Modeling Robotic Digital Twins for Medical Application

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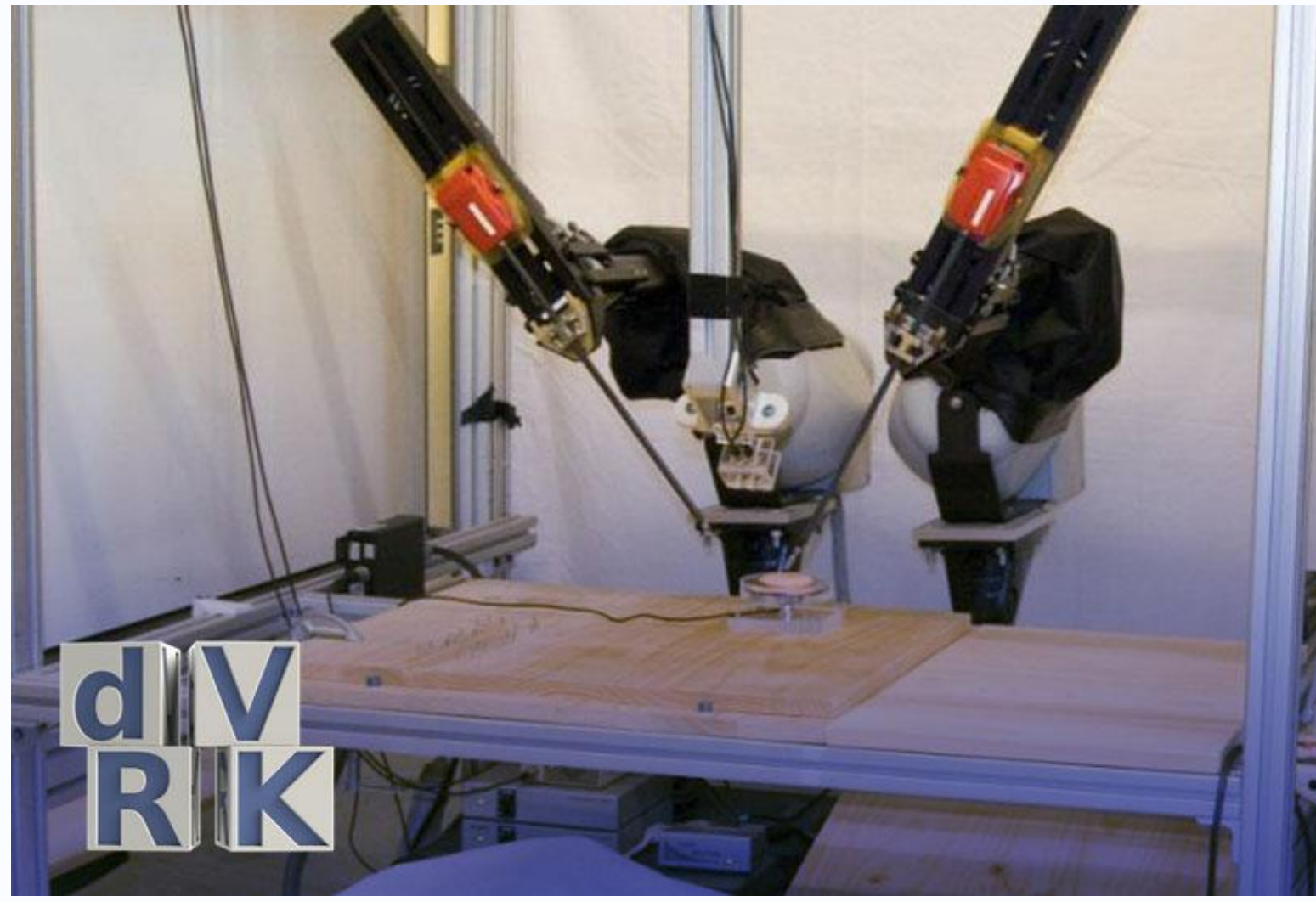
Introduction

