Microwave imaging for breast cancer detection: A non-contacting approach

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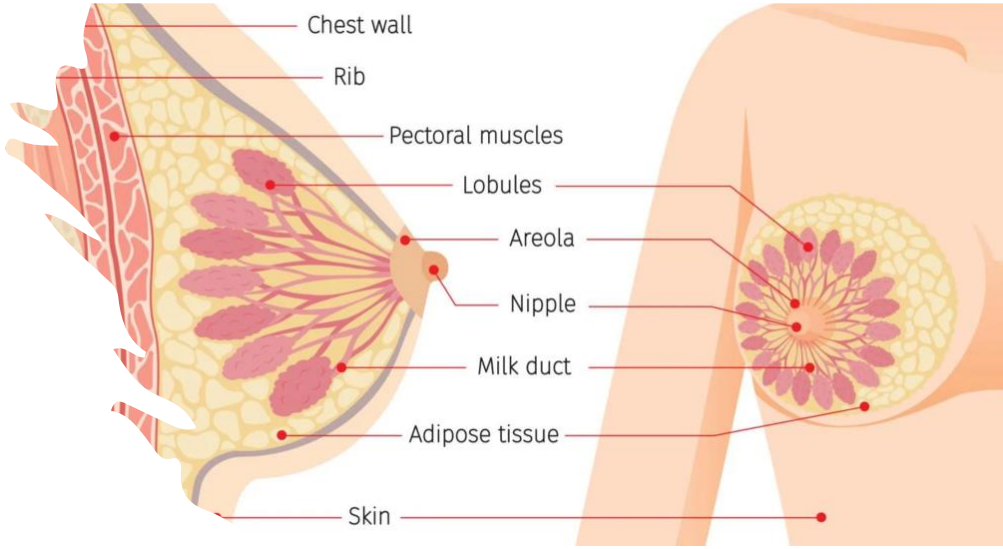
Motivation

- In Sweden breast cancer is the most common form of cancer among women
- Statistics for women in Sweden 2021:
  - 11 327 diagnosed
  - Incidence of 218,9
  - Prevalence was 122 166
  - Number of deaths 1 326
  - Since 1980 the number of cases has been increasing every year
- It is important to develop safe and comfortable methods for early detection

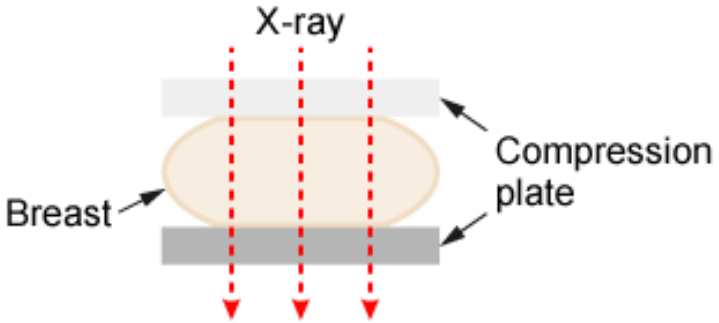


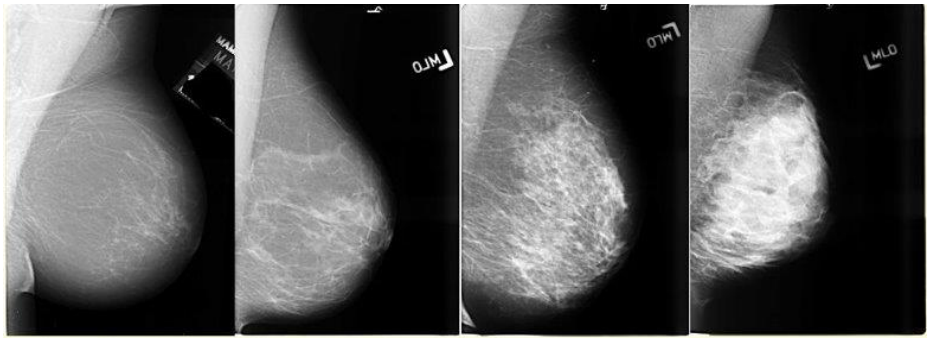
"CANCER I SIFFROR Populärvetenskapliga fakta om cancer 2023." Available: https://www.socialstyrelsen.se/globalassets/sharepoint-dokument/dokument-webb/statistik/cancer-i-siffror-2023.pdf

Breast cancer screening methods

X-ray mammography:

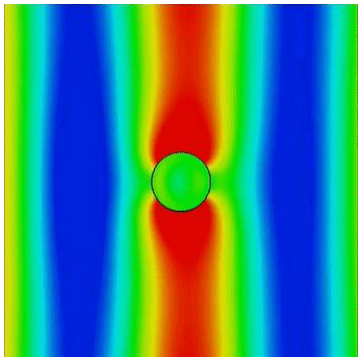
+ Primary method
+ High spatial resolution
+ Live imaging during biopsies
- Uncomfortable/painful breast compression
- Ionizing radiation
- Accuracy of result depending on radiologist experience
- Difficulty in distinguishing between tissues due to low contrast



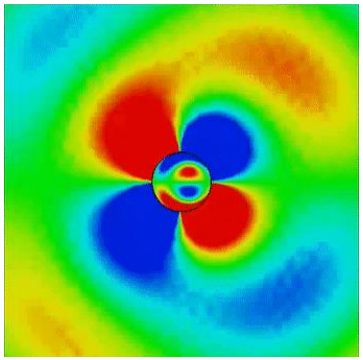


Microwave imaging (MWI)

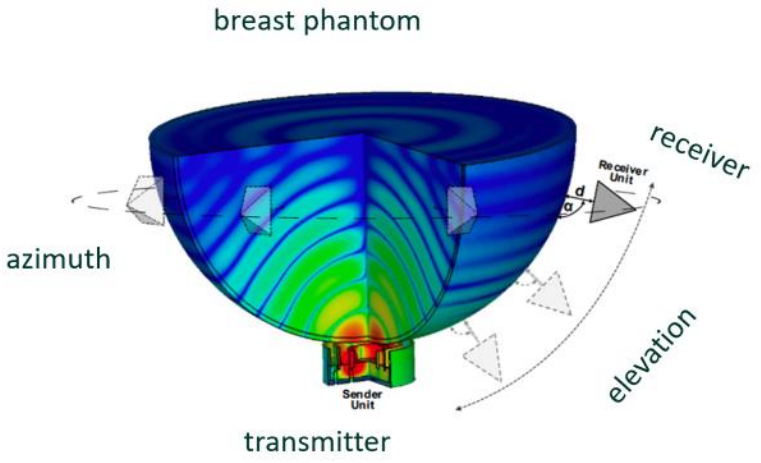
+ Possible complement for mammography
+ Early detection
+ Non-contacting
+ Non-ionizing radiation
+ Fairly high contrast among different tissues
- No widely adopted systems for routine clinical use
- Many years of research + engineering
- Signal nature
- Computationally expensive



Incident field

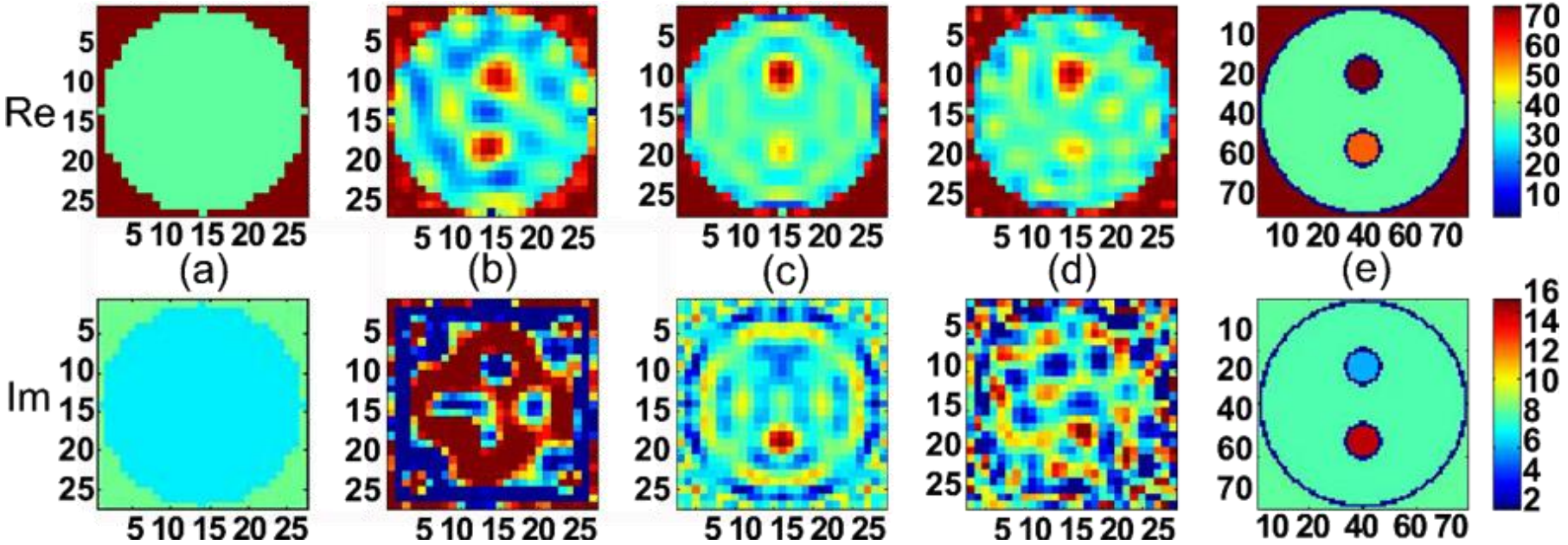


Scattered field



- Electromagnetic microwaves
- Microwaves penetrate, scatter, and reflect within the breast
- Scattered and reflected signals are received
- An internal breast image is constructed
- Dielectric properties of tumorous breast tissue differ from healthy tissue

