Tele-auscultation Bot

CS225a Final Project

November 17, 2020
Meet the team

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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.

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- Pneumonia (fluid in lungs) is a serious symptom of COVID-19
- Healthcare workers perform auscultations to assess pneumonia
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Teleoperated robotic auscultation can make such procedures safe without losing effectiveness.

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?

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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

![Diagram of patient's chest and patient with moving chest](image.png)

![Graph of chest position over time](graph.png)
High-level State Machine

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

**MODE** Autonomous

**METHOD** Online trajectory generation

**CONTROLLED VARIABLES**
Position and orientation of mobile base in ground plane

- NAVIGATE
  - Approach chest/back
  - Go to front/back
  - Stop

- MANIPULATE
  - Stop

- REST
  - Stop

- AUSCULTATE
  - Operator ready
  - Ausc. new point
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

NAVIGATE
- Approach chest/back
- Go to front/back
- Stop

MANIPULATE
- Operator ready

AUSCULTATE
- Stop

REST
- Ausc. new point
- Stop
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

- **Control strategies**
  - NAVIGATE
  - MANIPULATE
  - AUSCULTATE
  - REST

  - Approach chest/back → MANIPULATE
  - Go to front/back → NAVIGATE
  - Operator ready
    - Ausc. new point → AUSCULTATE
    - Stop
  - Stop → REST
  - Stop

  - Stop
- 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
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

Diagram:

1. NAVIGATE
   - Approach chest/back
   - Go to front/back
   - Stop

2. REST
   - Stop

3. MANIPULATE
   - Operator ready
   - Ausc. new point

4. AUSCULTATE
   - Stop

Flow:
- From NAVIGATE to MANIPULATE via Approach chest/back
- From NAVIGATE to REST via Stop
- From REST to MANIPULATE via Stop
- From MANIPULATE to AUSCULTATE via Operator ready
- From AUSCULTATE to NAVIGATE via Ausc. new point
- From NAVIGATE to REST via Go to front/back
- From REST to NAVIGATE via Stop

Additional Actions:
- Approach chest/back
- Go to front/back
- Stop
- Ausc. new point
- Operator ready
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](https://grabcad.com/library/sitting_mannequin-1)
  - Bed: [https://grabcad.com/library/adjustable-hospital-bed-1](https://grabcad.com/library/adjustable-hospital-bed-1)

- **Symbols Images**
  - Red cross symbol: [https://www.crwflags.com/fotw/flags/int-red.html](https://www.crwflags.com/fotw/flags/int-red.html)

- **Background Images**
  - Wall 1: [https://www.pinterest.ca/pin/69524387987517925/](https://www.pinterest.ca/pin/69524387987517925/)
  - Wall 2: [https://swedese.com/references/teenage-cancer-trust-london-uk](https://swedese.com/references/teenage-cancer-trust-london-uk)
  - Wall 4: [https://www.huffingtonpost.co.uk/entry/coronavirus-latest-29-april_uk_5ea91a95c5b6f98a2b4e16d?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AA994MuJdMvSdUlSb-B00cD9Y3JLi4PAlP6N99-QPomqSe9VgIpYPxDYDoTe-UROqekf0UuoX35lbVTz7Jh1w16oGK1-HGAJRAB701gBqvVAAQ7ceJlp6eCpa39YGAMSti-byF_MlKWSjYk0UR_zVNOMUXp7cBuLN-5A8MeEHlbsA](https://www.huffingtonpost.co.uk/entry/coronavirus-latest-29-april_uk_5ea91a95c5b6f98a2b4e16d?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AA994MuJdMvSdUlSb-B00cD9Y3JLi4PAlP6N99-QPomqSe9VgIpYPxDYDoTe-UROqekf0UuoX35lbVTz7Jh1w16oGK1-HGAJRAB701gBqvVAAQ7ceJlp6eCpa39YGAMSti-byF_MlKWSjYk0UR_zVNOMUXp7cBuLN-5A8MeEHlbsA)
  - Ceiling and Floor: [https://www.freepik.com/free-photo/texture-background_1167463.htm#page=1&query=Dark%20wood%20background&position=16](https://www.freepik.com/free-photo/texture-background_1167463.htm#page=1&query=Dark%20wood%20background&position=16)

- **Texture Images**
  - Bed Sheet Texture: [https://www.pinterest.ch/pin/639933428279814517/](https://www.pinterest.ch/pin/639933428279814517/)
  - Skin Texture: [https://madmattterstatic.wordpress.com/2014/03/23/texturing-skin-texture/](https://madmattterstatic.wordpress.com/2014/03/23/texturing-skin-texture/)
  - Pillow and Hat Texture: [https://www.needpix.com/search/white%20cloth%20background](https://www.needpix.com/search/white%20cloth%20background)
  - Stethoscope Texture: [http://www.solidbackgrounds.com/2048x2048-electric-blue-solid-color-background.html](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](http://freemusicarchive.org/music/Jason_Shaw)