Updating CAD Model through 3D Scanned Point Cloud for Automated Dismantling

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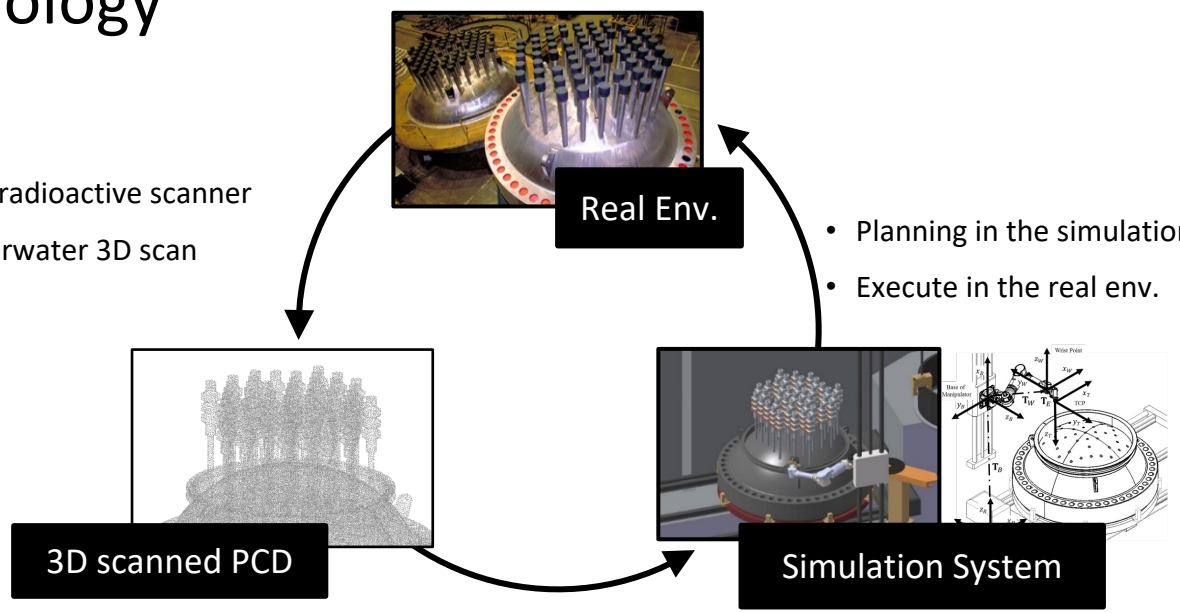
Project Introduction

- Development of the remote and automated cutting tech.
  - Laser cutting with a robot manipulator in an underwater env.
    - Our laser cutter's stand off distance is 10 mm
    - To cut structures with complex geometry

