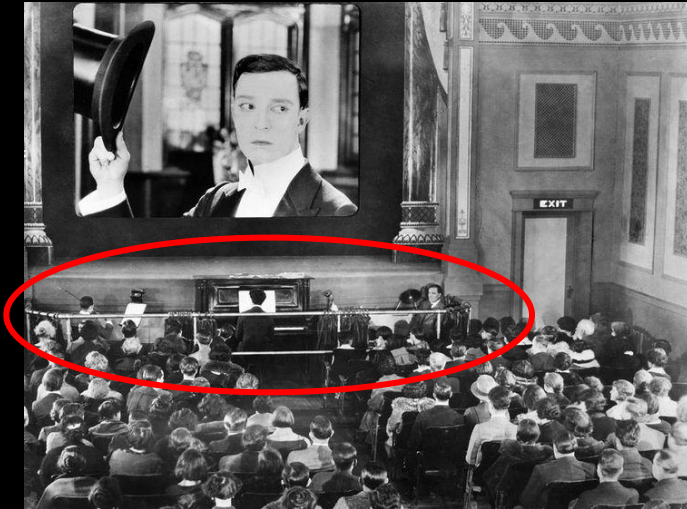


Technologies In Modern Film Production

The image shows the Hollywood sign, a famous landmark in Los Angeles, California. The sign is composed of large, white, three-dimensional letters spelling out "HOLLYWOOD" in all caps. It is situated on a steep, dry hillside covered with sparse, low-lying vegetation and small trees. The sky is a clear, bright blue. In the background, above the sign, there are some utility poles and a small structure with a white dome, possibly a radio tower or a small building. The overall scene is a classic view of the Hollywood sign from a distance.

HOLLYWOOD

Technologies has been revolutionize film industry for centuries



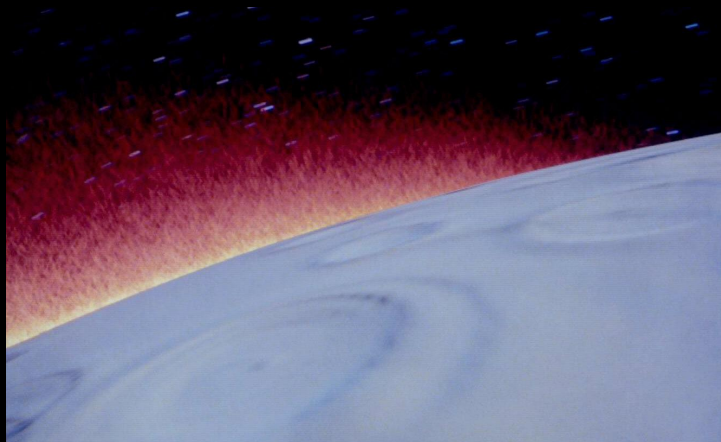
Movies in 1920, with orchestra playing the musical



First Movie with sound, 1927



First True Color movie, by [Edward R. Turner](#) in 1899 and tested in 1902.



Star Trek II, 1982



First full length CG Anim, 1995



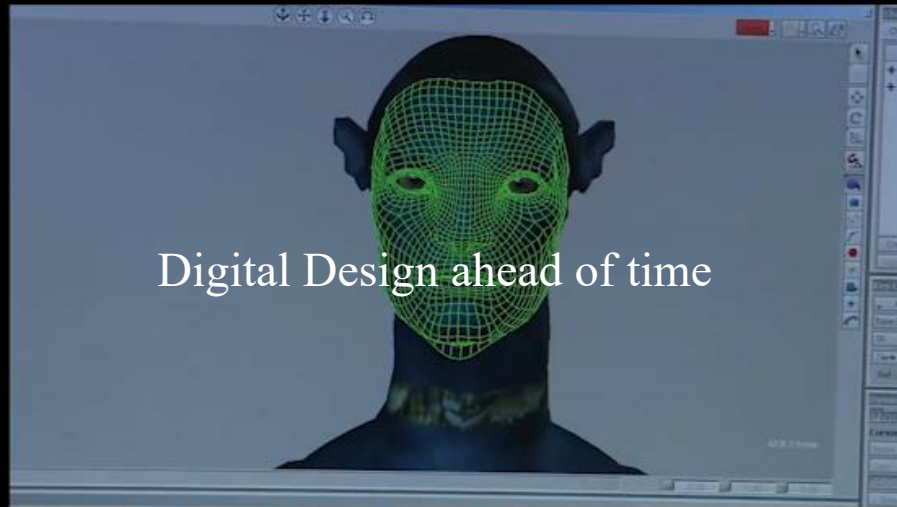
~\$40 Billion/year Industry

*Technology inspires art,
Art Challenges Technology.
– Pixar*

During a Movie Production

- Computer Science's role:
 - Motion and Facial Capturing
 - Least Square Optimization
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 - Off-line Graphics
 - Physically based Simulation and Rendering
 - Image Processing, AI driven graphics
 - Systematic integration with
 - Hi-speed network
 - Filming Hardware
 - Artists

Post-production now is Pre-production



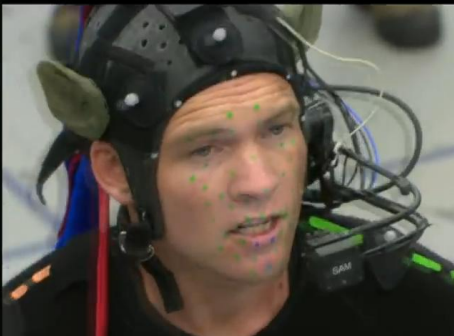
Performing



Director's Monitor

+ Realtime Performance Capturing and Directing

Final-Cuts



What you thought “Real” are actually “Digital”



Dawn of the Planet of Apes

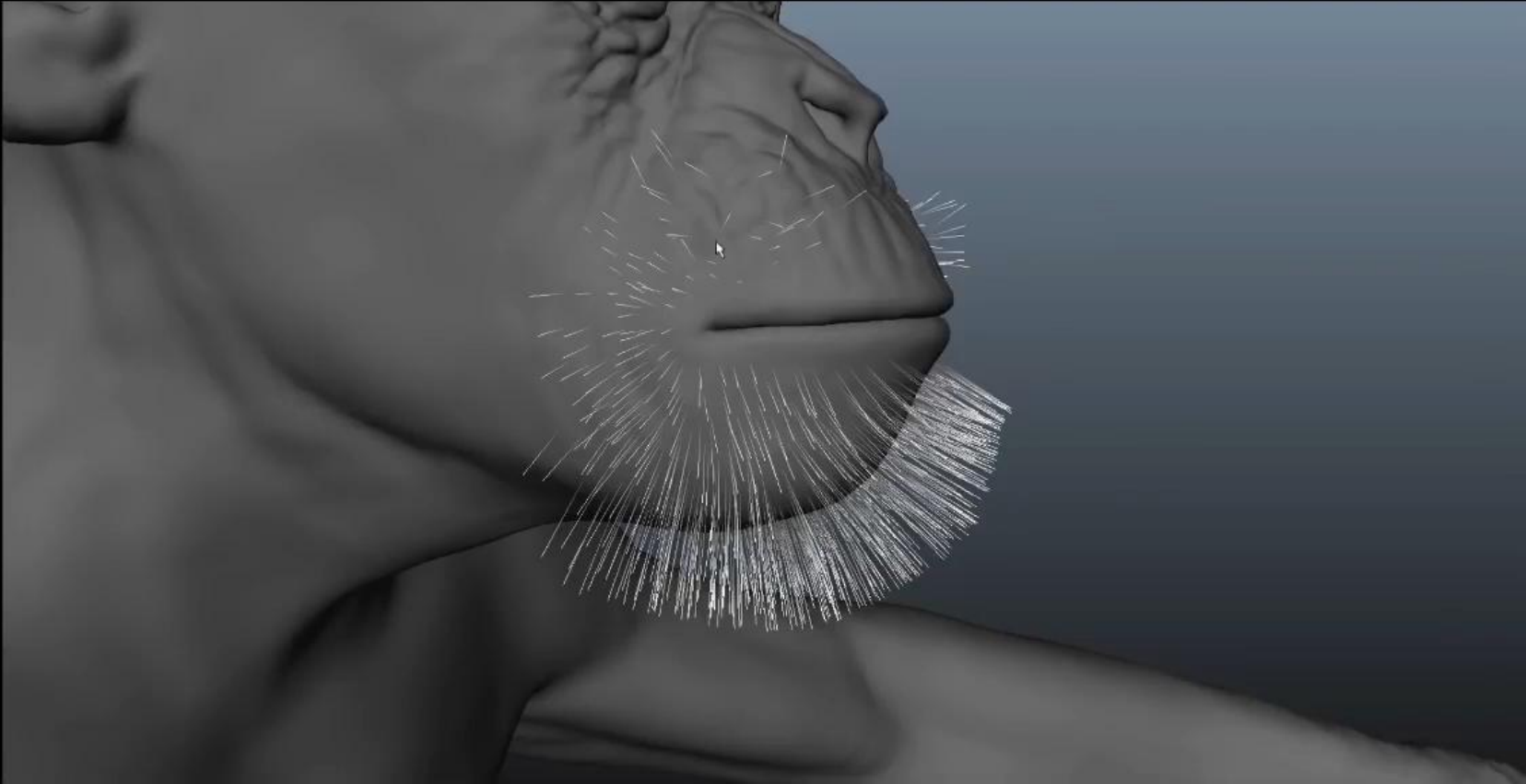
What you thought “Real” are actually “Digital”



