

Intelligent Tools for Creative Graphics

SIGGRAPH 2020 Course

Intelligent Tools for Creative Graphics

- Geometric Reasoning
- Physical Constraints
- Data-Driven Techniques and Machine Learning
- Crowdsourcing

About myself



Nobuyuki Umetani

Associate Professor @ The University of Tokyo

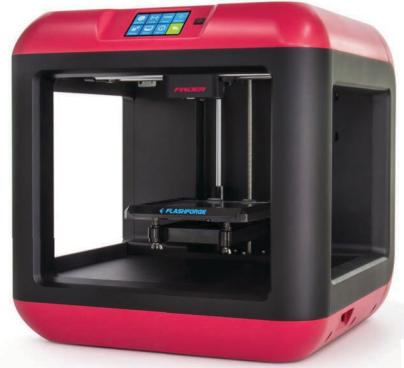


Formerly, Research Scientist @ Autodesk Research(Toronto)



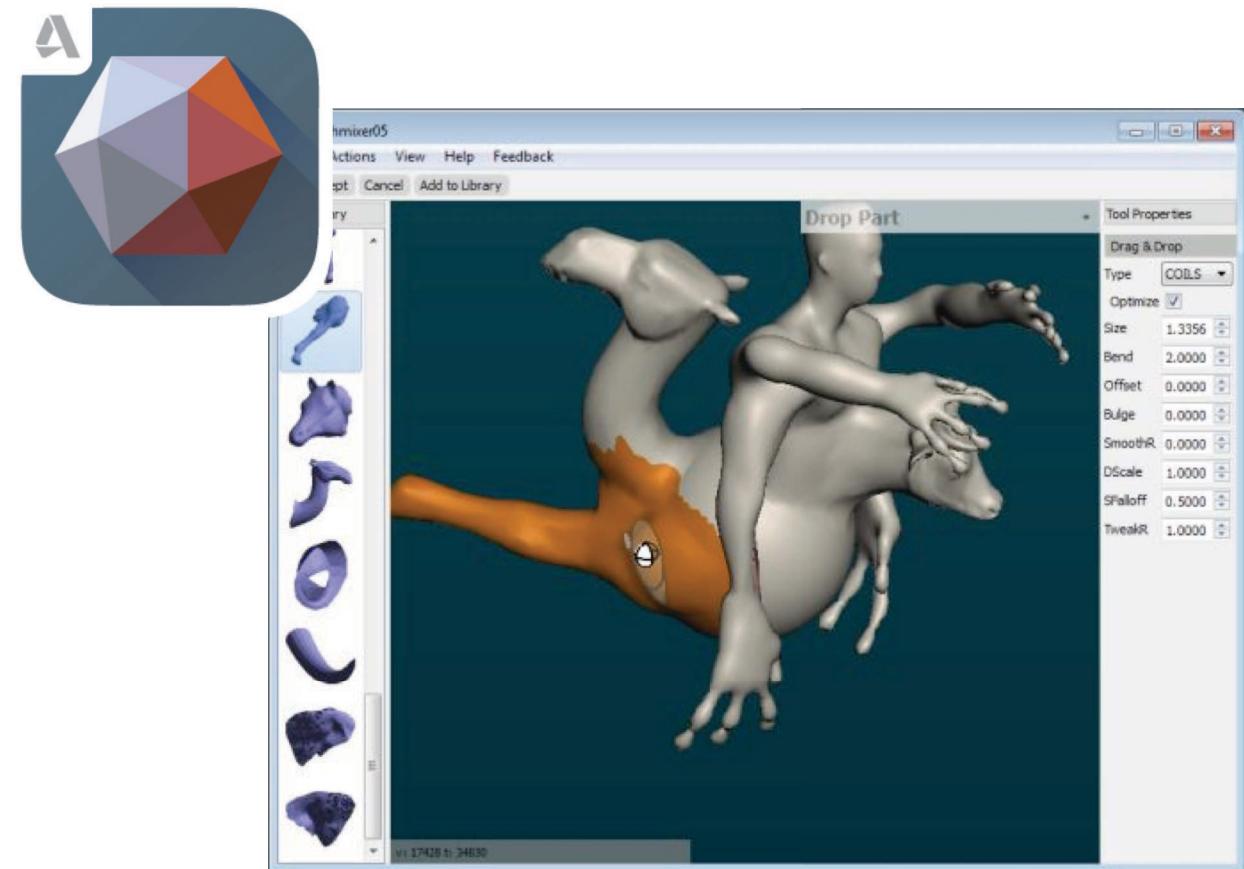
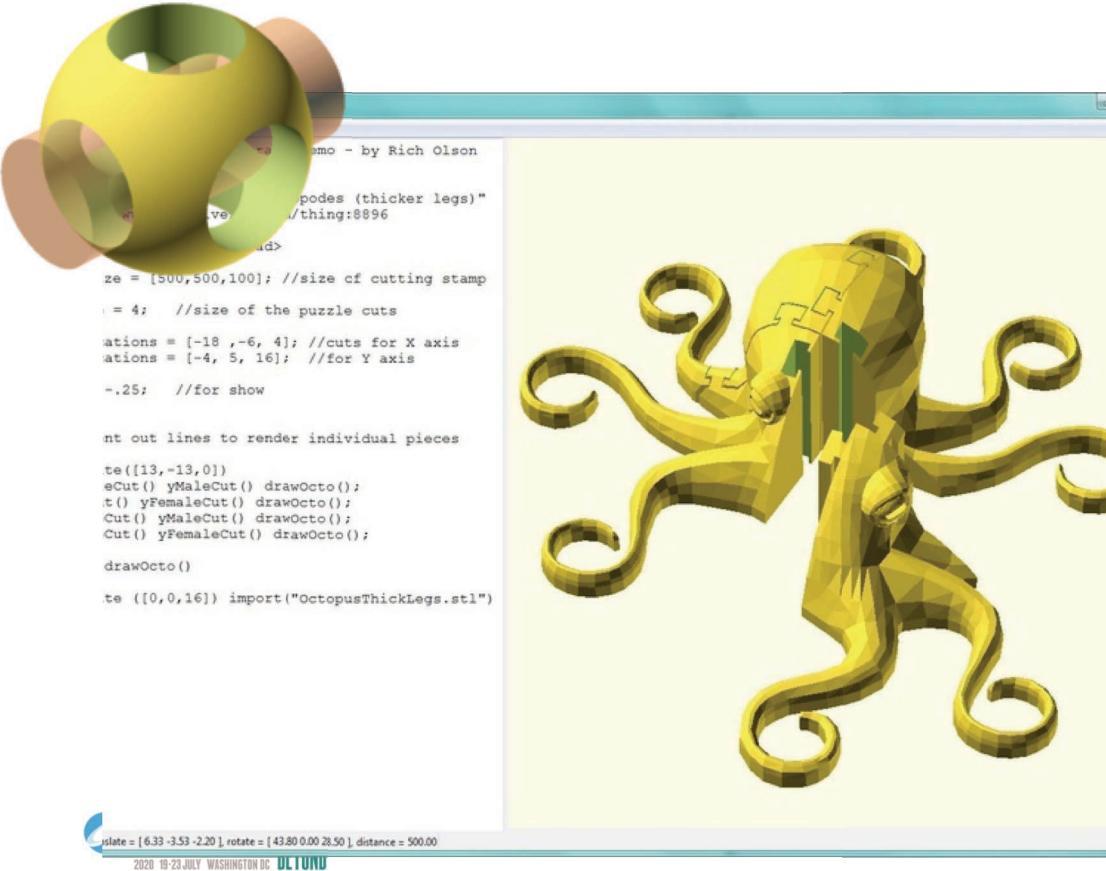
Motivation

- Fabrication devices are widely available to public



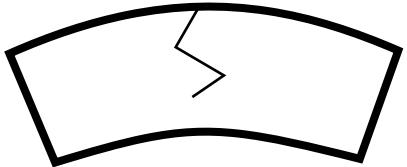
Motivation

- There are fantastic software, but difficult to design functional objects

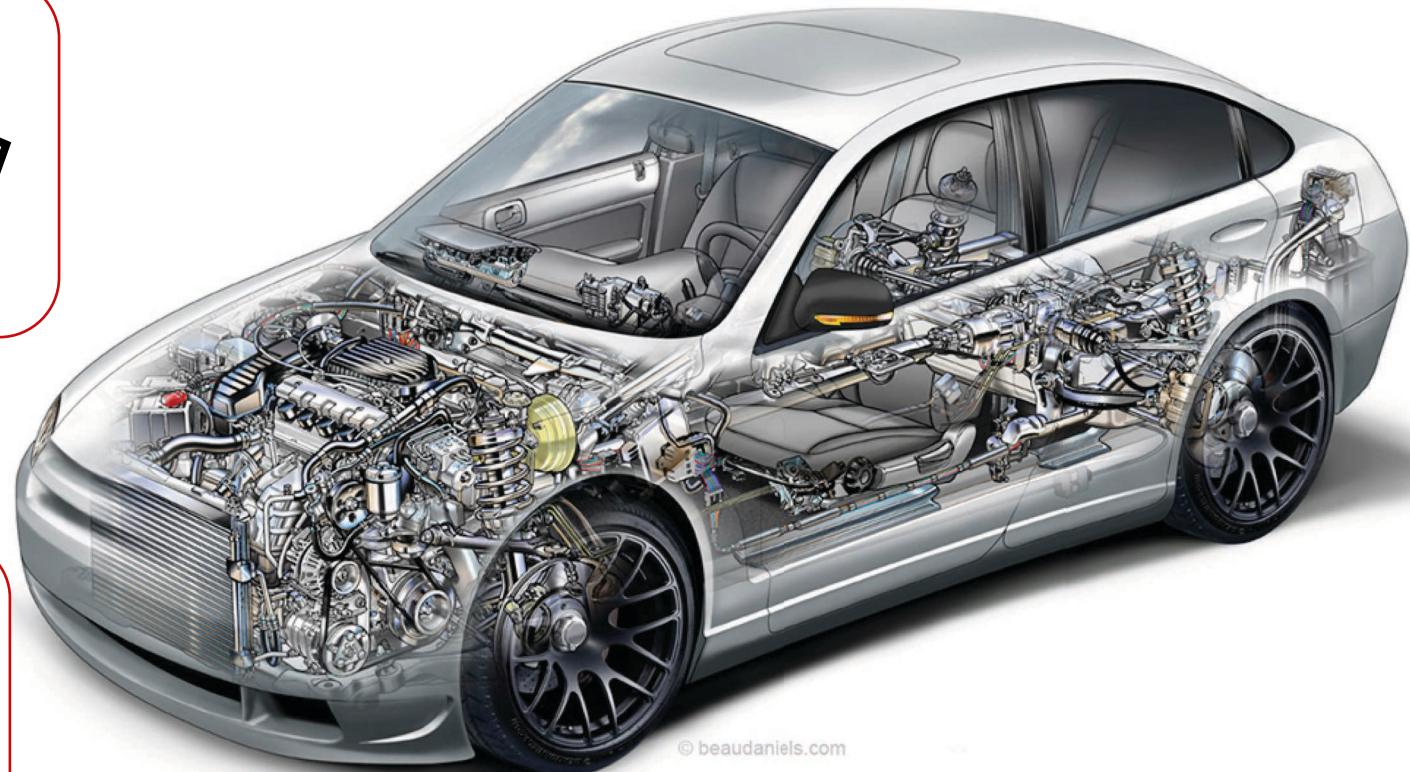
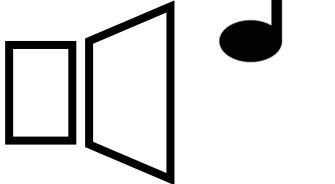