Resulting images

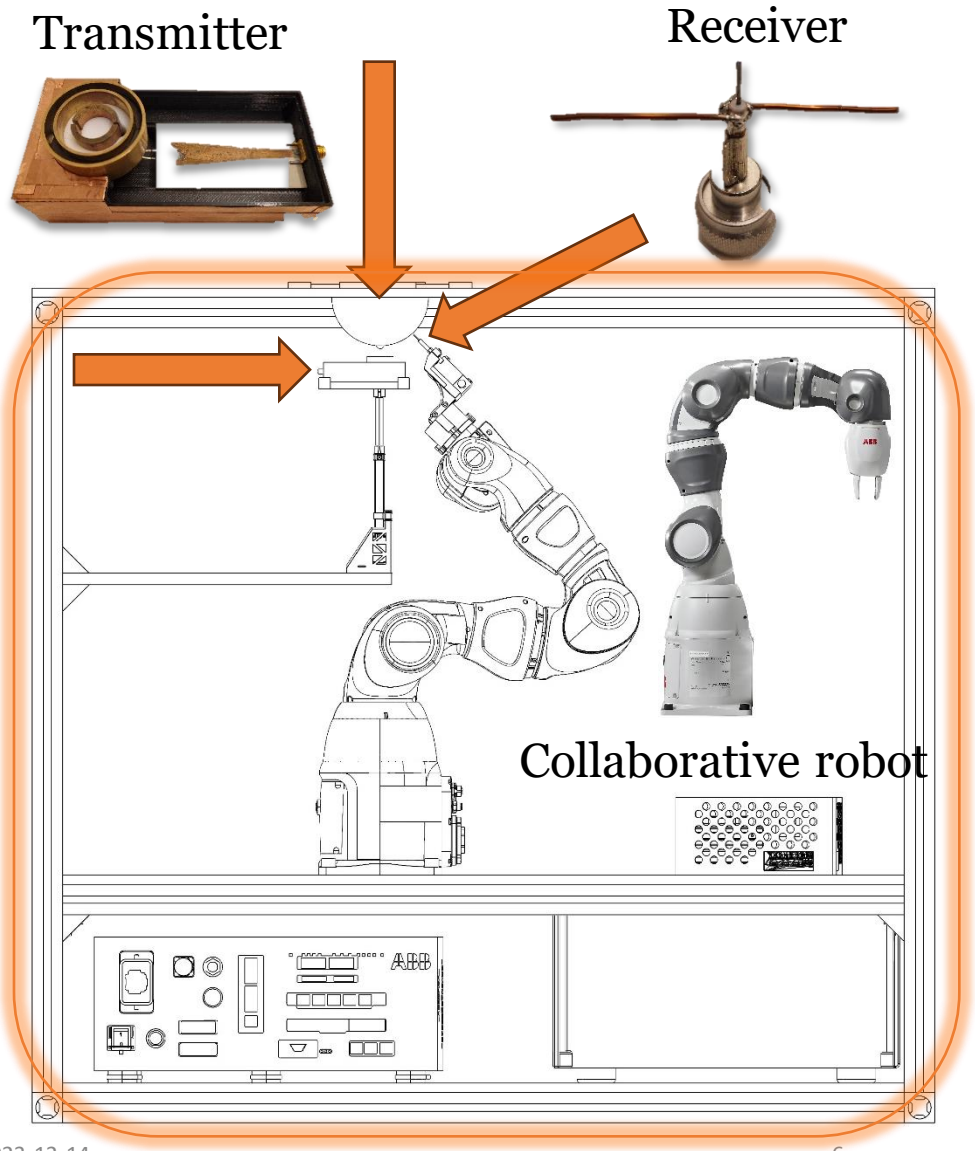


Our project

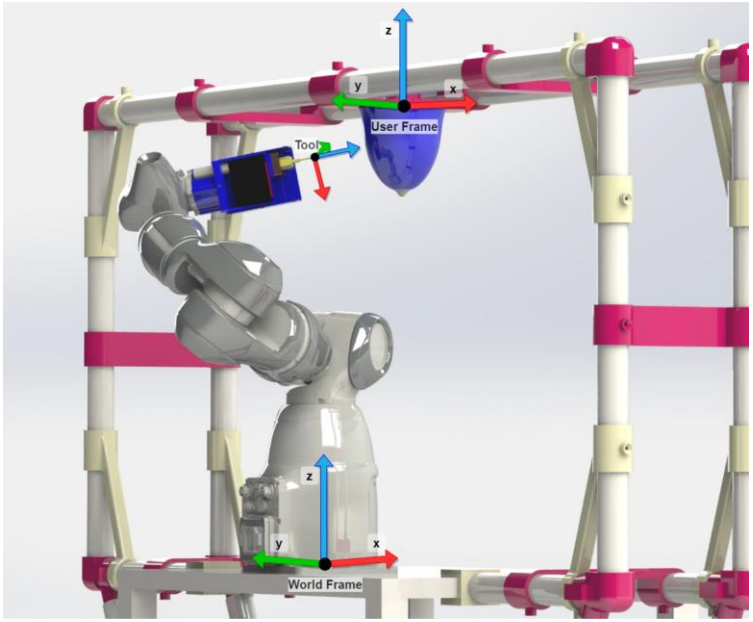
- Microwave sensors for breast cancer detection
- Developed by researchers at MDU
- Goal: Automated measurements on a simple breast phantom with known/unknown geometry
- Problem: Need to find a way to move the microwave sensors automatically to various positions around the breast
- Laser-based surface estimation for unknown, irregular geometry
- Collaborative robot:
  - ✓ Different from current approaches
  - ✓ Safe
  - ✓ Flexible
  - ✓ High accuracy and repeatability
- Second iteration

Known phantom

Unknown phantom



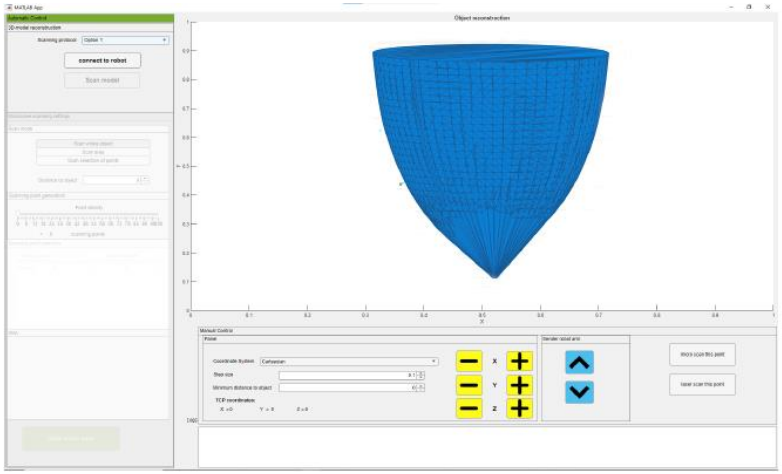
Last year's iteration



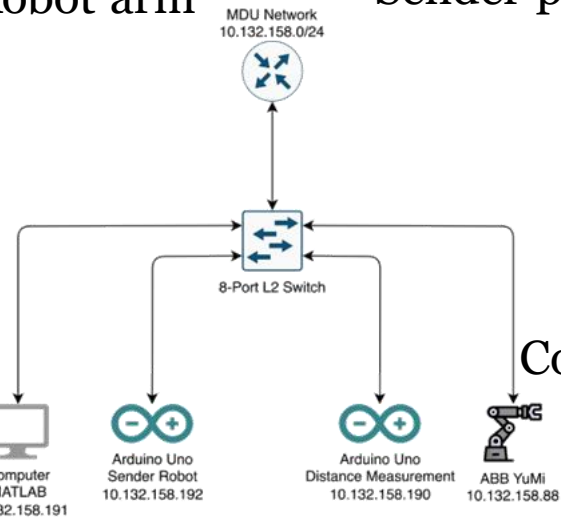
System overview

Robot arm

Sender platform

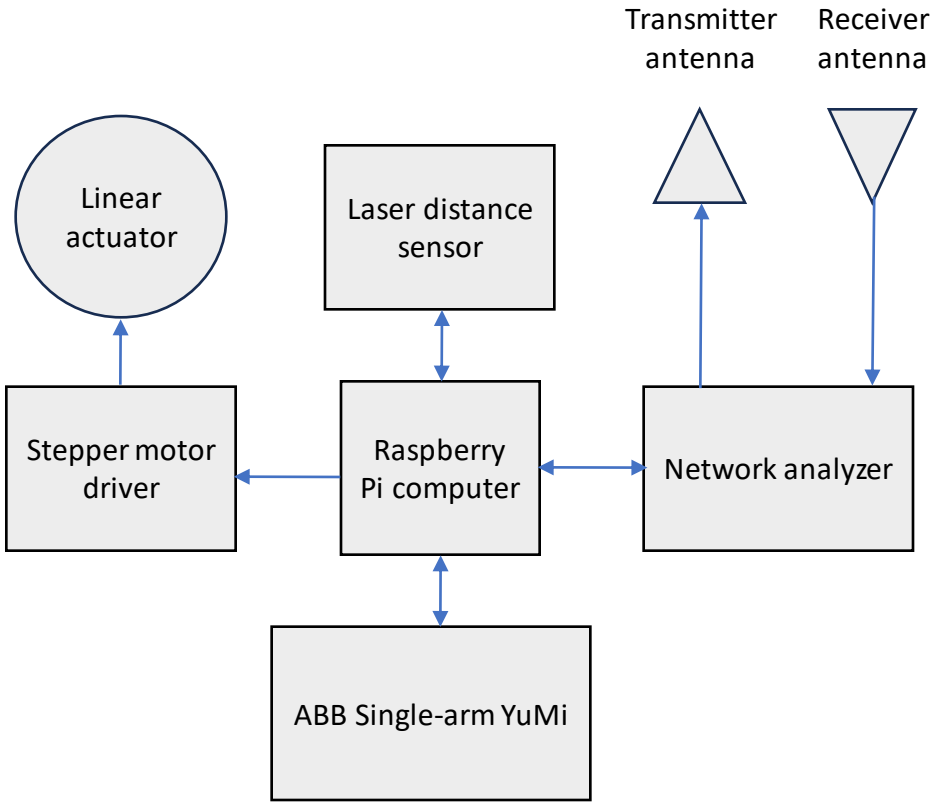


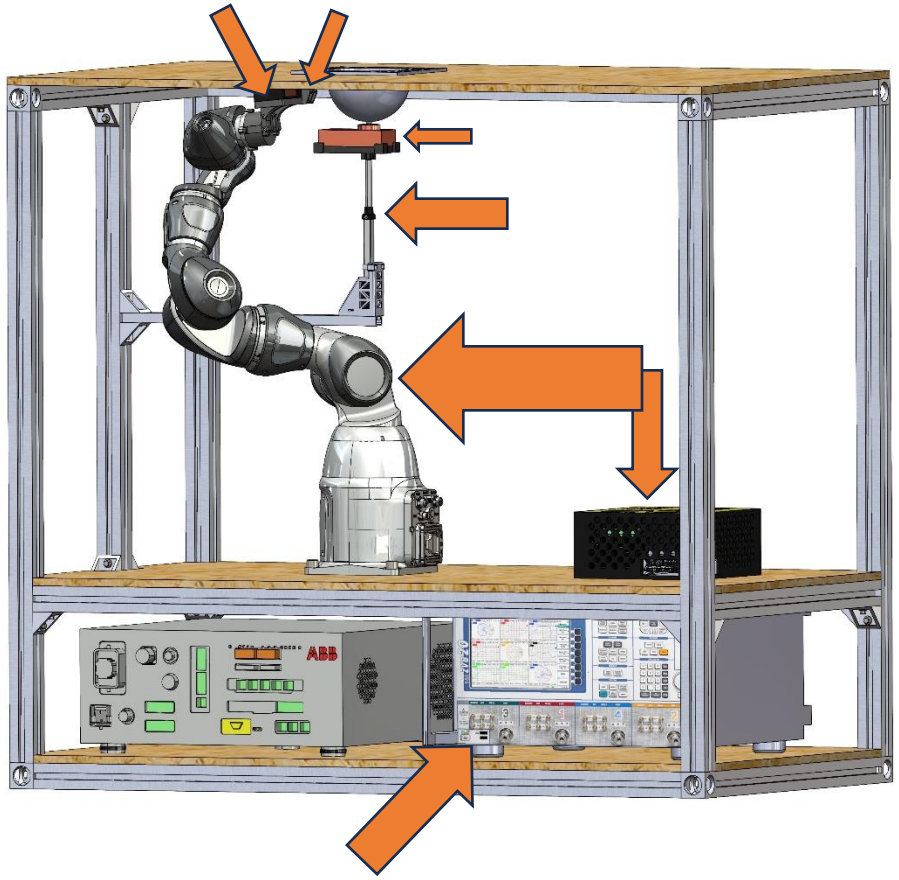
MATLAB GUI



Control system

Hardware – System overview



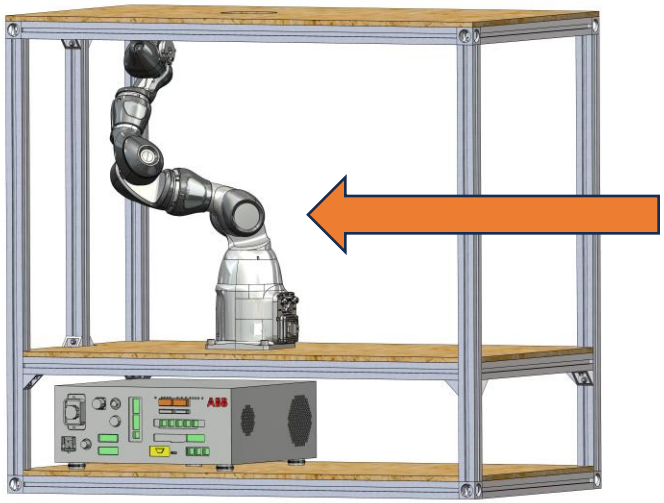


Hardware

- Frame

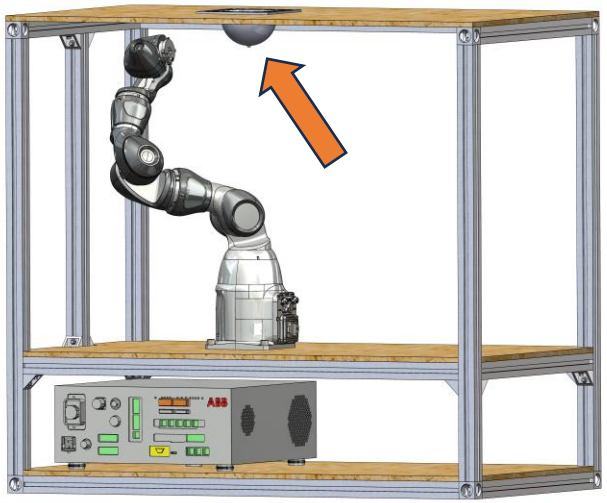
Hardware

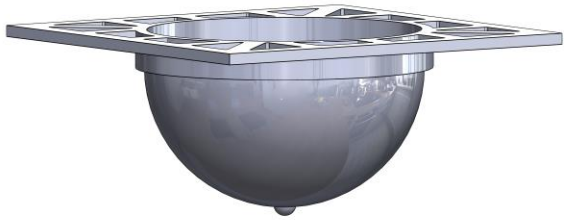
- Frame
- Single-arm YuMi with controller



