# Review continued
# Next steps in Computer Graphics

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## Today

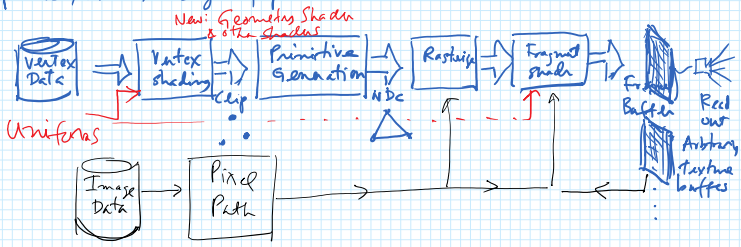
- Announcements
  - This is the last class (as voted on Monday). You have Friday off!
  - Don't forget to do the Course Evaluation (online). It will close on Monday.
  - Assignment Spotlights will be posted as videos after the end of term. Will let you know when it's ready. Code will not be posted.
- Review continued
- Next steps in computer graphics

# The big picture

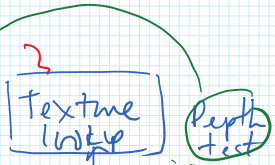
November 27, 2017 9:46 AM

TO BE CONTINUED NEXT CLASS...

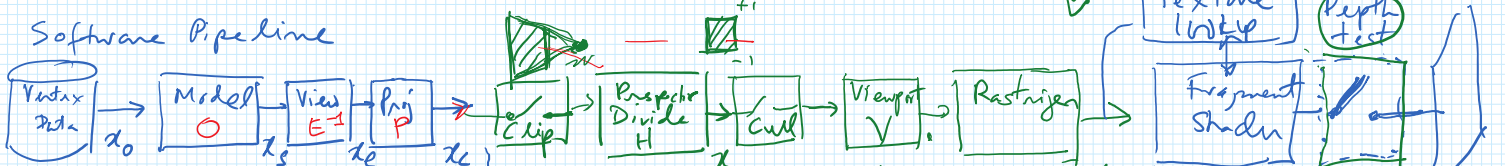
OpenGL / DirectX style pipeline




Early z-cull




Software Pipeline




$x_o$ Object

$x_s$ Scene/World

$x_e$ Eye

$x_c$ Clip

$x_n$ Divide by $w_c$

Set knob with glViewport()

$x_w$ Window coords (2D point)

Frame Buffer

Usually computed in client app & passed as uniforms

Fixed function.

Normals $n_o$ → Normal Matrix $N = (E^{-1}O)^{-T}$ → Varying out

Interpolates Varying Variables

## Switch to Tablet

3

# Beyond Pretty Pictures:

# Fast and Accurate Human Simulations

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# The Promise

5

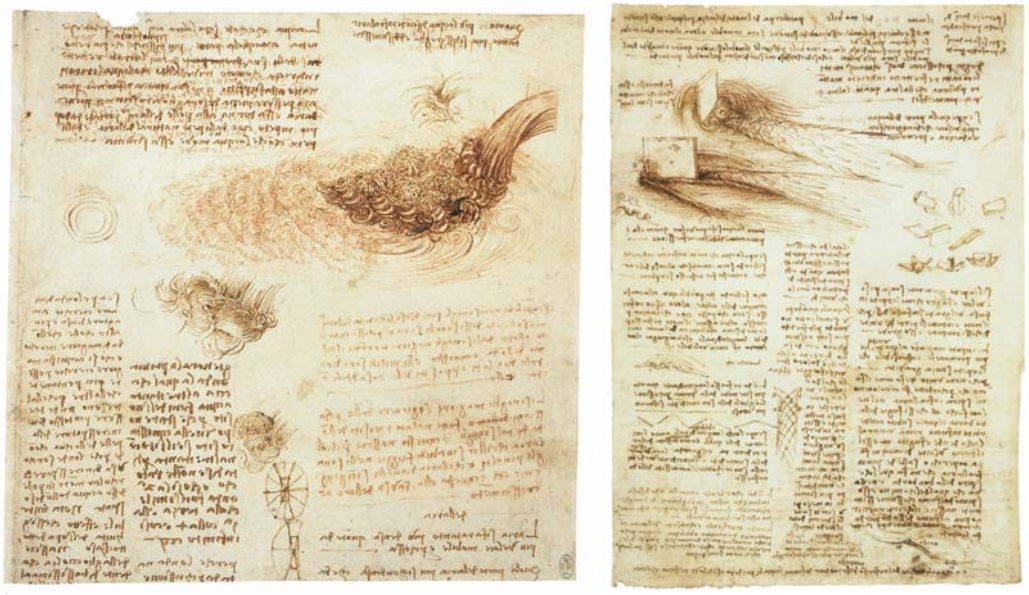
## The Promise

- "Before 2020, character animation will mainly be character simulation [of biomechanics and neural control]"
- In scare quotes because I'm on record saying this ca. 2010
  - I thought 10 years was far away…
  - I'm not the only one to believe this
- Yes, artists will control the animation, but at a high-level. Like directors, rather than as puppeteers

