Introduction to Robotics

Lecture 11

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Technical Aspects of Multimodal Systems

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Outline

Outline (cont.)

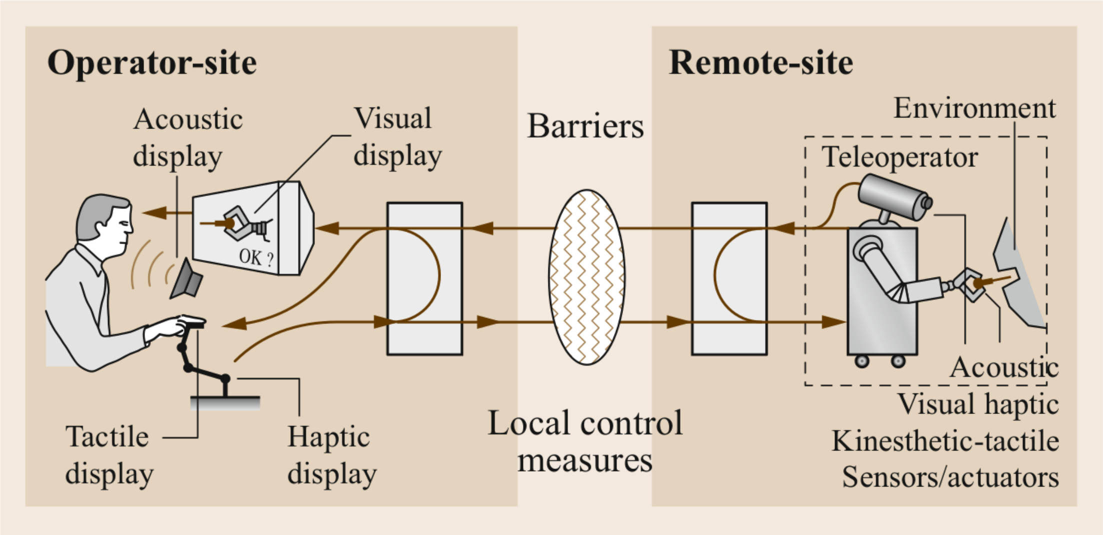
Motivation

Motivation

- Human-in-the-loop
- Handle unknown and hazardous environments
- Take fast decisions and dealing with corner cases

Telerobotics is perhaps one of the earliest aspects and manifestations of robotics.[30]

Telerobotics system



Terminologies

- *Telerobotics*
- *Teleoperation*
  - task-level operations
- *Telemanipulation*
  - object-level manipulation
- *Master-slave systems*
- *Telepresence*
  - an ultimate goal of master–slave systems and telerobotics in general
  - Bilateral telemanipulation

