263-5805-00L
Physics-based Modeling for Computational **Fabrication** and **Robotics**

Moritz Bächer

ETH zürich

Disney Research

Agenda

- **Introduction**
- Course Overview
- Course Topics

Introduction

- Master in CS, ETH Zurich
- PhD in CS, Harvard University
- Research Scientist, Disney Research
- Stampfenbachstrasse 48, 8006 Zurich
- moritz.baecher@disneyresearch.com
- http://www.baecher.info

Agenda

- Introduction
- **Course Overview**
- Course Topics

Course Overview: Lectures

- HG E 1.2, Wednesdays 3-5 pm
- http://crl.ethz.ch/teaching.html
- Slides / course material available on website

Course Overview: Lectures

Date	Lecture	Lecturer
Feb. 20	Introduction	Stelian / Moritz
Feb. 27	Primer on Numerical Optimization	Stelian
Mar. 6	Kinematics of Mechanisms (Simulation & Design)	Stelian
Mar. 13	Rigid Body Dynamics / Mass Distribution Optimization	Moritz
Mar. 20	Modeling Elastic Objects (FEM)	Moritz
Mar. 27	Design Optimization (Sensitivity Analysis)	Stelian
Apr. 3	Project Proposals	All
Apr. 10	Material Characterization	Kristina
Apr. 17	Generative Design: Shape Grammars	Kristina
Apr. 24	NO CLASS	
May 1	NO CLASS	
May 8	Generative Design: Graph Grammars	Kristina
May 15	*Advanced Topics*	?
May 22	*Advanced Topics*	?
May 29	Project Demonstrations	All

Course Overview: Tutorials & Assignments

- **Tutorials**: CAB G 56, Fridays 1-3 pm
- 3 programming assignments
- ~2 weeks
- done individually
- Grading: 15% each

Moritz Geilinger
moritz.geilinger@inf.ethz.ch

Course Overview: Tutorials & Assignments

Date	Tutorial	Assignment
Feb. 22	GitHub Classroom	
Feb. 29	Code Framework for Assignments	**A1**
Mar. 8	Q&A A1	
Mar. 15	A2	A1 due; **A2**
Mar. 22	OnShape Tutorial / Q&A A2	
Mar. 29	A3	A2 due; **A3**
Apr. 5	Q&A A3	
Apr. 12	NO TUTORIAL	
Apr. 19	NO TUTORIAL	A3 due
Apr. 26	NO TUTORIAL	
May 3	Q&A Project	
May 10	Q&A Project	
May 17	Q&A Project	
May 24	Q&A Project	

Course Overview: Project

- Physics-based modeling
- Implements (*one* or *more*) techniques from lecture / discussed papers
- Groups of 1-2 students (3 students: approval required)
- Grading: 55%
- There will be **awards**!

Course Overview: Project

Date	Lecture	Project
Feb. 20		
Feb. 27		**start planning**
Mar. 6		
Mar. 13		
Mar. 20		
Mar. 27		
Apr. 3	Project Proposal	**plan due; start project**
Apr. 10		
Apr. 17		
Apr. 24	NO CLASS	
May 1	NO CLASS	
May 8		**status update due**
May 15		
May 22		
May 29	Project Demonstrations	**project due**

Course Overview: Project

- Create a **project plan containing**
  - overall **idea** of the project *(abstract)*
  - lecture / paper **topics** that will be implemented *(scope)*
  - **milestones** and corresponding deadlines *(roadmap)*

- Reports / presentations / code
  - Apr. 3: **project plan** (report / presentation)
  - May 8: **status update** (report)
  - May 29: **project due** (report / presentation / code)

Course Overview: Project Plan (Apr. 3)

- Create a **project plan containing**
  - overall **idea** of the project *(abstract)*
  - lecture / paper **topics** that will be implemented *(scope)*
  - **milestones** and corresponding deadlines *(roadmap)*

- Hand in by Apr. 2:
  - **1 page** summary of project plan (**PDF**)
  - **3 min** presentation (**PPT**)
  - email link to zipped folder (Moritz Geilinger)

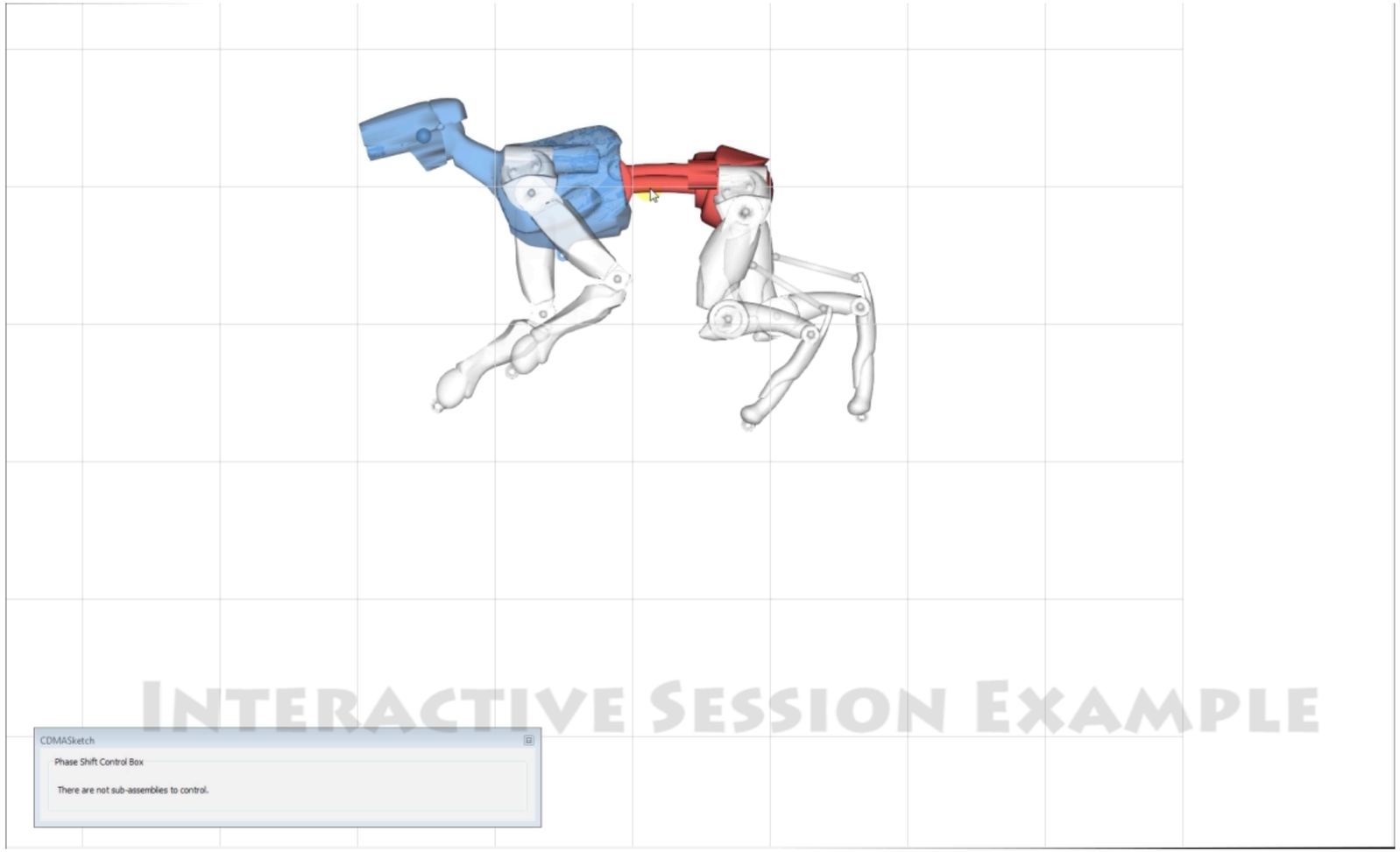
Course Overview: Grading

- Assignments: 15% + 15% + 15%
- Project: 55% (10% proposal; 30% project; 15% presentation)

Agenda

- Introduction
- Course Overview
- **Course Topics**

Course Topics: Kinematics of Mechanisms



[Coros et al. 2013]

Course Topics: Kinematics of Mechanisms

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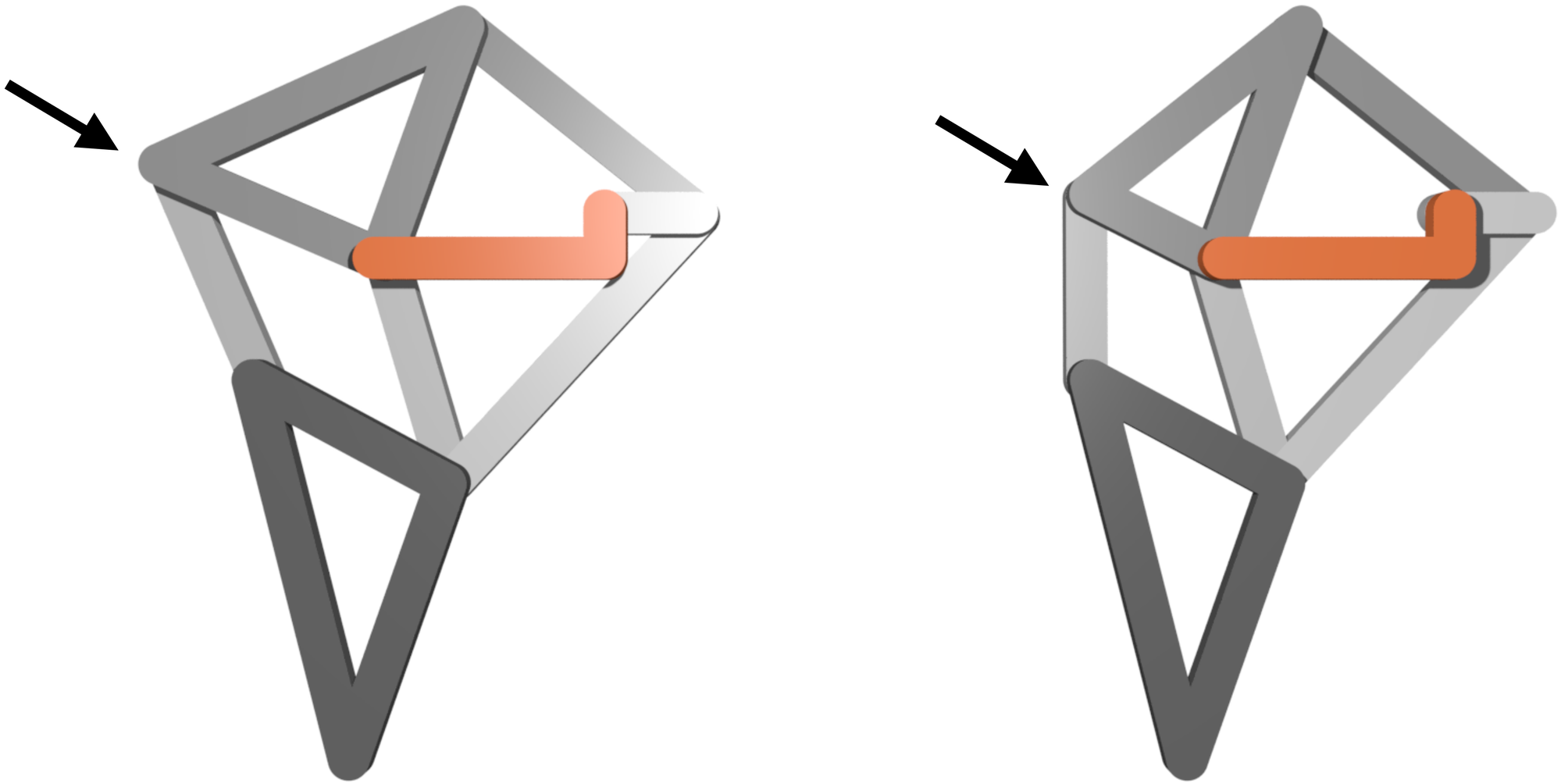
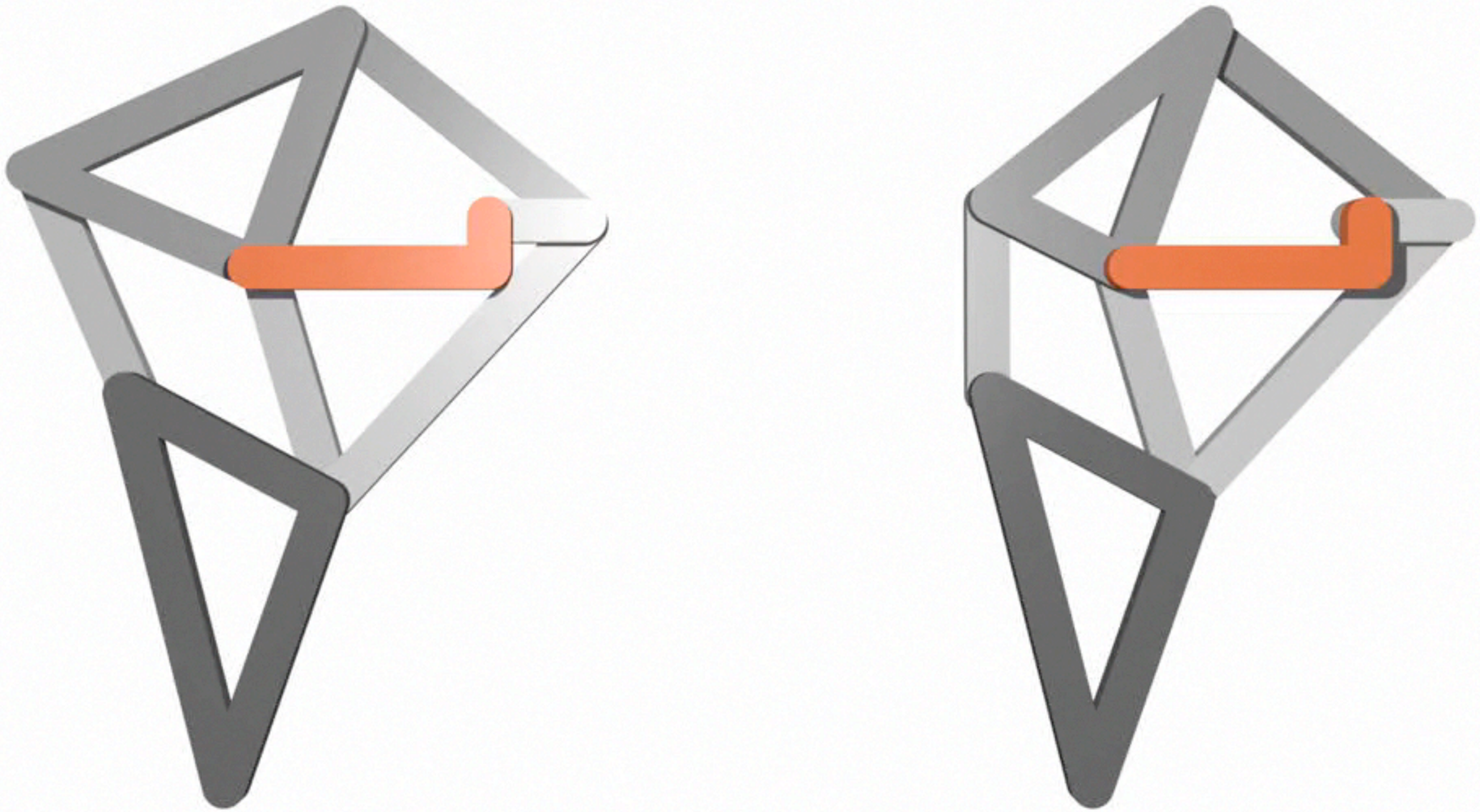


[Bächer et al. 2015]