## Could this work?

- Inspiration: the amazing success of physically based animation

## da Vinci's fluid animations, ca. 1500

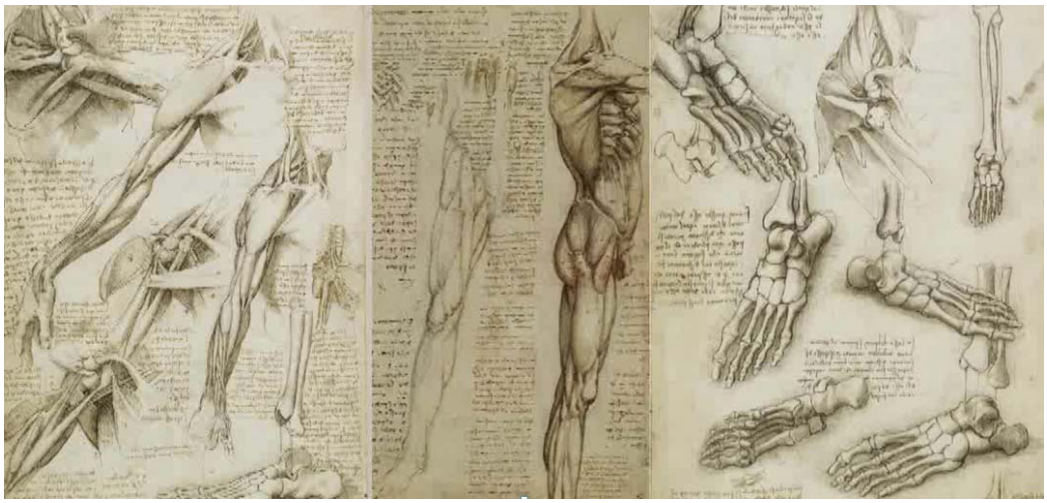


## Fluid animations, ca. 2010


## Could this work?

- Inspiration: the amazing success of physically based animation
  - Fluids
  - Cloth
  - Sound
  - Destruction
  - …
- With help from the usual suspects:
  Moore's Law, Software is Eating the World, etc.

# What about Character Animation?



**Leonardo da Vinci, ca. 1500**

11

# What about Character Animation?

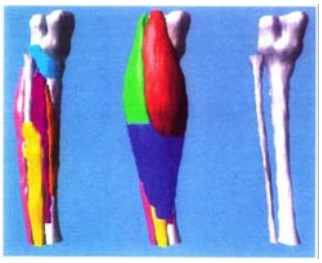
**Avatar (2009)**

A Physically Based Approach to Virtual Character Deformations [Siggraph 2010 talk] 12

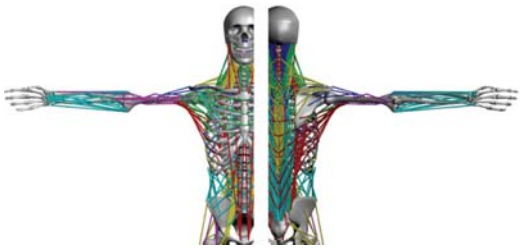
# The Pitfalls

## Myth: Biomechanics is well understood

- Computer scientists just need to take these principles and make them faster, more scalable, and make prettier pictures
- This myth is believed by many in the field of biomechanics as well!



Chen & Zeltzer 1992



Lee, et al. 2010

## Challenges of Biomechanics

- Constraints
- Contacts
- Large deformations
- Volumetric data

## New Approach to Biomechanical Simulation

- Use Reduced Coordinates whenever possible
  Most biological tissues are (or built from) thin structures, particularly
  - 1D strands (proteins, muscle fibers, tendons,…)
  - 2D sheets (skin, many muscles, aponeuroses, …)
- Use Eulerian discretizations
  - Pai, Levin, and Fan “Eulerian Solids for Soft Tissues, and more”, SIGGRAPH 2014 Course (plus original literature cited there)

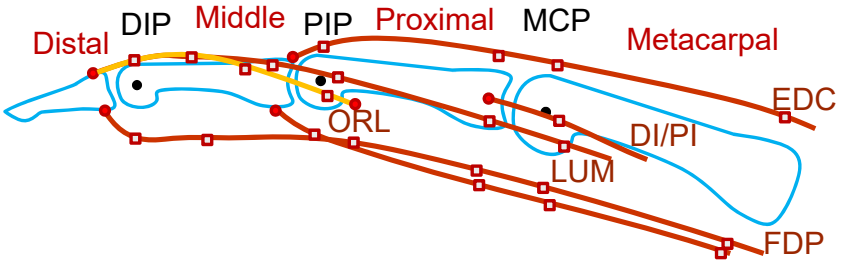
# Technology for modeling the mechanics of the human body

- Levin, et al. “Eulerian Solid Simulation with Contact,” SIGGRAPH 2011
- Sueda, et al., “ Large-Scale Dynamic Simulation of Highly Constrained Strands,” SIGGRAPH 2011
- Li, et al. “Thin Skin Elastodynamics,” SIGGRAPH 2013
- Fan, et al. “Eulerian on Lagrangian Simulation,” ACM Transactions on Graphics, 2013
- Fan, et al., “Active Volumetric Musculoskeletal Systems,” SIGGRAPH 2014
- Sachdeva, et al., “Biomechanical Simulation and Control of Hands and Tendinous Systems,” SIGGRAPH 2015

