AR/MR based pipe inspection

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Risks in oil and gas industries

Previously

- Cracks, corrosion, misalignments, and dents can affect structural integrity of pipes
- Maintaining Pipelines is significant
- Pipeline failures can lead to serious complications and even fatalities

Cracks

Corrosion

Welding defects

Related Work

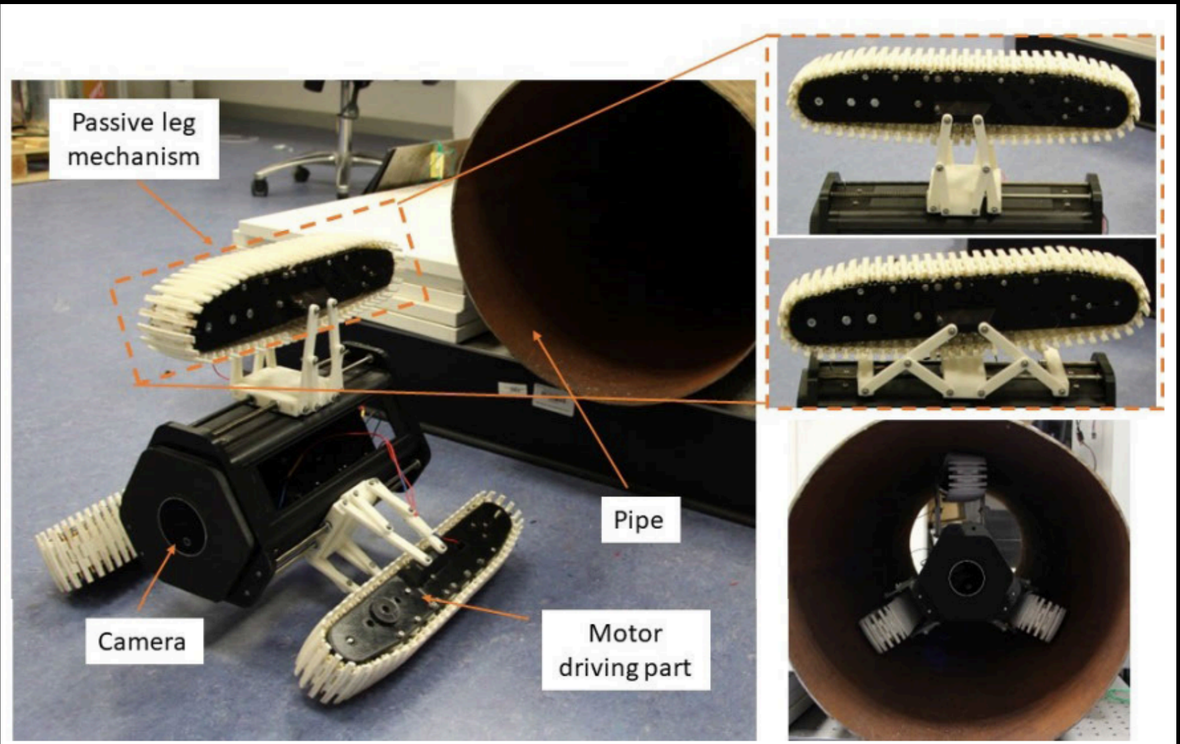
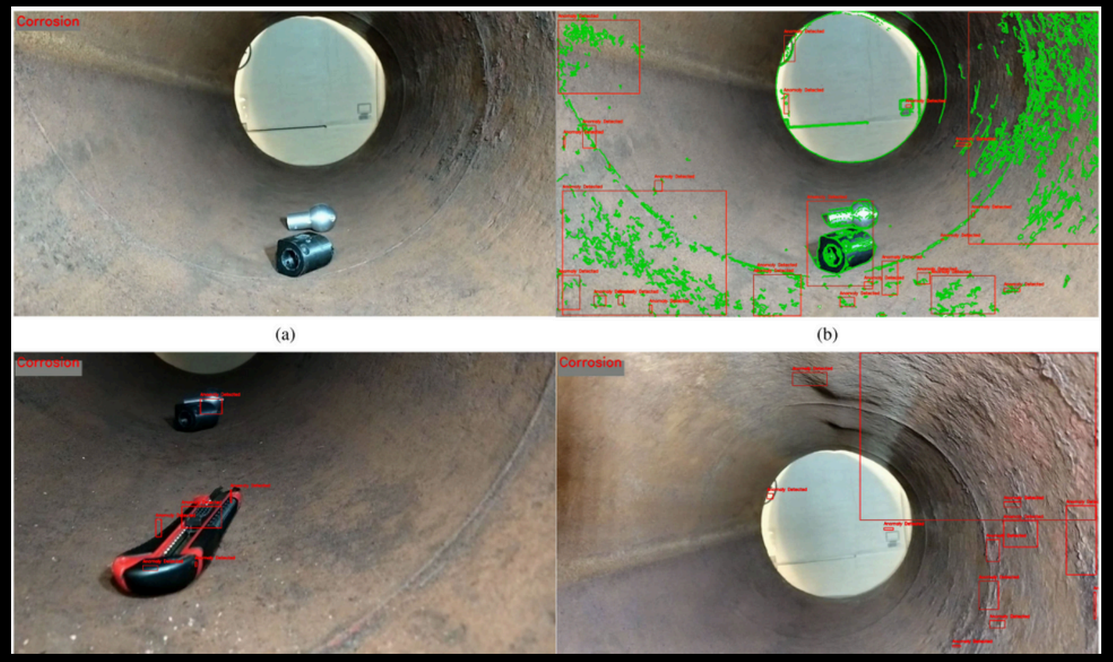
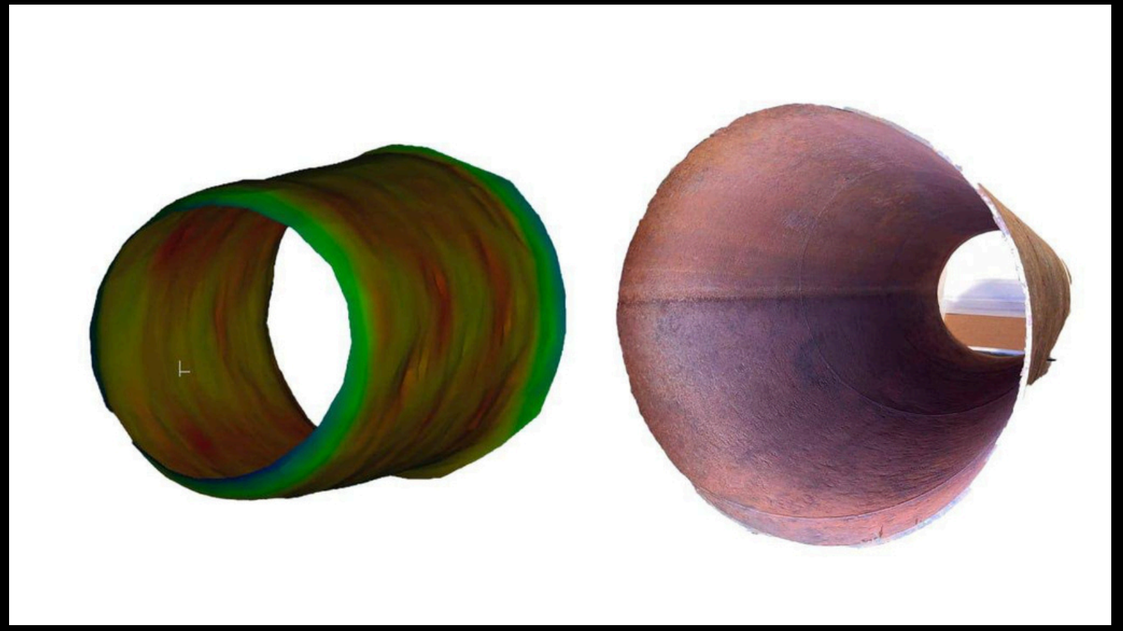


FIGURE 7. Experimental robot prototype SIPIR.





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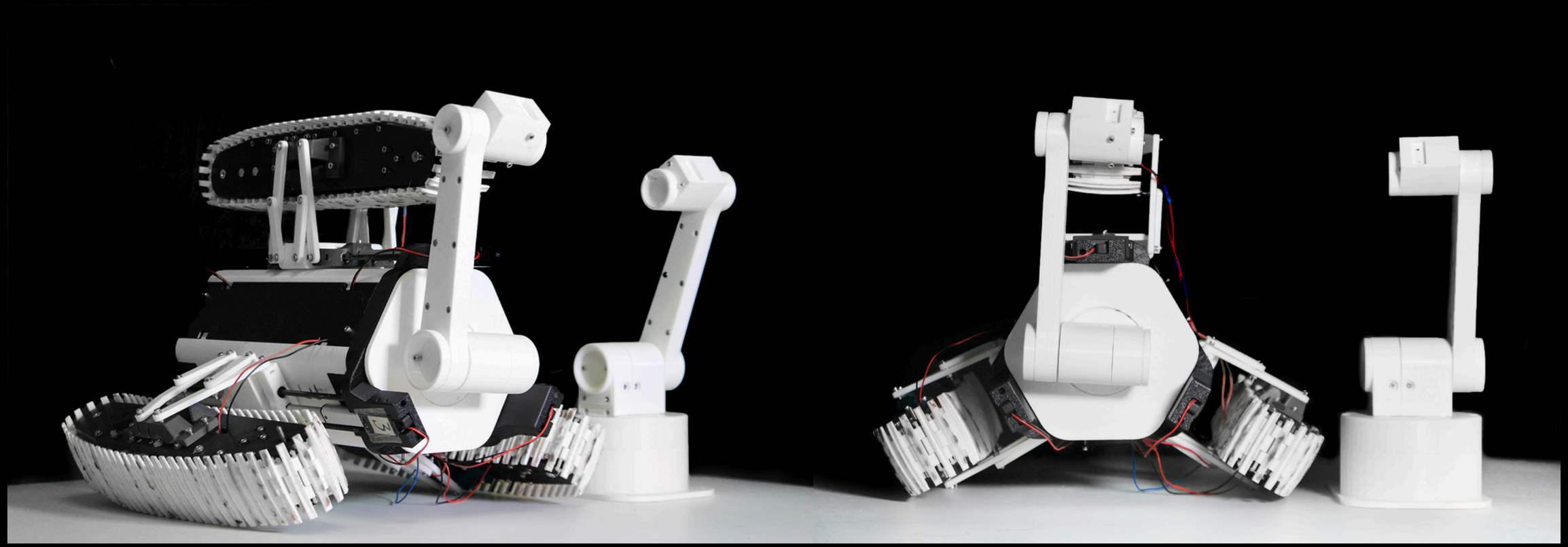

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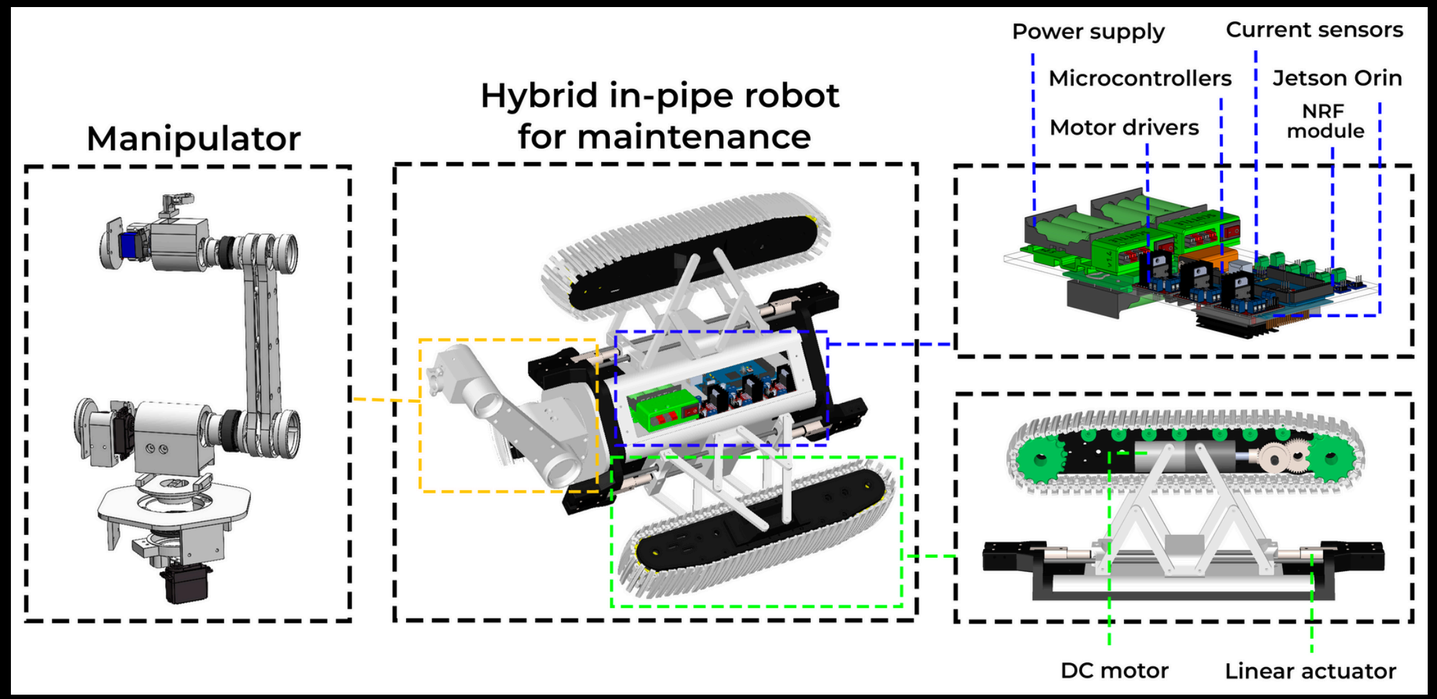

