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A Data-Driven Recommendation Framework for Optimal Walker Designs

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Motivation

- Very little data-driven research has been conducted on optimization of the fundamental aspects of a walker
- More than 41,000 walker-related injuries annually

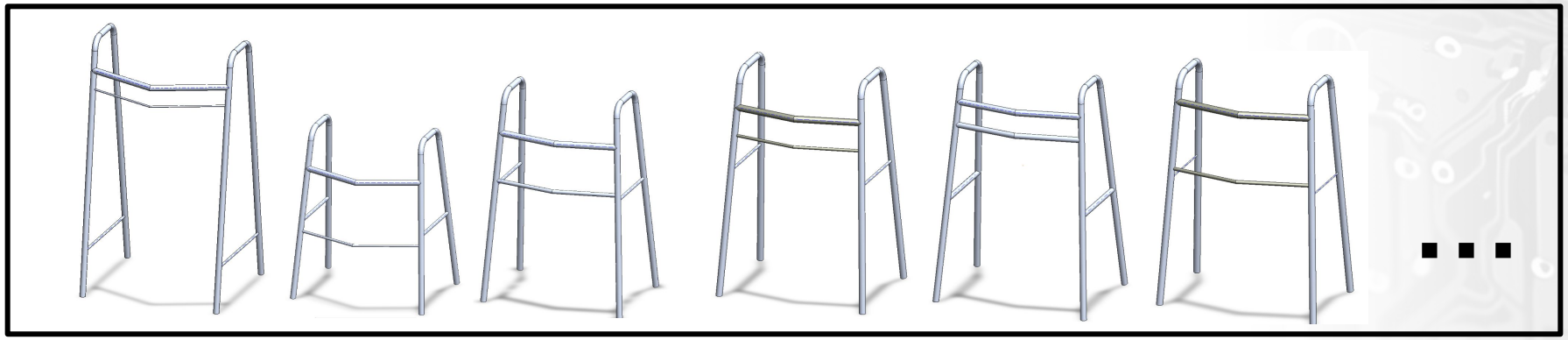
Improving Public Health & Life Expectancy