17

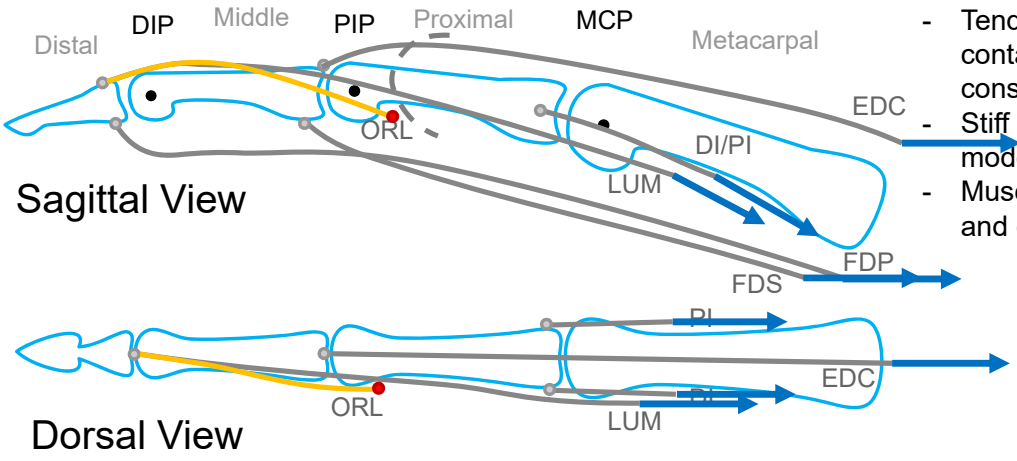
# Example: Eulerian Biomechanics in 1D (tendons and other fiber structures)

See [Sachdeva, et al, SIGGRAPH 2015]



# Challenges

Eulerian discretization





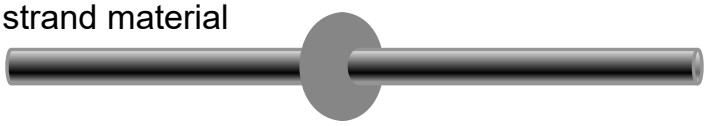


- Tendon sheaths: close contact and routing constraints
- Stiff tendon/ligament modeling
- Muscles: Material model and control

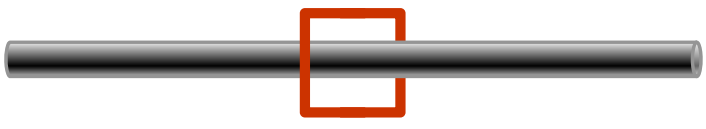
14

# Lagrangian vs Eulerian Nodes

- Lagrangian Nodes
  - Fixed to strand material



- Eulerian Nodes
  - Allows strand material to pass

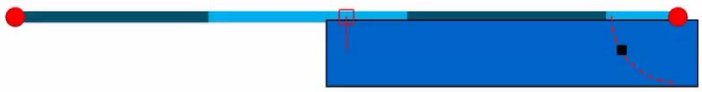


[Sueda et al. 2011]

