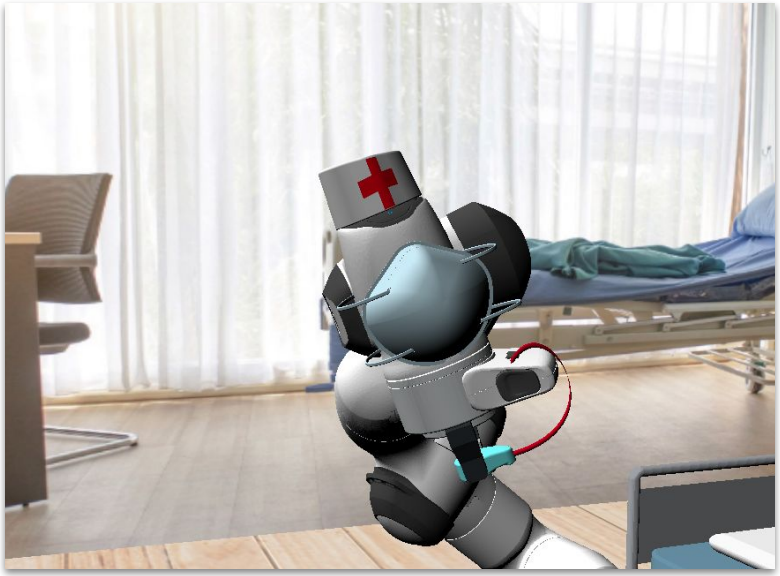
Tele-auscultation Bot

CS225a Final Project



Stanford University

November 17, 2020

Stanford ENGINEERING

Meet the team

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Tracy Chen

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Motivation

- Pneumonia (fluid in lungs) is a serious symptom of COVID-19
- Healthcare workers perform auscultations to assess pneumonia
- Forceful exhalation poses a serious risk for airborne transmission.

https://www.ekuore.com/the-ekuore-pro-electronic-stethoscope-helps-reduce-covid-19-spreading-among-health-workers/

Motivation

- Pneumonia (fluid in lungs) is a serious symptom of COVID-19
- Healthcare workers perform auscultations to assess pneumonia
- Forceful exhalation poses a serious risk for airborne transmission.

Teleoperated robotic auscultation can make such procedures safe without losing effectiveness.

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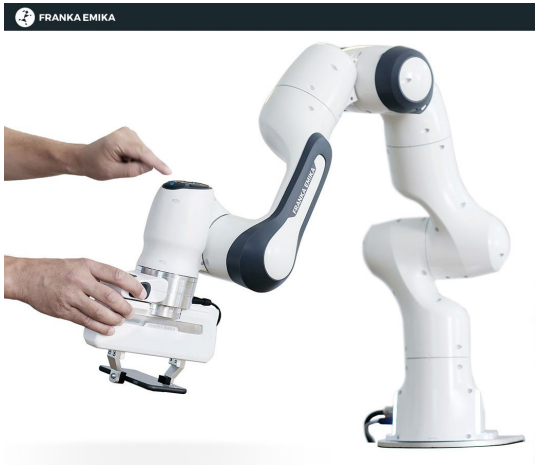
How can auscultation be done remotely?

A robot instead of a human doctor in the room



Why the Franka Panda?

- Designed for safe interactions
- Provides torque control
- Less expensive than most robots

How can we design this from home?

A robot instead of a human doctor in the room

Why the Franka Panda?

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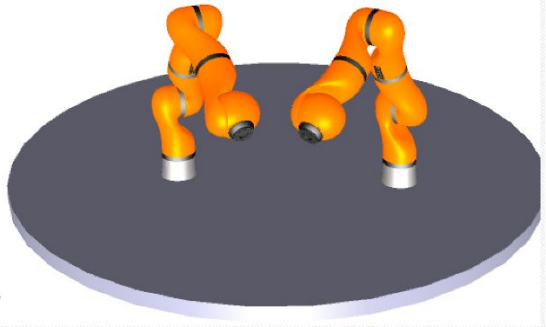
A simulated human patient and a simulated robot

Simulation and Active Interfaces (SAI 2.0)

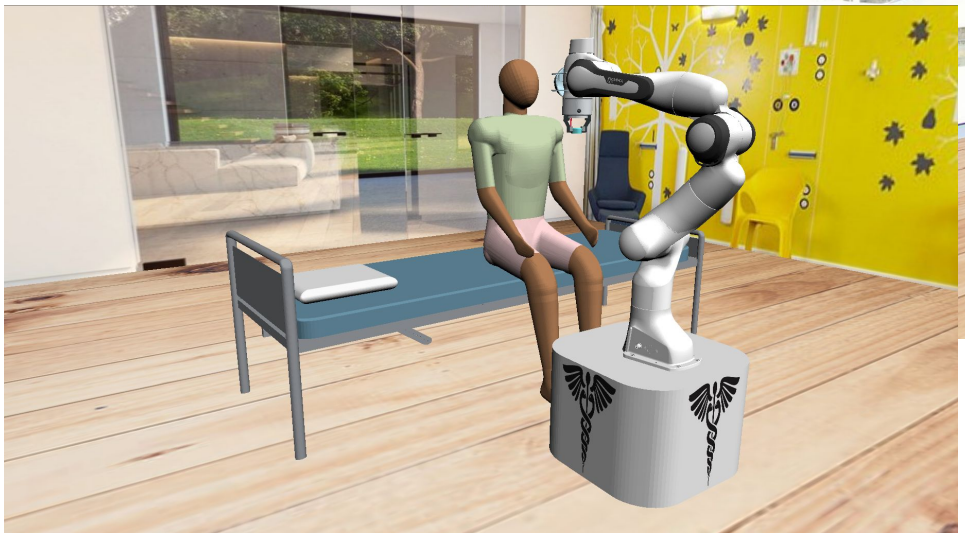


Why the SAI2 environment?

