



UNIVERSITÀ DEGLI STUDI
DI GENOVA

Design and implementation of an open source visuo-haptic simulator for surgical training

Candidate: Chiara Saporetti

Supervisors: Professor Maura Casadio, Dr. Serena Ricci

Robotics Engineering Course – Master Thesis

Context and motivation

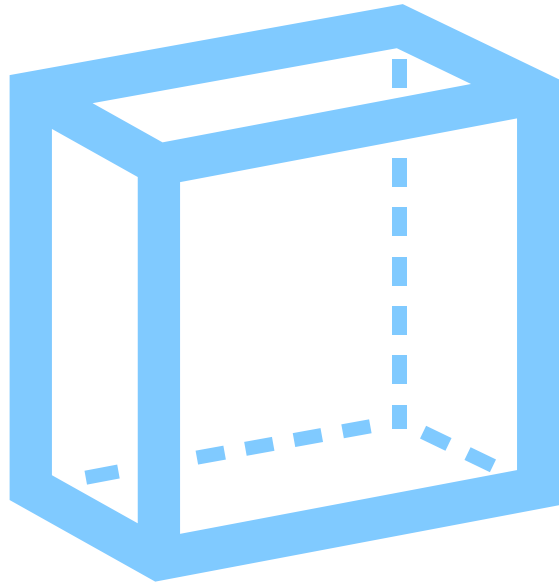
- ▶ **Surgical training:** involves the use of tactile sense. Various teaching options have been tested: ethical/practical problems.
- ▶ Increasing interest in Robotic Minimally Invasive Surgery: still lacks **haptic feedback**.
- ▶ Visuo-haptic simulation advantages provides multi-sensory feedback, shows different real-case scenarios, allows repeatability.



Context and motivation

- ▶ **Open-source** software, accessible to everyone on GitHub: SOFA Framework.
- ▶ My contribution: visuo-haptic simulations of:
 - ▶ a dexterity task
 - ▶ an incision task
 - ▶ a single-device suture task
 - ▶ a double-device suture task





Virtual Environment Models



MODEL



DEVICE



TASKS



GUI

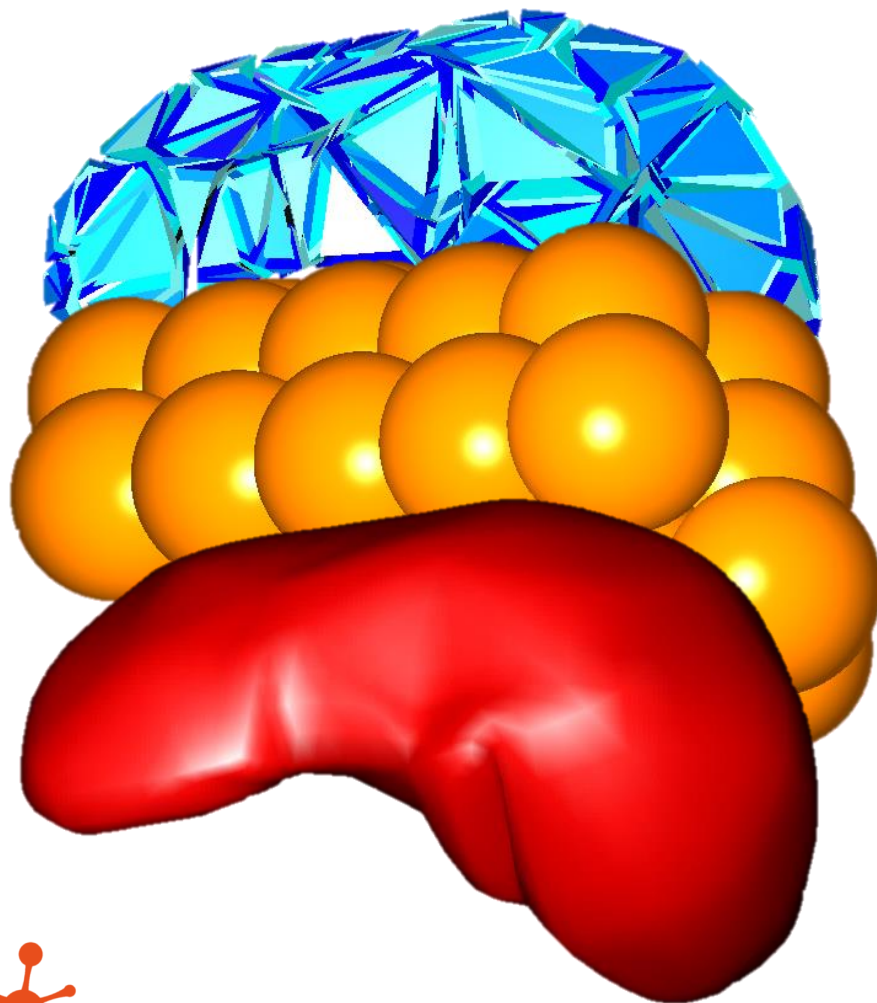


TESTS



RESULTS

Software: SOFA Framework



Behavior model:

$$F = ma$$



Collision model:

Three phases pipeline

Visual model:

Graphical rendering



MODEL

Skin virtual model



DEVICE



TASKS



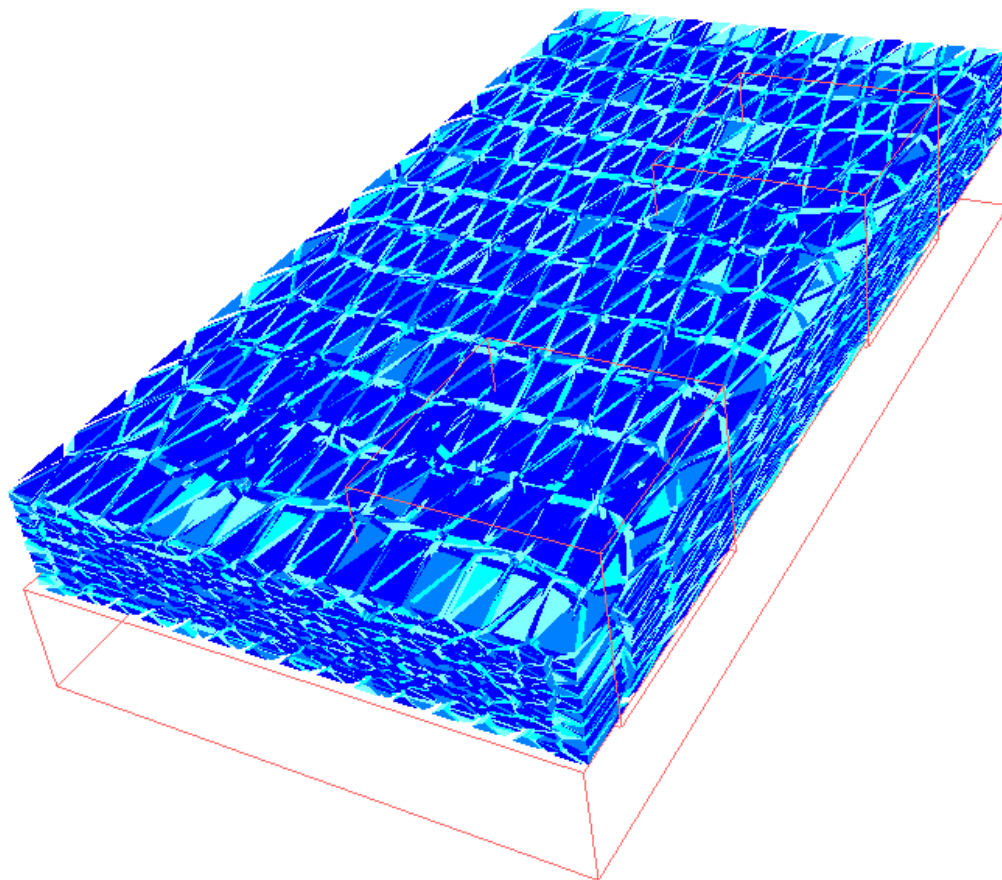
GUI



TESTS



RESULTS



Tetrahedra to triangles

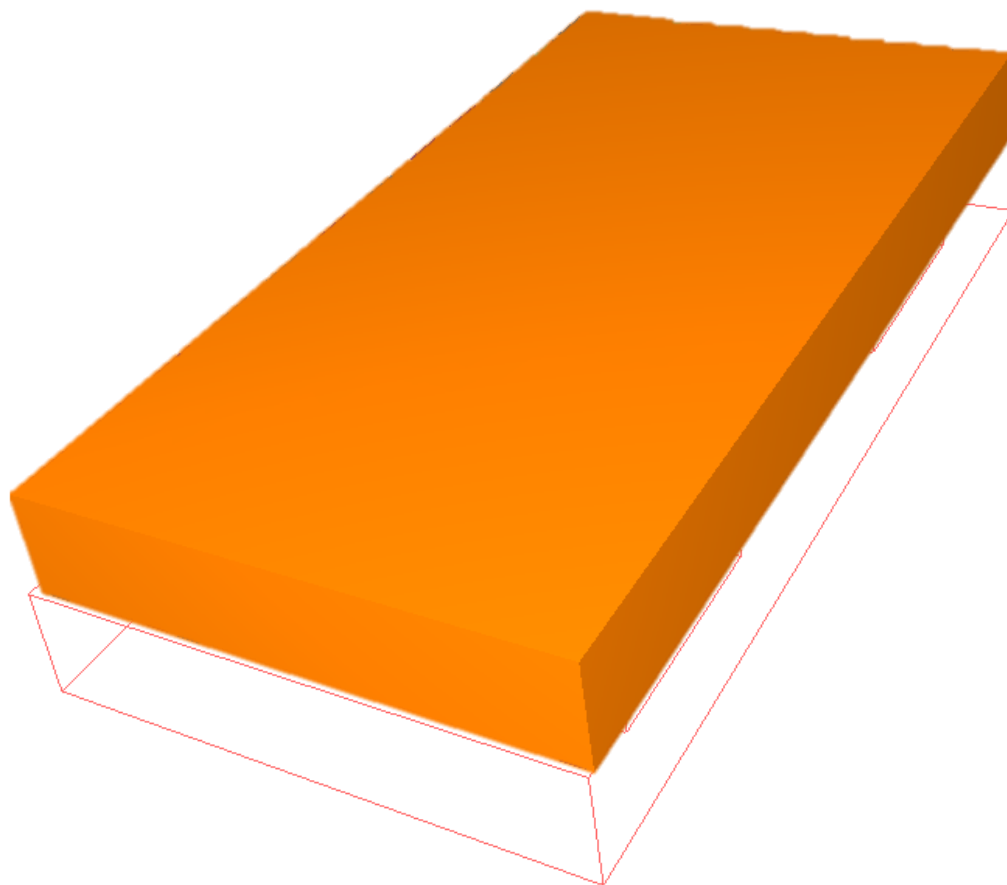
Behavior model:

- Tetrahedral meshes
- Box to keep it fixed
- Other boxes to compute indices



MODEL

Skin virtual model



Tetrahedra to triangles

Behavior model:

- Tetrahedral meshes
- Box to keep it fixed
- Other boxes to compute indices

Collision model:

- Triangular meshes



DEVICE



TASKS



GUI



TESTS



RESULTS



MODEL



DEVICE



TASKS



GUI

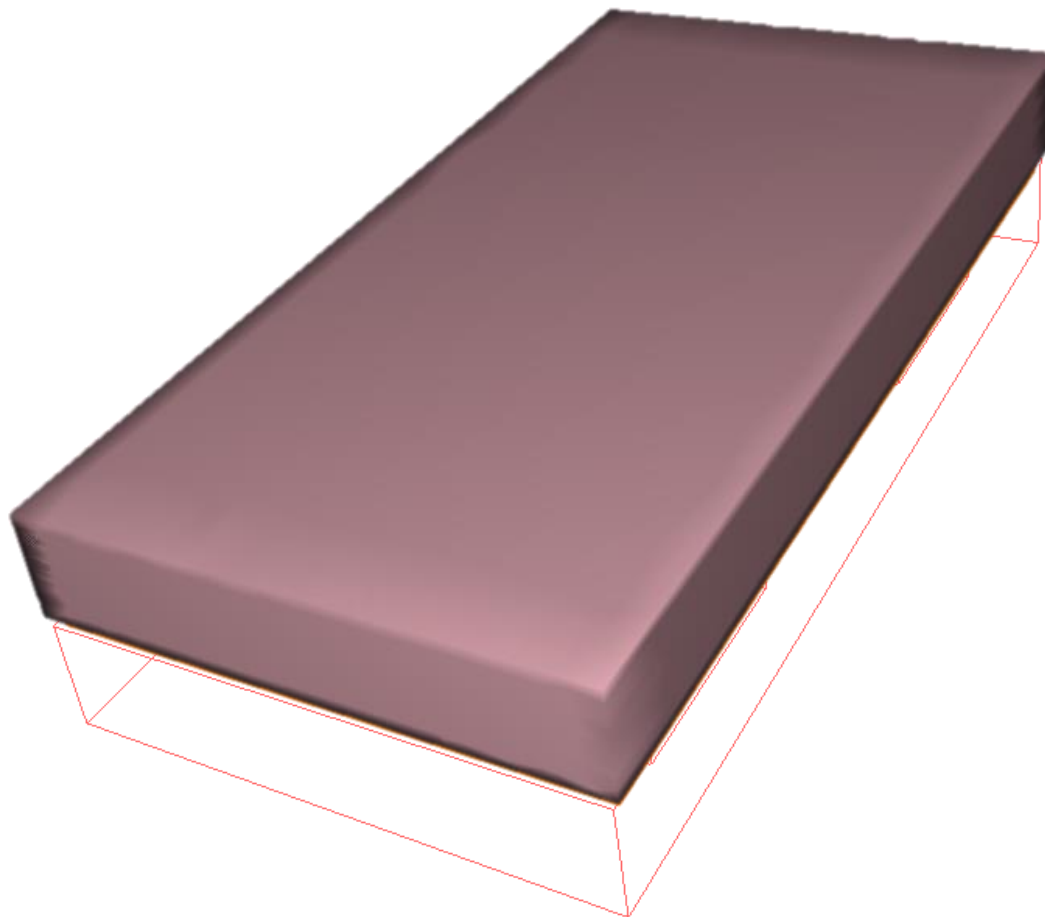


TESTS



RESULTS

Skin virtual model



Tetrahedra to triangles

Behavior model:

