



Robot Calibration

Niharika Arora

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Overview



Robot Calibration

- Robot calibration is the process of determining the actual values of kinematic parameters of an industrial robot.
- Why does it matter?
 - Design tolerances
 - Variances in assembly
 - Other imperfections

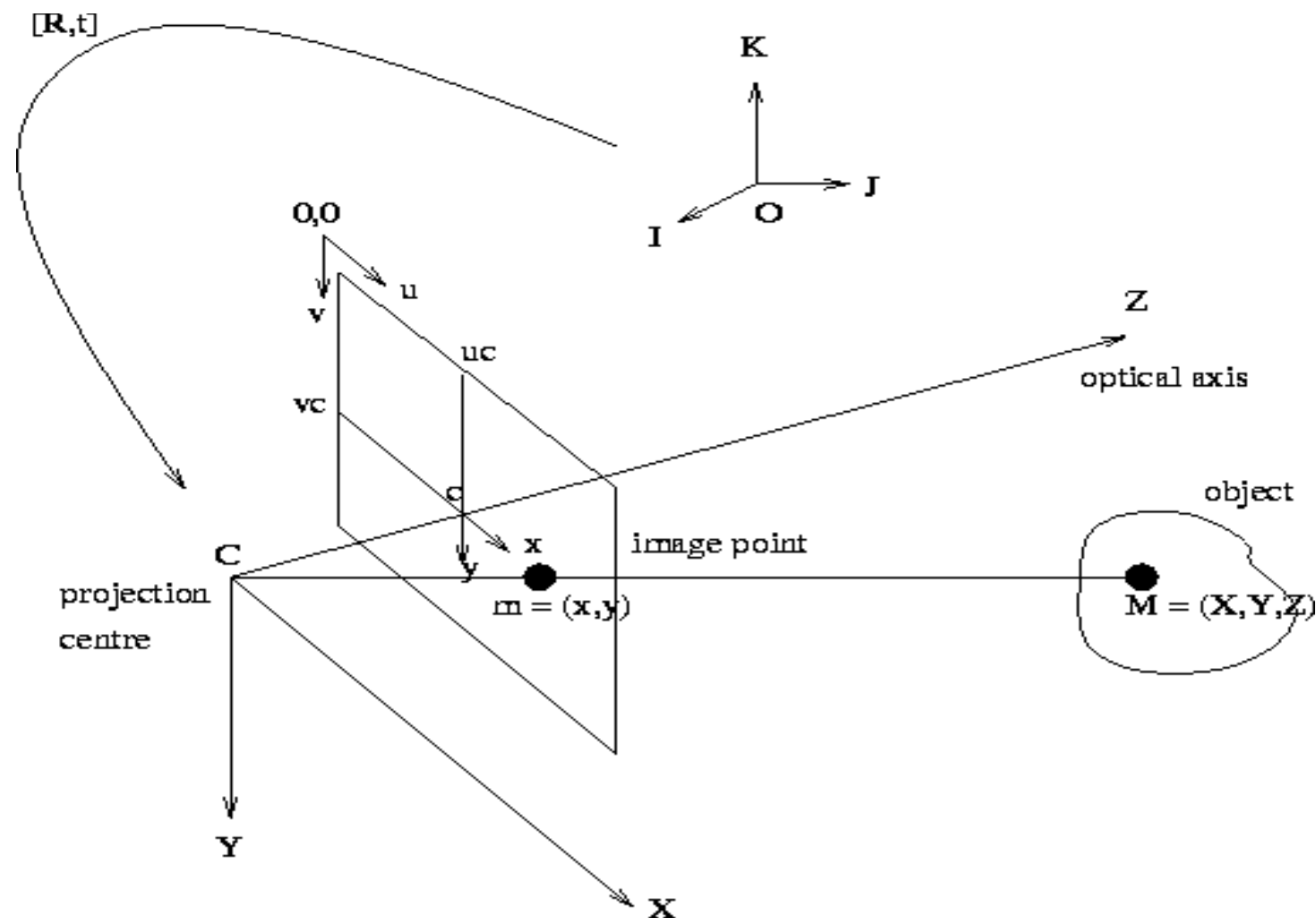
Camera Calibration

Intrinsic Calibration:

- Estimating focal length, optical center.

Extrinsic Calibration:

- Estimation of rotation and translation of the camera in the world



Robot Sensor - Joint Calibration

- Calibration of the sensors and the kinematic chains



Existing Systems

Challenges of existing calibration systems:

- An inability to generalize across sensor and platforms.
- Slow calibration times.
- Lack of robustness.

