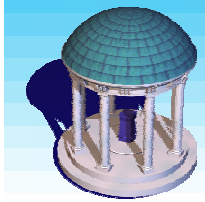
Development of Games
Appendix 1 to lecture 18

Physically-based Facial Modeling

COMP 259

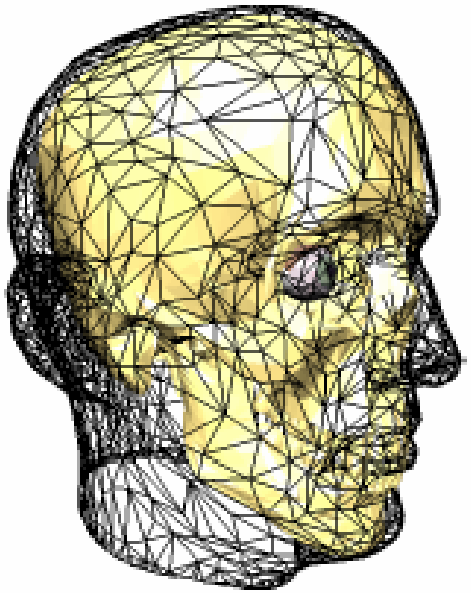
Spring 2006

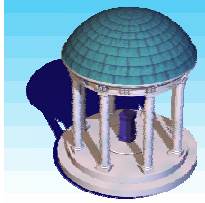
Ming C. Lin



Overview

- Motivation
- Facial Anatomy
- Historical view
- Techniques
  - Traditional animation
  - Muscle-vector techniques
  - Mass-spring + muscles
  - Finite-element + muscles
- An aside: speech



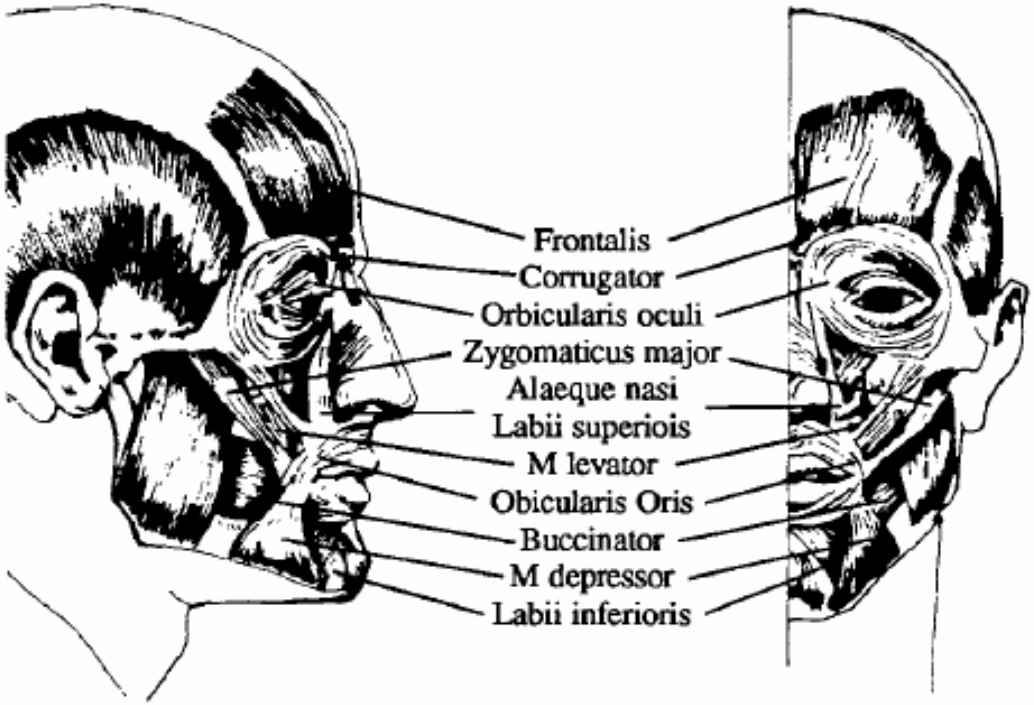


Motivation

- **Why a talking head?**
  - ♦ **Enhanced communication for people with disabilities**
  - ♦ **Training scenario software**
  - ♦ **Entertainment: Games and Movies**
- **Why physically based?**
  - ♦ **Unburdens animators**
  - ♦ **Provides more realistic looking simulations**

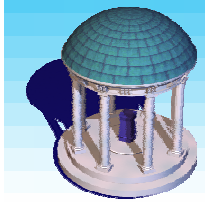
Anatomy of the face

- **There are 268 voluntary muscles that contribute to your expression!**



Three main types:

- **Linear muscles (share a common anchor)**
- **Sheet muscles (run parallel, activated together)**
- **Sphincter muscles (contract to a center point)**

