ETH zürich

Estimation of Actuation Configuration for a Multi-Actuated Blimp

Final Presentation (Semester Thesis)

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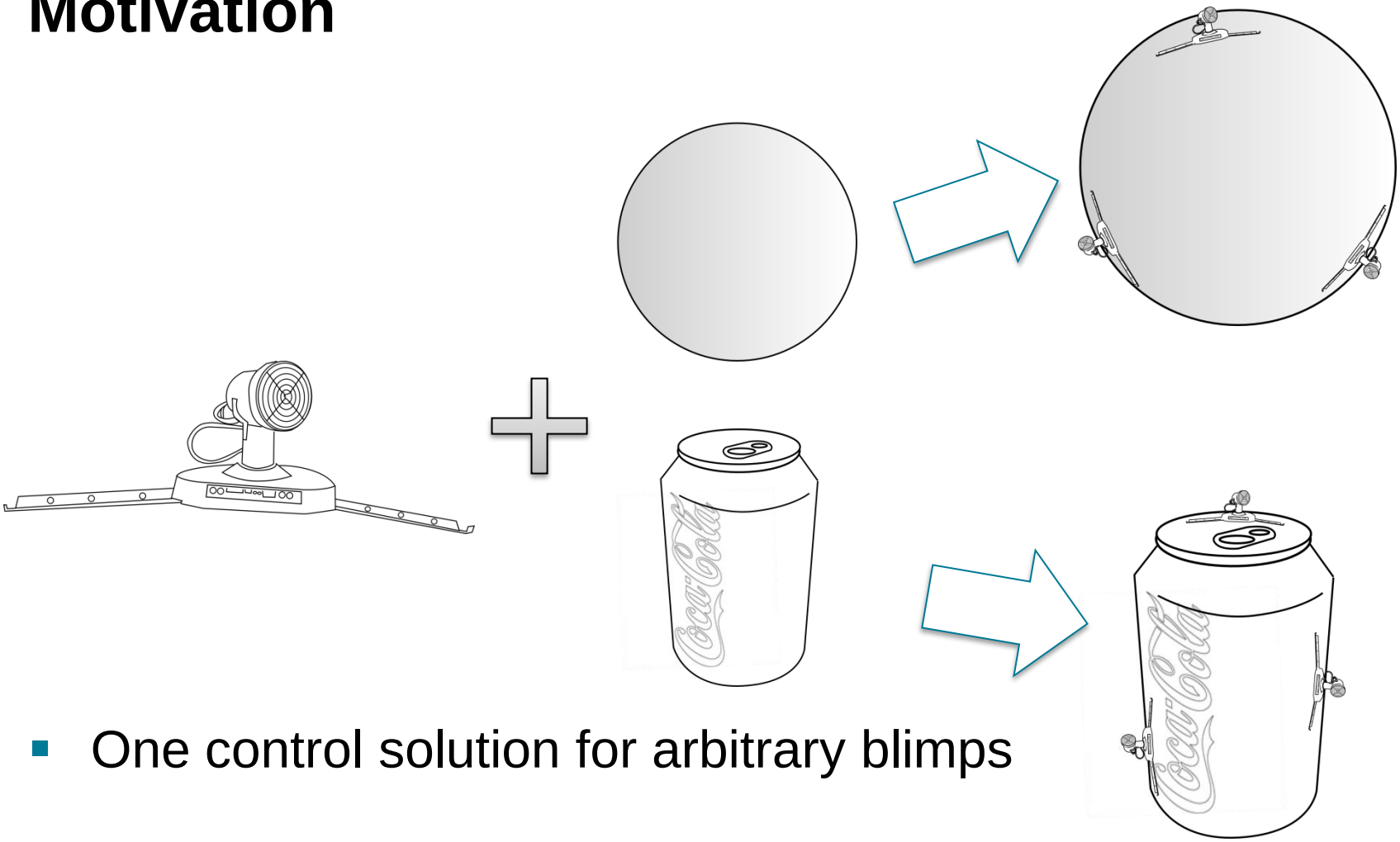
Advisors: Kostas Alexis, Markus Achtelik

Motivation



- One control solution for arbitrary blimps

Goal

- Find Blimp model parameters
- Use IMU measurements

Content

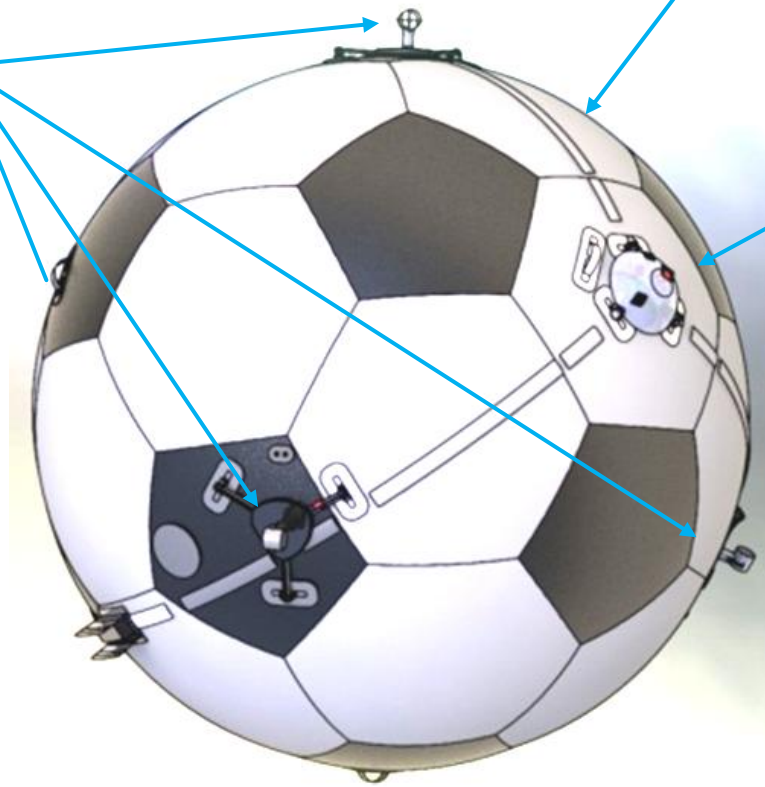
- System Overview
- Problem Formulation
  - Parameters
  - System Model
  - Input Pattern
  - Optimization
- Results
  - Simulation Results
  - Experimental Results
  - Ground Truth
- Conclusion & Outlook

