THE BIOROBOTICS INSTITUTE

NeuRo Touch Lab

Sant'Anna
School of Advanced Studies – Pisa

European University

Hands-on workshop with sensorized mechatronic platforms

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3rd February 2025

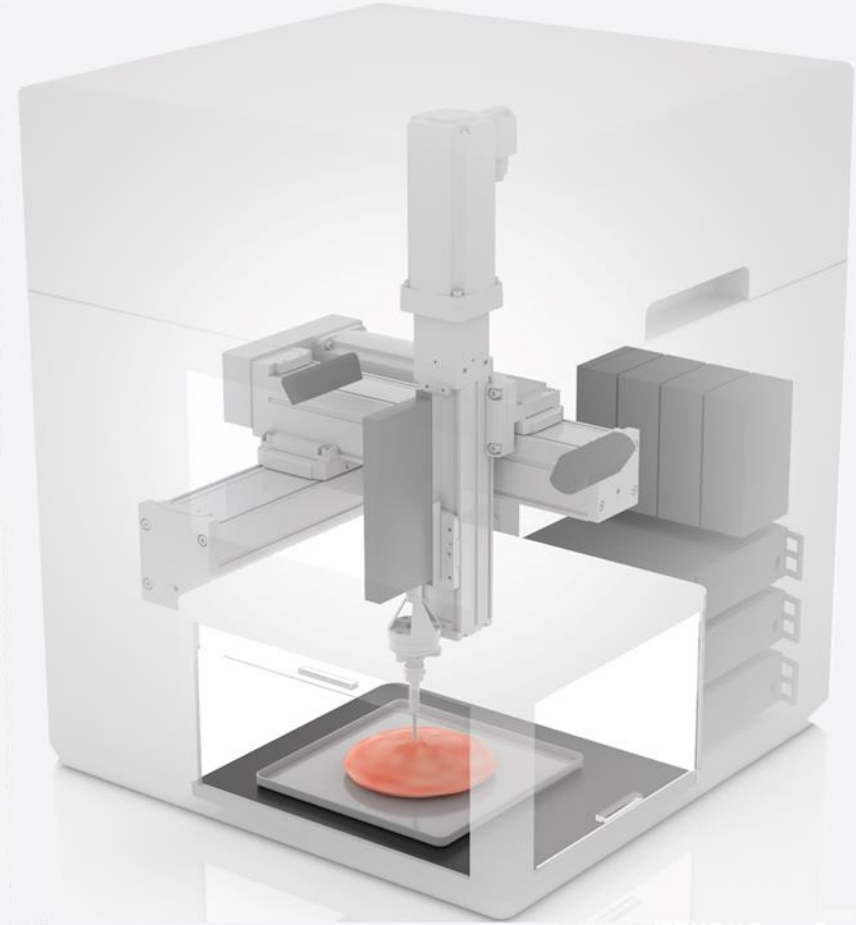
The Multisensory Scanner integrates:

Tactile data for biomechanics detection

Vision data for surface 3D reconstruction

Acoustic data for bio-material ultrasonic characterization

AI technologies for data integration and processing



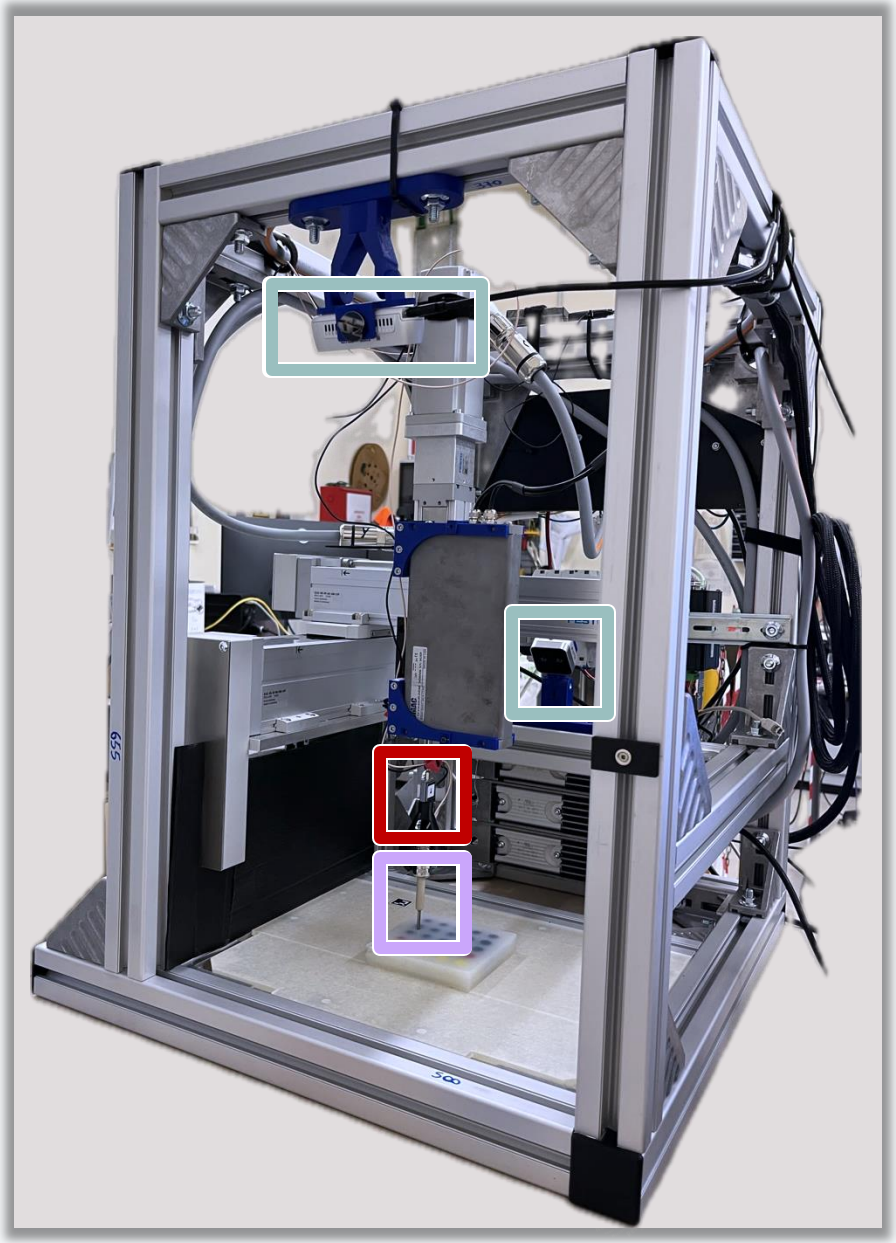
Our core technology integrates:

Tactile data from uniaxial load cell

Vision data from n.2 RGB-D cameras

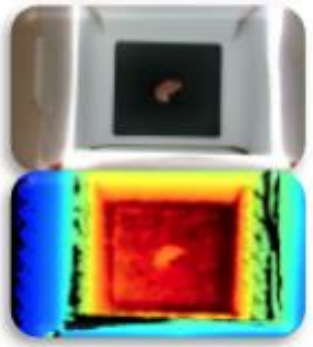
Acoustic data from 16 MHz needle ultrasonic probe

AI technologies run on a dedicated workstation (e.g., PC, Desktop)

