T.PLAY

(Tracking Platform for multi-modaL Augmented realitY)

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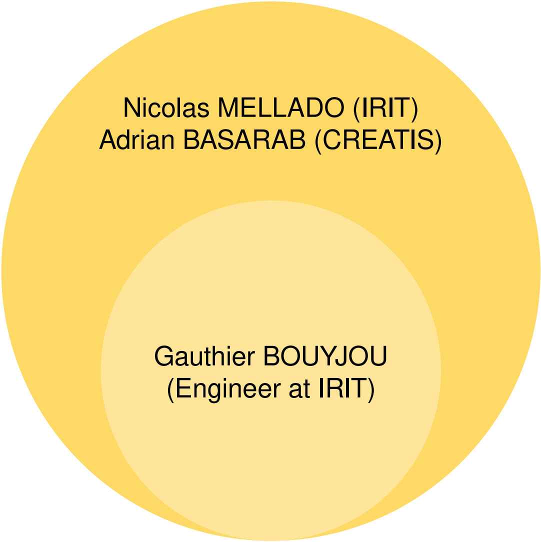
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T.PLAY

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Toulouse Tech Transfer
INNOVATIVE IMPACT

MINDS
Computational Imaging and Vision

IRIT

STORM
Structural Models and Tools in Computer Graphics

IRIT

Fabien VIDAL
(Surgeon at the Croix du Sud clinic)

ULA-OP 64 (University of Florence)
Ultrasound Scanner

© ULA-OP

40 Hz
Ultrasound Image

Intel L515
Lidar

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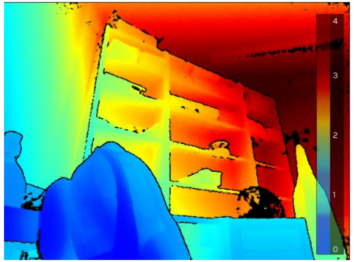
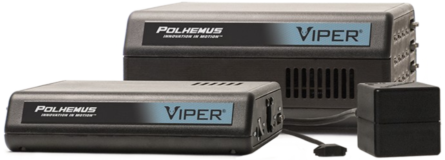


30 Hz
Depth map

Polhemus Viper
6DOF motion tracking solution



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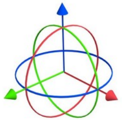
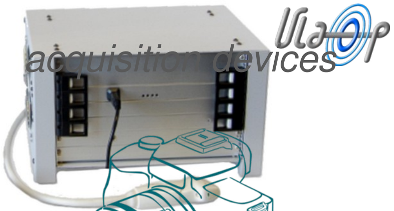
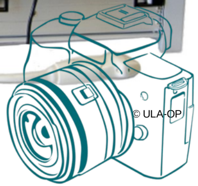


240 Hz
Position and quaternion

acquisition devices





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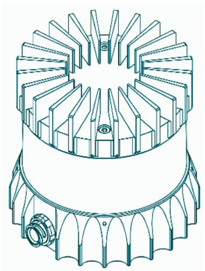

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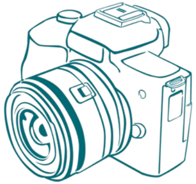
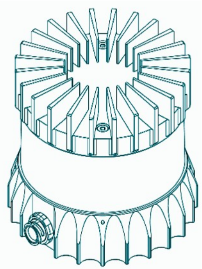
Original problem

acquisition devices





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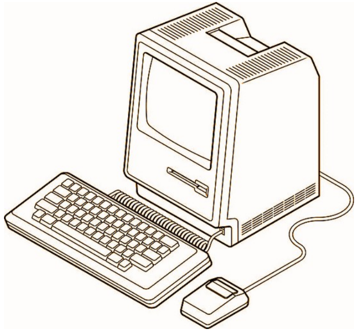
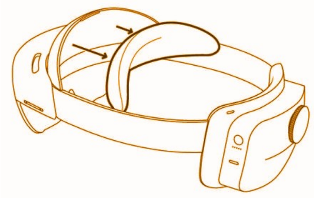
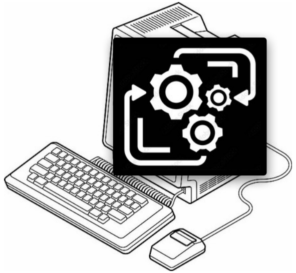
viewers





algorithms

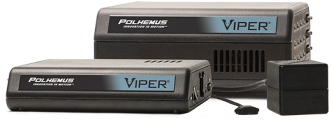


Example : fusion (sync)

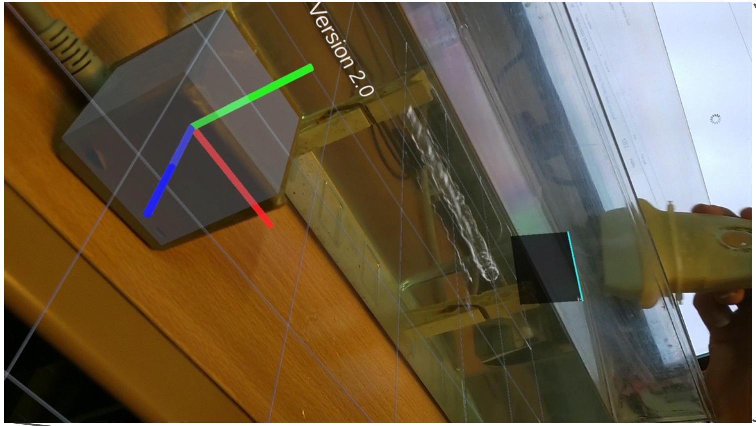
acquisition devices

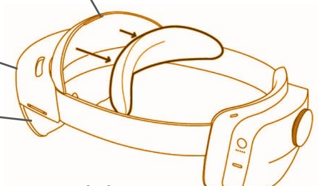
viewers

Ultrasound Scanner
40 Hz



6DOF motion tracking solution
240 Hz





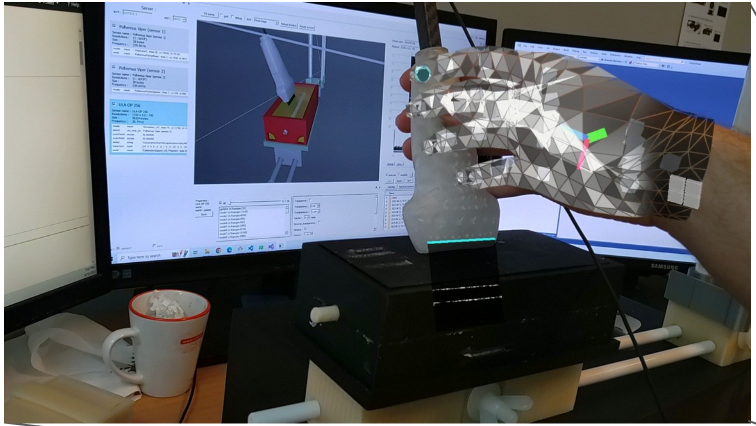
Hololens 2

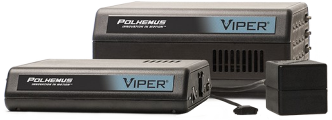
Disclaimer:
Hololens recording negatively impacts performances, users see the scene with lower latency
Water is moving during the acquisition and disturbing the ultrasonic waves

Example : simulation

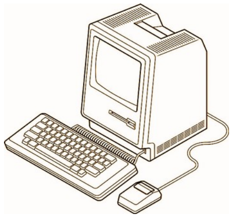
acquisition devices

viewers

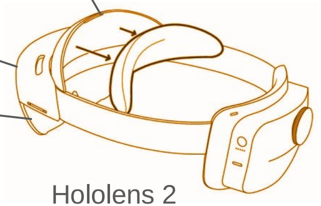




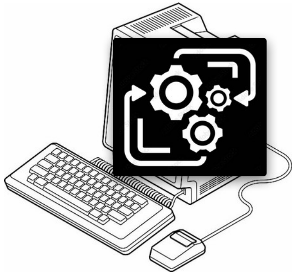
6DOF motion tracking solution
240 Hz



3d monitoring



Hololens 2

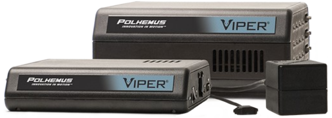


Ultrasound
simulator

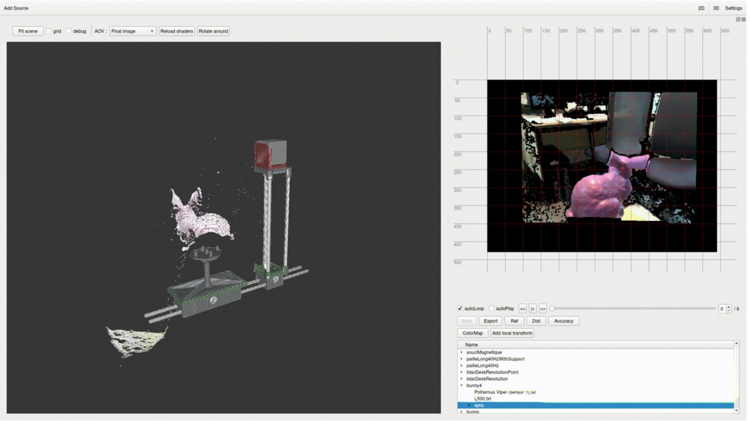
Example : reconstruction (calib)

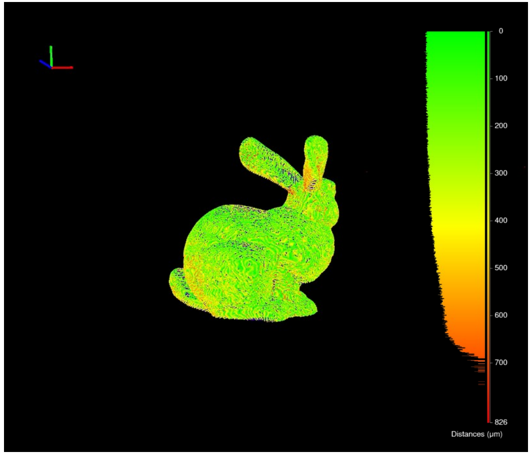
acquisition devices

Lidar
30 Hz

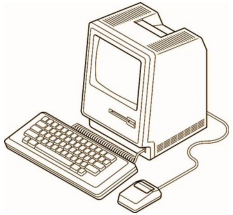


6DOF motion tracking solution
240 Hz





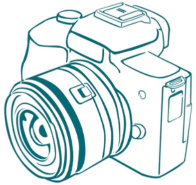
viewers

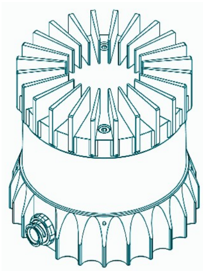


3d monitoring

Challenges

acquisition devices

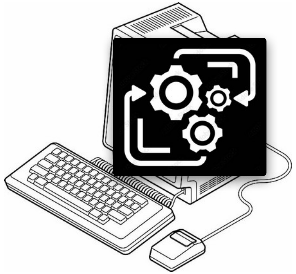




- Heterogeneous trackers
  - (Can)not (be) synchronised
  - ≠ frequencies
  - ≠ types of data

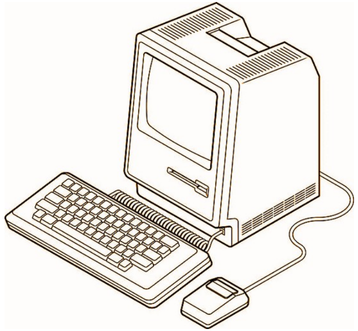
?

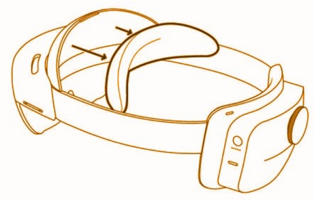
algorithms



- Algorithms
  - Loop/chains between trackers/viewers

viewers

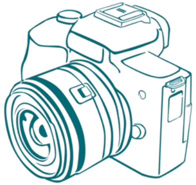


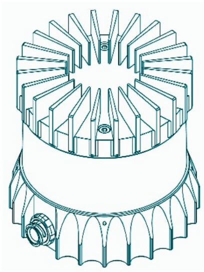


- Heterogeneous displays
  - AR/VR = interactive data transfer
  - Multi-viewers

Solution

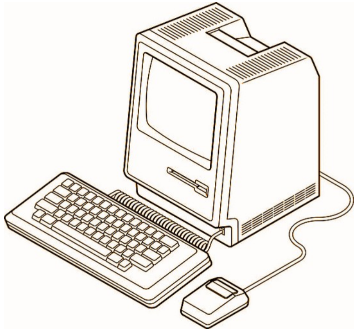
acquisition devices

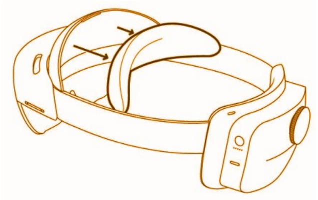




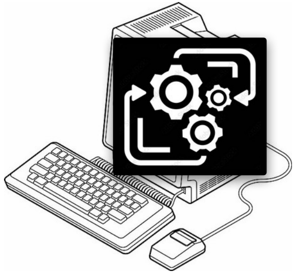
Hub

viewers





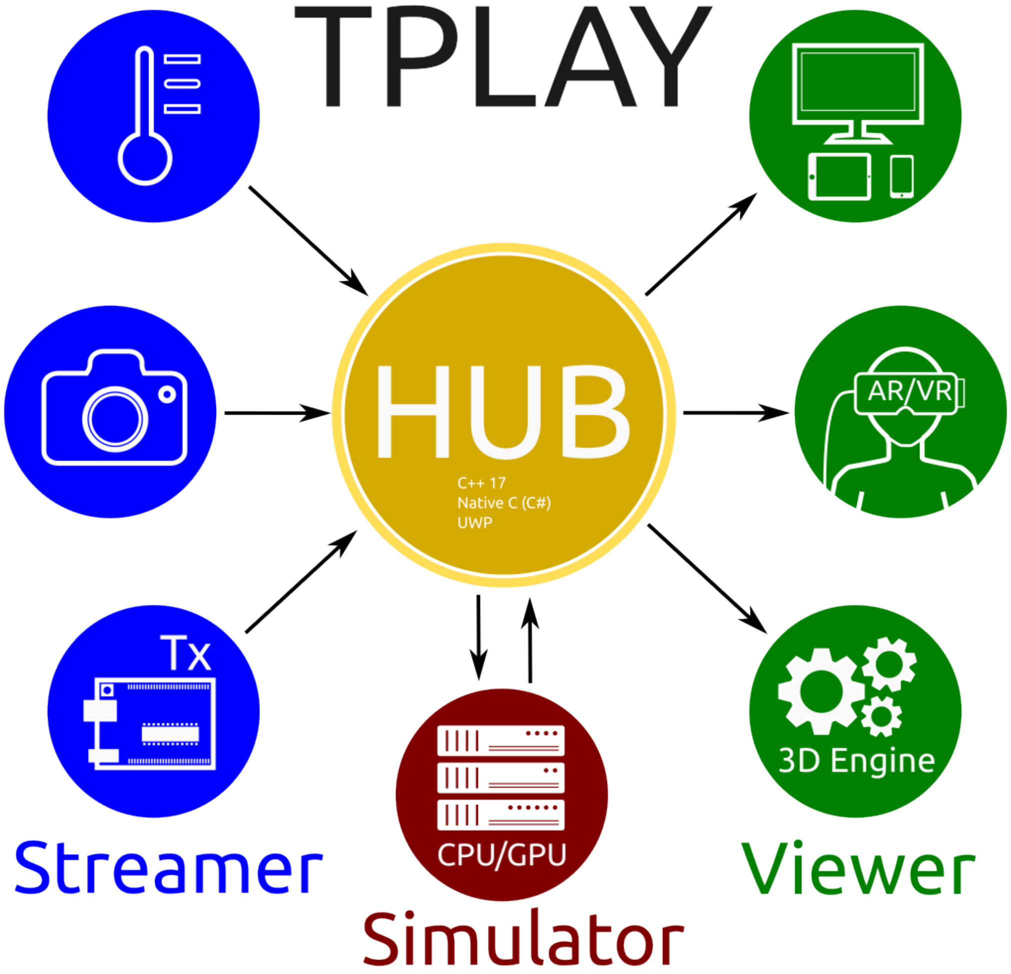
algorithms



open source

GitHub

https://github.com/T-PLAY



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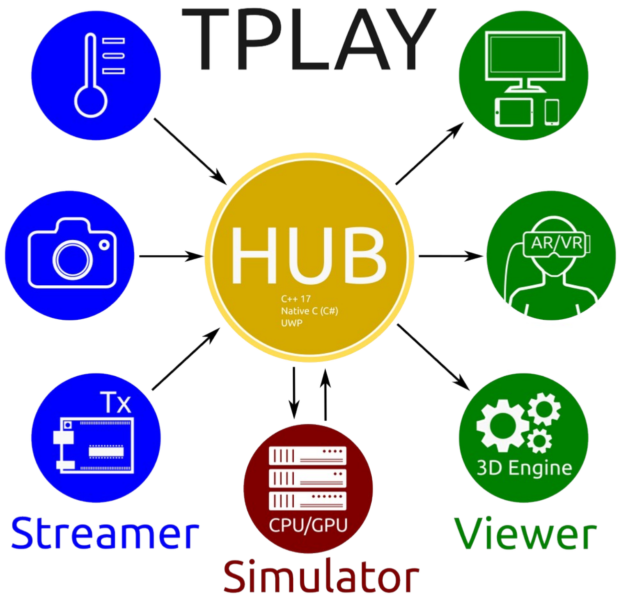

- Software environment (open-source)
  - Abstraction of sensor flows (e.g. time series)
  - Sensors post-synchronisation (CPU clock)
  - Tools
    - Visualization, including AR
    - Simulation
    - Monitoring/Calibration
  - Client/server architecture
  - Communication protocol (based on TCP/IP sockets)
  - C/C++ API, compatible C# (unity), or any language through the communication protocol

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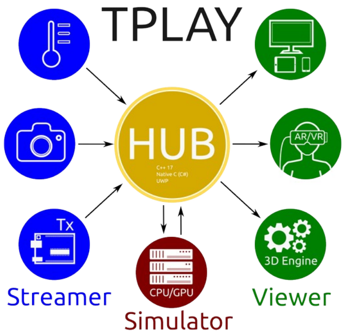


Any sensor compatibility

API C++ (std17)

Streamer

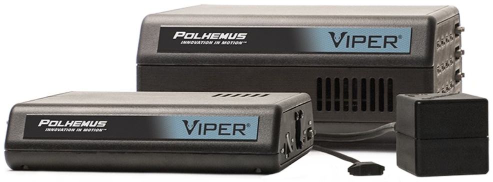
ULA-OP 64

ULA-OP 256

Lidar L515

...

