ETH zürich

Estimation of Actuation Configuration for a Multi-Actuated Blimp

Final Presentation (Semester Thesis)

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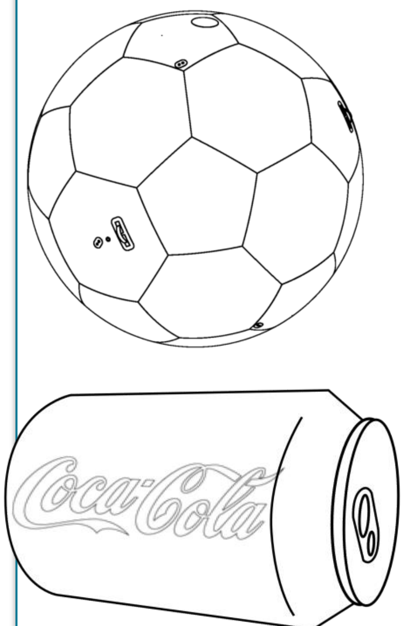
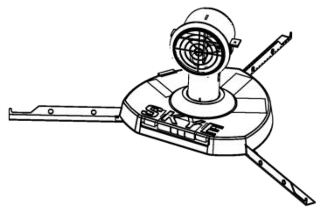
Advisors: Kostas Alexis, Markus Achtelik