      → **Workpiece localization** is required

- Methodology



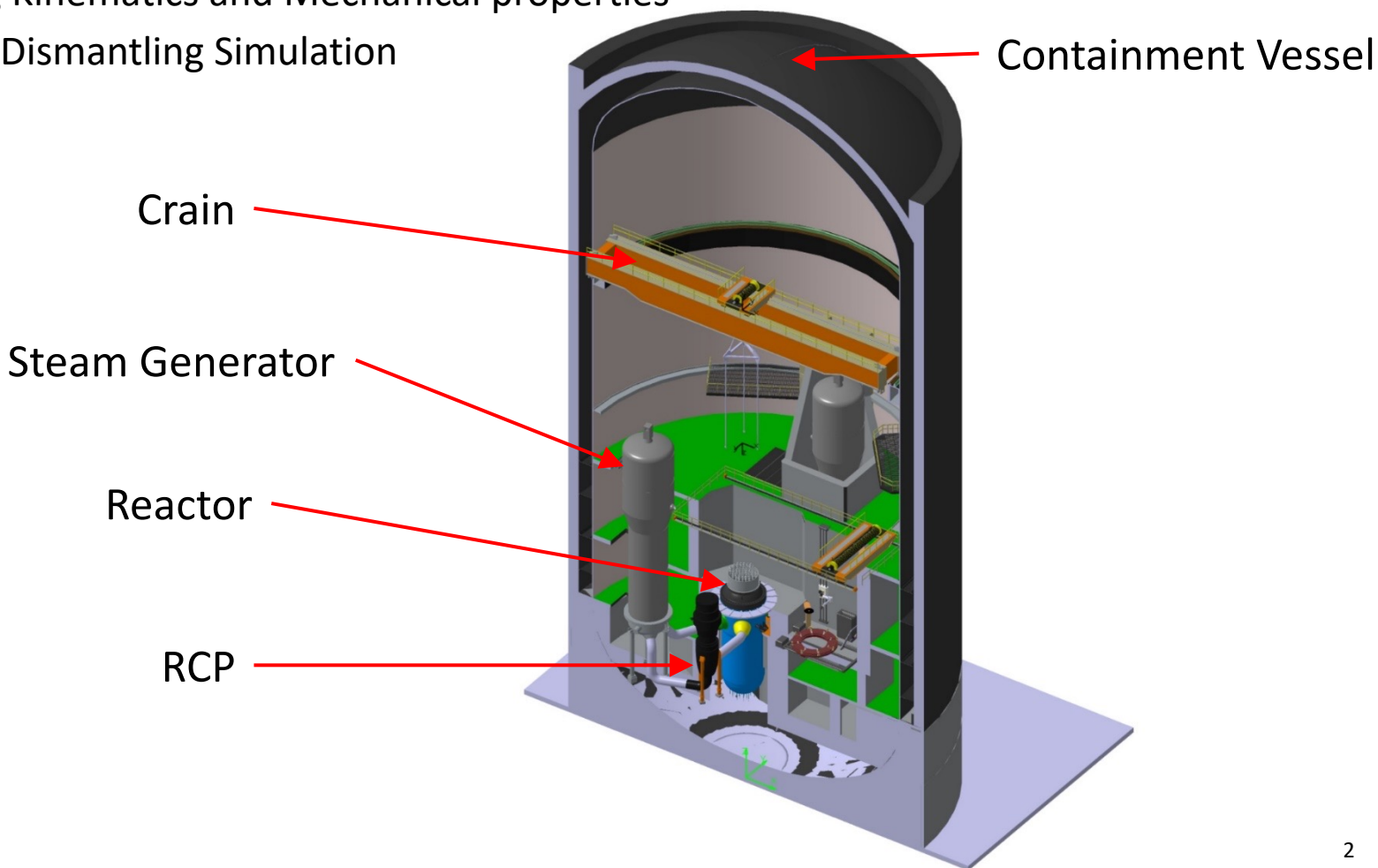
- High radioactive scanner
- Underwater 3D scan

- Planning in the simulation system.
- Execute in the real env.