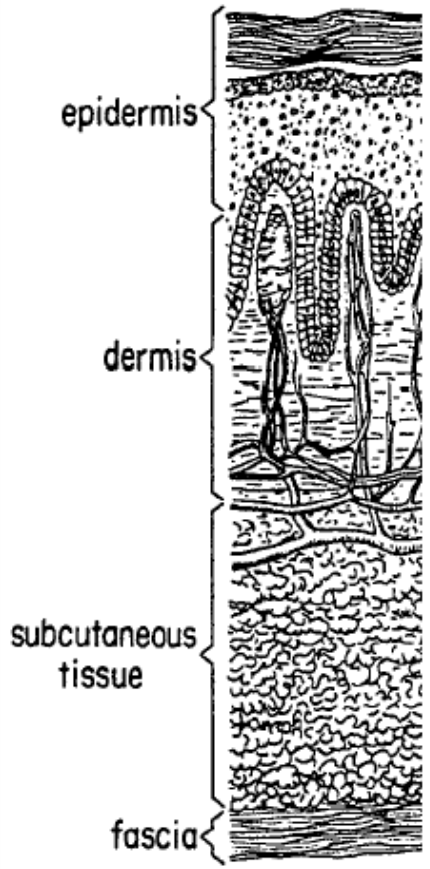


Muscles

- **Bundles of thousands of individual fibers**
  - **Thankfully, can be modeled as these bundles**
  - **When activated, all of the fibers contract**
- **Contraction only**
  - **Most parts of the body use opposing pairs of muscles, but the face relies on the skin**
- **Bulging**
  - **Occurs due to volume preservation**
  - **Thicker on contraction, thinner on elongation**
  - **Important for realistic faces (e.g. pouting lips)**

Skin

- **Epidermis**
  - ♦ Thin, stiff layer of dead skin
- **Dermis**
  - ♦ Primary mechanical layer
  - ♦ Collagen and Elastin fibers
- **Subcutaneous or Fatty tissue**
  - ♦ Allows skin to slide over muscle bundles
  - ♦ Varies in thickness

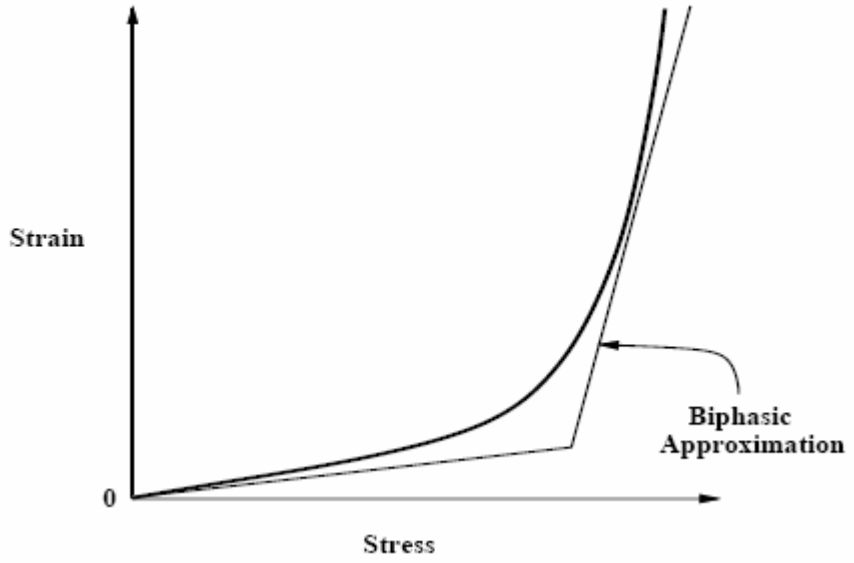


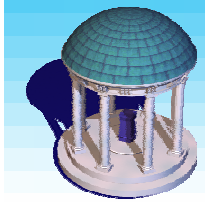
Modeling viscoelastic skin

- Collagen fibers - low strain for low extensions
- Near maximum expansion, strain rises quickly
- When allowed to, elastic fibers return system to rest state quickly

Biphasic model:

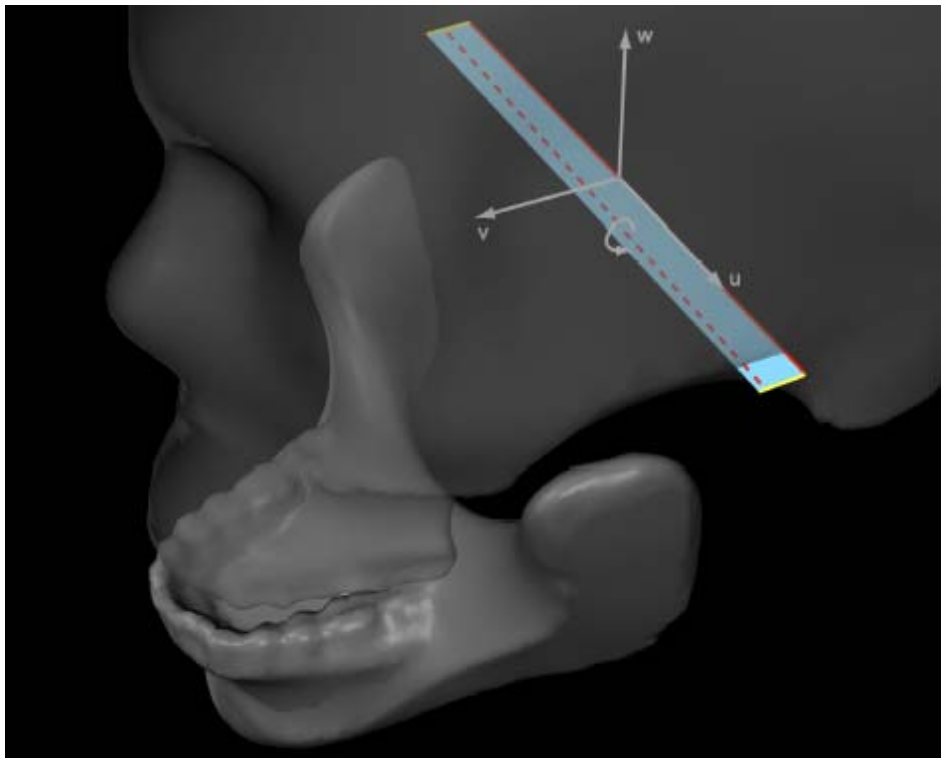
- Two piecewise linear modes
- Threshold extension to pick spring constant

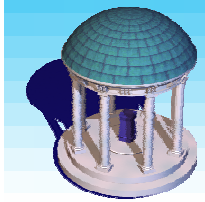




The skull

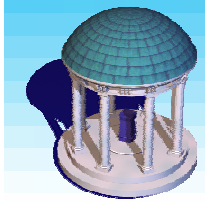
- Unlike most of the body, the face only has a single joint
- All other expression is due to computer-unfriendly soft tissues
- Can be treated as a rigid body





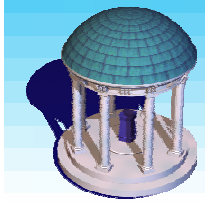
Facial Action Coding System (FACS)

- Proposed by Ekman and Friesan in 1978.
- Describes facial movement in terms of the muscles involved
- Purposely ignores invisible and non-movement changes (such as blushing)
- Defines 46 action units pertaining to expression-related muscles
- Additional 20 action units for gross head movement and eye gaze.



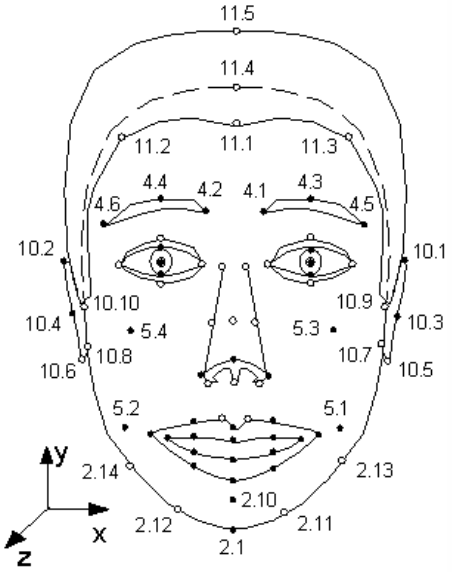
Traditional techniques

- **Key-framing**
  - ♦ Extremely fast
  - ♦ Extremely hard to model appropriately
  - ♦ Large storage footprint
  - ♦ Basically never used to edit faces, but works as a final format, especially for games
- **MPEG-4 approach**
  - ♦ Defines 84 feature points with position and zone of influence on a few basis keyframes of a standard 3D mesh
  - ♦ Defines animation independently of the visual rep.

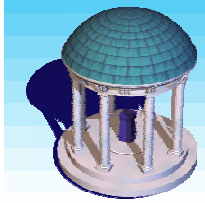


MPEG-4 Facial Animation

- **68 facial action parameters (FAPs), defined in terms of face independent FAP units (FAPUs)**
- **Most define a rotation or translation of one or more feature points, with a few selecting entirely new key frames (e.g. an emotion basis)**
- **Same animation can be used on different model, provided the model is properly annotated**

