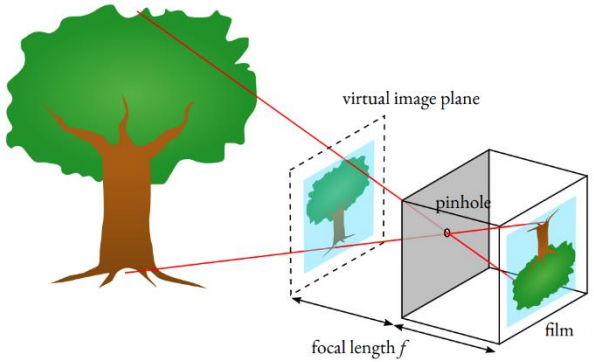
Camera Calibration

ROS Industrial Training

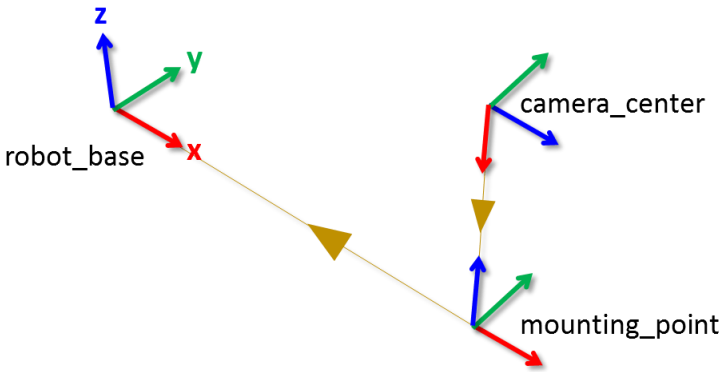
Feb 2024

What is Calibration

- Intrinsics: how the camera sees the world

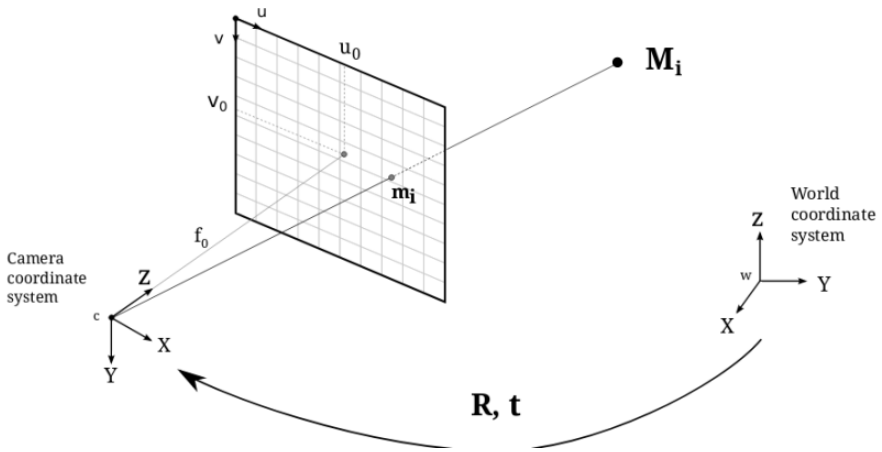


- Extrinsics: Where the camera is in the world



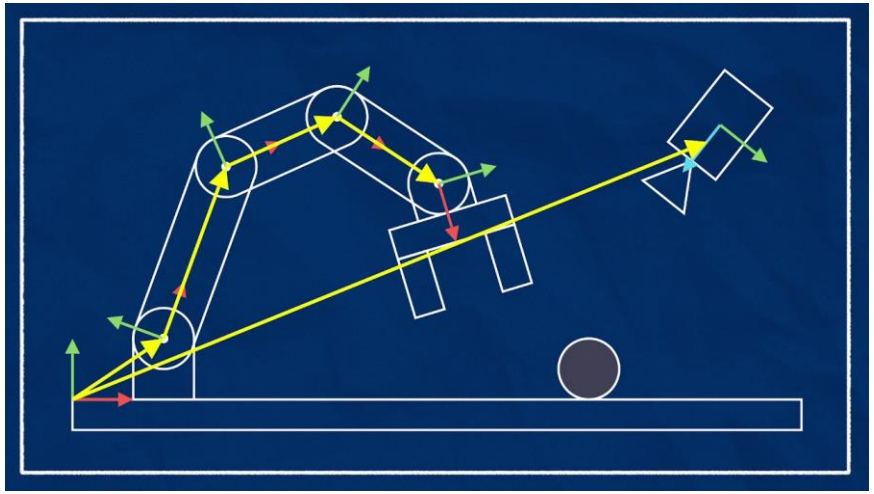
What is Calibration

- Intrinsics
  - Pinhole model of a camera
  - Distortion
- Parameters
  - Focal length
  - Offset
  - Distortion params