- Robot assisted surgery is widely applied for benefits of minimally invasive usage[1]

the Da Vinci surgical robot[1]

- Before procedures, robotic modeling is used to scope out functions and positioning
- Most software used for robotics (ROS, Gazebo) lack ability to **model patient data alongside robot** for surgery simulation
- Medical visualization platform **3D Slicer[2]** has potential to model robots from commonly-used URDF (Unified Robot Description Format) files
- URDF files represent robots in:
  - **links** - parts of a robot
  - **meshes** - 3D models that represent the parts
  - **joints** - connect links, can move either rotationally or translationally
  - also contain limits on joint movement and info about positioning individual parts

Objective: Develop a 3D Slicer module with python to create "digital twin" representation of robots by importing kinematic models; test by comparison to accurate RViz representation, an
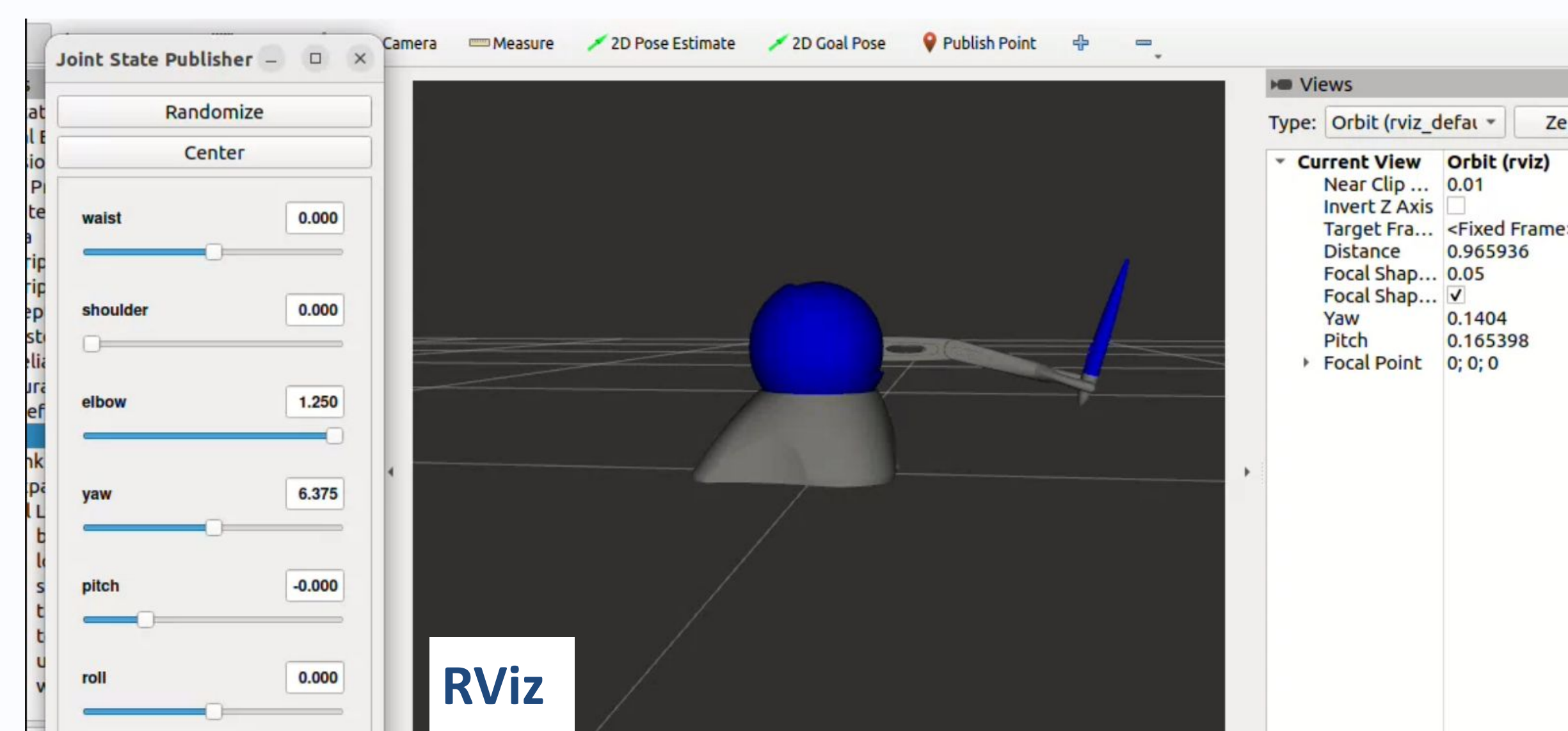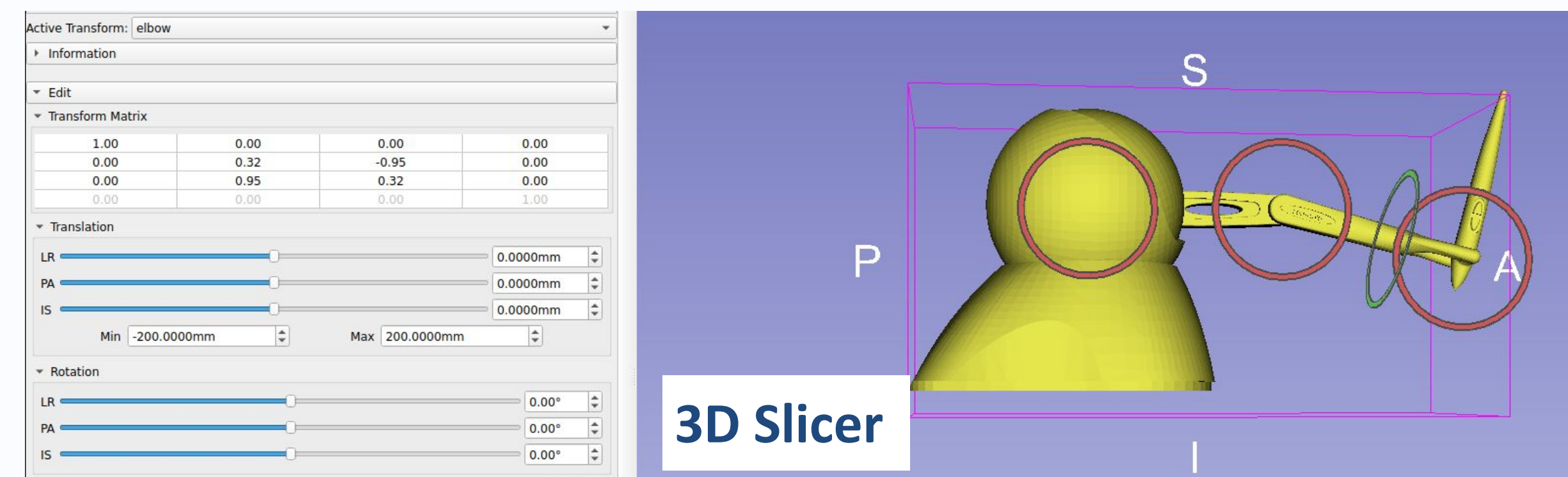
Results

