ECE160 / CMPS182
Multimedia

Lecture 15: Spring 2008
Animation of Humans

Dead Week Lectures

- Thursday, June 5, is Capstone Day
- There are no ECE160 Lectures on
  June 3 or June 5.
  Next week's lectures are the last lectures.

Simulating Human Motion

- **People are skilled at perceiving the subtle details of human motion. We can, for example, often identify friends by the style of their walk when they are still too far away to be recognizable otherwise.**
- **If synthesized humans in computer animations and virtual environments are to be compelling, they must appear realistic when they move.**
- **The kinematics and dynamics of the figure as well as control algorithms influence the way that the figure performs.**
- **Algorithms allow a rigid-body model of a man or woman to stand, walk, run at a variety of speeds, and to perform gymnastic vaults.**
- **The rigid-body models of men and women are realistic in that their mass and inertia properties are derived from data in the biomechanics literature, and the degrees of freedom of the joints are chosen so that each behavior can be completed in a natural-looking fashion.**

Simulating Human Motion

- **Although various behaviors are very different in character, the control algorithms are built from a common toolbox:**
- **State machines enforce a correspondence between the phase of the behavior and the active control laws**
- **Synergies cause several degrees of freedom to act with a single purpose**
- **Limbs without required actions in a particular state are used to reduce disturbances to the system**
- **Inverse kinematics compute the joint angles that cause a foot or hand to reach a desired location**
- **Low-level control is performed with proportional-derivative control laws.**

Tracking and Modifying Human Motion Data with Dynamic Simulation

- Subtle details in the motion of animated, humanlike characters affect the believability, aesthetic and impact of an animation or virtual environment.
- Human motion capture produces characters with rich detail in their motion but the data is difficult to modify for new characters and situations.
- Dynamic simulation generates physically correct motion for characters that can respond interactively in a changing environment. However, the controllers required for simulated characters are difficult to construct because we do not know how to specify the details of human motion procedurally.
- Use dynamic simulation to track and modify motion capture data of human movements.
- Combining simulation and motion capture can retain the interactivity and realism of dynamic simulation, and the subtle details of the human motion while avoiding the disadvantages of each approach.

Tracking and Modifying Human Motion Data with Dynamic Simulation

- This interactive 3D model animates a normal adult male gait.
- A video motion capture system at a medical research laboratory collected the data.
- Human Gait Analysis with motion capture video systems and interactive 3D modeling systems can help doctors analyze, diagnose, and document aberrant gaits with tools that compare the gaits of patients before and after treatment to historical case studies of normal and abnormal gaits.

Basic Tracking

- **Use motion capture data as the desired inputs to a tracking controller for a dynamic simulation of the character.**
- **The simulation is created using the mass, moment of inertia and limb lengths of the animated character.**
- **Thus, the generated motion is physically correct for that character.**
- **Driven by the tracking controller, the simulation follows the input motion with similar trajectories, thereby maintaining the style of the human data.**
- **A collision handler generates realistic dynamic impacts, such as a hand hitting the head of a drum. The dynamic model applies reaction forces and the hand collides with the drum in a believable way.**

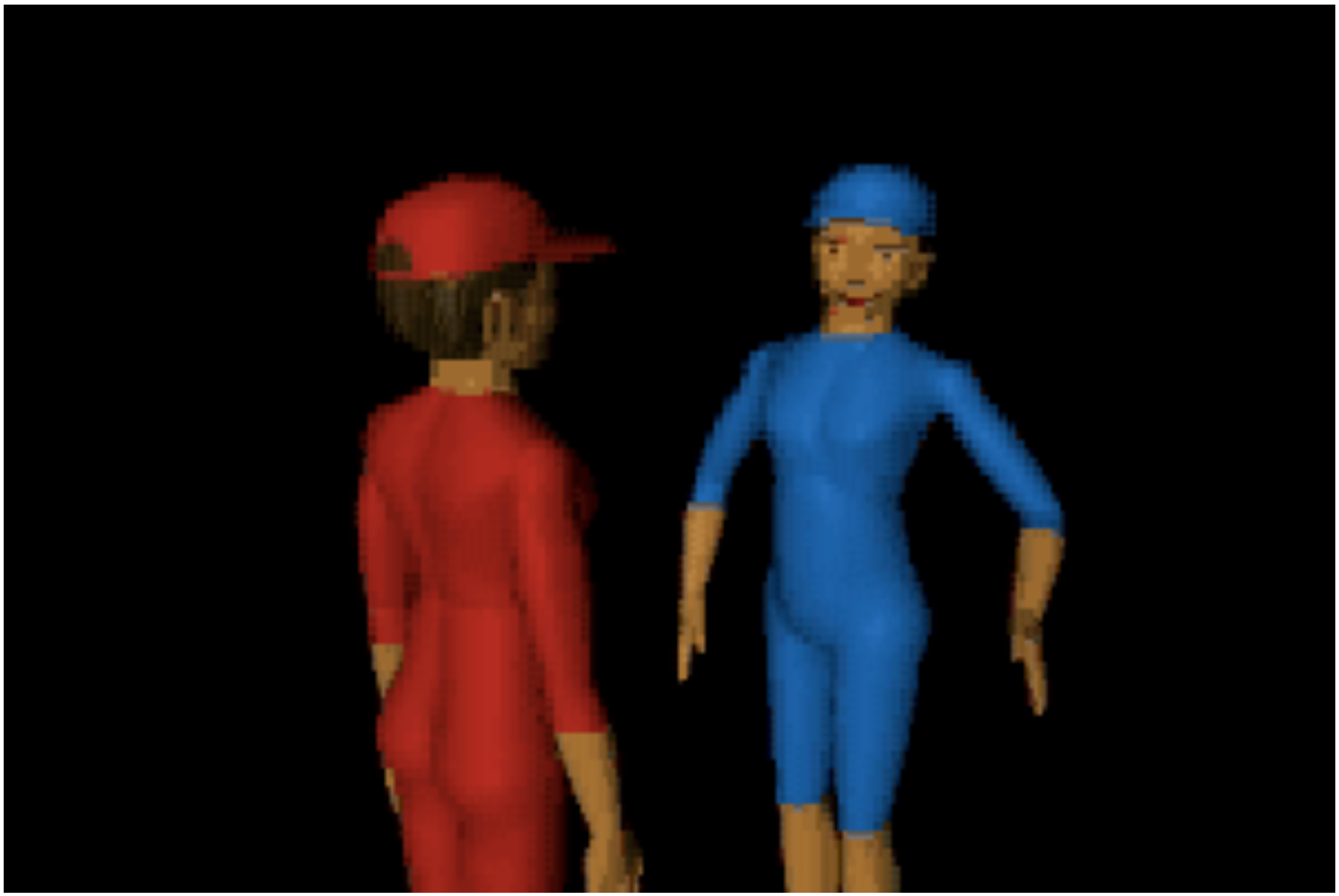
Adding Task Control

- **Specialized task controllers allow editing at the task or behavior level.**
  - **As a simple example, consider the task of moving a staff up and down rhythmically.**
  - **Kinematic differences between the motion capture subject and the animated character will cause the staff to wave around rather than move vertically.**
  - **A task controller sets the desired angle of the wrist to keep the hand and the staff in the correct orientation.**
- **The remaining degrees of freedom of the upper body track and maintain the style of the input motion.**
- **A balance controller for the degrees of freedom in the lower body tracks motion capture data for the upper body to produce full-body motion.**