Diverse Needs and Situations

Extendable to many assistive mobility devices

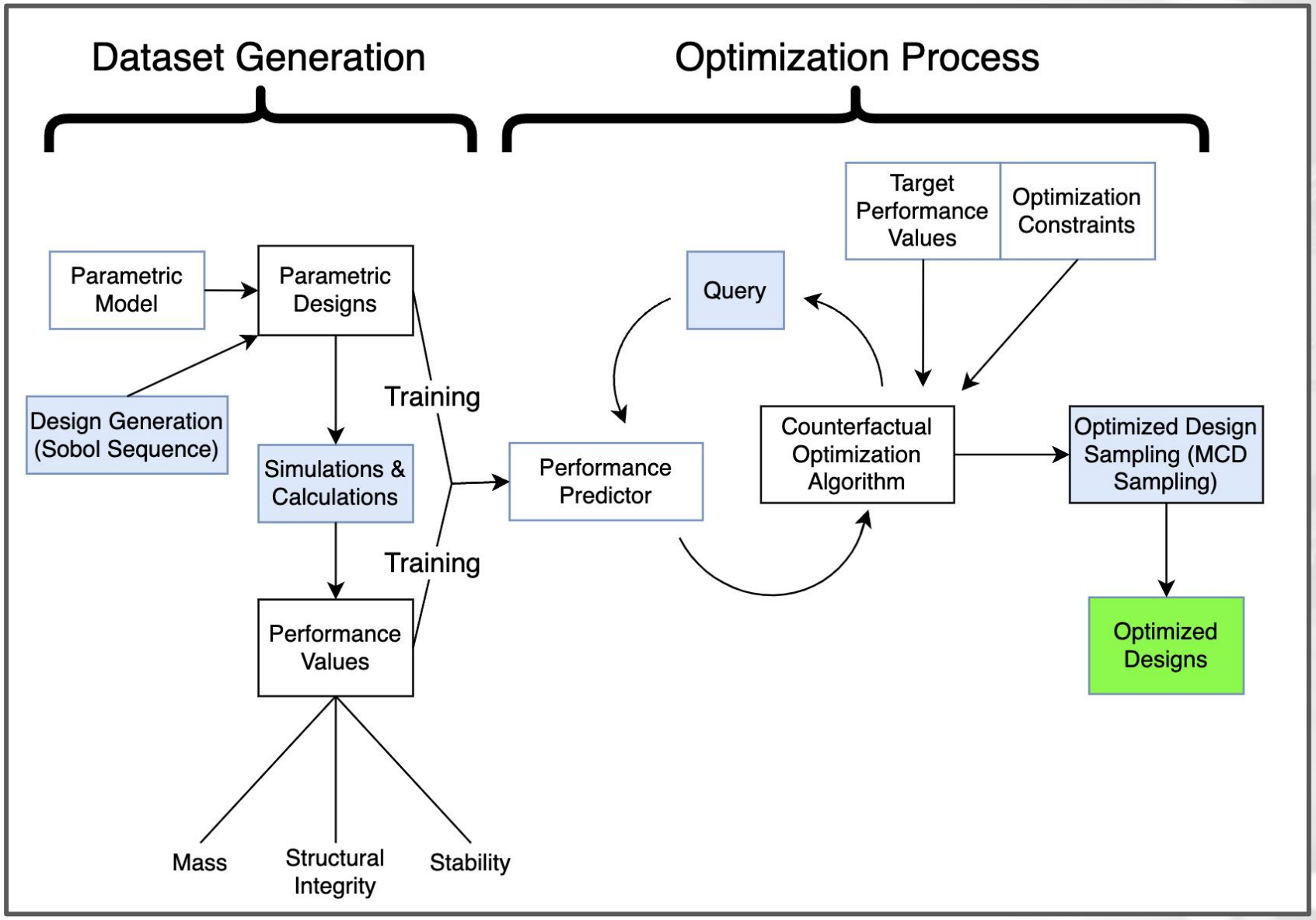
Key Contributions

- Create a Dataset of 5006 Parametric Walker Designs



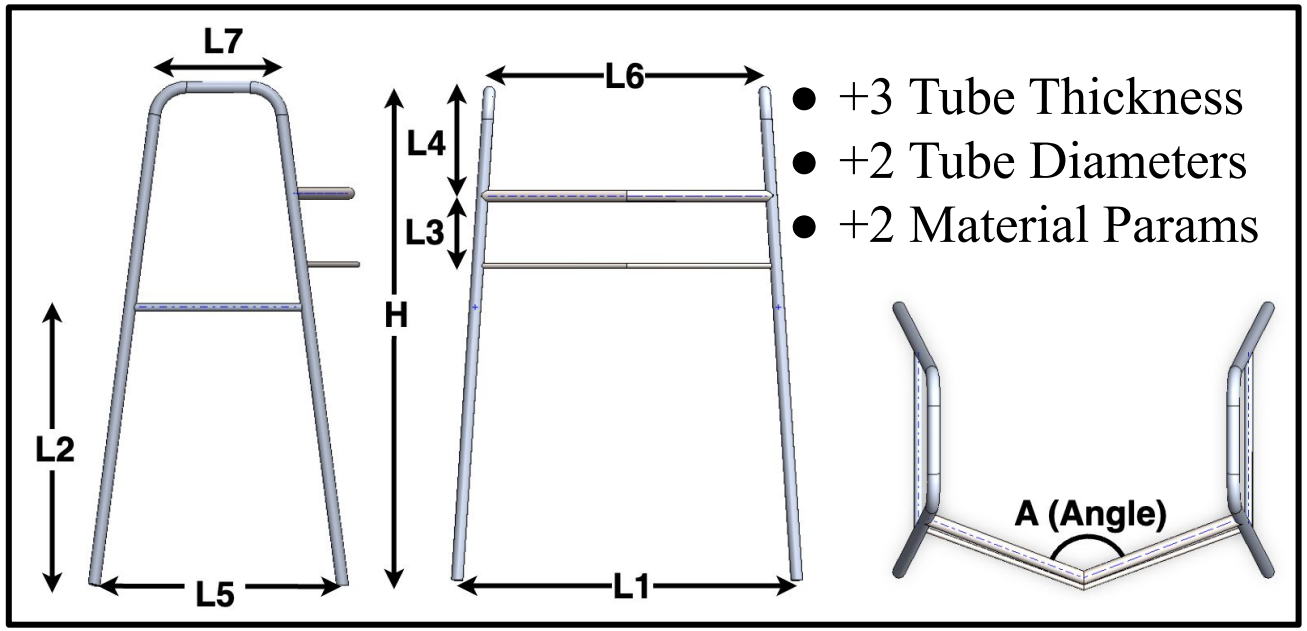
- Surrogate Model to predict 8 performance values from 16 parameters
- Method of calculating walker static stability
- Open-Sourced code and dataset

Framework Overview



Parametric Model

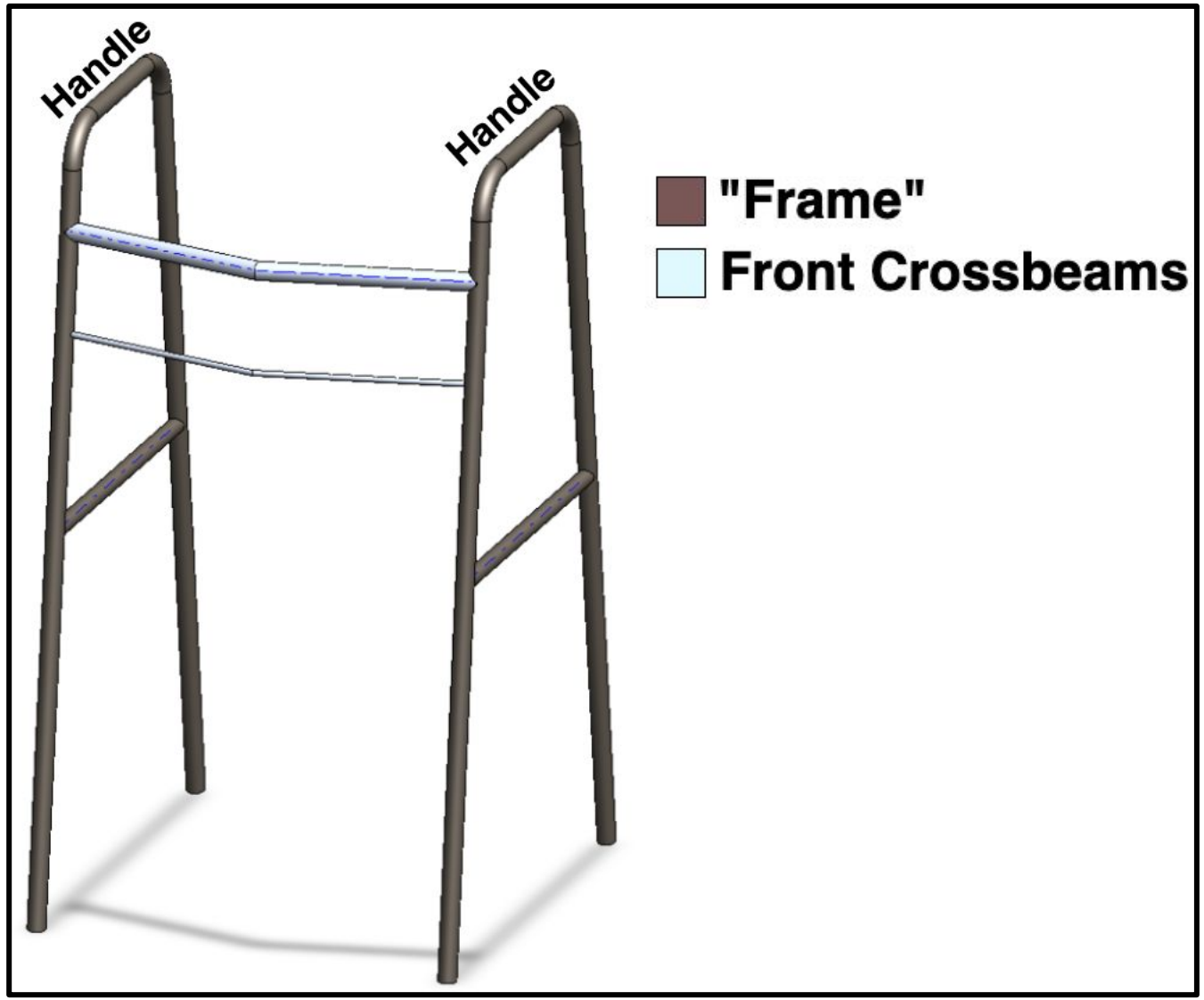
Parameter Type	Data Type	Count
Geometry Relations	Continuous	9
Tube Inner Diameter	Continuous	3
Tube Thickness	Continuous	2
Material	Categorical	2
Total		16