Fast and Furious 7

How to achieve such quality?

- Develop new tools(Coding and Engineering)

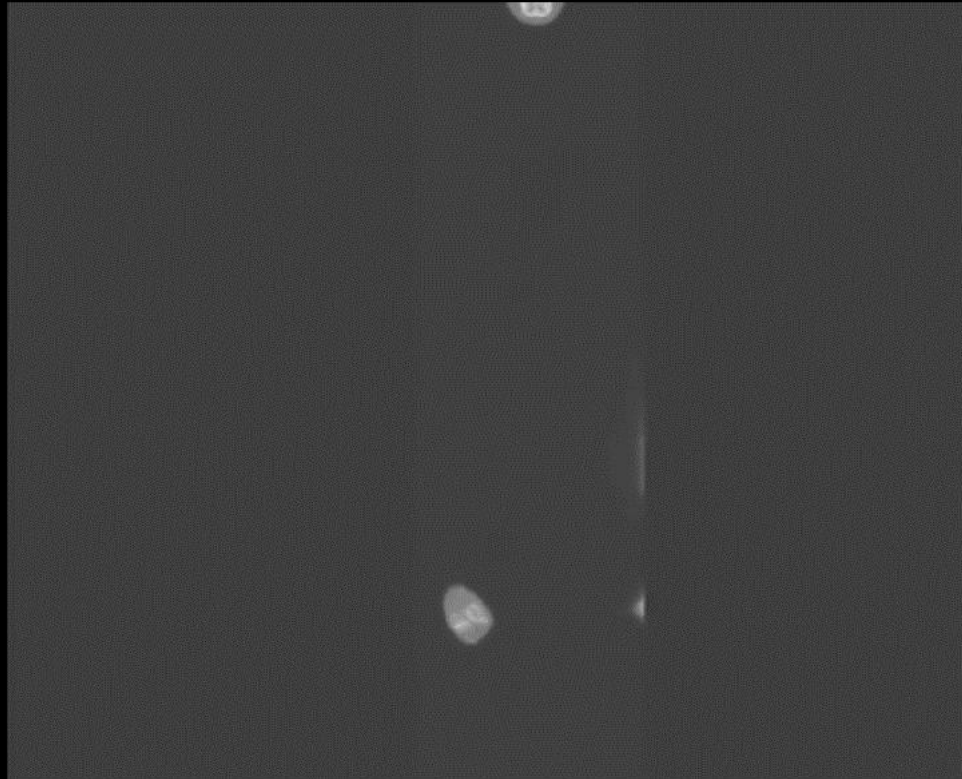


How to achieve such quality?

- Study the physics of light transporting models(Science)

How to achieve such quality?

- Even Study the Anatomy of digital characters



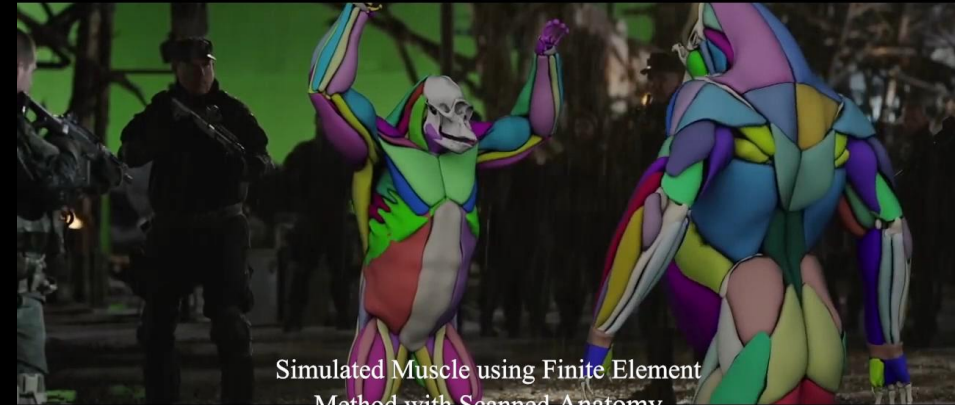
How to achieve such quality?

Put together: From Capture to Simulation and Rendering



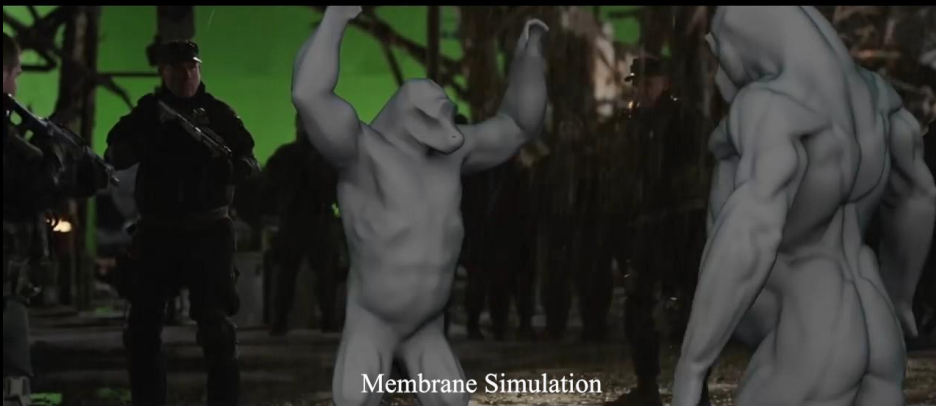
Motion Captured Skelton Animation

Motion Capture



Simulated Muscle using Finite Element
Method with Scanned Anatomy

FEM Muscle Simulation



Membrane Simulation

Membrane/Skin/Hair/Fur Simulation



Final Result

Final Render(Lighting Simulation)

How to achieve such quality?

