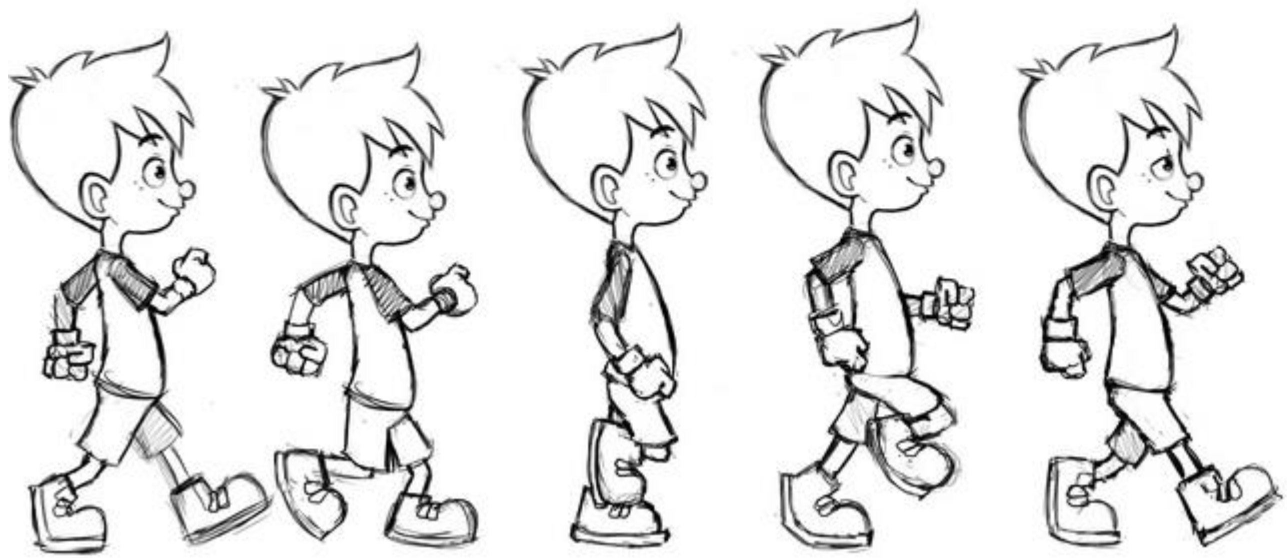
Animation

Animation

Motion over time



Animation

Motion over time

Usually focus on **character animation**
but environment is often also animated

- trees, water, fire, explosions, …

Animation

Motion over time

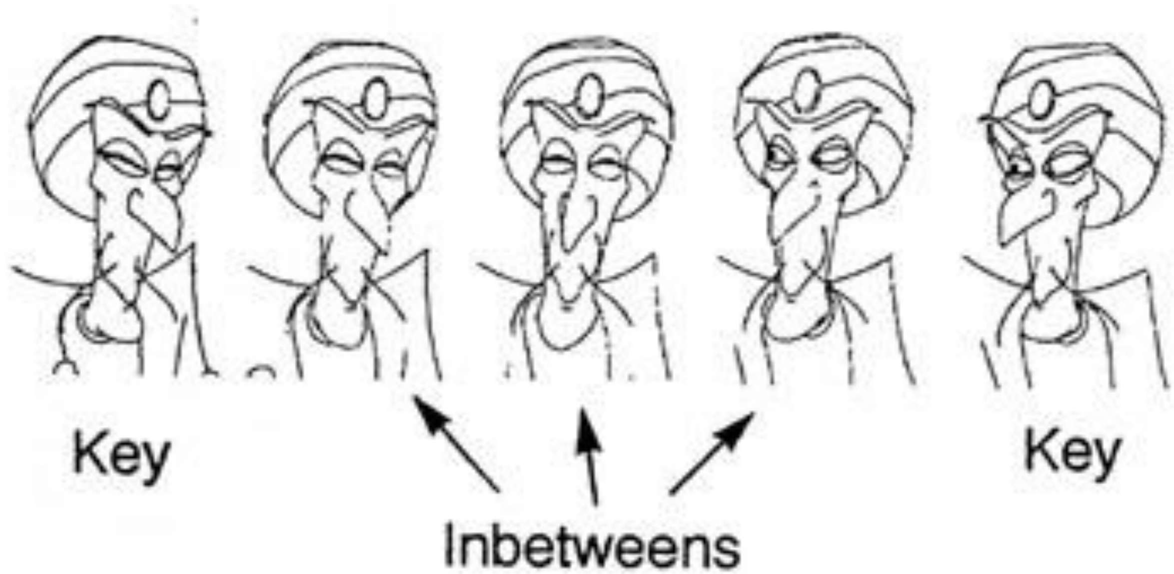
Usually focus on **character animation**
but environment is often also animated

- trees, water, fire, explosions, …

Could be physically realistic, or stylized

Traditional Character Animation

Lead animator draws sparse **key frames**



Secondary artists fill in (by hand) the intermediate frames: **inbetweening**

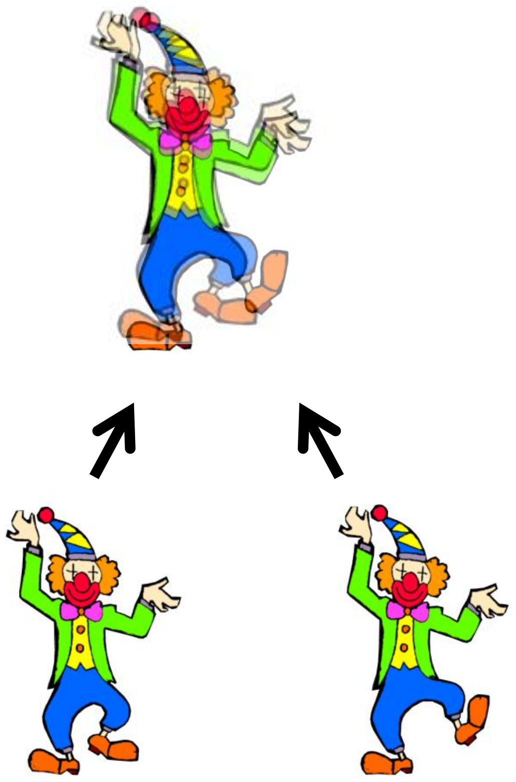
Computer Character Animation

How to inbetween automatically?

Linear interpolation?

Computer Character Animation

How to inbetween automatically?



Linear interpolation?

- No

Computer Character Animation

How to inbetween automatically?

Need way to **parameterize motion**

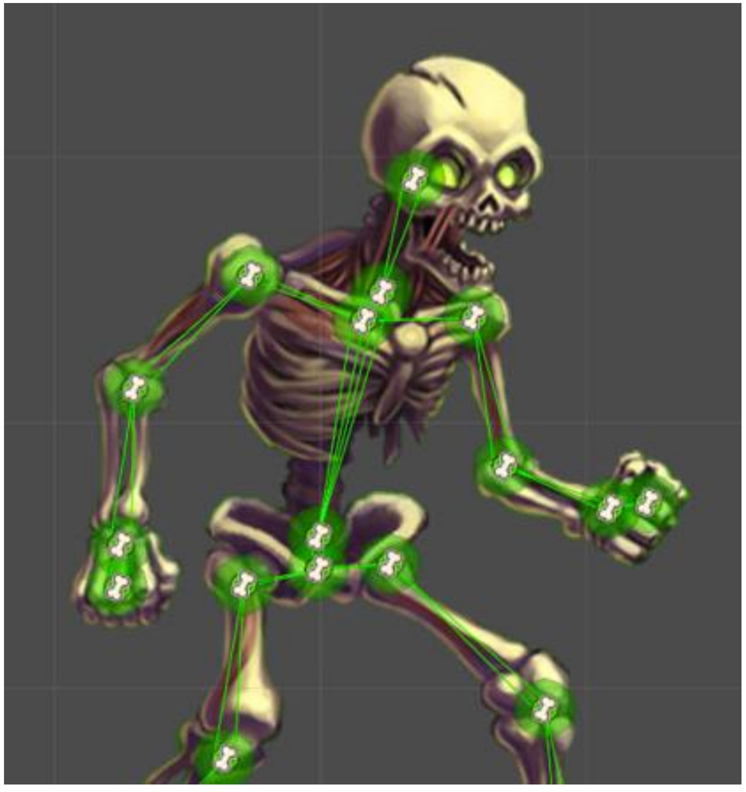
Handle-Based Animation

Pick special points (**handles**) on object

Moving handles moves nearby points

Joint-Based Animation

Extend this idea to line segments:

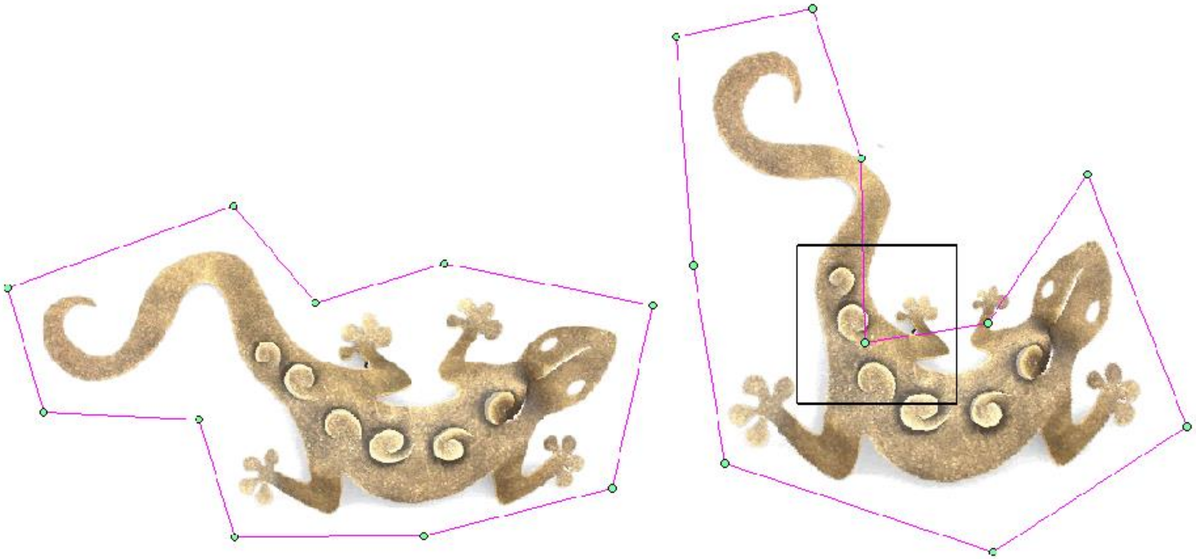


set of bones inside a character is called a **rig**

we will discussing rigging in detail next lecture

Cage-Based Animation

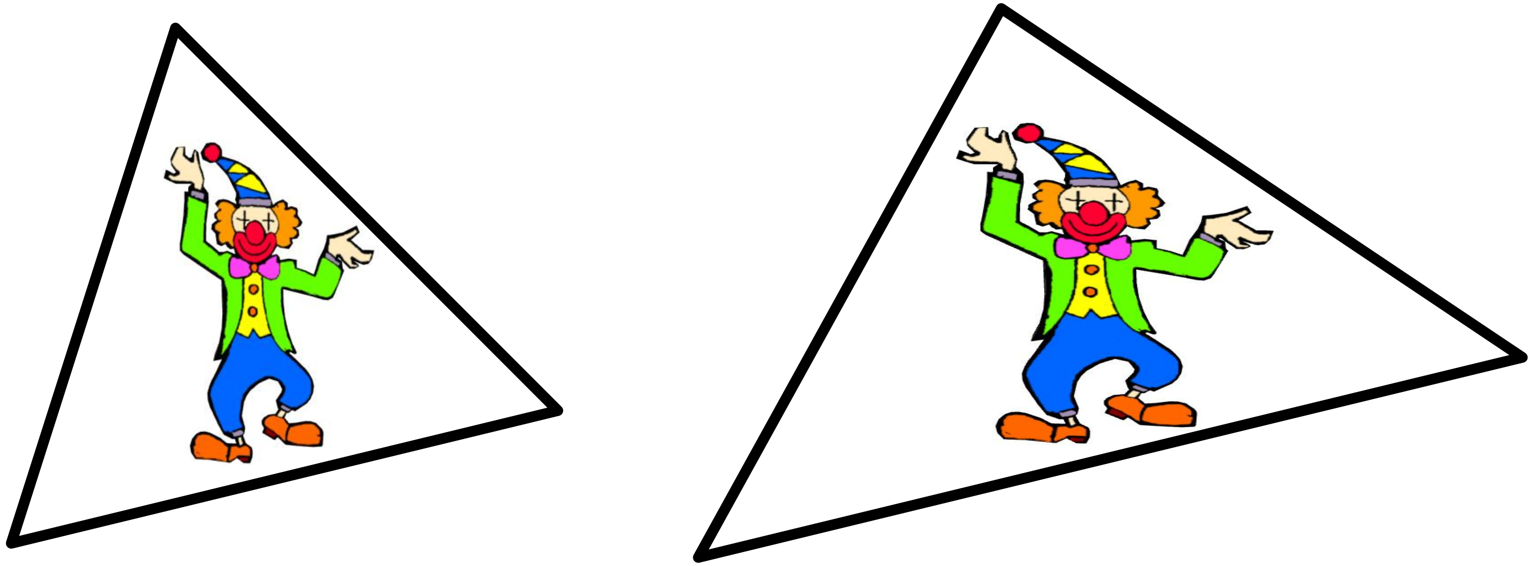
Surround object with **animation cage**



Moving the cage moves interior points

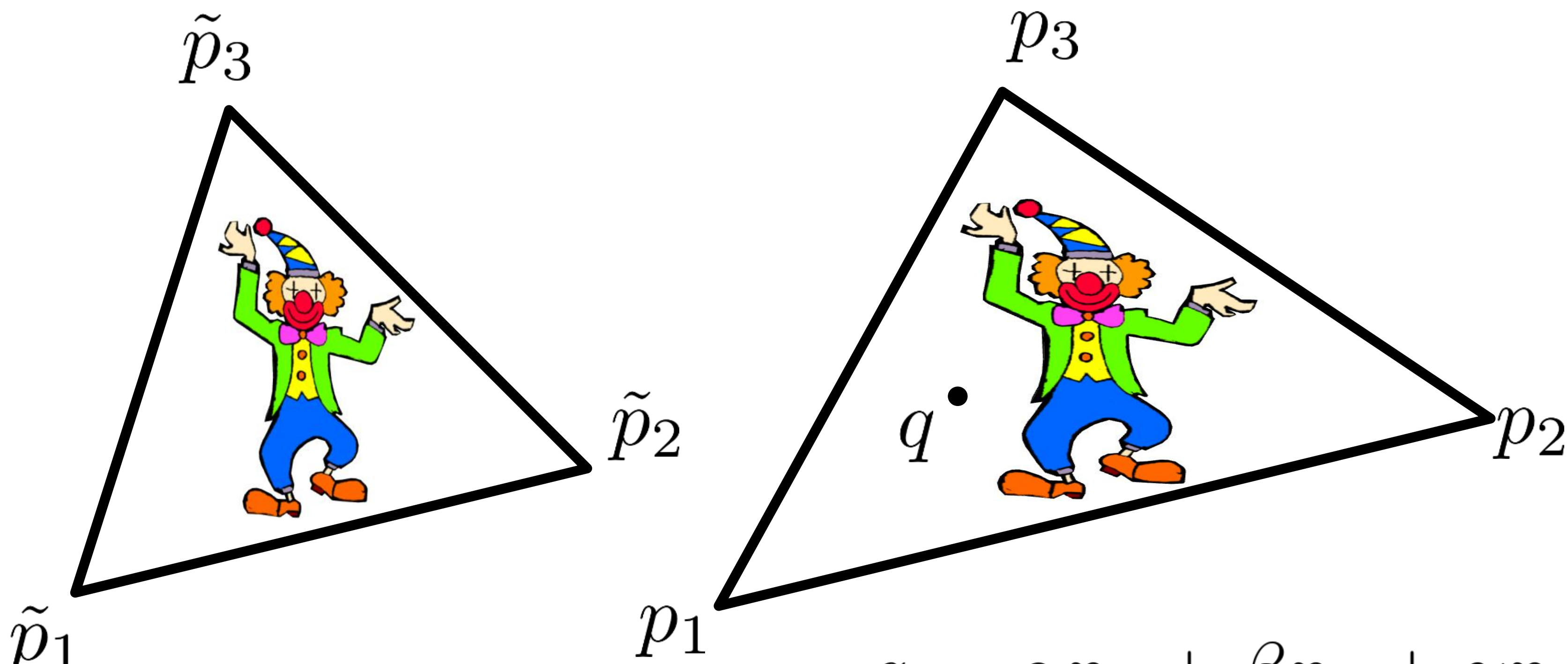
Simplest Cage: Triangle

Use **barycentric interpolation**



Simplest Cage: Triangle

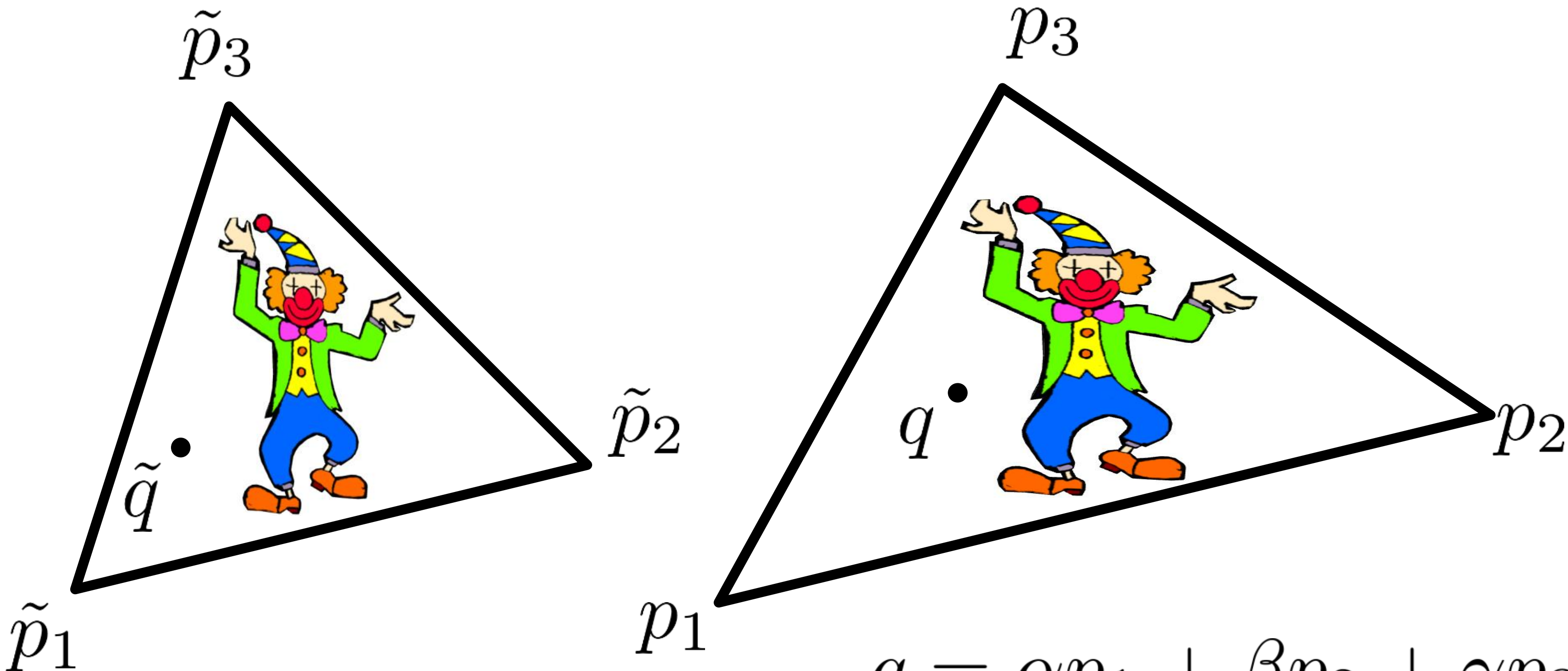
Use **barycentric interpolation**



$$q = \alpha p_1 + \beta p_2 + \gamma p_3$$

Simplest Cage: Triangle

Use **barycentric interpolation**



$$q = \alpha p_1 + \beta p_2 + \gamma p_3$$
$$\tilde{q} = \alpha \tilde{p}_1 + \beta \tilde{p}_2 + \gamma \tilde{p}_3$$