Key simplifications to the 2-wheeled walker model:

1. **Wheels act as roller joints.**
2. **Laterally symmetric frame**
3. **Disregard folding/adjusting mechanisms.**
4. **Disregard joints at tube junctions.**
5. **Rectangular Base**

Parametric Model: Material Parameters



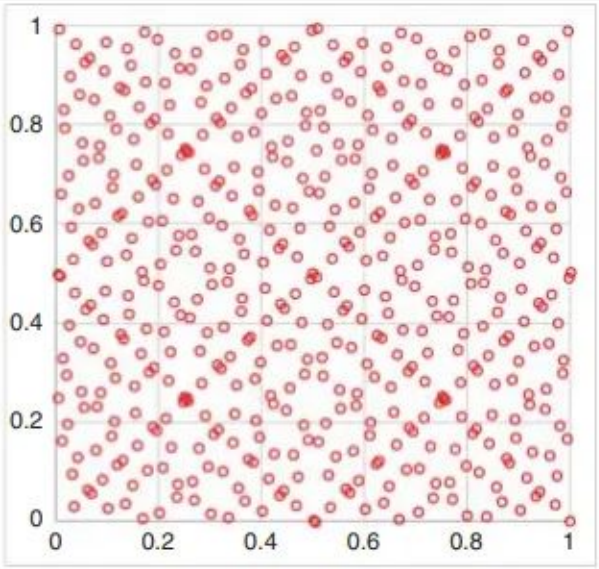
Front Crossbeams and Frame have separate material parameters

Material Categories:

1. Aluminum
2. Steel
3. Titanium

Parametric Generation

Sobol Sampling



Scaling with Parameter Ranges

Parameters Ranges are broad without compromising on data point density

Feasibility and Invalidity Dropping

- ~66% of designs systematically dropped
- 394 designs failed in simulation runtime
- 5006 valid models for the final dataset