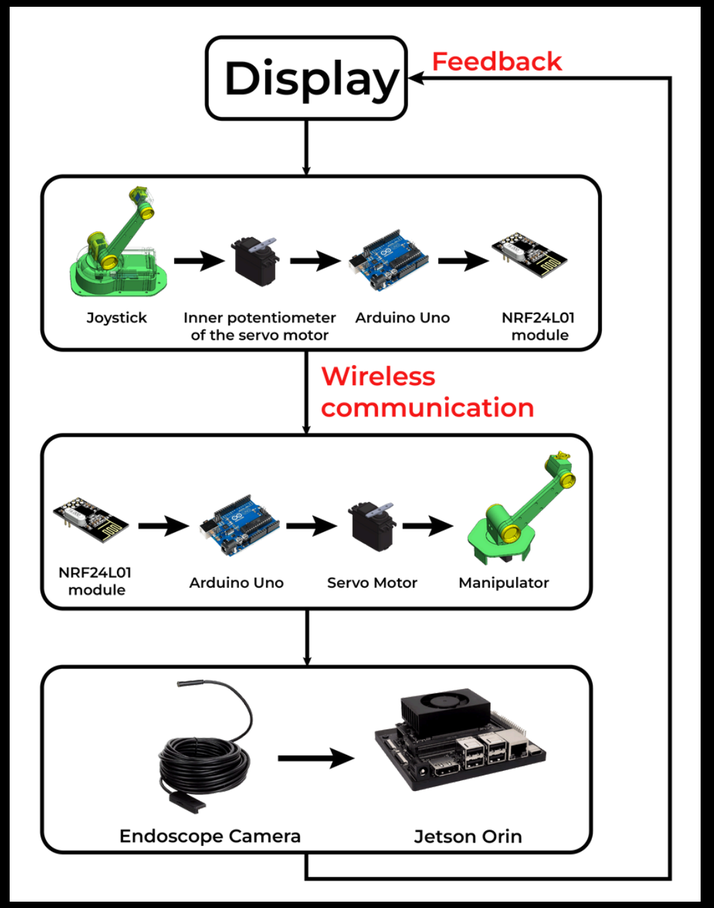

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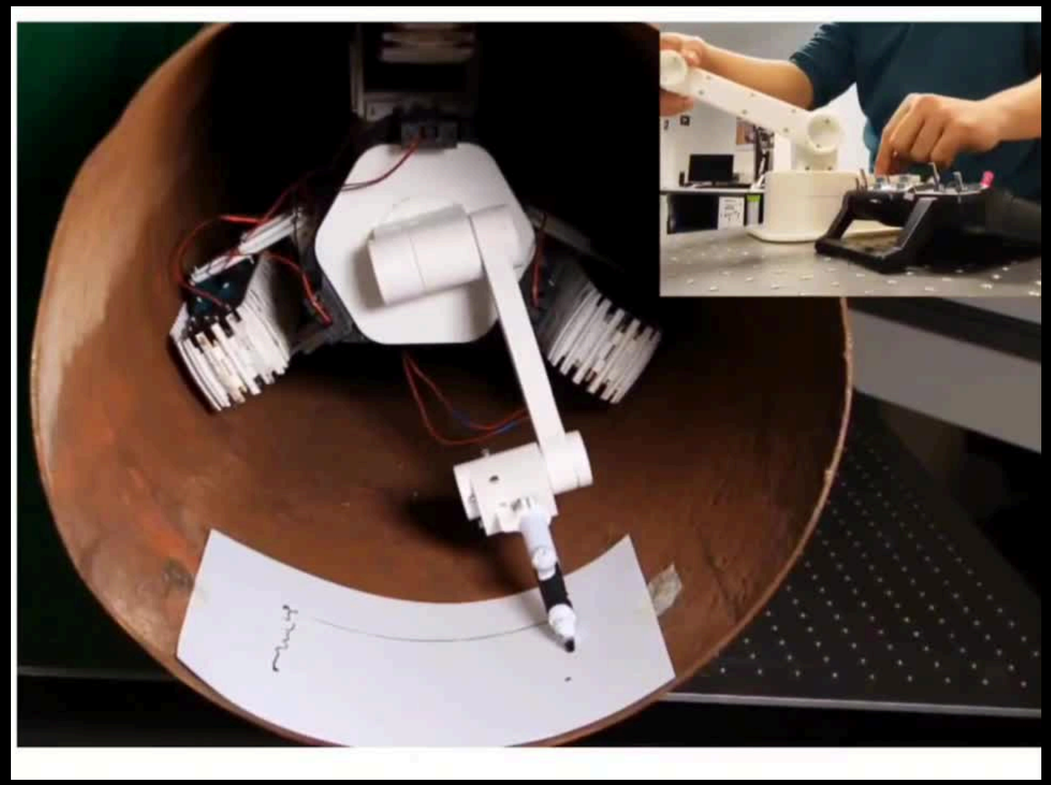

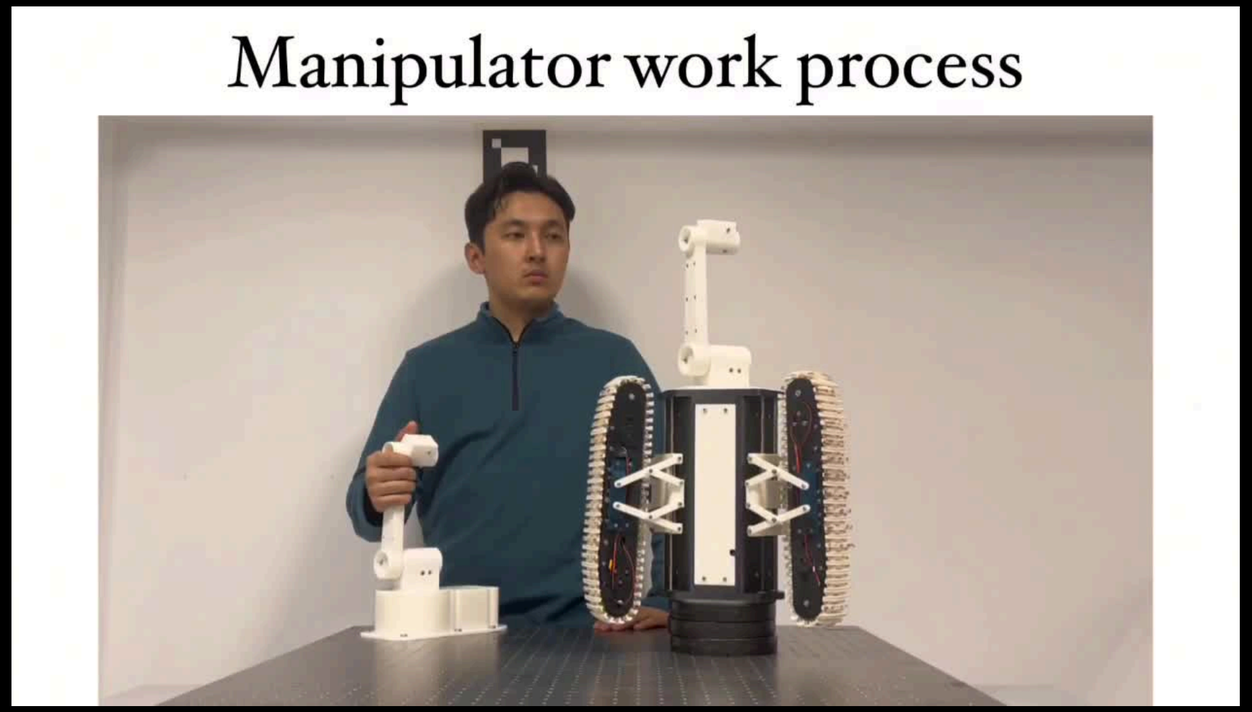

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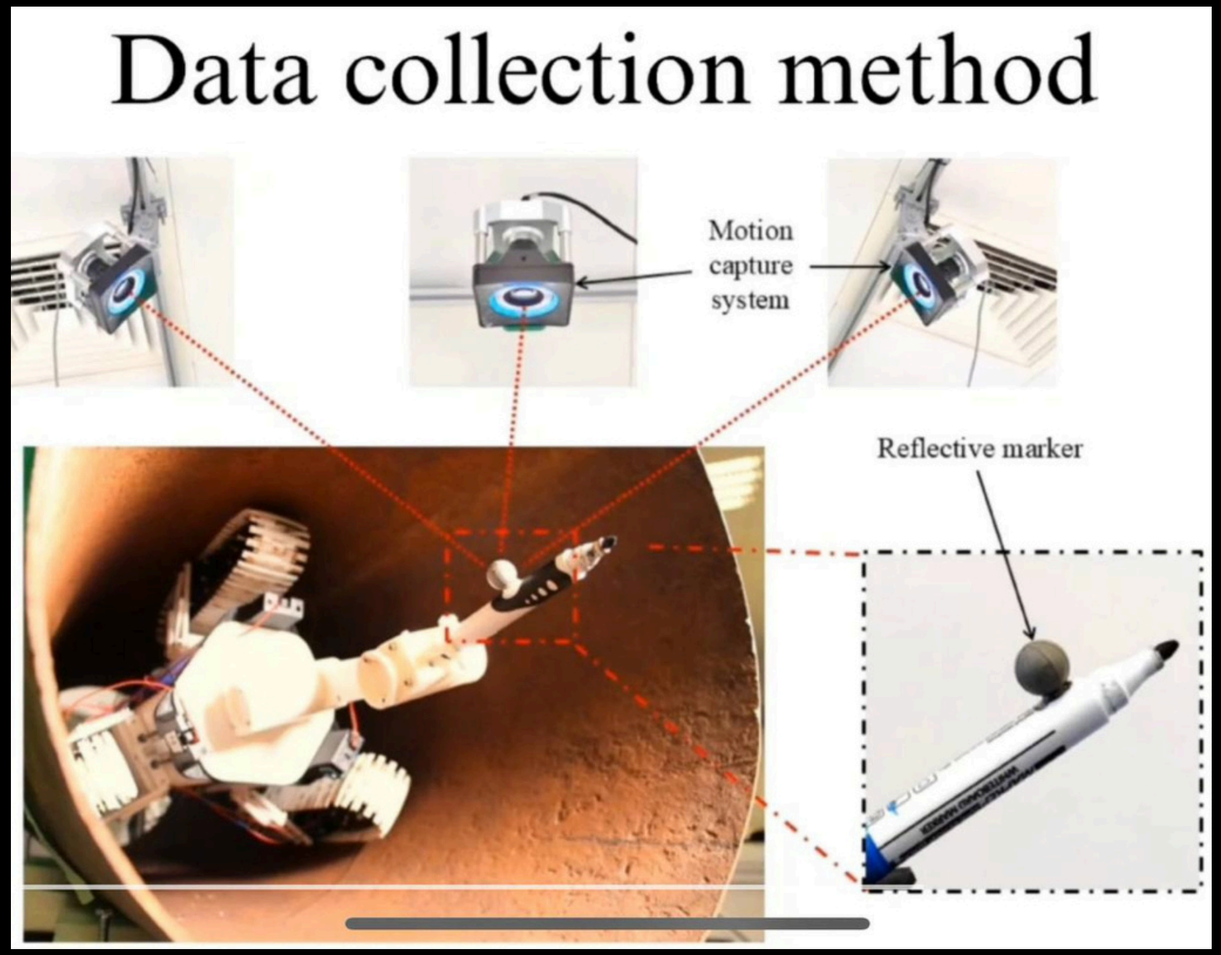
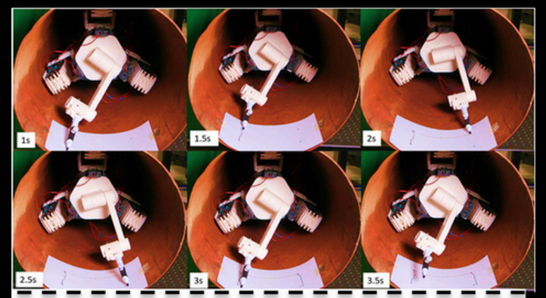
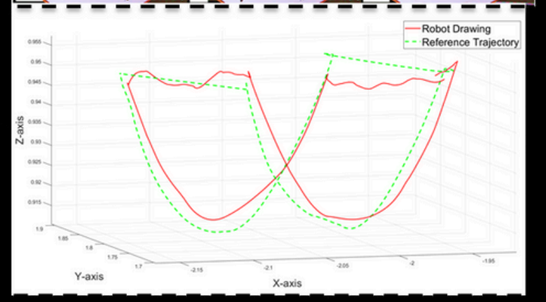
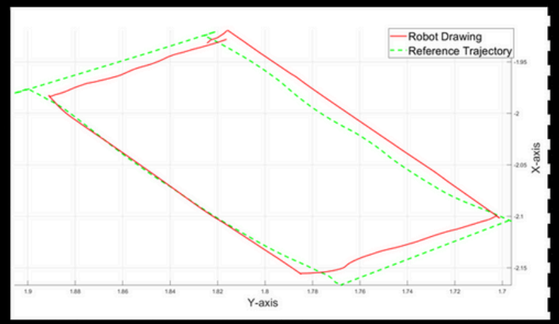
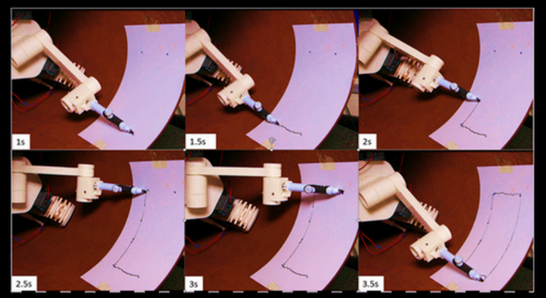
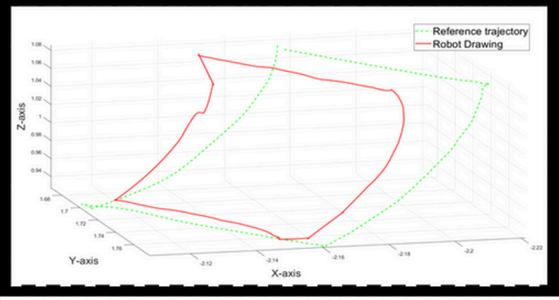