Fig 2, 3: Comparison of 3D Slicer URDF importer and RViz Phantom Omni maximum angles. RViz is a widely-used robot visualization software that represents URDF files.
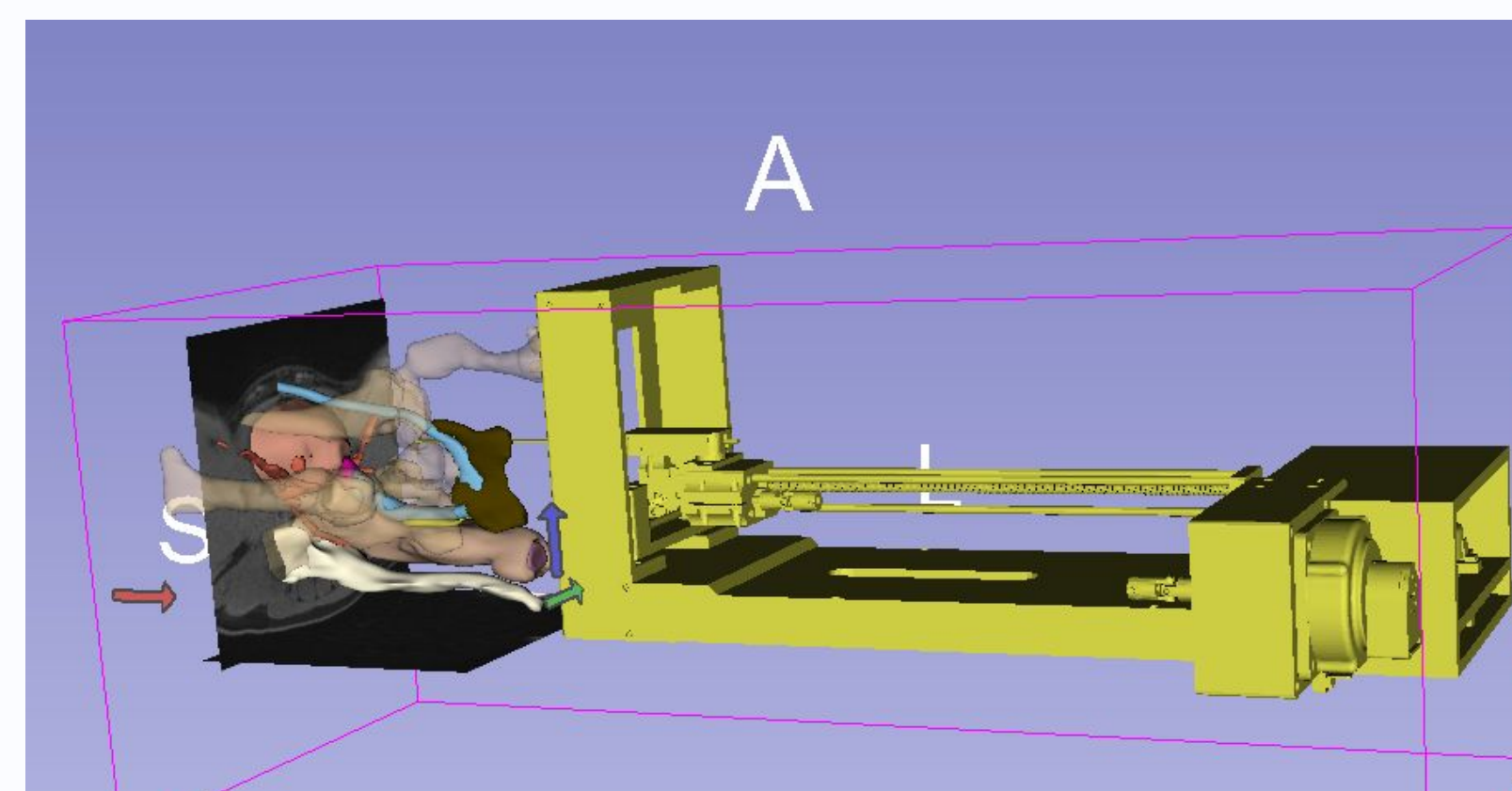