Hardware

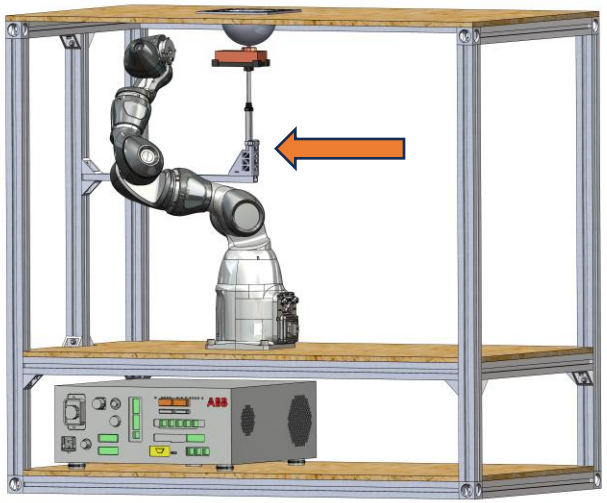
- Frame
- Single-arm YuMi with controller
- Breast phantom





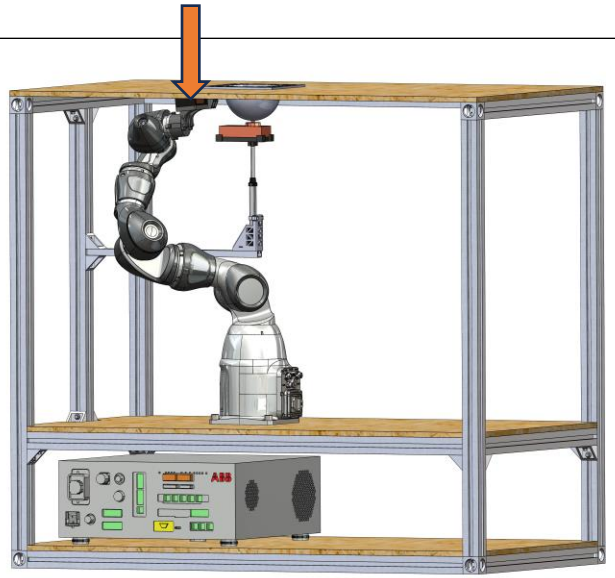
Hardware

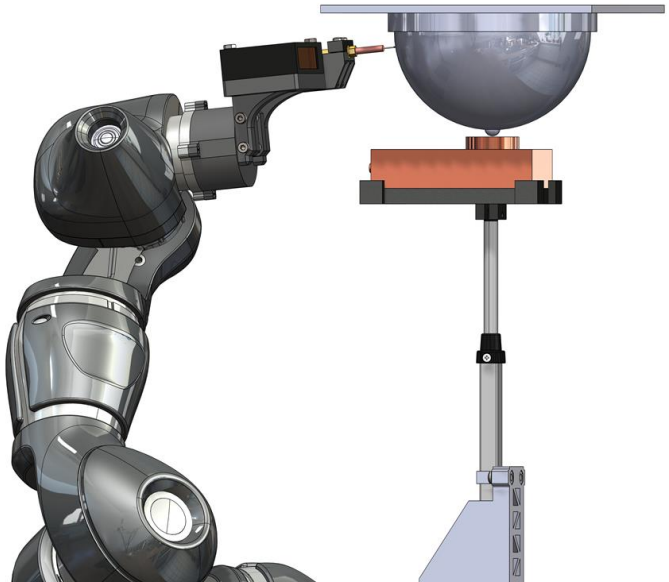
- Frame
- Single-arm YuMi with controller
- Breast phantom
- Transmitter platform

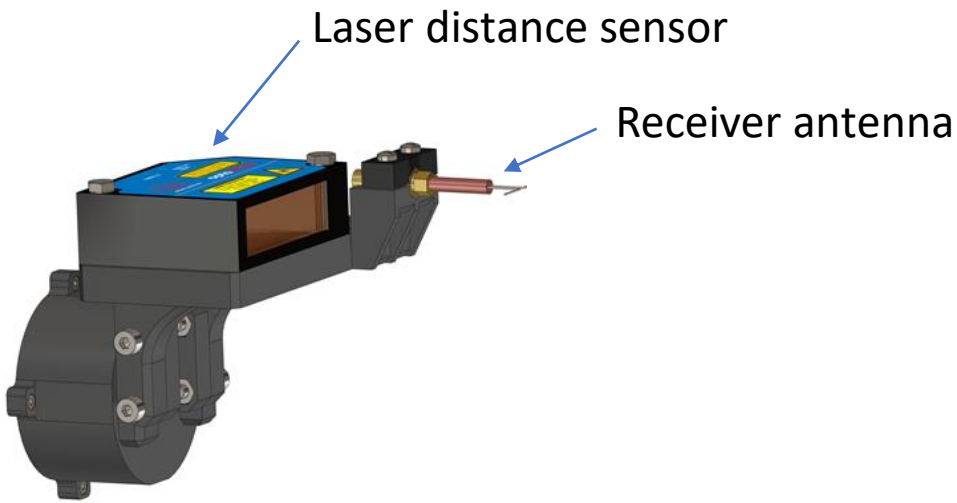


Hardware

- Frame
- Single-arm YuMi with controller
- Breast phantom
- Transmitter platform
- Robot end effector

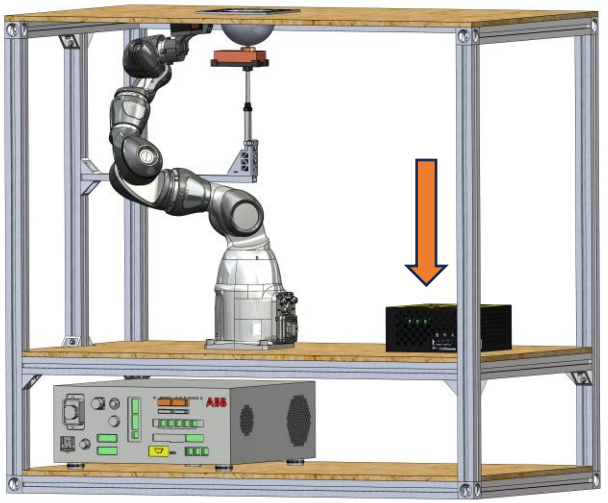


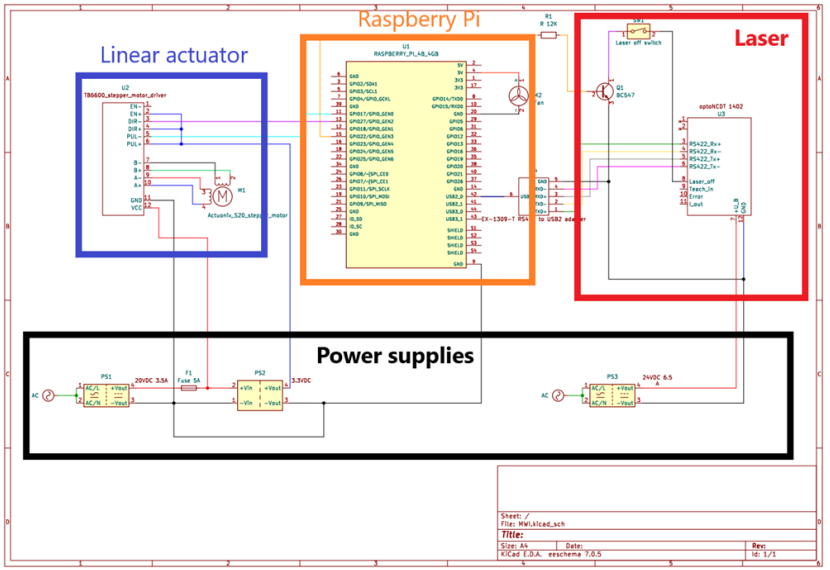




Hardware

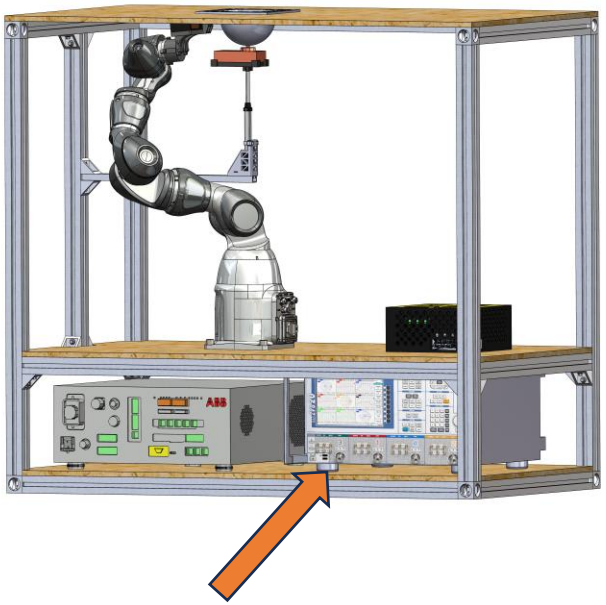
- Frame
- Single-arm YuMi with controller
- Breast phantom
- Transmitter platform
- Robot end effector
- Control box

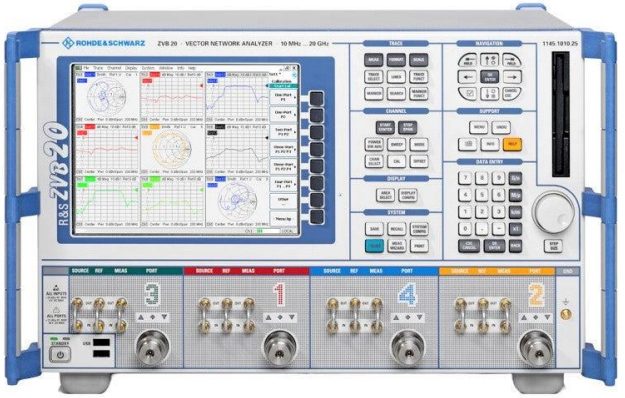




Hardware

- Frame
- Single-arm YuMi with controller
- Breast phantom
- Transmitter platform
- Robot end effector
- Control box
- Network analyzer





Software components

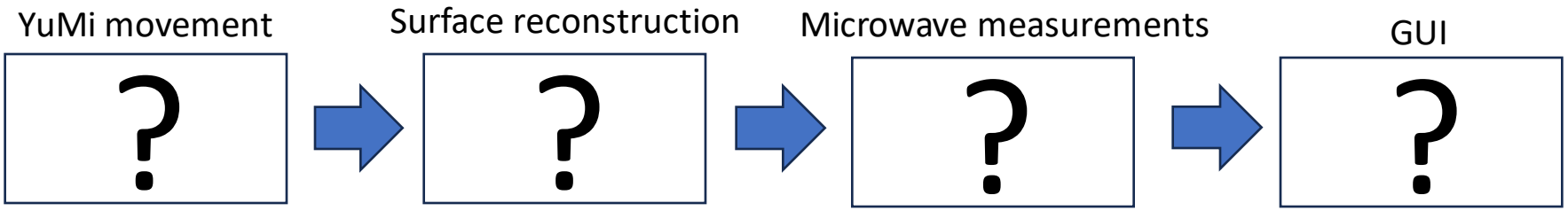
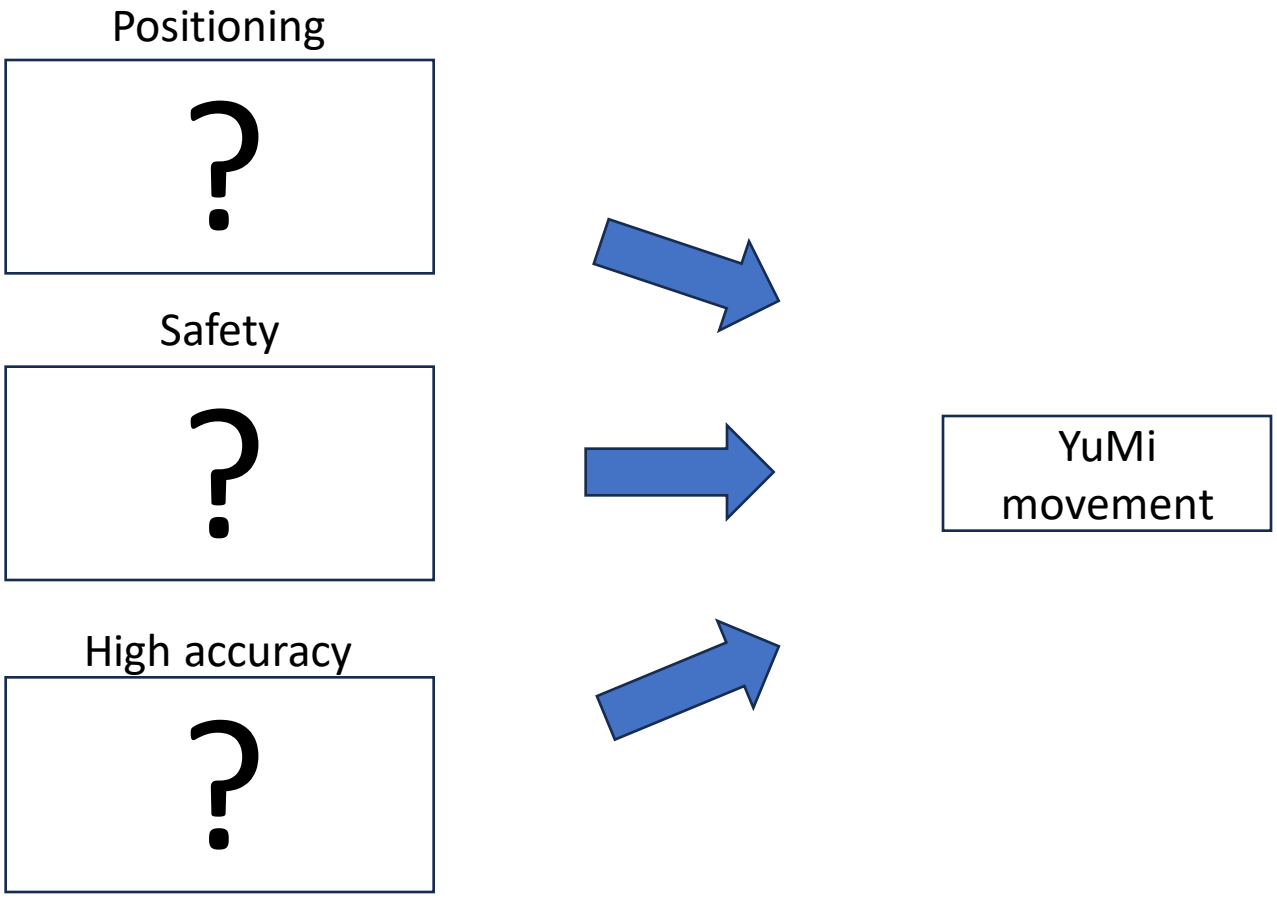