- Tetrahedral meshes
- Box to keep it fixed
- Other boxes to compute indices

Collision model:

- Triangular meshes

Visual model:

- Triangular meshes

Identity mapping



MODEL



DEVICE



TASKS



GUI



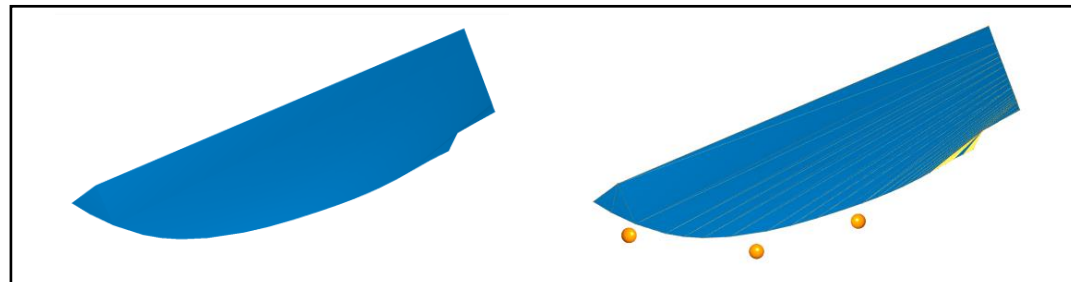
TESTS



RESULTS

Instrument virtual models

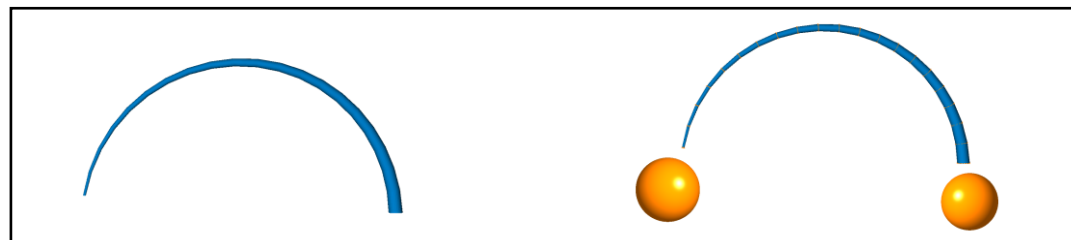
- ▶ Four different interaction objects.
- ▶ Model: downloaded and modified on Blender.
- ▶ Physics: defined with SOFA scripts.
- ▶ Positioned in the simulation structure.



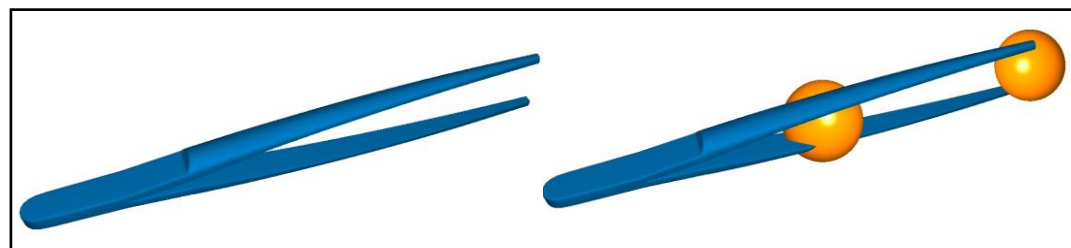
Incision



Dexterity



Suture



Suture
(double)



MODEL



DEVICE



TASKS



GUI



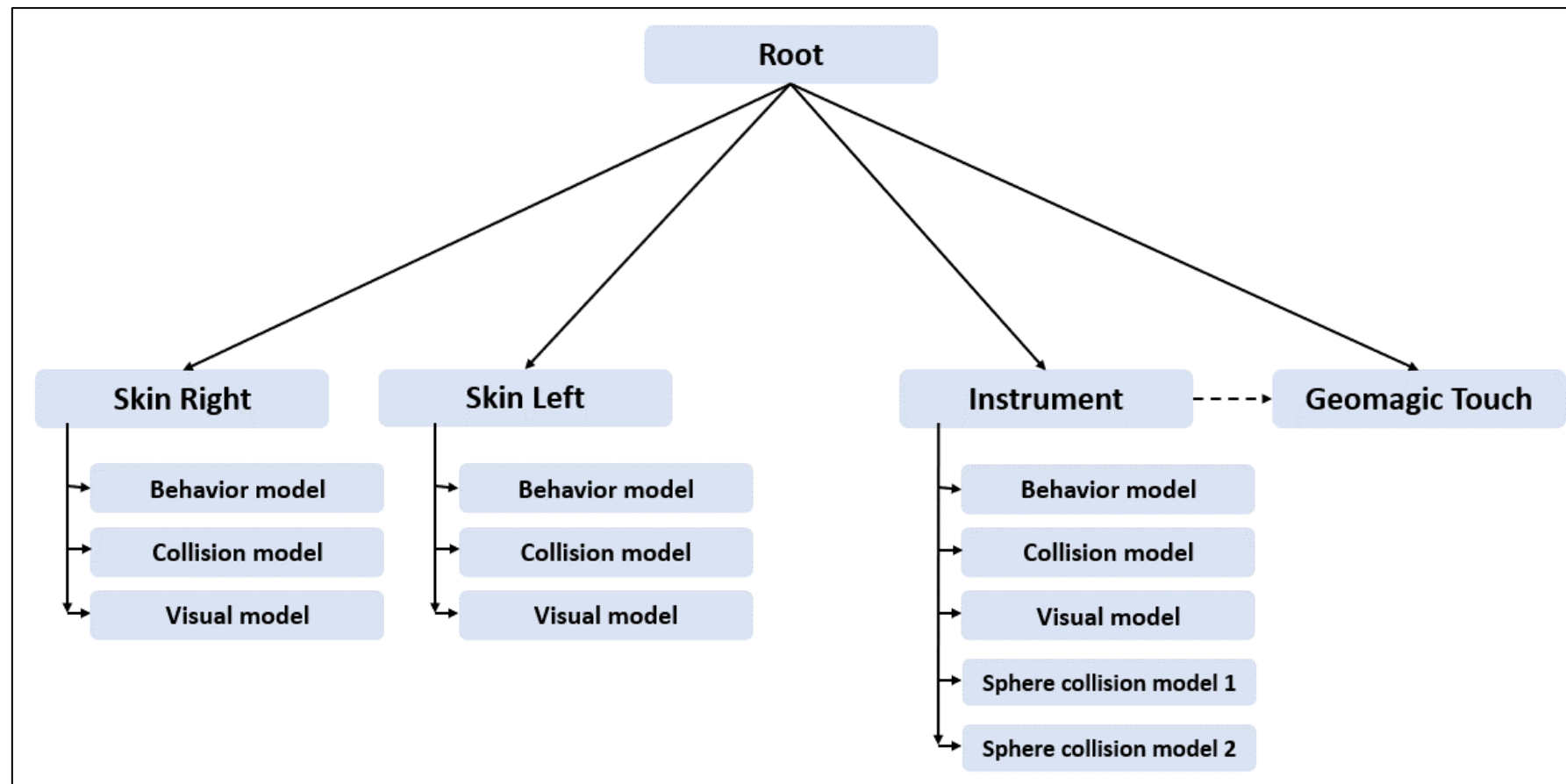
TESTS

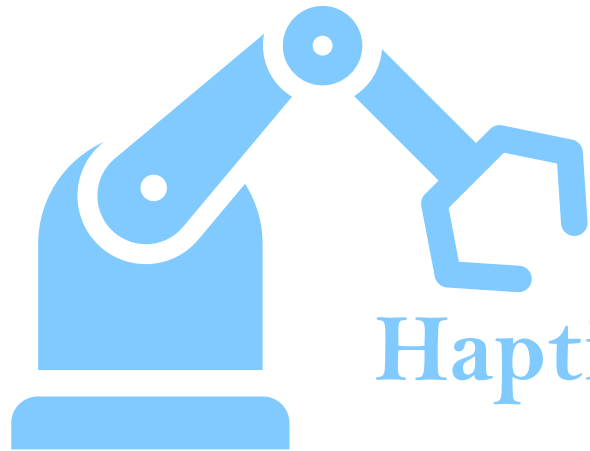


RESULTS

Instrument virtual models

- ▶ Four different interaction objects.
- ▶ Model: downloaded and modified on Blender.
- ▶ Physics: defined with SOFA scripts.
- ▶ Positioned in the simulation structure.





