Animating Virtual Characters

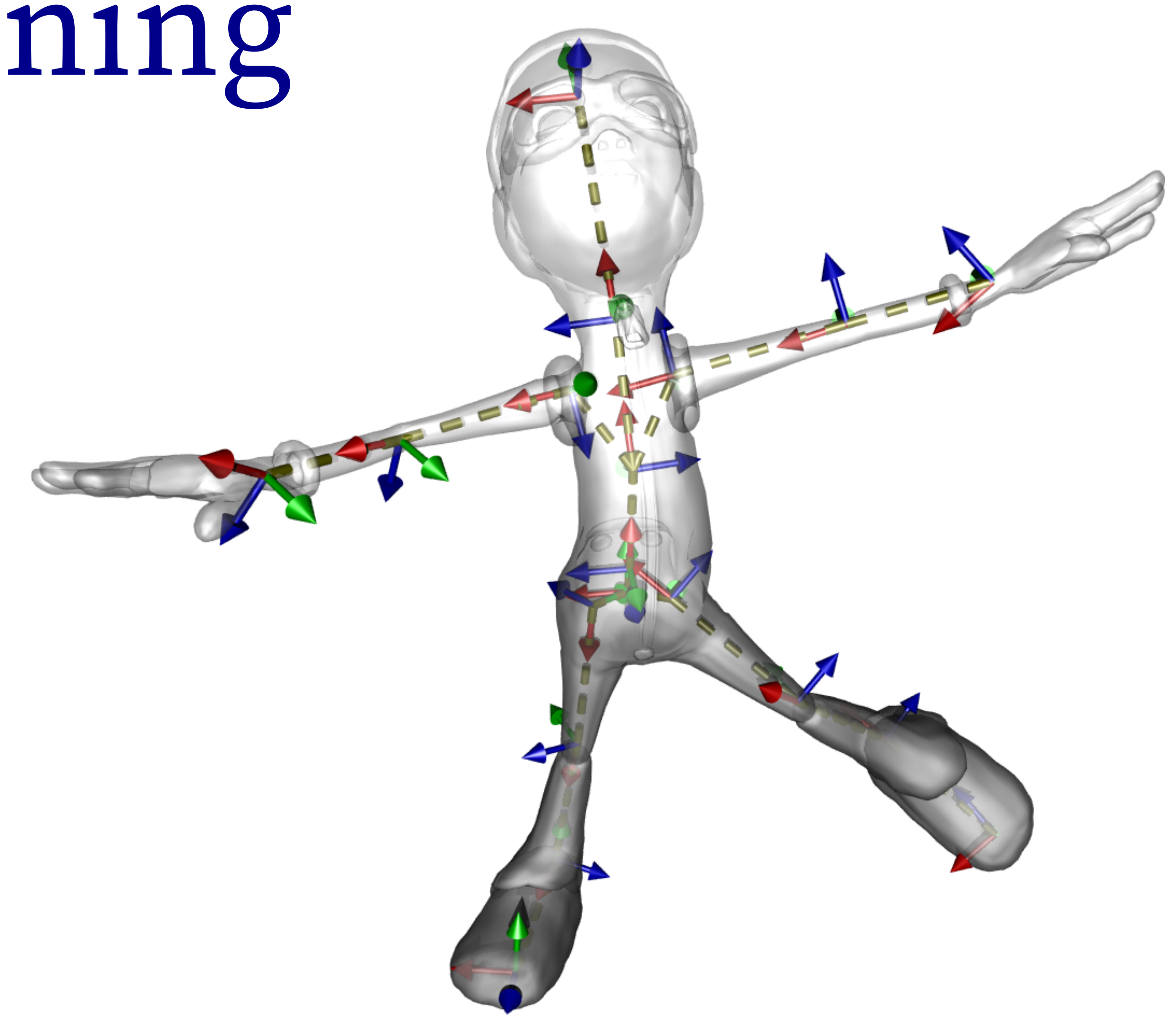
Skin deformation

Skeleton based deformation - Skinning

Objective: Deform articulated character

Idea: Use skeleton to control limbs