Design Involves Multiple Physics

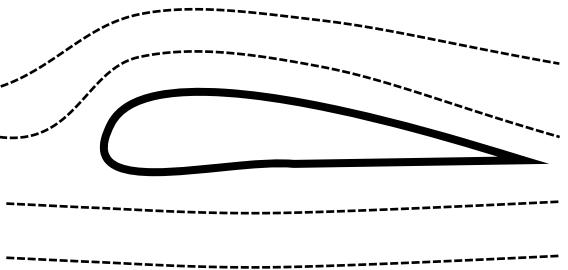
Strength



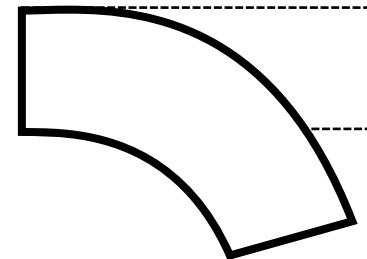
Sound



Aerodynamics



Deformation

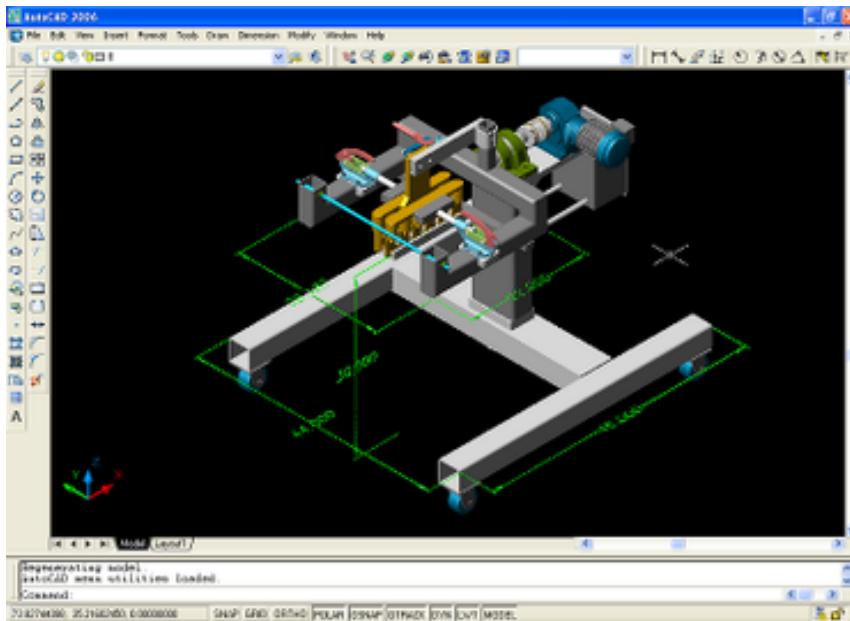


Beau and Alan Daniels

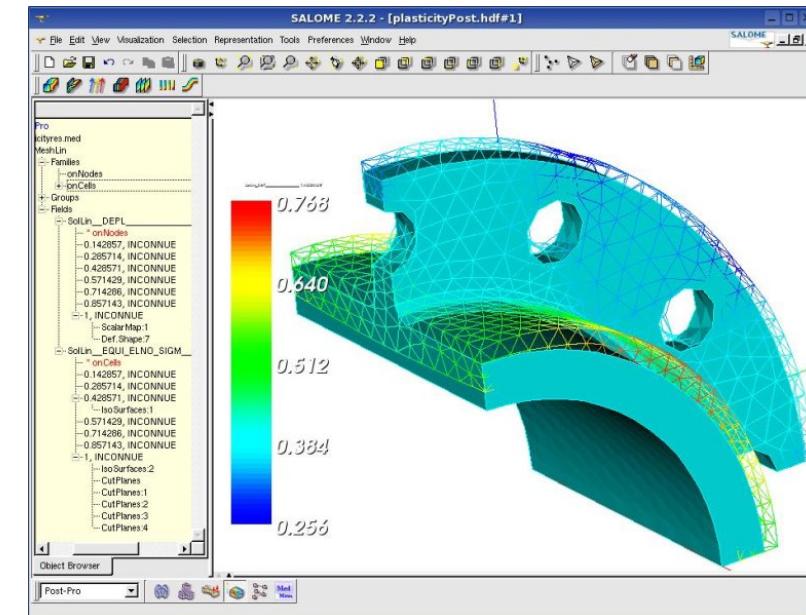
<https://beaudaniels.com/generic-cutaway-car>

Design and Simulation is Typically Separated

Design



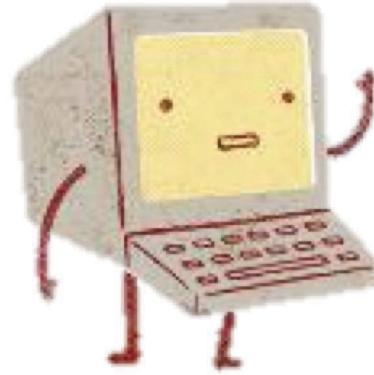
Physics simulation



https://en.wikipedia.org/wiki/Autodesk#/media/File:AutoCAD_2006_drawing.png

https://en.wikipedia.org/wiki/Computer-aided_engineering#/media/File:Plasticity.jpg

Empower Designers using Interactive Simulation

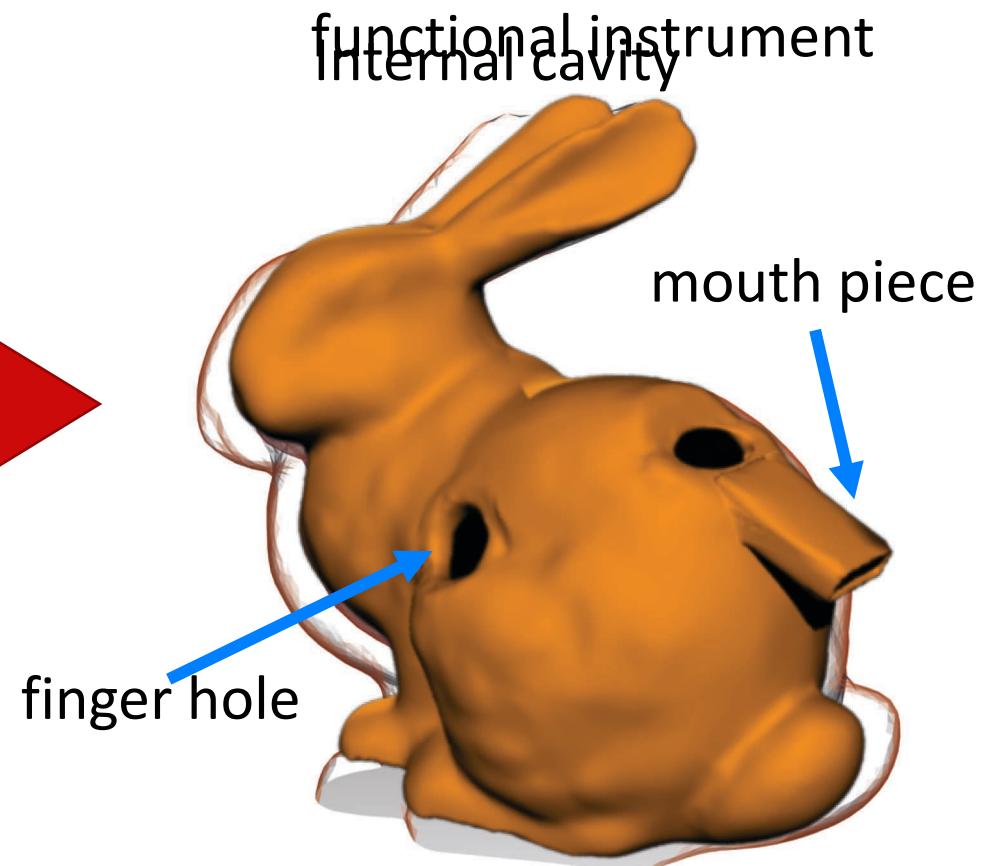
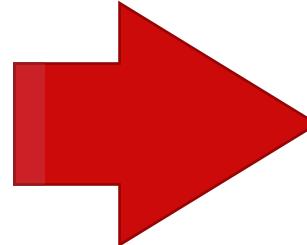
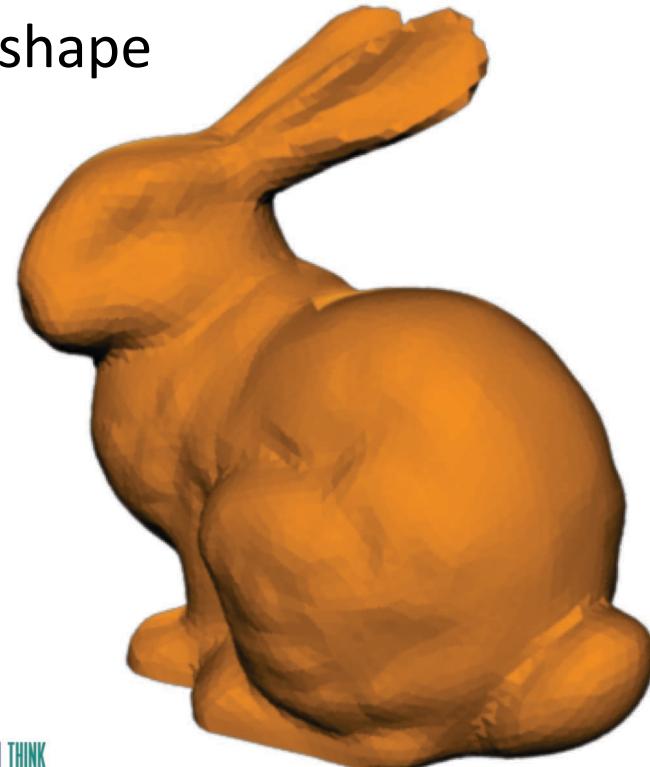


- Aesthetics
- Usability
- Manufacturability
- Solving physics equation
- Optimize physical properties