Polhemus Patriot



Polhemus Viper

Server (hub)

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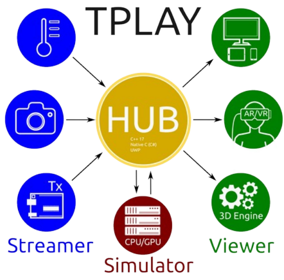
Multi visualizations
API C++ (std17)
Native C compatibility

NATIVE C/CPP LIBRARY

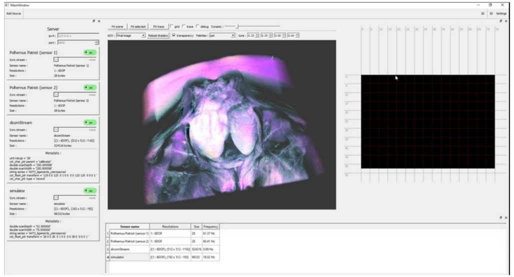


Viewer

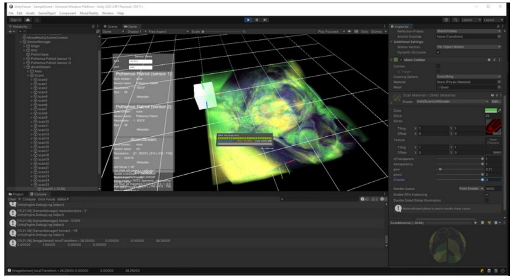
Server (hub)

Event dispatcher

3D Application



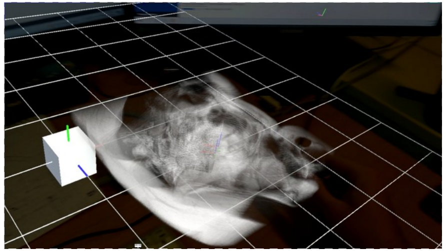
Qt and Radium 2D/3D viewer



Unity viewer

...

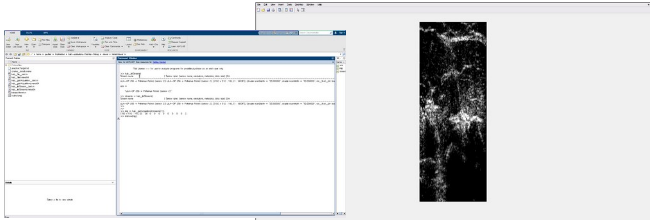
AR Application



Hololens 2 viewer

2D Application

- Matlab viewer
- Octave viewer



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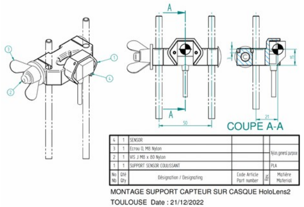
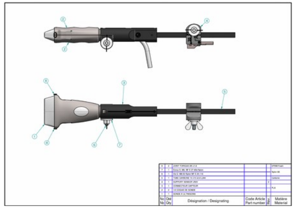
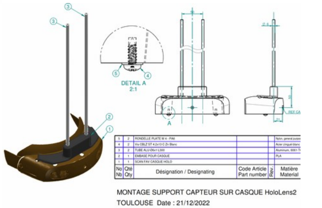






- Outcomes
  - Produce data for research
  - Provide an interactive environment to support research
  - Measurement and certification of ground truth
  - Generating and simulating data for learning purposes
  - Replicability of experiments

- Publications
  - Ultrasound volume reconstruction from 2D freehand acquisitions using neural implicit representations. F. Gaits, N. Mellado, A. Basarab. 21st IEEE International Symposium on Biomedical Imaging (ISBI 2024) (poster), 2024
  - Efficient stratified 3D scatterer sampling for freehand ultrasound simulation. F. Gaits, N. Mellado, G. Bouyjou, D. Garcia, A. Basarab. IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, 2023

  - T.PLAY: Tracking Platform for Multi-Modal Augmented Reality (demo). Journées Visu 2024, 18-19 Juin, Lyon.

T.PLAY

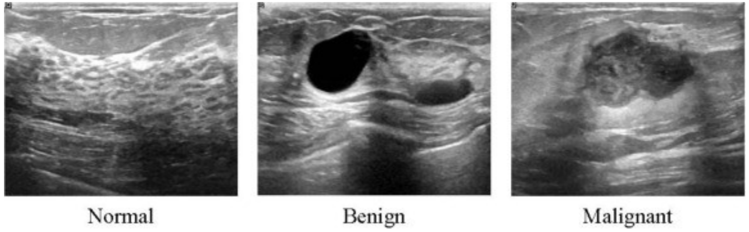
How it started

Fabien VIDAL
(Surgeon at the Croix du Sud clinic)

- The genesis of this work
    - SATT (2020 - 2021) and Occitanie Region fundings (2021 - 2023)

Breast cancer surgery:

- 58,500 new cases and 12,000 deaths in 2017
- Detection of nonpalpable tumors (30%) by mammography



Per-operative localization

- Wire-guided localization:
    - Most widely used approach
    - Percutaneous placement into or next to the lesion of a flexible self-retaining wire under ultrasound or stereotaxic guidance
    - Very good accuracy

- Cost
- Organizational and logistical constraints
- Discomfort felt by the patient
- Risk of complications (hematoma)

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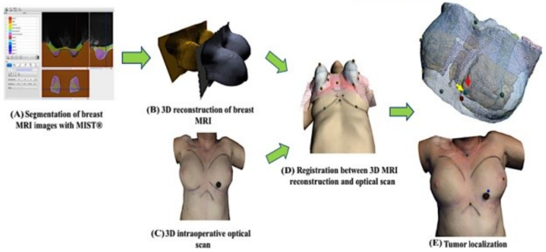
Per-operative localization

MRI + 3D optical scanning

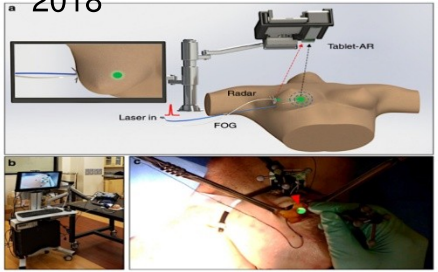
Duraes et al, Breast J, 2019



- MRI not a standard in breast cancer
- Localization error of ~20 mm

Opto-acoustic fiber

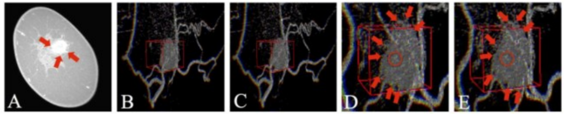
Lan et al, Light Sci Appl, 2018



1) Cost
2) No evaluation

Per-operative scanner

Douglas et al, J Nat Sci, 2016



1) No evaluation
2) Registration challenges
3) TDM needed

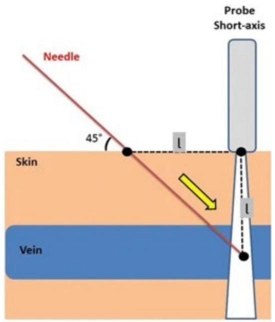
T.PLAY
Per-operative localization

Motivates the need for an accurate tracking system

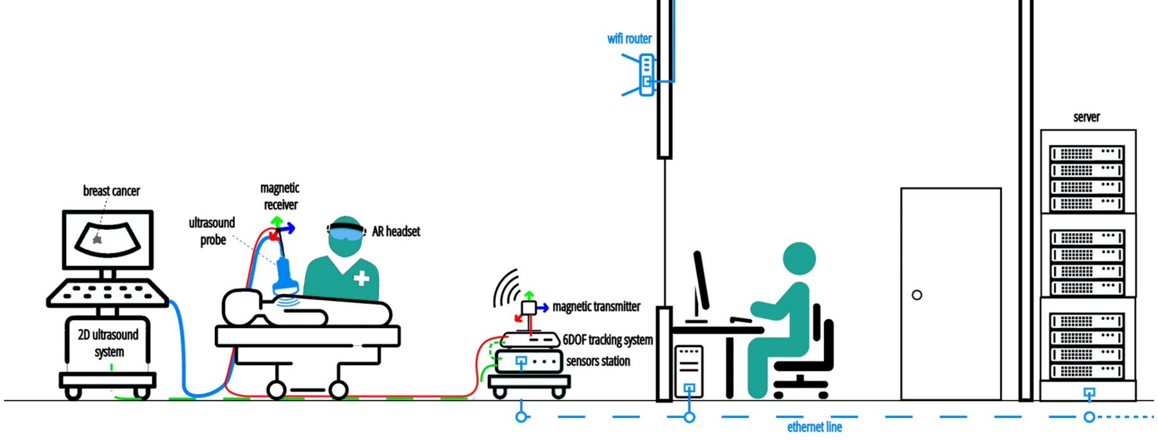
- Original idea:
  - AR procedure based on automatically segmented US images of the tumor
  - 3D tumor reconstruction
  - Breast US acquisitions in the operating room, at the onset of surgery

- Challenges:
  - Deformations caused by the US probe pressure
  - Surgeons move the breast: need interactive deformation systems for complex tissues

- Other use-cases:
  - Surgery: Vessel puncture
  - Other: Multi-view LiDAR acquisition
  - Maturation program with Market Research (on-going)

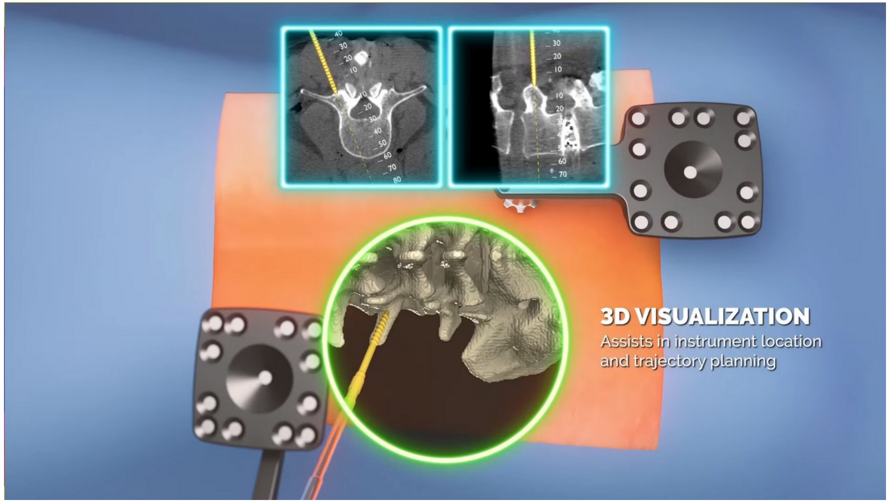


Piton, G., Capellier, G. & Winiszewski, H. Ultrasound-guided vessel puncture: calling for Pythagoras' help. *Crit Care* 22, 292 (2018).



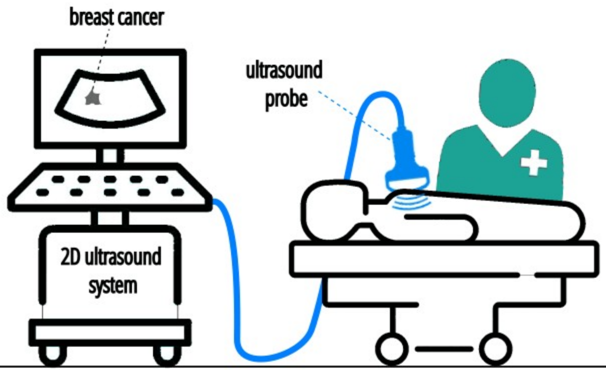
Surgical guidance

Surgical guidance



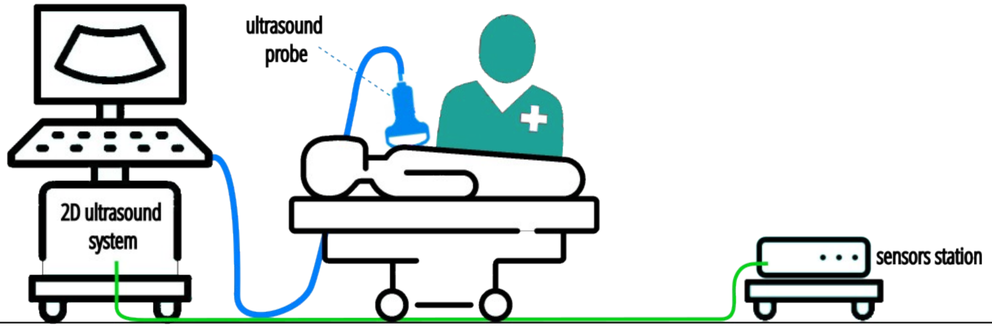
Augmedics xvision
(give surgeons “x-ray vision”)
Source : https://www.youtube.com/watch?v=DXxRFcbduho&ab_channel=Augmedics

Standard case
Ultrasound scanner



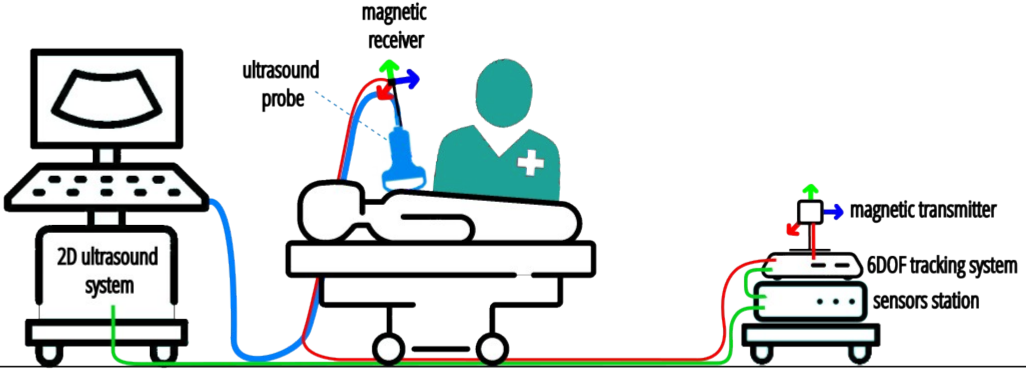
- Intraoperative detection of sub-clinical surface lesions or tumors
- Percutaneous operations (punctures, heart operations)
- Biopsy
- Medical diagnostics
- Exeresis

