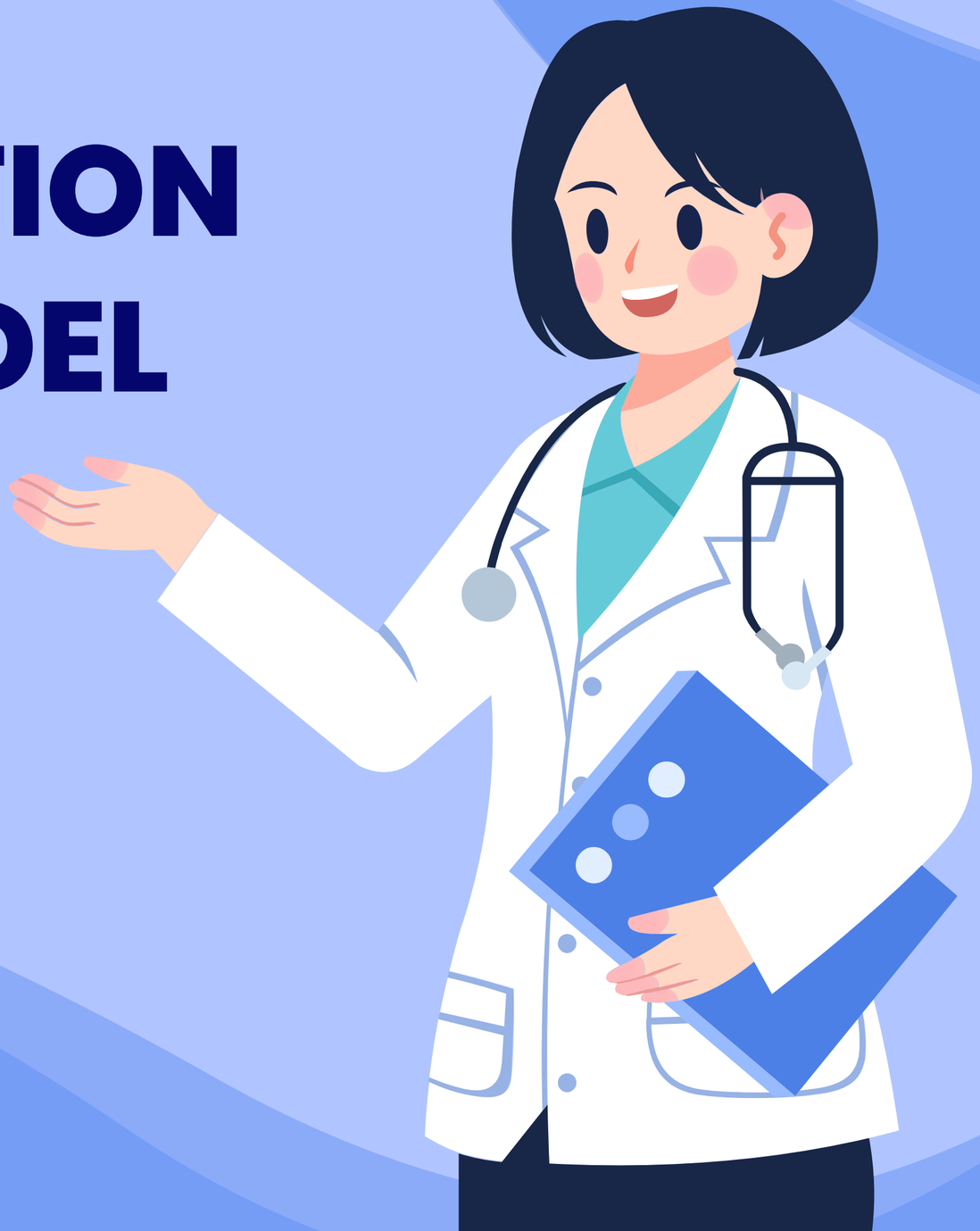
NEEDLE INSERTION TRAINING MODEL

Digital Twins of Medical Devices
4CBLW00-26



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THE PROJECT

PROCEDURE

- Patient’s arm is comfortably positioned, and an appropriate vein is selected.
- Needle is inserted at a shallow angle approximately 15°–30°
- Successful insertion is indicated by a slight resistance followed by a distinct sensation "pop" or visual blood return.
- Once confirmed, blood is drawn or an IV line is established, followed by careful needle withdrawal.