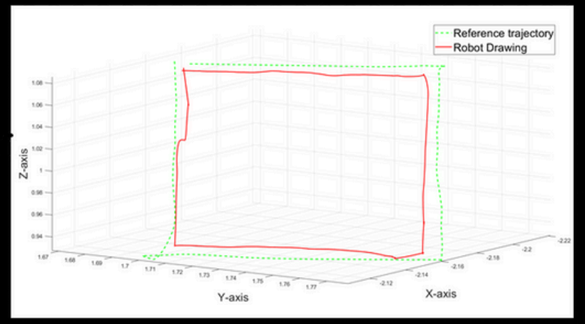




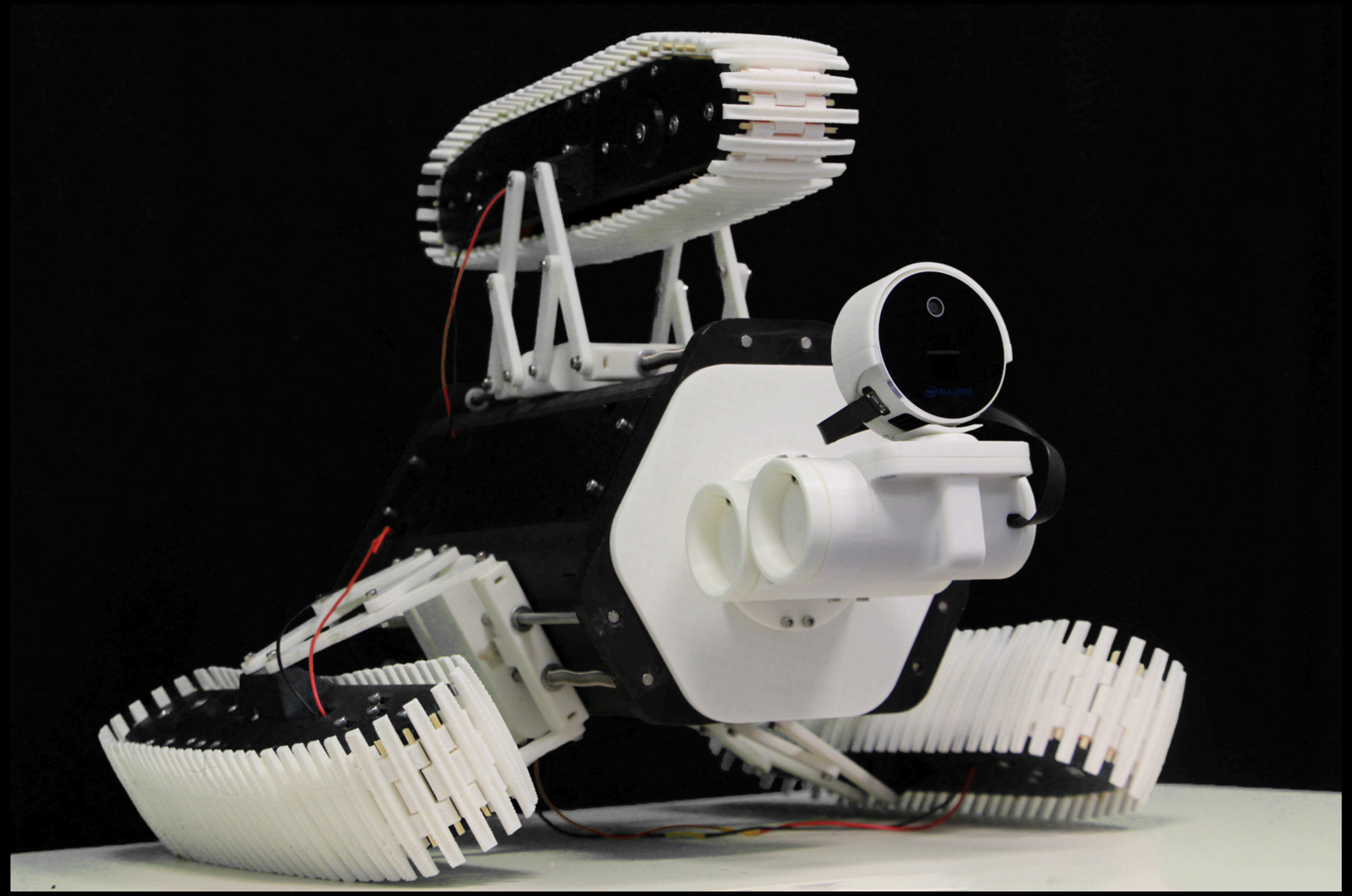






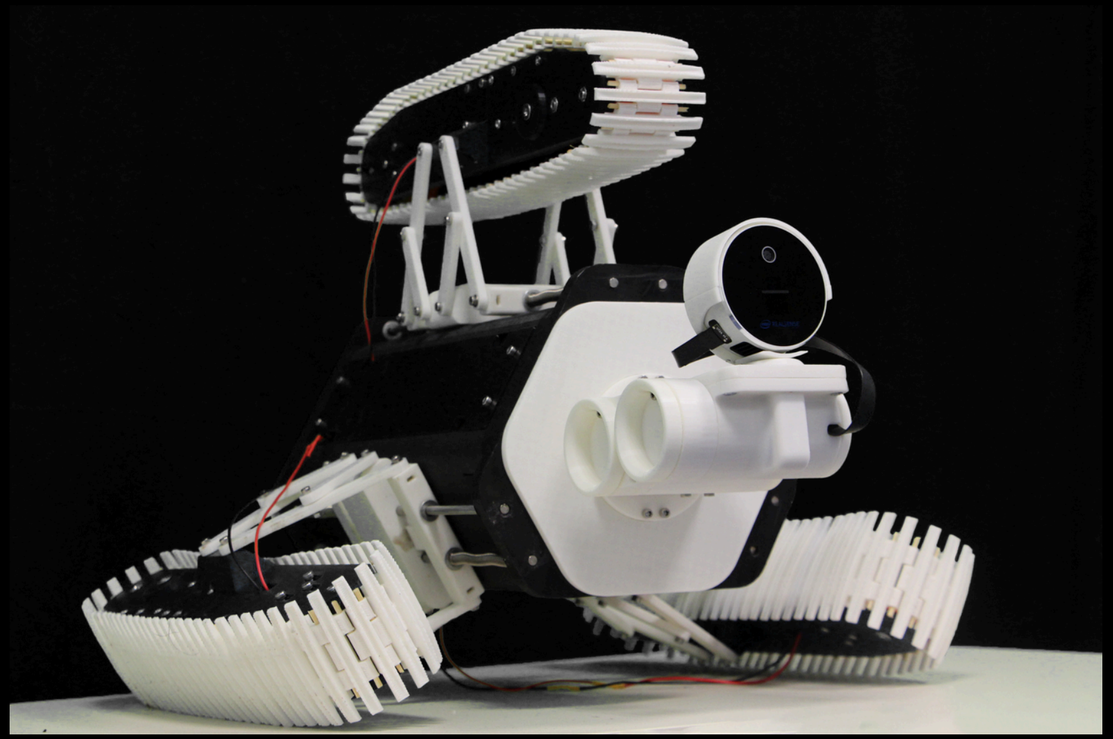


SIPIR - Smart In Pipe Inspection Robot



SIPIR - Smart In Pipe Inspection Robot

- Real-Time MR Experience
- While navigating to detect defficiencies, holes, objects
- To get virtual scan for MR experience
- Understanding the sizes of those objects

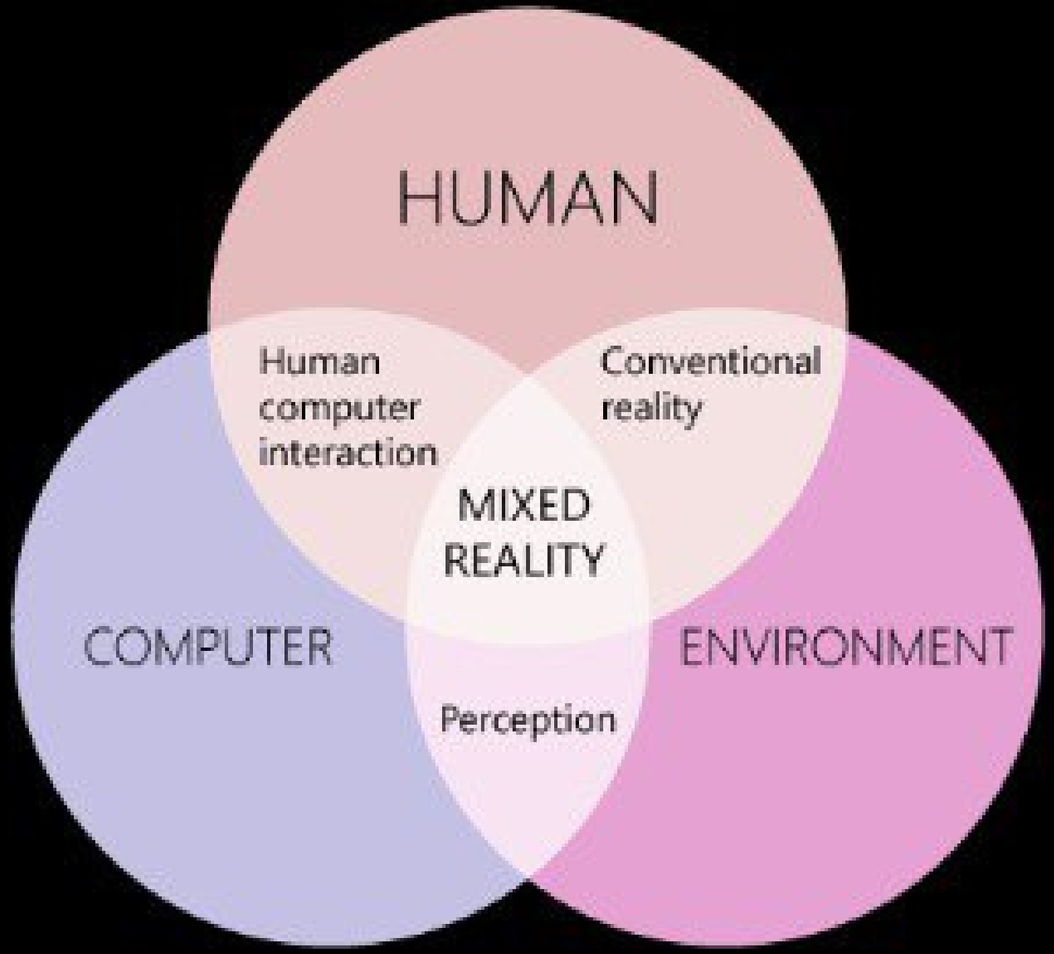


Motivation

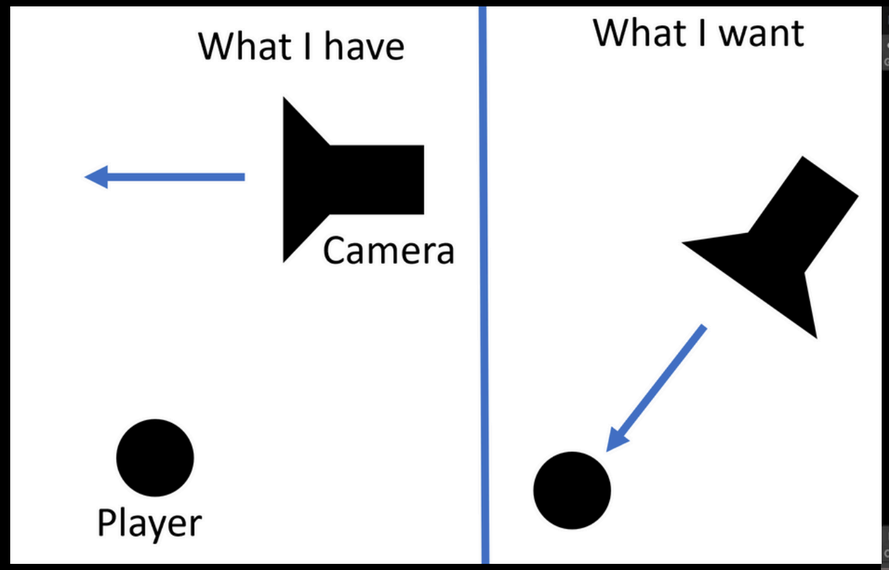
- Objective 1: Master and Slave control to stream
- Task1: RGB, Depth, Infrared stream
- Task 2: Anomalies detection