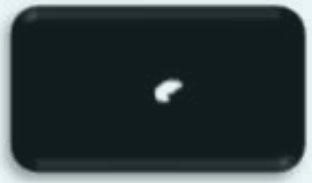


The Multisensory Scanner **ideal** workflow

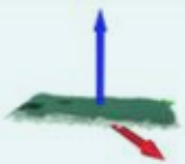
Image/Depth Acquisition



Segmentation



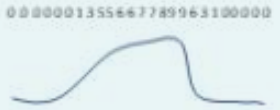
3D reconstruction



Indentation pattern

Platform actuation

Measurements



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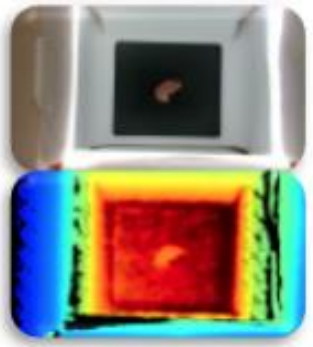
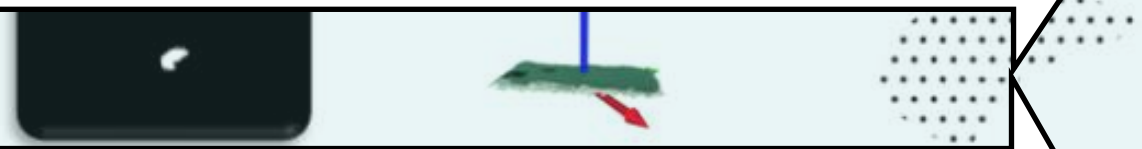
The Multisensory Scanner **hands-on** workflow

Image/Depth Acquisition



- Object detection in camera reference frame and transformation in scanner reference frame
- Definition of the point to inspect



- Communication with platform
  - Get platform state and data
  - Send point to inspect to platform
  - Set platform state:
    - to move actuators to point
    - to touch the object
    - to stop contact and return home

Platform actuation

Measurements

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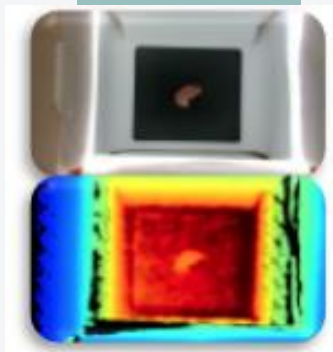
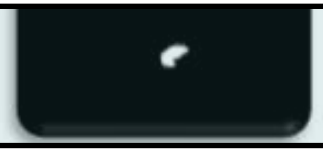
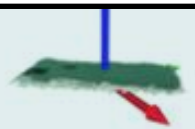
The Multisensory Scanner **hands-on** workflow

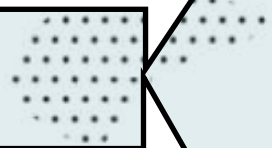
Image/Depth Acquisition

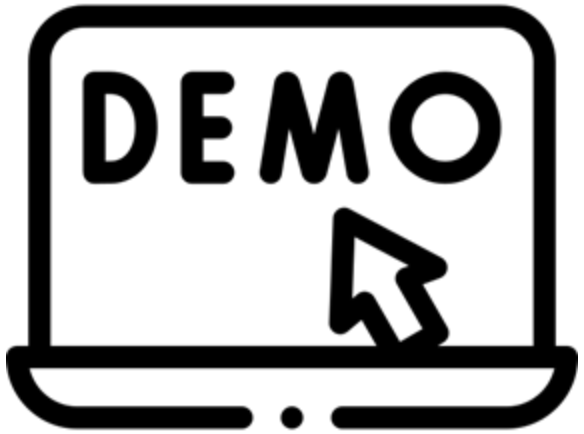
- Object detection in camera reference frame and transformation in scanner reference frame
- Definition of the point to inspect











Platform actuation

Measurements

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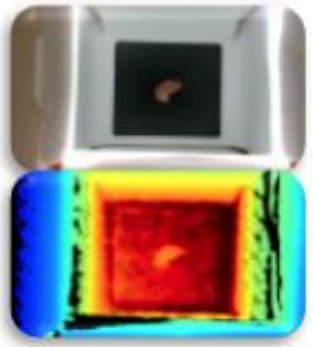
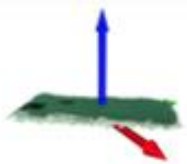
The Multisensory Scanner **hands-on** workflow

