A MOVABLE JAW MODEL FOR THE HUMAN FACE

Uğur Güdükbay

University of Pennsylvania
Dept. of Computer and Information Science,
200 South 33rd Street
Philadelphia, PA 19104-6389

OUTLINE OF THE PRESENTATION

1. Introduction
2. Previous Work on Facial Animation
   - 2.1. Parametric Models
   - 2.2. Structure-Based Models
   - 2.3. Physics-Based Models
3. Face Modeling
4. Face Animation
   - 4.1. Face Skin Generation During Jaw Motion
   - 4.2. Spring Mass Equations
5. Simulation Examples
6. Conclusions and Future Work

1. INTRODUCTION

Human jaw has two widely separated identical joints behaving like a single joint.

This allows (to a limited extent) jaw to

- **translate** in any direction and/or
- **rotate** about any axis in 3D space.

Objective: *Develop a jaw model covering major motions of jaw.*

We model the face as a two-layer model:

- *Inner layer* moves kinematically as dictated by the jaw.
- *Outer layer* moves with the effect of springs connecting it to inner layer.

Motion of outer layer is calculated using *spring-mass* equations.

2. PREVIOUS WORK ON FACIAL ANIMATION

2.1. Parametric Models [Parke 82]

- A set of parameters (which are generally a group of vertices) are selected to represent shape of face.

- To give face different expressions, parameters are modified.

- To animate face, parameters are interpolated using interpolation techniques.

Advantages: Not computationally demanding.

Disadvantages:

- Very difficult to develop truly complete parameter sets.
- Parametric models are unable to blend expressions because of the localized effect of parameters controlled independently.
- They cannot be easily adapted to different face models.

2.2. **Structure-Based Models** [Platt 85]

- Face is represented as a hierarchically structured regionally defined object.

- Each region can be treated as a single functional block and face is a hierarcy of these regions connected in a natural manner.

- Based on this regional decomposition, and a set of primitive actions, an encoding of a large set of high level facial action descriptors is defined.

Advantages:

- *Descriptive Information* could be placed at high levels in the hierarcy and inherited by lower level regions.

- *Expressive Control*

  - an action affecting an entire region could be applied to entire region (and would propagate down to constituent regions),

  - an action affecting only portions of a region could be applied to those particular regions.

Disadvantages:

- Very difficult to obtain a true regional decomposition and to model interactions between these regions.
- Cannot produce very realistic results.
- Cannot be easily adapted to different face models.

2.3. **Physics-Based Models** [Terzopoulos and Waters 90]

- Physics-based models use physics-based quantities, such as *positions, velocities and forces*, to animate models.

- To model elastic properties of skin, *mass-spring systems* or *finite element networks* are used.

Terzopoulos and Waters model face as a trilayer spring-mass system.

Their model incorporates

- a physics-based approximation to facial tissue (a layered deformable lattice of point masses connected by elastic springs)

- a set of anatomically-motivated facial muscle actuators.

A numerical simulation computes large-scale tissue deformation by continuously propagating through lattice local stresses induced by activated muscle fibers.

Advantages:

- Produces most realistic results.
- Can be adapted to different face models [Lee et al. 95].

Disadvantages:

- Difficult to implement.
- Computationally demanding.

3. FACE MODELING

The face model is composed of

1. upper and lower jaw bones,

2. upper and lower teeth attached to jaw bones, and

3. a two-layer skin model.

Two-layer skin model composed of

1. *Inner layer:* attached to jaw bones and moves kinematically as dictated by jaw bones.