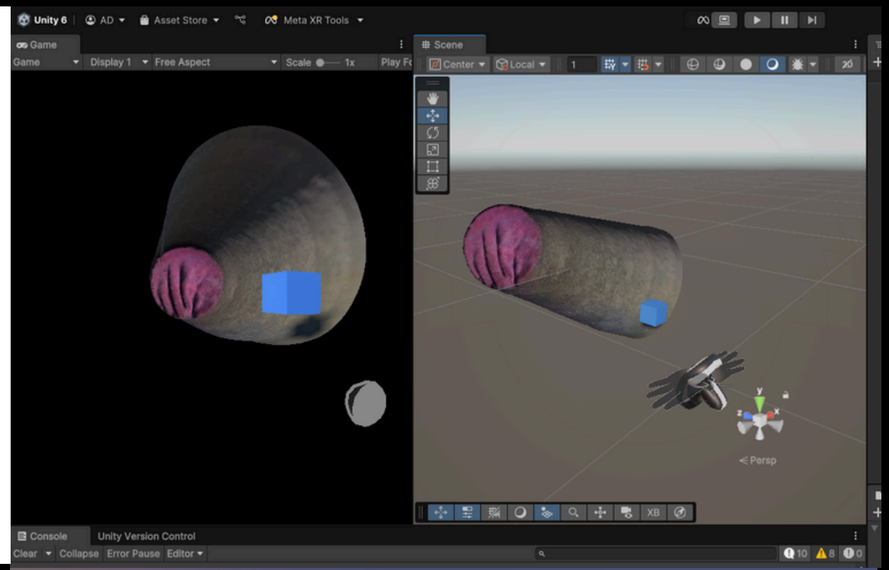
- Objective 2:
- Scanning the pipe and then visualizing in Headset

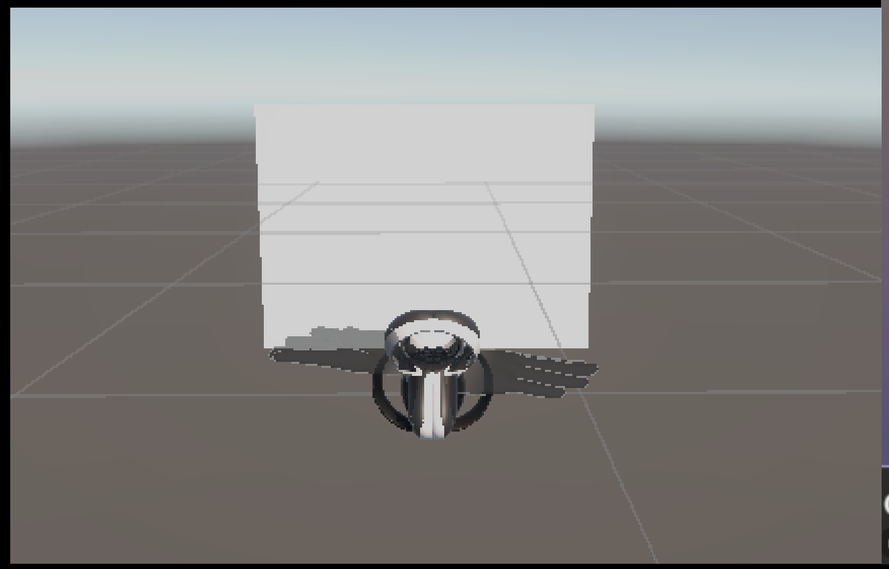
Mixed Reality



Unity - main software tool

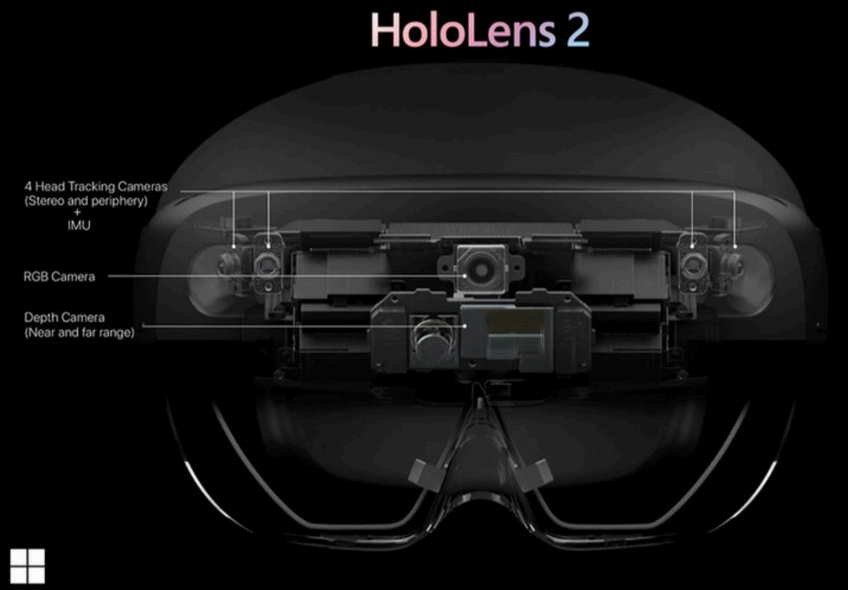






Device?

Meta Quest Pro

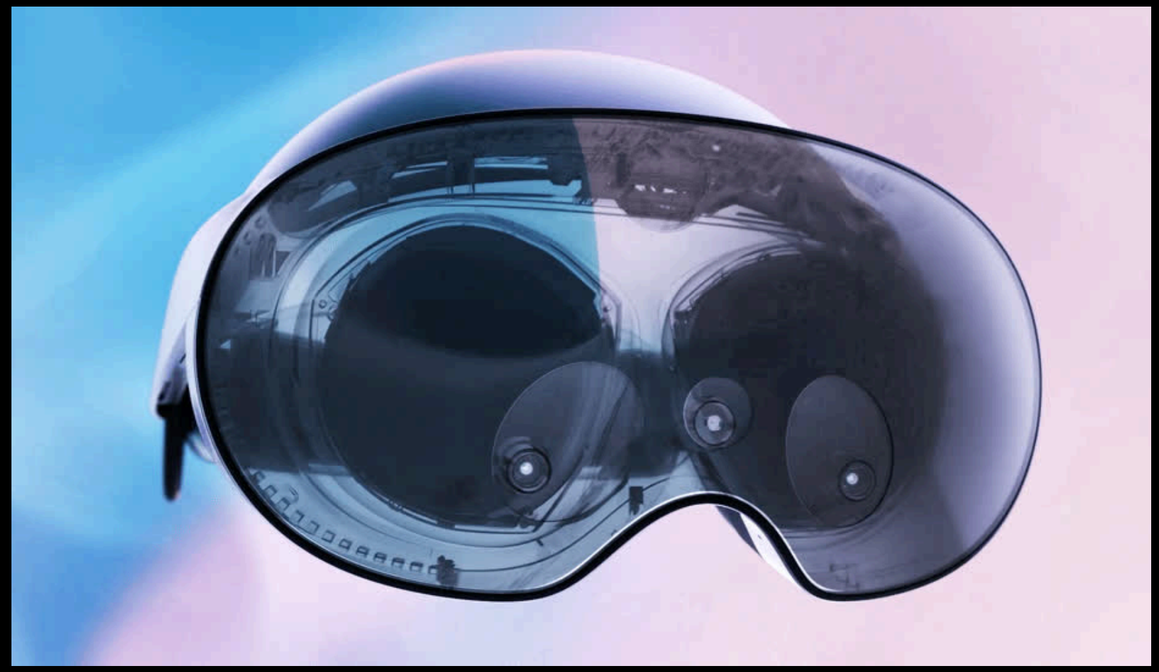


Hololens 2

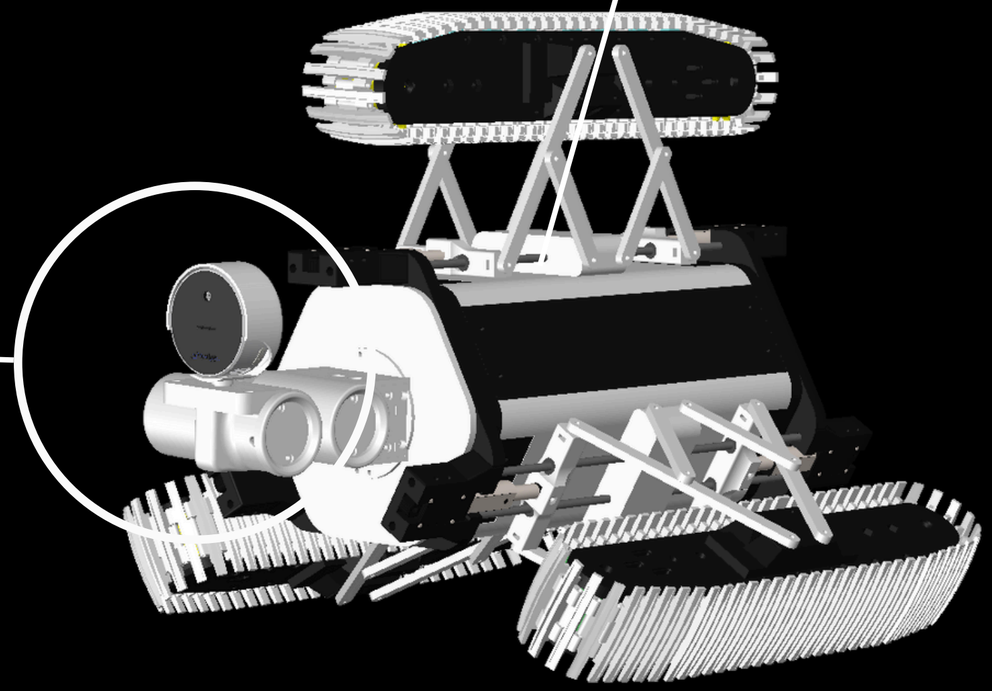
Previously

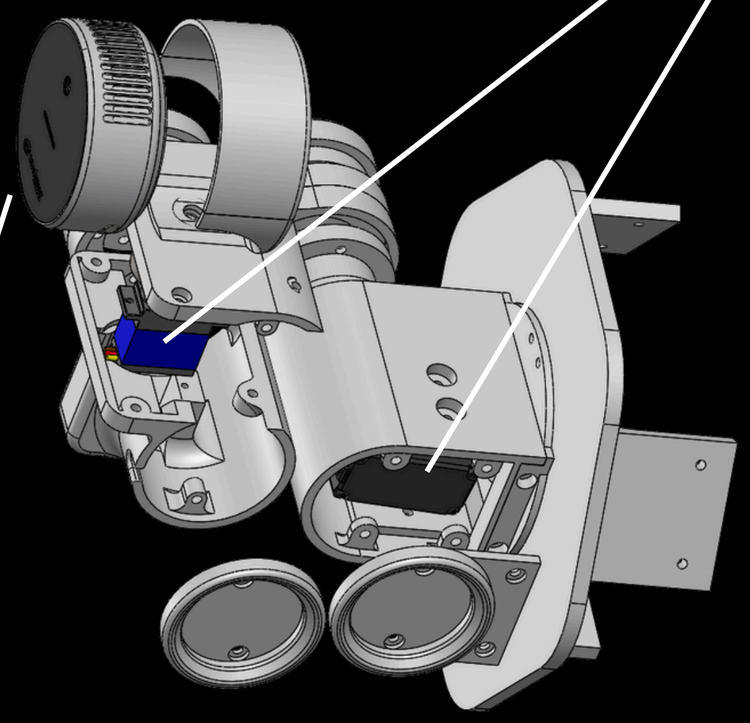
Meta Quest over Hololens

- Mature ecosystem for development
- Deployment takes faster
- MetaLink provides testing opportunities
- Field of view is more broader