Simplest Cage: Triangle

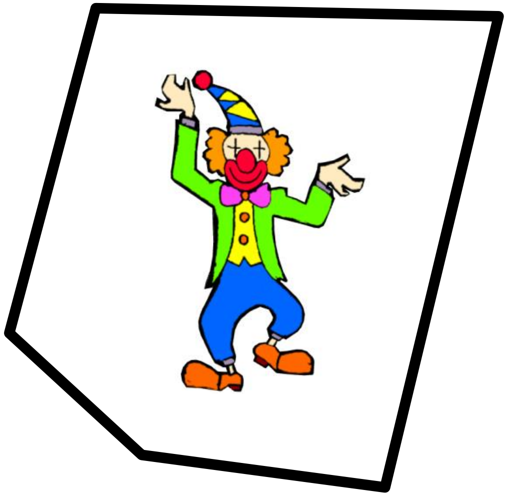
Use **barycentric interpolation**

For every pixel:

- find its barycentric coordinates
- look up point with same coordinates on **undeformed** shape
- copy pixel at that point

Polygonal Cages

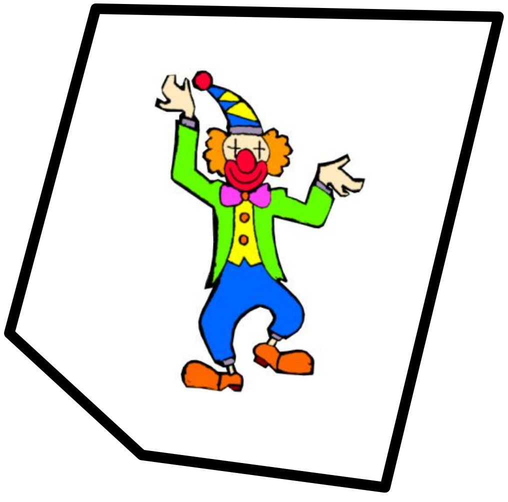
Must generalize barycentric coordinates to arbitrary polygons



$$q = \alpha p_1 + \beta p_2 + \gamma p_3 + \delta p_4 + \epsilon p_5$$

Polygonal Cages

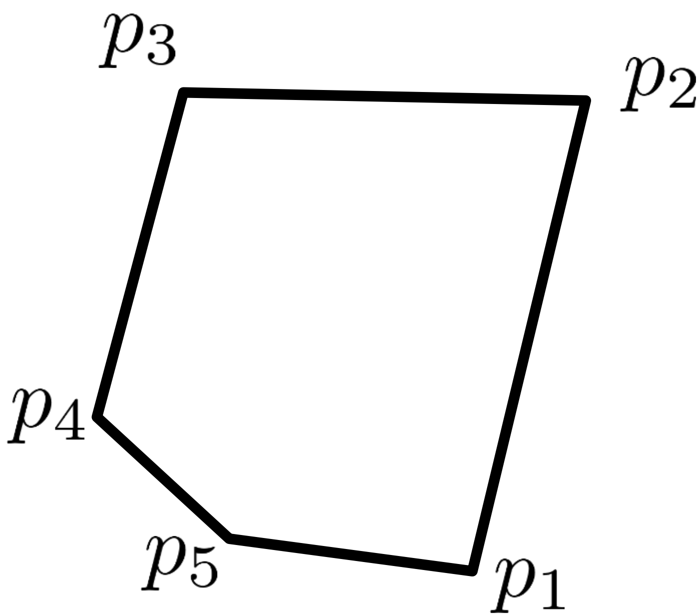
Must generalize barycentric coordinates to arbitrary polygons



Many ways to do this: generalized barycentric coordinates **not** unique

$$q = \alpha p_1 + \beta p_2 + \gamma p_3 + \delta p_4 + \epsilon p_5$$

Generalized Barycentric Coords



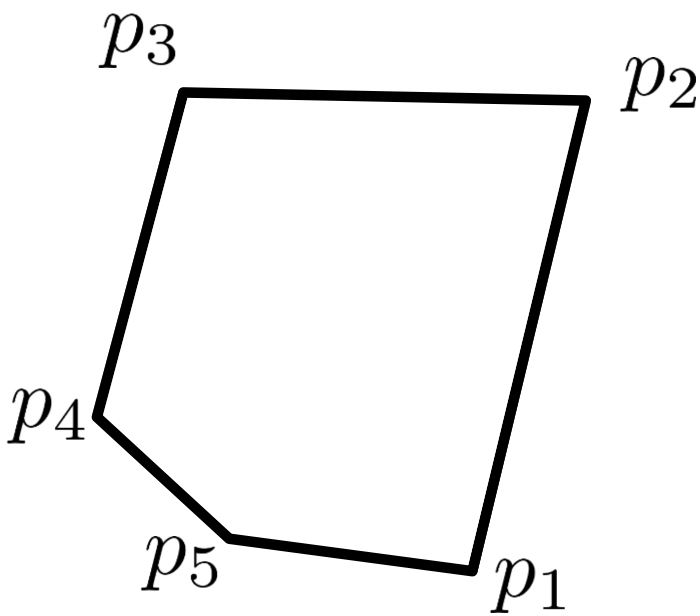
$$q = \sum \alpha_i p_i$$

Partition of unity:

$$1 = \sum \alpha_i$$

why important?

Generalized Barycentric Coords



$$q = \sum \alpha_i p_i$$

Partition of unity:

$$1 = \sum \alpha_i$$

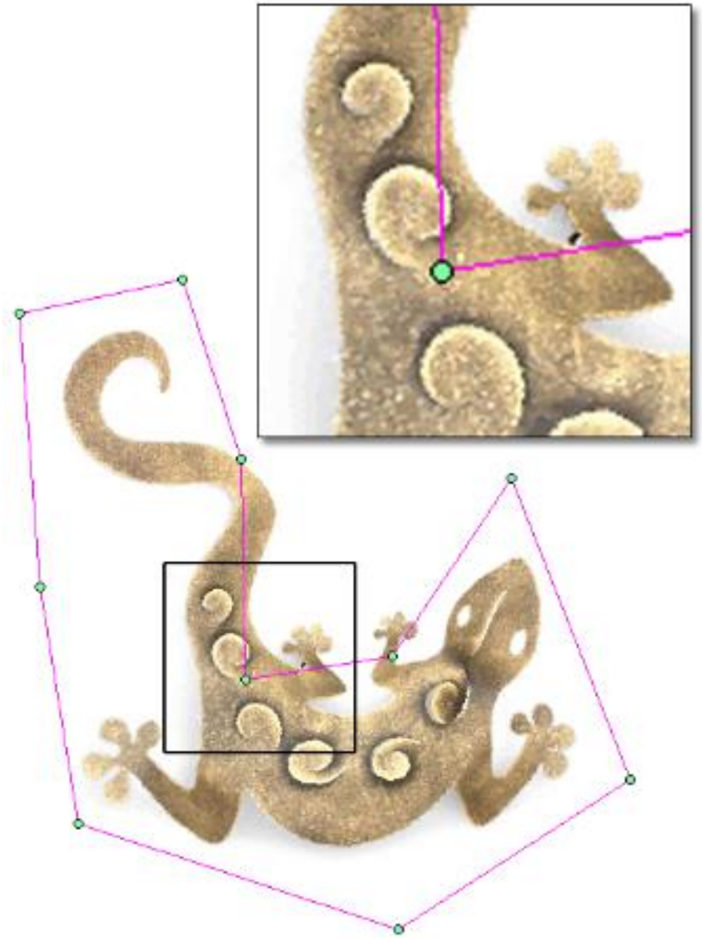
Reproduces the verts:

$$\alpha_i(p_j) = \begin{cases} 1, & i = j \\ 0, & i \neq j \end{cases}$$

Polygonal Cages

Other properties:

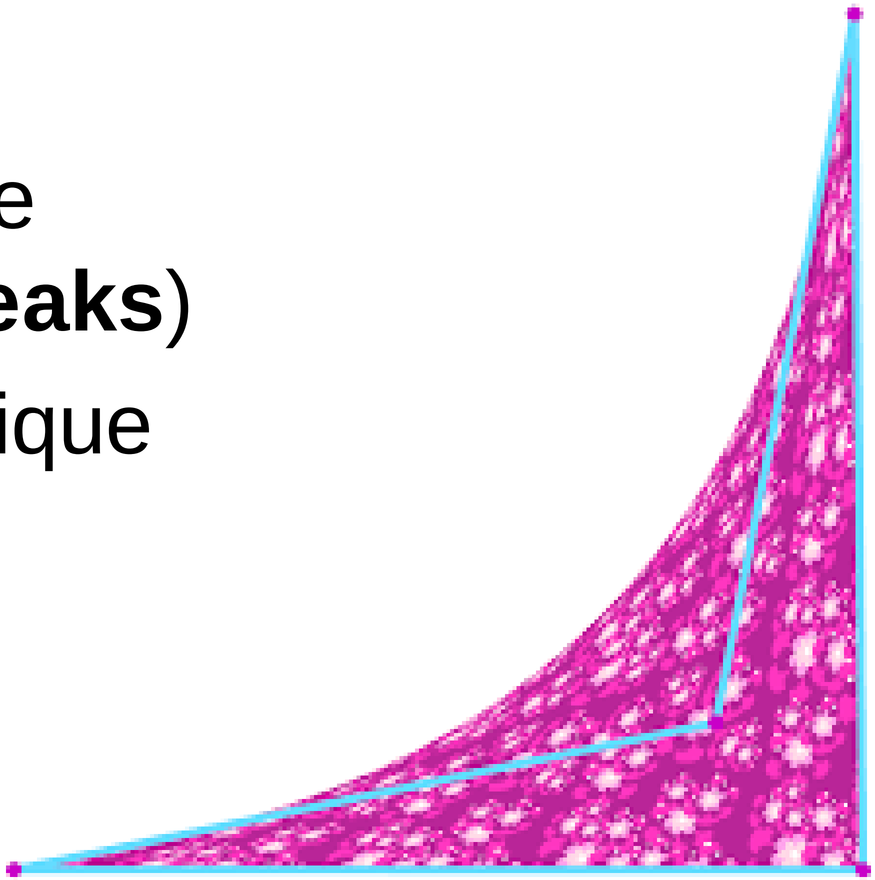
1. Weights must be positive inside the polygon (or get **leaks**)



Polygonal Cages

Other properties:

1. Weights must be positive inside the polygon (or get **leaks**)
2. Weights must unique (or get **flips**)



Polygonal Cages

Other properties:

1. Weights must be positive inside the polygon (or get **leaks**)
2. Weights must unique (or get **flips**)
3. Smooth
4. Easy to compute

Many Possible Schemes

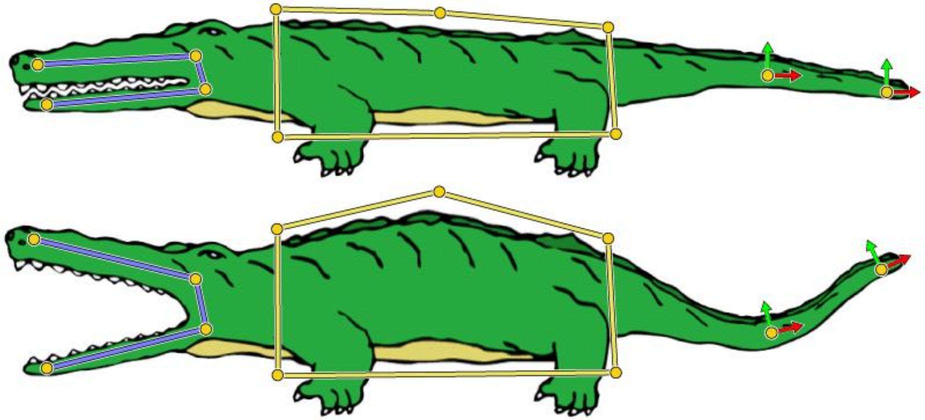
Wachspress Coordinates

Mean-value Coordinates

Green Coordinates

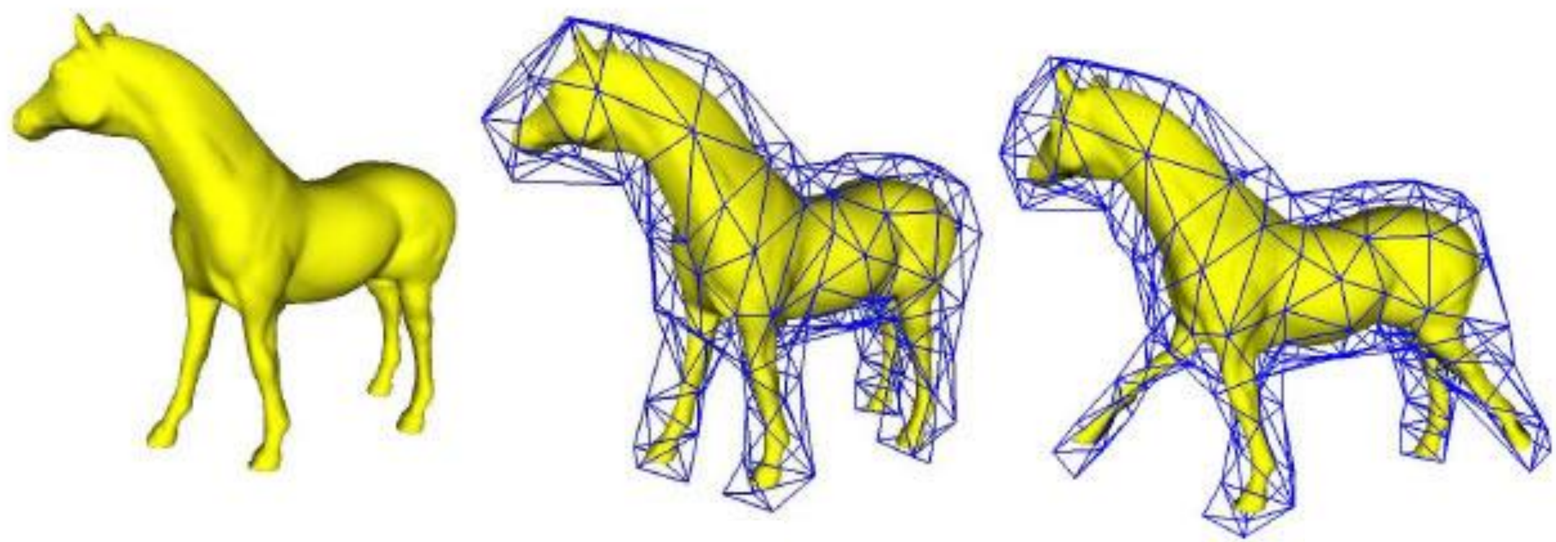
Bounded Biharmonic Weights

…



Cage-Based Animation

Extends to 3D from 2D naturally



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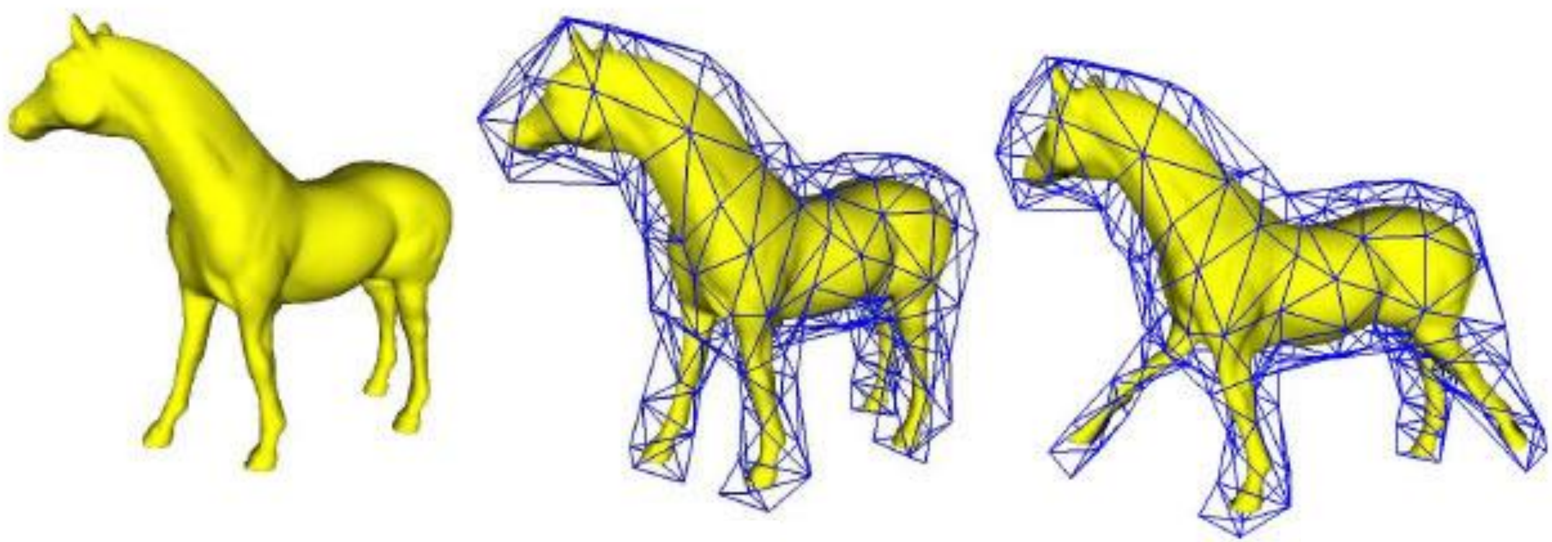
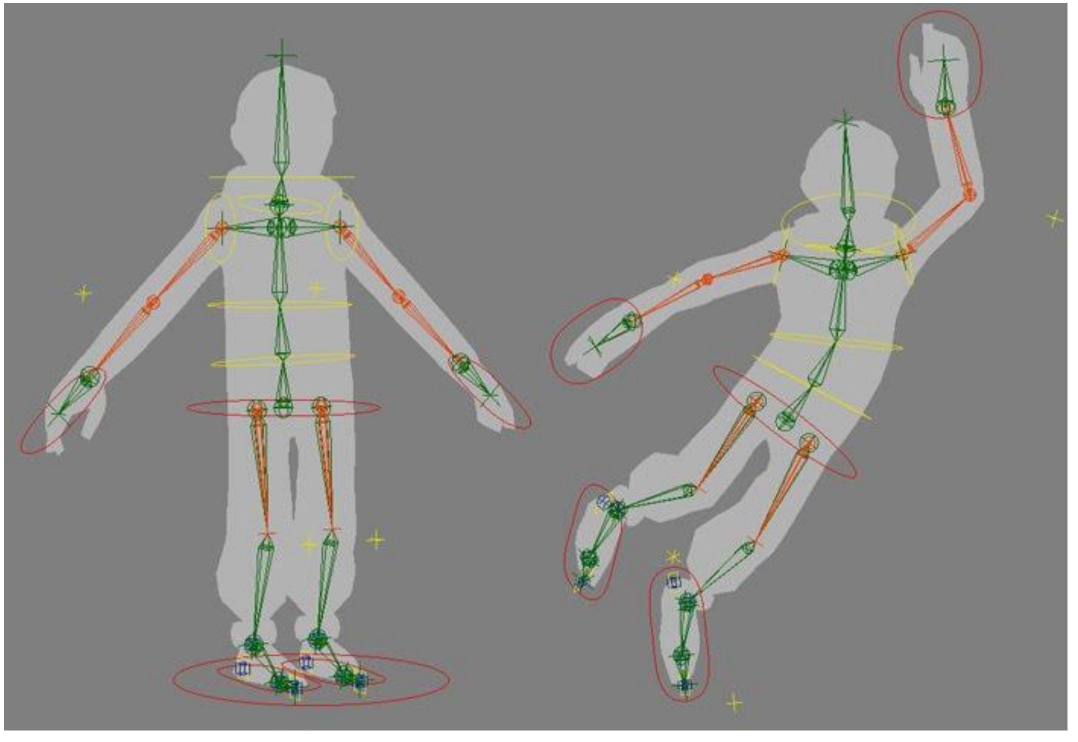