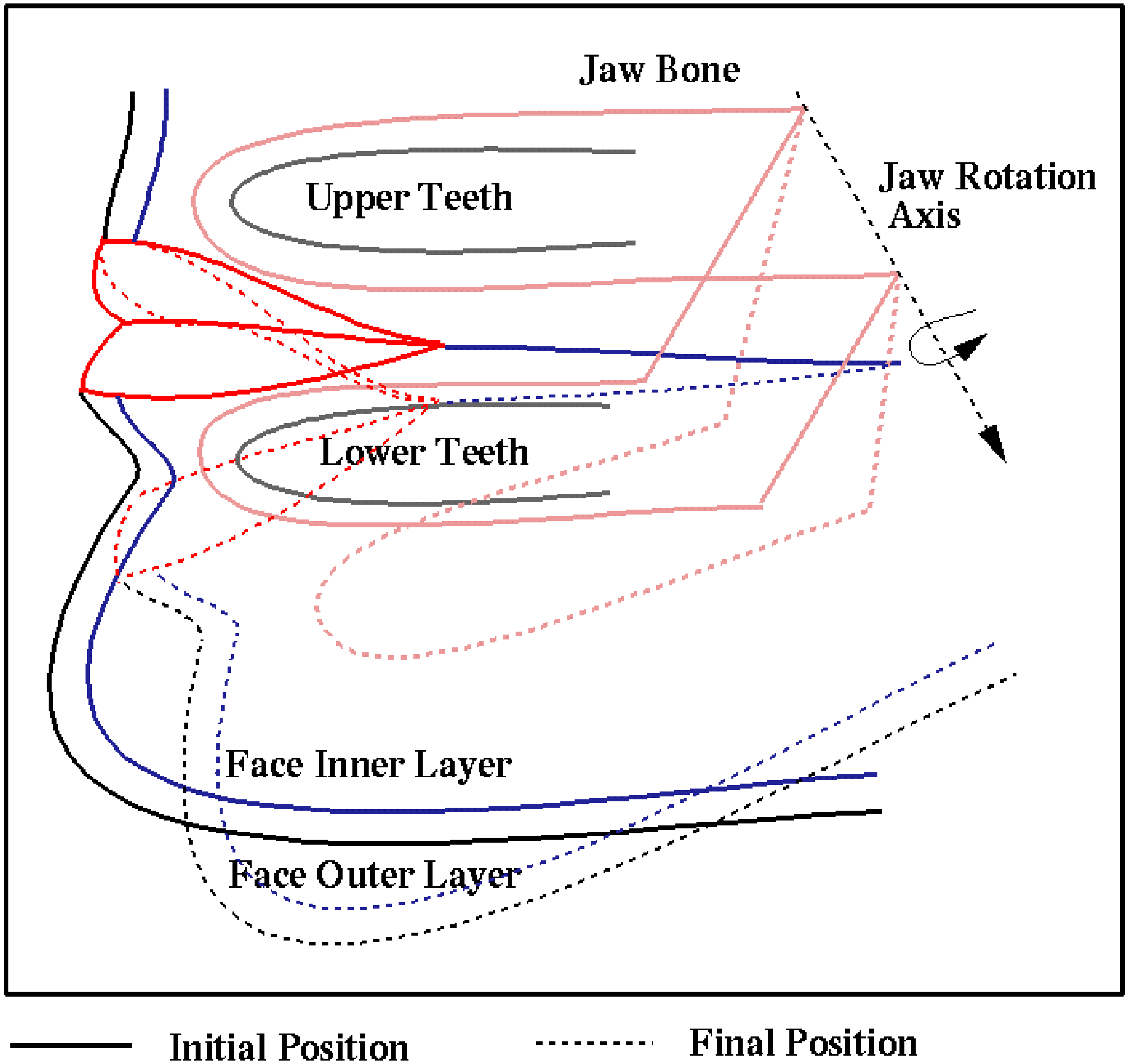
2. *Outer layer:* attached to inner layer with springs.

Each outer layer node is also attached to its neighbors with springs.

Jaw Model

We model the jaw as a joint which can

- rotate around the axis connecting two ends of jaw bone and
- make small translational motions.