System Overview

Spherical Hull filled with Helium

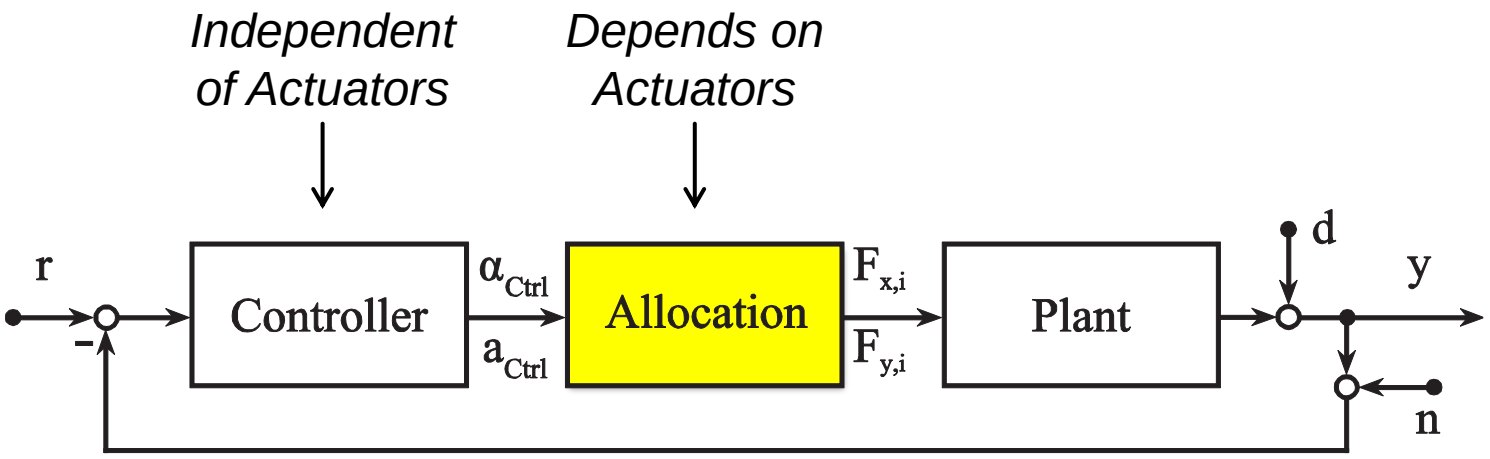
4 Actuation Units (AU)