- Implements operational space control
- Good at handling multi-point contact in real-time
- Provides for haptic interaction
- Lots of support available (thanks teaching team!)

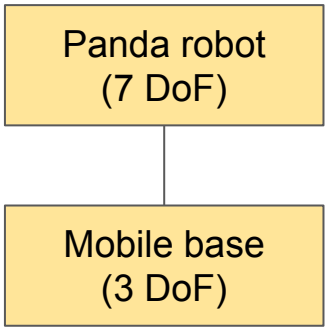
Simulation Environment Modeling

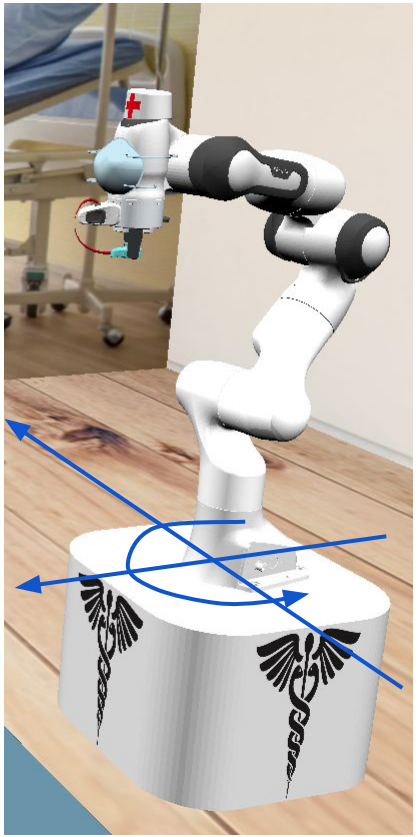
- World (clinical room)



Simulation Environment Modeling

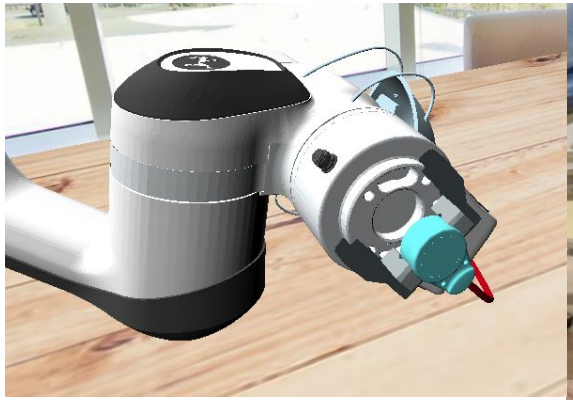
- World (clinical room)
- Panda arm with mobile base

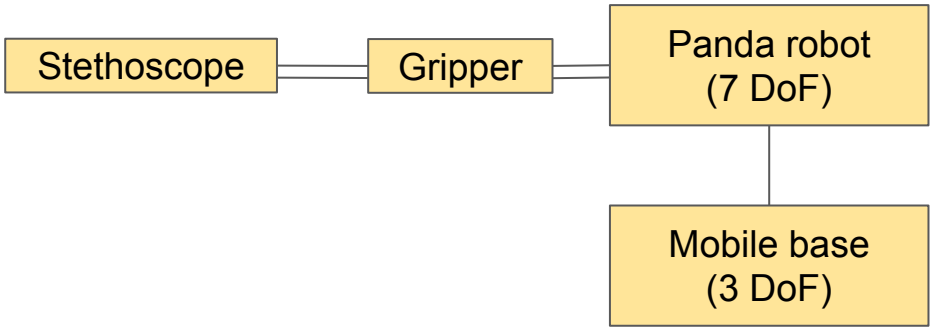




Simulation Environment Modeling

- World (clinical room)
- Panda arm with mobile base
  - Digital stethoscope





https://grabcad.com/library/stethoscope-10

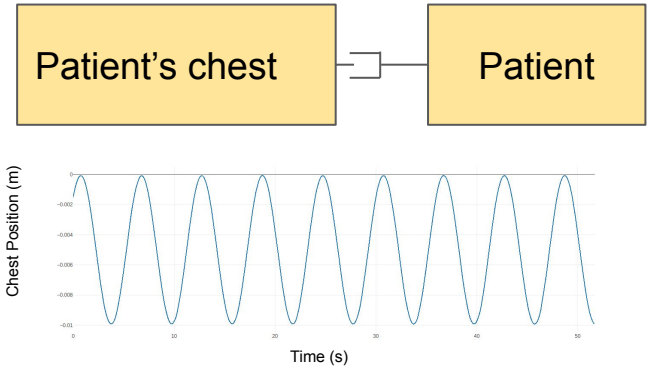
Simulation Environment Modeling

- World (clinical room)
- Panda arm with mobile base
  - Digital stethoscope
- Bench
- Patient

