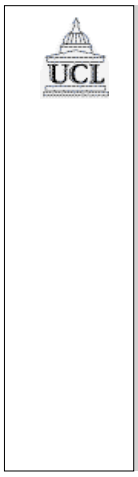
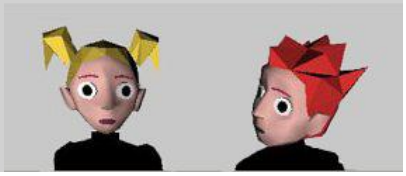


Computer Animation

Aitor Rovira
March 2010

Based on slides by Marco Gillies



Human body animation

Human Body Animation

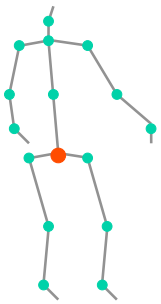
- Skeletal Animation (FK, IK)
- Motion Capture
- Motion Editing (retargeting, styles, content)
- Motion Graphs
- Skinning
- Multi-layered Methods

Skeletal Animation

- The fundamental aspect of human body motion is the motion of the skeleton.
- The motion of rigid bones linked by rotational joints.

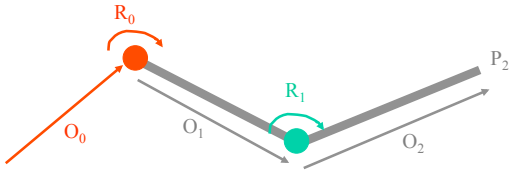
Typical Skeleton

- Circles are rotational joints lines are rigid links (bones)
- The red circle is the root (position and rotation offset from the origin)
- The character is animated by rotating joints and moving and rotating the root



Forward Kinematics (FK)

- The position of a link is calculated by concatenating rotations and offsets



Joint Limits

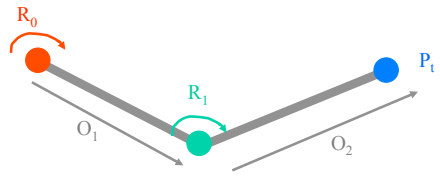
- Joints are generally represented as full 3 degrees of freedom quaternion rotations.
- Human joints can't handle that range.
- Either you build rotation limits into the animation system.
- Or you can rely on the methods generating joints angles to give reasonable values.

Forward Kinematics (FK)

- Pros:
  - Simple.
  - Used for the majority of real time animation systems.
- Cons:
  - It can be fiddly to animate with in some cases, e.g. if you want to make sure that a hand is in contact with an object it can be difficult.

Inverse Kinematics

- Given a desired position for a part of the body (end effector) work out the required joint angles to get it there.
- In other words, given P_t what are R_0 and R_1?



Inverse Kinematics

- Pros:
  - Very powerful tool.
  - Generally used in animation tools and for applying specific constraints.
- Cons:
  - Computationally intensive.
  - Underconstrained for more than 2 links.

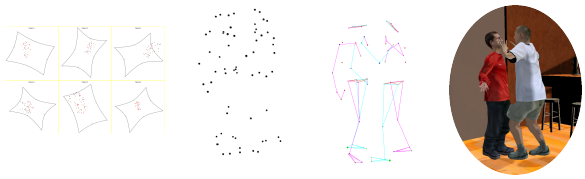
Motion Capture

- Record motion from a real actor performing actions and map it to a skeleton.
- Very heavily used in film industry and computer games.

Motion Capture

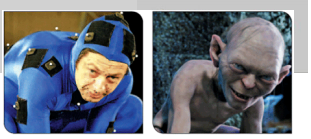
- Put markers on the body.
- Track the positions of the marker points.

Motion Capture - Pipeline



Motion Capture

Optical Motion Capture



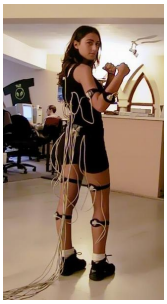
- Use reflective passive markers and infra-red to avoid problems of colour.
- Pros:
  - Lightweight, Cheap.
  - Most commonly used.
- Cons:
  - Problems of occlusion.
  - Restricted to a certain 3D space.

Markerless Optical Motion Capture

- Just point a camera at someone and figure out their motion.
- Pros:
  - Almost perfect in theory.
- Cons:
  - Very, very, difficult computer vision issues
  - Still at the stage of research prototypes

Magnetic Motion Capture

- Magnetic transmitters on the body (active markers)
- Base station measures relative positions
- Pros:
  - Very accurate
- Cons:
  - Expensive



Mechanical Motion Capture

- Put strain gauges etc. on the body

- Pros:
  - Self contained (less constrained by area in which you do it)
  - Can directly output joint angles
- Cons:
  - Bulky

Mocap - Conclusions

- Pros:
  - Motion capture produces highly realistic animation.
- Cons:
  - Cleaning process can be really time consuming.
  - it is inflexible, you can only play back what you have captured.
  - difficult to apply to new physical situations (picking up a cup from a different place)
  - or new styles (different emotion)

Motion Editing

- How can we transform motion data to that we can re-use it in new contexts?
- If we can do this in real time it allows us to have characters that respond to events realistically.

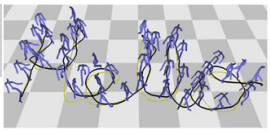
Motion Editing – Style and Content

- A motion can be separated into a Content component and a Style component
  - Content: walking, sitting down, jumping
  - Style: angry, masculine, proud
- Attempt to separate style and content
  - change style of a motion
  - apply style of one motion to another

Motion Editing - Retargeting

- Retargeting: maps the motion of a performer to a character of different proportions.
- Motion Warping: smoothly add small changes to a motion to adapt it to a different style.