Motivation: Control Arbitrary Blimp

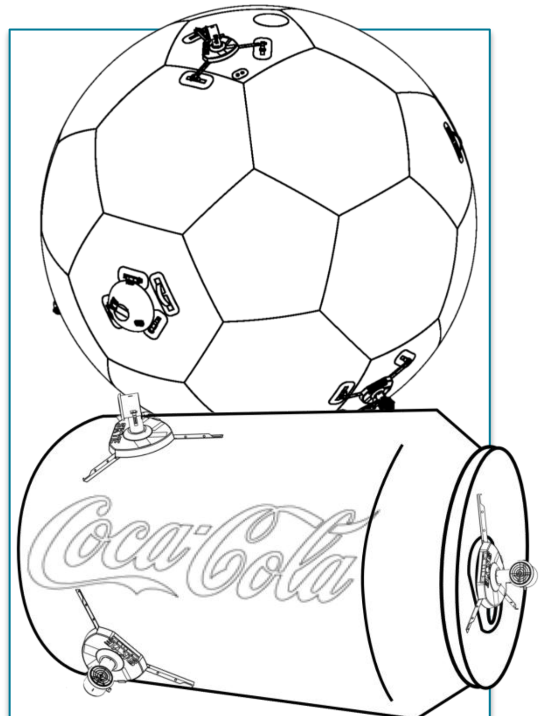


Arbitrary Blimp Hulls



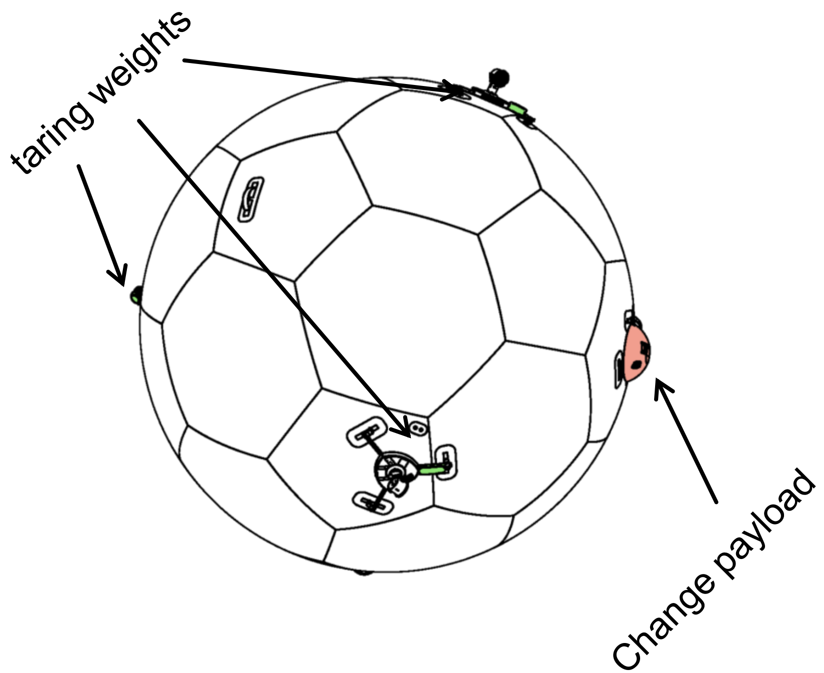
Skye Actuation Unit

Parameter Identification

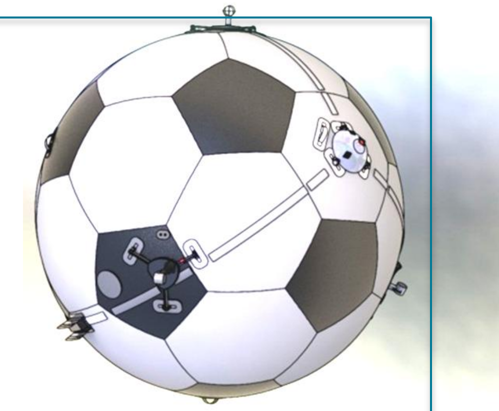


Elegant Movement

Motivation: Improve Usability & Control



Help with system taring



Controller

Hard to measure

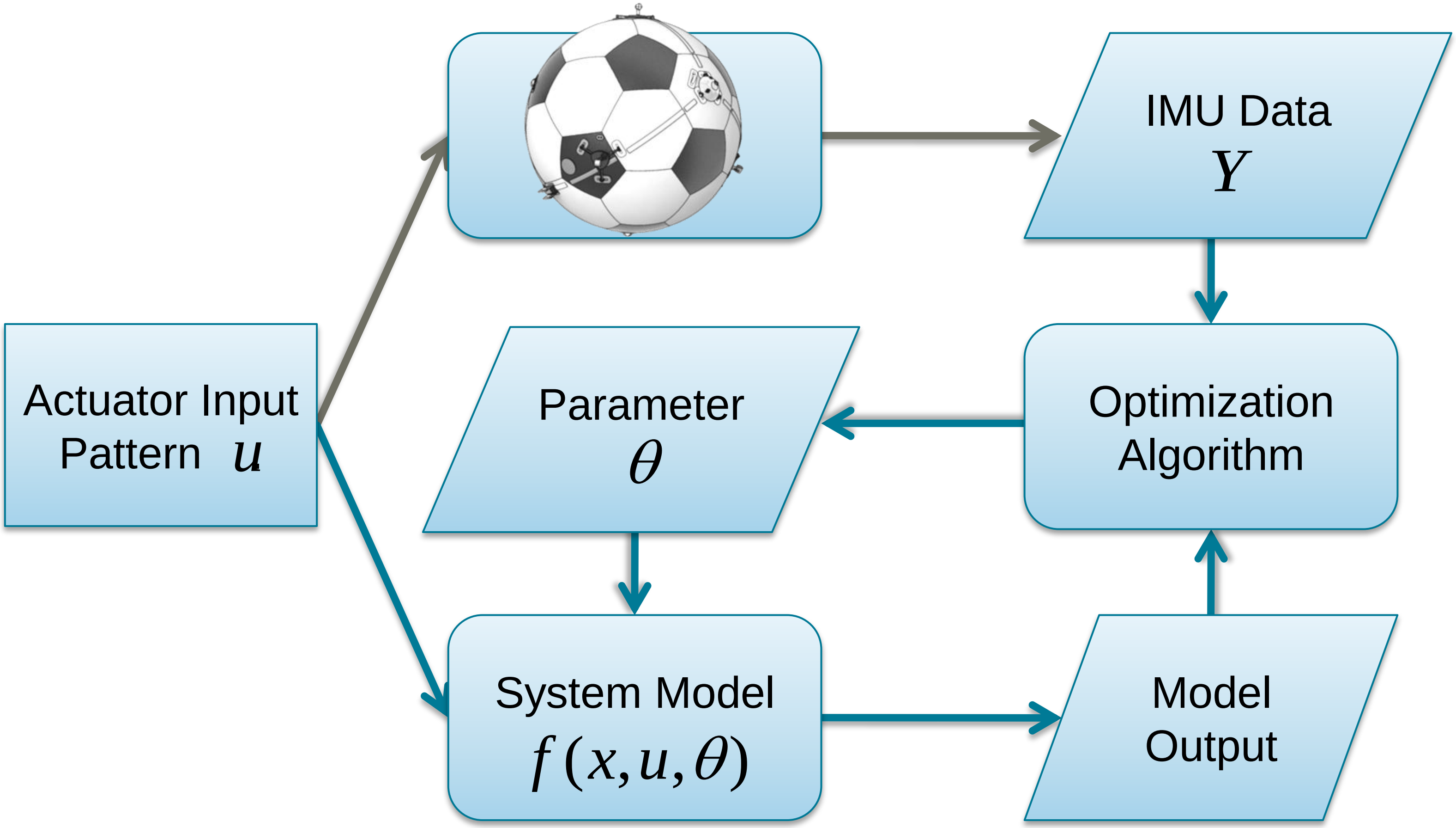
J cog C_{bm}

Determine hard to measure parameters

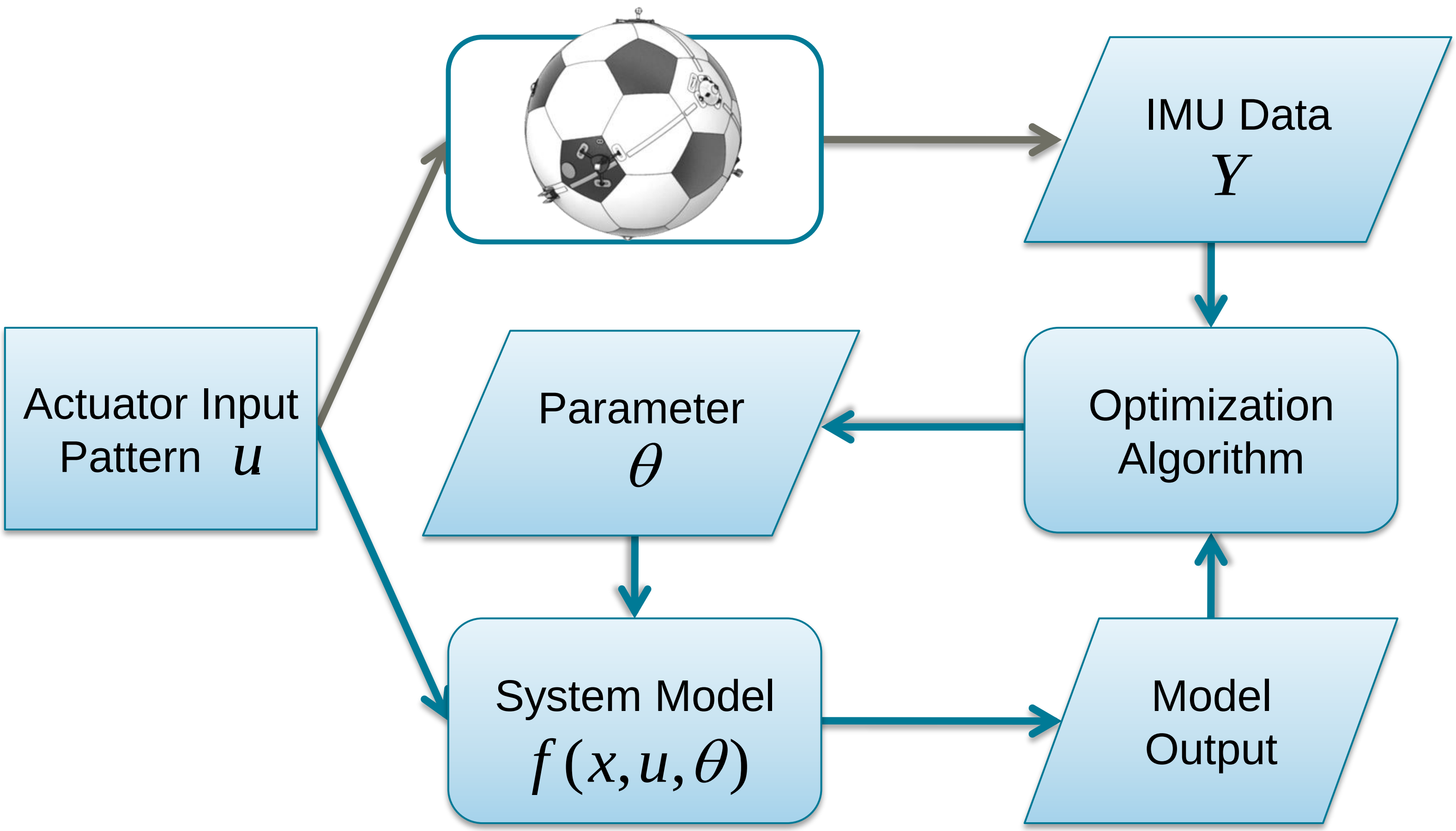
Content

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

