ARLAB

Inspection Guidance with Visible Object Detection Support

In-space Inspection Workshop, Jan 31-Feb 2, 2017

Rafael Radkowski

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Assembly Assistance (Video)

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Real time

Augmented Reality Assembly Demo

with

Marker-less Tracking

Rafael Radkowski
Jan. 2016

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YouTube https://youtu.be/VTBYPyWVEsE

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3D Shape-based Registration

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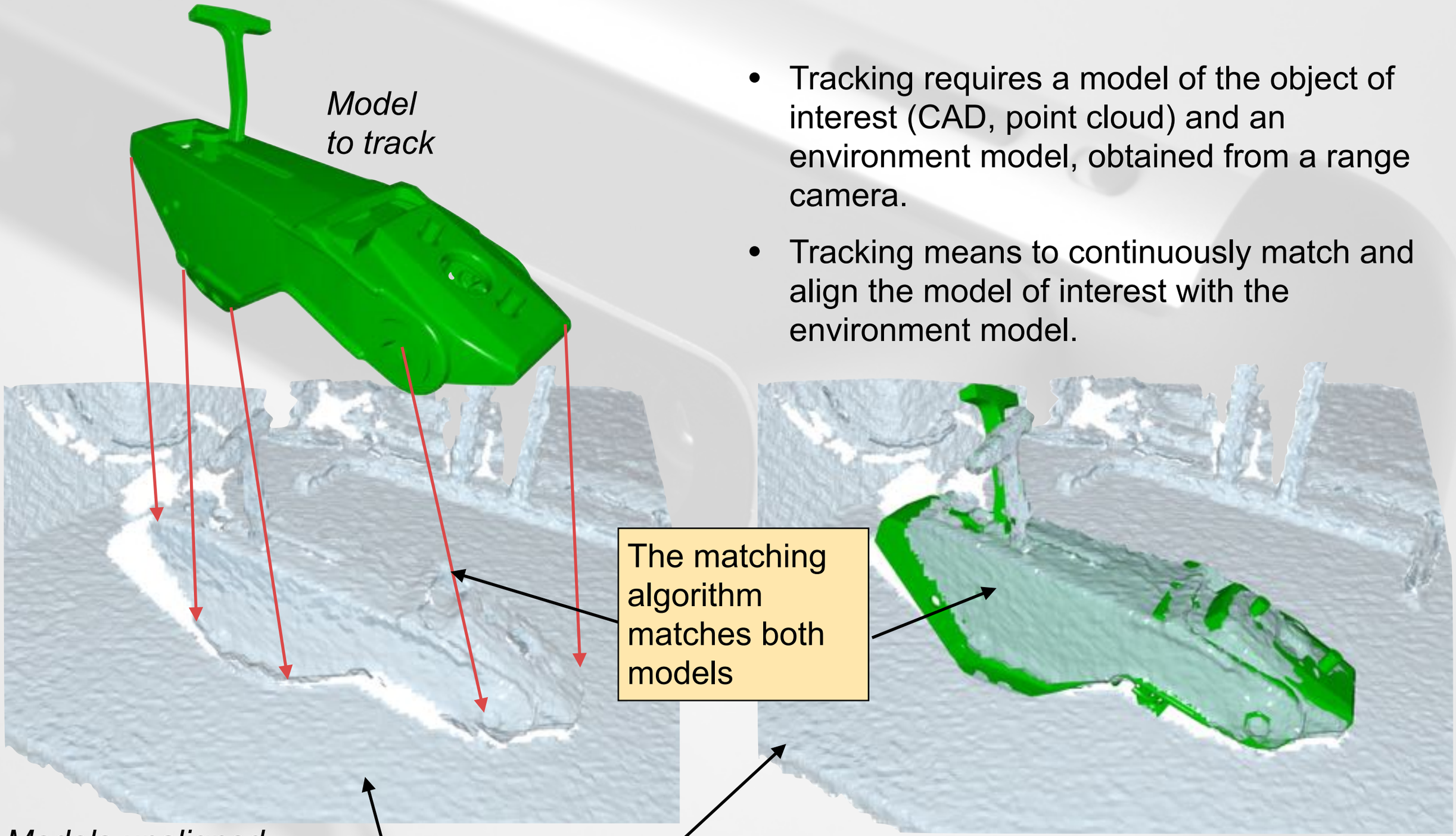

- Tracking requires a model of the object of interest (CAD, point cloud) and an environment model, obtained from a range camera.
- Tracking means to continuously match and align the model of interest with the environment model.

Models unaligned and unmatched.

Matched models

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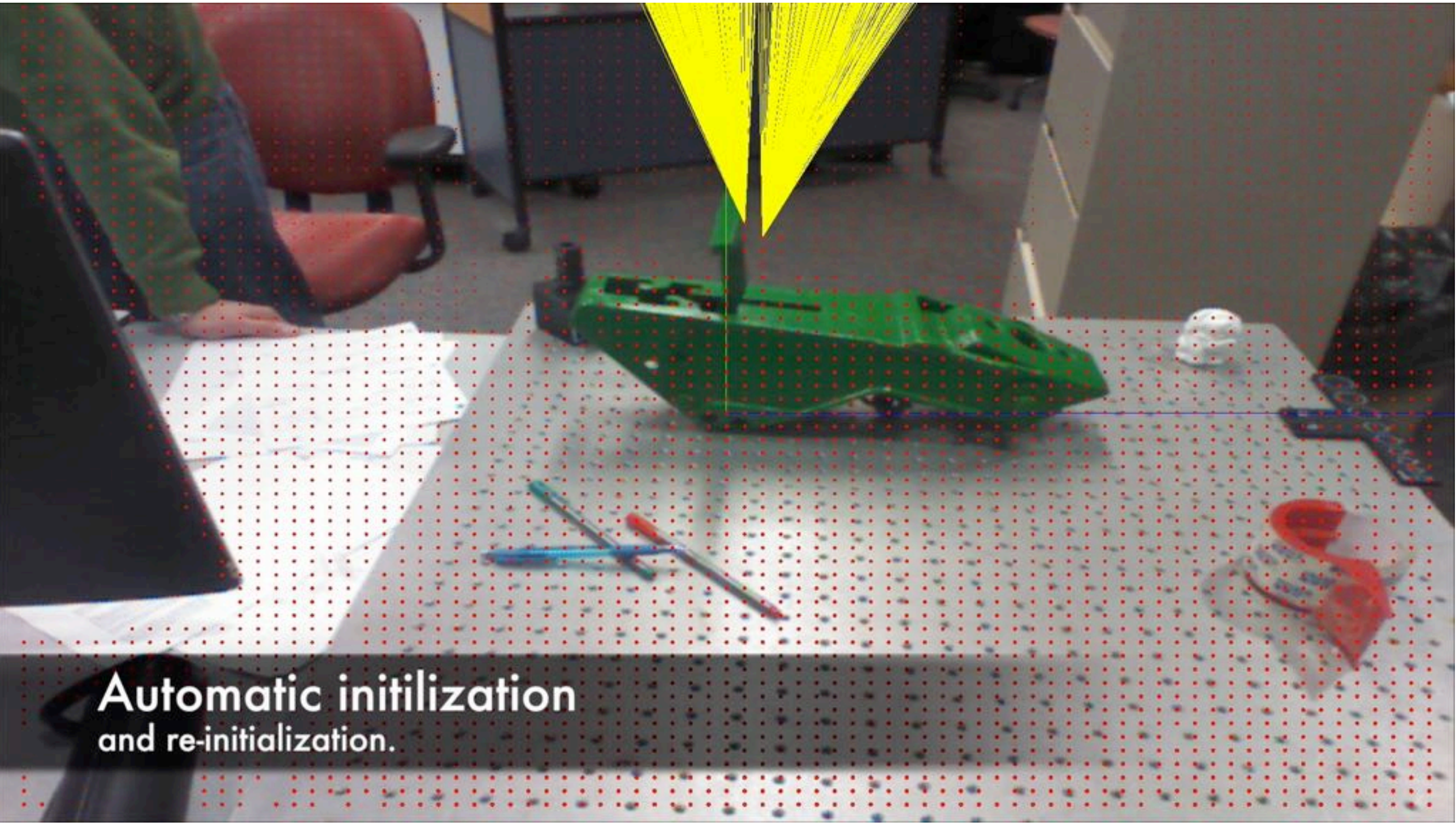
3D Shape Registration (Video)

ARLAB



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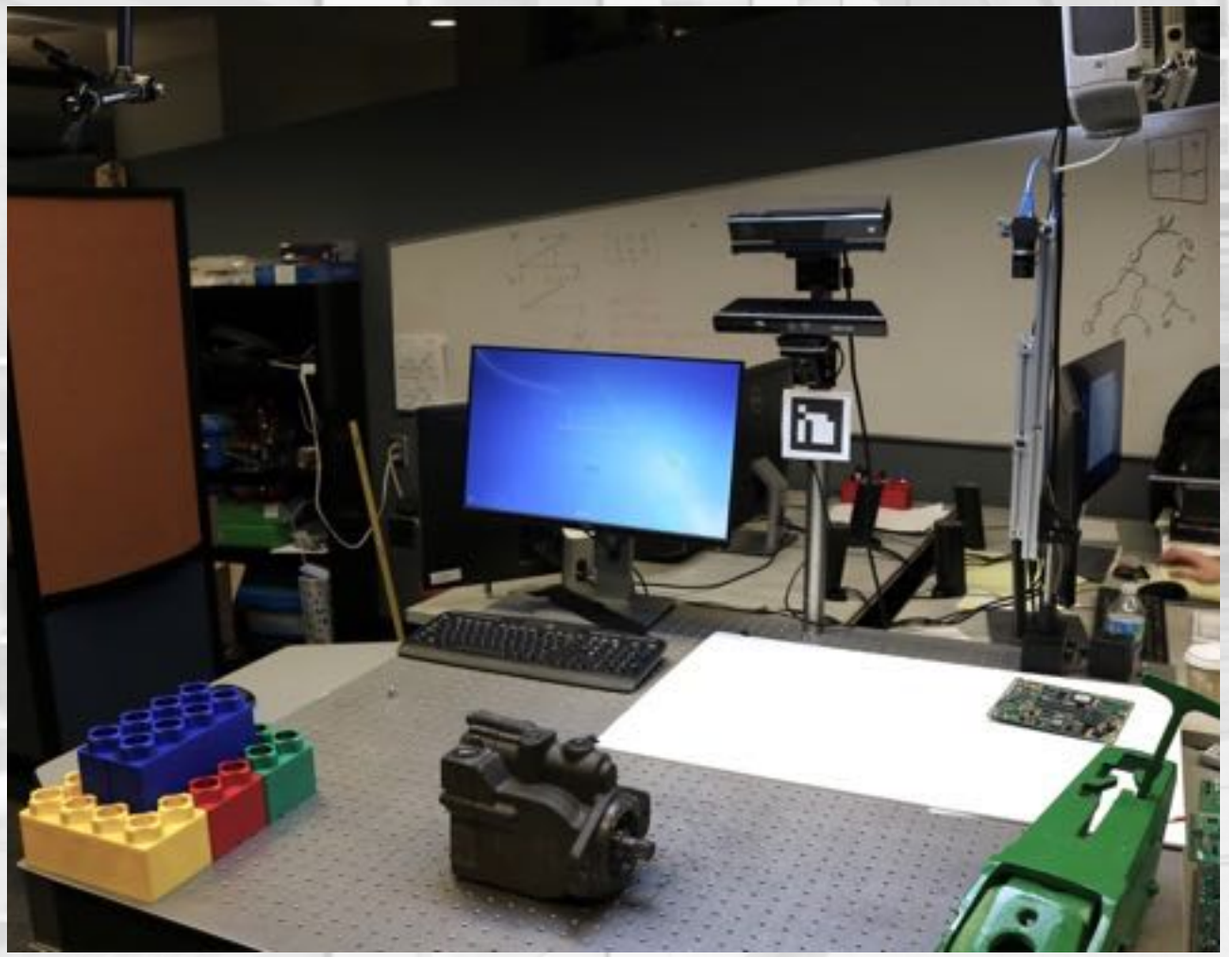
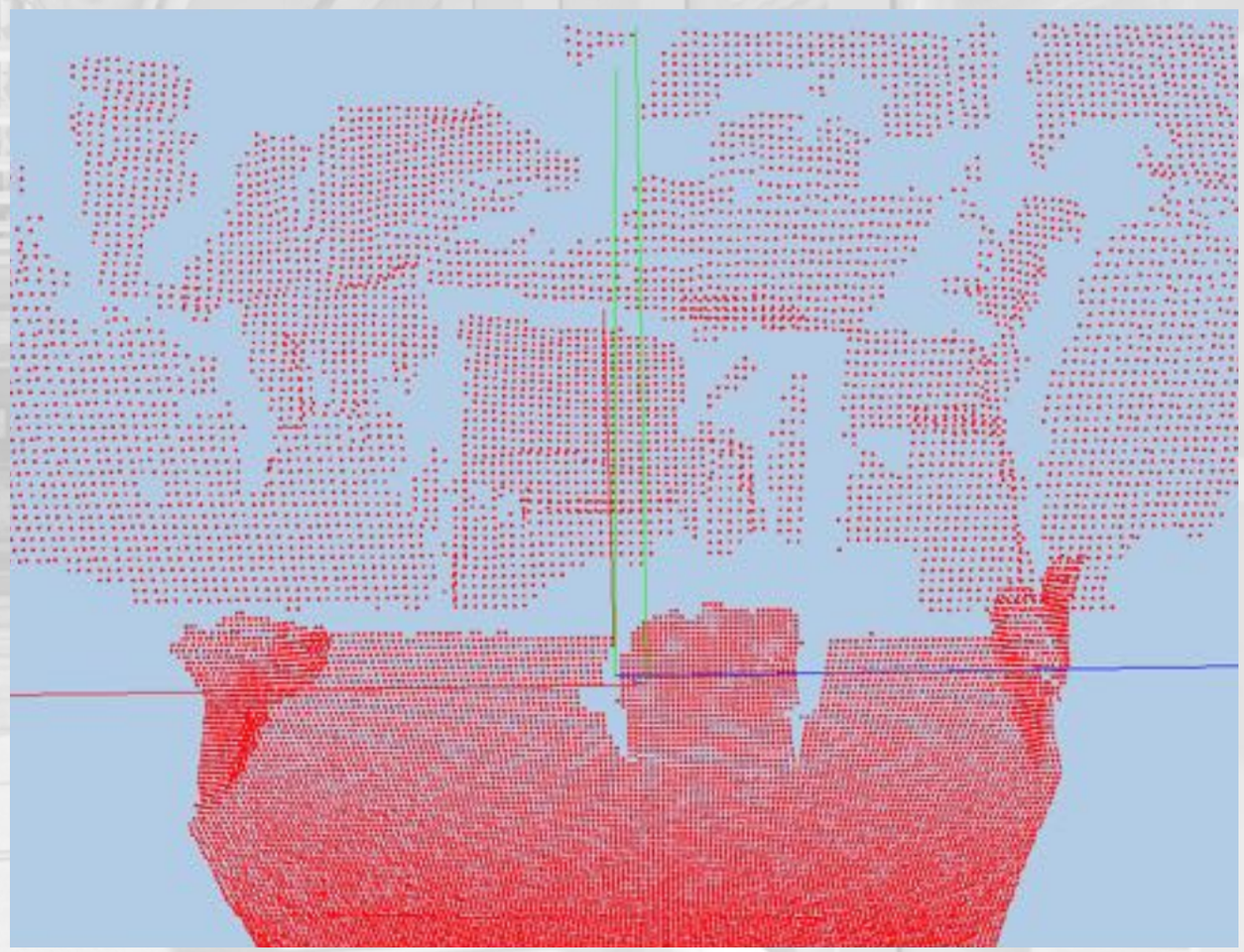
Find an object in the scene