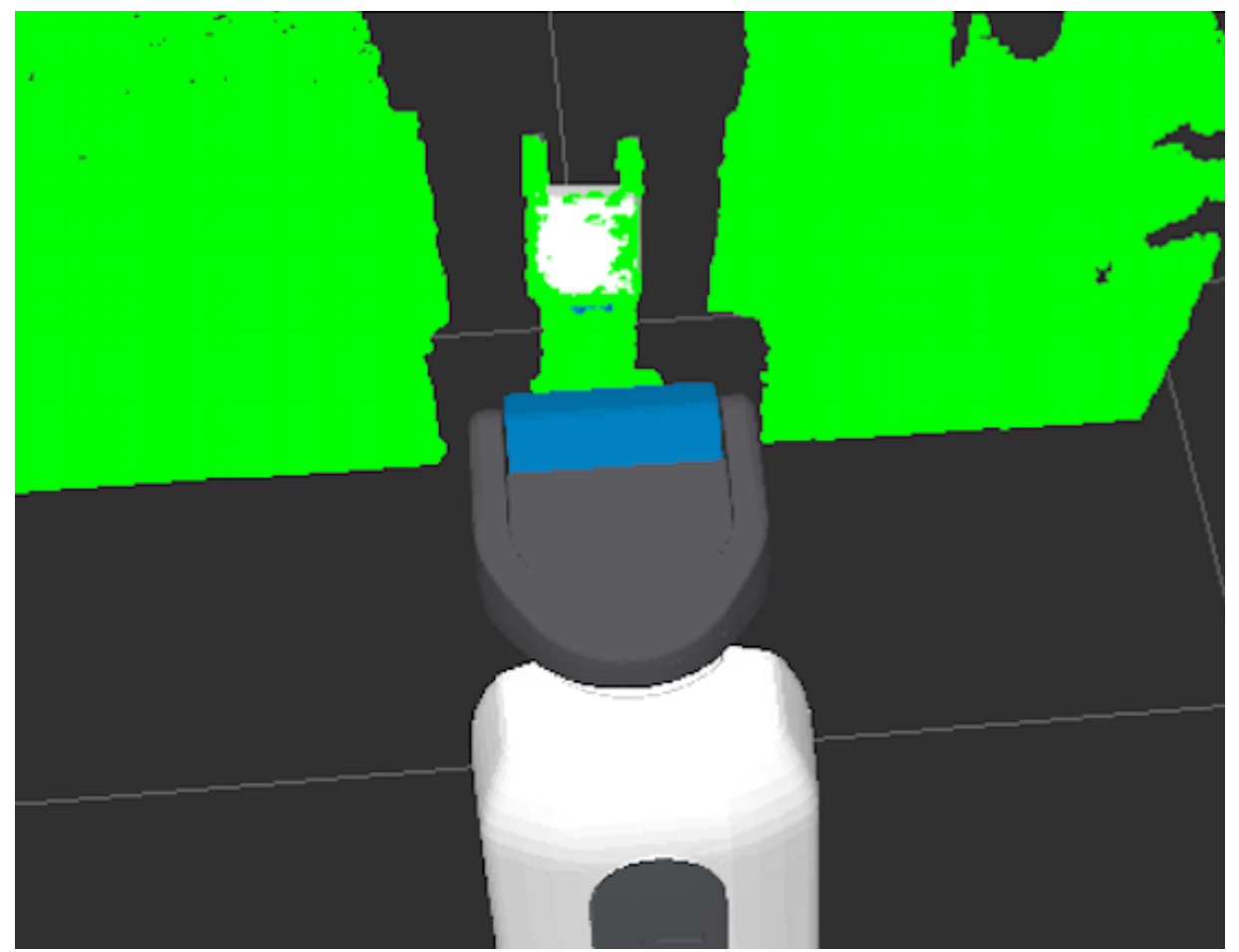


Fetch



*fetch*calibration

- *fetch*calibration is a hand-eye calibration system.
- Advantages
 - Fast, less than 3 minutes
 - Repeatable results
 - Robust