Electronics:
- IMU
- Controller
- XBee

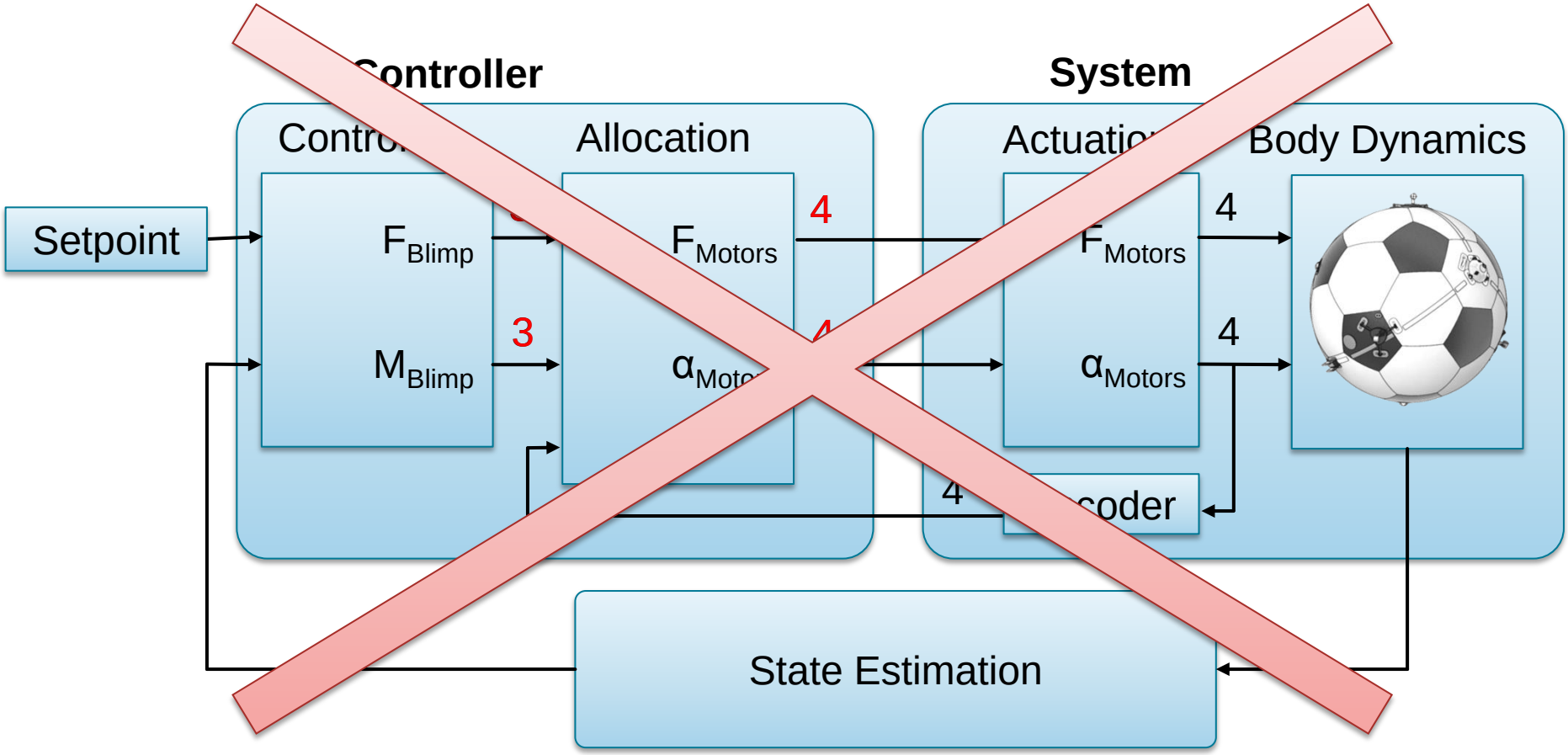


Rotation

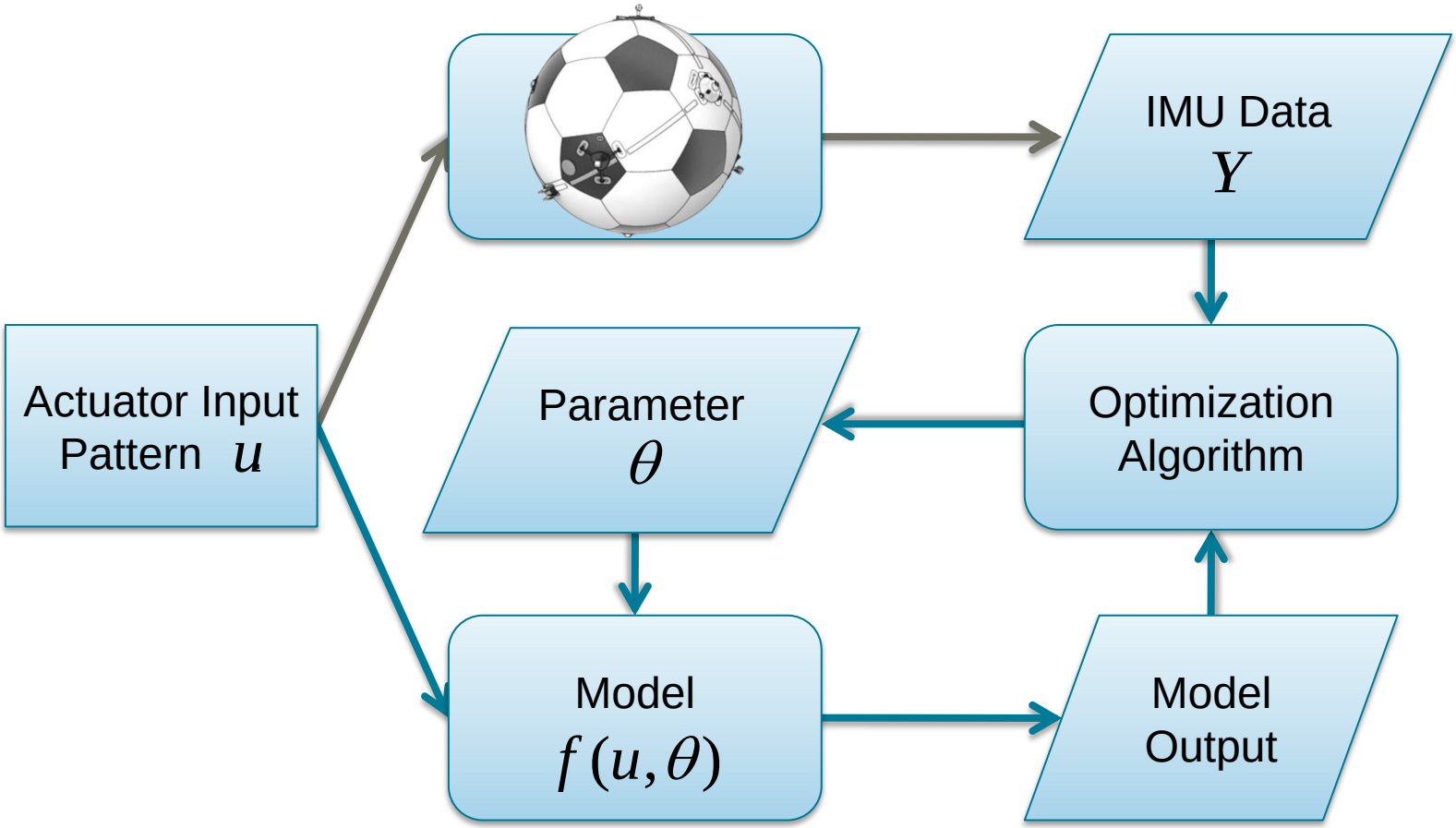
System Overview: Control



System Overview



Problem Formulation



Problem Formulation: System Model

- Angular Acceleration

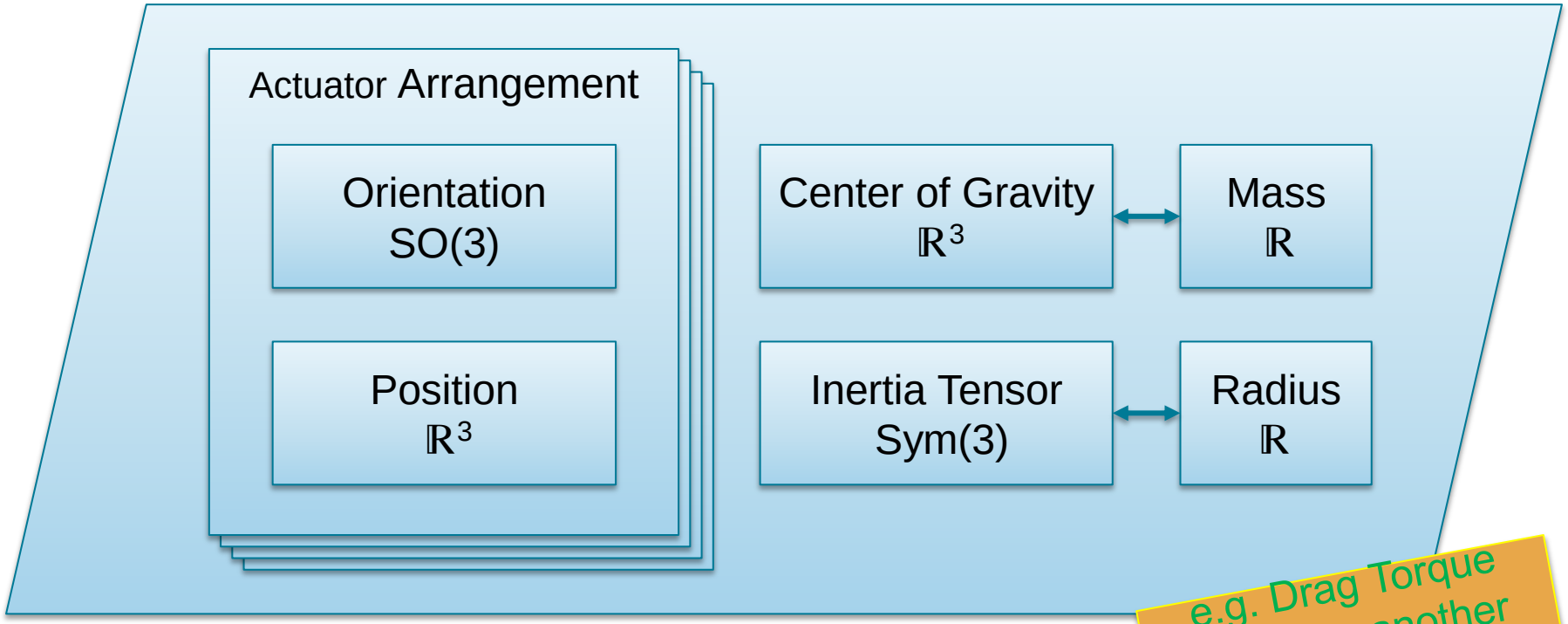
$$\mathbf{f}(\mathbf{x}, \mathbf{u}, \boldsymbol{\theta}) = \hat{\boldsymbol{\alpha}}_b = \mathbf{J}_b^{-1}(\mathbf{M}_b - \boldsymbol{\omega}_b \times \mathbf{J}_b \boldsymbol{\omega}_b)$$

with

$$\mathbf{M}_b = \underbrace{\sum_{k=1}^{N} \left[\mathbf{C}_{b,m_k} \left(\mathbf{p}_{m_k}^{m_k,cog} \times \mathbf{F}_{m_k}\right)\right]}_{\mathbf{M}^{actuation}} - \underbrace{\left(\mathbf{p}_b^{cob,cog} \times (\mathbf{C}_{b,w} m \mathbf{g}_w)\right)}_{\mathbf{M}^{gravity}}$$