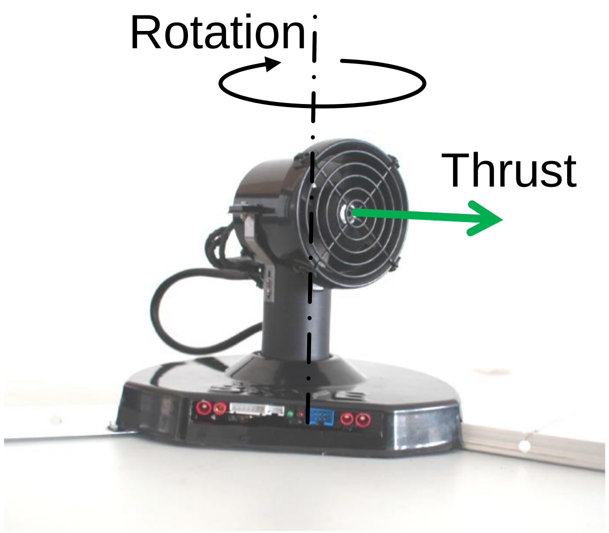
Problem Formulation

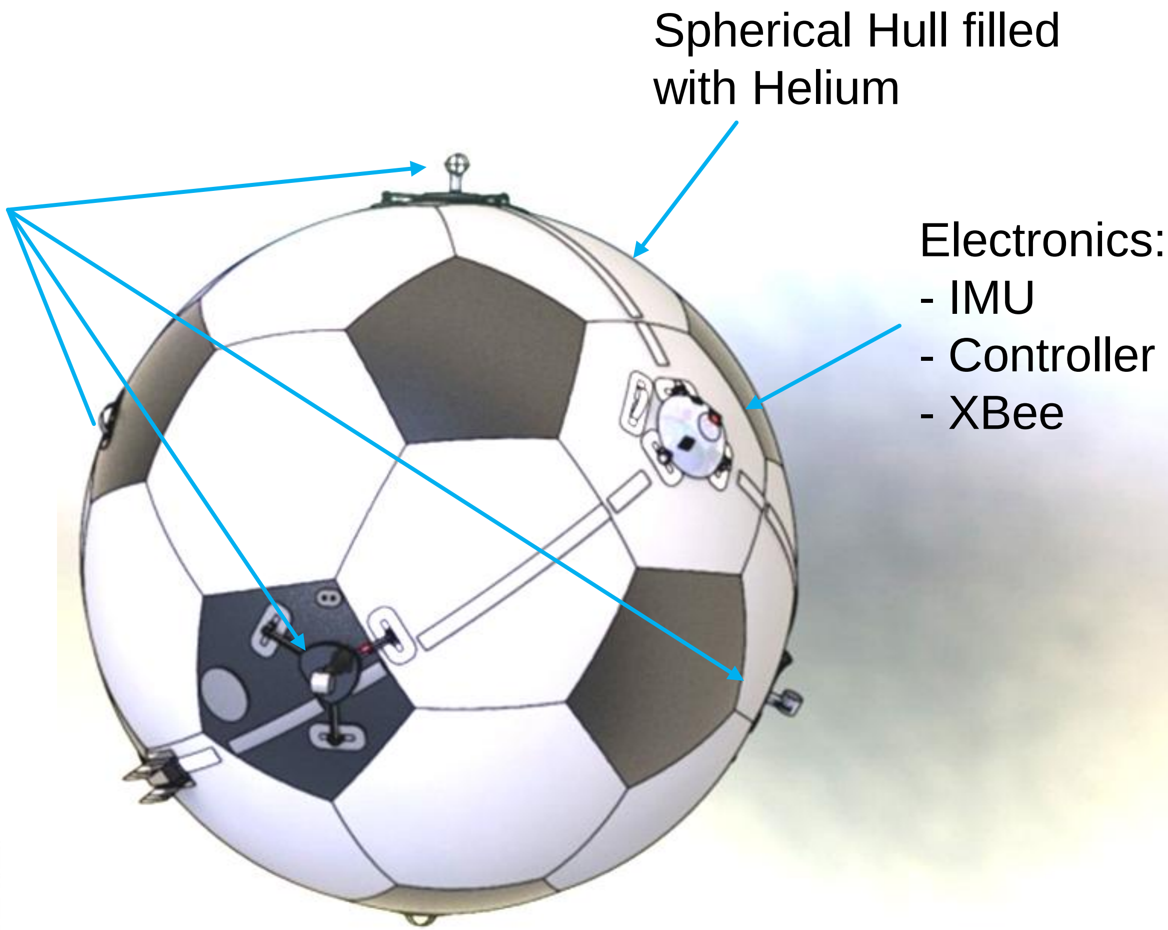


Problem Formulation

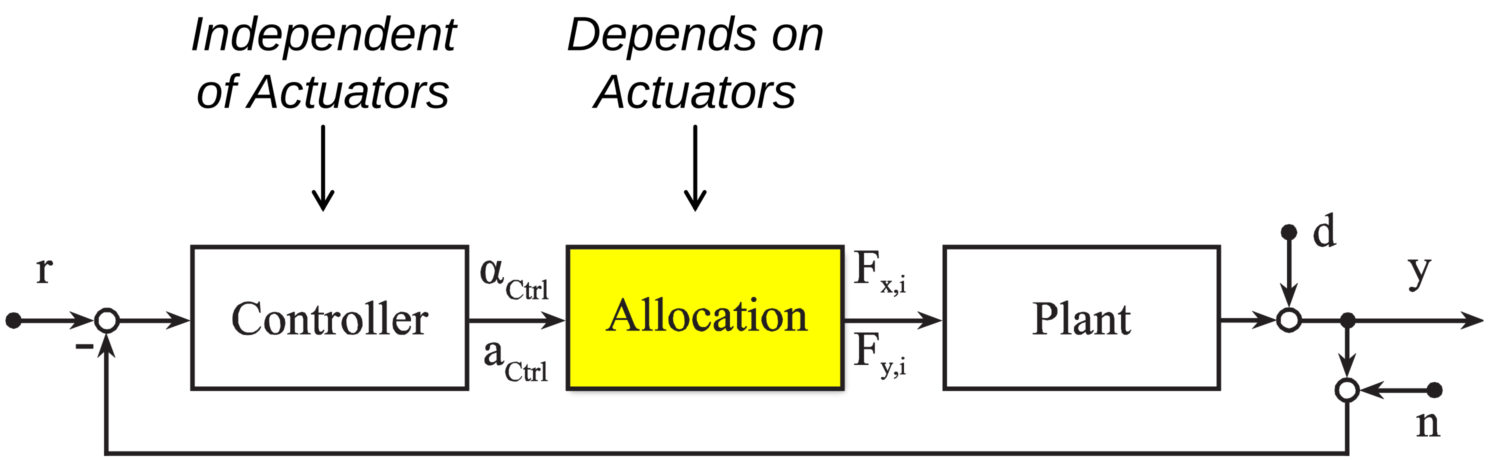


System Overview

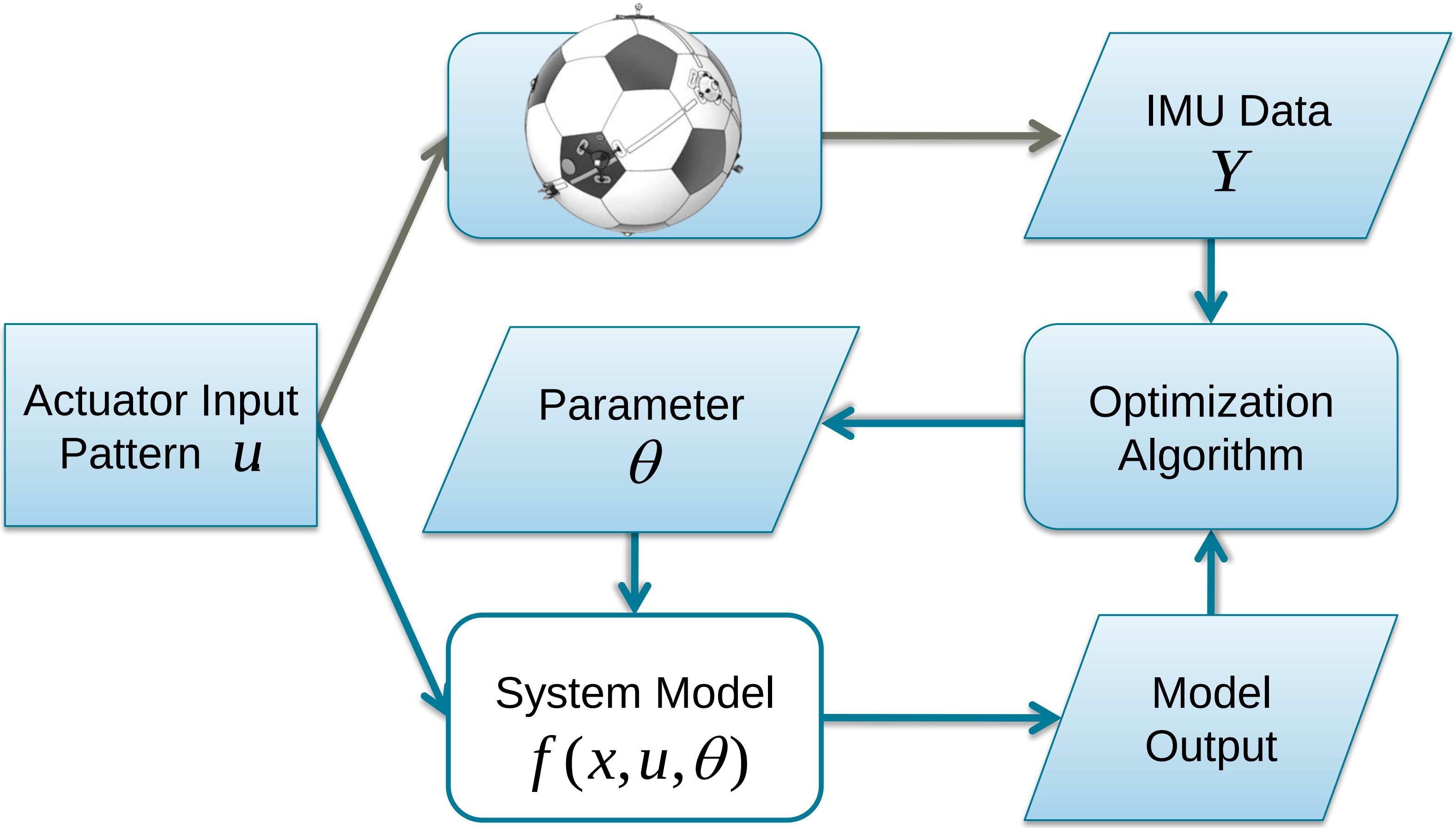




System Overview: Control



Problem Formulation



Problem Formulation: System Model

- Angular Acceleration

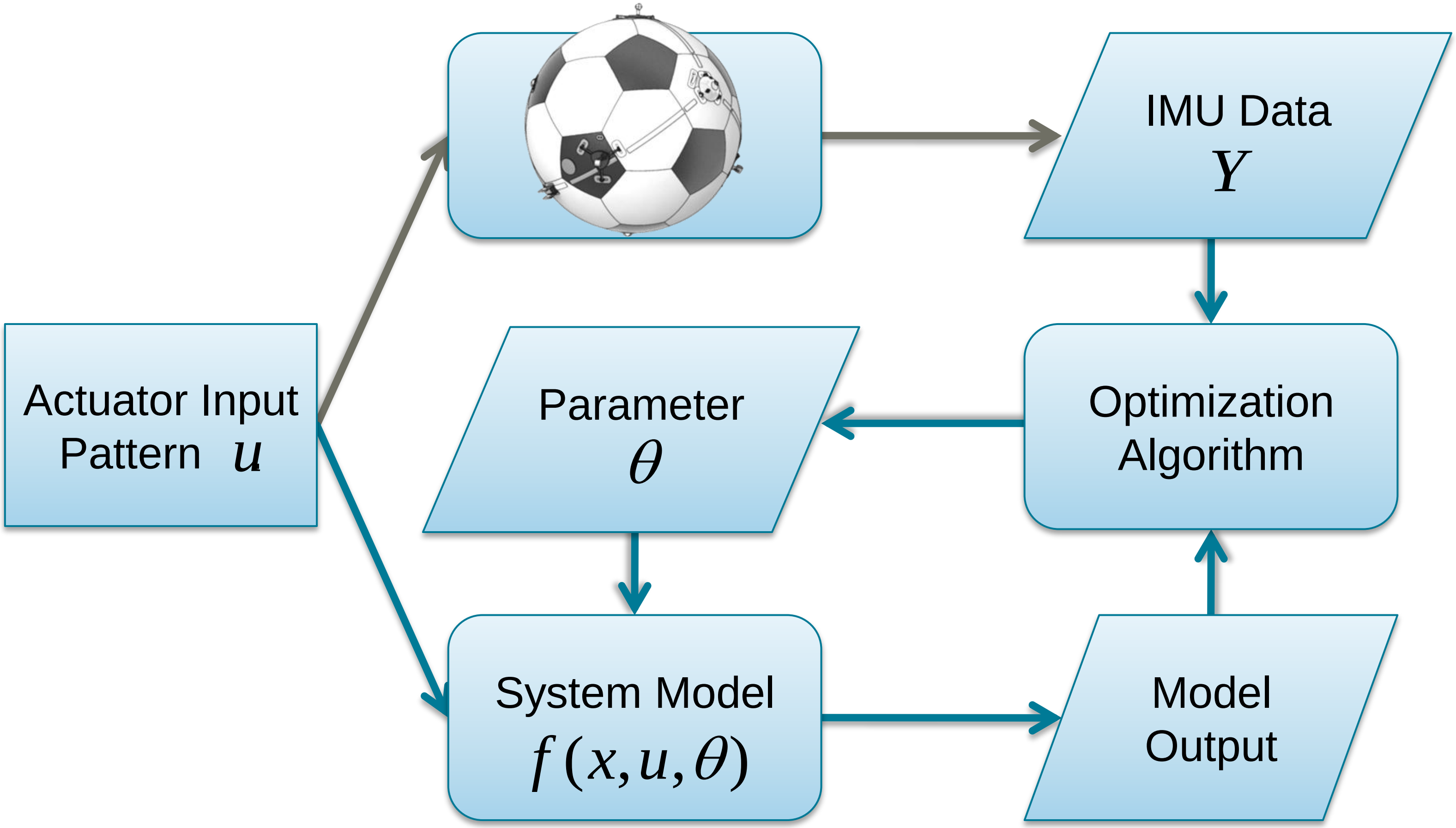
$$\mathbf{f}(\mathbf{x}, \mathbf{u}, \boldsymbol{\theta}) = \hat{\boldsymbol{\alpha}}_b = \mathbf{J}_b^{-1}(\mathbf{M}_b - \boldsymbol{\omega}_b \times \mathbf{J}_b \boldsymbol{\omega}_b)$$