Full control, but not intuitive

Character Rigs

Skeletons inside the geometry



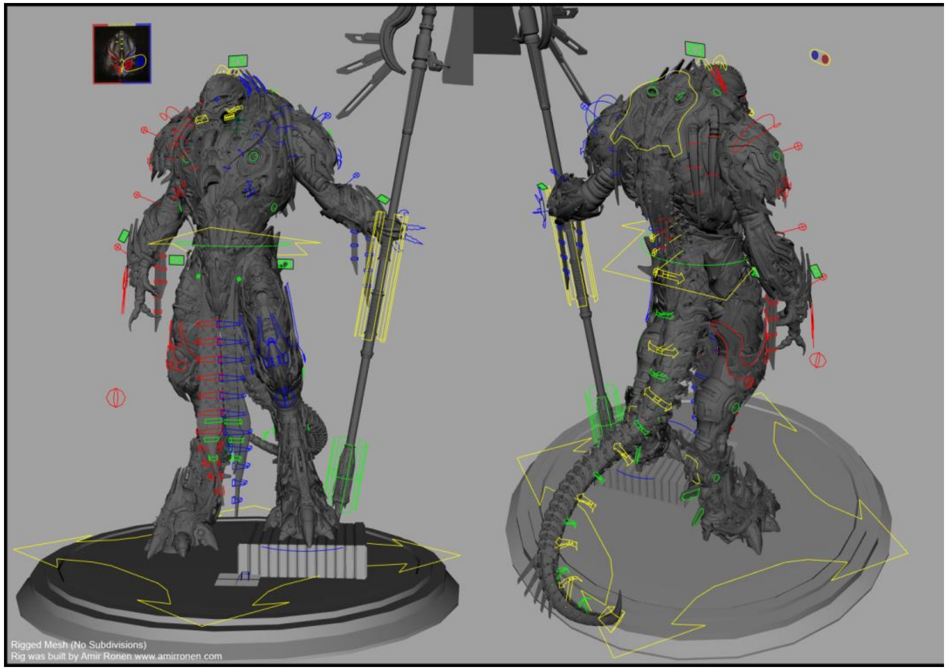
moving bones moves surrounding geometry

the industry standard for character animation

how to build rig?

Building a Rig

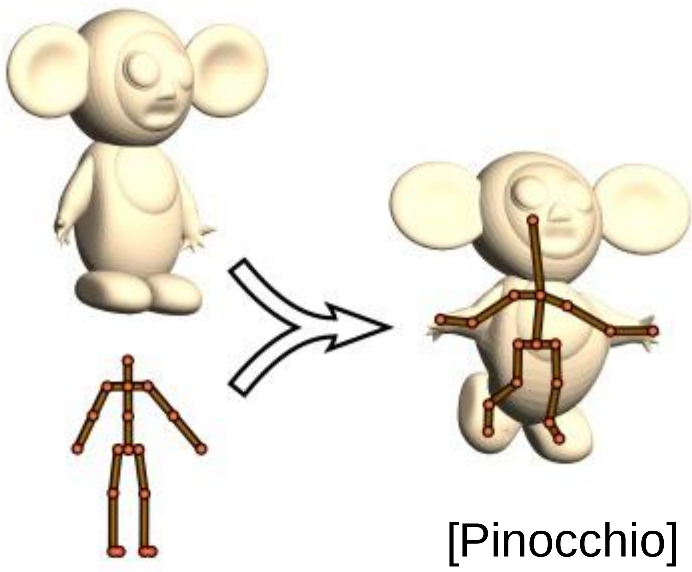
Usually done by hand using Maya etc.



Expressiveness/complexity tradeoff

Building a Rig

Some automatic tools exist

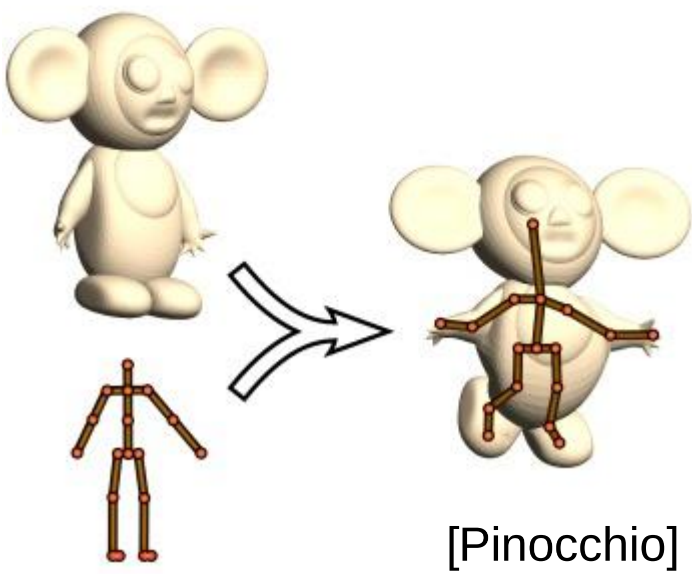


[Pinocchio]

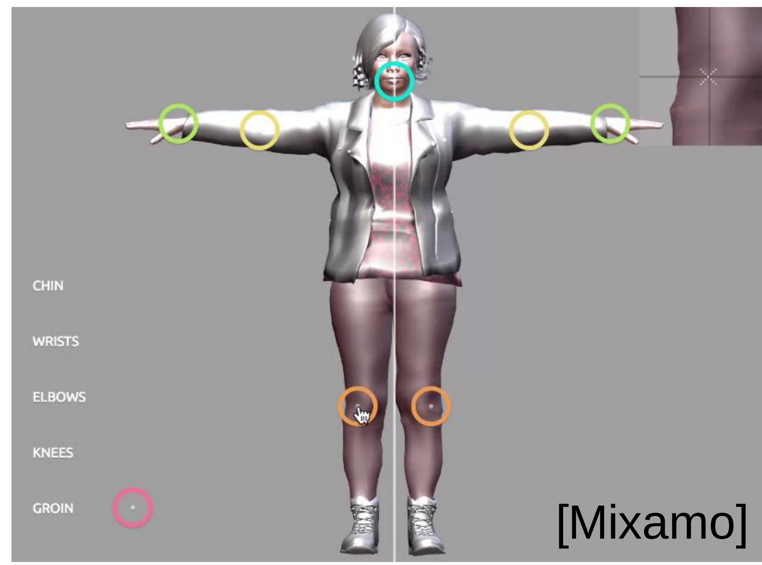
[Mixamo]

Building a Rig

Some automatic tools exist



[Pinocchio]



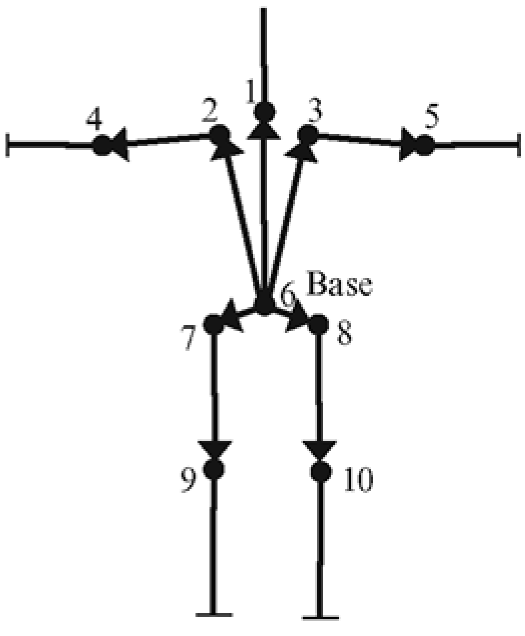
[Mixamo]