- Aerodynamic effects on rotation neglected ($\mathbf{M}^{aero} << \mathbf{M}^{actuation}$)

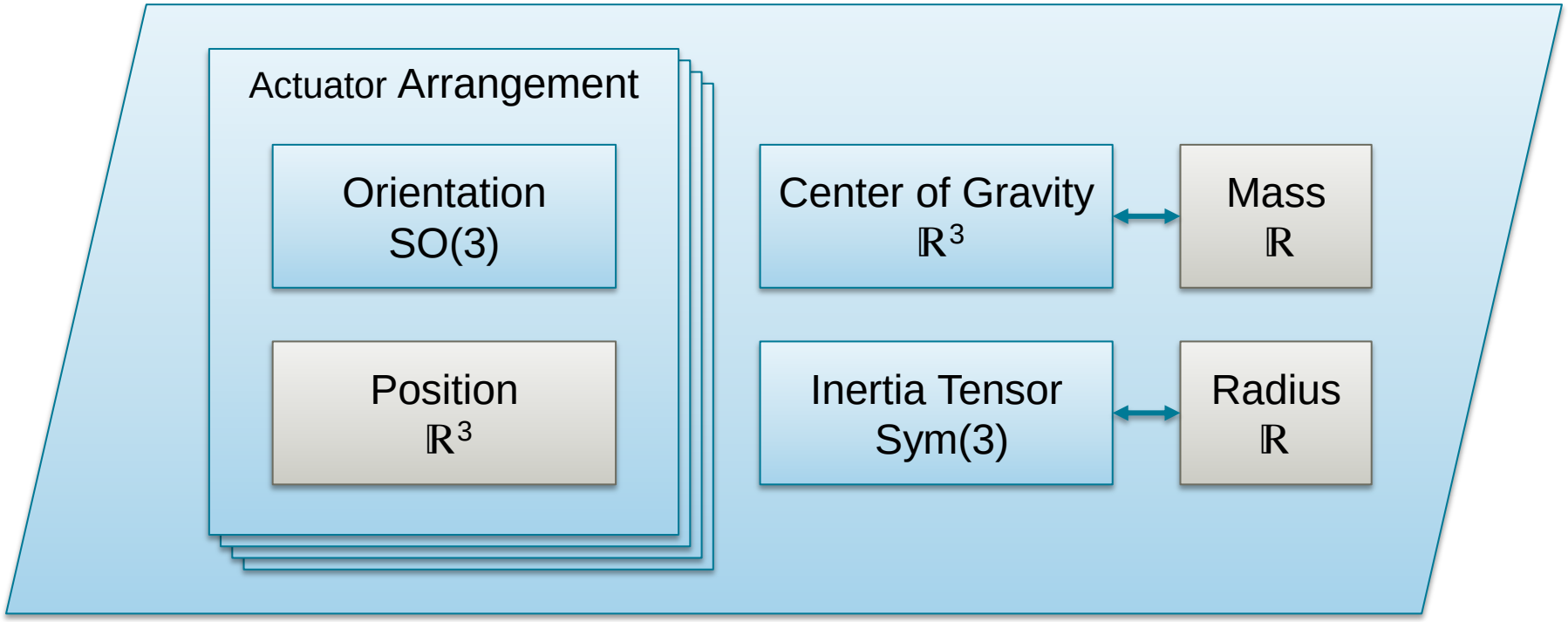
Problem Formulation: Parameters



- Full Parameter set is only jointly observable

e.g. Drag Torque would be another jointly observable param

Problem Formulation: Parameters



- Position is assumed to be on sphere
- Radius and mass are assumed to be known (scales J & cog)

Problem Formulation: System Model

- Angular Acceleration

$$\mathbf{f}(\mathbf{x}, \mathbf{u}, \boldsymbol{\theta}) = \hat{\boldsymbol{\alpha}}_b = \mathbf{J}_b^{-1}(\mathbf{M}_b - \boldsymbol{\omega}_b \times \mathbf{J}_b \boldsymbol{\omega}_b)$$

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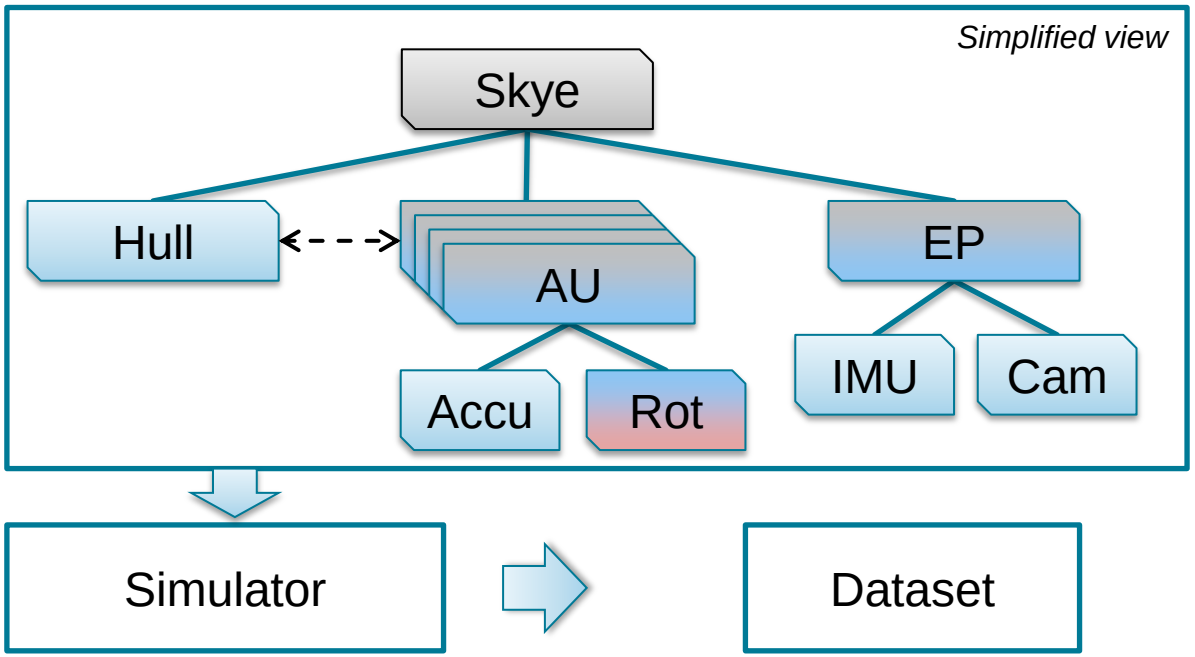
Simulator