Haptic Device



MODEL



DEVICE



TASKS



GUI



TESTS

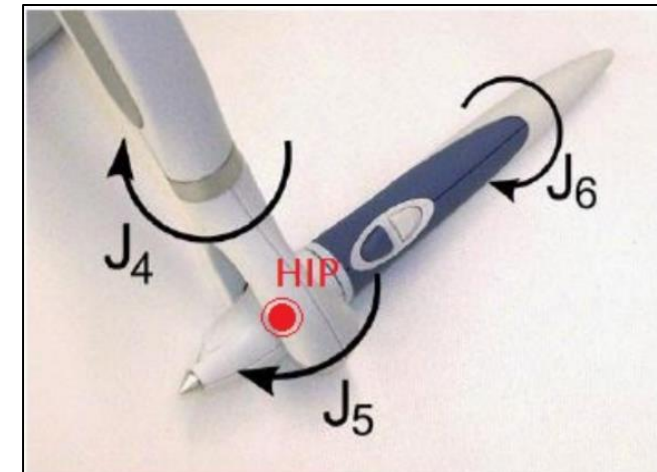


RESULTS

Hardware: Geomagic Touch



ACTUATED JOINTS – position of the HIP



PASSIVE JOINTS – orientation of the stylus

Instruments models



Dexterity



Incision



Suture



MODEL



DEVICE



TASKS



GUI

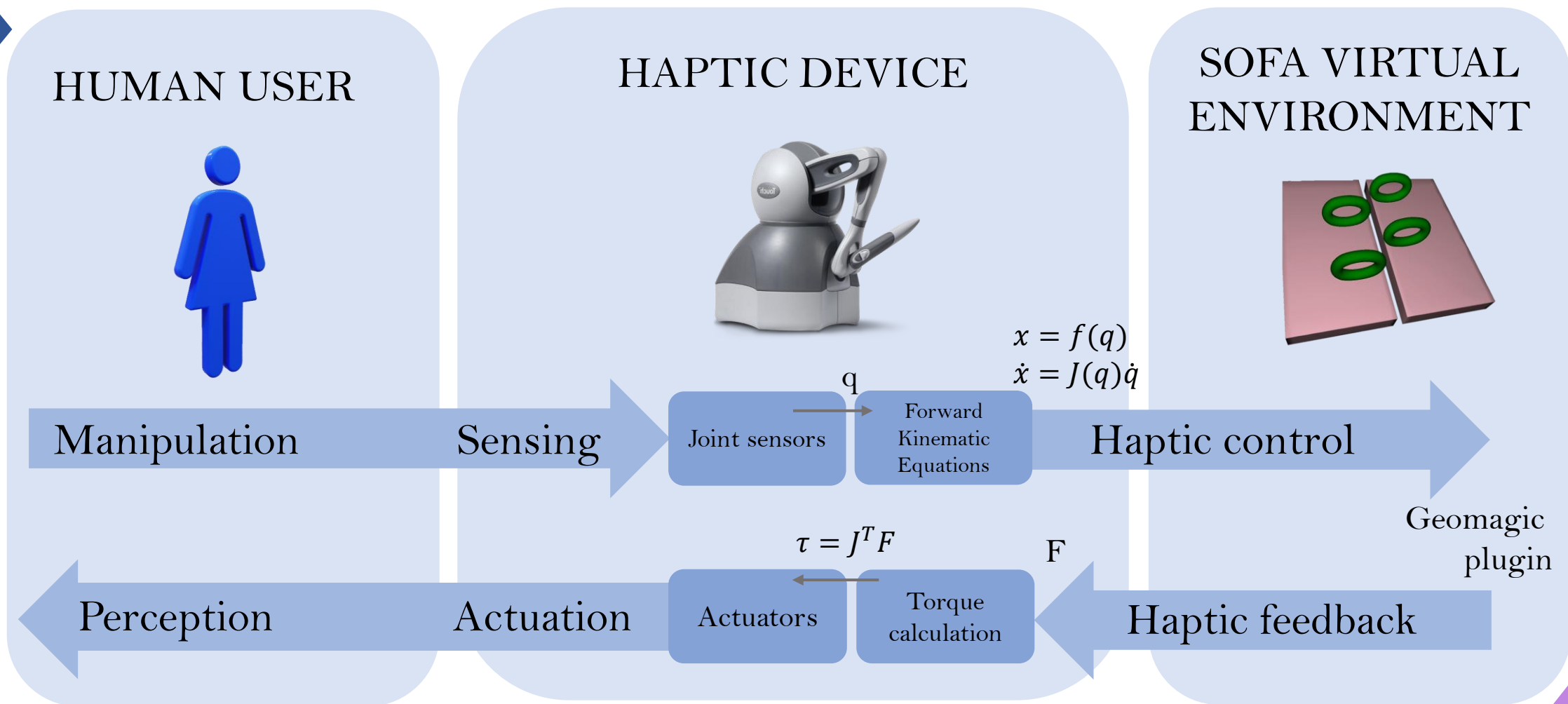


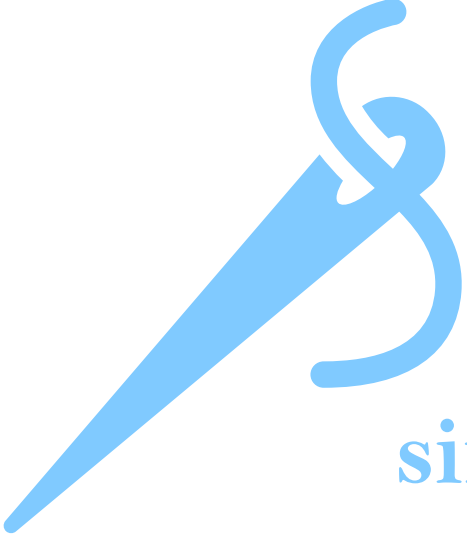
TESTS



RESULTS

Haptic interaction scheme





Medical task simulations: implementation



MODEL



DEVICE



TASKS



GUI

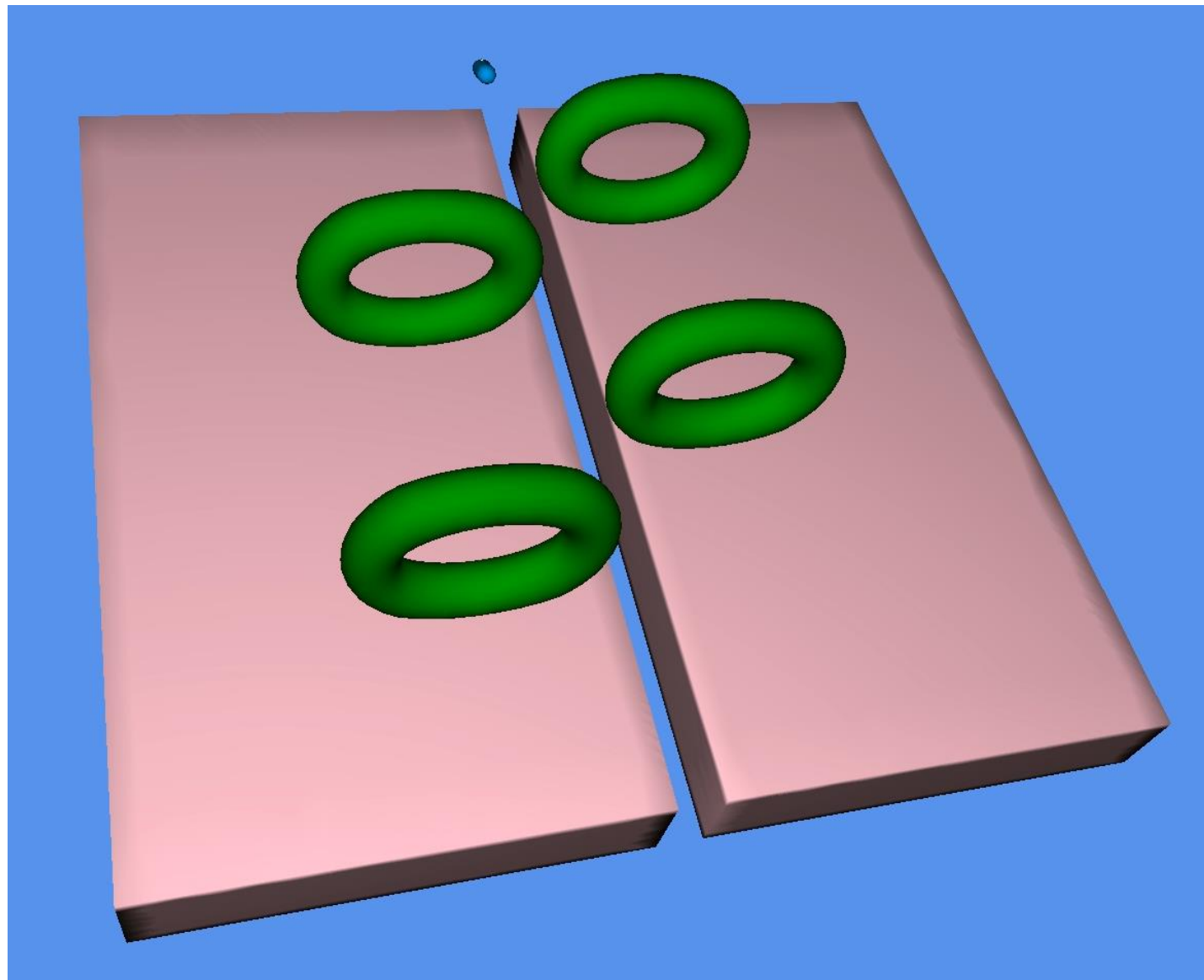
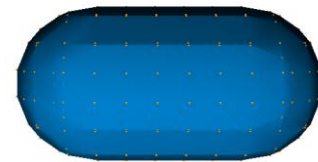


TESTS



RESULTS

Dexterity task





MODEL



DEVICE



TASKS



GUI

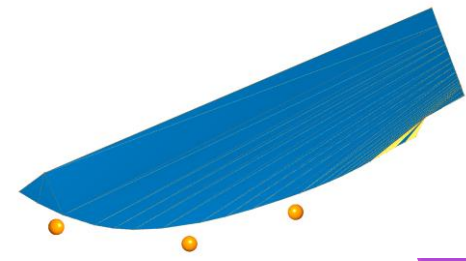
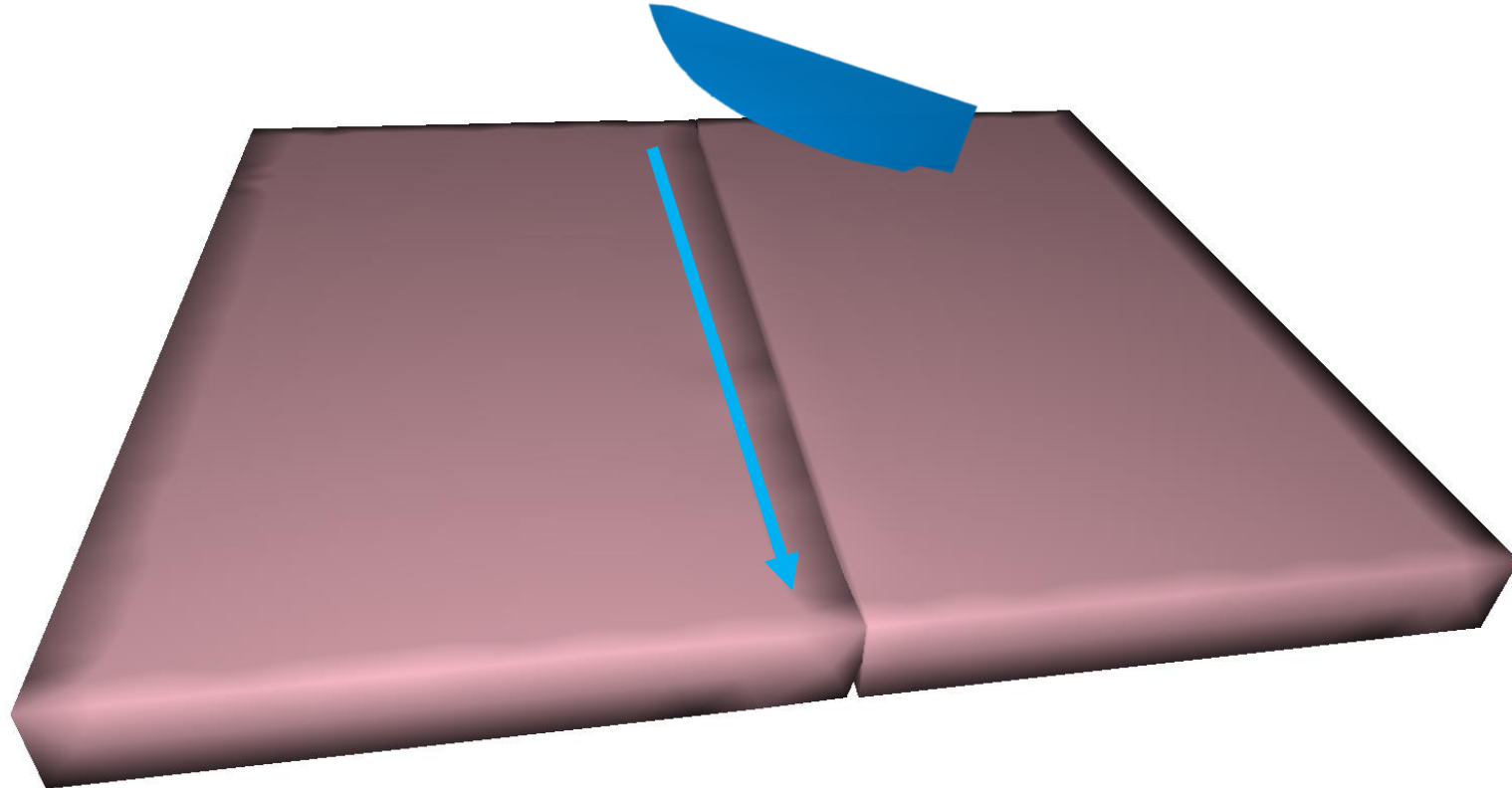