17

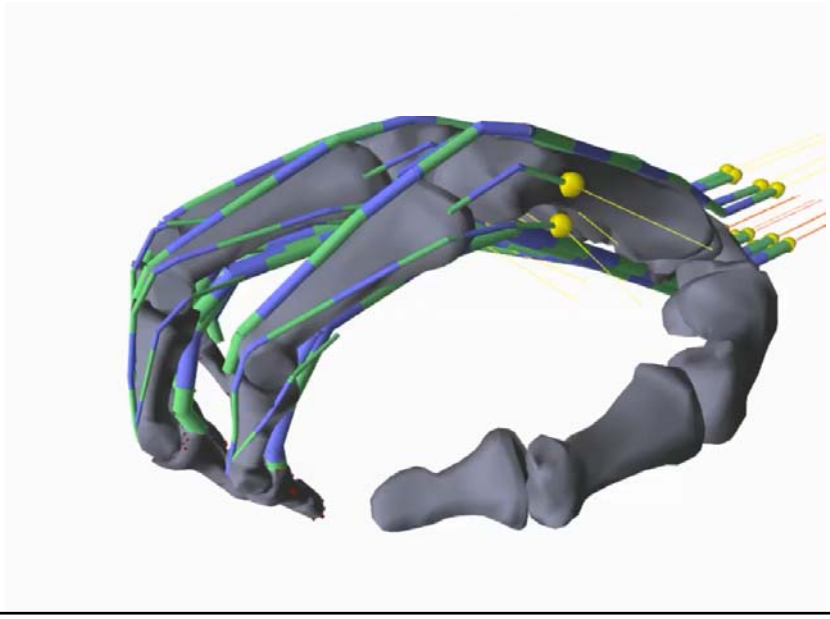
## Eulerian-on-Lagrangian Strands

- Node can be both Eulerian and Lagrangian



18

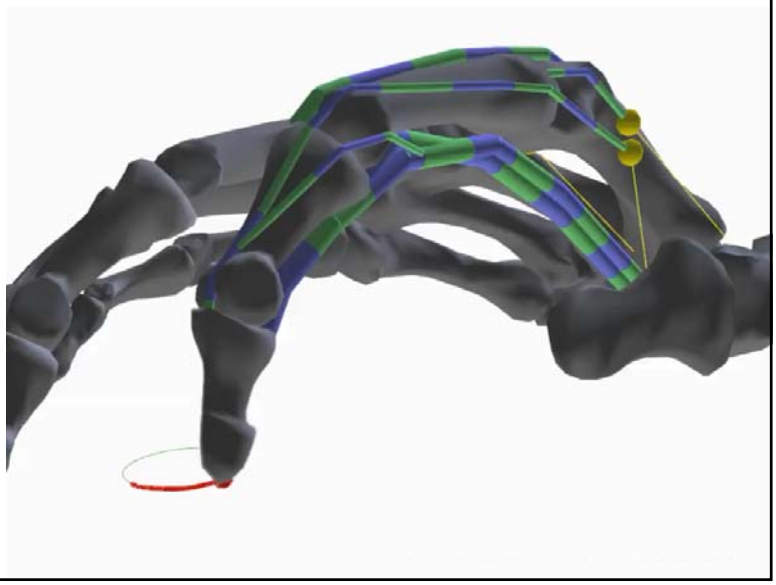
## Finger Model (with simplified extensor hood) proof of concept



