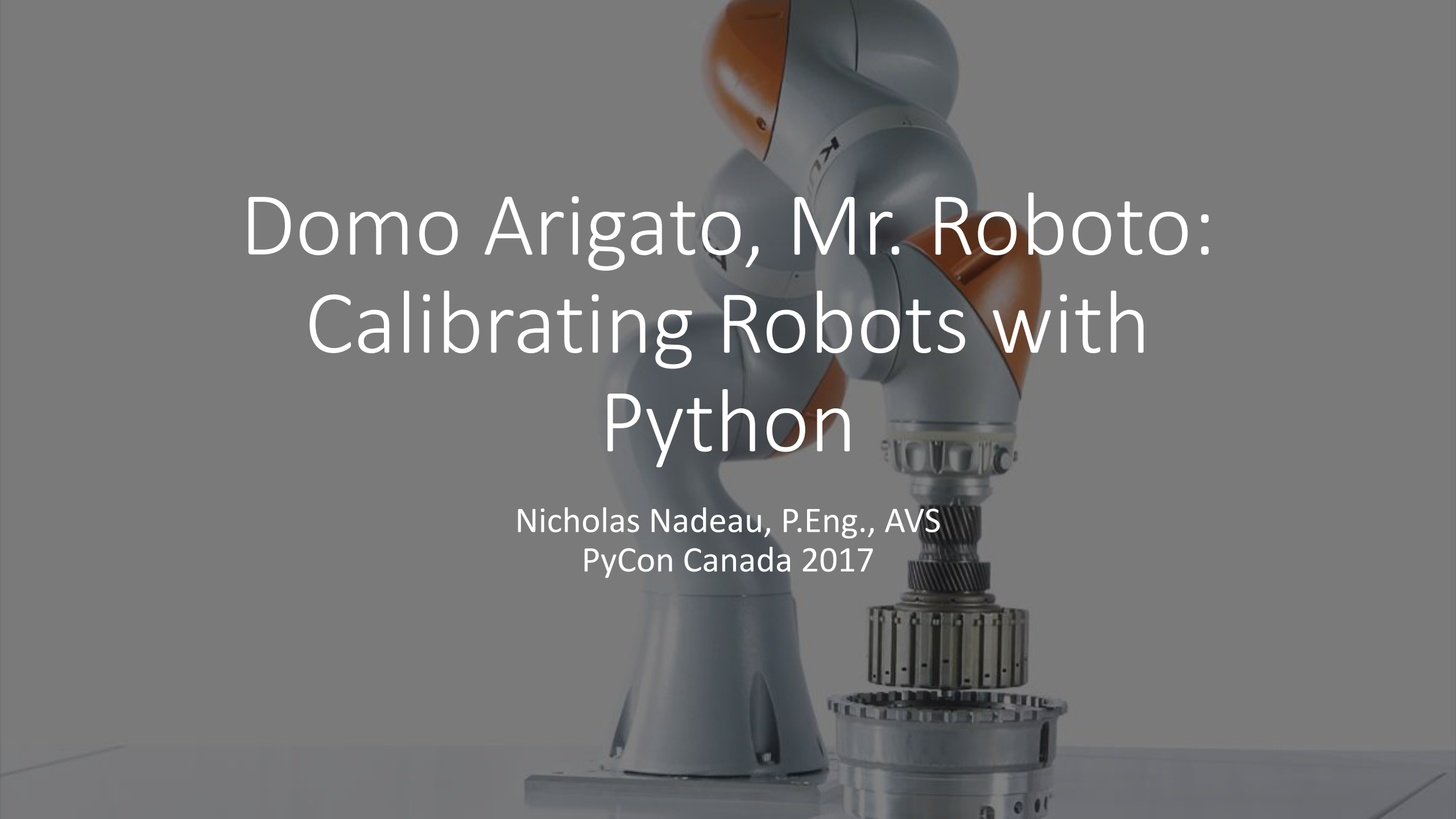
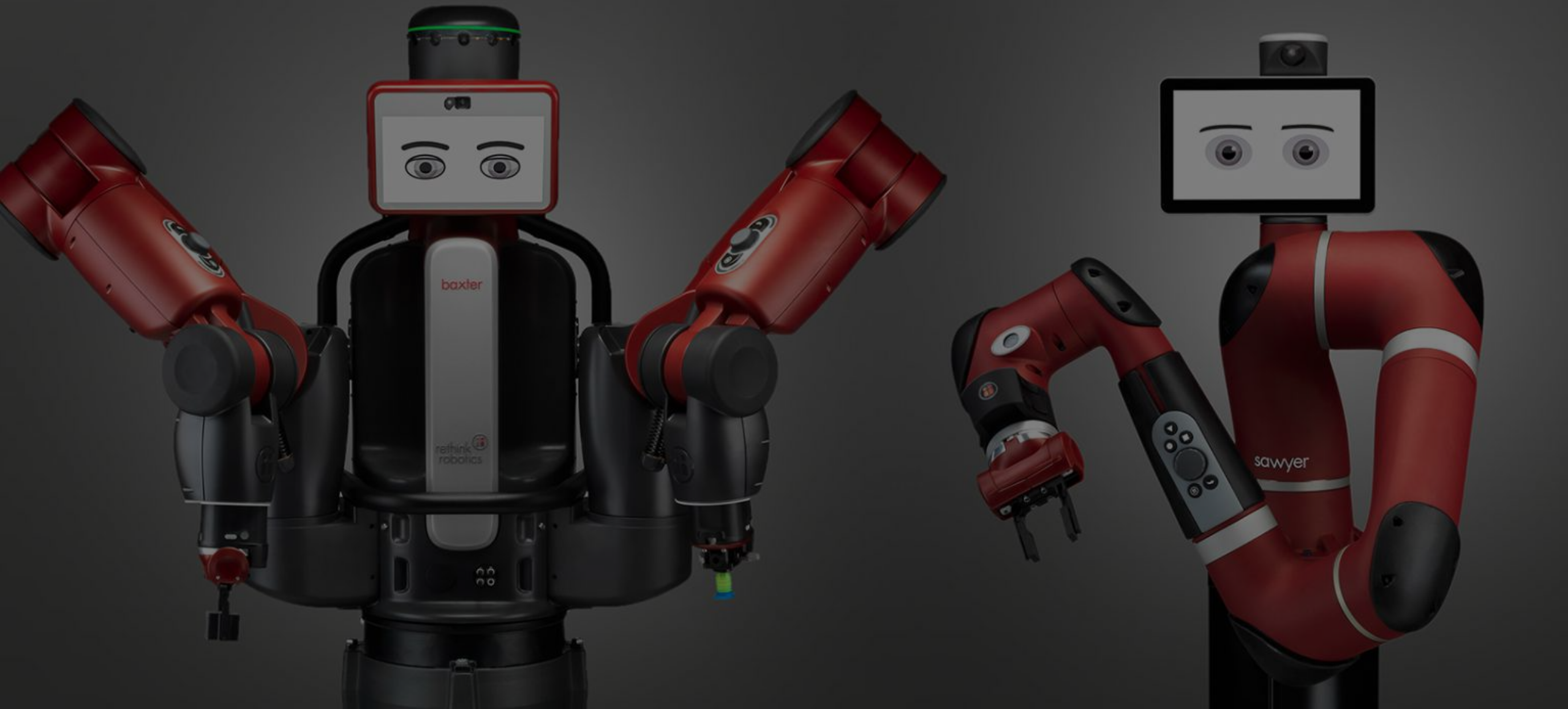