TESTS



RESULTS

Incision task





MODEL



DEVICE



TASKS



GUI

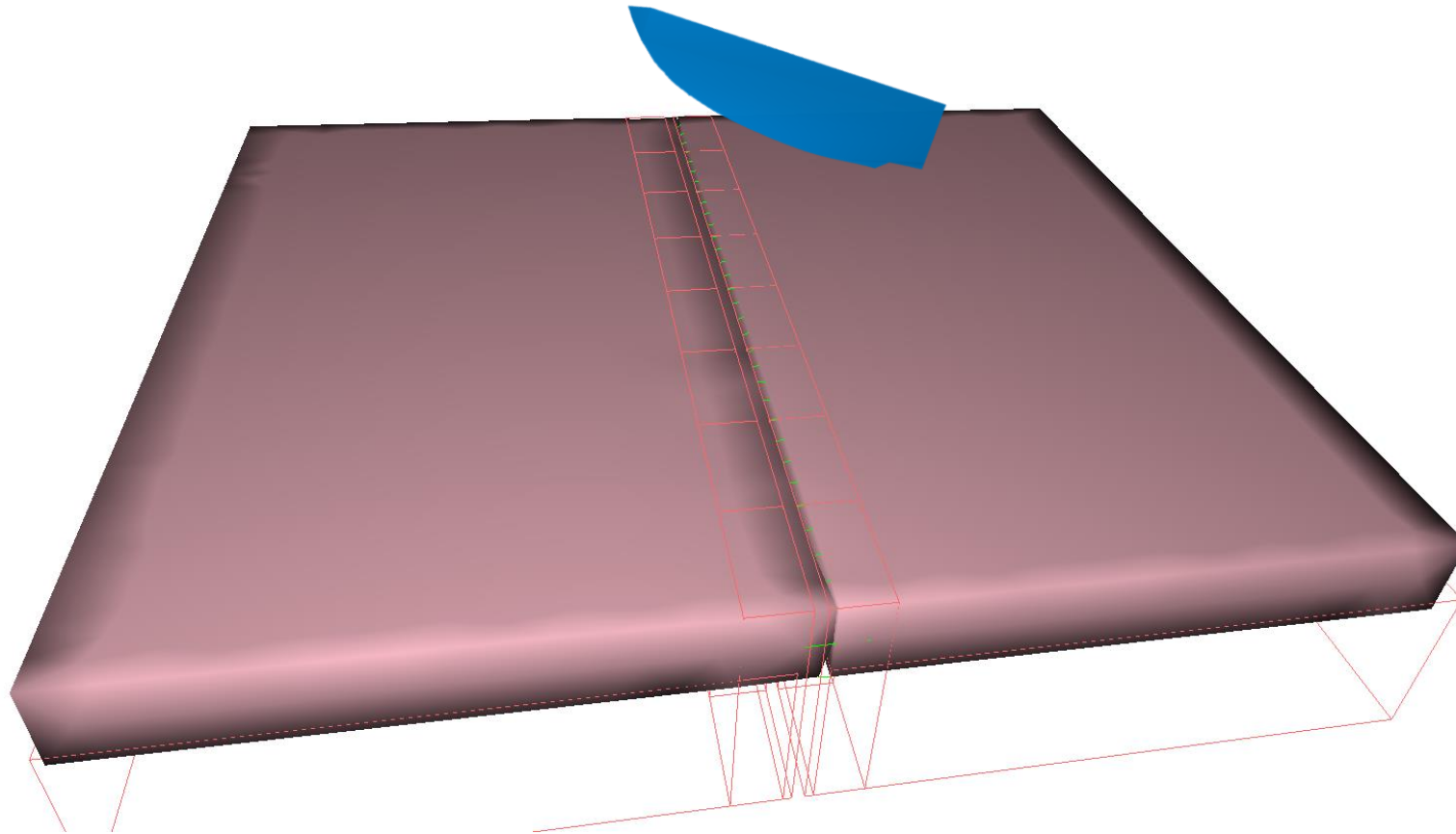


TESTS



RESULTS

Incision task





MODEL



DEVICE



TASKS



GUI

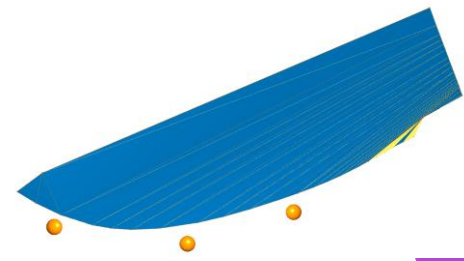
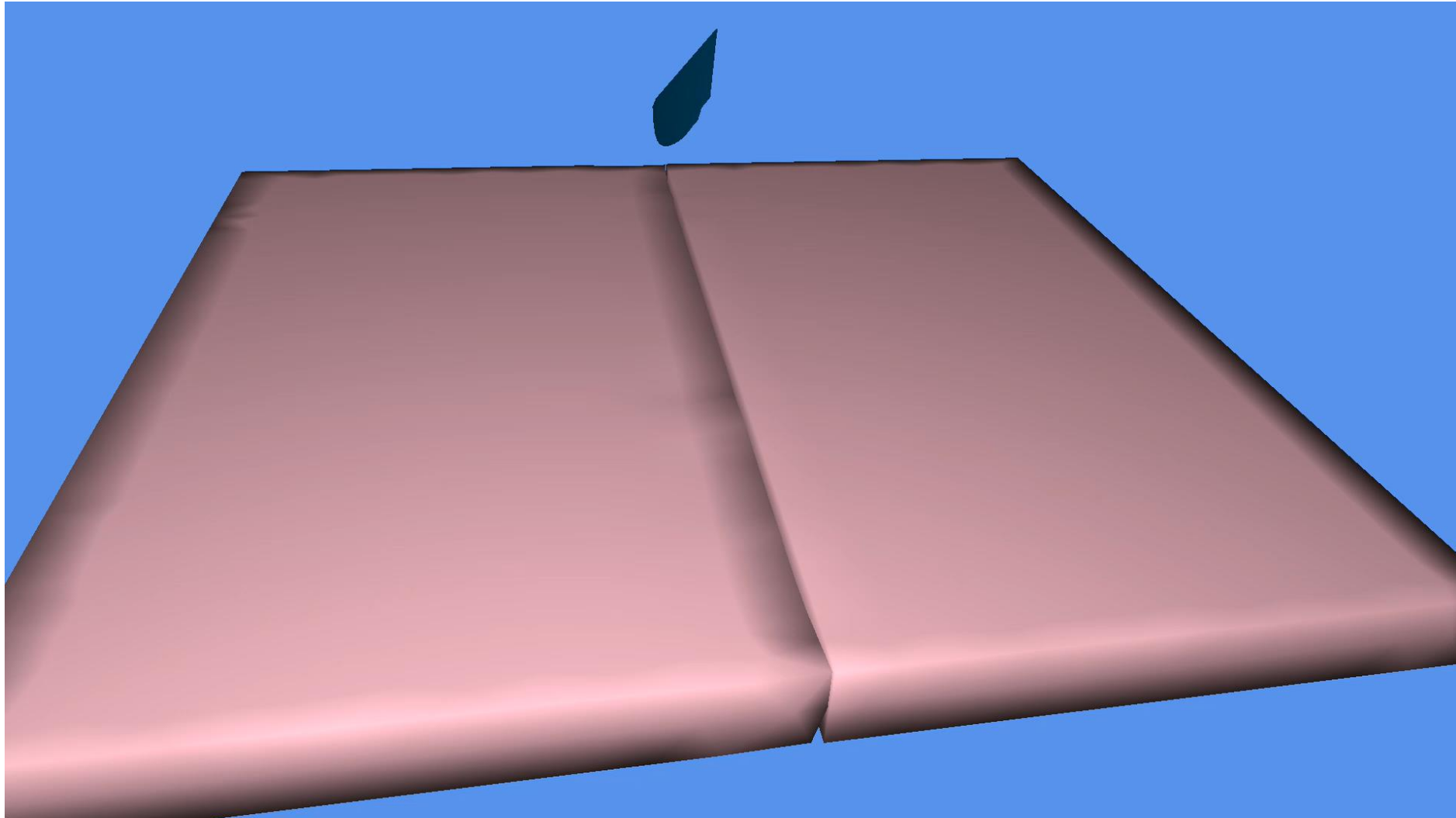


TESTS



RESULTS

Incision task





MODEL



DEVICE



TASKS



GUI

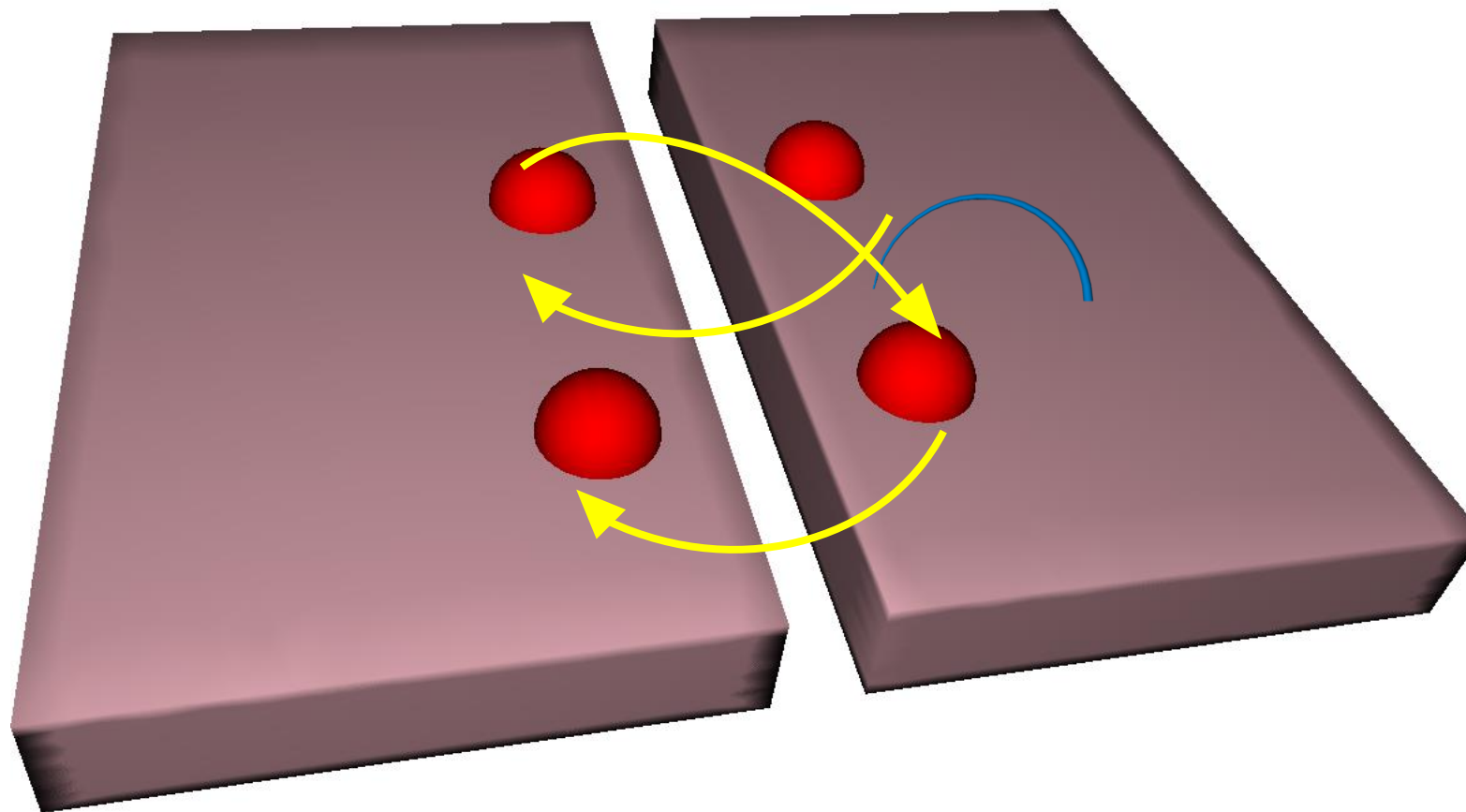
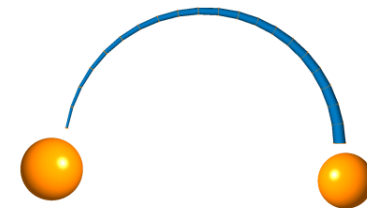


TESTS



RESULTS

Suture task: single-device





MODEL



DEVICE



TASKS



GUI

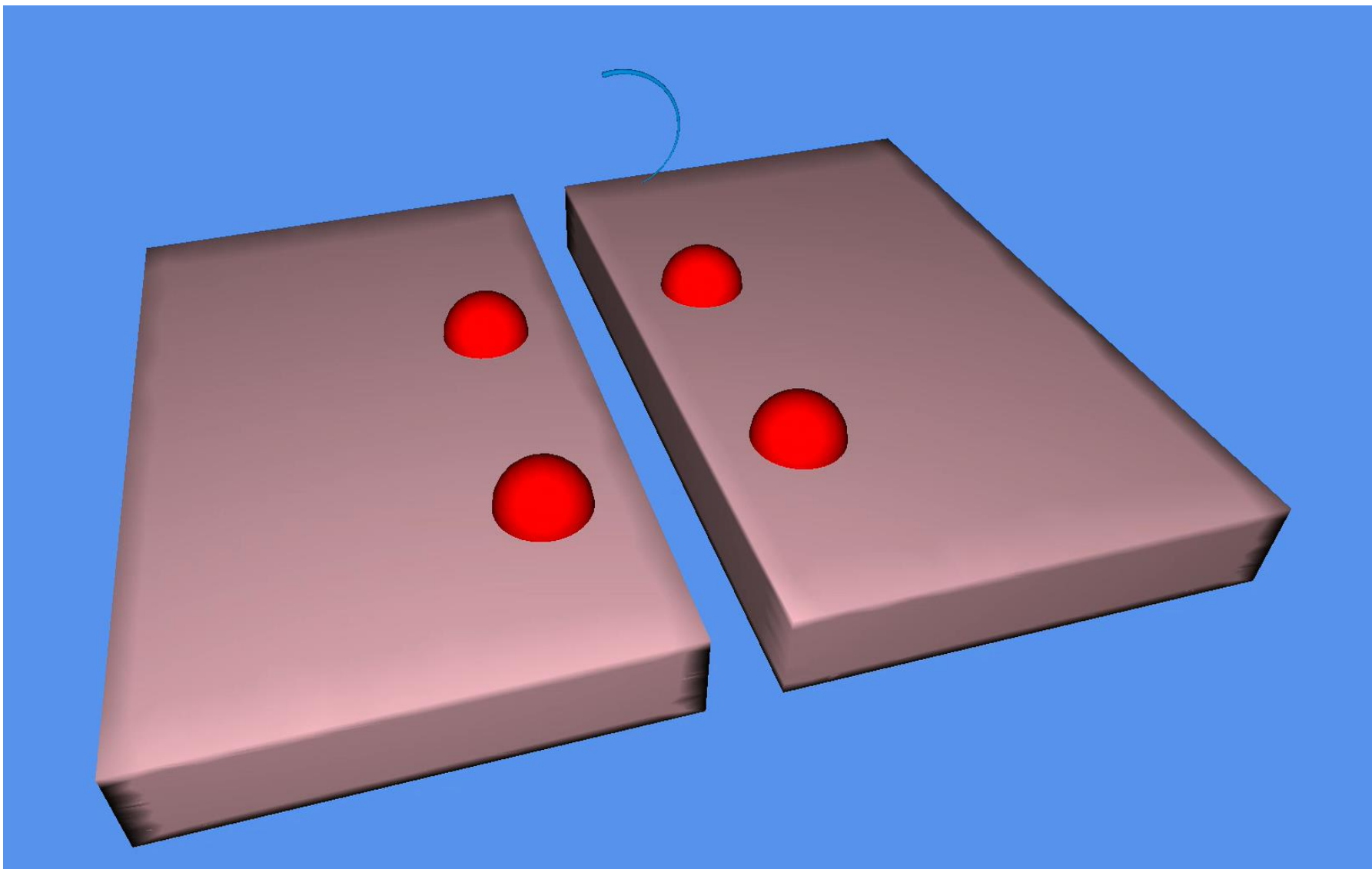
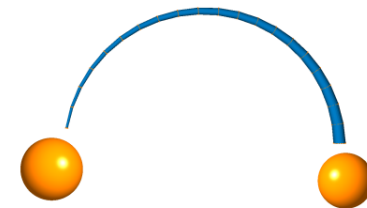