13

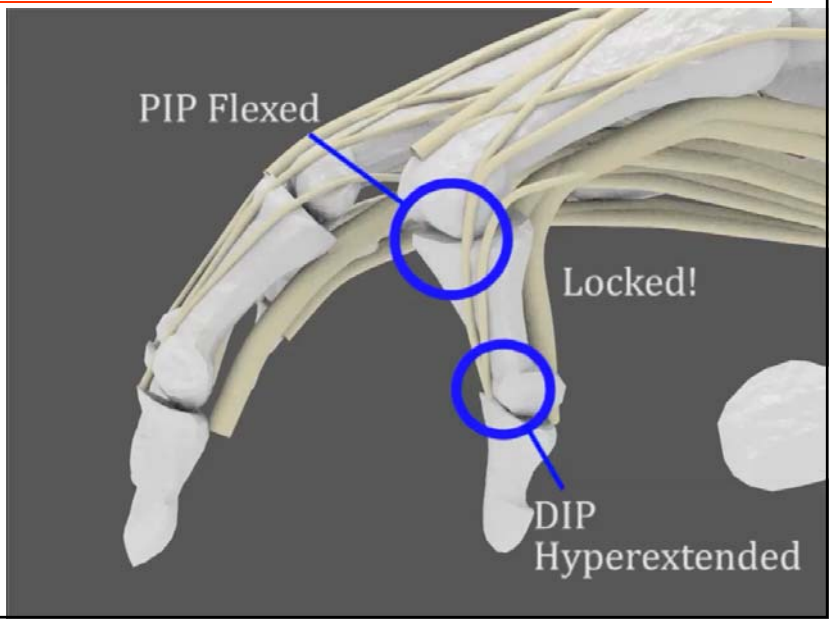
## Controlled through muscle activation

- Controller learns from experience



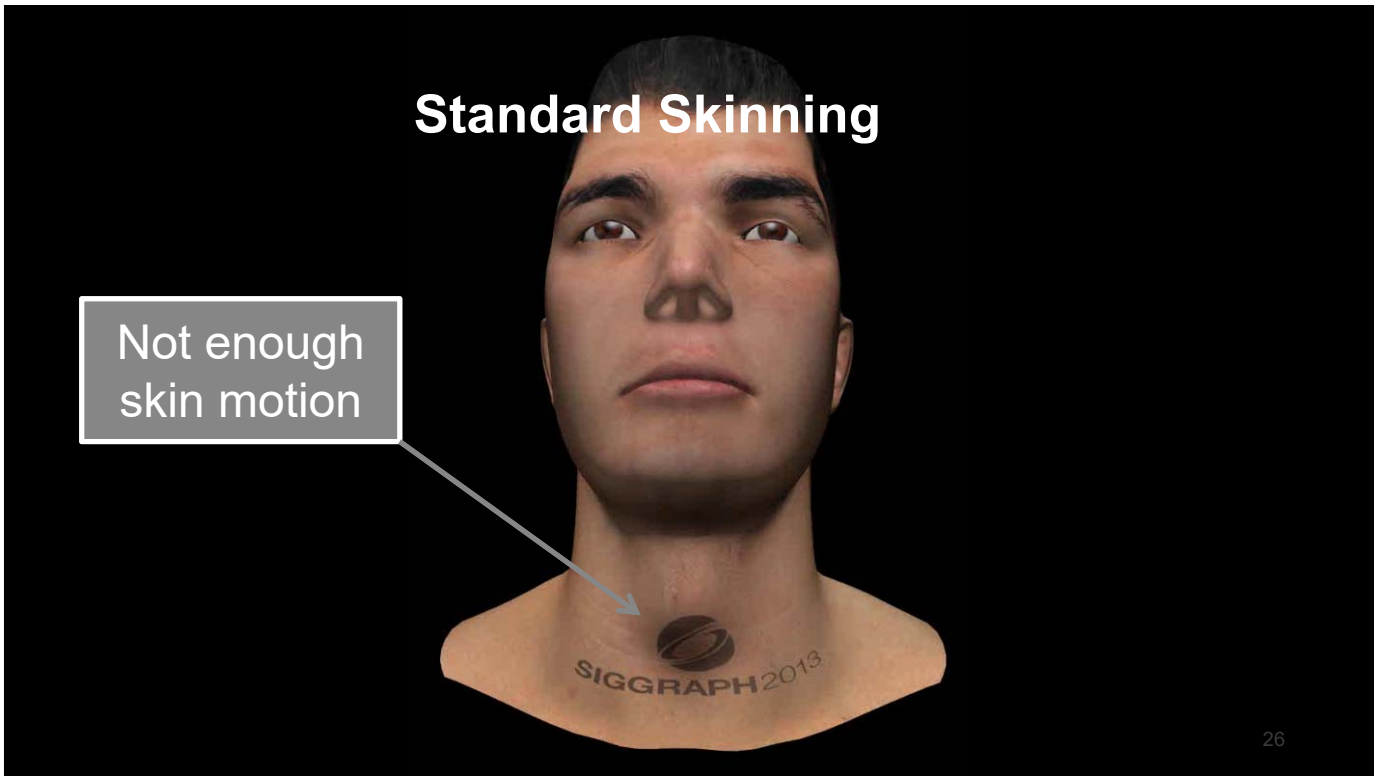
## Can simulate some deformities

- Swan neck deformity
