Tampereen yliopisto
Tampereen ammattikorkeakoulu

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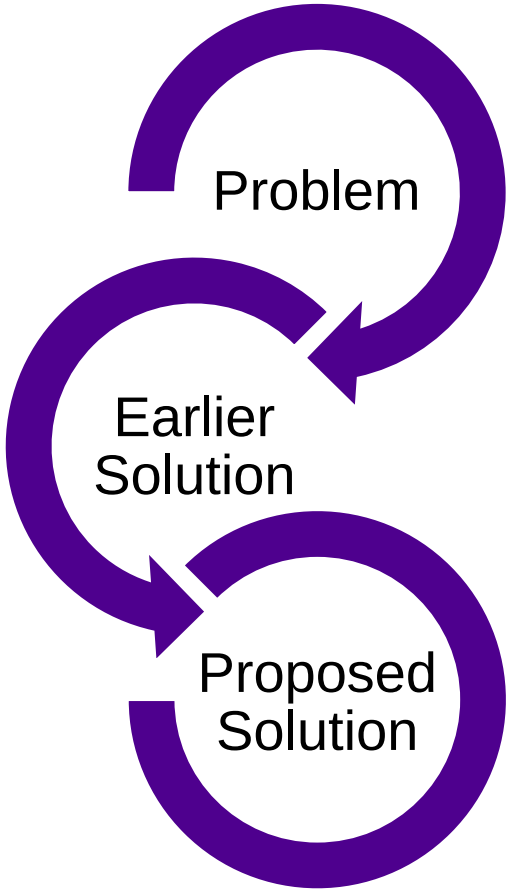
Target Tracking Using Optical Markers for Remote Handling in ITER

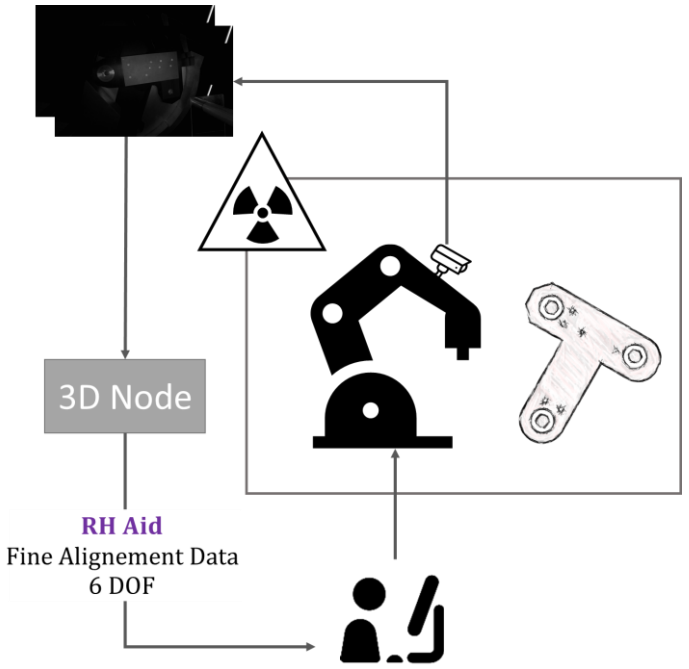
Outline



- **ITER grade optical markers**
- **Marker identification** and **pose estimation**

The Problem

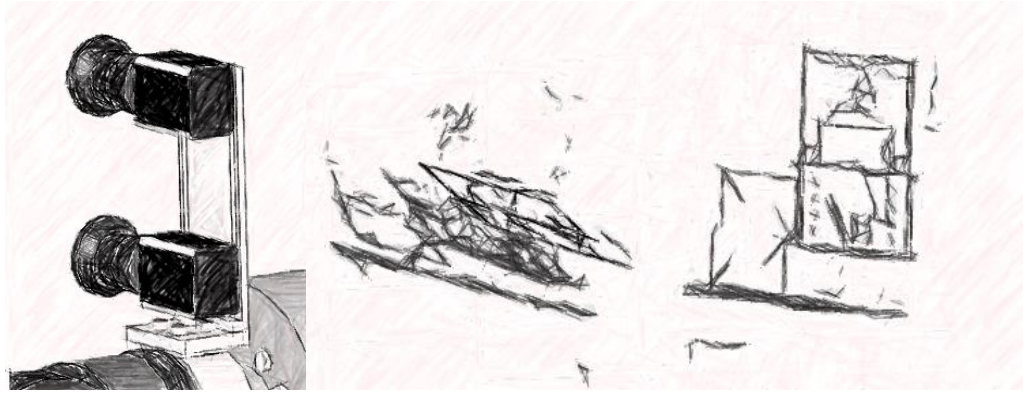
- **Cassette assemblies** need be replaced by RH
- Operation requires **mm level precision**
- Need **reliable mm level accurate computational methods** for pose estimation