ARLAB



A test environment in the lab



This is how we perceive the environment

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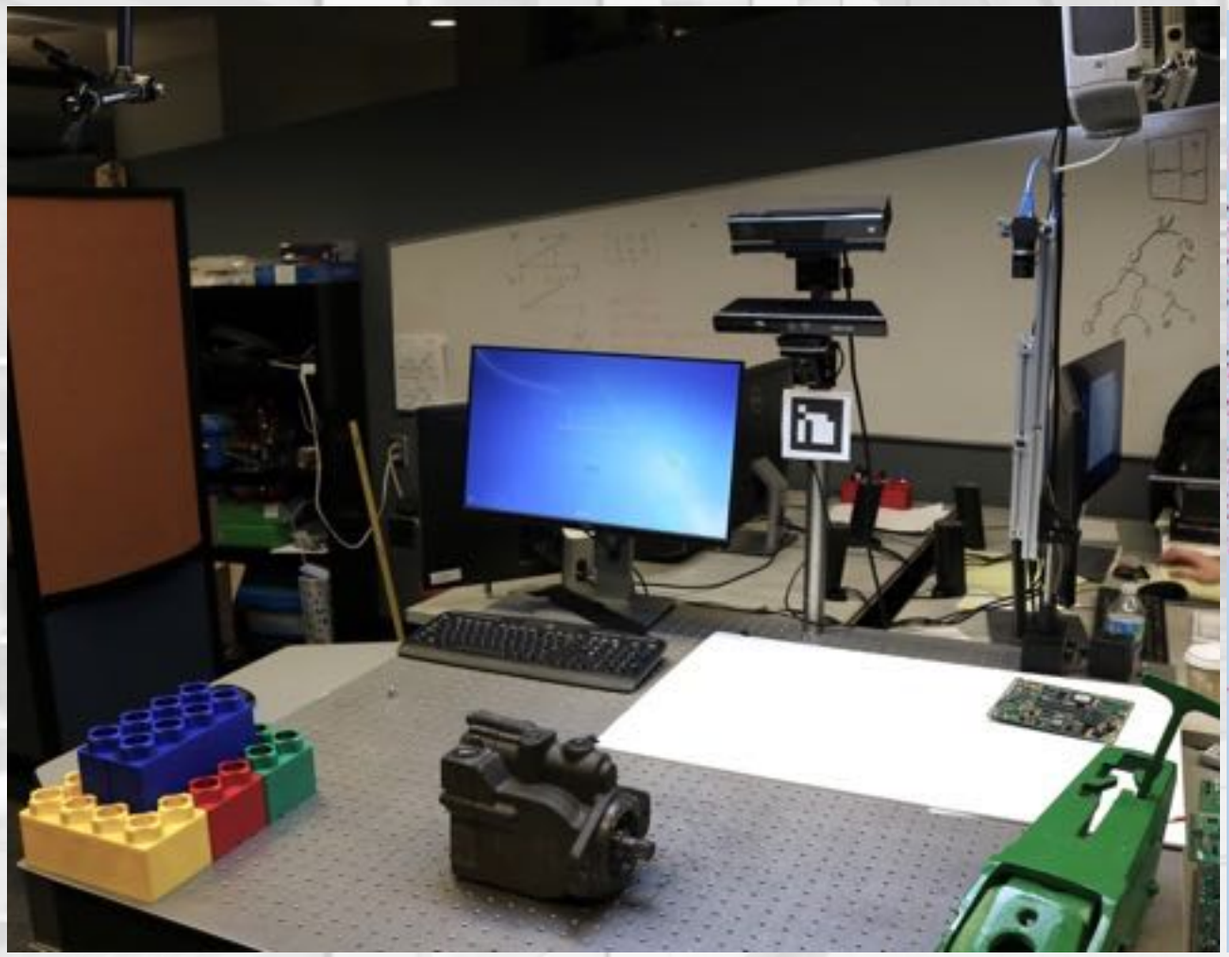
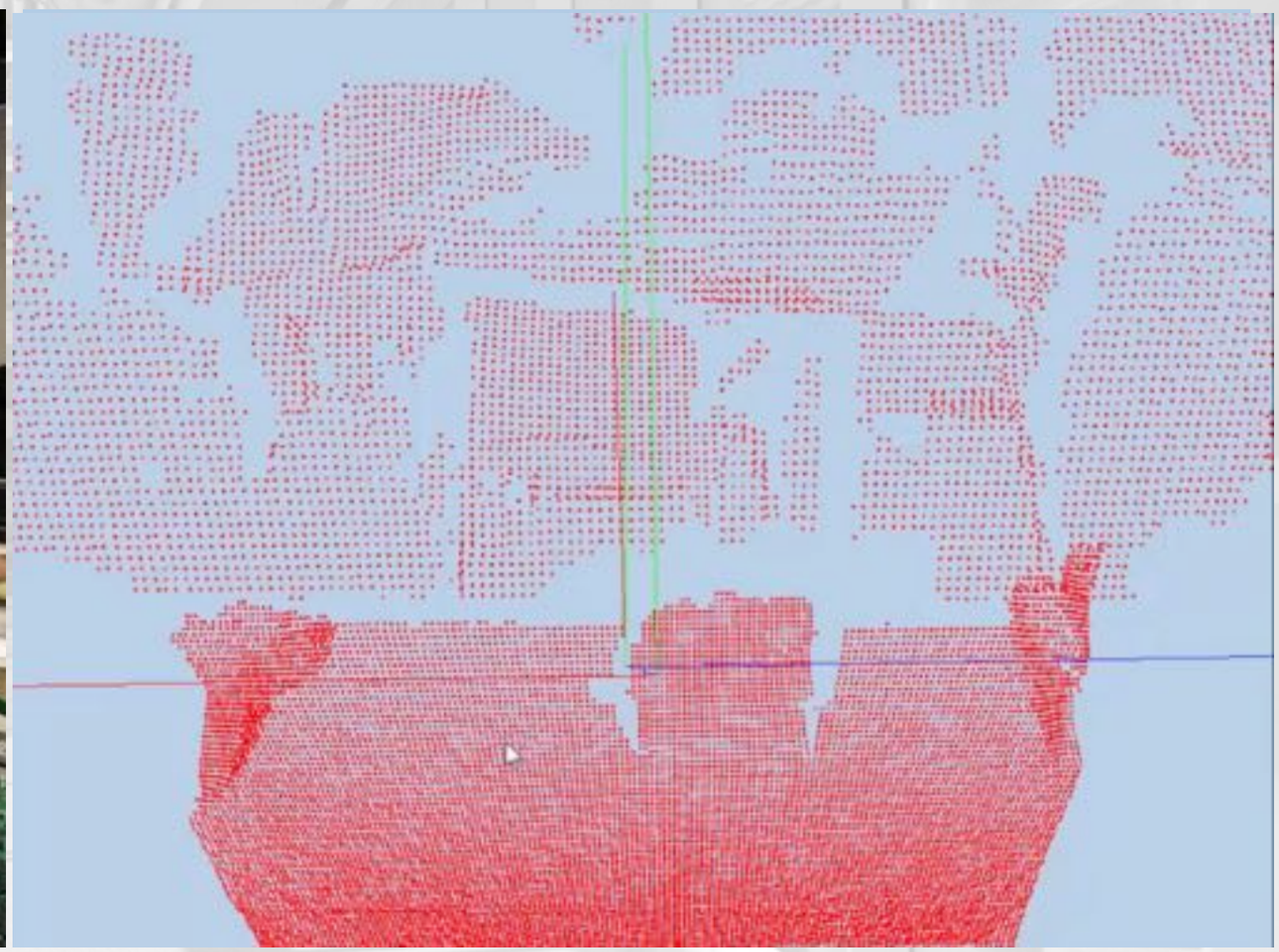
Find an object in the scene

ARLAB



A test environment in the lab



This is how we perceive the environment

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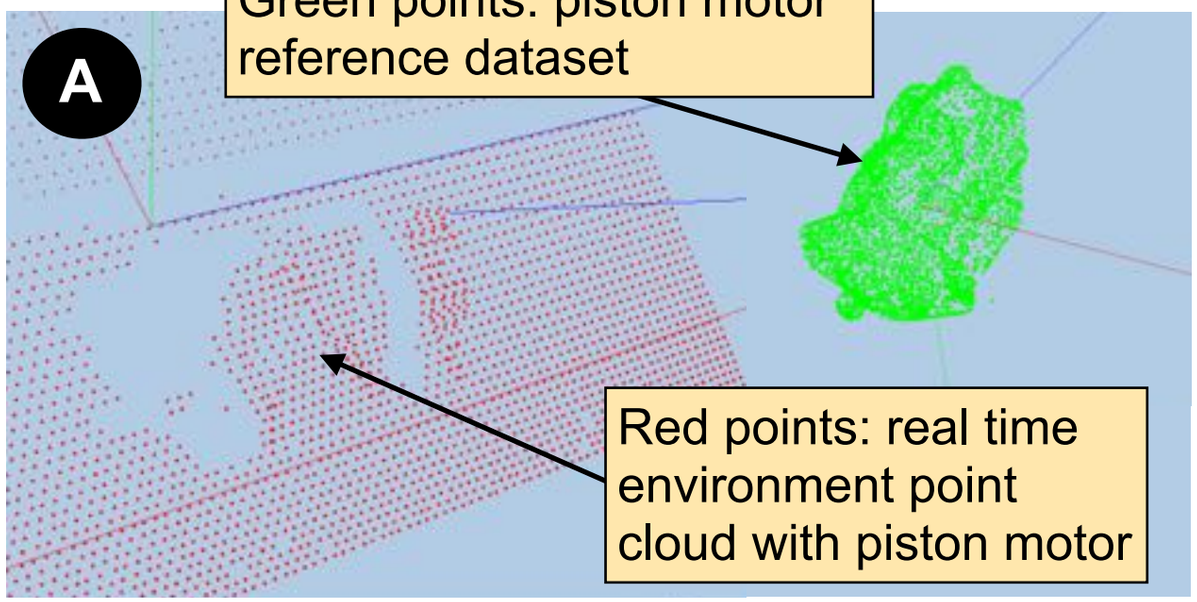
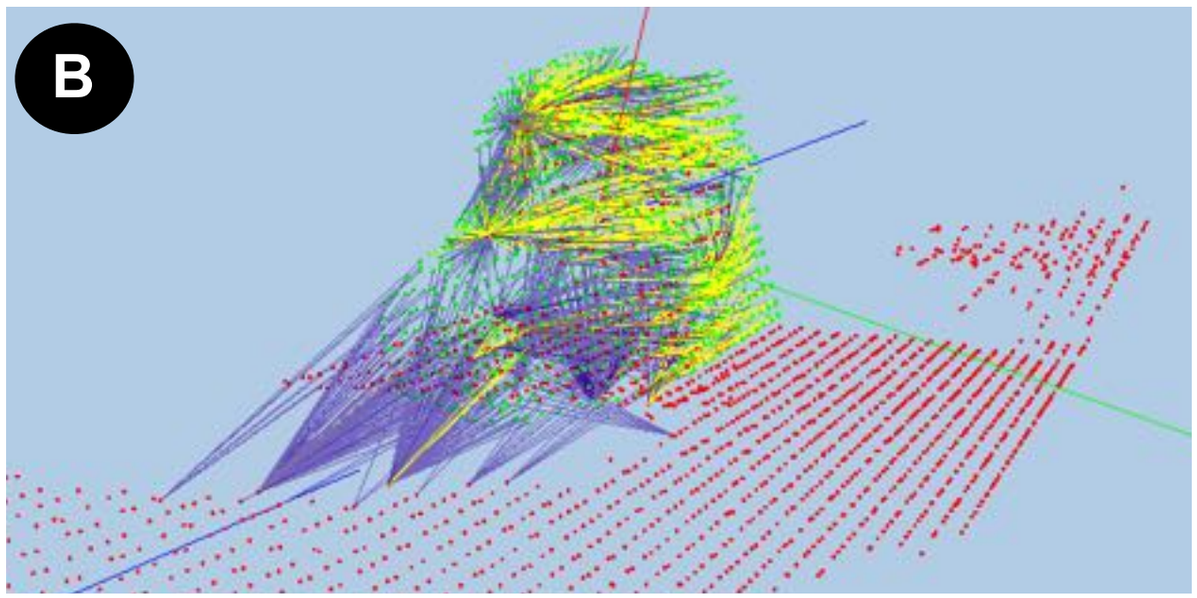
Find an Object in the Scene

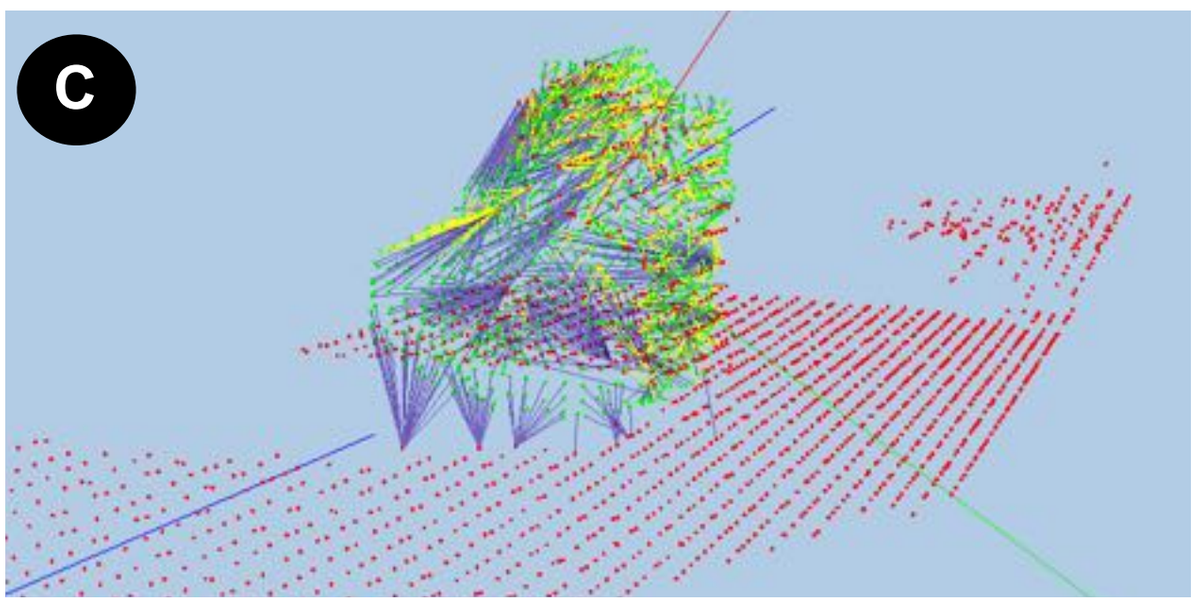
ARLAB



Object of interest: a piston motor.