- Object oriented simulator in MATLAB
- Modular concept for (almost) arbitrary blimps

Assembly
parts, Hamiltonians, …

Part
mass, dimension, drag coeff., …

Actuator
States, active forces …



Problem Formulation: Optimization

- Nonlinear Least Squares

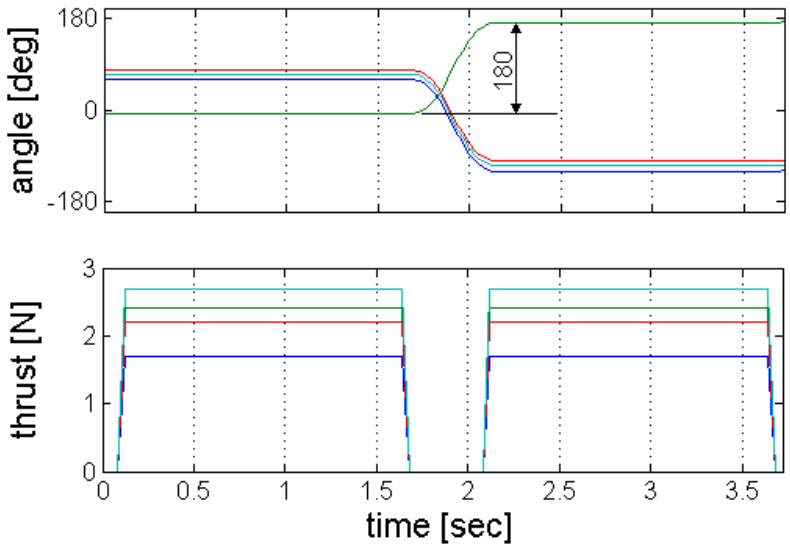
$$S(\boldsymbol{\theta}) = \sum_{i=1}^{N} \|\mathbf{y}_i - \mathbf{f}(\mathbf{x}_i, \boldsymbol{\theta})\|^2$$

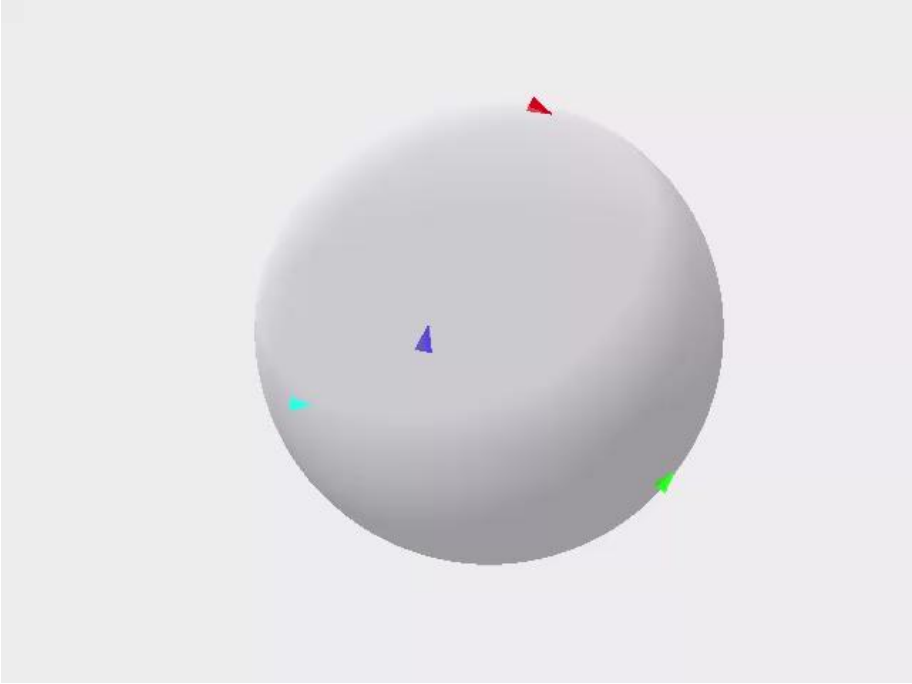
- Levenberg-Marquardt
  - Gradient based minimization
  - Robust and fast convergence

$$(\mathbf{J}^\top \mathbf{J} + \lambda \mathrm{diag}(\mathbf{J}^\top \mathbf{J}))\boldsymbol{\delta} = \mathbf{J}^\top [\mathbf{y} - \mathbf{f}(\boldsymbol{\theta})]$$

Problem Formulation: Input Pattern

- Inputs must be **applicable** and **sufficiently excited**
  - Apply sequence of **forward/backward** force patterns in **varying directions** for all actuation units
  - Steady state motor dynamics





Results

- Simulation Results
  - Confidence Region
  - Convergence Region
  - Casestudies
- Experimental Results
- Groundtruth with Leica