A simplified view of two-layer face and jaw model

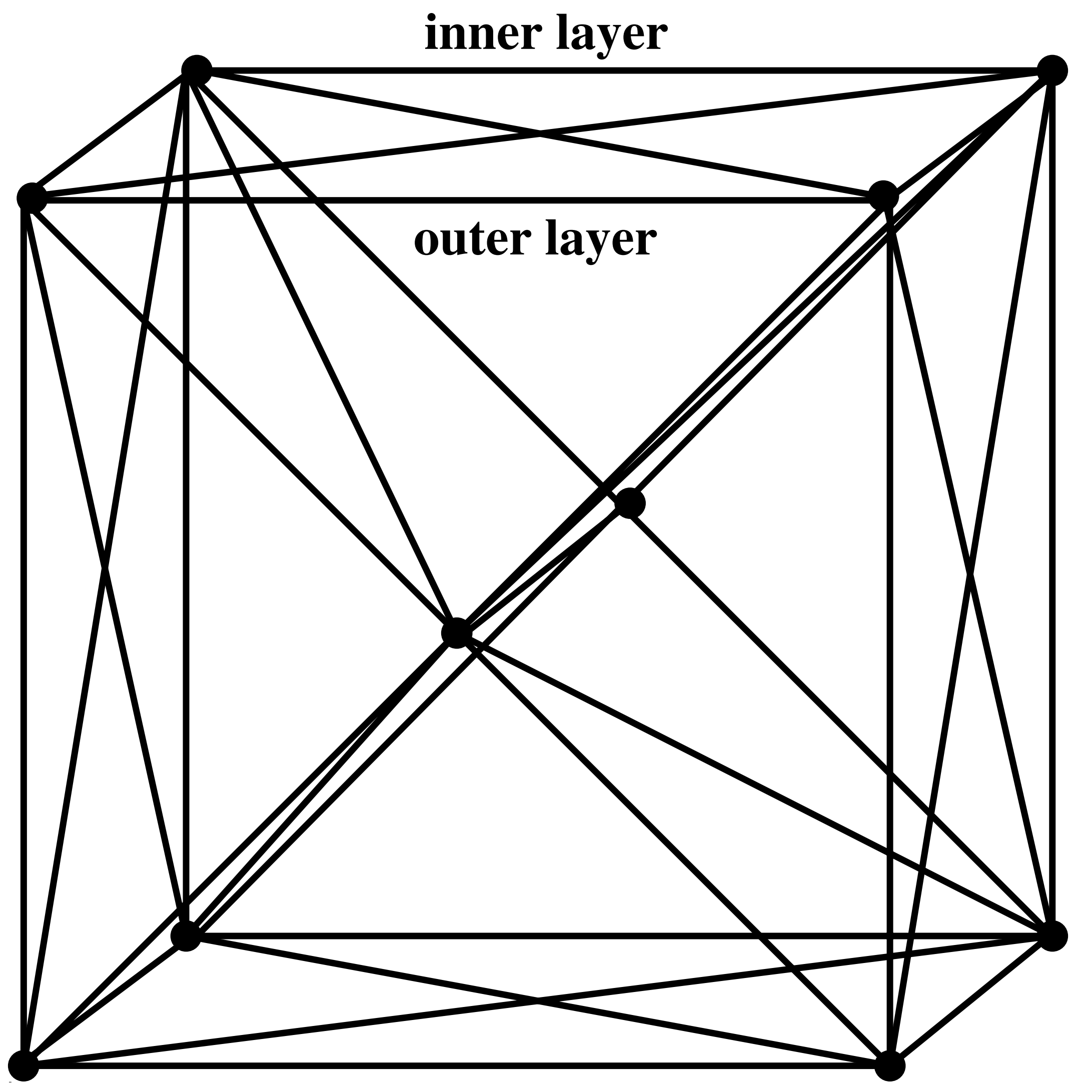
4. FACE ANIMATION

The inner layer is modeled as two pieces;

i) upper face   ii) lower face.

