CENG 732
Computer Animation

Spring 2006-2007
Week 8
Modeling and Animating Articulated Figures:
Modeling the Arm,
Walking,
Facial Animation

This week

- Modeling the arm
  - Different joint structures
- Walking
- Facial Animation

Challenges in Human Modeling

- Human figure is a very familiar form
- Human form is very complex
  - About 200 degrees of freedom
  - Some of the parts are deformable
- Humanlike motion is not computationally well defined
  - There is no one definitive motion that is humanlike
  - Different characteristics for different people

Terms Related to Human Body Animation

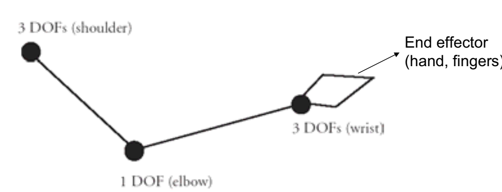
- **Sagittal plane**
  - Perpendicular to the ground and divides the body into right and left halves
- **Coronal plane**
  - Perpendicular to the ground and divides the body into front and back halves
- **Transverse plane**
  - Parallel to the ground and divides the body into top and bottom halves
- **Distal**
  - Away from the attachment of the limb
- **Proximal**
  - Toward the attachment of the limb
- **Flexion**
  - Movement of the joint that decreases the angle between two bones
- **Extension**
  - Movement of the joint that increases the angle between two bones

Modeling the Arm: Reaching and Grasping

- To simplify the modeling process, it is usually assumed that the arm operates independently from the other body parts
  - not realistic
  - to provide realism one can add additional joints in a preprocessing step and position the body and make it ready for the independently considered arm motion

Basic Arm Model

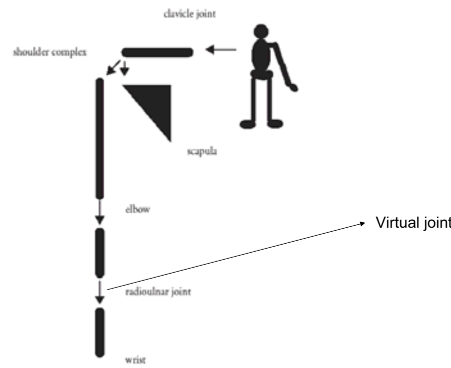
- 7 degrees of freedom (DOF)



Basic Arm Model

- Sometimes the forearm is modeled differently. Because in reality the forearm rotation is not associated with a localized joint.
  - The two forearm bones rotate around each other.
  - We can associate this rotation with the elbow or the wrist, or sometimes a virtual joint in the middle is used to handle forearm rotation

Forearm Rotation



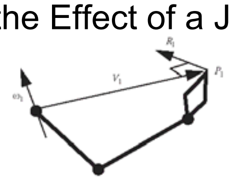
Basic Arm Joint Limits

- In reality each joint has specific limits
  - Example: the elbow flexes at most to 20 degrees and extends to 160 degrees
- Some of these limits depend on the situation
  - Example: It is difficult to fully extend the knee when one is bending at the hip

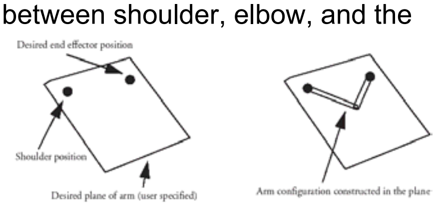
Inverse Kinematics

- The Jacobian technique can be used and the solution can be biased towards desired joint angles.
- To produce more humanlike motion the Jacobian can be replaced by a procedural approach
  - The joints farther away from the hand has more effect on the position of the hand
  - The joints closer to the hand are used to perform fine orientation changes

Finding the Effect of a Joint Angle

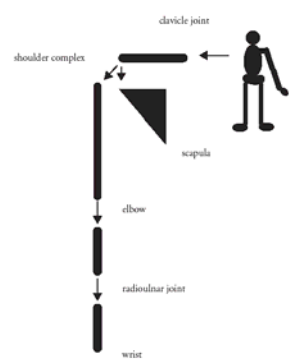


- Alternatively, the user can specify the plane between shoulder, elbow, and the wrist