Experimental platform

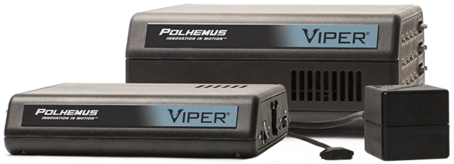


- Computer with real time clock (RTC) and one cpu core per sensor

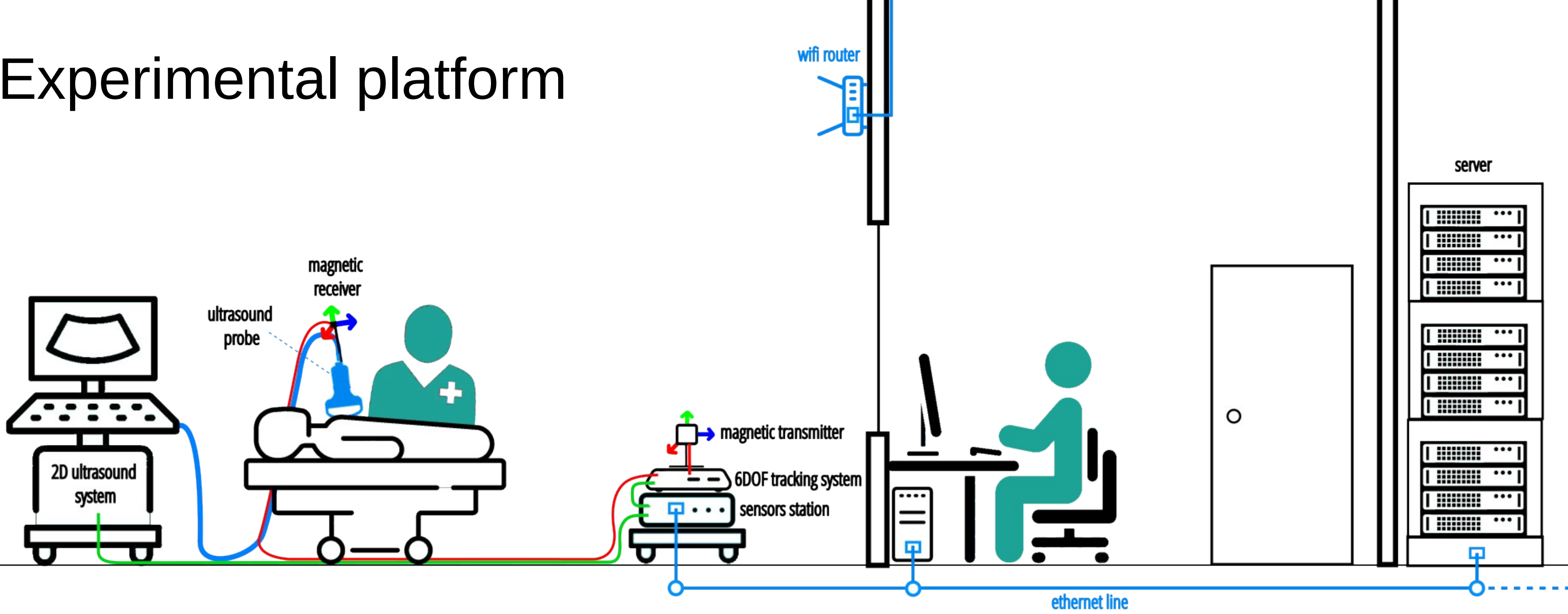
Experimental platform



- 6DOF tracking system (C++ SDK)

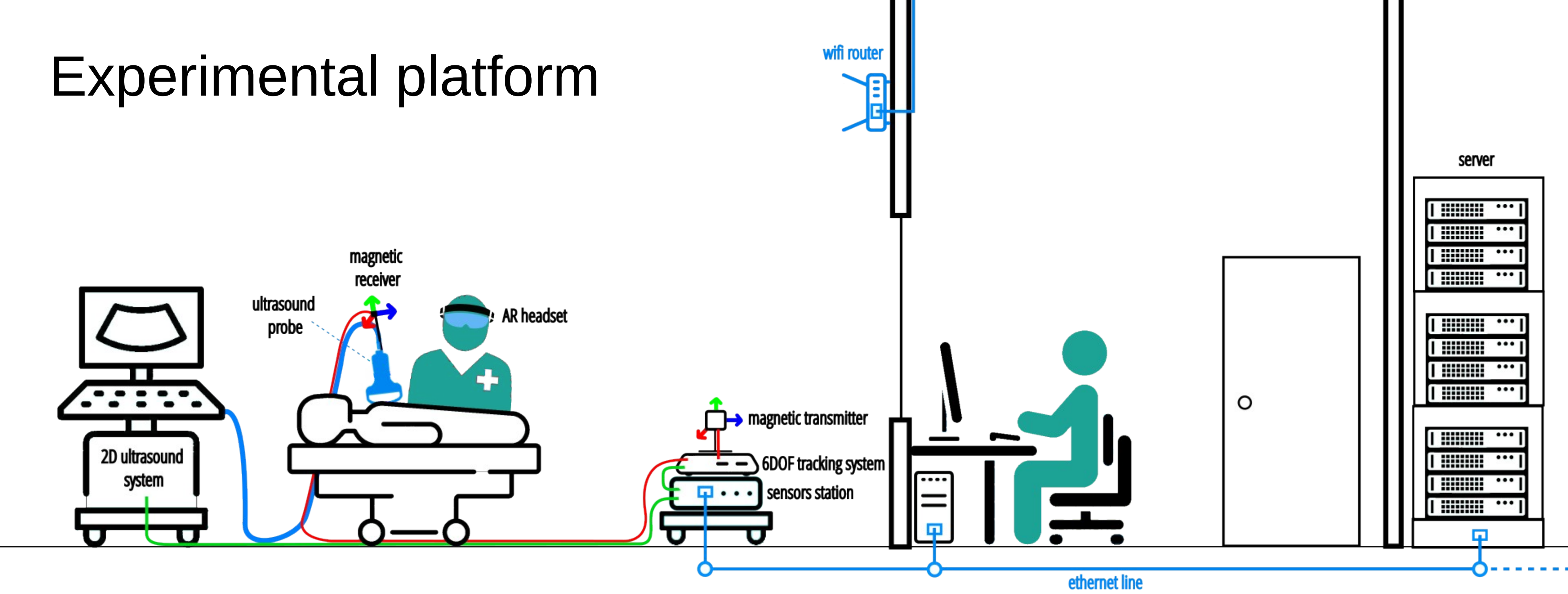


Experimental platform



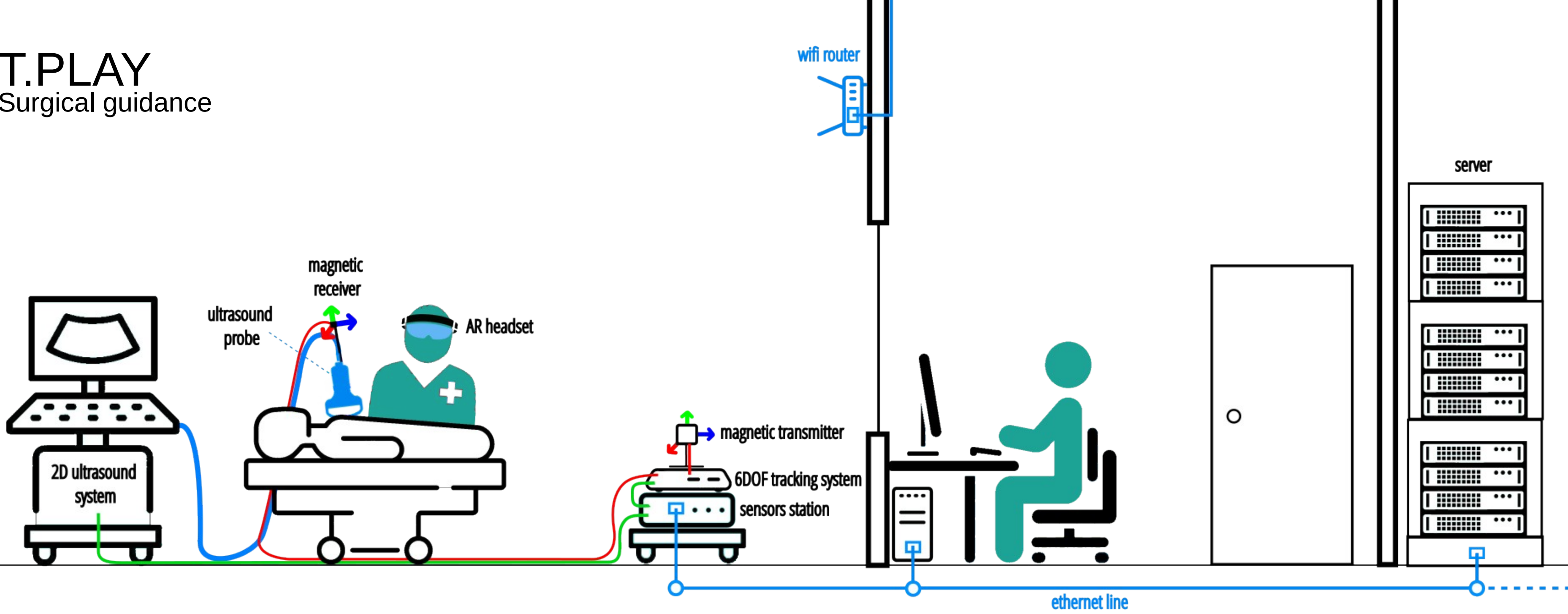
- Computer with a screen application using the generalized collected data

Experimental platform



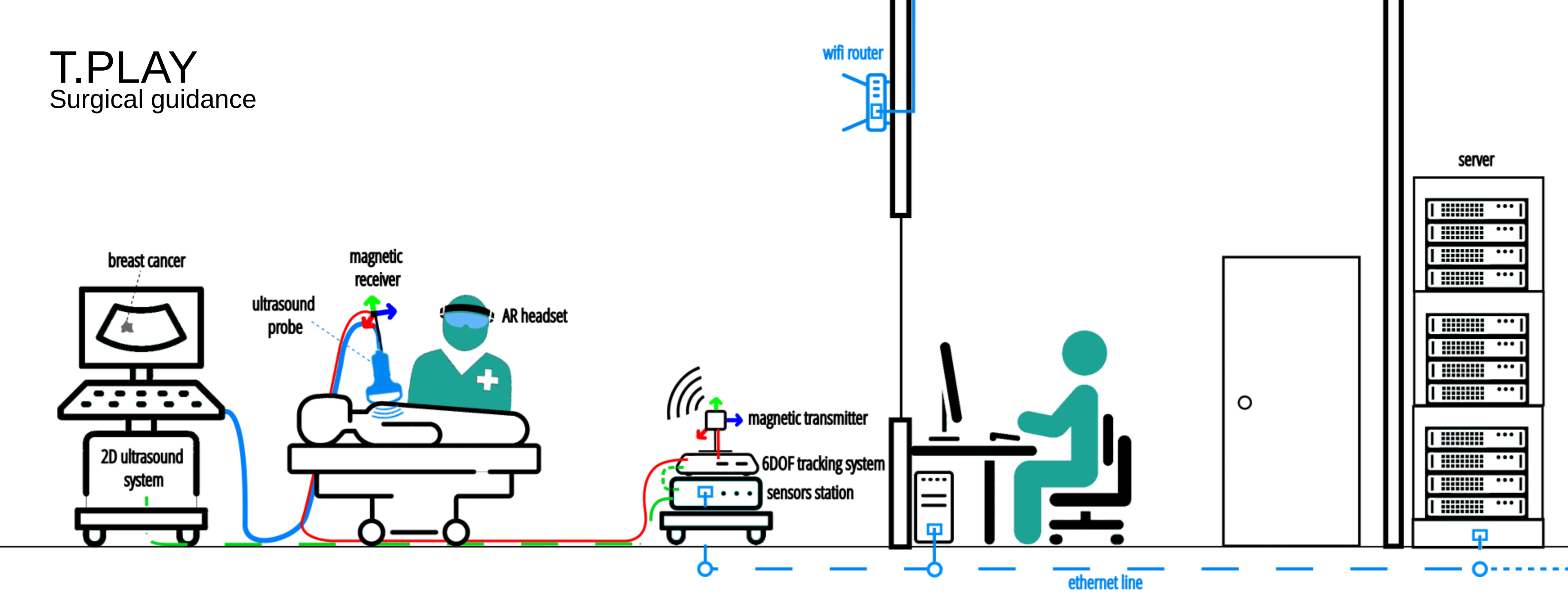
- Augmented Reality (AR) device

T.PLAY
Surgical guidance



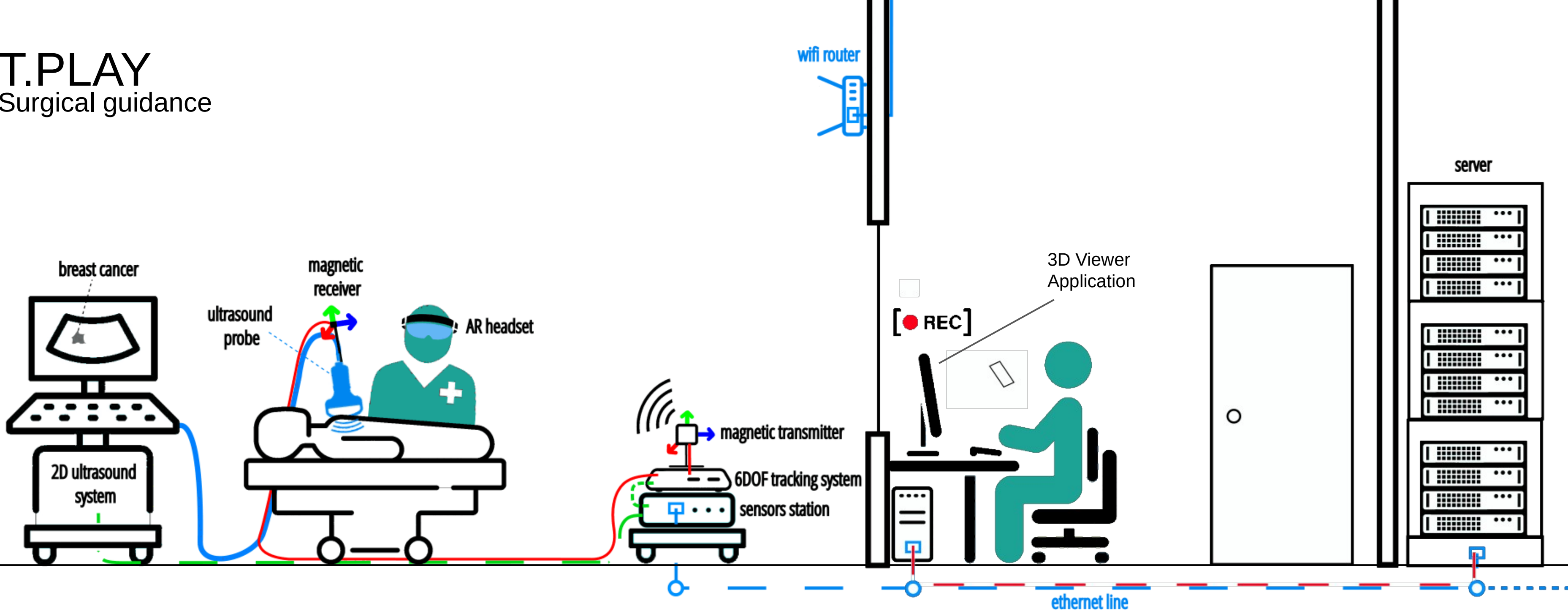
Goal: Avoiding the use of a metal guide to spatially locate breast cancer during excision

T.PLAY
Surgical guidance



Goal: Avoiding the use of a metal guide to spatially locate breast cancer during excision