Course Topics: Kinematics of Mechanisms



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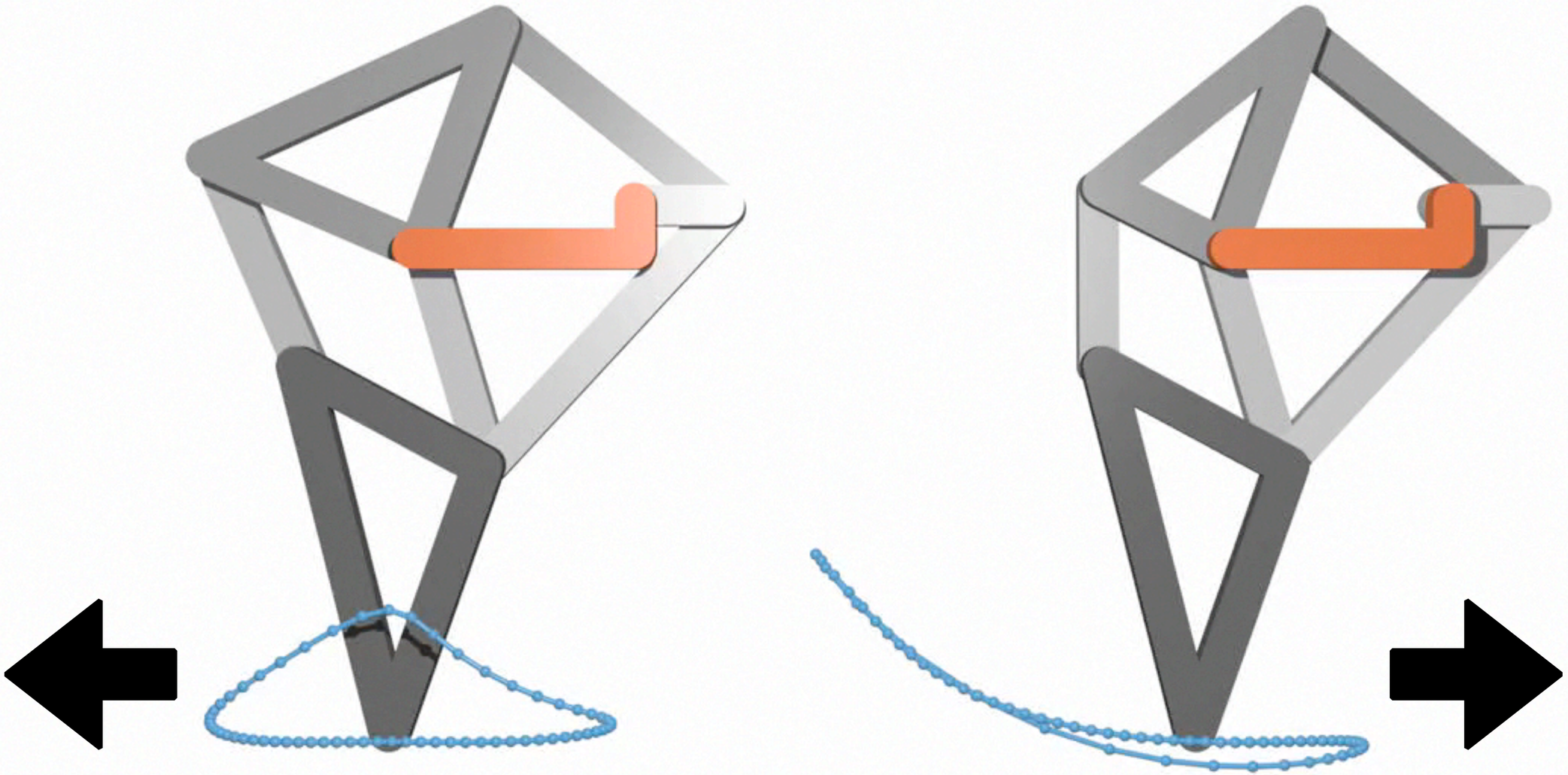

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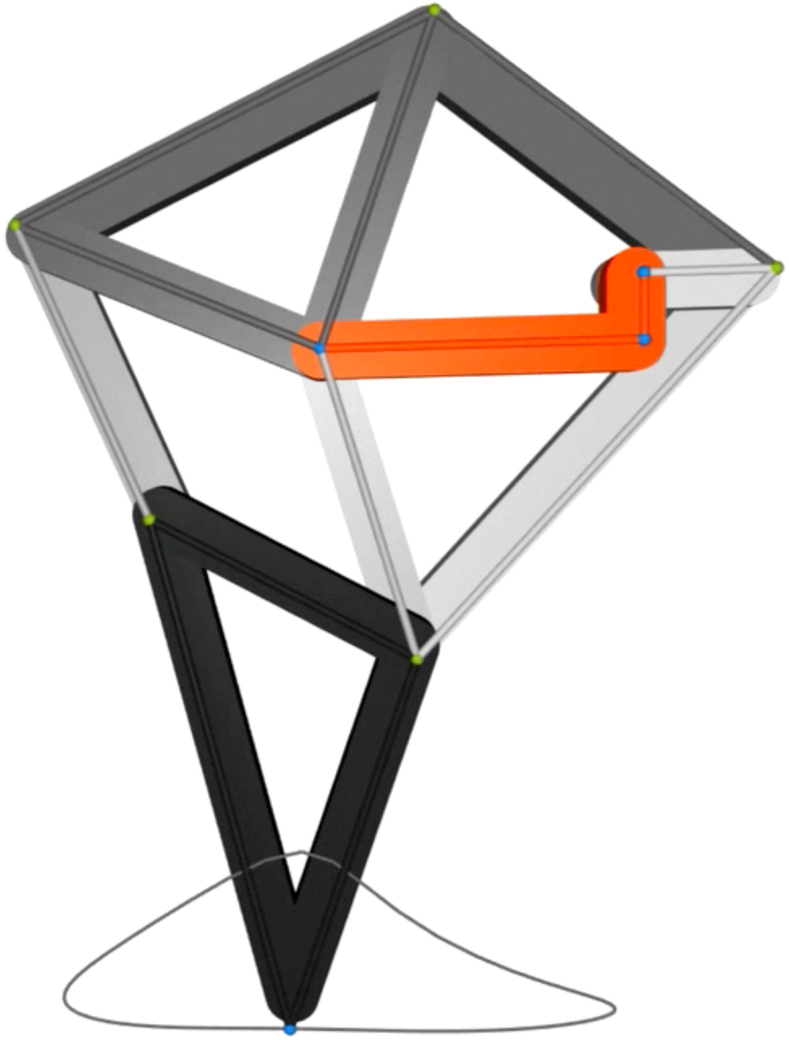

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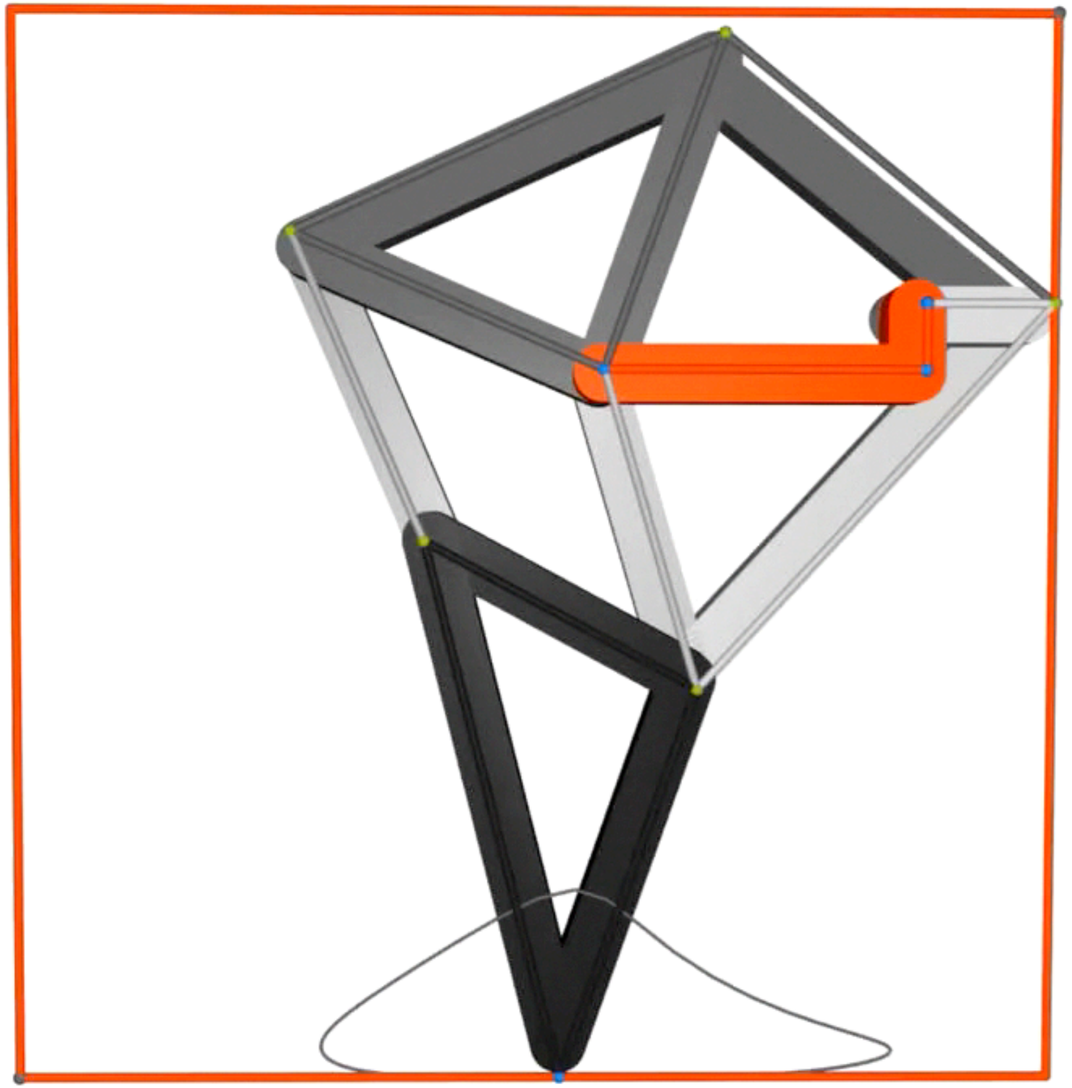
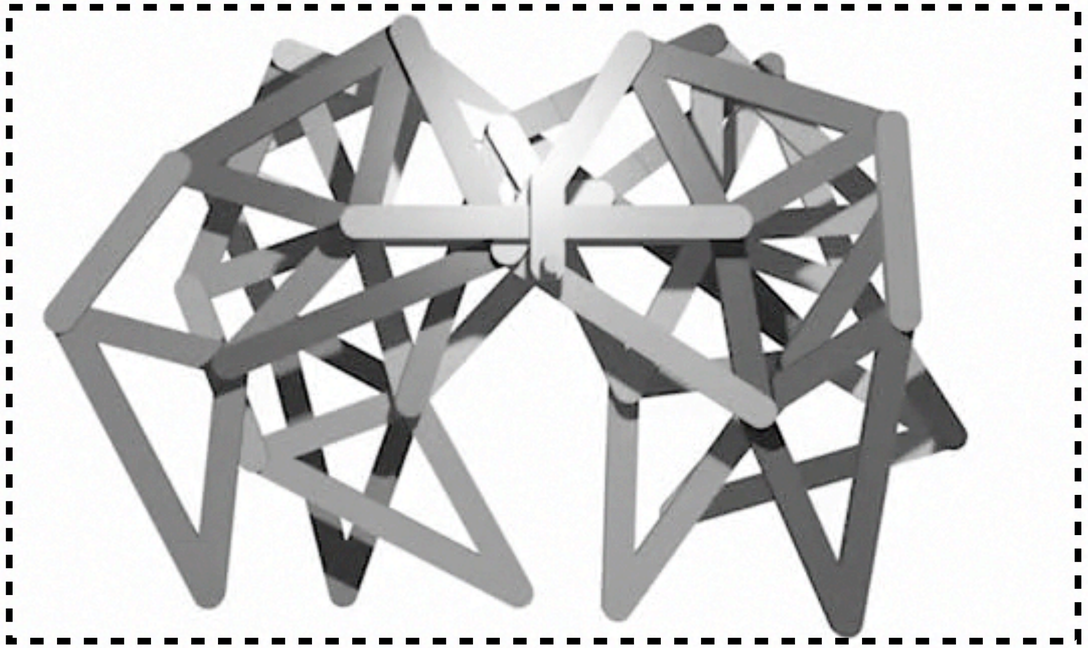


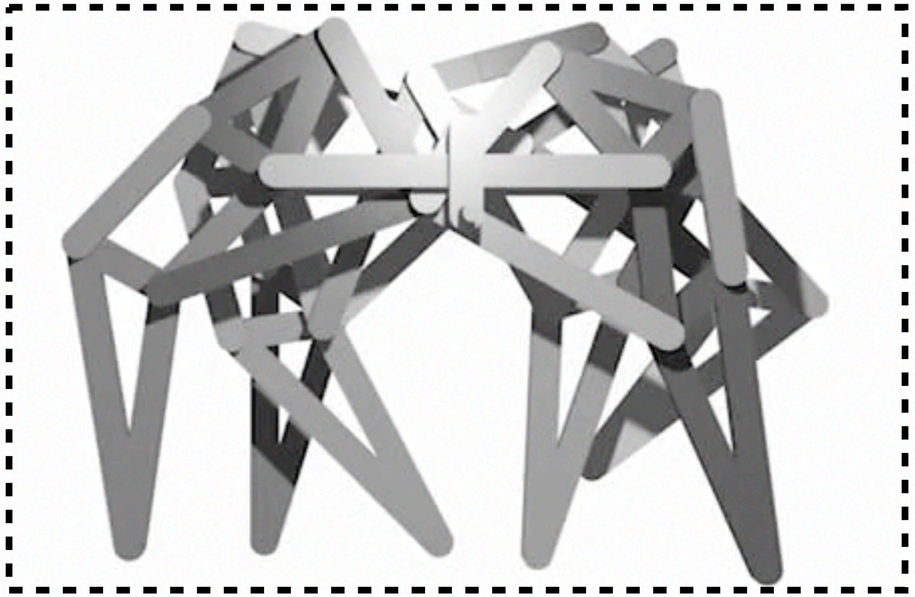
[Bächer et al. 2015]

Course Topics: Kinematics of Mechanisms

aspect ratio: ~1.7



aspect ratio: ~1.5



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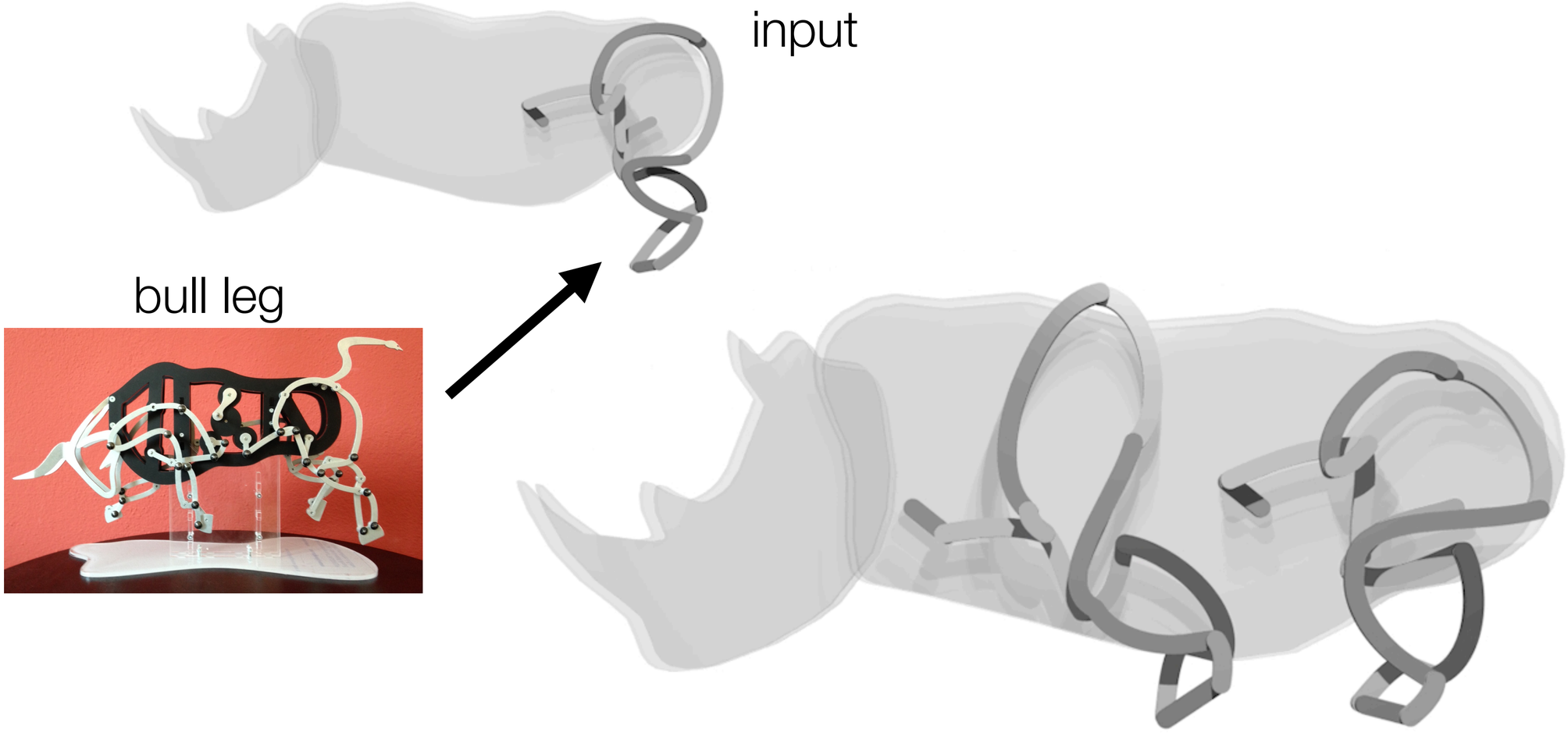