Image/Depth Acquisition

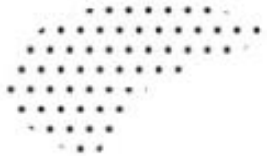


Segmentation

3D reconstruction



Indentation pattern



Platform actuation

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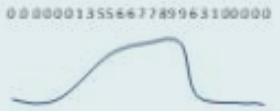
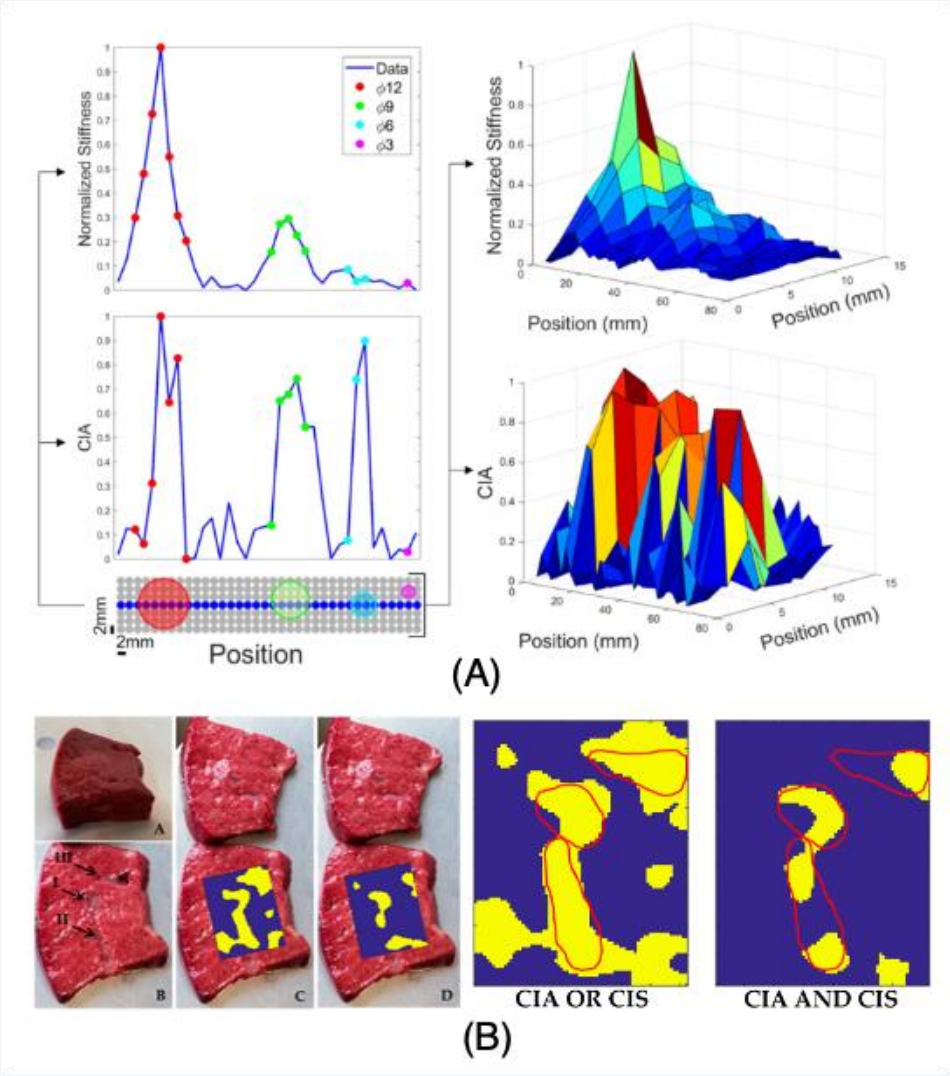


Multisensory Scanner research results

Experimental results of the first prototype of the platform proved its ability to localize areas of different biomechanical characteristics inserted in

laboratory-made Agar phantoms, based on mechanical (a, top panel) and acoustic (a, bottom panel) measurements [1],
excised animal liver, based on the combined evaluation of amplitude (CIA) and shape (CIS) of the acoustic signal measured by the ultrasound probe [2].