with

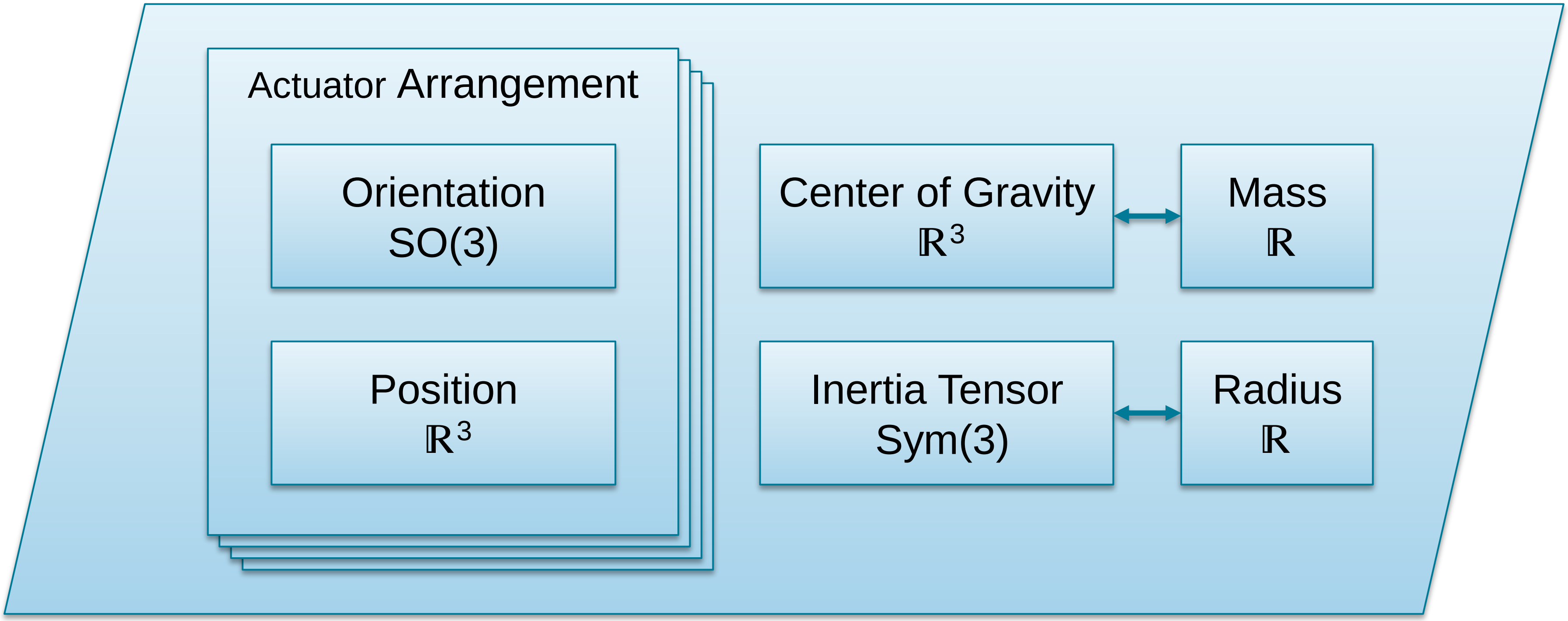
$$\mathbf{M}_b = \underbrace{\sum_{k=1}^{N} \left[\mathbf{C}_{b,m_k} \left(\mathbf{p}_{m_k}^{m_k,cog} \times \mathbf{F}_{m_k}\right)\right]}_{\mathbf{M}^{actuation}} - \underbrace{\left(\mathbf{p}_b^{cob,cog} \times (\mathbf{C}_{b,w} m \mathbf{g}_w)\right)}_{\mathbf{M}^{gravity}}$$