First, feature descriptors are used to roughly find the piston motor in the point cloud.



Second, ICP further aligns the reference object with the associated points in the point cloud (recognition by alignment).

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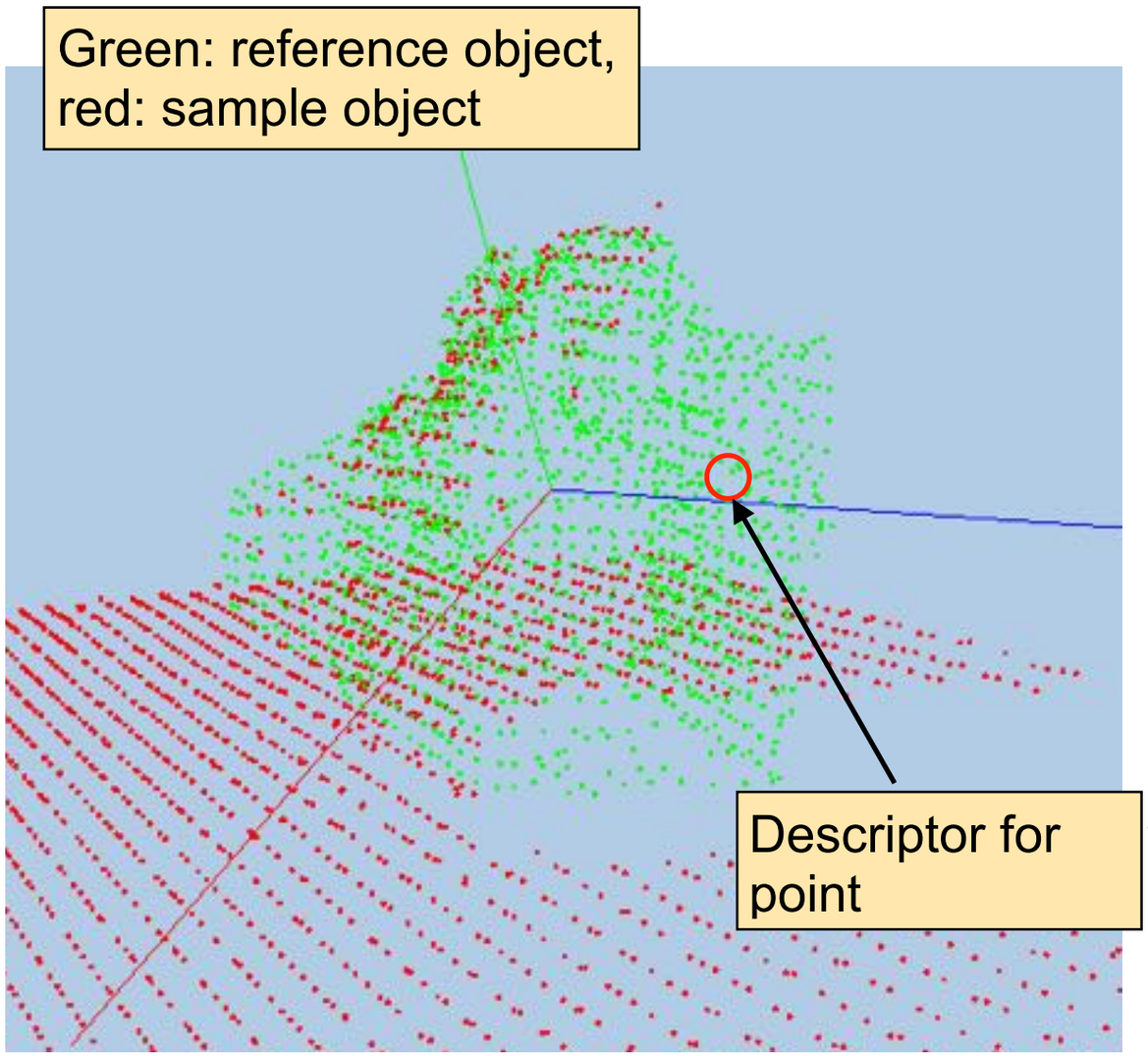
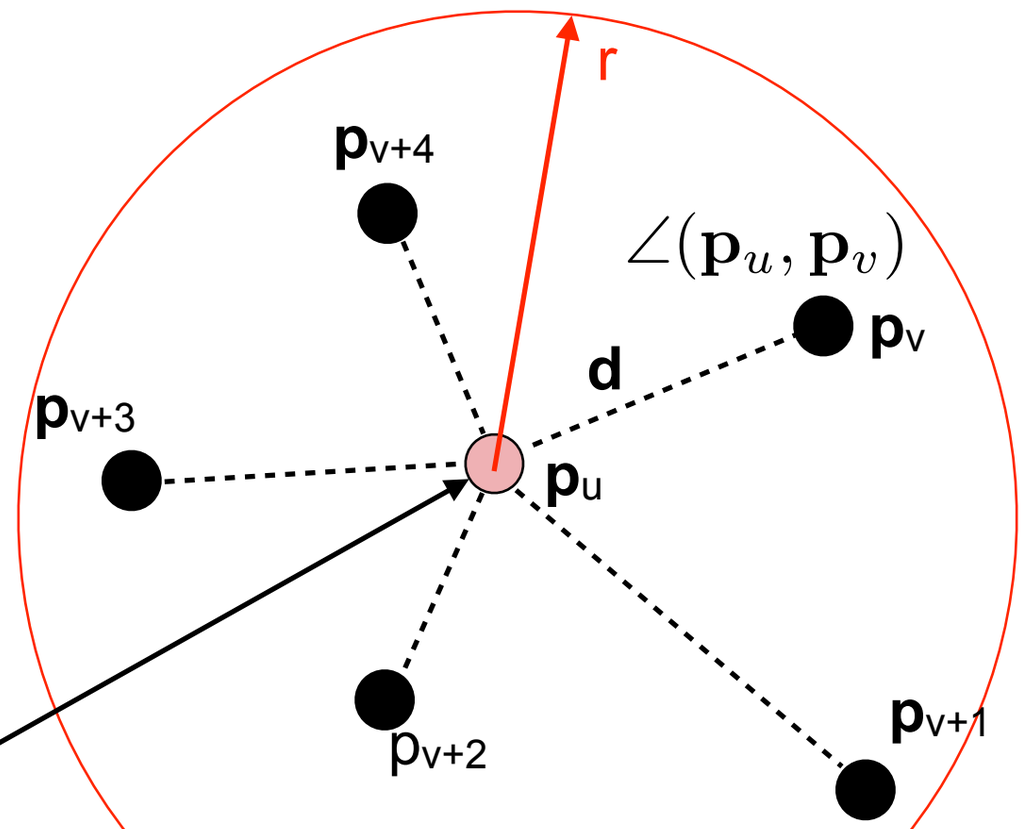
Feature Descriptor

A feature descriptor is a mathematical model to describe the characteristics of the surface curvature around a point.





$$f(\mathbf{u},\mathbf{v}) = \begin{pmatrix} f_1(\mathbf{u},\mathbf{v}) = ||\mathbf{p}_v - \mathbf{p}_u|| \\ f_2(\mathbf{u},\mathbf{v}) = \angle(\mathbf{n}_v, \mathbf{n}_u) \\ f_3(\mathbf{u},\mathbf{v}) = \angle(\mathbf{n}_v, \mathbf{p}_u - \mathbf{p}_v) \\ f_4(\mathbf{u},\mathbf{v}) = \angle(\mathbf{n}_u, \mathbf{p}_v - \mathbf{p}_u) \end{pmatrix}$$

inspired by:
Rusu, R. B., Blodow, N., and Beetz, M., 2009. “Fast point feature histograms (fpfh) for 3d registration”. In Int. Conf. on Robotics and Automation, pp. 3212 – 3217.

Drost, B., Ulrich, M., Navab, N., and Ilic., S., 2010. “Model globally, match locally: Efficient and robust 3d object recognition”. In Proc. IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pp. 998 – 1005.

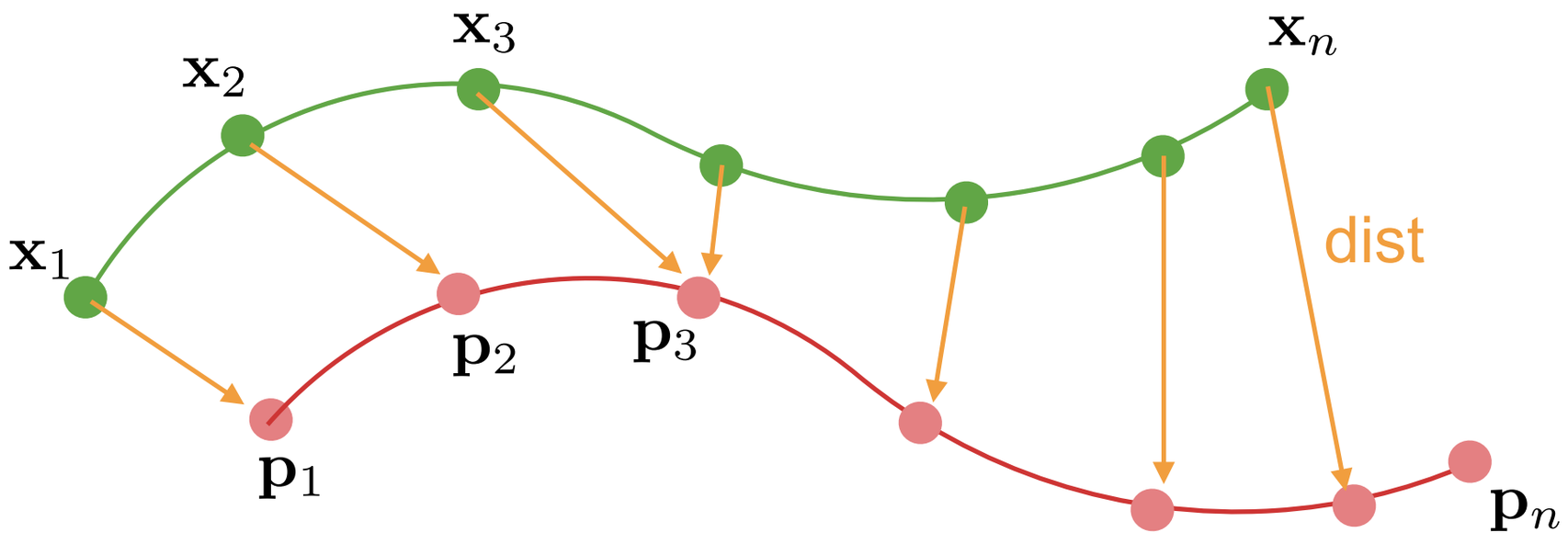
ICP Error Metric

Alignment error:

$$E(R, \mathbf{t}) = \frac{1}{N} \sum_{i=1}^{N} ||\mathbf{p}_i - R\,\mathbf{x}_i - \mathbf{t}||^2$$

Minimize the error *E:*

$$\arg\min(E(R, \mathbf{t}))$$



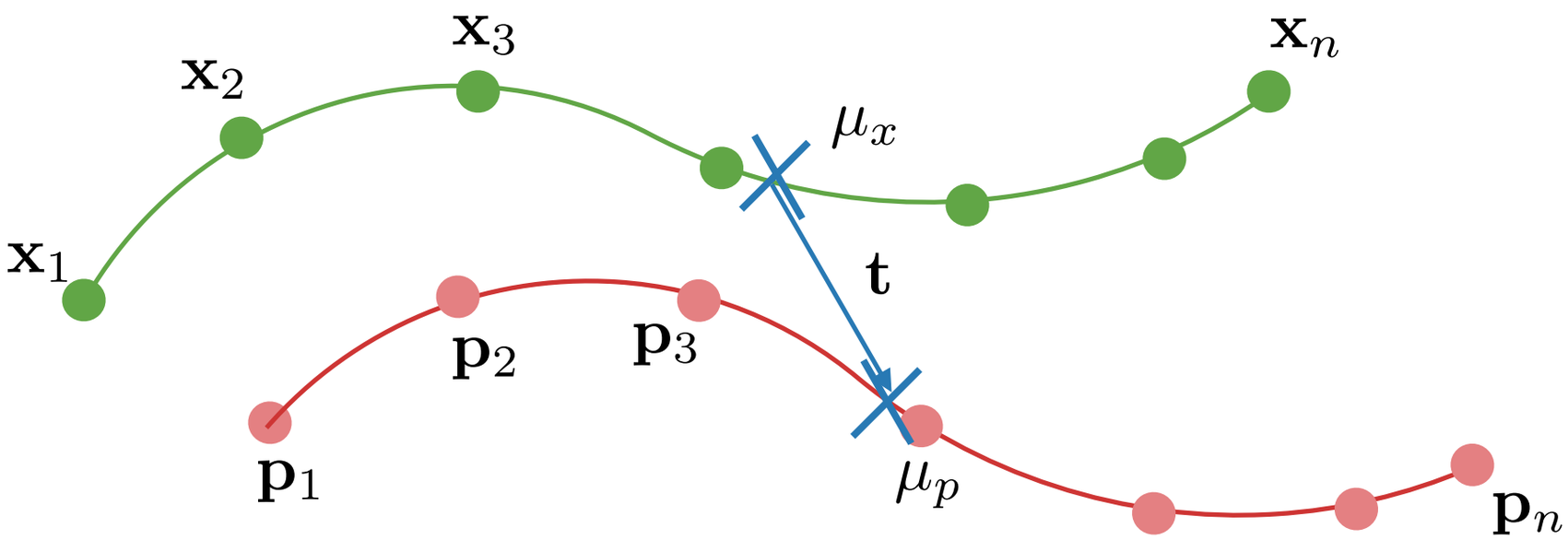
Translation

Calculate the centroid between of both point clouds

$$\mu_x = \frac{1}{N}\sum_{i=1}^{N}\mathbf{x}_i \text{ and } \mu_p = \frac{1}{N}\sum_{i=1}^{N}\mathbf{p}_i$$