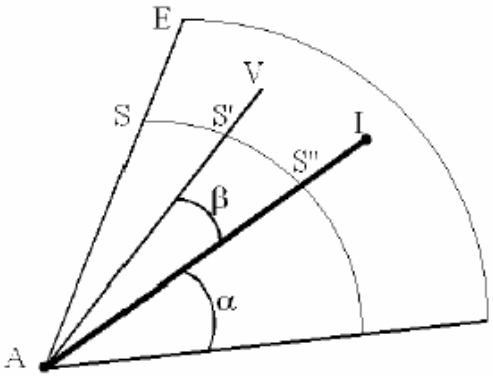


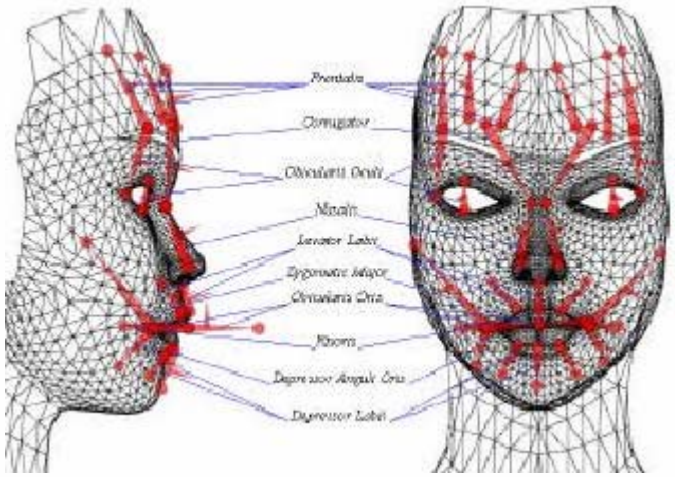
Some MPEG-4 feature points

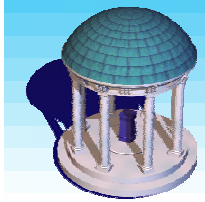


Muscle vectors

- **Muscle vector properties**
  - ♦ **Attachment point (to bone)**
  - ♦ **Insertion point (to skin)**
- **Influences nearby skin vertices, more strongly along the direction vector and close to the muscle.**

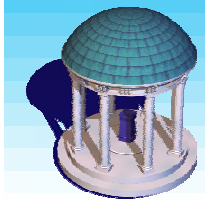






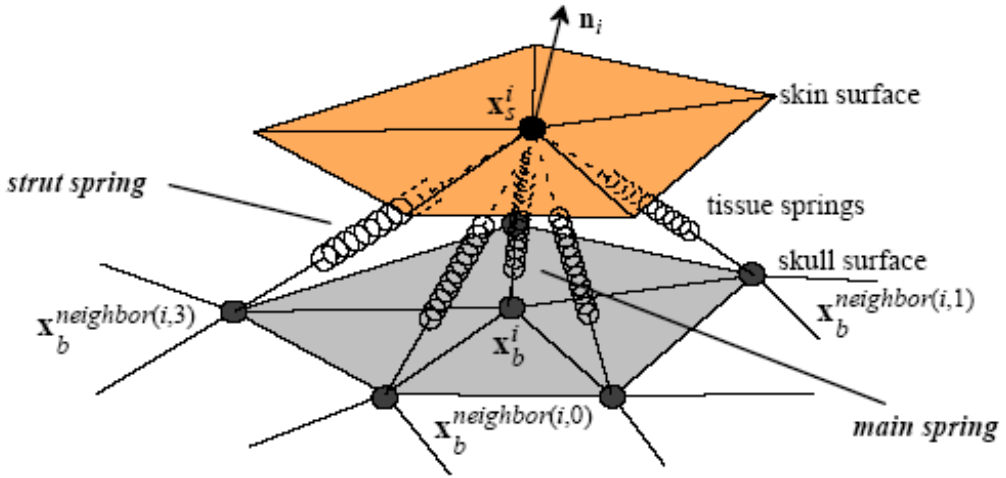
Muscle vectors (2)

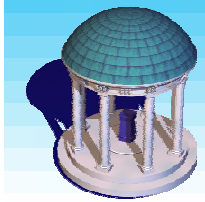
- **Advantages**
  - **Fast**
  - **Compact, easily controlled**
- **Disadvantages**
  - **Treats the skin like a 2D surface, no concept of curvature**
  - **Artifacts when vertices are within two influences**
- **For more information, see Jason Jerald's slides from 2004 (on course website)**



Mass-spring models

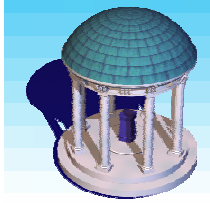
- **Model the skin (and sometimes muscle and bones) as a number of point masses connected by springs, like a cloth**



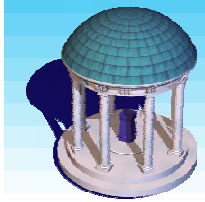


Terzopoulos and Waters

- **Terzopoulos90 models the entire face as a three-layer mass-spring system**
- **Horizontal layers and interconnects:**
  - **Epidermis**
  - **Fatty tissue**
  - **Underlying bone.**
- **Vertical interconnects:**
  - **Top-to-middle springs correspond to the dermis**
  - **Middle-to-bottom springs provide the simulation of muscle fibers.**

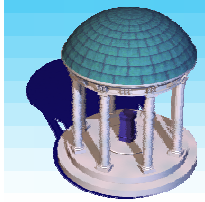


Terzopoulos and Waters (cont)