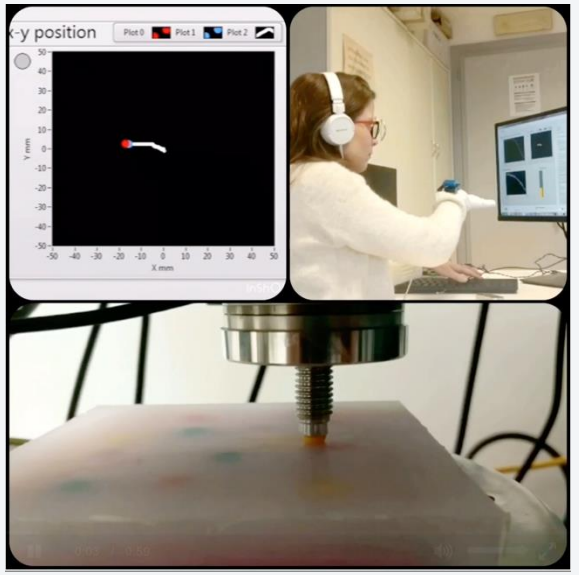


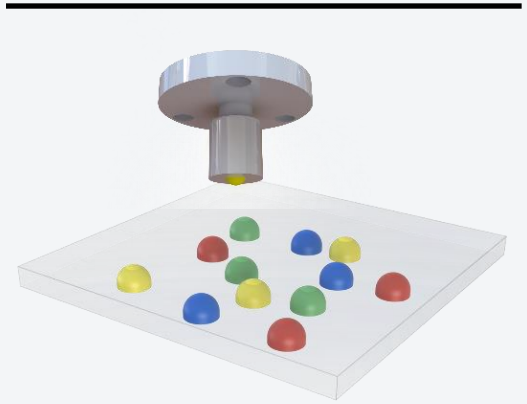
[1] **Massari** et al. "A mechatronic platform for computer aided detection of nodules in anatomopathological analyses via stiffness and ultrasound measurements." Sensors 19.11 (2019)
[2] **Bulletti** et al. "An improved strategy for detection and localization of nodules in liver tissues by a 16 MHz needle ultrasonic probe mounted on a robotic platform." Sensors 20.4 (2020)

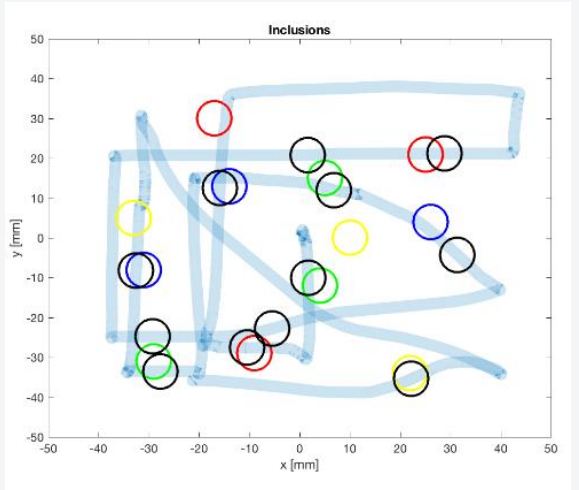
Multisensory Scanner research results

- The first apparatus was coupled with a novel tele-palpation apparatus [1] to enable the detection of nodules with various distinct stiffness buried in an ad-hoc polymeric phantom [2]

- The effectiveness was proved under two experimental conditions of real-time telepresence:
  - with the platform placed in the visible range of a user
  - with the platform and the user being 50 km apart.