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

Problem Formulation

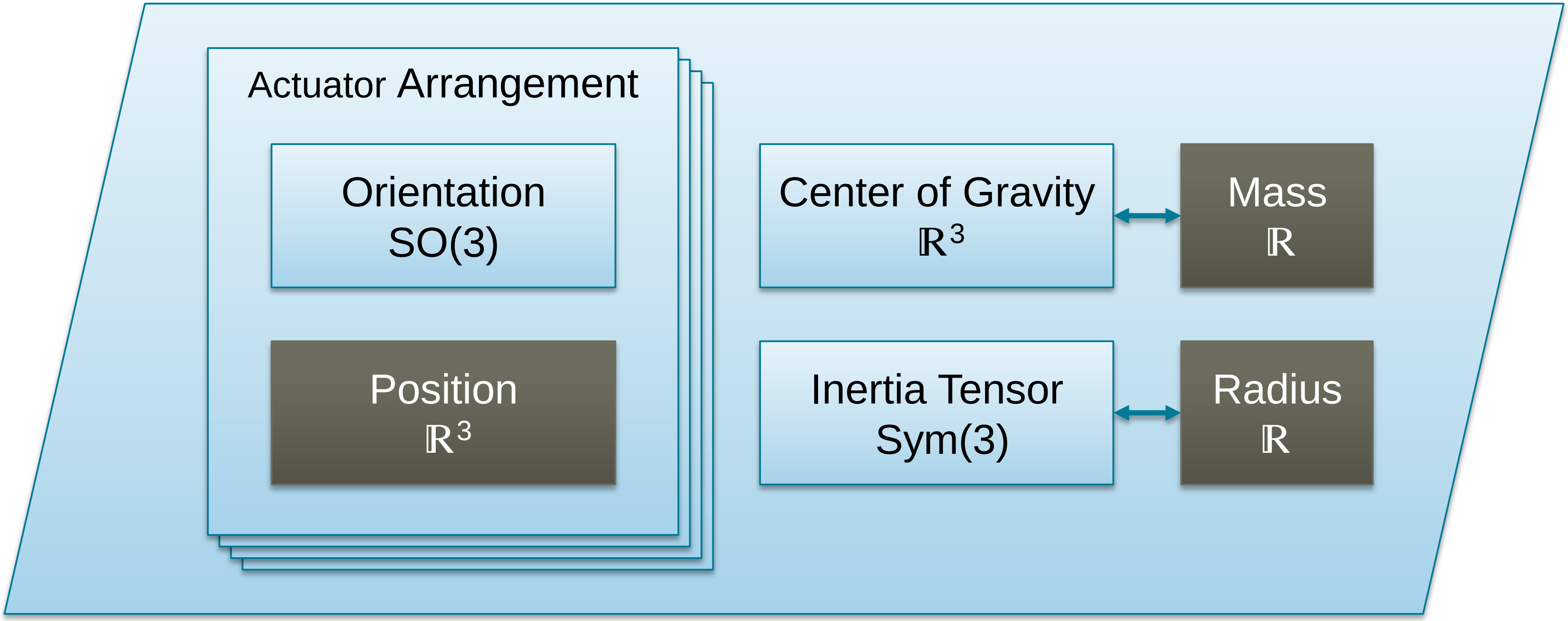


Problem Formulation: Parameters



- Full Parameter set is only jointly observable

Problem Formulation: Parameters



- Position is assumed to be on sphere
- Radius and mass are assumed to be known

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

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

Problem Formulation: System Model

- Angular Acceleration

Parameter

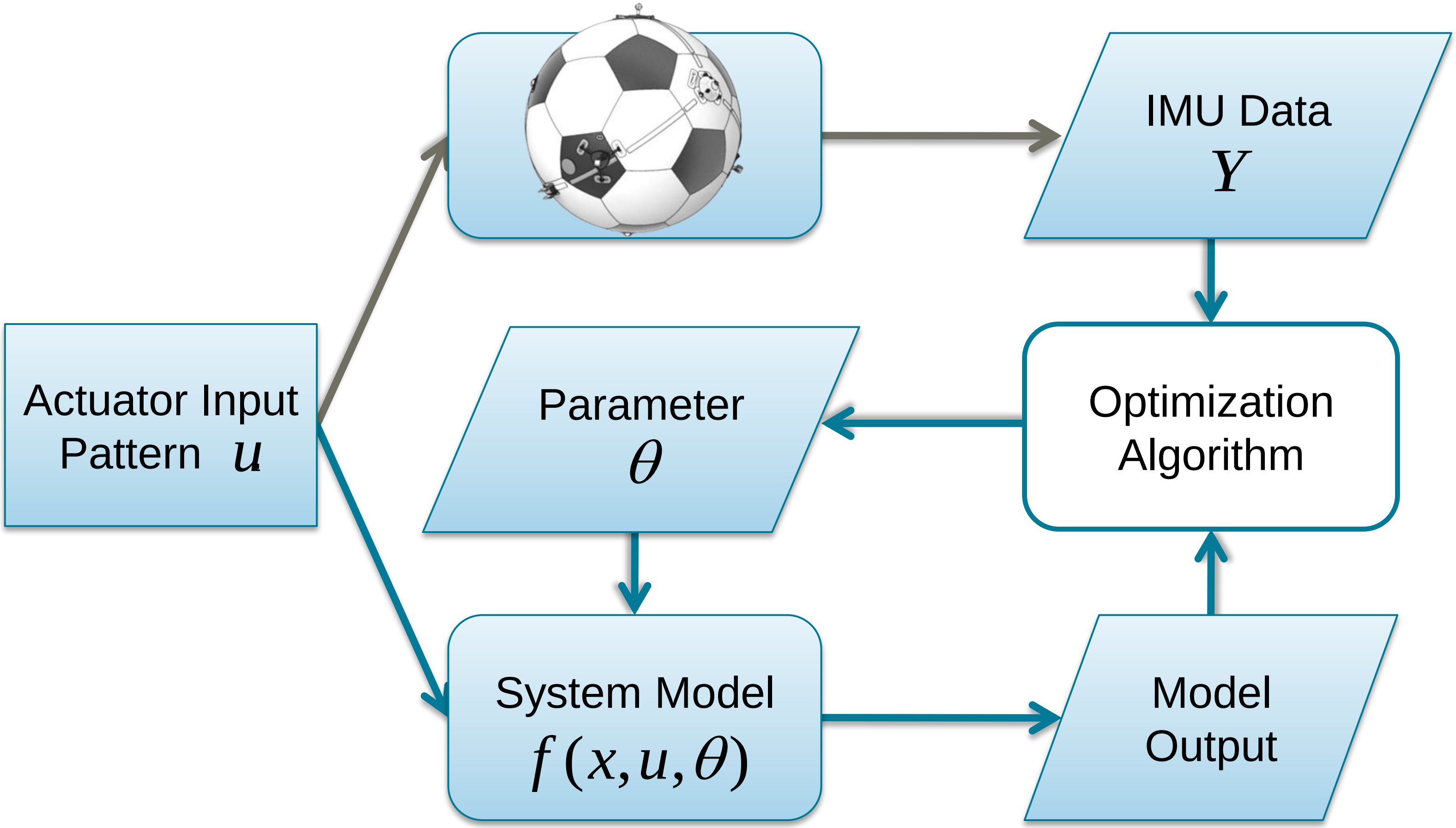
Constant (known)

State (known)

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

$$\mathbf{M}_b = \sum_{k=1}^{N}\left[\mathbf{C}_{b,m_k}\left(\begin{bmatrix}0\\0\\-r\end{bmatrix} \times \begin{bmatrix}F_x^{m_k}\\F_y^{m_k}\\0\end{bmatrix}\right)\right] - \underbrace{\left(\mathbf{p}_b^{cob,cog} \times (\mathbf{C}_{b,w} m\mathbf{g}_w)\right)}_{\mathbf{M}^{gravity}}$$

Problem Formulation



Problem Formulation: Optimization

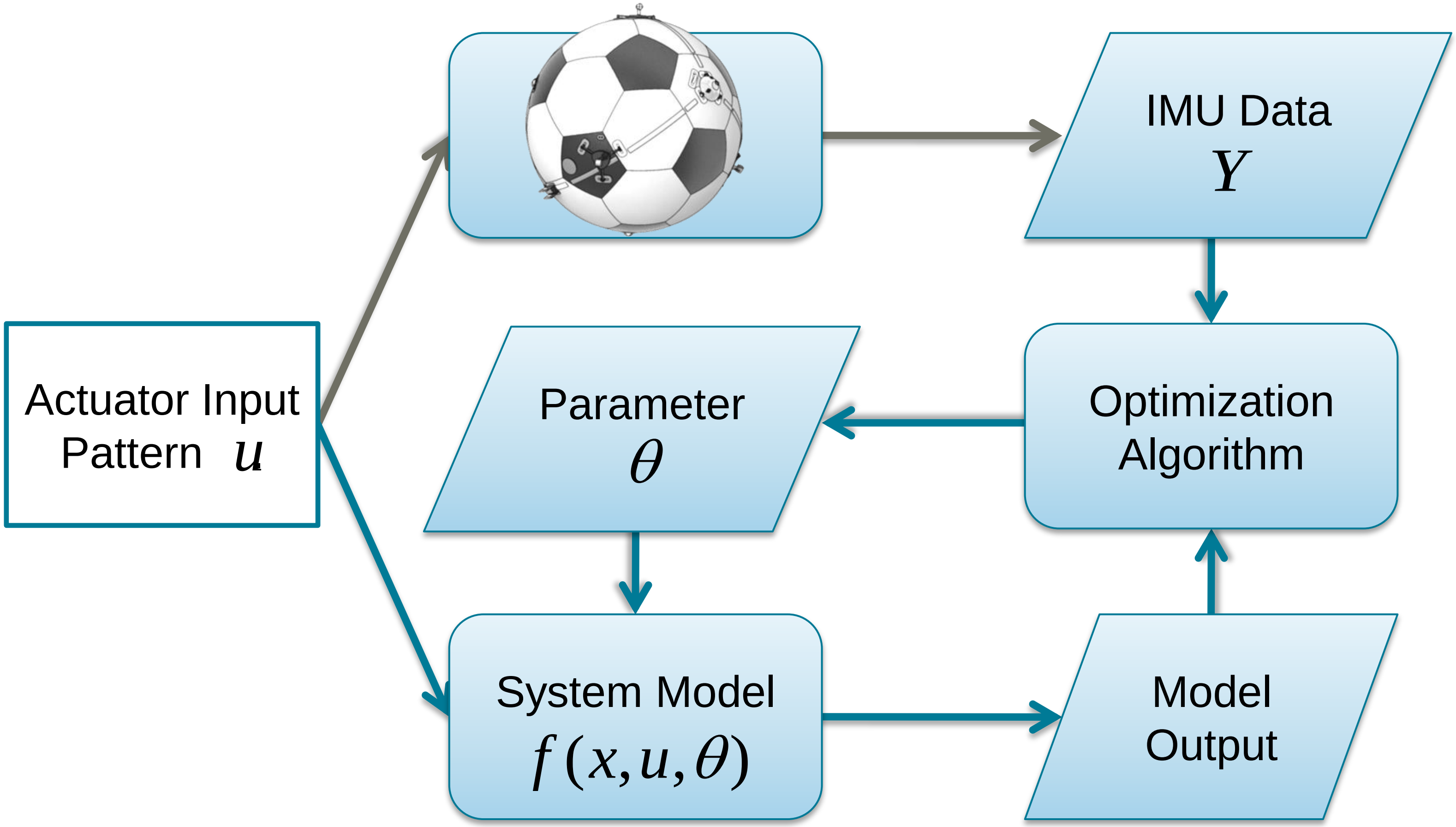
- Nonlinear Least Squares

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

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

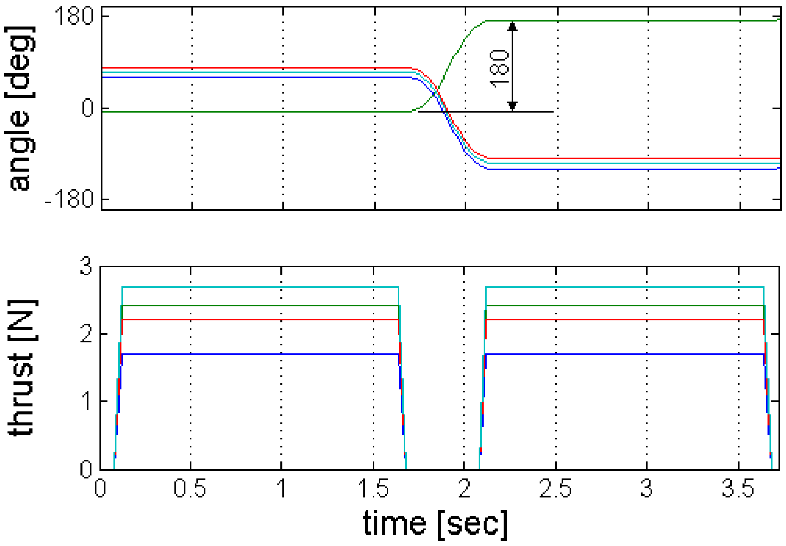
$$(\mathbf{J}^\top \mathbf{J} + \lambda \operatorname{diag}(\mathbf{J}^\top \mathbf{J}))\boldsymbol{\delta} = \mathbf{J}^\top [\mathbf{y} - \mathbf{f}(\boldsymbol{\theta})]$$