TESTS



RESULTS

Suture task: single-device





MODEL



DEVICE



TASKS



GUI

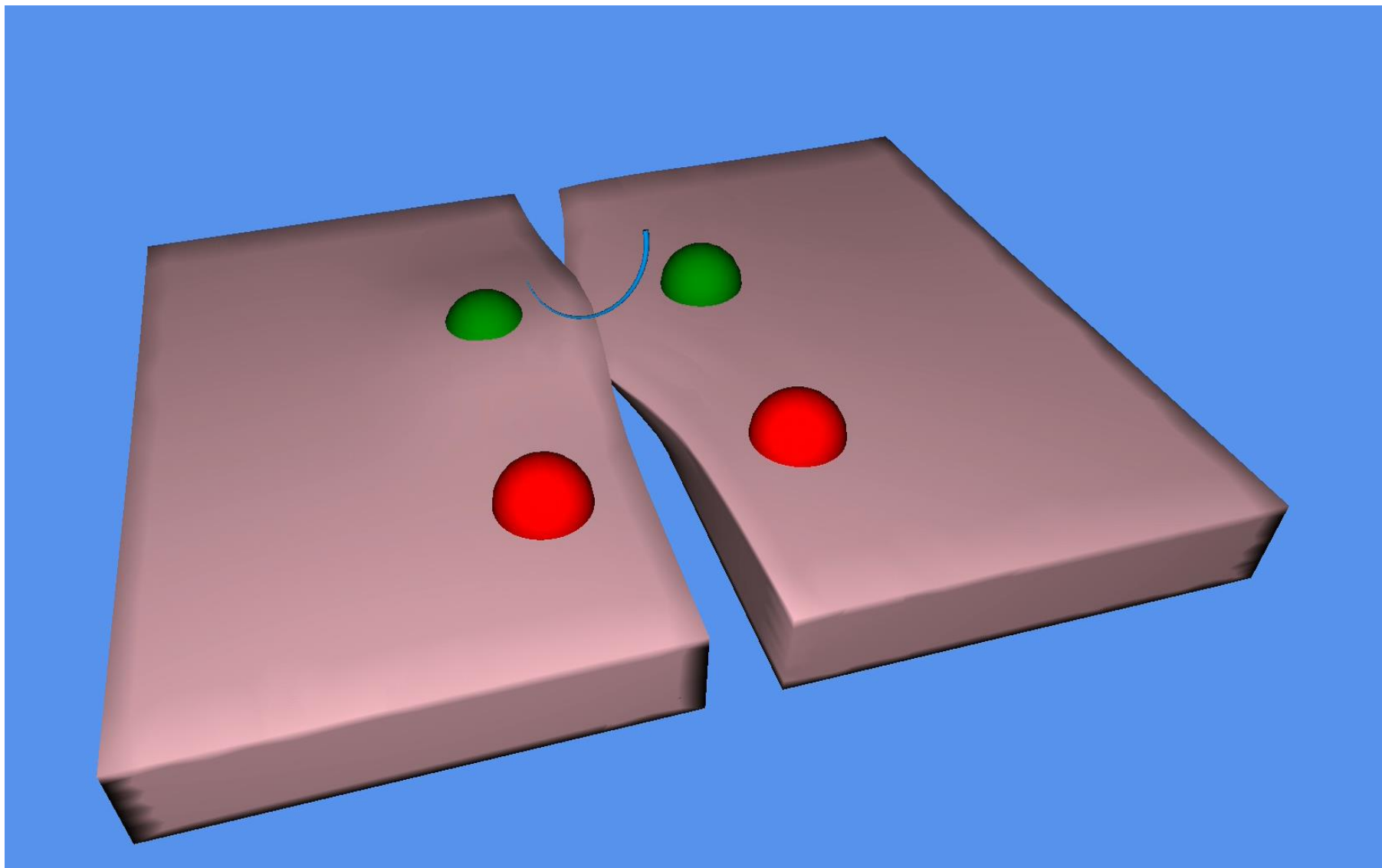
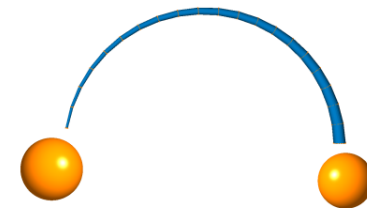


TESTS



RESULTS

Suture task: single-device





MODEL



DEVICE



TASKS



GUI

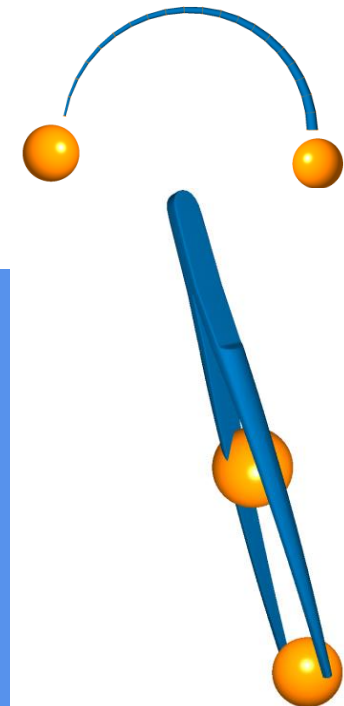
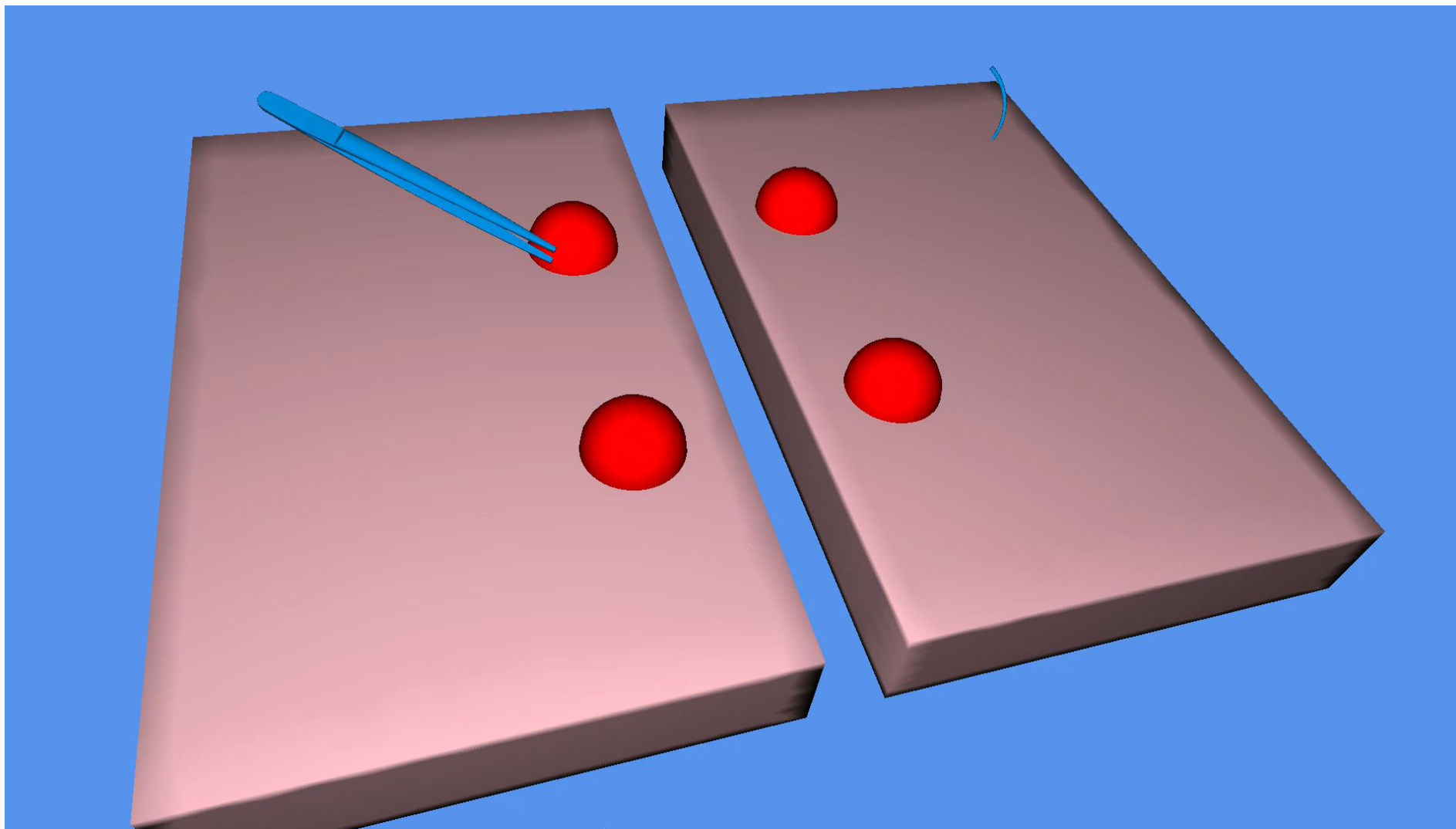


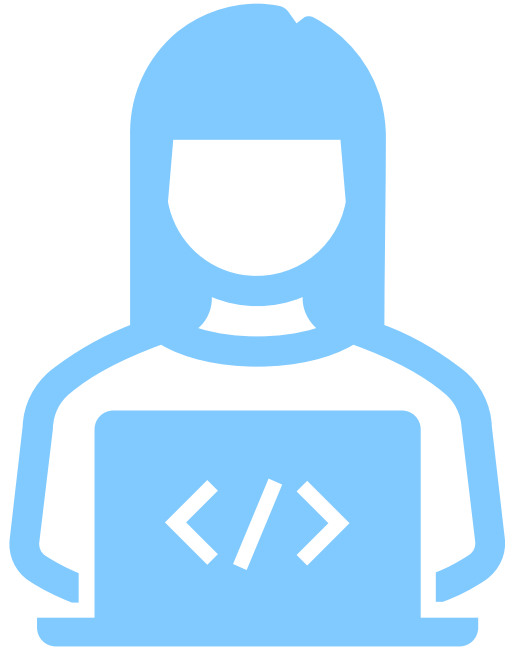
TESTS



RESULTS

Suture task: double-device





Graphical User Interfaces



MODEL



DEVICE



TASKS



GUI



TESTS



RESULTS

Graphical User Interface

tk

Run your SOFA Framework medical simulation



Insert your name here

Chiara

Suture

Single

Right

Submit



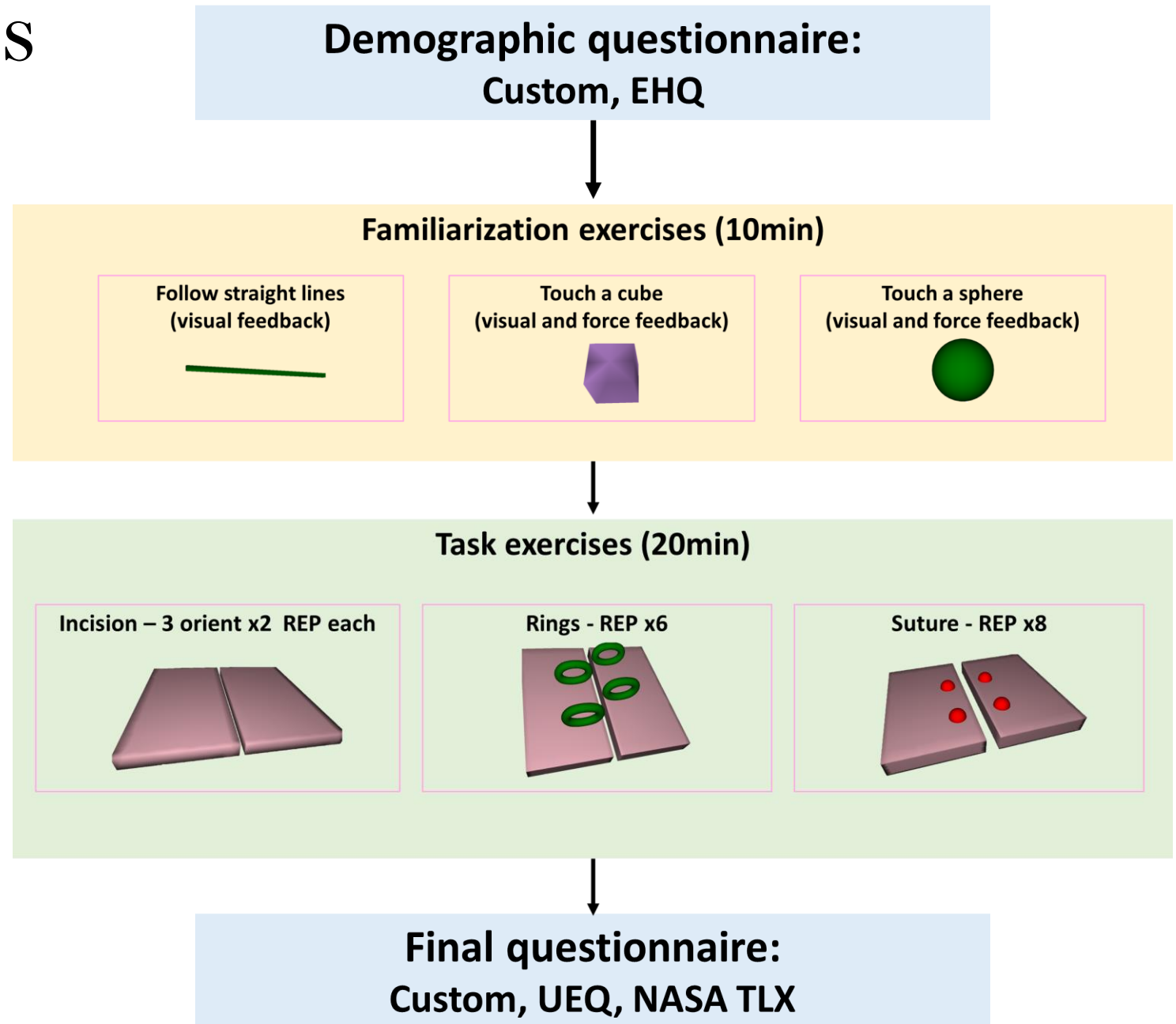
Testing phase



Experiments

Eight surgeons
Average age: 46 ± 16.2
4 Female, 4 Male
Average years of experience: 22.4 ± 19.1
All right-handed