Domo Arigato, Mr. Roboto: Calibrating Robots with Python

Nicholas Nadeau, P.Eng., AVS

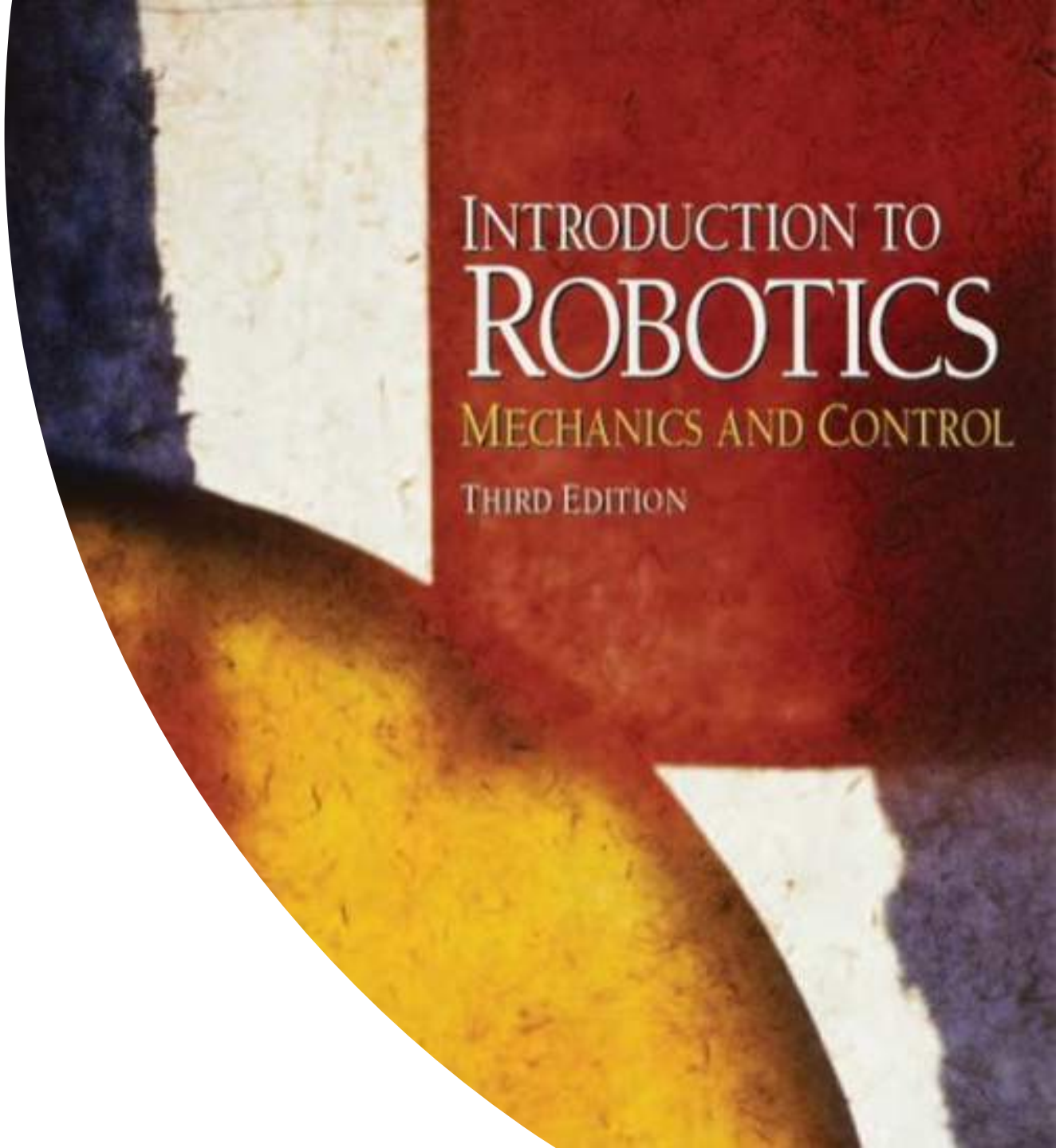
PyCon Canada 2017

The Robots Are Coming!

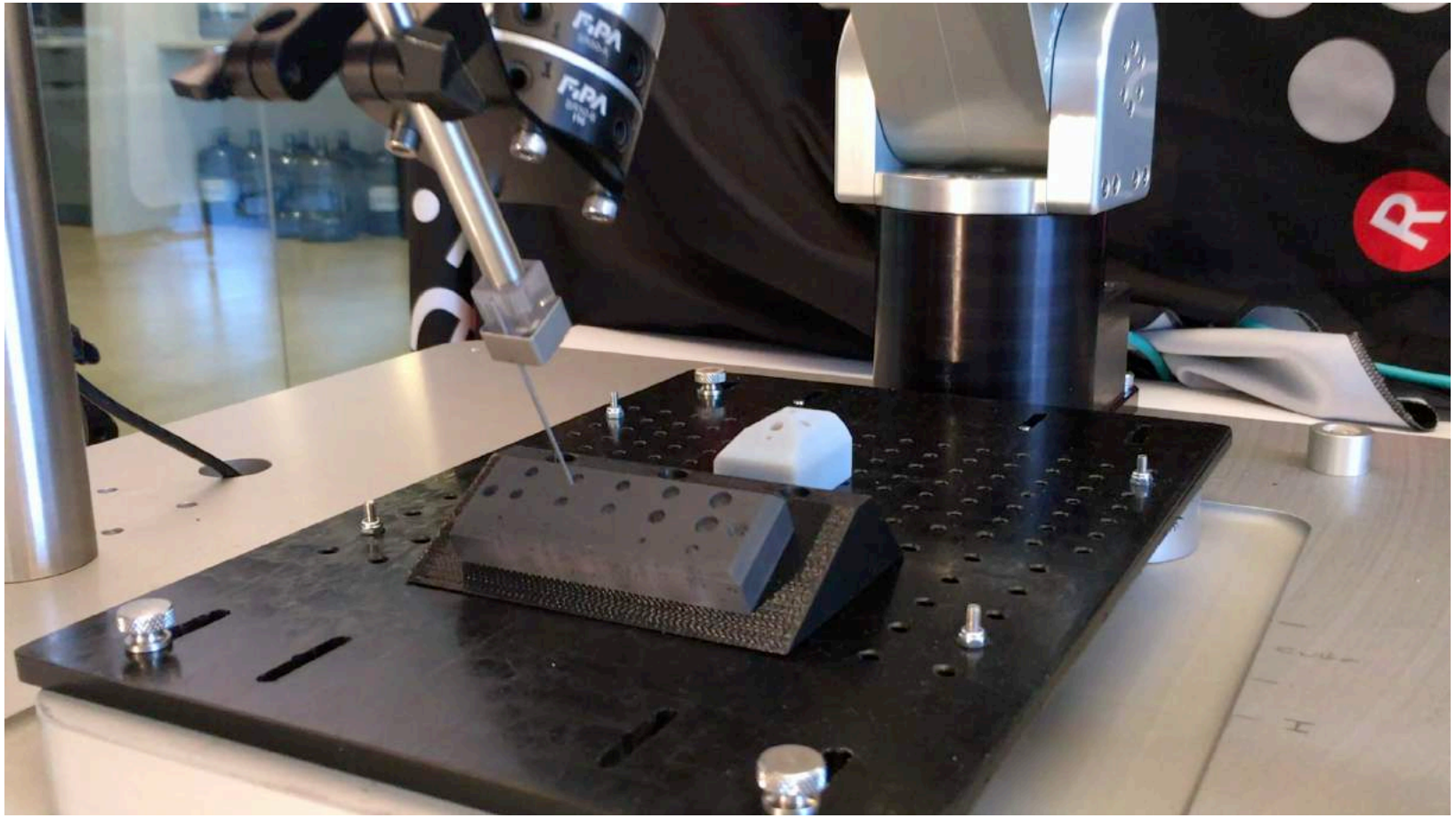


What’s the difference?

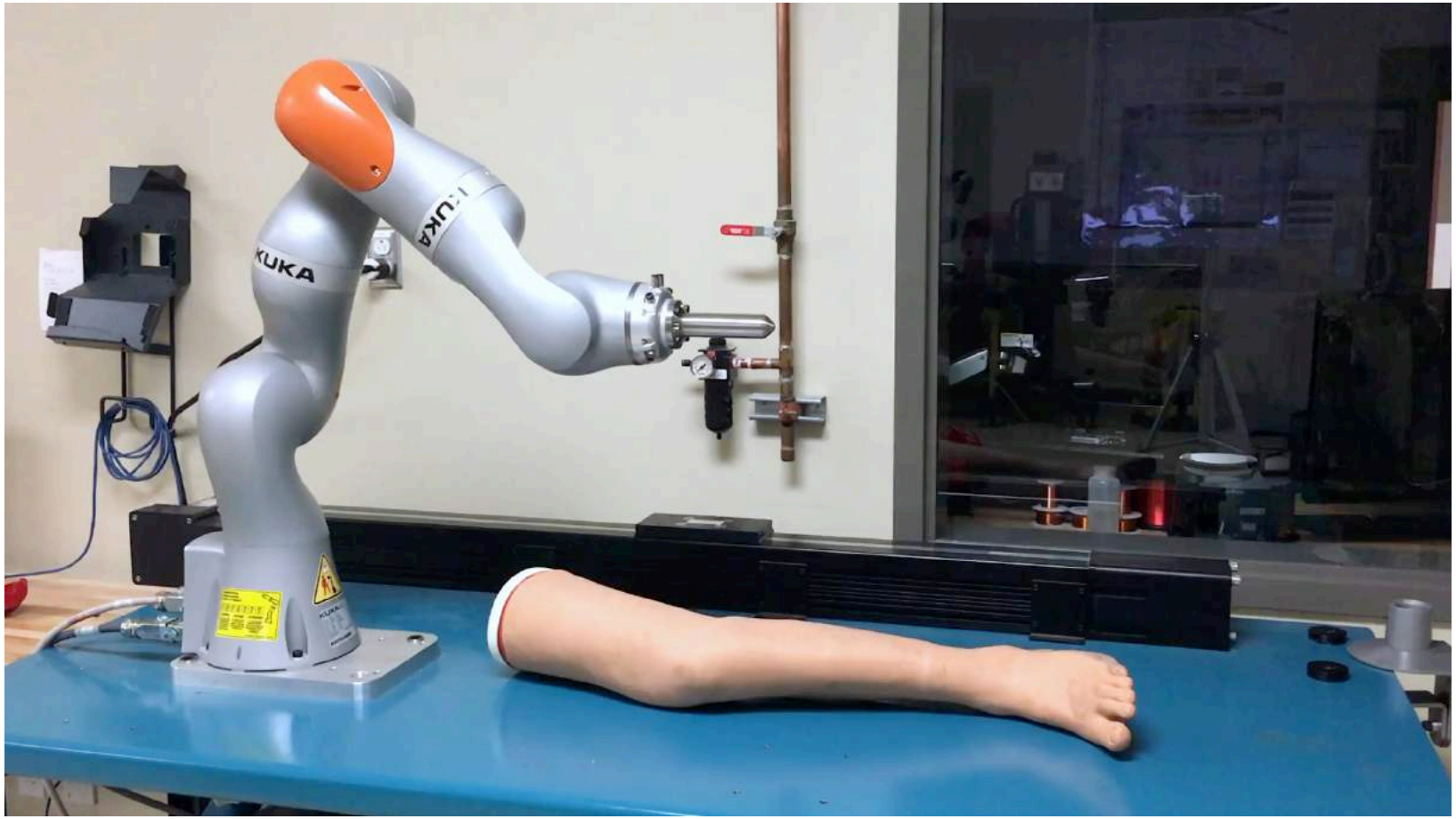
Introduction to Robotics: Mechanics and Control, 3rd Edition
John J. Craig