What is Calibration

- Extrinsics
  - Where is my camera attached on my model?
- Parameters
  - 3D position
  - 3D orientation



Why Calibration

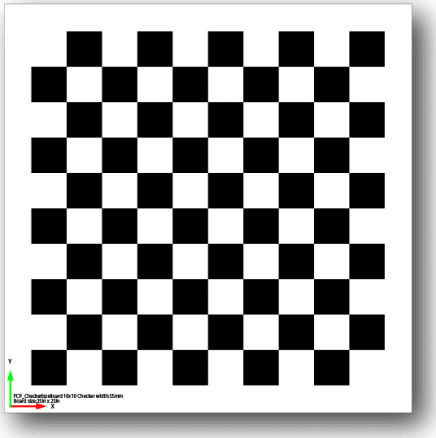
- Intrinsics
  - Necessary for reasoning in 3d space
  - May come with camera, may not
- Extrinsics
  - Necessary for reasoning in 3d space
  - Always necessary
    - A vendor can’t tell you where you put it!

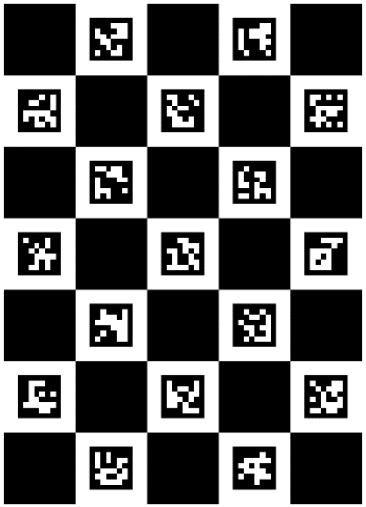
When Calibration

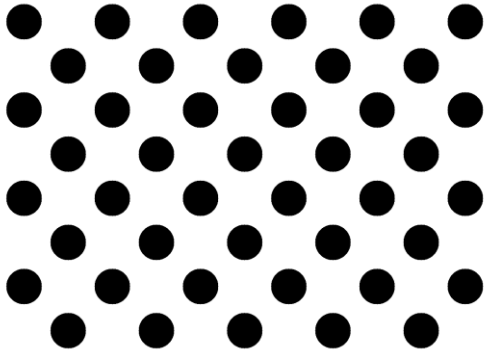
- What applications
  - Anything where a camera needs to reason within space
  - Can avoid if just sensing just presence
- What part in your process
  - Ideally when things are becoming more stable
  - Avoid redoing many calibrations

How Calibration

- Targets
  - Checkerboard, Circle grid, ChArUco, and more
  - Ideally high quality, ChArUco or similar preferred
  - Accuracy of target = accuracy of calibration