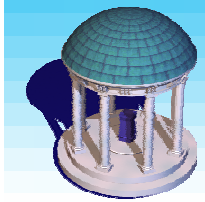
Terzopoulos and Waters (cont)

- Simplifies implementation: everything is handled in a single system
- Fast: interactive rates in 1990 (not on a desktop PC)
- Provides some wrinkle effects
- Unrealistic model of muscles and bone
- Cannot control via muscle activations

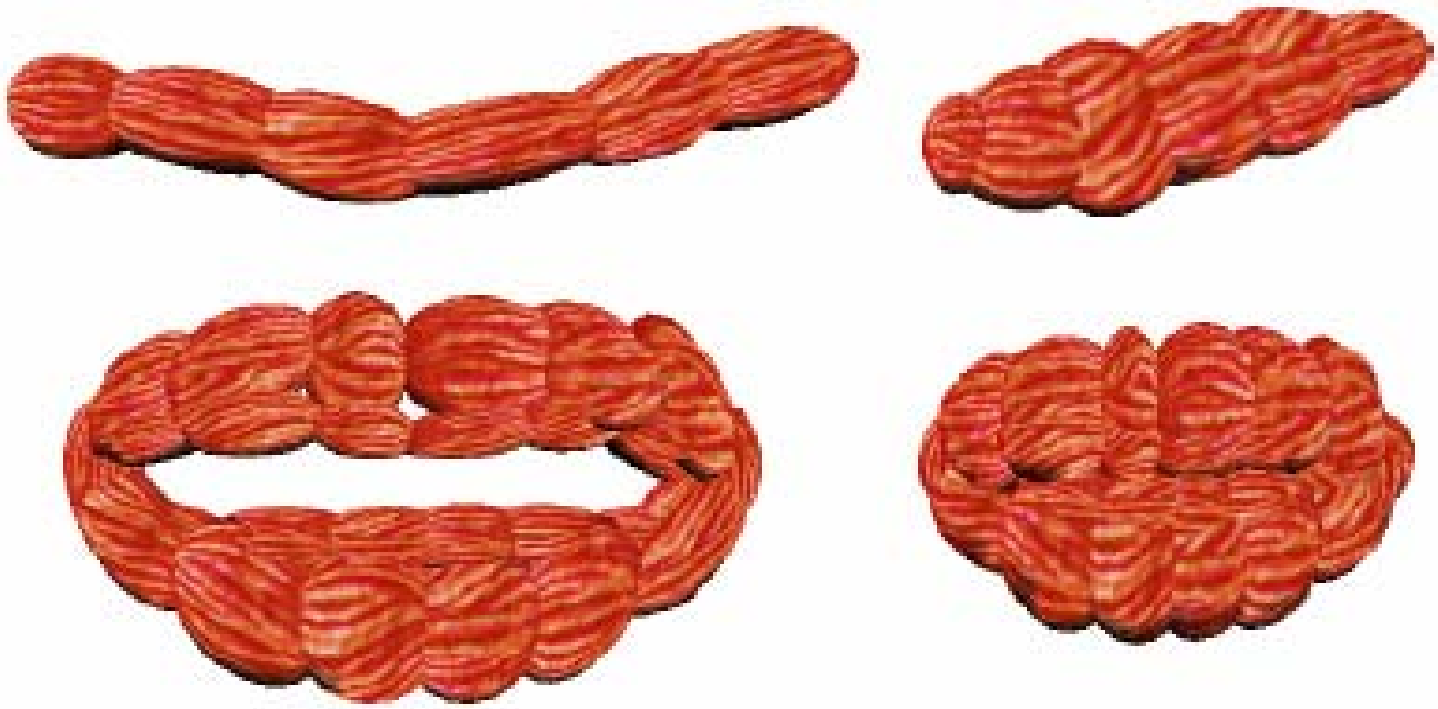


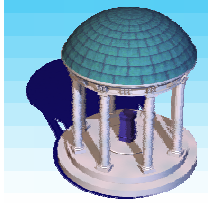
Kähler, *et al.*

- Model the muscles as ellipsoids
- Long or curved muscles are broken into piecewise linear segments
- Scale the diameter as length changes to implement bulging in a nearly volume-preserving manner.