Simulation: Confidence Region

- Zeige Konvergenz & Anzahl Iterationen mit LMA

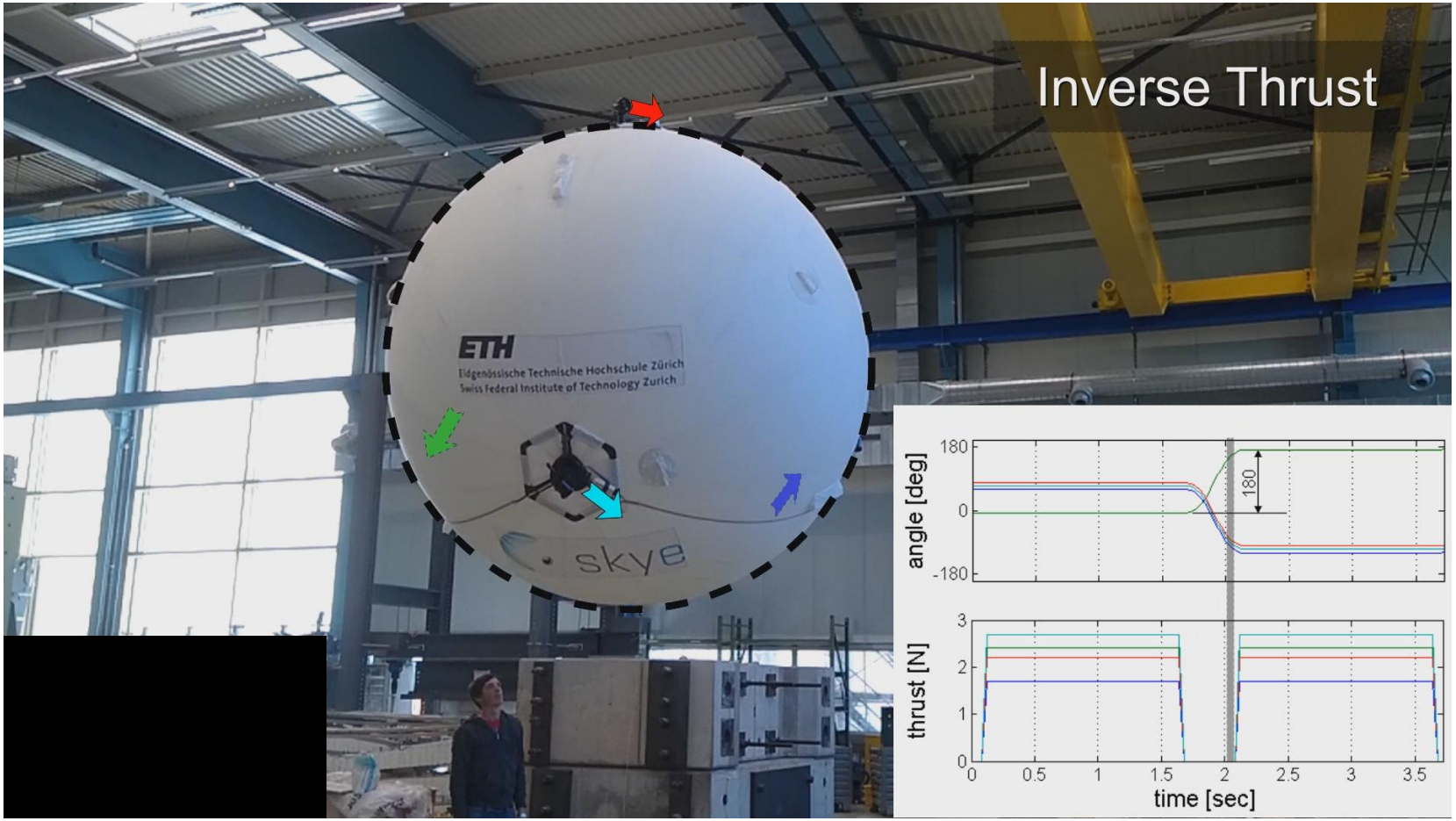
Simulation: Casestudies

mean	AU4 x	AU4 y	J	cog
4 AUs	6.18e-04	7.66e-04	6.12e-02	6.94e-05
No drag	-4.89e-04	1.38e-03	5.16e-02	1.81e-05
Single AU				
std	**AU4 x**	**AU4 y**	**J**	**cog**
4 AUs	3.65e-03	7.19e-03	3.00e-02	1.35e-04
No drag	4.29e-03	7.96e-03	3.35e-02	1.21e-04

