system's uncertainty over user's goals represented in a POMDP.
- **Key insight**: Select the right time to switch modes by formulating it as a time-optimal assistance problem, or by learning it from human demonstration.

Publications

- Herlant, Holladay, Srinivasa, "Assistive Teleoperation of Robot Arms via Automatic Time-Optimal Mode Switching," *HRI*, 2016.
- Nikolaidis, Kuznetsov , Hsu, Srinivasa, "Formalizing Human-Robot Mutual Adaptation via a Bounded Memory Based Model," *HRI*, 2016.
- Admoni, Srinivasa, "Predicting User Intent Through Eye Gaze for Shared Autonomy," *AAAI Fall Symposium: Shared Autonomy*, 2016.
- Jain, Argall, "Robot Learning to Switch Control Modes for Assistive Teleoperation," *RSS Workshop: Planning for HRI*, 2016.

Scientific impact: Mathematical formalism for mode switching with real-world evaluations

- **Identify the expense of mode switching** during representative tasks (Herlant et al., 2016)

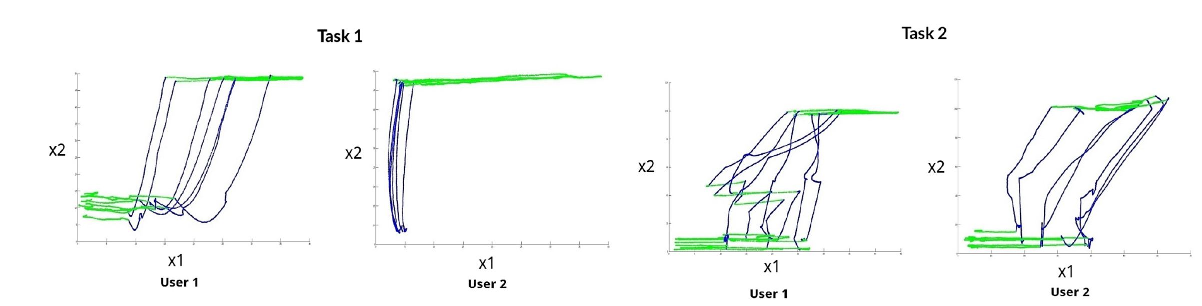


Mode switches (dots) per user (rows) for each task (blue: pouring; brown: unscrew jar; red: dial phone). X axis represents task time, and y axis represents mode switch time.

- **Learn when to switch control modes** by observing a human operating the robot

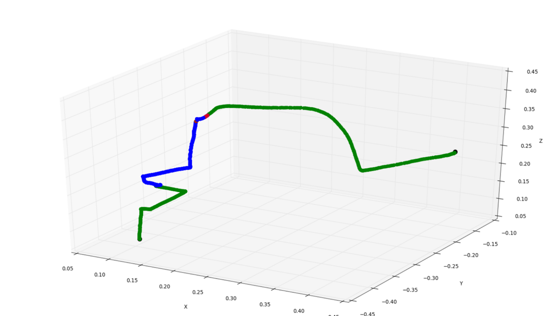
1. From teleoperation control signal (Jain and Argall, 2016):

Step 1: Record data trajectories during human teleoperation of a robot arm



Data from user teleoperation in SVM feature space. Green: translational mode; blue: rotational mode.

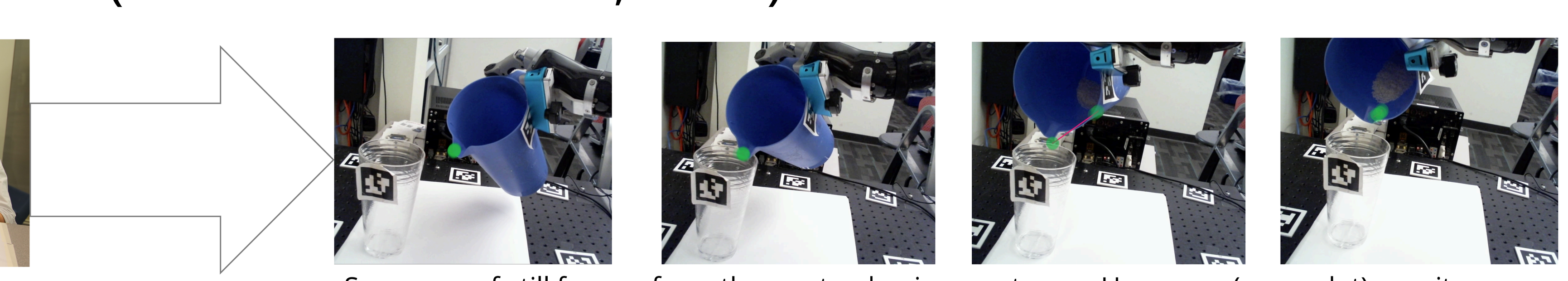
Step 2: Train a classifier to predict a control mode



Automated mode switches during a trajectory in Cartesian space. Green: translation mode; blue: rotational mode; red: incorrect predictions.

2. From eye gaze data (Admoni & Srinivasa, 2016):

Recording eye gaze with a head-mounted eye tracker.



Sequence of still frames from the eye tracker image stream. User gaze (green dot) monitors spout position and pitcher contents as pouring begins, and can reveal the user's next action.

Broader impact: Quality of life for people with motor impairment

- Significant public health implications by **increasing independence** for people with severe motor impairment
- Partnerships with rehabilitation hospitals (Rehabilitation Institute of Chicago) and assistive arm manufacturers (Kinova Robotics) enables **real-world evaluations** and **broad dissemination of technologies**