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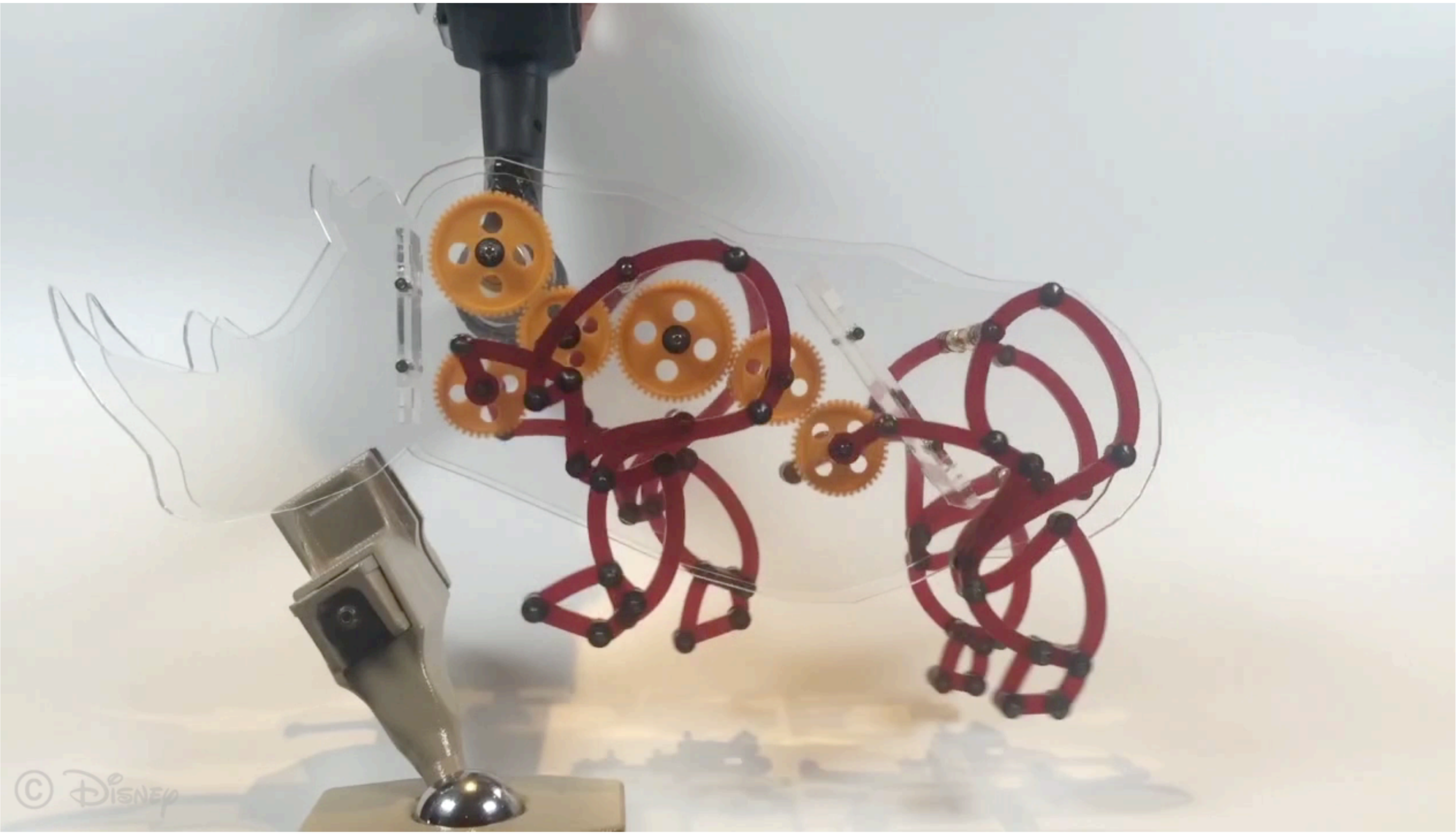

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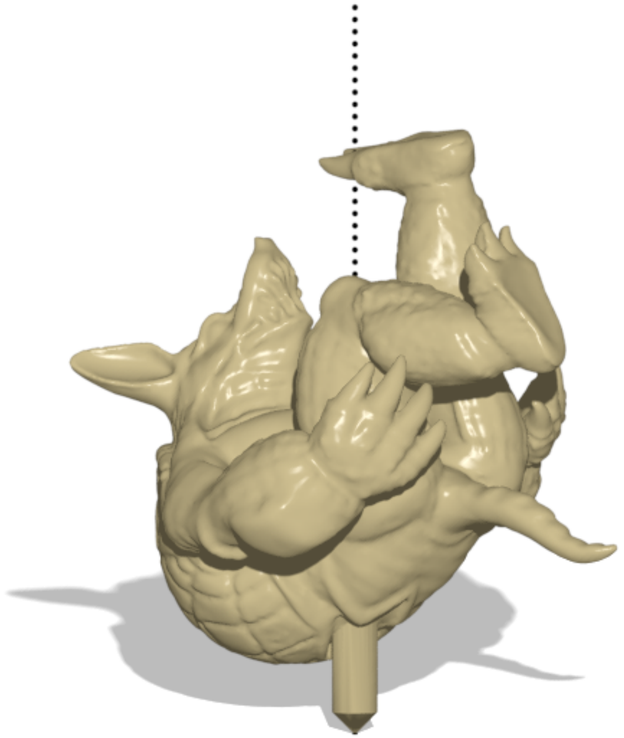
Course Topics: Mass Distribution Optimization



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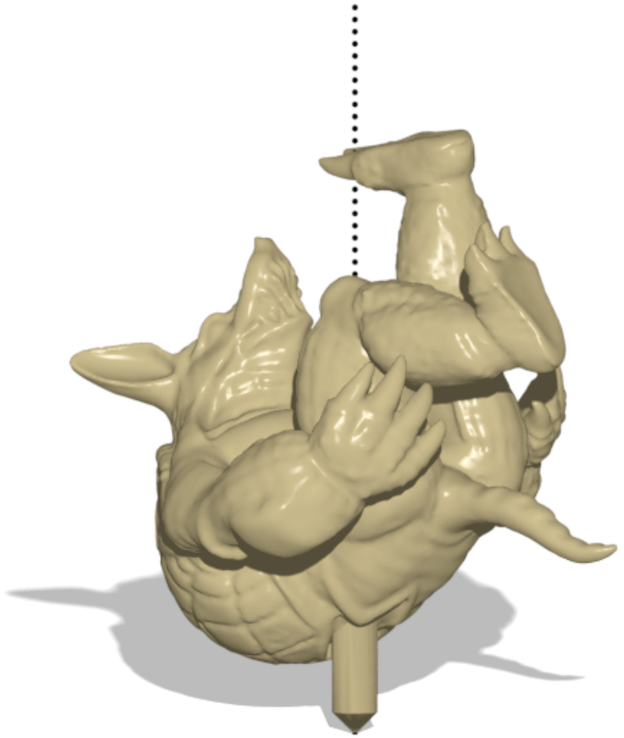

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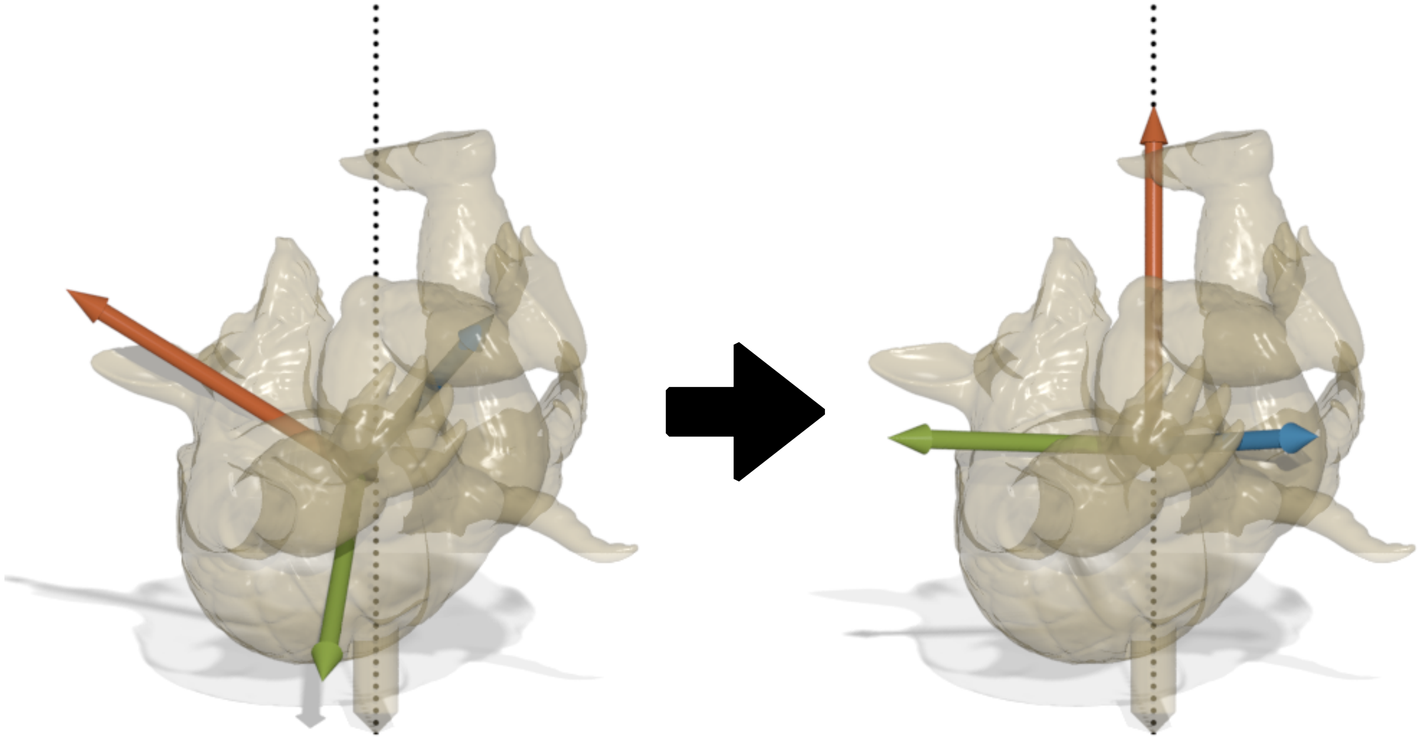

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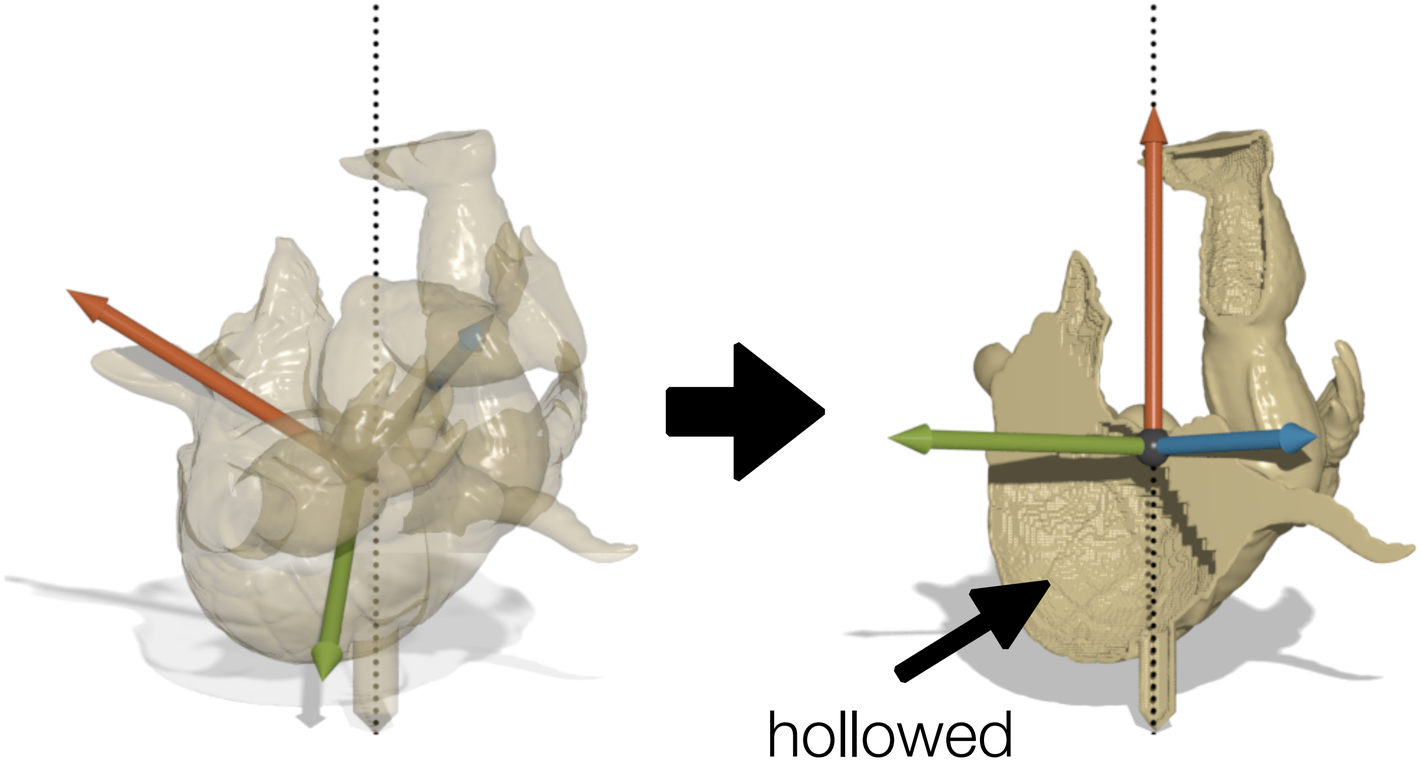

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Course Topics: Mass Distribution Optimization

[Hager, http://www.hager-drechseln.de/]

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Course Topics: Mass Distribution Optimization

[John Hopkins University]

[Wikimedia Commons]

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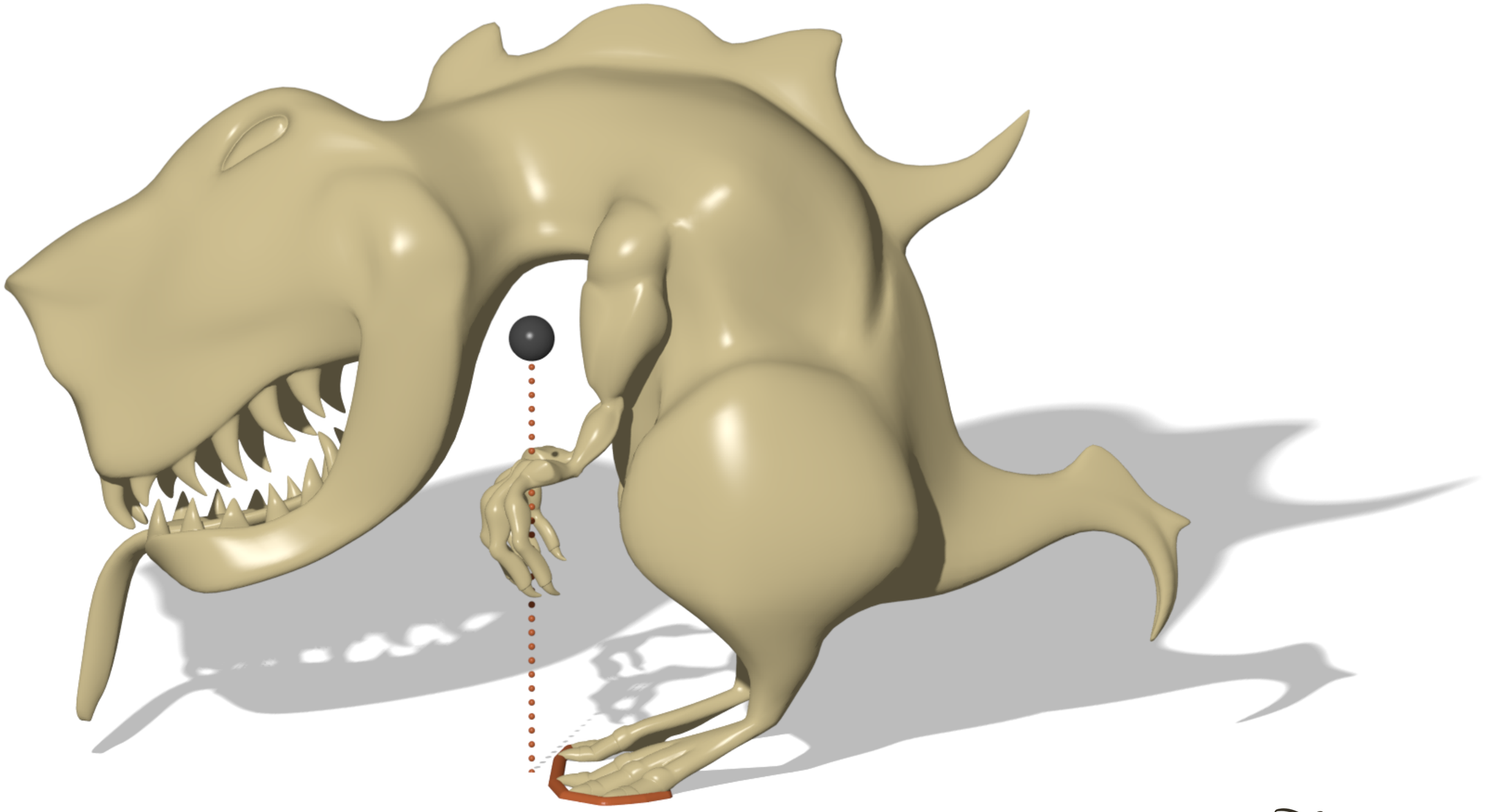