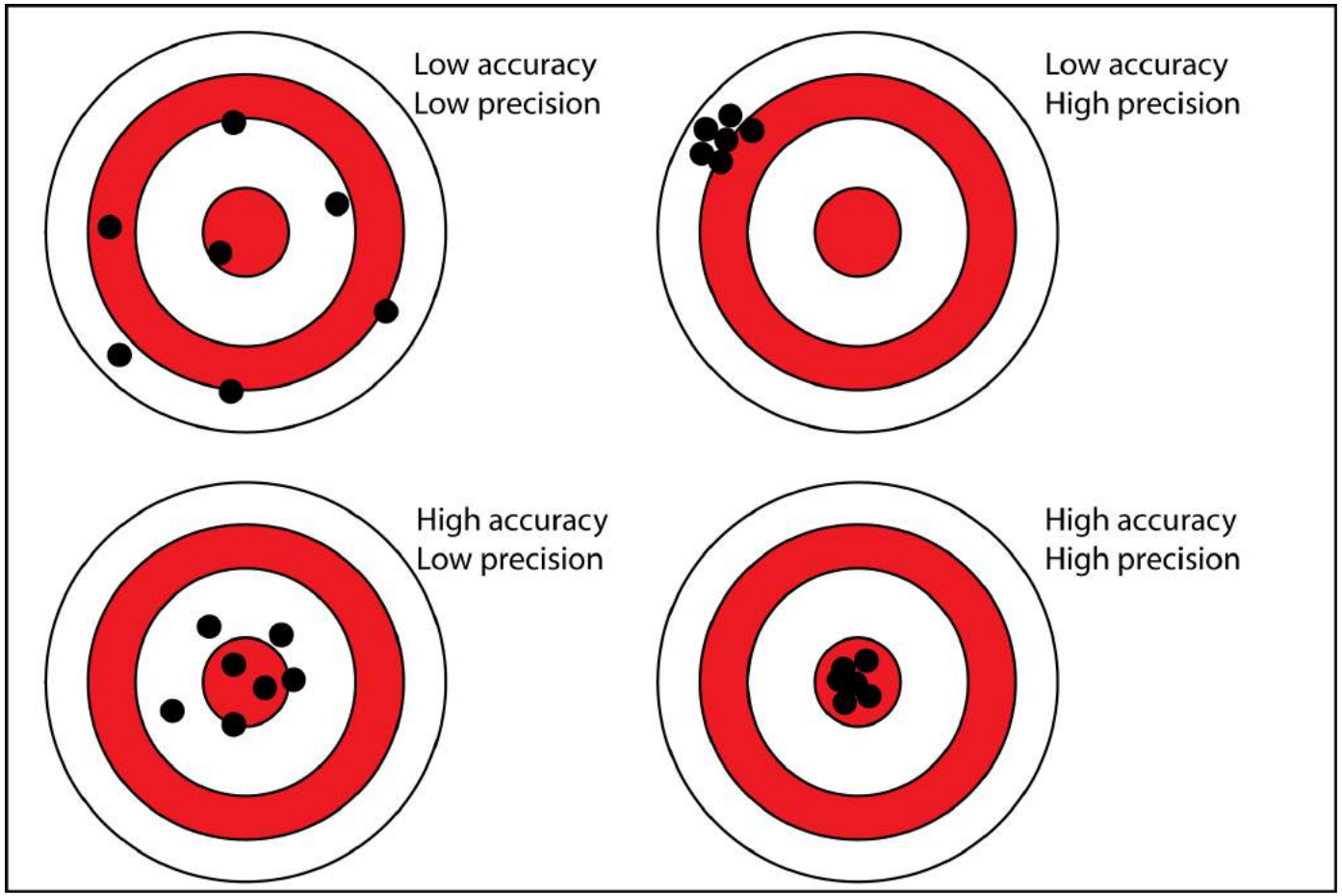
Rogue Research Inc.

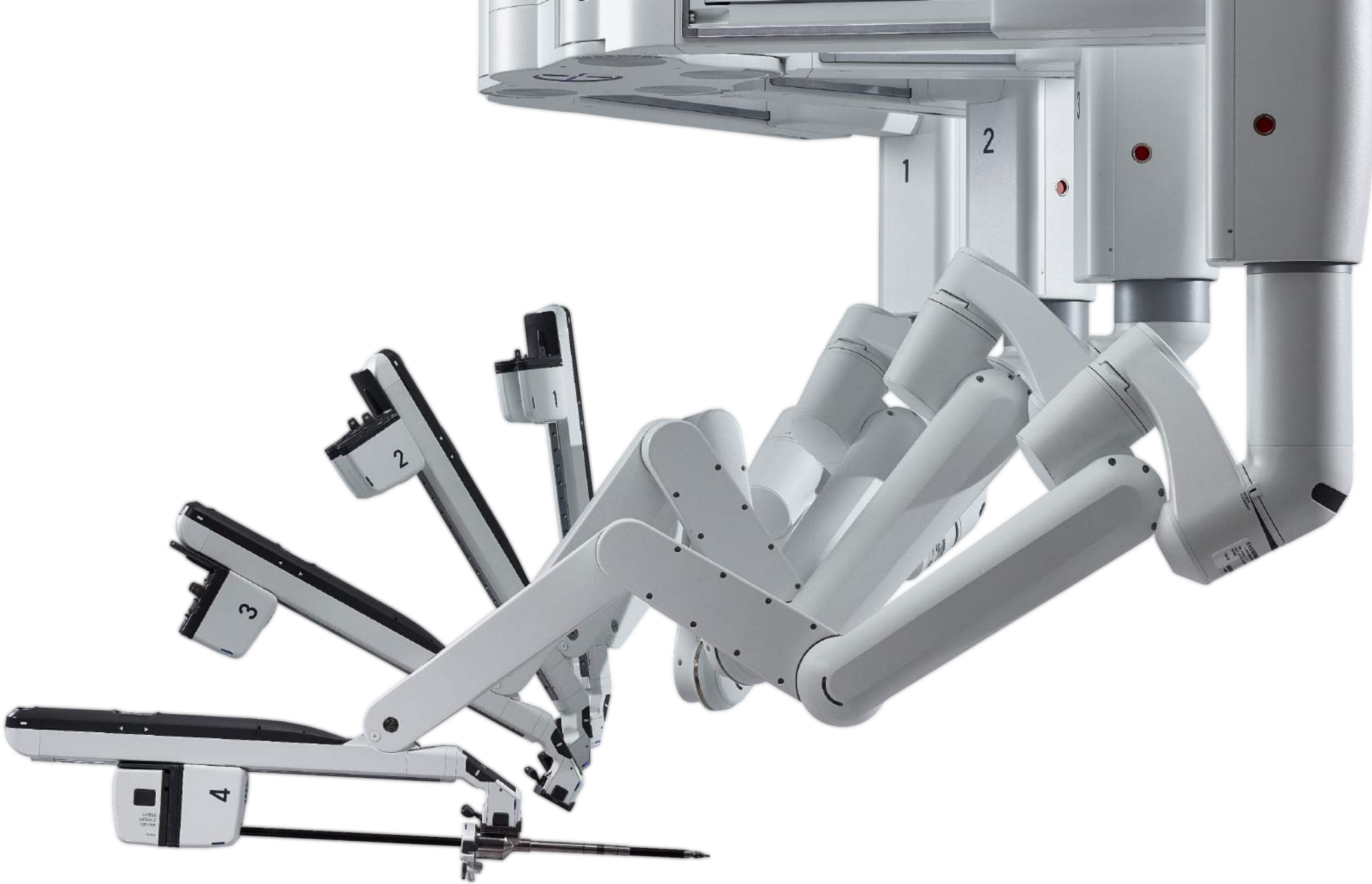


ETS



Why Calibrate?