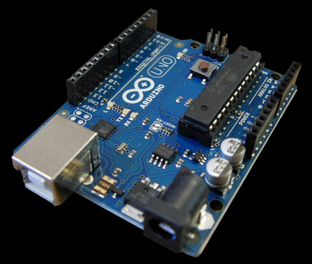


Main agent





master and slave + frame streams



angles

TCP
protocol

vector
transmission

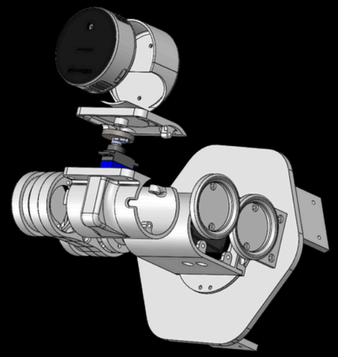
angles

camera
frames

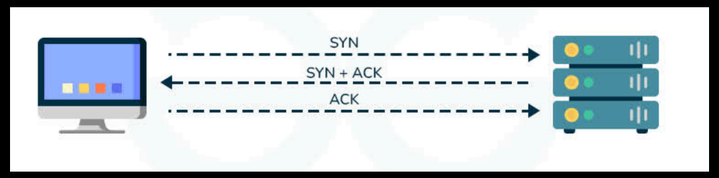
camera
frames

Unity®

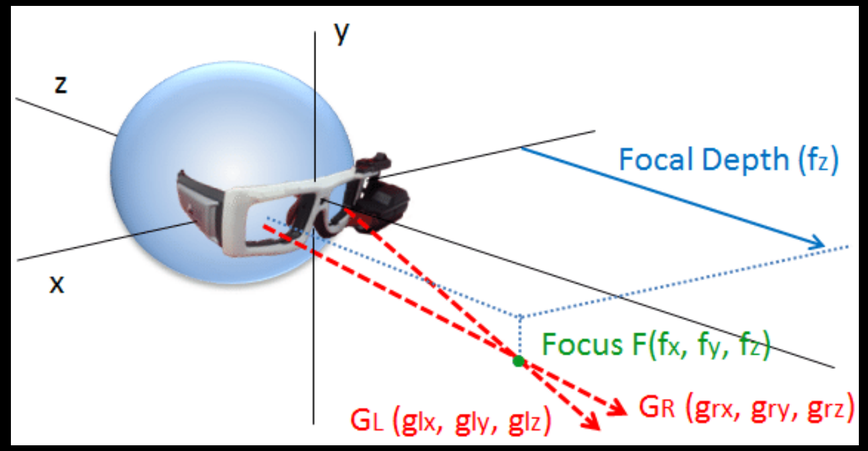
unity app

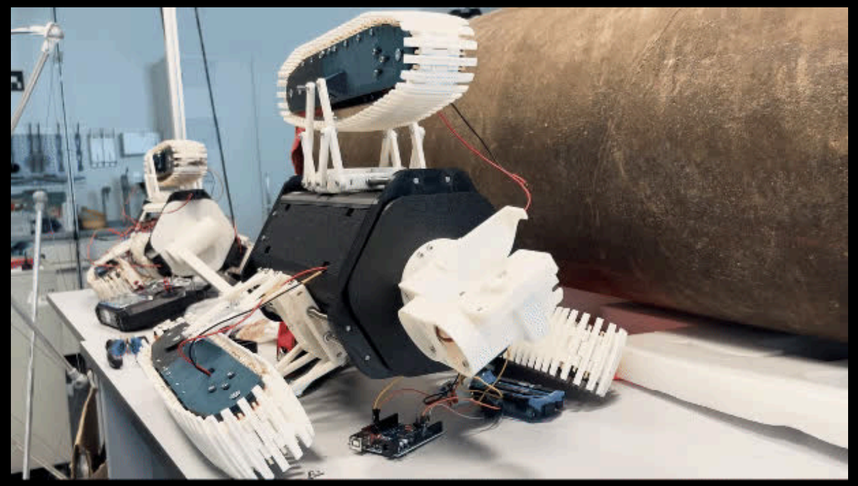


Umnitsa



3 Way Handshake



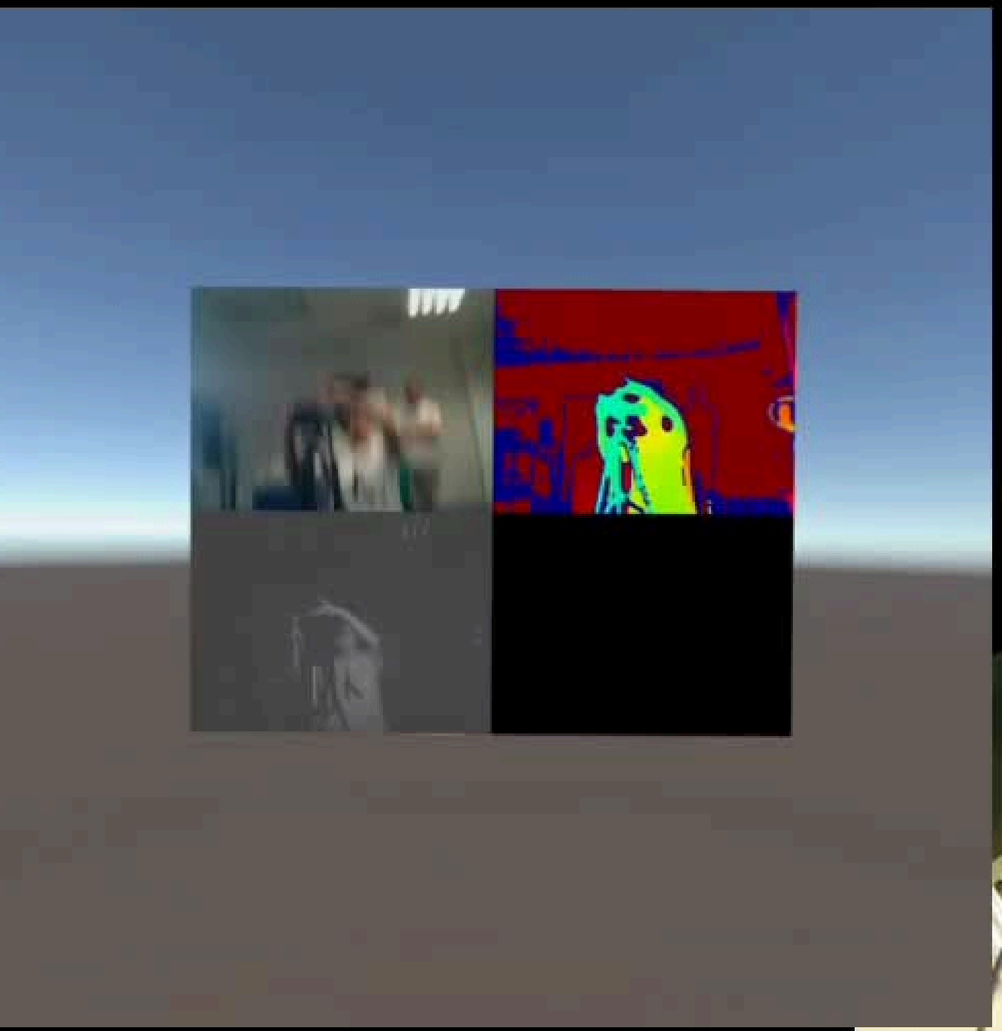


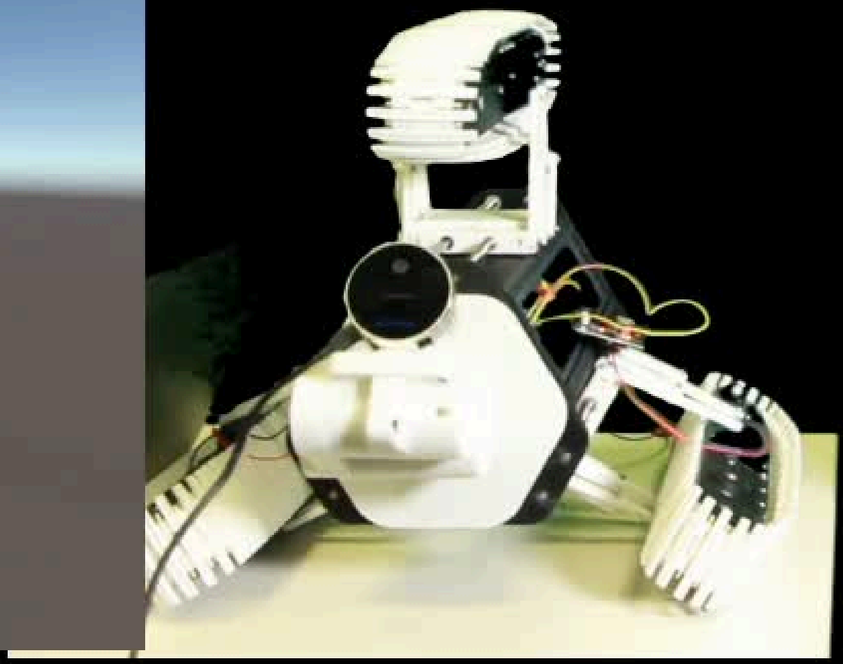
$$\mathbf{v} = (x, y, z)$$

$$\theta_{\text{pan}} = \arctan\left(\frac{z}{x}\right) \cdot \frac{180}{\pi}$$

$$\theta_{\text{tilt}} = \arctan\left(\frac{y}{\sqrt{x^2 + z^2}}\right) \cdot \frac{180}{\pi}$$

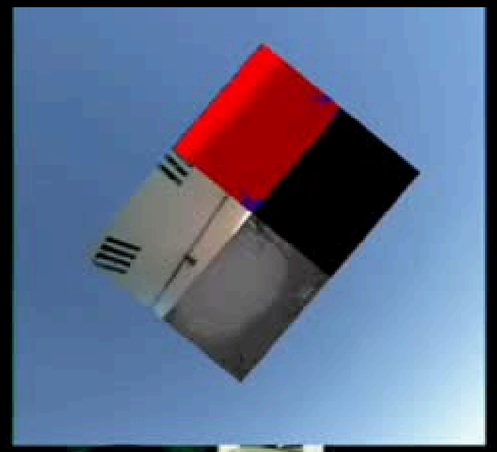
$$0 \leq \theta_{\text{pan}} \leq 180 \quad \text{and} \quad -90 \leq \theta_{\text{tilt}} \leq 90$$

