Robot Learning from Human Teachers

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Quiz (10 point)

• What did the four EMG lectures covered?
  • List at least two things you have learned from the four EMG lectures
What the lectures have covered

- Basic EMG sensing and signal processing
- Use EMG sensors to track the subjects daily activities, to diagnose motor disease and validate treatment efficacy
- Decompose EMG signals to Motor Unit (MU) drives, for real-time prosthetic arm control
Project proposal: report & presentation
Proposal report (Due Nov 7)

- Introduction (Motivation, background, and Significance)
- Related work
- Problem Description
- Proposed Method
- Preliminary Work
- Plan and Timeline for B term
- Reading plan for literature review
- Contribution so far from each teammates
- Reference

- At least 2 pages, can be more
- Everyone must contribute
- Follow IEEE conference paper template
Proposal Presentation

• Timeline
  • Standard project: 15 min talk + 3 Q&A
  • Fatigue study team: 12 min talk + 2 min Q&A
  • Other small projects: 8 min + 2 Q&A

• Oct 29
  • Three shared autonomous teams (reach2grasp, locomotion, perception-action coordination) + Kinect interface (small project)

• Oct 31
  • Handover team + high-level learning team + fatigue study team + soft hand evaluation (small project)
Proposal presentation

• Presentation slides due **Nov 7**

• Prefer more pictures, diagrams, tables and video
  • No more than 1/3 text content

• Make sure to practice in group

• Time limit will be enforced strictly
Assignments on Robot Kinematics
Derive the FK and IK for dual arm exoskeleton

• Why give out this homework now?
  • You may have learned robotics kinematics in RBE 500
  • Need a practice to wrap up A term

• Group homework, work with your team
  • Assignment 5 – Due on Nov 14
  • Assignment 6 – Due on Nov 28

• Code in Python or Matlab
Assignment 5

- Derive the forward and inverse kinematics for EXO-UL7, for both left and right arms
  - Derive DH parameters (choose a convention and stick to it)
  - Compute swivel angle for a given arm configuration
  - Resolve the IK analytically
  - Compute the joint angles given an end-effector pose and swivel angle

- Coding
  - Functions for FK, Swivel angle computation, and IK
  - Plot in 3D to arm configuration of FK and IK
• **Zhi Li**, Dejan Milutinovic and Jacob Rosen, “*Spatial Map of Synthesized Criteria for the Redundancy Resolution of Human Arm Movements*”. IEEE Transactions on Neural Systems & Rehabilitation Engineering, 23(6), pp. 1020 - 1030, Nov. 2015

• **Zhi Li**, Hyunchul Kim, Dejan Milutinovic and Jacob Rosen, “*Synthesizing Redundancy Resolution Criteria of the Human Arm Posture in Reaching Movements*”, In Redundancy in Robot Manipulators and Multi-robot systems (pp. 201-240). Springer Berlin Heidelberg, 2013
Assignment 6

- Derive the FK and IK for Baxter robot, both arms
  - Look up online for robot parameters
  - Resolve IK analytically, given the elbow position

- Coding
  - Function for FK and IK
  - Plot in 3D to arm configuration

- Tools you may use
  - Baxter model in ROS Rviz; TF package
The framework of learning from demonstration (LfD)
Recap

• In the past, we have studied human-robot synergy in terms of:
  • Human-compatible robots – Upper limb exoskeletons for stroke rehabilitation
  • Human-teleoperated robots – EMG interface for prosthetic arm control

• From now on, we focus on a new kind of synergy

Robot learning from human teachers
Reference


• Link for pdf download
Overview

- The framework of learning from demonstration (LfD)
- Human social learning
- Models for interacting with a human teacher
Motivation

Customize the robot’s policy of behavior
Learning from Physical Human Corrections, One Feature at a Time

Task 2: Correct Two Features

All-at-Once  One-at-a-Time
Imitation + Reinforcement Learning
LfD versus Machine Learning

• LfD builds upon many standard machine learning methods

• Difference? Or additional challenges?
  • Limited human availability and patience
  • Inconsistency in user input (novice user, sub-optimal demo)

• Open questions
  • How to learn in real-time interaction?
  • When and how should a human user be involved in the teaching process?
Design choices in interactive learning

- Data collection
- Feature selection
- Reward Function
- Sub-tasking
Choice for data collection

- Data to be collected (training data, testing data)
- Data must be representative (states, actions)
- Size and diversity of data set

- Choices
  - Teacher – what training data should be include?
  - Robot – Influence teacher’s decision?
Choice for feature selection

- Choices of input features and similarity metrics
  - Good feature selection leads to good learning performance

- Define a concise and sufficient feature space
  - Exclude redundant and non-discriminatory features

- Who’s responsible for feature selection?
Choice for reward function

- Reinforcement learning, reward function is critical

- Does LfD need a reward function? And why?
  - Evaluating learning performance

- A good reward/objective function can accurately define the task to be learned
Choice for sub-tasking

• Learning speed can be improved dramatically by sub-tasking

• Challenges?
  • What is the appropriate task segmentation?
  • Task structure – defined by teacher or robot automatically?
  • Can the robot guide the teacher’s task structure choices and provide feedback?
The Framework of LfD

- Feedback loop
- Assumption:
  - There exists a Human Teacher who demonstrates execution of a desired behavior

What if the assumption breaks?
The Framework of LfD

Social learning mechanisms used by humans, particularly children

- Human Teacher
- Demonstrations
- High-level Task Learning
- Low-level Skill Learning
- Output Skill/Task Execution

Why?
The Framework of LfD

Common modes of human-robot interaction that are used to provide demonstrations

[Diagram showing the workflow of LfD]
The Framework of LfD

How to reproduce, generalize and refine a learned motion/skill
Conduct experiment to evaluate the learning results
All the possible names for the same thing

- Learning by Demonstration (LbD)
- Learning by Experienced Demonstrations
- Programming by Demonstration (PbD)
- Learning from Demonstration (LfD)
- Assembly Plan from Observation
- Learning by Showing
- Imitation (learning)
- Learning from Observation
- Learning by Watching
- mimicry
- behavioral cloning
Human Social Learning
Overview

• **Human psychology** that affect the design of learning robots
  • Situated learning
  • Teacher’s role
  • Learner’s role
  • Coupling in learning process

• Compare LfD to
  • Machine learning, reinforcement learning
Human motivation for learning
Intrinsic vs extrinsic motivation

- Intrinsic motivation
- Self-motivated learning
- Extrinsic motivation
- Situated learning
Children are motivated to interact

• What enables a children to interact?
  • Being able to recognize, seek proximity to, and interact with (caregivers)

• A big assumption
  • Children assume that the caregiver has their best interest

• Assisted imitation
  • A dynamic **turn-taking** activity