T.PLAY
Surgical guidance

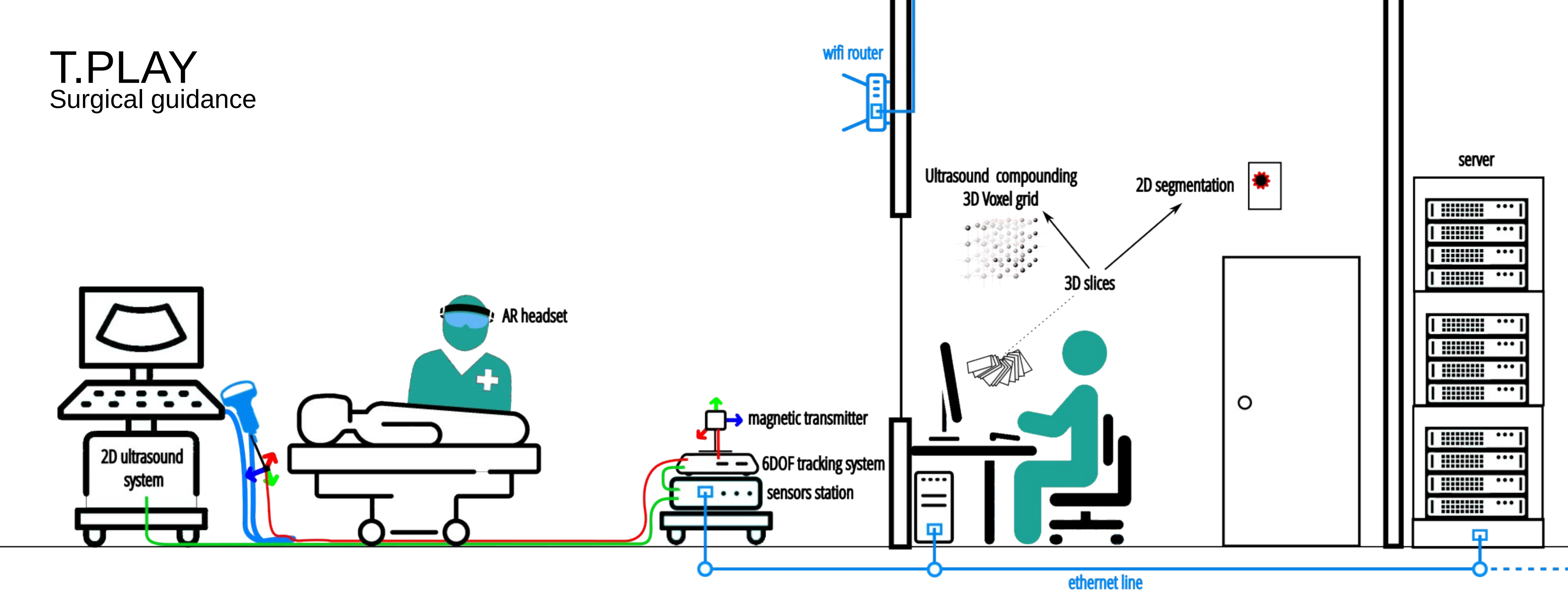


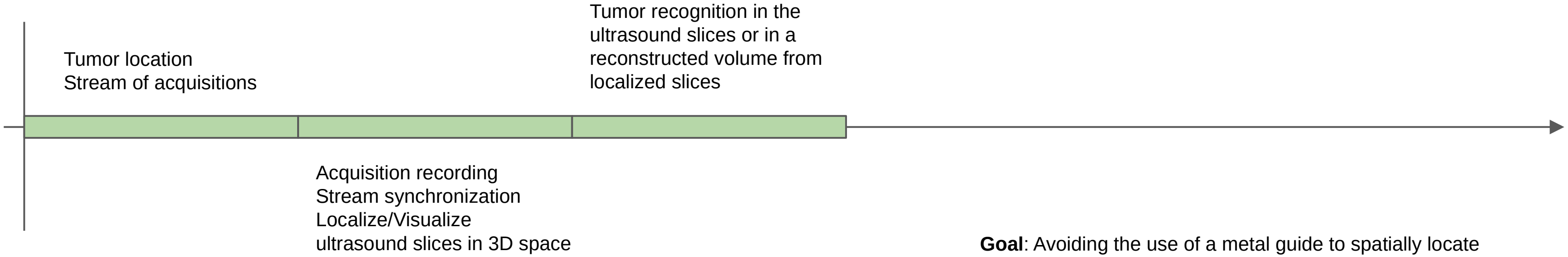
Tumor location
Stream of acquisitions

Acquisition recording
Stream synchronization
Localize/Visualize
ultrasound slices in 3D space

Goal: Avoiding the use of a metal guide to spatially locate breast cancer during excision

T.PLAY
Surgical guidance

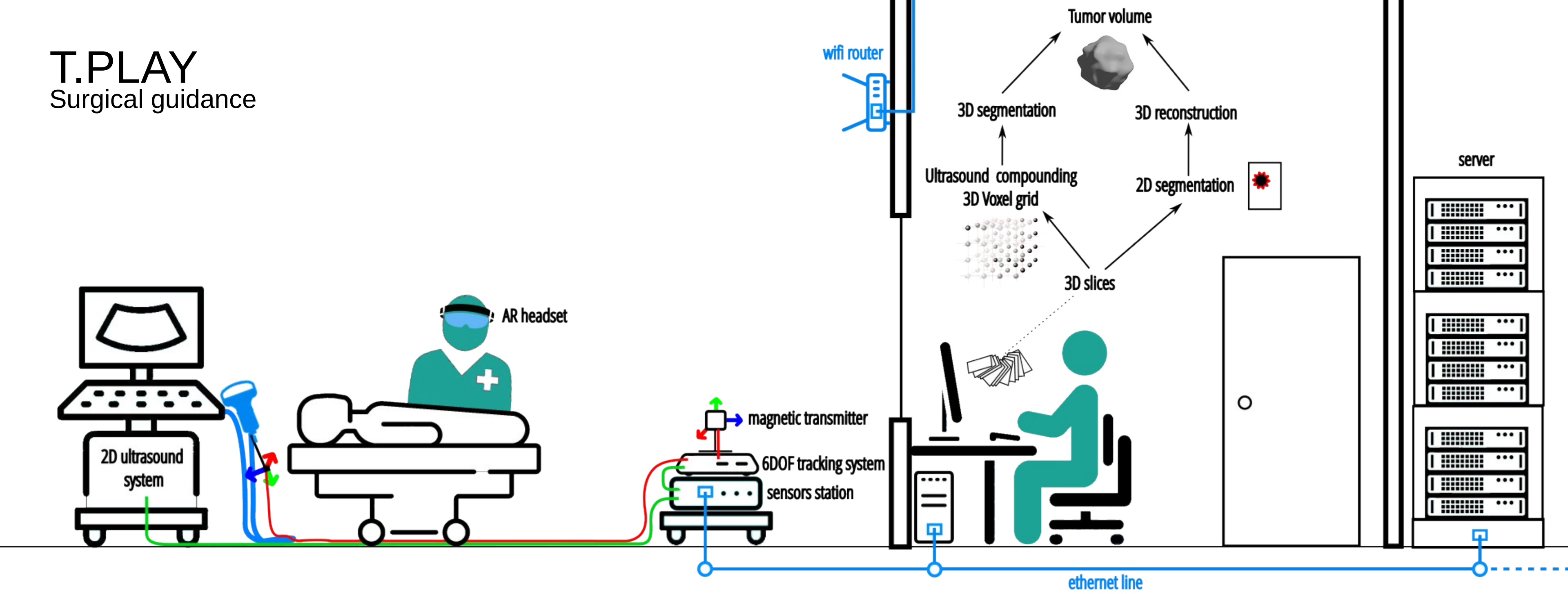




Goal: Avoiding the use of a metal guide to spatially locate breast cancer during excision

T.PLAY

Surgical guidance



Tumor location
Stream of acquisitions

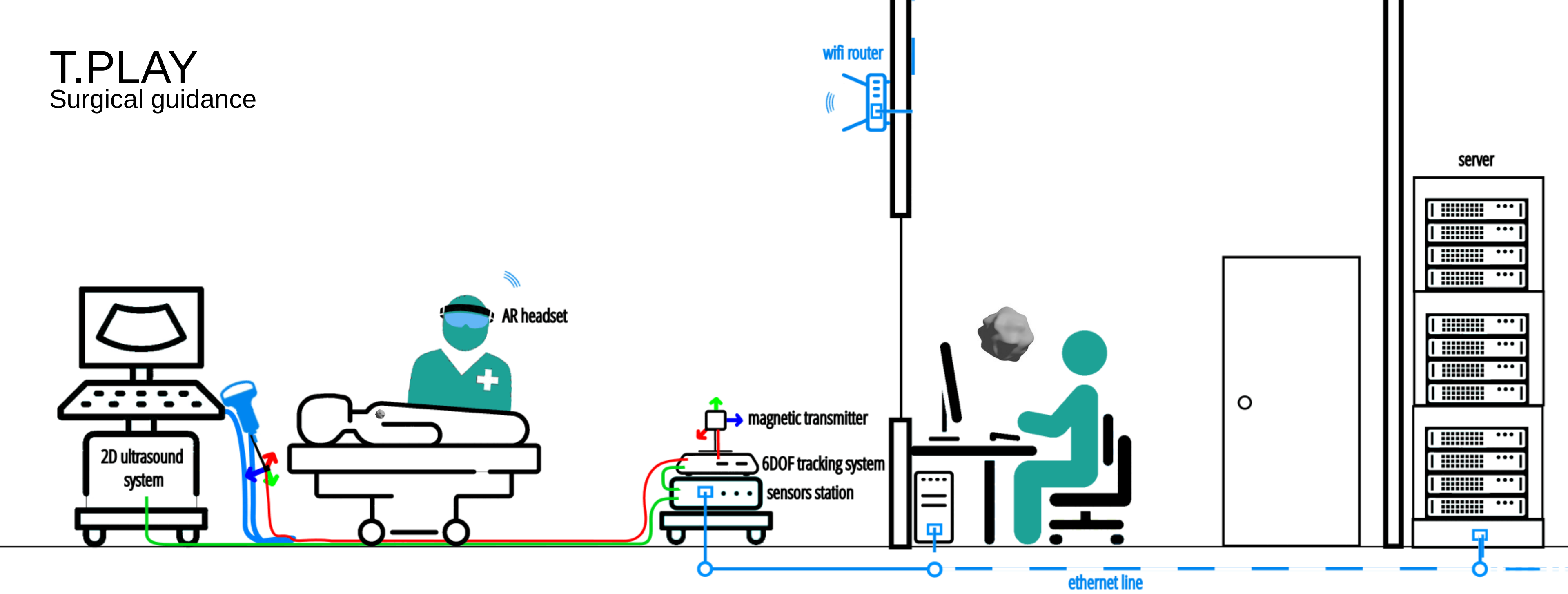
Tumor recognition in the ultrasound slices or in a reconstructed volume from localized slices

Acquisition recording
Stream synchronization
Localize/Visualize
ultrasound slices in 3D space

Reconstruct tumor volume

Goal: Avoiding the use of a metal guide to spatially locate breast cancer during excision

T.PLAY
Surgical guidance



Tumor location
Stream of acquisitions

Acquisition recording
Stream synchronization
Localize/Visualize
ultrasound slices in 3D space

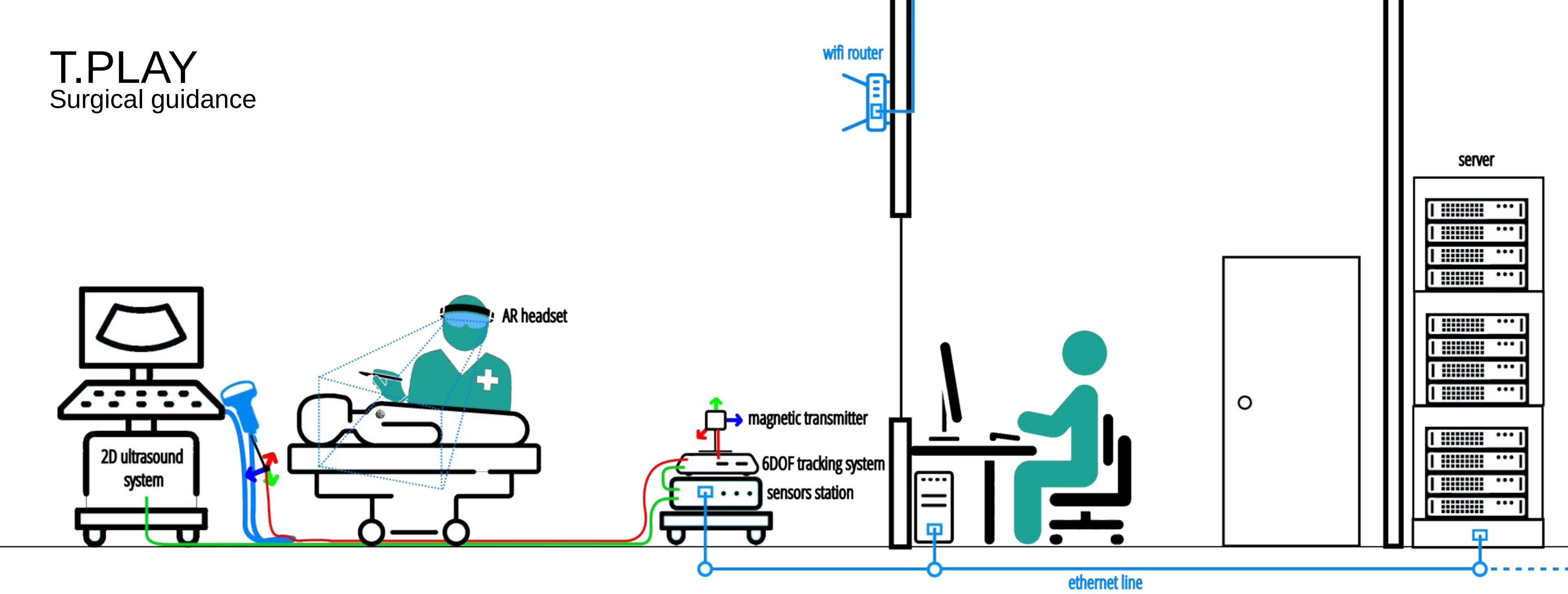
Tumor recognition in the ultrasound slices or in a reconstructed volume from localized slices

Reconstruct tumor volume

Stream tumor 3D volume
Visualization of the tumor's volume with AR device (Ray marching)

Goal: Avoiding the use of a metal guide to spatially locate breast cancer during excision

T.PLAY
Surgical guidance



Tumor location
Stream of acquisitions

Acquisition recording
Stream synchronization
Localize/Visualize
ultrasound slices in 3D space

Tumor recognition in the ultrasound slices or in a reconstructed volume from localized slices

Reconstruct tumor volume

Stream tumor 3D volume
Visualization of the tumor's volume with AR device (Ray marching)

Operate the tumor removal

Goal: Avoiding the use of a metal guide to spatially locate breast cancer during excision

Standard case

Nerve puncture

Per-operative localization

- **Main idea:**
    - **Augmented reality procedure based on automatically segmented US images of the blood vessels**
    - **3D vein, artery reconstruction**
    - **Puncture guidance**

Ultrasound images

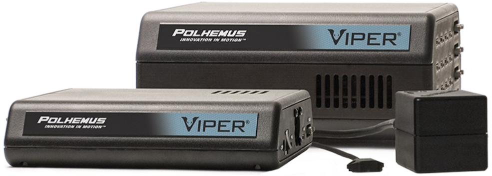
Ultrasound probe

Ultrasound phantom

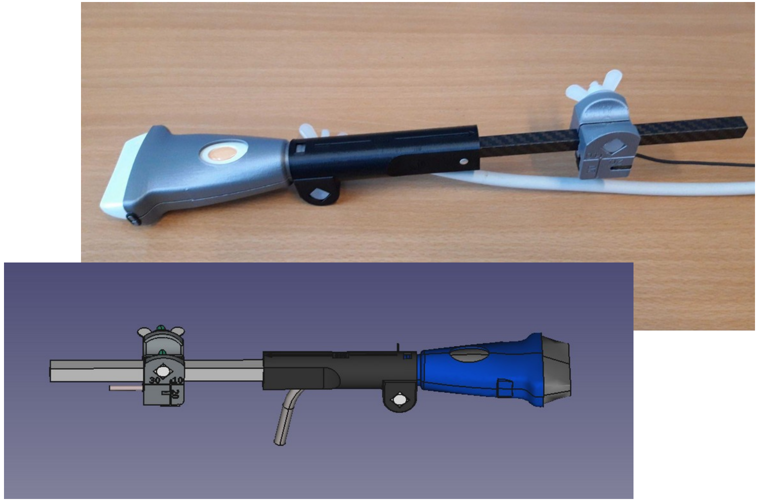
Needle

T.PLAY
Tools

ULA-OP 64



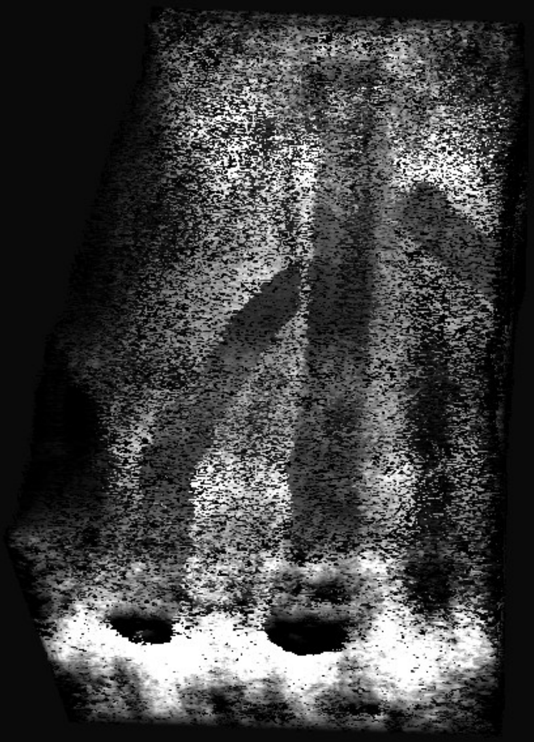
Polhemus Viper



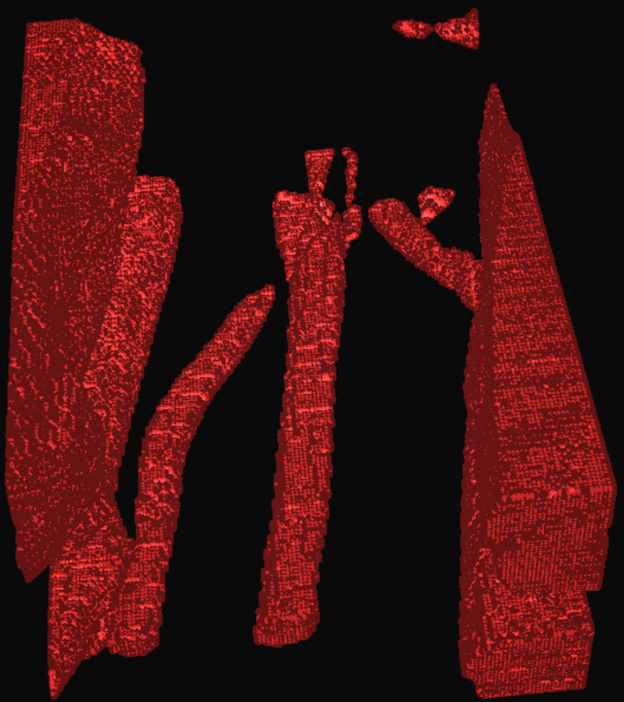
Tracked US probe

Tracked needle holder

Ultrasound volume reconstruction from 2D freehand acquisitions using neural implicit representations. F. Gaits, N. Mellado, A. Basarab. 21st IEEE International Symposium on Biomedical Imaging (ISBI 2024) (poster), 2024