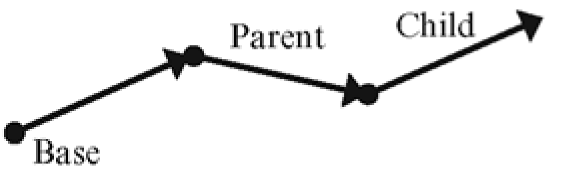
Work well for humans/humanlike objects

Not so impressive for arbitrary characters

Representing a Rig

Tree of **bones** connected by **joints**





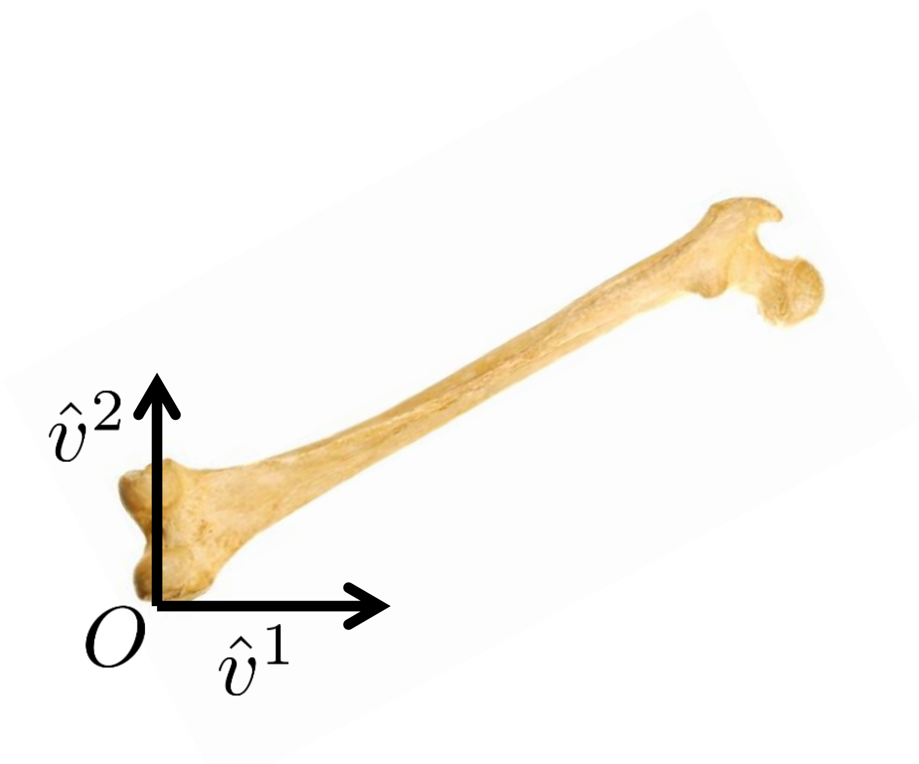
bones have two endpoints

- first attached to **parent**

Joint Local Coordinates

Origin O at joint location

Coordinate axes: initially, same as world



Joint Local Coordinates

Origin O at joint location

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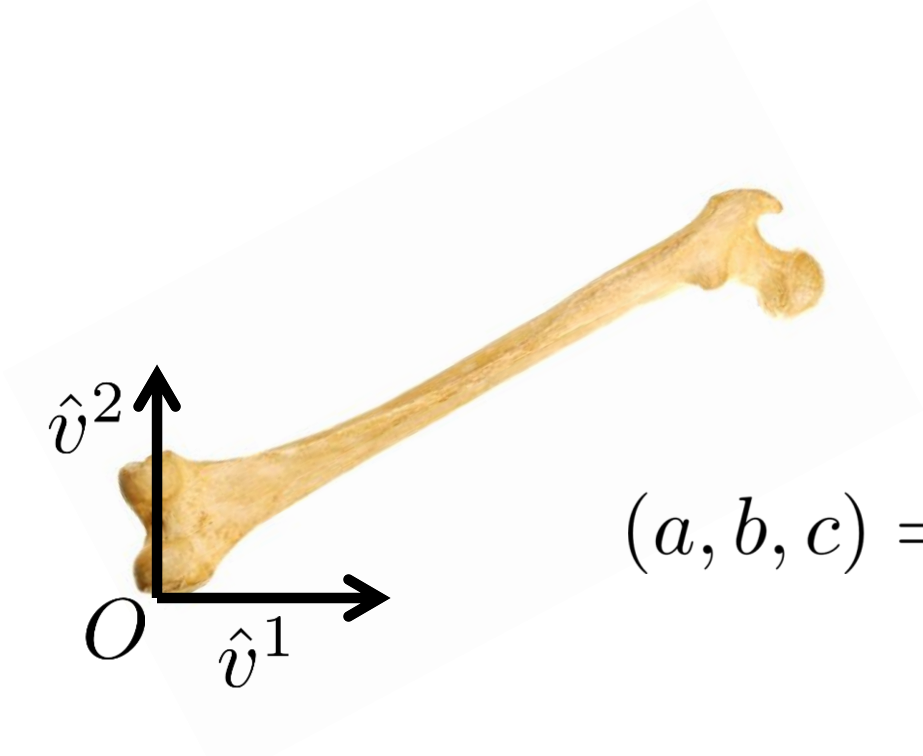
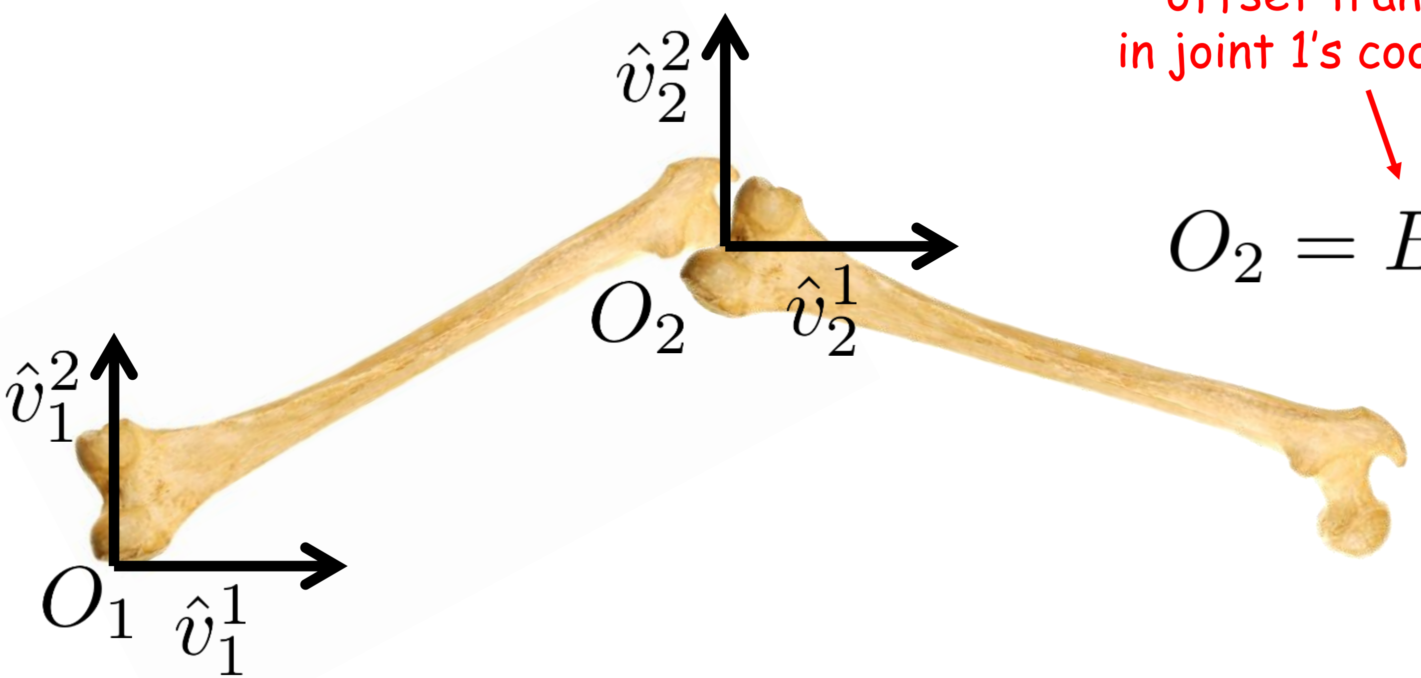


$$(a, b, c) = O + a\hat{v}^1 + b\hat{v}^2 + c\hat{v}^3$$

Joint Local Coordinates

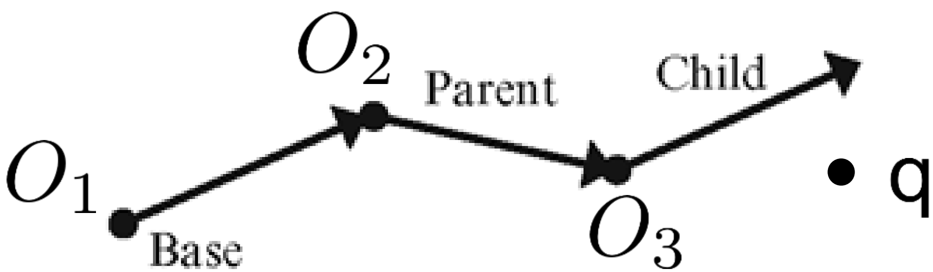
Child bone can be expressed in terms of **parent** coordinate system



offset translation in joint 1's coordinates

$$O_2 = B_{12} O_1$$

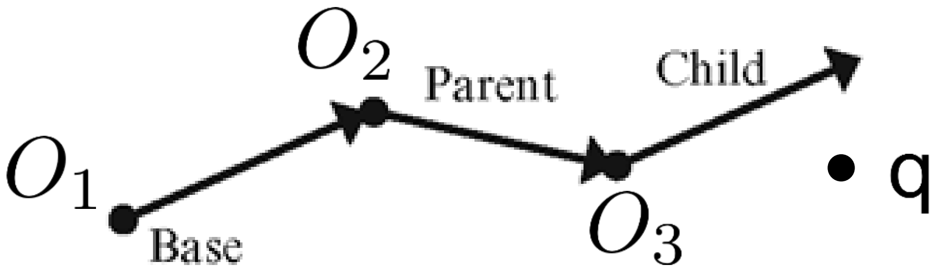
Joint to World Coordinates



In local coordinates:

$$q = (x, y, z)$$

Joint to World Coordinates



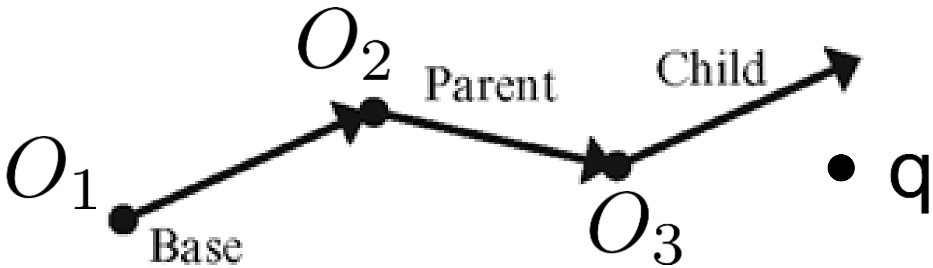
In local coordinates:

$$q = (x, y, z)$$

In world coordinates:

$$q = O_3 + x\hat{v}_1^3 + y\hat{v}_2^3 + z\hat{v}_3^3$$

Joint to World Coordinates



In local coordinates:

$$q = (x, y, z)$$

In world coordinates:

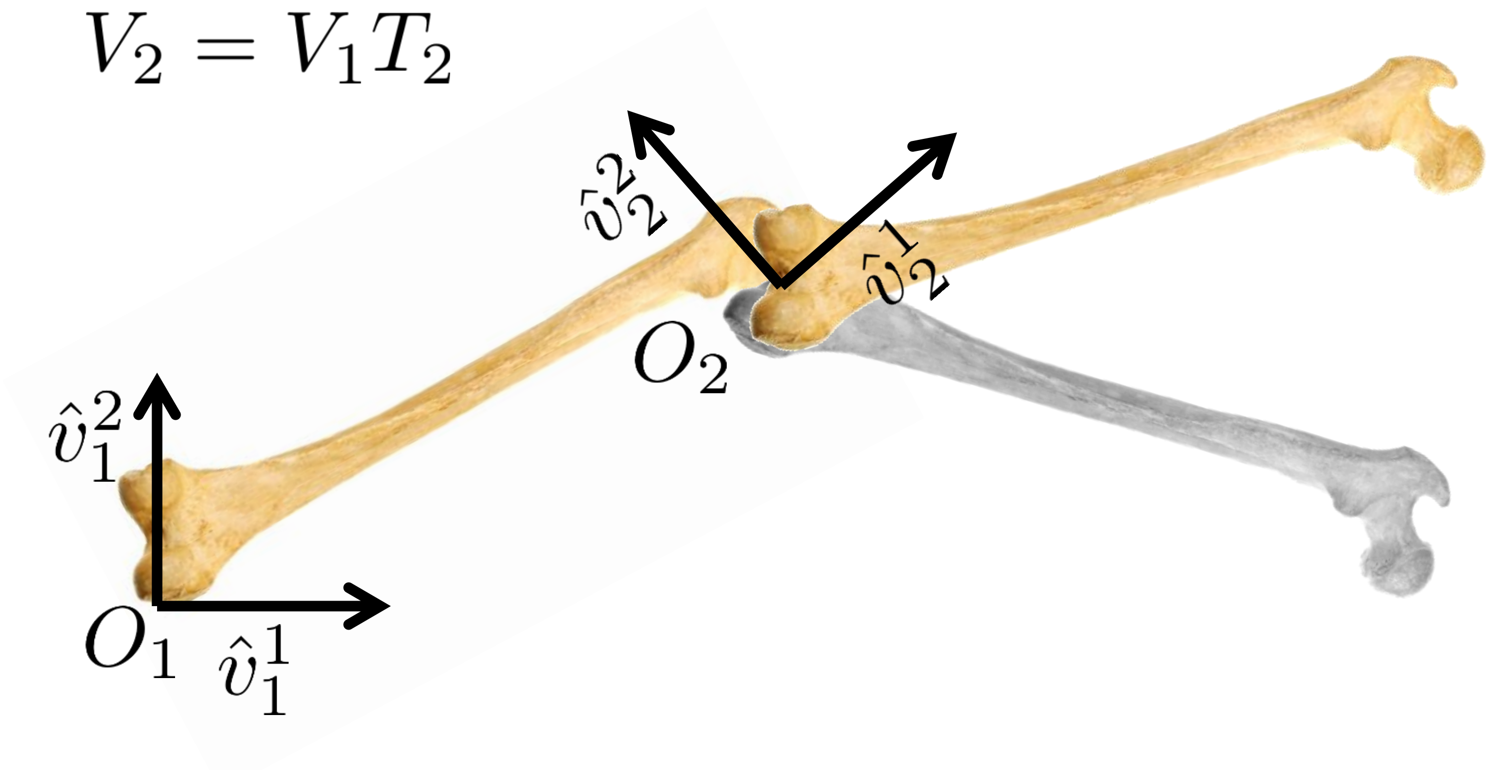
$$q = O_3 + x\hat{v}_1^3 + y\hat{v}_2^3 + z\hat{v}_3^3 = U_3 \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

$$U_{i+1} = U_i B_{i(i+1)}$$

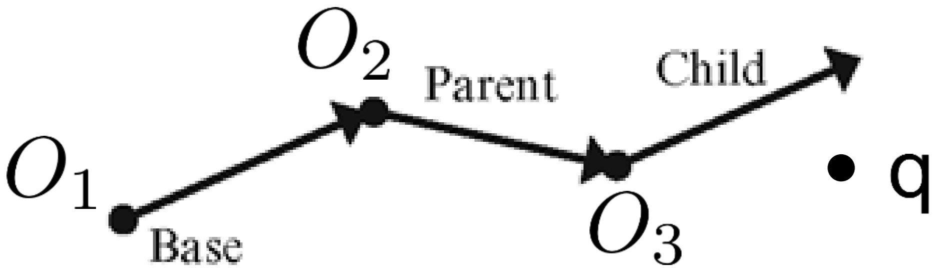
Articulating the Joints

Represent motion by a rotation T_i per joint

$$O_2 = B_{12} O_1$$
$$V_2 = V_1 T_2$$



Deformed Joint to World



In local coordinates:

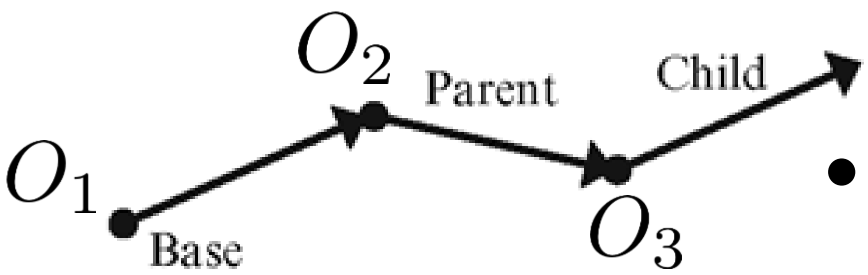
$$q = (x, y, z)$$

In world coordinates:

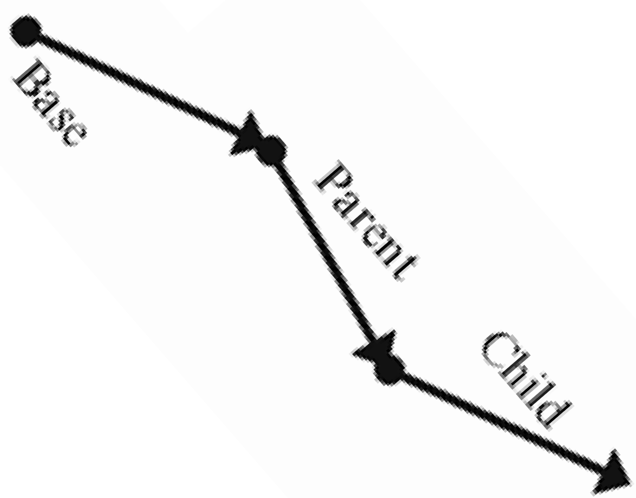
$$q = O_3 + x\hat{v}_1^3 + y\hat{v}_2^3 + z\hat{v}_3^3 = D_3 \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

$$D_{i+1} = D_i B_{i(i+1)} T_{i+1}$$

Forward Kinematics



- $q_{\text{world}} = U_3 q_{\text{local}}$



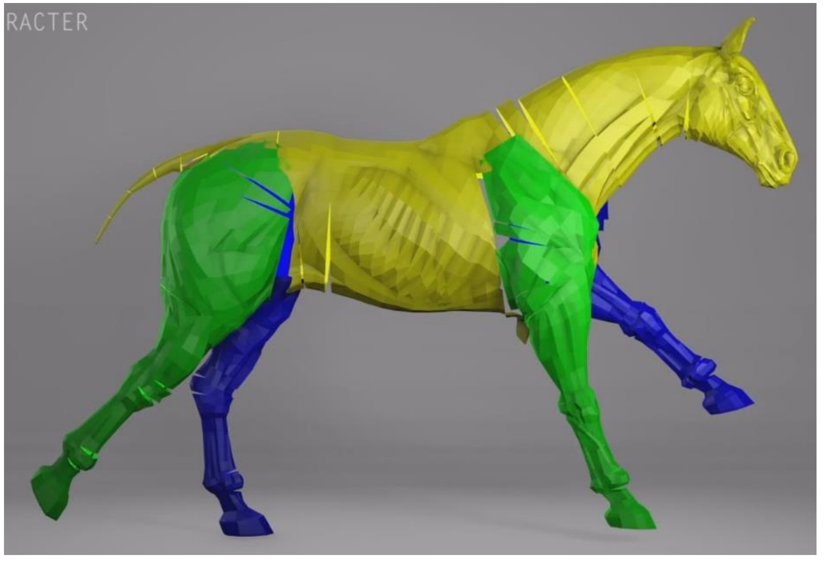
changing T_1 **also** changes child coordinate systems