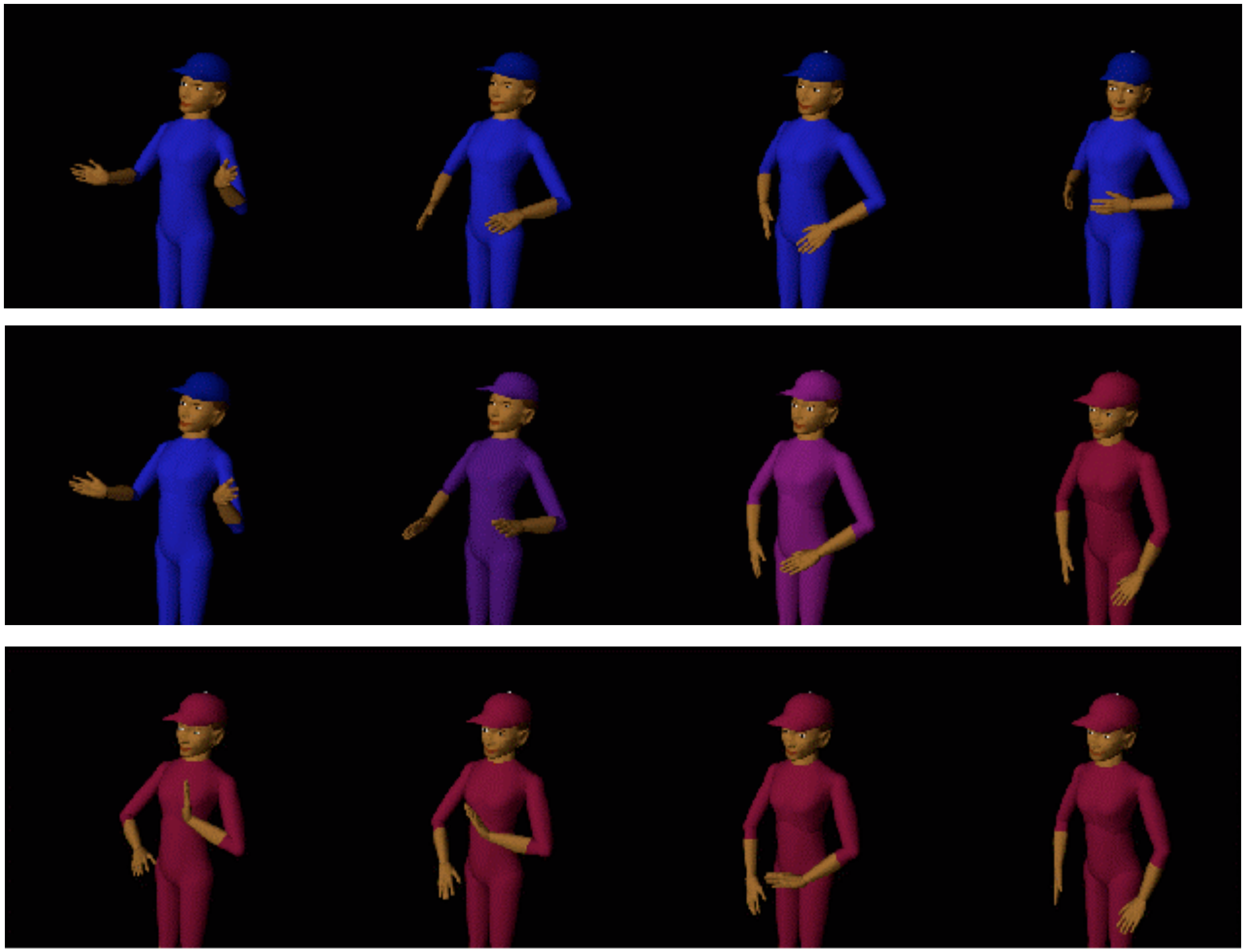
Modifying the Input Data

- Modifying the input data allows the user to edit motions at a high level while relying on the simulation to maintain physical correctness.
- The system creates physically realistic transitions between two distinct sequences by interpolating between two input motions and tracking the resulting data. The transitions are smooth because the resulting sequence obeys a consistent set of physical constraints for the duration of the motion.