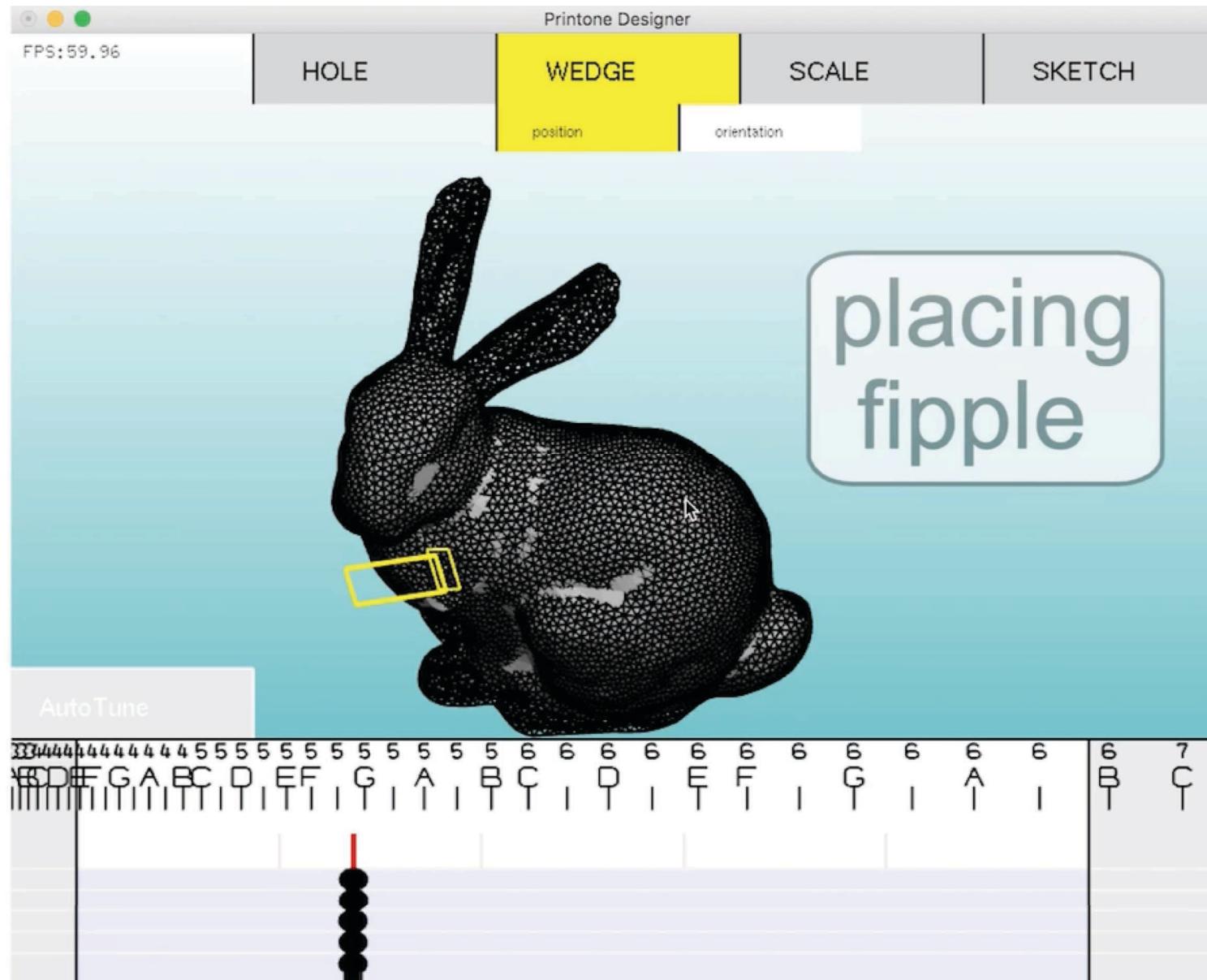
Free-form Wind Instrument

Simulation & optimization to guide the instrument design with correct tones

input shape



Interactive Design Interface

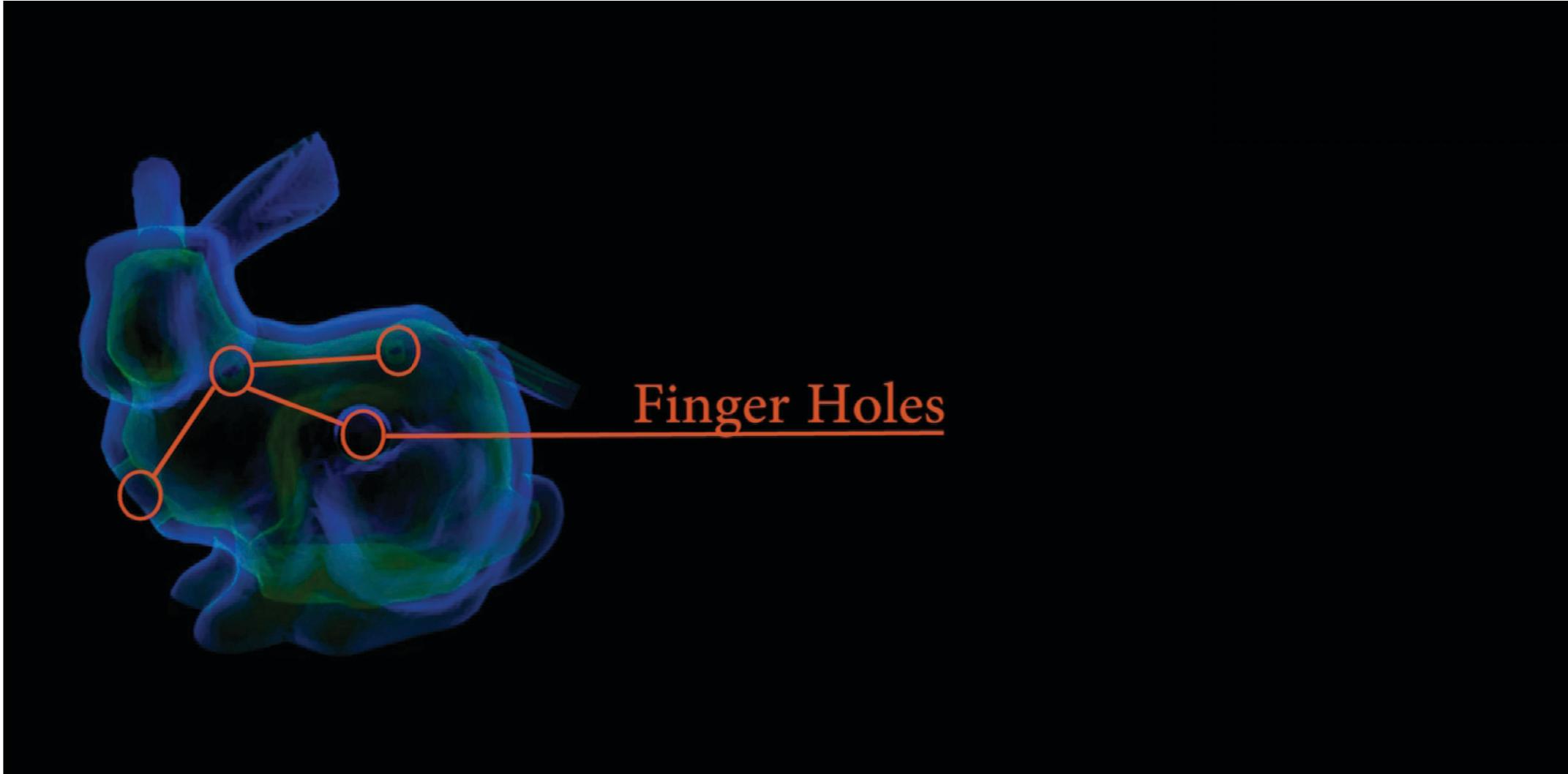


2x speed
(pitch shifted)

← note

← finger
configuration

Bunny Ocarina

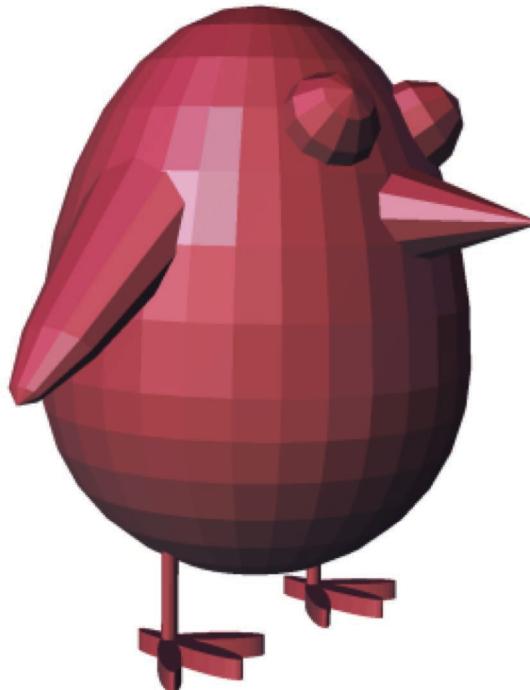


Little Peter Rabbit

Tones E F G A B C D E

Designing for 3D Printing is Difficult

Beginners cannot design structurally sound shape



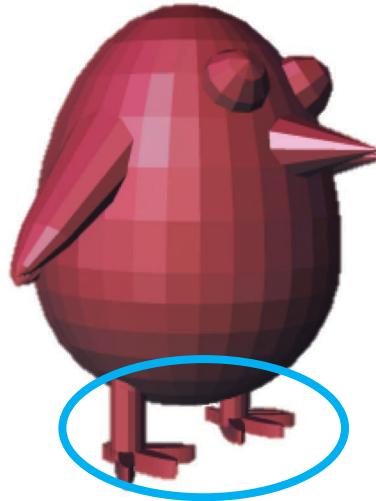
3D printing
→



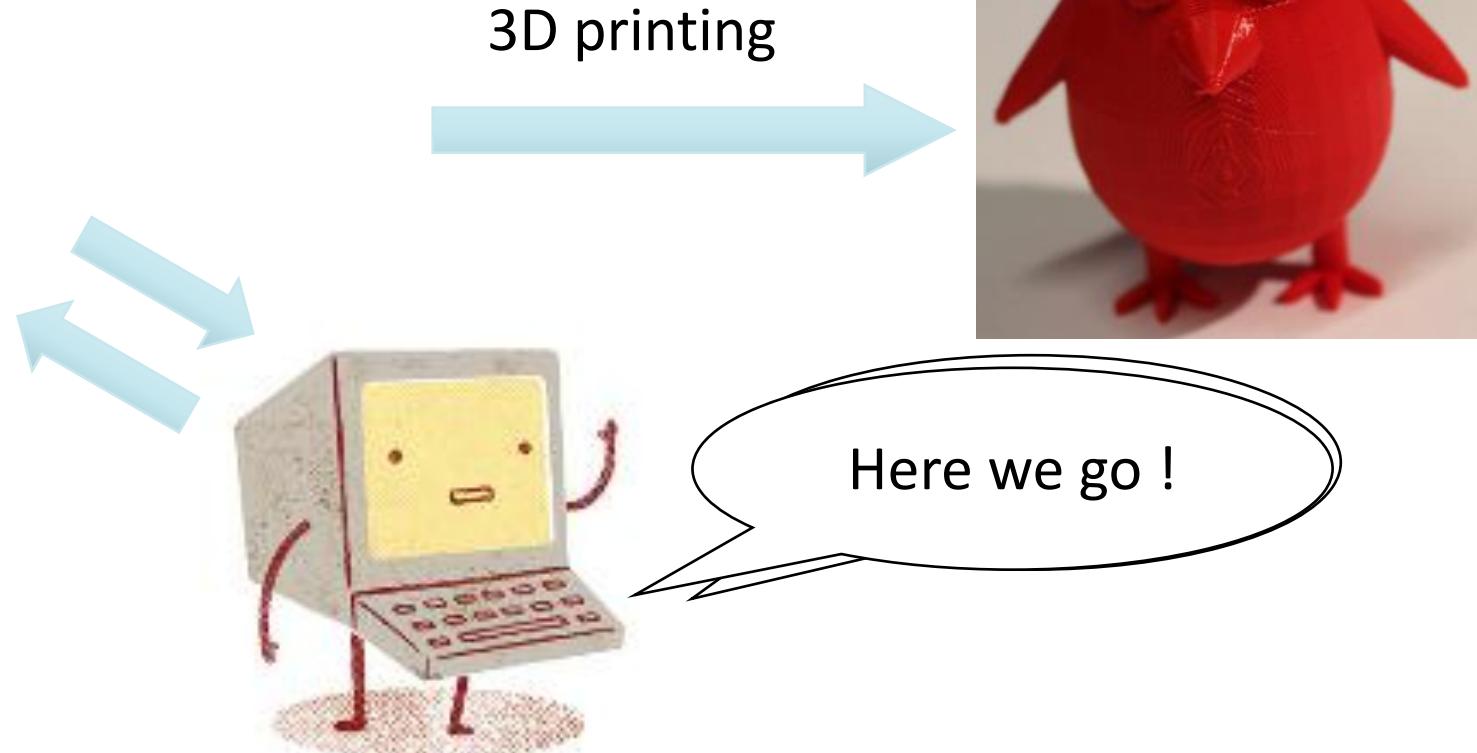
[source: DBrager14@Thingiverse]