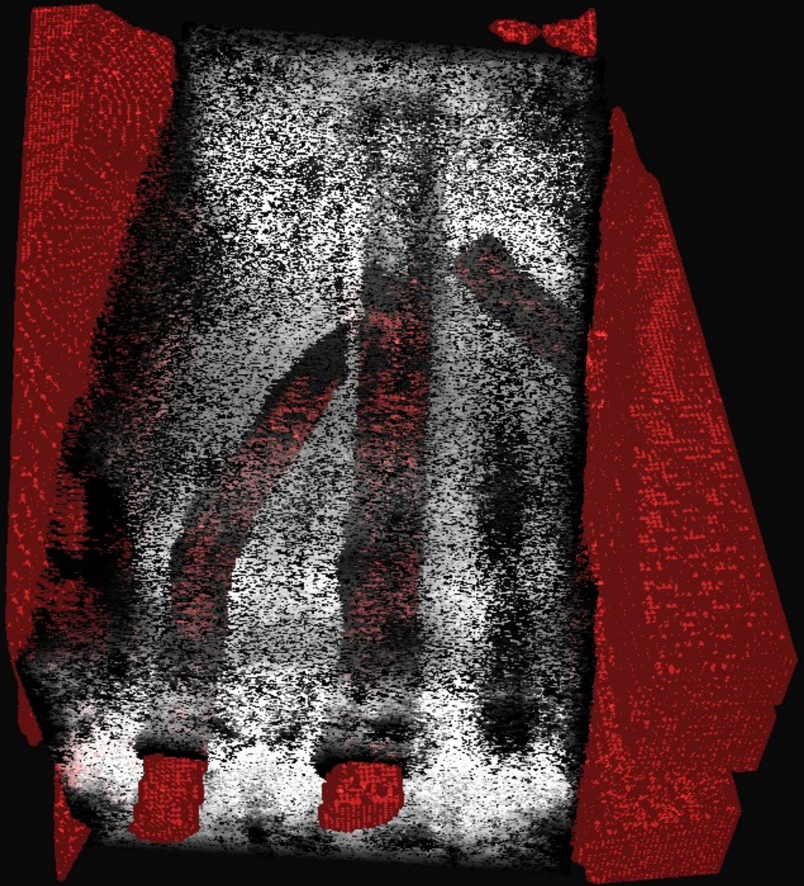


Packed US slices

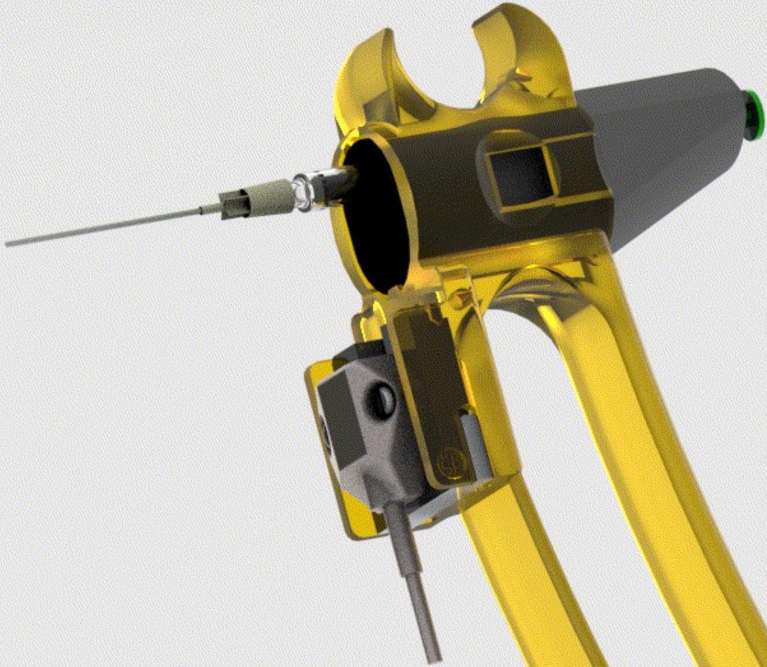


Neural Implicit Volume (density < 10)

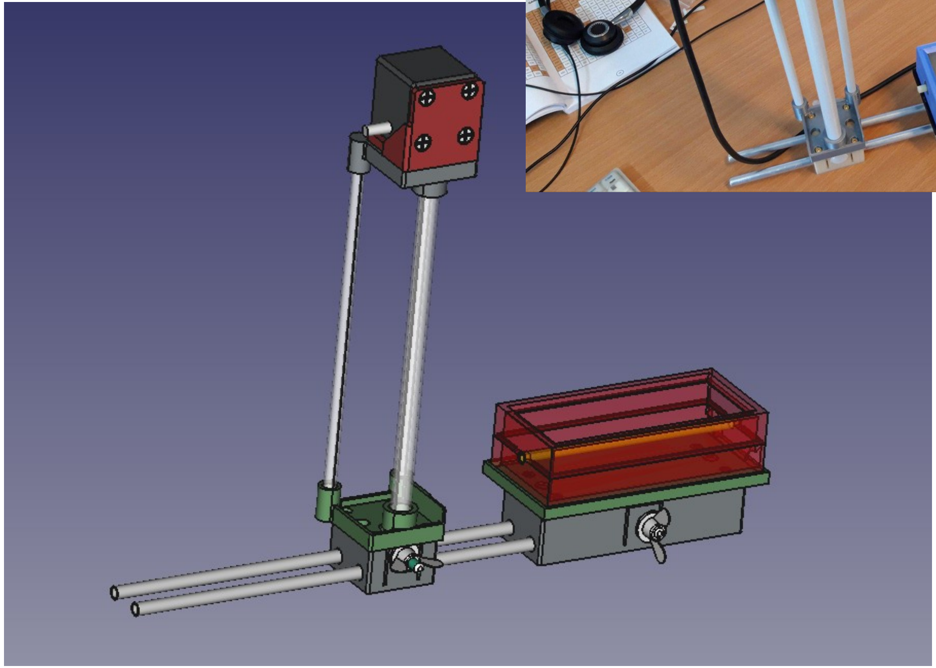
Ultrasound volume reconstruction from 2D freehand acquisitions using neural implicit representations. F. Gaits, N. Mellado, A. Basarab. 21st IEEE International Symposium on Biomedical Imaging (ISBI 2024) (poster), 2024

