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Sant'Anna
School of Advanced Studies – Pisa

Teleoperated Multimodal Robotic Interface for Telemedicine: a Case Study on Remote Auscultation

Sara Falleni, **Alessandro Filippeschi**,
Emanuele Ruffaldi and Carlo Alberto Avizzano

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Introduction and motivation

- Population is aging in all developed countries
  - Increased need for examinations
  - Shortage of specialists

- Situations in which examinations are required, but specialists are not available
  - Countries with limited Healthcare systems
  - Countryside
  - War scenarios

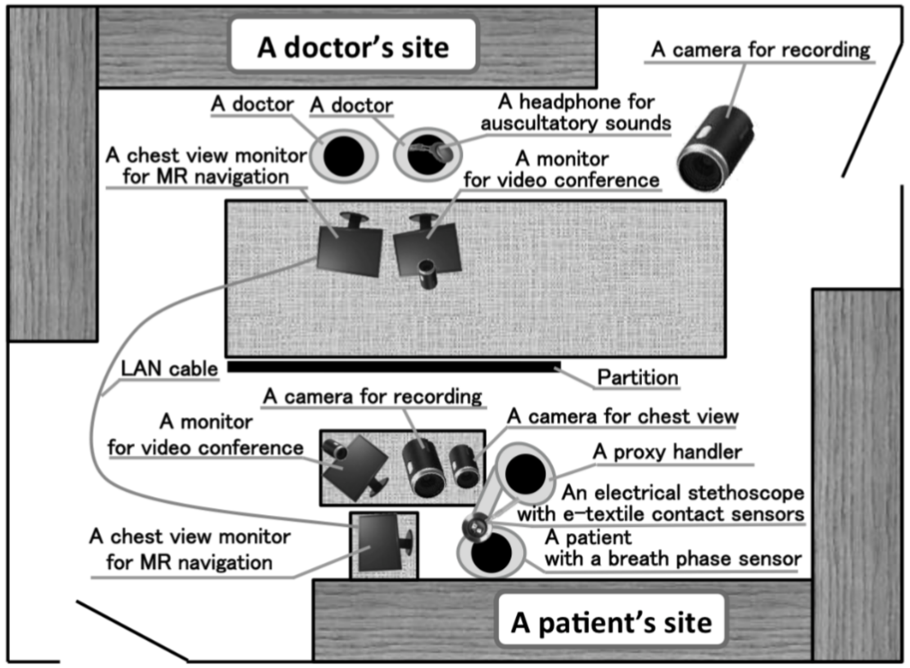
Telemedicine is a valuable answer to these problems, problem tackled within the ReMeDi project

Auscultation is one of the most common and important exams for patients screening

Importance of investigation of robotics technologies for teleauscultation, in particular the role of haptic feedback

State of the art

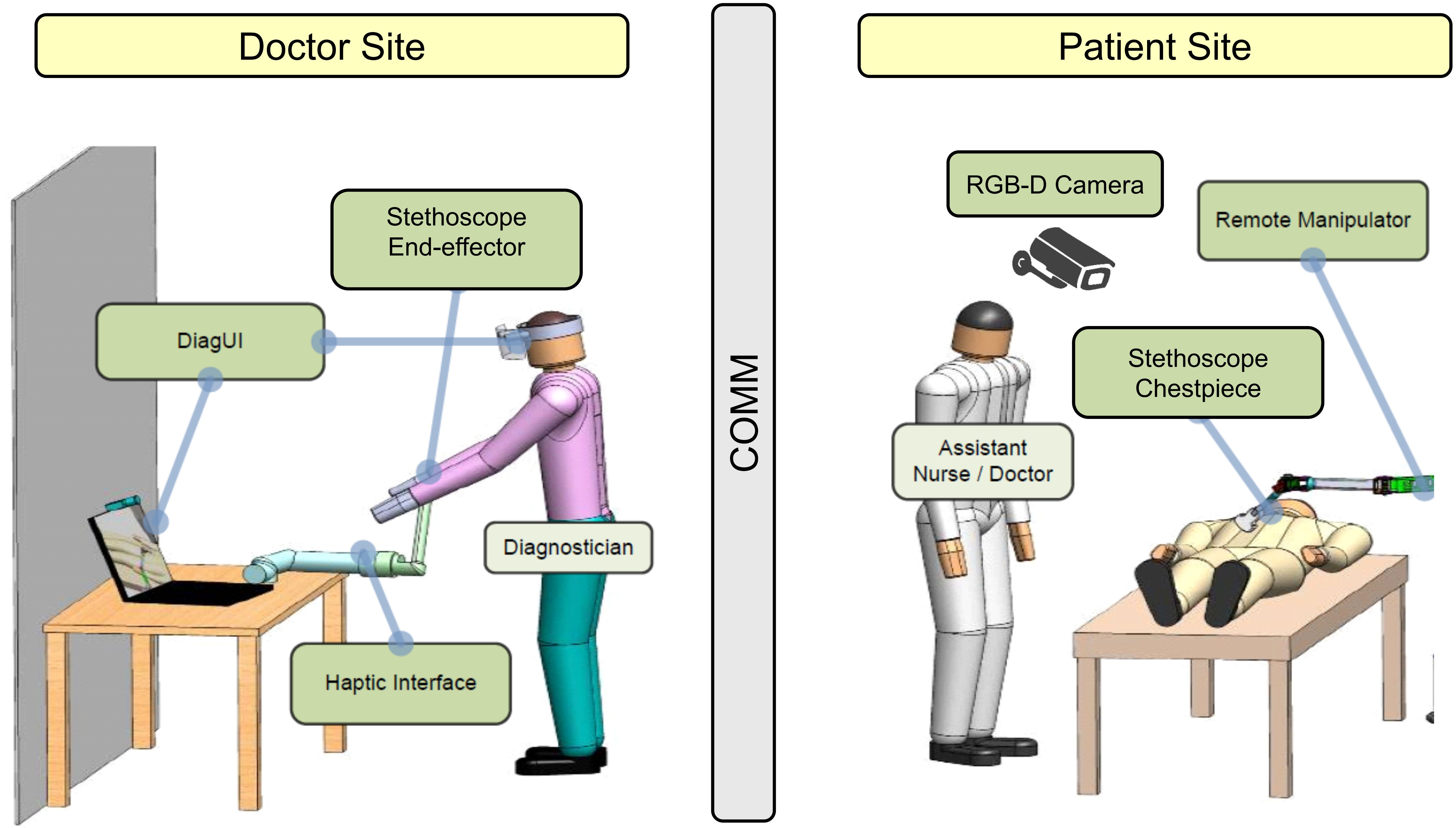
- Most of the telemedicine systems focus on videoconference, i.e. exploitation of visual and auditory channels, this applies also to auscultation