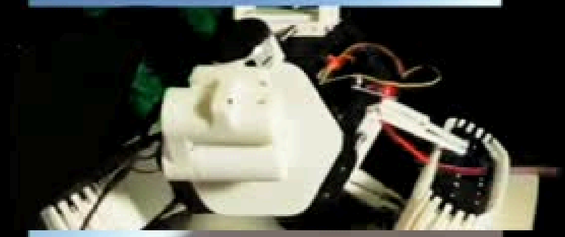


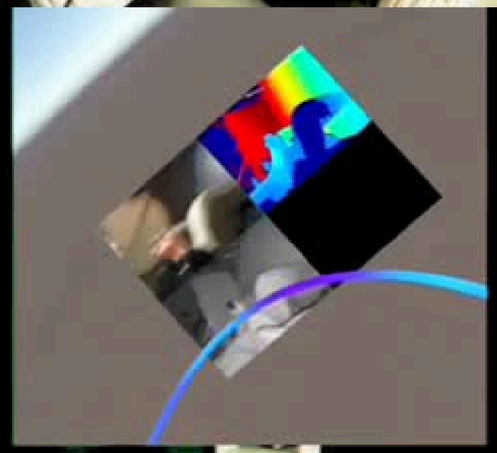


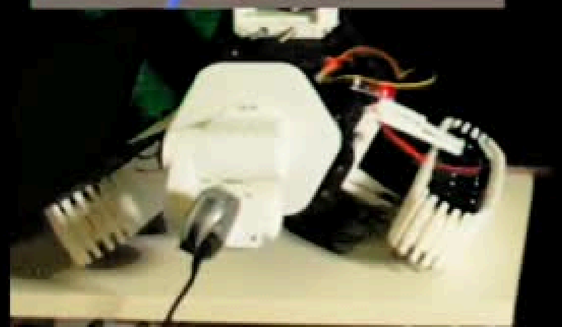
Testing

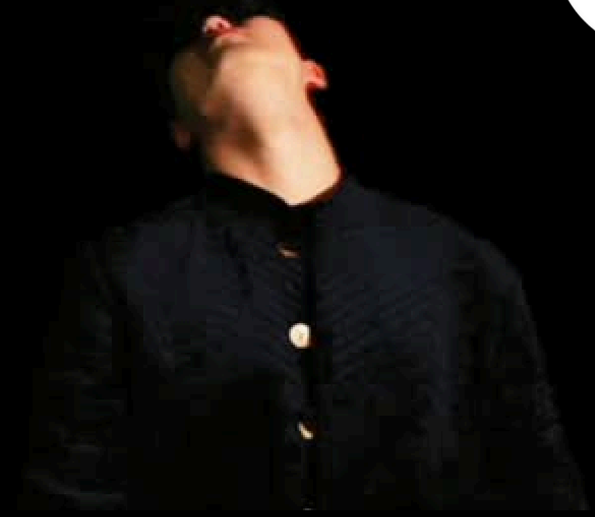
- Up-Down
- Right-Left movements



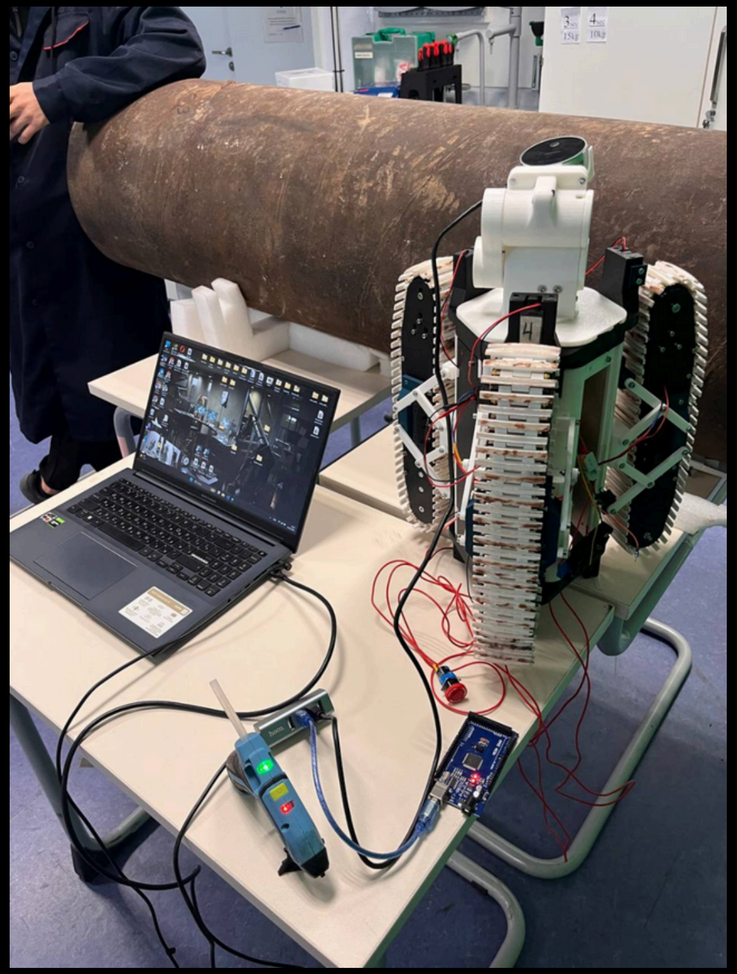


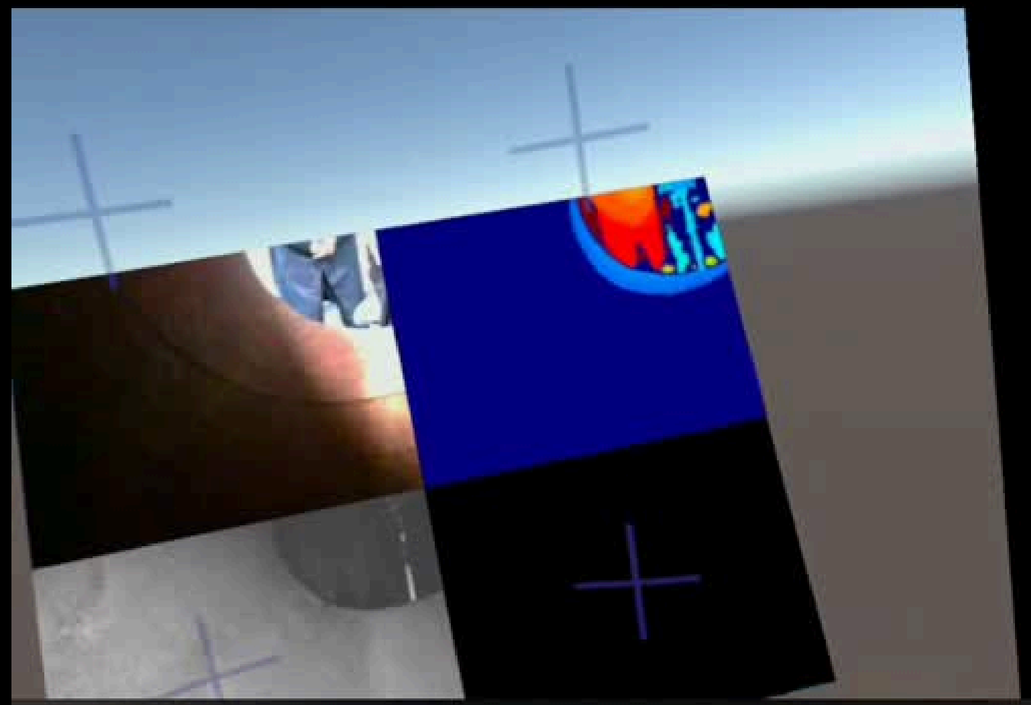






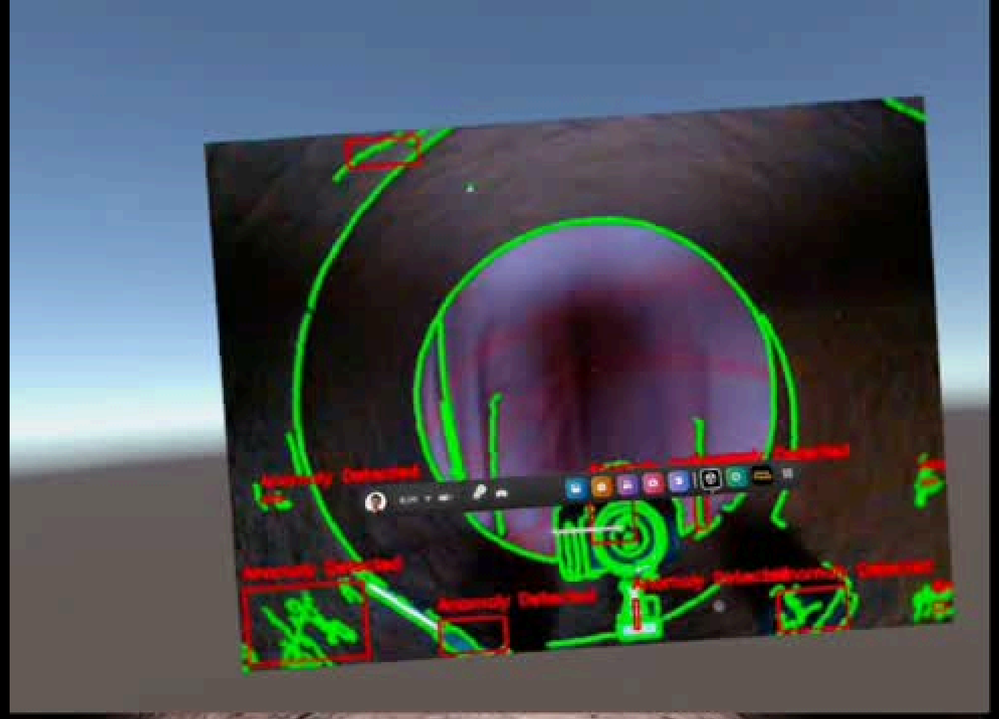
Experimental Setup






ASUS Vivobook

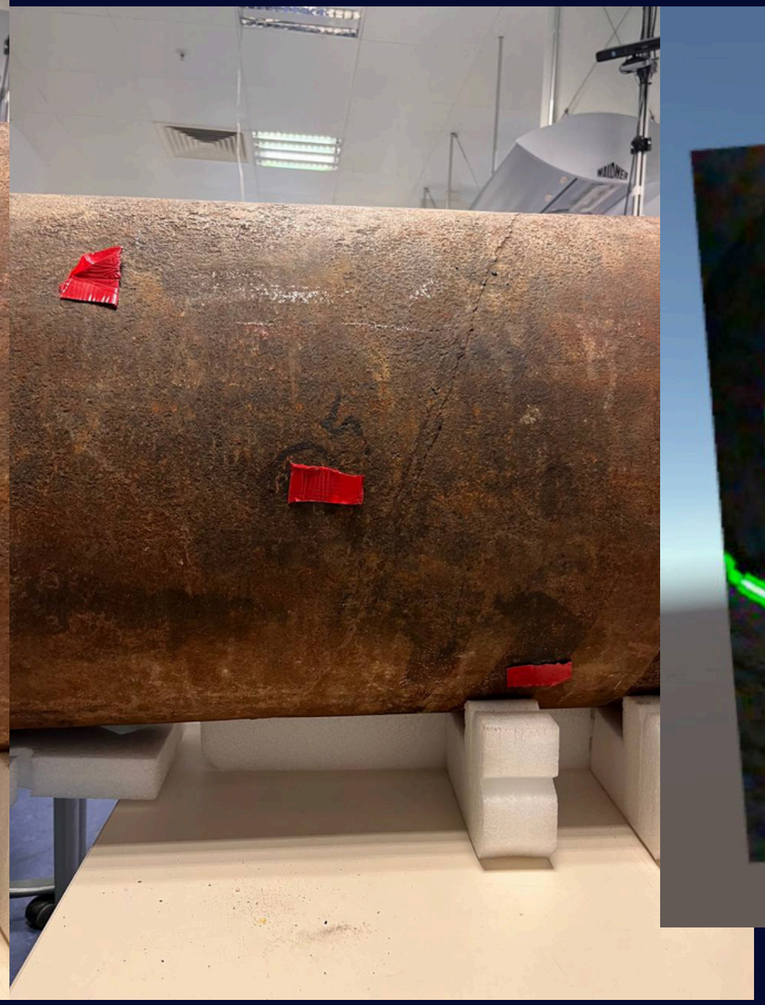
Placed objects for anomaly detection

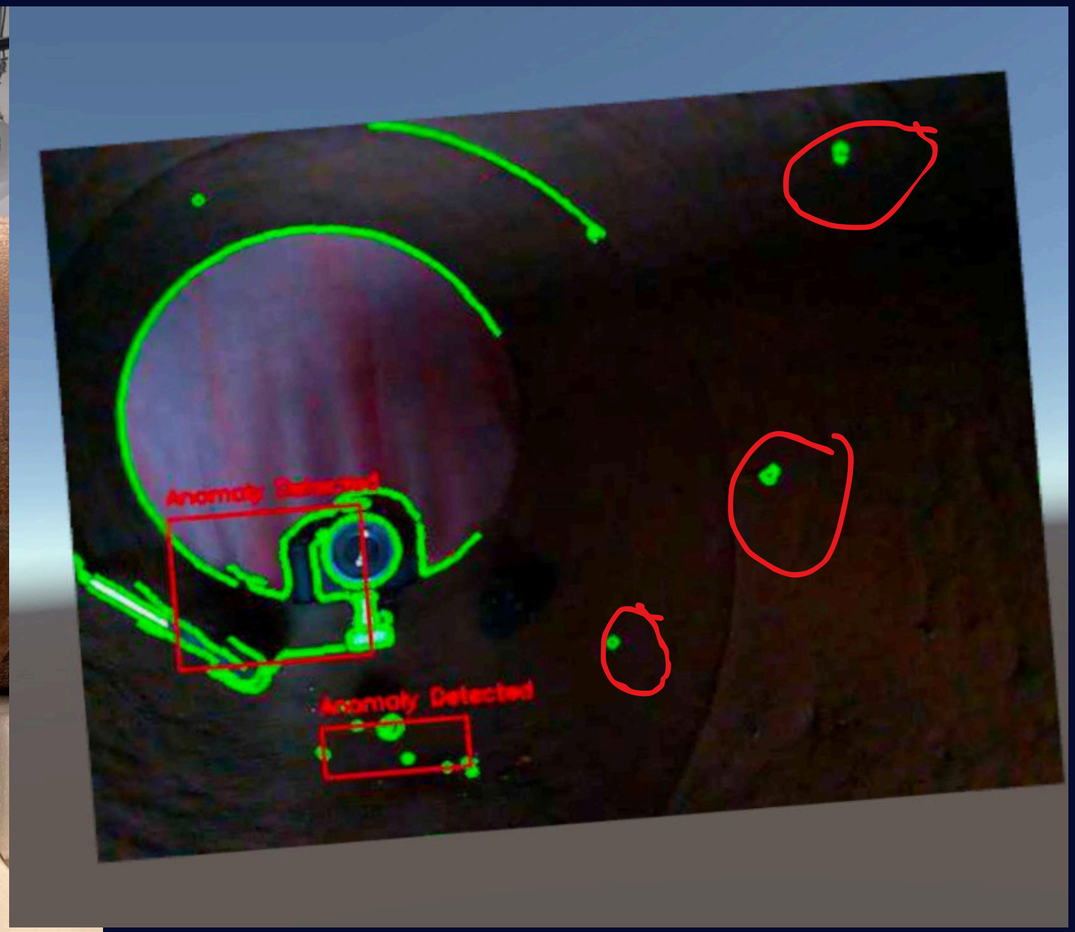



ASUS Vivobook


ASUS Vivobook

Results





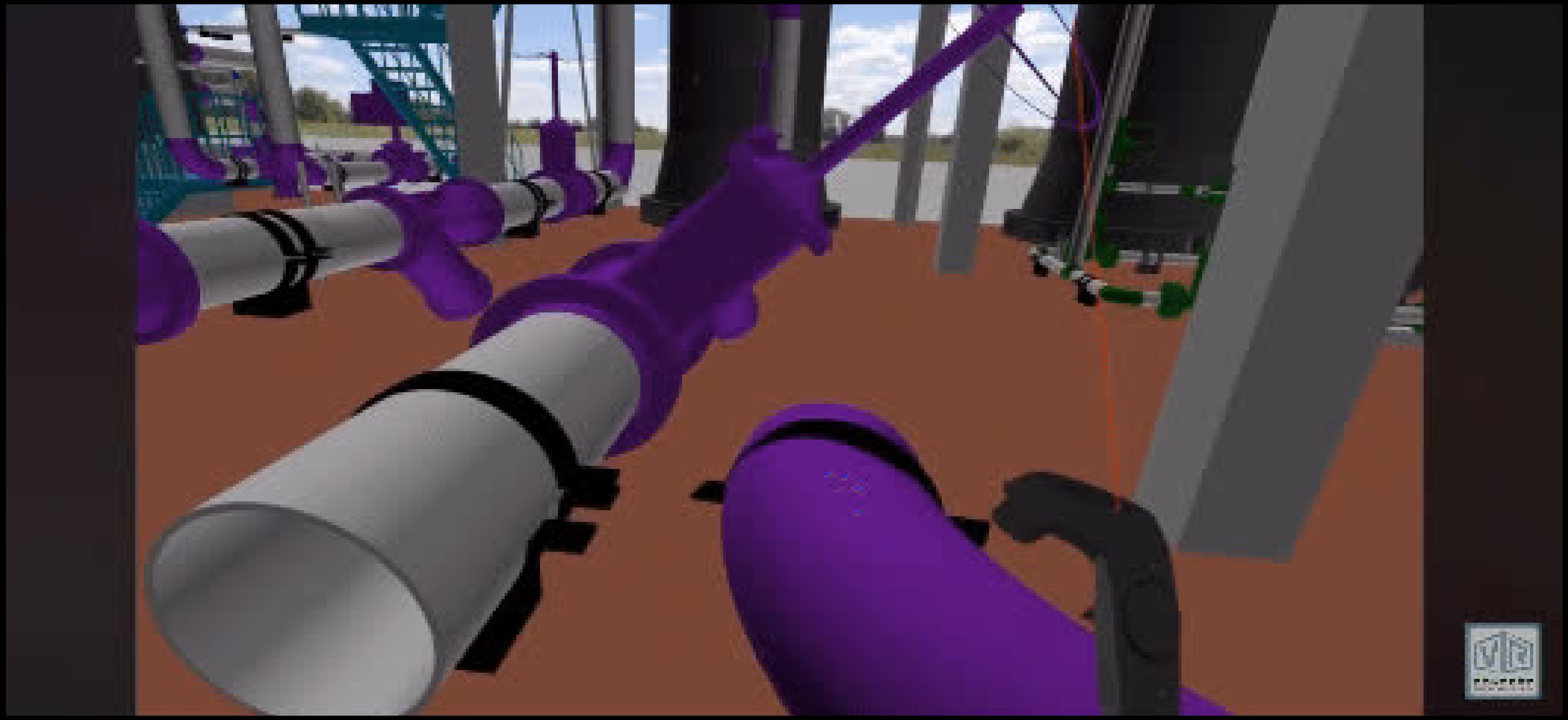
Observations

- Immersive spatial awareness - instead of flat screen
- Intuitive control - no reliance on joystic or keyboard
- reduced mental burden
- Like your eyes and brain investigating the environment
- Additional Anomaly detection algorithm assists the operator

