CARL
Cognitive Assistive Robotics Lab

University of New Hampshire

Robust Learning of Sequential Motion from Human Demonstrations to Enable Robot-guided Exercise Training

Project Duration: Jan 2019- Dec 2021

NCE: 2022

PI: Momotaz Begum[1]; Co-PIs: Dain LaRoche[2] and Sajay Arthanat[3];

Award ID: 1830597 ; [1] Computer Science, [2] Exercise Science, [3] Occupation therapy

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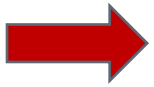
Motivation

What does a robot need to learn from an expert and then teach to a patient?



- Trajectory Learning
- Good evaluation metric
- An HRI study for evaluation
- High-level policy learning

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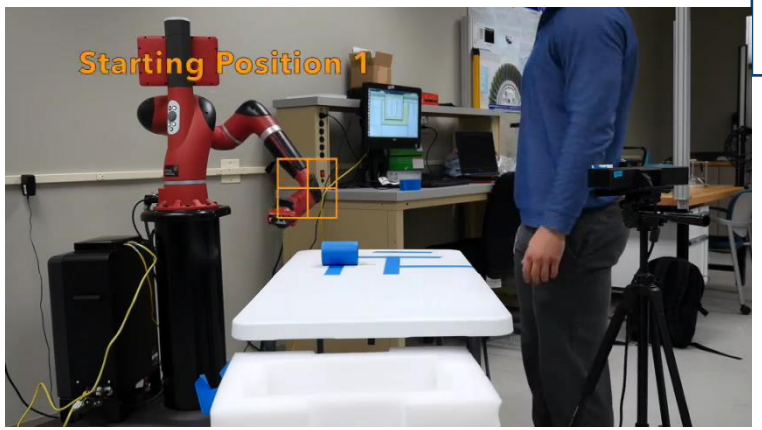
- Trajectory Learning

1. Phase Space Model (PSM) for trajectory LfD

A DS model that learns kinematic constraints, both position and velocity, and is robust to spatial and temporal perturbation during execution

Gesel et al. Learning Motion Trajectories from Phase Space Analysis of the Demonstration, ICRA 2019



ICRA 2019

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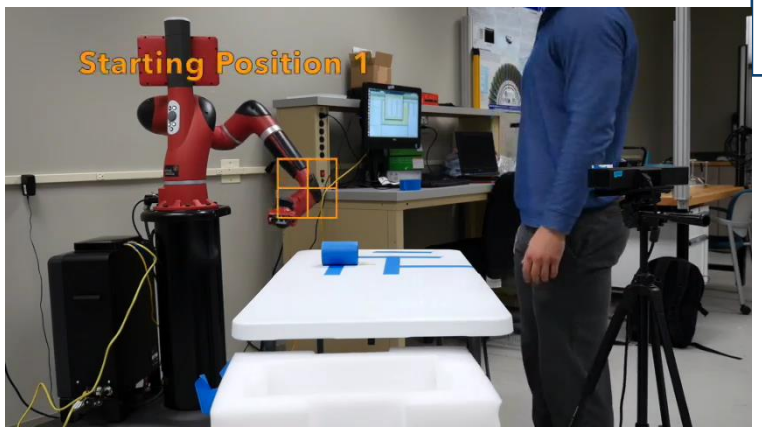

ICRA 2019

2**. PSM Trajectory optimization**

- Learning trajectory while minimizing energy, torque, jerk and observing dynamic constraints of the robot
- A vector-based approach for corresponding problem

Gesel et al. Learning Optimized Human Motion via Phase Space Analysis IROS 2021

IROS 2020

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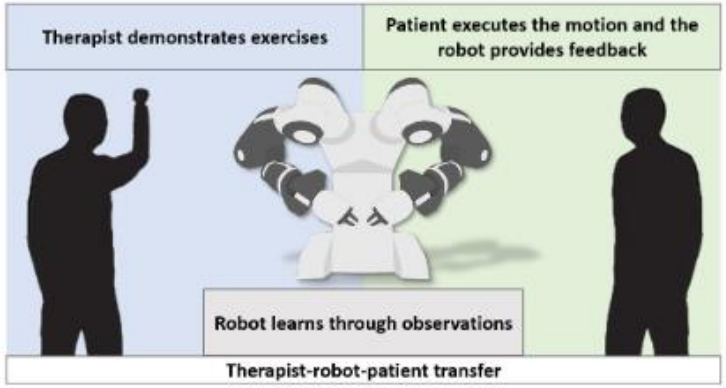
- Good Evaluation Metric