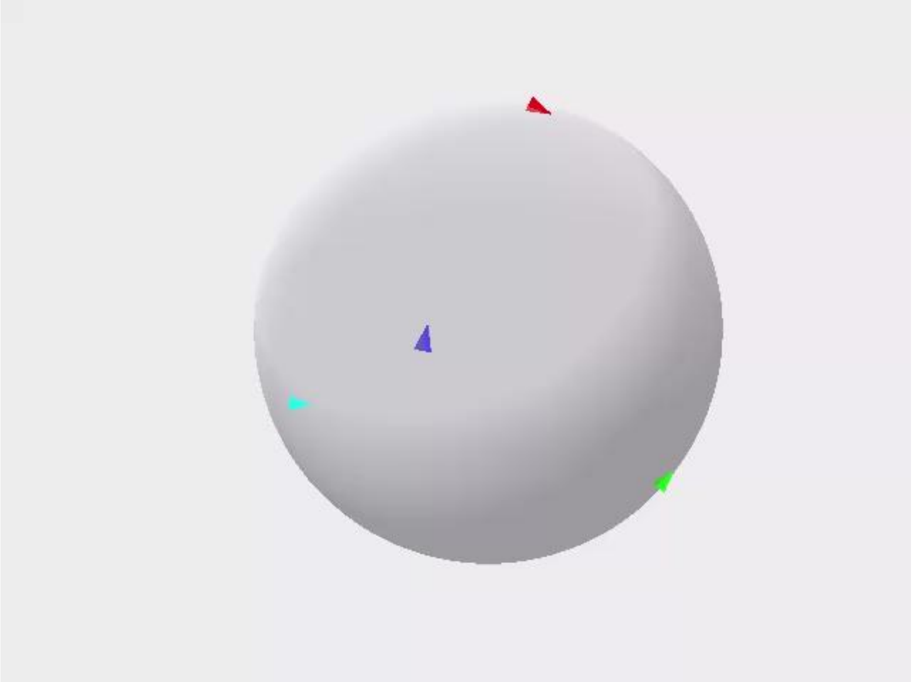
Problem Formulation



Problem Formulation: Input Pattern

- Inputs must be **applicable** and **sufficiently excited**
  - **Forward/backward**
  - **Varying directions**
  - Steady state motor dynamics



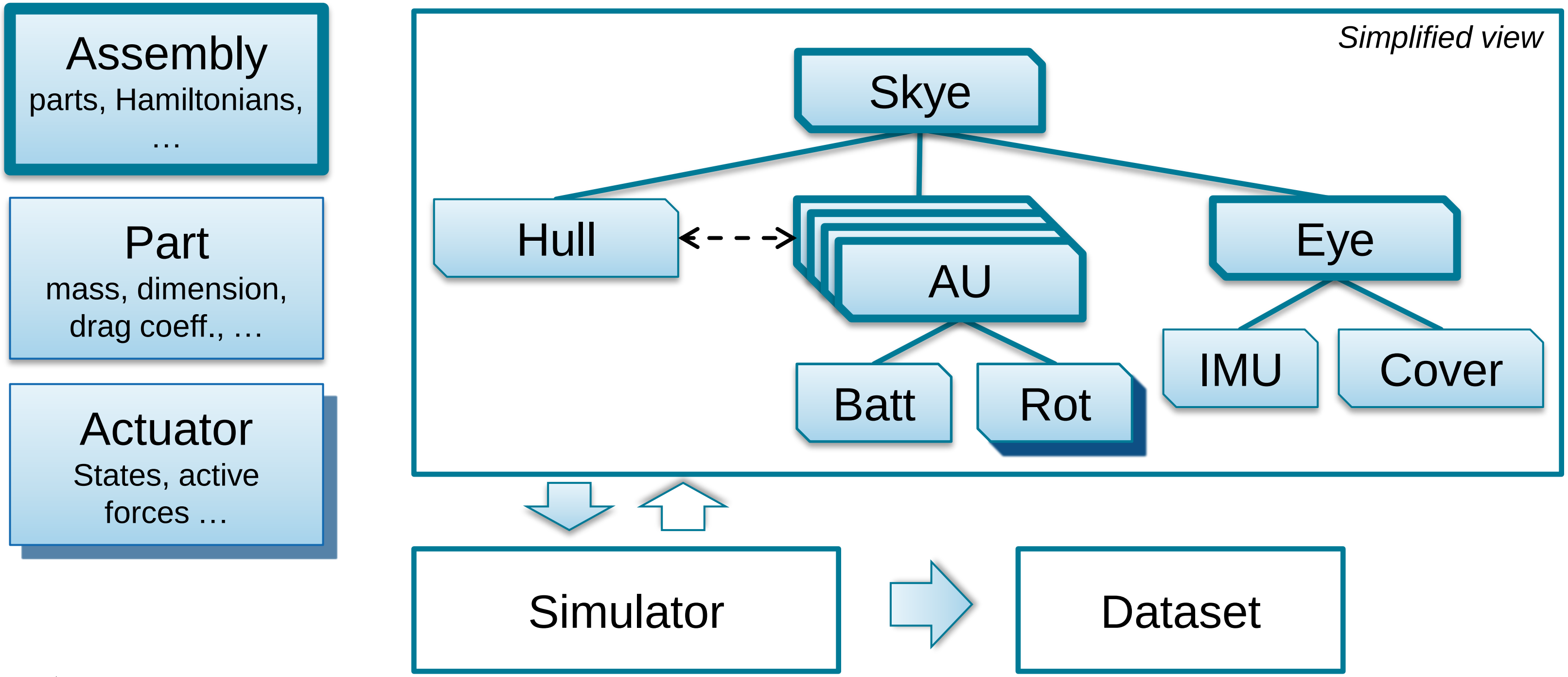


Results

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

Simulator

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



Results

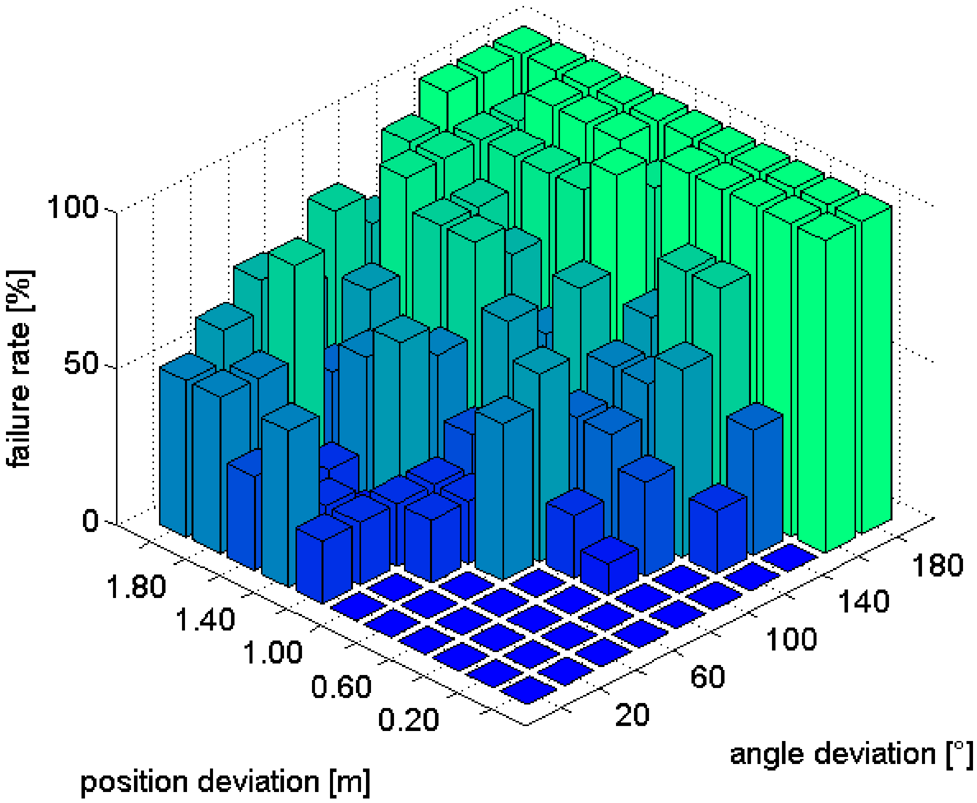
- Zeige Konvergenz & Anzahl Iterationen mit LMA
- Tangential ebene einführen, damit wir resultate vergleichen können
- Erläutern dass init deviations

- Das ding das dreht
- Evt Tangentialebene auf Kugel

Simulation: Confidence Region

- Zeige Konvergenz & Anzahl Iterationen mit LMA

Simulation: Convergence Region



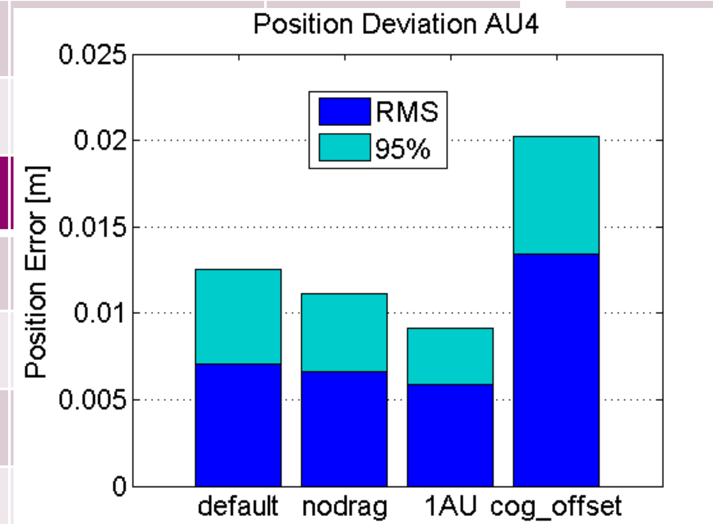
Initial Parameters can be about **1m or 120°** apart of the true value