Robot calibration

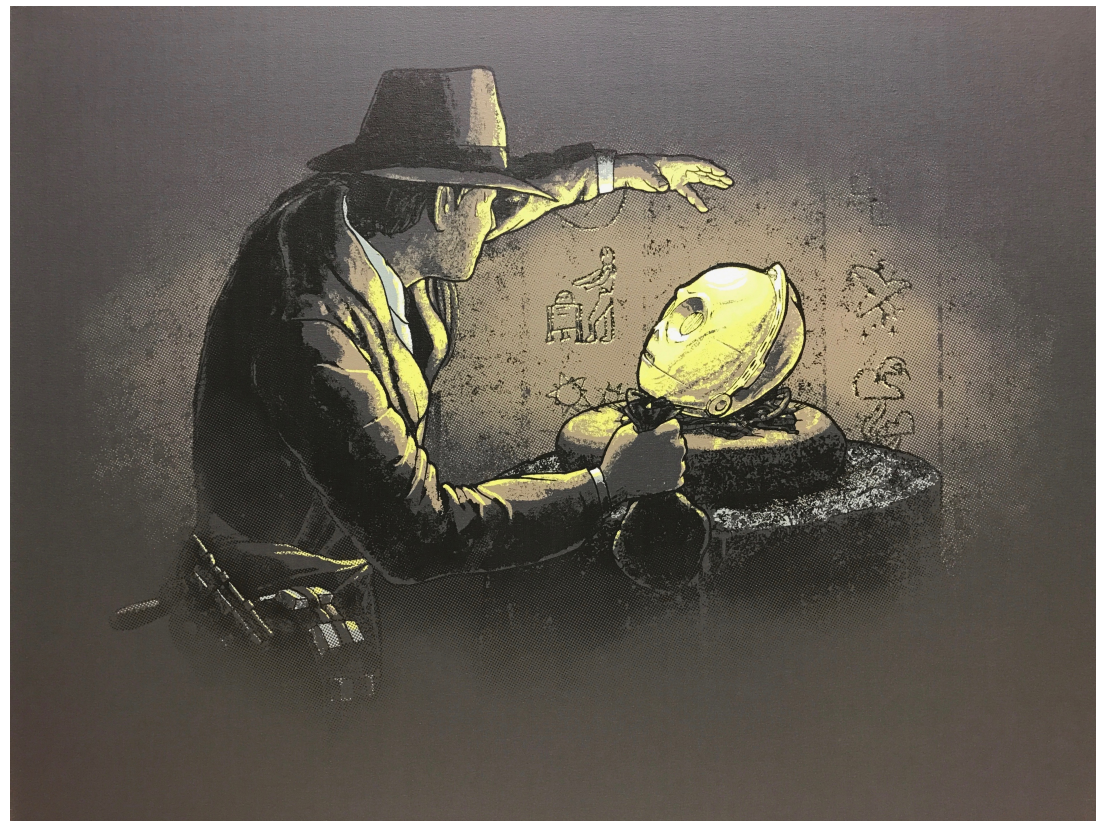
Two phases:

1. Capture phase:

- Capture data about calibration targets

2. Calibration phase:

- Optimizing parameters of the system



Capture

- The robot moves through a set of predefined poses.
- We have three finders available in the package:
 - Led finder
 - Checkerboard finder
 - Ground plane finder



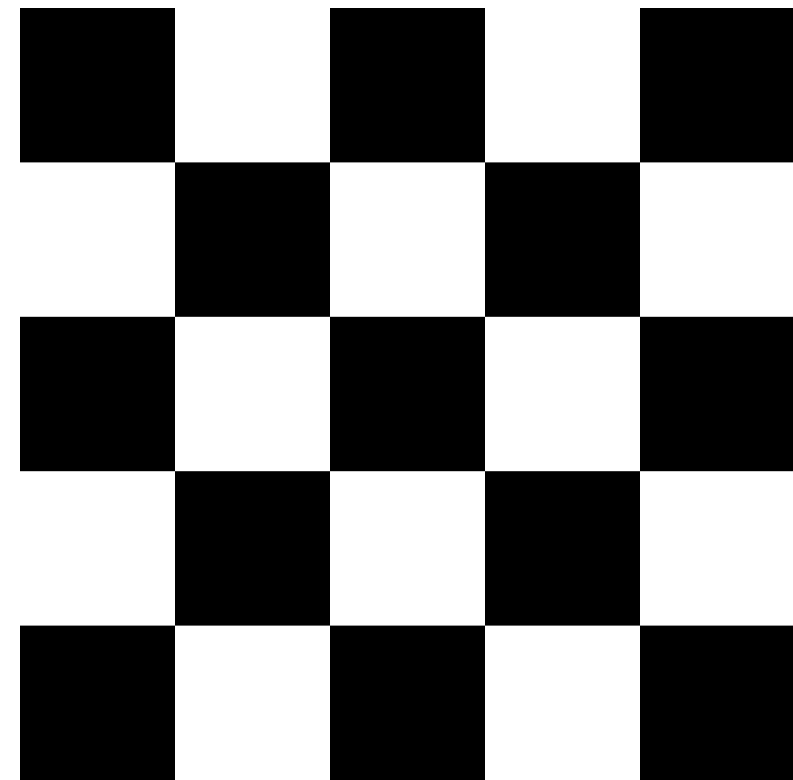
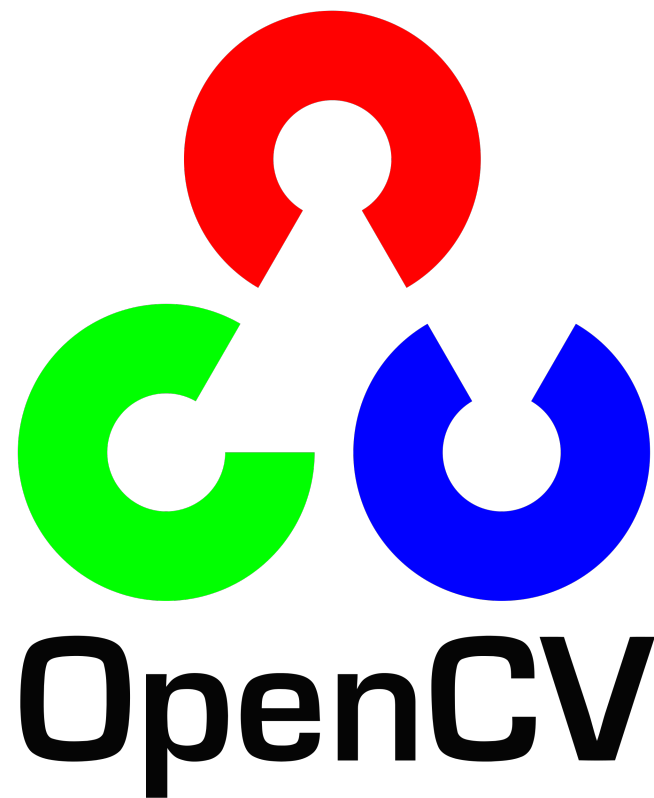
Led Finder