Calculate the distance

$$\mathbf{t} = \mu_x - \mu_p$$



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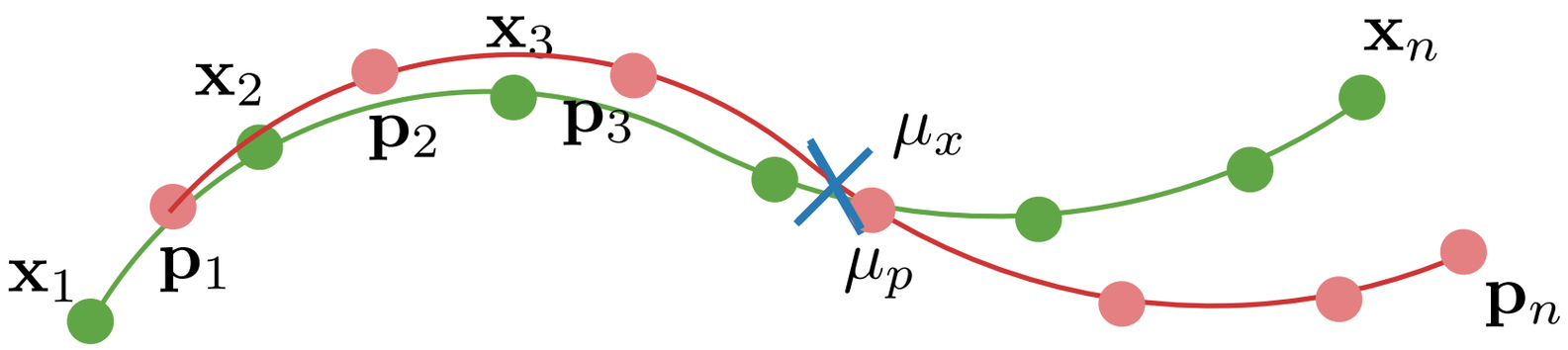


Move the centroids to each other

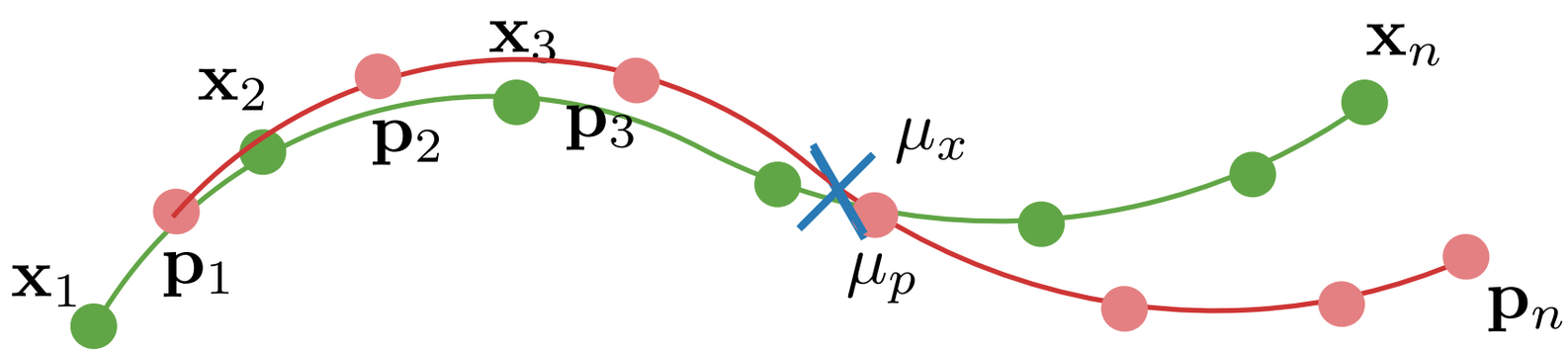
Rotation

The center for the transformation is the centroid of both point sets:

$$\mu_x = \frac{1}{N}\sum_{i=1}^{N}\mathbf{x}_i \text{ and } \mu_p = \frac{1}{N}\sum_{i=1}^{N}\mathbf{p}_i$$

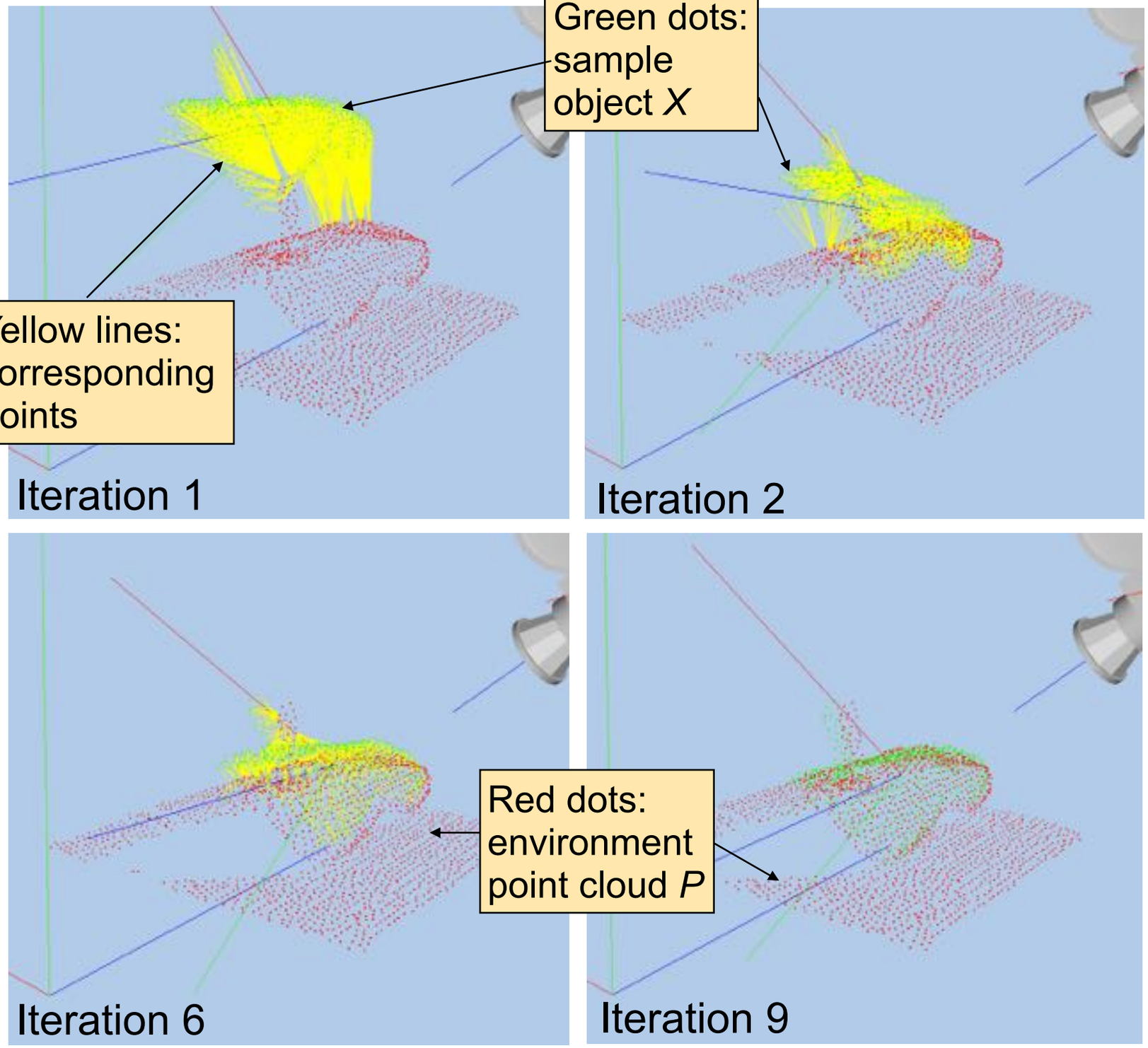
The rotation between two point clouds can be calculated as:

$$R = VU^T$$



Arun, K.S.; Huang, T. S.; Blostein, S. D., "Least-Squares Fitting of Two 3-D Point Sets," Pattern Analysis and Machine Intelligence, IEEE Transactions on , vol.PAMI-9, no.5, pp.698,700, Sept. 1987

Iterations



The entire ICP process requires multiple iterations to perfectly align an object.

Stop iteration when

$$\arg\min(E(R, \mathbf{t})) < min$$

or

when additional iterations do not improve the matching

or

after x iterations (prevent deadlocks)

Inspection, Assembly, Maintenance Assistance & Training

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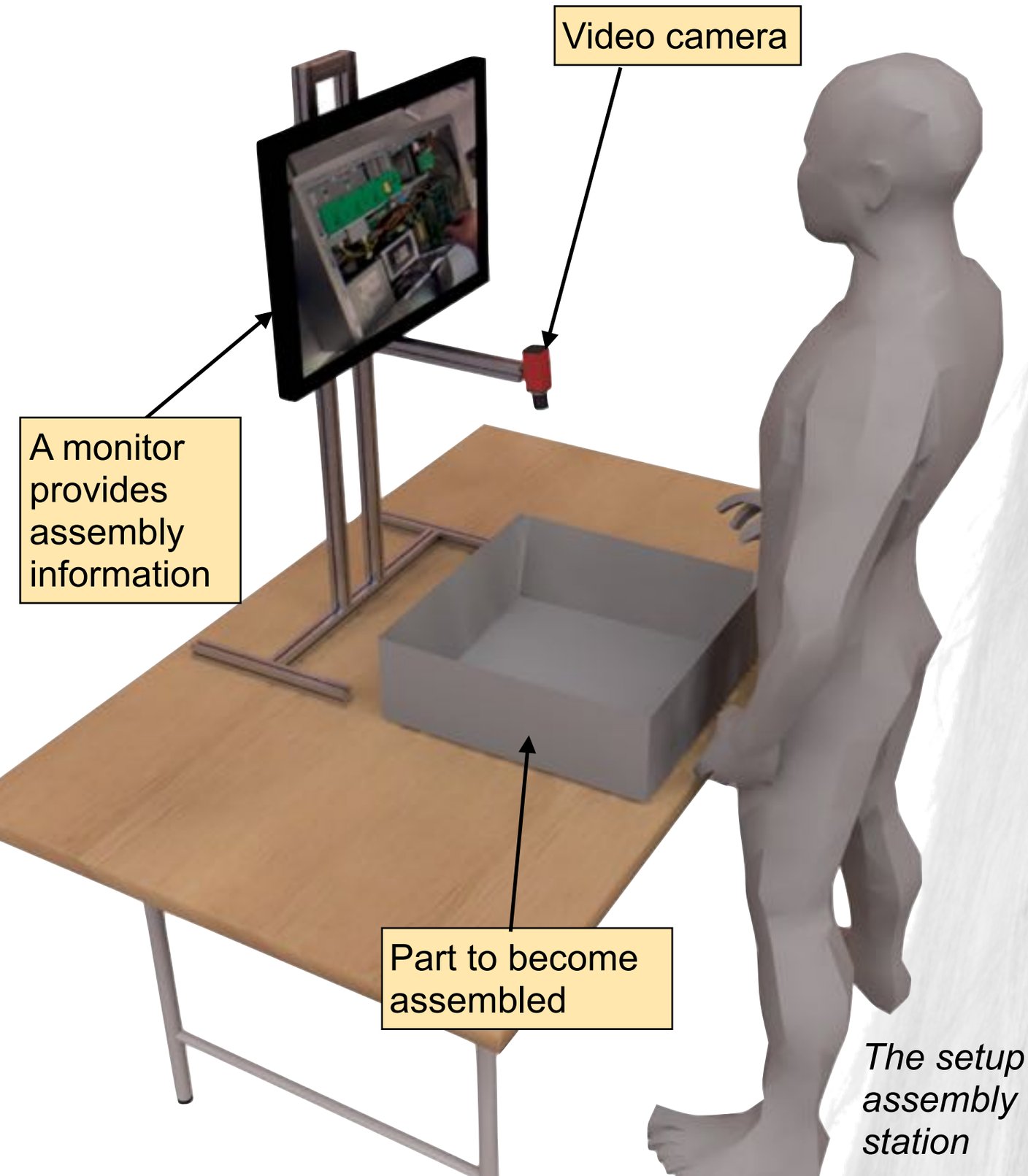

The setup of the AR assembly training station

We use augmented reality for training and in-field assistance in various domains and investigate approaches to effectively convey information to the user.