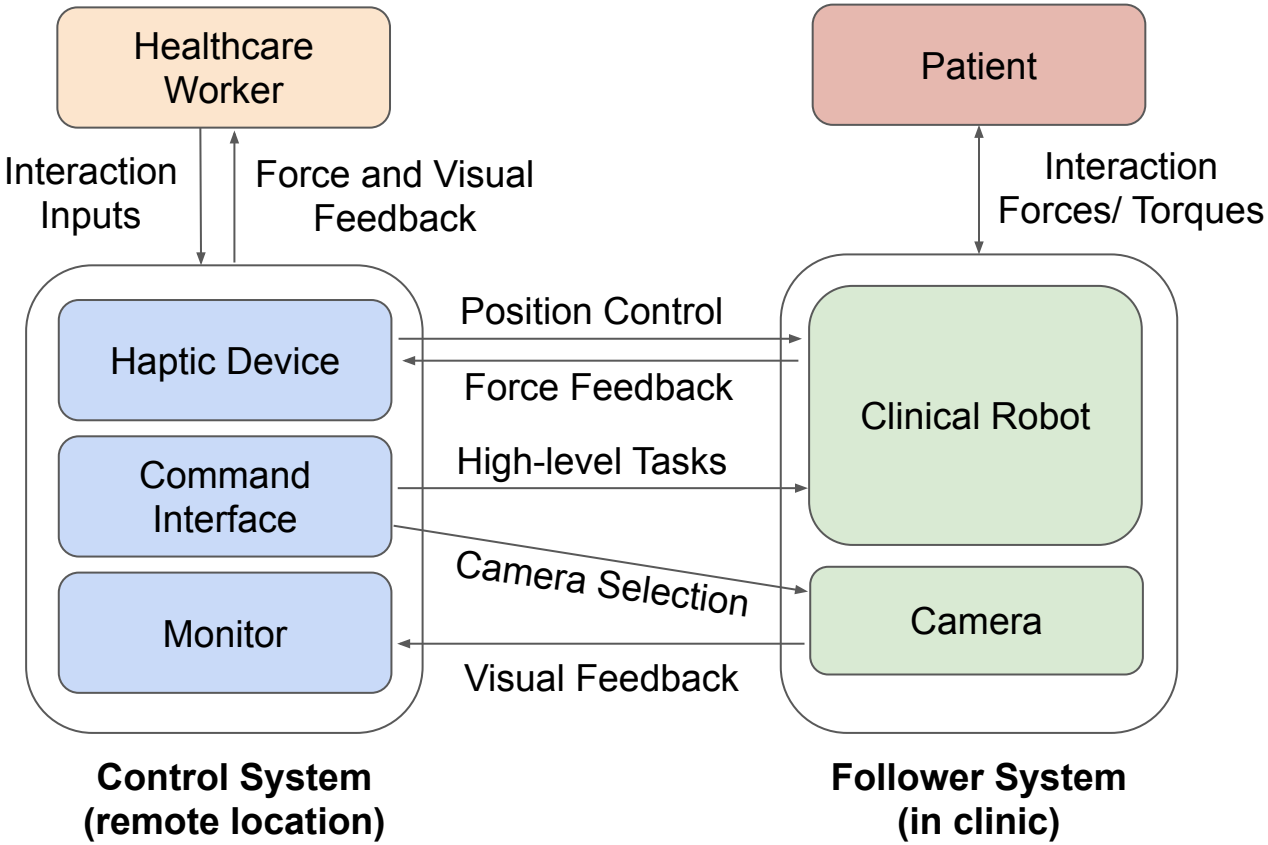
https://grabcad.com/library/sitting_mannequin-1
https://grabcad.com/library/adjustable-hospital-bed-1