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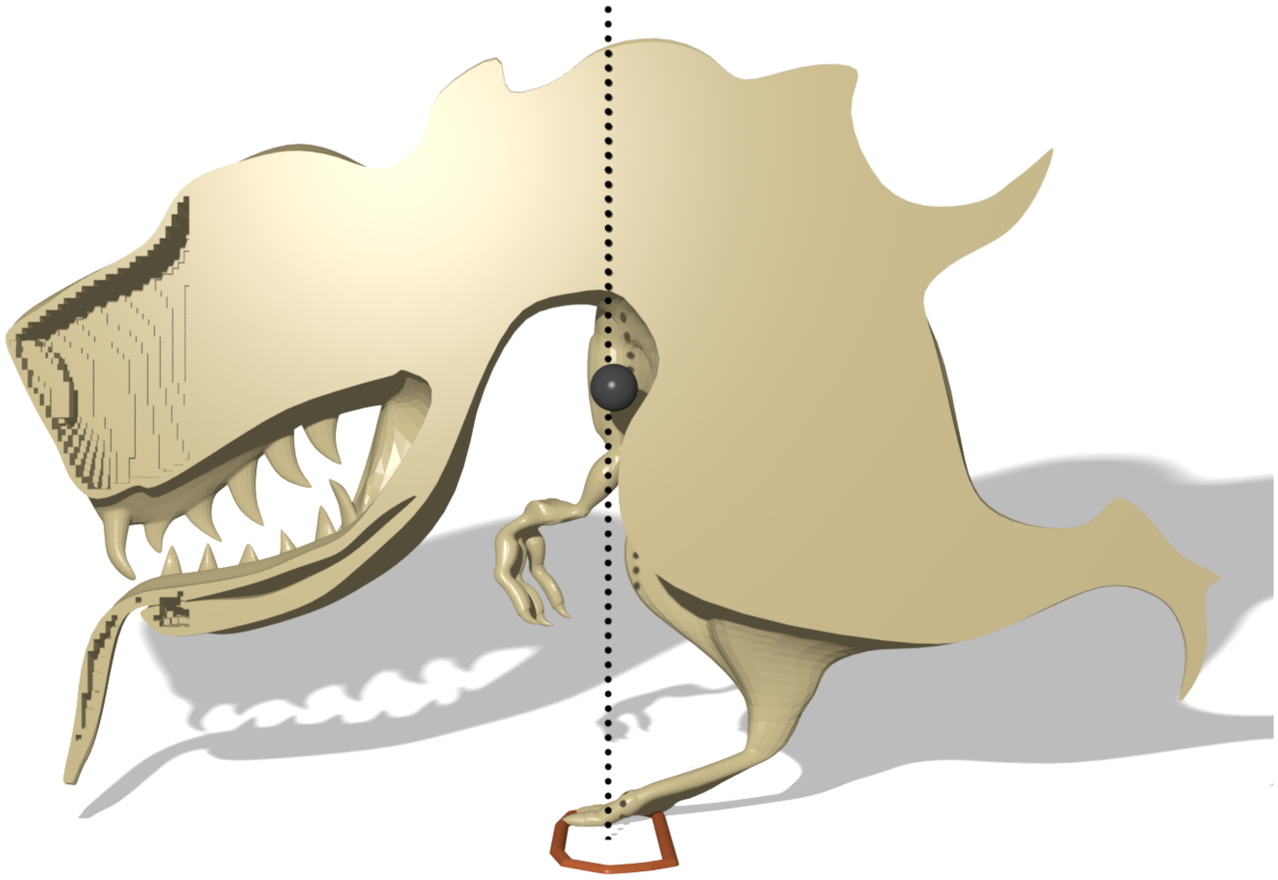
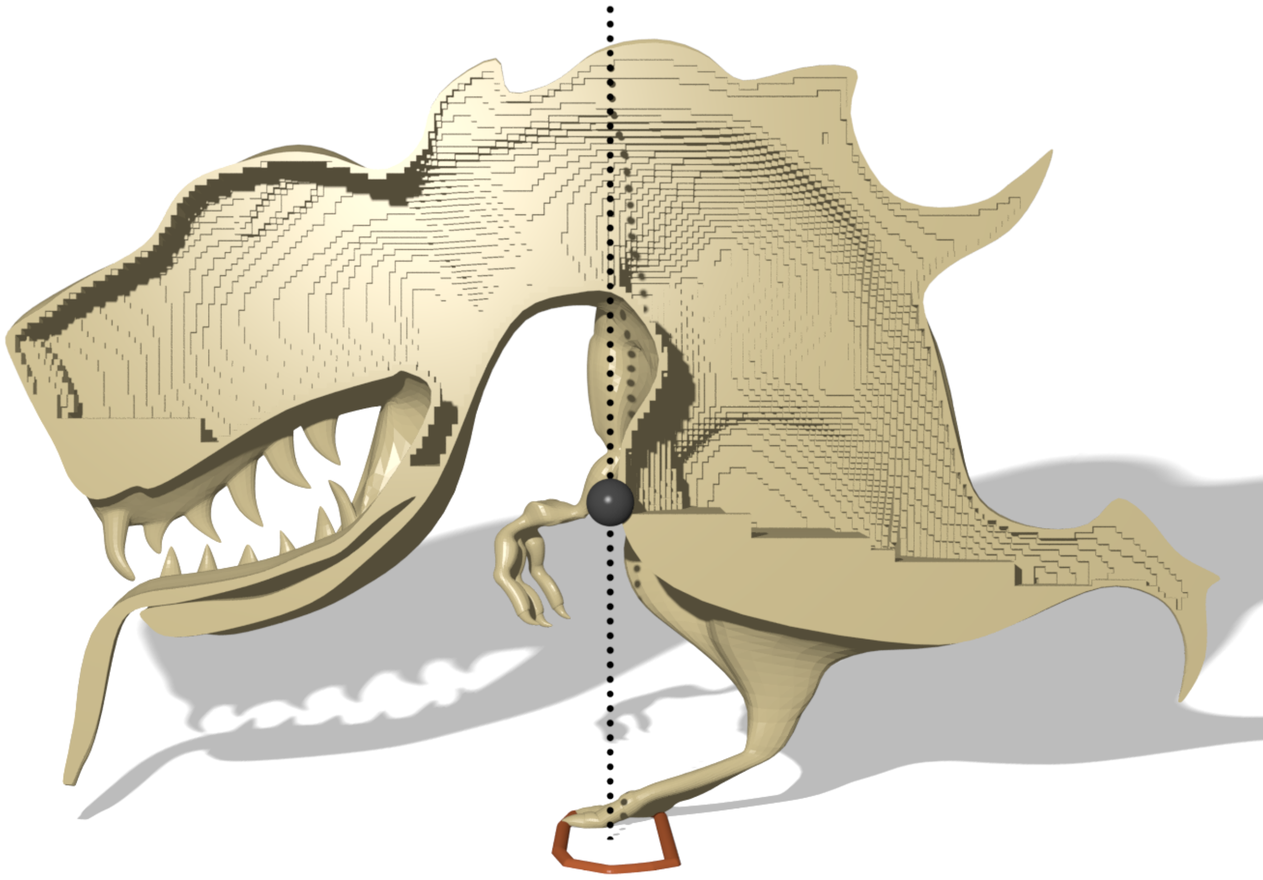


[Prévost et al. 2013]



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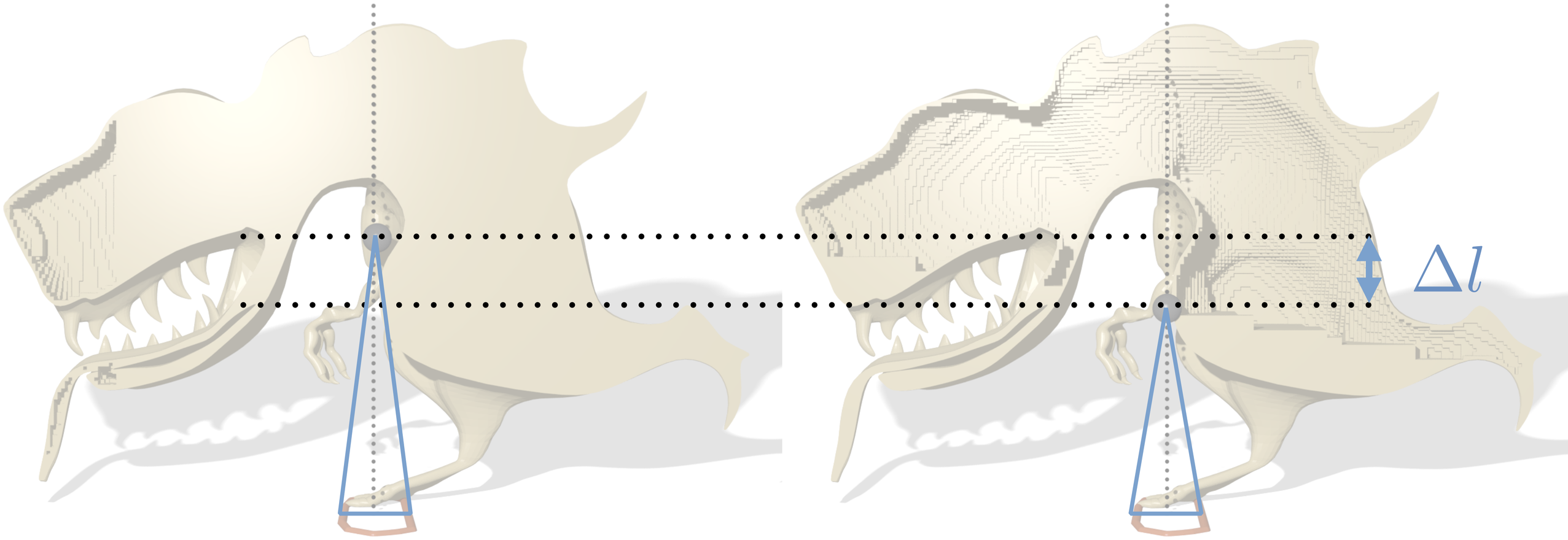

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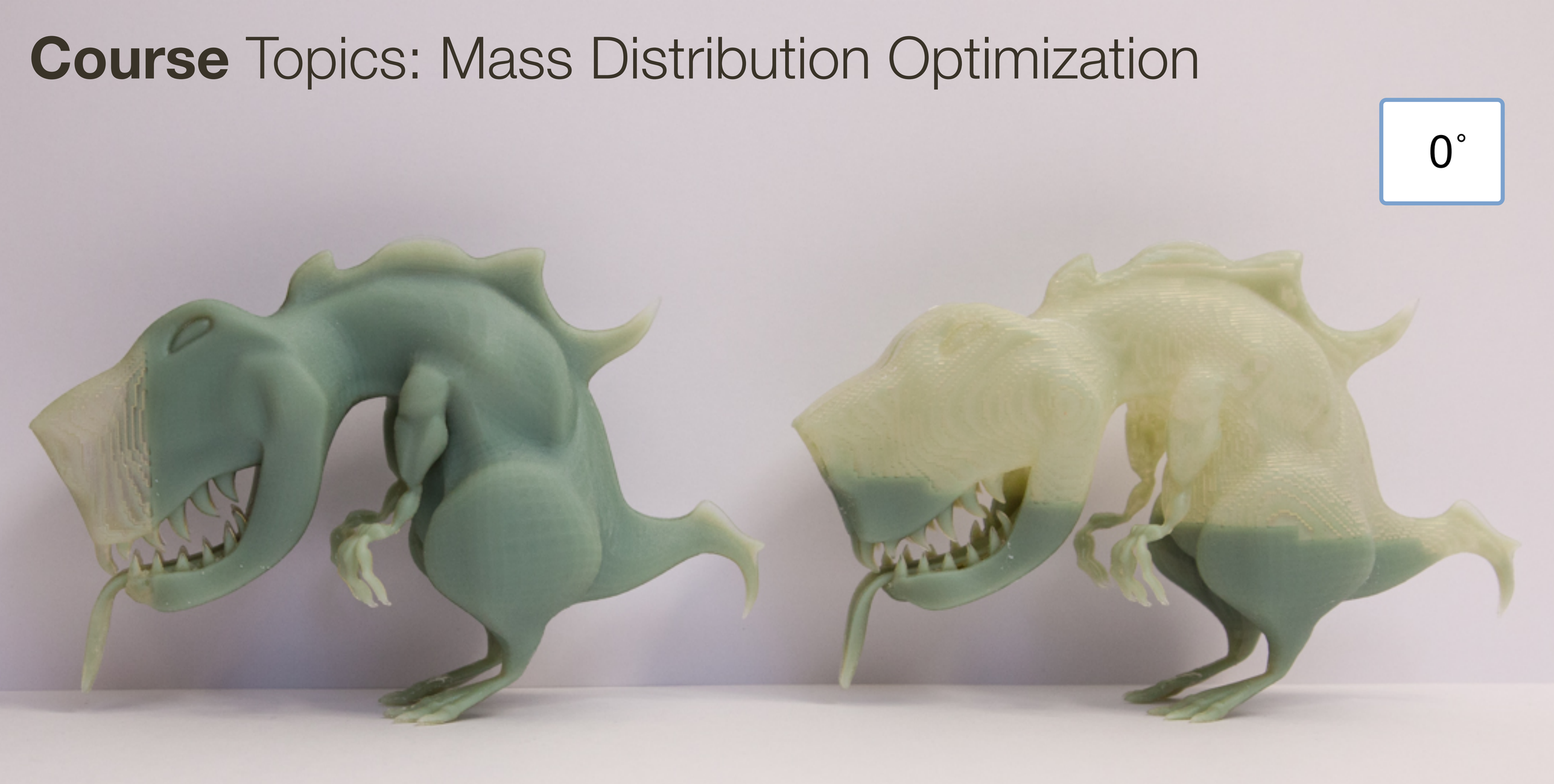

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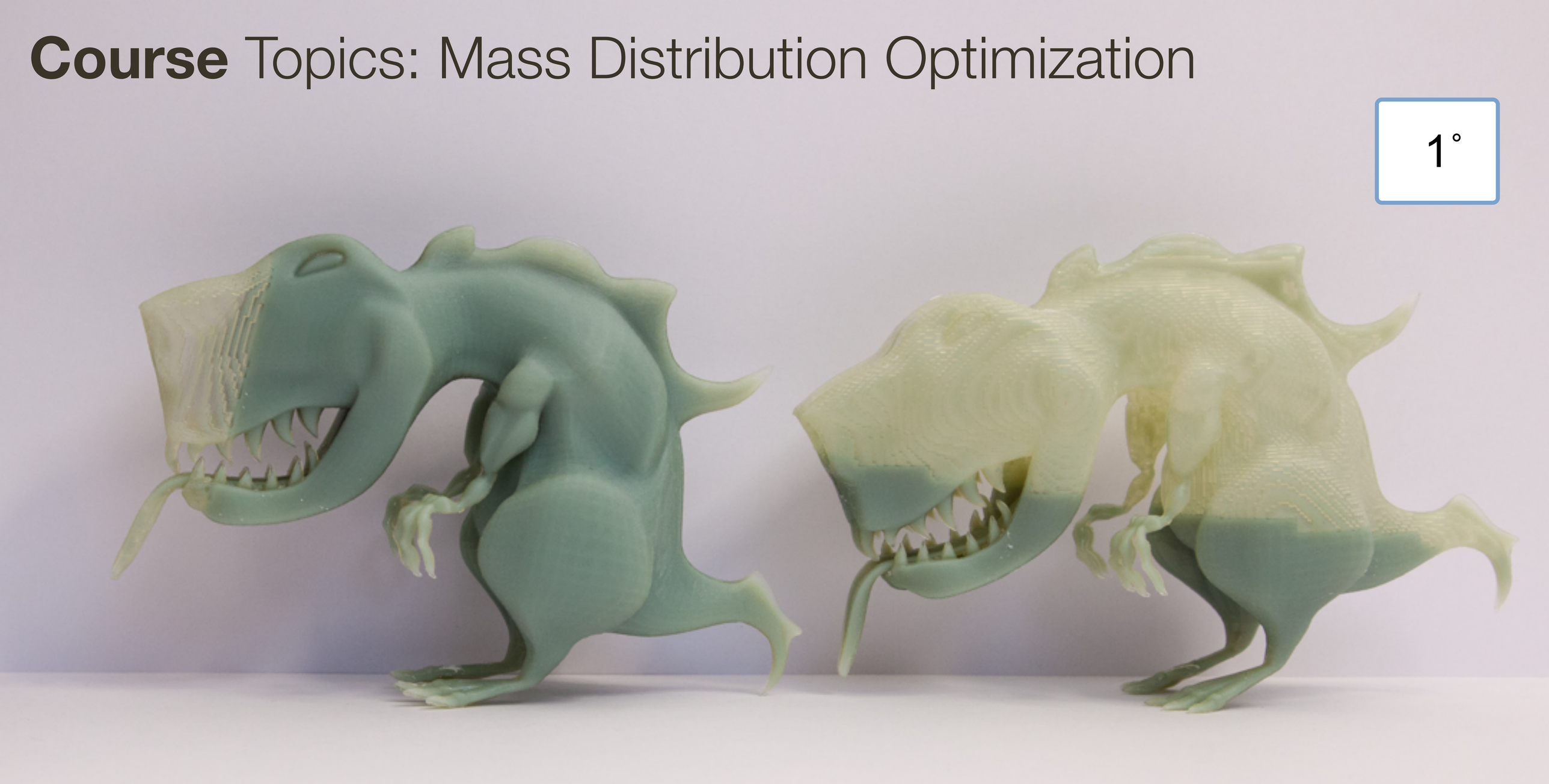
Course Topics: Mass Distribution Optimization