Articulations as rotations



Animation Skeleton

Set of frames T_i: position, orientation

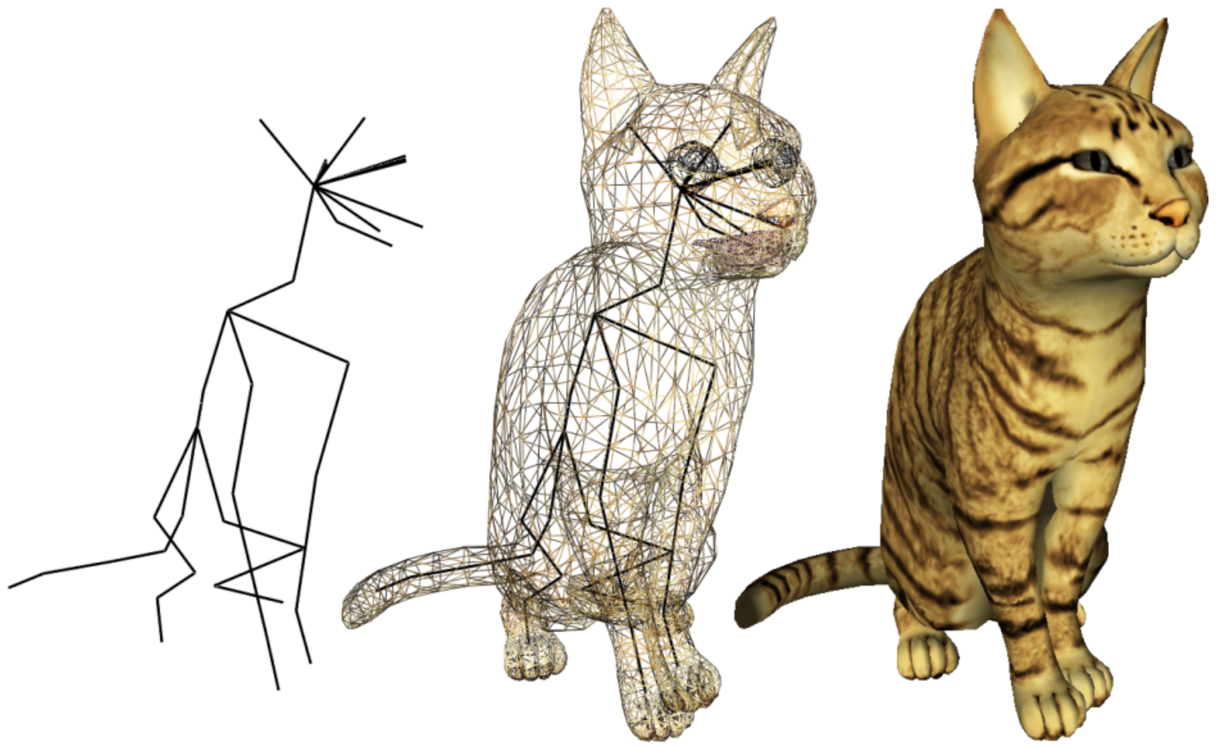
Describe non-rigid parts of the character (dof)