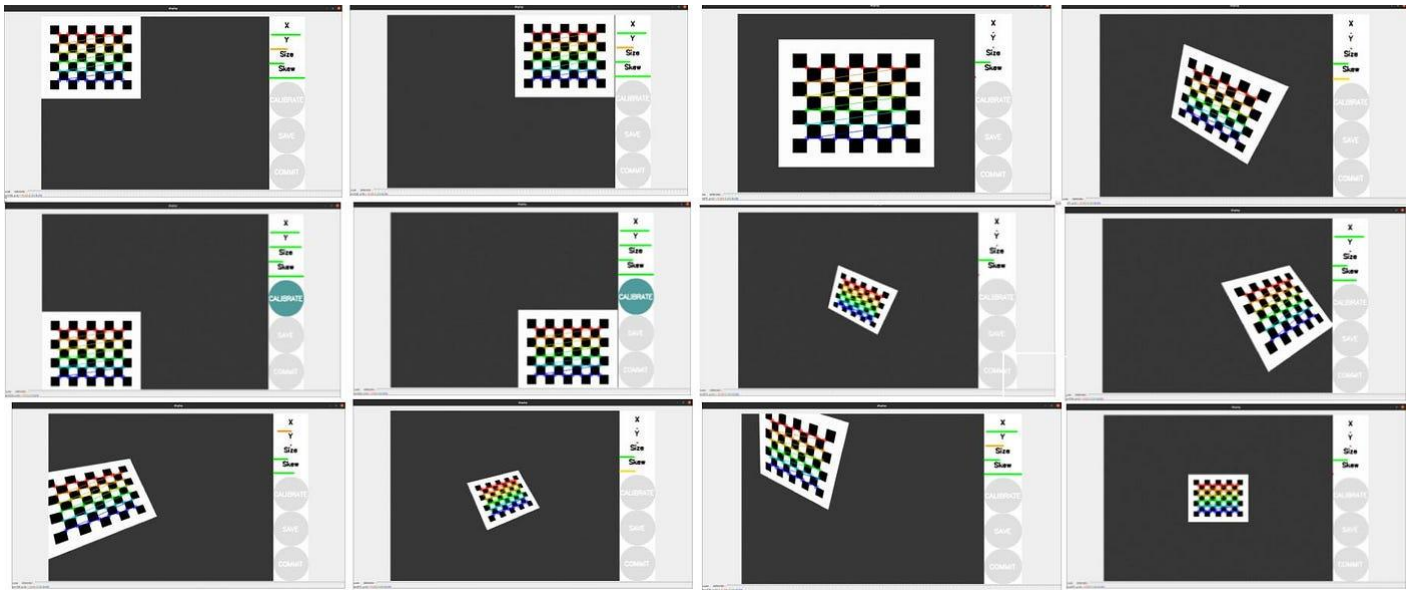






How Calibration - Intrinsics

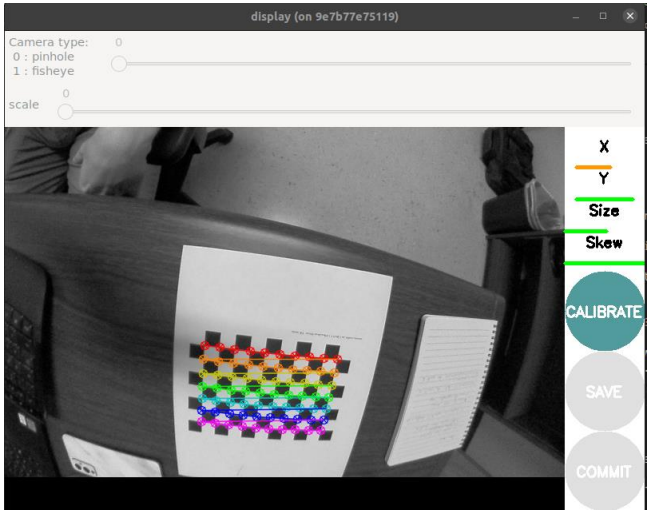
- Data
  - Coverage
  - Redundancy



How Calibration - Intrinsics

- Optimization
  - Find points
  - Find parameters that give best fit across all data

- Focal Length
- Offset
- Distortion



How Calibration - Intrinsics

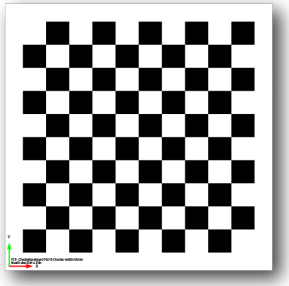
- Verification
  - Get reprojection error
    - Want something <1 pixel
  - Examine rectified images
    - Reprojection error may seem ok, but visual inspection may show flaws

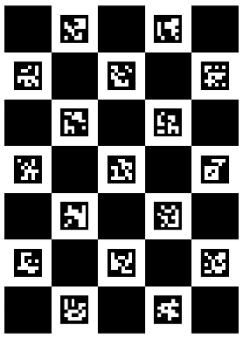
This is an optimization – it can overfit!