POSSIBLE COMPLICATIONS

- Bruising or hematoma
- Pain or discomfort during insertion
- Difficulty in accessing the vein (multiple attempts needed)
- Patient anxiety or faintness

THE PROJECT

PROBLEM STATEMENT

- Limited hands-on practice for needle insertion
- Insufficient real-time visual feedback
- Existing simulators are expensive and not customisable

PROJECT GOAL

Develop a low-cost, customizable digital twin providing a realistic tactile experience and immediate, sensor-driven feedback.

STAKEHOLDERS

- Nurses (in training)
- Doctors (in training)

USE

Practise needle insertion technique into the lower arm
(for IV and blood collection).

REQUIREMENTS

Must have

R1. Real-time tracking of needle pose

R2. Measurement of insertion force

R3. Physics-based tissue simulation

R4. User safety and reset capability

Should have

R5. Visual feedback interface

R6. Realistic physical prototype

Could have

R7. Exact vein location

R8. Precise and accurate sensors

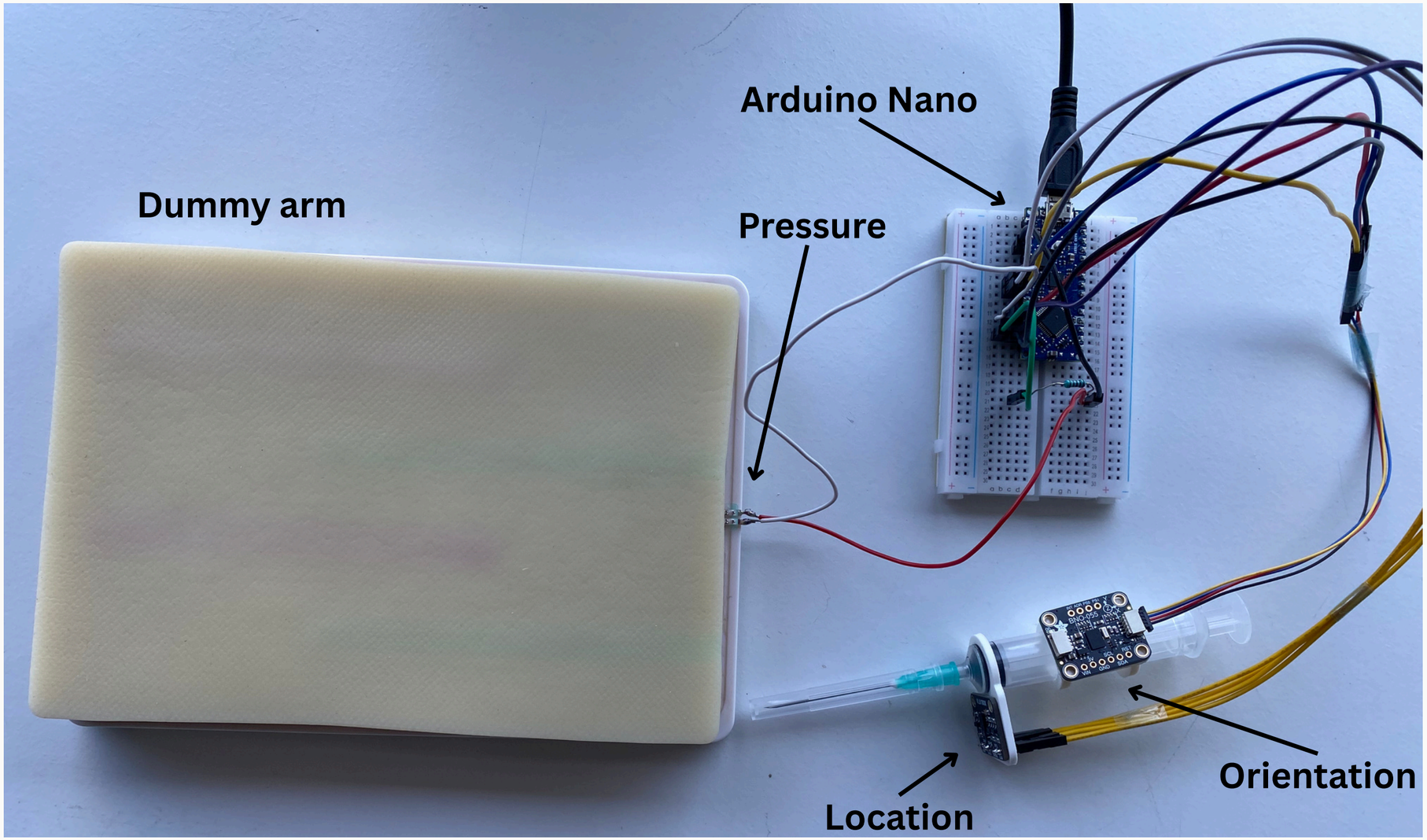
Will not have