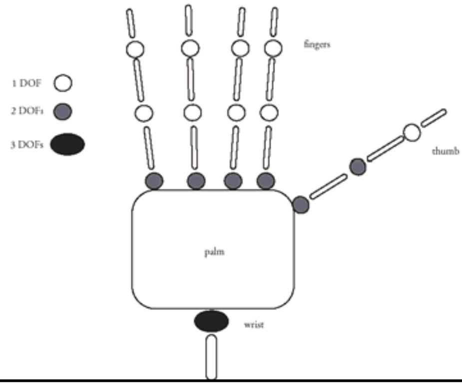


The Shoulder Joint

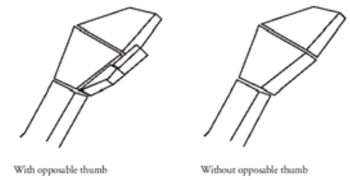
- It can be modeled as a ball joint or three separate joints



Modeling the Hand

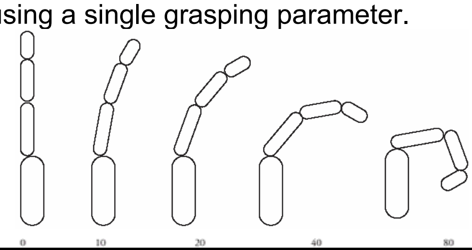


Simpler Hand Models



Simpler Coordinated Movement

- The model can be complex to provide detailed high quality hand model. But, one can coordinate the movement of the joints using a single grasping parameter.



Coordinated Movement

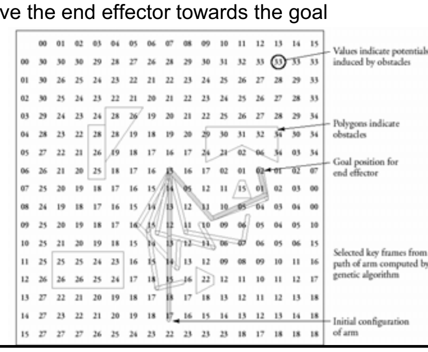
- Modeling interjoint cooperation is not easy
  - Example:
    - Stretch out your arm to the side, face palm up
    - Rotate the hand so the palm is facing down
    - Continue rotation so that the pals is facing up again
    - Which joints are involved? Moving the torso makes it easier?
  - Body parts cooperate to relieve muscle strain or maintain equilbrium

Reaching Around Obstacles

- The volume of space swept by the limb should not intersect with the obstacles in a scene
- Several path planning algorithms have been developed

Potential Field Approach

- We can use a gradient of Genetic algorithm approach to move the end effector towards the goal



Strength

- Strength may be incorporated into the motion planning of the arm
- For underconstrained problems (i.e., problems with many solutions), the solution space can be searched for the configurations which places least amount of strain on the figure
  - Strain can be computed by computing the torque at each joint
  - Comfort is defined as the ratio of the currently requested torque and the maximum possible torque

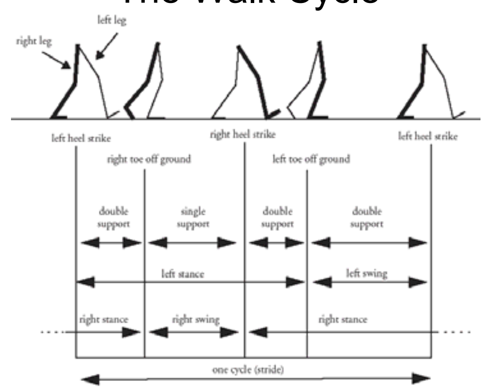
Walking

- It is a cyclic motion
  - Acyclic components
    - Turning, tripping
- Responsible for transportation of the body and maintaining balance
- Dynamics is more important in walking
- Walking is dynamically stable, but it is not statically stable
  - E.g., When a body freezes in the middle of the walk, it may fall on the ground

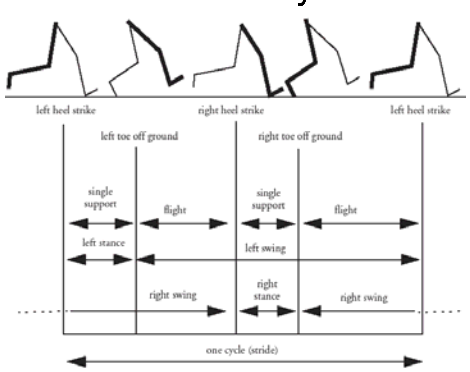
Walking

- Experimentally gathered data or a set of adjustable control parameters are used.
  - Example parameters:
    - Stride length
    - Hip rotation
    - Foot placement
- State transition diagrams are used to specify the walking process
- Kinematics can be used for the general walking motion and forces may be computed to determine the motion of the upper body