Expected Input (Radiation tolerant cameras): **greyscale, VGA resolution, low signal to noise ratio**

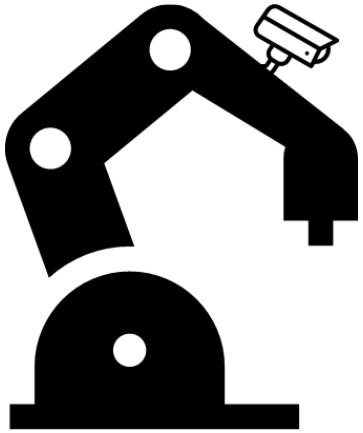
Solution: Optical Markers

Early Version of 3D Node:
Matching sparse point cloud to 3D Model

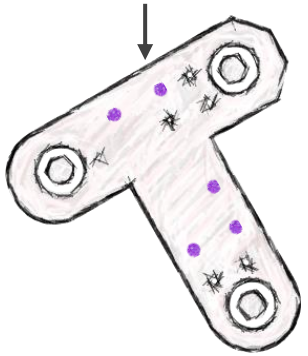


Challenging visual conditions
Not robust enough!

Takes full advantage of problem's contraints

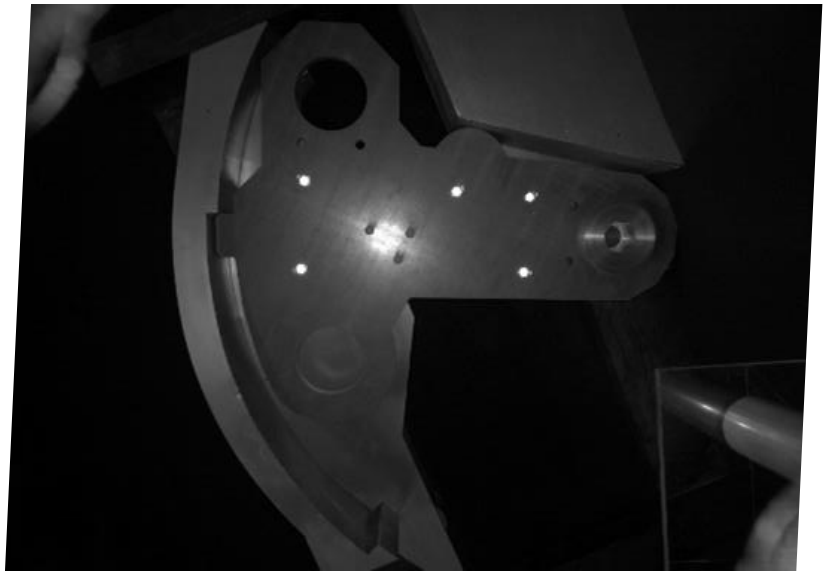


Optical Markers



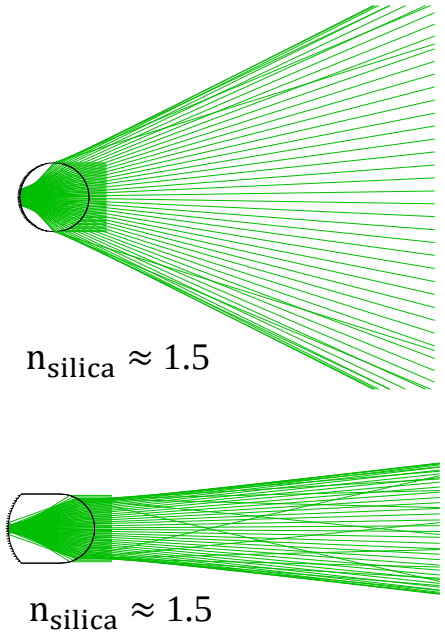
Why retro-reflective markers?