R9. Complicated needle insertion model

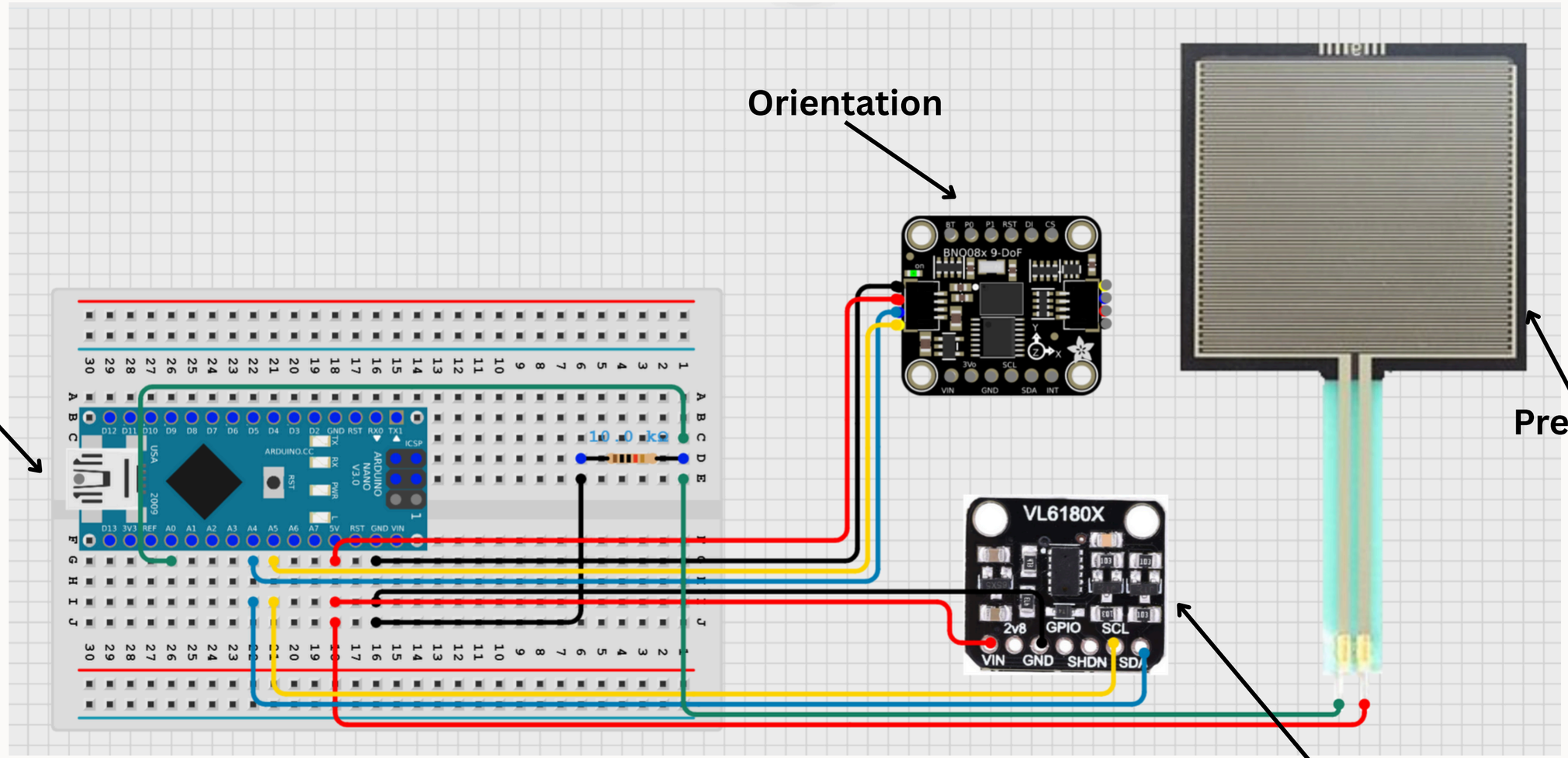
R10. Identical syringe

PHYSICAL MODEL

Final Setup

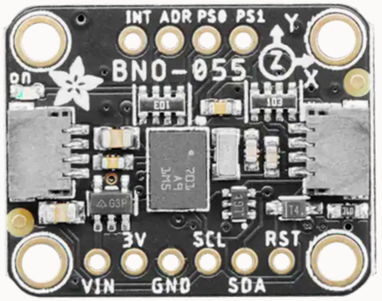


PHYSICAL MODEL



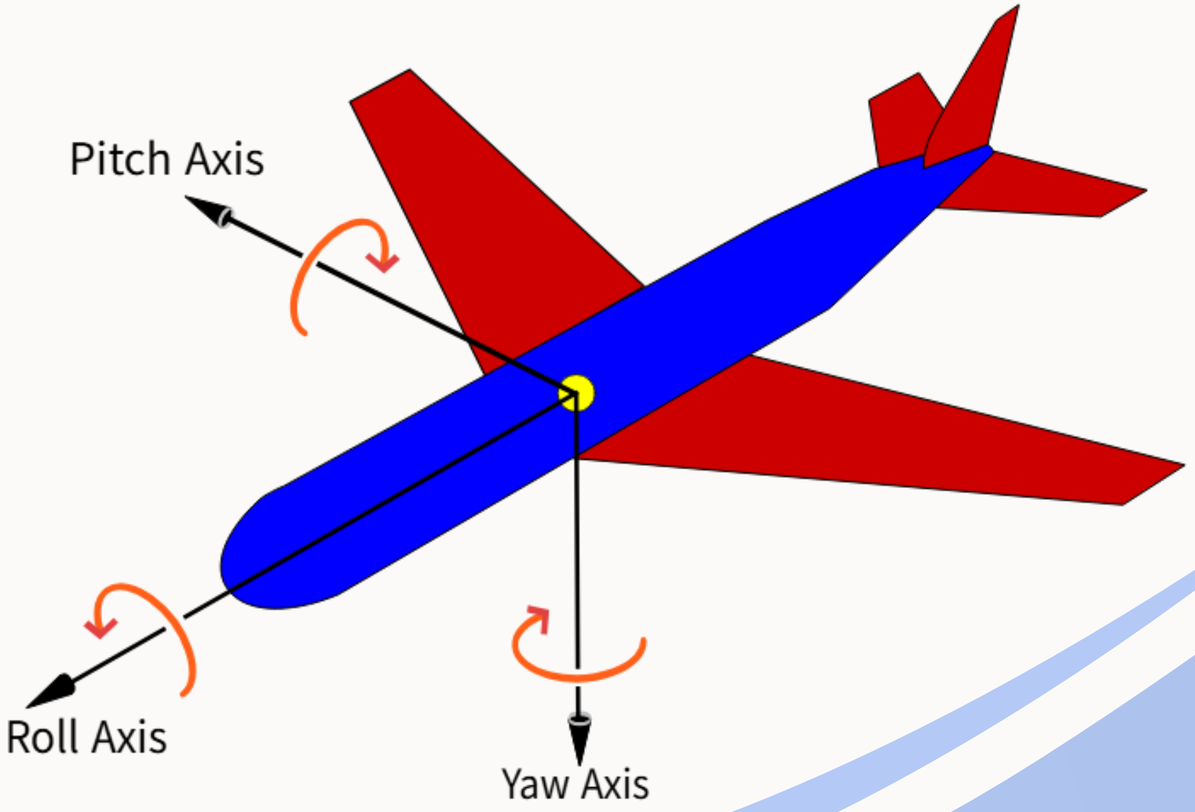
PHYSICAL MODEL

Orientation, location and pressure



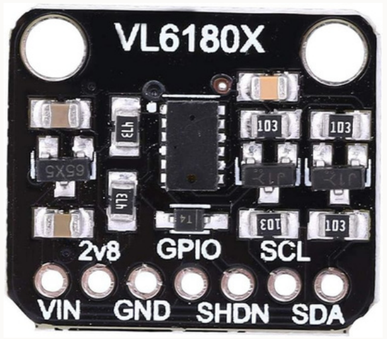
Orientation

- BNO055 motion sensor outputs Euler angles and quaternions
- Mounted on the barrel
- Visualizes needle tilt and rotation in real time
- Assists maintaining correct insertion angle (target 15°–30°)