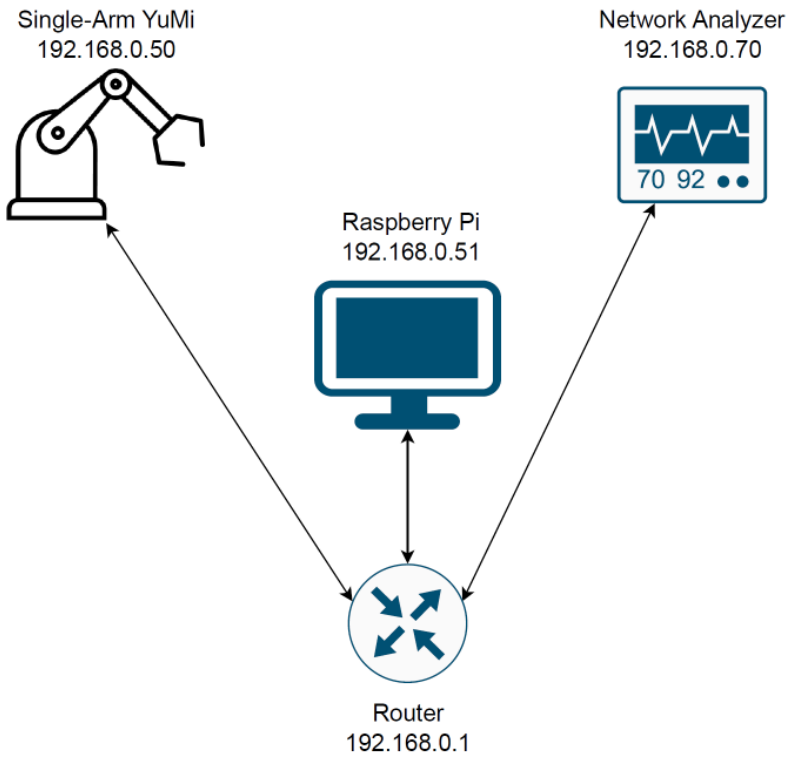
ABB RAPID

Software – YuMi movement



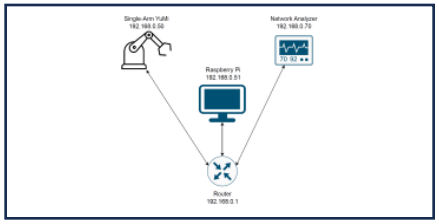
Software – YuMi Positioning

- Main control system using a Raspberry Pi
- Raspberry Pi determines the position of the YuMi
- Network Analyzer samples Microwave data once Raspberry Pi confirms the position of the YuMi



Software – YuMi movement

Positioning



Safety

?

High accuracy

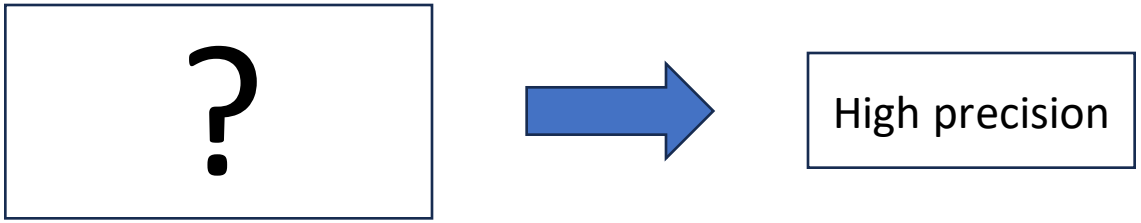
?

YuMi movement

Software – YuMi movement

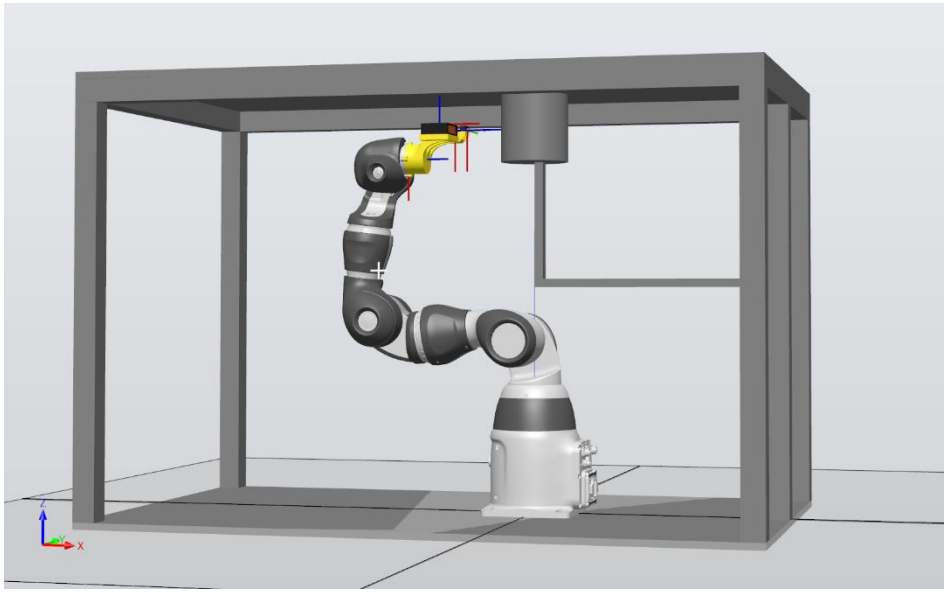
1. Simulation

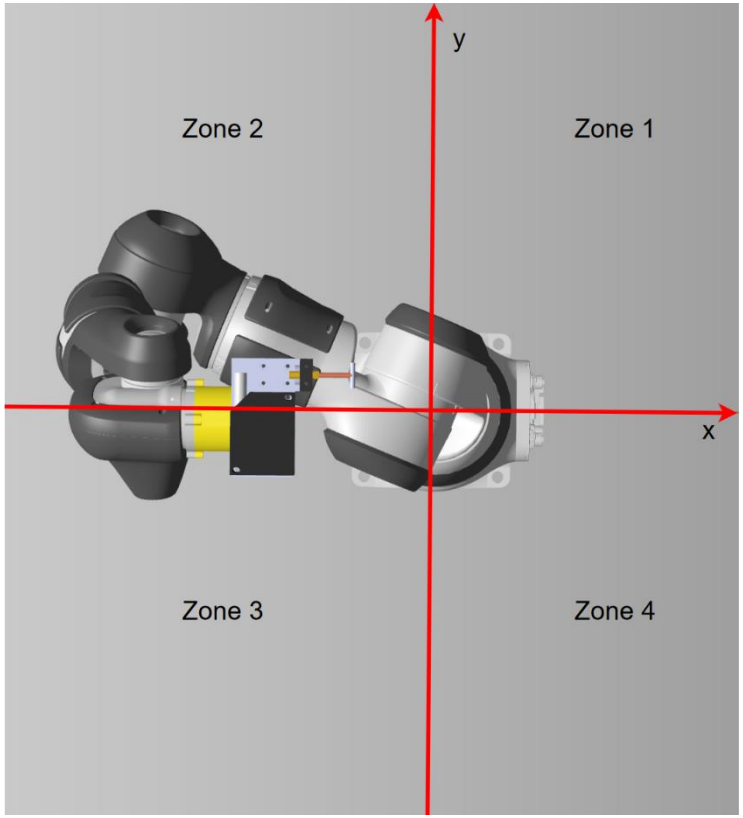
Position and Safety



Software – Position and Safety

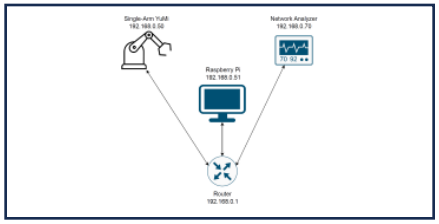
- Done with *RobotStudio* and *Python*
- Test system functionality before deployment
- Create logical zones to avoid collisions



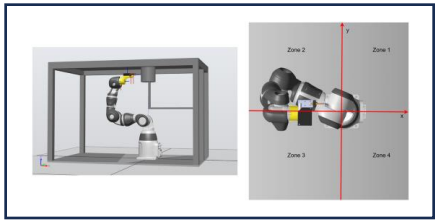


Software – YuMi movement

Positioning



Safety



High accuracy

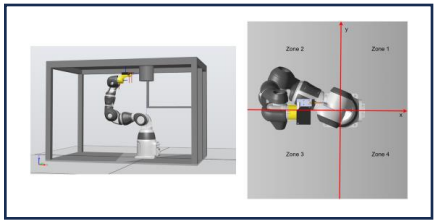
?

YuMi movement

Software – YuMi movement

1. Simulation

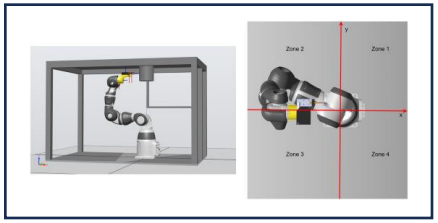
Position and Safety



High precision

2. Physical YuMi

Position and Safety



Max Error: 10.75 mm

Low precision

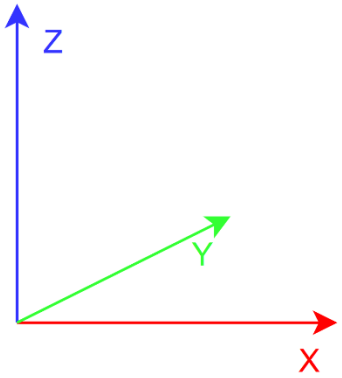
Calibration

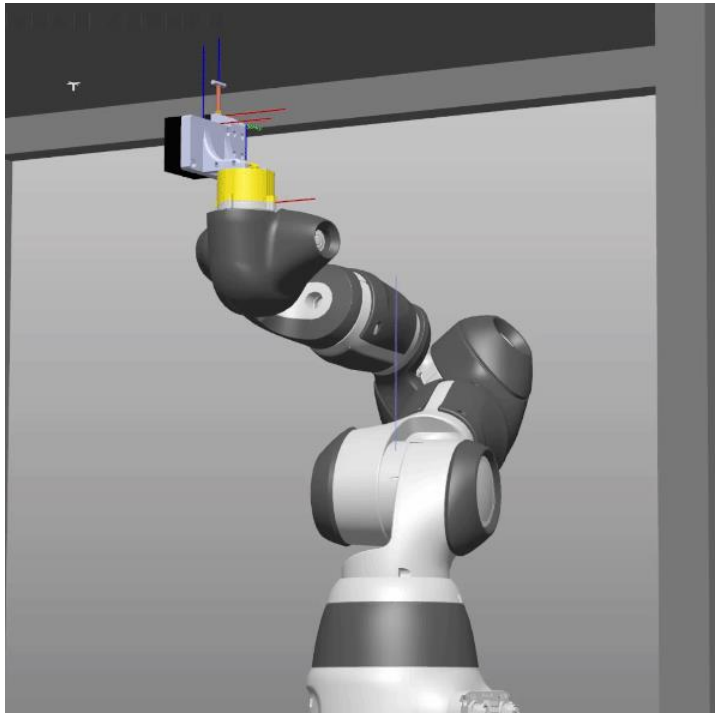
?