Simulation Environment Modeling

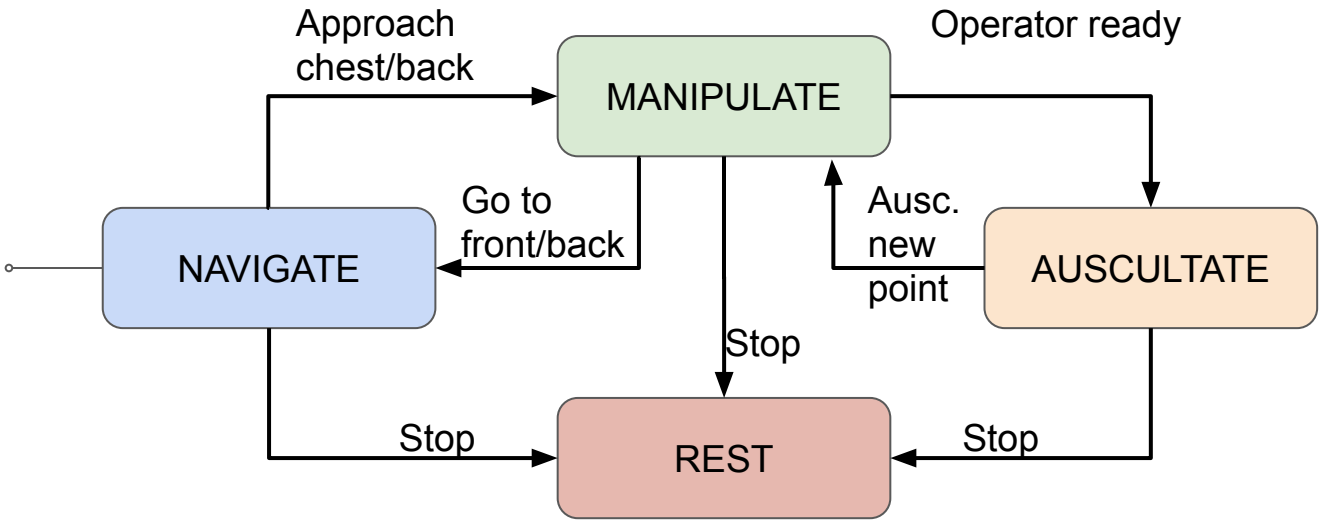
- World (clinical room)
- Panda arm with mobile base
  - Digital stethoscope
- Bench
- Patient
  - Moving chest to imitate breathing



System Diagram



High-level State Machine

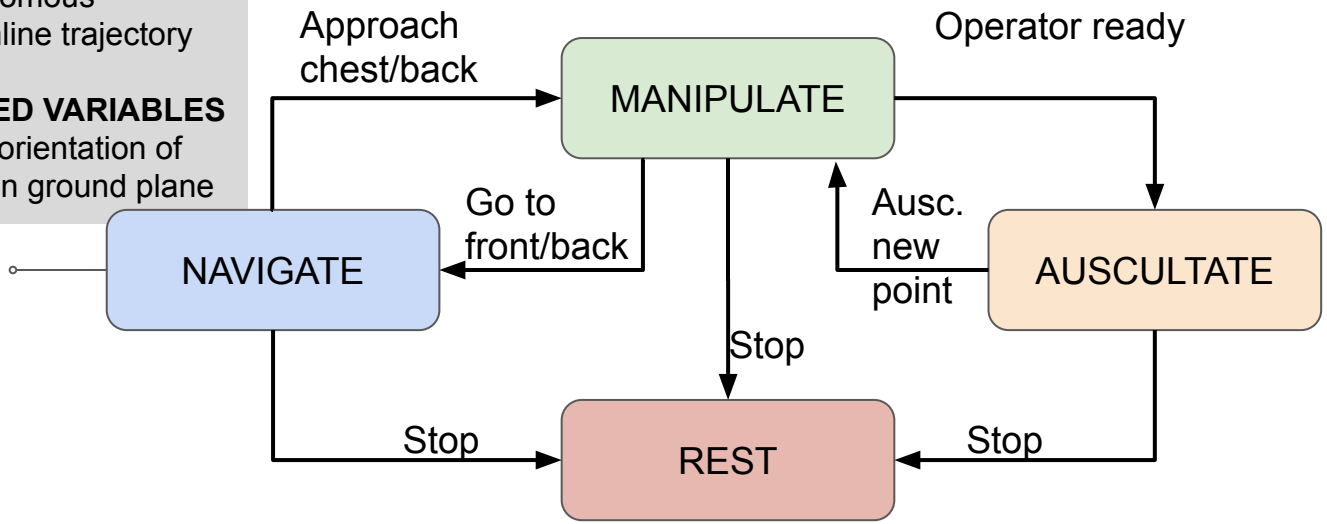


(State transitions occur in response to changes to a Redis key)

redis

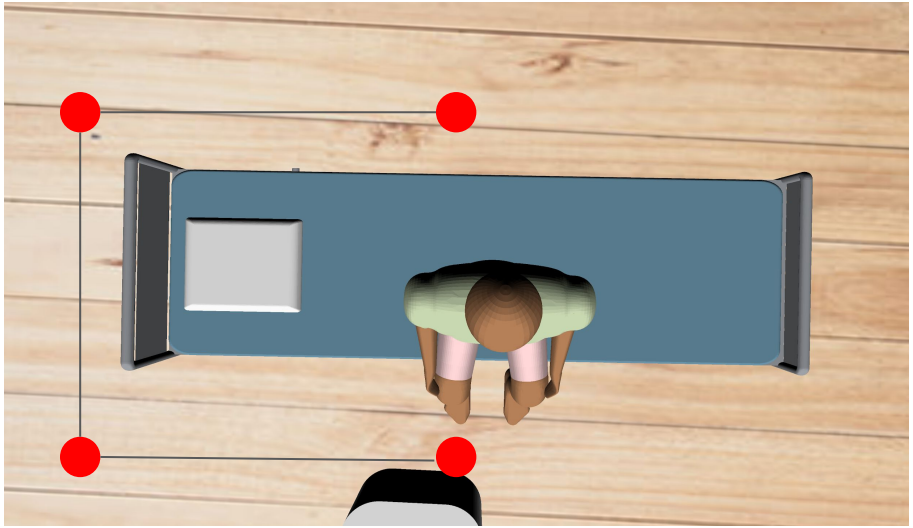
Control strategies

MODE Autonomous
METHOD Online trajectory generation
CONTROLLED VARIABLES Position and orientation of mobile base in ground plane