- Boutonniere deformity

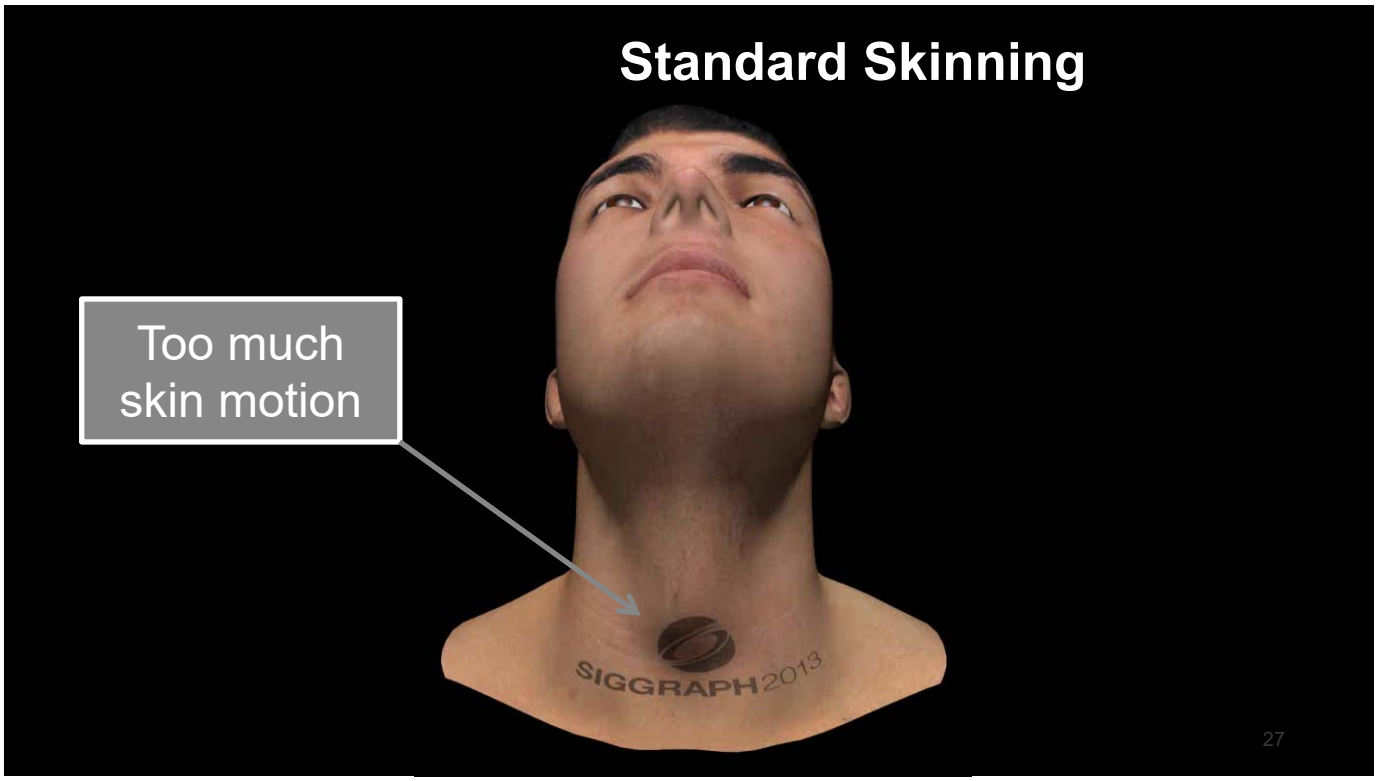


# Simulating Skin

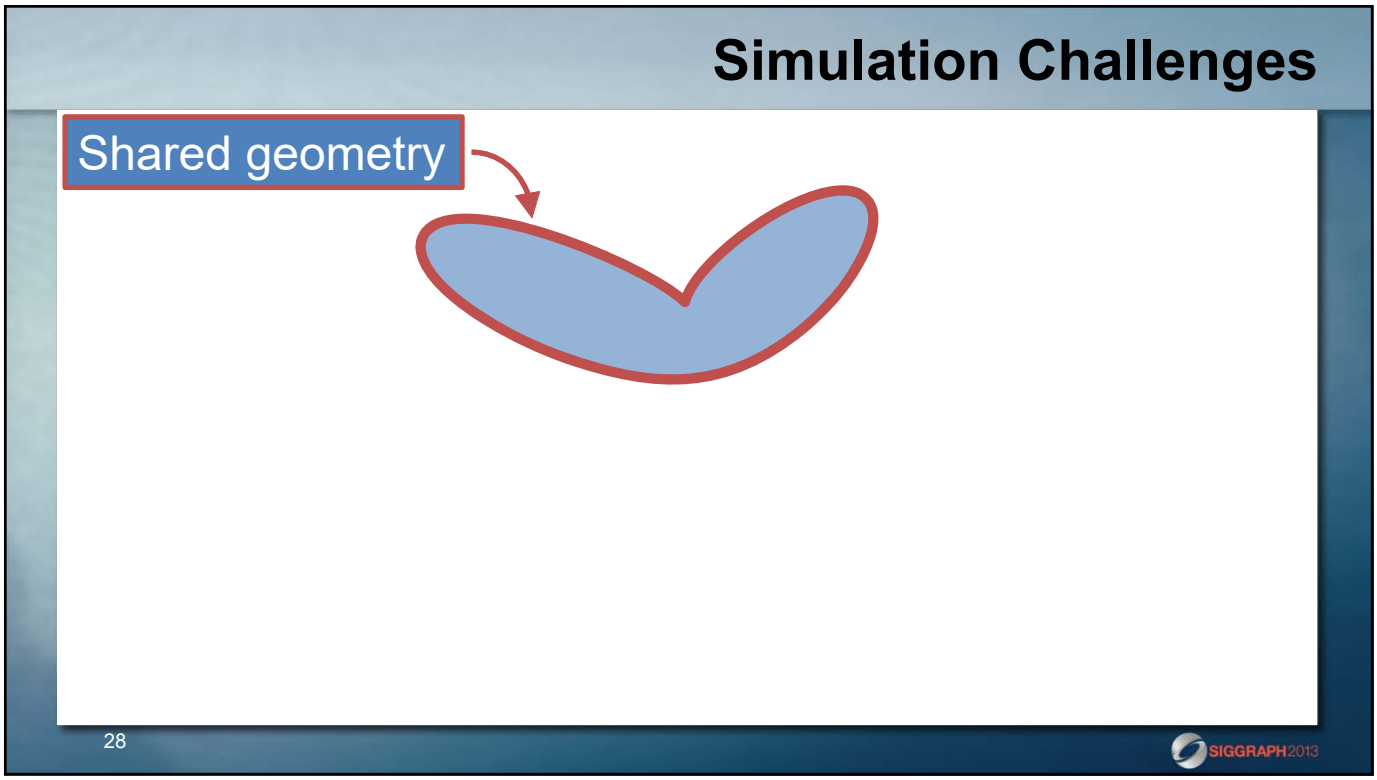
[Li, Sueda, Neog, Pai SIGGRAPH 2013]
[Neog, Cardoso, Ranjan, Pai Web3D 2015 (best paper)]