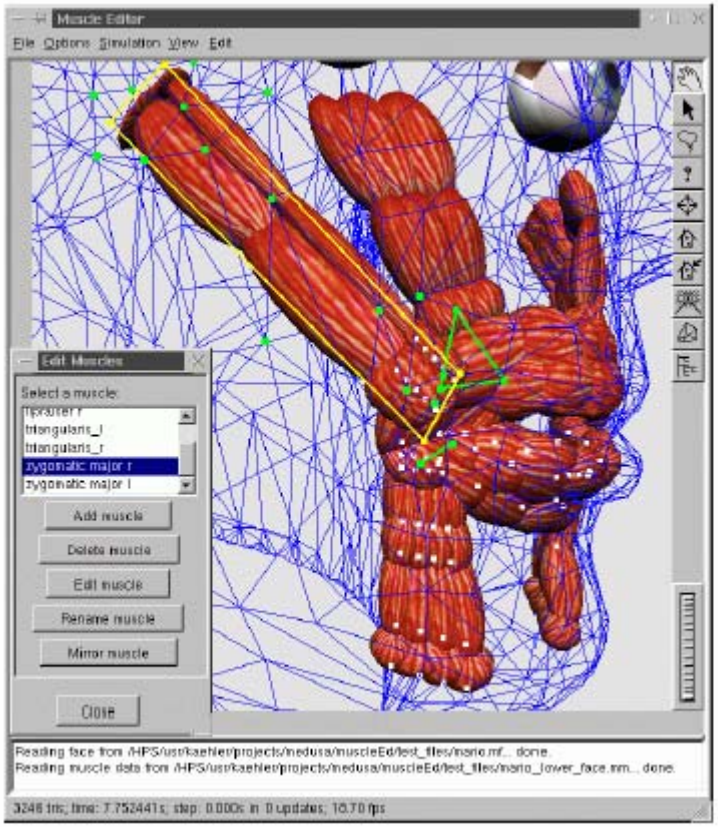


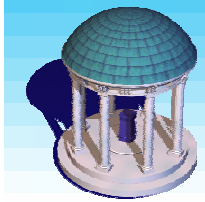
Kähler, *et al.*





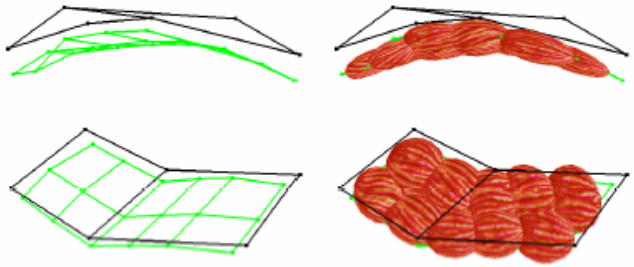
Kähler, *et al.*

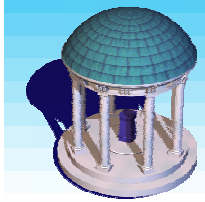

Muscle Editor
File Options Simulation View Edit
Edit Muscles
Select a muscle:
triangularis_l
triangularis_r
zygomatic major r
zygomatic major l
Add muscle
Delete muscle
Edit muscle
Rename muscle
Mirror muscle
Close
Reading face from /HPS/usr/kaehler/projects/medusa/muscleEd/test_files/mario.mf... done.
Reading muscle data from /HPS/usr/kaehler/projects/medusa/muscleEd/test_files/mario_lower_face.mm... done.



Kähler, *et al. - Editor*

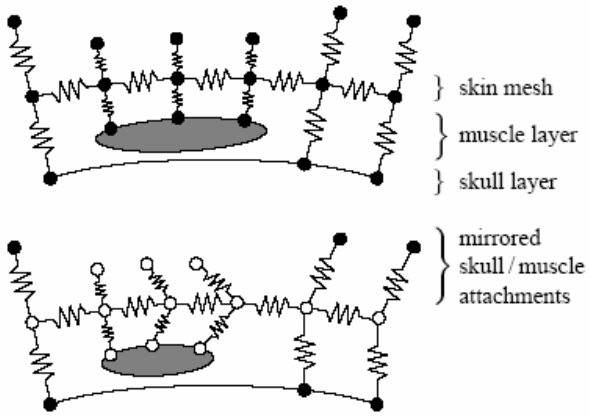
- **Also present an easy-to-use editor to define muscles**
  - **Provided a skin model, automatically creates skull**
  - **Users sketch sheets of muscles and they are iteratively subdivided into individual muscle chains of ellipsoids**
  - **Automatic fitting process to place the ellipsoids underneath the skin.**

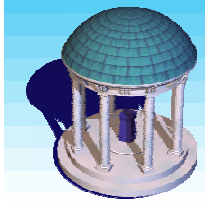




‘Preservation’ springs

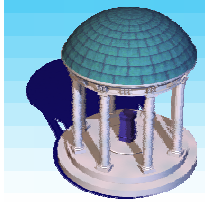
- To prevent interpenetrations, Kähler use preservation springs.
- Each skin-muscle and skin-bone attachment point gets a mirrored phantom preservation spring acting on it.
- Similar to penalty based approaches