Eight age-matched non experts
Average age: 44.1 ± 18.3
4 Female, 4 Male
Two left-handed





MODEL



DEVICE



TASKS



GUI



TESTS



RESULTS

Experiments

Eight surgeons

Average age: 46 ± 16.2

4 Female, 4 Male

Average years of
experience: 22.4 ± 19.1

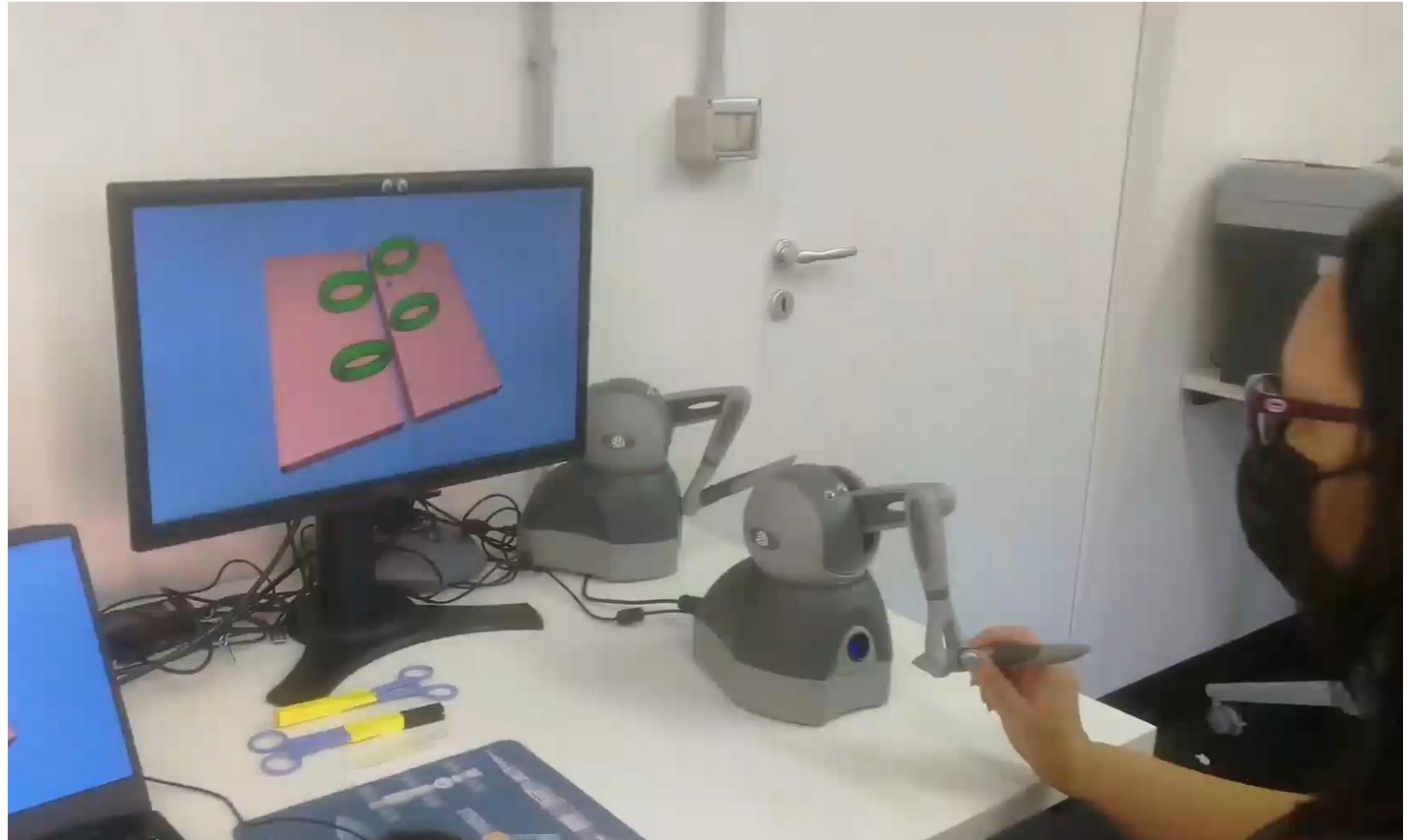
All right-handed

Eight age-matched non experts

Average age: 44.1
 ± 18.3

4 Female, 4 Male

Two left-handed





Results



MODEL



DEVICE



TASKS



GUI

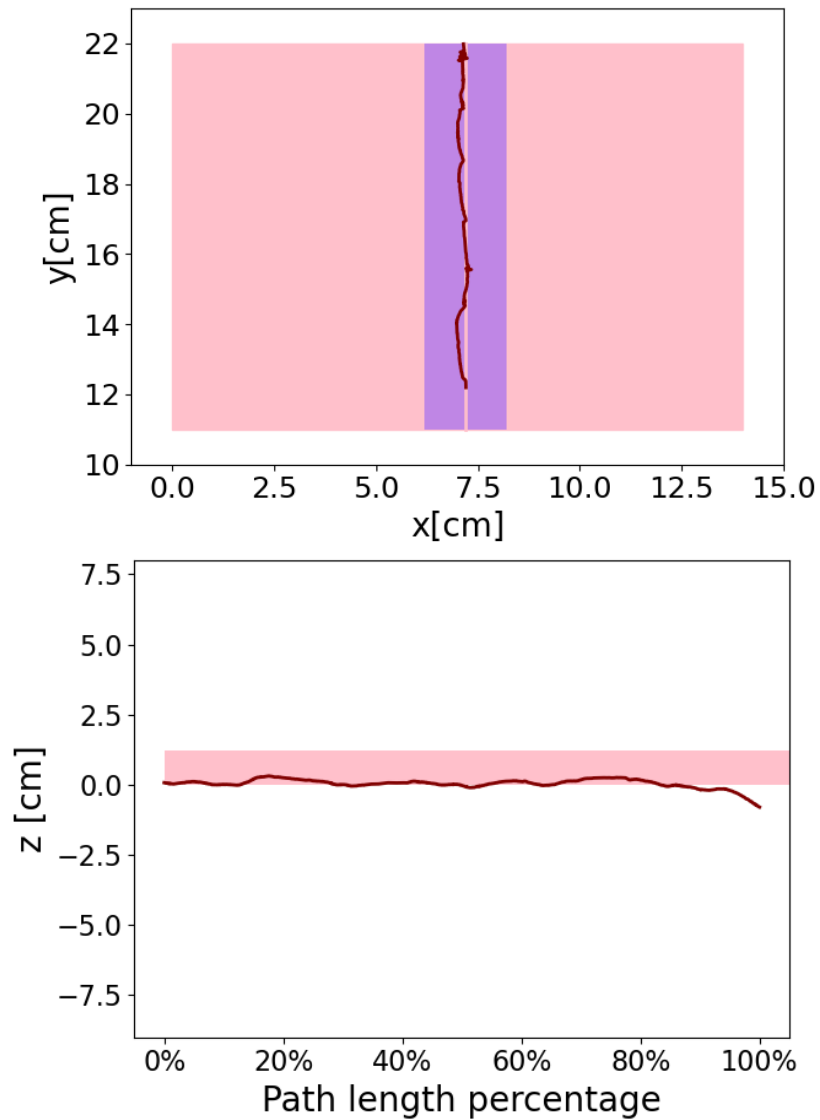


TESTS



RESULTS

Incision: Behavioral data



Plot color legend:

- Pink: skin, violet: incision area

Metrics...

- Incision: maximum deviation from cutting line along x and z

...compared to:

- Group
- Age



MODEL



DEVICE



TASKS



GUI

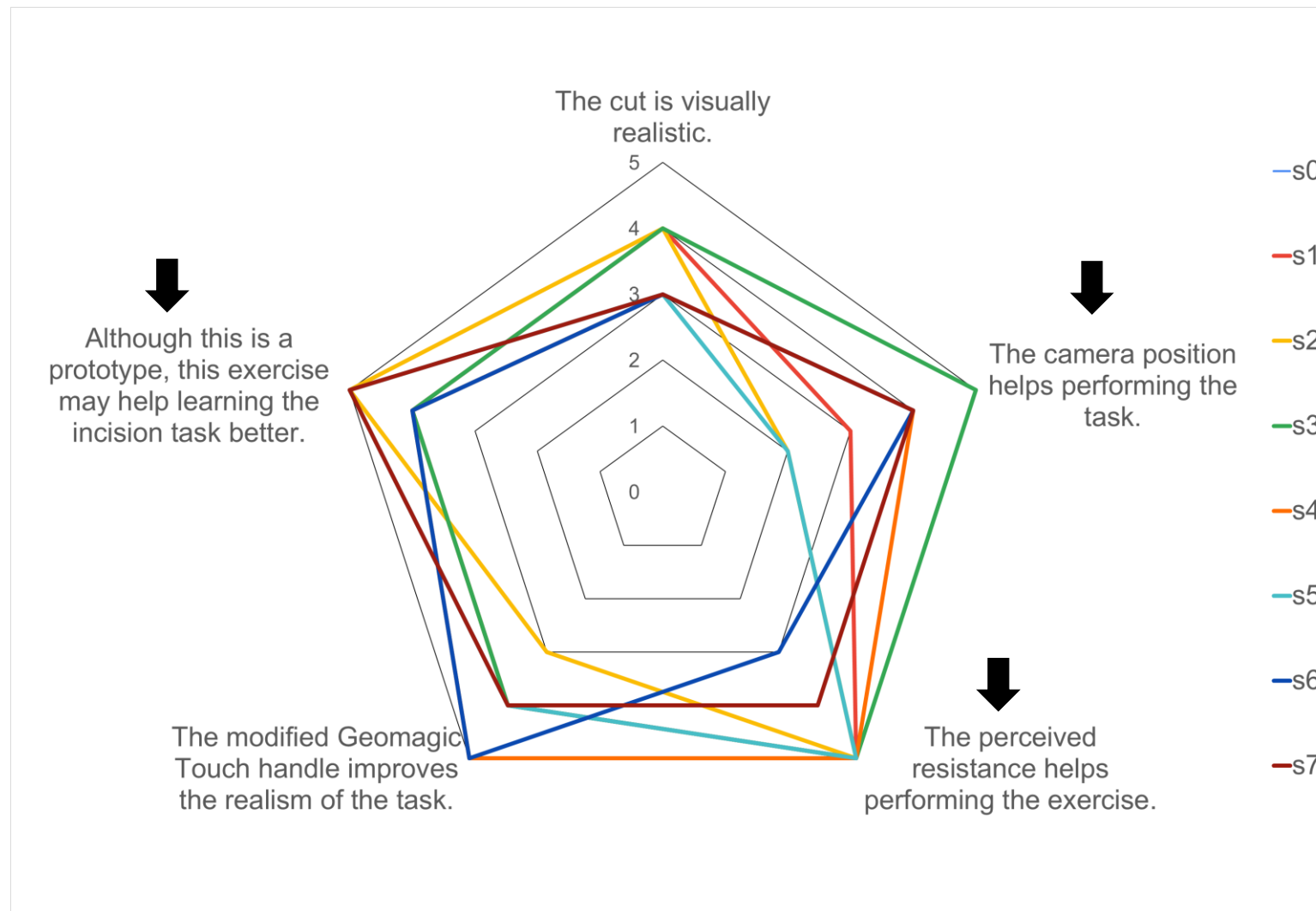


TESTS



RESULTS

Incision: Survey data



Range: 1 (I totally do not agree) to 5 (I totally agree)