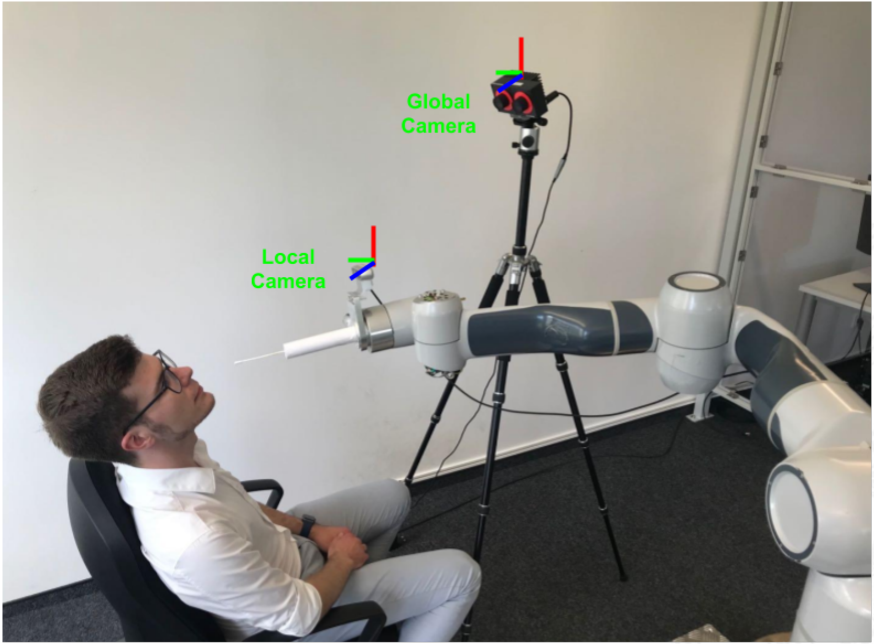
Control architectures in Telerobotics

- *Direct control/manual control*
  - the user is controlling the motion of the robot directly
- *supervisory control*
  - the users only provide high-level commands
  - allow more autonomy and intelligence to shift to the robot system
  - is advantageous to the telerobotic systems with large time delays
- *shared control*
  - combine the basic reliability and sense of presence achievable by direct control with the smarts and possible safety guarantees of autonomous

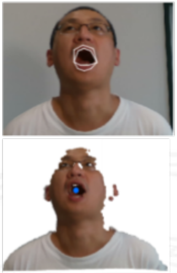
Swab sampling robot – shared control

Automatic swab robot

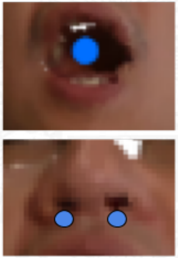
Automatic swab robot



Global Camera



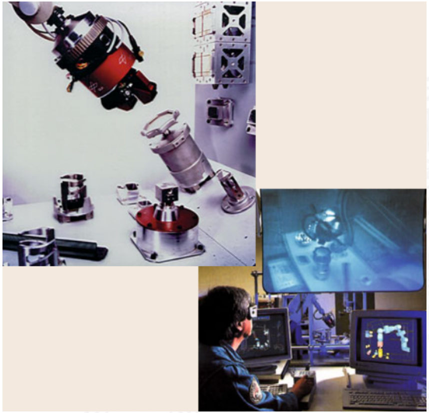
Local Camera



Telerobotic applications

- Robots in hazardous/unstructured workplaces
  - Nuclear robots – where telerobotics starts
  - Space robots
  - Rescue robots

Raymond C. Goertz

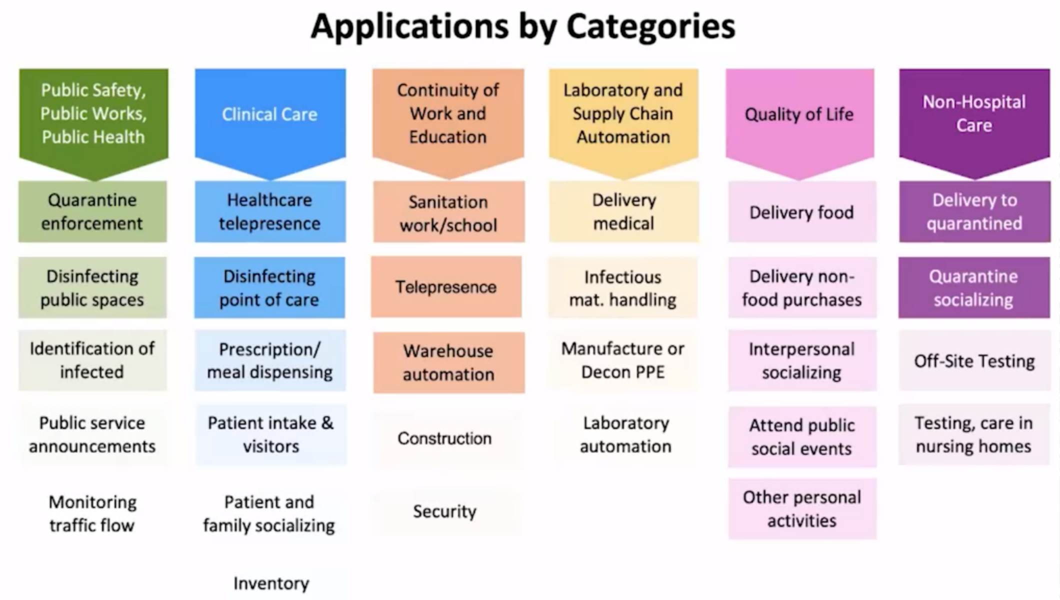


ROTEX
the first teleoerated space robot

- Medical robots – Da vinci robots

Medical robots

- ICRA2020 Plenary Panel - COVID-19 : How Roboticist Can Help?