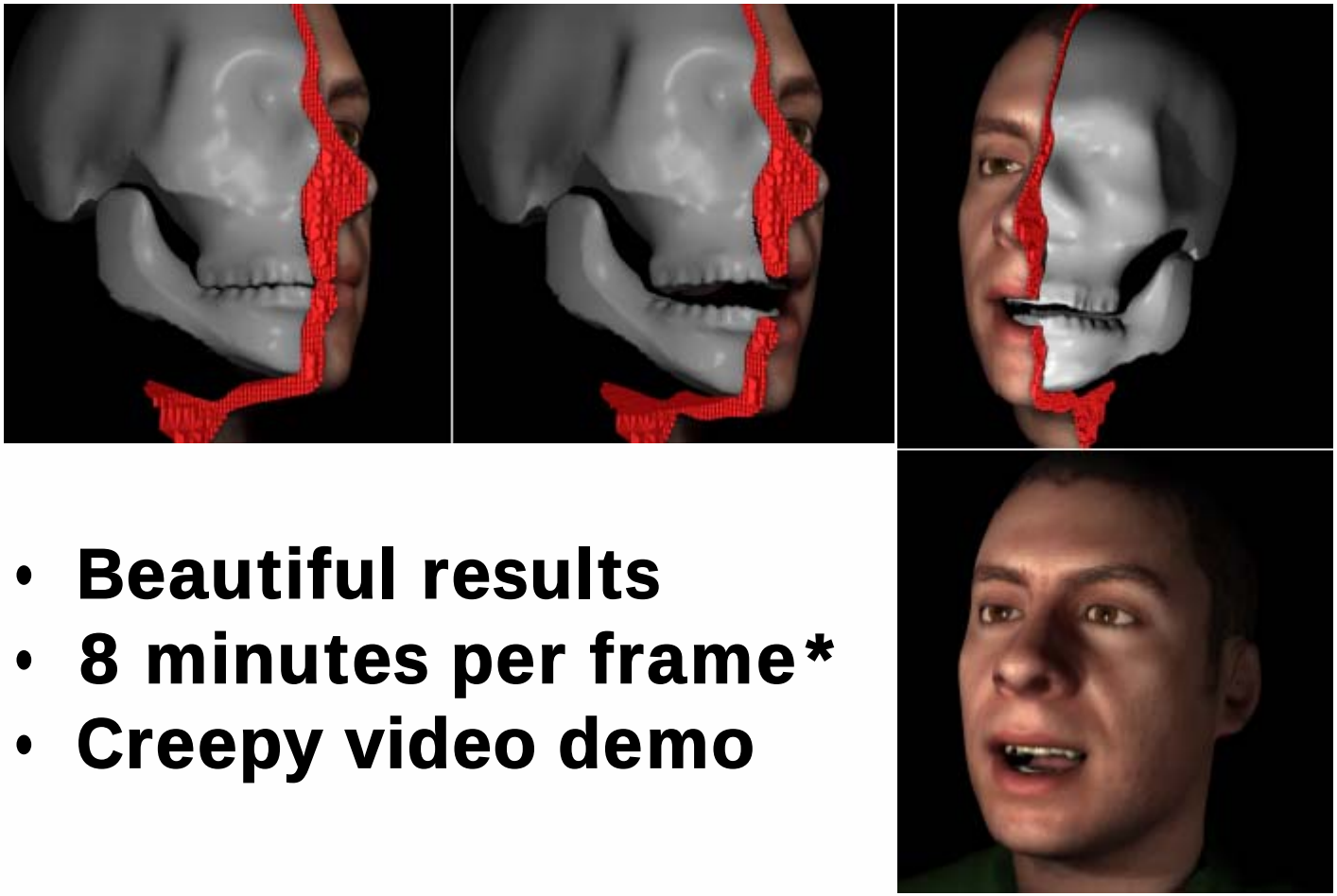


Finite-element models

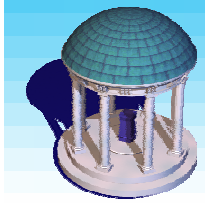
- Break the system down into a regular discretized representation (e.g. tetrahedrons)
- Comparison to mass-spring
  - ♦ More accurate
  - ♦ More stable
  - ♦ Far more expensive