Observations

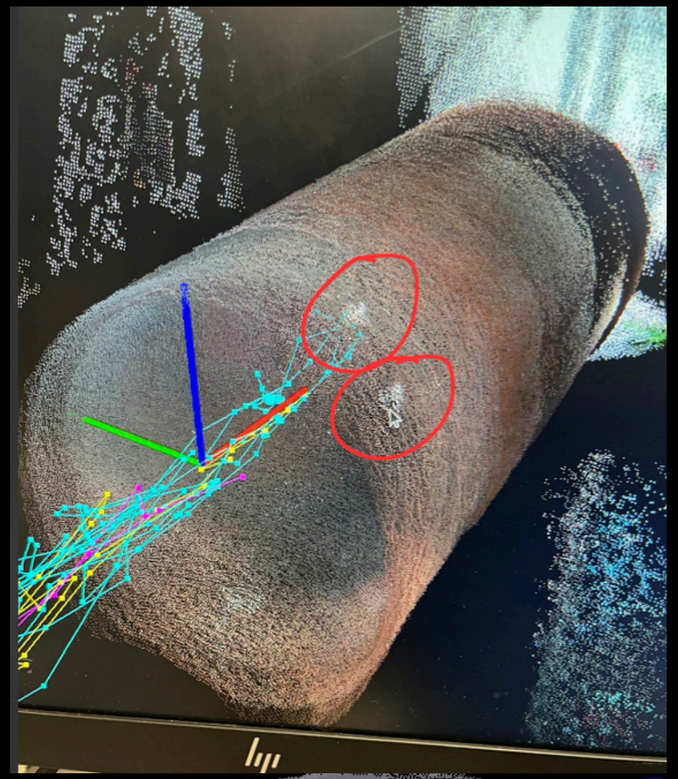
- One frame of combined image weighs 3.5MB
- Sending the constant frames loads the TCP socket, and some routers can’t handle it
- After making compressions per frame, the performance rate of FPS increased from 0.4FPS to 3 FPS.

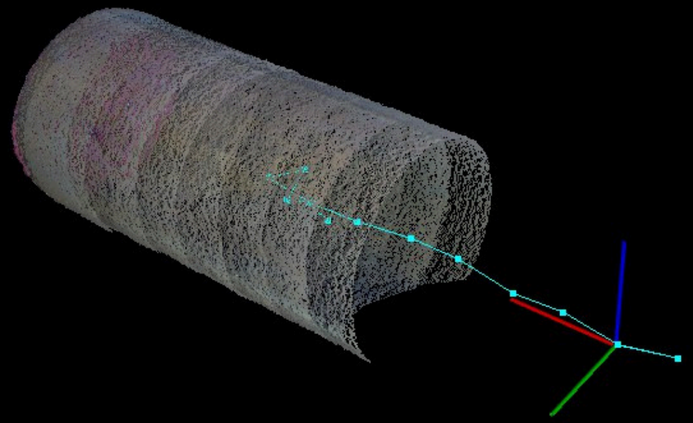
Training in Virtual Reality

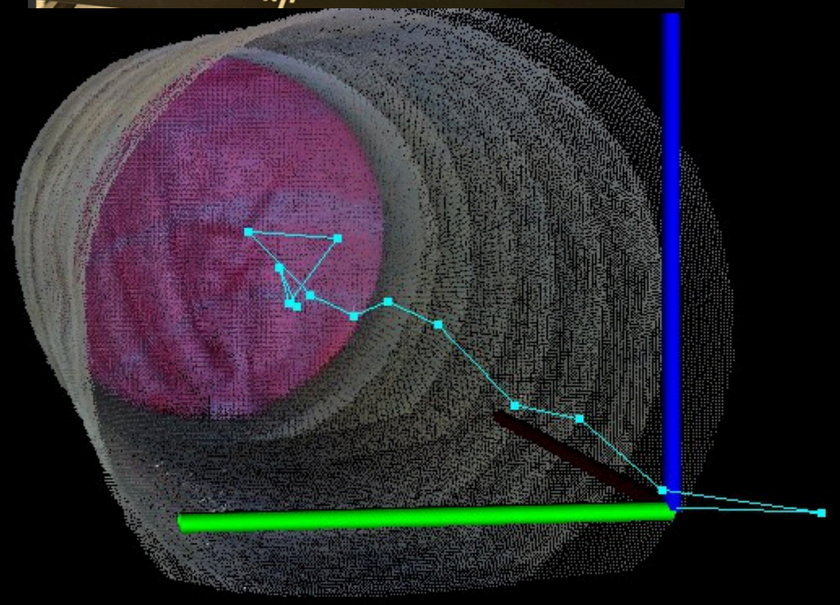


Generated SLAM

RTAB Map (Real Time Appearance Based) SLAM approach that can construct the MAP of the environment based on the Color and Depth Frames



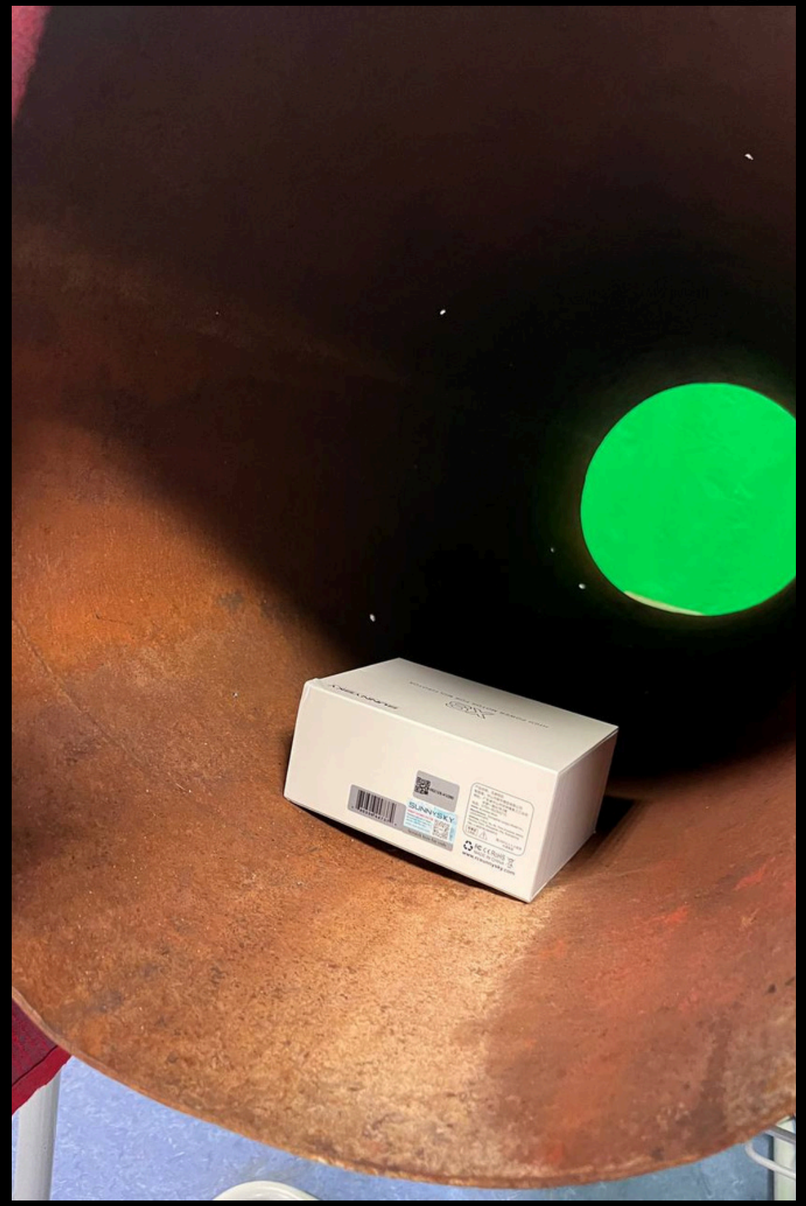




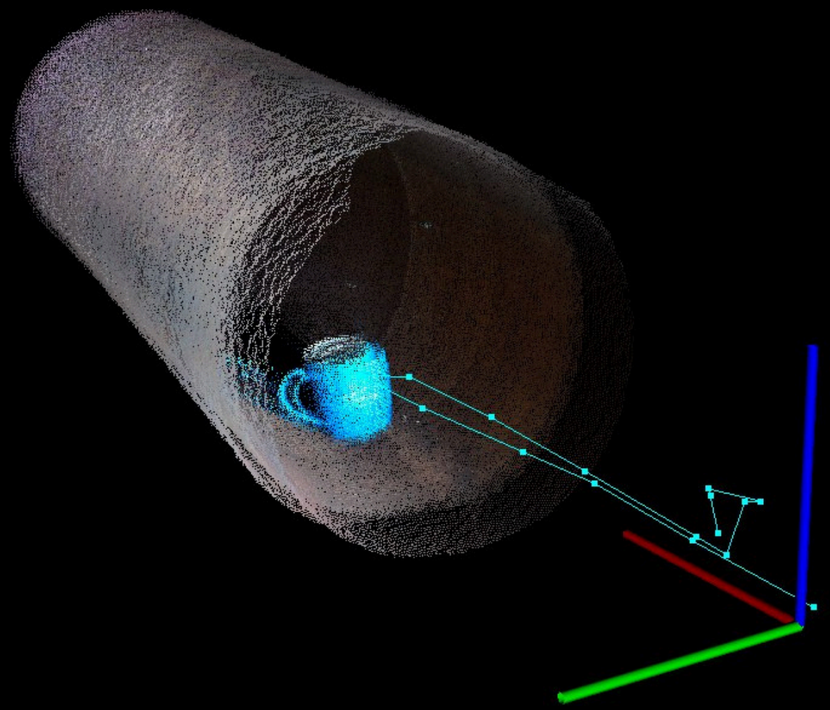
Previously

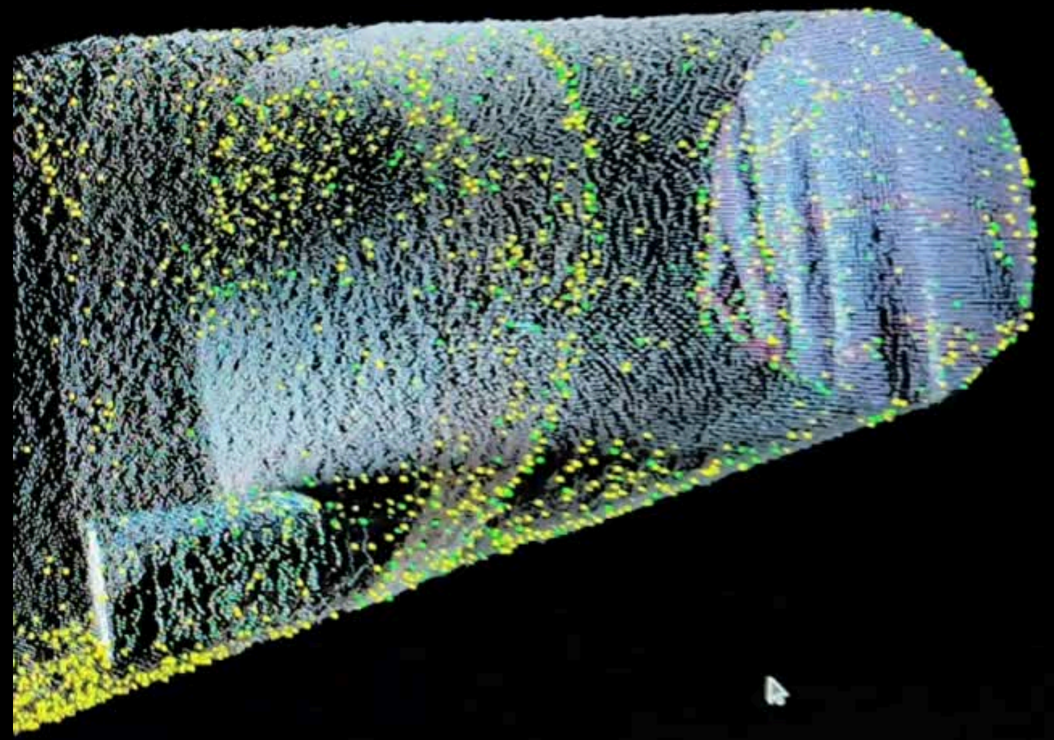
- How mixed reality looks
- Deformations can be noticed
- If scanned pipeline is long, we can travel through it.