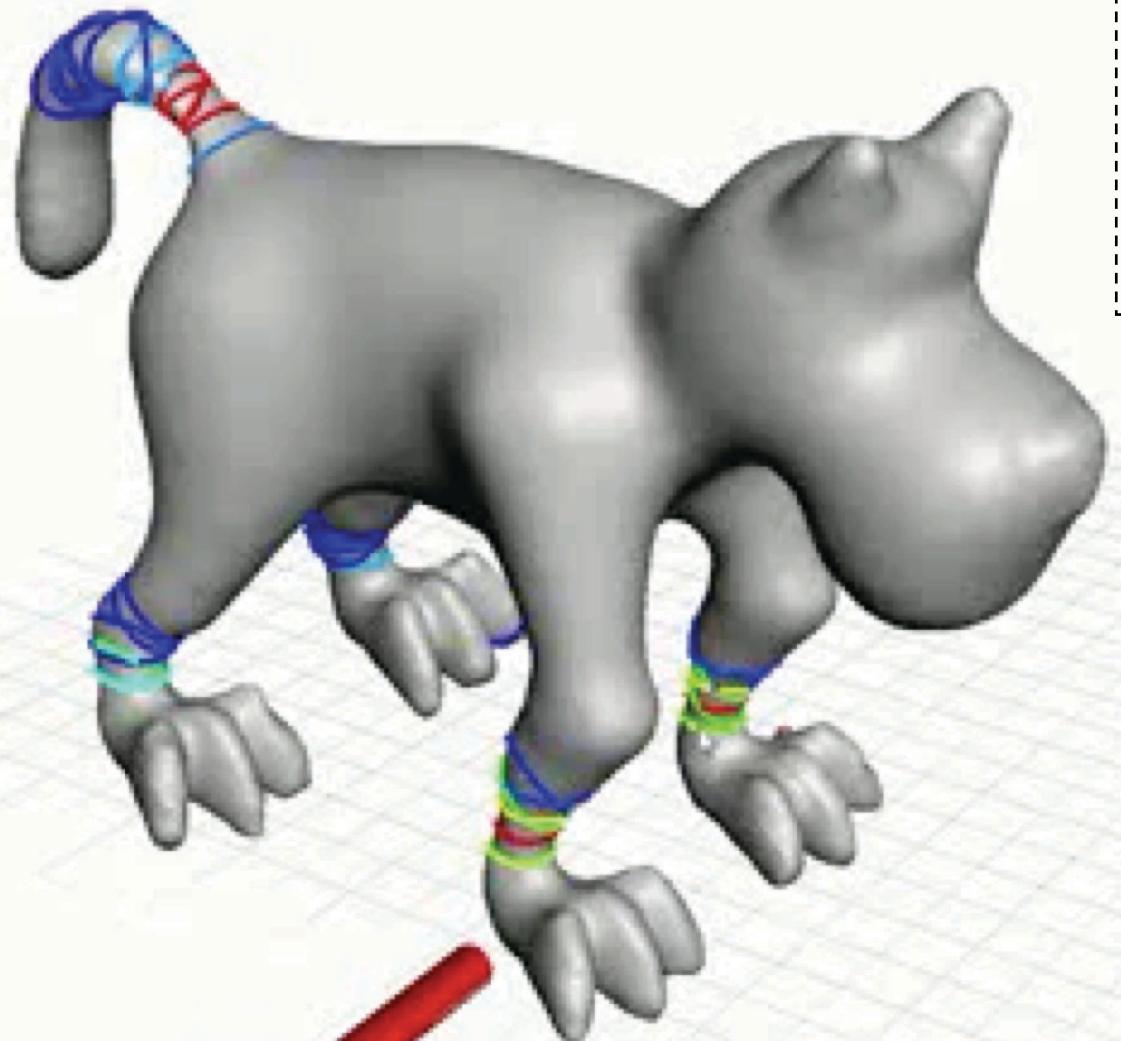
Interactive Weakness Detection

Design with interactive trial & error



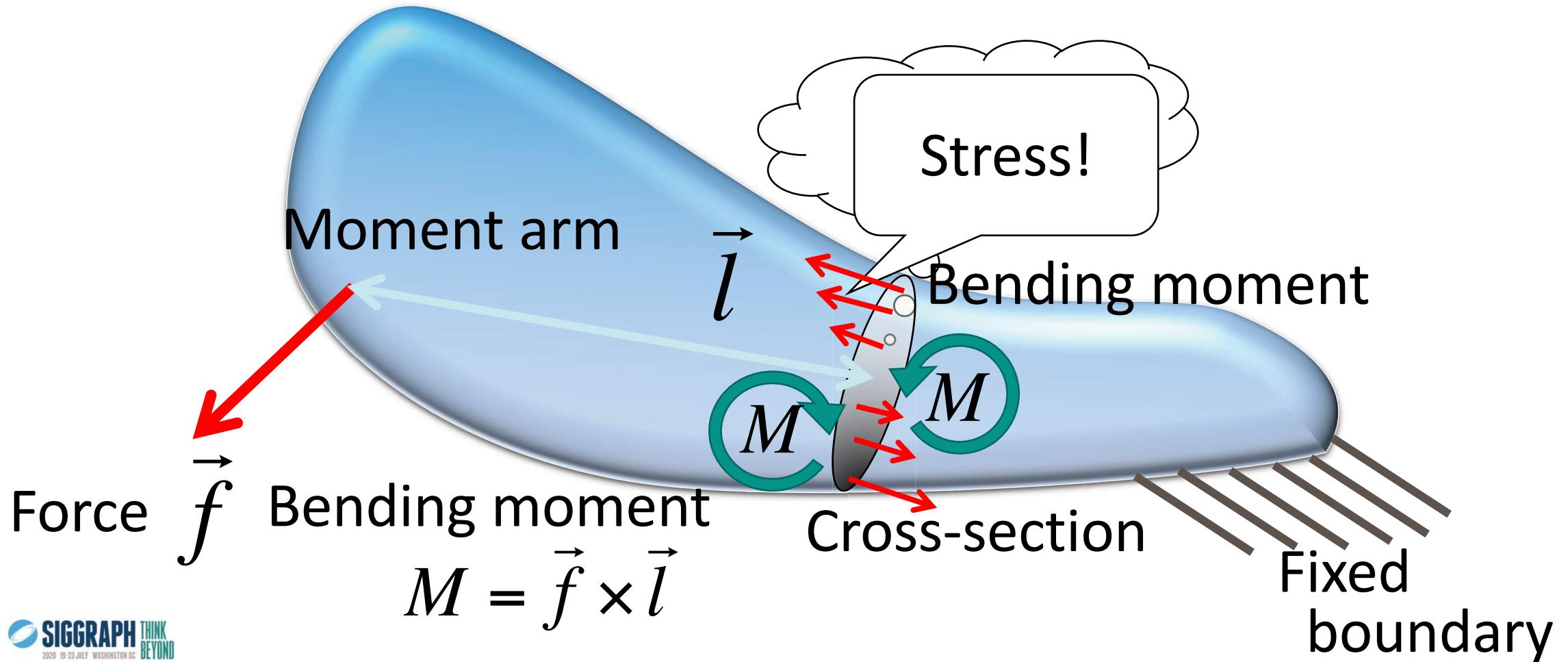
The user thicken leg





Solution: Cross-Sectional Analysis

Key idea: bending momentum conservation

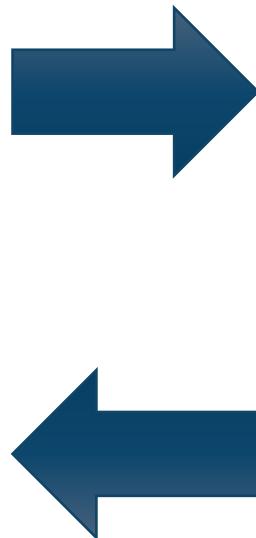


Motivation: Fashion Design

How to design a new garment?



Drawing a pattern



Fitting on a mannequin

2D

3D

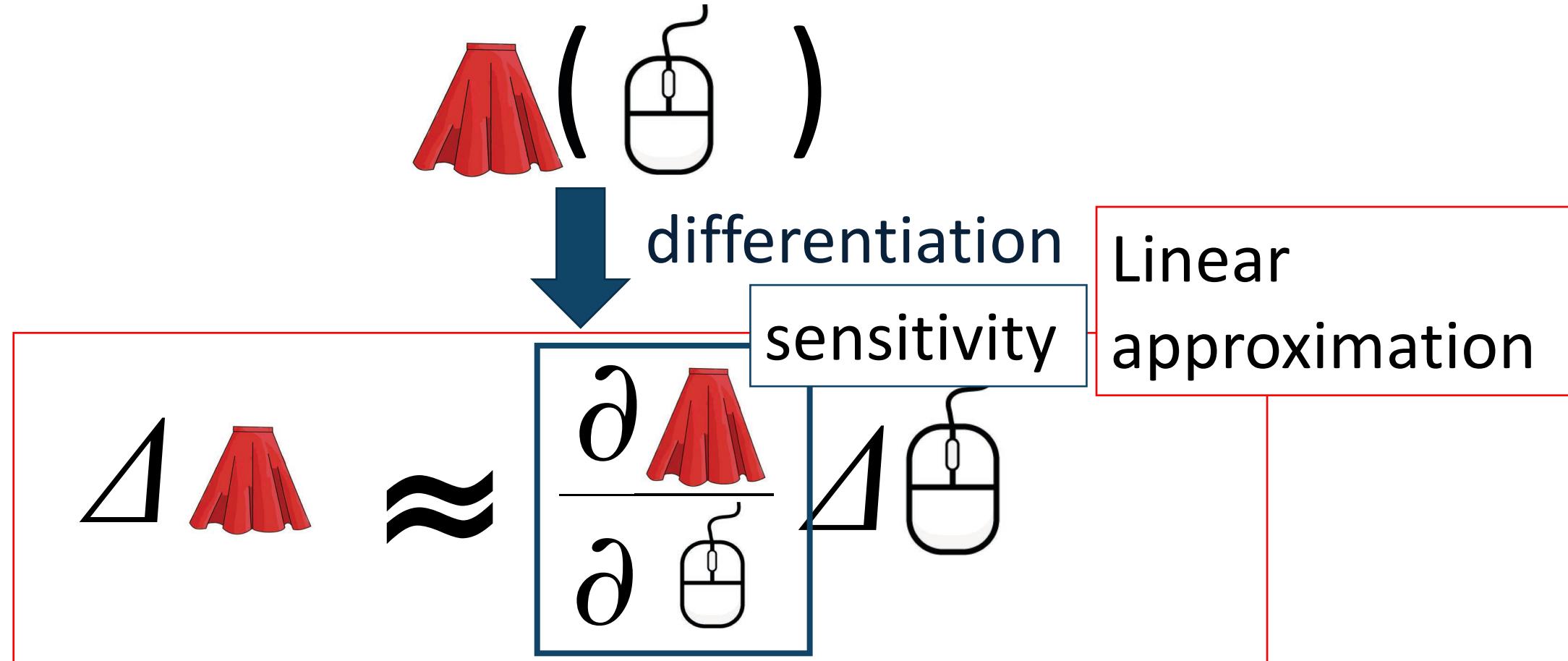
Live Demo!!

Source code is available online:

<http://nobuyuki-umetani.com/>

Basic Idea

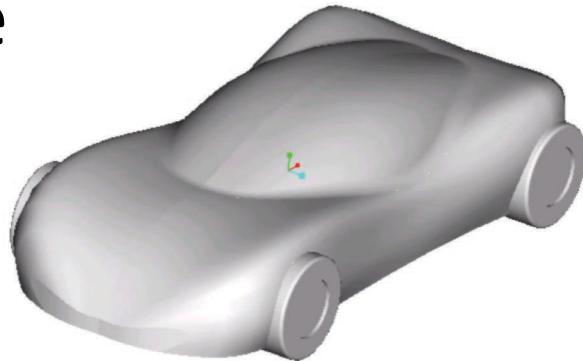
The simulation result and design is **one-to-one** map in the static analysis



Computational Fluid Dynamics (CFD)

Input

- Shape

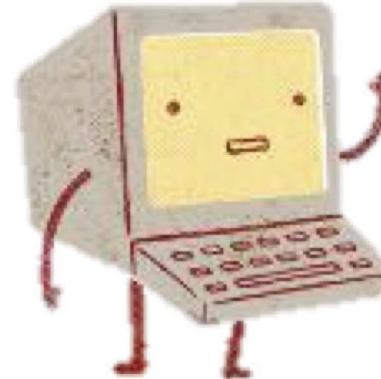


- Physics parameters
 - flow velocity, V_∞
 - density, viscosity

ρ

μ

Predictor

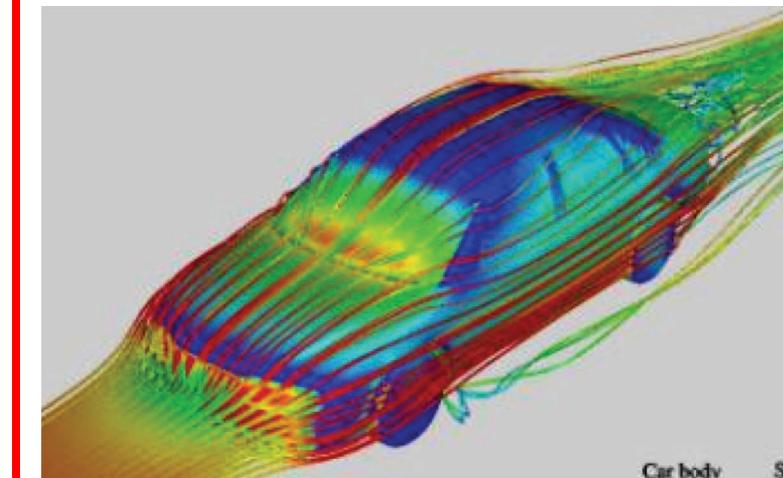


Neural network
Navier-Stokes Equation

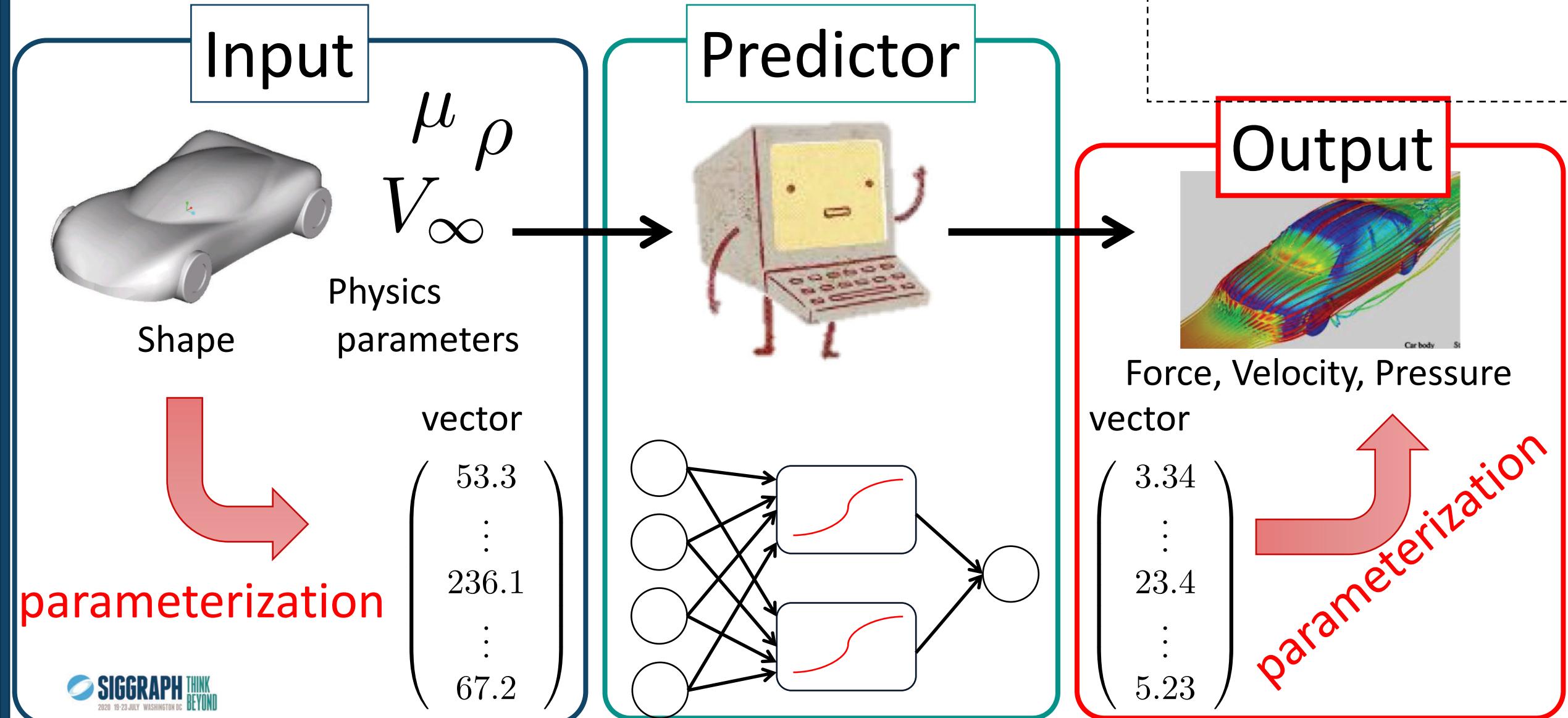
$$\rho \left(\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{u} - \mathbf{V}_\infty \right) - \mu \nabla^2 \mathbf{u} + \nabla p = 0$$
$$\nabla \cdot \mathbf{u} = 0$$