- Fast and automatic digital mockup and scenario update

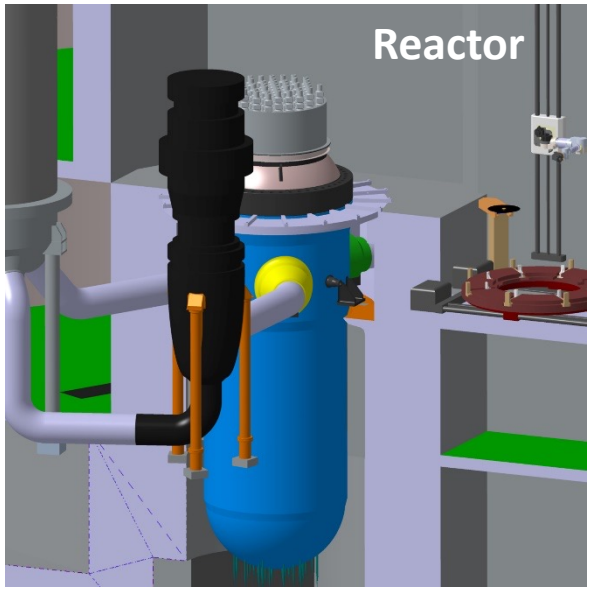
Digital mockup of GORI 1

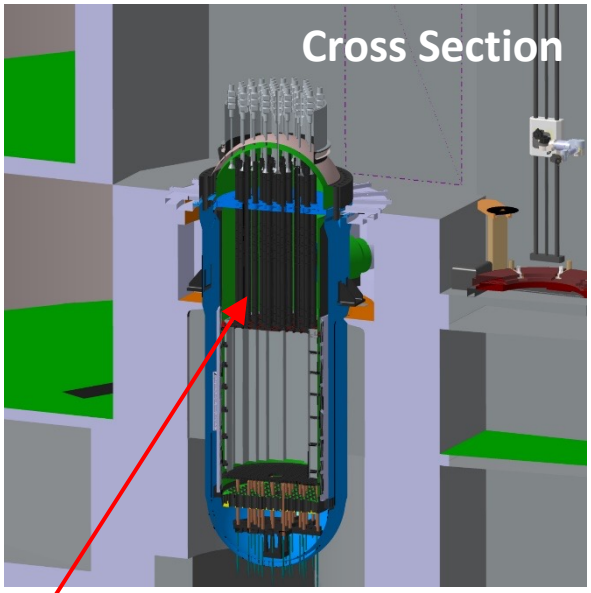
- Model of the target facility
  - GORI 1 NPP of KHNP, Korea
  - 3D CAD Modeling based on 2D Drawings (Dassault CATIA V5)
  - Including Kinematics and Mechanical properties
  - Used for Dismantling Simulation

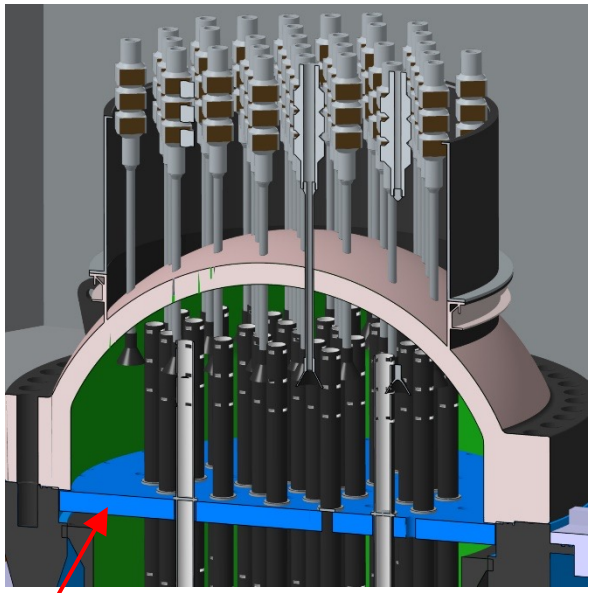


Target Products

- Target model: Upper support plate of Reactor Internal





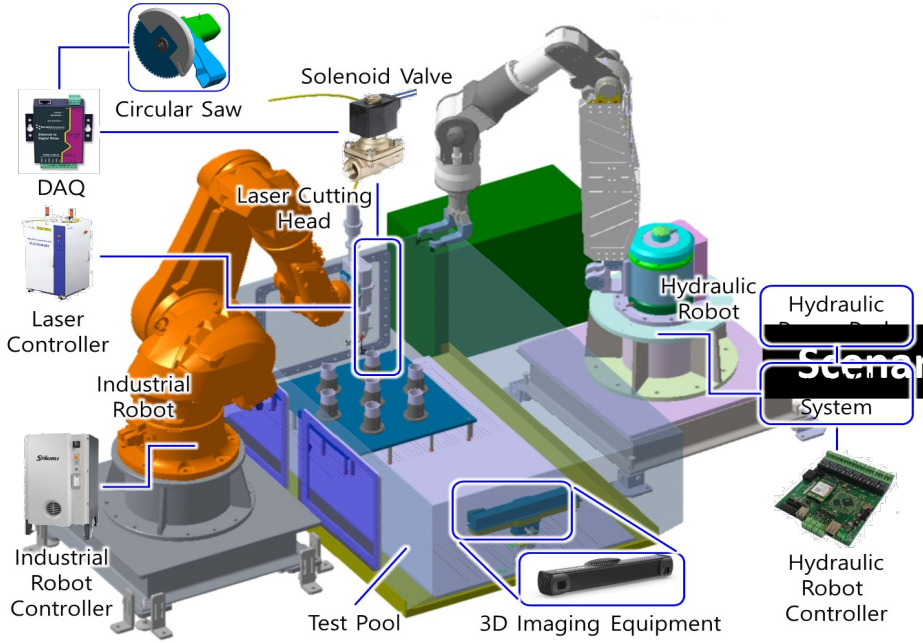


Reactor Internal Structure
→ High radio activity
→ Complex Geometry

Upper Support Plate

Testbed Preparation

- Planning in the Digital mockup
- CAD model update and path update
- Execute in the Testbed