Procedure:Placing objects



Scanning the pipe

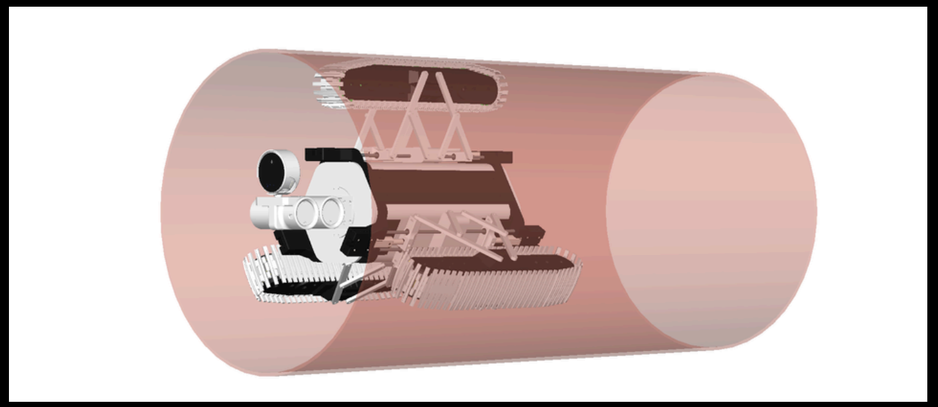




Flowwork of the Experiment

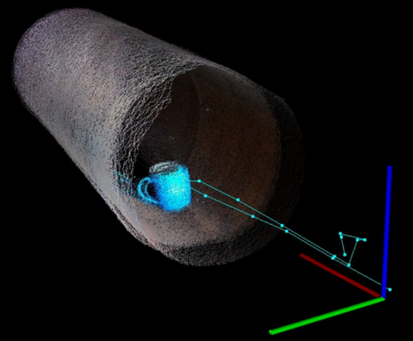
Cup

Scanning



Robot

Map building



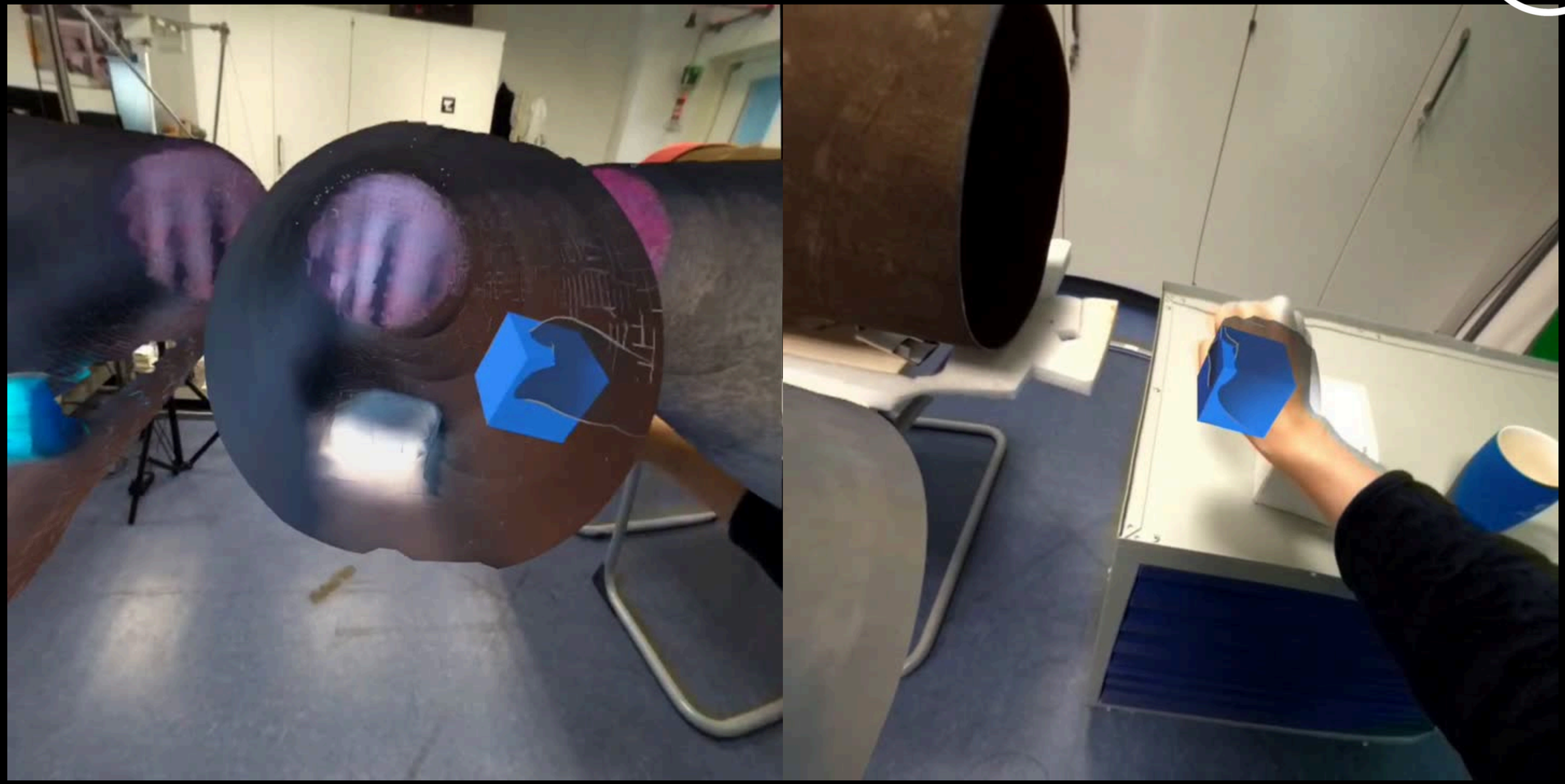
Exporting ply

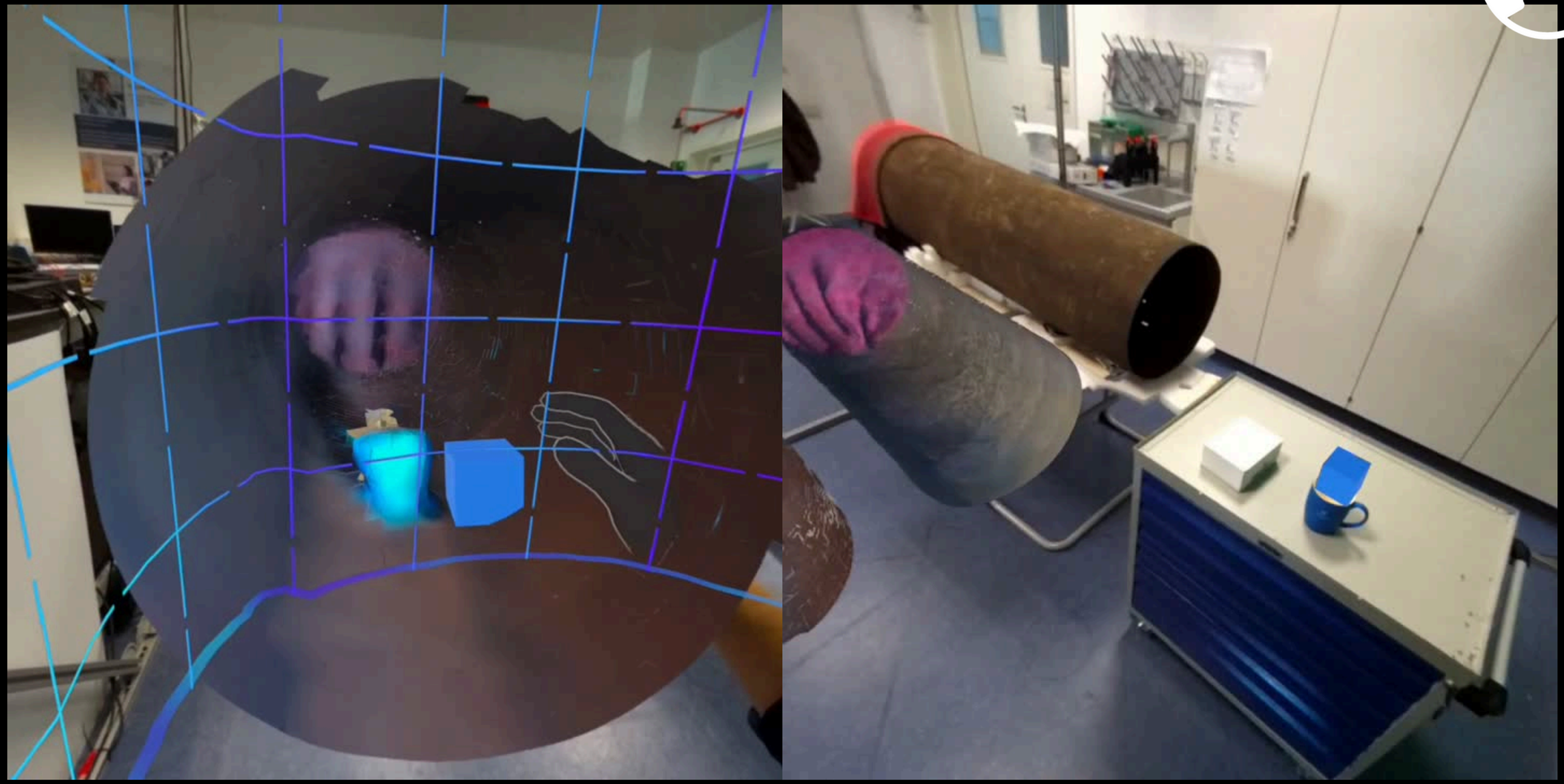
Unity®

Deploying as an app

Interaction

MR Experience





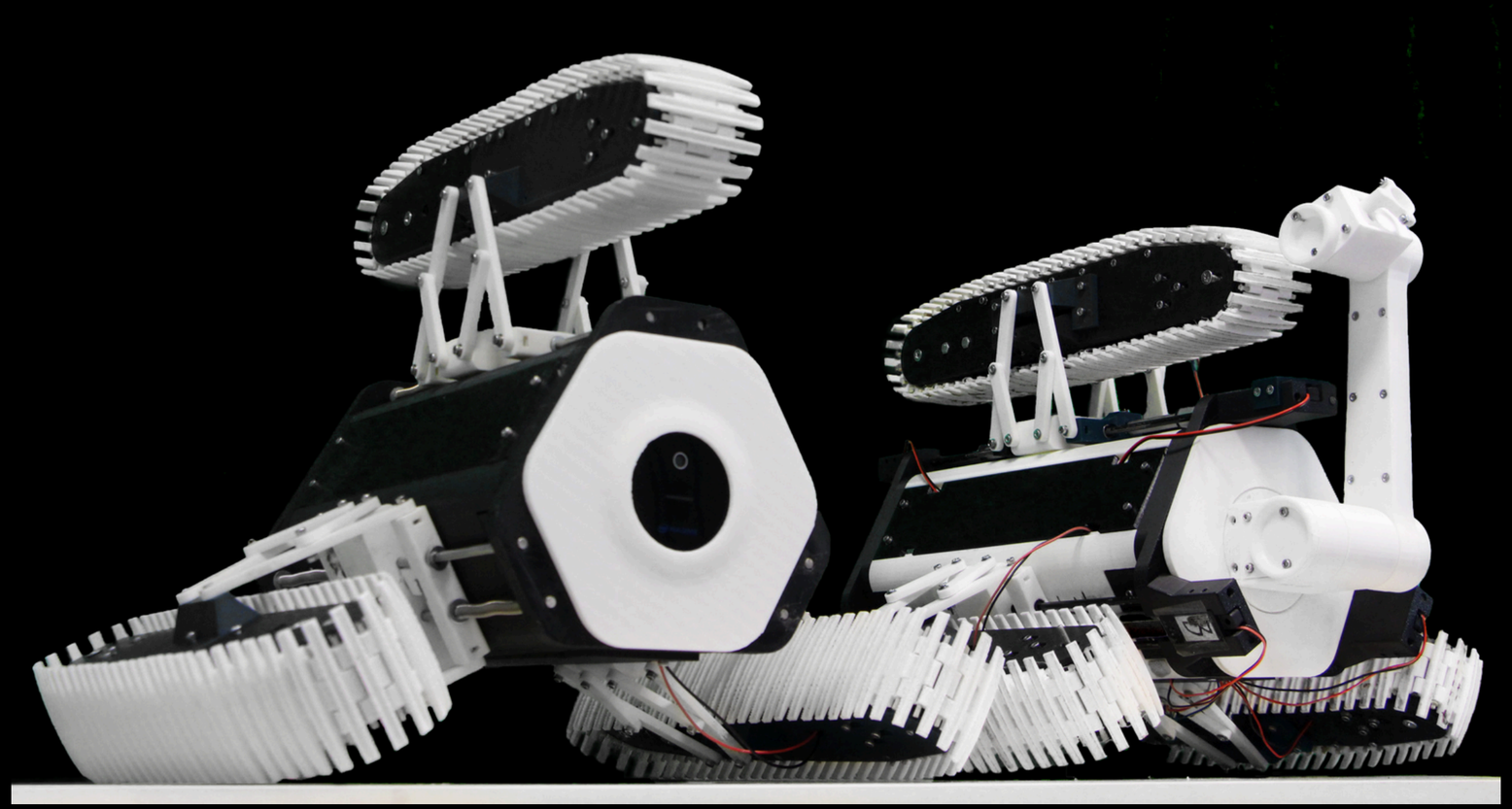
Observation

- We can detect deformations
- Hole and anomalies detection hard depends on Slam approaches, camera, computation and stabilization
- Exported 3D maps can be accurately scaled in Unity if the real pipe size is known
- Like the grabbable cube, any virtual object can be used as a size reference.
- This helps check which tools or parts can fit for maintenance.

Observation

- Remote size and fit validation
- Compare current physical conditions to the scanned baseline
- Workers can rehearse maintenance steps in AR/MR before working in hazardous or confined spaces
- Trainees can learn to identify which tools or parts are needed for specific pipe configurations
- To analyze the risks

Progress



Publication in the Q1 journal IEEE Access.

Under review in the Q1 journal IEEE Robotics & Automation Magazine (RAM)

AR based inspection is on the stage of collecting data.
Aiming for paper

Thanks for our supervisor - Dr Azamat Yeshmukhametov