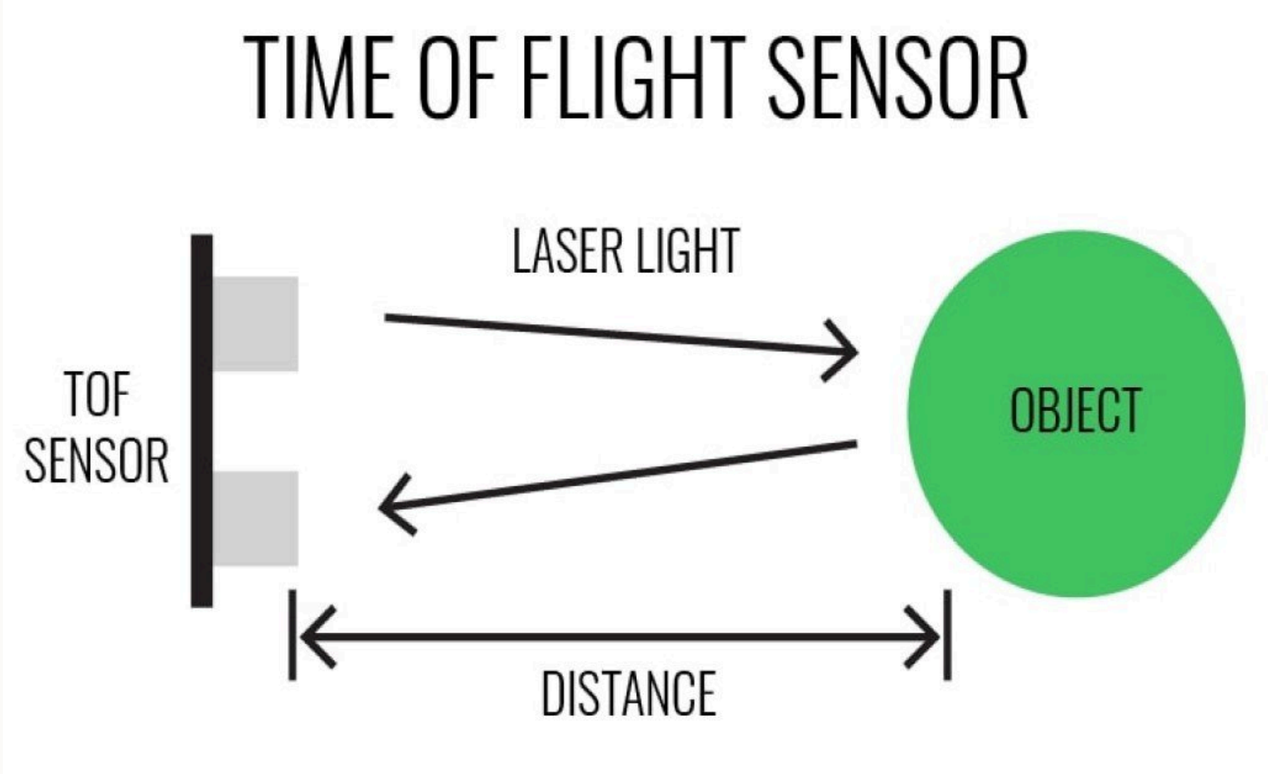
PHYSICAL MODEL

Orientation, location and pressure



Location

- VL6180X ToF sensor (15–200 mm range)
- Mounted under syringe barrel
- Measures distance to skin
- Needle insertion depth
- Find needle location by using orientation