Goals:

- Efficient training of new employees
- Reduction of time and mistakes

Advantages:

- Fast information retrieval
- Prevent loss of focus

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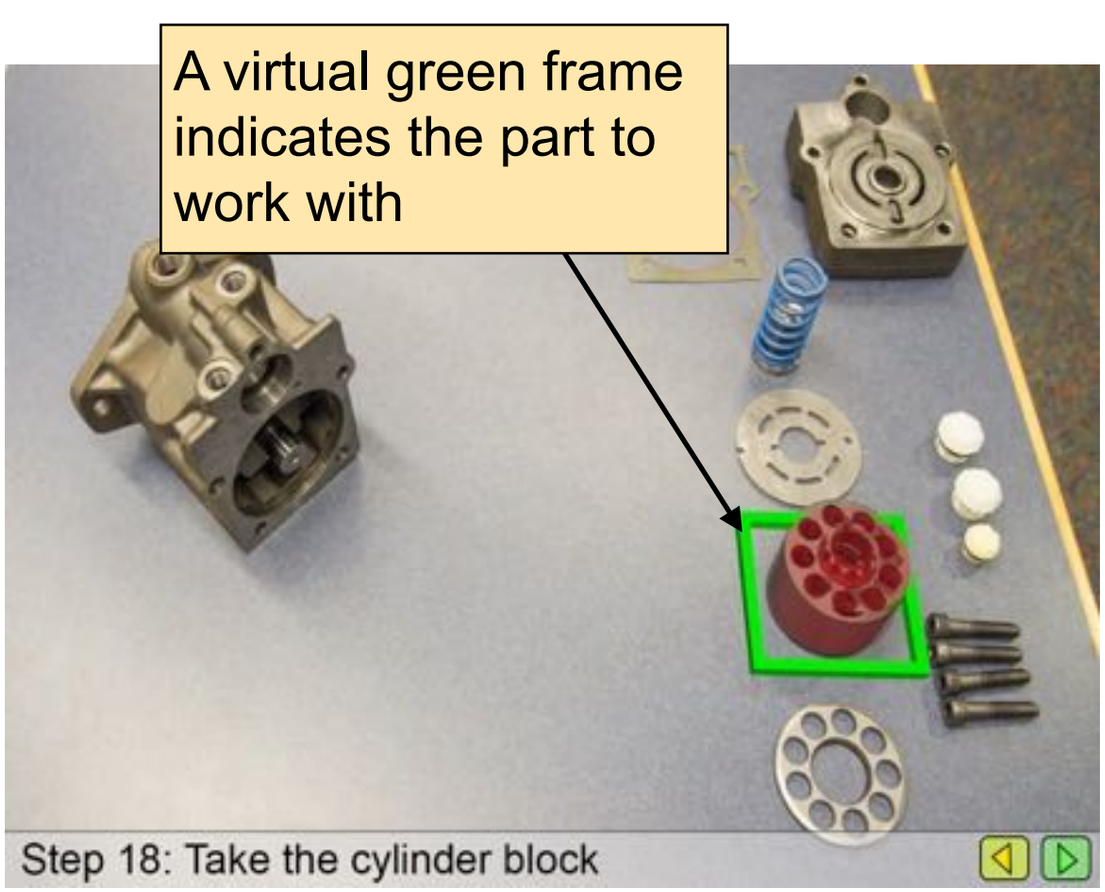
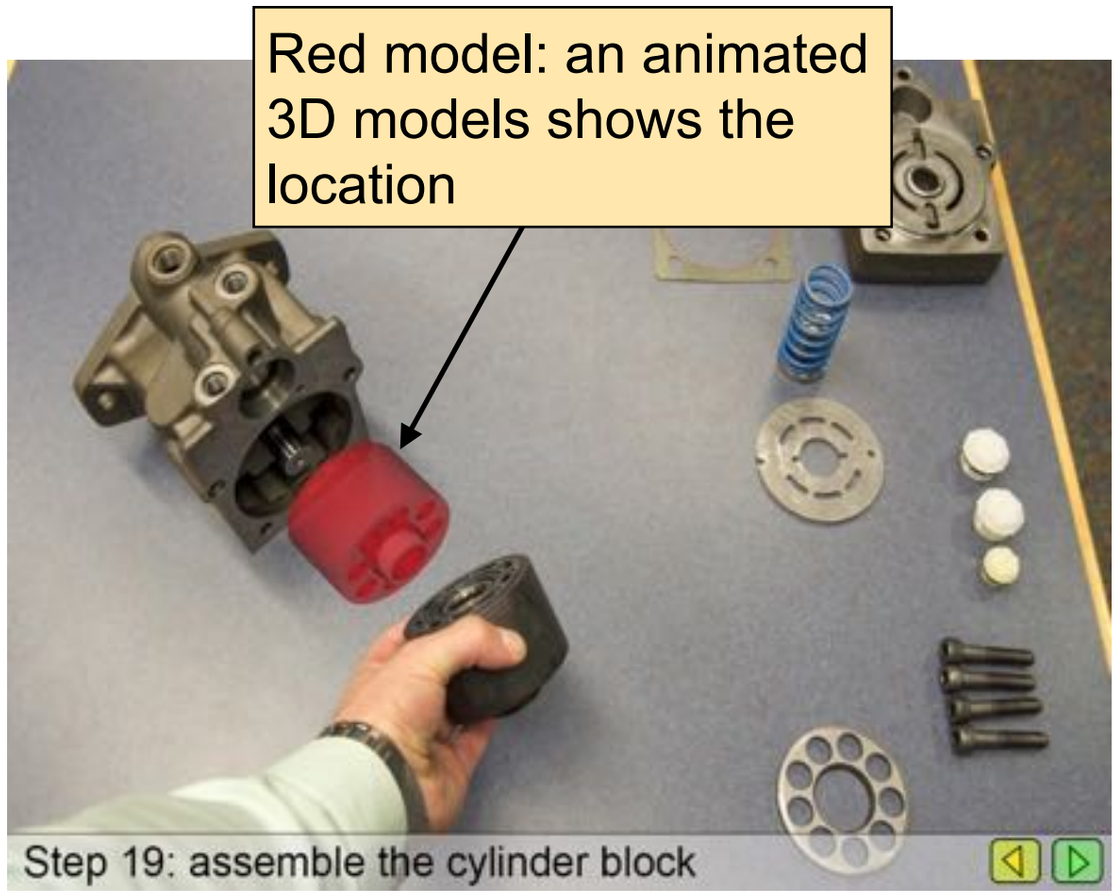
Visual Widgets

3D models indicate which parts need to be assembled as well as the assembly location.





Piston motor assembly

Visual widgets are used to:

- Identifies and shows the right part to inspect, assemble, disassemble, etc.
- Shows the assembly, inspection, etc. location
- Provides task-related information, tailored to the user's needs

Assembly Assistance (Video)

Real time

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Work in progress

Augmented Reality Assembly Support

with

a Hololens

Rafael Radkowski
Jarid Ingebrand
Dec. 2016

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YouTube https://youtu.be/VTBYPyWVEsE

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The Hololens

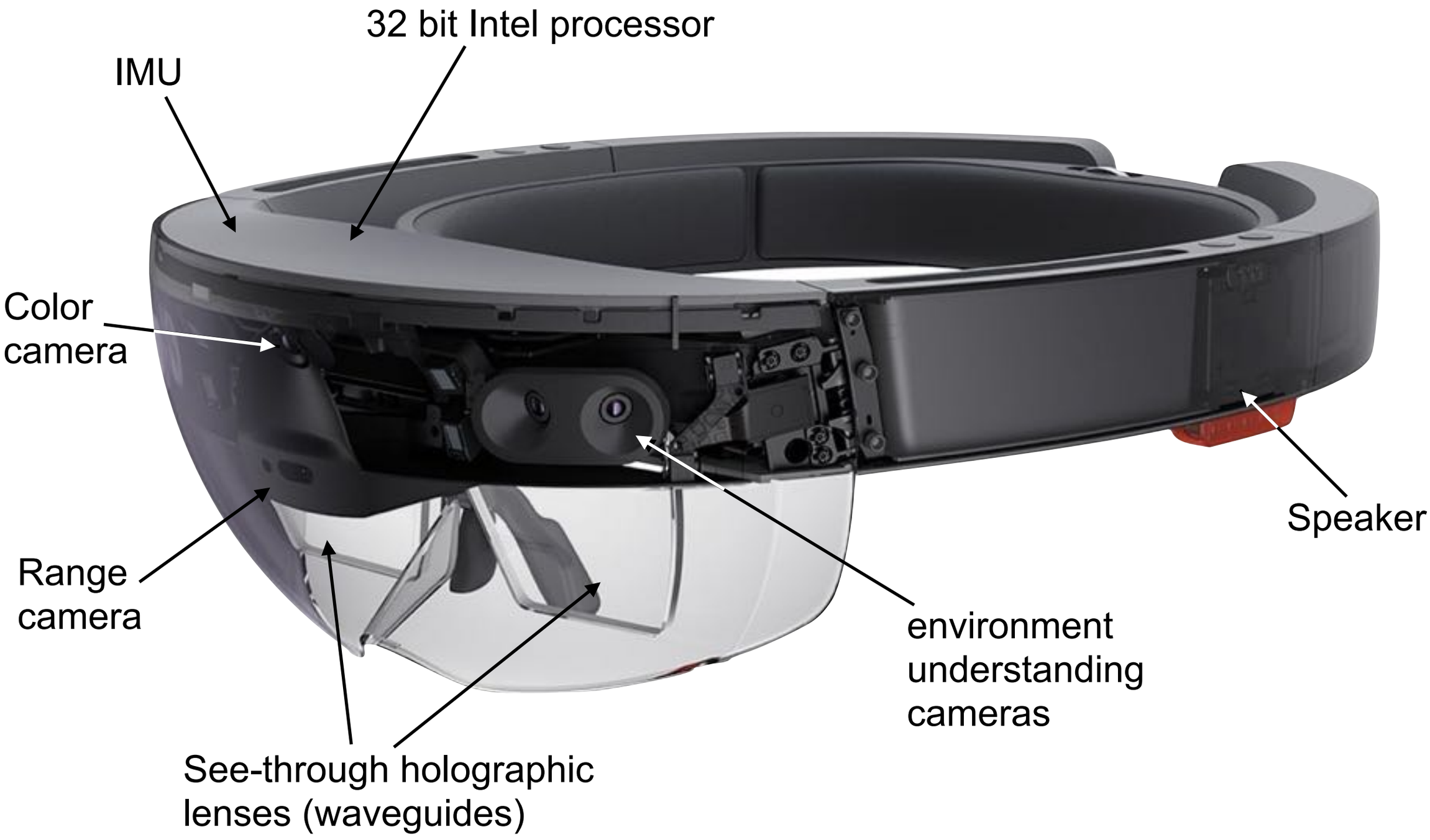

image source: Microsoft

Inspection, Maintenance & Service

Conveying object-related information is the key feature

Service instructions on a mobile device

Vehicle maintenance instructions on a tablet computer (http://vr-12.com)

Going Big

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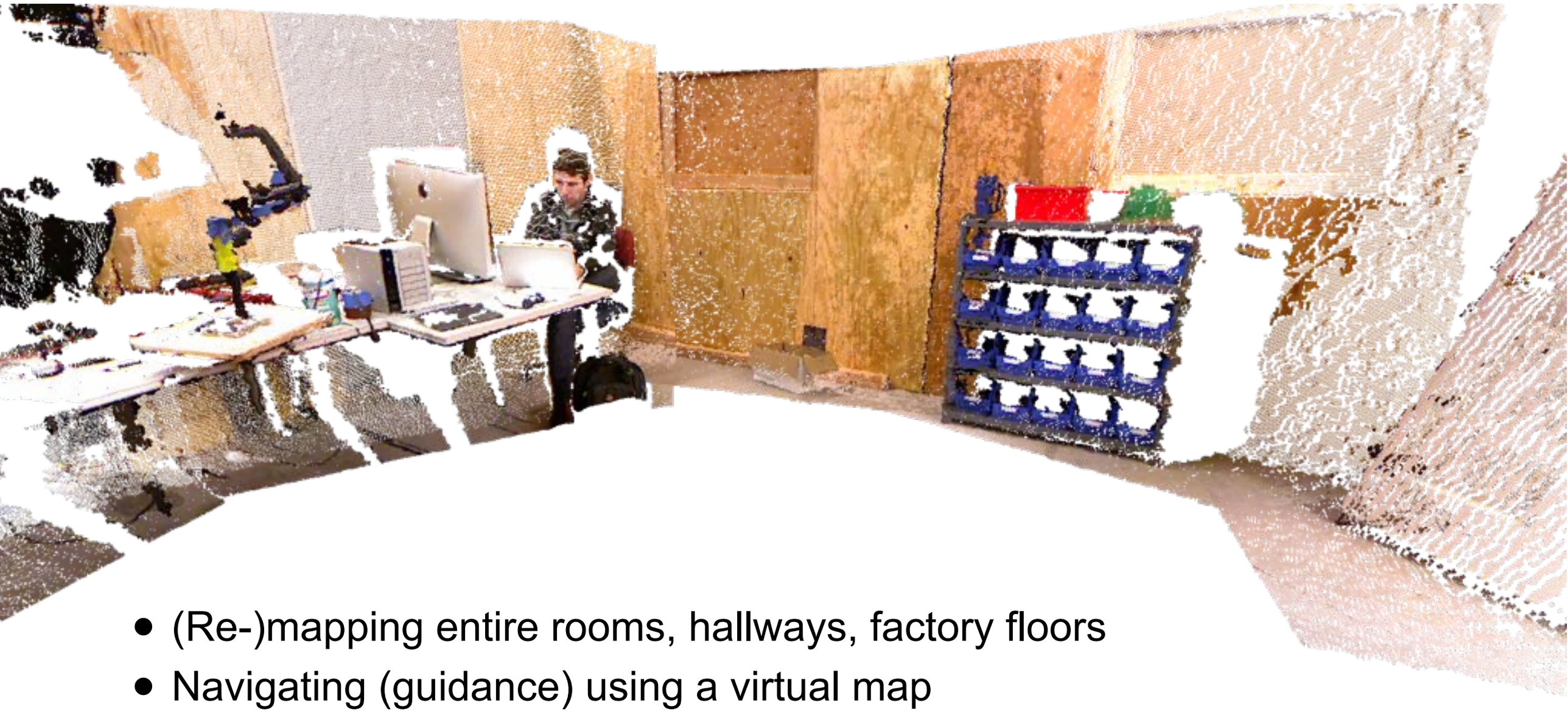
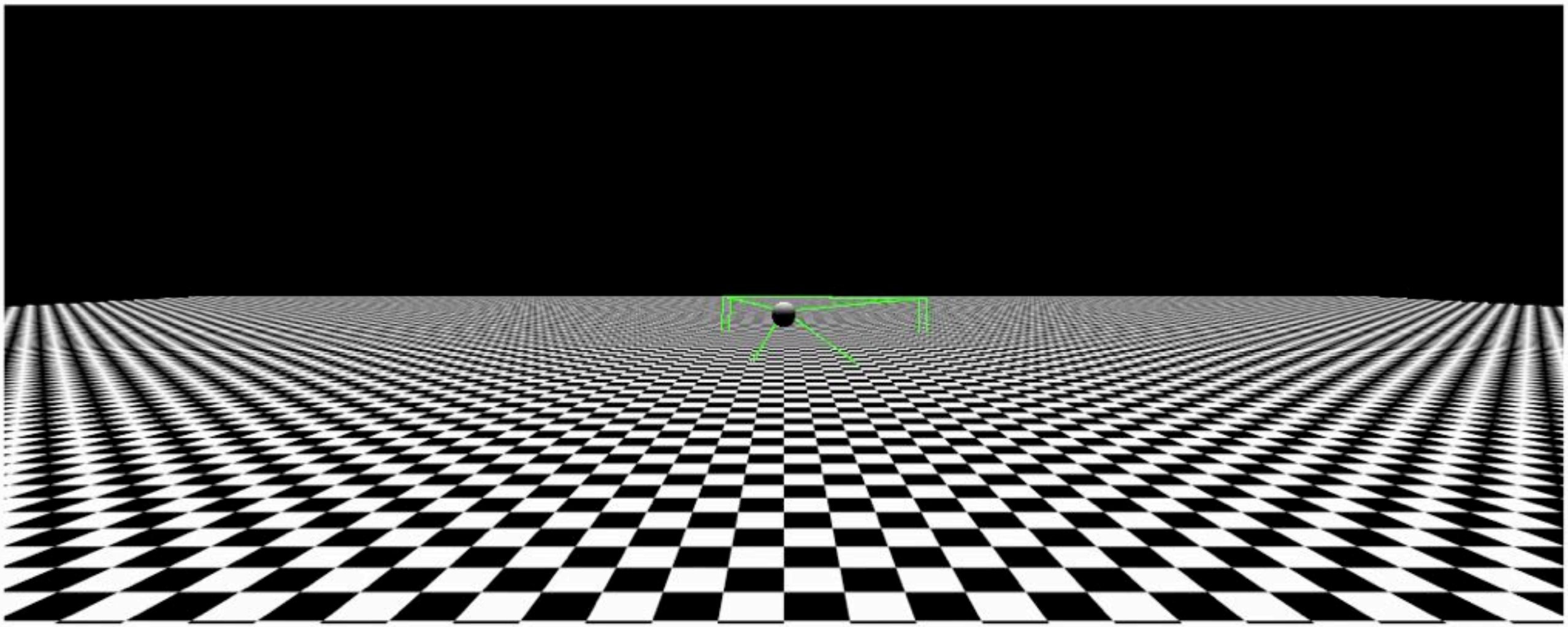