Software – YuMi Calibration

- Done by creating a new user frame

1. Measure three points in the ceiling
2. Compute the difference in height of the of the three points
3. Rotate the three axes of the user frame to adjust for the measured error

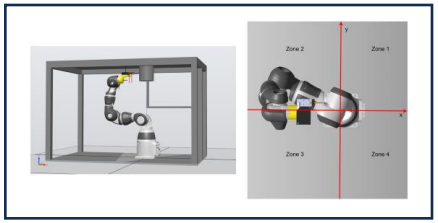




Software – YuMi movement

1. Simulation

Position and Safety

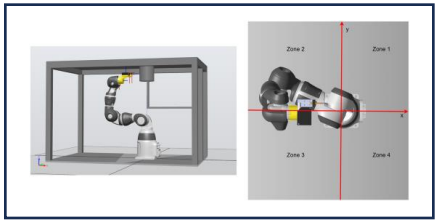


Max Error: 0.42 mm

High precision

2. Physical YuMi

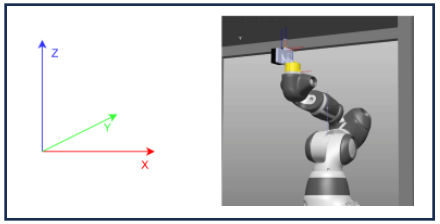
Position and Safety



Max Error: 10.75 mm

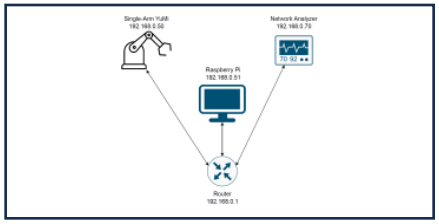
Low precision

Calibration

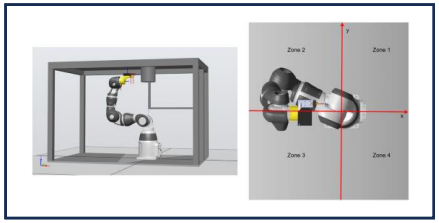


Software – YuMi movement

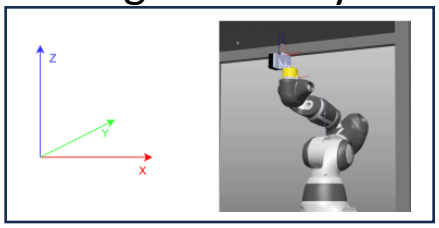
Positioning



Safety

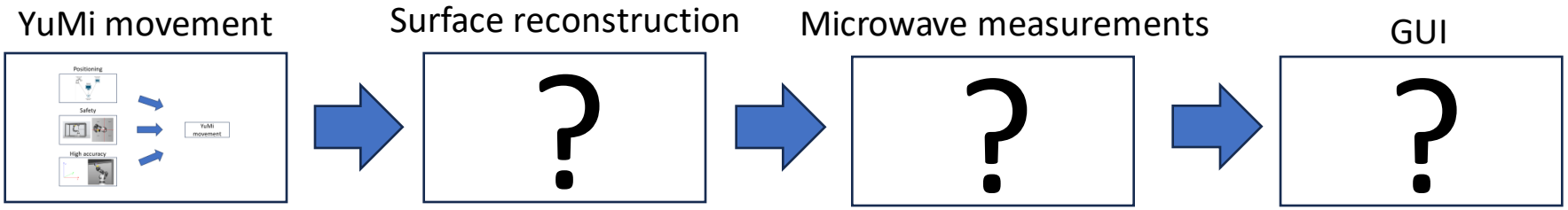


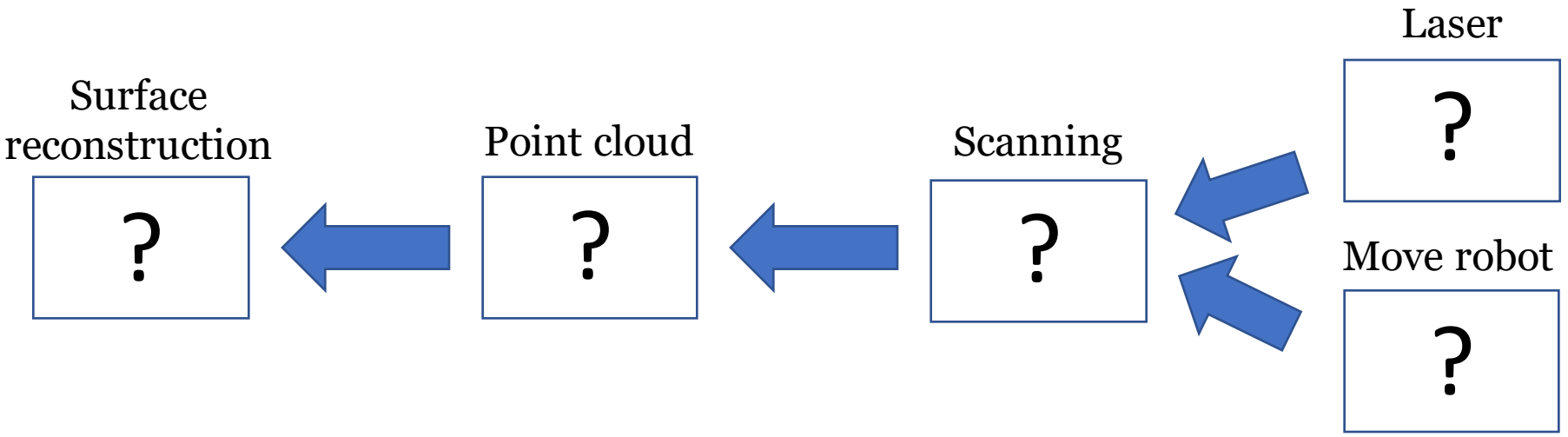
High accuracy



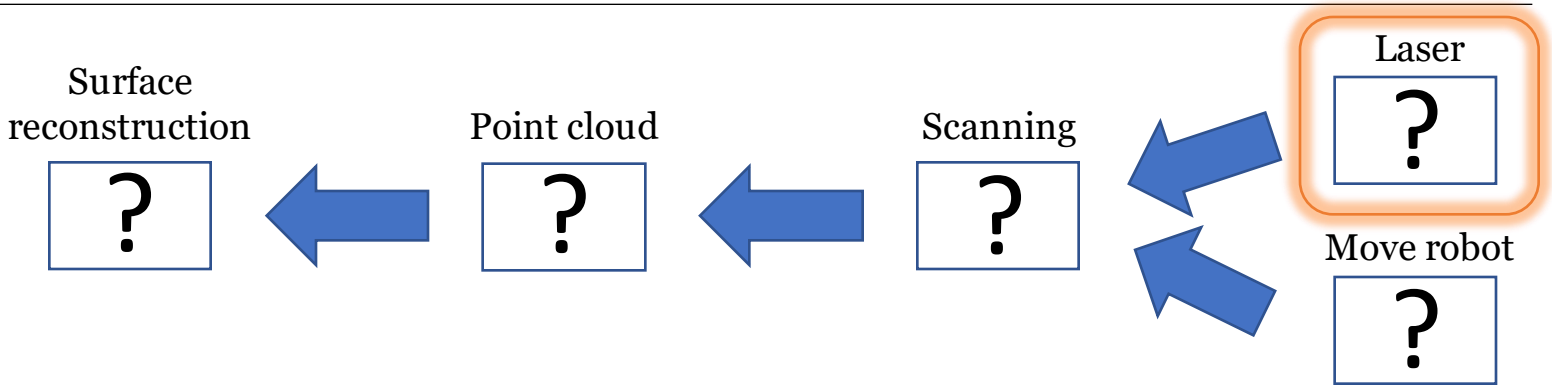
YuMi movement

Software components

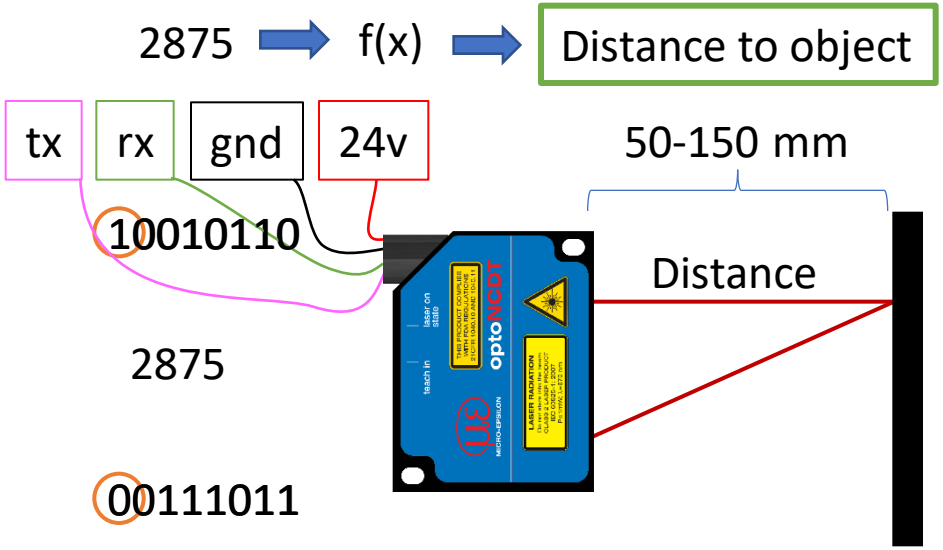



Surface reconstruction
?
Point cloud
?
Scanning
?
Laser
?
Move robot
?