NAVIGATE

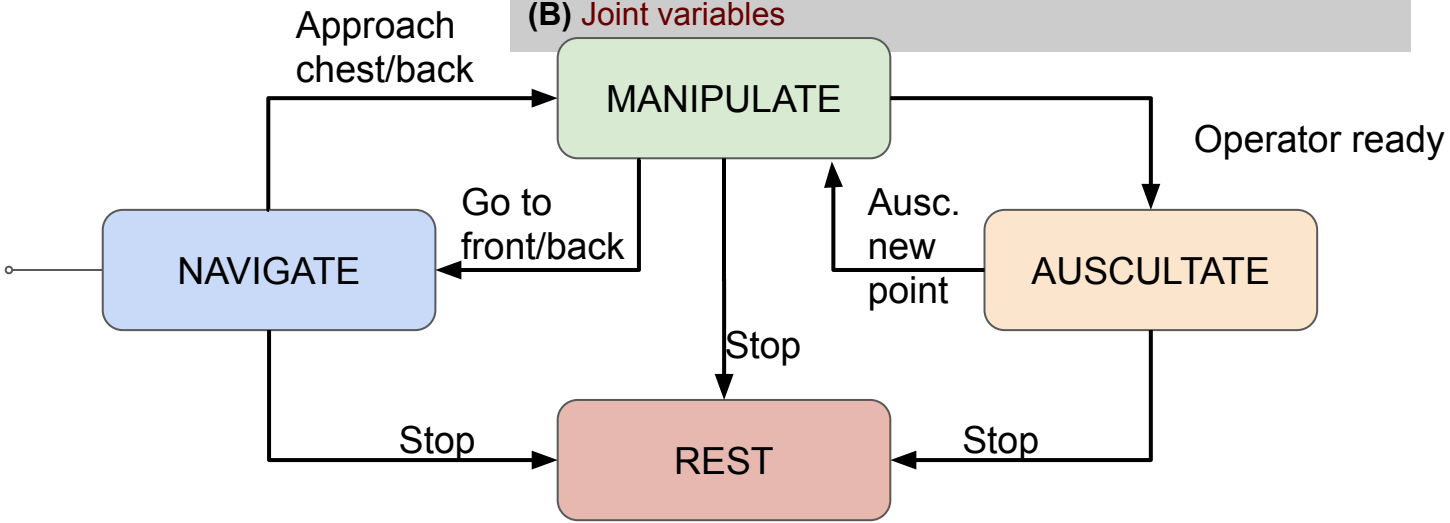
Move to Front/Back



- Pre-define way-points to navigate around the bench
- Use Redis client to command robot to move from the front to the back, or vice versa
- Proceed to manipulation state for the region to be examined

Control strategies

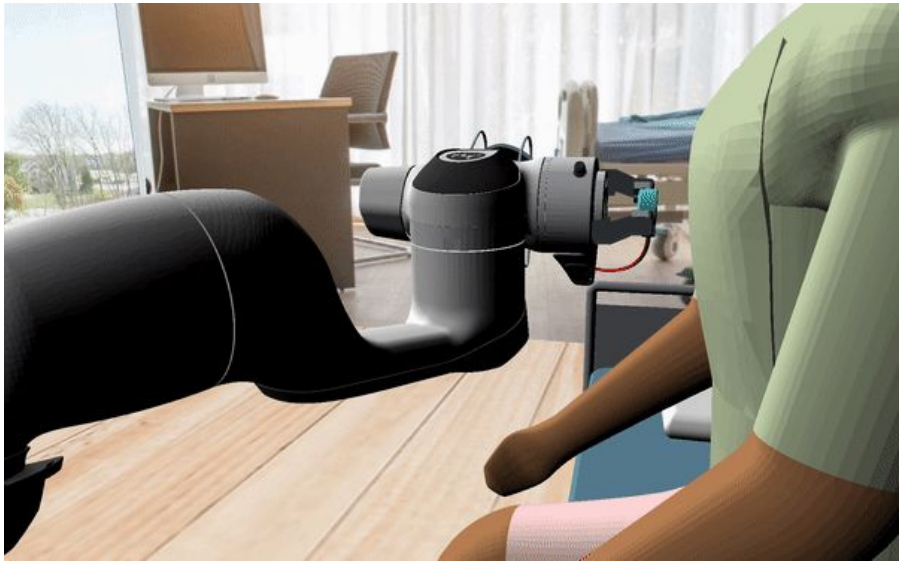
MODE Autonomous
METHOD Operational space control (A);
Nullspace joint motion damping, gravity compensation (B)
CONTROLLED VARIABLES
(A) Position and orientation of stethoscope
(B) Joint variables