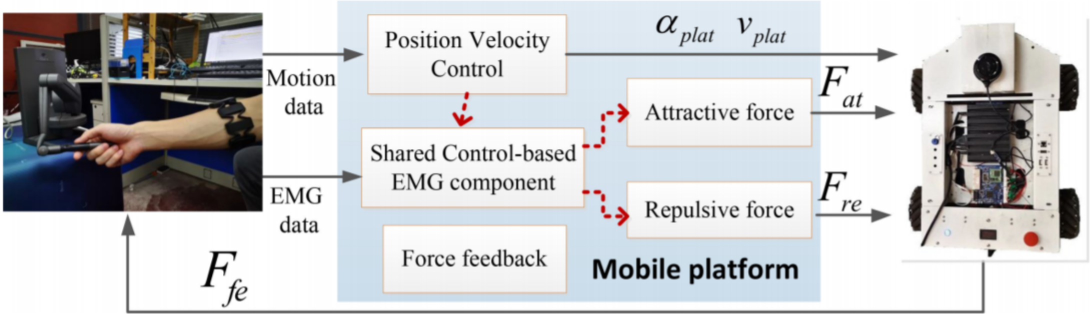


Telerobotics in medical robots

- Surgical robots
- Incorporate haptic feedback
- Multisensory (image (endoscopy), haptic, IMU) fusion
- most are shared control

Telerobotics in mobile robots

- Shared control
- Obstacle avoidance



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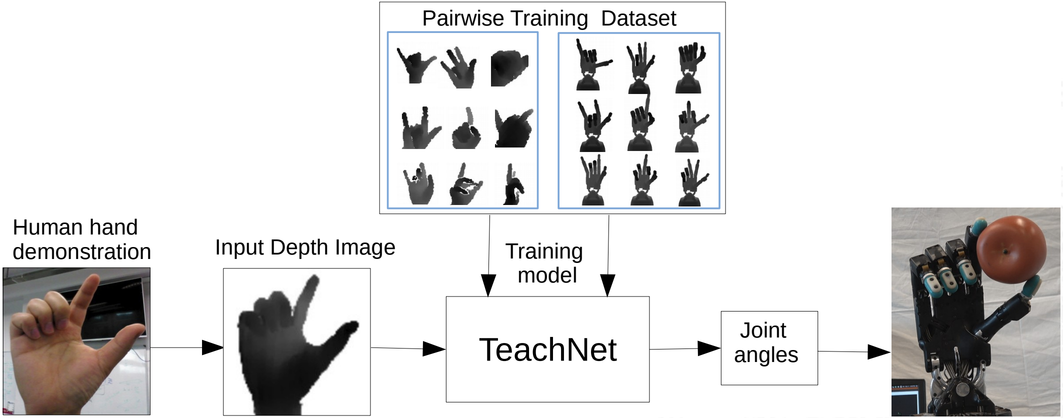
[50] Luo et al. A Teleoperation Framework for Mobile Robots Based on Shared Control. IEEE Robotics and Automation Letters. 2020

Teleoperation in a dexterous robotic hand

- Direct control
- An end- to-end fashion



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[51] Li, et al. TeachNet: Vision-based Teleoperation for Shadow Hand. ICRA2019