- Looks for the four calibration LEDs
- Simple thresholding algorithm



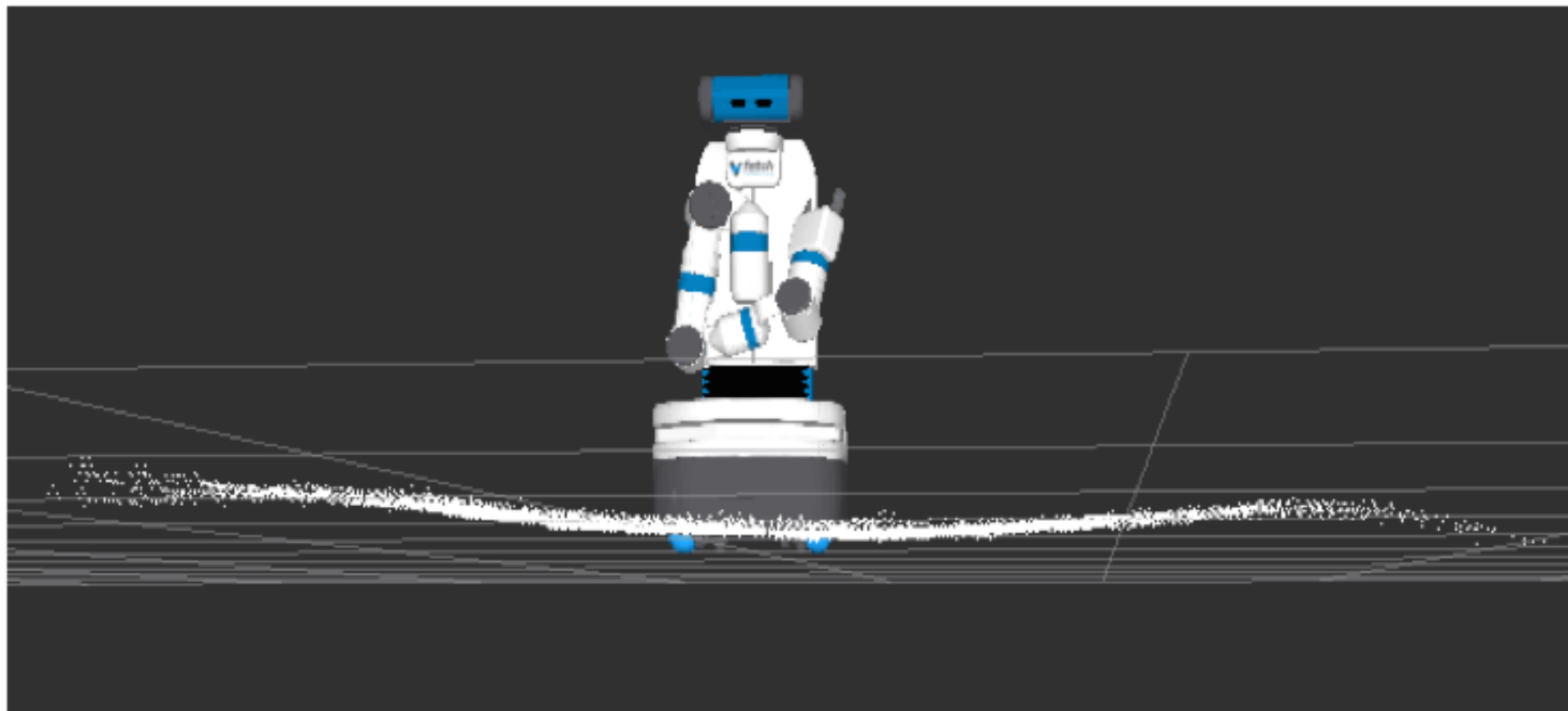
Checkerboard Finder

- Detects the position of each of the corner points in the checkerboard.