- When inner layer moves by the movement of the jaw bones, outer layer also moves as dictated by the springs between outer and inner layer nodes.

- The springs connecting outer layer nodes to their neighbors provide that outer layer (face skin) remains smooth and connected during jaw motion.



The spring connections between a skin point and its neighbors

4.1. Face Skin Generation During Jaw Motion

- When jaw moves kinematically for each time step of an animation, the inner layer also moves as dictated by the jaw.

- When lower part of inner layer moves as a rigid body, a gap occurs between upper and lower part of inner layer. This gap is closed by outer layer which is much like in real face.

- To generate face skin points during jaw motion, we form a spring-mass system on skin points.

- The outer layer points moves with the effect of springs until springs come to rest.

4.2. Spring Mass Equations

Equations of motion for outer layer in Lagrange's form:

$$\mathbf{M}\frac{d^2}{dt^2}\mathbf{x} + \mathbf{C}\frac{d}{dt}\mathbf{x} + \mathbf{f}_K(\mathbf{x}) = \mathbf{f}(\mathbf{x}) \tag{1}$$

where

$\mathbf{x}$ is position vector for model points (T denotes transpose):

$$\mathbf{x}^T = [\, \mathbf{x}_1^T \ \mathbf{x}_2^T \ \cdots \ \mathbf{x}_n^T \,] \tag{2}$$

where $\mathbf{x}_i$ represents the position vector of point i,

M is the *mass matrix*,

C is the *damping matrix*,

$\mathbf{f}(\mathbf{x})$ is the external force vector and

$\mathbf{f}_K$ is the vector of spring forces acting on model points to represent elastic properties.

The spring forces between a pair of particles at $\mathbf{a}$ and $\mathbf{b}$ are

$$\mathbf{f}_a = -k_s \frac{(||\mathbf{l}|| - r)}{||\mathbf{l}||} \mathbf{l} \ , \ \ \mathbf{f}_b = -\mathbf{f}_a \tag{3}$$

where

$\mathbf{f}_a$ and $\mathbf{f}_b$ are the forces on $\mathbf{a}$ and $\mathbf{b}$,

$\mathbf{l} = \mathbf{a} - \mathbf{b}$,

r is the spring rest length and

k_s is the spring constant.

The total spring force on a point i

$$\mathbf{f}_K(i) = \sum_{j \in \mathcal{N}_i} \mathbf{f}_{ij} + \sum_{k \in \mathcal{A}_i} \mathbf{f}_{ik} \tag{4}$$

where

$\mathcal{N}_i$ are neighbours of node i and

$\mathcal{A}_i$ are anchors of node i on the inner layer.

For each frame of an animation,

- jaw joint moves and inner layer moves as dictated by jaw.

- outer layer points moves to their new positions after a certain number of iterations of differential equation solver.

We integrate the system of differential equations using

- *Explicit Euler*,

- *Midpoint* and

- *Fourth Order Runge-Kutta*

methods with adaptive time-stepping.