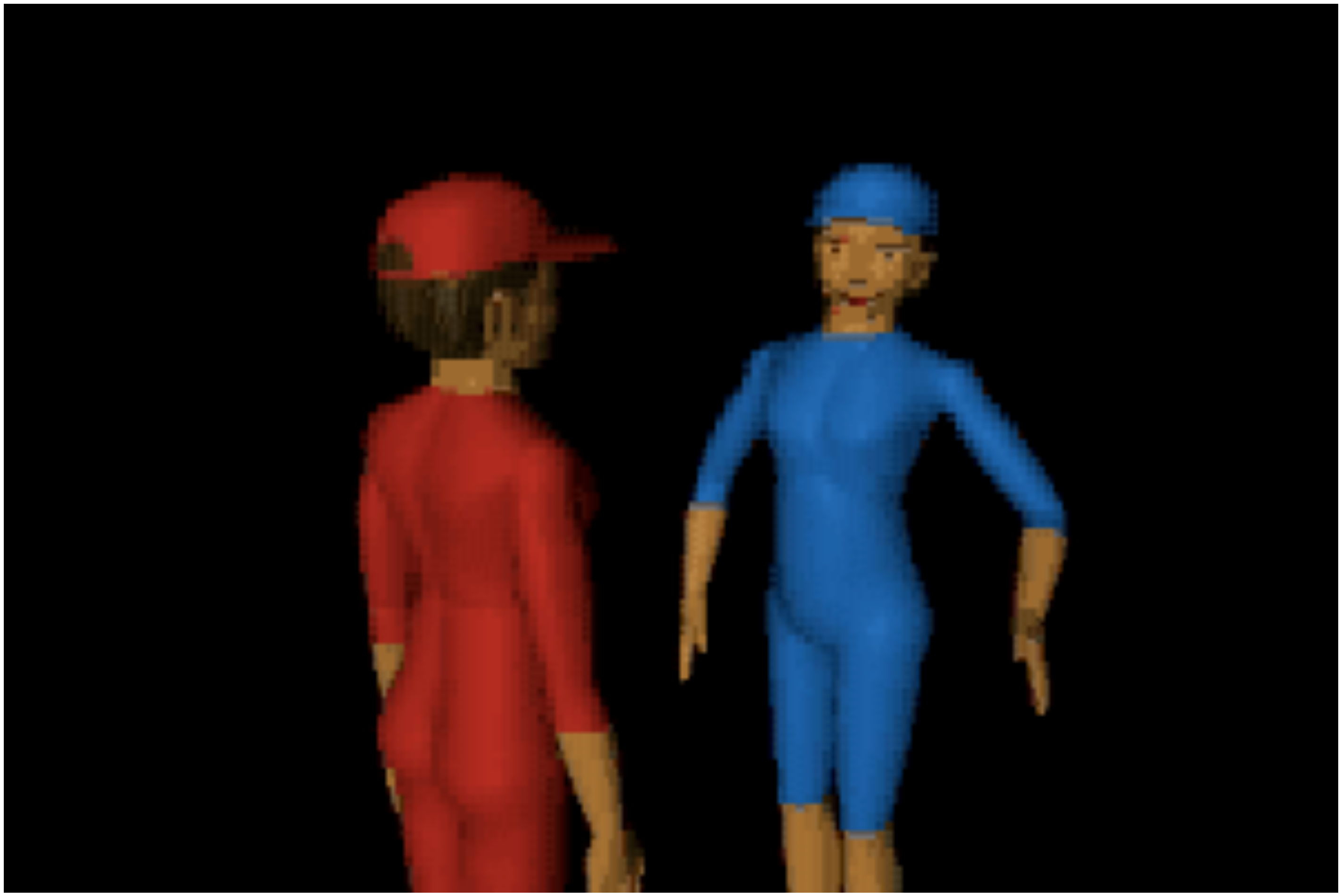
Patty Cake Example



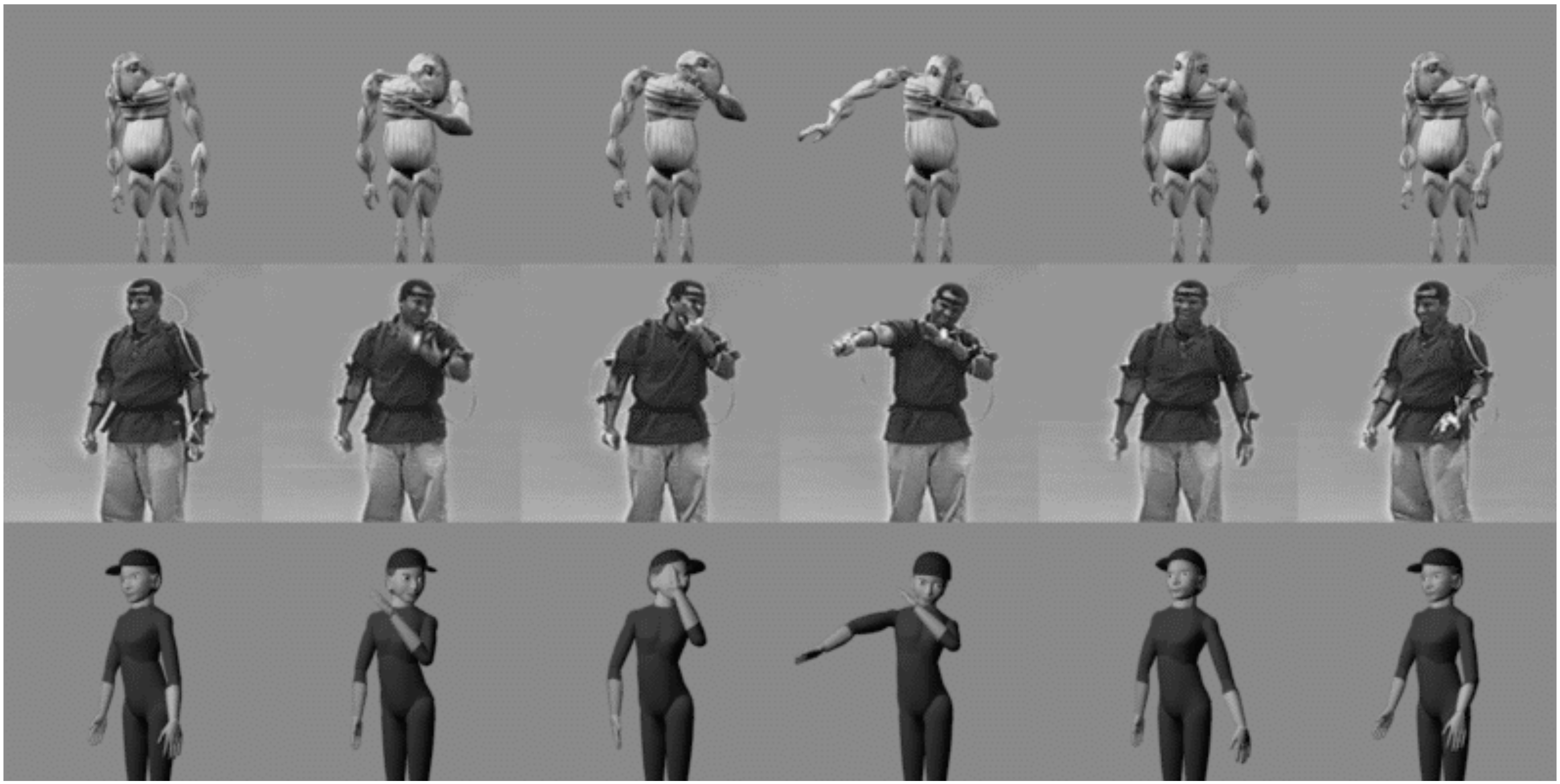
Patty Cake Transition



Patty Cake Slap



Applying the same motion to different characters



Running

- Running is a cyclic behavior in which the legs swing fore and aft and provide support for the body in alternation.
- Because the legs perform different functions during the phases of the locomotion cycle, the muscles are used for different control actions at different times in the cycle.
  – When the foot of the simulated runner is on the ground, the ankle, knee, and hip provide support and balance.
  – During the flight phase, a leg is swung forward in preparation for the next touchdown.
- These distinct phases and corresponding changes in control actions make a state machine a natural tool for selecting the control actions that should be active at a particular time.