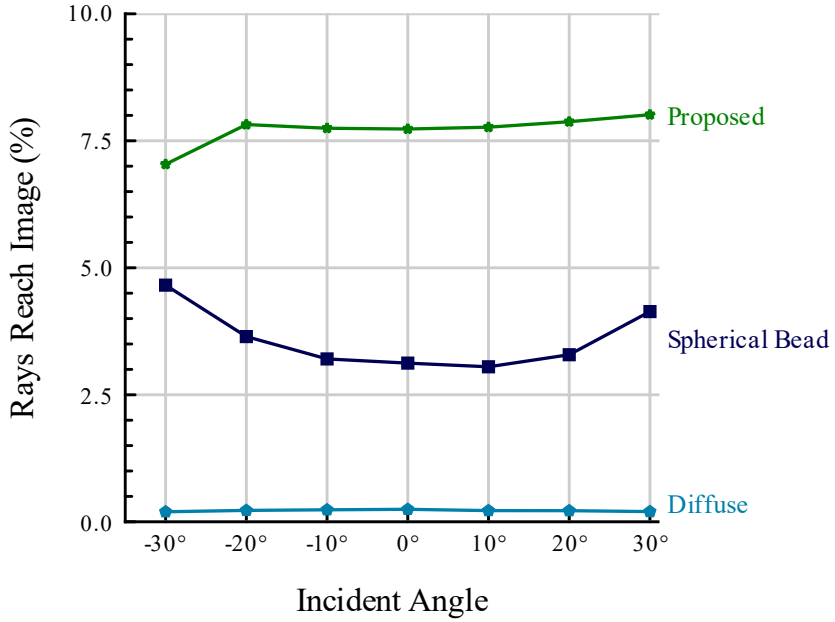
Also known in FI as
”heijastin”
Used for traffic safety



Easy to discriminate by underexposing other structures

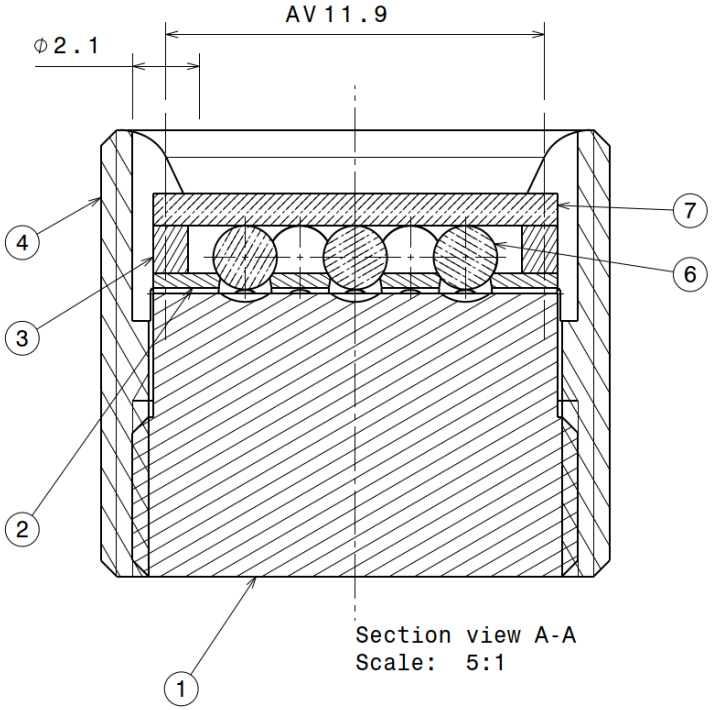
Divertor grade optimized retro reflector