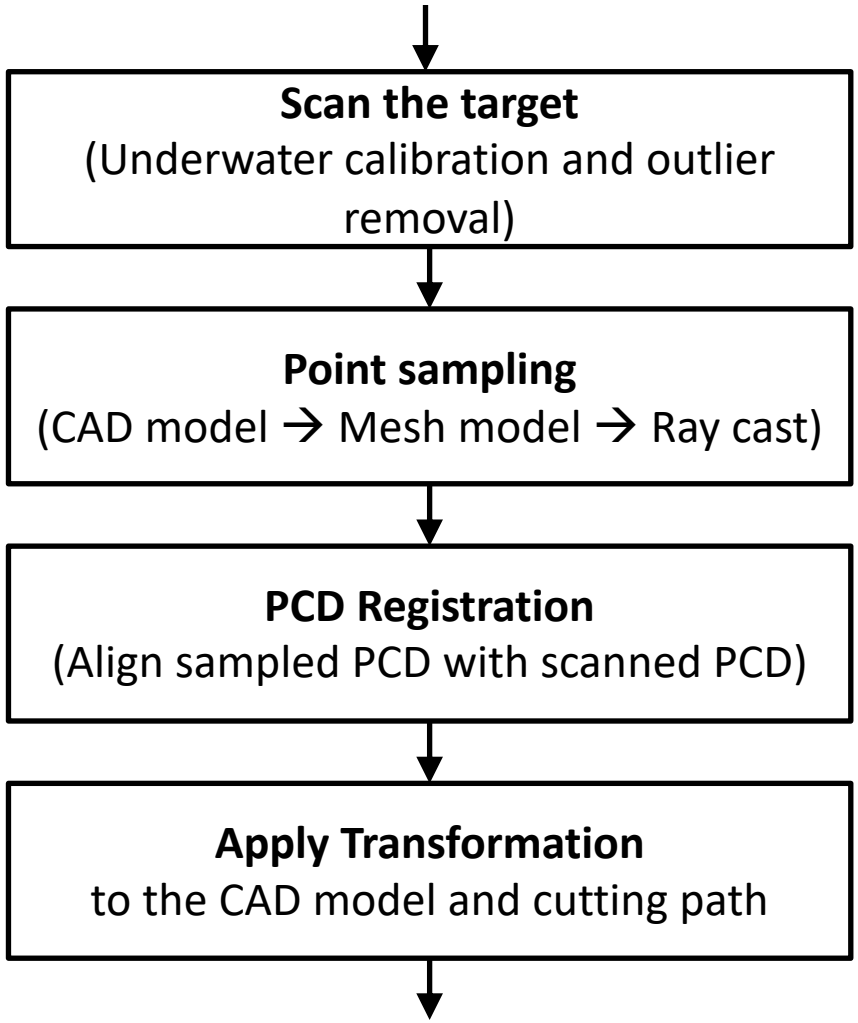


Digital mockup

Testbed

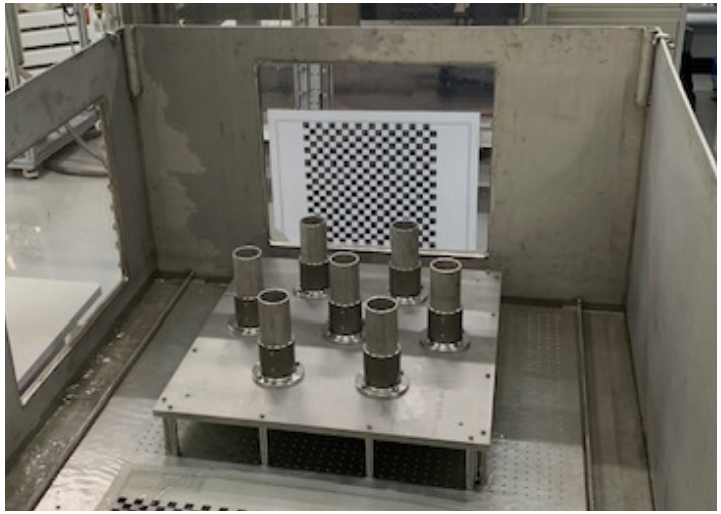
CAD Model Update

- Overall procedure