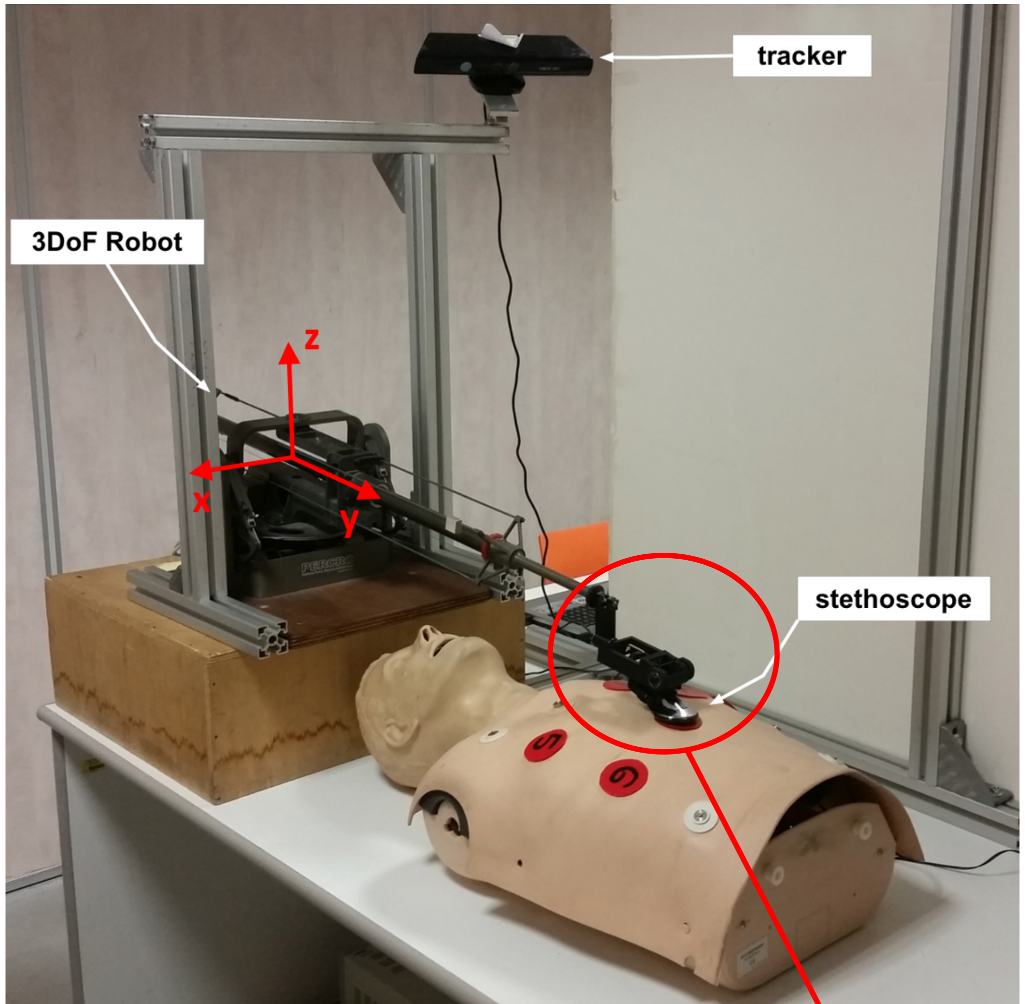
- Examinations is mediated by an assistant, who is often a crucial medium of the specialist during the examination