- $q_{\text{world}} = D_3 q_{\text{local}}$

Skinning

Moving bones moves the character

Closer bones have more influence

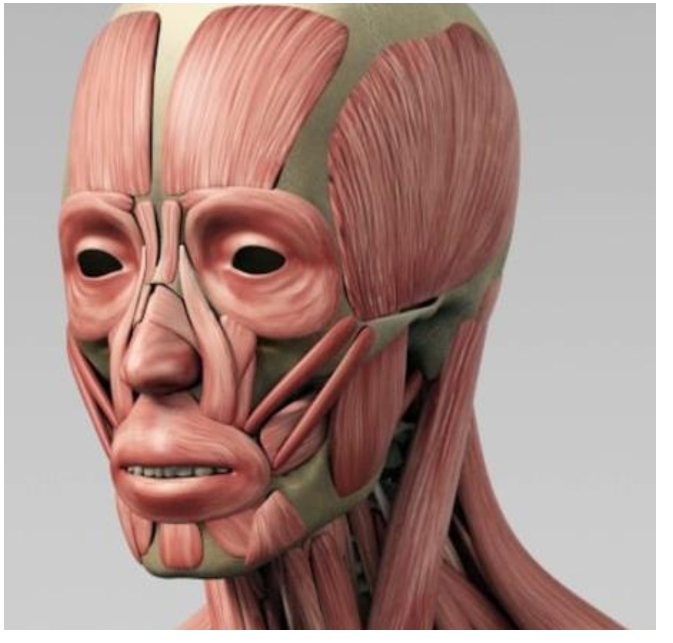


We will discuss the details on Thursday

Other 3D Animation Techniques

Anatomy-based animation

- simulate the tendons and muscles



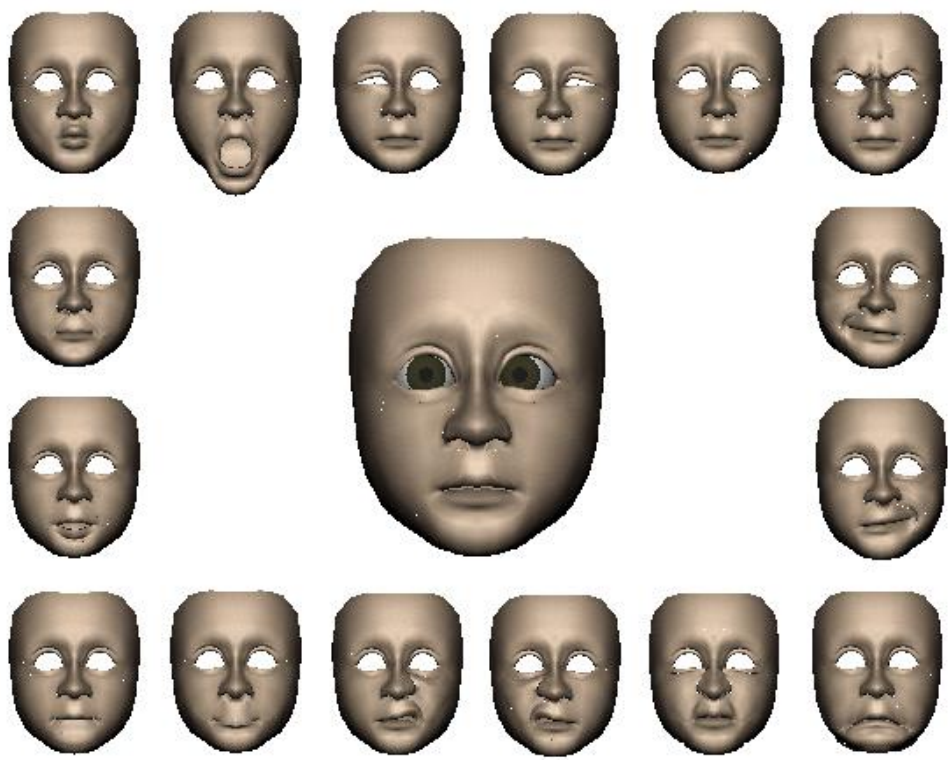
Most correct motion

Restricted to “real” animals

Slow

Other 3D Animation Techniques

Faces are hard to rig: many muscles

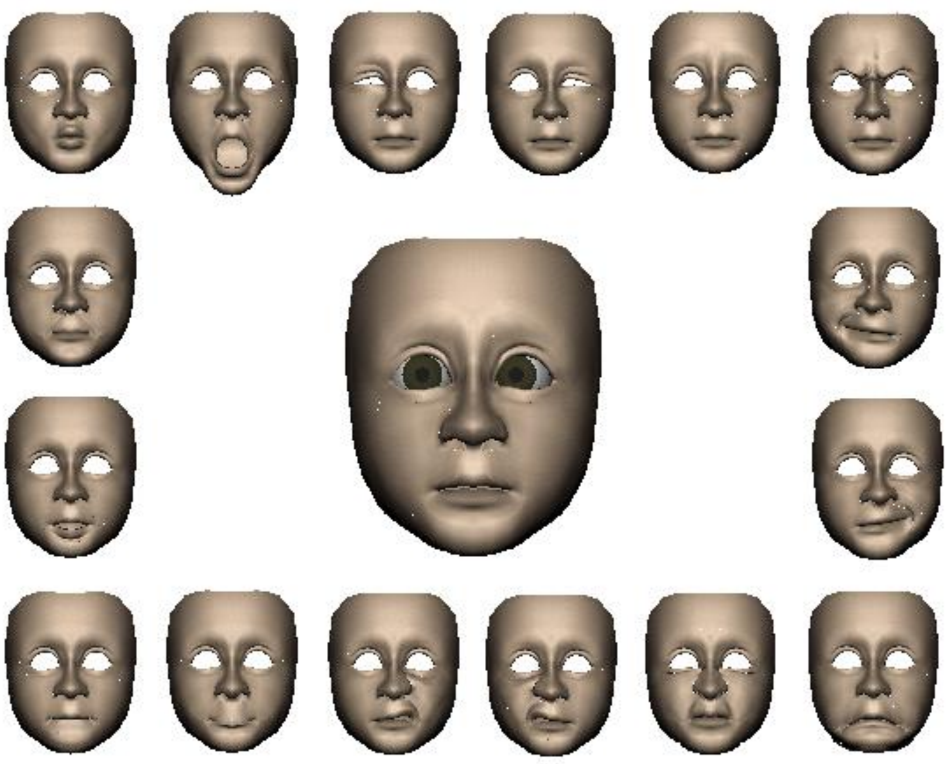


instead, precompute a small set of **basis deformations**

blend between them (**blendshapes**)

Other 3D Animation Techniques

Faces are hard to rig: many muscles



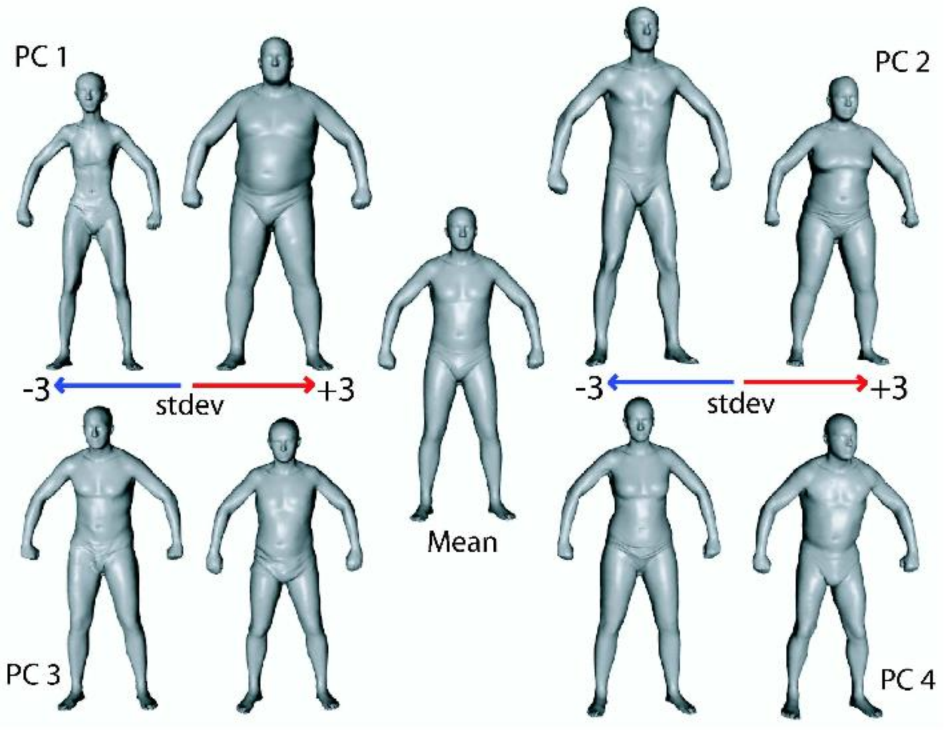
instead, precompute a small set of **basis deformations**

blend between them (**blendshapes**)

knobs not always intuitive

Other 3D Animation Techniques

SCAPE: data-driven statistical model of human body shapes



rig a “mean” template human once by hand

for an arbitrary human, transfer the rig by fitting to a SCAPE model

works well only for (nearly) naked humans