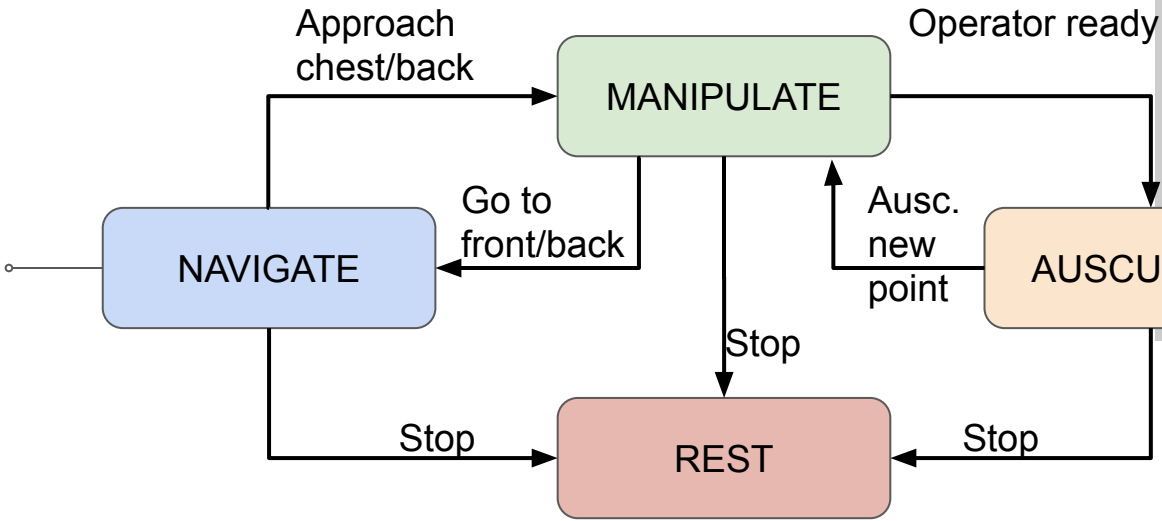
MANIPULATE

Approach Chest Position

- Pre-define set of desired positions several inches from the chest
- Use Redis client to command robot to move to these points
- Task space control with cap on velocity and joint damping in the null space
- Wait for auscultation to take over control



Control strategies



MODE
Manual (A);
Autonomous (B)
METHOD*
Bimodal teleoperation with 3-DoF Falcon haptic device (A);
Virtual compliance (B)

CONTROLLED VARIABLES
(A) Position of stethoscope
(B) Orientation of stethoscope

*nullspace joint damping

AUSCULTATE

- Falcon is 3-DoF
  - can command position and give force feedback
  - cannot command orientation at the same time
- Contact compliance
  - Weaken orientation control: conform to environment and makes flush contact
  - Strengthen translation control: prevent slip

MODE
Manual (A);
Autonomous (B)
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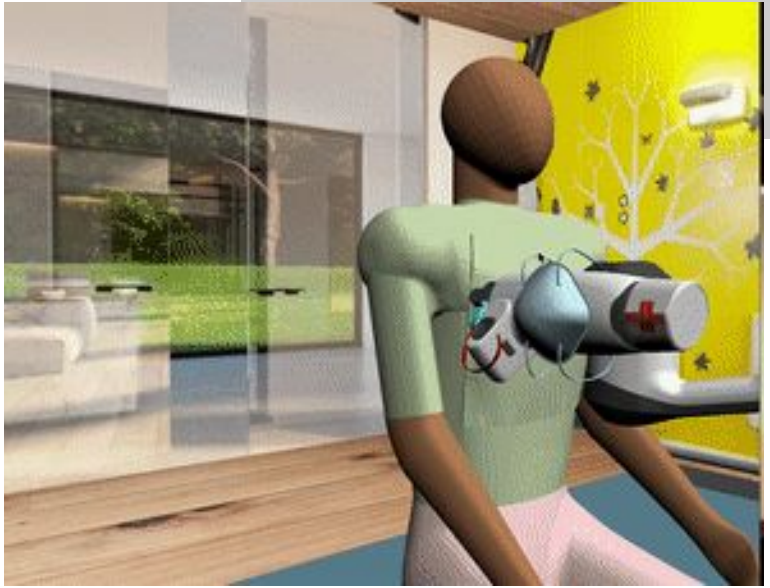
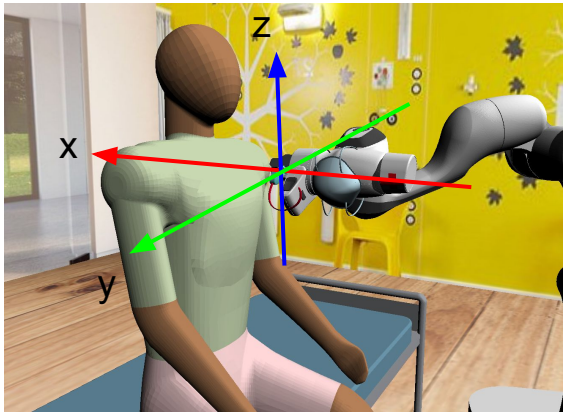
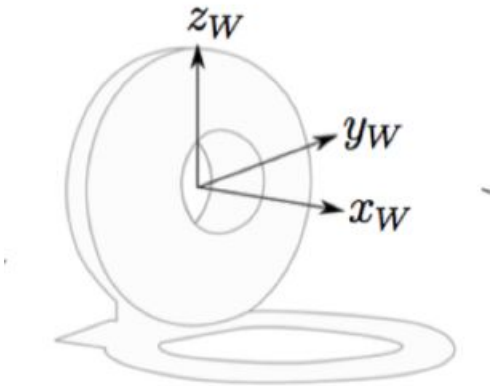