Control variables in hand teleoperation

- joint mapping
- fingertip mapping
- pose mapping

Problems in Telerobotics

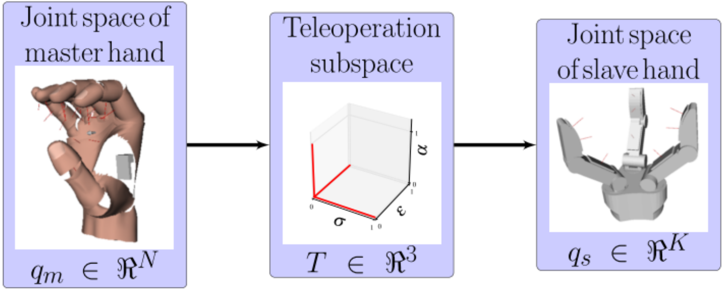
- Time delay
- Force feedback
- Teleoperation between dissimilar kinematic structures
- Multilateral Telerobotics

Robot classification by input devices

- Contact devices
  - Joystick
  - Apriltags
  - wearable gloves/suits/glass
    - Data glove
    - Optical markers
    - IMU (Inertial and magnetic measurement unit)
    - EMG (Electromyography)
    - VR/AR device
    - Haptic devices
- Contactless devices
  - Depth camera(s)
  - Ultraleap

Dataglove

- Cyberglove or wired glove
- Intuitive Hand Teleoperation
  - a low-dimensional and continuous teleoperation subspace
  - mapping between different hand pose spaces



[1]

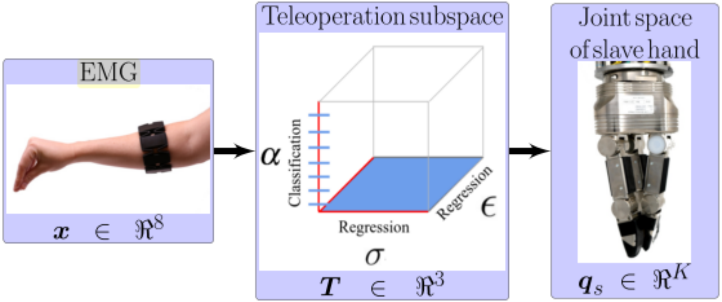
[1] Meeker, et al. Intuitive Hand Teleoperation by Novice Operators Using a Continuous Teleoperation Subspace. ICRA2018

Markers-based teleoperation

- Multi-camera motion capture systems, such as PhaseSpace, OptiTrack
  - accurate point tracking solutions
  - suits must be customized and easily obstruct natural joint motions
  - the correspondence problem between markers on the fingers and cameras

EMG-based teleoperation

- Commercial devices, such as Myo Armband
- EMG-controlled hand teleoperation
  - extracted force information from skeletal muscles through surface EMG
  - mapping forearm EMG into a subspace relevant to teleoperation



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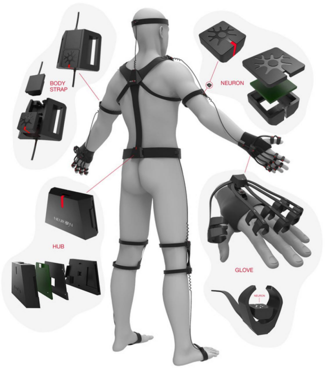
[1] Meeker, et al. EMG-Controlled Hand Teleoperation Using a Continuous Teleoperation Subspace. ICRA2019

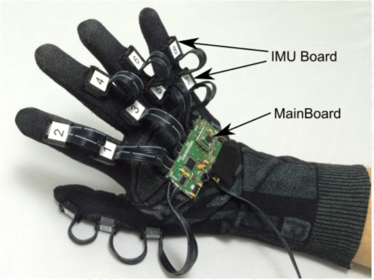
[2] Wen, et al. Force-guided High-precision Grasping Control of Fragile and Deformable Objects using sEMG-based Force Prediction. ICRA2020

IMU-based teleoperation

- Commercial devices, such as PerceptionNeuron
- Sensitive to magnetic/metal environments
- Convert the orientation, angular velocity and acceleration information of human into the control instruction flow of the robotic hand-arm



PerceptionNeuron



Cie-dataglove

Summary of EMG- and IMU-based methods

Advantages:

- Inexpensive
- Easy to setup and use

Disadvantages:

- Provide less versatility and dexterity
- Necessary calibration before start to use it
- More suitable for robotic arms