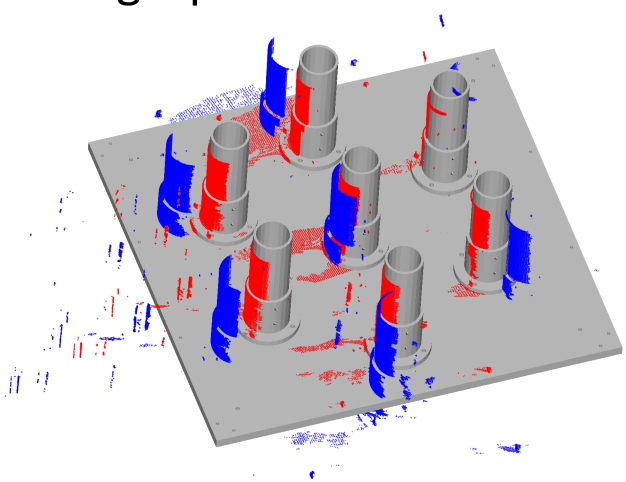


3D Laser Scanning

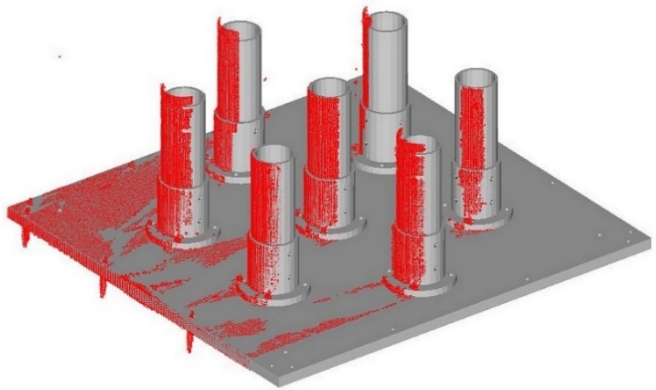
- Laser scanner
  - Phoxi 3D Cam L
  - We build Underwater, anti-radiation case