PHYSICAL MODEL

Orientation, location and pressure

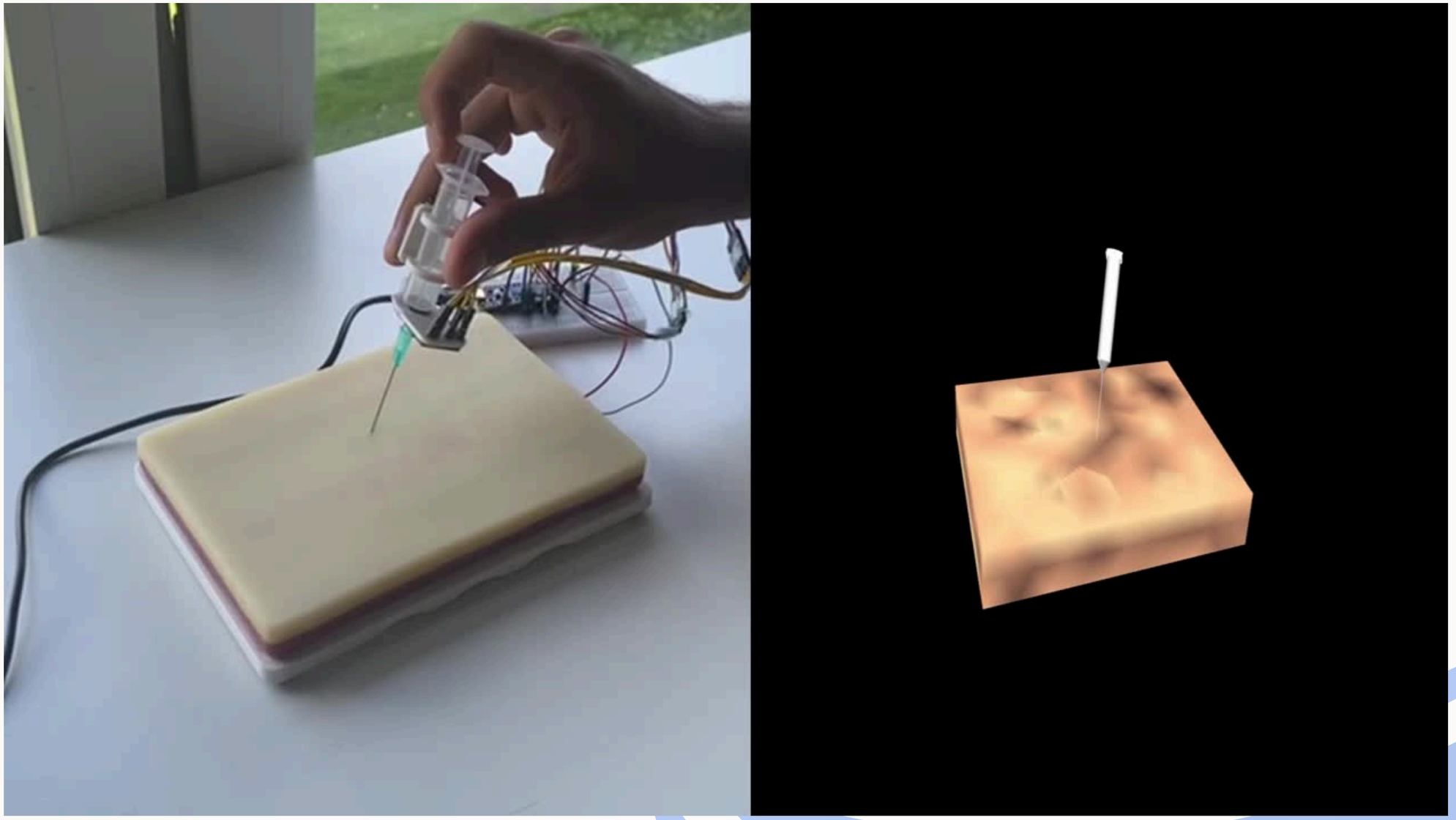
Pressure

- FSR (RP-S40-ST) pressure sensor
- Detects resistance change, not exact Newton values
- Senses force changes during insertion
  - Initial contact => small force
  - Insertion => increasing force
  - Vessel entry => sudden drop
- Placed under the dummy arm

Data integration

- All sensor values are transmitted via Arduino Nano Every
  → Sent to Python-based simulation using serial communication

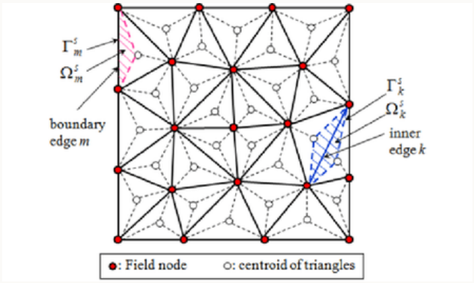
FINAL MODEL



SIMULATION

Deformable tissue

- Using a custom FEM (finite element method) triangular mesh
- Implemented with Young’s modulus and Poisson ratio