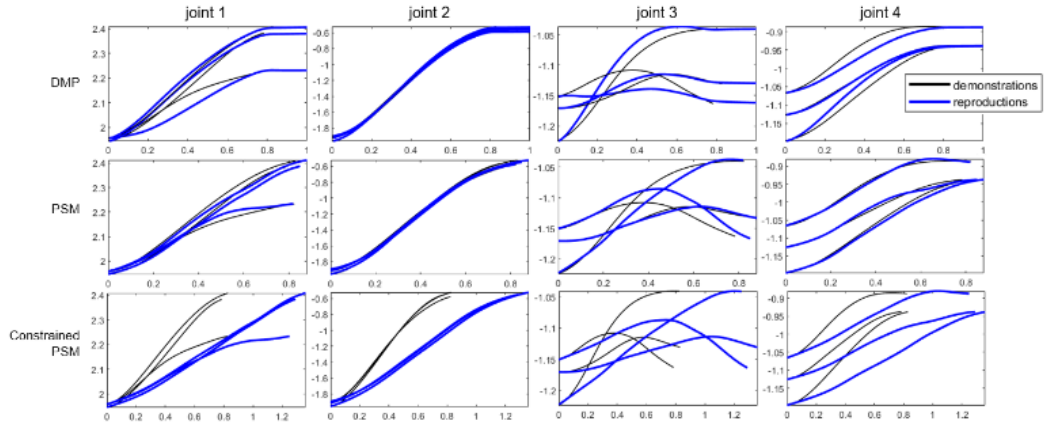


IROS 2021

- Learning an optimal time-invariant PSM controller that minimizes energy, torgue and jerk.

- An evaluation metric is derived from the learned expert's objective functions related to energy, torgue and jerk

Gesel et al. Learning to Optimize Control Policies and Evaluate Reproduction Performance from Human Demonstrations, IROS 2021



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An HRI Study (Ongoing)

- YuMi is trained with 4 shoulder exercises from 192 demonstrations from 8 subjects
- Occupational therapists will evaluate YuMi-Human movement agreement in an in-person and online study in April.
- The robot will be tested with patients in the next study (2022-2023)

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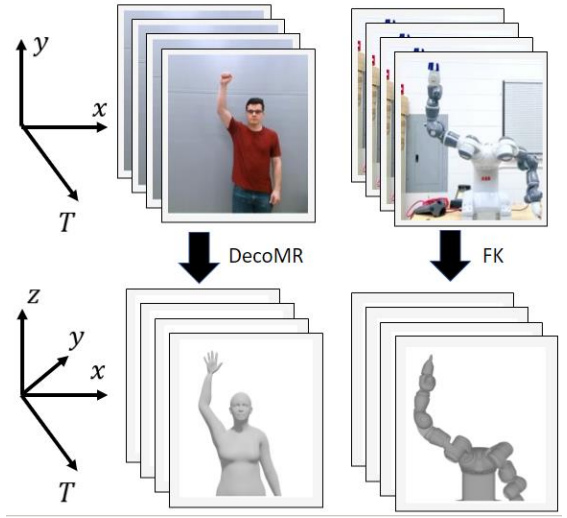
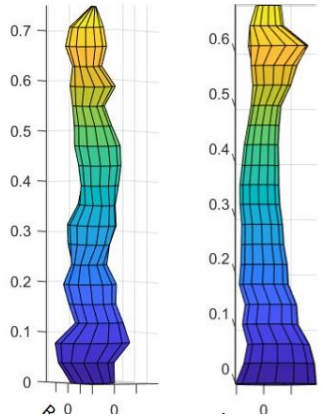
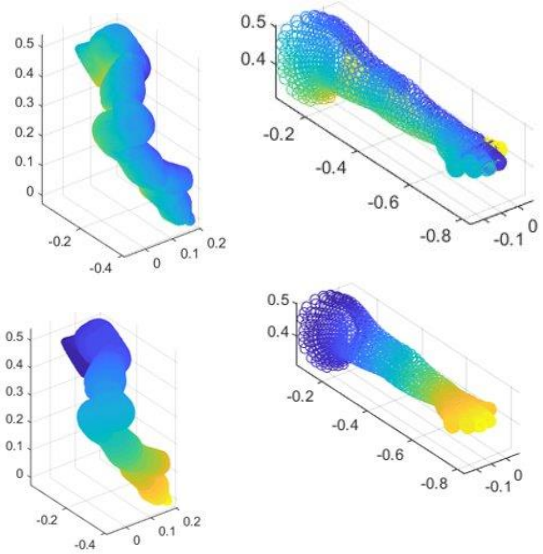
- A further extension: Learning from visual demonstrations (Ongoing)
  - No marker, no depth camera **- Visual Correspondence problem**