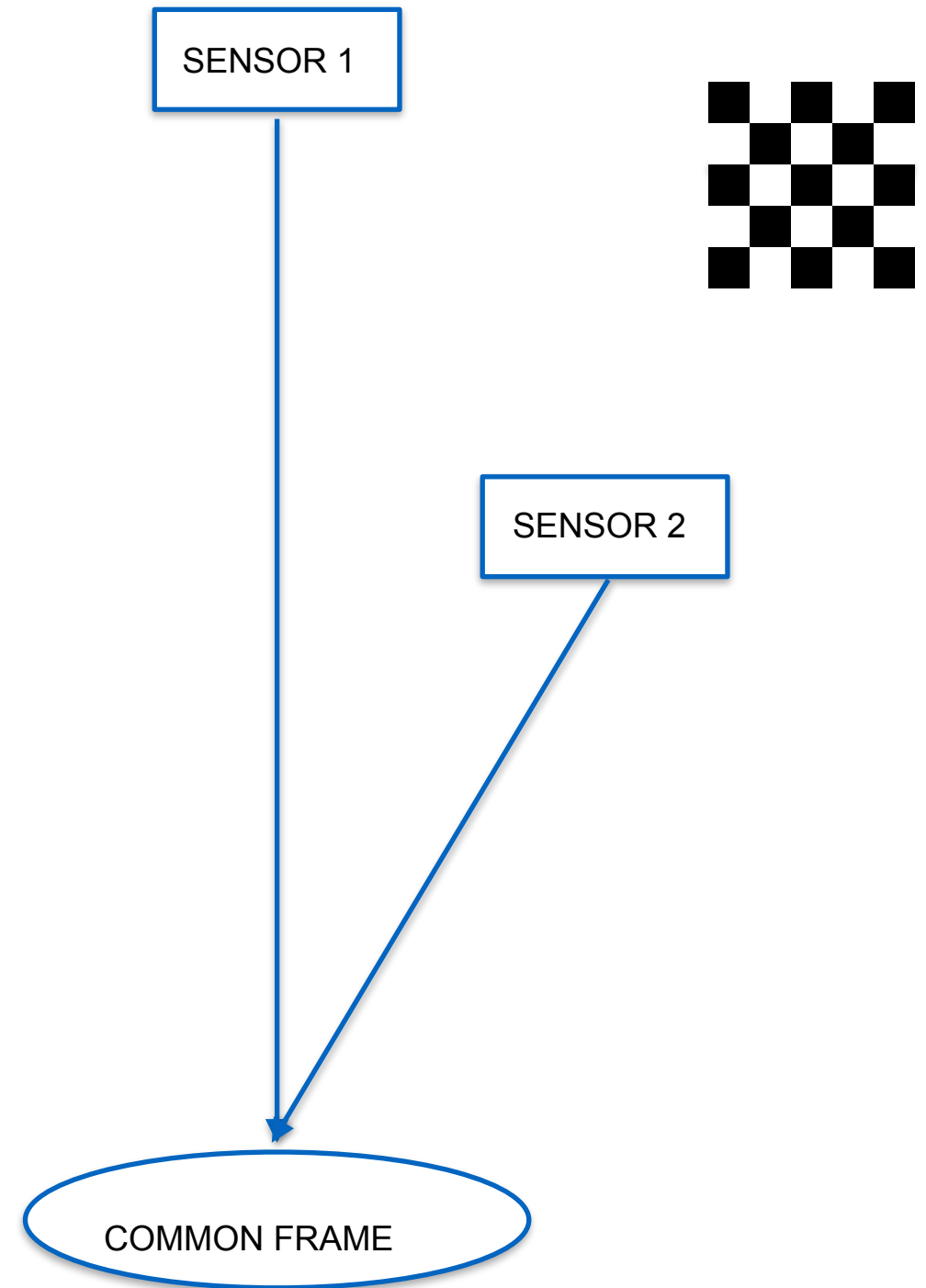
Ground Plane Finder

- Finds the 'ground'.
- Calibrate the the pitch of camera mounted on a freight.