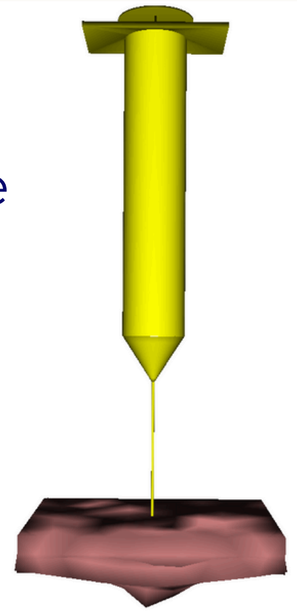


Goal

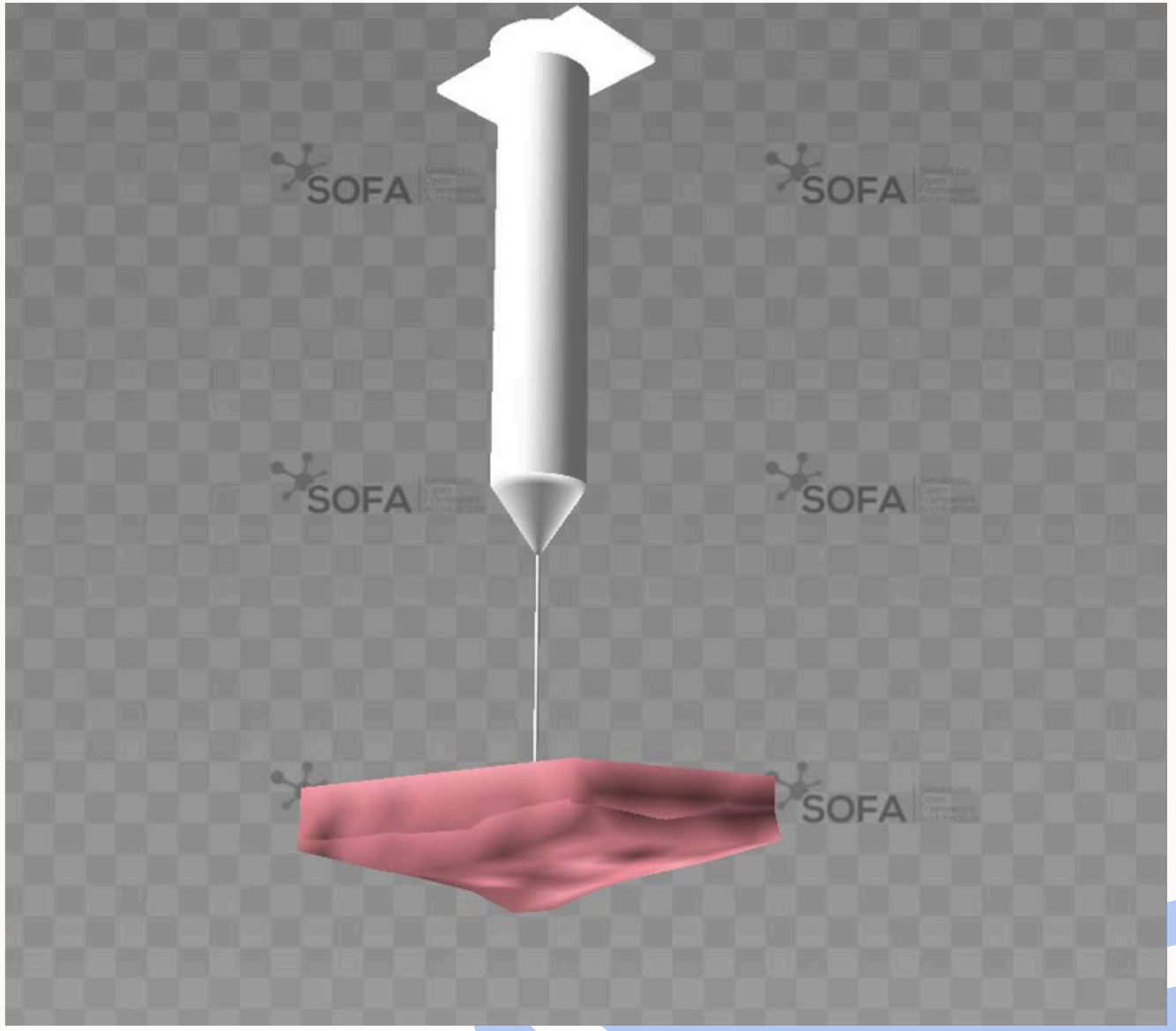
- Adding more realism
- Improving the quality for medical training purposes

Performance issues

- Real-time deformation in the simulation required much performance
- A lot of lag when active deformation took place (dropping under 5 fps)
- Not feasible for our project's purpose and goal
- Decided to remove the component for final product