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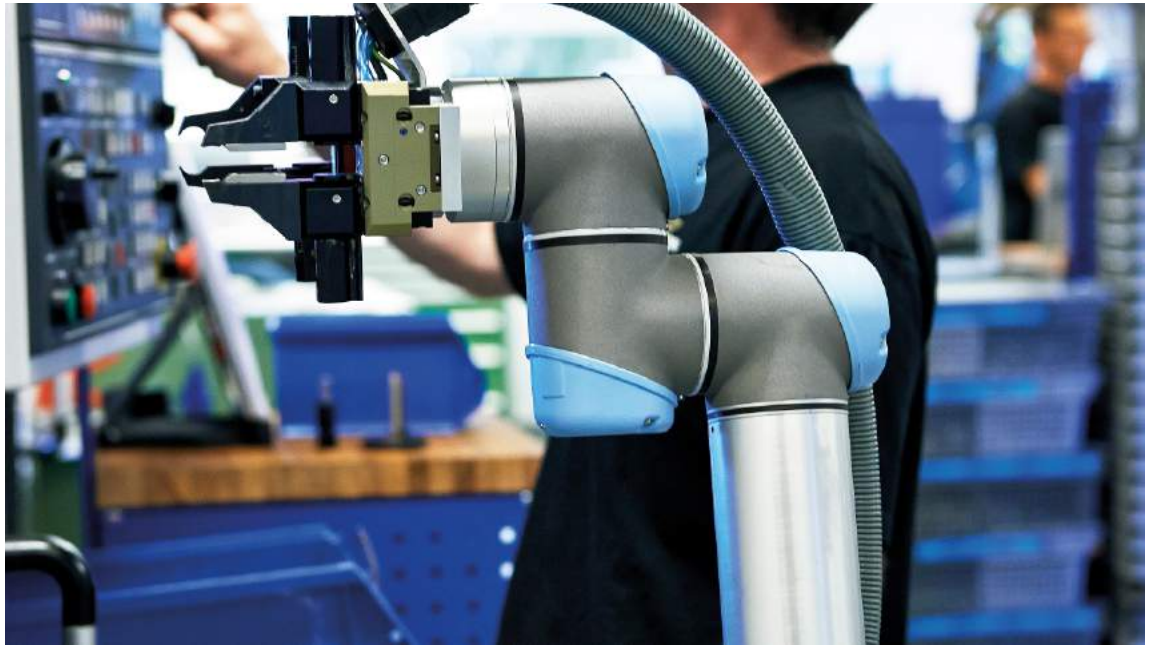
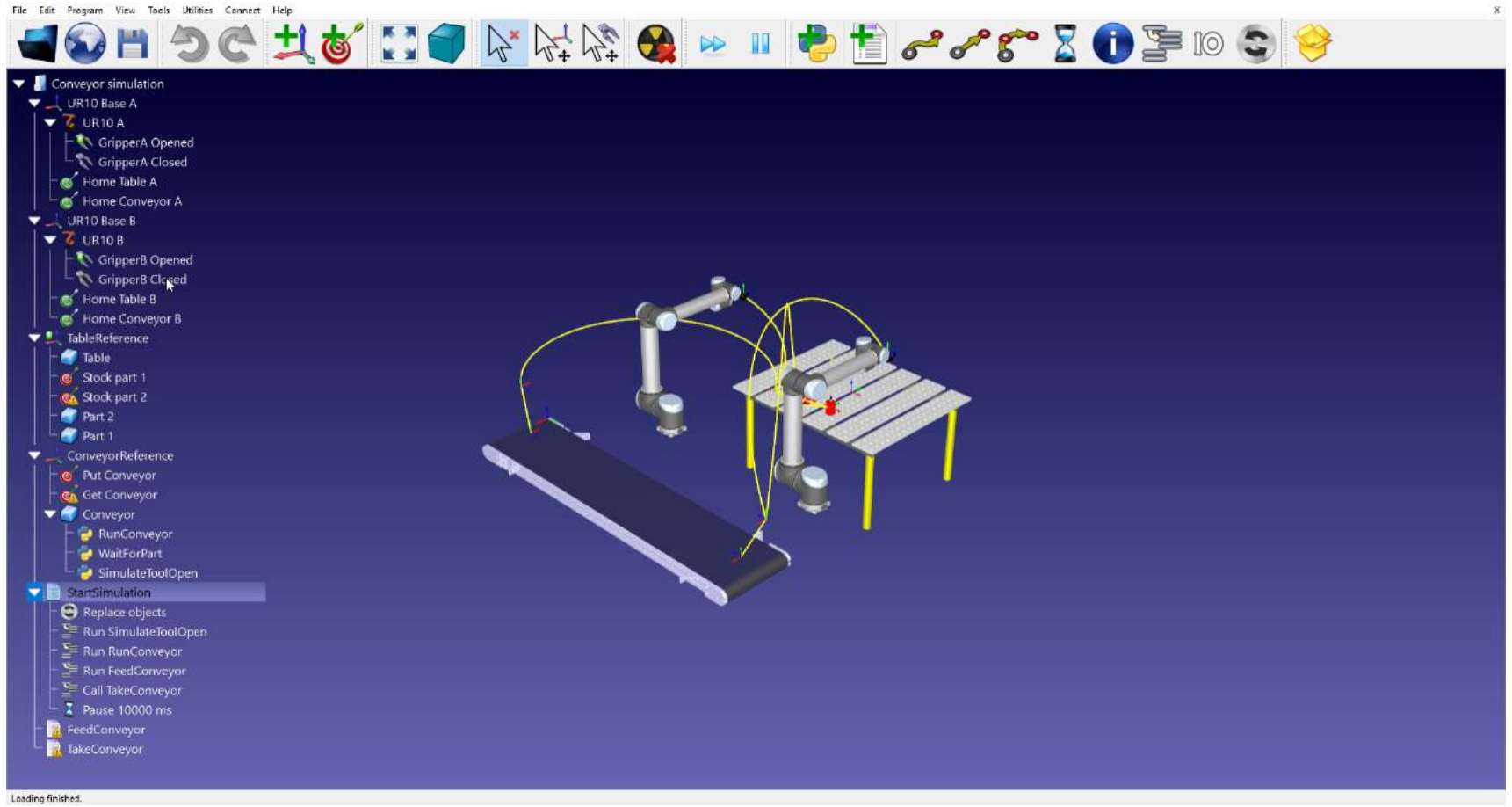
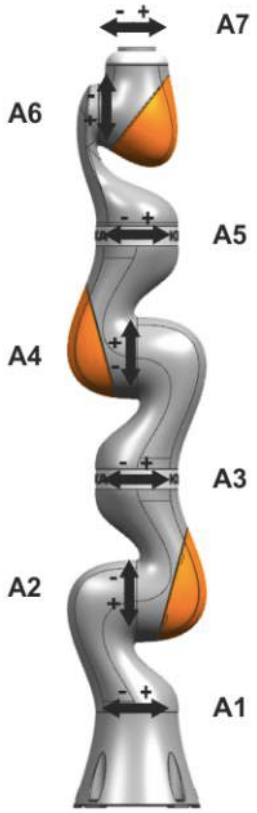
KUKA
KUKA