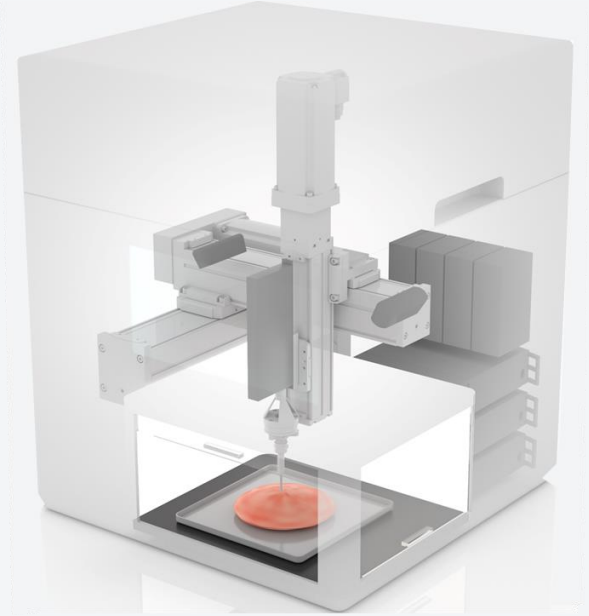






[1] **Sorgini** et al., Encapsulation of piezoelectric transducers for sensory augmentation and substitution with wearable haptic devices. Micromachines, (2017).
[2] **D'Abbraccio** et al., Haptic Glove and Platform with Gestural Control For Neuromorphic Tactile Sensory Feedback In Medical Telepresence, Sensors, (2019).

Available data



Camera RGBD images

Scanner State

Scanner position

Load cell data

Ultrasound data

Timestamp

- Camera images uploaded in shared folder (link)
- Remaining data, shared over UDP connection
  - port 8190
  - Semicolon (;) separated string, containing either 16 or 4017 numbers (double)

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Available data – interpretation

Scanner State | Scanner position | Load cell data | Ultrasound data | Timestamp

- Said **s(i)** the received string via UDP:
  - S(0) == 1 if platform is operative, 0 otherwise
  - S(1) == 1 if platform is in the set position, 0 otherwise
  - S(2) == 1 if linear actuator is touching the sample, 0 otherwise
  - S(3) == 1 if linear actuator exceeded its travel range, 0 otherwise
  - S(8) == 1 if linear actuator is in position (0,0,0), 0 otherwise
  - S(9) state id of the PLC state machine
  - S(14) timestamp in seconds of scanner data acquisition
  - S(15) timestamp in seconds of ultrasound data acquisition

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Available data – interpretation

Scanner State | Scanner position | Load cell data | Ultrasound data | Timestamp

- Said **S(i)** the received string via UDP:

  - S(4) + S(11)/1000 millimeters, is position X
  - S(5) + S(12)/1000 millimeters, is position Y
  - S(6) + S(13)/1000 + S(7)/200 millimeters, is position Z

  - S(10) / 27648 (if |S(10)|< 27648) Newton, is Force along Z
    S(10) / 32767 (otherwise)
  - S(16:4017) Ultrasound data

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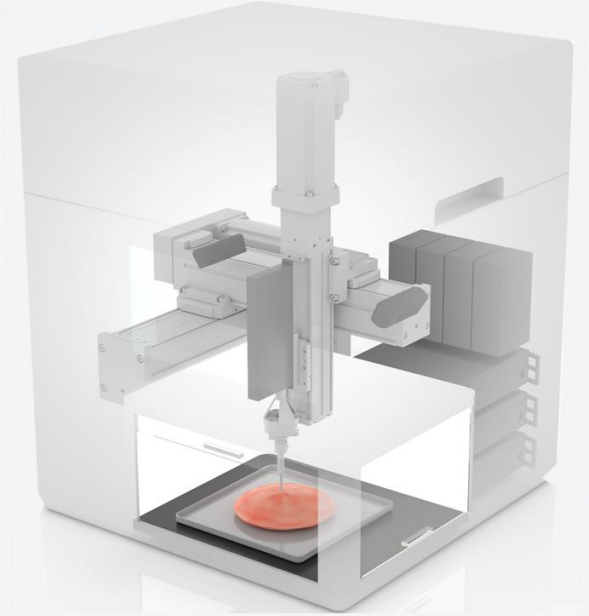
To be received data