Finite-element skin

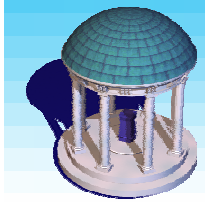


- **Beautiful results**
- **8 minutes per frame***
- **Creepy video demo**

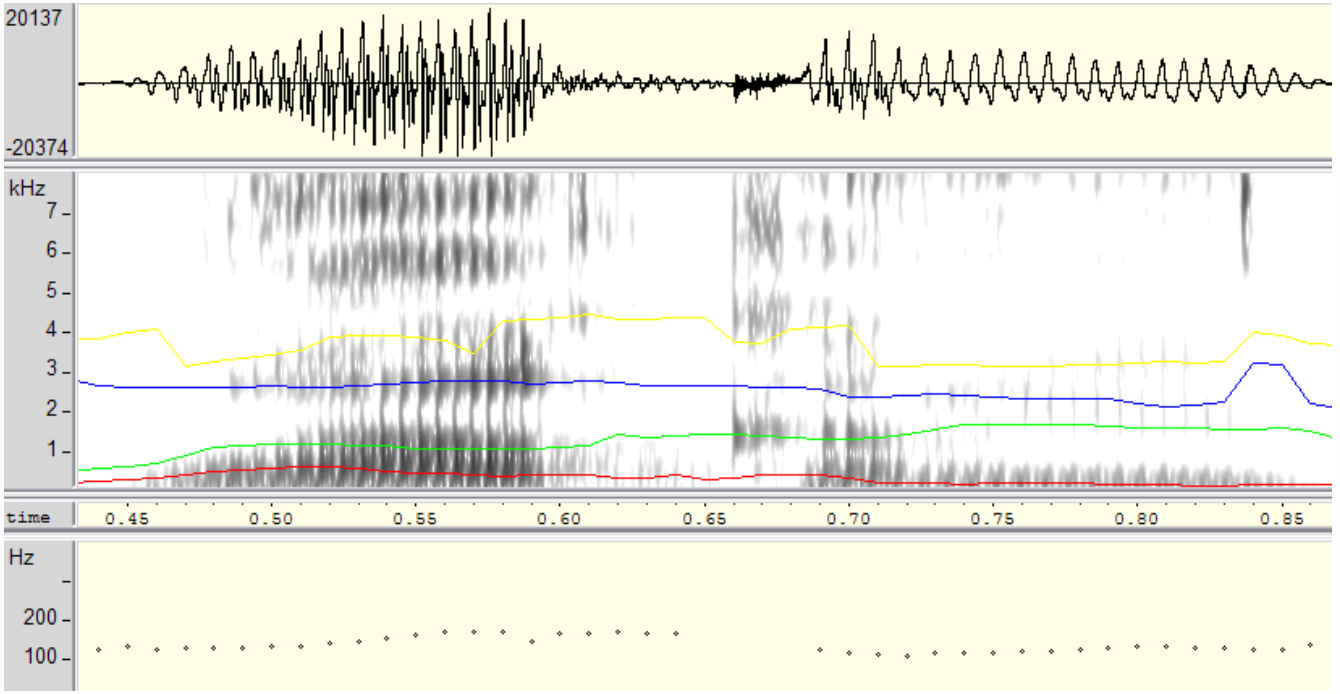


An aside: Speech

- Phones and phonemes: Unit of sound versus unit of perception
- English is considered to have 44 phonemes: 20 vowels and 24 consonants, less per dialect
- Distinguishing factors:
  - ♦ Place of articulation (teeth, lips, etc…)
  - ♦ Manner of articulation (flow rate, sort of)



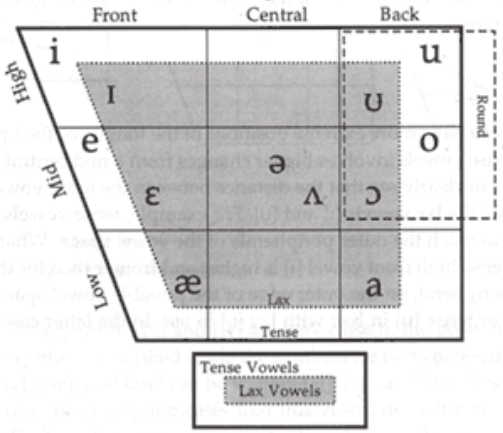
An aside: What is speech?



From top to bottom: Amplitude, spectrogram, timeline, and pitch contour, for the word "Welcome" (W EH L - K AH M)

Parts of speech

- **Not all changes are visible**
  - **Try saying ‘b’, ‘p’, ‘t’**
- **Concept of Visemes**
  - **Speech readers say 18**
  - **Disney says 12**
  - **Some games use 6**
- **Coarticulation**
  - **Or, why we don’t have good speech interfaces yet**

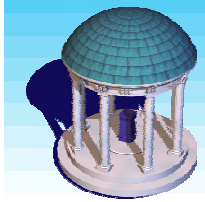


Vowels

Manner of Articulation	Place of Articulation: Bilabial	Labio dental	Inter dental	Alveolar	Alveo-palatal	Palatal	Velar	Glottal
Stop	p b			t d			k g	ʔ
Fricative		f v	θ ð	s z	ʃ ʒ			h
Affricate					tʃ dʒ			
Nasal	m			n			ŋ	
Lateral Approximant				l				
Retroflex Approximant				ɹ				
Glide	ʍ w					j		

State of the Glottis: Voiceless | Voiced

Consonants



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- D. Terzopoulos, Waters, K., Physically-Based Facial Modeling, Analysis, and Animation, The Journal of Visualization and Computer Animation, 1990
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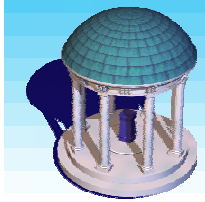

Video References

- http://graphics.stanford.edu/~fedkiw/