Terminology

Joint = A frame T_i

Bone = Segment between two joints

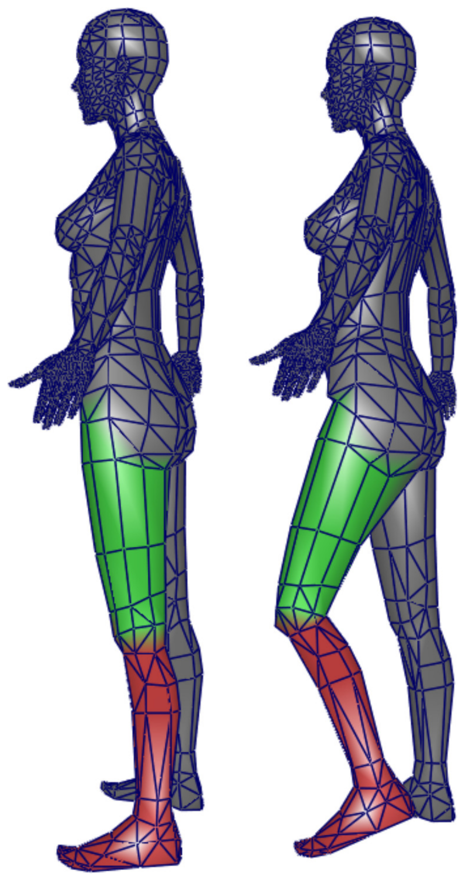
Note: Animation skeleton $\neq$ *Anatomical skeleton*

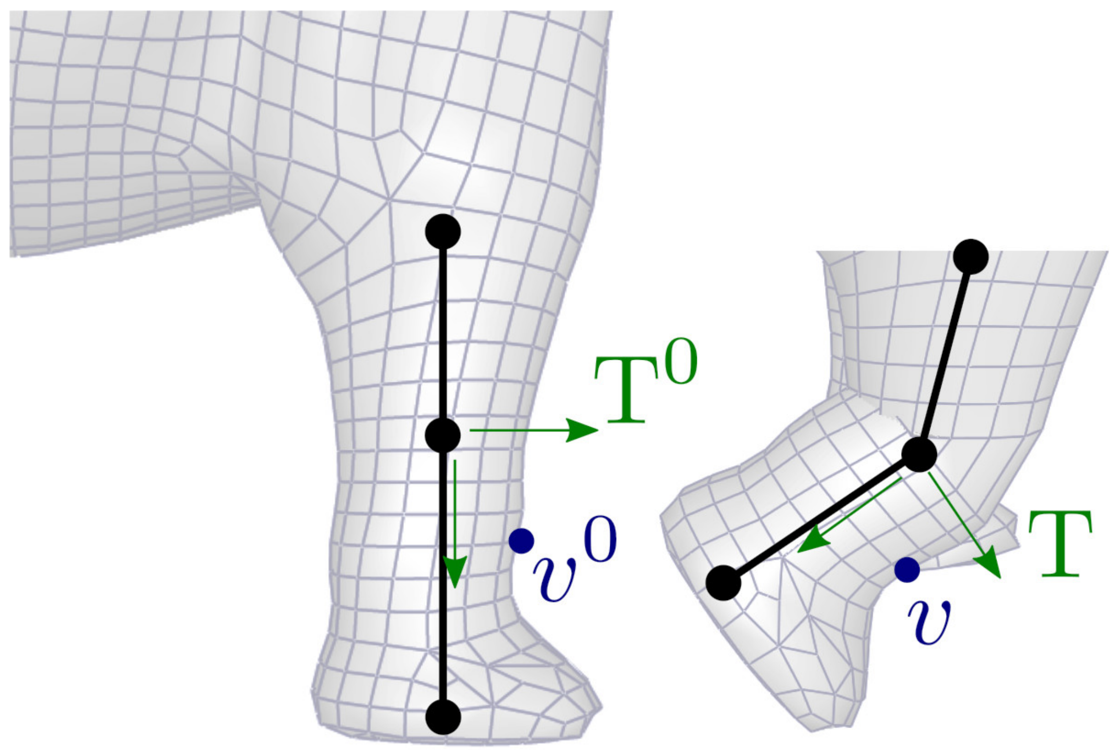


Rigid Skinning

Attach rigidly subset of vertices to specific bones, described by its root joint/frame.

Vertices are following rigid deformation of their associated frame.





Deformation formulation

Consider, at rest pose/initial state

- A frame T^0
- A vertex v^0 attached to this frame

After deformation

- New frame T
- New vertex position v

Question: What are the new coordinates v w/r T, T^0, v^0 ?