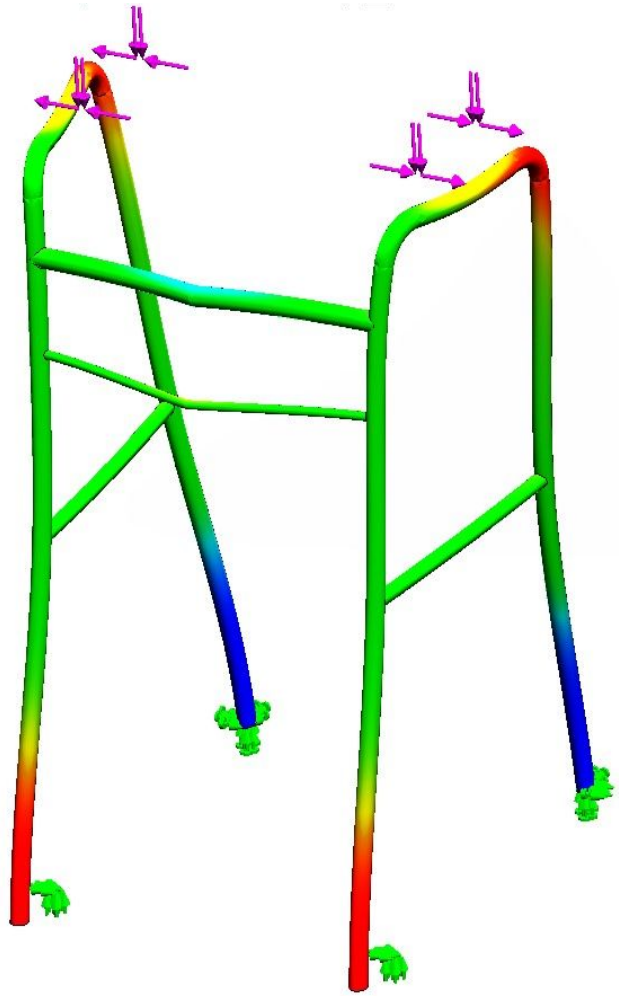
Performance Category: Mass

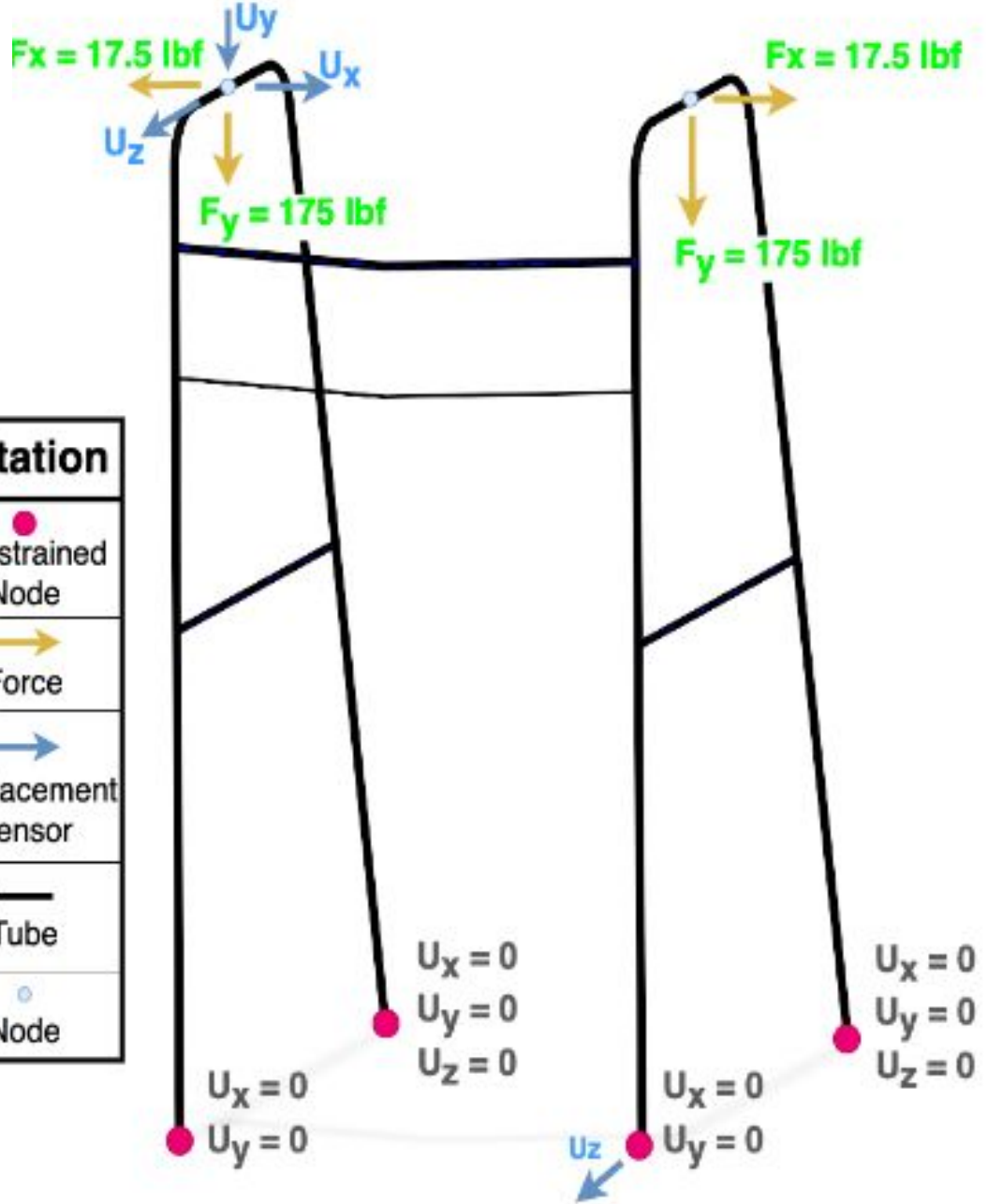
- Minimize
- Measured from SolidWorks
- Typical Walker: 7.5 lbs / 3.4 kg