Simulation: Casestudies

Es fehlt 5AU dataset

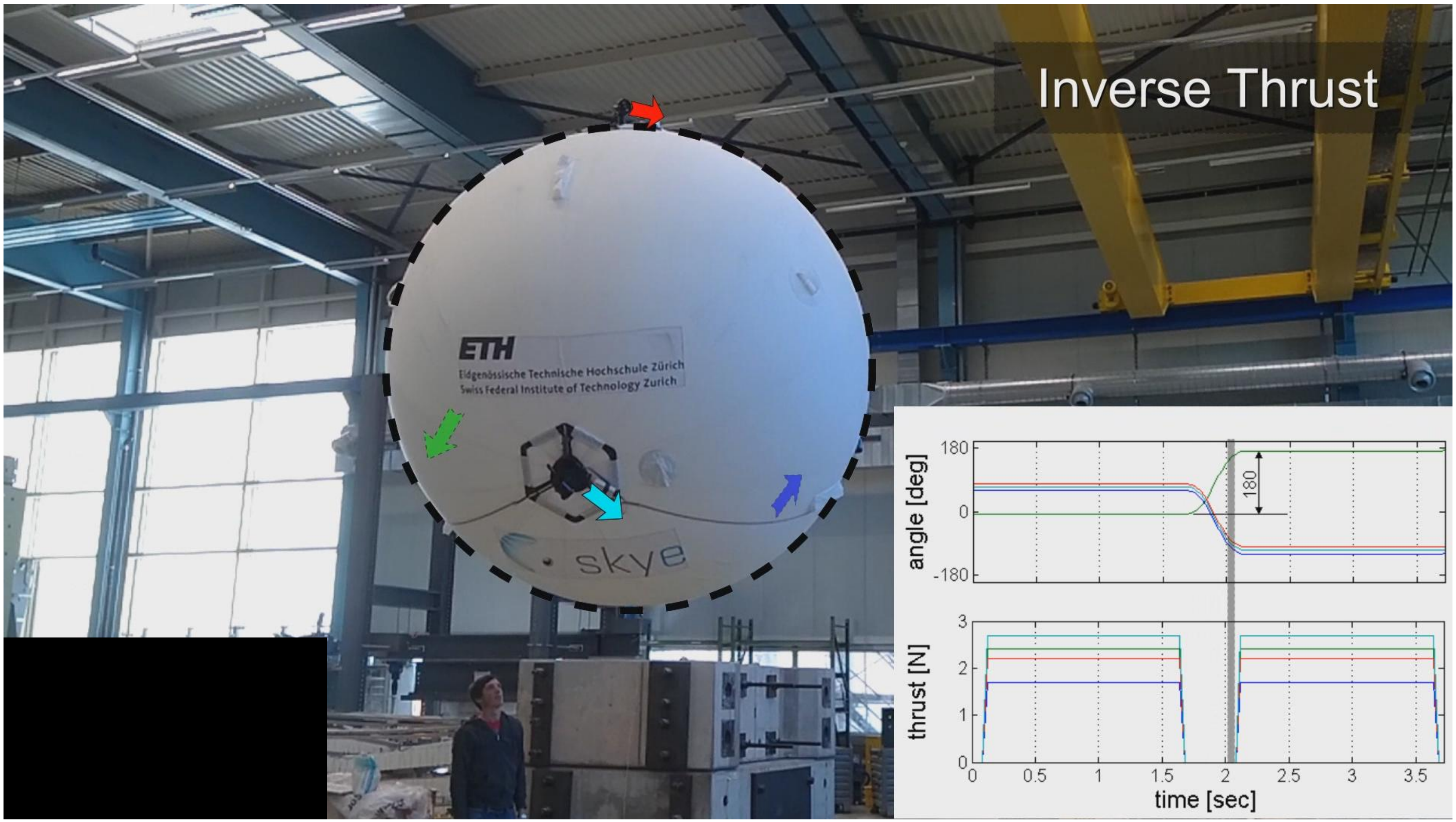
mean	AU4 x	AU4 y	J		Resnorm [rad/s2]
4 AUs	6.18e-04	7.66e-04	6.12e-02	6.94e-05	6.73e-04
No drag	-4.89e-04	1.38e-03	5.16e-02	1.81e-05	6.88e-04
Single AU					