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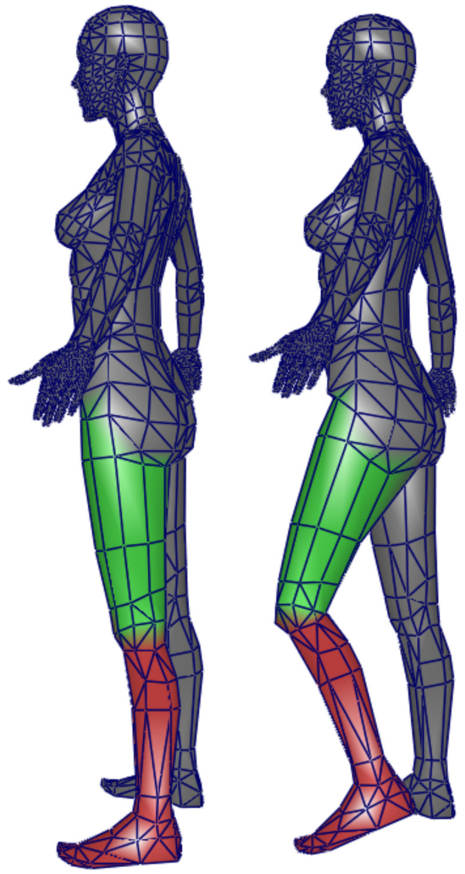
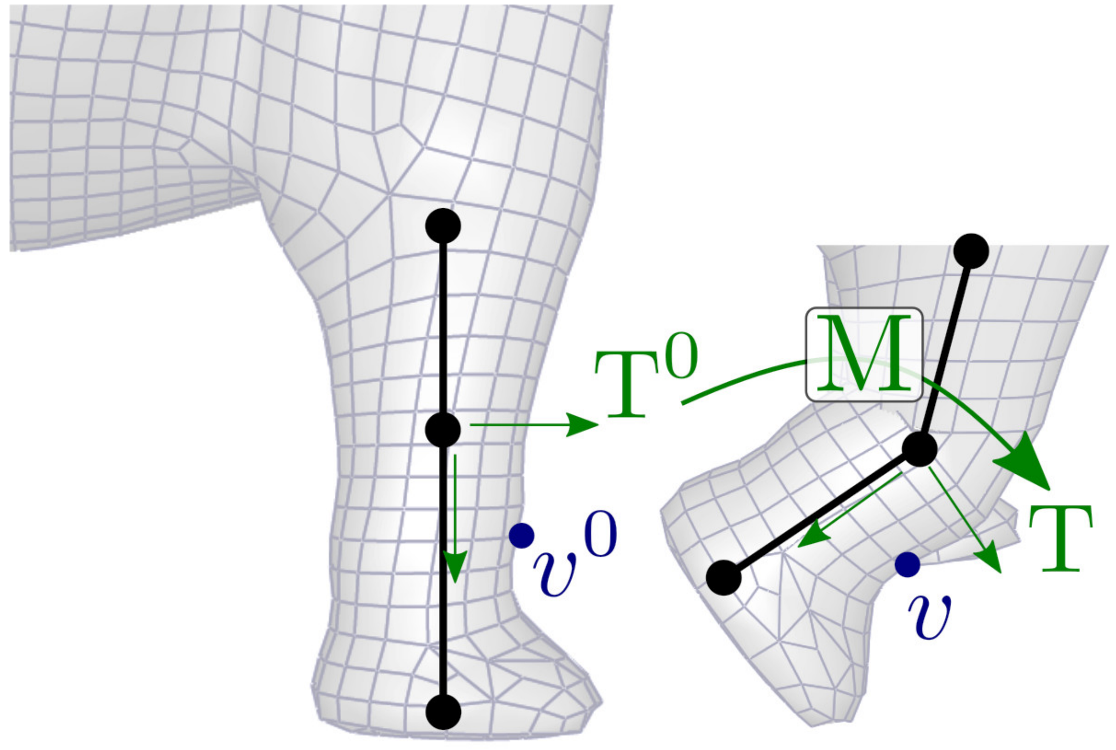