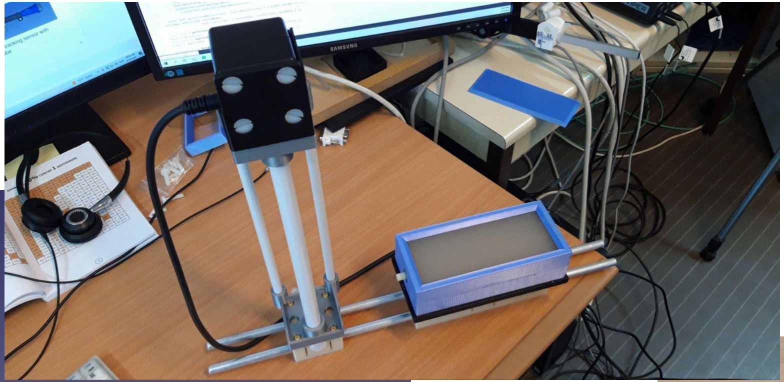


T.PLAY
Universal needle holder

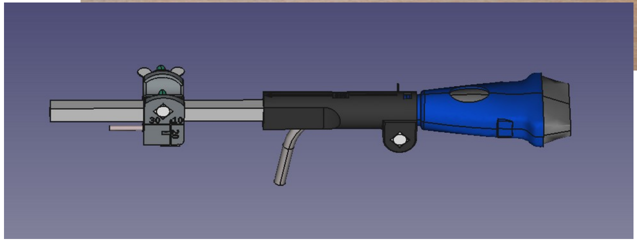


T.PLAY
Accuracy



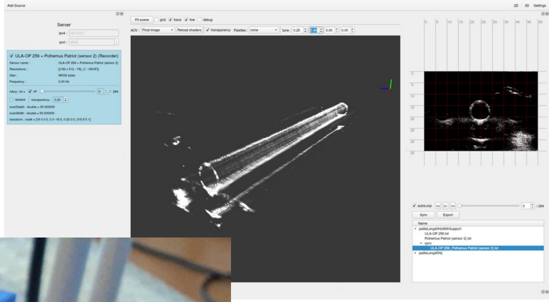


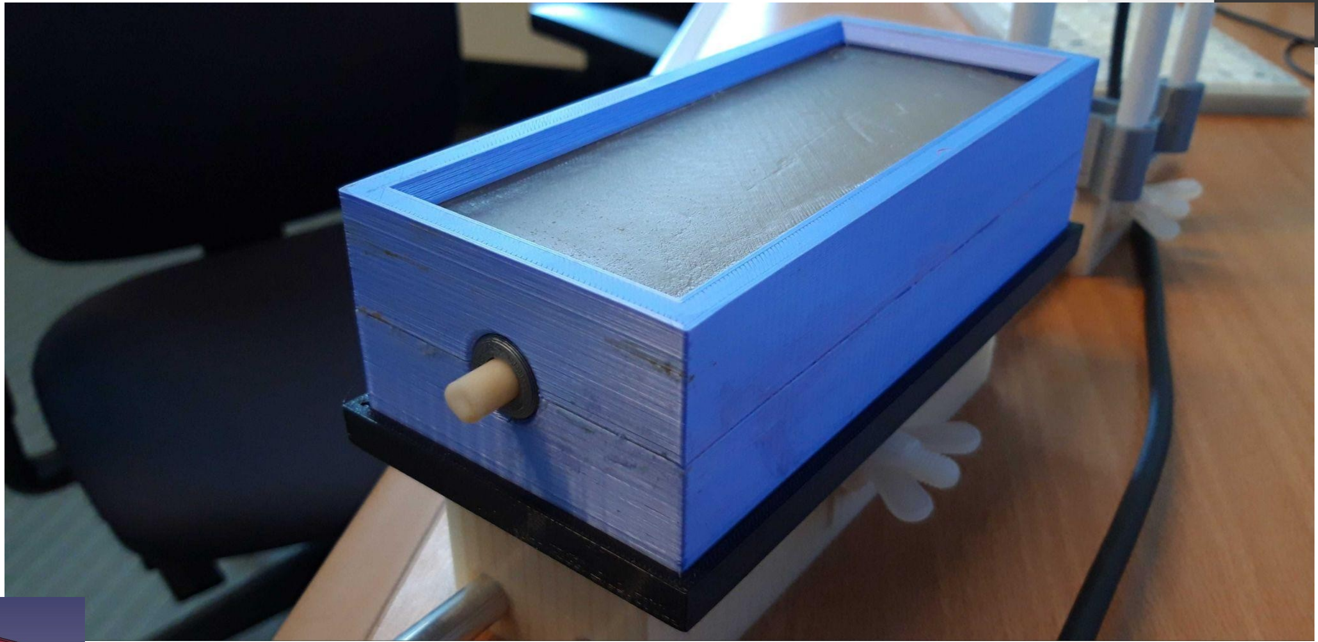
Printed calibration support

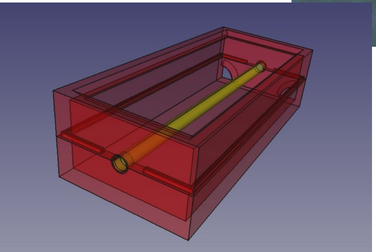


Printed tracking sensor with US probe

T.PLAY : DIY US 3D Phantom
Accuracy

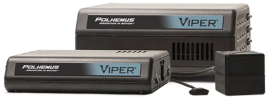


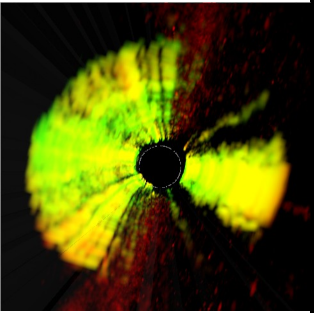


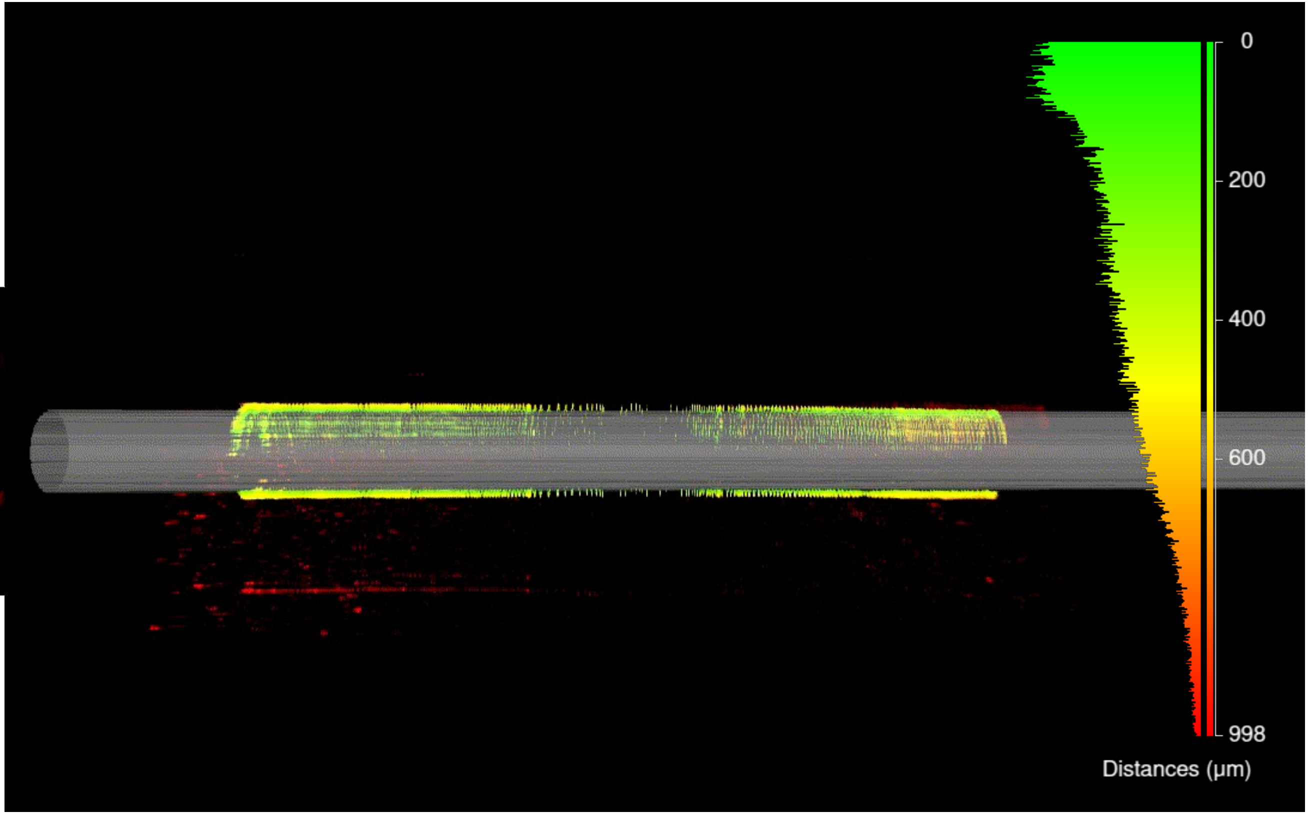


DIY US Phantom
2% agar by-weight

T.PLAY
Accuracy



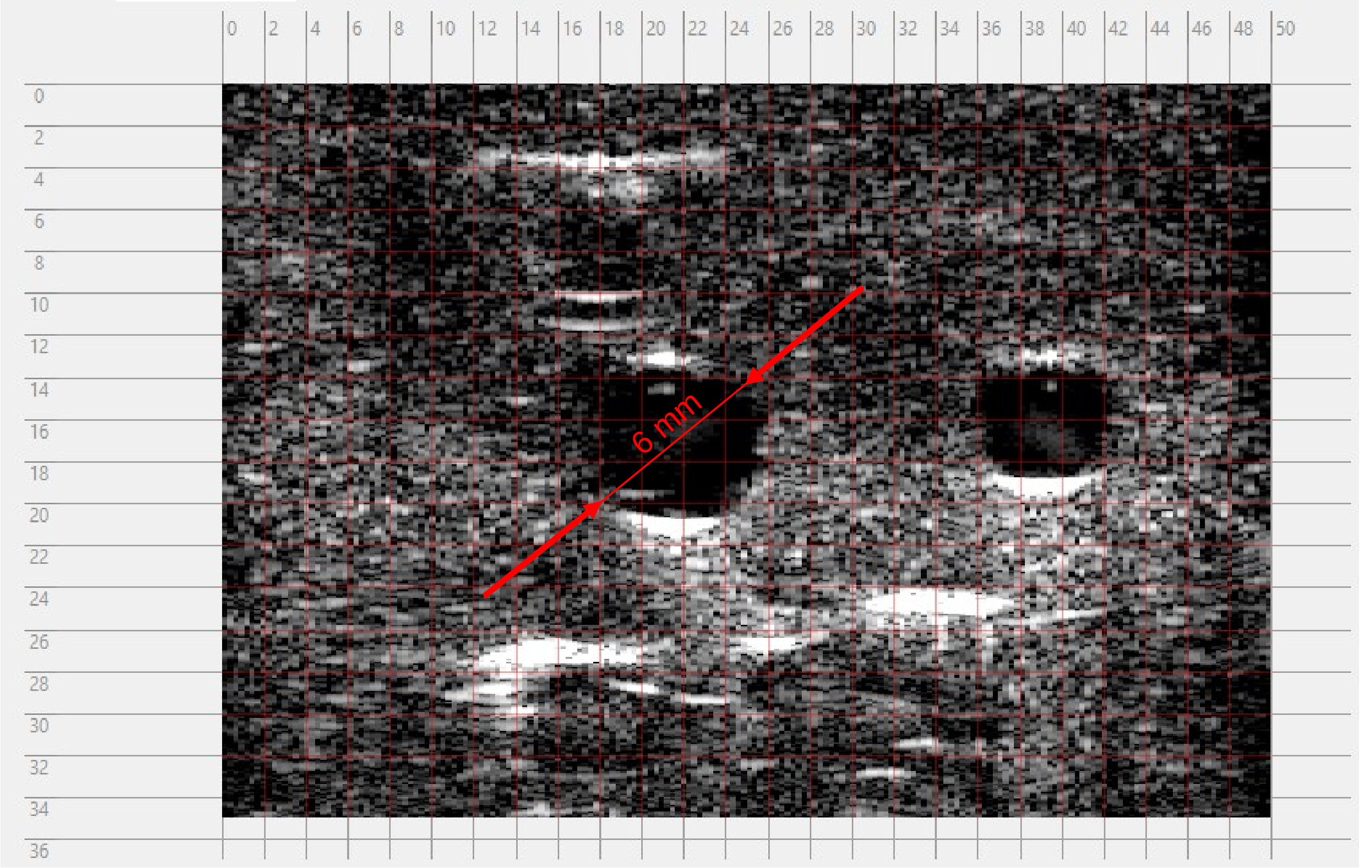




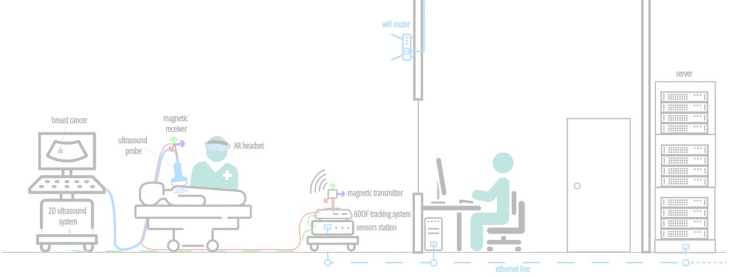
Scalar field's color scale for distance of original acquired US slices compare to reference mesh (point to mesh distances)