1°



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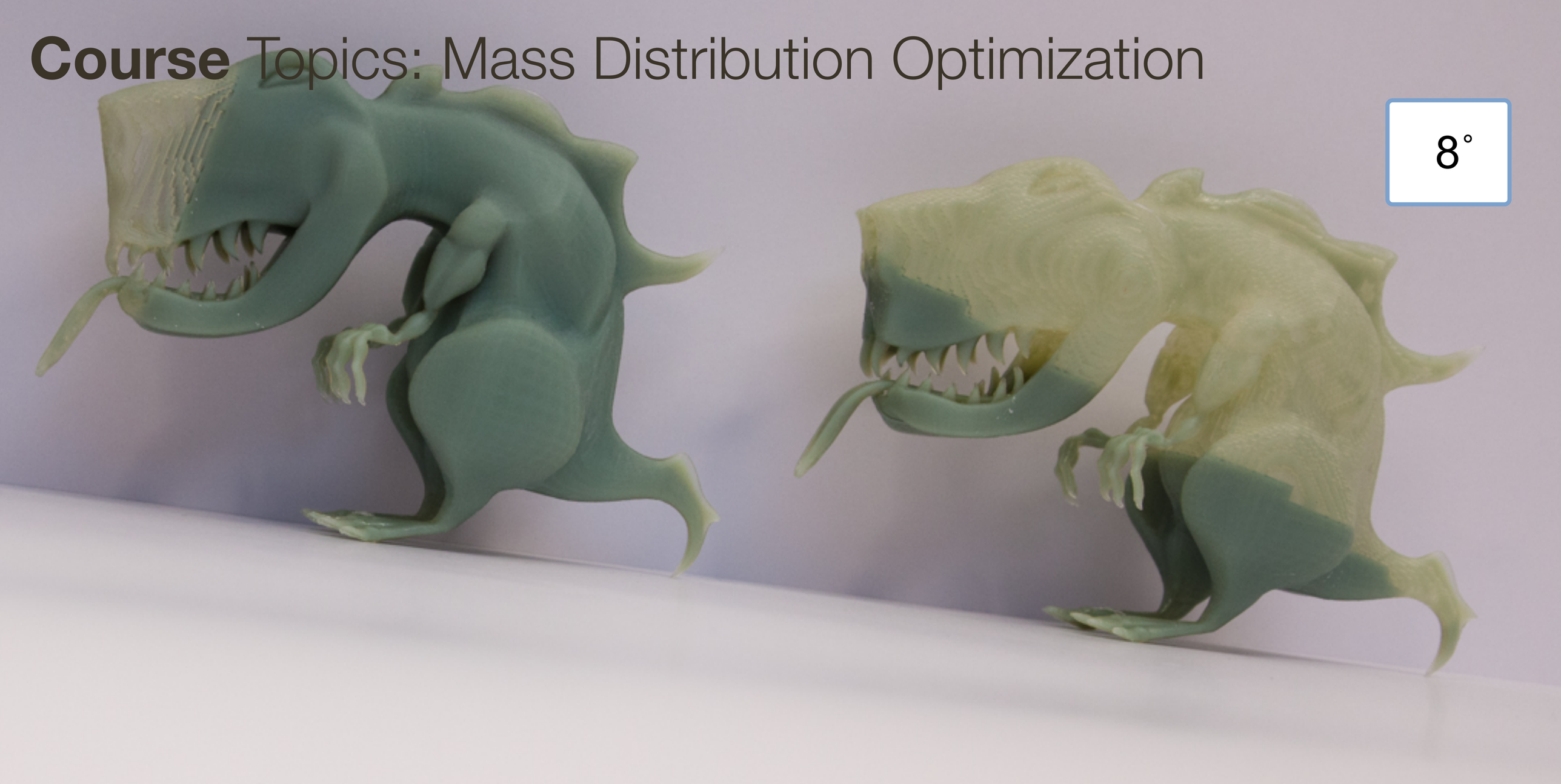

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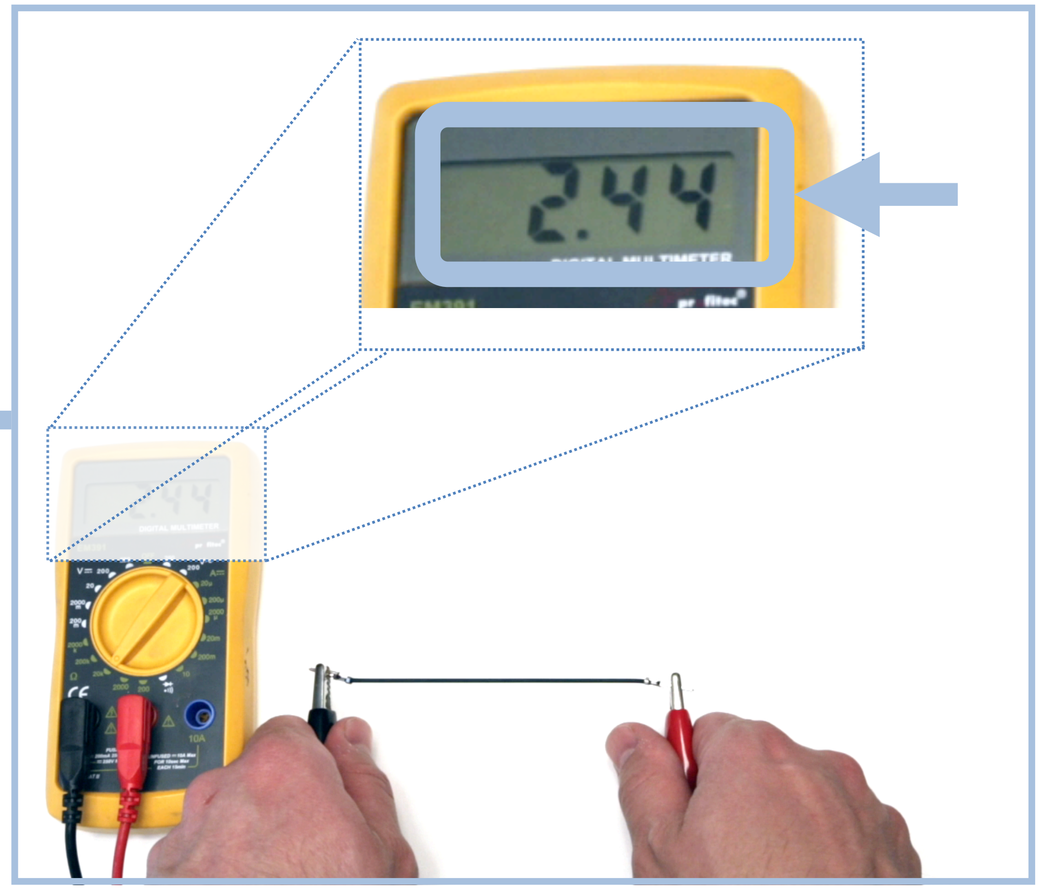
Course Topics: Mass Distribution Optimization

[Gravity-Defying Elephant Sculpture, Daniel Firman]

Course Topics: Modeling Elastic Objects



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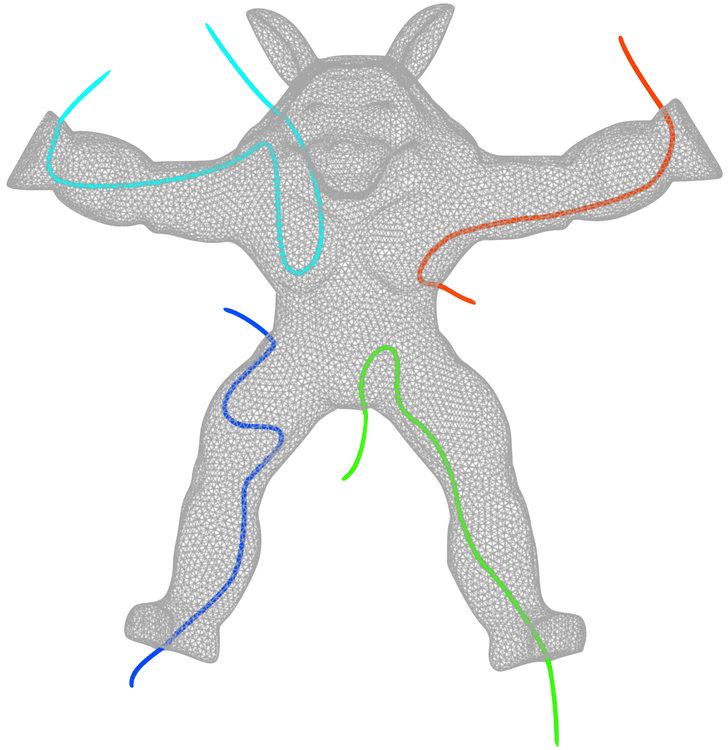

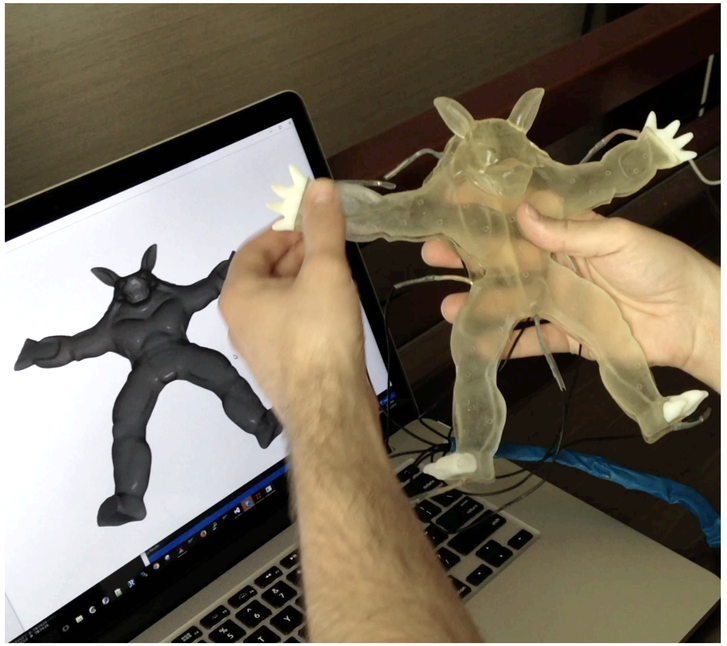

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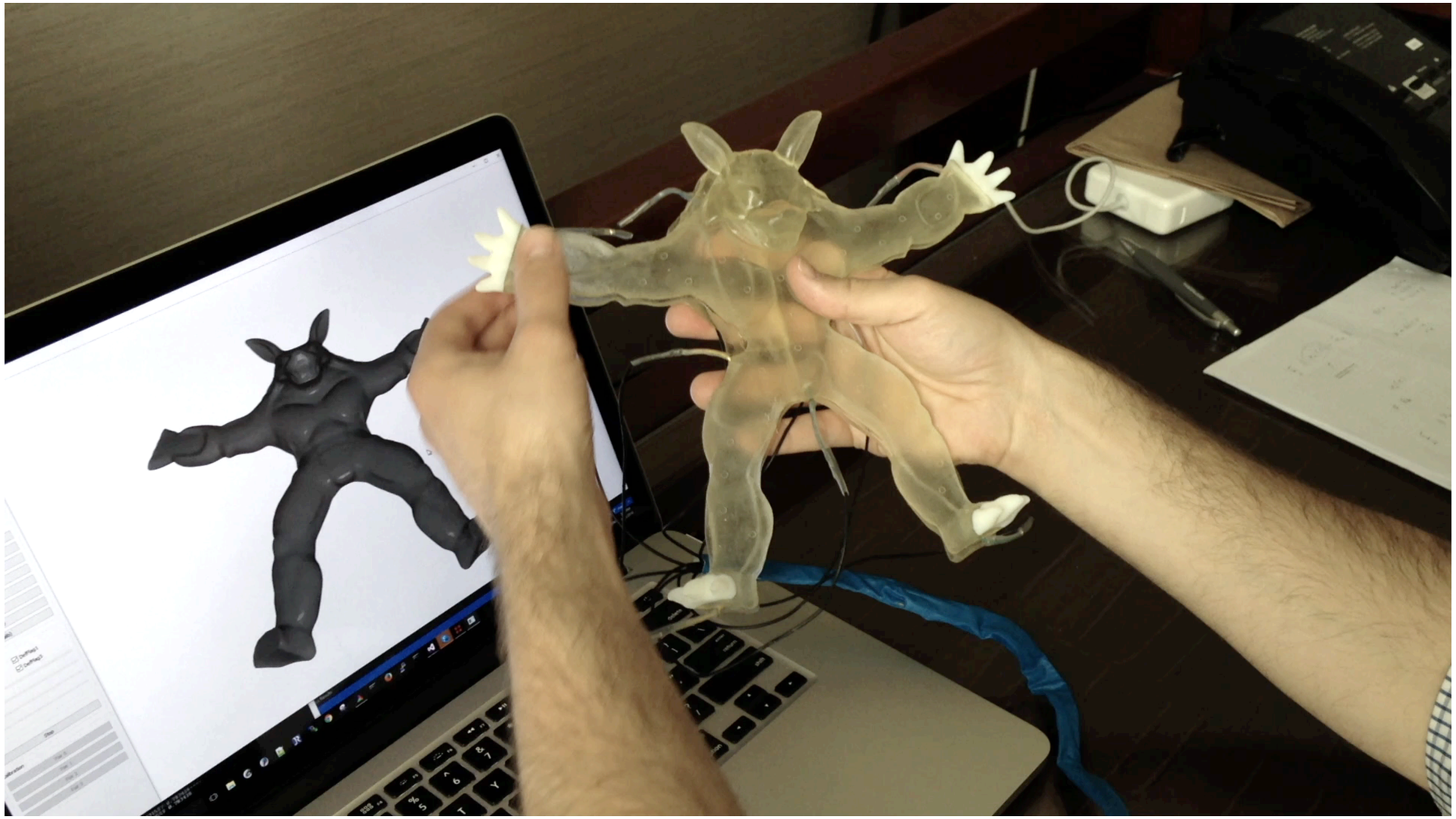