Question: What are the new coordinates v w/r T, T^0, v^0 ?

v^0 and v have similar local coordinates w/r to T^0 and T

$\Rightarrow \mathrm{T}^{-1} v = (\mathrm{T}^0)^{-1} v_0$

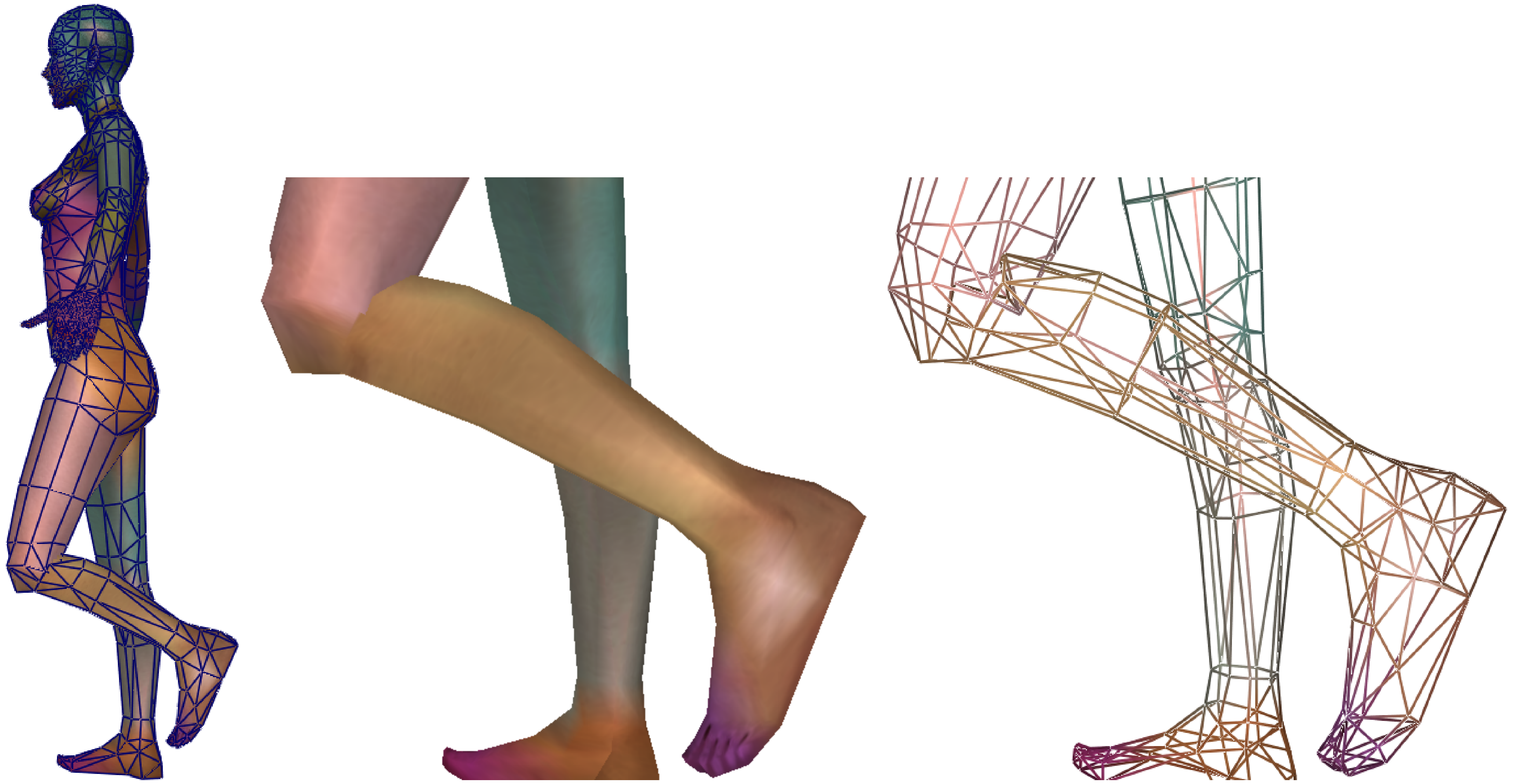
$$\Rightarrow v = \mathrm{T}\,(\mathrm{T}^0)^{-1} v_0 = \mathrm{M}\, v_0$$