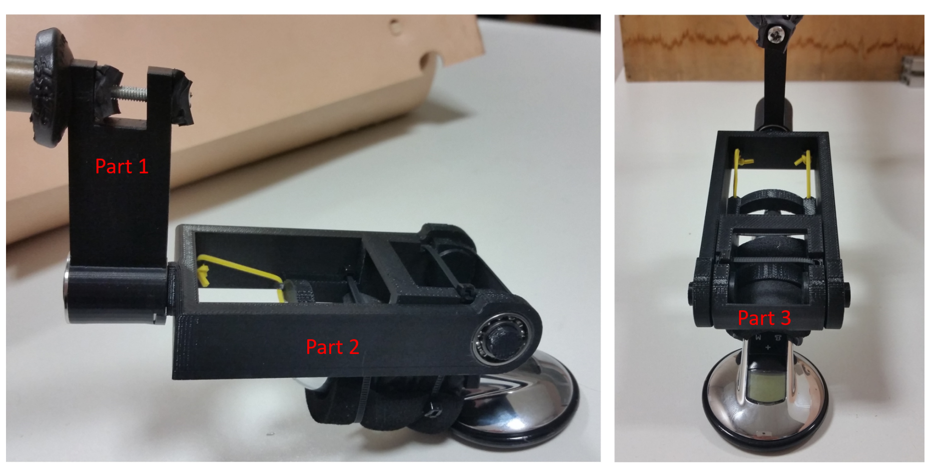
- Whereas haptic feedback is explored in other examinations (e.g. palpation and ultrasonography), the role of haptic feedback in teleauscultation has not been explored.