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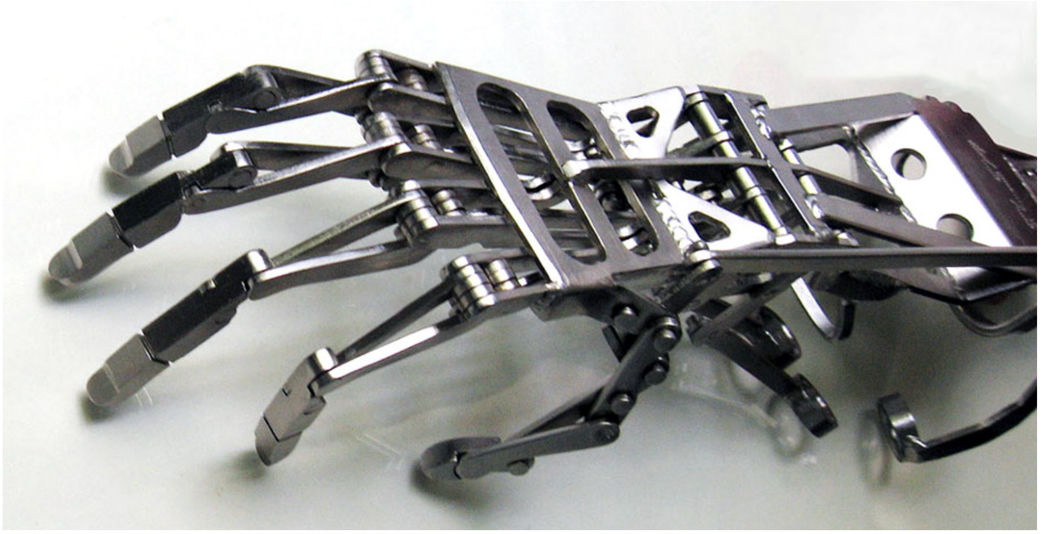
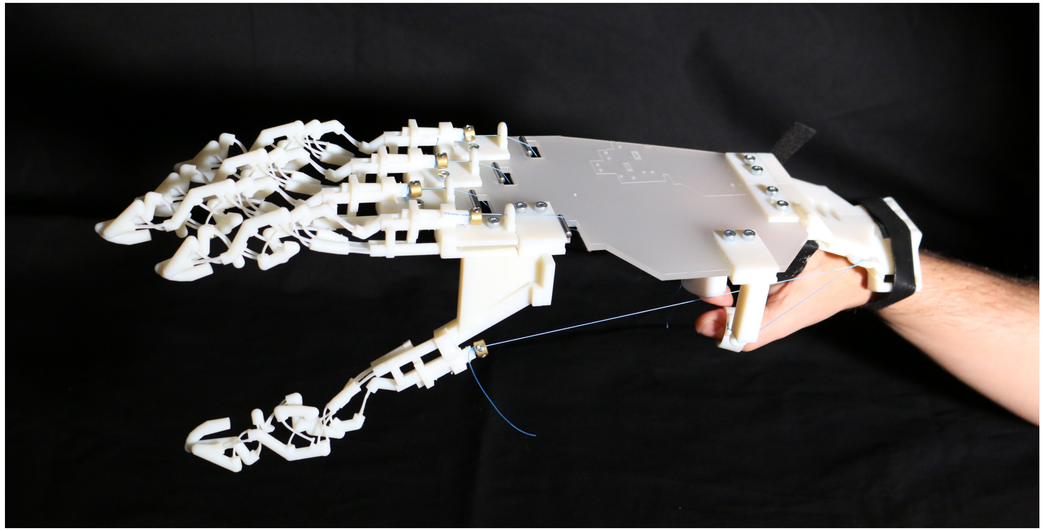
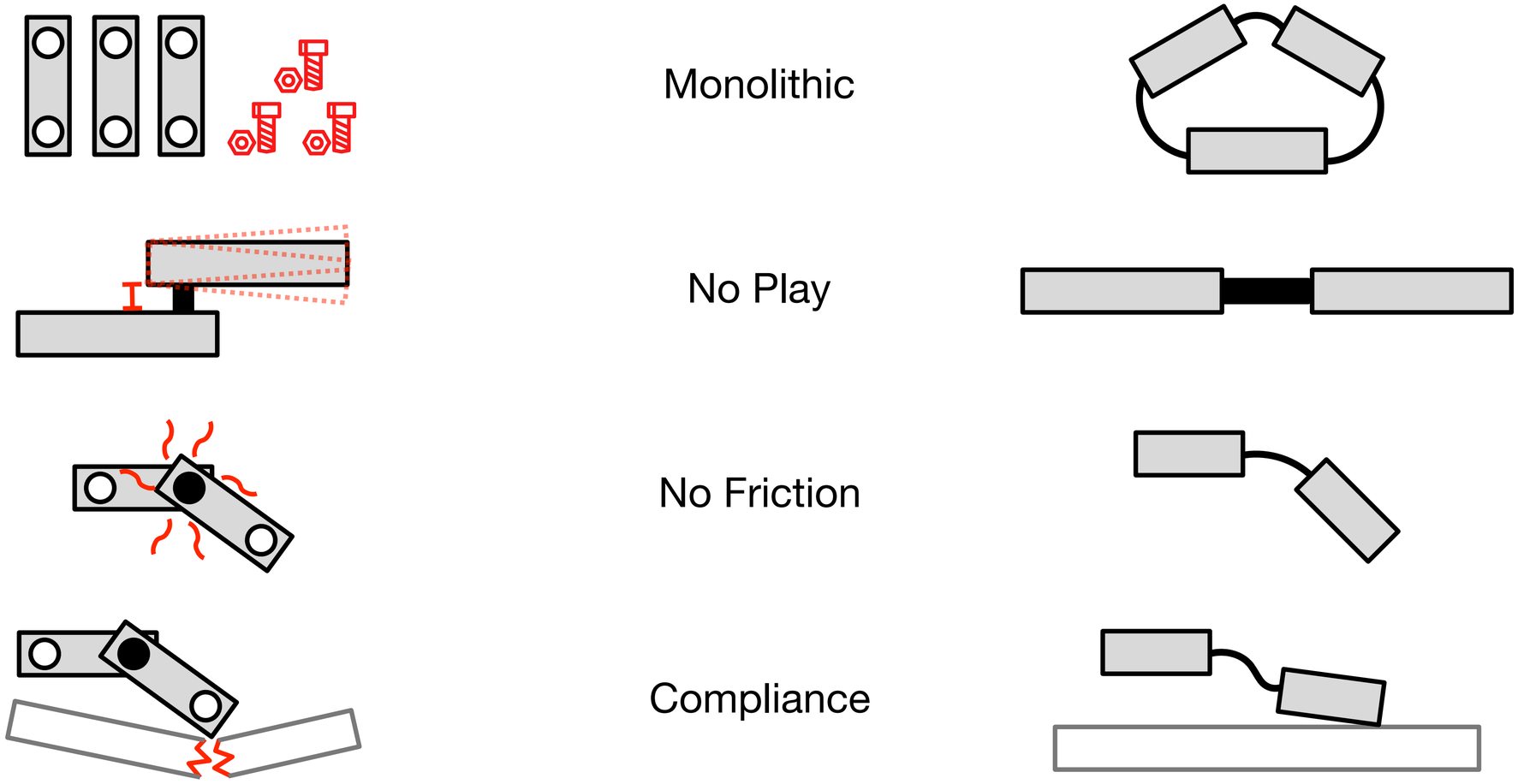
Course Topics: Design Optimization





[Megaro et al. 2017]

Course Topics: Design Optimization



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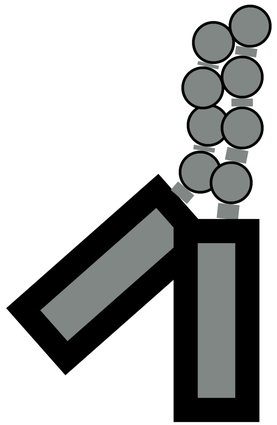
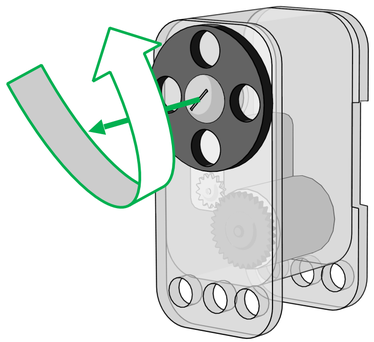
Course Topics: Design Optimization

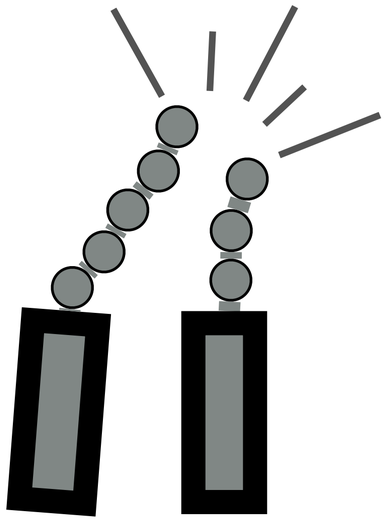
Trajectory Matching



Collision Avoidance



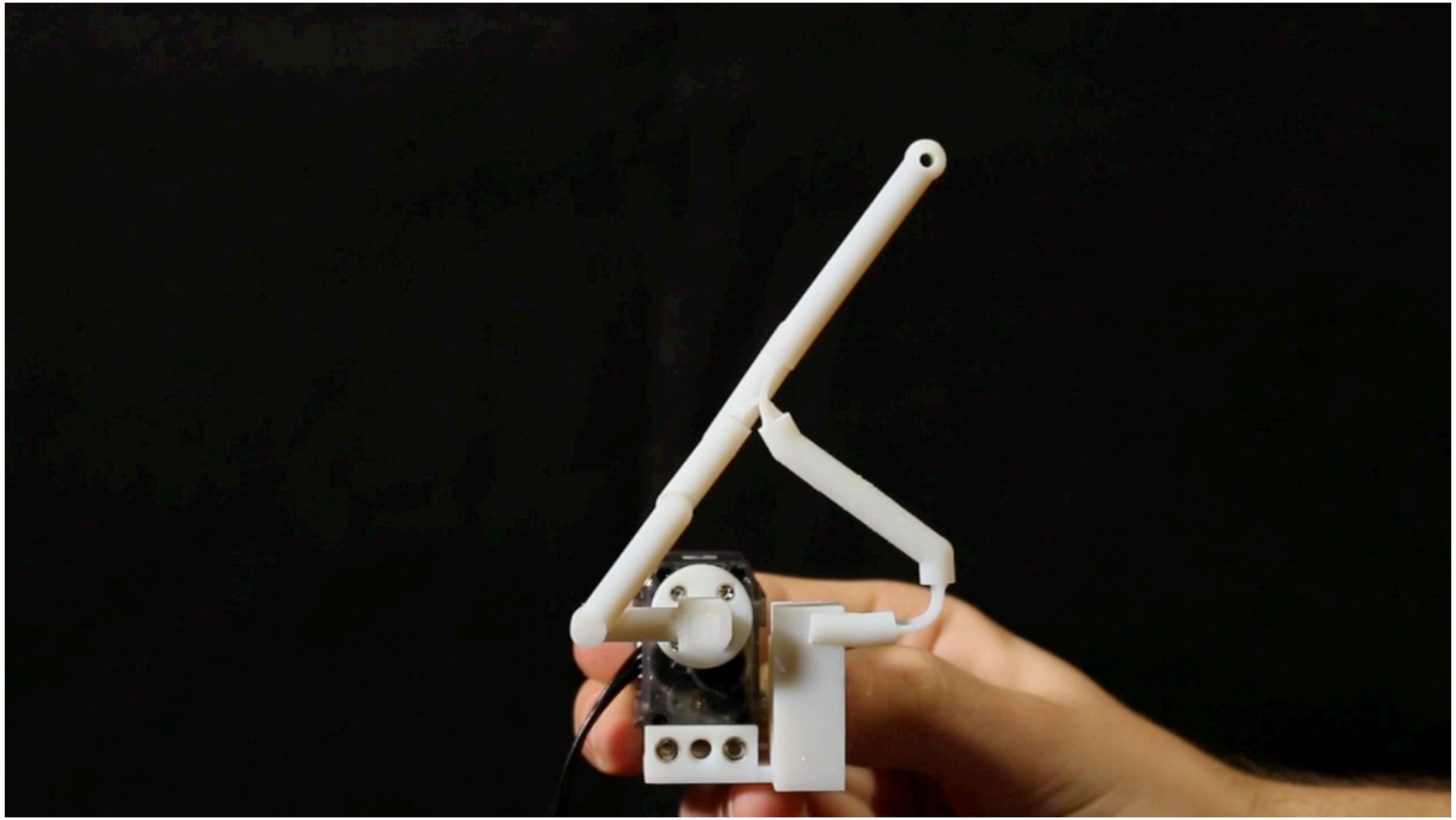
Torque Reduction



Failure Avoidance

[Megaro et al. 2017]

Course Topics: Design Optimization



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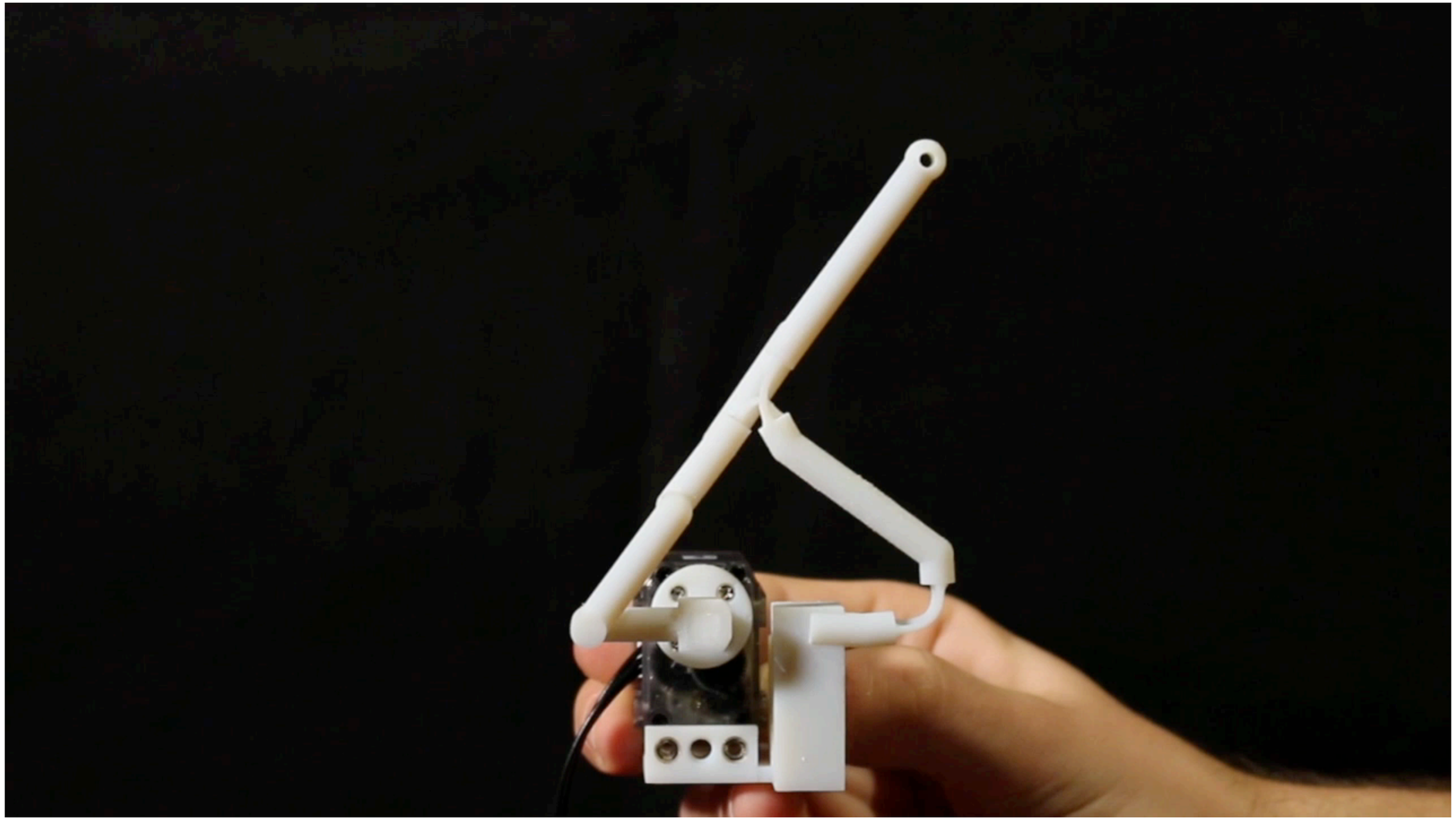
Course Topics: Design Optimization



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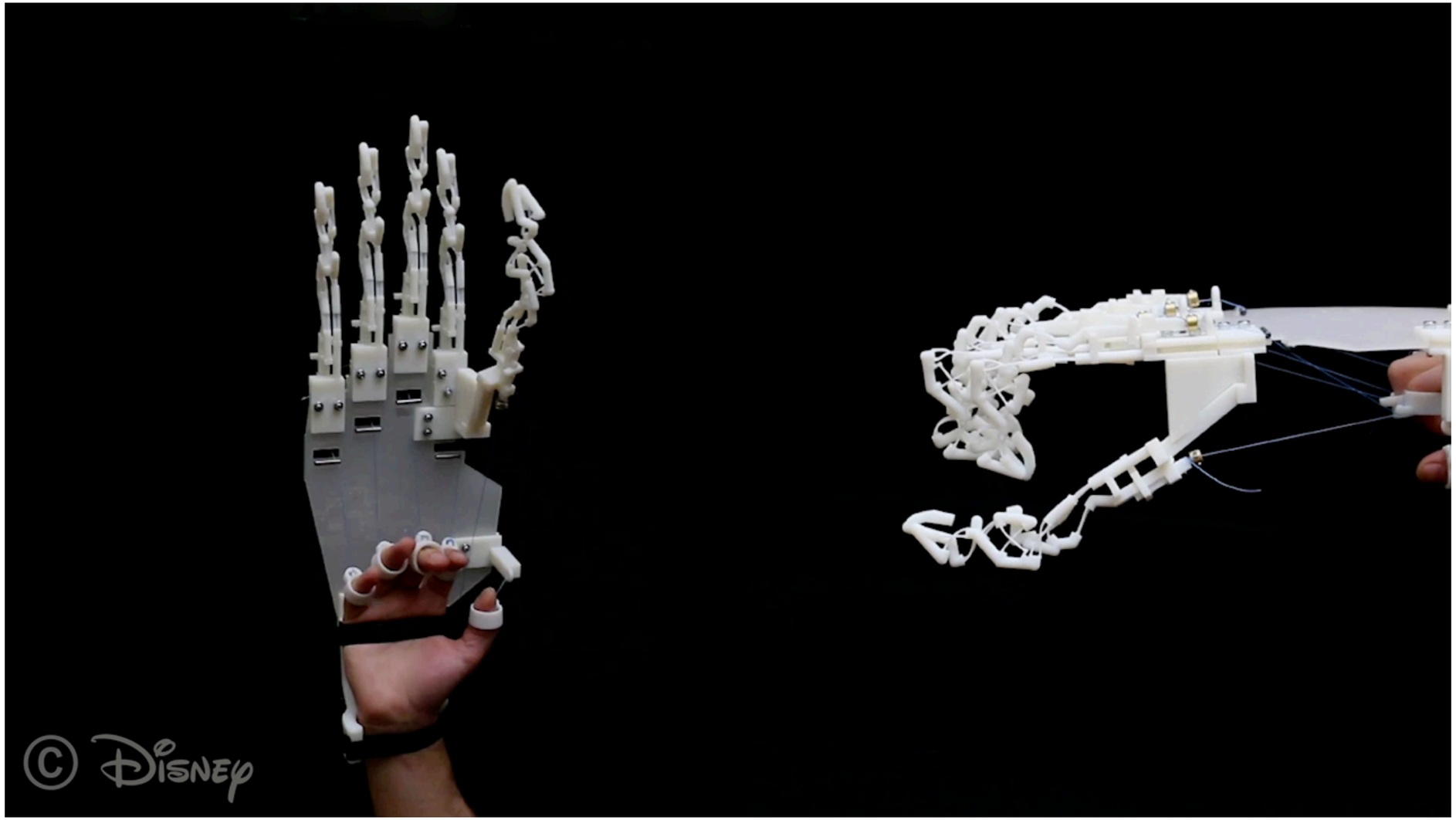