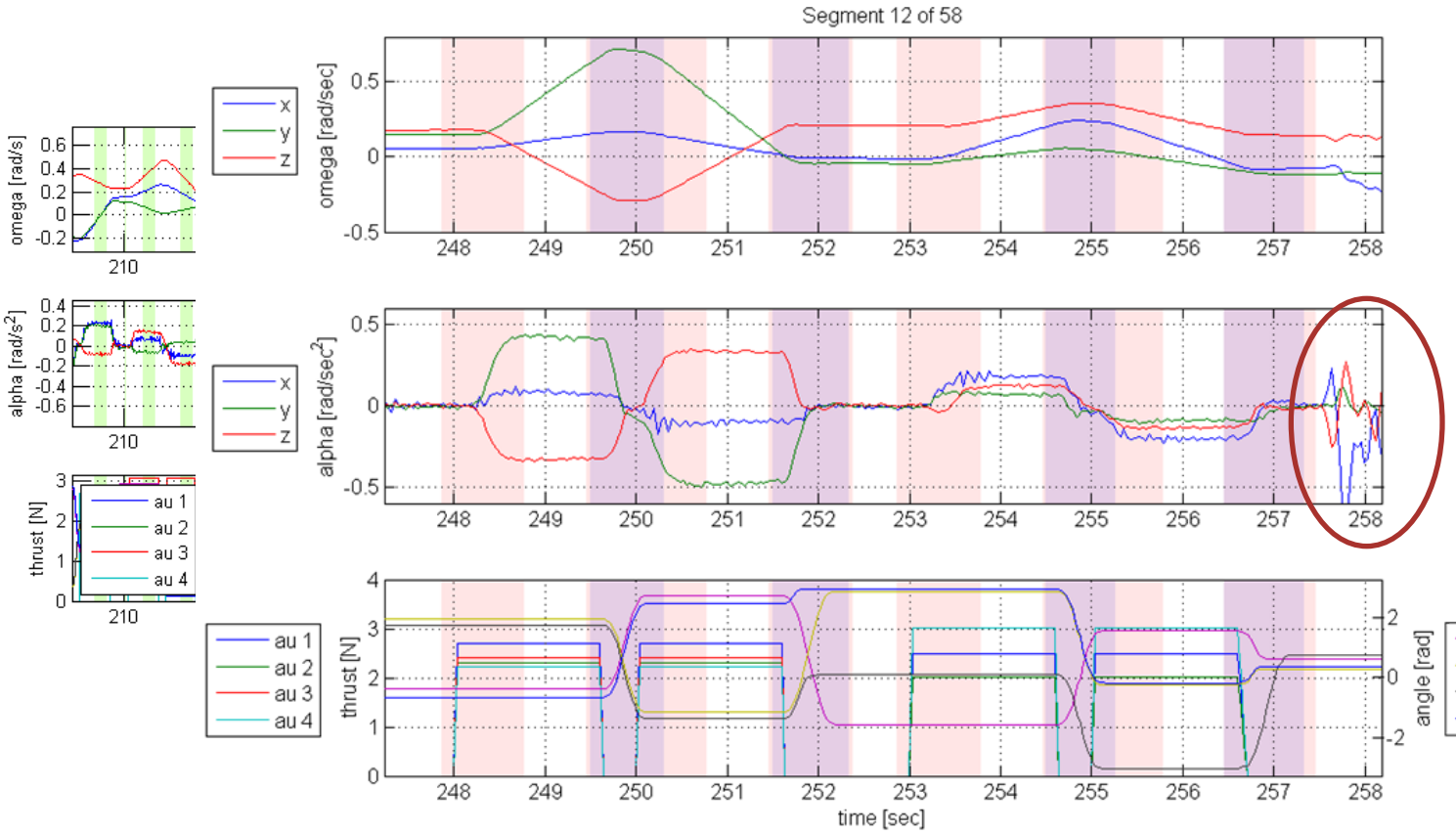
Resnorm [rad/s2]
6.73e-04
6.88e-04

32 simulations à 2000 raw datapoints

Problem Formulation: Input Pattern



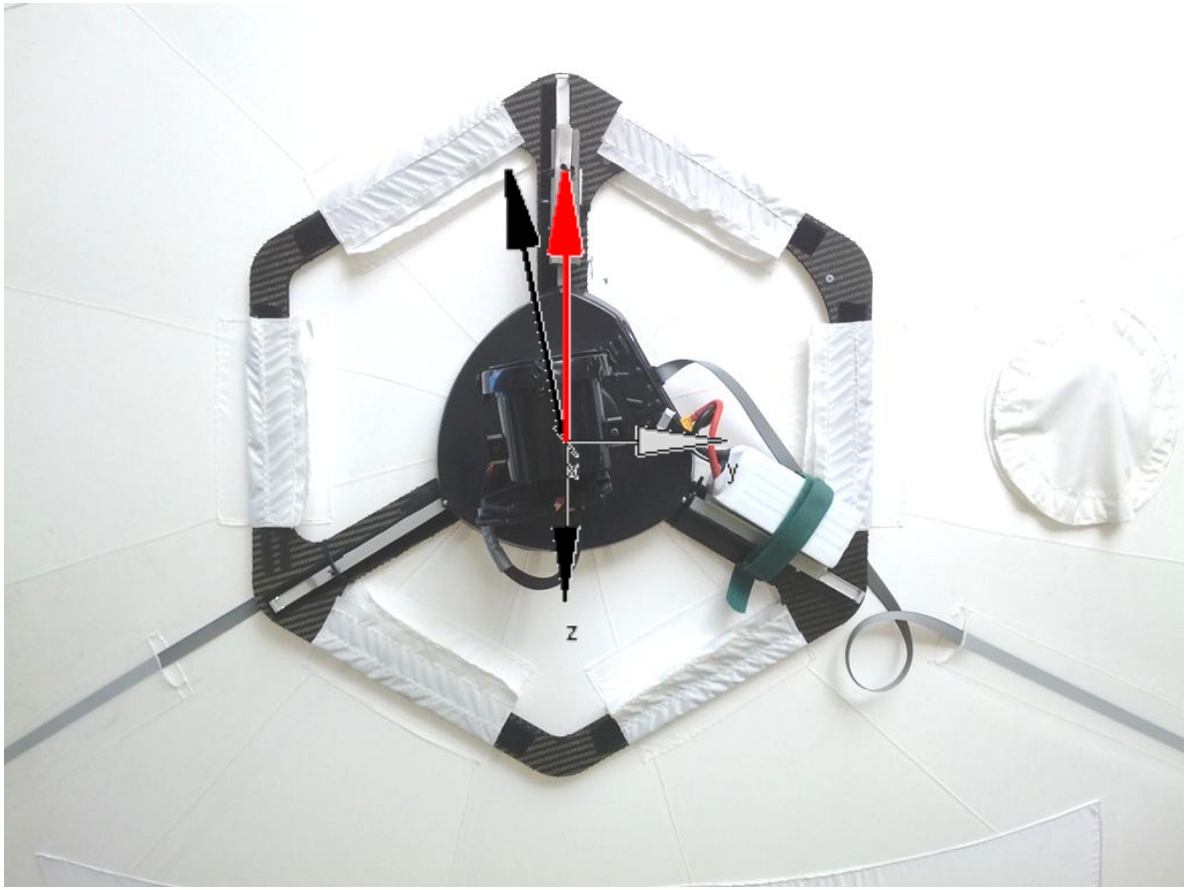
Data Acquisition (Preprocessing)