Output

- Force
- Pressure field
- Velocity field



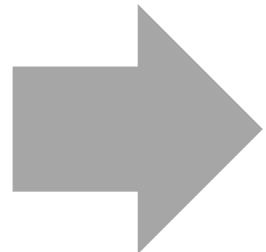
Parameterization is the Key to ML



Interactive Airplane Design

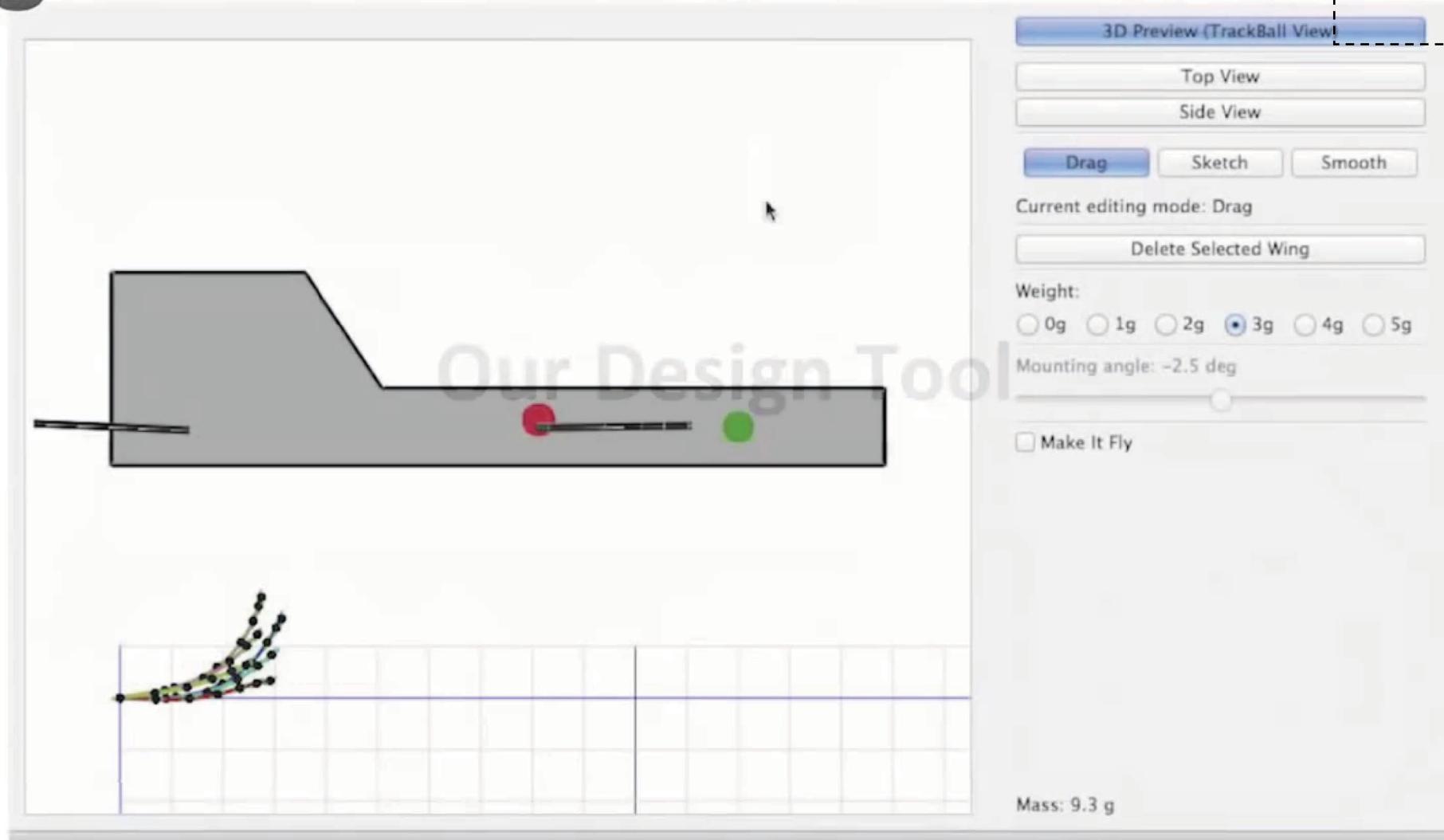


Fabrication



x5

Concurrent Flight Simulation



Our system enables the design of freeform flyable gliders



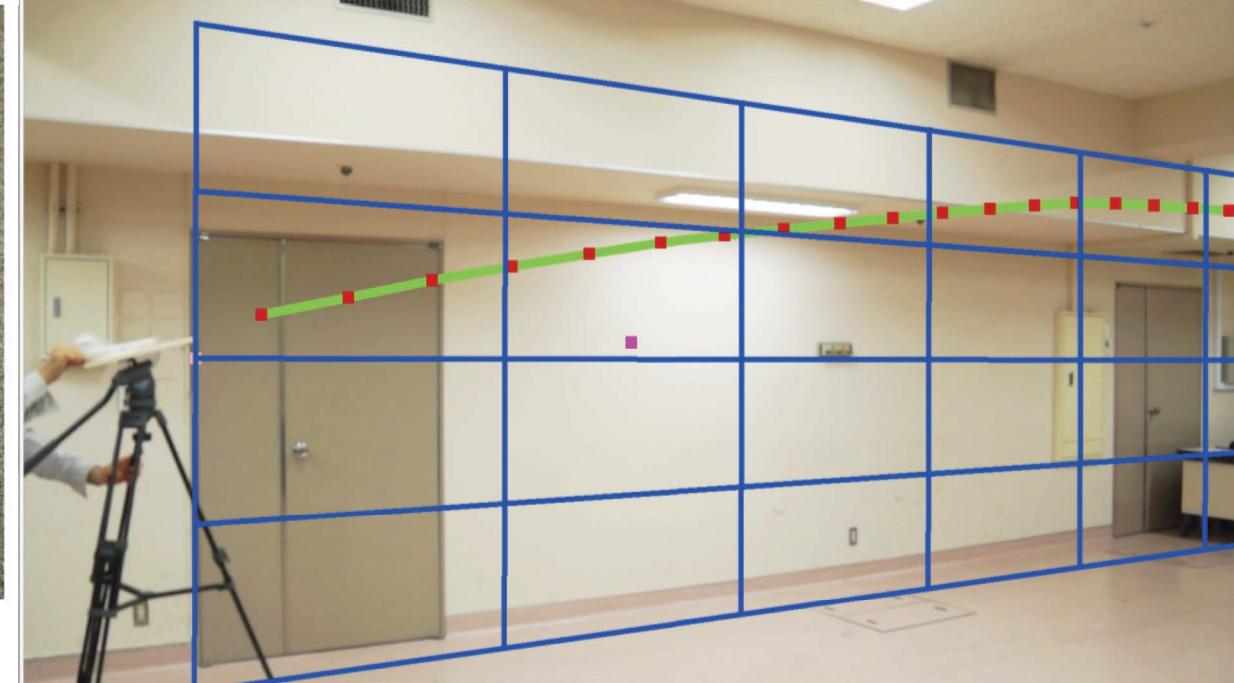
Machine-Learning from Measured Data

- Accurate fluid simulation is difficult in real-time
- We use actual data to simulate flight trajectory

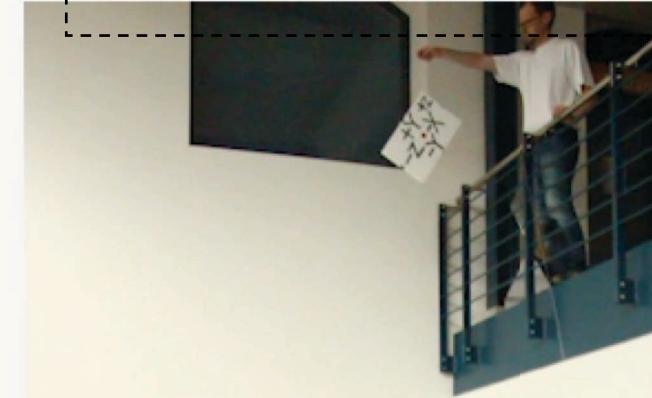
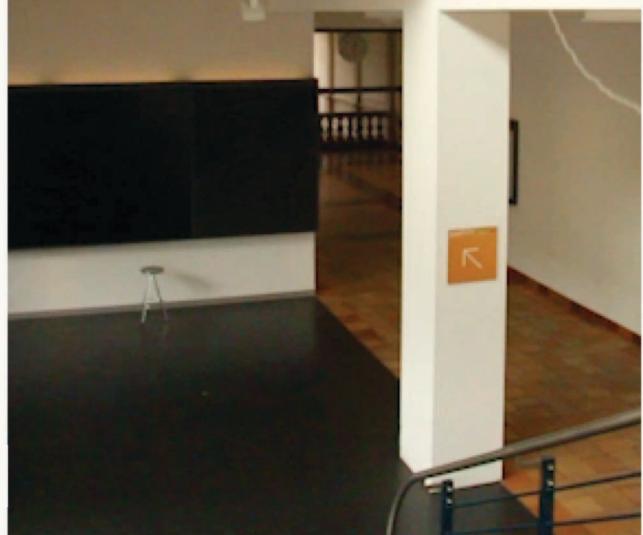
Sampling airplane



Tracking flight

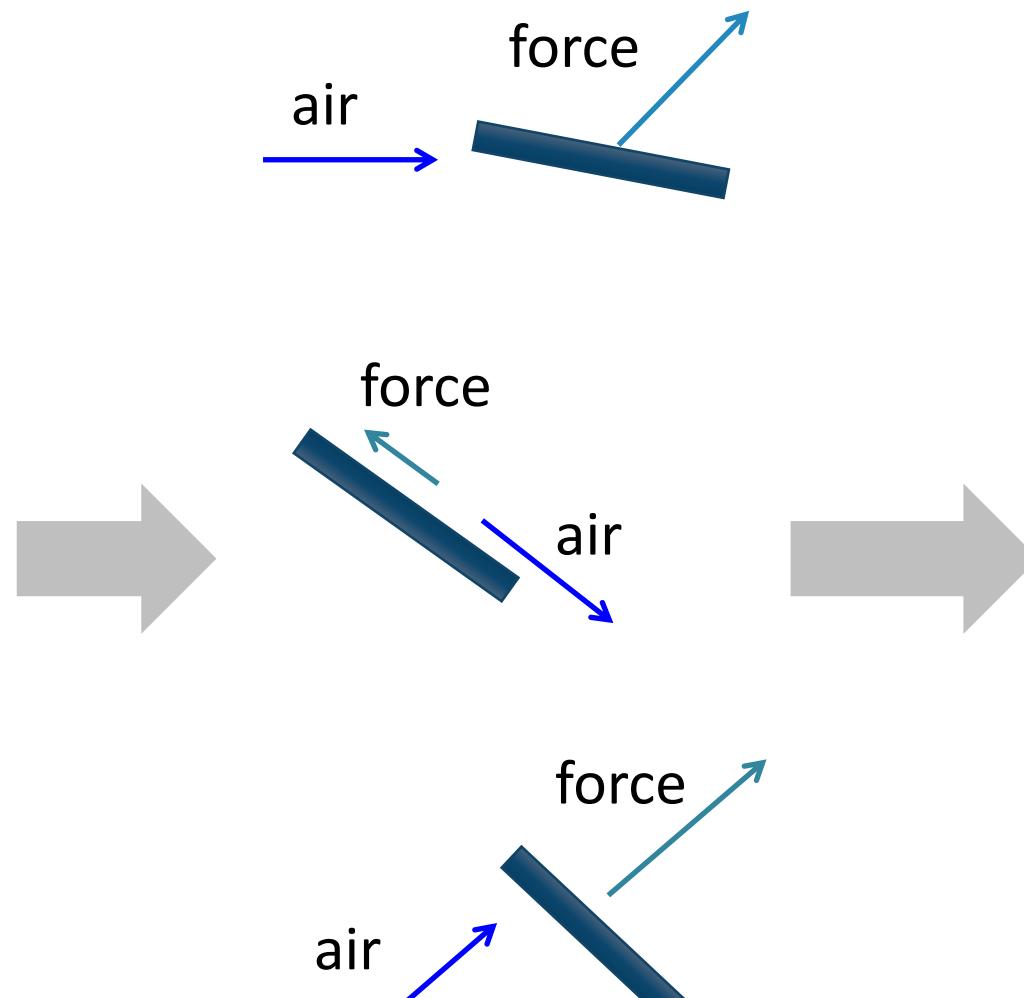
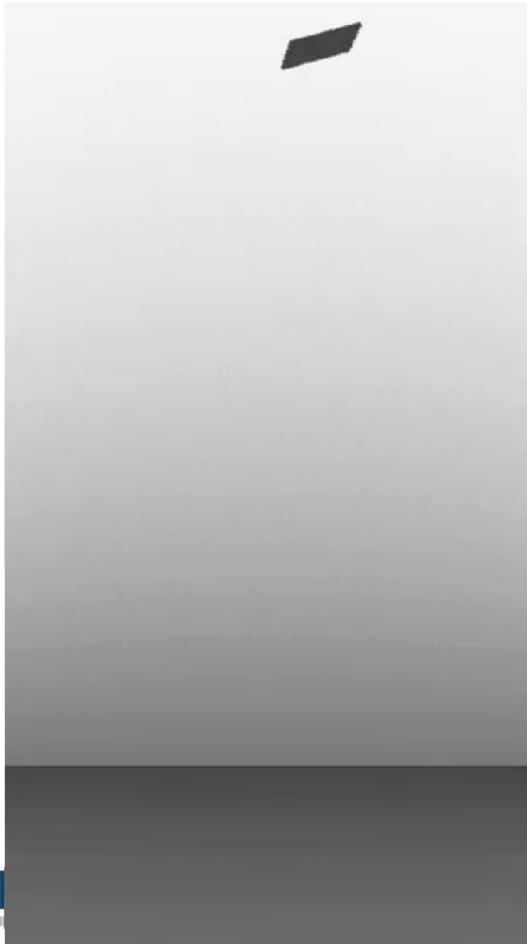