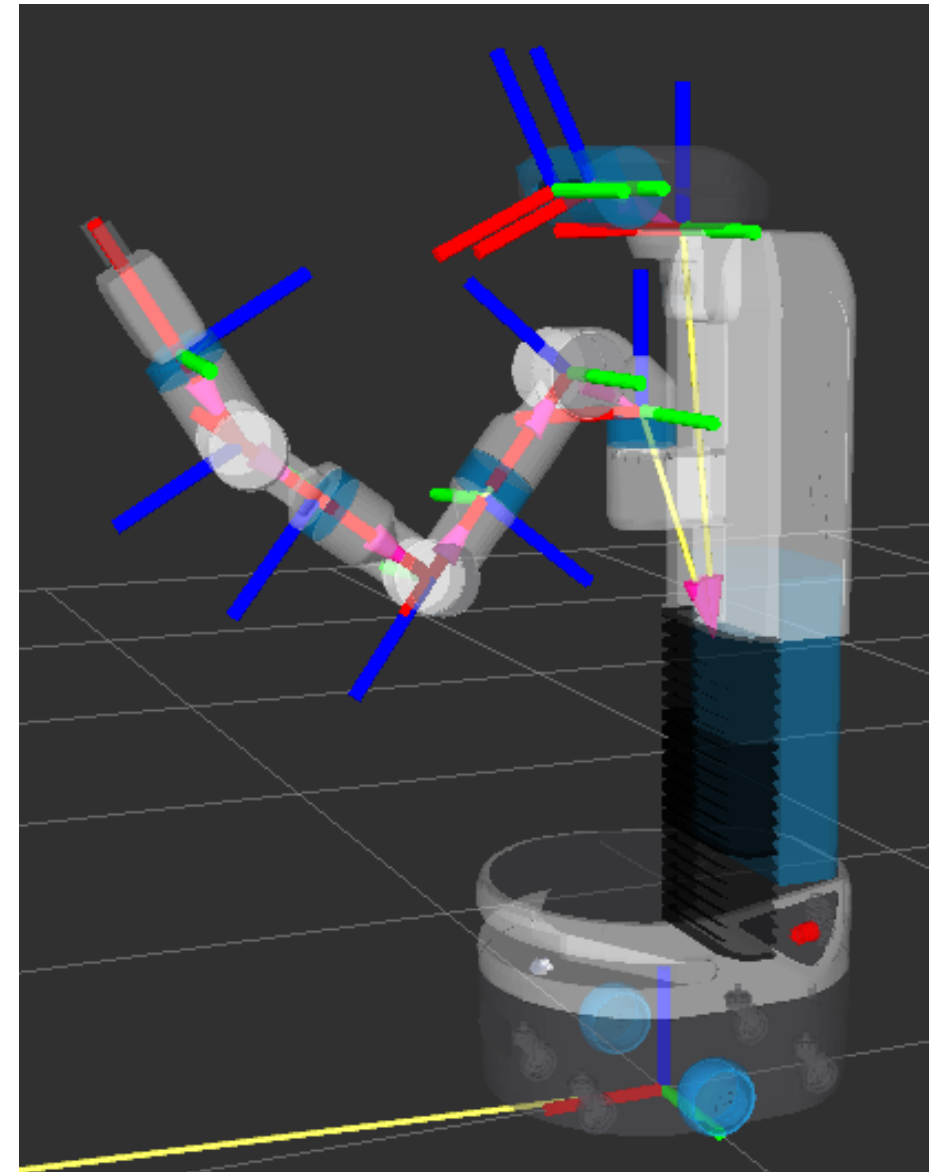
Optimization

- Use Ceres optimizer
 - solve the re-projection error minimization problem.
- Ceres
 - problem
 - free parameters
 - error blocks