SIMULATION



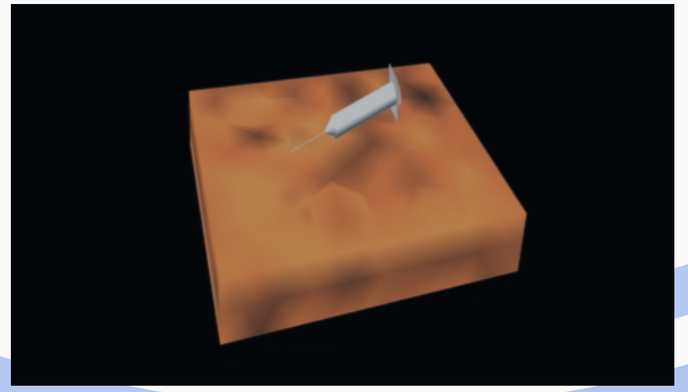
SIMULATION

Color feedback

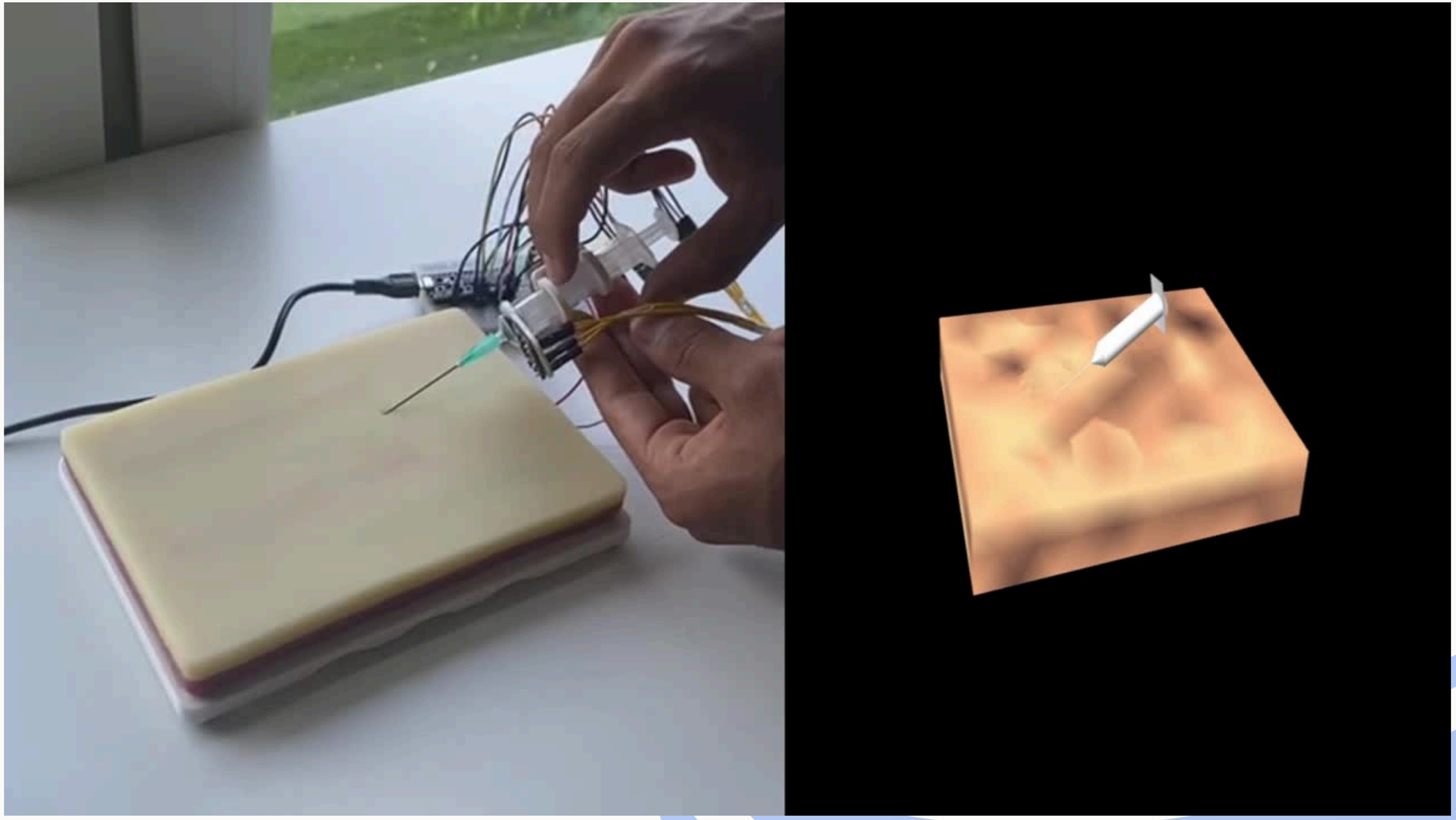
- Offers direct feedback about the needle insertion to the user of the model
- Based on the pressure sensor the tissue block turns red in the simulation
- Simulation offer real-time direct feedback

Acheived goals

- This version of the simulation runs very smooth, making it suitable for training
- By implementing feedback by color we still managed to have an effective training model with direct feedback to the user



REAL SCENARIO



LIMITATIONS

Sensors

- Fixed location insertion point
- Attachment wires on needle
- Only measure insertion depth
- Pressure measured under entire arm

Software

- Detailed OR Fast
- Still runs in SoFa
- Optimising visual feedback
- Deformable tissue had performance issues

FUTURE DEVELOPMENT

In the future, this model can be further developed to train medical students for more **complicated needle insertion procedures** on the lower arm.

The twin could also be improved by using more advanced sensors, that can track 3D location of the needle.

THE END

THANKS FOR LISTENING