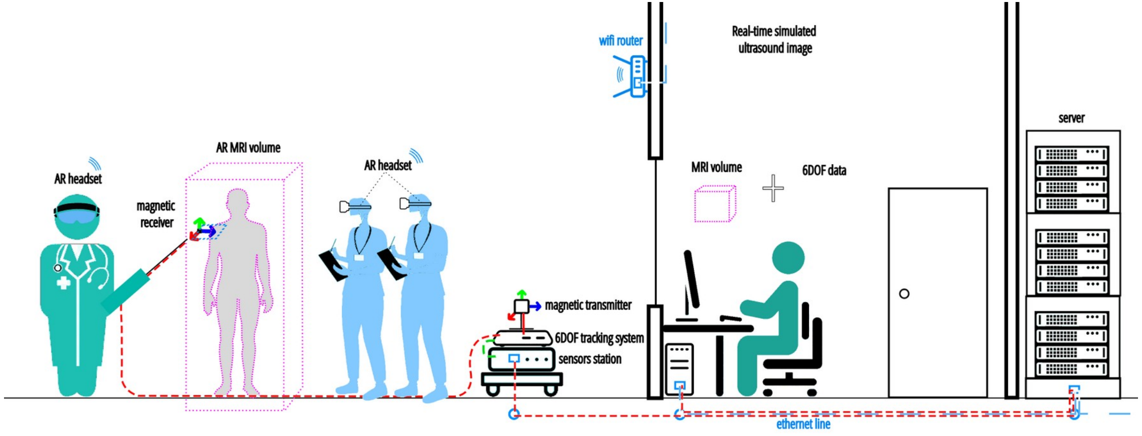
T.PLAY

Reachable



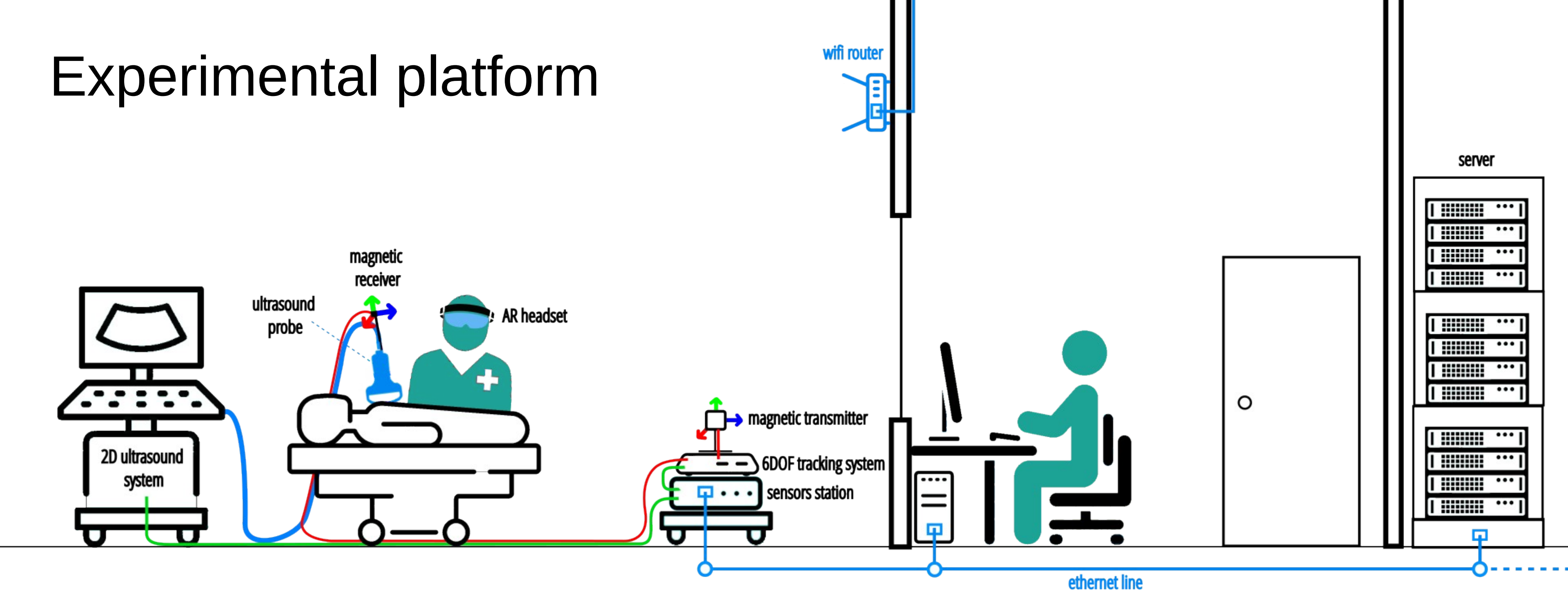
T.PLAY
Applications



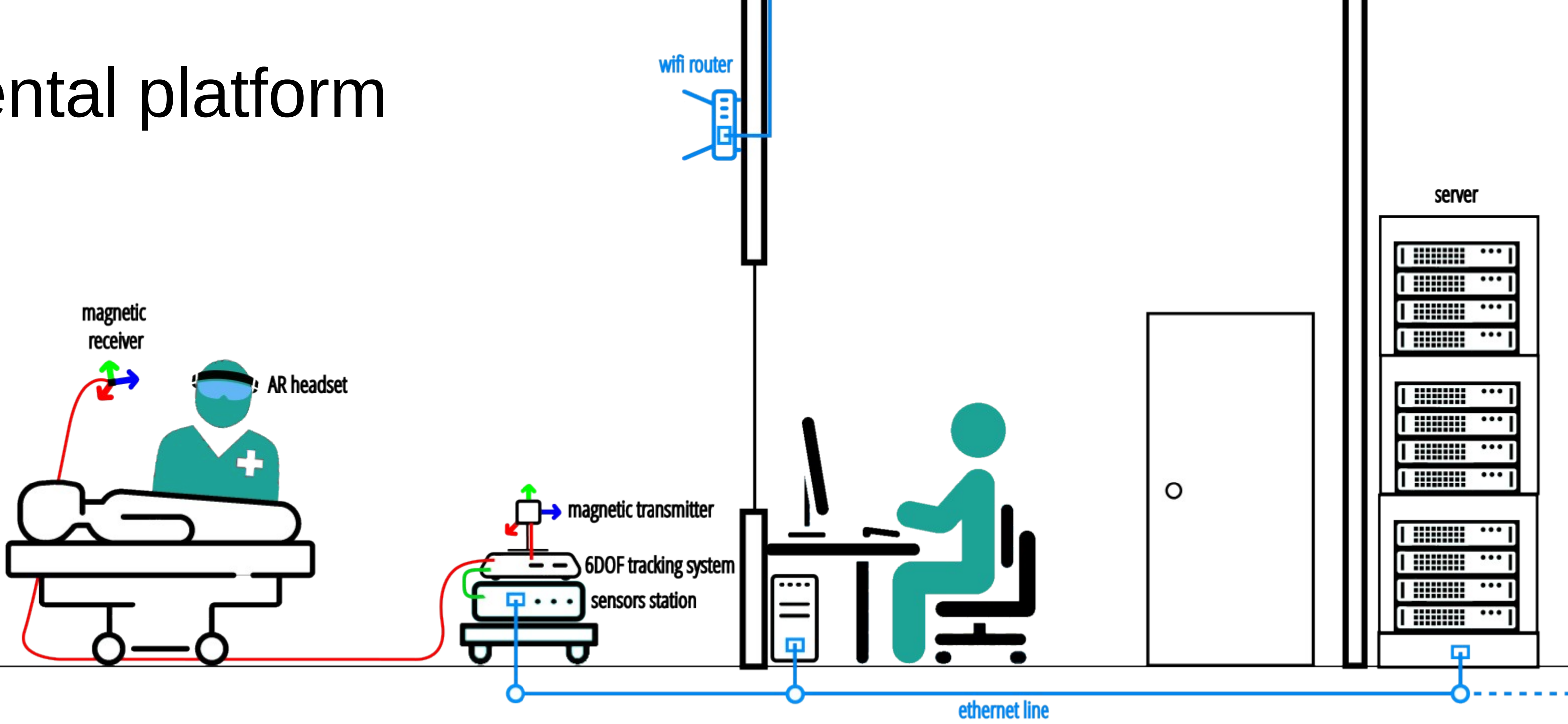


Simulation training

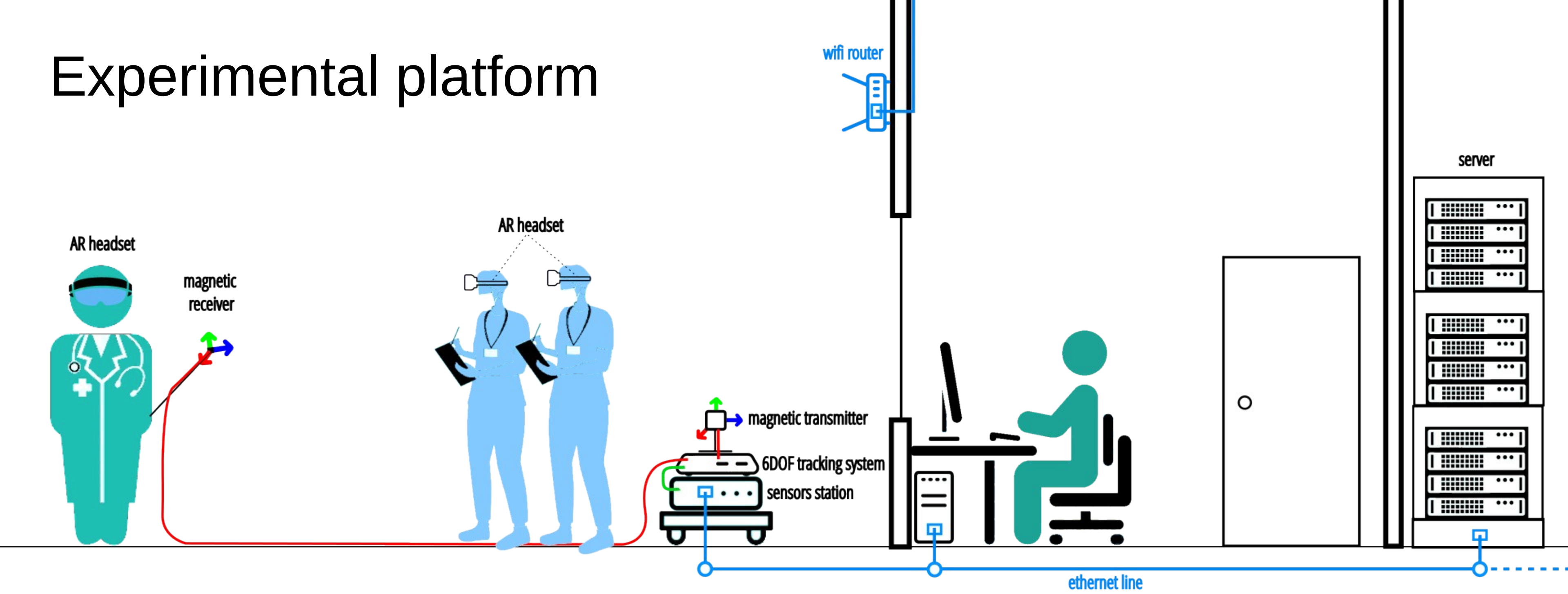
Experimental platform



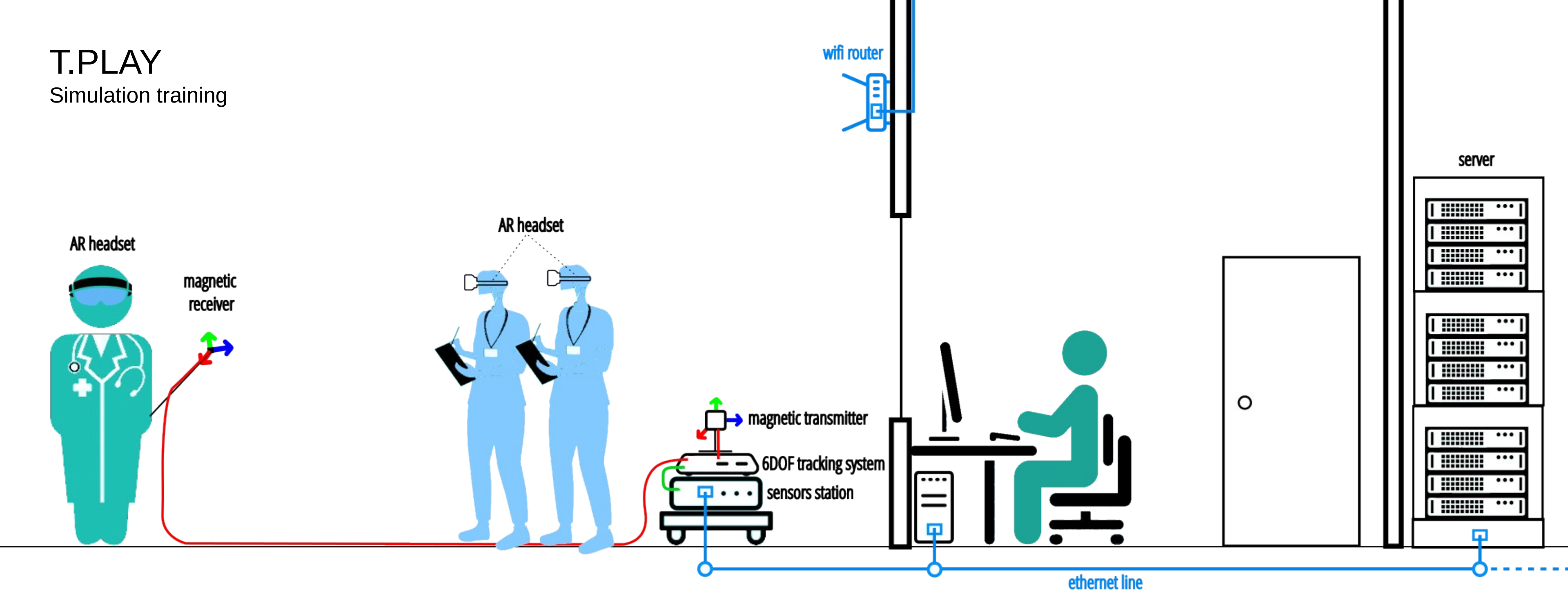
Experimental platform



Experimental platform

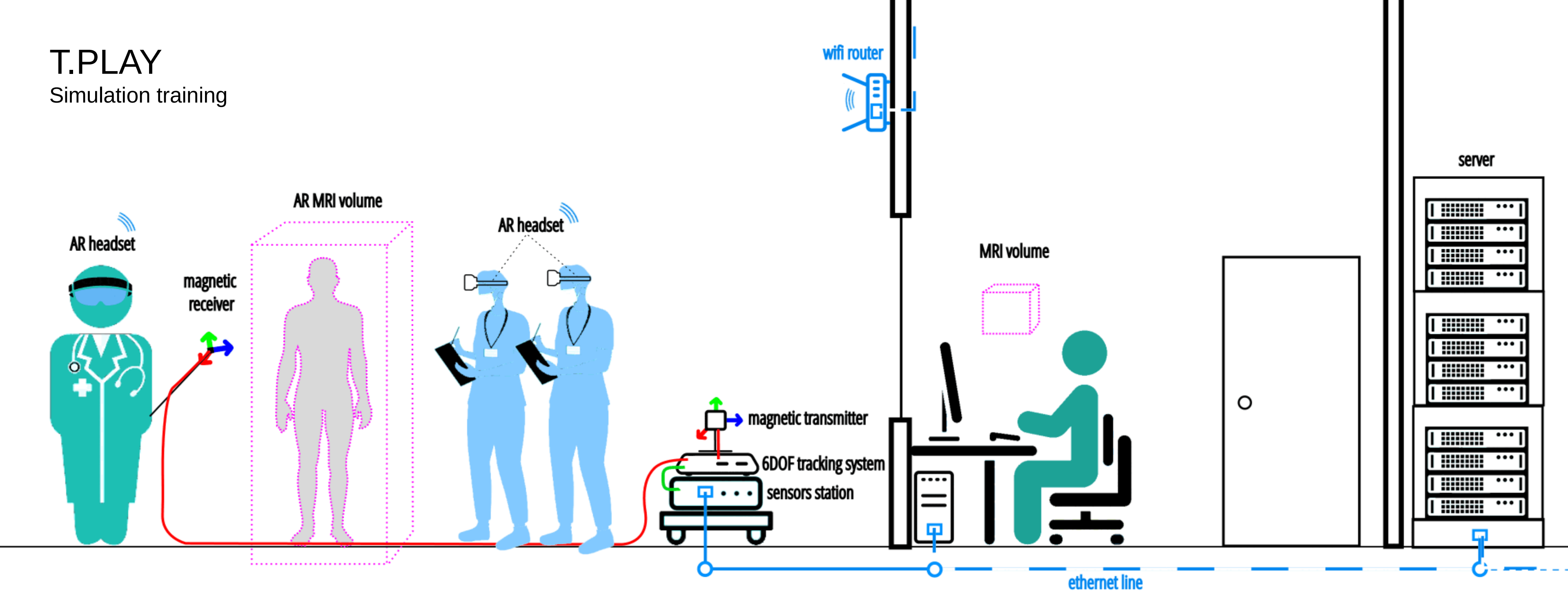


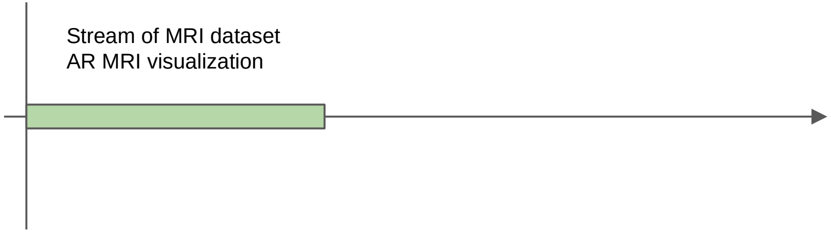
T.PLAY
Simulation training



Goal: Collaborative training in diagnostic ultrasound images without using an ultrasound scanner

T.PLAY
Simulation training

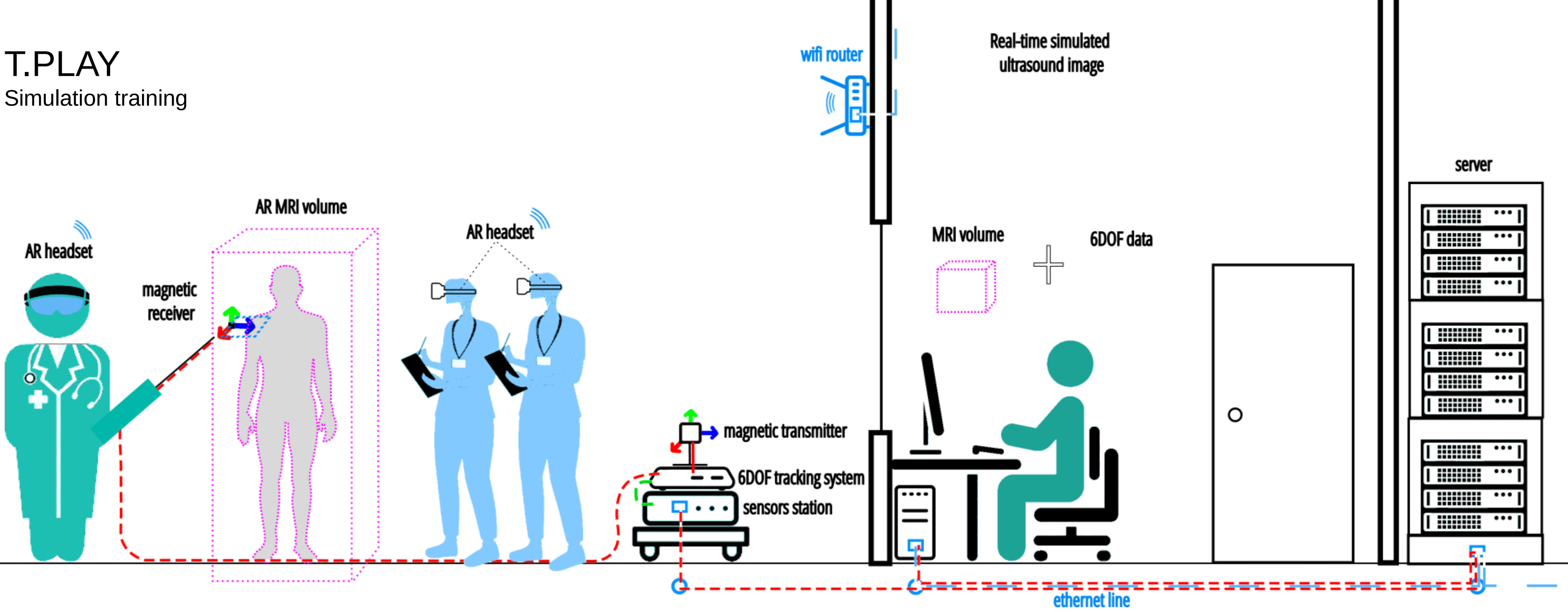




Goal: Collaborative training in diagnostic ultrasound images without using an ultrasound scanner

MRI : Magnetic resonance imaging

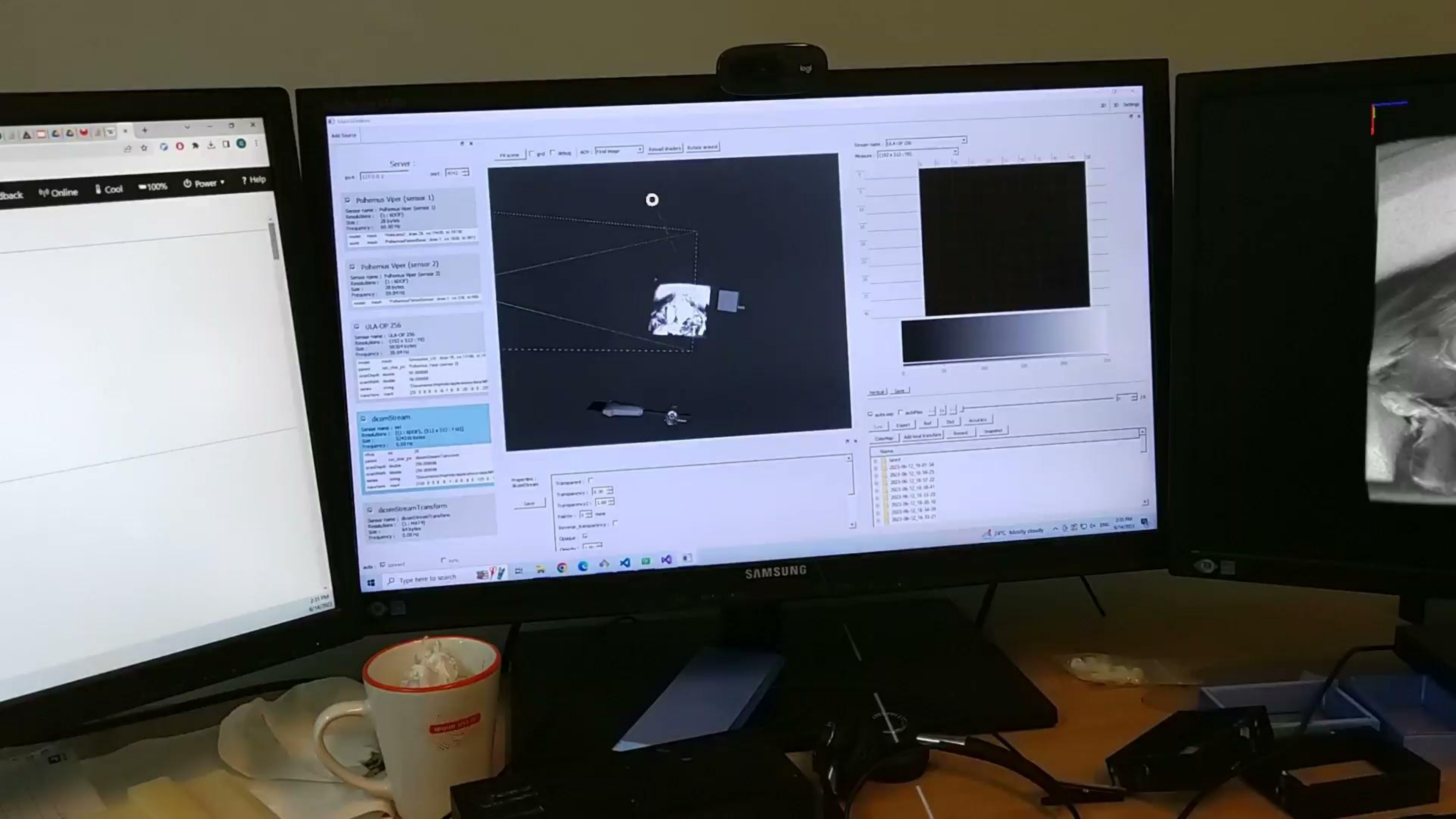
T.PLAY
Simulation training



Stream of MRI dataset
AR MRI visualization

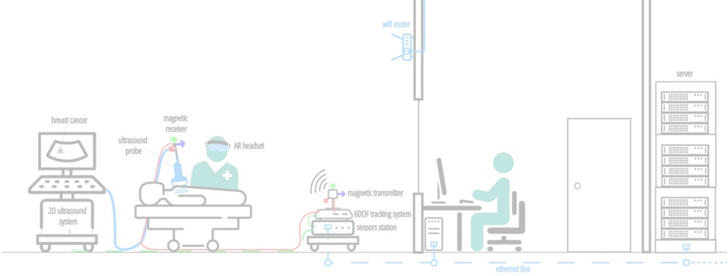
Simulate ultrasound image from
6DOF data in real time
Visualize simulated slice in AR devices

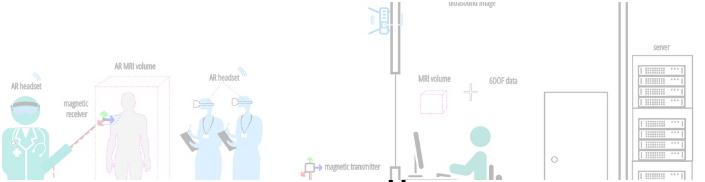
Goal: Collaborative training in diagnostic ultrasound images without using an ultrasound scanner



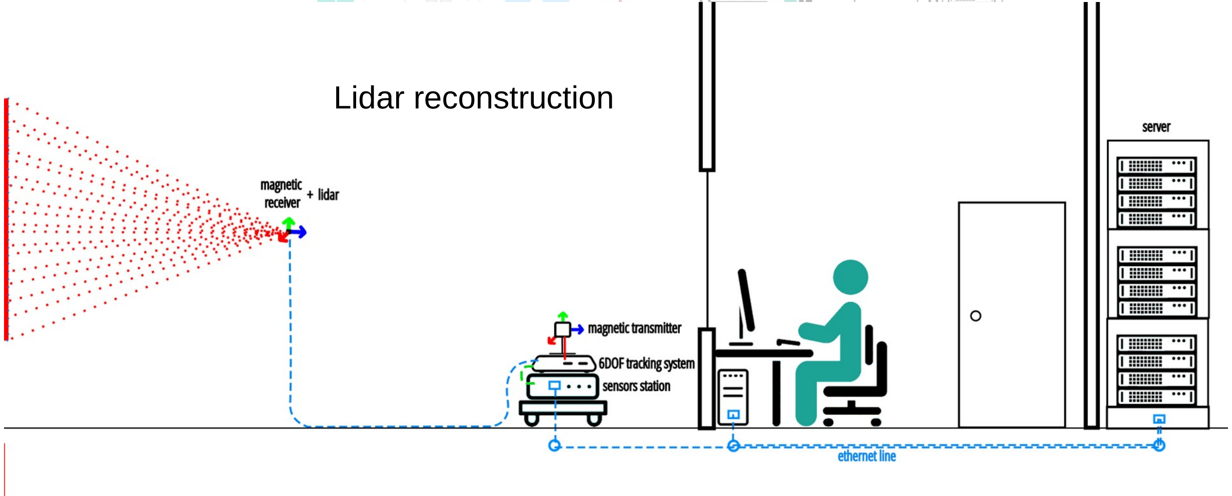
Online
Cool
100%
Power
Help
Server :
Polhemus Viper (sensor 1)
Polhemus Viper (sensor 2)
ULA-OP 256
dicomStream
dicomStreamTransform
Reload shaders
Rotate around
Type here to search
SAMSUNG