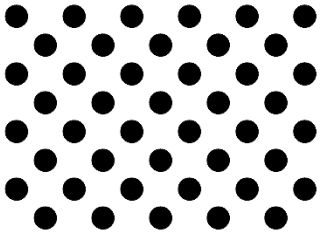
How Calibration - Extrinsics

- Target
  - Now we need to know a transform between links that connect target and camera

- Otherwise, target options are the same







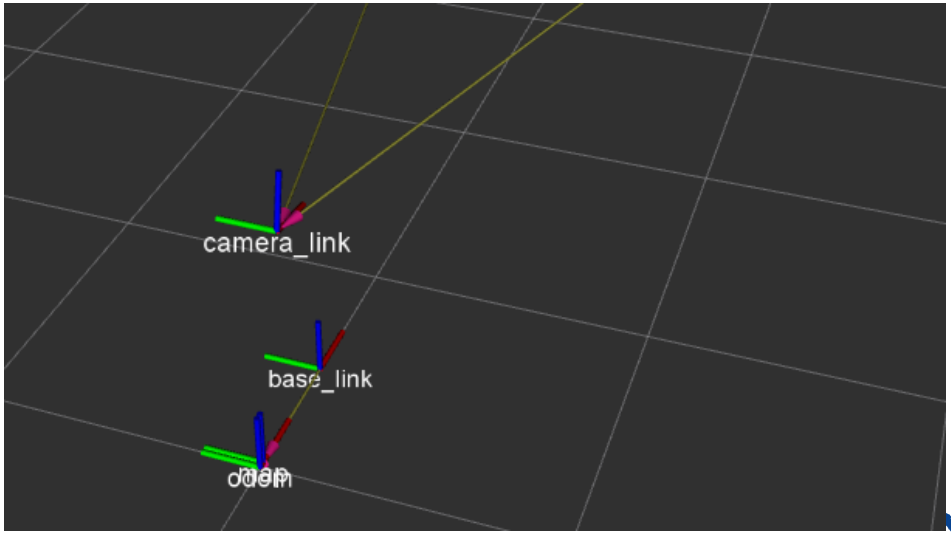
How Calibration - Extrinsics

- Data
  - Now collecting image/pose pairs
- Deliberately stop the robot at a position
  - Capture an image
  - Capture the pose
  - Save together

How Calibration - Extrinsics

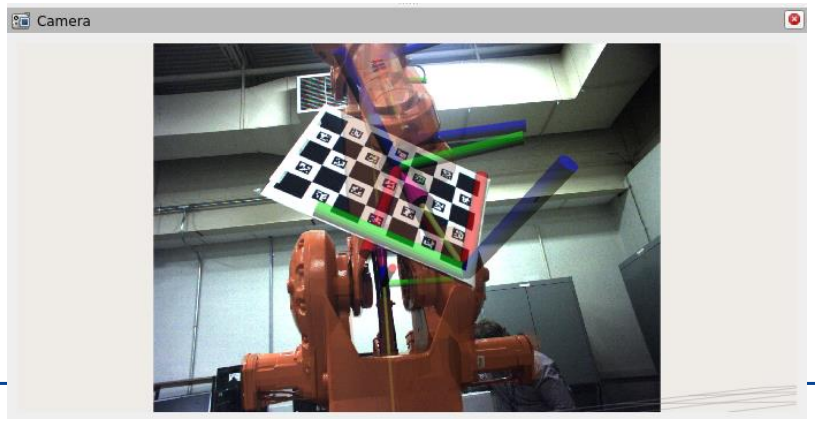
- Optimization
  - Find points
  - Find parameters that give best fit across all data

- 3D position
- 3D orientation



How Calibration - Extrinsics

- Verification
  - Reprojection
    - Most calibration tools show where it would project the points given the result
  - Rviz camera plugin
    - Can show how well your sim lines up with reality
    - Transparent image over sim image



Common Issues

- Bad quality target
- Poor coverage of camera image space
- Poor coverage of pose space
- Not enough samples
- Incorrect configuration of software

What to use

- camera_calibration
  - Easy to use intrinsic and stereo calibration
- image_proc
  - Apply intrinsics easily
- robot_cal_tools
  - ROS way of data collection and camera calbiration

Other options to explore

- industrial_calibration
  - ROS agnostic
  - PnP
  - Noise characterization
  - Kinematic calibration

- MoveIt hand-eye calibration
  - Friendly interface
  - Never ported to ROS 2