Performance Category: Structural Integrity

Single load case for normal and eccentric loading

- **4 Displacement Sensors**
- **Safety Factor**





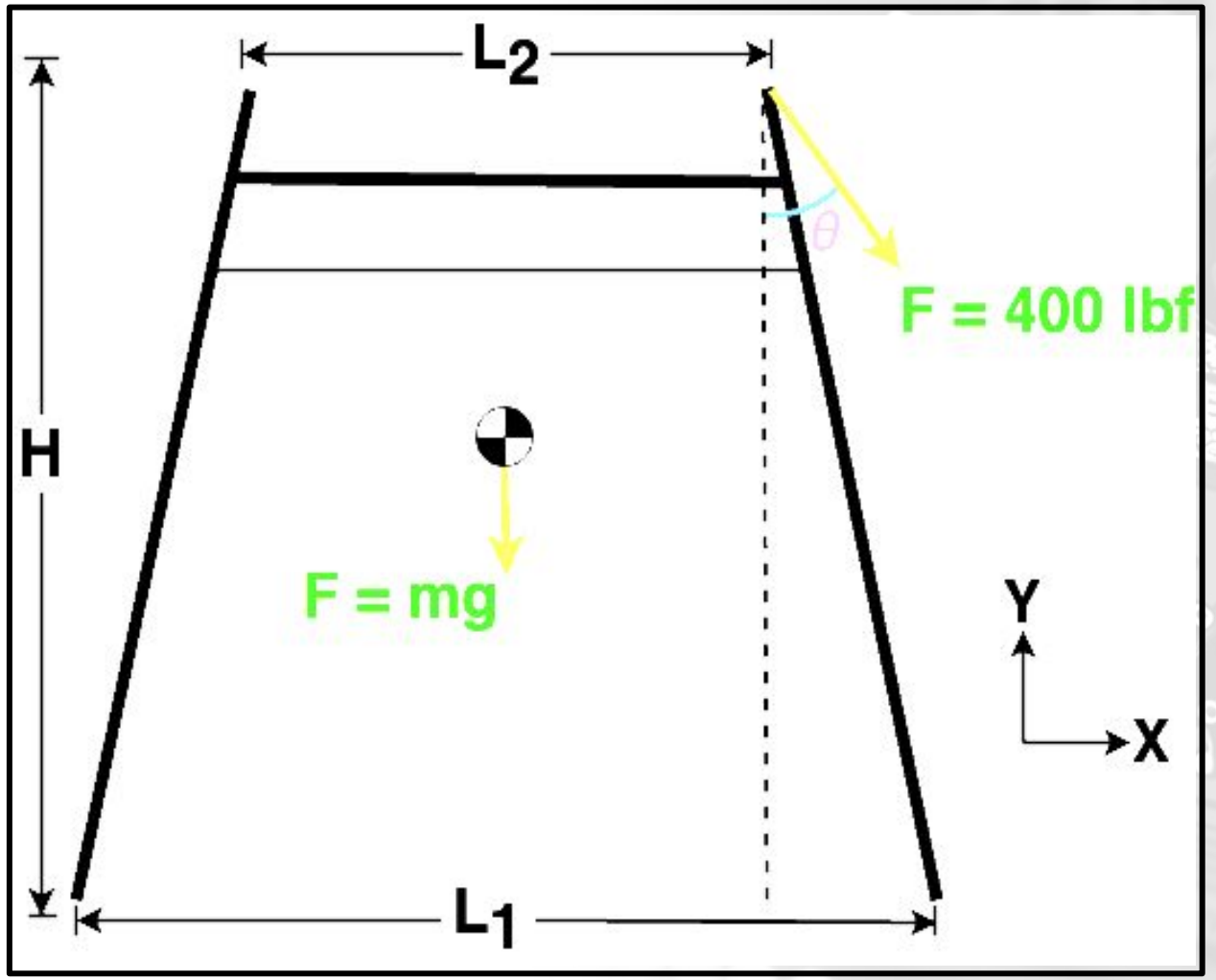
Performance Category: Stability

Static Stability: Tipping Force angle should be maximized

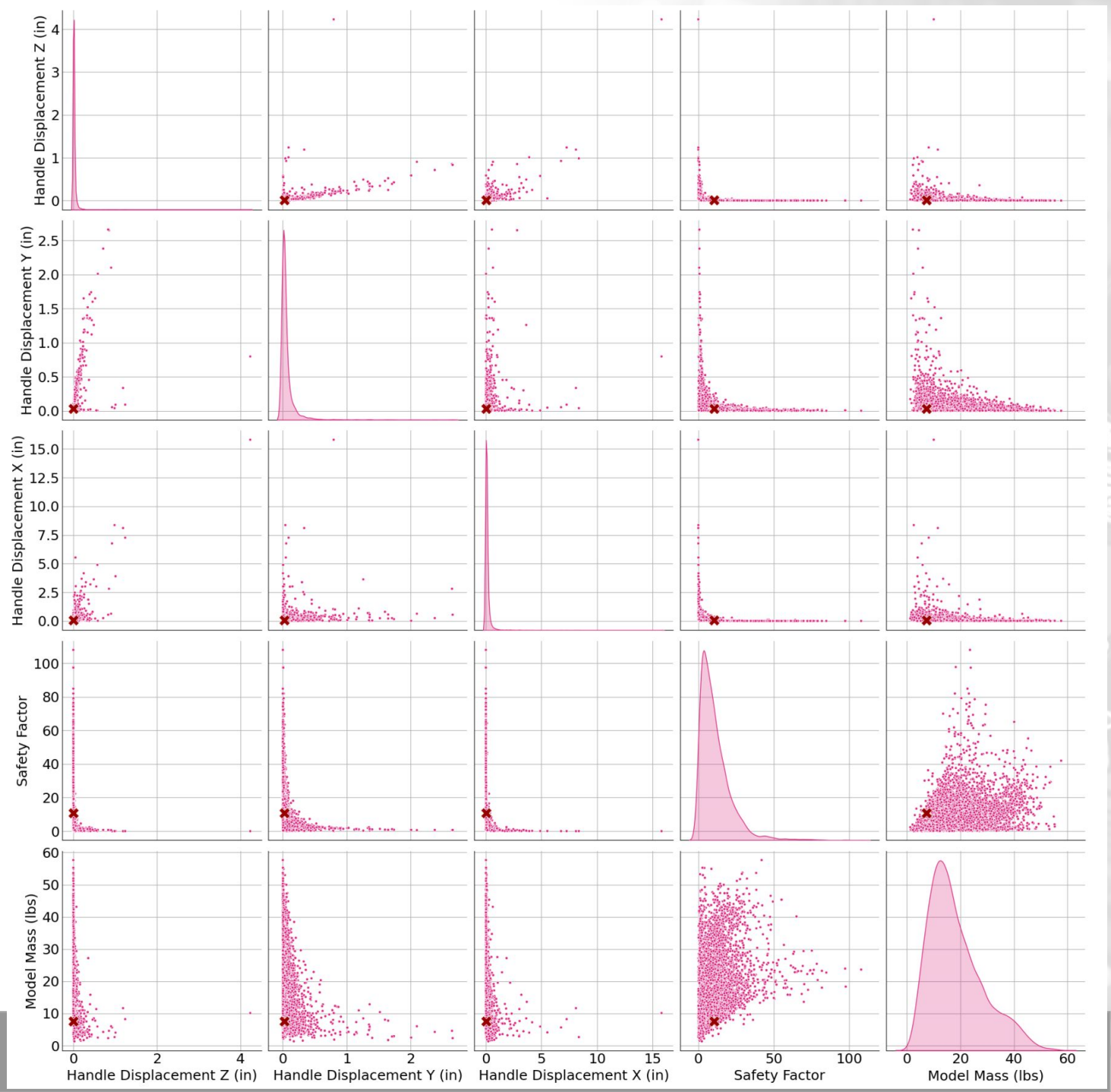
$$\phi = \arcsin\left(\frac{mgL_1}{2F\sqrt{H^2 + \left(\frac{L_1 - L_2}{2}\right)^2}}\right)$$