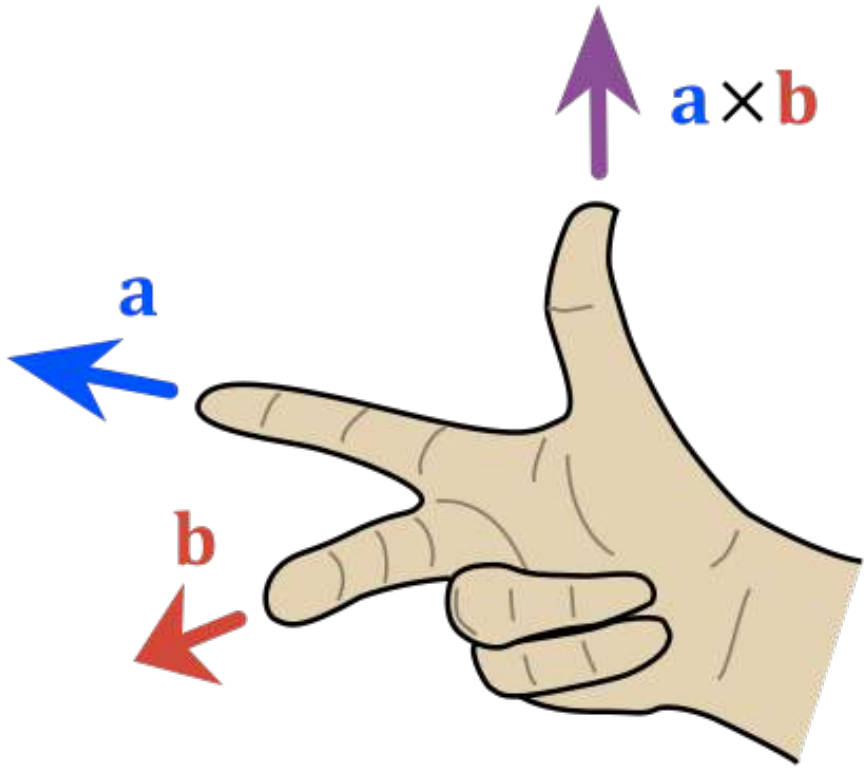

KUKA



Offline Programming



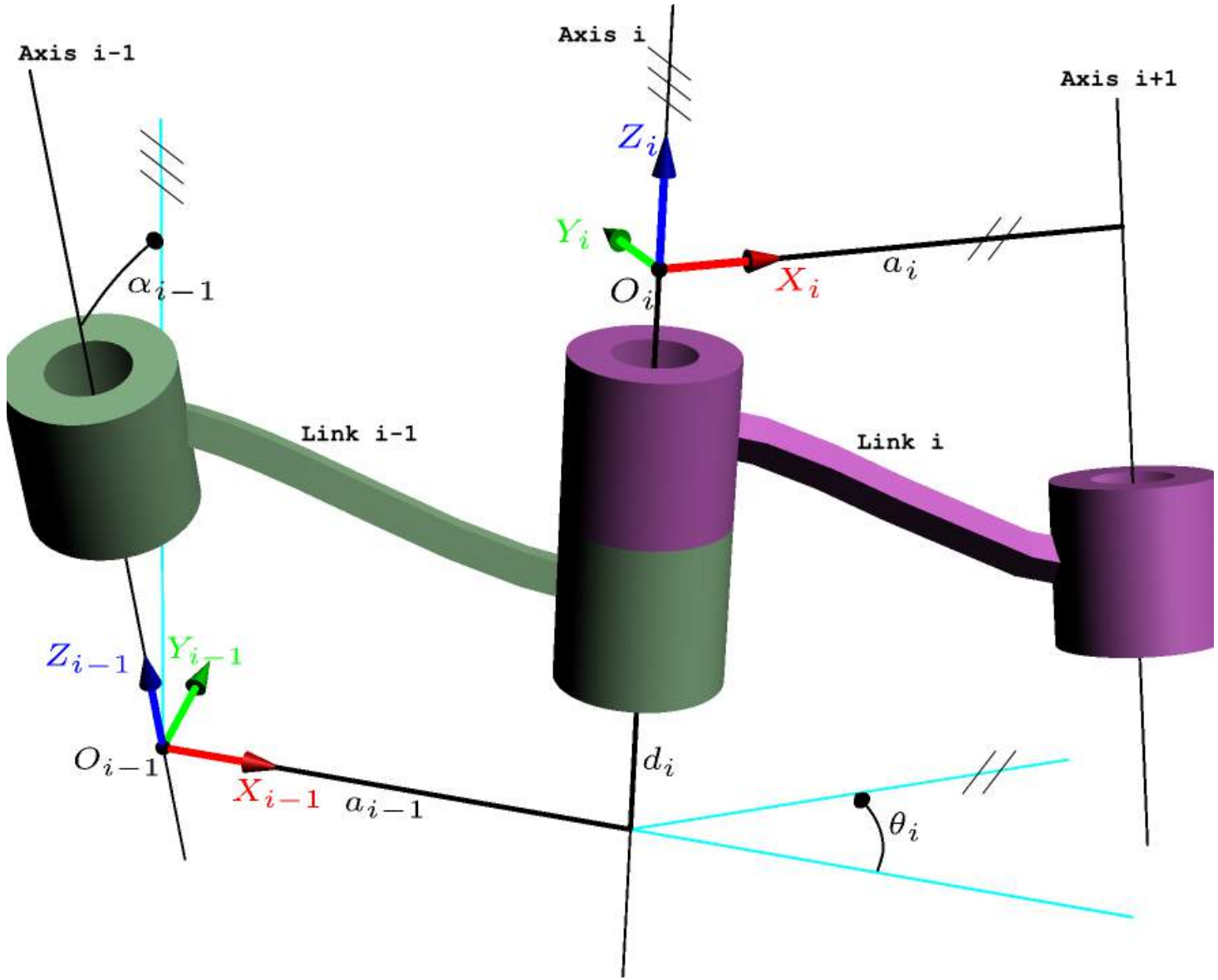




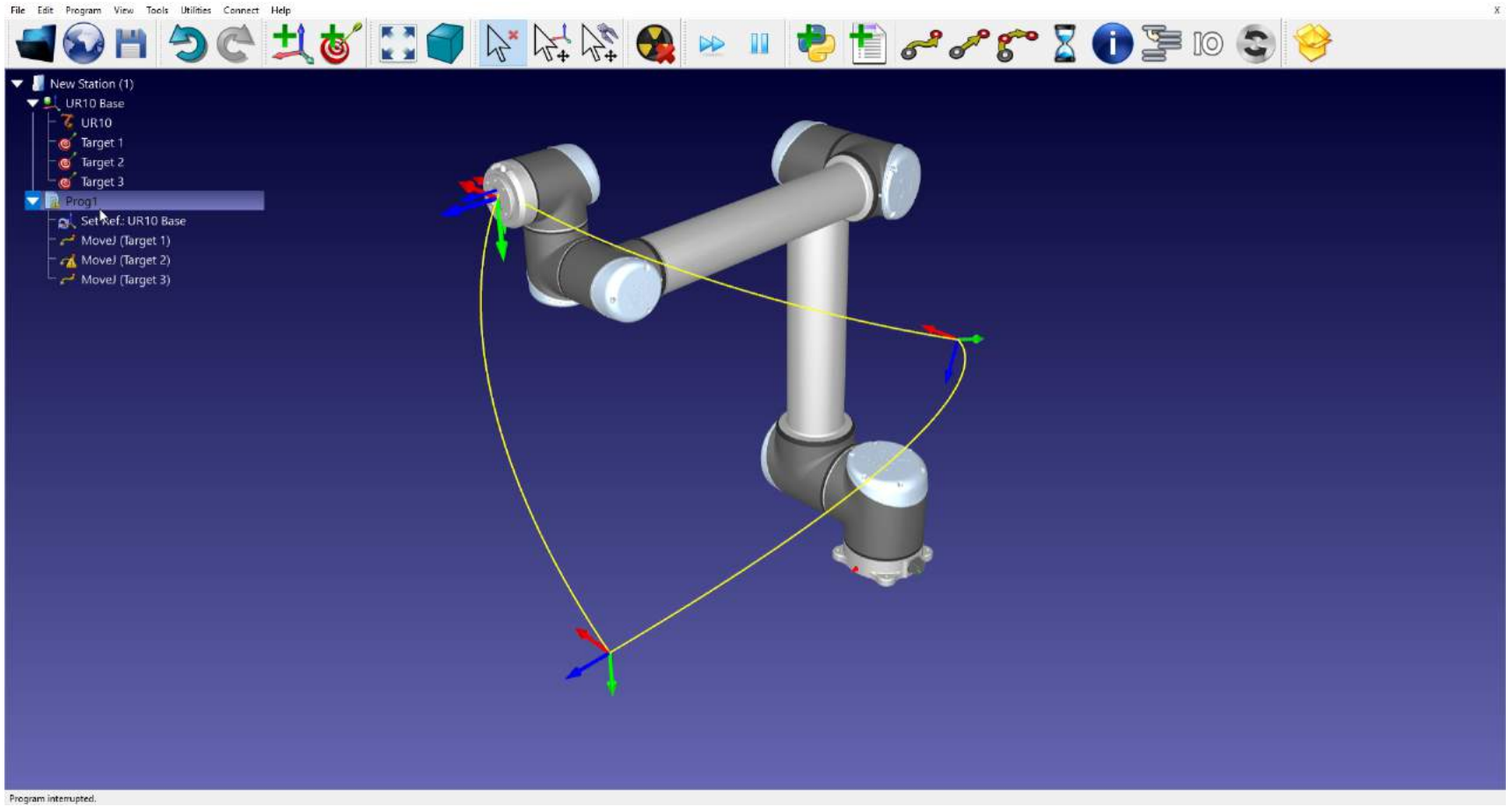
Kinematic Parameters

Kinematic Parameters

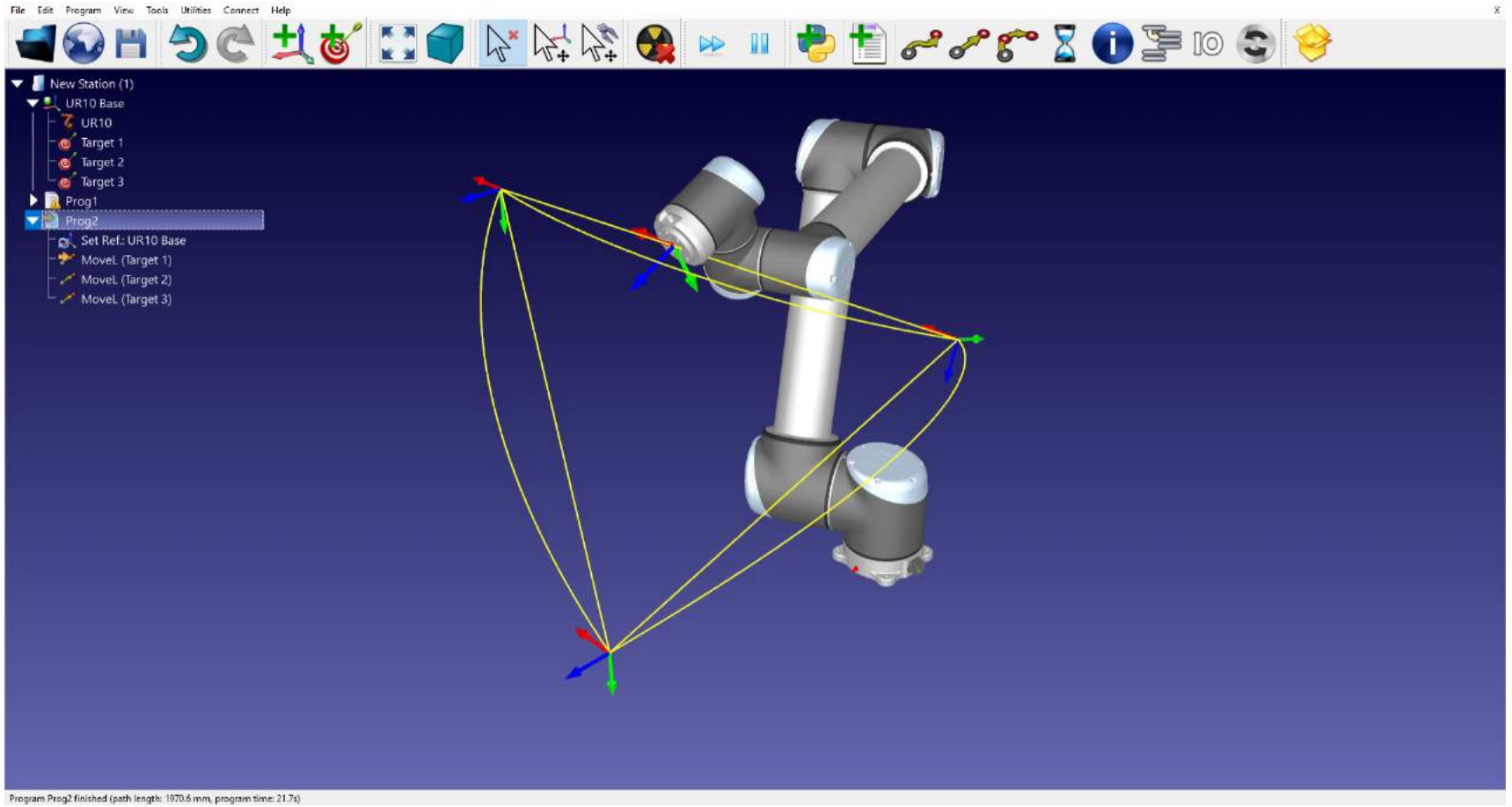
i	α	a	θ	d
0	0	0	0	118
1	π/2	0	π	0
2	0	612.7	0	0
3	0	571.6	0	163.9
4	-π/2	0	0	115.7
5	π/2	0	π	92.2



Joint-Space Motion