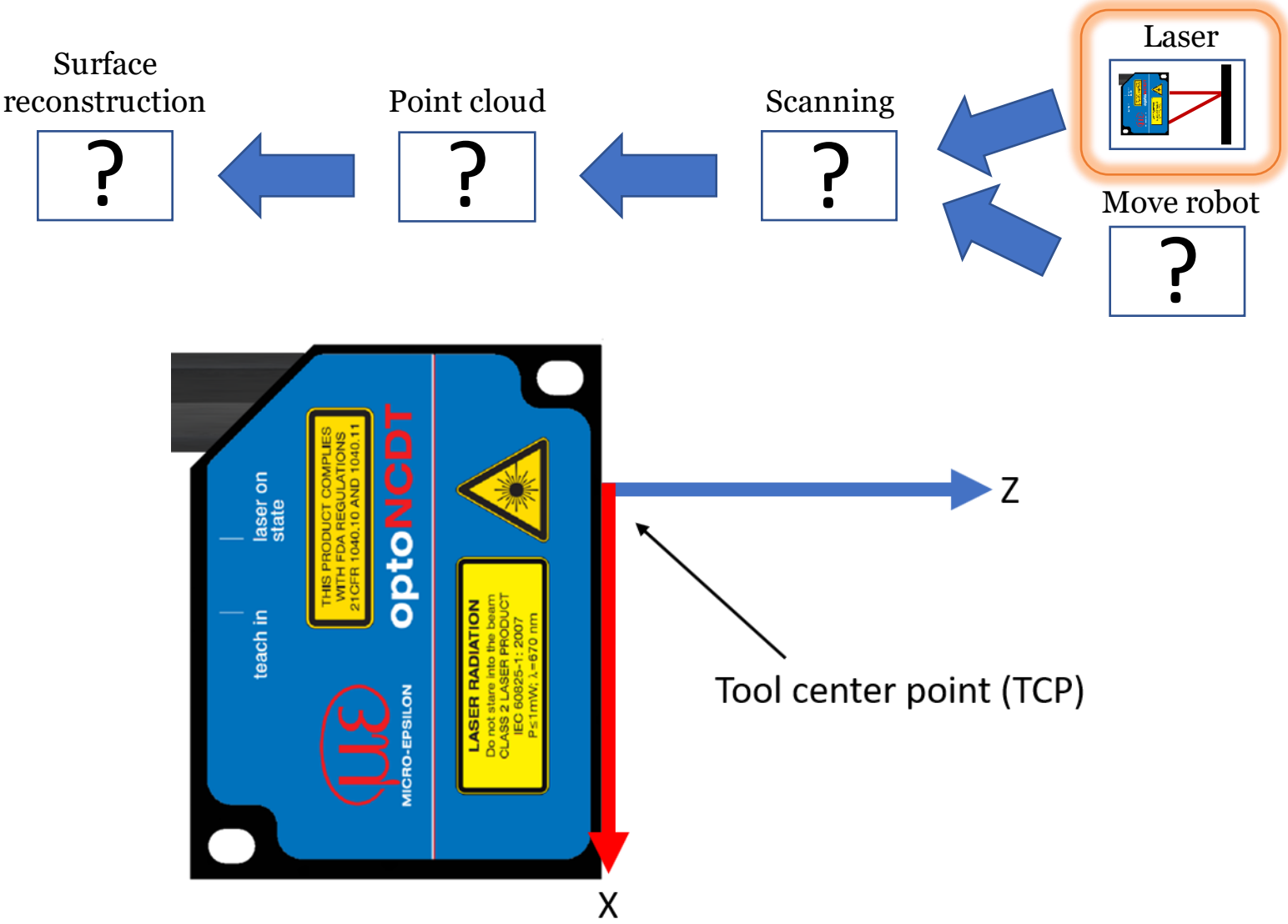
Software - Laser



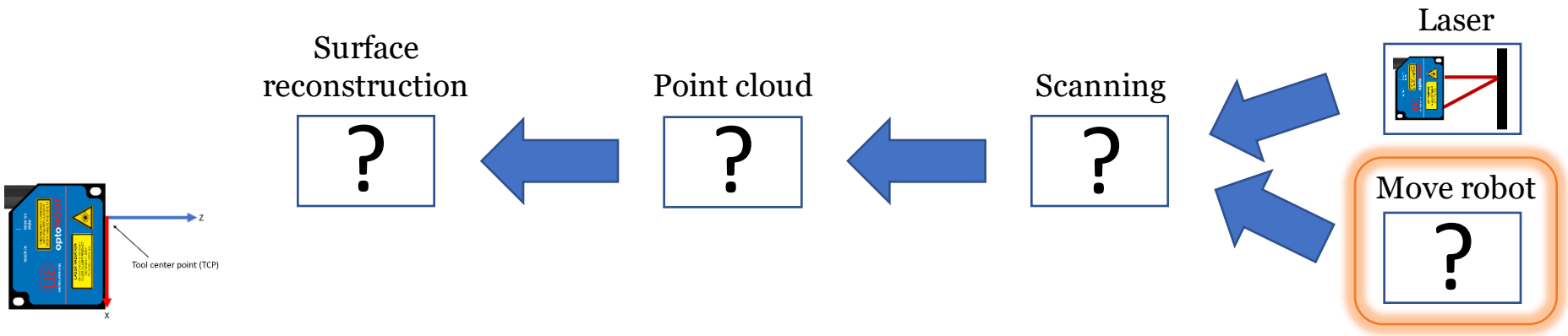
- OptoNCDT1402
  - 50 - 150 mm
  - Serial
- Shoots laser
- Sensor at an angle
- Triangulation
- Two bytes
- Concatenate to 14-bit number
- Convert to a distance