Multimodal Telauscultation System



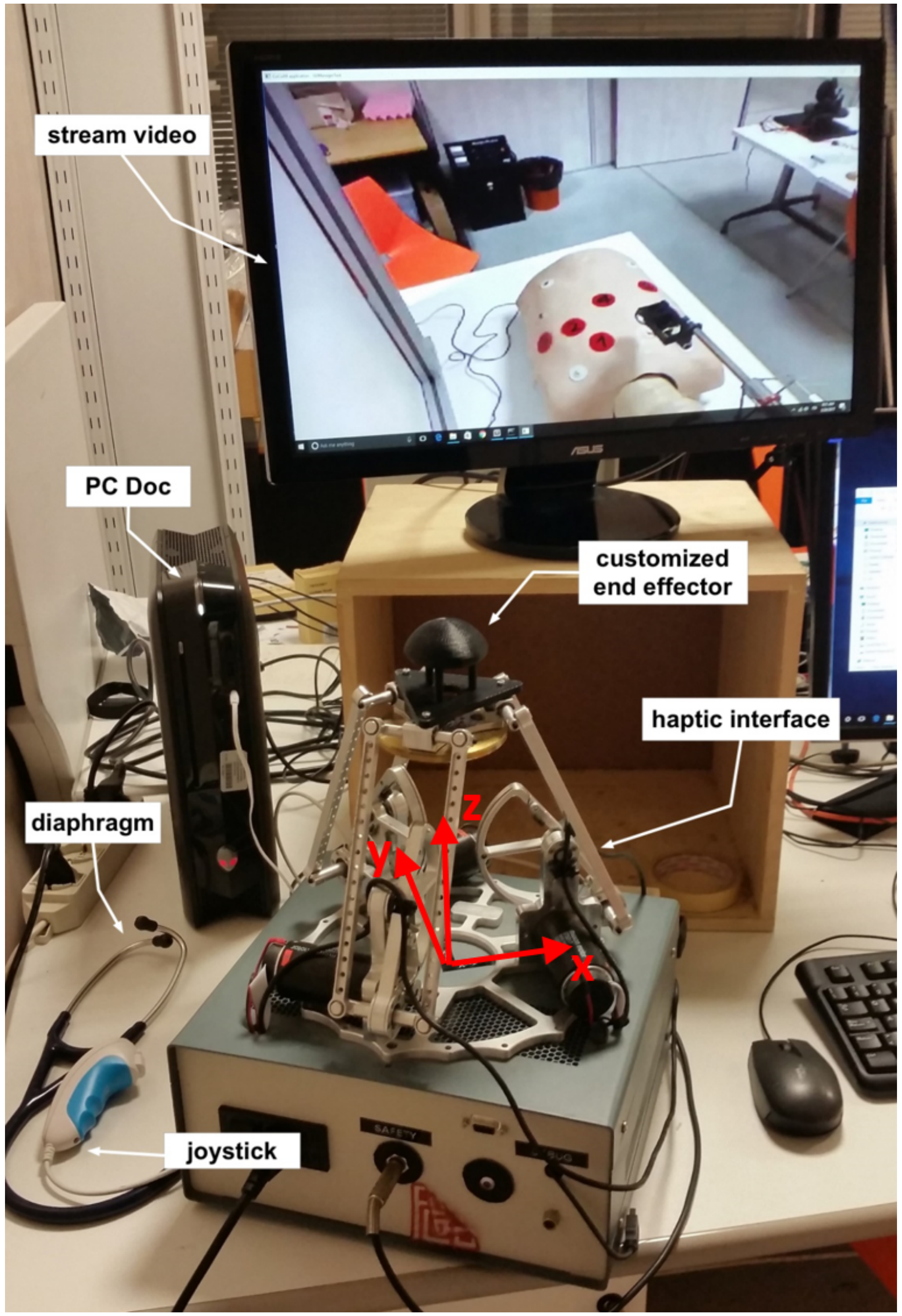
Patient Site





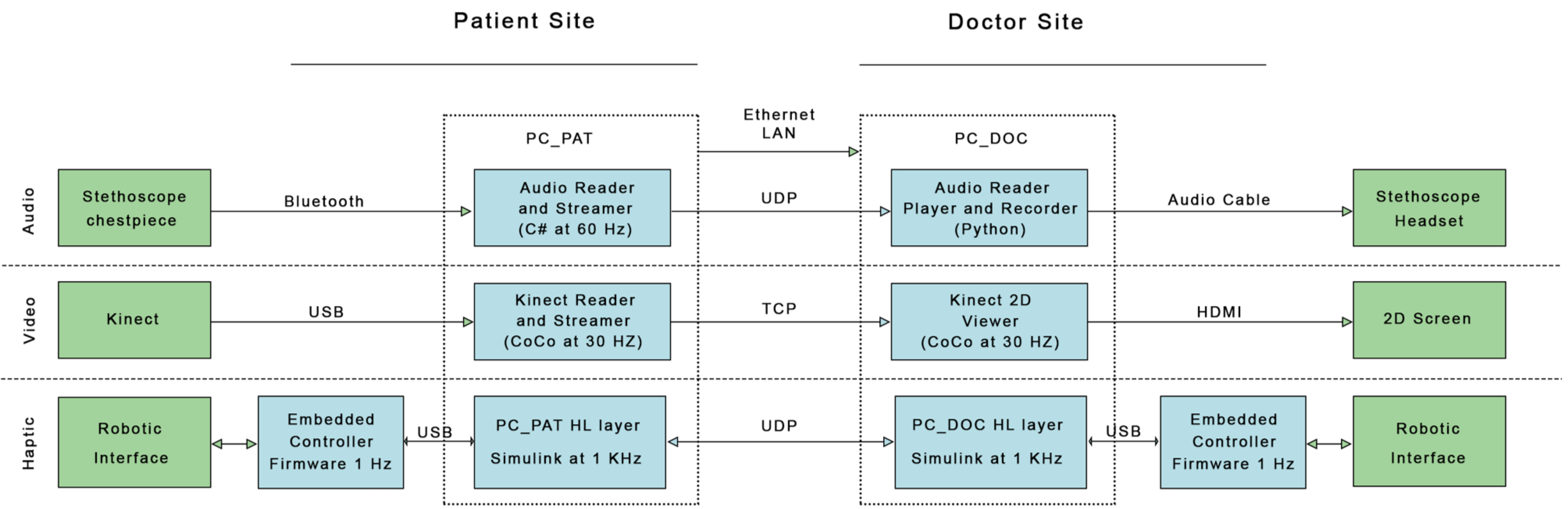
- Bluetooth Sthetoscope (Littmann 3200) chestpiece
- Custom designed mechanical attachment
- 3 DOFs robotic interface which features accurate force rendering and sensing
  - Force limited to 4N for the safety of the patient
- RGB-D Camera for 3D scene reconstruction
- Embedded controller
- PC-PAT

Doctor Site



- 3 DOFs haptic interface
  - Force limited to 20N
  - Translational motion of the EE
- Speakers and stethoscope diaphragm
- LCD Screen
- PC-DOC
- Embedded controller
- Joystick