std	AU4 x	AU4 y
4 AUs	3.65e-03	7.19e-03
No drag	4.29e-03	7.96e-03

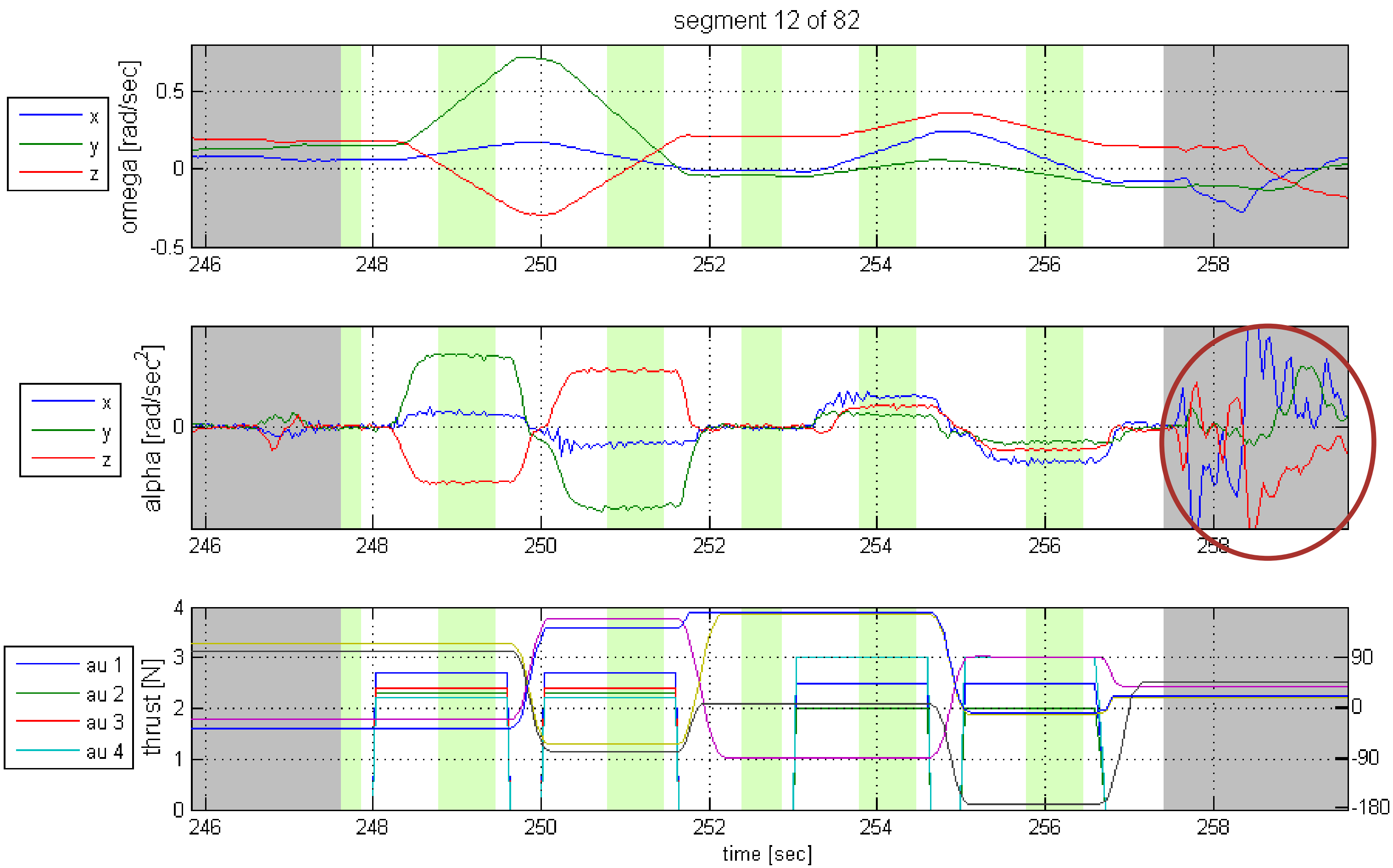


32 simulations à 2000 raw datapoints

Problem Formulation: Input Pattern

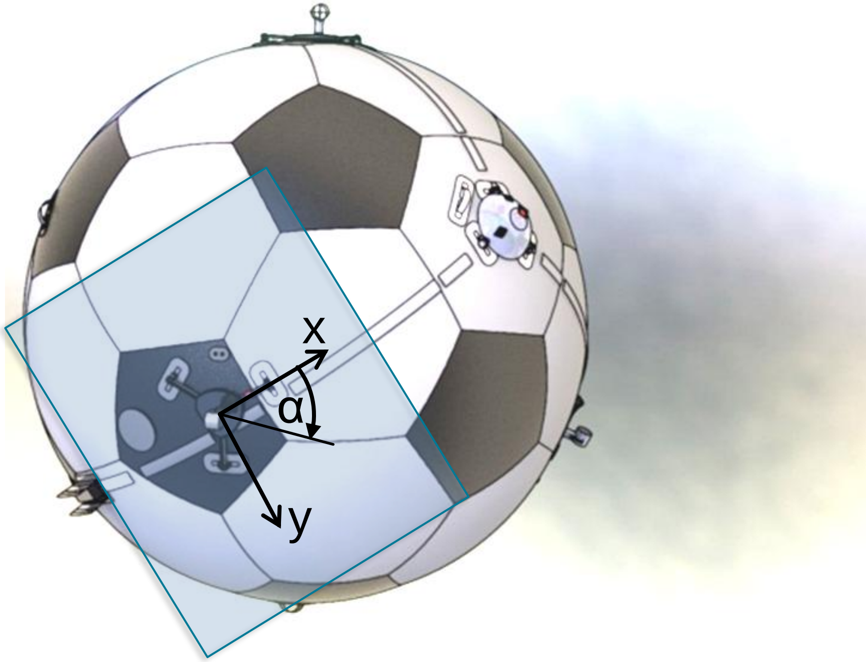


Data Acquisition

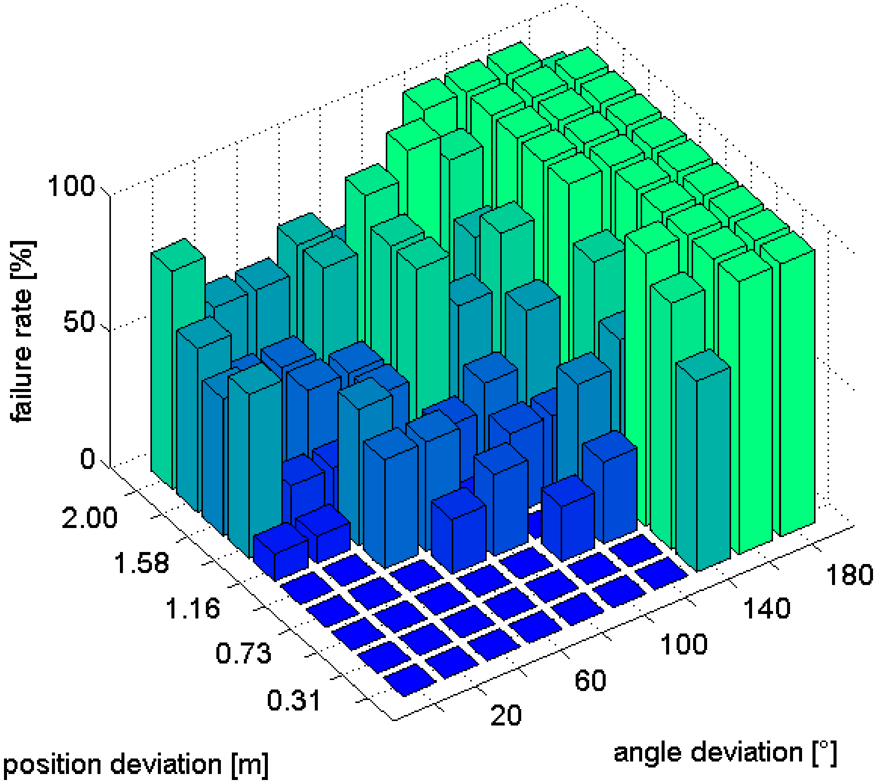


Disturbance: Skye has been catched

Results: Experiments



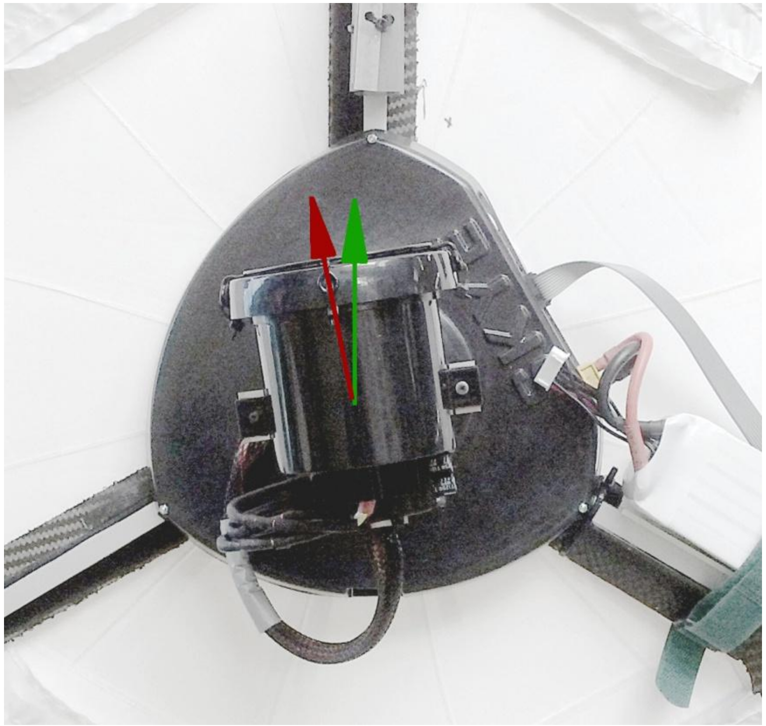
Experiment: Convergence Region



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

Very Similar to Simulation case.

Experiments



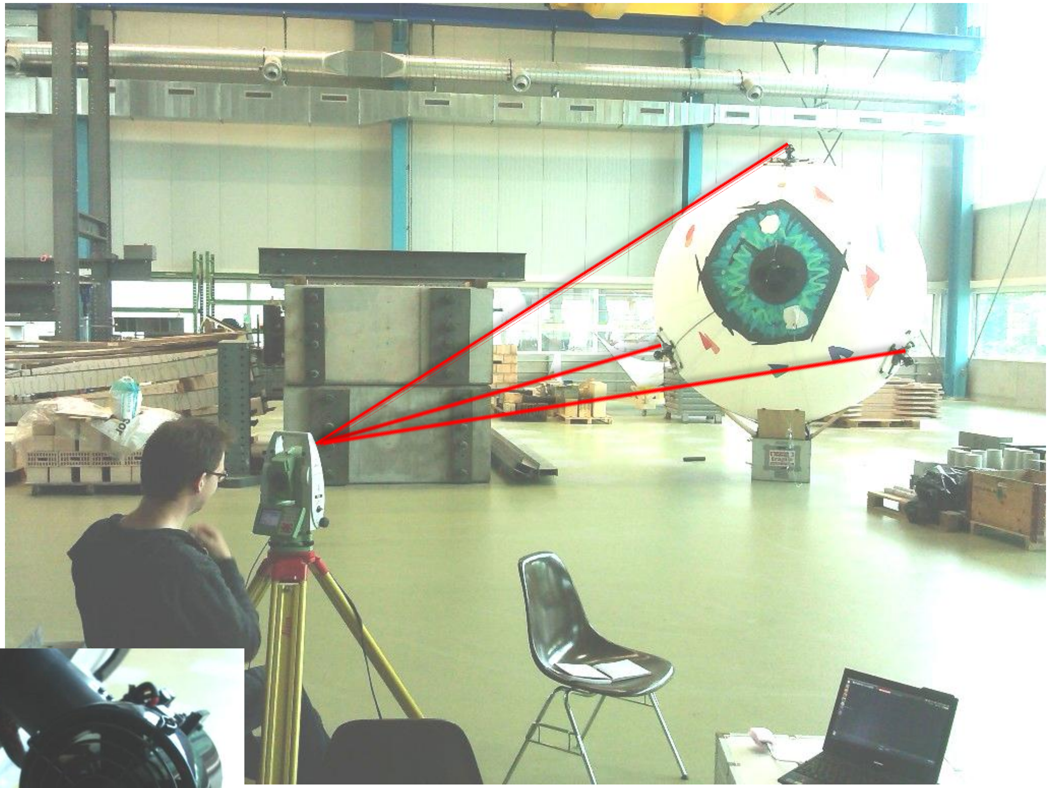
assumed

batch sol.

Results: „Ground Truth“ (Leica)

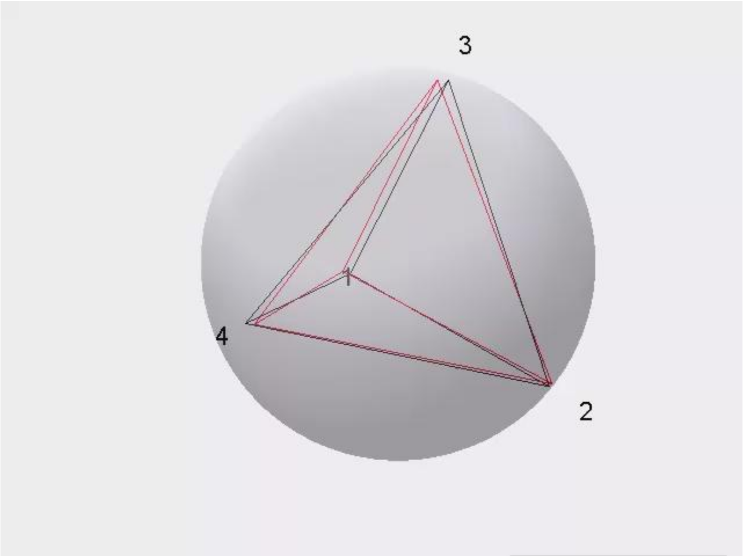
- 3 AU‘s visible at once
- Use different views

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



Results: Compare Leica and Batch Solution

Relative tetrahedral edge length error			
%	AU2	AU3	AU4
AU1	1.68	0.86	2.76
AU2		0.67	2.47
AU3			3.78



Leica
Batch

Conclusion

- What did we do?
  - Showed applicable method to estimate actuator configuration
- How accurate?
  - Actuator positions can be estimated within centimeters
- Where to use?
  - Automatically update parameters before flight within minutes

Thanks