- (Re-)mapping entire rooms, hallways, factory floors
- Navigating (guidance) using a virtual map

Mapping the Room



Recorded with the Microsoft HoloLens

Environment Sensing Capabilities

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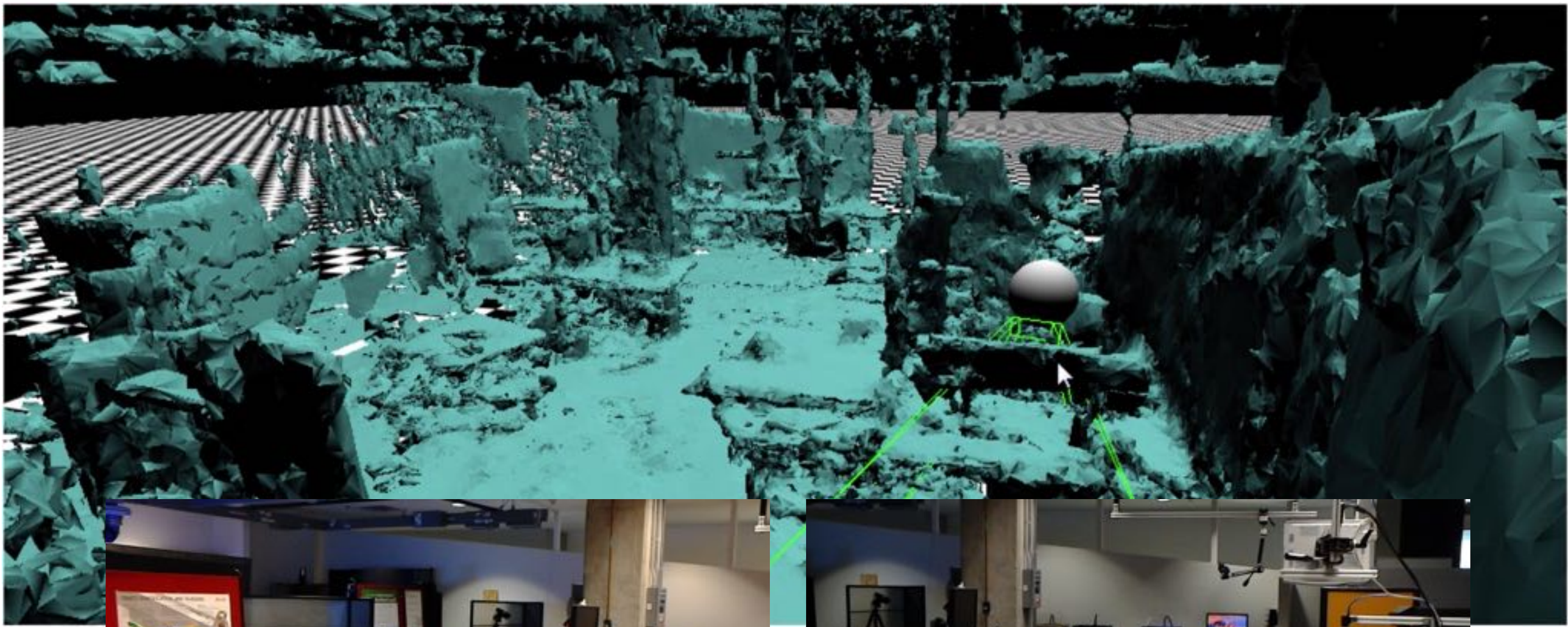

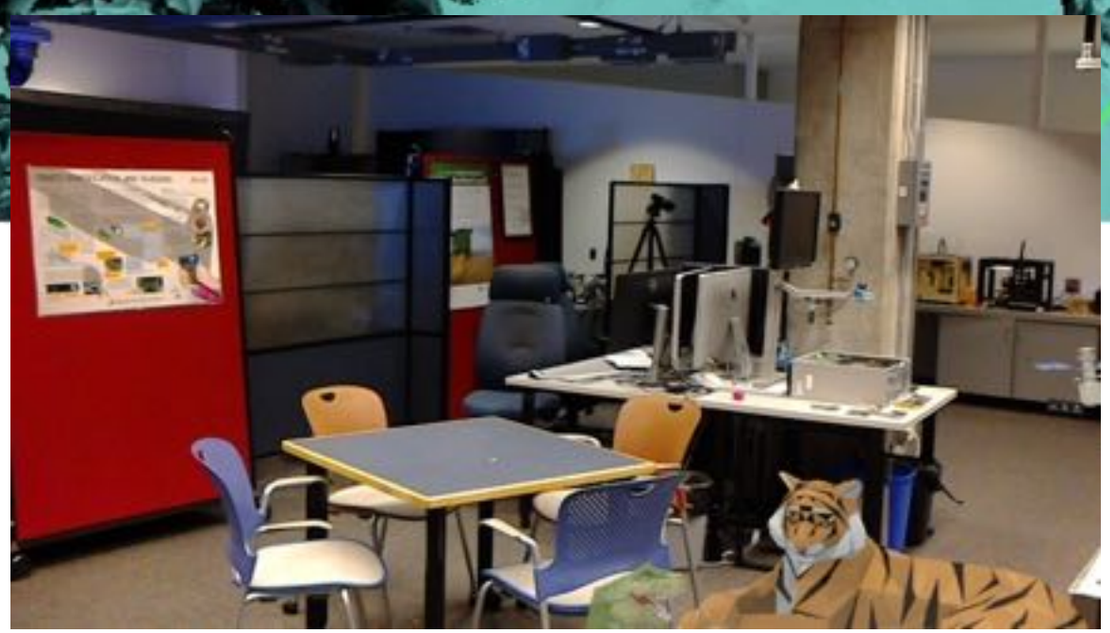

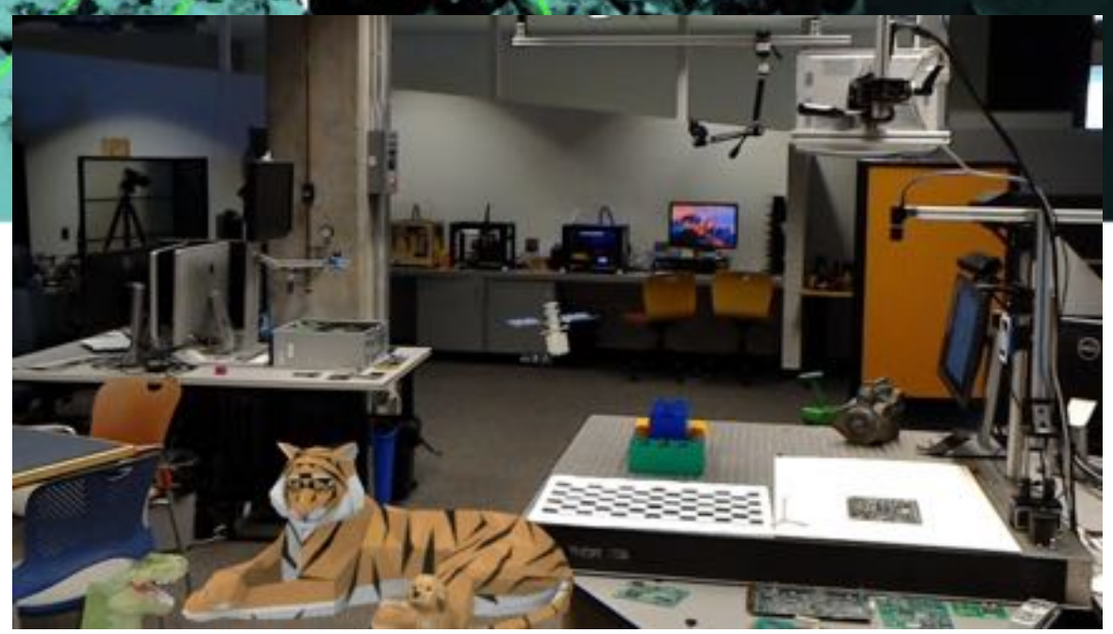

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Detect and Map Objects

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Detecting locations (= objects) and tag them.

Concept Drawing

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User Guidance

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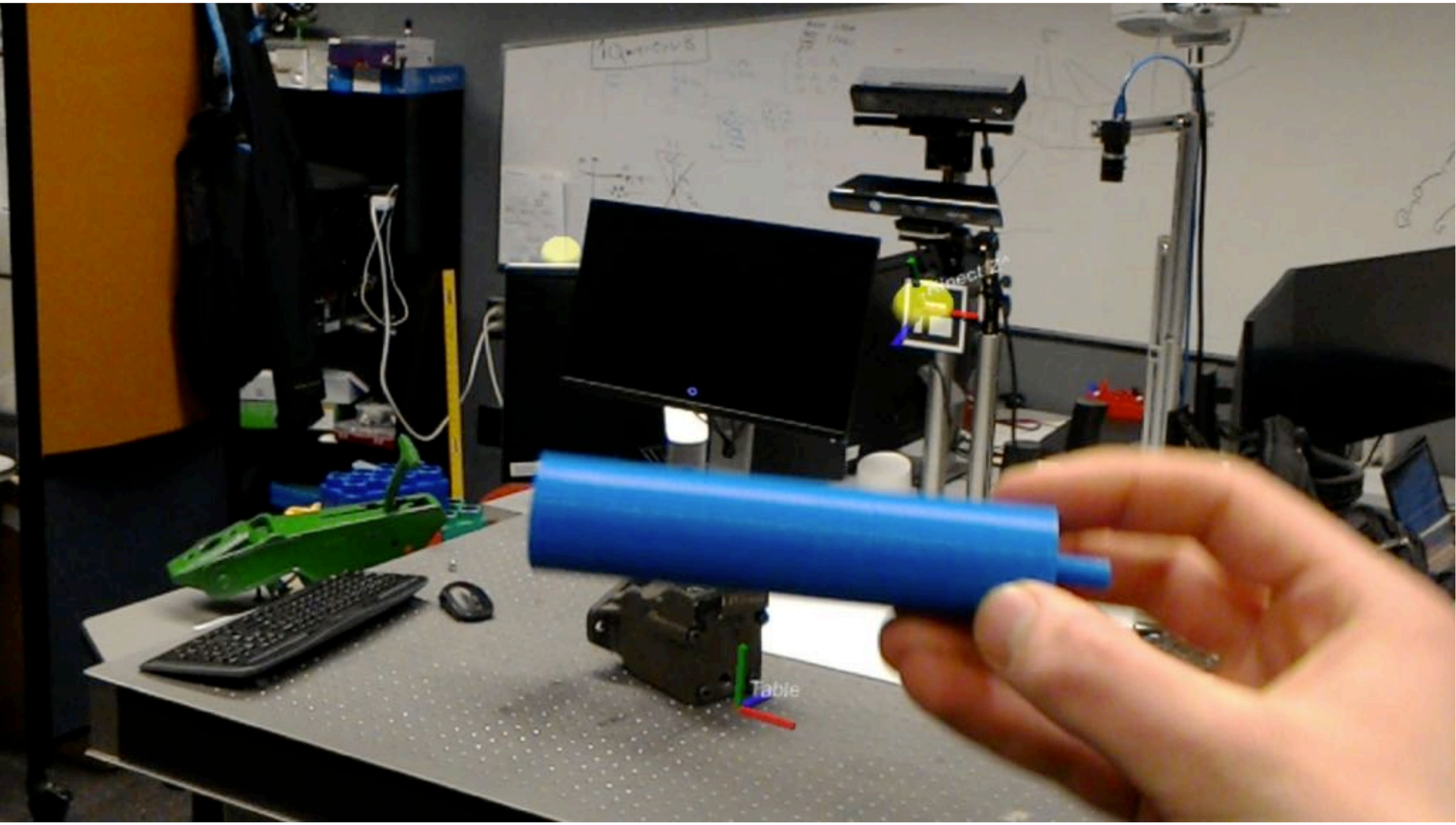

Kinect behind the user

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Video

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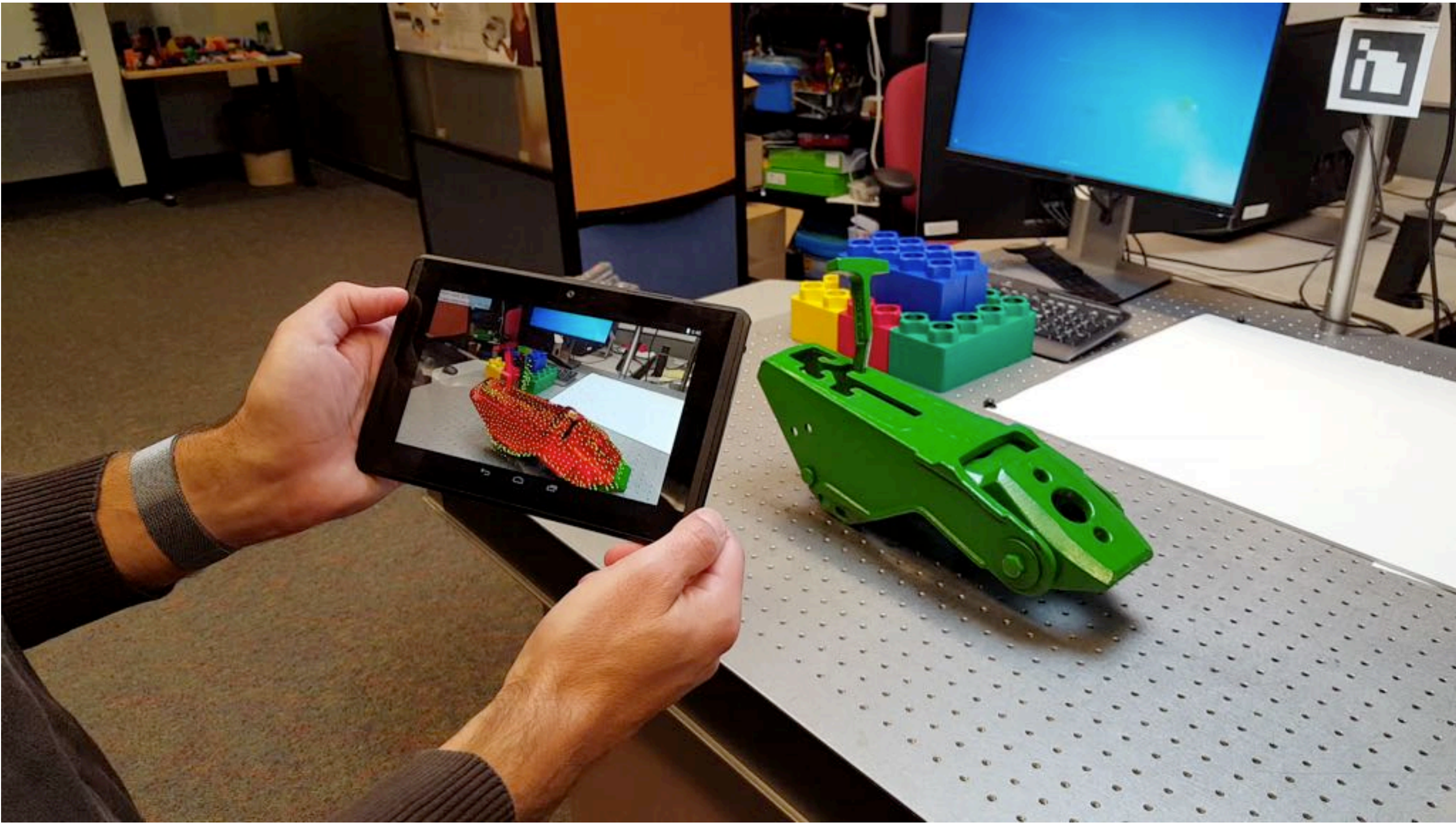