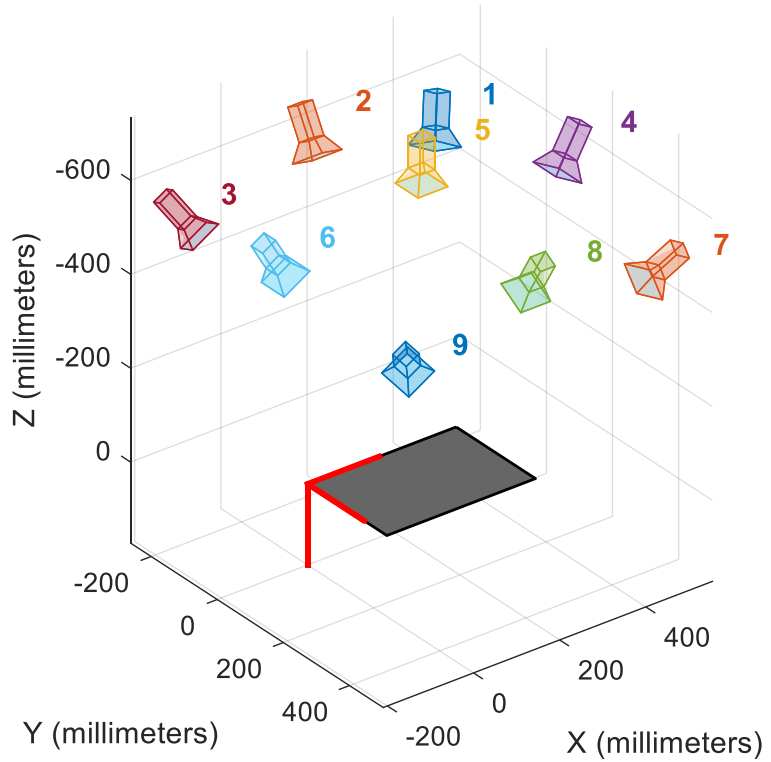


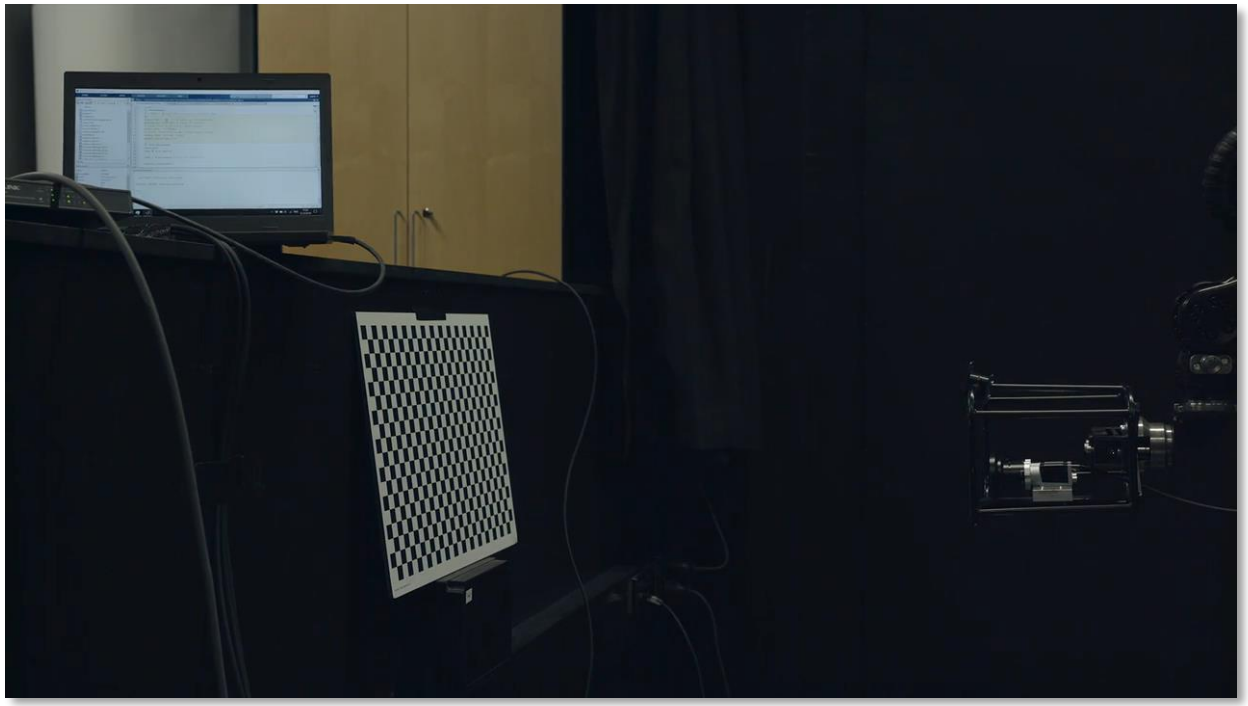
~ 100% gain in performance over previous design