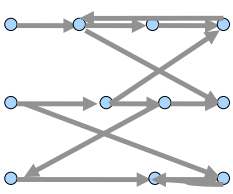
Motion Graphs



- Useful to create sequences of random motions.
- Given a corpus of motion capture data (usually short clips), automatically construct a directed graph connecting the different motions and the transitions.
- L.Kovar, SIGGRAPH ‘02

Motion Graphs

- Each node is a possible transition point.
- Each edge is a motion clip to go between transition points.
- Walking the graph generates a motion.



Motion Graphs

Making it look good

- A skeleton is a great way of animating a character but it doesn't necessarily look very realistic when rendered.
- The simplest way is to make each joint a transform.
- OK, but body is broken up.

→ We need to add a graphical "skin" around the character.

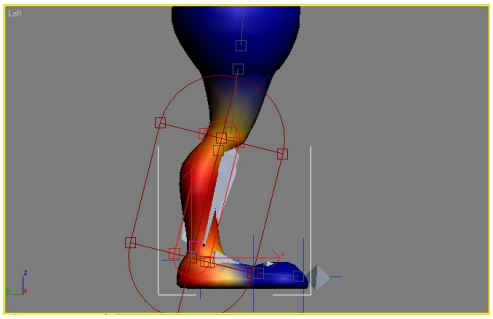
Smooth Skinning

- We want to represent a character as a single smooth mesh (a "skin").
- This should deform smoothly based on the motion of the skeleton.

Smooth Skinning

- Associate each vertex in a mesh with one or more joints.
- The vertices are transformed individually by their associated joints.
- Each vertex has a weight for each joint.
- The resulting position is a weighted sum of the individual joint transforms.

Smooth Skinning



Multi-layered Methods

- The deformation of a human body does not only depend on the motion of the skeleton.
- The movement of muscle and fat also affect the appearance.
- Soft tissues need different techniques from rigid bones.

Multi-layered Methods

- More advanced character animation systems use multiple layers.
- Geometric methods.
  - e.g. free form deformations (based on NURBS)
- Physical models based on fat and muscle layers.

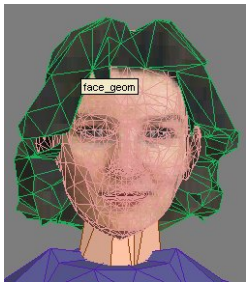
Facial Animation

Facial animation

- Concepts
- Methods
  - Facial Bones
  - Muscle Models
  - Facial Motion Capture
  - Morph Targets
- Visemes and Lip Sync

Facial Animation

- Do not have a common underlying structure like a skeleton.



Concepts

- Psychologist Paul Eckman defines a set of six universal human emotions:
  - Joy, sadness, surprise, anger, disgust, fear
- All are independent of culture.
- Each has a distinctive facial expression.

Methods

- There is plenty of methods:
  - Facial bones
  - Muscle models
  - Facial Motion Capture
  - Morph Targets

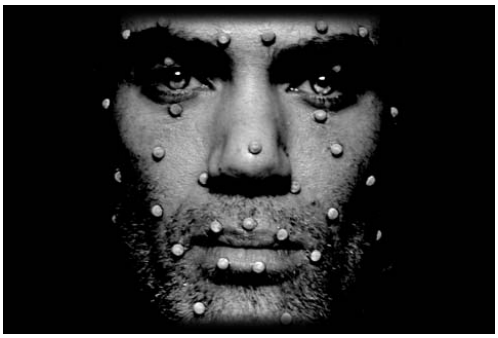
Facial Bones

- Similar to bones in body animation
- A set of underlying objects that can be moved to control the mesh
  - Position change
  - Springs
- Each bone affects a number of vertices with weights in a similar way to smooth skinning for body animation.

Muscle Models

- Model each of the muscles of the face.
- Each muscle is affected by a bone.
- Or there could be a more complex physical simulation as mentioned for multi-layered body animation.

Facial Motion Capture



Facial Motion Capture

- Markerless motion capture techniques can also be considered.
- Better developed than for body motion.
- Gives reasonable results.

→ The motion capture is mapped to the mesh, not to a set of bones.

Morph Targets

- Have a number of facial expressions, each represented by a separate mesh.
- Build new facial expressions out of these base expressions.
- Transition from one to another smoothly.

Morph Targets

Morph Targets

Morph Targets

- Pros:
  - A good low level animation technique. No restrictions to design them.
- Cons:
  - Making them can take a lot of time if done manually.
  - Requires a lot of memory.
  - We might need higher level ways to animate faces.

Visemes and Lip-sync

- An important problem is how to animate people talking.
- In particular how to animate appropriate mouth shapes for what is being said.

Visemes and Lip-sync

- Each sound (phoneme) has a distinctive mouth shape
- Can create a morph target for each sound (visemes)
- Analyse the speech or text into phonemes (automatically done by text to speech engine)
- Match phonemes to visemes and generate morph target weights

Visemes and Lip-sync

- Very hard to do well (I've never seen it done perfectly).
- Speech and mouth shapes are more complex than phonemes and visemes
  - e.g. running one word into another

Thanks