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Video

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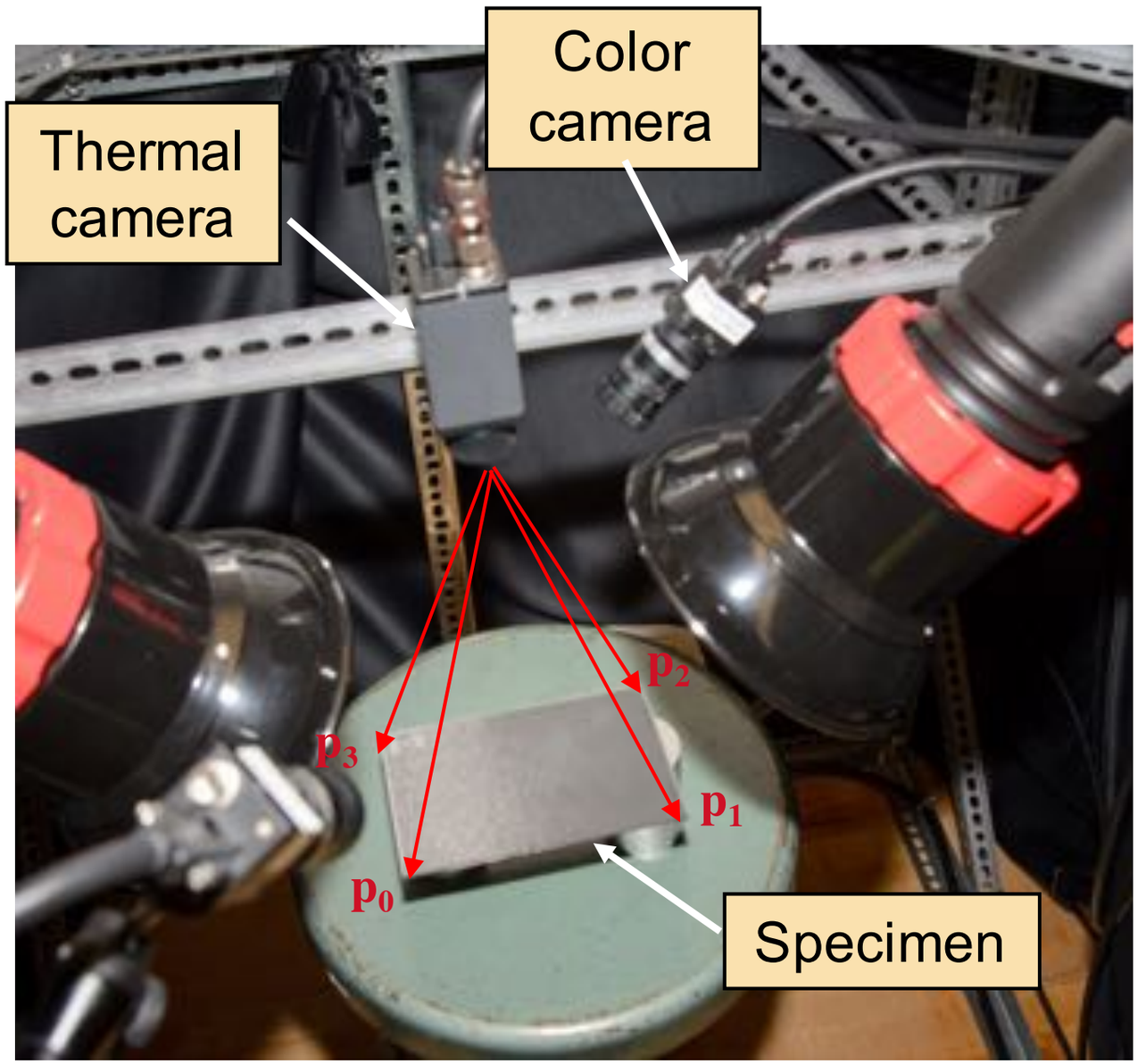
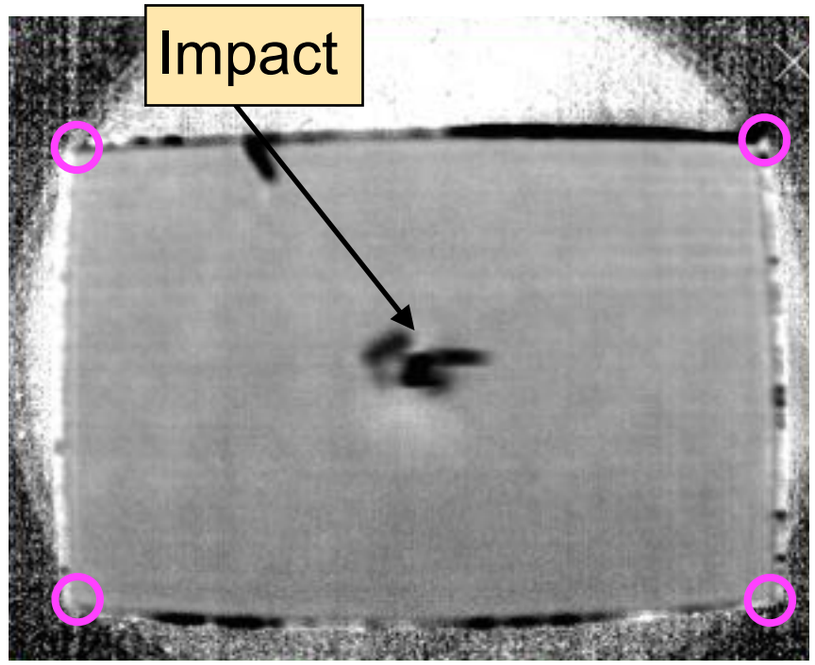
Flash Thermography



Flash-thermography test setup at the CNDE

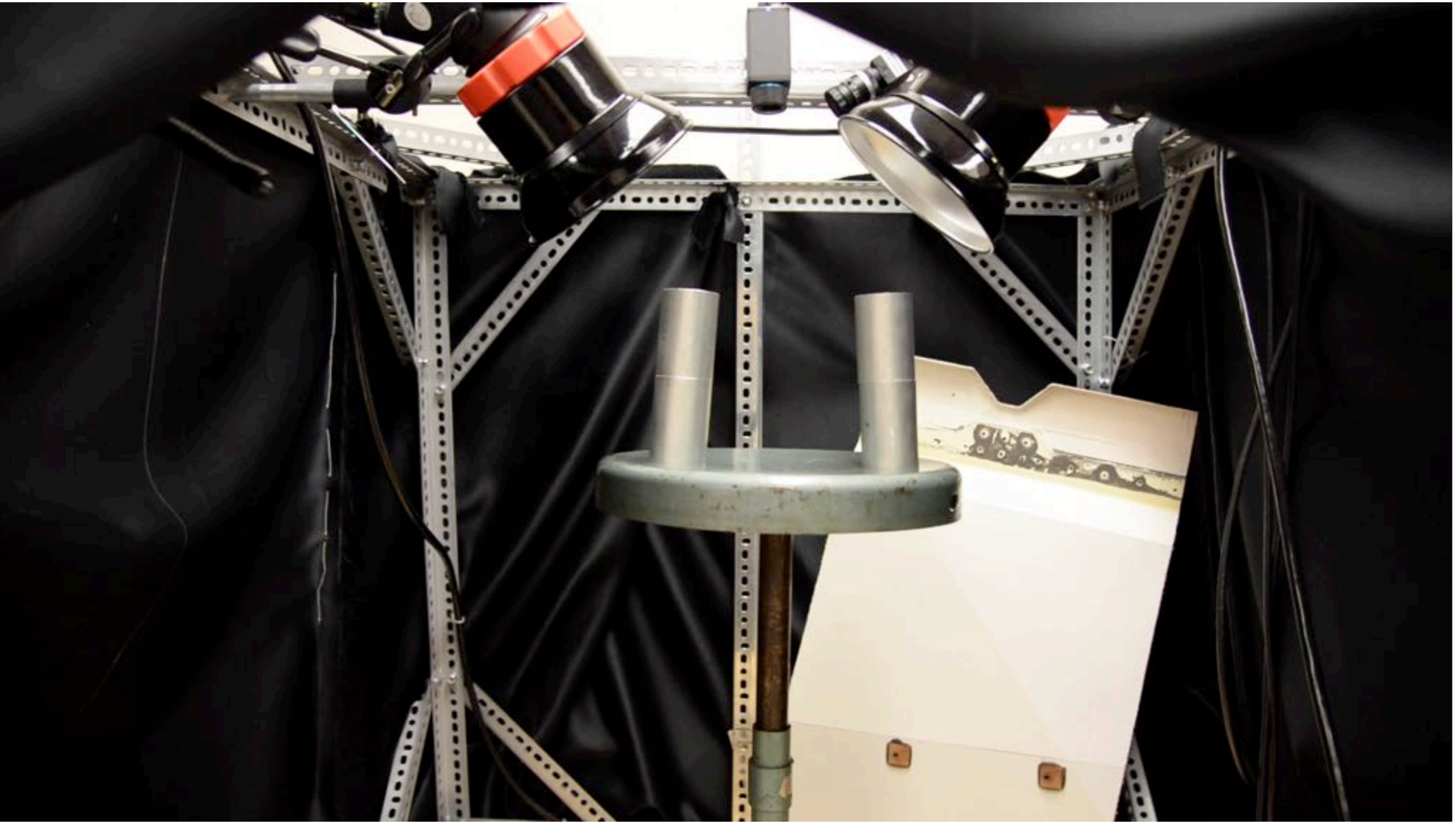
The goal of this project is an inspection location tracking system utilizing optical metrology, for specimen / component / product tracking in complex environments with focus on:



Radkowski, R., Wehr, D., Gregory, E., and Holland, S., "**Object Motion Tracking in the NDE Laboratory by Random Sample Iterative Closest Point**," Quantitative Nondestructive Evaluation, QNDE 2015, July 26-31, 2015, Minnesota, MN

Video

ARLAB



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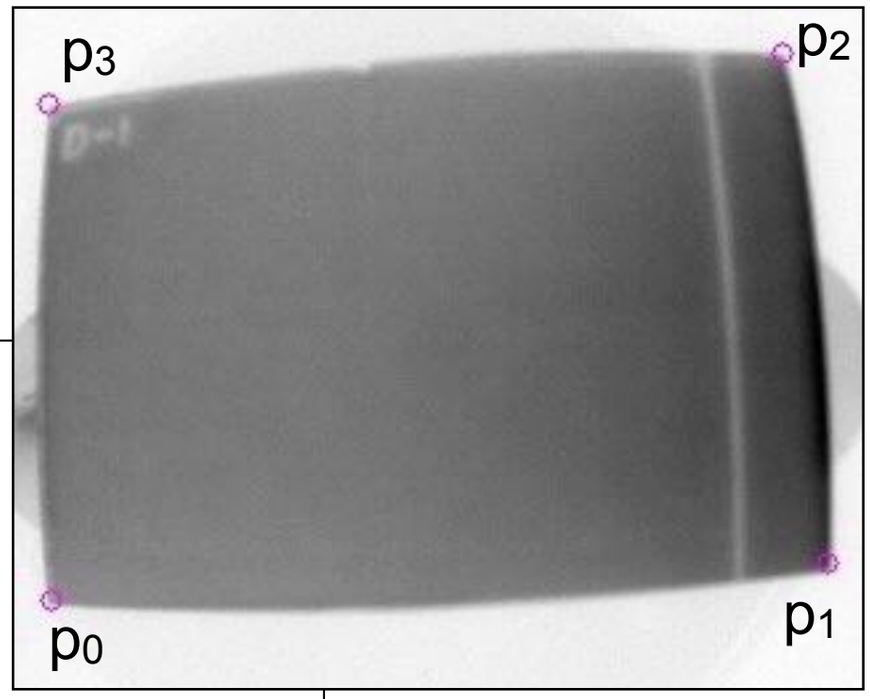
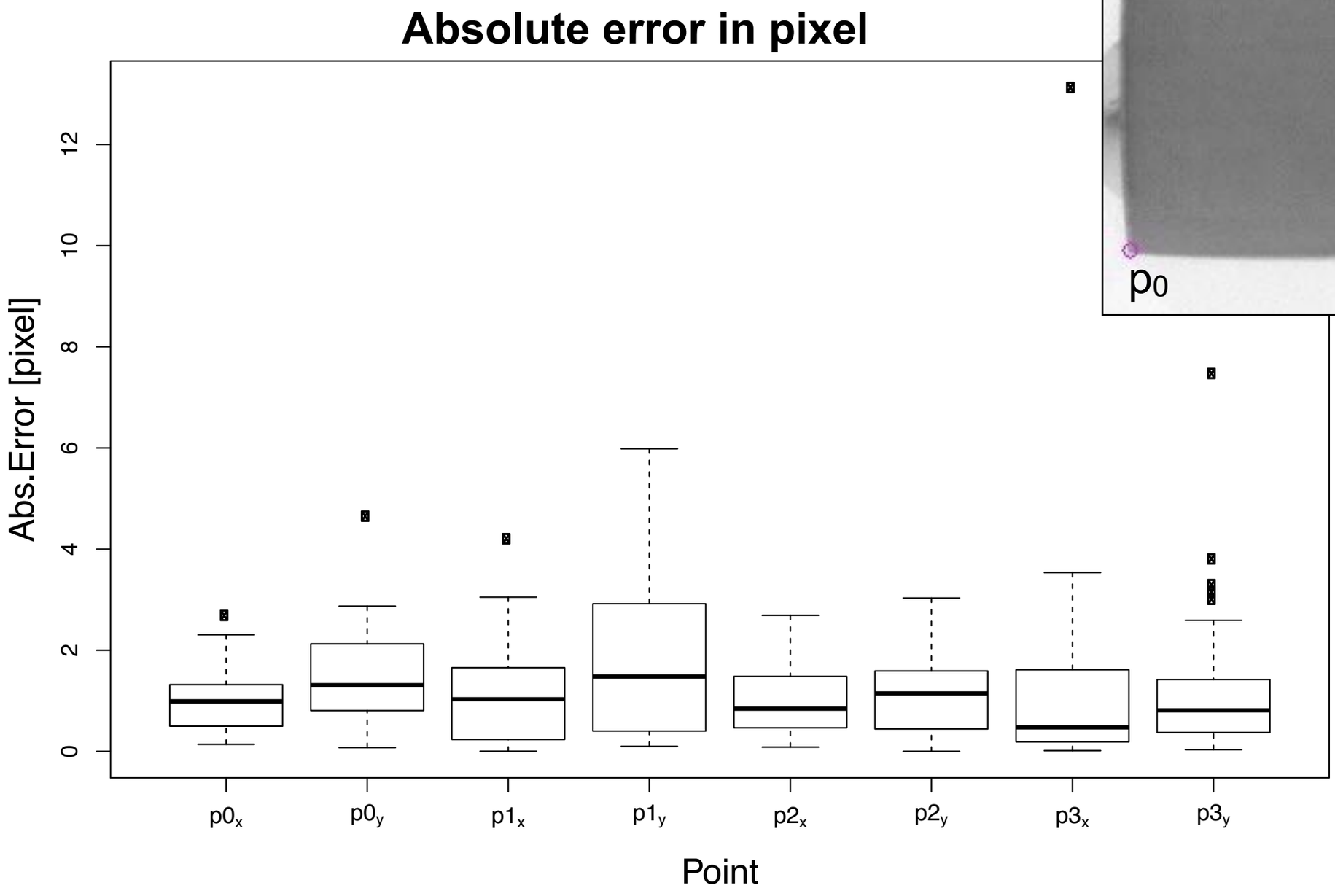
Results