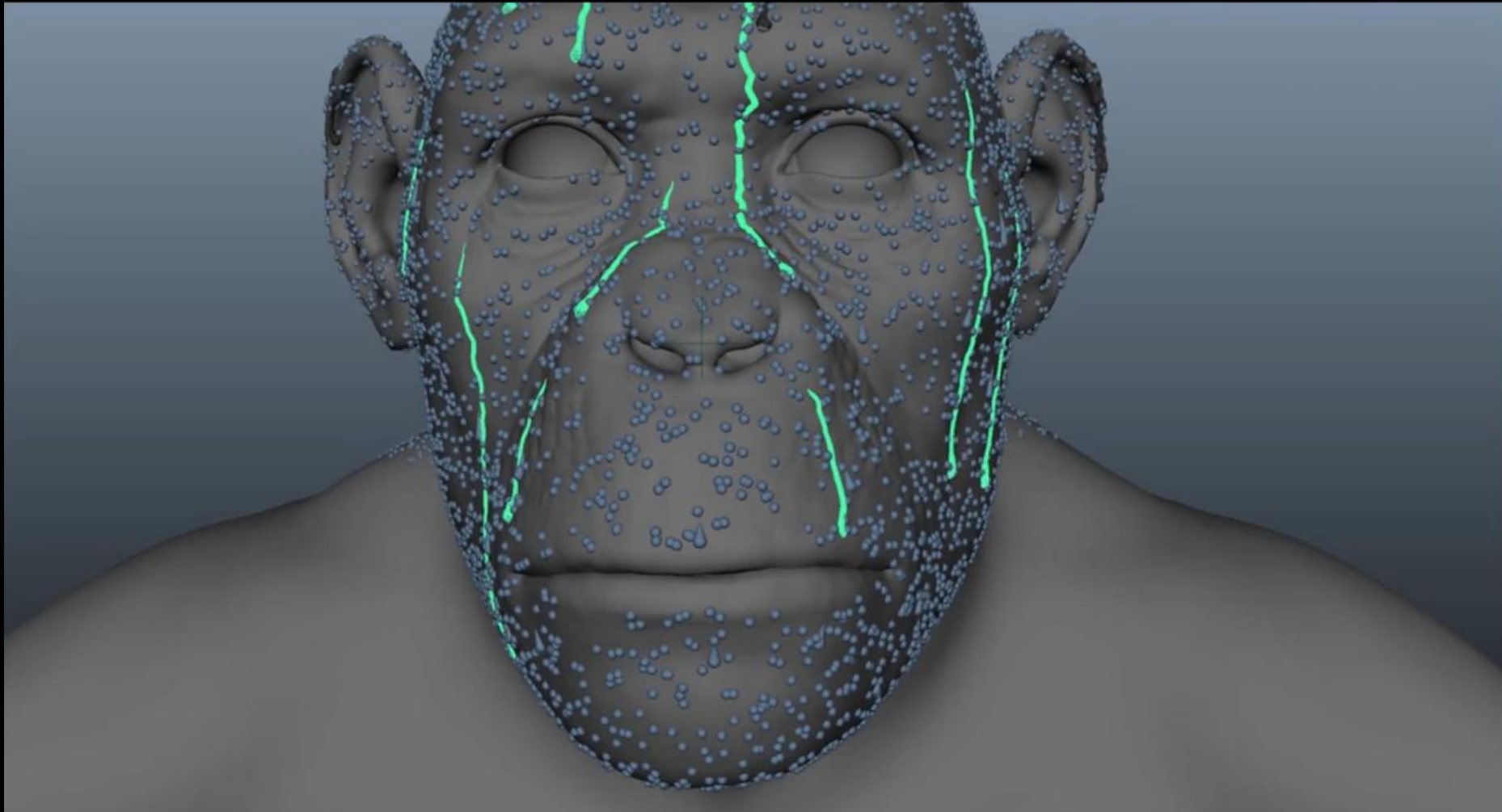
Polish to even tiny details!



Modeling the Snow on the Fur

How to achieve such quality?

Don't forget to run Physically Based Simulations!



How to achieve such quality?

Virtual Production + Performance Capturing brings Life Like Digital Characters!



How to achieve such quality?

While apes use tools to act like human, human also use tools to act like apes.



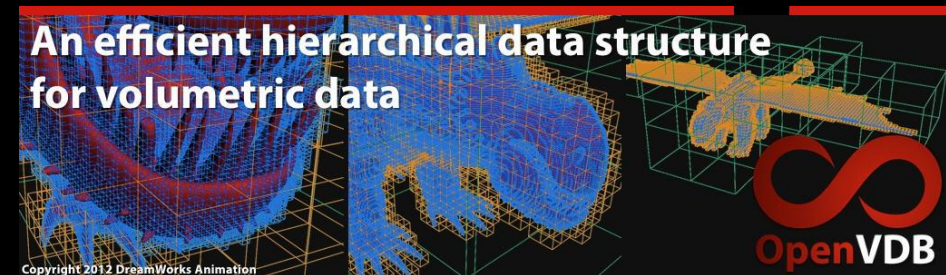
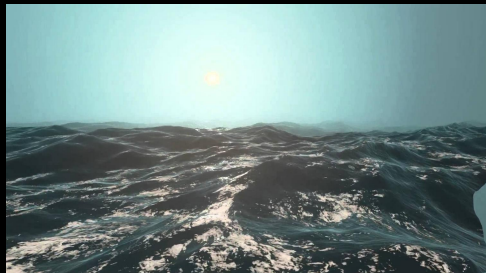
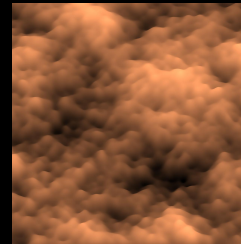
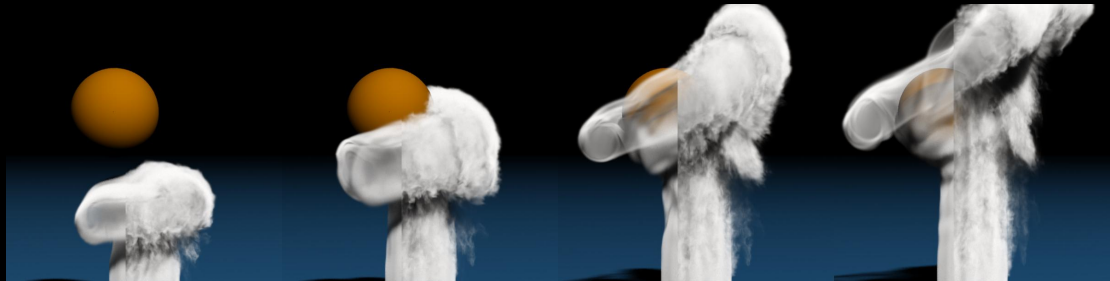
How to achieve such quality?

New Researches



How to achieve such quality?

Award Oscar Statues to Comp. Scientist and
Mathematicians!



Copyright 2012 DreamWorks Animation



How to achieve such quality?

Computer Scientists to get Oscar Statue!

- Wavelet Turbulence (Nils Thuerey, etc. TUM)
- Bullet Engine (Erwin Coumans, Google)
- PhysBam(Ron Fedkiw, Stanford)
- FFT based Ocean Simulation(Jerry Tessendorf, ClemsonU)
- Perlin Noise(Ken Perlin, NYU)
- OpenVDB(Ken Museth, Weta Digital)
- Sparse Voxel(Robert Bridson, UBC, Autodesk)
- Fast FEM Solver for Fracture(James O'Brien, UC Berkeley)
- Too many names to put here(Columbia U, UCLA, Cornell, etc.).
- One of you guys!(PKU)



Research aspects in Computer Graphics

- Computer Science's role:
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 - Artists

Same Equation

$$\underset{P_j, X_i}{\operatorname{argmin}} \sum_i \sum_j \| P_j X_i - x_i \|_2$$

Knowns

The diagram illustrates the determination of variables in the equation $\underset{P_j, X_i}{\operatorname{argmin}} \sum_i \sum_j \| P_j X_i - x_i \|_2$. It features three colored arrows: a red arrow pointing from P_j to the text 'Pre-determined in motion capture, solved for in SLAM'; a blue arrow pointing from X_i to the text 'Solved for, both in SLAM and MoCap.'; and a vertical blue arrow pointing from x_i to the same text. A diagonal red arrow also points from the \sum_j term to the 'Pre-determined...' text.