Materials: fused silica and stainless steel



Automatic in Hot Cell Calibration Procedures

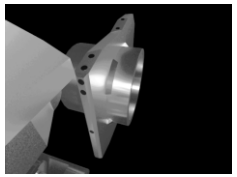




Calibration images for camera calibration, hand-eye calibration, etc.

Robust, Explainable Marker Identification

Classical

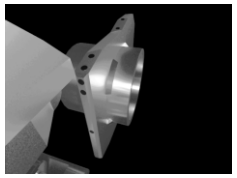


Lots of Heuristics

$$I_{i,j} = I + C \quad maxT = 10$$
$$\text{threshold} \geq 2$$
$$T < 5 \quad if\ N \geq 7$$

Coordinates
Correspondence
model

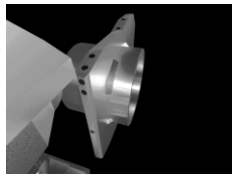
Complex, hard to explain models



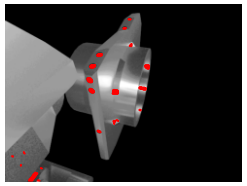
Black Box

Coordinates
Correspondence
model

99% **100%** **95%**



Input Image

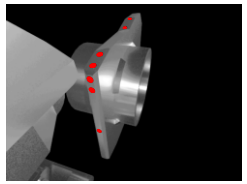


MSER Candidates

Area
Eccentricity
Perimeter
…

Numeric
Features

Random
Forest



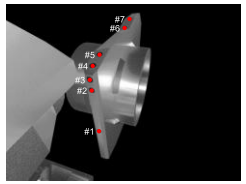
Filtered Candidates

Centroid
distances

Numeric
Features

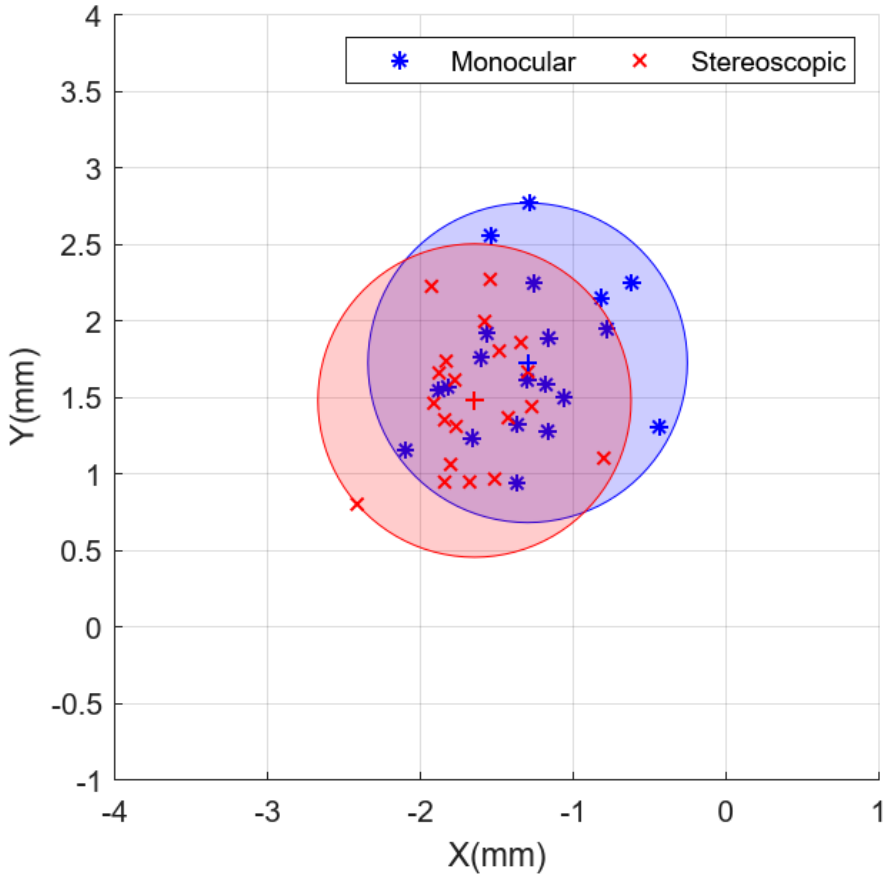
Feedforward
Neural Network