Sampling Force & Velocity Relationship

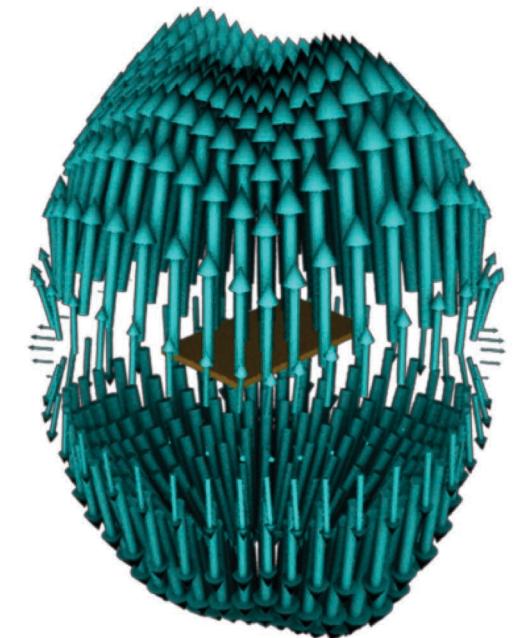


Sampling Force & Velocity Relationship

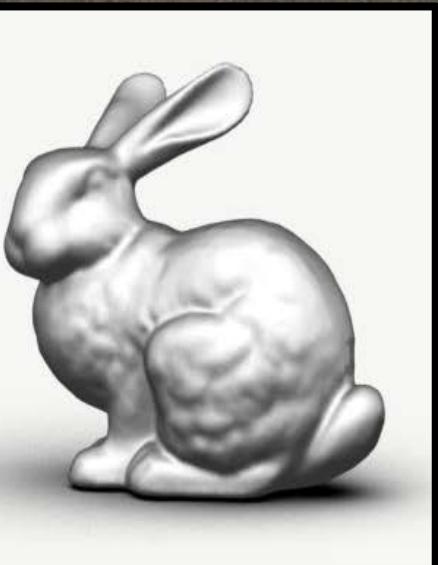
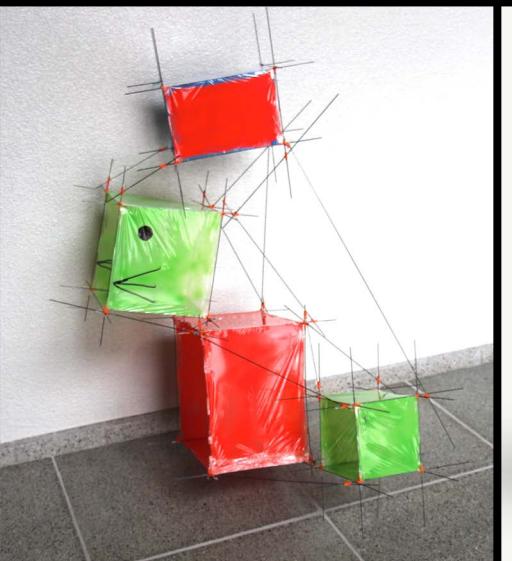
3D motion



omni-directional aerodynamic force



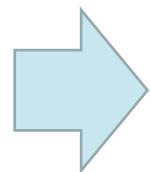
Stanford Bunny Kite



Parameterization problem

- Shape need to be represented by fixed dimensional vector/tensor

2D Image



$$\begin{pmatrix} 53.3 \\ \vdots \\ 236.1 \\ \vdots \\ 67.2 \end{pmatrix}$$

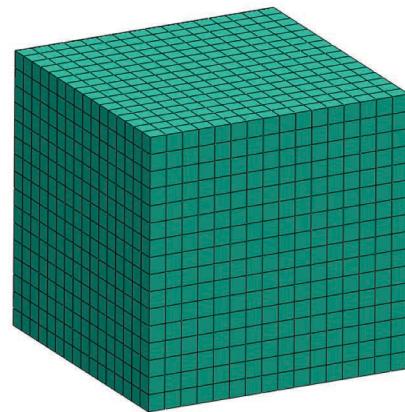
3D shape



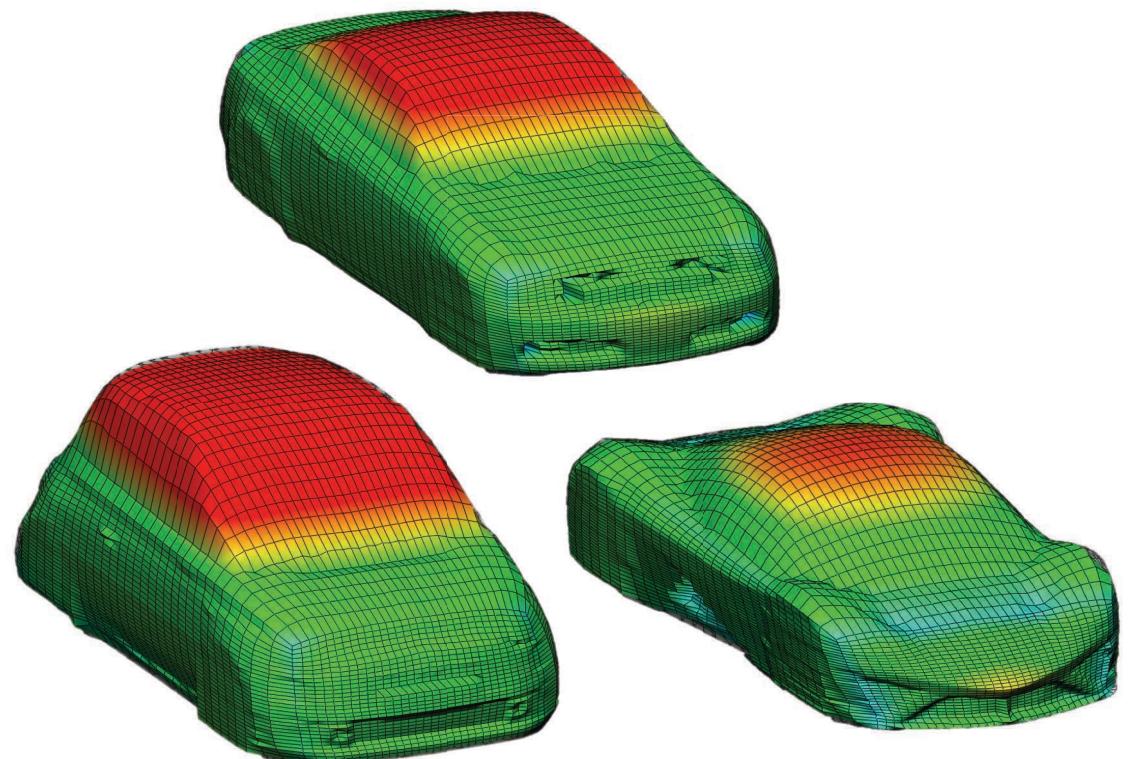
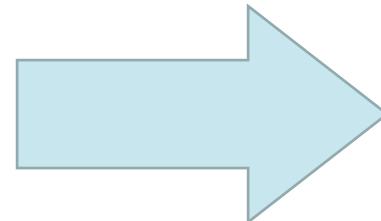
$$\begin{pmatrix} 53.3 \\ \vdots \\ 236.1 \\ \vdots \\ 67.2 \end{pmatrix}$$