Pre-determined in motion capture, solved for in SLAM

Solved for, both in SLAM and MoCap.

Different aspects

$$\operatorname{argmin}_{P_j, X_i} \sum_i \sum_j \|P_j X_i - x_i\|_2$$

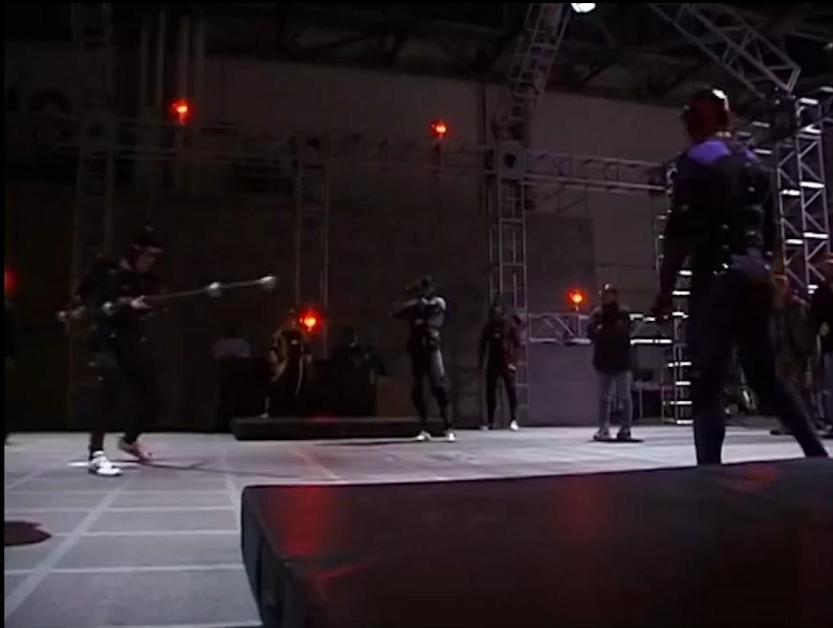
Once P_j is Pre-determined, this is a **Linear System**,

Linear Solvers – fast ☺

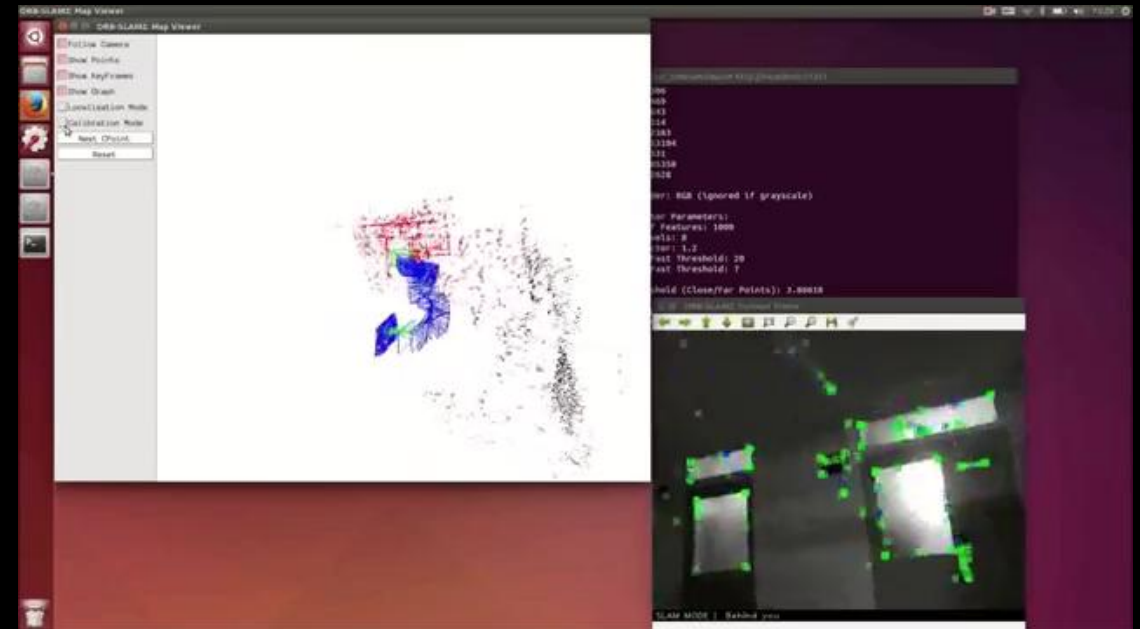
Once it is the Unknown, this is a **Non-linear Least Square**

Newton Solvers – slow ☹

Different aspects



Focus on locating the Object,
In A **Well-Conditioned** Environment



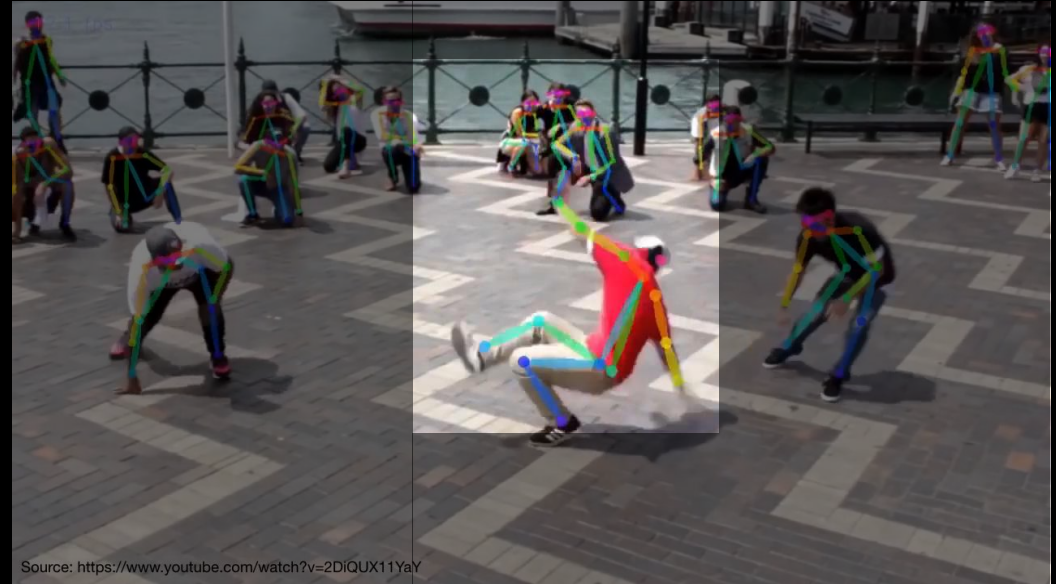
Focus on locating the Observer,
In an **UnConditioned** Environment

Different aspects



Jitter is **Not Acceptable**.

Realtime Multi-Person 2D Human Pose Estimation using Part Affinity Fields, CVPR 2017 Oral



Jitter is probably **Acceptable**.