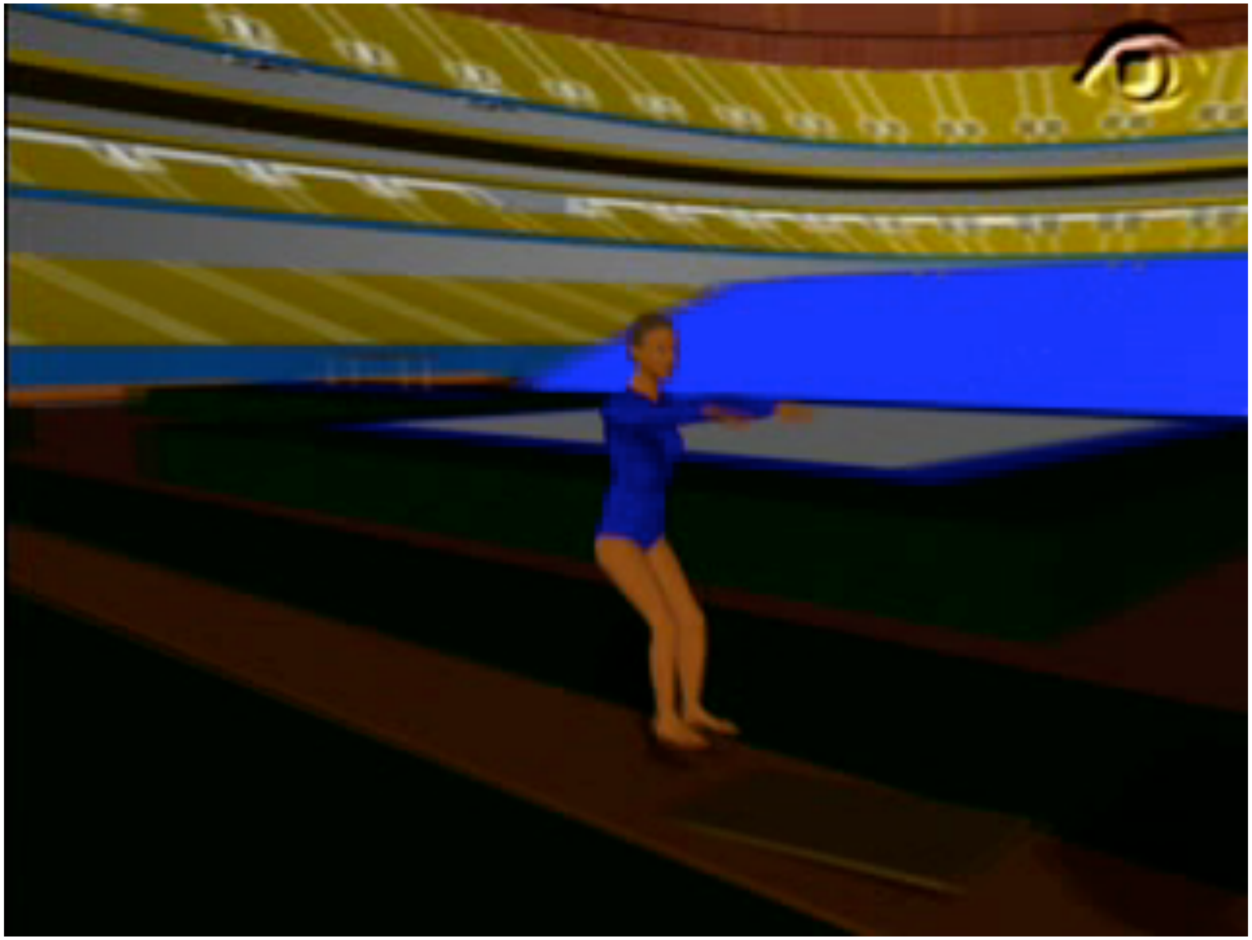
Running

Scaling

- If simulated, human-like characters are to be useful in animations and virtual environments, we must be able to create new, appealing actors easily.
- Appealing human motion has several components: the kinematics and dynamics of the figure must be physically correct and the control algorithms must make the figure perform in ways that appear natural and are stylistically appropriate for the setting and character.
- When simulation is used for animation, adapting behaviors to new actors is difficult because a control system that is tuned for one actor will not work on an actor with different limb lengths, masses, or moments of inertia.
  - First, the control system parameters are scaled based on the size and moment of inertia of the dynamic models for the new and the old actors.
  - Then a subset of the parameters is fine-tuned using a search process based on simulated annealing.
- Compare the motion of a simulated child and woman with that of a man.

Scaling

A Vaulter

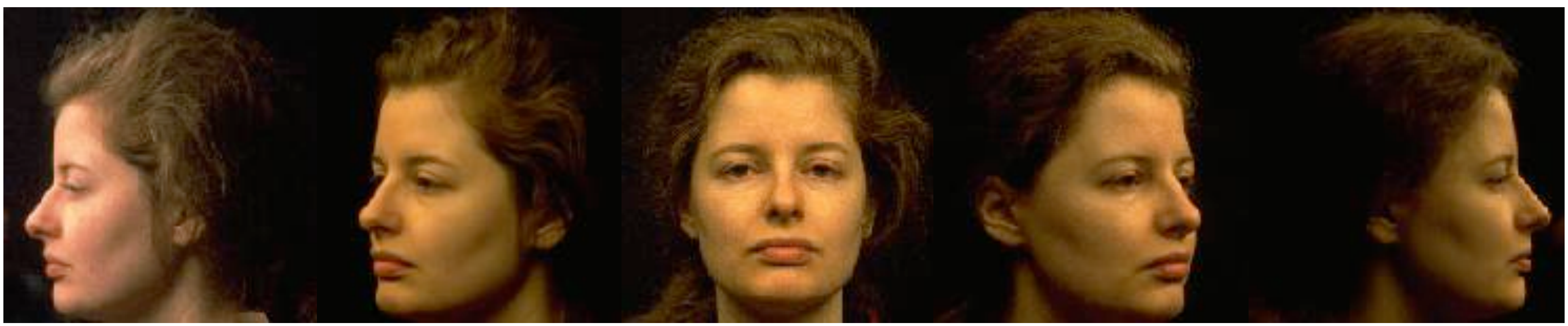


Synthesizing Realistic Faces

- Photorealistic textured 3D facial models can be created from photographs of a human subject, and smooth transitions between different facial expressions can be created by morphing between these different models.
- Starting from several uncalibrated views of a human subject, user-assisted techniques can recover the camera poses corresponding to the views as well as the 3D coordinates of a sparse set of chosen locations on the subject's face.
- A scattered data interpolation techniques is used to deform a generic face mesh to fit the particular geometry of the subject's face.
- Having recovered the camera poses and the facial geometry, one or more texture maps for the model are extracted
- This process is repeated for several facial expressions of a subject.
- For transitions between facial expressions, 3D shape morphing between the corresponding face modes is used, while blending the corresponding textures.