T.PLAY
Applications

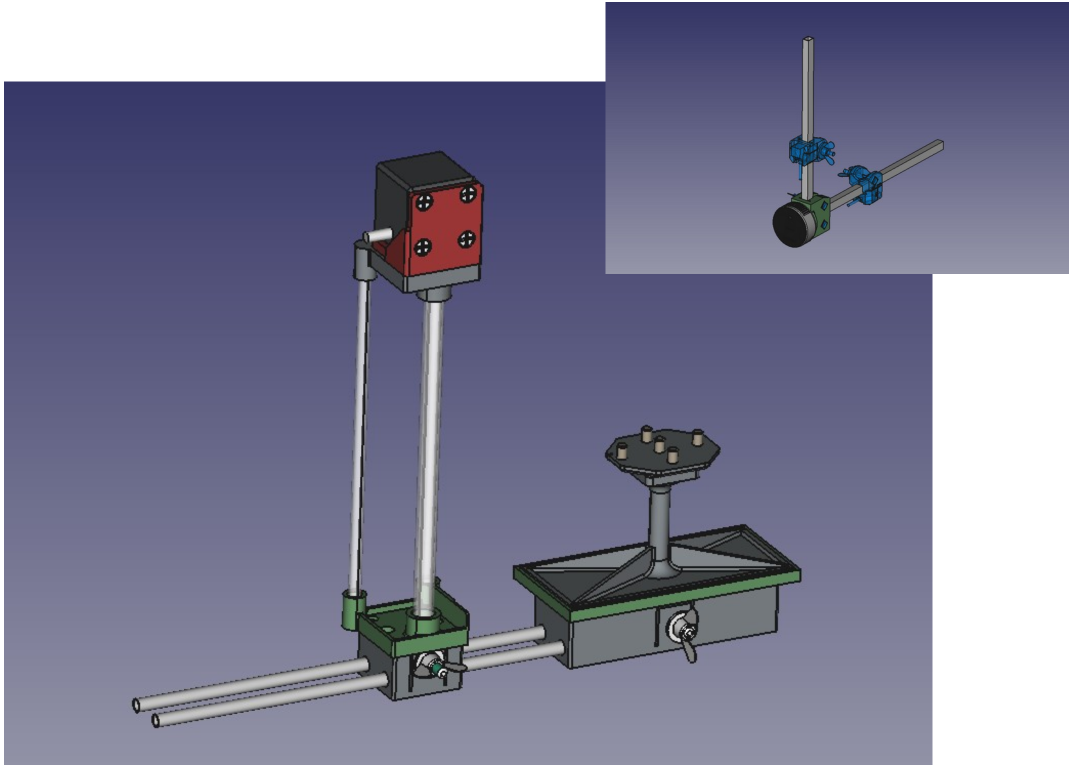




Lidar reconstruction



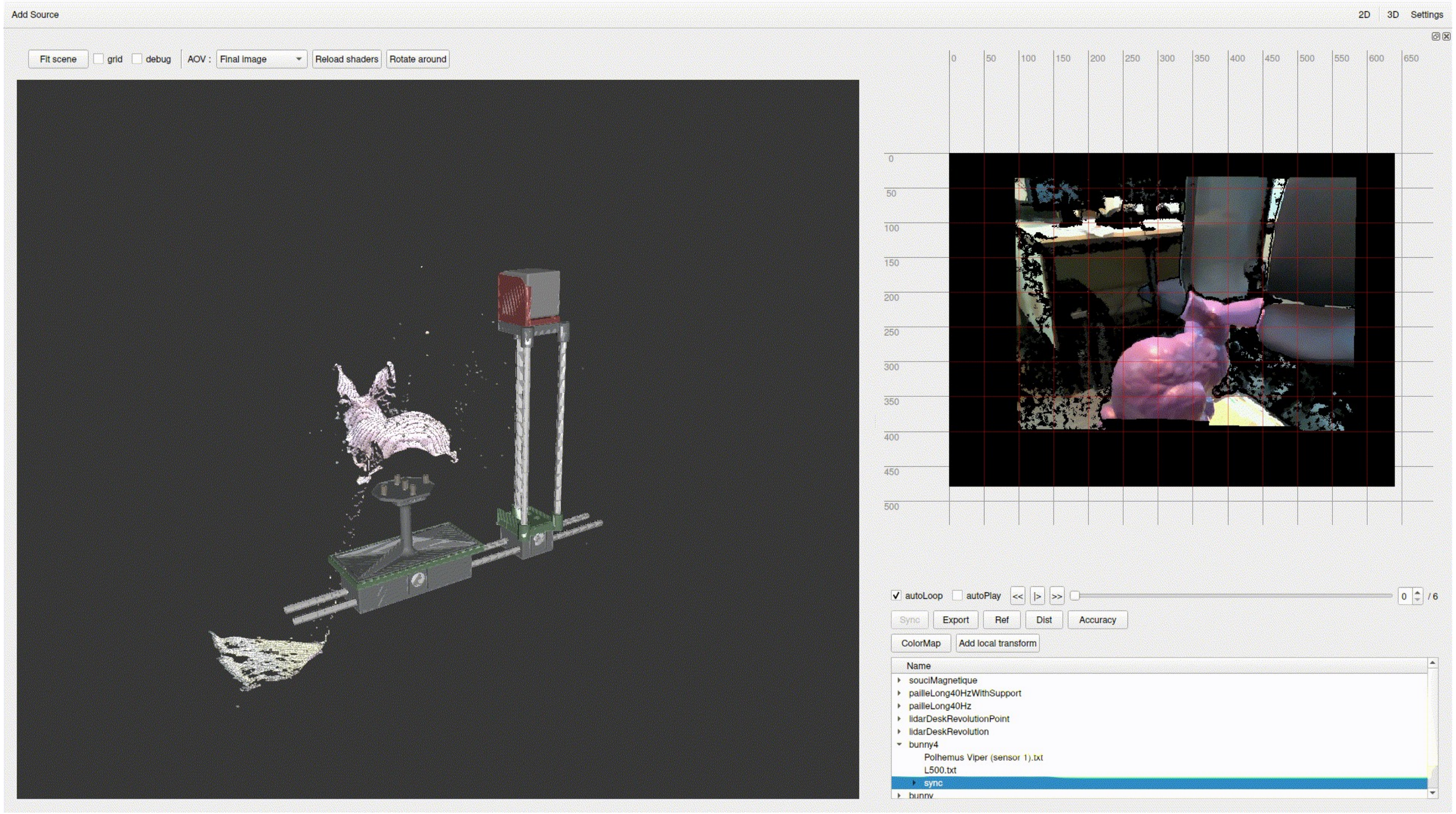
T.PLAY : LiDAR Calibration Platform



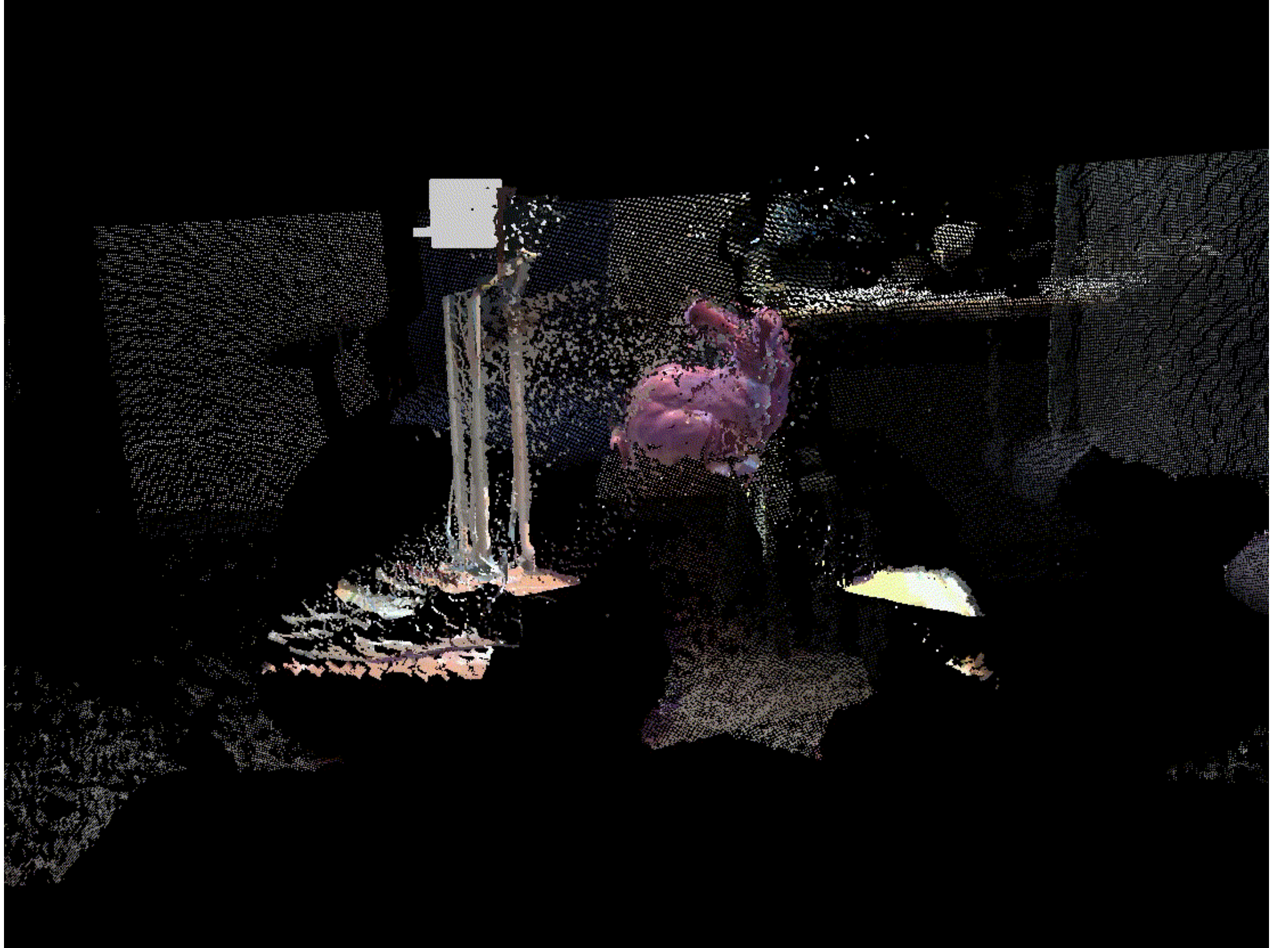
3D printed support

Printed geometry to reconstruct

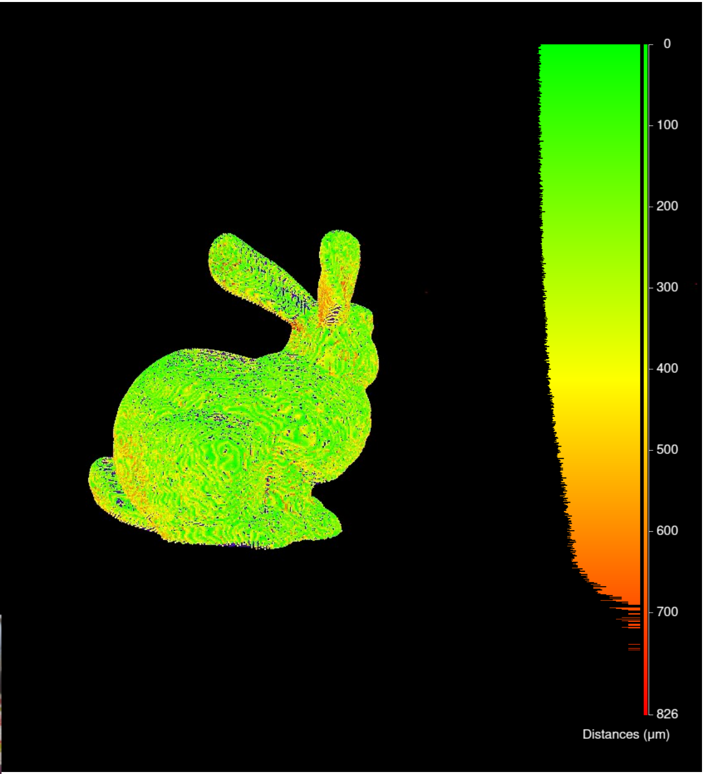
T.PLAY : Acquisition around the target (6DOF tracking)

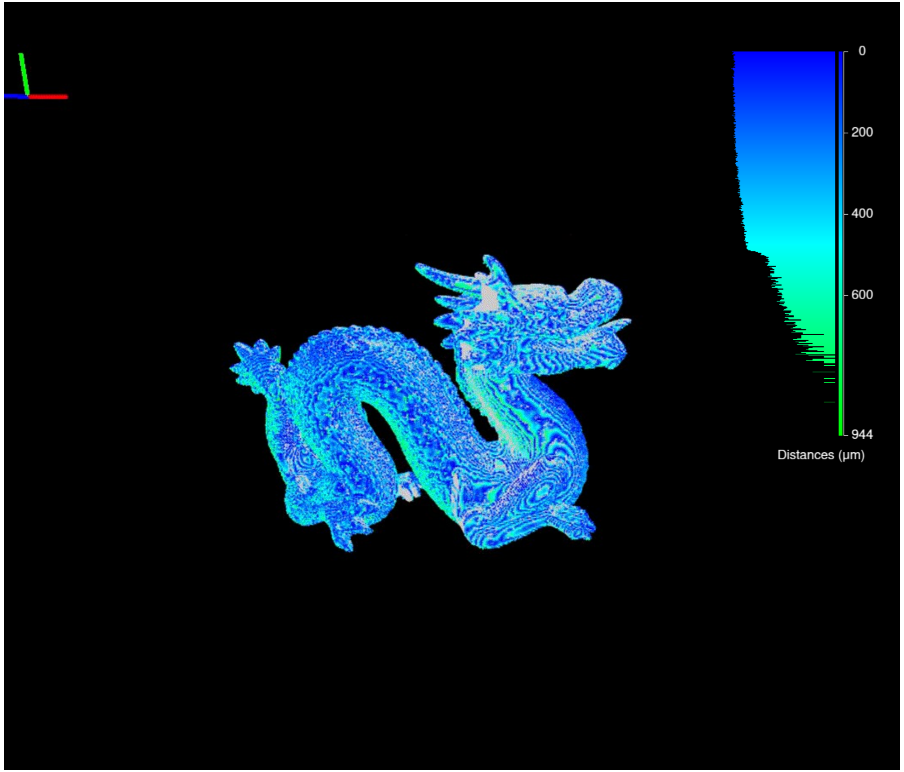


T.PLAY : Synchronization



T.PLAY : Accuracy



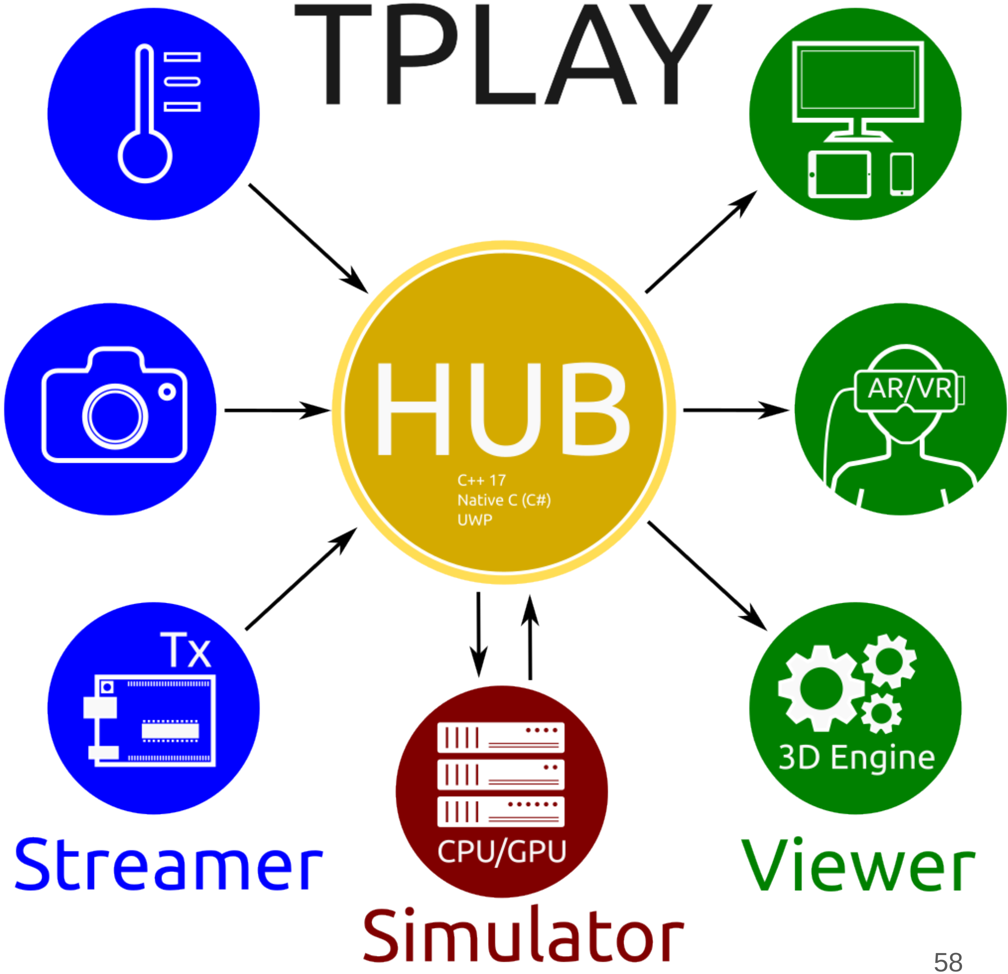


log(y) scales, point to mesh distances

Question for the audience

- Can T.PLAY be useful for you ?

https://github.com/T-PLAY



Publications

Ultrasound volume reconstruction from 2D freehand acquisitions using neural implicit representations. F. Gaits, N. Mellado, A. Basarab. 21st IEEE International Symposium on Biomedical Imaging (ISBI 2024) (poster), 2024

Efficient stratified 3D scatterer sampling for freehand ultrasound simulation. F. Gaits, N. Mellado, G. Bouyjou, D. Garcia, A. Basarab. IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, 2023