Dense mesh trajectories from one Demonstration by robot and human

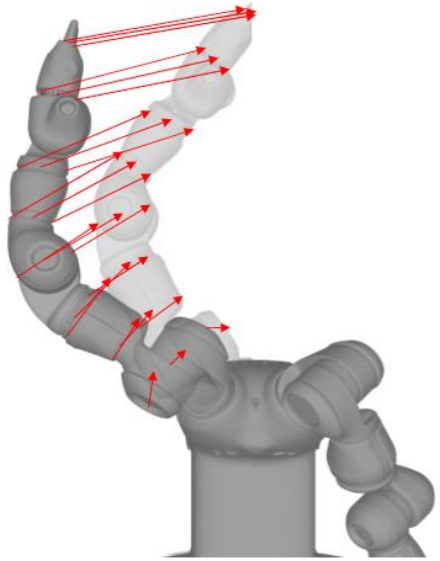


A new parametric mesh representation



Projection to UV space

NN is trained for correspondence



Iterative Jacobian IK for joint angles

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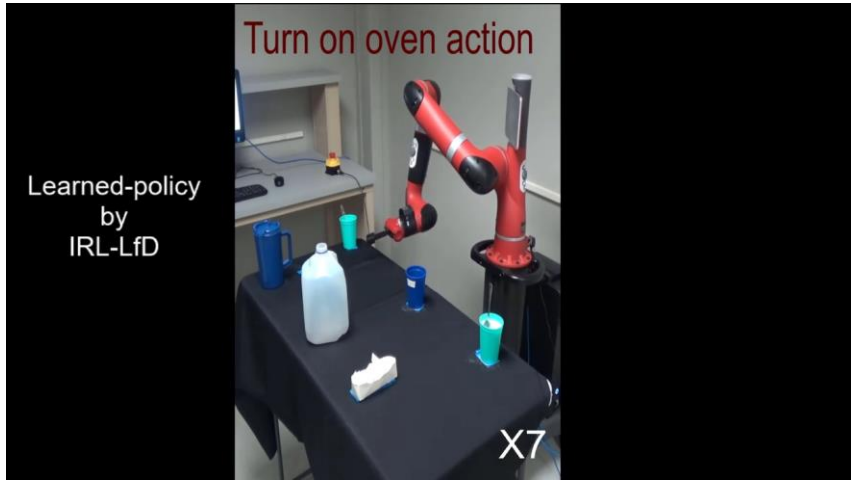
- High level policy learning: Adversary detection

- Entropy analysis of features in demonstrations to identify the ones that is inconsistent with the majority – hence an adversarial demonstration.

Hussein et al. Robust Behavior Cloning with Adversarial Demonstration Detection, IROS 2021

Hussein et al. Robust Maximum Entropy Imitation Learning, Robot learning workshop, NeurIPS 2020



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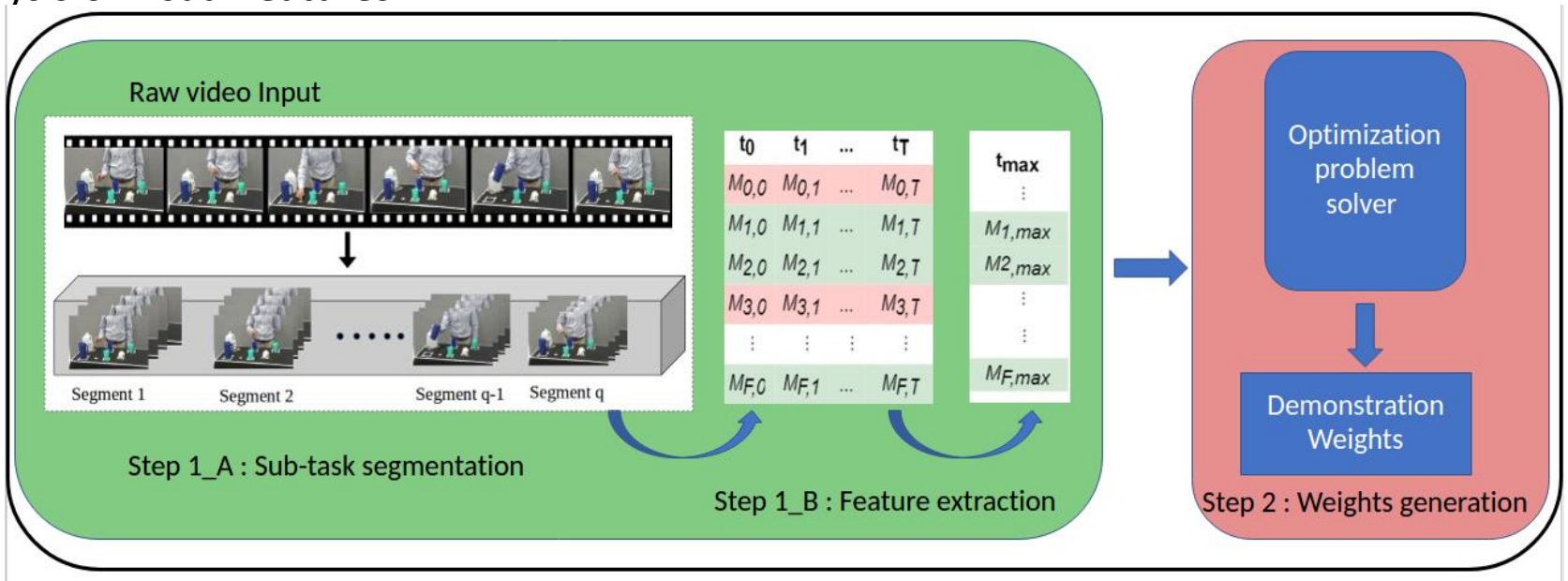
- Ongoing work: Adversarial visual demonstration detection

  - Entropy analysis of visual features.



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Thank You!