Correspondence
Model



Hybrid pipeline with higher degree of explainability / interpretability

Results and Proof of Concept Demonstration



Reliable millimeter level end to end accuracy

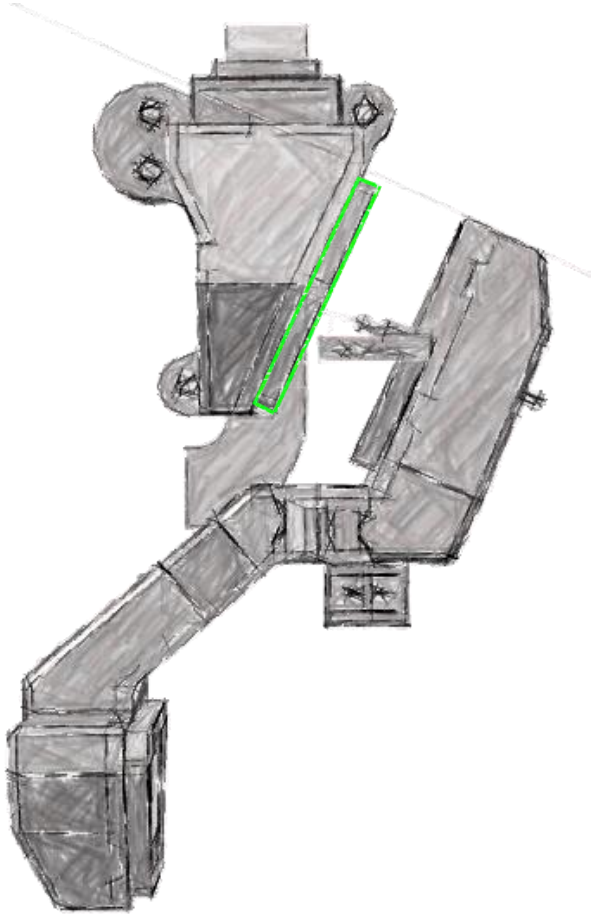
Other divertor RH usecases

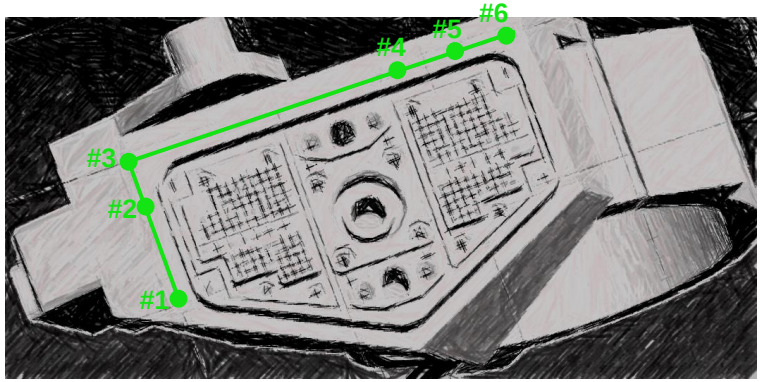
Pipe maintenance tool clamping to **Pipe Flange**

Engagement of **Bridging Link** to in-vessel connector

Commonalities:

- Tight tolerances
- Narrow working environments
- Challenging visual conditions





Takeaways

- Our Work / Core Expertise:
  - Modelling and optimization of retroreflectors
  - Computational methods for robust detection of markers in camera images
  - End to end evaluation of pose estimation accuracy

- More generally, how take full advantage of engineered environments and solve pose estimation in an **explainable** way

Contact me for more details.

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