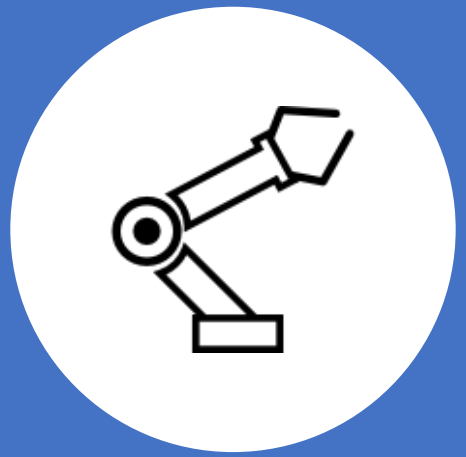


Cartesian Motion



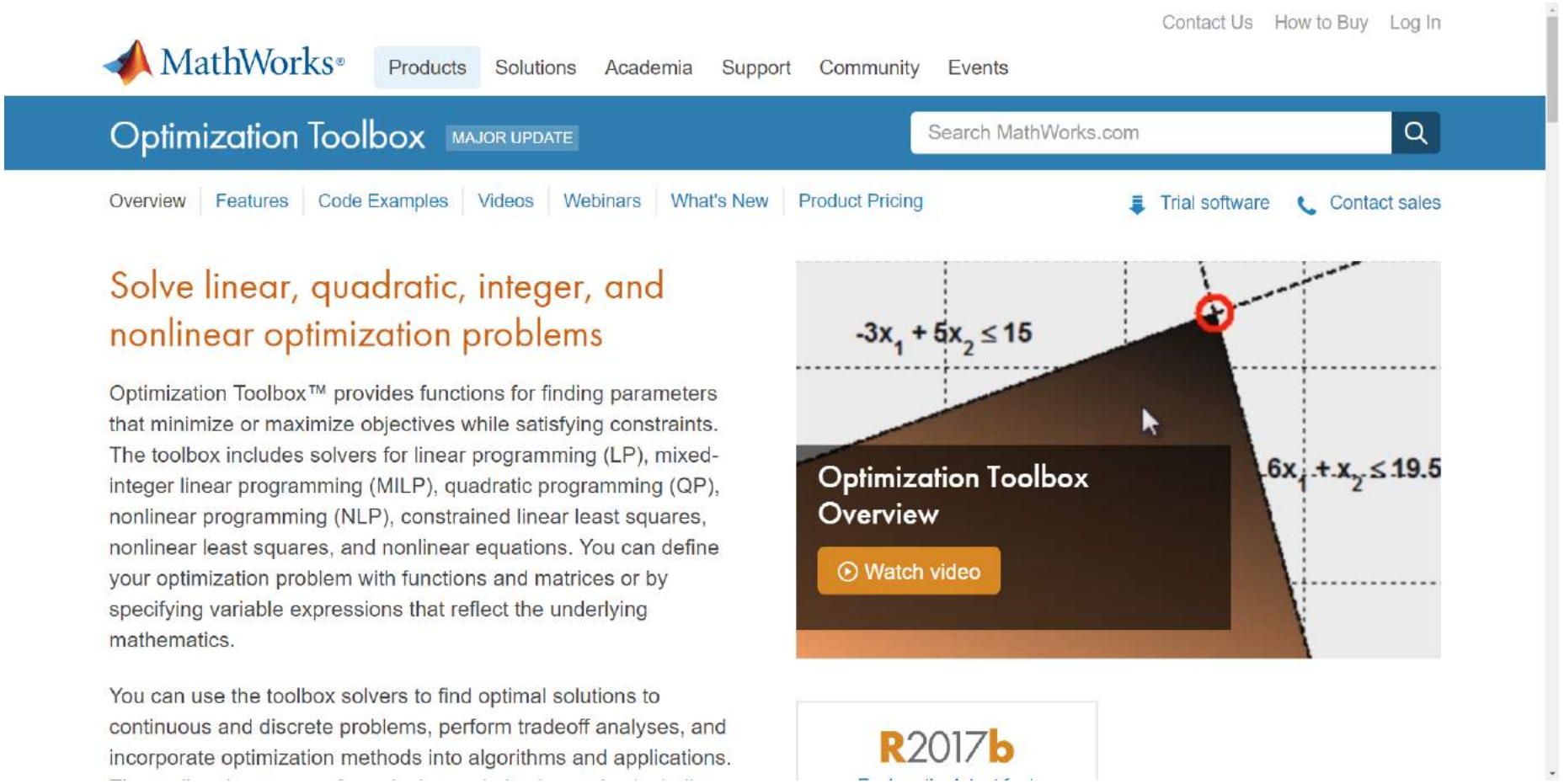
Recap

- Robot theory = math
- Robot simulation
  - Model robot motions and operations
  - Save time
  - Save $$$
  - Improve performance
- Accuracy is very important when trying to do medical procedures
  - Else, “You're Going to Have a Bad Time”