AUSCULTATE

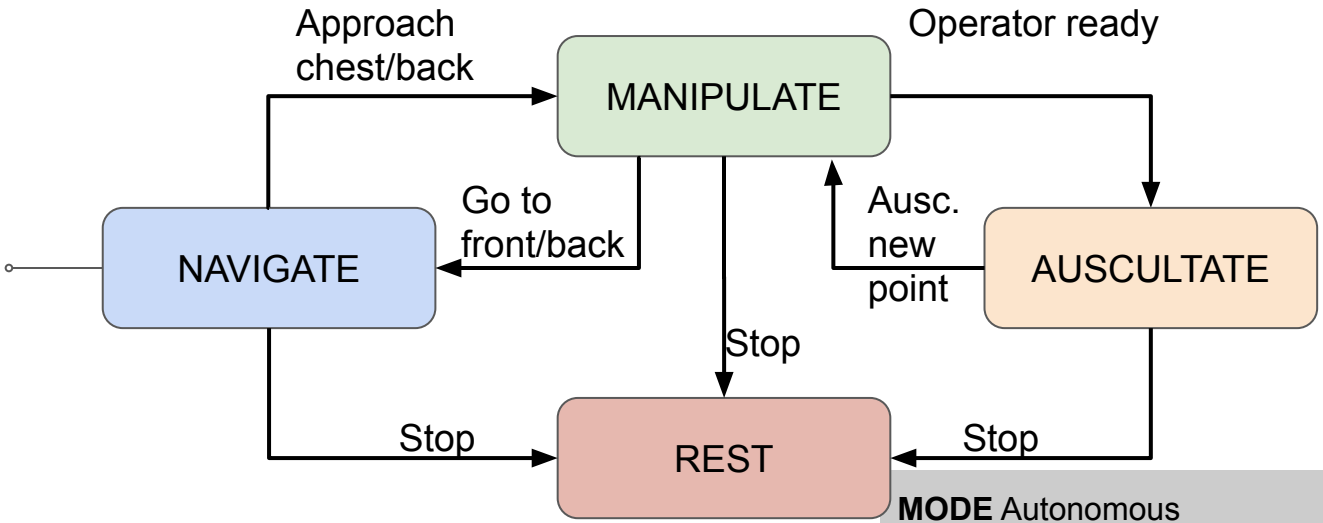
Teleoperated Auscultation



- Read haptic position and write to global desired point (frame change)
- Read end-effector force and moment, damp and cap, and write force to haptic device



Control strategies



MODE Autonomous
METHOD Gravity compensation;
hold current configuration
CONTROLLED VARIABLES Joint variables