Rigid Skinning

(+) Skeleton is easy to build

(+) Skeleton interaction is intuitive to model rigid articulation

(-) Discontinuities/Inter-penetrations



Idea of smooth skinning: Blend discontinuous transformation around articulation

Smooth skinning

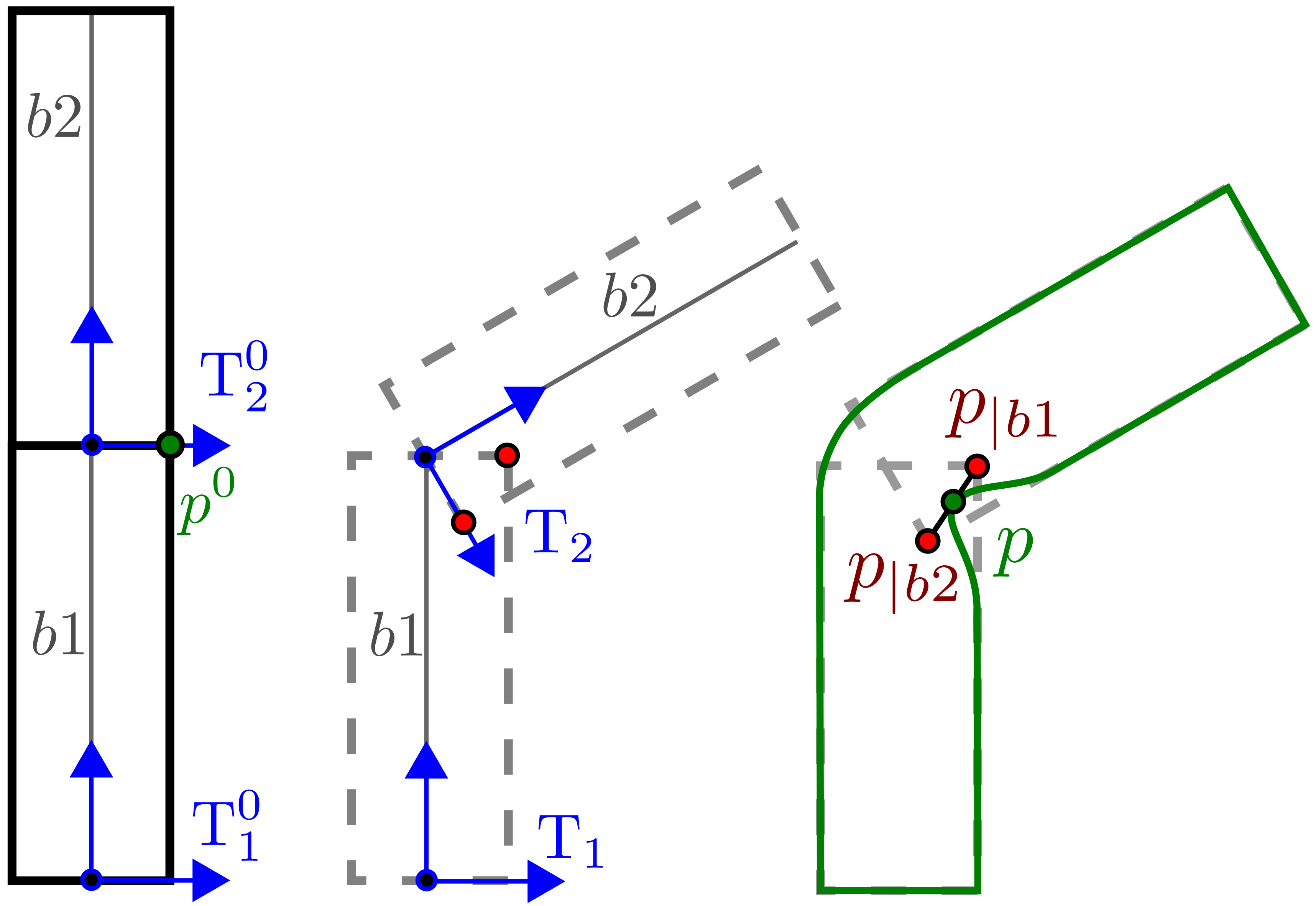
Linear Blend Skinning (LBS): Linear interpolation of positions between associated frames