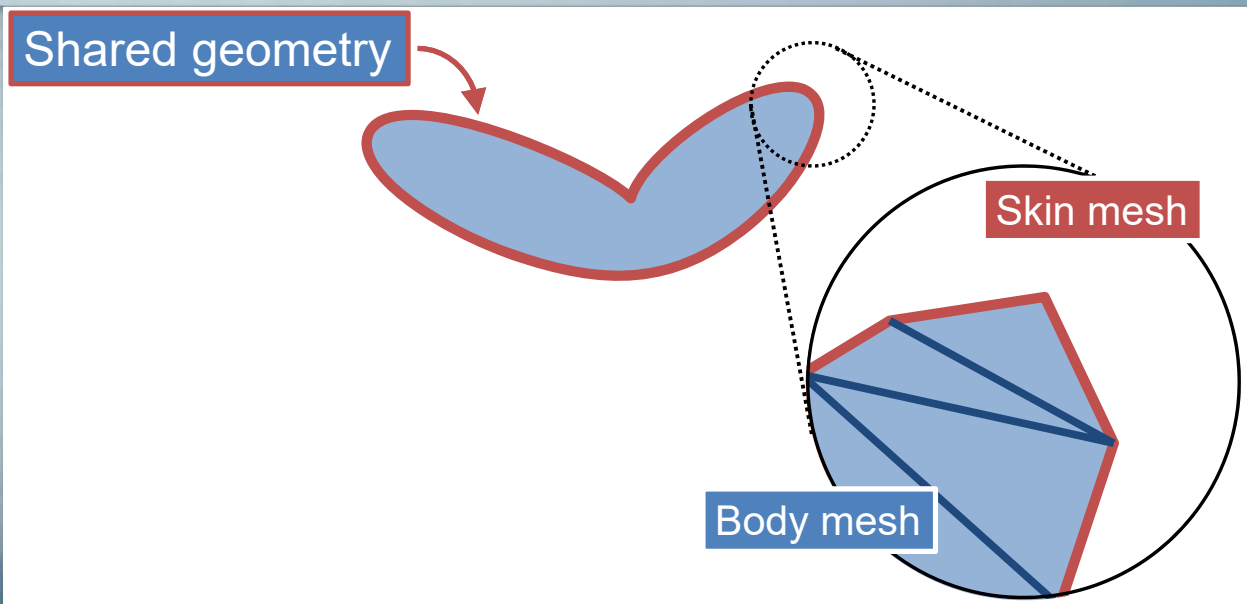
## Standard Skinning




## Simulation Challenges



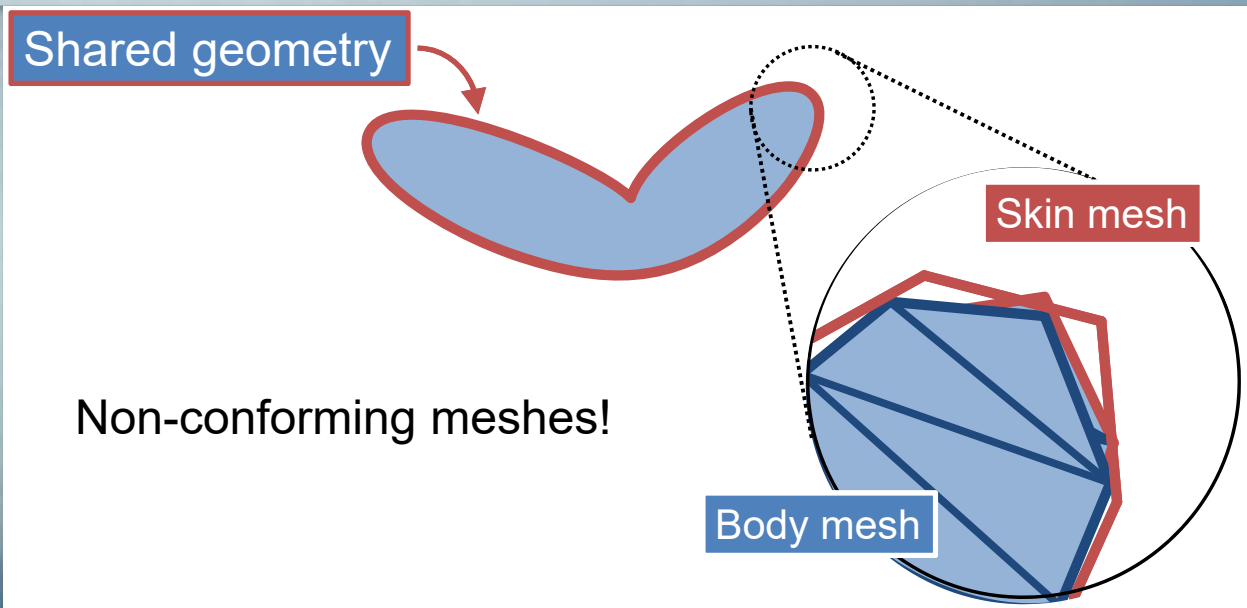
## Simulation Challenges




29

SIGGRAPH2013

## Simulation Challenges




Non-conforming meshes!

30

SIGGRAPH2013

## Human Head Movements



31

## Translating Ideas to Innovations

- Initially funded by NSERC I2I Phase 1 grant
- Spun off startup: Vital Mechanics Research Inc.
  - Currently in ICICS Hatch incubator

Simulation corrects unrealistic skin movement around joints.

## VitalSkin used in Fantastic Beasts


## Skin Capture: Estimating the Physical Properties of Human Skin

Austin Rothwell, Pearson Wyder-Hodge, + many others in Sensorimotor Systems Lab

# Motivation

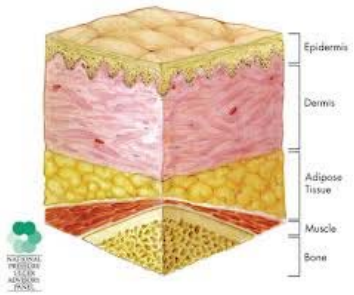
- Human Tissue is a heterogeneous, anisotropic, viscoelastic, non-linear material making it difficult to model
- Being able to accurately model human tissue is important:

**Clinical**

- Surgery
- Diagnosis of disease
- Biomedical device design

**Graphics**

- Virtual surgery
- Gaming
- Cinema




37

# Measurement Based Model Fitting

Pai et al., 2001

38

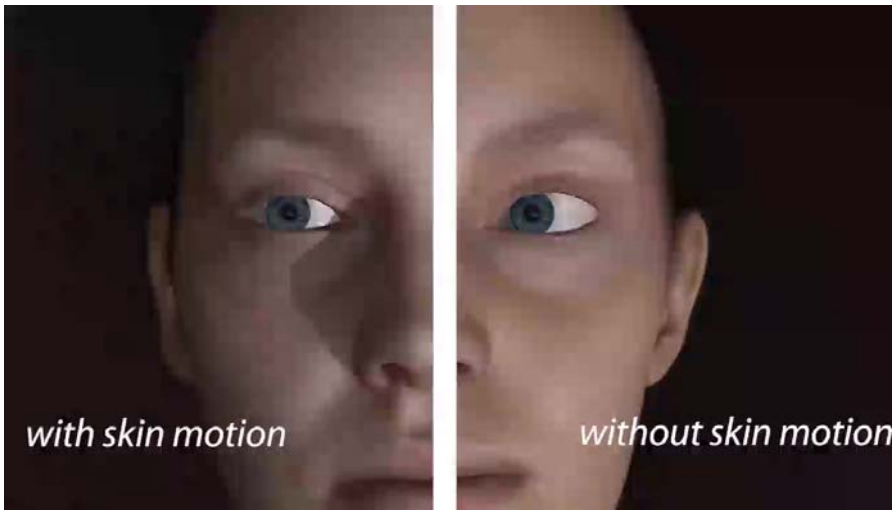
# Other projects in the lab

- Data-driven modeling of skin movement around the eyes
- Scientific Computing for human body simulation
- Perception of motion in VR
  - Oculus Rift DK2 with SMI eye tracker built in

39

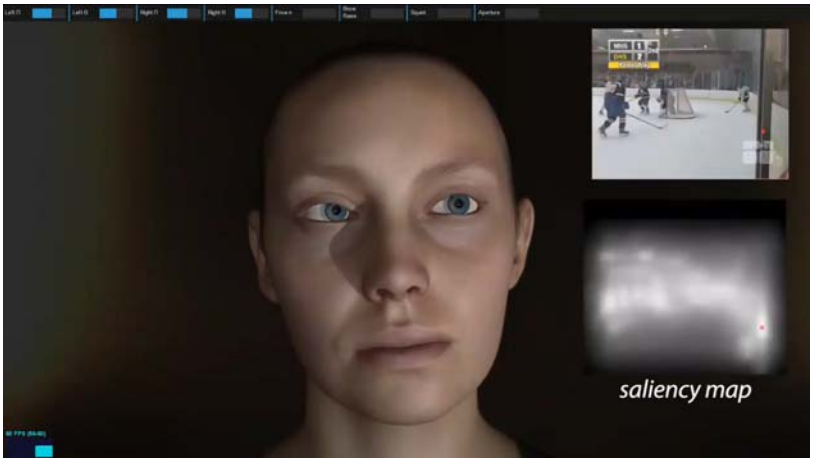
# Simulating Skin Around the Eyes

**Neog, Cardoso, Ranjan, Pai, Web3D 2016 (Best Paper Award)**




40

# Application to Interactive Animation




You can try the application in a browser at
http://www.cs.ubc.ca/research/eyemoveweb3d16/

41

# To learn more

- Get involved in projects in research labs
  - Contact me if you're interested in getting involved in current topics
- CS offers both 4th year and grad courses in graphics
- Huge Opportunity: SIGGRAPH is coming to Vancouver!!


42

## Term 2 Grad Course

- CPSC 530P Sensorimotor Computation
  MW 13:30-15:00 Dempster 101
- Focus on modeling and simulation of biomechanical systems (soft tissues, musculoskeletal systems, skin, etc.).
- Also a (gentle?) introduction to physically based modeling and numerical simulation methods that are useful in computer animation and robotics

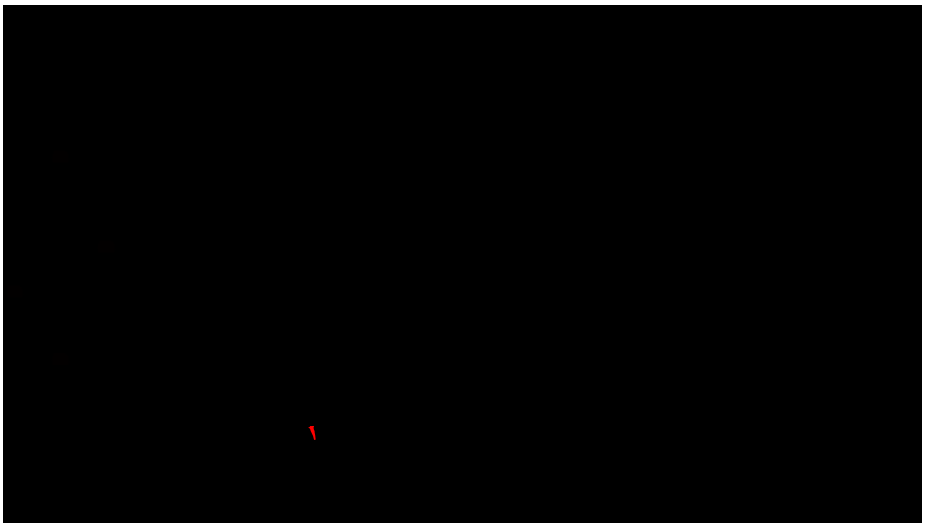
43

## In Lecture 1, I said:

- *The following are essential for success*
  - *good grasp of linear algebra*
  - *exposure to calculus; "mathematical maturity"*
  - *programming experience in C++*
- *This is not an easy course!*

44

## Yet, you chose to stick with it :-)



45

## All the best for the finals
## and
## Happy Holidays!

46