- Underwater calibration
  - Using Optics and AI



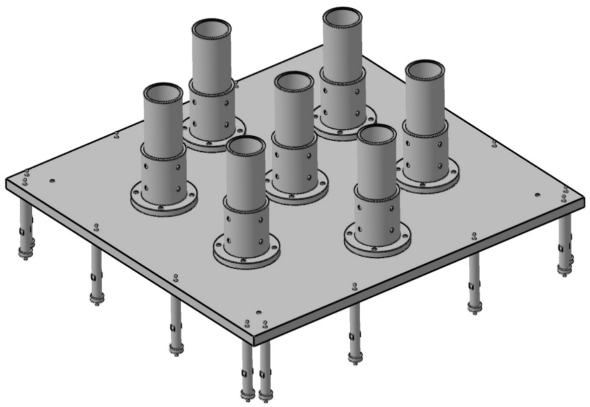
Blue: raw PCD, Red: calibrated PCD



Result Point Cloud

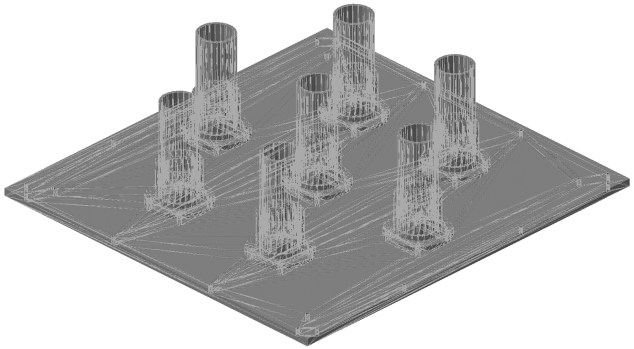
Point Sampling

- Convert CAD model to Mesh model



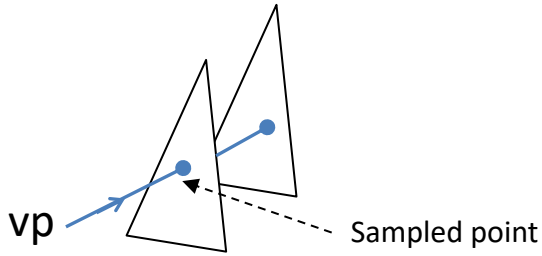
B-rep solid model

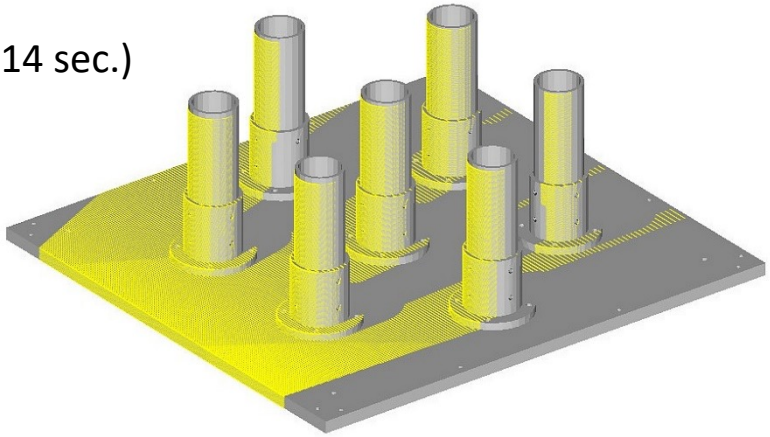
Tesselate



Mesh model (10,168 facets)

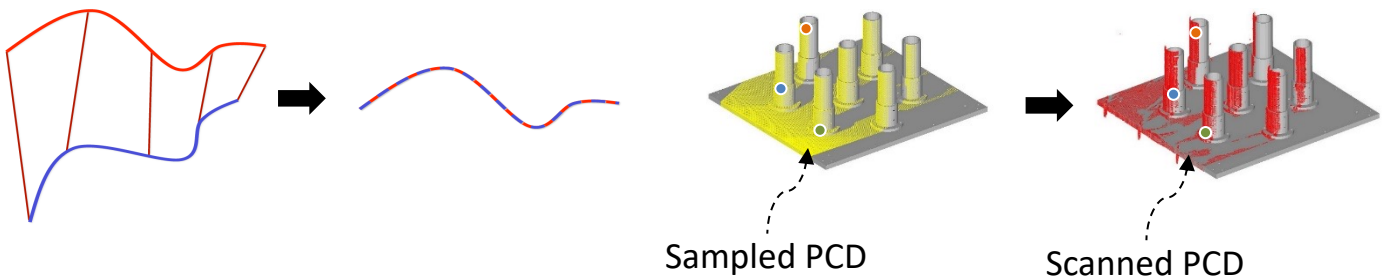
- Ray cast to the mesh
  - Delete hidden facets for speed up
  - Calc. Intersection point between facet and ray.
    - 250 X 250 Ray cast → generates 42,313 points (6.14 sec.)





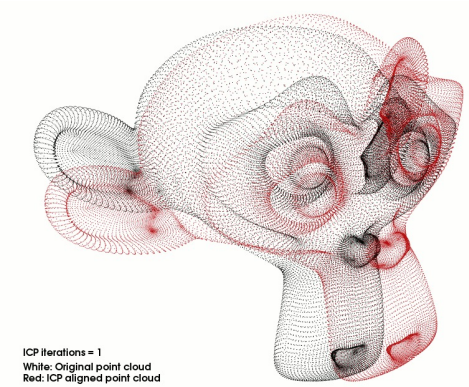
PCD Registration

- Iterative Closest Point (ICP)
  - If we know the corresponding points, it's possible to calculate the transformation



  - ICP Algorithm

① Random points selection (e.g., 1000) ($\boldsymbol{p}_i$)
② Select closet points from $\boldsymbol{p}_i$ in the other point cloud ($\boldsymbol{q}_i$)
→ Sensitive to initial position
③ Delete Long-distance pair
→ Two PCDs have to be close enough
④ Calculate transformation by SVD (Rotation (R), Translation(t))
⑤ Error function $E := \sum_i (R\boldsymbol{p}_i + t - \boldsymbol{q}_i)^2$ minimize the E