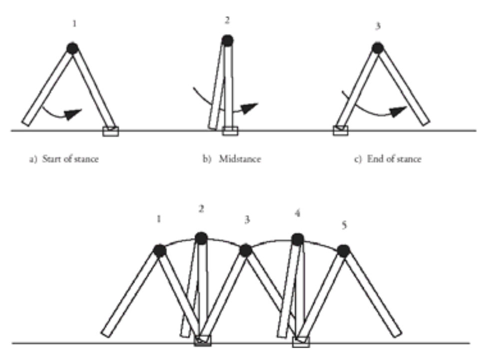
The Walk Cycle



The Run Cycle

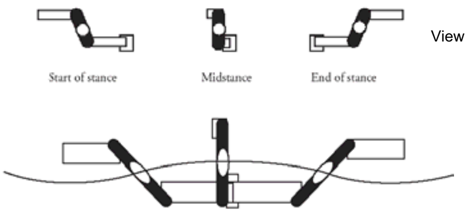


Pelvic Transport



Pelvic Rotation

- The pelvis separates the legs in the third dimension

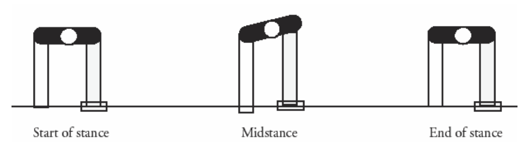


View from top

Path of the pelvic center viewed from the top

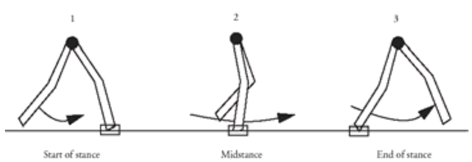
Pelvic Tilt

- The pelvis tilts to one side to help lift the legs



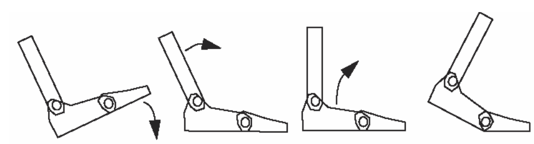
Knee Flexion

- Bending at the knee joint prevents the leg to penetrate the floor during pelvic tilt.
- It also helps to absorb shock



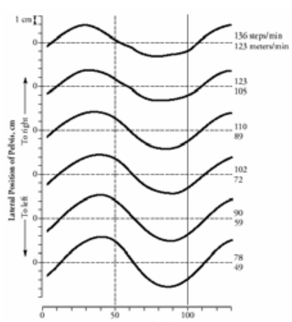
Ankle and Toe Joints

- Ankle and toe joints help flatten out the rotation of the pelvis above the foot as well as to absorb some shock
- A simple model:

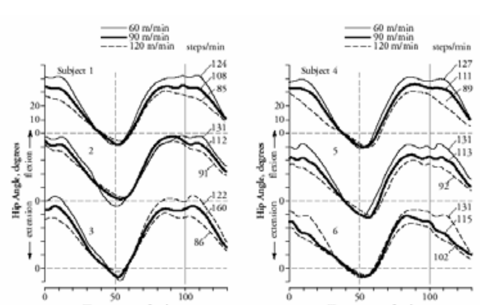


The Kinematics of the Walk

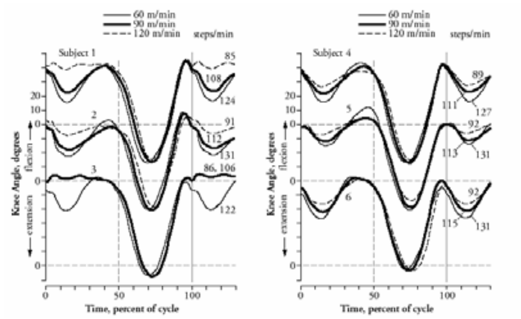
- Specification of all the joint angles and the lateral displacement of the pelvis.
- Provided by experimental data