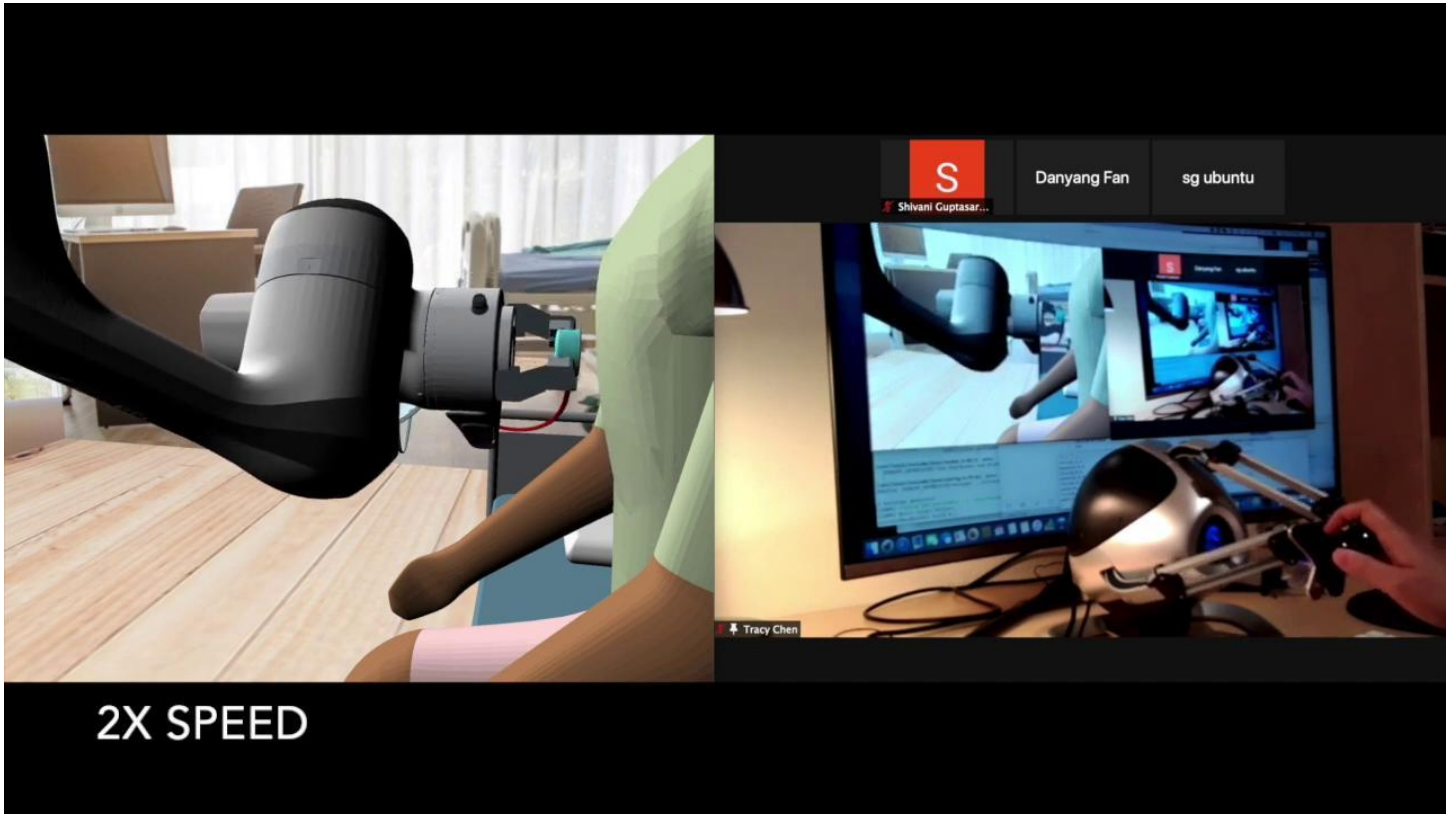
Future work

- Sensing and localization for real-world implementation
  - Computer vision for variability across patients and sitting positions
  - Mapping of the room; fixed and moving obstacles
  - Force/torque sensing at the stethoscope;
    or calibration for sensor placed at robot end-effector
- Real-time collision avoidance for navigation
- Tool design for stable grasp/attachment of other medical equipment
- Extension to other medical procedures

Lessons Learned and Challenges

- Don’t be lazy and cut corners with Git
- Reduce sampling frequency of tasks that do not need high sampling (OTG)
- Test on multiple machines to check compatibility
- Stiffness and damping tuning takes time
- Be careful with how environments handle collision meshes

Video Demonstration



Media Citations

- CAD Files
  - Mannequin: https://grabcad.com/library/sitting_mannequin-1
  - Bed: https://grabcad.com/library/adjustable-hospital-bed-1
  - Hat: https://grabcad.com/library/nepali-topi-hat-1
  - Mask: https://grabcad.com/library/n95-mask-version-2-1
  - Stethoscope: https://grabcad.com/library/experimental-stethoscope-1
- Symbols Images
  - Med symbol: http://www.vitalmedicalservices.com/caduceus-medical-symbol-vector-1023774/
  - Red cross symbol: https://www.crwflags.com/fotw/flags/int-red.html
- Background Images
  - Wall 1: https://www.pinterest.ca/pin/69524387987517925/
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  - Wall 3: https://www.virtually-anywhere.com/hospital-virtual-tours/
  - Wall 4: https://www.huffingtonpost.co.uk/entry/coronavirus-latest-29-april_uk_5ea91a95c5b6fb98a2b4e16d?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAMuJeLmsduLSn-B0CdQ9Y3JLit4PAiP6Nr99-QPomqSe9VgiLpxYDoTe-URZoqekfkUuoX35IbVTz7Jh1w16oGKl-HGAJRAB7O1gBOyyAaQ7ceJIg6eCpai39YGAMstj-bvF_McIKWSjYk0UR_zVNOMUxp7cBuIN-5AzMeEhLbsA
  - Ceiling and Floor: https://www.freepik.com/free-photo/texture-background_1167463.htm#page=1&query=Dark%20wood%20background&position=16
- Texture Images
  - Mask texture: https://www.pinterest.com/pin/521784306819527423/
  - Shirt texture: https://media.istockphoto.com/photos/cotton-linen-woven-fabric-texture-background-in-light-pale-lime-green-picture-id1130187683?k=6&m=1130187683&s=170667a&w=0&h=BS15OJZMBeS-CNpzAaJXSztS8SMAfFXcaCoPtlwqsxk=
  - Bed Texture: https://cutewallpaper.org/21/stainless-steel-background/view-page-21.html
  - Shorts Texture: https://www.fabric.com/buy/0342767/michael-miller-cotton-couture-broadcloth-blush
  - Bed Sheet Texture: https://www.pinterest.ch/pin/639933428279814517/
  - Skin Texture: https://madhatterstatic.wordpress.com/2014/03/23/texturing-skin-texture/
  - Pillow and Hat Texture: https://www.needpix.com/search/white%20cloth%20background
  - Stethoscope Texture: http://www.solidbackgrounds.com/2048x2048-electric-blue-solid-color-background.html
- Video Music
  - SOLO ACOUSTIC GUITAR by Jason Shaw http://freemusicarchive.org/music/Jason_Shaw