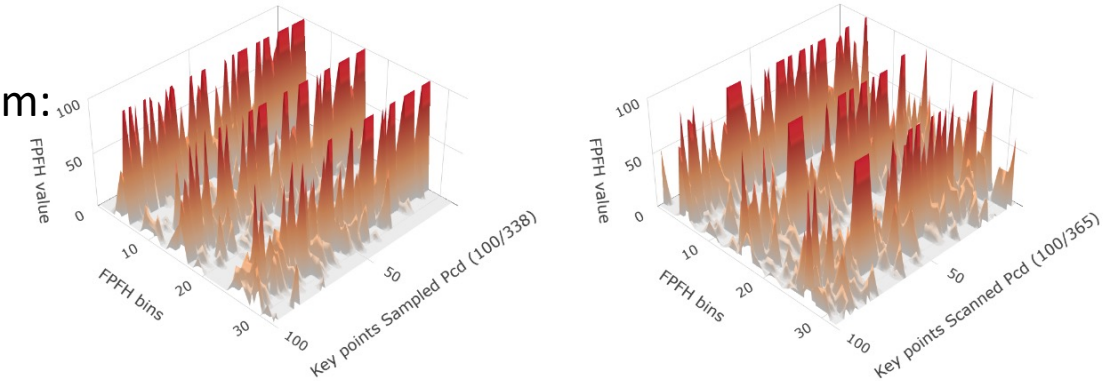


Initial Registration

- Calculate Geometrical feature as histogram
- Matches two histograms to align
  - Use as ICP initial position
- Fast Point Feature Histogram (FPFH)*
  - Key point sampling (Uniform sample)
  - Calc feature histogram on each key point
    - Baesd on the geometry info (normal vector) Each key point and its neighbor keypoints

Sampled Key points:

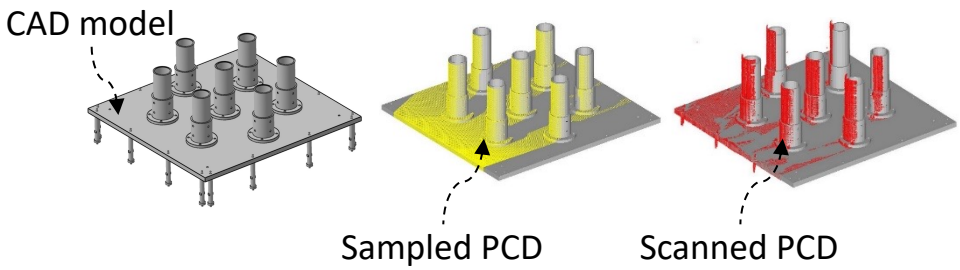
Feature Histogram:



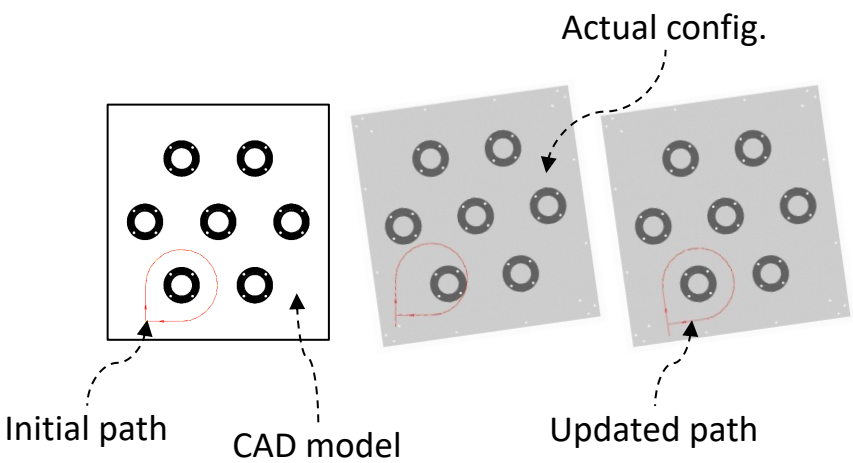
*R. B. Rusu et al., Fast point feature histograms (FPFH) for 3D registration, Robotics and Automation, 2009. ICRA'09. IEEE