Teleauscultation system architecture

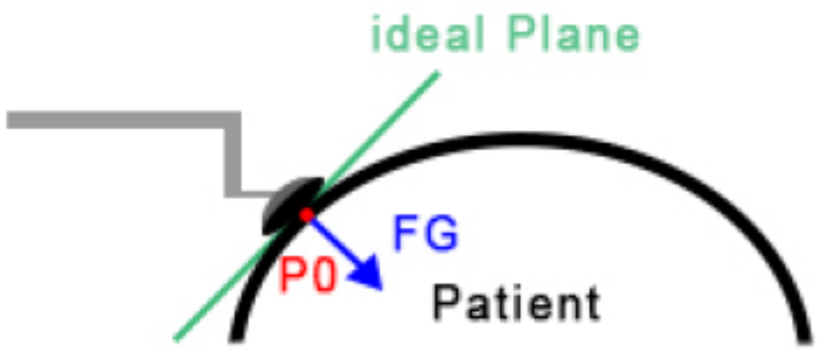


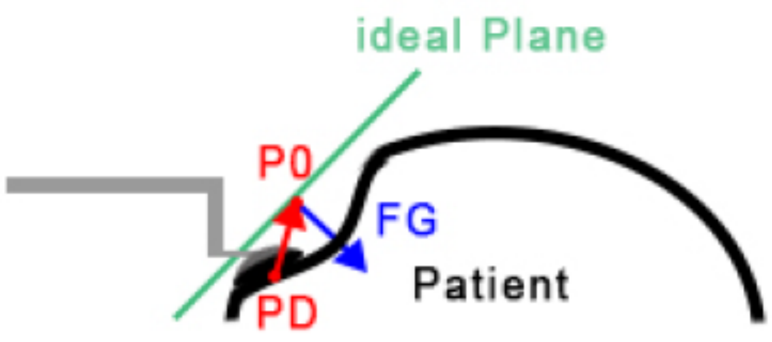
HW (green) and SW (blue) components in the architecture of the teleauscultation system

Three layers for the three sensory channels

Model for haptic rendering in teleoperation

Model of the patient at the doctor site for force rendering





FG, P0 and the ideal plane are recorded when the stethoscope touches the skin and force exceeds 4N

Interaction force at the doctor site is calculated as

$$F = \begin{cases} k(P0 - PD) + cv, & \text{if } (P0 - PD)FG < 0 \\ 0, & \text{otherwise} \end{cases}$$

Algorithm tested under small time varying latency (average 8.9ms, 75th percentile 50ms, peak 200ms)

Assessment of the system

Rationale

- Assess whether the system allows users to carry out auscultation-like tasks
- Assess whether haptic feedback has a role in the positioning of the stethoscope

Participants

- Ten inexperienced users (27.1 ± 2.51 years)

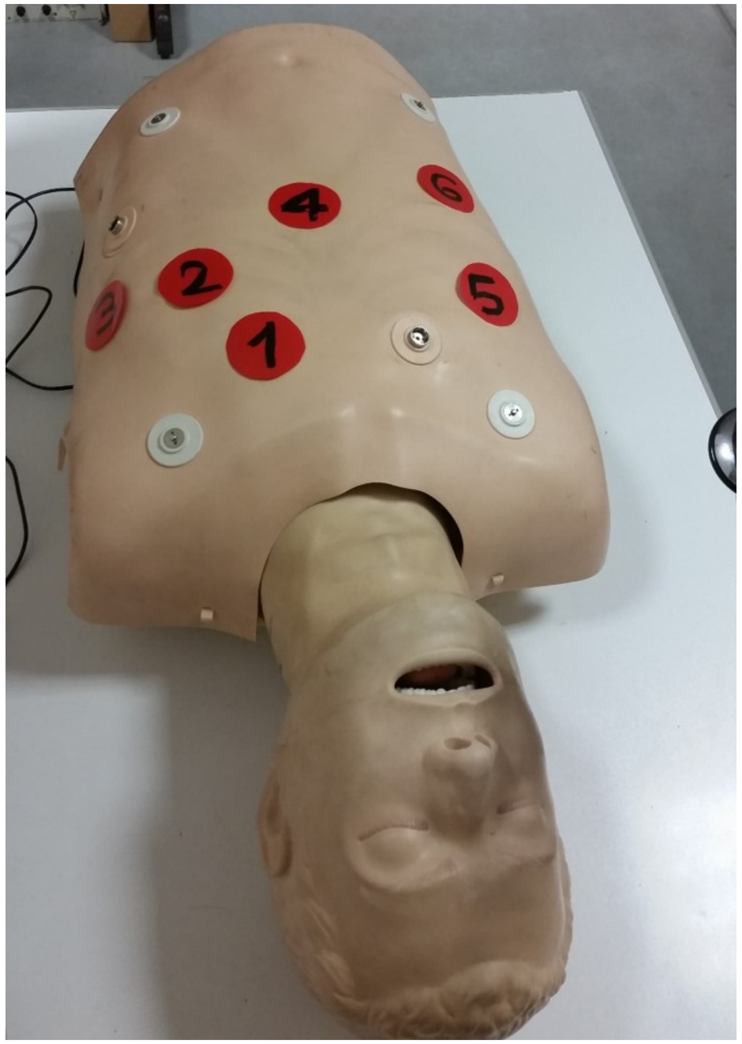
Materials

- Teleauscultation system
- A second LCD screen at the doctor site
- Mannequin as virtual patient
- Audio player and speakers inside of the mannequin