During a Movie Production

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Same Equation

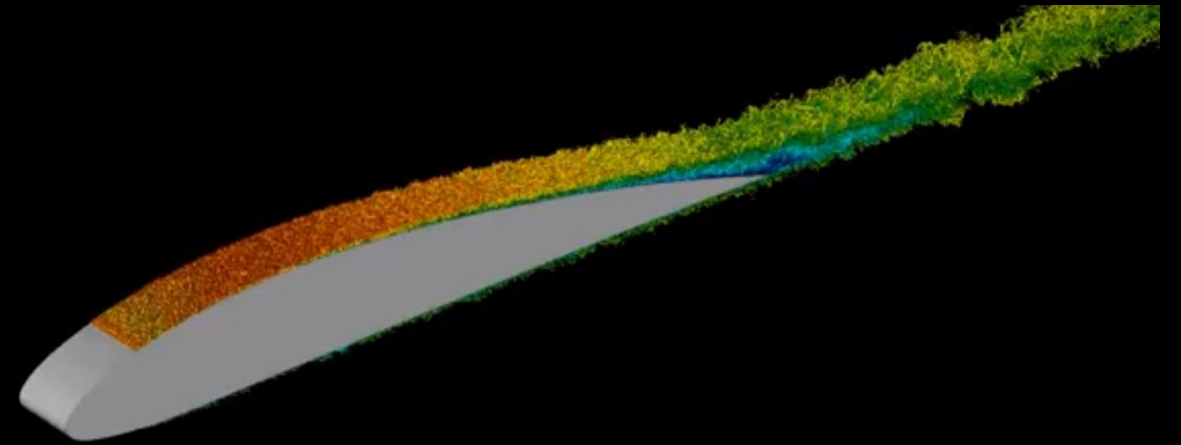
$$\frac{\partial u}{\partial t} + u \cdot \nabla u = -\frac{1}{\rho} \nabla p + \nabla^2 u + f$$
$$\nabla \cdot u = g$$



Different aspects



Stability of Numerical Integrator is more Important, Usually $CFL > 10$, simulation done in **hours**.



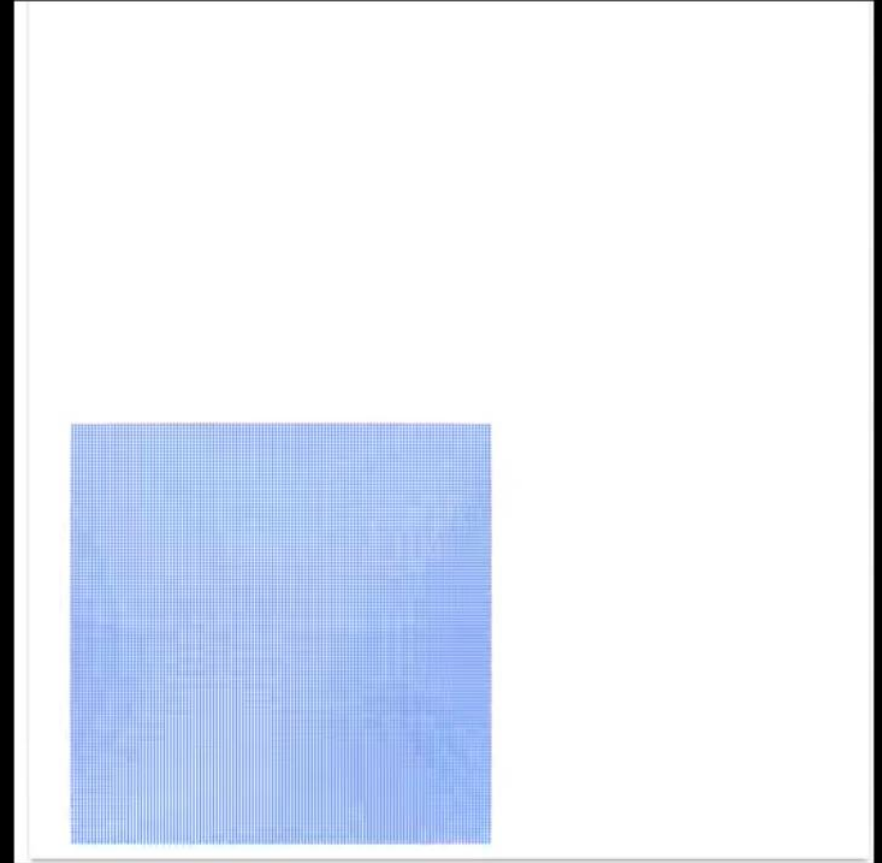
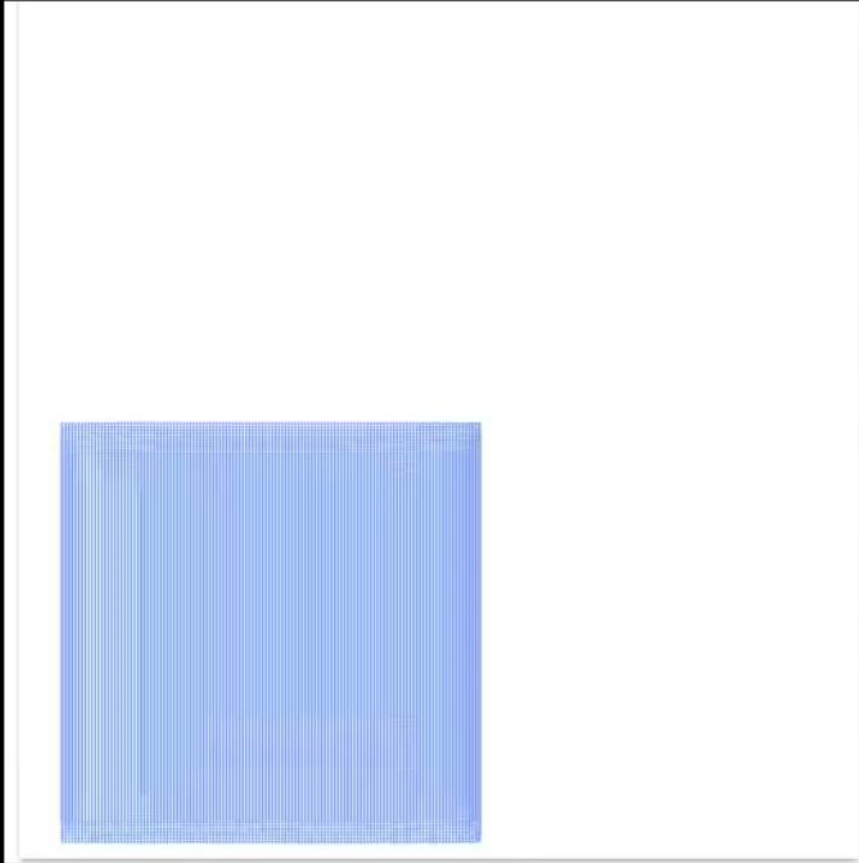
Accuracy of Numerical Integrator is more Important, Usually $CFL < 1$, simulation done in **Weeks**.

Different aspects



Time is Money!!! -- faster Algorithm with
better visual quality

Different aspects



But first it has to be **correct!**

Bigger Computing (Data) !



Big Visual Effects(Simulations) are done with Super Computers!!!