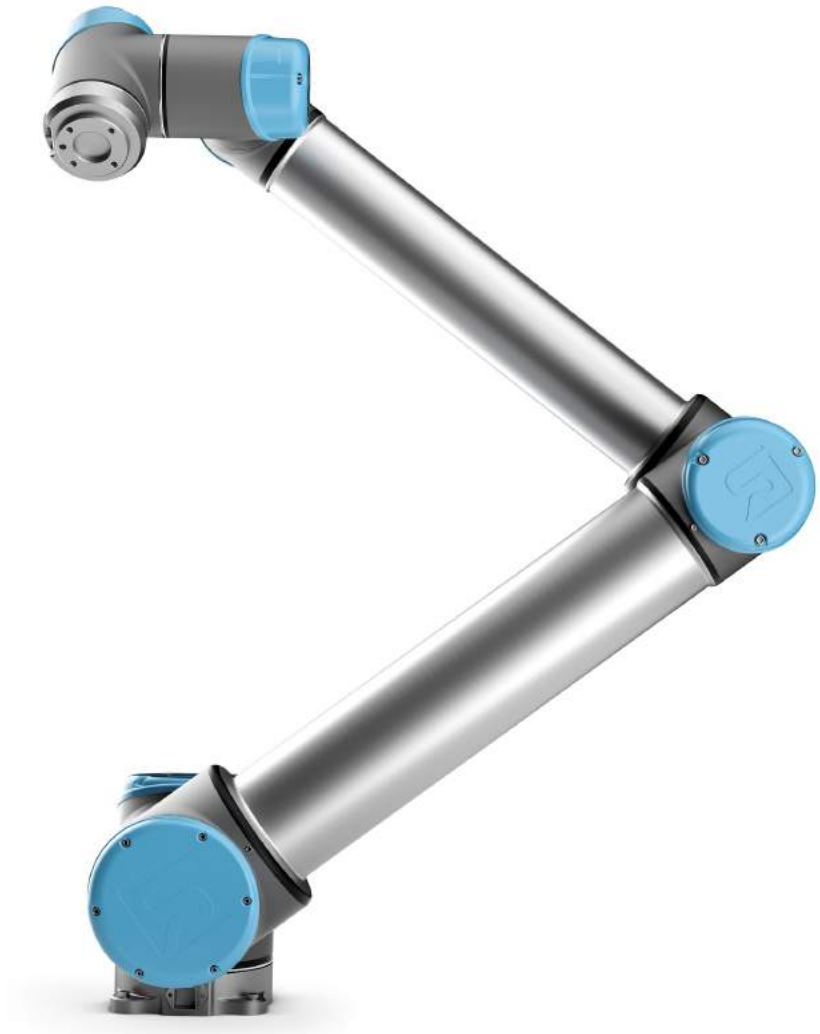


pybotics

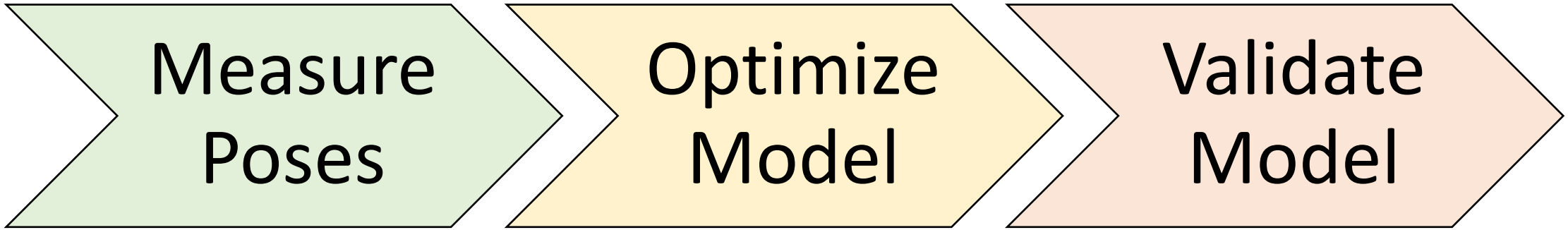
Motivation #1



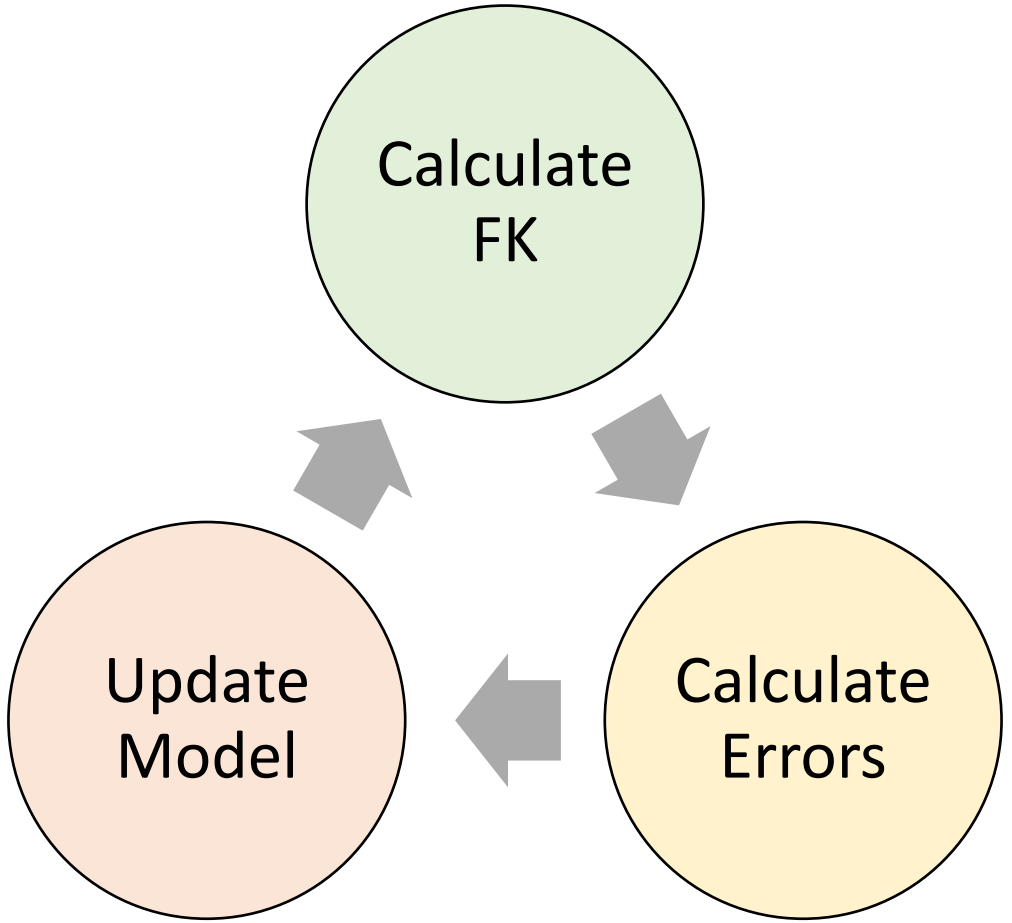
Motivation #2



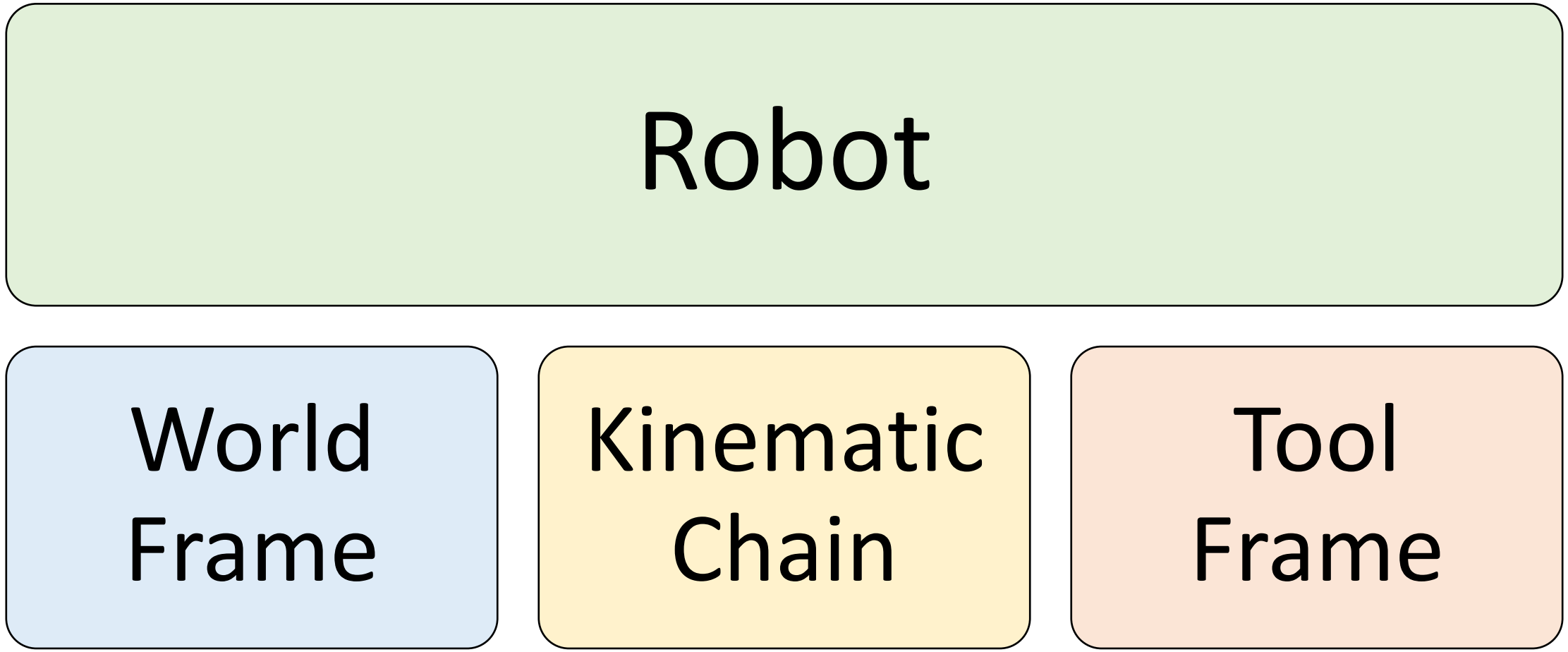
Calibration Overview



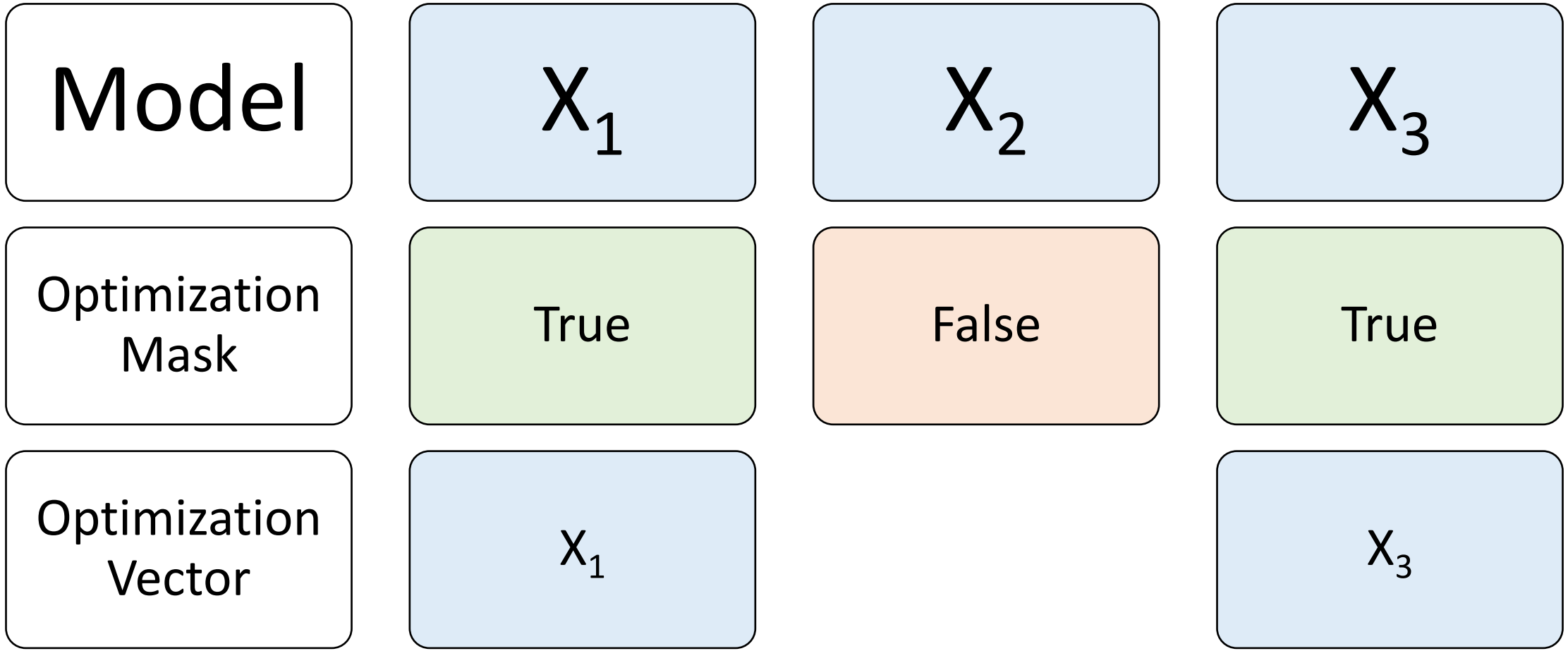
Optimization Cycle



Optimization Vector

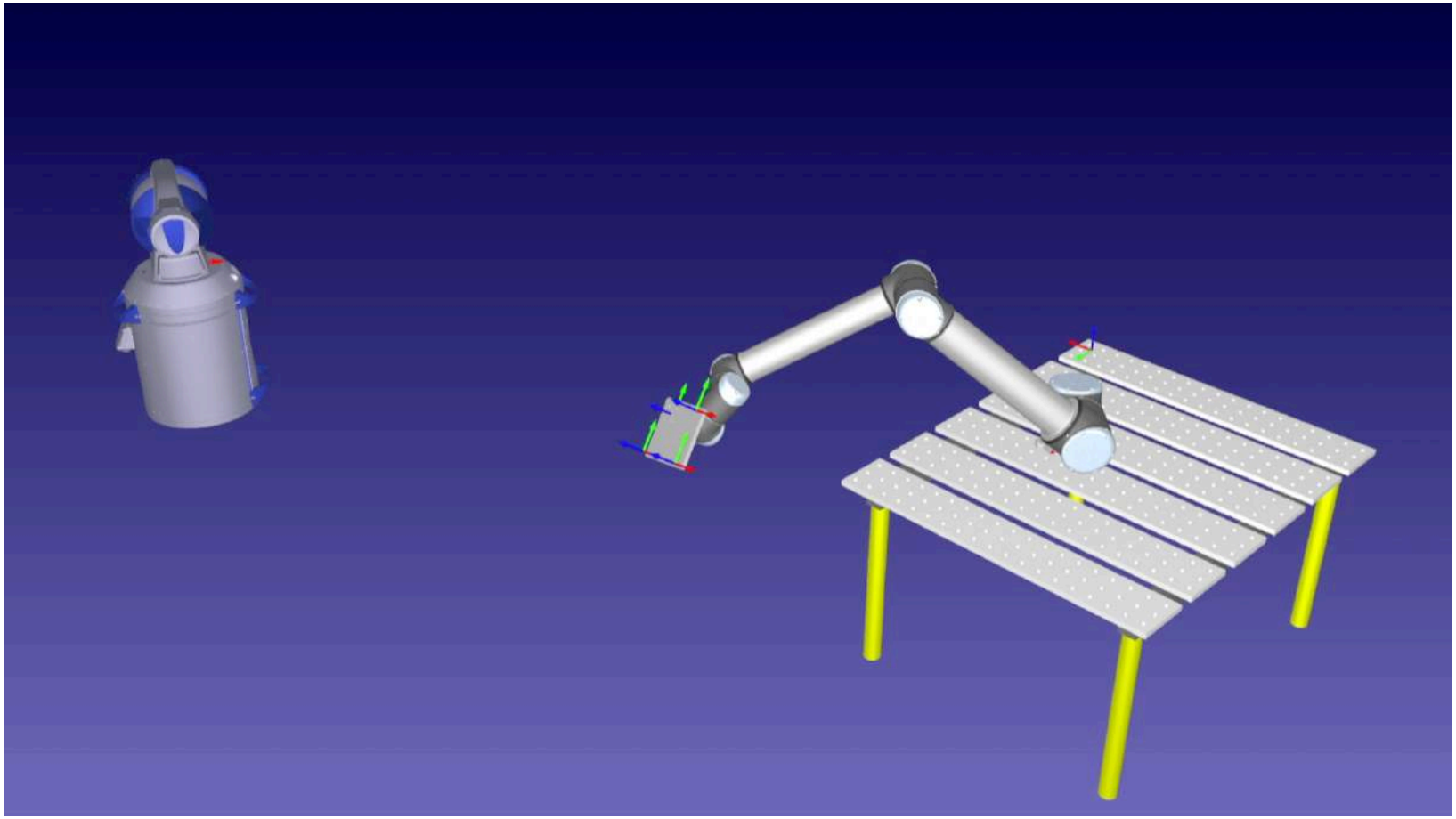


Optimization Mask



FARO ION

UR10 Measurements



Calibration Demo

Jupyter Notebook!

Recap

- Scientific Python Ecosystem are fundamental building blocks for the community
  - Bridge the gap between science, engineering, and software development
- Robots are not very accurate out-of-the-box
  - But we can fix that!

I ❤ Robots
Now What?

- Hardware continuous integration!
  - Continuous calibration
  - Robot performance forecasting and machine learning
- Contribute!
  - Robots & devices
  - Wrappers, server-client interfaces, drivers
  - Frameworks and toolboxes
- Graduate degree!
  - Control and Robotics Laboratory (CoRo) @ ÉTS

Thank You!

- @EngNadeau
- nicholasnadeau.me