Model fitting

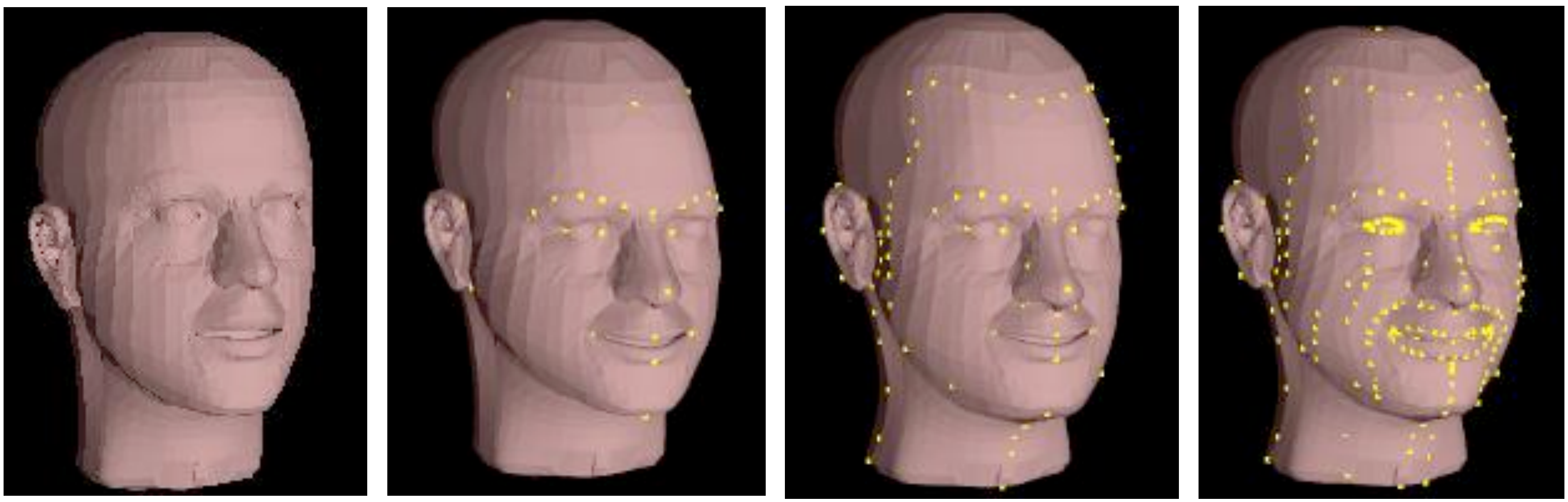
- To fit a 3D generic face model to a set of images, start with a set of 4 or 5 images, all taken simultaneously from different viewpoints.



Model fitting

- The mesh is fitted to the photograph by selecting feature points on the mesh and specifying where the points should project on the photo.
- From these annotations, recover the 3D location of the feature points and the camera parameters corresponding to the photographs.
- A sparse data interpolation technique deforms the mesh based on the recovered position of the feature points
- The mesh is adjusted until you are satisfied with its shape.
- To facilitate the annotation process, a set of polylines are used on the 3D model that corresponds to easily identifiable facial features. These features can be quickly annotated by outlining them on the photographs.