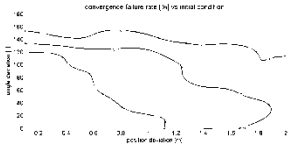
Disturbance: Remove manually

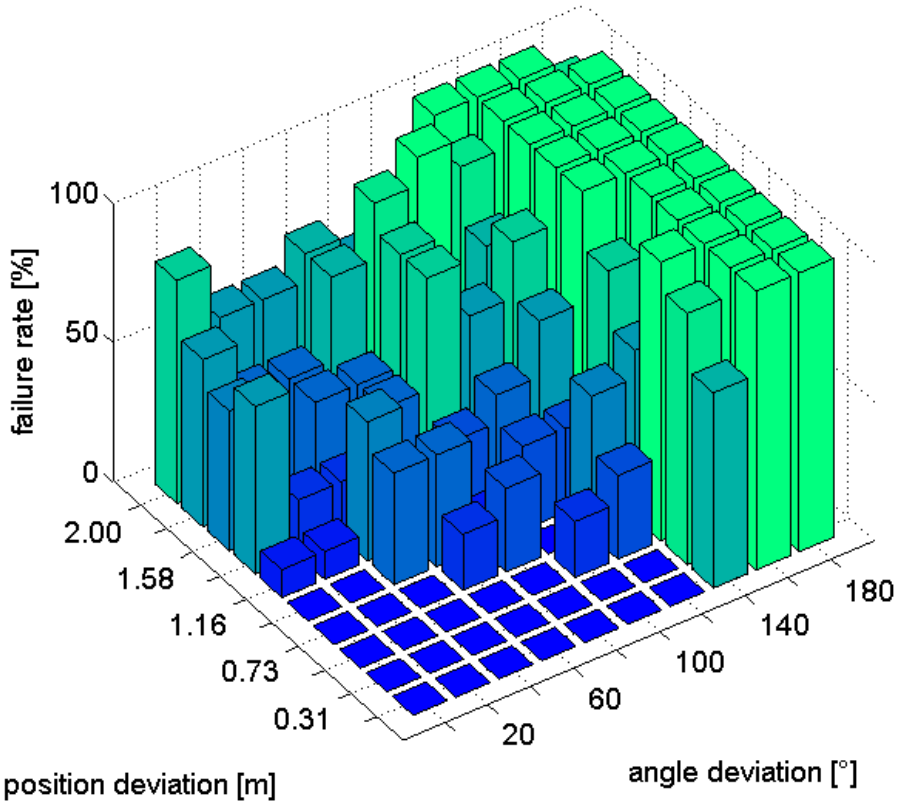
Results: Experiments

Experiments



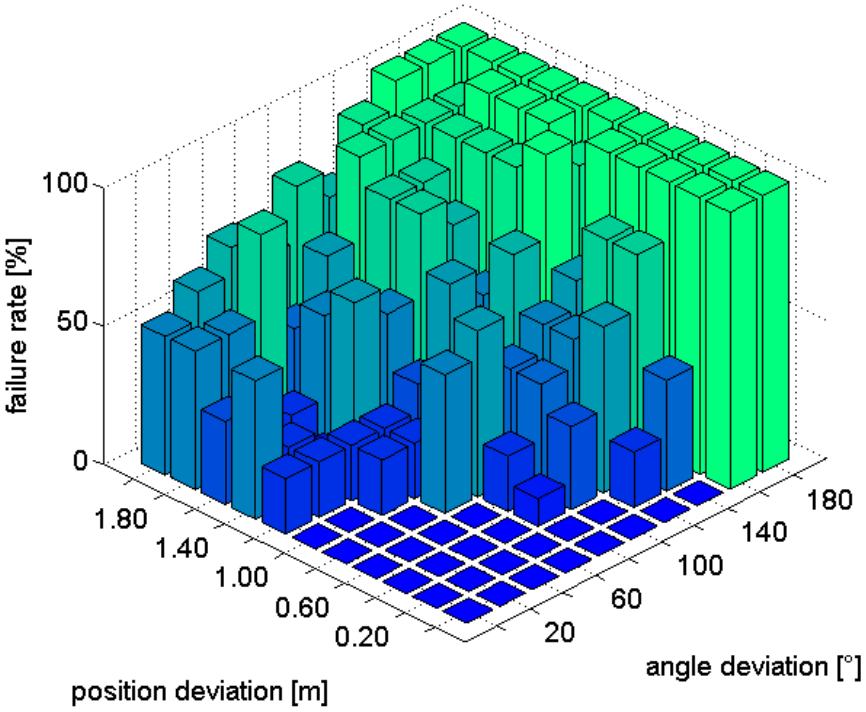
Simulation: Convergence Region





Initial Parameters can be about **1m or 120°** apart of the true value

Experiment: Convergence Region

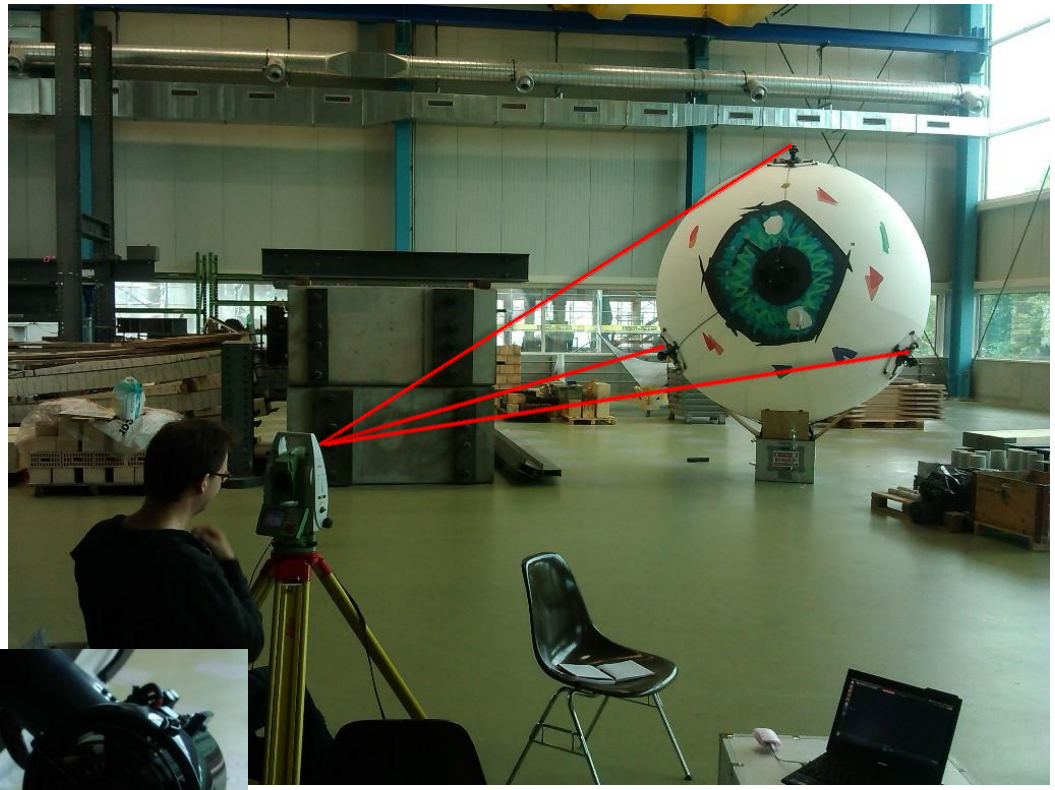


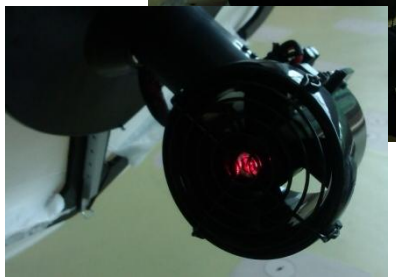
Initial Parameters can be about **1m or 120°** apart of the true value

Results: „Ground Truth“ (Leica)

- 3 AU‘s visible at once
- Use different views

- Fit data to get tetrahedral‘s edge length
  - Residual below 0.01m

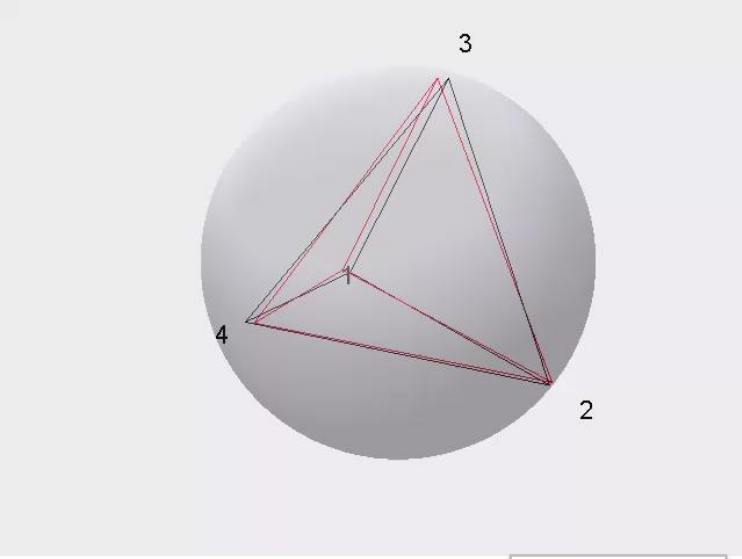




Results: Compare Leica and Batch Solution

- Compare tetrahedral edge length

Relative error of batch solution			
%	AU2	AU3	AU4
AU1	1.68	0.86	2.76
AU2		0.67	2.47
AU3			3.78



Discussion

- To be done!
- How can data be used

Outlook

- To be done

- Use data for allocation
- Best length of input patterns
- Use it for different Blimps