Our Approach: Mesh Representation

- Quad mesh with constant topology
- Deforming a template mesh into input shape



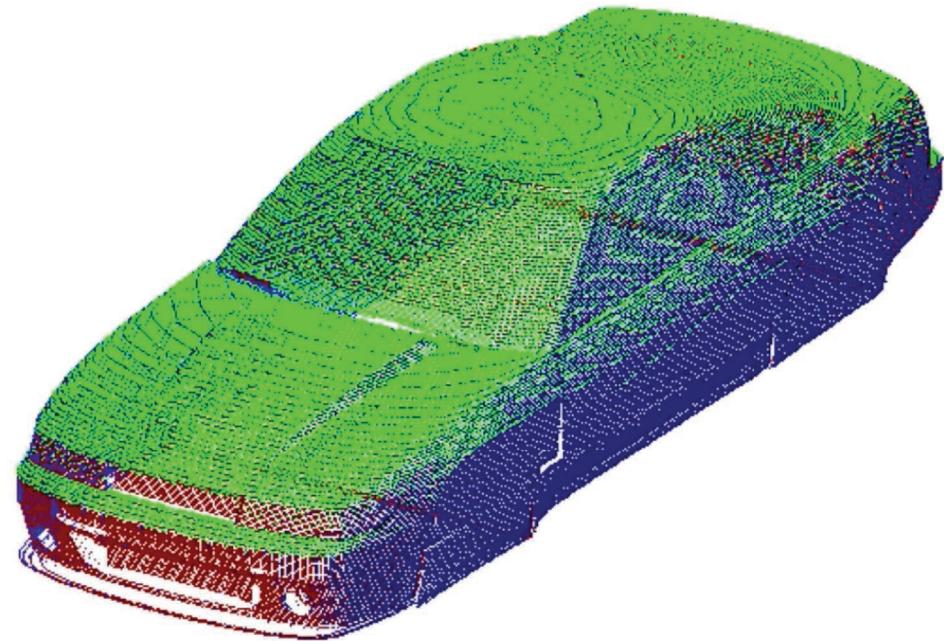
deformation



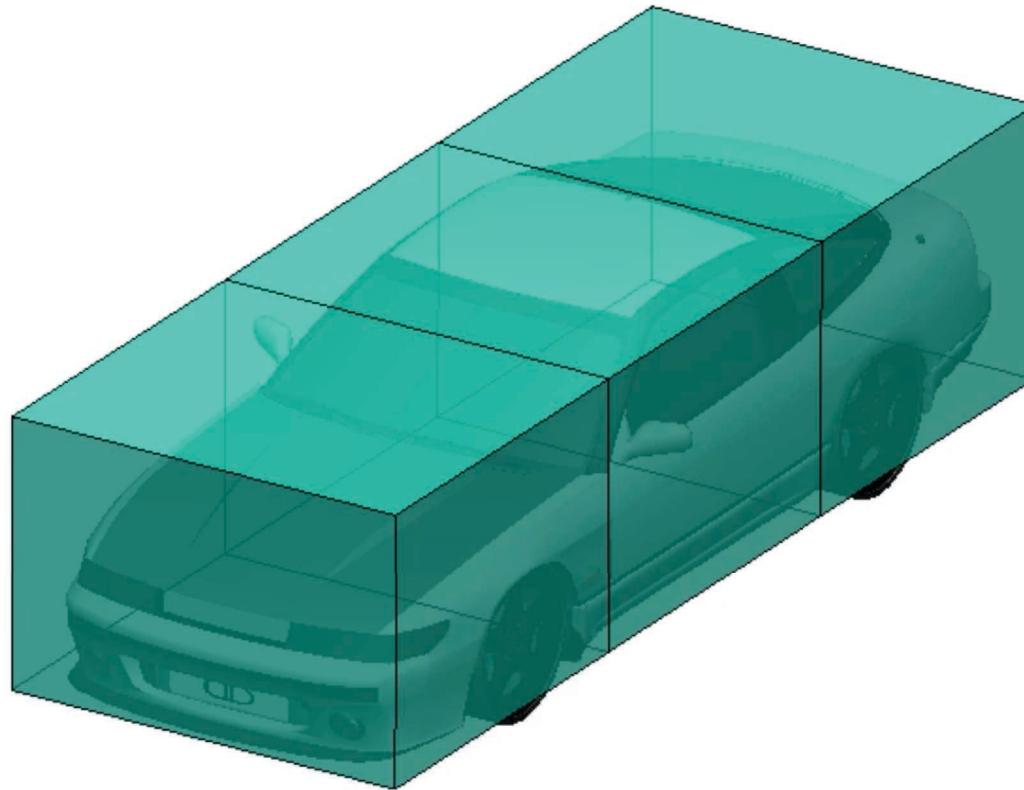
Parameterization Example



Parameterization Example



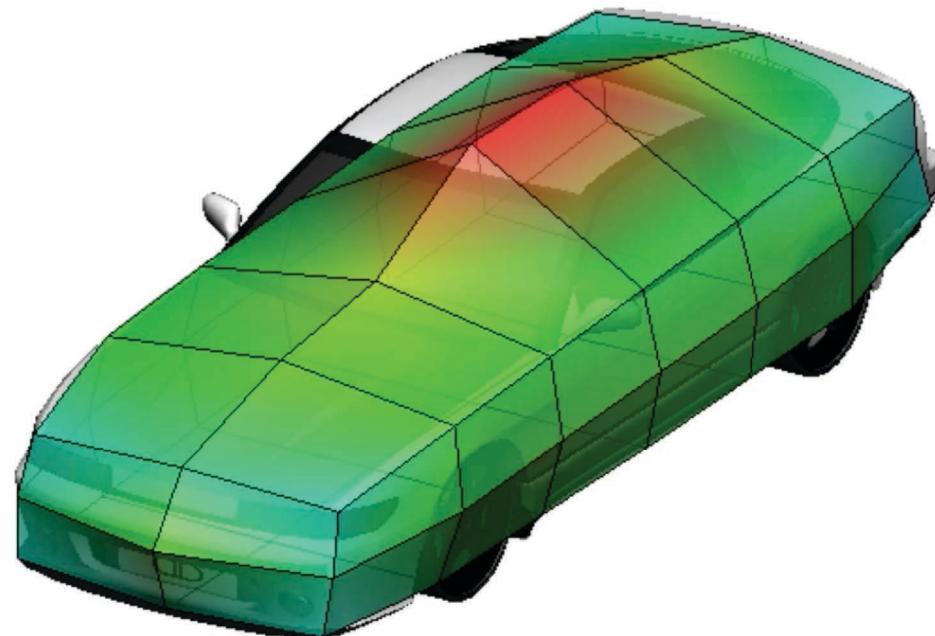
Parameterization Example



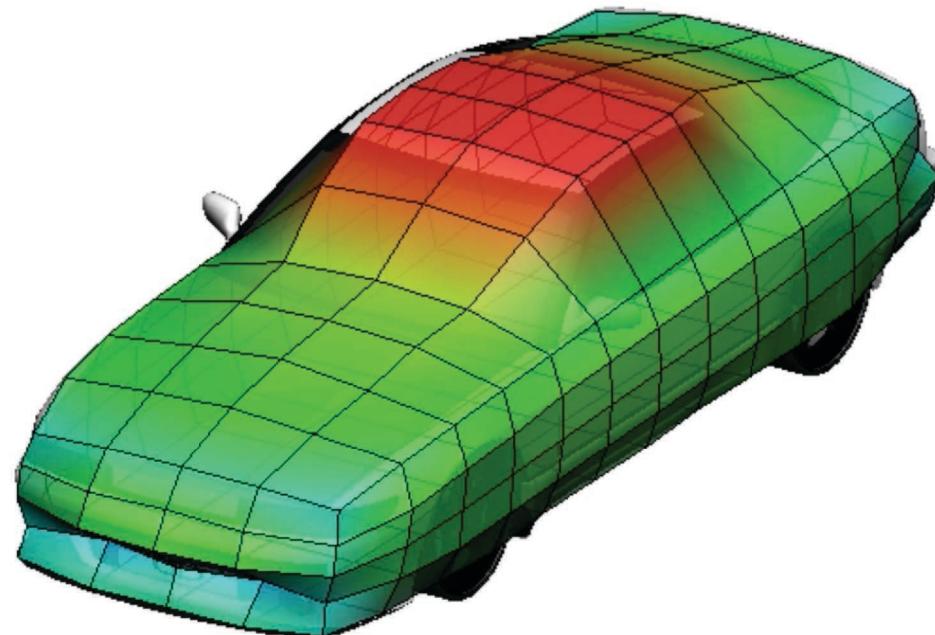
Parameterization Example



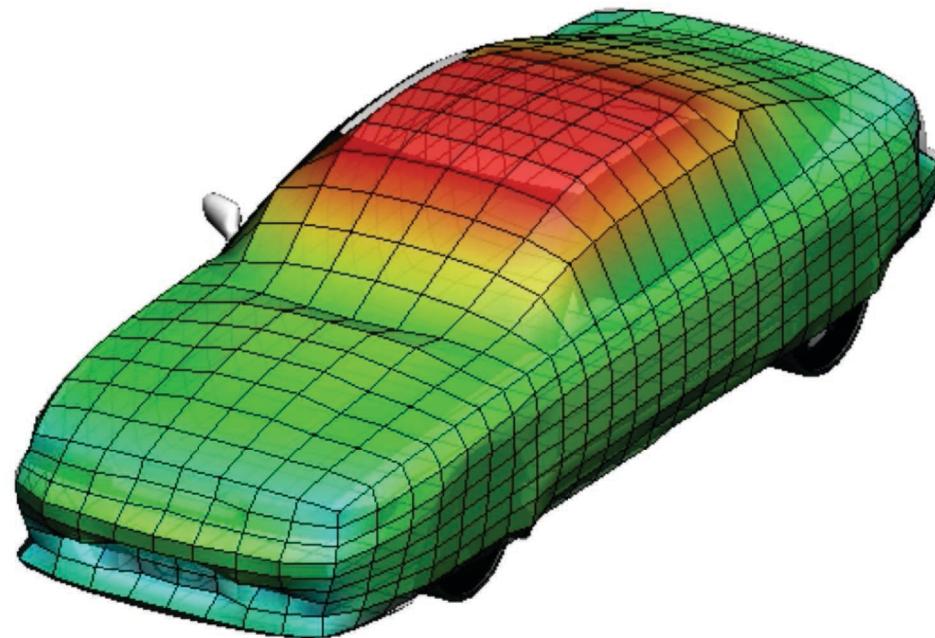
Parameterization Example



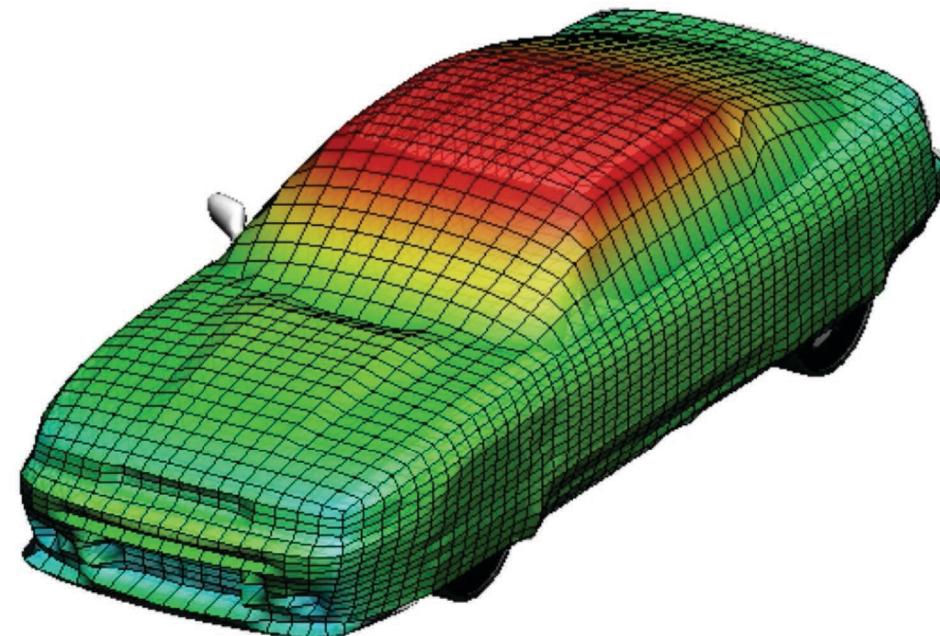
Parameterization Example



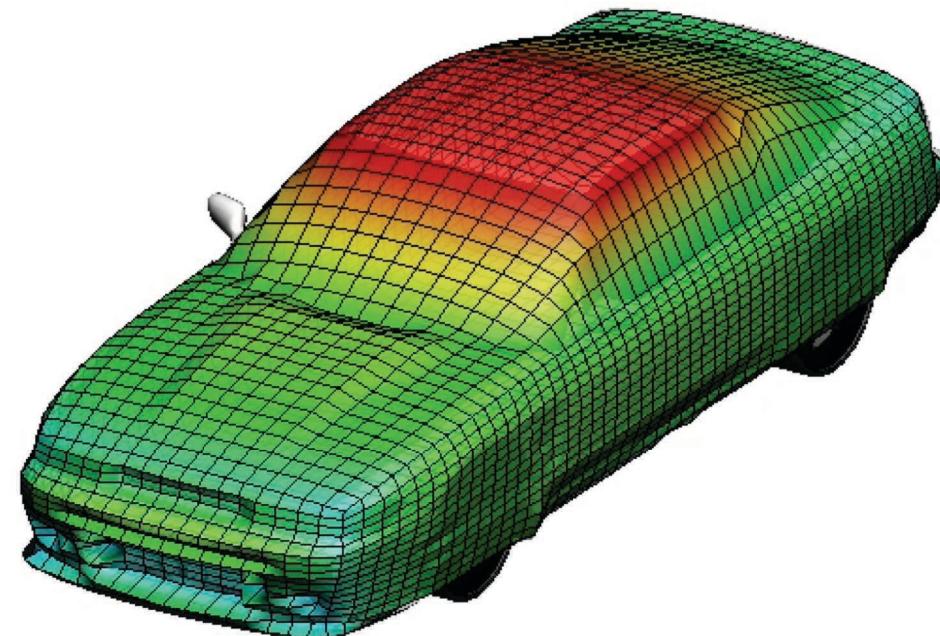
Parameterization Example



Parameterization Example

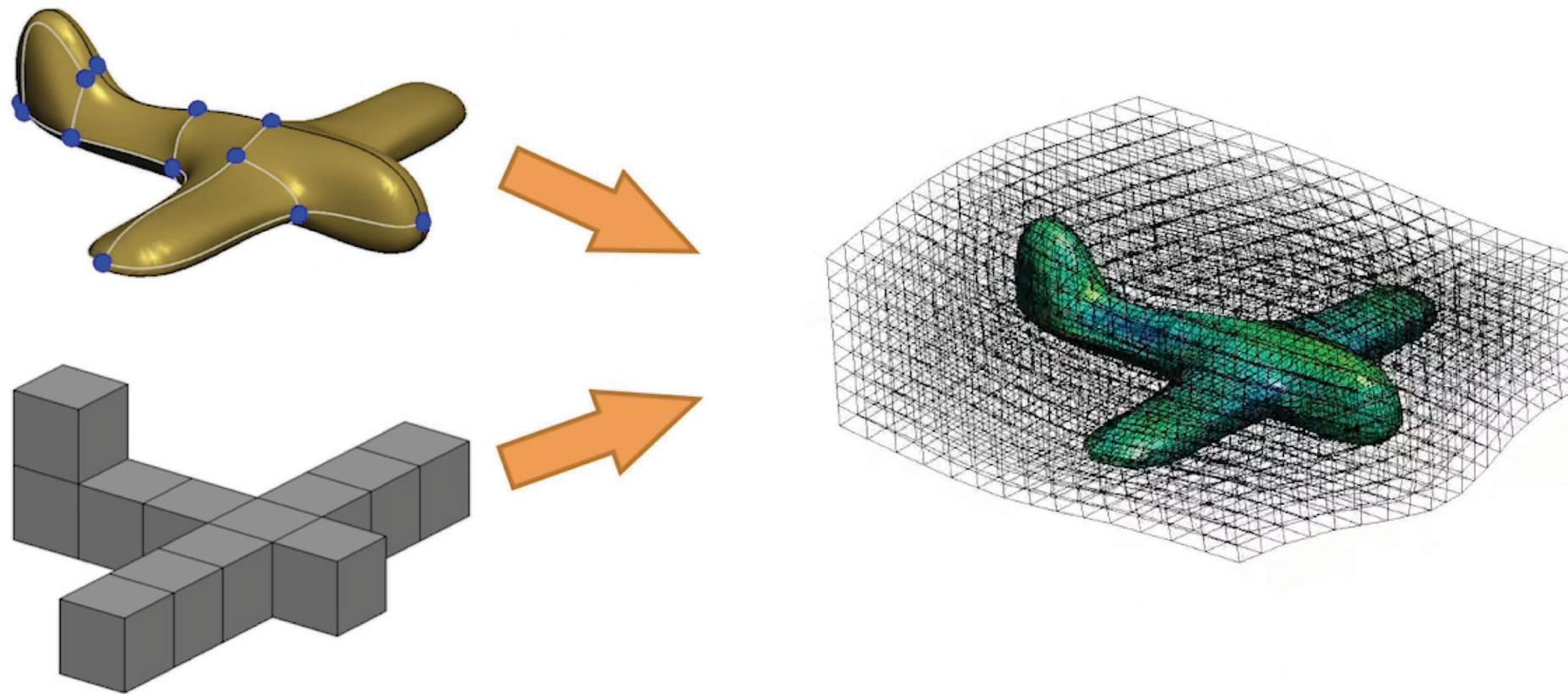


Parameterization Example



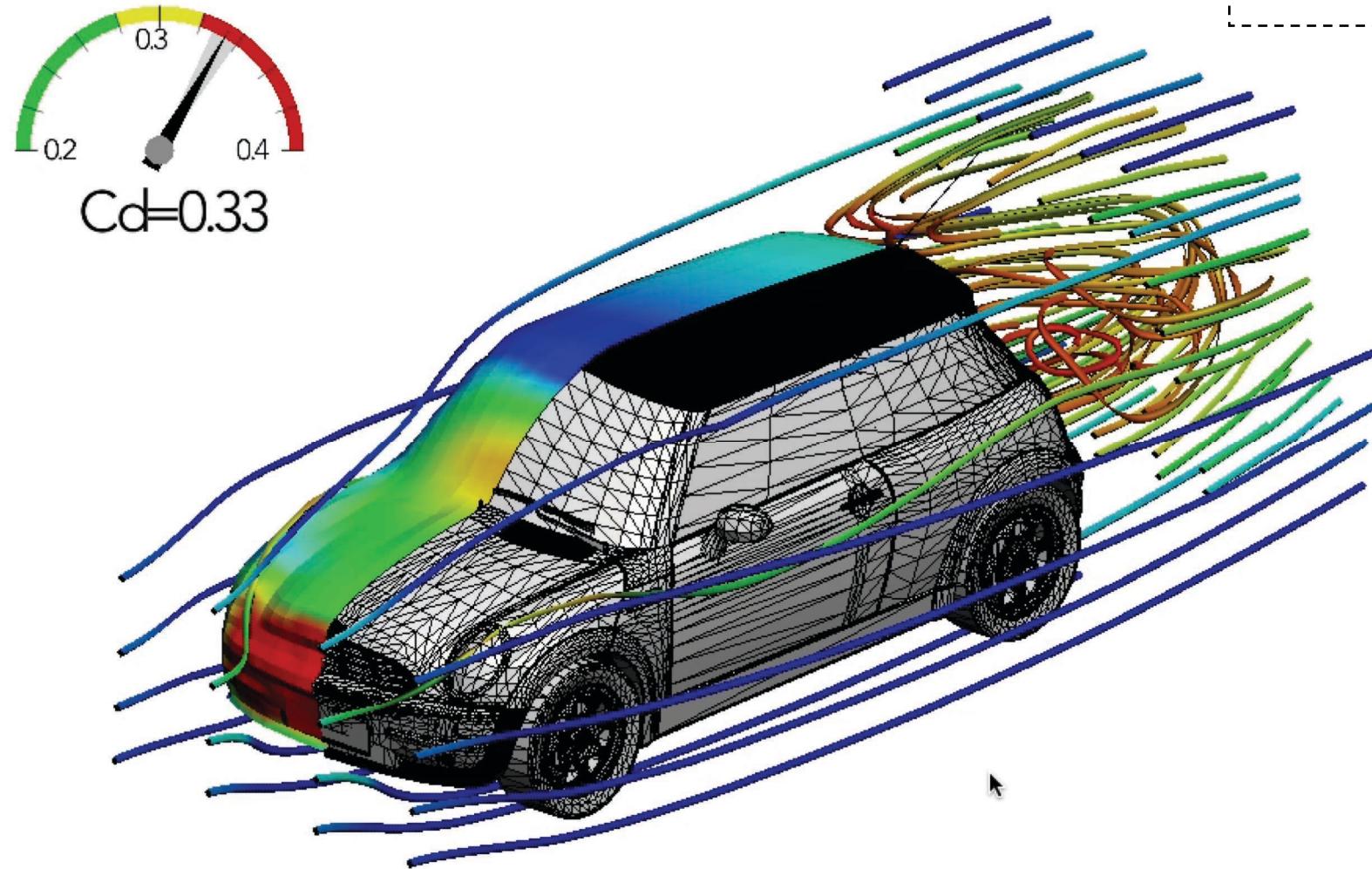
Parameterization of Fields

.19

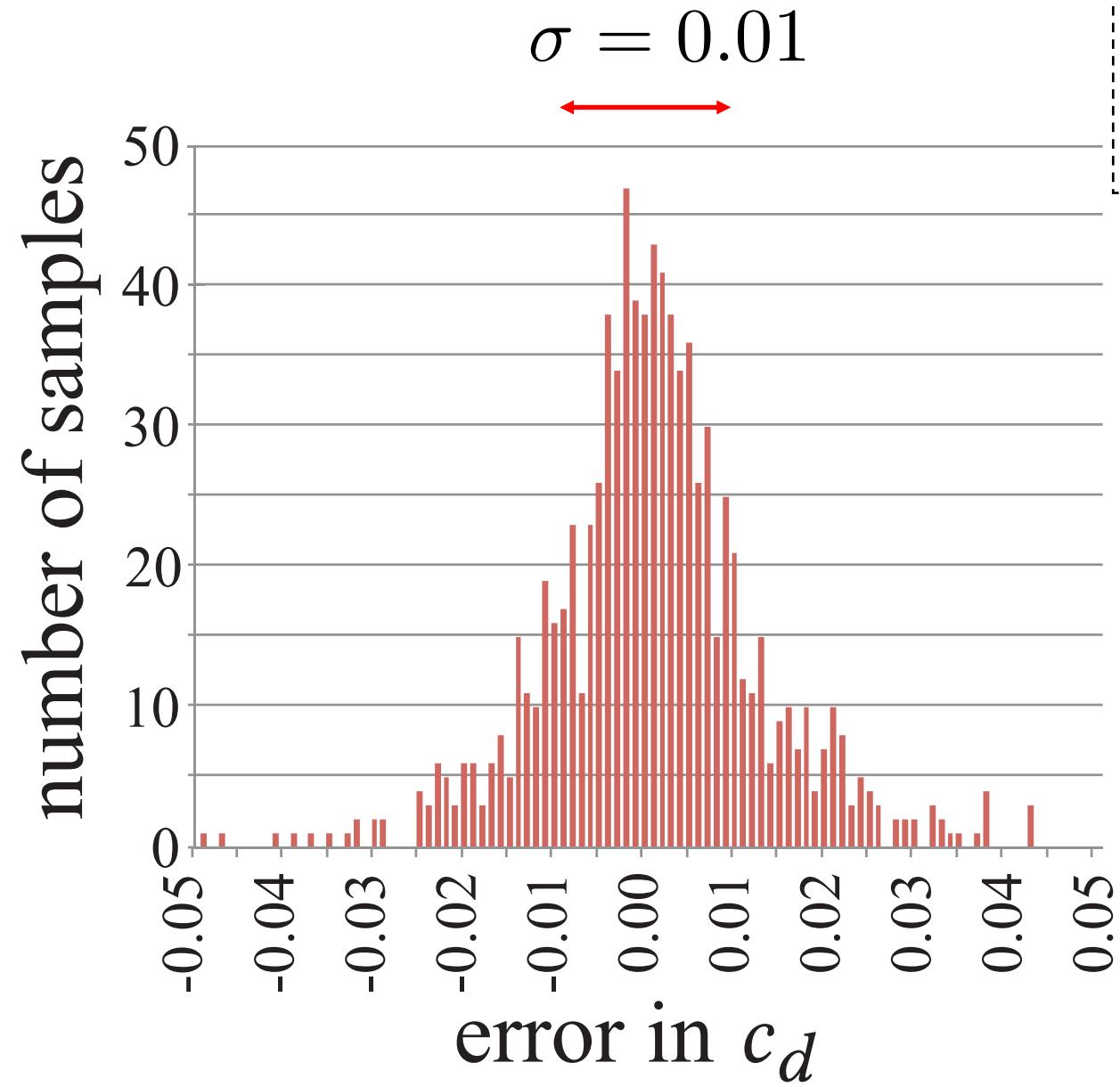


Application to CFD

- Predicting aerodynamics at an interactive rate