- github.com/nnadeau

Third-Party Media

- KUKA Aktiengesellschaft
  - https://www.kuka.com/en-ca/press/media-library
- Courtesy of Rethink Robotics, Inc
  - http://www.rethinkrobotics.com/press/
- uArm Swift Pro
  - https://www.sparkfun.com/products/14342
- Introduction to Robotics: Mechanics and Control, 3rd Edition
  - https://www.pearson.com/us/higher-education/program/Craig-Introduction-to-Robotics-Mechanics-and-Control-3rd-Edition/PGM11887.html
- Precision and accuracy
  - http://www.antarcticglaciers.org/glacial-geology/dating-glacial-sediments-2/precision-and-accuracy-glacial-geology/
- da Vinci Xi
  - https://www.intuitivesurgical.com/company/media/images/da-vinci-xi/
- Universal Robots
  - https://www.universal-robots.com/media/
- KUKA LBR Joints
  - https://www.kuka.com/-/media/kuka-downloads/imported/48ec812b1b2947898ac2598aff70abc0/spez_lbr_iiwa_en.pdf
- Right-hand Rule
  - https://en.wikipedia.org/wiki/Right-hand_rule
- DH Parameters
  - https://en.wikipedia.org/wiki/Denavit%E2%80%93Hartenberg_parameters