Hobbits 3: The Battle of 5 Armies

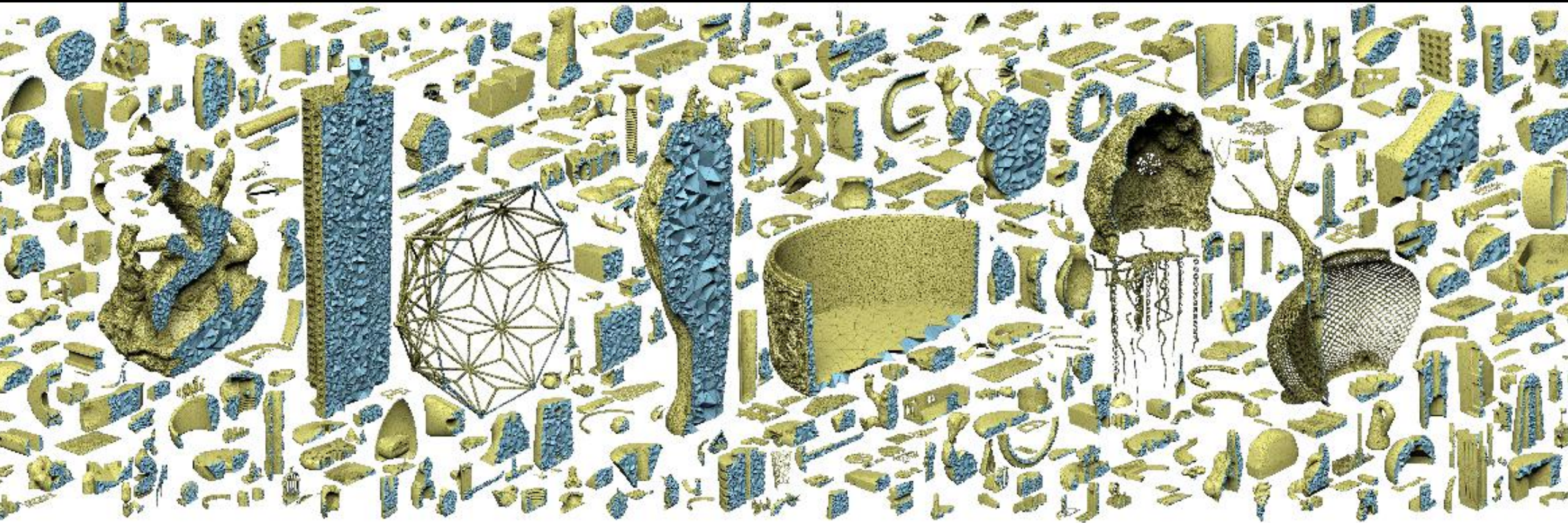
Same Equation

$$f_i = -\frac{\partial E}{\partial x_i} = \sum_e \left(\frac{\partial E_e}{\partial x_i} \right) = \sum_e f_i^e$$

Different aspects

Stability
15 CG

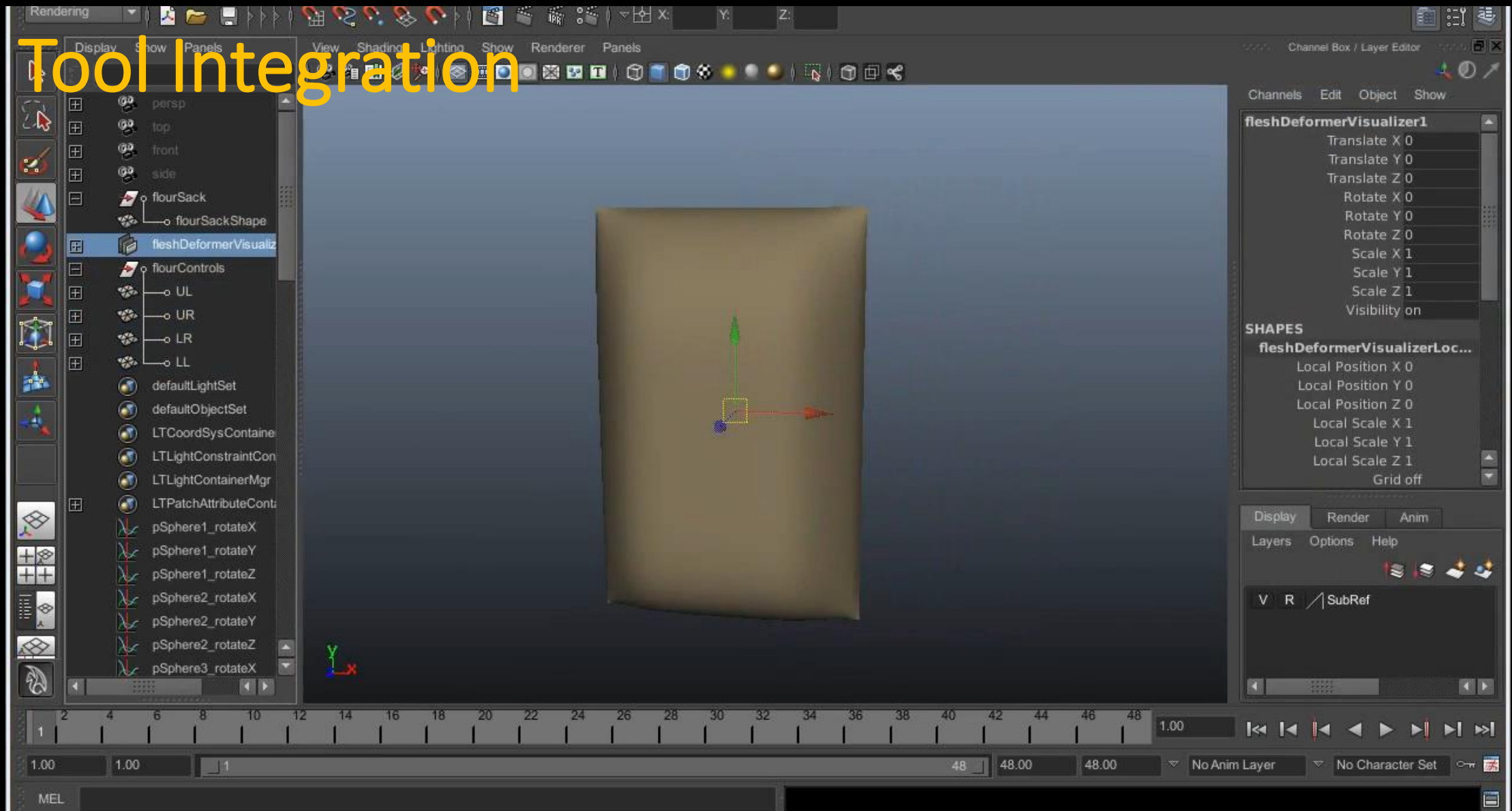
Different aspects



Tetrahedral meshing in Wild, Yixin Hu, et. al., SIGGRAPH 2018.

Computer Graphics industry often has the requirement to deal with extremely bad mesh inputs. (Degenerated mesh, non-manifold mesh, self-intersection meshes, etc.)