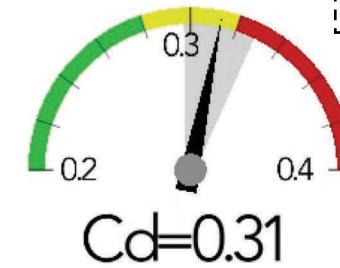
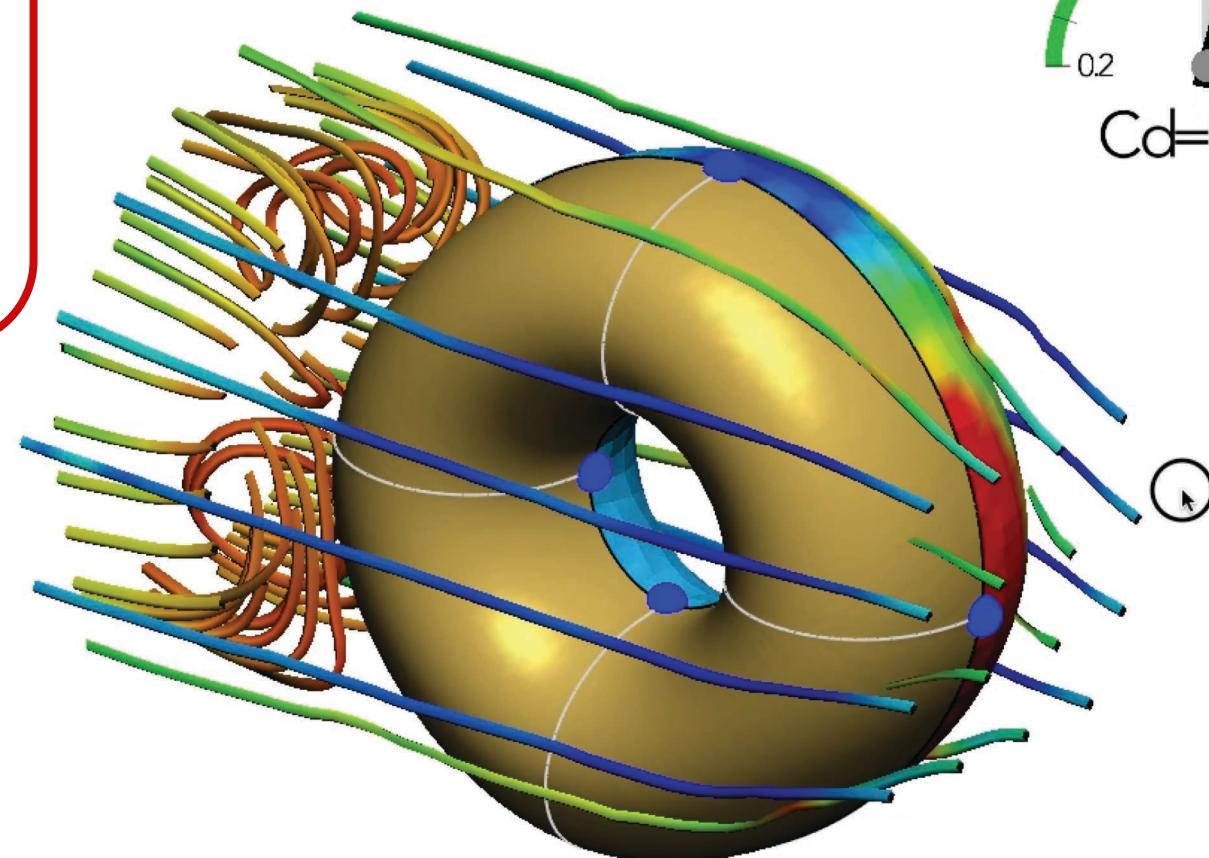
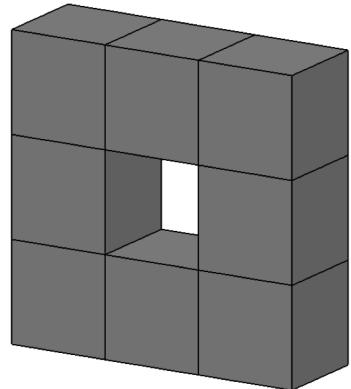


Accuracy



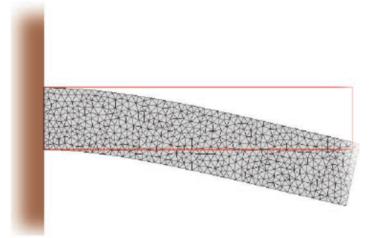
Shape with Genus One Topology

PolyCube



Conclusion

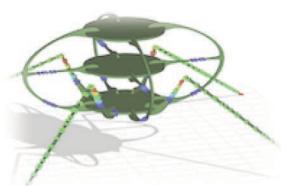
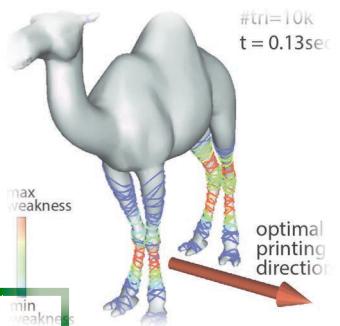
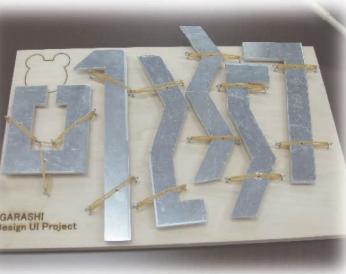
numerical method



Integrated
Design
Simulation
Interaction

mechanical engineering

interaction technique



Thank you!



Co-authors:

Takeo Igarashi, Ryan Schmidt, Bernd Bickel, Eitan Grinspun, Niloy Mitra, Xin Tong, Weiwei Xu, Kees Oosterlee, Jos Stam, Emily Whitting, Kenshi Takayama, Yuki Koyama, Danny Kaufman, Mitani Jun, Rubiat Habib, Jie Mao, Tobias Martin, Athina Panotopoulou, Shunsuke Saito

Intelligent Tools for Creative Graphics

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