Scanner next state

Scanner next position

- UDP connection
  - port 8191
- Semicolon (;) separated string

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To be received data

Sequence of command to send	Expected behavior
ID *	• Scanner recognize user and allow user control
ID; S0; X; Y; Z **	• Scanner moves to position X, Y, Z
ID; S1	• Scanner start moving downward and stop if in contact
ID; S2	• Scanner stop contact and returns home

* Each user will set their own ID
** X, Y, Z represent the position in millimiters

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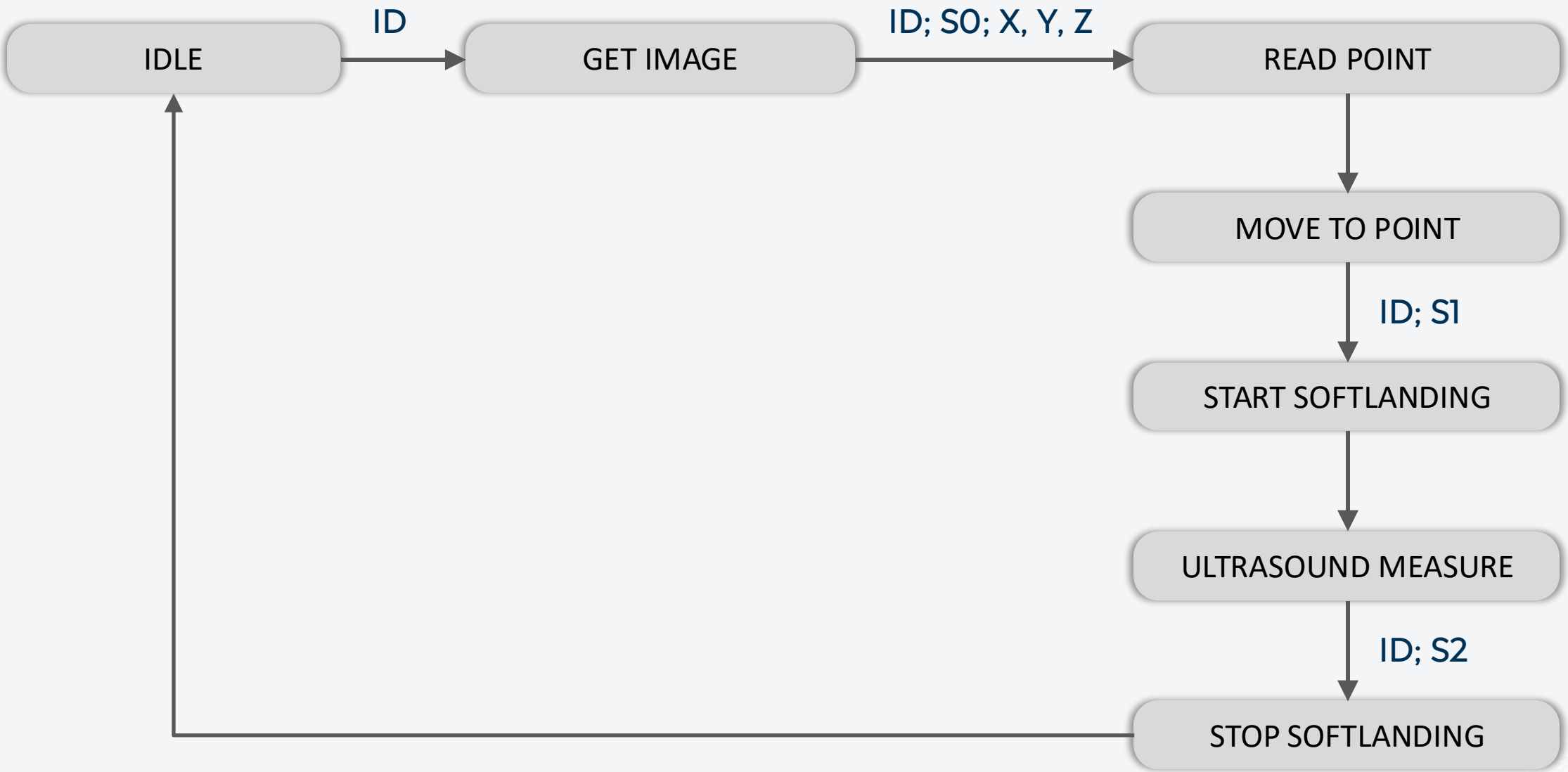
Multi sensory scanner – state machine