Update Model and Path

- Cutting Path Update
  - Register Sampled PCD (Ray casting) to Scanned PCD



  - Apply transformation, calculated by the registration



Test Environment and Result

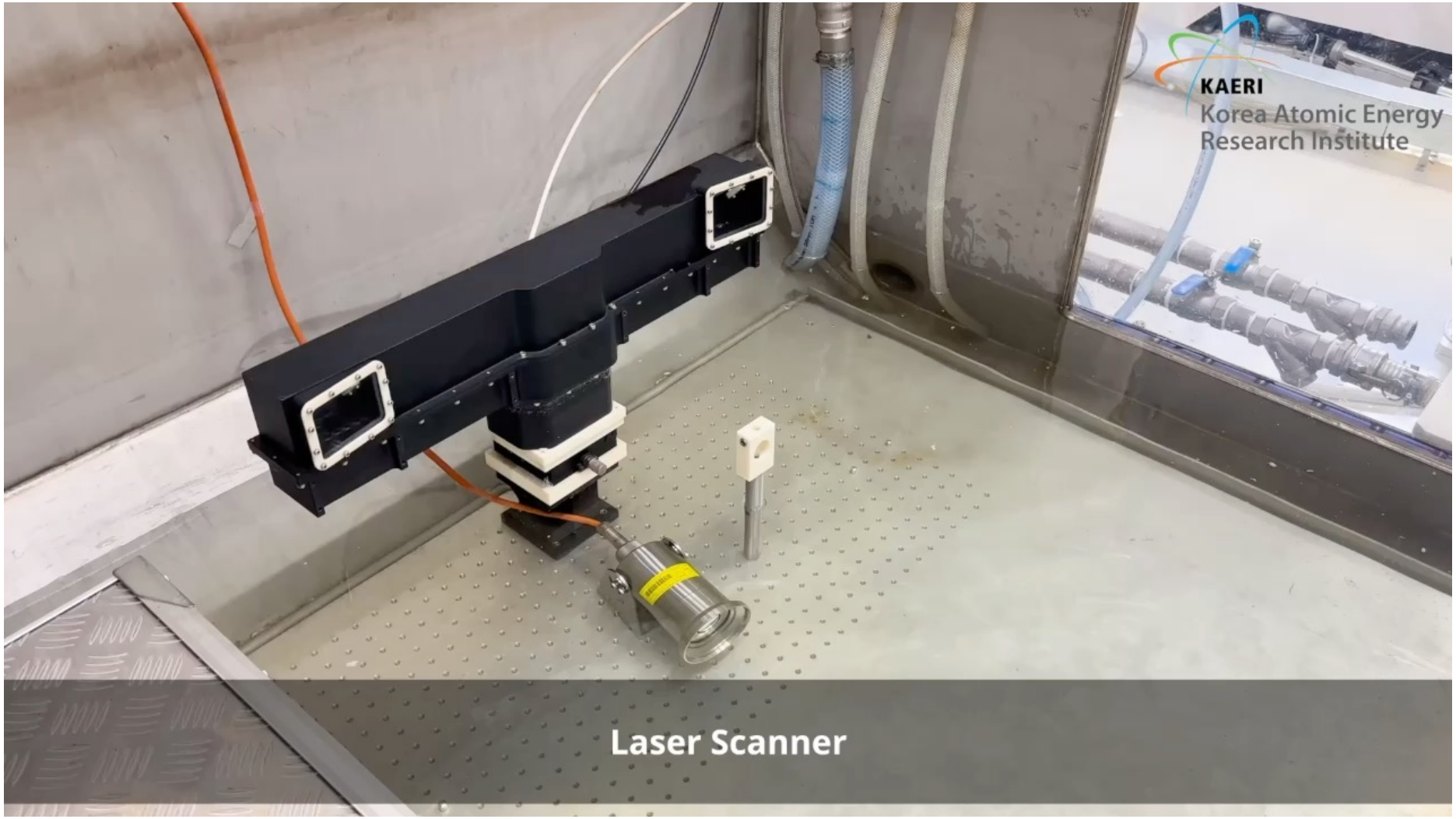
- Implementation Environment
  - Language: C++
  - Point Cloud Handling: PCL 1.8.1
  - Mesh and Point Sampling: VCGLib
  - CAD system: Dassault CATIA V5

- Target model setup
  - Same shape with the digital mockup
  - Rotational error < 10 degree
  - Translational error <50 mm

- Registration method
  - Initial align by FPFH
  - Fine registration by ICP

- 104 cutting test succeeded

Demo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Laser Scanner

Conclusion

- Project result
  - Development digital mockup update methodology
    - Ray cast point sampling
    - PCD alignment using FPFH and ICP
    - Update CAD model position and Cutting Path
  - Fast automatic update of position of the digital mockup
- Future works
  - Plan to study on the different shape, not exist or redundant cases
    - Shape update, shape generation

Thank you.

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