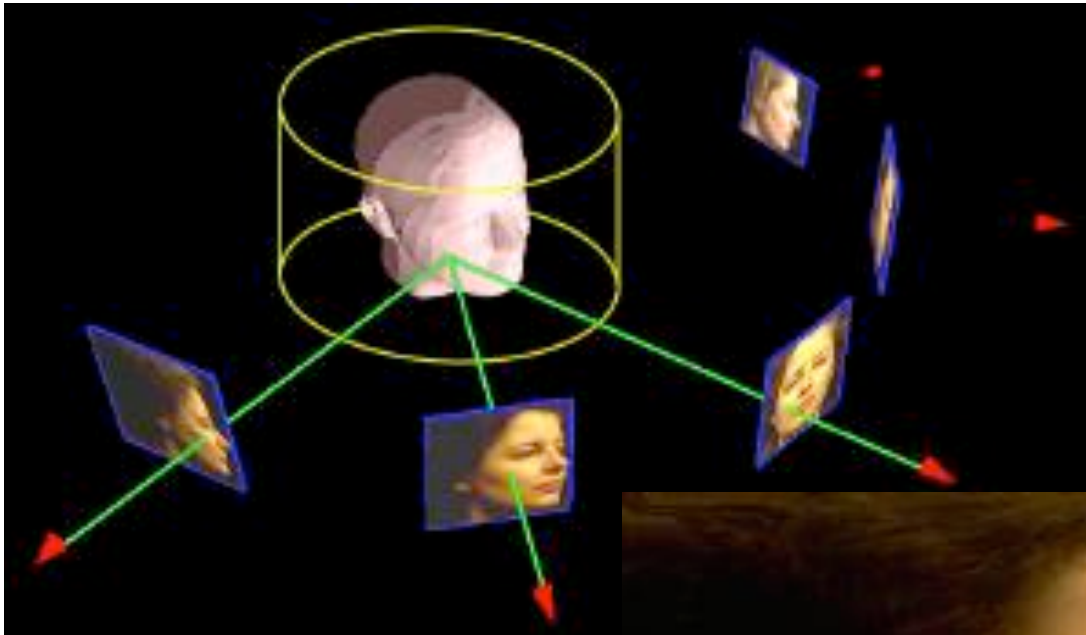
Model fitting

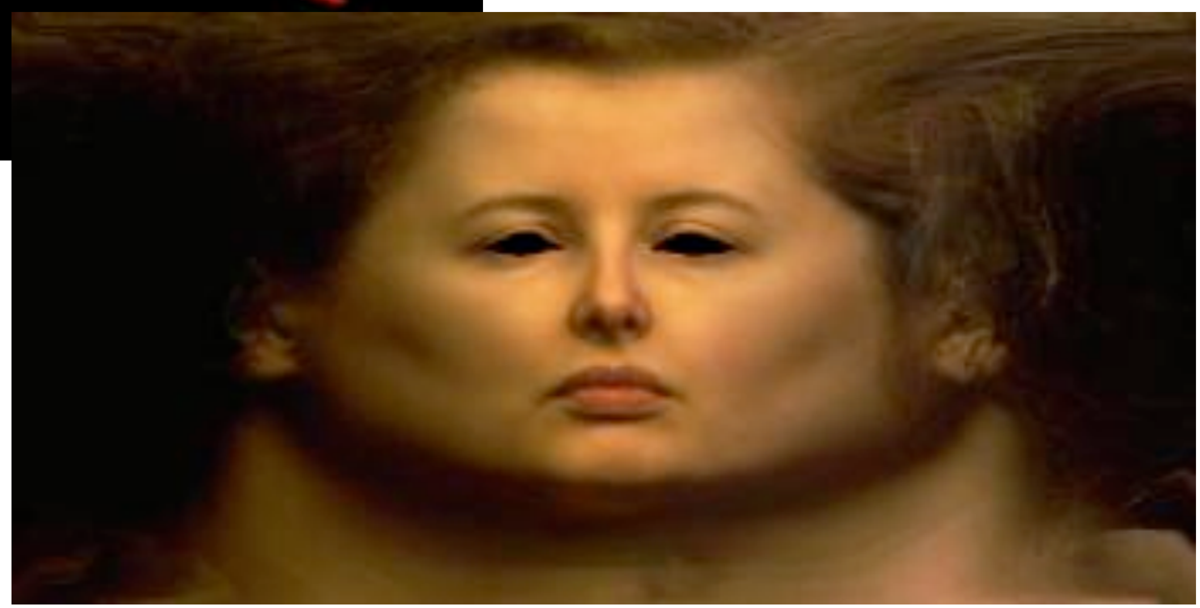


Texture extraction

- To dress up the 3D face model, a texture map is extracted from the photos.
- The texture is obtained by projecting each of the photographs onto a virtual cylinder.
- Using the recovered camera parameters rays are traced from each point on the face surface back to the image planes.
- The different image samples are then combined in a weighted sum to produce the final texture.

Texture extraction





Expression generation

- Generating complex facial expressions from a 3D face model is usually a difficult task. Traditionally several hundreds parameters would be necessary to precisely control the face. Such complexity makes the task acessible only to seasoned animators. More intuituve parameterizations in term of emotions usually yield a fairly limited range of expressions.
- We can generate facial expressions from a library of expressions by combining 3D face models using 3D morphing techniques:
  - Interpolate the geometry
  - Blend the textures.
- A combination of faces is specified for each contributing expression as a set of weights, one for each vertex in the model.
- The simplest way to combine facial expressions is to assign a single weight or percentage to each contributing expressions.
- The following example shows the blend of 50% of "surprise" and 50% of "sadness" yielding a "worried" expression.

Expression generation

Transfer of Expressions from One Character to Another

Animation

- An animation interface is split into three sections:
  - Expression Gallery
  - Facial Design Interface
  - Timeline
- The expression gallery hold thumbnails of the set of facial expressions available.
- The facial design interface performs the blends of expressions
- The timeline positions expressions and poses in linear time.
  - Each keyframe for expressions and poses has a user-controlled cubic bezier function that specifies the speed at which the adjacent frames are interpolated.

A Synthetic Animation

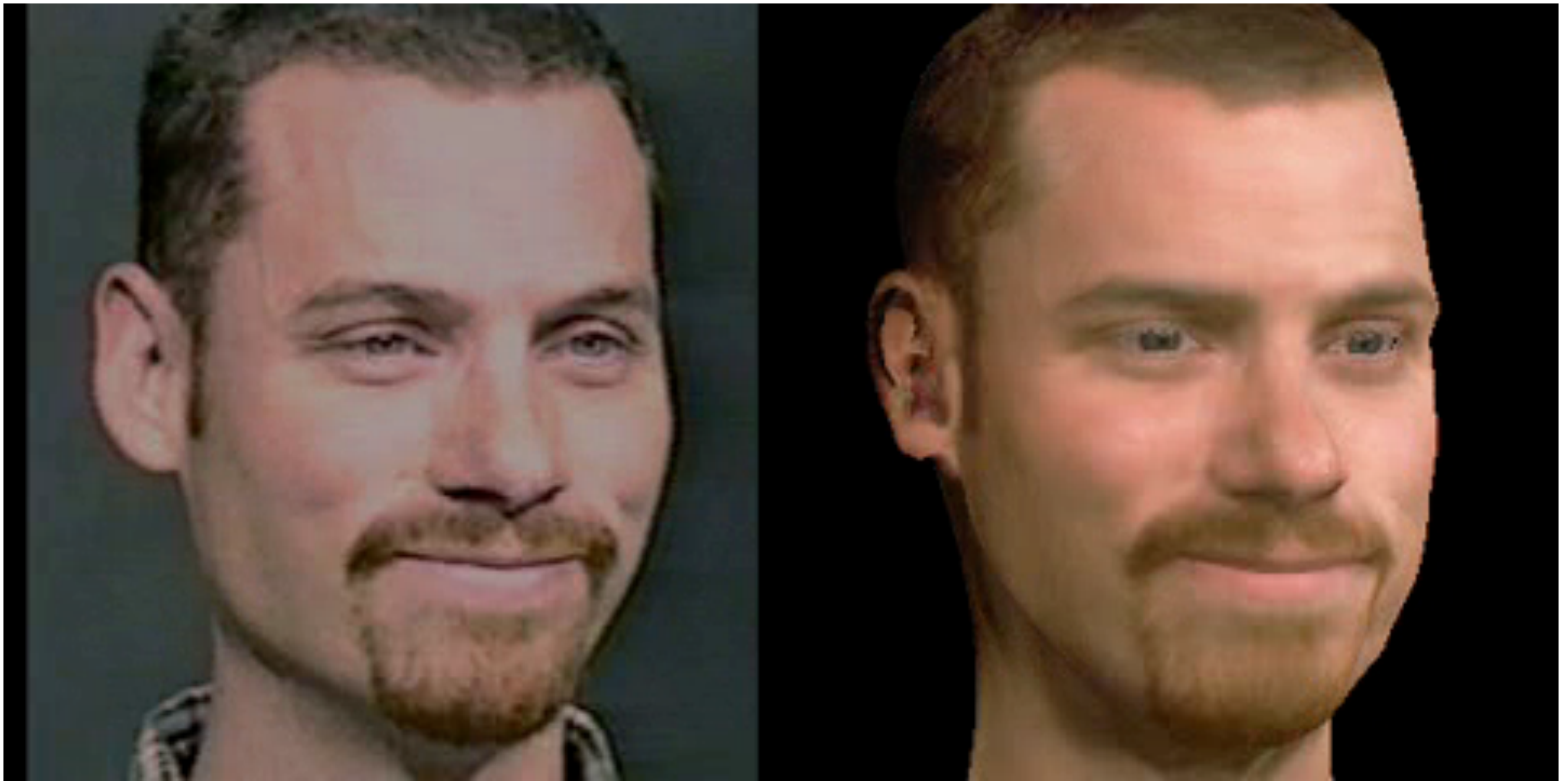
Model-based tracking

- Given video footage of a person's face, new techniques automatically recover the face position and the facial expression from each frame in the video sequence.
- A 3D face model is fitted to each frame using a continuous optimization technique.
- The model is based on a set of 3D face models that are linearly combined using 3D morphing.
- Applications include
  - Applying the recovered position and expression of the face to a synthetic character to produce an animation that mimics the input video
  - Relighting the face
  - Varying the camera position
  - Adding facial ornaments such as tattoos and scars.