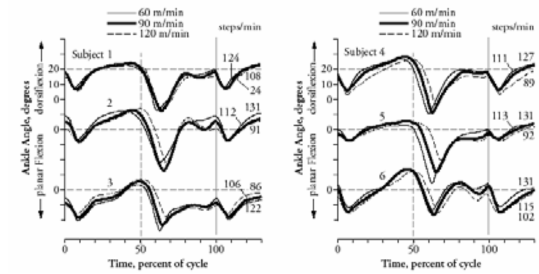
Hip Angles



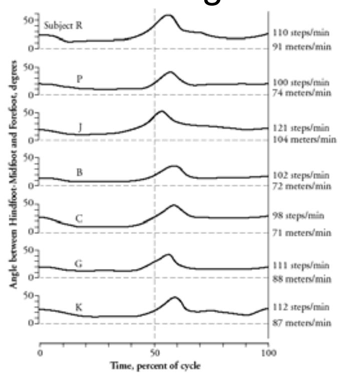
Knee Angles



Ankle Angles

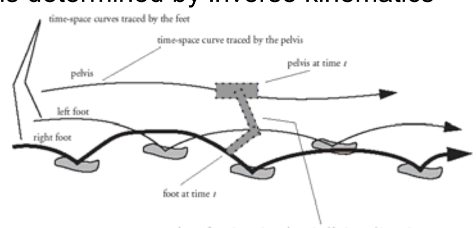


Toe Angles



Specifying a new walk

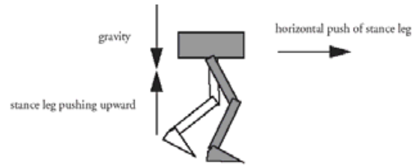
- The animator specifies the kinematic values for pelvic movement, foot placement, and foot trajectories. The rest is determined by inverse kinematics



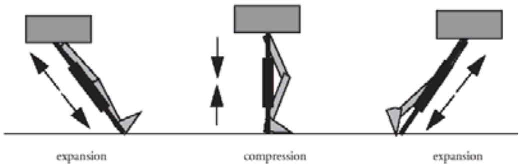
Dynamics

- Dynamic models may help produce more realistic motion
  - However, the animator looses control over some parameters
- Simplifications
  - Some dynamics effects are ignored, such as the effect of the swing leg on balance
  - Forces are considered constant over some time interval
  - Leg model is simplified (to a small DOF)
  - Several components (e.g. horizontal and vertical) are computed separately and combined .

Dynamics



1 DOF (telescopic) leg

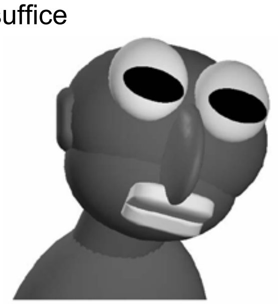


Facial Animation

- Face is a deformable object.
- Lip-synching
  - Animation of the movement of the lips, the muscle deformation of the tongue, the articulation of the jaw, and the deformation of the surrounding face during speech
- Cartoon animation
- Realistic character animation

Cartoon Faces

- Simple models suffice



Facial Models

- Acquisition of the geometry of the head
- Acquisition of the motion
  - How does the geometry change
- Face geometry
  - Polygon models
  - Splines
  - Subdivision surfaces

Polygon Models

- Easy to create and can be deformed easily
- However, the model should be complex in order to ensure smoothness

Spline Models

- Cubic, quadrilateral Bezier or B-spline surface patches are used
- However, a regular rectangular grid of control points is not suitable for modeling the detailed parts of the face
  - Hierarchical B-splines are introduced to overcome this problem

Subdivision Surfaces

- A polygonal control mesh is refined to match the face geometry
- They are able to create local complexity regions without global complexity
- However, modeling a specific face is difficult using subdivision surfaces
  - They are difficult to interpolate to a specific data set

Creating the Model

- Using CAD systems
  - A cartoon like figure can be created with modeling tools like 3DS Max.
- Digitization
- Modification of an existing generic model

Faces

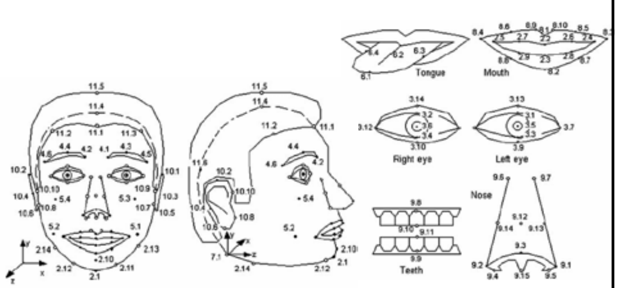
Cartoonish

Realistic looking

Parameterized Models

- Conformational parameters
  - 25 parameters in Parke's model
  - Symmetry between the sides of the face is assumed
  - 5 parameters to control the shape of the forehead, cheekbone, cheek hollow, chin, and neck
  - 13 scale distances between facial features
  - 5 parameters to translate chin, nose, and eyebrow
- Expressive parameters