Residuals for the finders

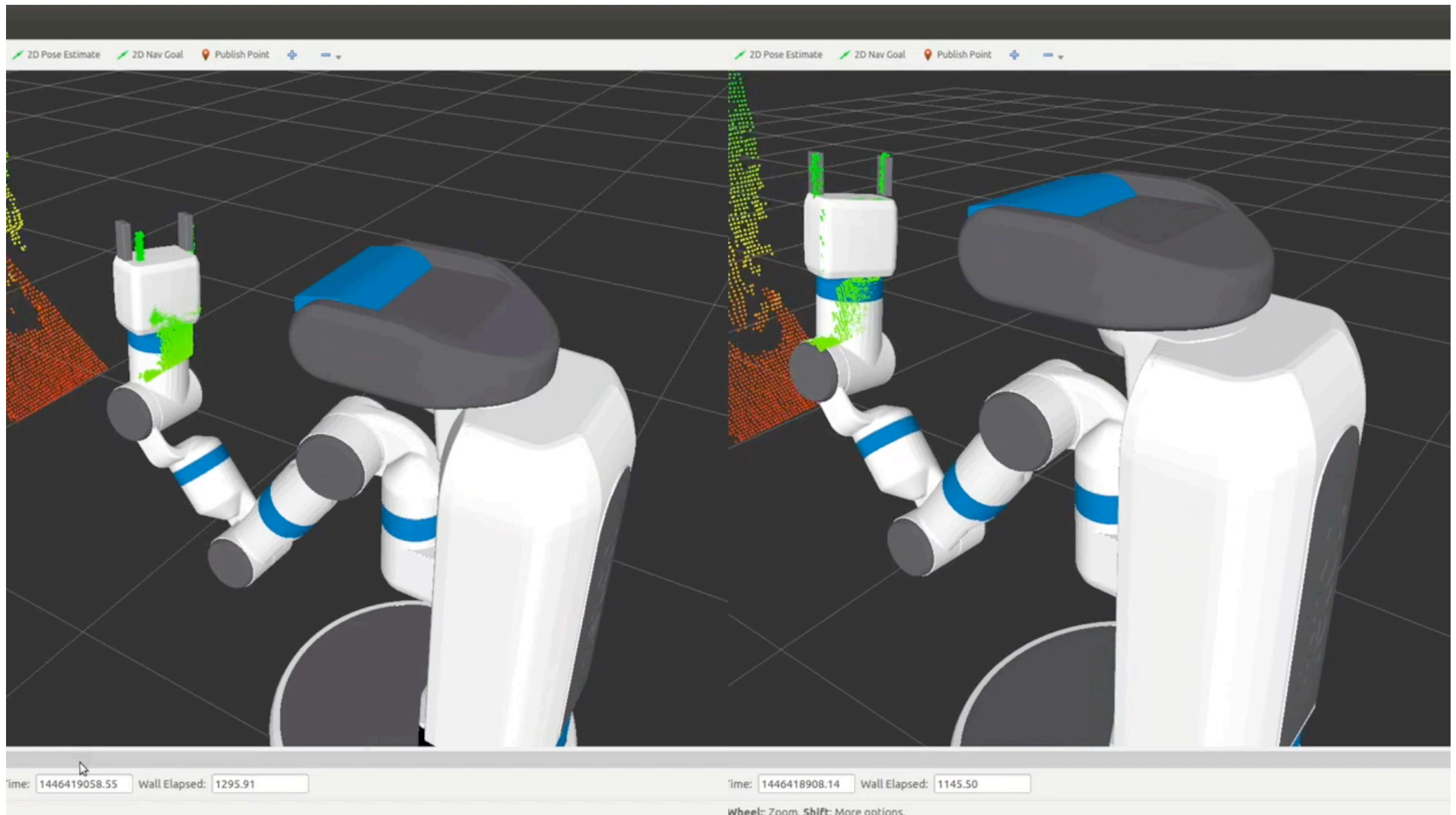
- **LED detector** - led points reprojected into the base link
- **Checkerboard calibration** - more points
- **Ground plane method** - only Z



Results

JOINTS	FETCH1	FETCH2	FETCH3
Shoulder Pan Joint	5.0320e-06	5.2546e-05	7.8241e-06
Shoulder Lift Joint	1.3376e-07	1.5427e-04	1.0073e-07
Upperarm Roll Joint	6.7229e-08	3.3959e-05	1.2355e-07
Elbow flex Joint	2.8776e-08	1.4416e-05	3.7454e-08
Forearm Roll Joint	2.6495e-07	5.2288e-07	1.5986e-07
Wrist Flex Joint	2.5105e-08	3.7200e-05	5.1110e-08
Wrist Roll Joint	9.1720e-07	2.9987e-06	1.1503e-06
Head Tilt Joint	1.8179e-07	2.3881e-05	2.0002e-07
Focal Length fx	2.2515e-05	6.8372e-04	2.1232e-05
Focal Length fy	2.6757e-05	8.6287e-04	2.0084e-05
Center cx	1.8679e-06	5.6485e-06	1.4719e-06
Center cy	1.4155e-05	8.7725e-05	1.7352e-05
Z scaling	8.6054e-06	1.9849e-07	1.5411e-06
Z offset	2.8598e-07	6.9011e-06	9.3637e-06
Camera joint x	9.4526e-06	6.5708e-05	7.6847e-06
Camera joint y	1.7924e-07	6.5242e-07	3.4685e-08
Camera joint z	3.6800e-07	7.5355e-08	5.6251e-07
Camera joint a	5.3193e-07	9.7933e-06	4.4715e-07
Camera joint b	1.0078e-07	2.8095e-05	1.4035e-07
Camera joint c	5.8759e-07	1.5675e-06	5.4968e-07
head pan joint x	1.0595e-08	6.0103e-06	9.9500e-09
head pan joint y	7.6362e-08	8.2762e-08	1.3644e-07
head pan joint z	1.2288e-08	1.1491e-05	2.1953e-08
head pan joint a	1.4428e-08	1.0040e-07	5.4682e-08
head pan joint b	7.2910e-08	3.5083e-07	1.6987e-08
head pan joint c	3.3001e-06	1.6960e-05	9.5201e-06