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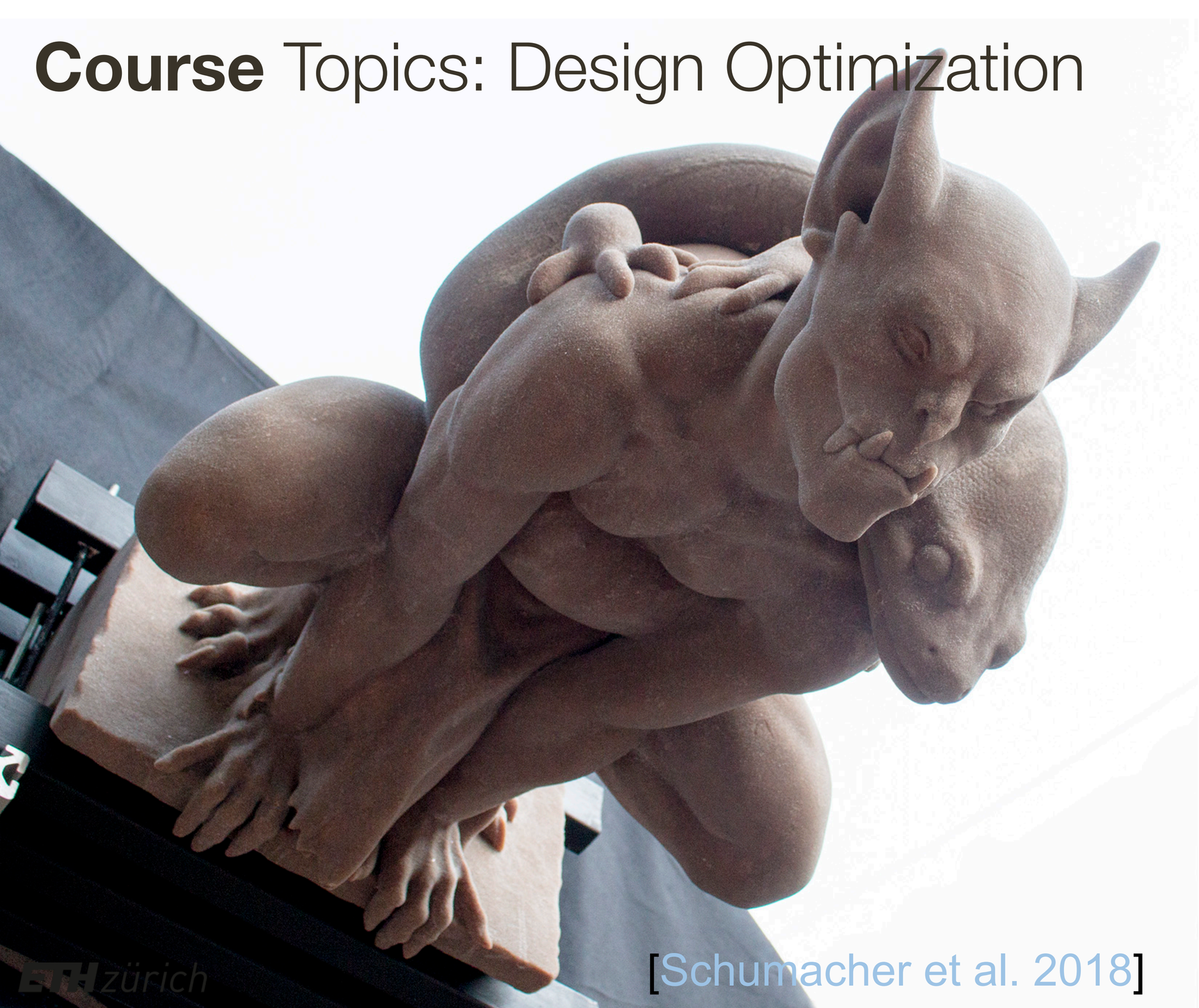
Course Topics: Design Optimization



[Schumacher et al. 2018]

Course Topics: Design Optimization

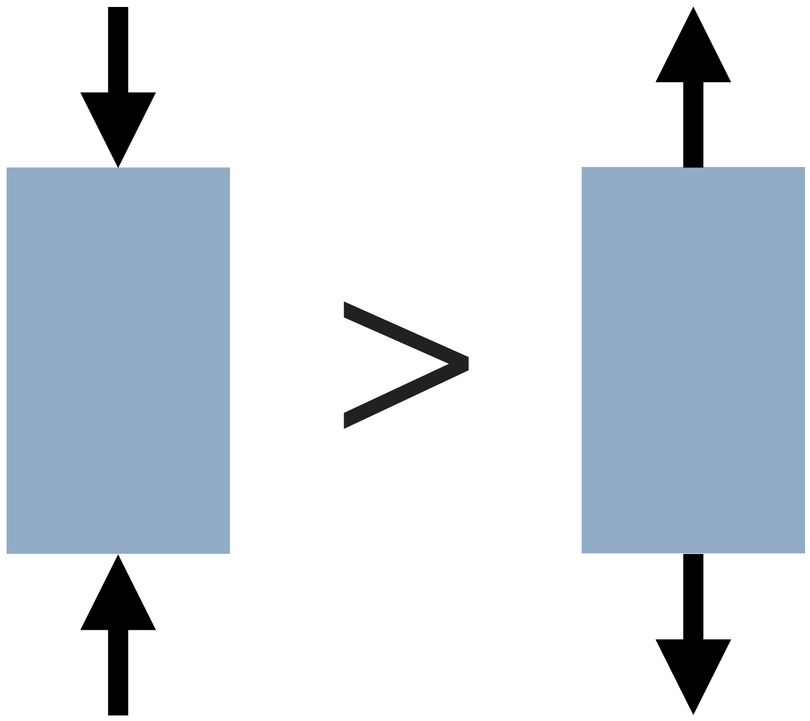
PRINTING . ARCHITECTURE

[Dillenburger and Hansmeyer 2013; 2017]

Course Topics: Design Optimization

[Dillenburger and Hansmeyer 2013; 2017]

Course Topics: Design Optimization



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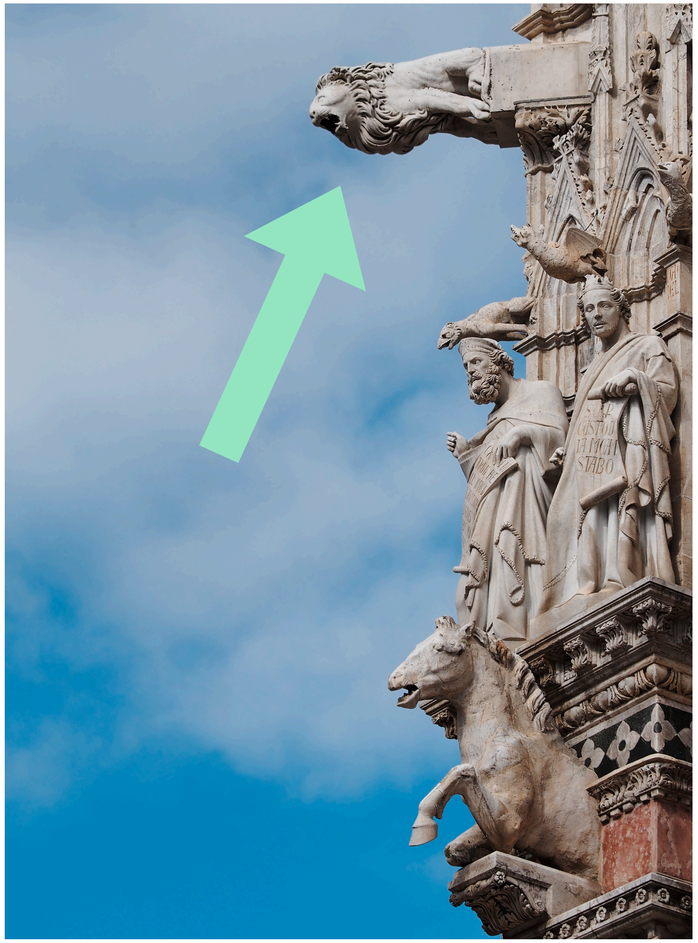
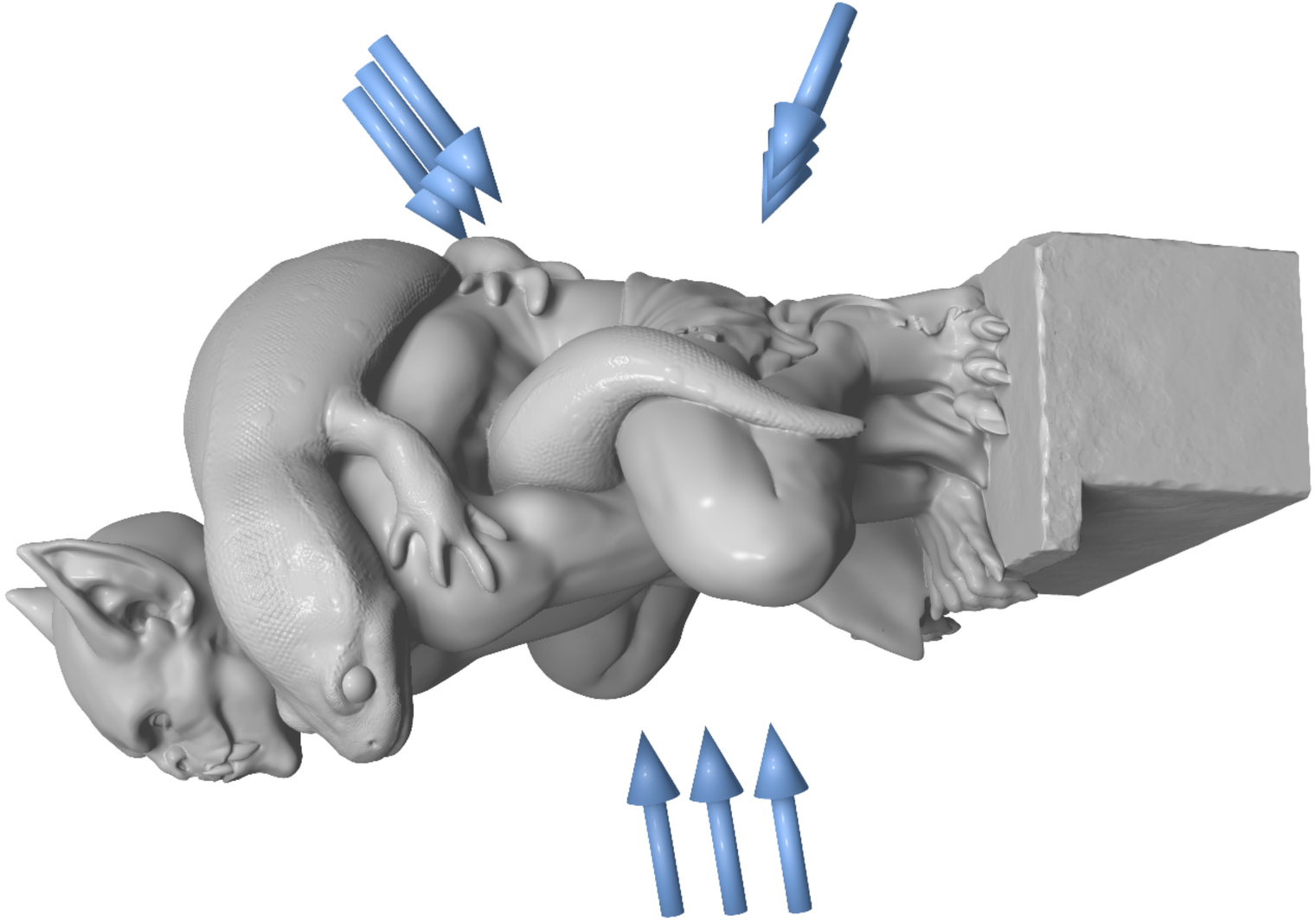
Course Topics: Design Optimization

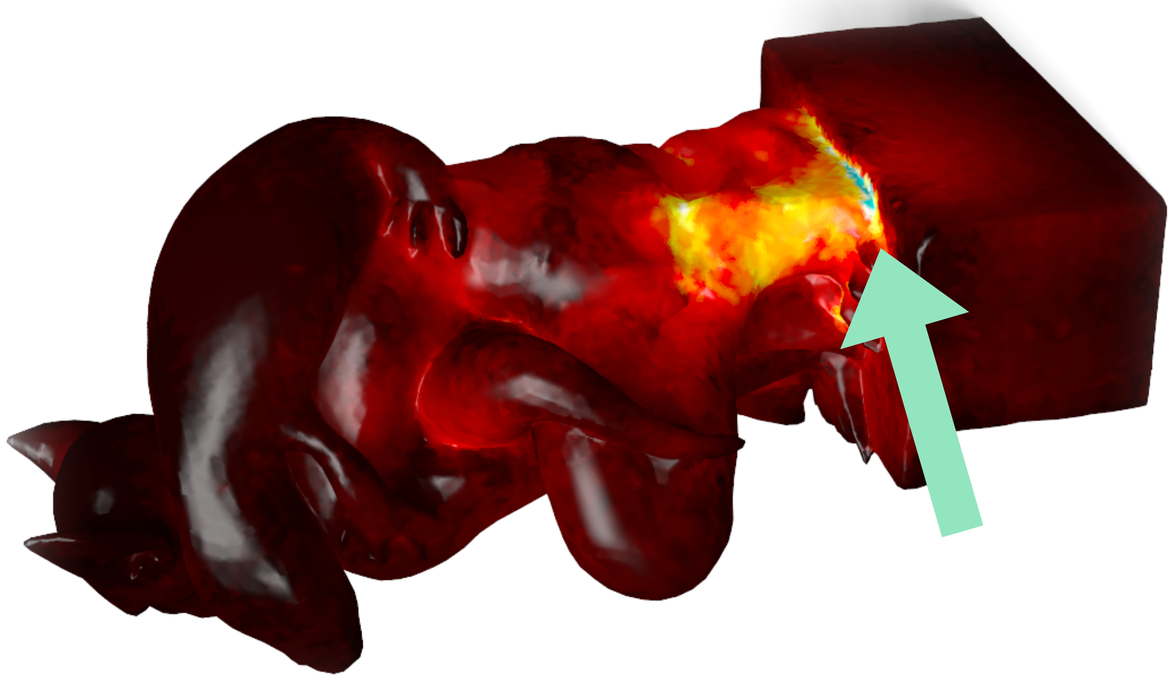




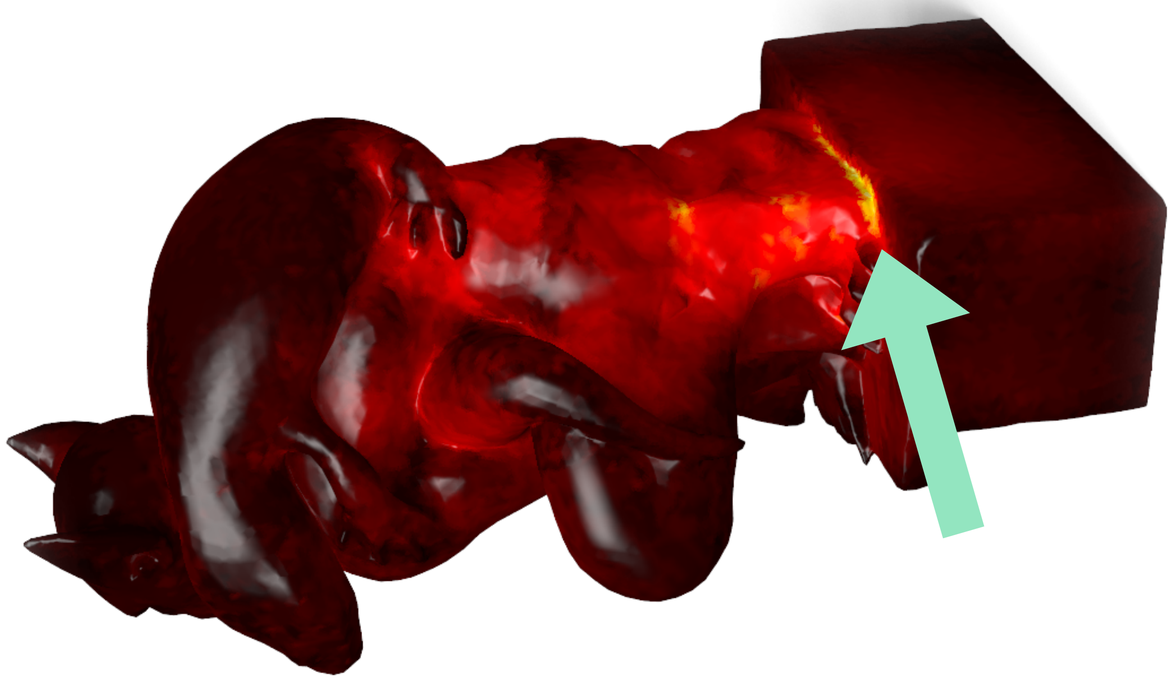
[Schumacher et al. 2018]