Fig 4: Smart template surgical robot with modeled MRI data for prostate surgery, showing use of the program for surgical preparation.
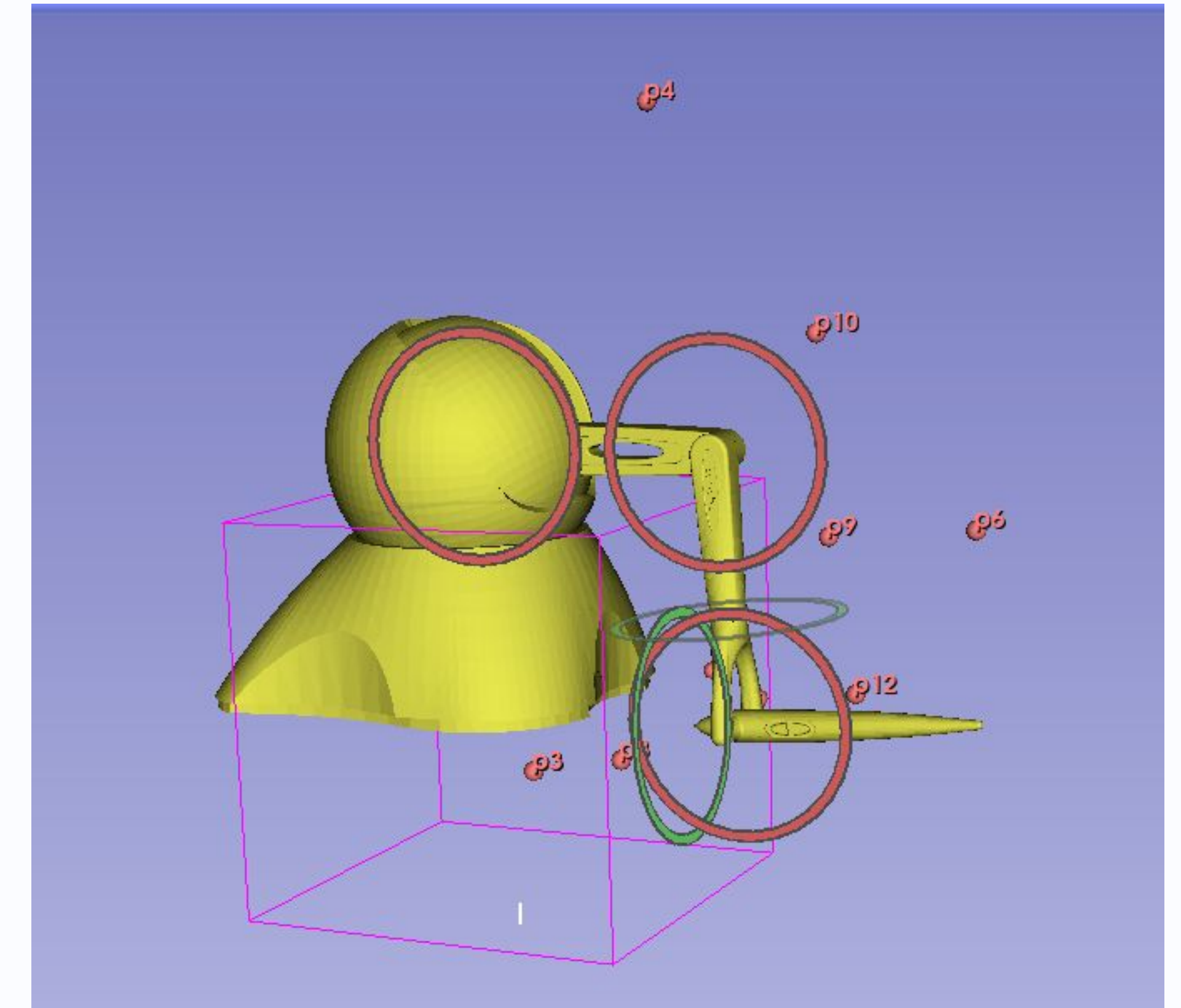

Fig 5: Rotation points tested for corresponding position values with RViz Phantom Omni model.