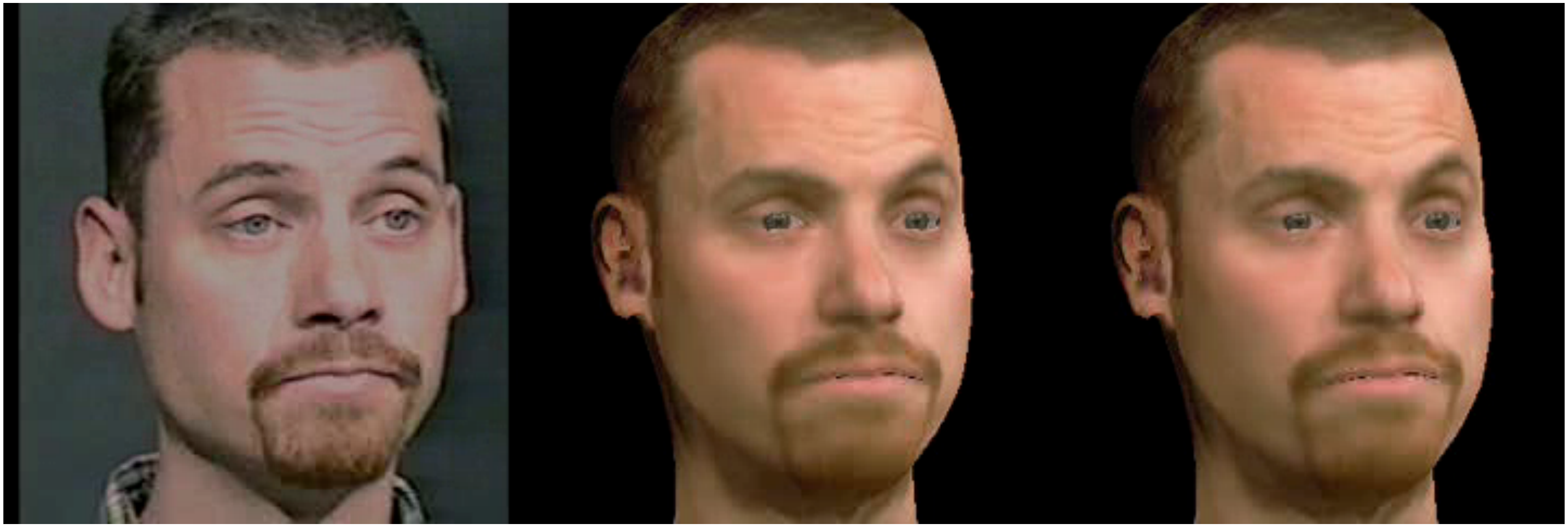
Model Fitting

- To fit the model to a target face image, an optimization technique computes parameters yielding a rendering of the model that best ressemble the target image.
- The discrepancy between the model rendering and the target image is evaluated by using the 2-norm of the difference image.
- The error function is mimimized using the Levenberg-Marquardt algorithm.