Course Topics: Design Optimization

unoptimized



optimized



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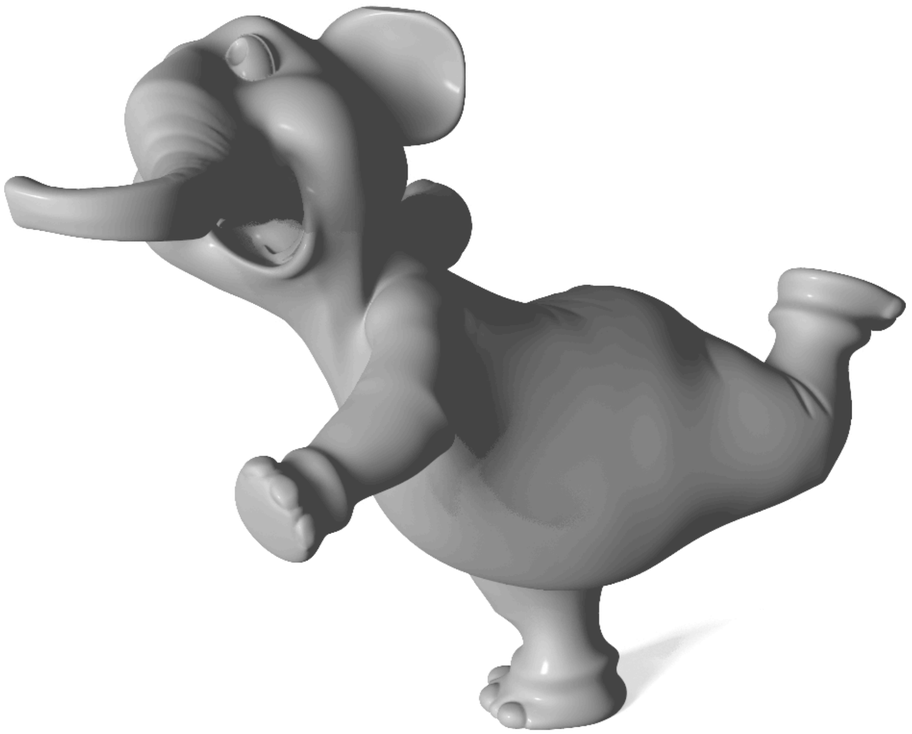
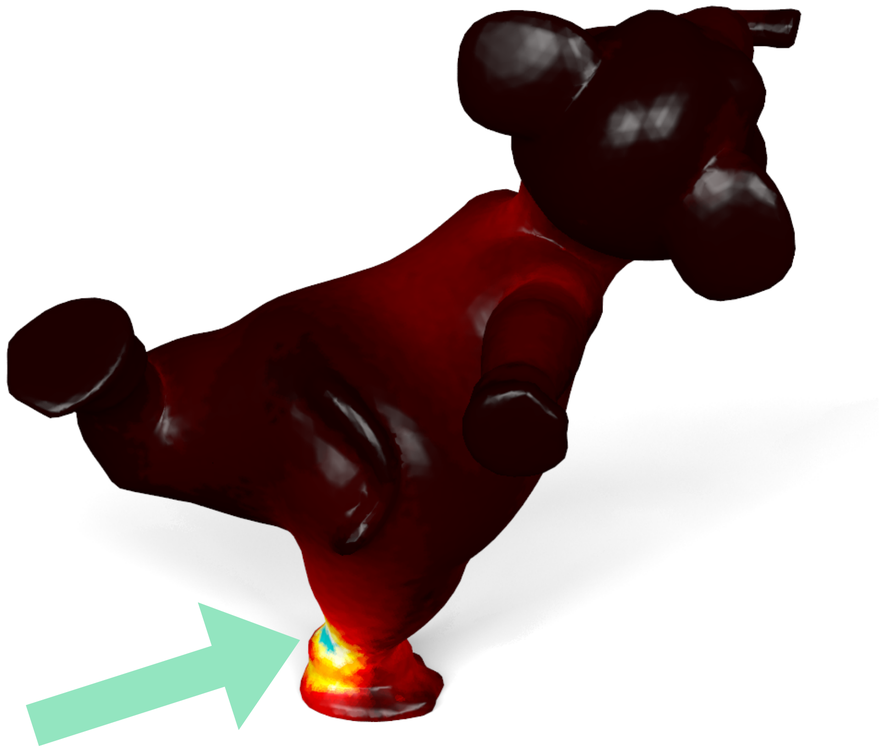
Course Topics: Design Optimization



[Schumacher et al. 2018]

Course Topics: Design Optimization

unoptimized

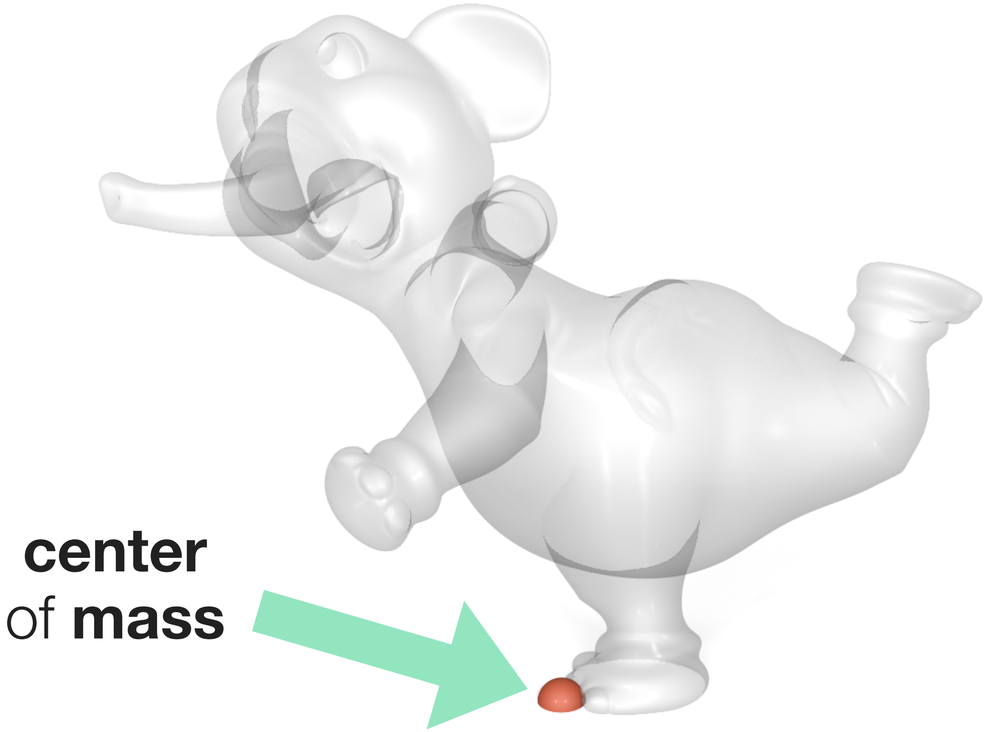


optimized

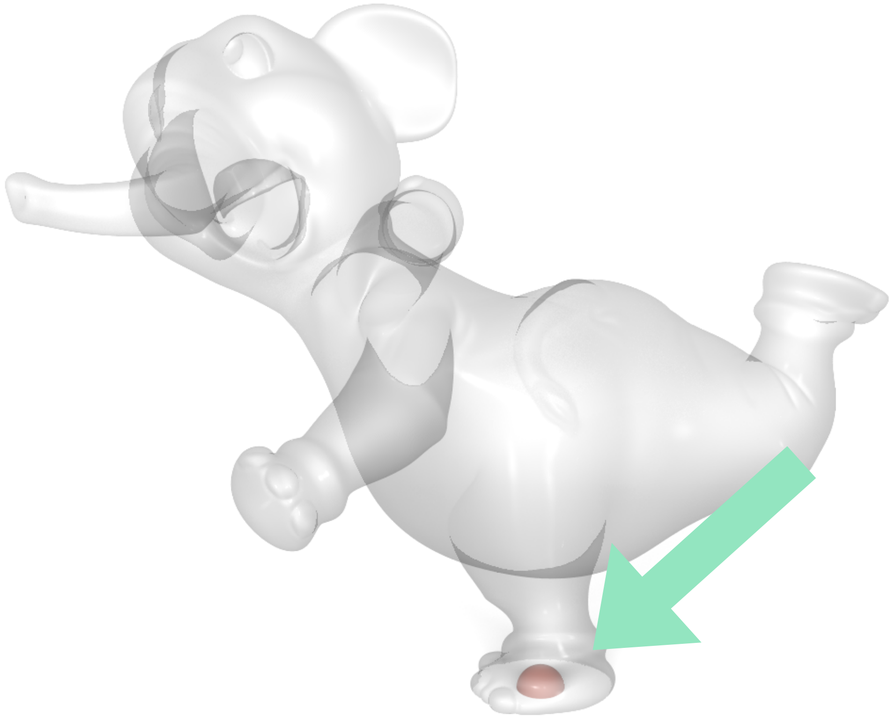
[Schumacher et al. 2018]

Course Topics: Design Optimization

unoptimized



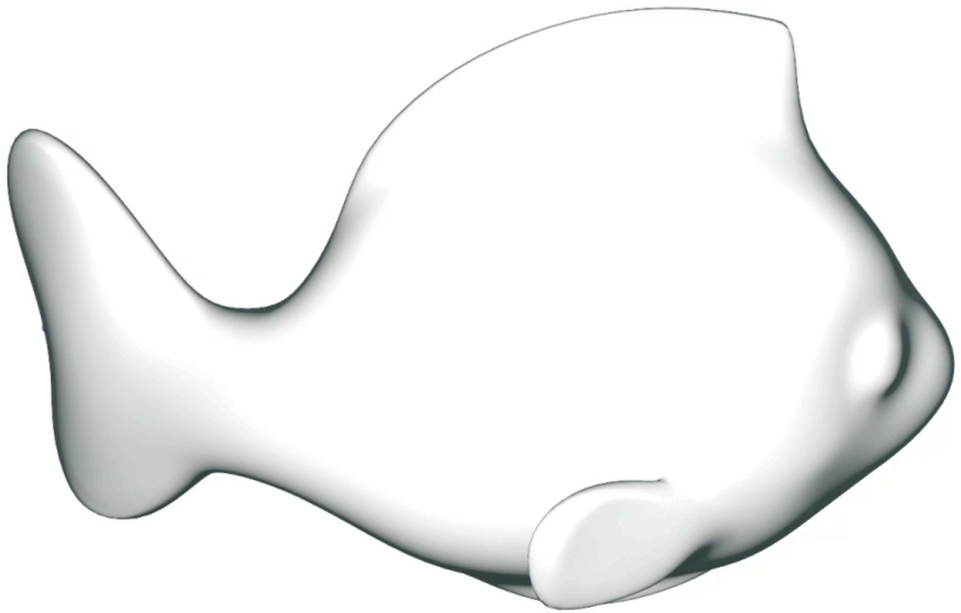
optimized



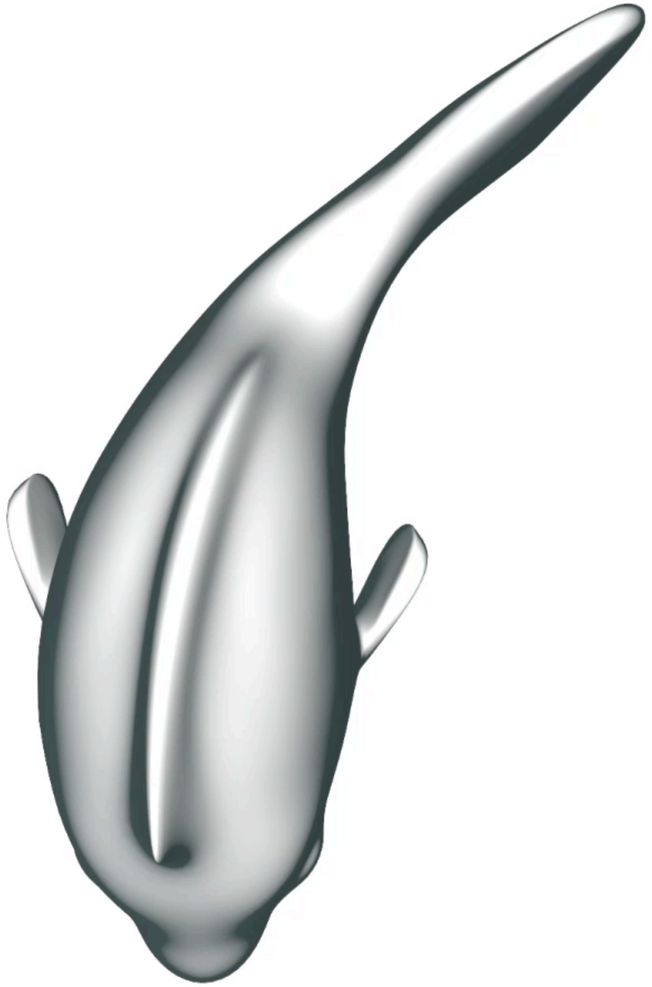
[Schumacher et al. 2018]

Course Topics: Design Optimization

Side View



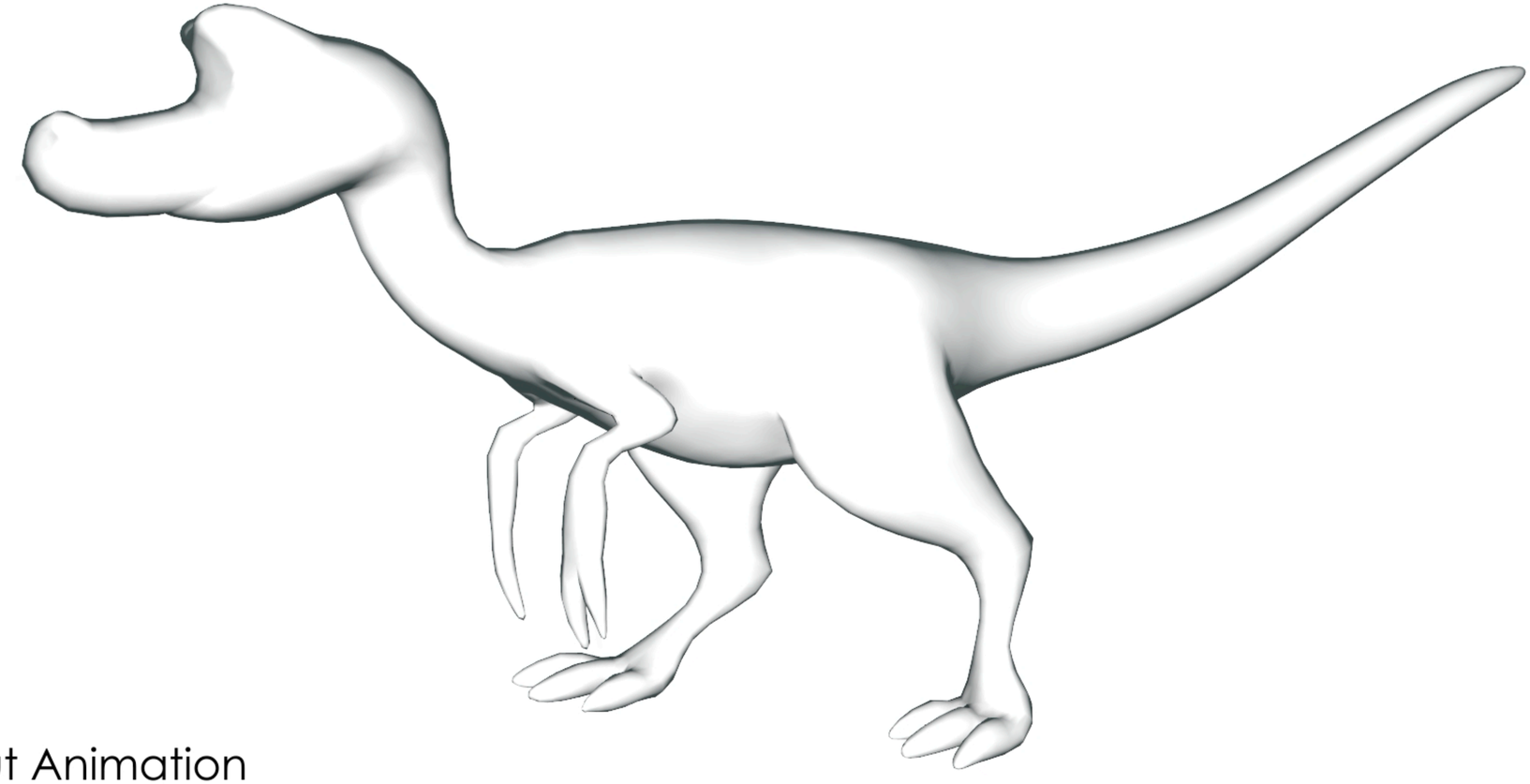
Top View



Input Animation
Blue: target positions

[Xu et al. 2018]

Course Topics: Design Optimization



Input Animation

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