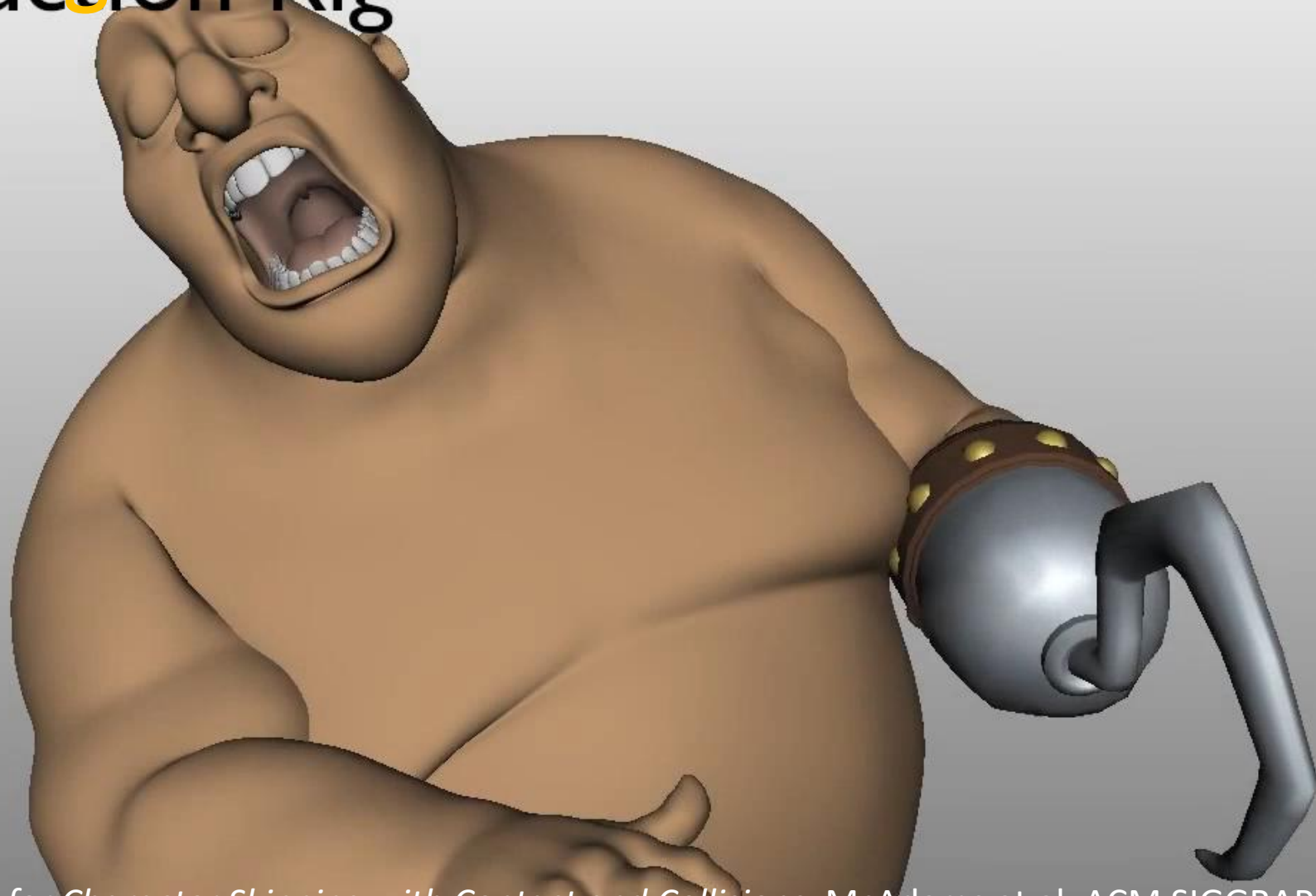
Tool Integration



Efficient Elasticity for Character Skinning with Contact and Collisions, McAdams et al, ACM SIGGRAPH 2011

Tool Integration

Production Rig

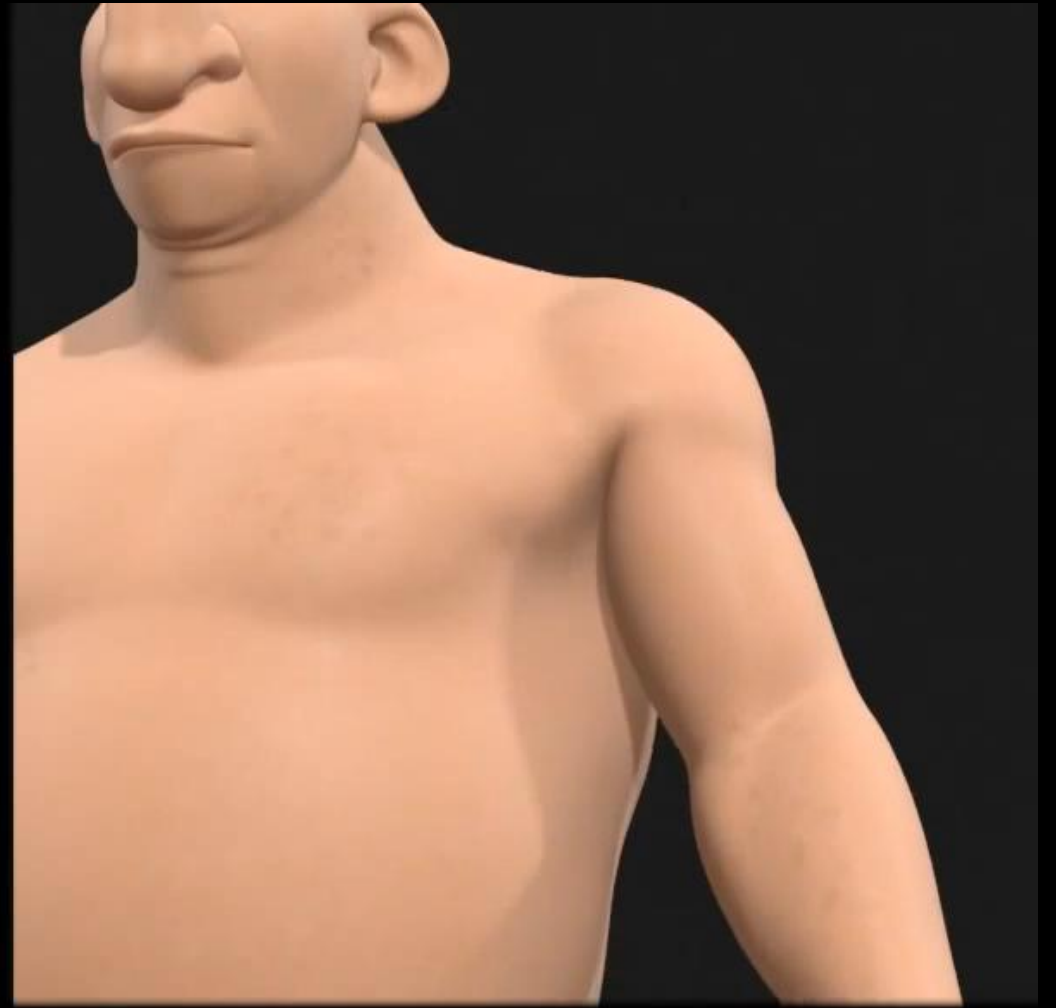


©Disney

Efficient Elasticity for Character Skinning with Contact and Collisions, McAdams et al, ACM SIGGRAPH 2011



Production Rig



Our Method

Efficient Elasticity for Character Skinning with Contact and Collisions, McAdams et al, ACM SIGGRAPH 2011 ©Disney

New Trend For Multi-Material Simulation

$$\frac{D\rho}{Dt} = 0, \quad \rho \frac{D\mathbf{v}}{Dt} = \nabla \cdot \boldsymbol{\sigma} + \rho \mathbf{g}, \quad \boldsymbol{\sigma} = \frac{1}{J} \frac{\partial \Psi}{\partial \mathbf{F}_E} \mathbf{F}_E^T$$

The Material Point Method for the Physics-Based Simulation of Solids and Fluids,
Chenfanfu Jiang, UCLA Computer Science Doctoral Dissertation (2015)

MPM Algorithm Overview

- A. Stomakhin, C. Schroeder, L. Chai, J. Teran, A. Selle,
- B. *A Material Point Method for Snow Simulation*, ACM Transactions on Graphics (SIGGRAPH 2013)

Art “Directablility” and Automate in Film Production

Art Directability



[A. Stomakhin, A.Selle. Fluxed Animated Boundary Method, SIGGRAPH 2017](#)

Art Directability

• • •

[Ongoing research](#)

More Automation!(ACM SIGGRAPH 2016)

The Proposed Method

Green screen keying using color unmixing, SIGGRAPH 2016



More Automation!(ACM SIGGRAPH 2018)