Assessment of the system

Tasks and Metrics

Task	Description	Metric of error
1	put the chestpiece of the stethoscope on six targets placed on the patient's trunk as accurately as possible	Euclidean distance between the correct position and the stethoscope position claimed by the participant
2	put the stethoscope on target 4 and listen to the audio stream from the chestpiece by means of the headset. Participants have to estimate the heart frequency they hear	Absolute value of the difference between the correct frequency and the one stated by the participant
3	listening to ten pairs of tracks by means of the stethoscope's headset. Participants are asked to rate which of the two tracks is better in terms of absence of noise and of overall sound quality. Tracks recorded manually or aided by the teleauscultation system.	5 points Likert scale to give their preference, one meant track one is totally preferable to track 2, 5 means total preference towards track 2

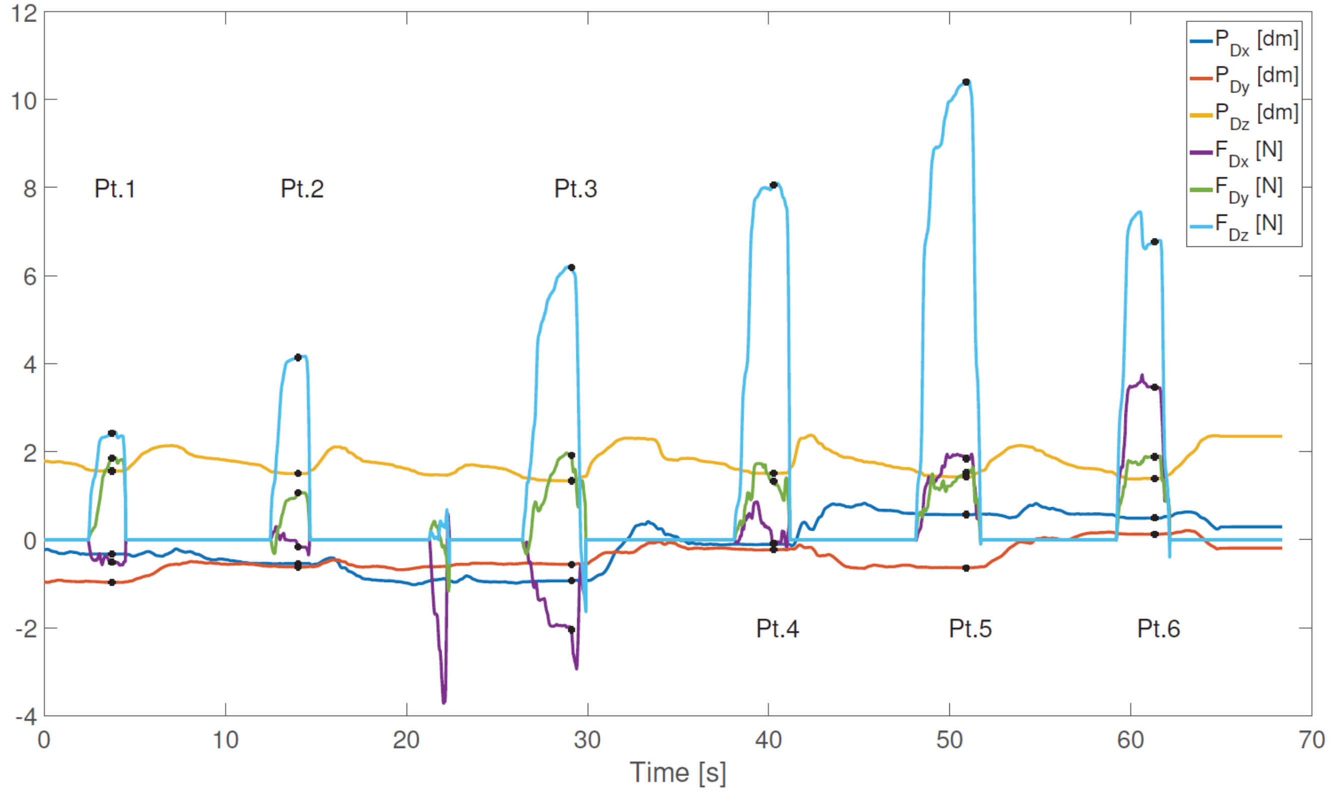


Teleauscultation system and its assessment

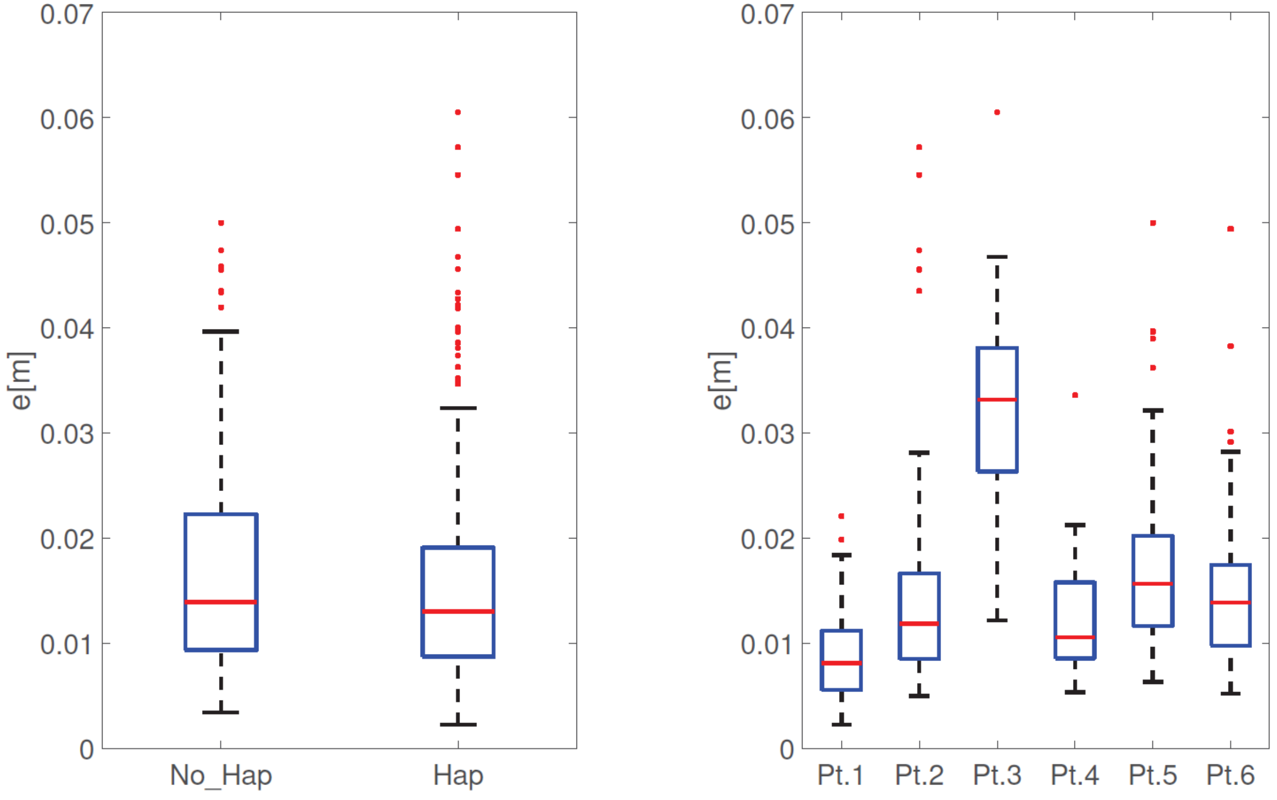
Forces Exterted
in contact phases

Results Task 1

Timeseries of a participant during task I

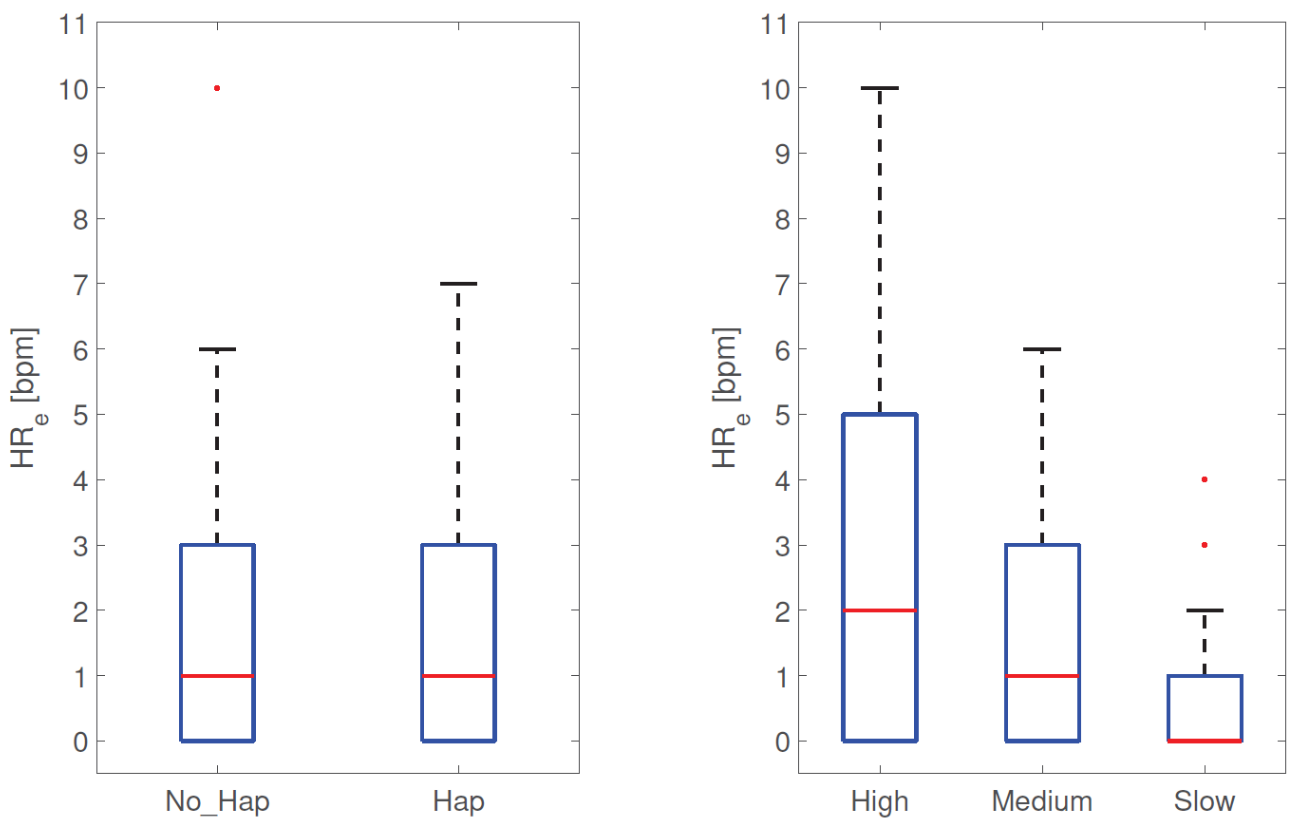


Error depending on haptic feedback and target point

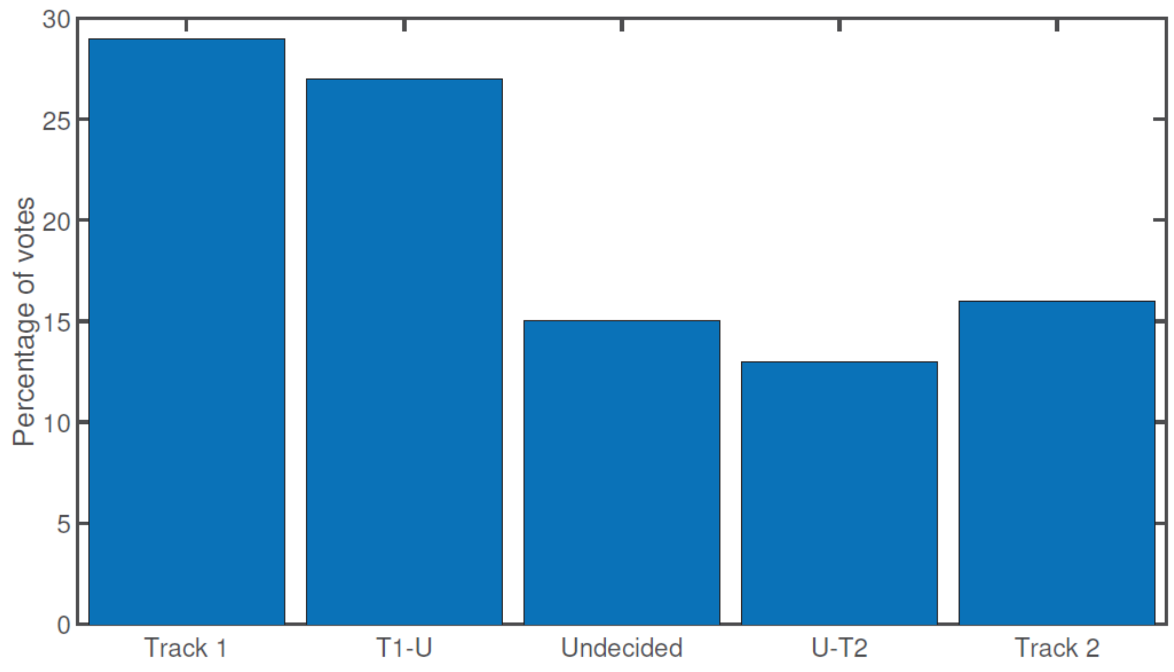


Results Tasks 2 and 3

Task 2 results. Error depending on haptic feedback and HR frequency



Task 3 results. Preferences distribution



Conclusions and Future Work

Conclusions

- The features of the systems were shown and demonstrated through experiments with inexperienced participants.
- The system allows the user positioning the stethoscope and to listen to the noises from the patient site fruitfully.
- No clear conclusions on the role of haptic feedback in teleauscultation

Future work

- Improvement of visualization system (e.g. VR)
- Deeper investigation of the role of haptic feedback
- Test of the system under larger communication delay and jitter

Any Questions?