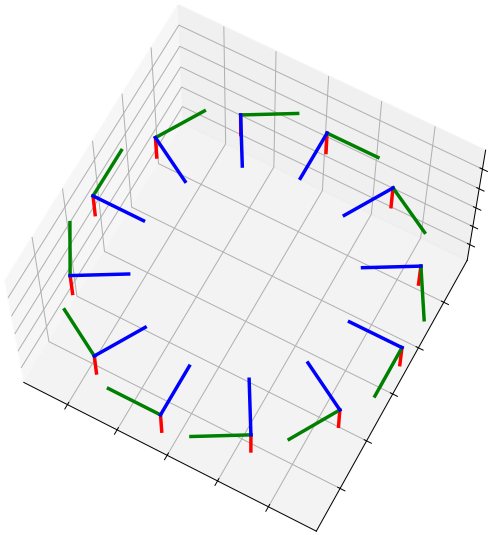
Software - Laser



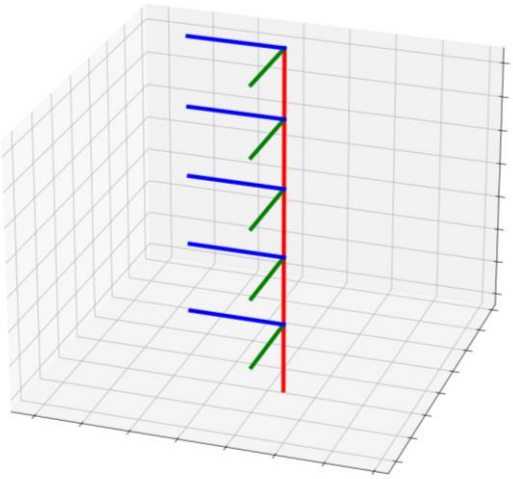
Software – Robot movement



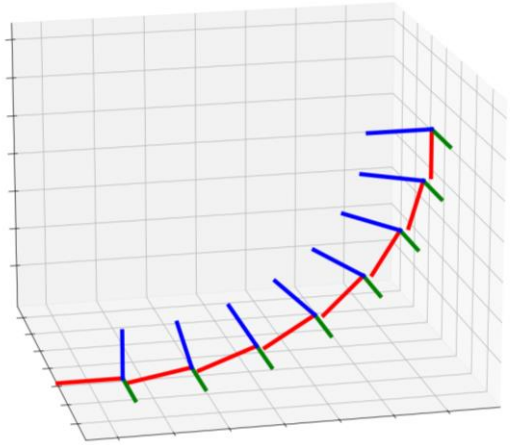
Circular



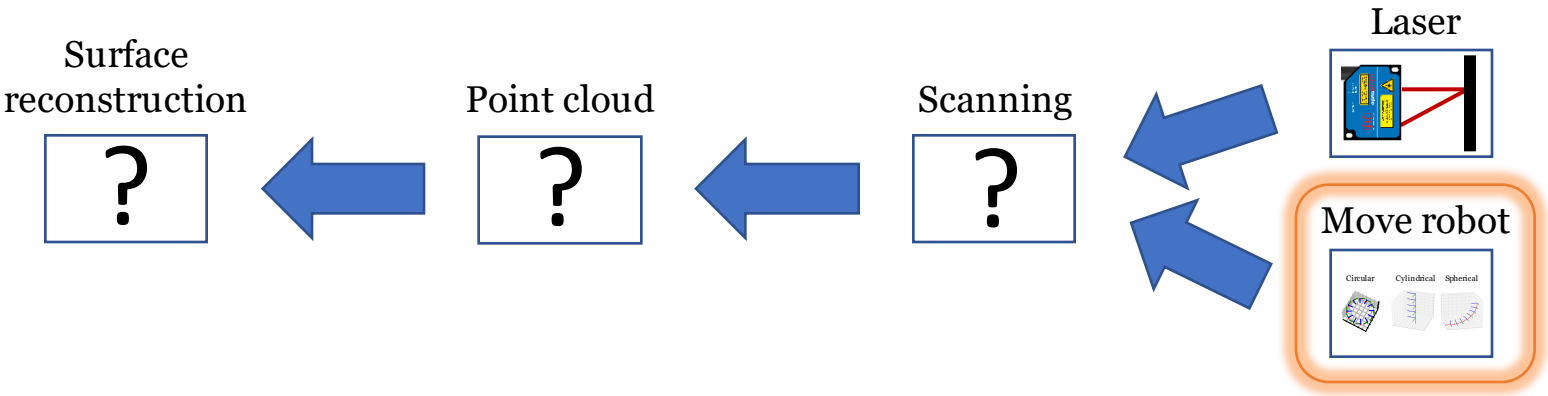
Cylindrical



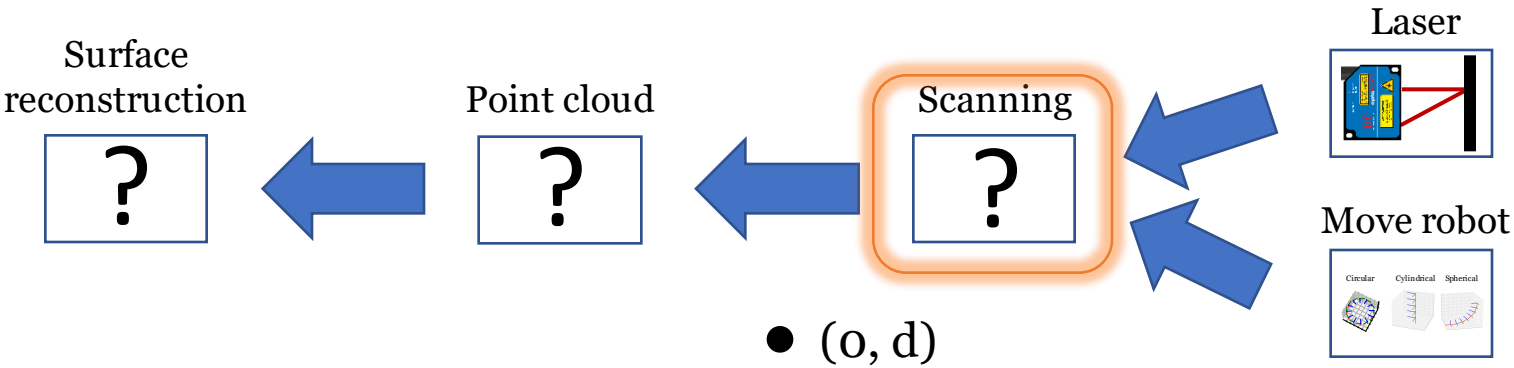
Spherical



Software – Robot movement

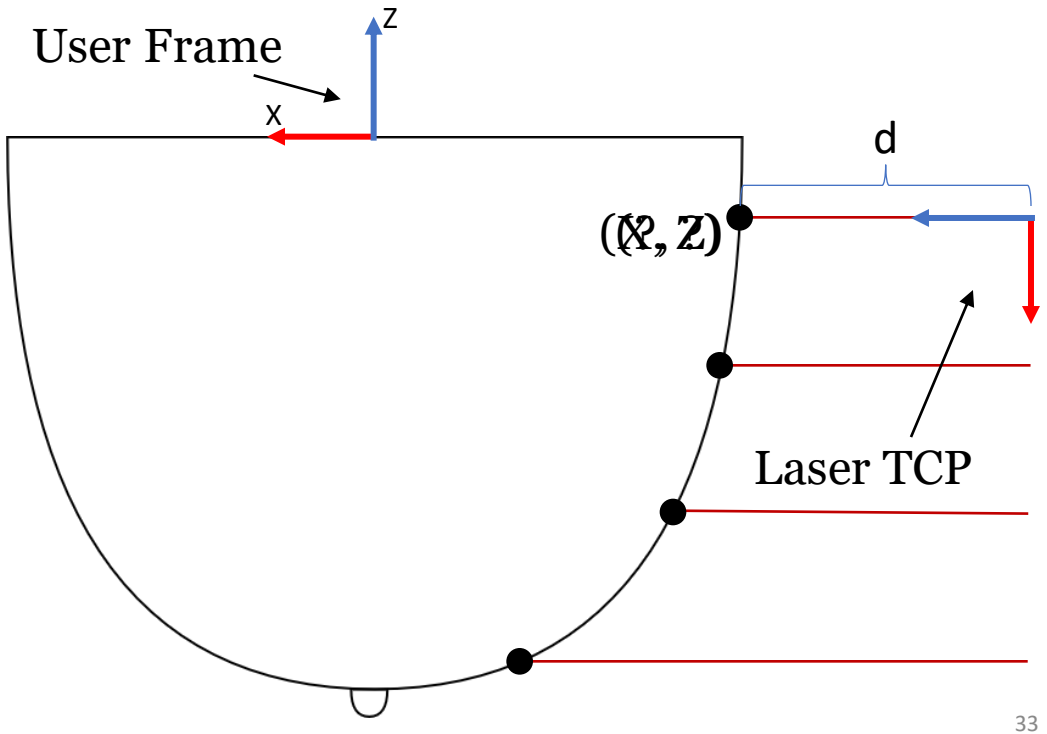


Software – Scanning procedure

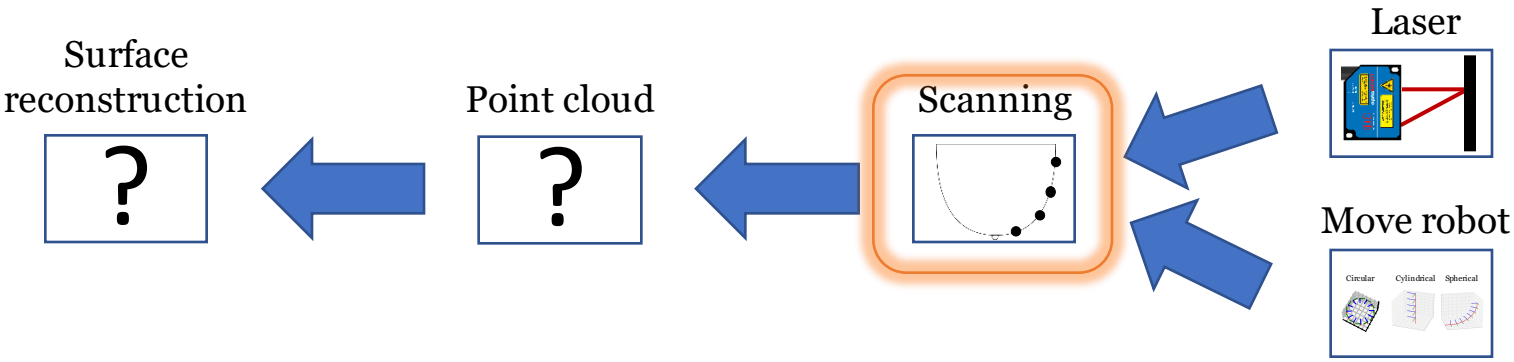


- Moves in User Frame

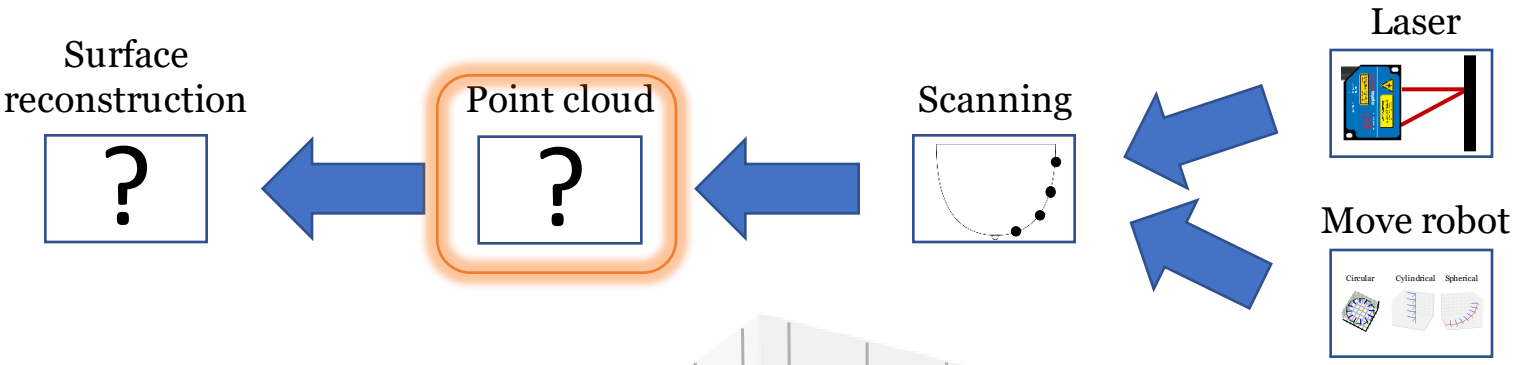
1. Distance measurement
2. Project along User Frame Z-axis
3. Transform to Laser TCP
4. Repeat



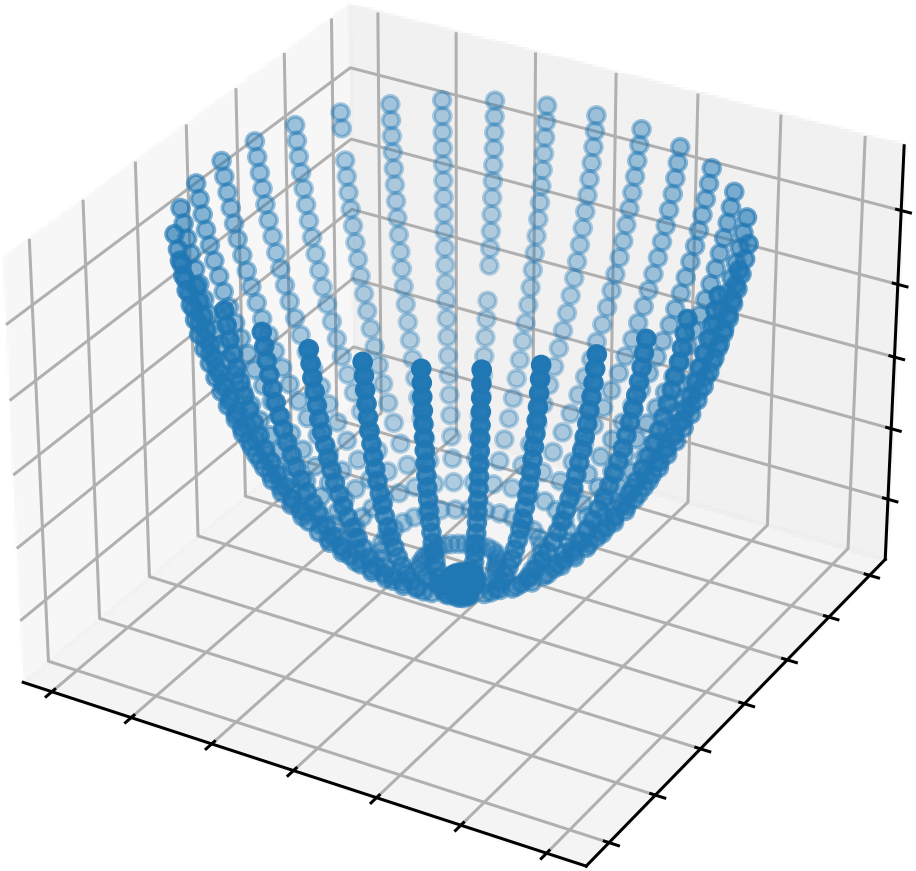
Software – Scanning procedure



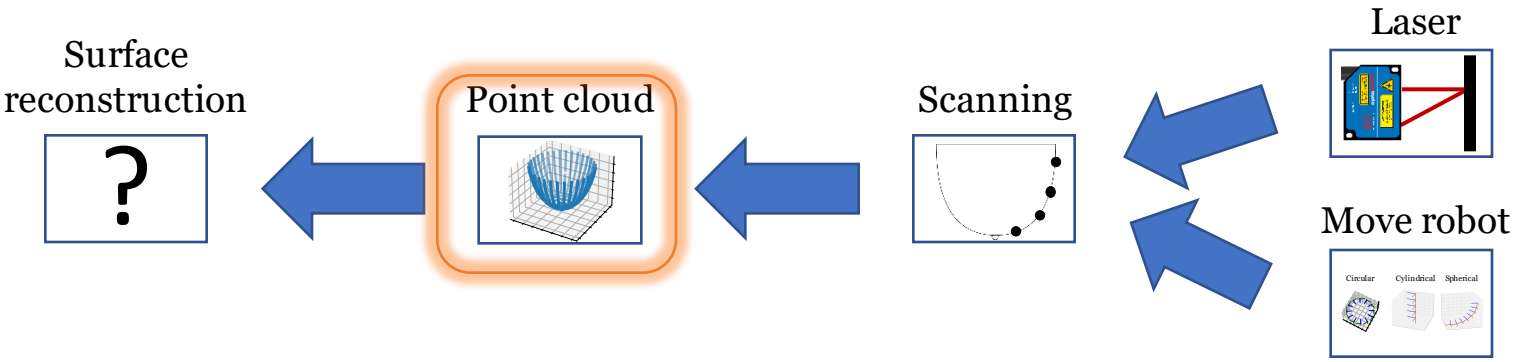
Software – Point cloud



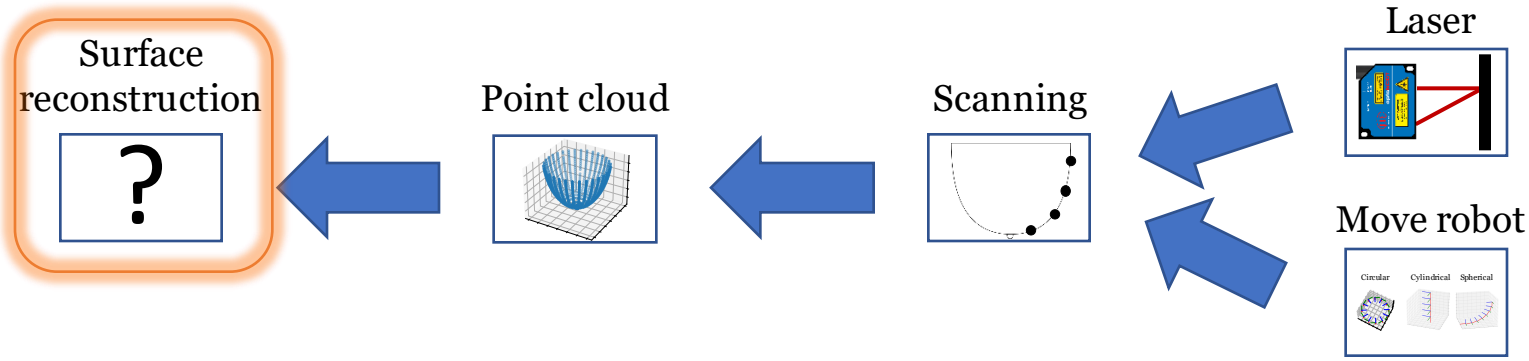
- Discrete points in space
- Resembles shape of object



Software – Point cloud



Software – Surface reconstruction

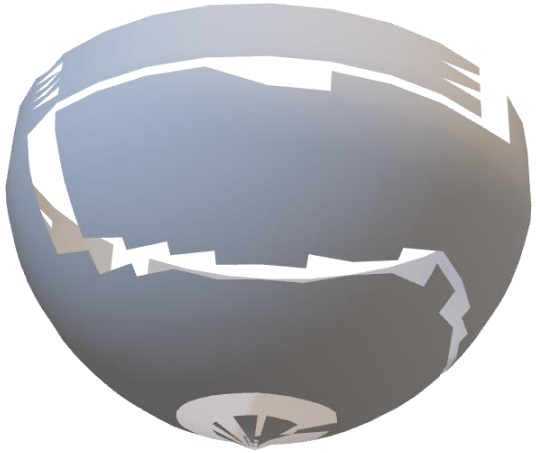


Surface reconstruction - evaluation

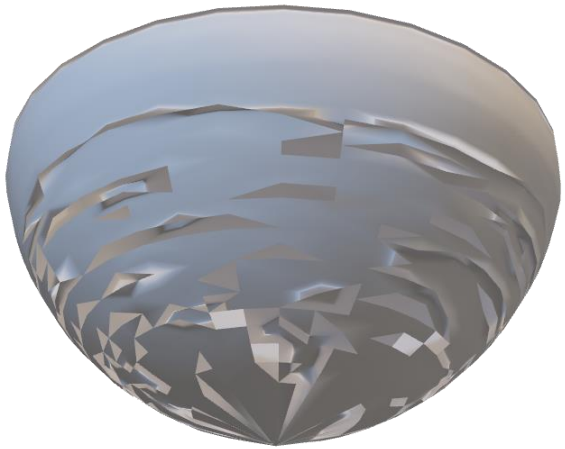
- Ball pivoting
  - Ball with fixed radius
  - Triangles
  - Not watertight

- Alpha shape
  - Ball with flexible radius
  - Triangles
  - Not watertight

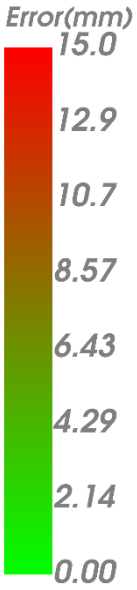
Ball pivoting



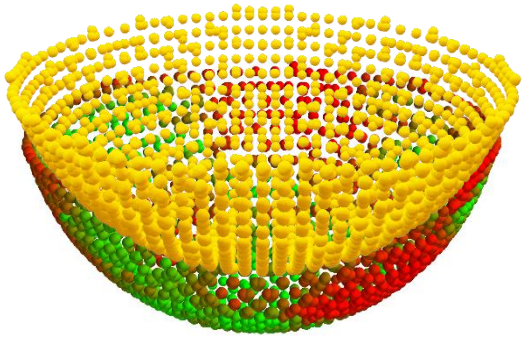
Alpha shape



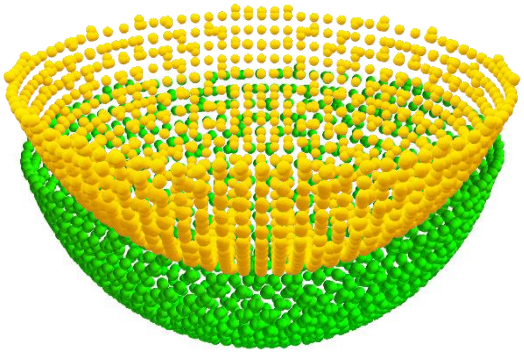
Surface reconstruction - evaluation



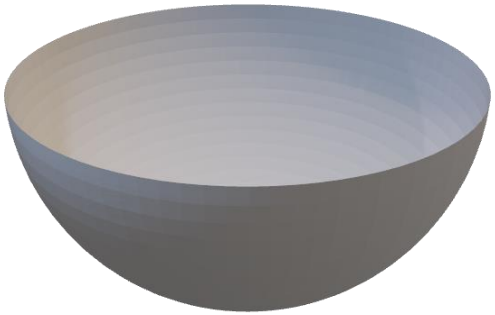
Cocone

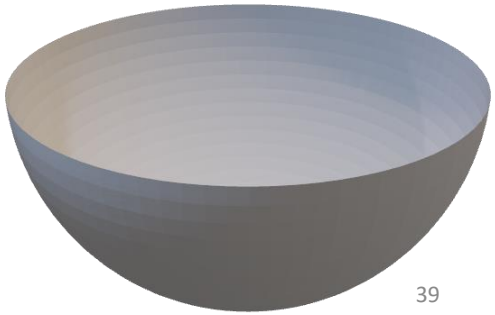


Poisson



- New metric
- Surface reconstruction inside known object
- Measure distance between points