Semantic Soft Segmentation, SIGGRAPH 2018, Adobe

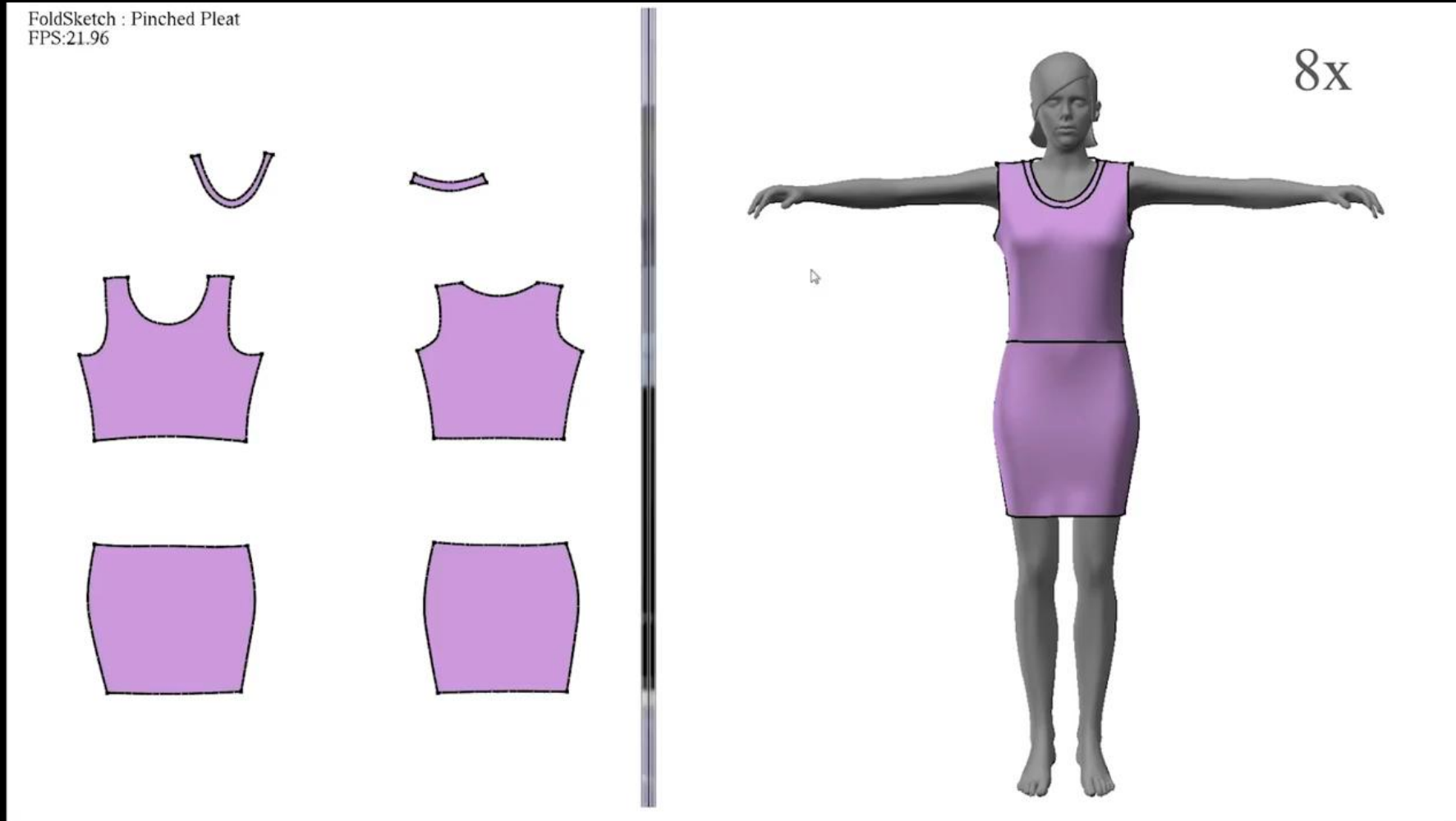
More Automation!(ACM SIGGRAPH 2018)

Optimizing for Different Target Speeds

Flexible Muscle-Based Locomotion for Bipedal Creatures,
Thomas Geijtenbeek, SIGGRAPH 2013

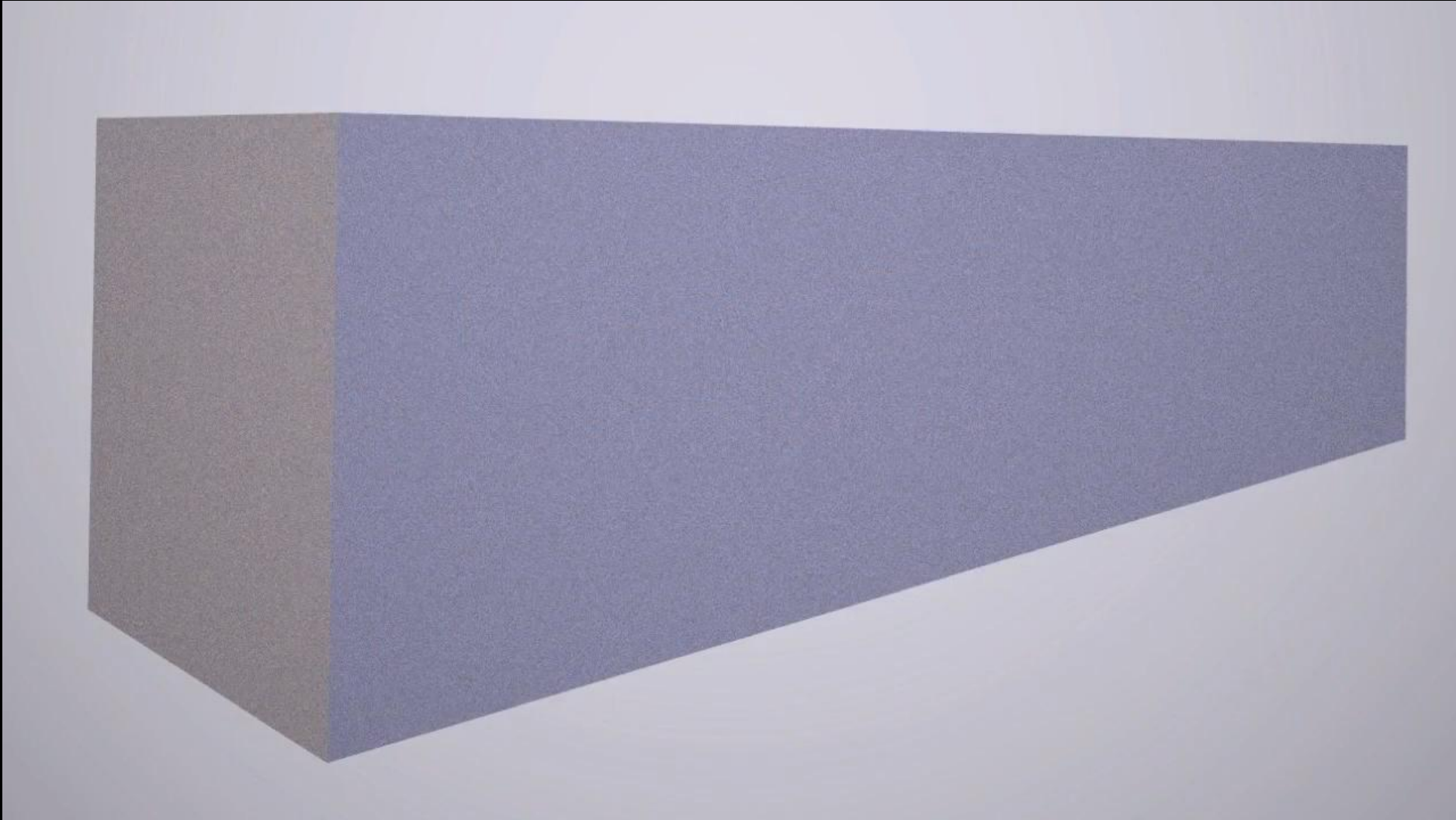
Creative Manufacturing

CS For Fashion Design!



*FoldSketch: Enriching Garments with Physically Reproducible
Folds, Minchen Li et. al., SIGGRAPH 2018*

CS For Engineering Design!



*Narrow-band Topology Optimization on a Sparsely Populated Grid,
Haixiang Liu et. al., SIGGRAPH Asia 2018*