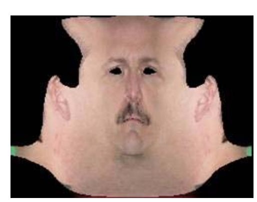
Facial Definition Parameters of MPEG-4



68 associated facial animation parameters (FAPs) are defined to animate the head

Textures

- Very important to produce realistic looking faces



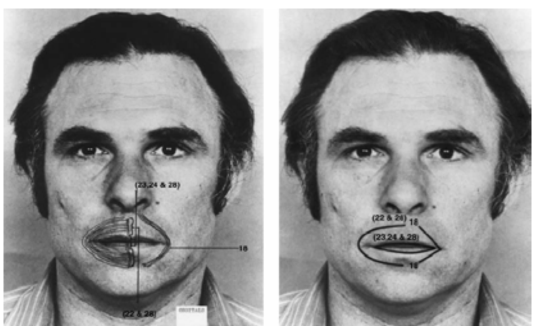
Animating the Face

- Simplest approach is to define a set of key poses
  - Animation is produced by interpolating between the positions of their corresponding vertices in the two key poses
  - Disadvantage: parts of the facial model are not individually controllable by the animator
- What are the primitive motions of the face?
- How many degrees of freedom are there in the face?

Facial Action Coding System (FACS)

- 46 basic facial movements, called Action Units (AUs) are defined, and used in combination to describe all facial expressions.
  - Examples:
    - Lower brow, raise inner brow, wink, raise cheek, drop jaw

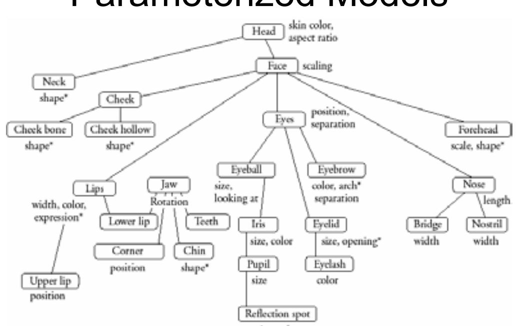
FACS example



FACS

- Disadvantages:
  - It is descriptive, not generative
  - It is not time based
  - Facial movements are analyzed only relative to a neutral pose
  - FACS describes facial expressions, not speech

Parameterized Models



Parke model; * indicates interpolated parameters

Muscle Models

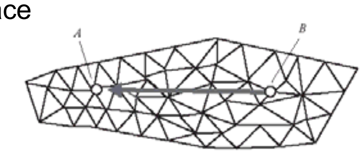
- Three types of muscles to model
  - Linear
    - Contracts and pulls one point (point of insertion) toward another (point of attachment)
  - Sheet
    - Parallel array of muscles. Attached to a line instead of a single point
  - Sphincter
    - Contracts radially toward an imaginary center

Muscle Models

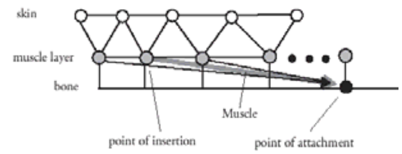
- Three aspects differentiate one muscle-based model from the other
  - the geometry of the muscle-skin arrangement
    - Are they modeled on the surface or attached to a structural layer beneath the skin
  - the skin model used
  - the muscle model used

Different Muscle-Skin Arrangements

- Surface



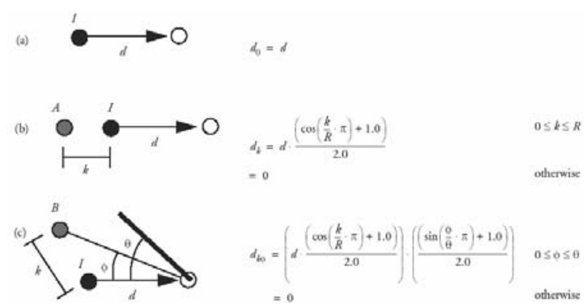
- Beneath the surface



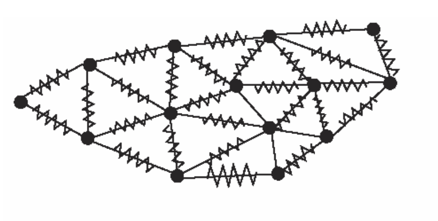
Different Skin Models

- How does the skin move as a result of muscle contracts?
- The deformation of other points may attenuate based on the distance from the point of insertion and angle of deviation from the displacement vector

Attenuation Model



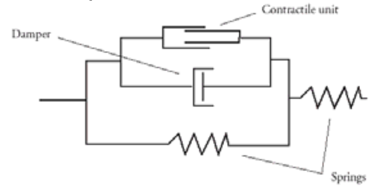
Spring Mesh Model



$F_i = k_i \cdot (|V_i^1 - V_i^2| - d_i)$ for the ith spring

Muscle Models

- Similar to skin models, but here muscles are the active elements (as compared to skin which is a passive element)
- In simple dynamic model, springs are used to represent muscles.



Hill's model for the muscle