MR-based teleoperation

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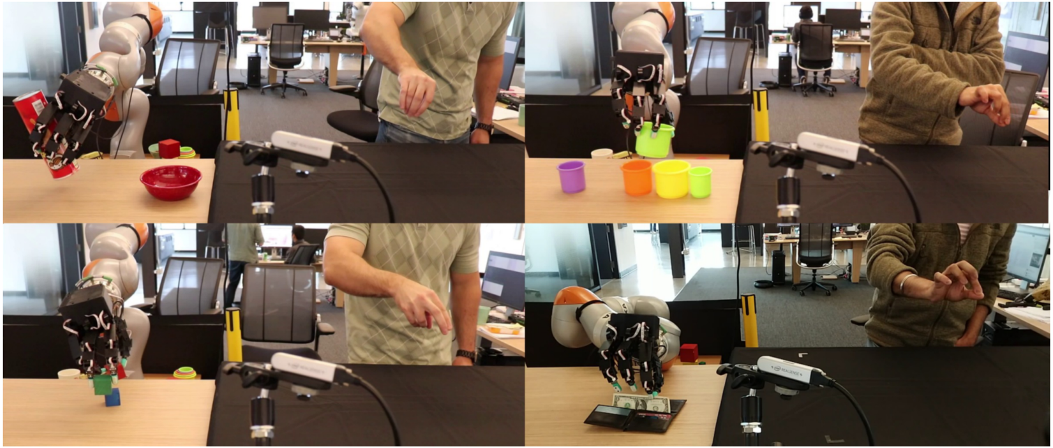
[52] Krupke, et al. Comparison of Multimodal Heading and Pointing Gestures for Co-Located Mixed Reality Human-Robot Interaction. IROS2018

DexPilot: Vision Based Teleoperation of Dexterous Robotic Hand-Arm System



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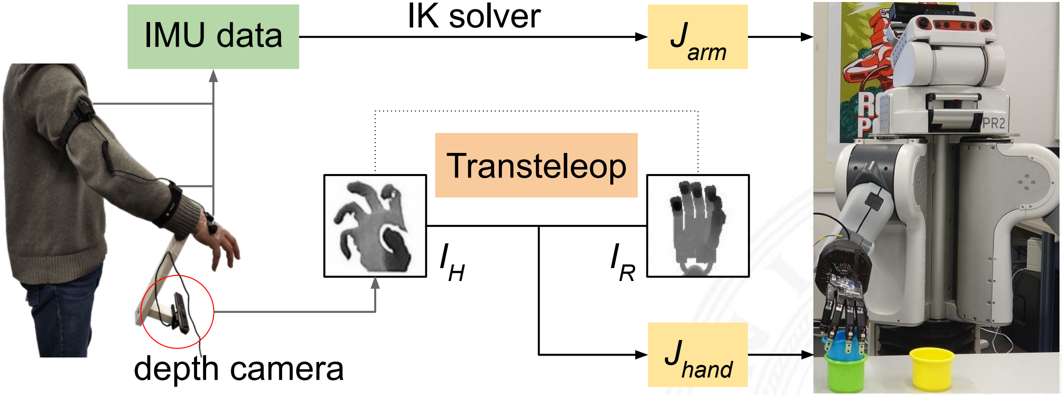
[53] Handa, et al. DexPilot: Vision Based Teleoperation of Dexterous Robotic Hand-Arm System. ICRA2020



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[54] Li, et al. A Mobile Robot Hand-Arm Teleoperation System by Vision and IMU. IROS2020

Summary of Vision-based methods

Advantages:

- Inexpensive
- Easy to setup and use
- Allow natural, unrestricted limb motions and be less invasive

Disadvantages:

- Highly based on human cognitive
- Open-loop control

Future research:

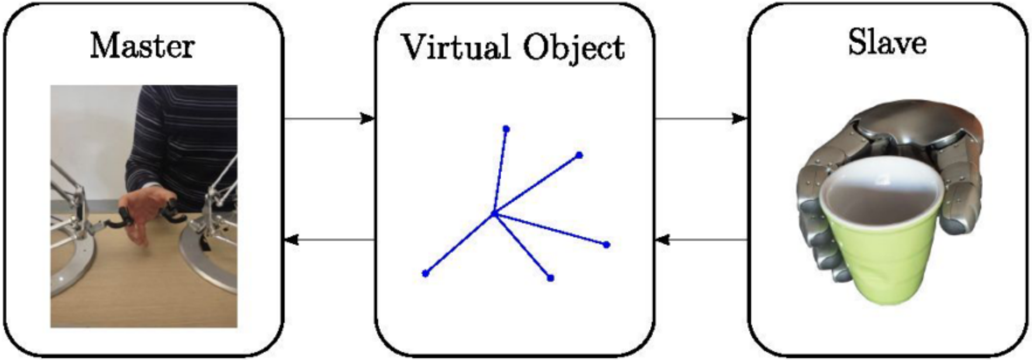
- Real-time hand tracking to achieve an unlimited workspace for the novice
- Closed-loop control (slip detection and force estimation)

Bilateral control and force feedback

- Provide both forward and feedback pathways from the user to the environment and back
- Explicit force feedback
  - the slave's controller forces, which include forces associated with the spring–damper and slave inertia
  - the external forces acting between the slave and the environment
- Also can use alternate displays, such as audio or tactile devices

Object-based Bilateral Telemanipulation

- The master sub-system setup has two Omega.3 haptic devices
- The slave robot is a DLR-HIT II Hand.



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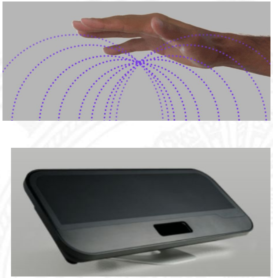
[55] Salvietti, et al. Object-based Bilateral Telemanipulation Between Dissimilar Kinematic Structures. IROS2013

Commercial devices

- CyberTouch (http://www.cyberglovesystems.com/cybertouch)
- HaptX gloves (https://haptx.com/technology)
- Ultraleap (https://www.ultraleap.com/haptics)

Cyber Touch

HaptX Gloves



Ultraleap

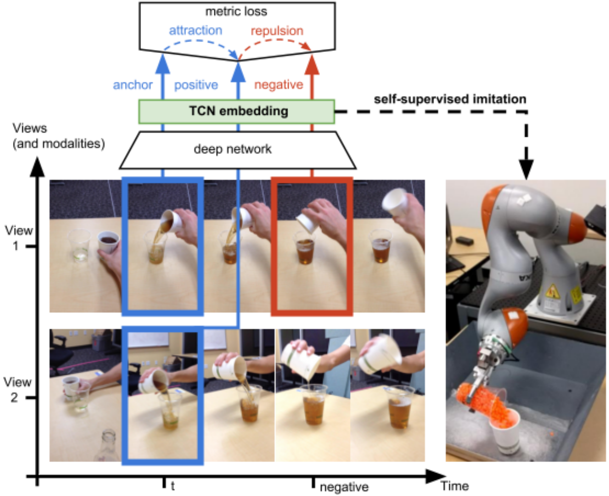
Imitation learning (learn from demonstration)

	Imitation learning	$\Longleftrightarrow$	Telerobotics
Given	demonstrations or demonstrator		demonstrations or demonstrator
Goal	train a policy to mimic demonstrations		repeat/copy demonstrations