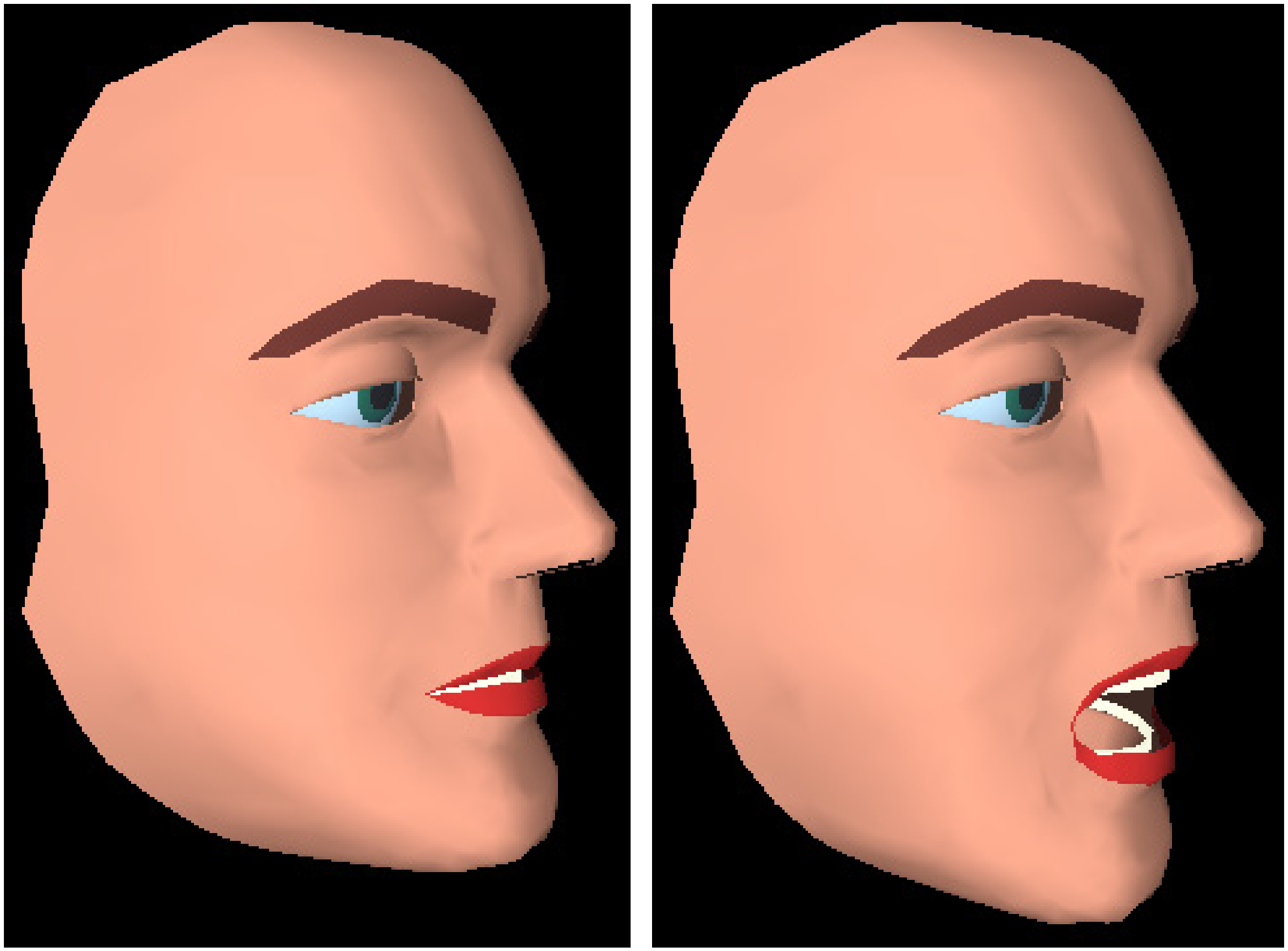
5. SIMULATION EXAMPLES

To simulate eating,

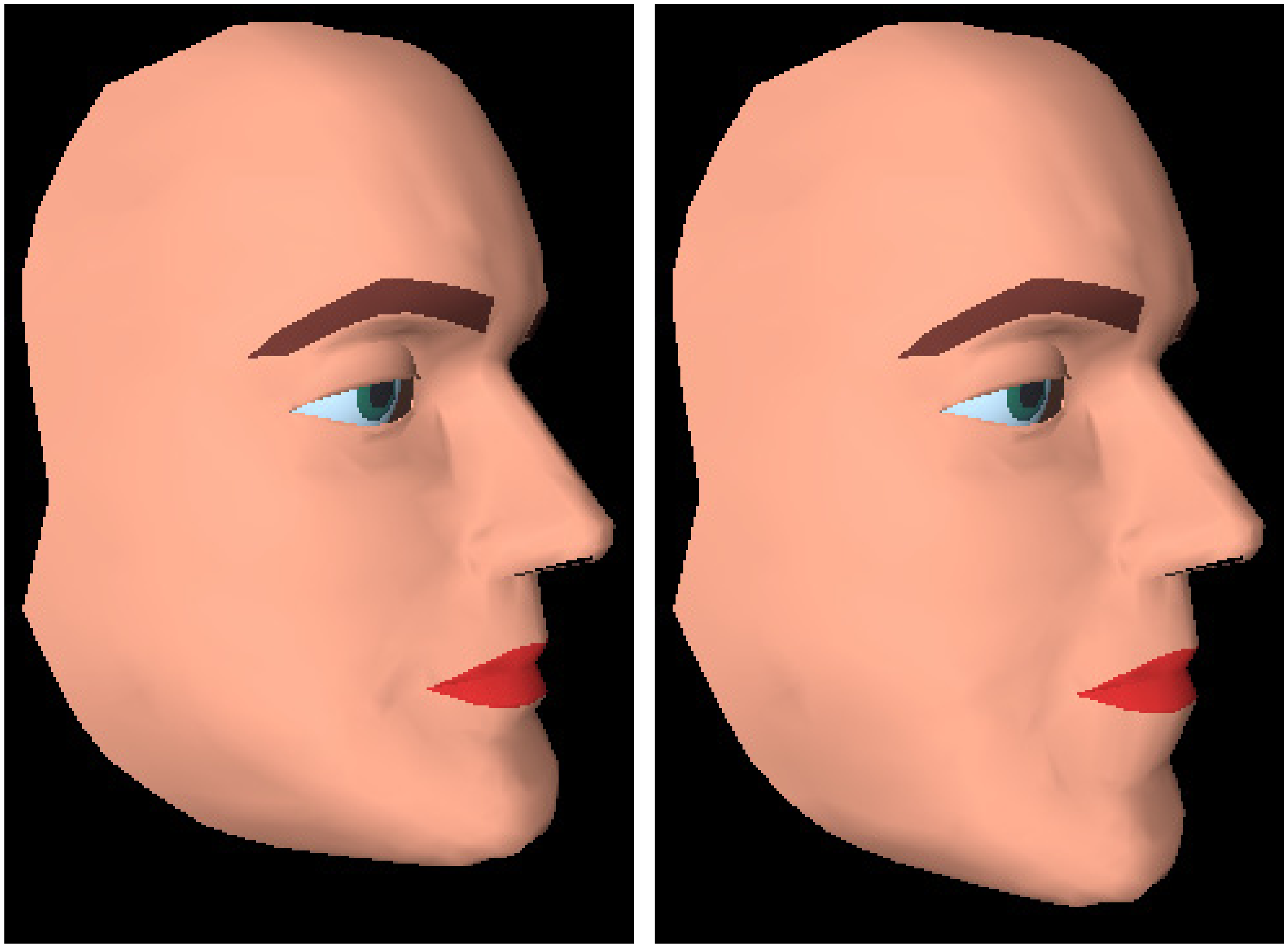
- mouth should be opened to take food mass into mouth and
- should be closed after taking food mass.

The main problem in simulating eating and chewing is

- to do appropriate jaw motions while mouth stays closed and
- face skin connected and realistic.



Initial and final appearance of face during jaw motion (open mouth)



Initial and final appearance of face during jaw motion (closed mouth)

6. CONCLUSIONS AND FUTURE WORK

We propose a movable jaw model for human face to simulate eating and chewing behaviors.

Future Work

- *Arm motions* could be simulated for insertion of food into mouth (feeding).

- *Material properties of food* could be simulated. Different foods have different elasticity, stickiness and viscosity.

- *Food mass reduction* during chewing could be simulated.

- *Swallowing motions* could be simulated by adding a throat to the model.