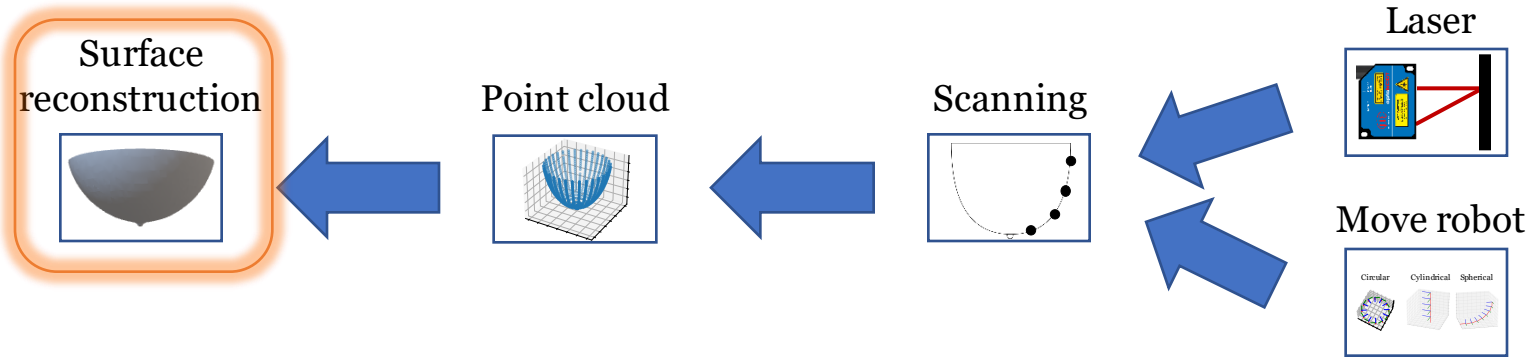


Surface reconstruction - Result

Surface reconstruction

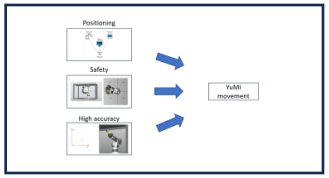
?

Software – Surface reconstruction

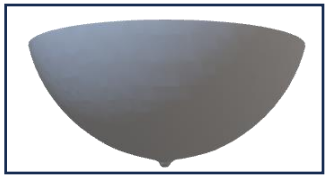


Software components

YuMi movement



Surface reconstruction



Microwave measurements

?

GUI

?

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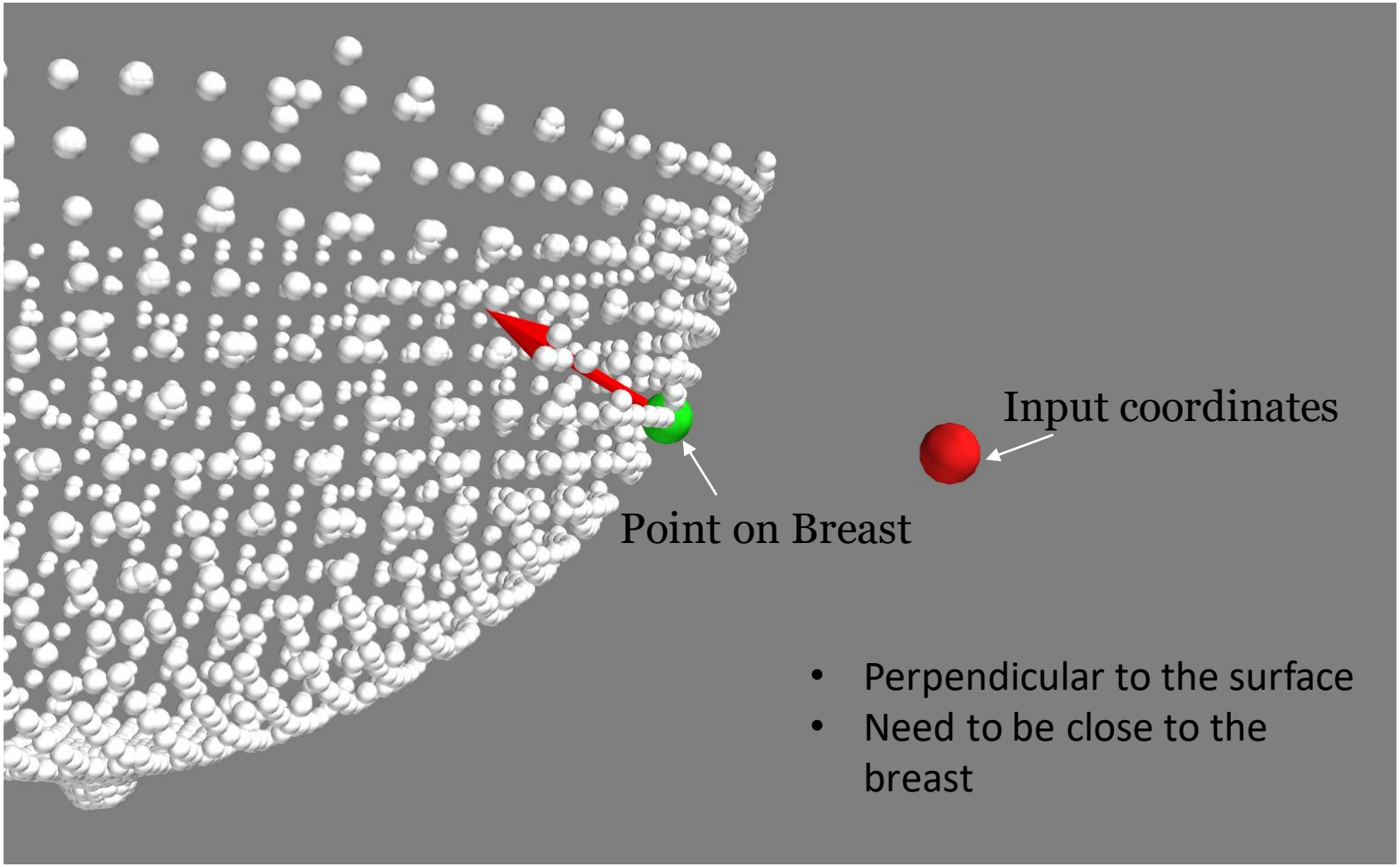
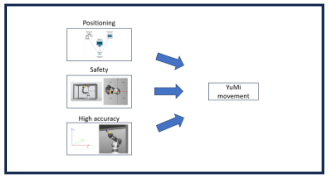
Software – Microwave Measurements

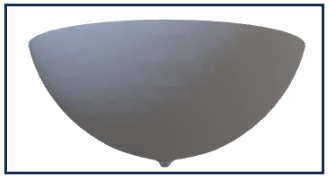


Software components

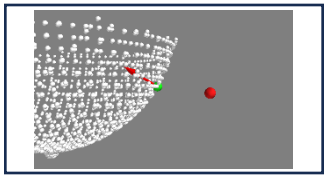
YuMi movement



Surface reconstruction



Microwave measurements



GUI

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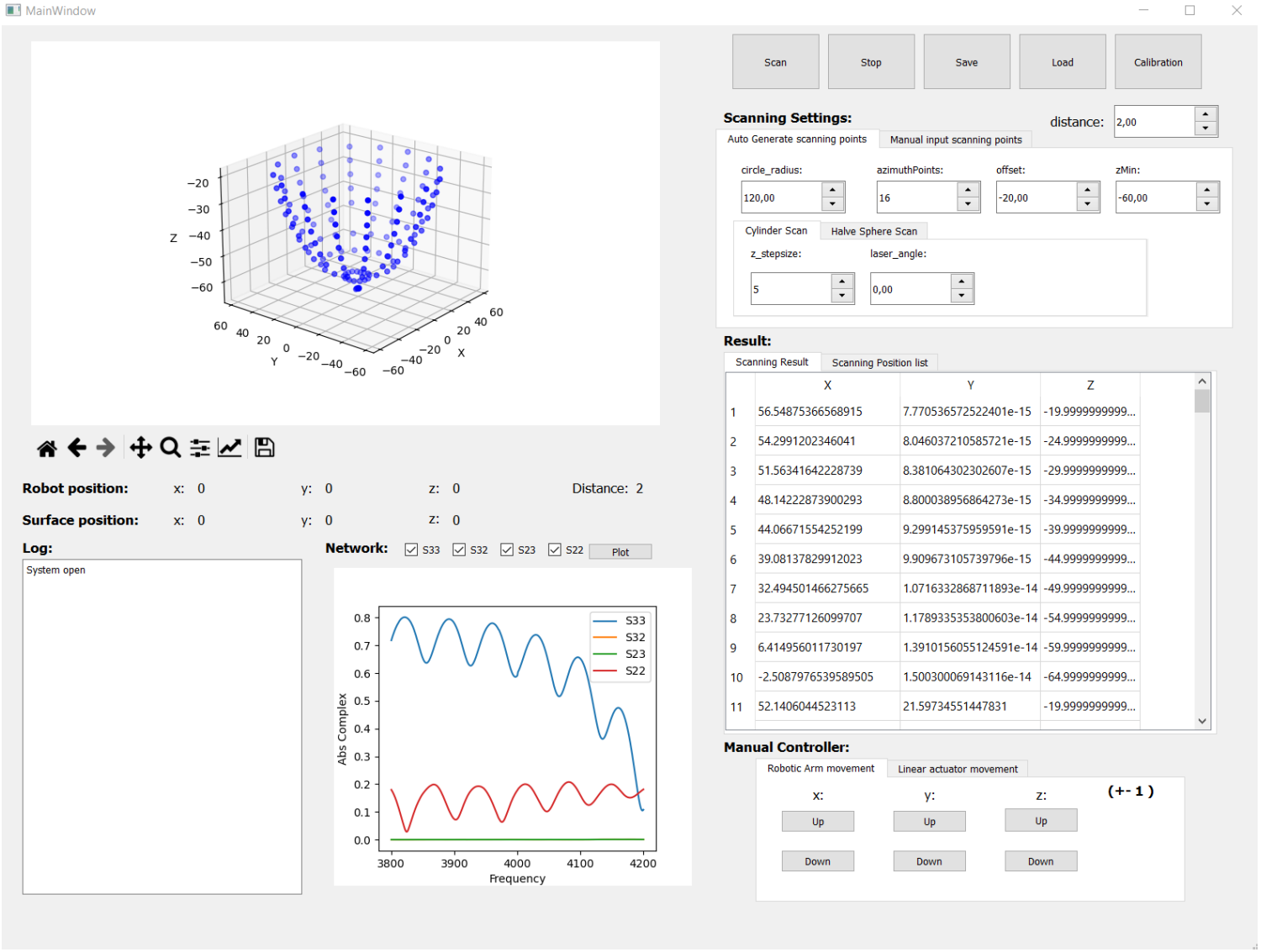
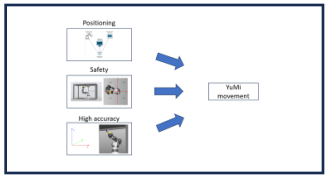
Software – Graphical User Interface (GUI) result

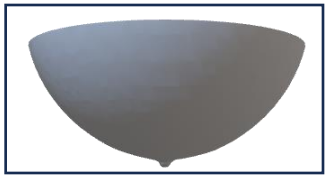


Software components

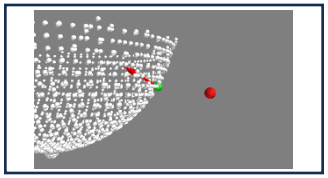
YuMi movement



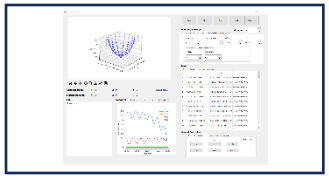
Surface reconstruction



Microwave measurements



GUI



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Conclusion and future work

- Goals:
  - ☑ Automated measurements on a breast phantom
    - ☑ With **known** geometry
    - ☑ With **unknown** geometry
  - ☑ Distance measurements using a laser
  - ☑ Surface reconstruction from the laser-based measurements
  - ☑ Microwave measurements based on the surface reconstruction
  - ☑ GUI to control the measurements and visualize the results
- System can be used to acquire more data
- The data can be processed, and images can be reconstructed to potentially find tumors

Thank you for listening!