Error testing with position:

- Between RViz and 3D Slicer module modeling with the same angular positions, the average Euclidean distance between points was **0.05 ± 0.01 millimeters**
- Error likely due to rounding in transform process with 3D Slicer, since angles are rounded somewhat between transform matrix and transform angle representations

Discussion

- Based on comparison to RViz representation, the URDF importer appears to **successfully model robotic "digital twins"**
- Since the module can load this data alongside patient data, it has potential for **use in robot assisted surgery** preparation without patient involvement
- The software will be published on 3D Slicer for public use

Future directions:

- Addition of xacro to URDF converter for more potential formats to import, current model only works with pre-converted files
- Implement accuracy to automated joint movement

Methods

Robot models used:

- *Phantom Omni* – commonly used haptics robot, has rotational joints with motion limit
- *Smart Template* – surgical robot used for prostate cancer operations, has translational joints
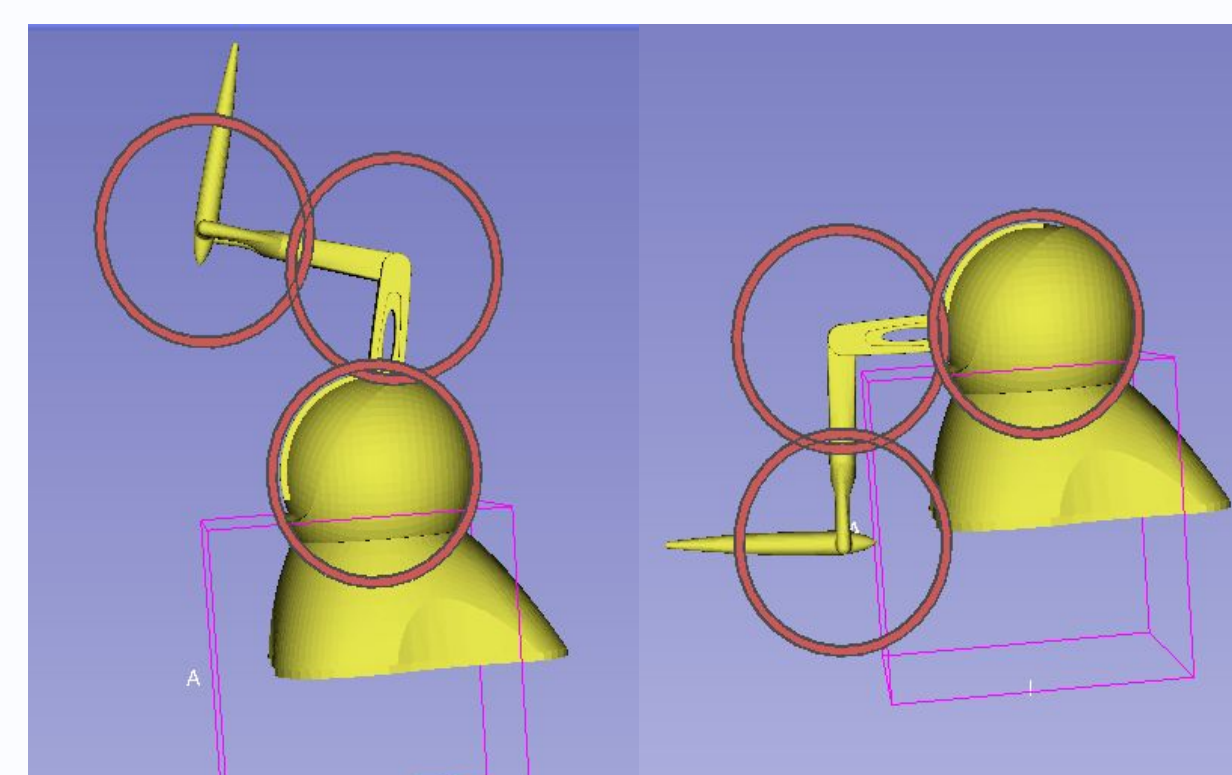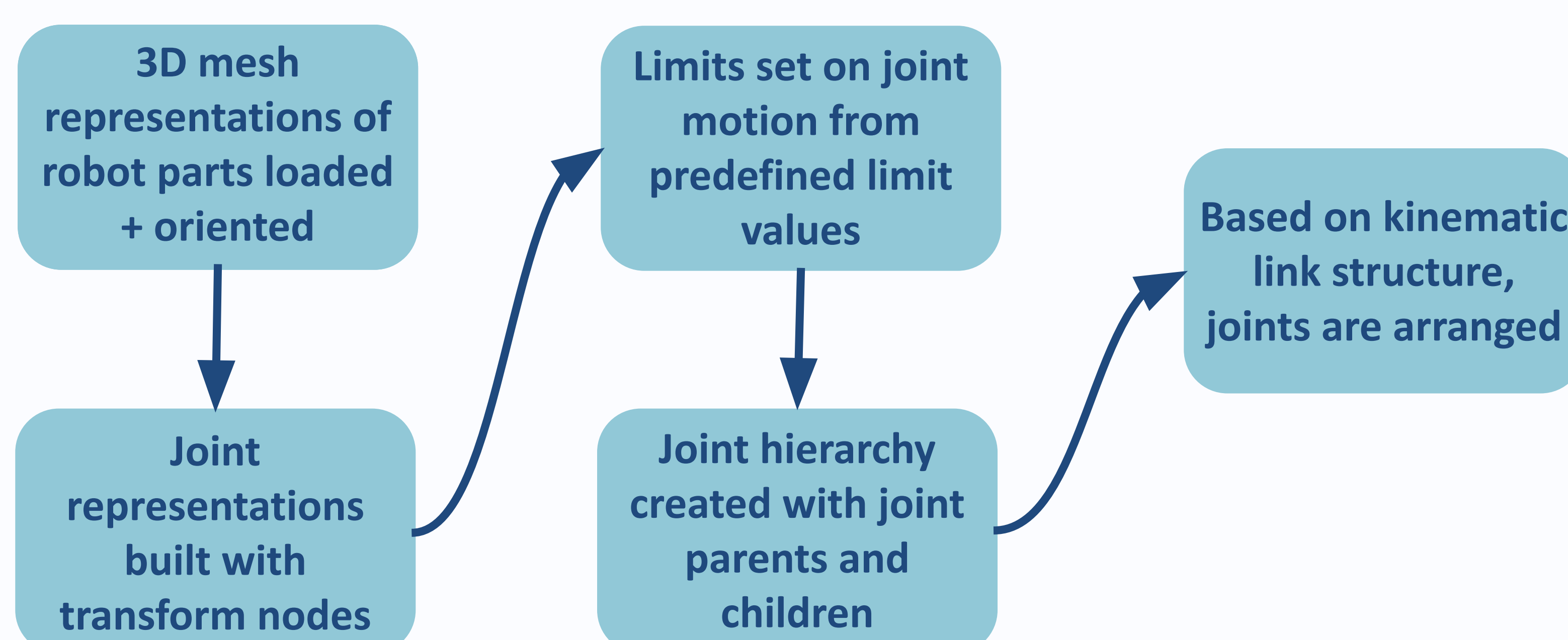
Both represented in URDF form

Fig 1: Visualization of joints and range of movement for Phantom Omni robot

Testing/Validation:

- Results visually compared to RViz (commonly used robot visualization software) representation
- End effector joint positions compared between models, analyzed with Euclidean distance

3D mesh representations of robot parts loaded + oriented → **Joint representations built with transform nodes** → **Limits set on joint motion from predefined limit values** → **Joint hierarchy created with joint parents and children** → **Based on kinematic link structure, joints are arranged**

References

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