Other resources available

- Transformation matrix in
  - folder name “test_cal”

- Images and pointcloud of the empty platform in
  - folder name ”test_0_empty_20250203” for rear RGBD camera
  - folder name “test_1_empty_20250203” for front RGBD camera

- Remember: **D405** identifies rear camera
  D435 identifies front camera

LET'S TRY IT


FBGs
Sensory augmentation
Collaborative robotics
Artificial
Bioelectronics
Tactile actuators
Consumer electronics
Fingertip
Mechanoreceptors
Skin
Sensory substitution
Touch
Medical robotics
Human-machine cowork
Wearable technologies
Haptics
MEMS
Cardiorespiratory monitoring
Wearable sensors
Tactile sensors
Industry 4.0
Telepresence
Haptic displays
Neuroprosthetics
Heart biomechanical sensing
Microneurostimulation
Restoration
Microneurography

Object detection suggestions

- Read information about the scene, including camera settings, images, and point cloud data.
- Load calibration files to understand how cameras are positioned.
- Load a base reference mask that represents the platform.

- Verify that the cameras used for capturing the scene are the same as those in the calibration.
- Ensure they have the same type and serial number to avoid mismatches.

- For each captured scene, get the point cloud data (3D points of the object).
- Use stored transformation data to align it to the platform.
- Apply the necessary transformations so that object points are placed in the platform's reference frame.

- Compare each captured image with a reference image from calibration.
- Identify the region where the object is located.
- Extract a mask (a filtered version of the point cloud) that contains only the object.

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Available data - recap

Scanner State | Scanner position | Load cell data | Ultrasound data | Timestamp

tri-axial motorized platform	isReady_Festo	1 if platform is operative, 0 otherwise	bit
	isArrived_Festo	1 if platform is in the set position, 0 otherwise	bit
	isTouching_SMAC	1 if linear actuator is touching the sample, 0 otherwise	bit
	isMaxStroke_SMAC	1 if linear actuator exceeded its travel range, 0 otherwise	bit
	posx	x-axis position (integer part)	mm
	posy	y-axis position (integer part)	mm
	posz	z-axis position (integer part)	mm
	posz2	voice coil z-axis position	a.u.
	isHome_SMAC	1 if platform is in position (0,0,0), 0 otherwise	bit
	state_Festo	state id of the PLC state machine	number
	Fz	normal force	a.u.
	posx	x-axis position (fractional part)	mm
	posy	y-axis position (fractional part)	mm
	posz	z-axis position (fractional part)	mm
	CPXEts	timestamp of data collection	seconds
Ultrasound	USts	timestamp of data collection	seconds
	0-3999	ultrasound signal	a.u.