$$\theta = \phi + \arctan\left(\frac{L_1 - L_2}{2H}\right)$$

“Dynamic” Stability: Height of Center of Mass should be minimized



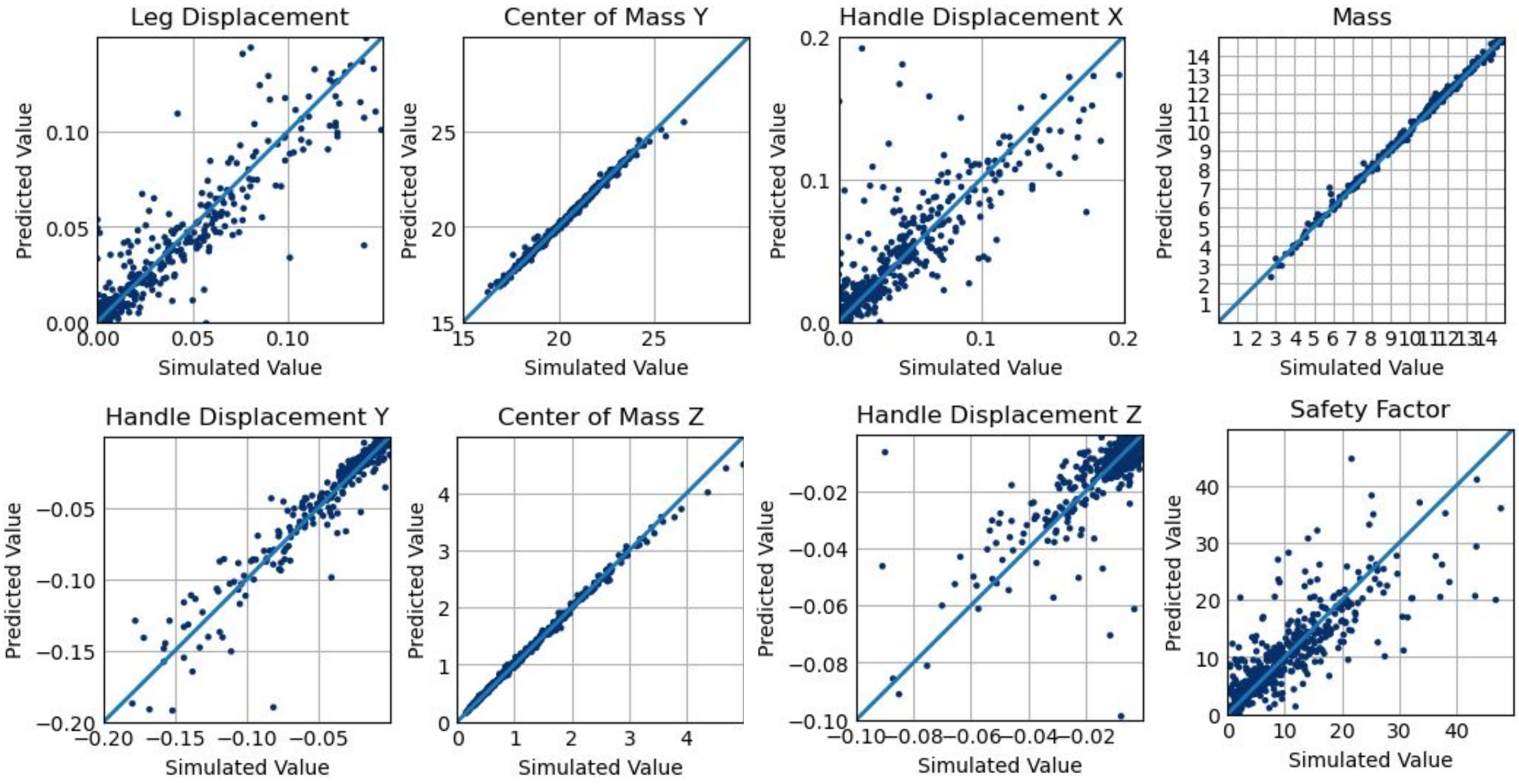
Dataset Visualization



Legend:

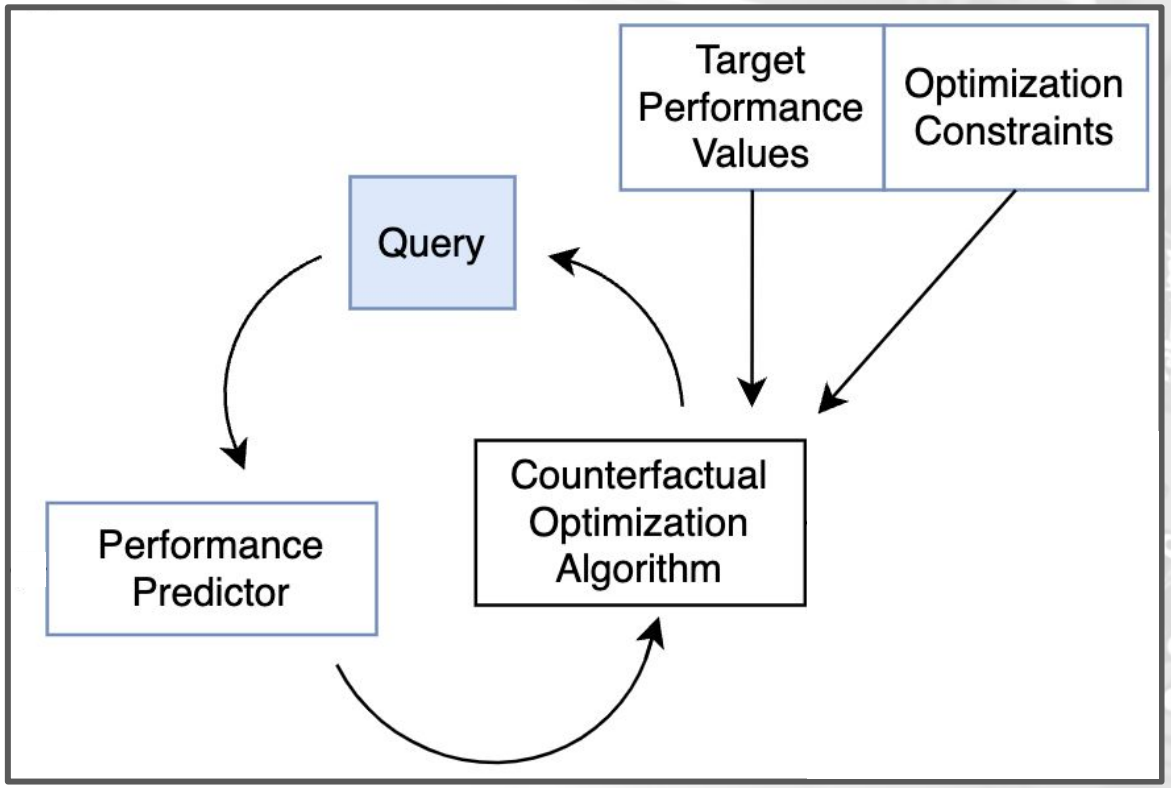
- Design
- Original Walker

Surrogate Performance Predictor



Multiobjective Optimization

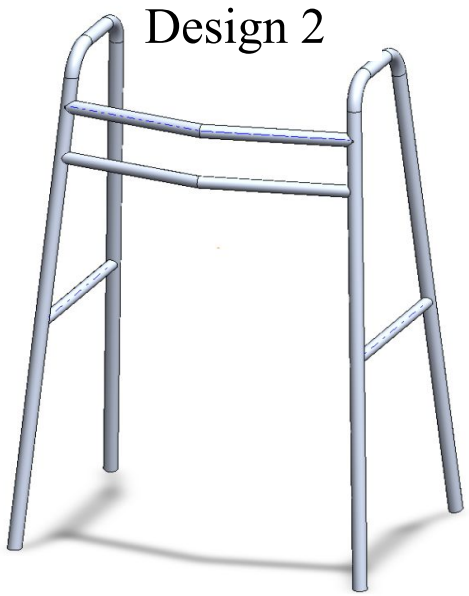
- Genetic Algorithm (NGSA-II)
  Finds constraint-fulfilling designs
- Exploration Space Constraints
  - Validity
  - User-specific needs
- Target Performance Values
  - Mass, structural integrity, and/or stability

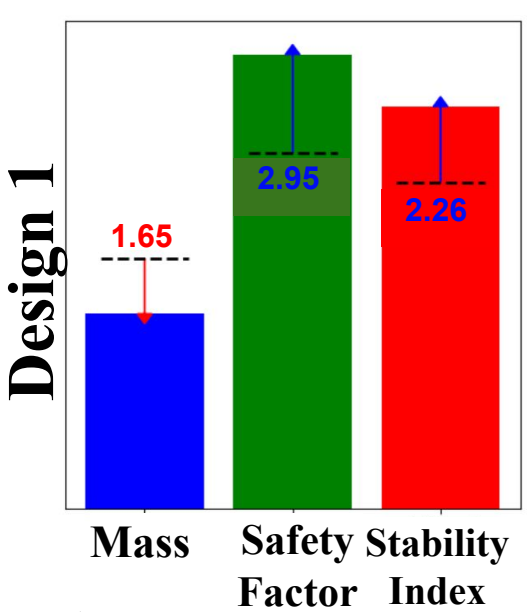


MCD Sampling

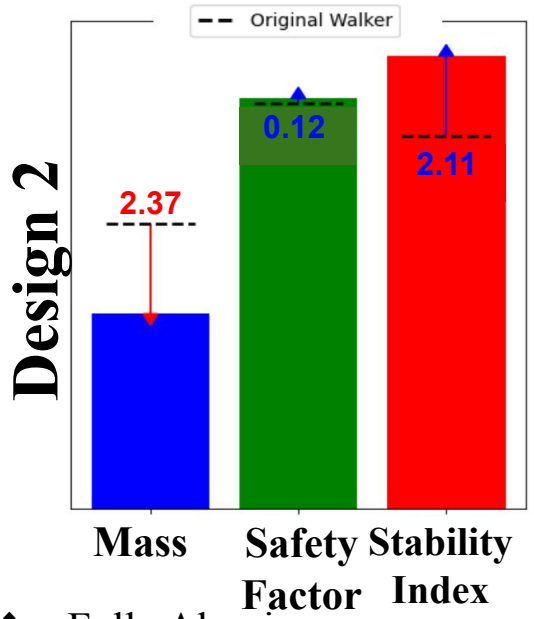
- Reduced 1000s of valid optimized designs to a select few
- Sampling Weights:
  - Diversity
  - Sparsity
  - Proximity