Result of Calibration



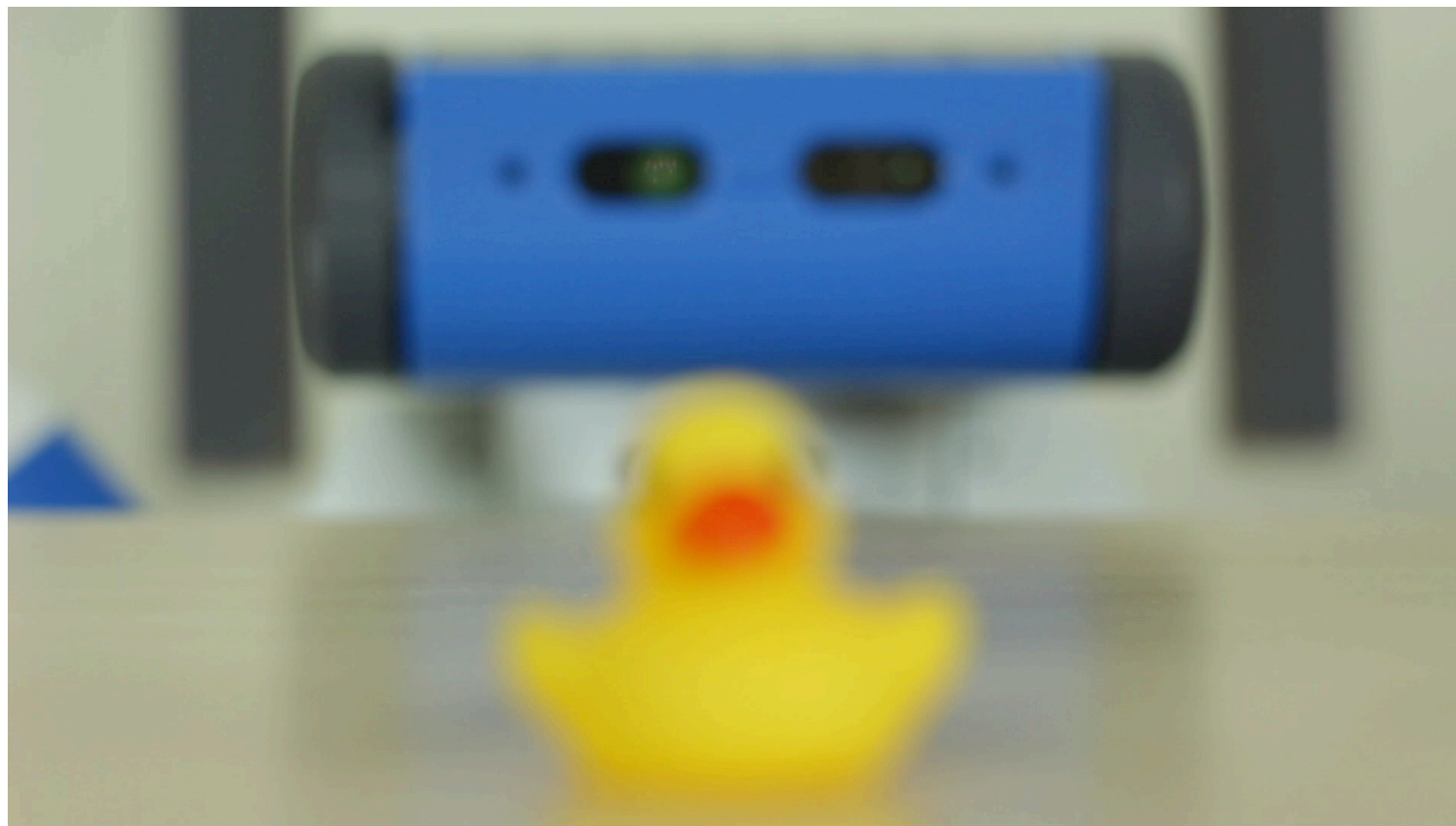
Calibrating the Freight!!

- Time of flight camera
- Calibrate the the pitch of the camera
- Ground Plane finder



Final Remarks

- ***fetch***calibration is awesome.
- Links
 - https://github.com/fetchrobotics/fetch_ros
 - https://github.com/mikeferguson/robot_calibration
 - <http://docs.fetchrobotics.com>



Questions?