Error in comparison to manually determined corner points.





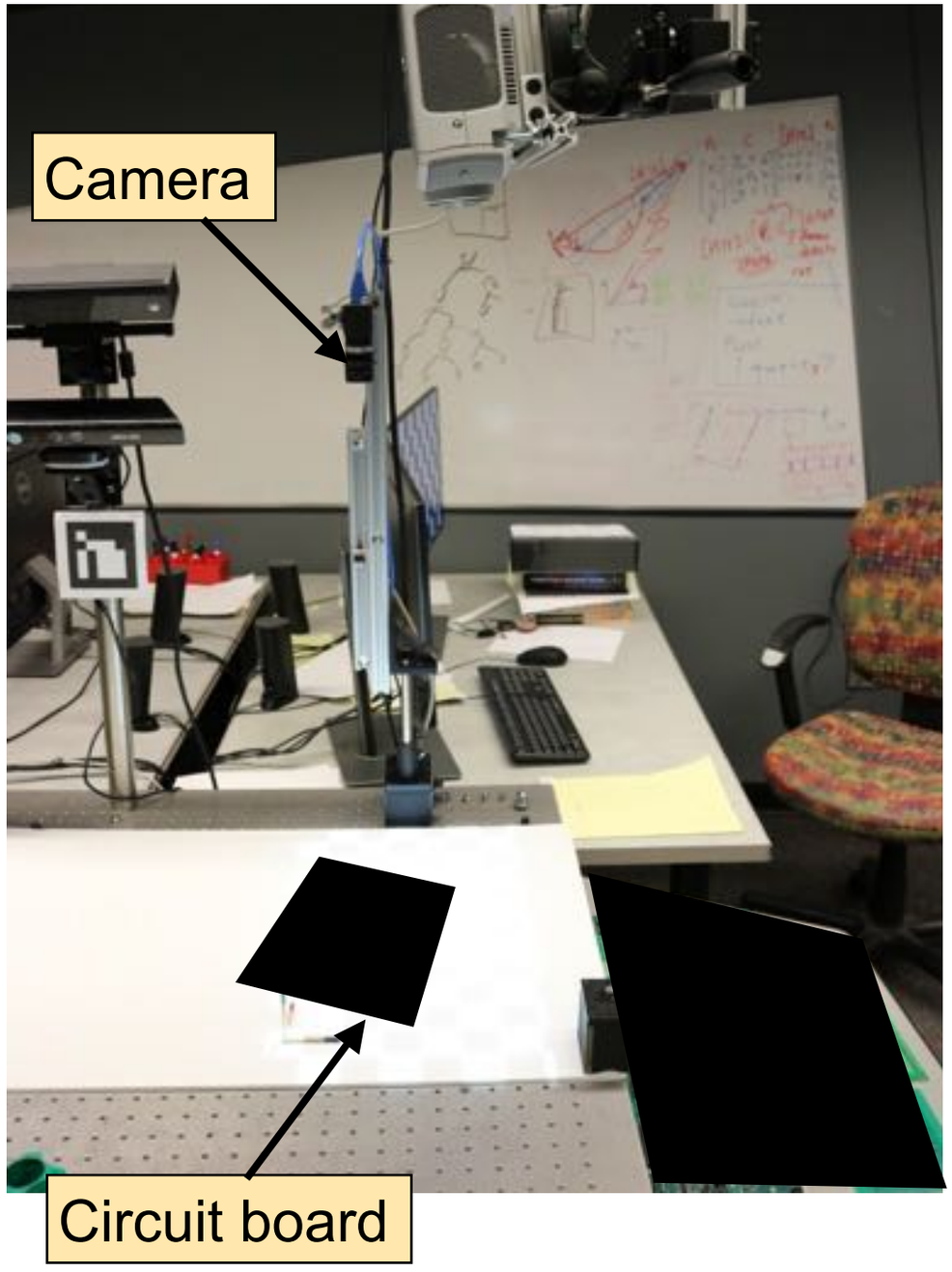
Mean: 1.2858

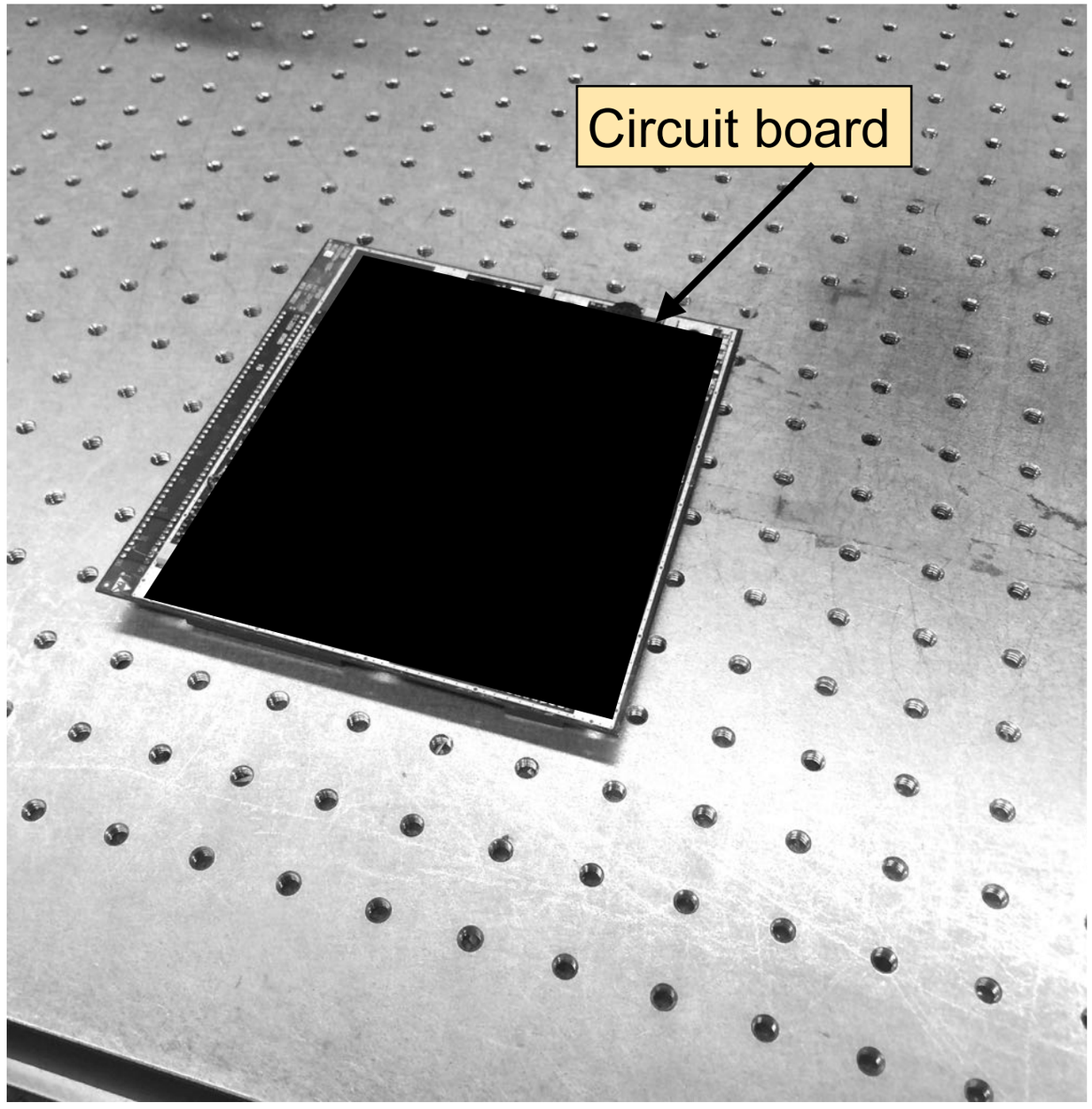
St Dev:1.3433

Circuit Board Inspection...

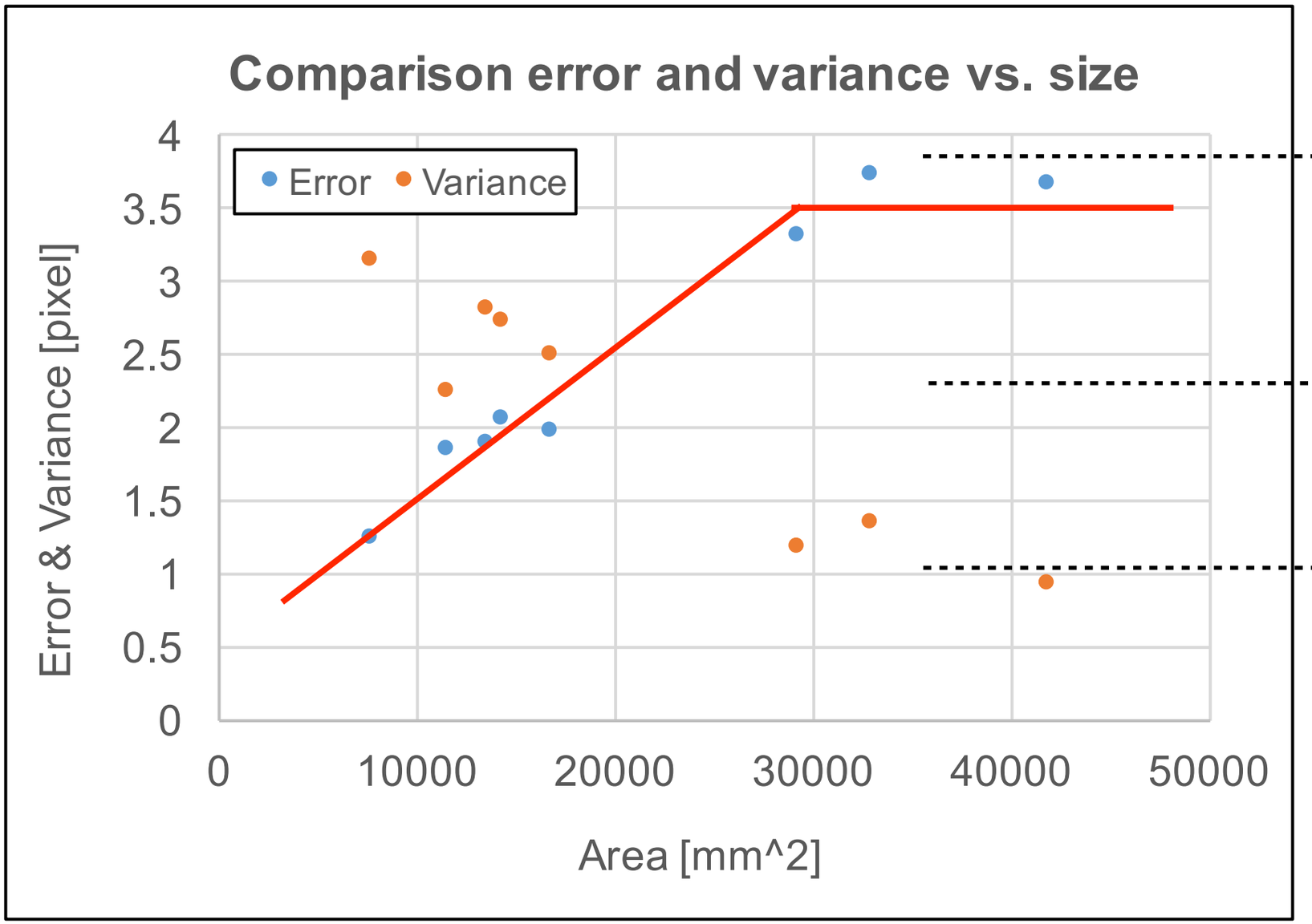
ARLAB

... of manually assembled components.





Circuit Board Inspection Results



1.8 mm

1 mm

0.5 mm

approximated with camera distance d = 640 mm

image size: 1280 x 1024 (pixel)

focal length: 9 mm

F: 8 (brightness 1:1.4)

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Summary

- Key Technologies: object recognition, tracking, and navigation
- Feature-based object recognition
- Navigation with large indoor maps
- Inspection applications

Future work:

- Ultrasonic inspection example (tracking the path of a transducer)
- Spatial registration of flash thermography data
- Factory floor inspection, maintenance, assembly training example

Thank you!

Questions

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