MODEL



DEVICE



TASKS



GUI

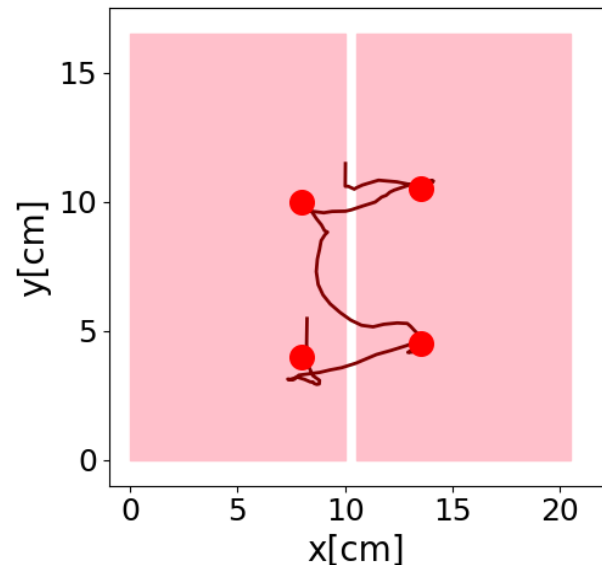


TESTS



RESULTS

Suture: Behavioral data



Plot color legend:

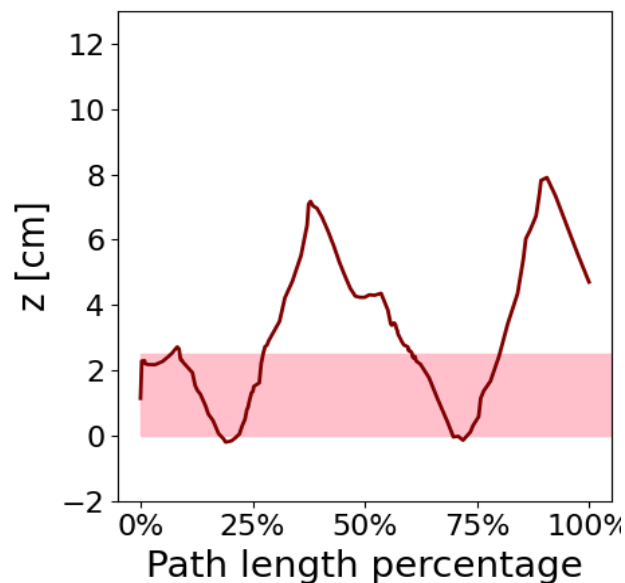
- Pink: skin, red: spheres

Metrics...

- Suture: 3D path length

...compared to:

- Group
- Age





MODEL



DEVICE



TASKS



GUI

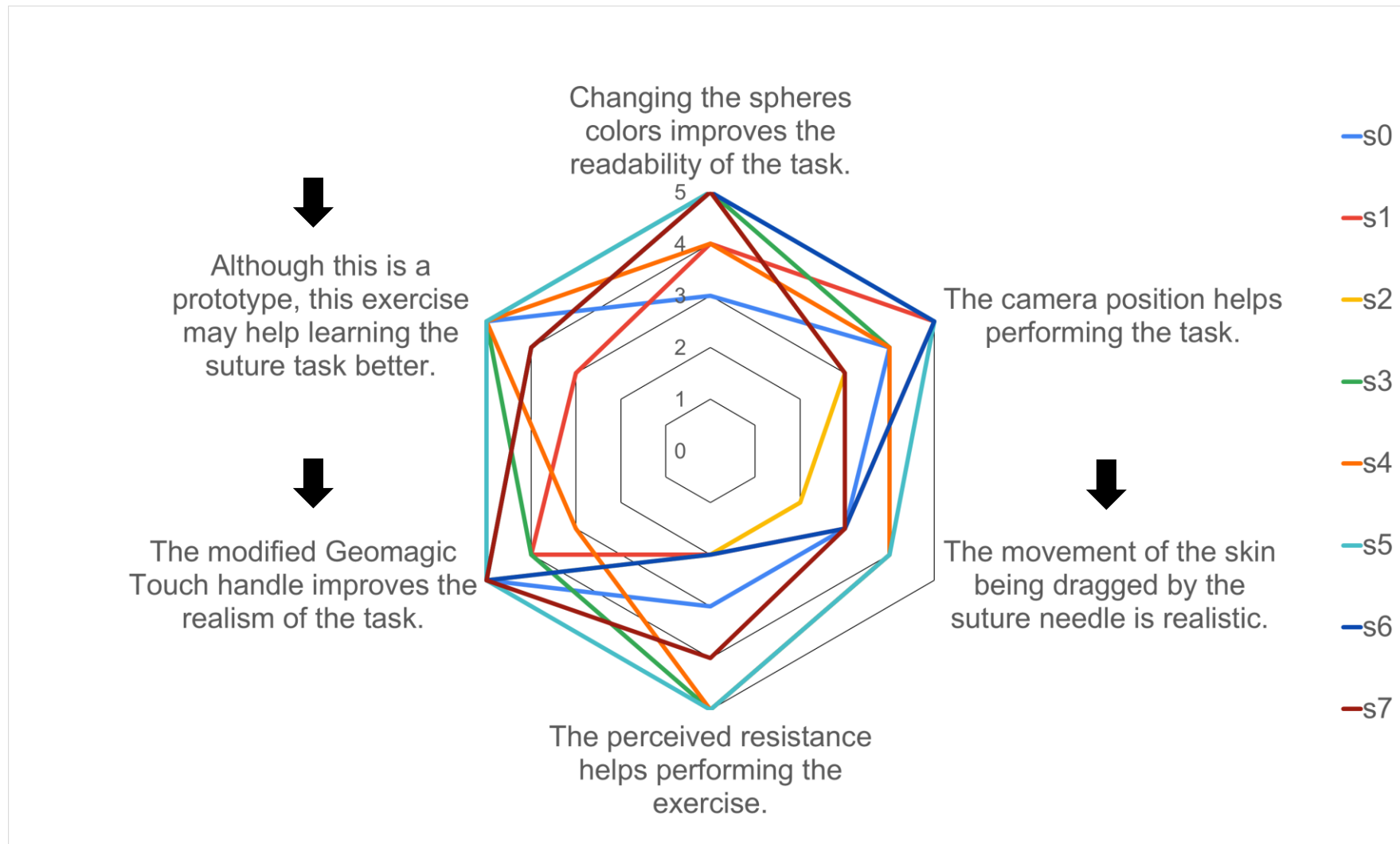


TESTS



RESULTS

Suture: Survey data



Range: 1 (I totally do not agree) to 5 (I totally agree)



MODEL



DEVICE



TASKS



GUI

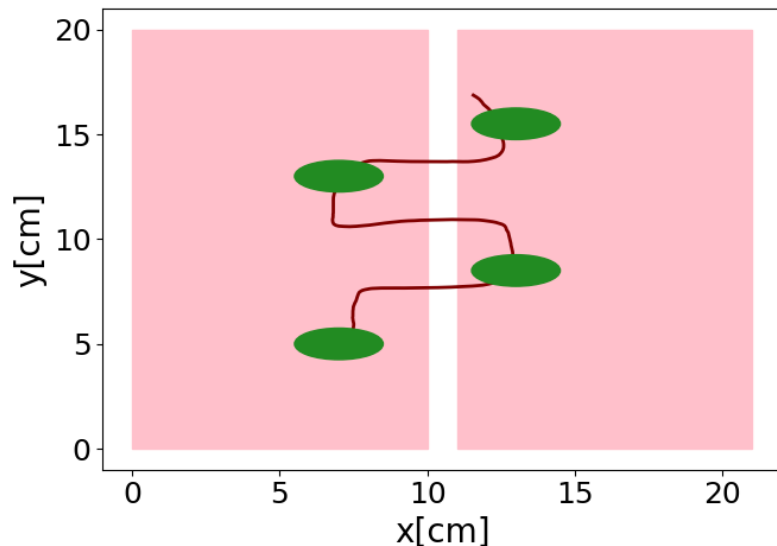


TESTS



RESULTS

Dexterity: behavioral data



Plot color legend:

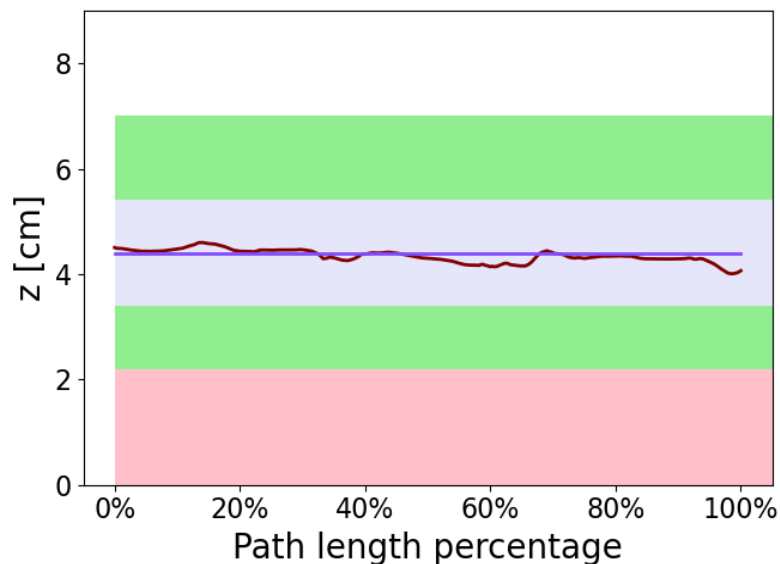
- Pink: skin, green: rings, violet: rings holes

Metrics...

- Dexterity: 2D and 3D path length

...compared to:

- Group
- Age





MODEL



DEVICE



TASKS



GUI

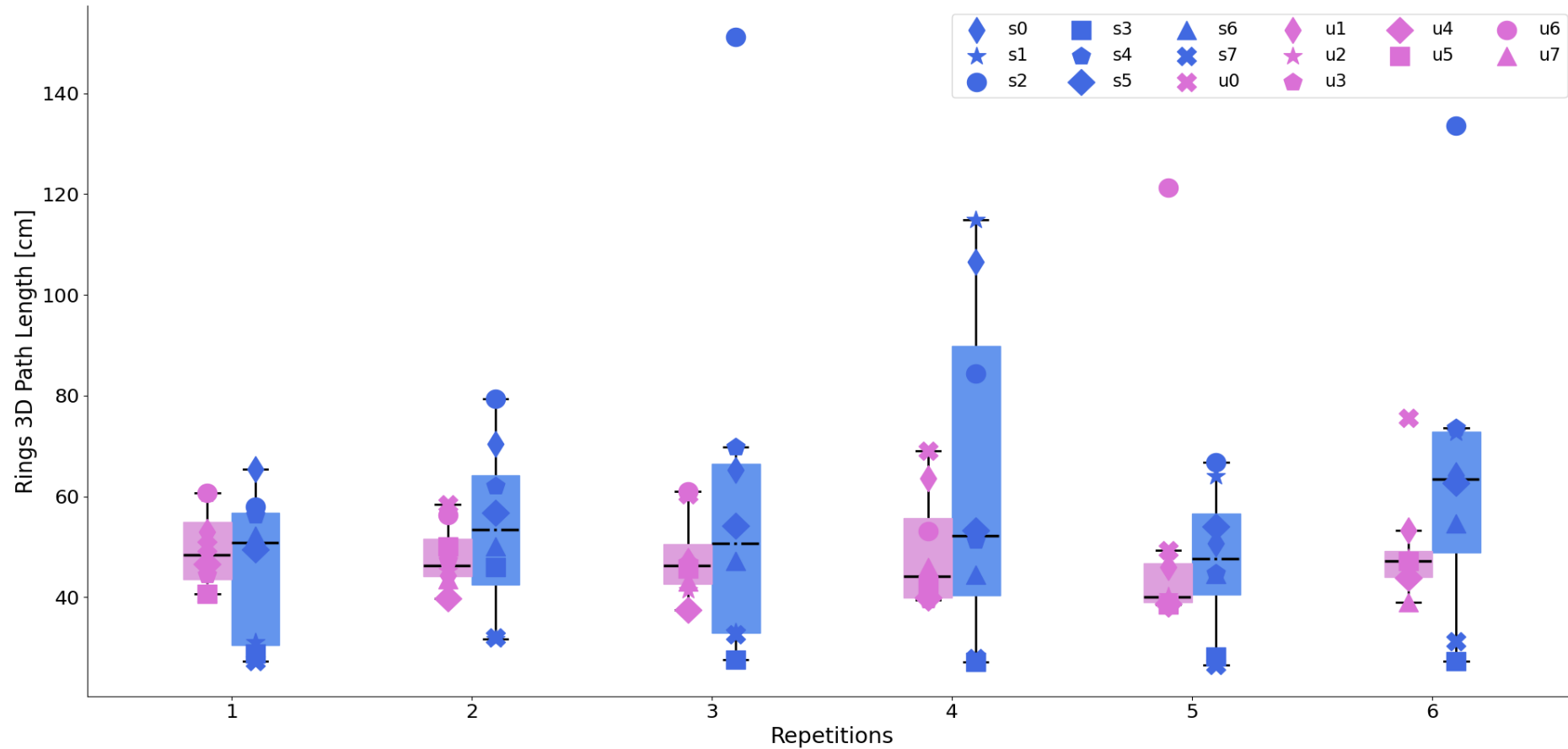


TESTS



RESULTS

Capsule trajectory Path Length



Spearman correlation value: $R=0.66$, $p=0.006$



MODEL



DEVICE



TASKS



GUI

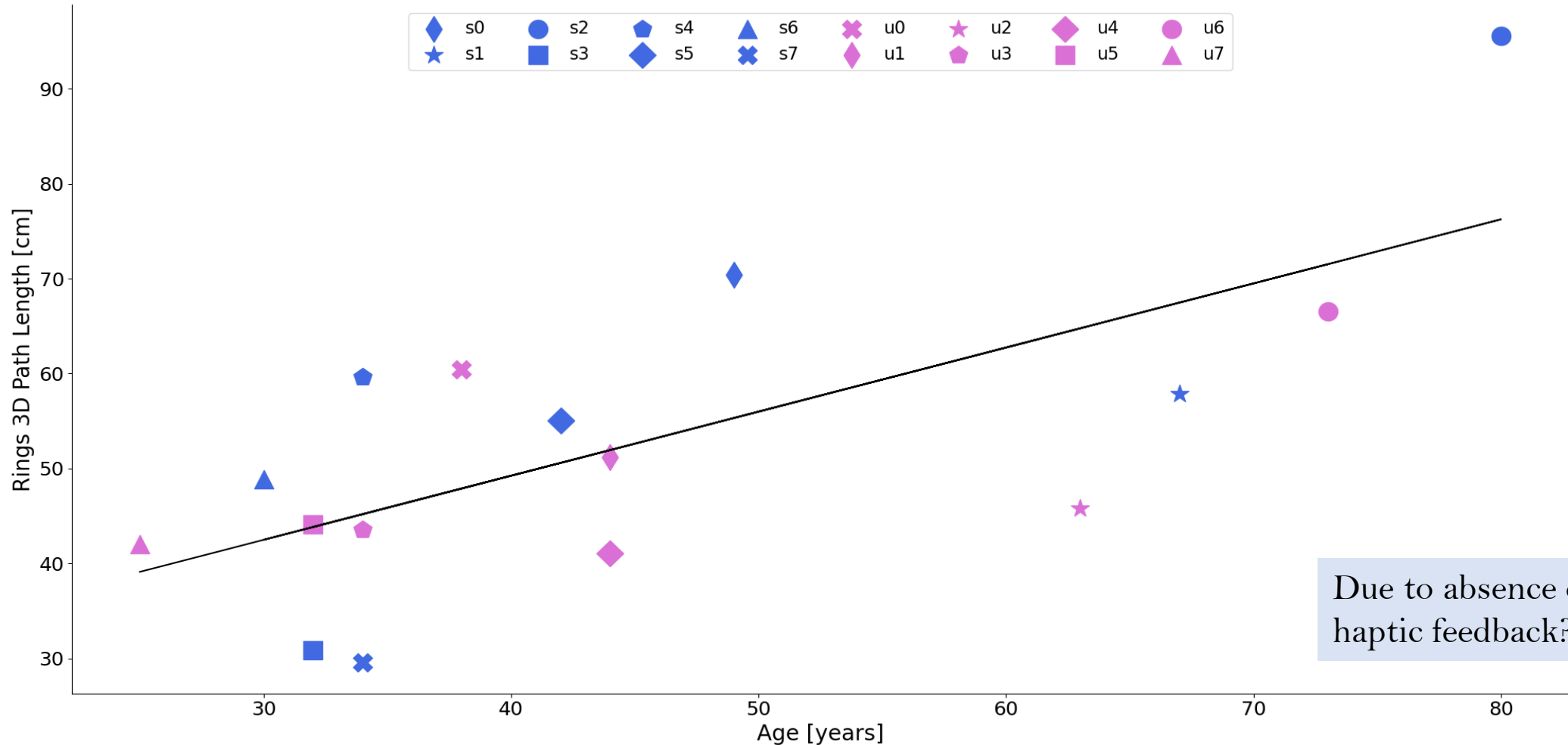


TESTS



RESULTS

Capsule trajectory Path Length



Spearman correlation value: $R=0.66$, $p=0.006$



MODEL



DEVICE



TASKS



GUI

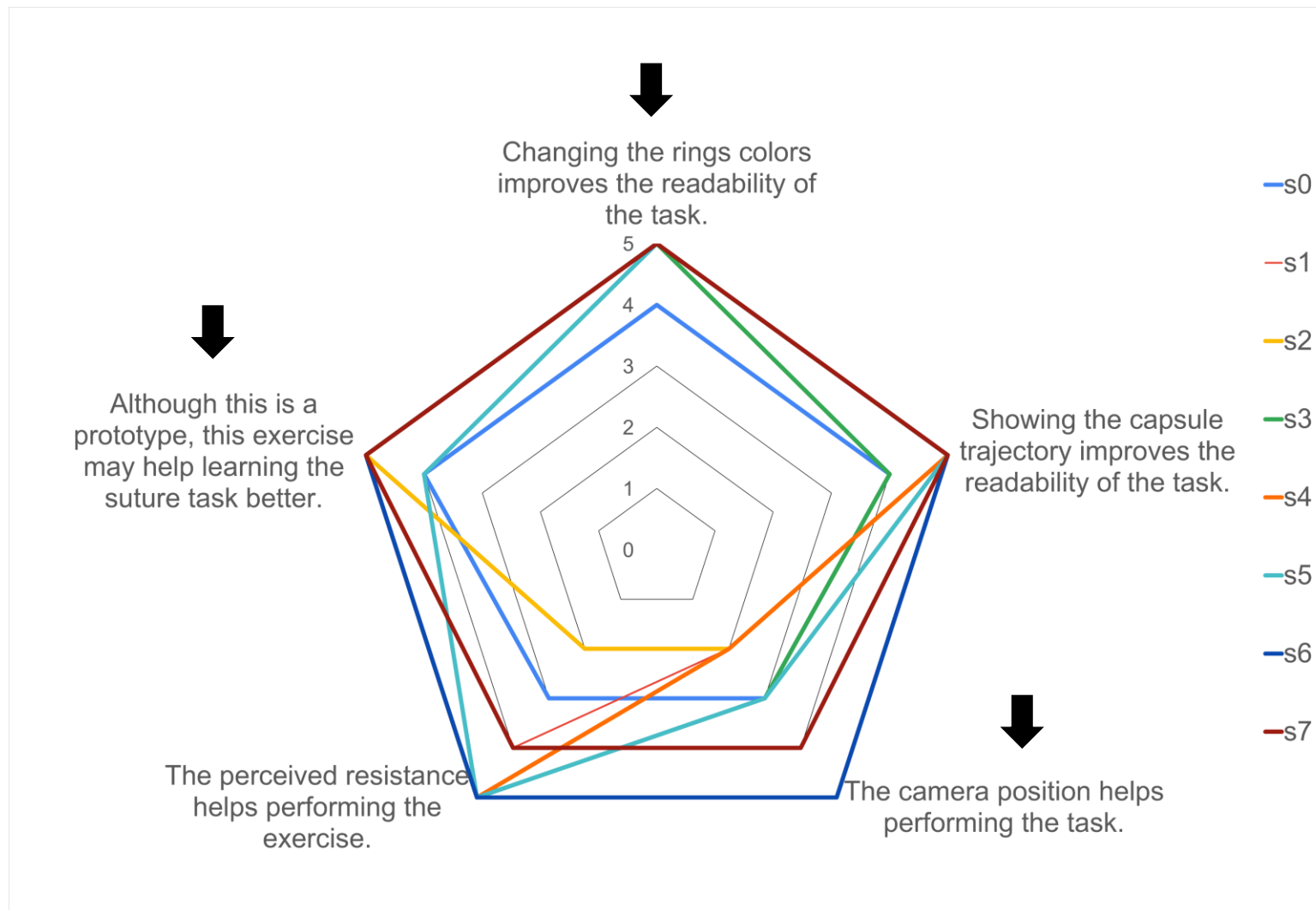


TESTS



RESULTS

Dexterity: survey data



Range: 1 (I totally do not agree) to 5 (I totally agree)



MODEL



DEVICE



TASKS



GUI

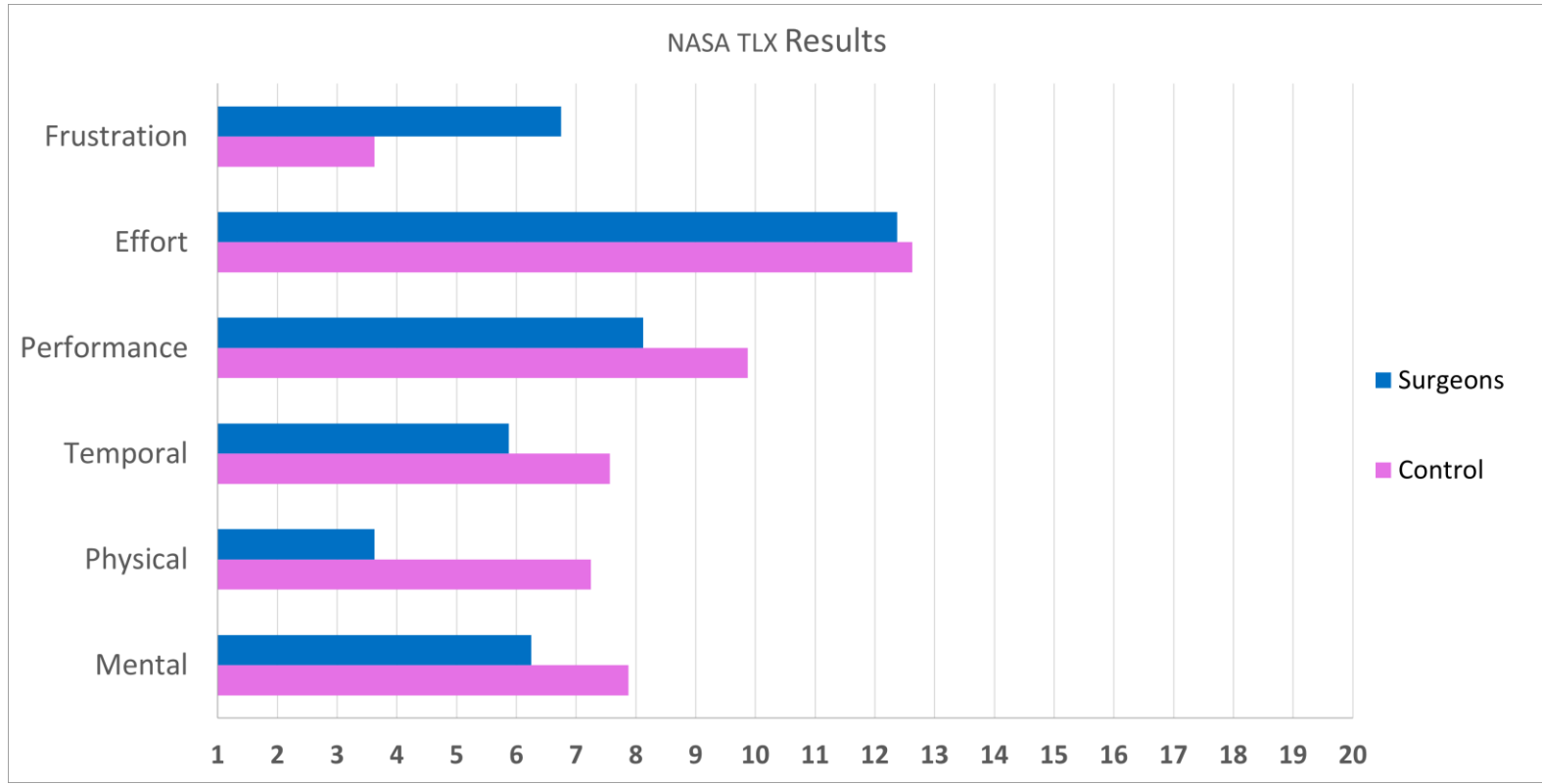


TESTS



RESULTS

NASA TLX Questionnaire data

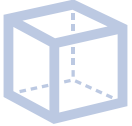


Range: 1 (Very low workload) to 20 (Very high workload)



Conclusions

Conclusions



Virtual models:

Skin, Scalpel blade, Suture needle, Forceps, Capsule



Haptic device handles:

Scalpel, Needle holder



Tasks algorithms:

Dexterity, Incision, Single-device suture, Double-device suture



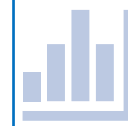
Graphical User Interface:

Installation, Task execution



Experiment:

Setup, Task definition, Surveys



Behavioral data analysis:

Visual inspection, Definition of metrics → correlation with age!



Questionnaire data analysis:

Further improvements, potentialities

Future Works



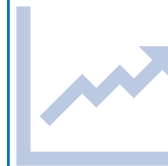
Improve skin model graphics:
color, texture



Improve skin model haptics:
tune parameters



Add more visual feedback:
suggestions, comments, reminders



Add a results GUI:
did the student learn in time?

The simulator now

📍 Festival della Scienza, Genova



IMSH* Abstract:

A haptic skin model to train surgical residents and analyze the neural correlates of surgical learning

S. Ricci, D. Torrigino, C. Saporetti, M. Chirico, G. Borgonovo, M. Minuto, M. Casadio

**International Meeting on Simulation in Healthcare (IMSH): a scientific conference that explores the latest innovations and best practices in healthcare simulation.*