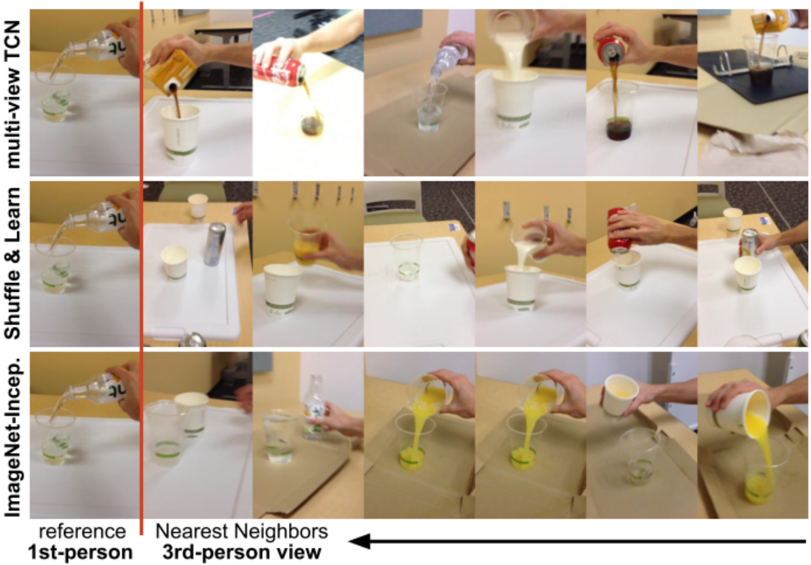
Research goals

1. Learn suitable representations for understanding object interaction and enabling robotic imitation of a human
2. One-shot/few-shot learning
3. ...

- learn robotic behaviors from unlabeled videos recorded from multiple viewpoints
- Anchor, positive, negative



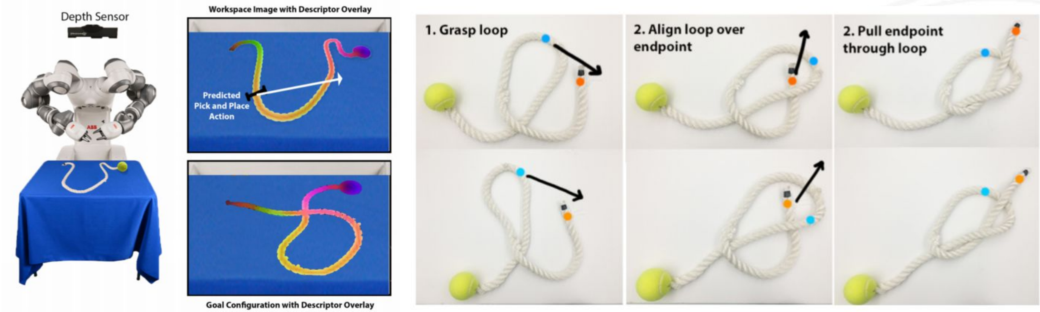
Label-free pose imitation by TCN



Label-free pose imitation by TCN

Learning Rope Manipulation Policies

- Dense depth object descriptors
- Learn from video demonstrations
- Trained on synthetic depth Data



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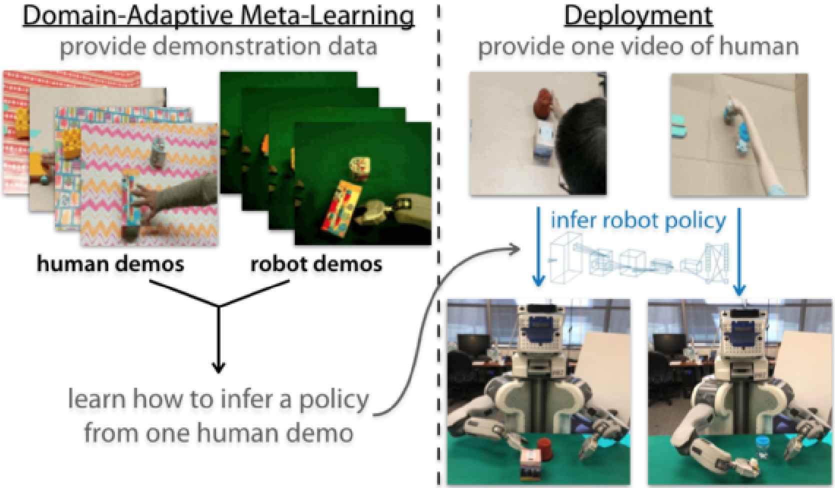
[56] Sundaresan, et al. Learning Rope Manipulation Policies Using Dense Object Descriptors Trained on Synthetic Depth Data. ICRA2020

One-shot/few-shot imitation learning

- quickly learn a new task from a small amount of demonstrations
- Model-Agnostic Meta-Learning (MAML)[32]



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