Generic Optimization Case Studies

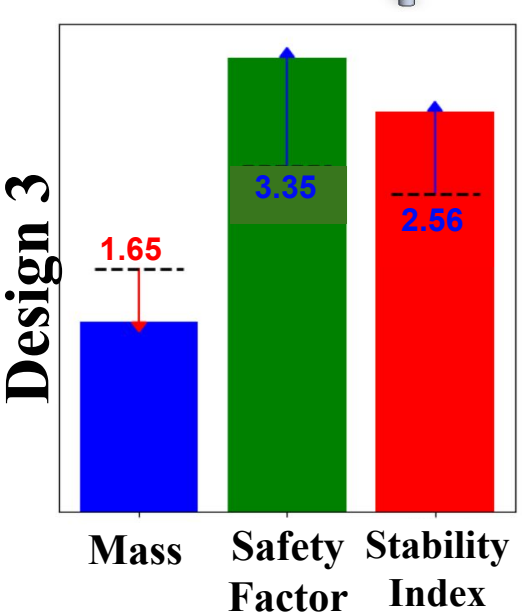




- Titanium Crossbeams
- Aluminum Frame

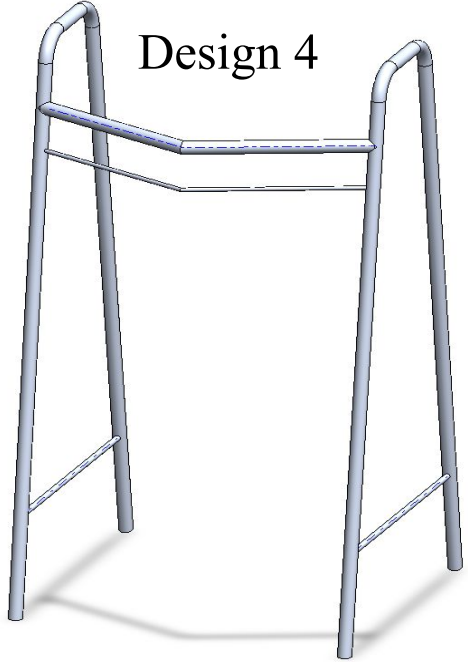


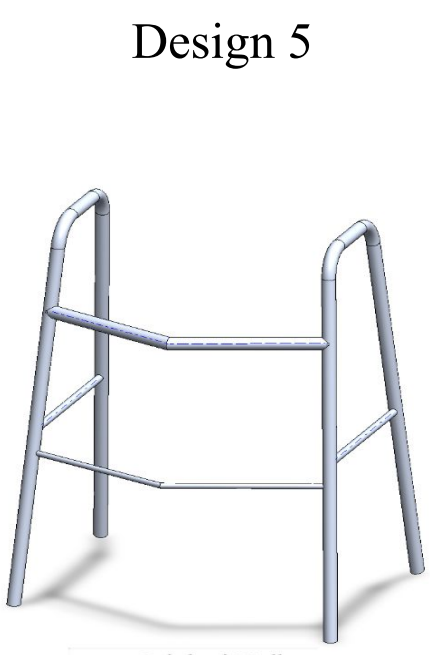
- Fully Aluminum
- Compromised Structural Integrity

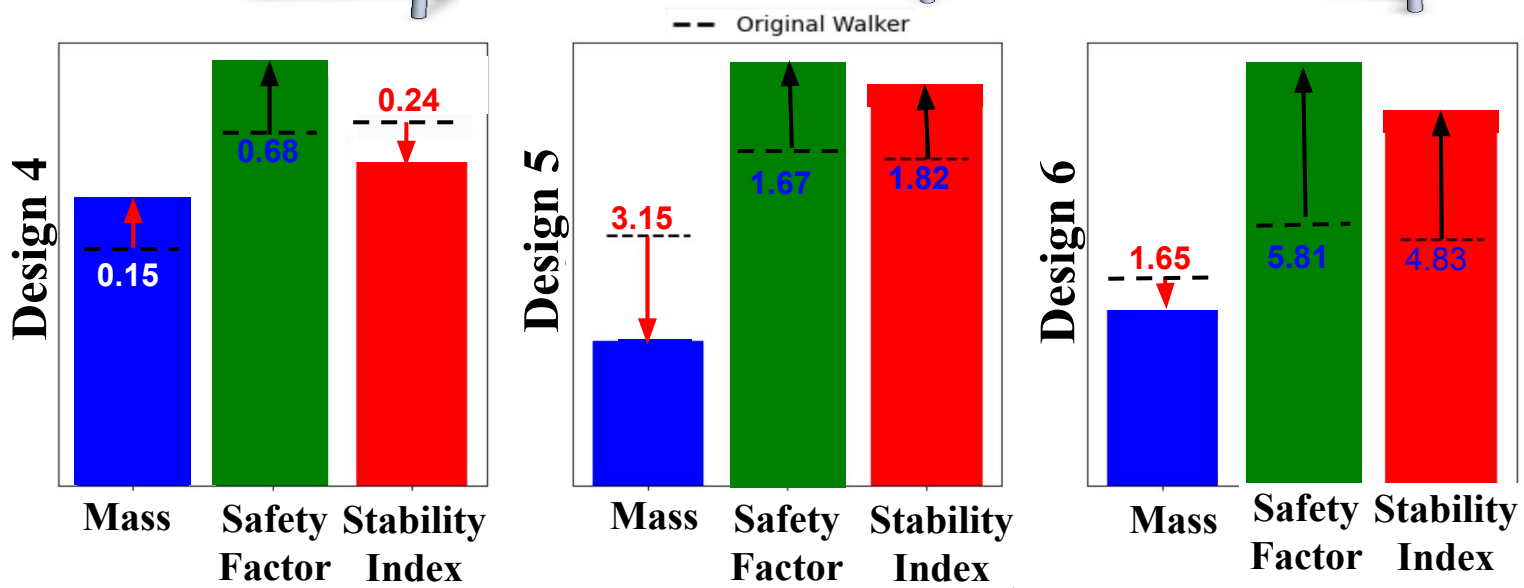


- Titanium Crossbeams
- Unique Frame

Custom Optimization Case Studies







- Designed for those of tall stature
- Relatively Unstable

- "Pediatric" walker

- Extra Stability & Structural Integrity
- Mass is compromised

Conclusion

Limitations:

- Parametric Expressivity
- Dataset Size
- Simulation vs Reality

Full Paper:
https://arxiv.org/pdf/2310.18772.pdf

Access the Open-Source Code a
https://github.com/AdvaithN1/Walk

Questions?