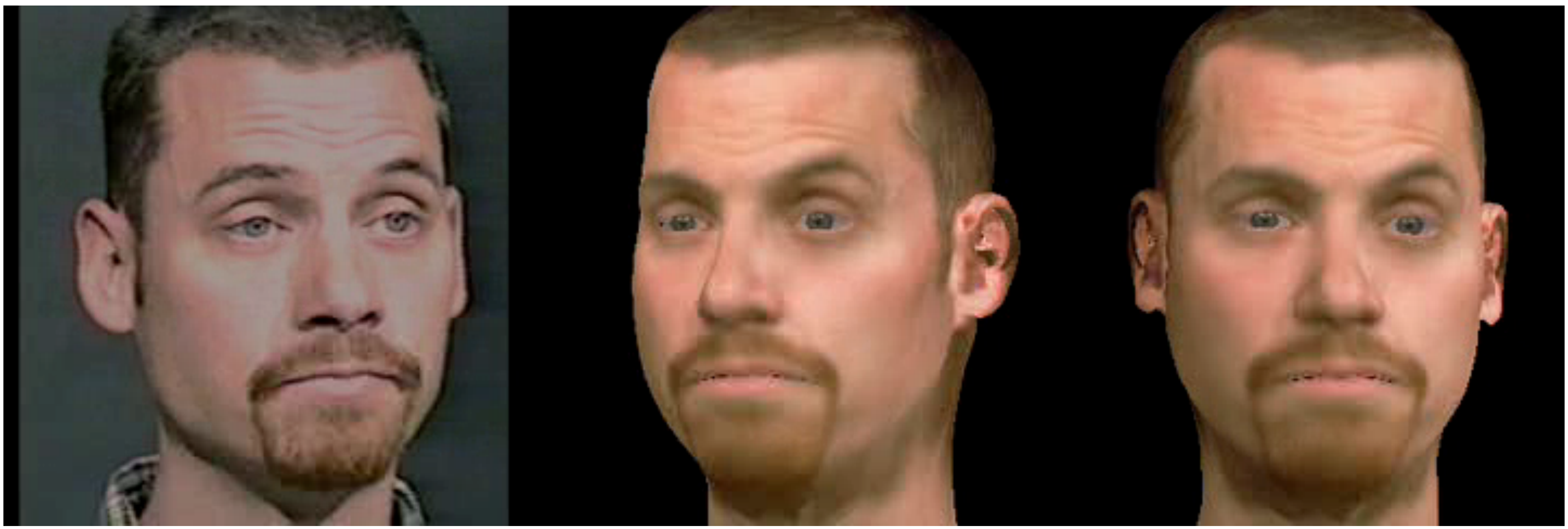
Example of Modeling



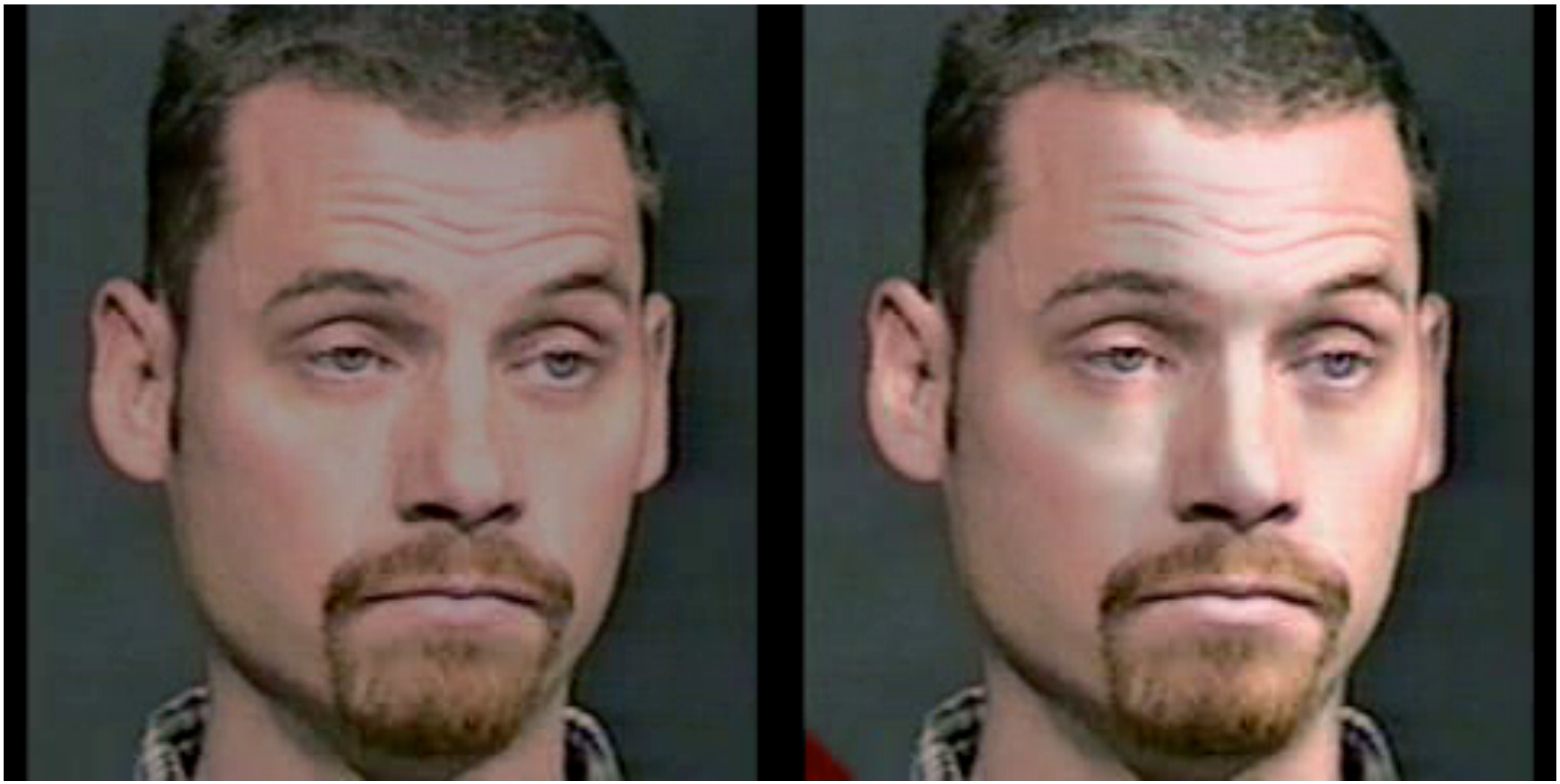
Exageration of Expression



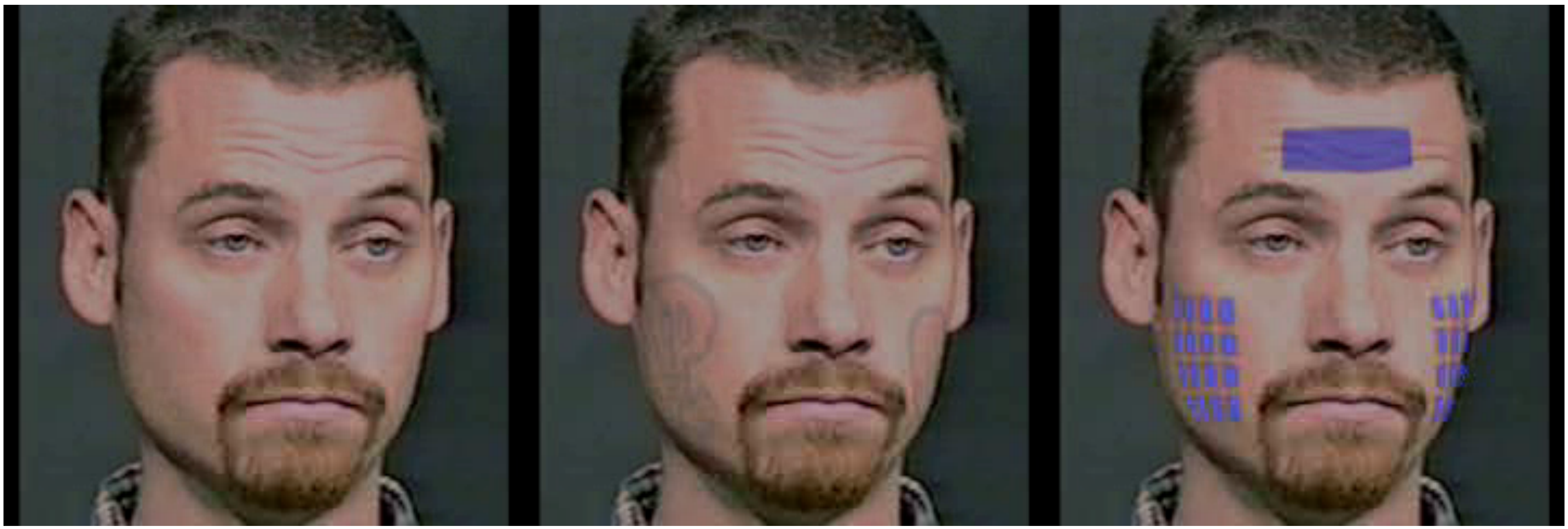
Change in Viewpoint



Change in Lighting



Synthetic Additions



Transfer to a Different Person