Example at middle vertex position of a bending cylinder

$$p = 0.5\, p_{|b1} + 0.5\, p_{|b2}$$

$$p = 0.5\, \underbrace{\mathrm{T}_1\, (\mathrm{T}_1^0)^{-1}}_{\mathrm{M}_1}\, p^0 + 0.5\, \underbrace{\mathrm{T}_2\, (\mathrm{T}_2^0)^{-1}}_{\mathrm{M}_2}\, p^0$$

$$p = (0.5\, \mathrm{M}_1 + 0.5\, \mathrm{M}_2)\, p^0$$



Smooth skinning

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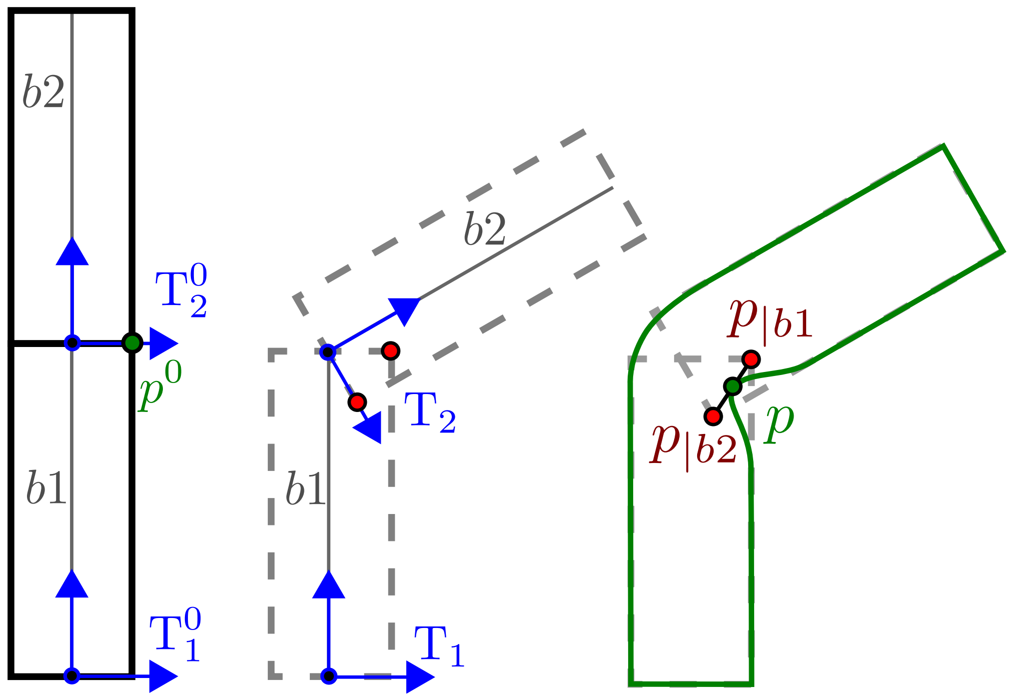
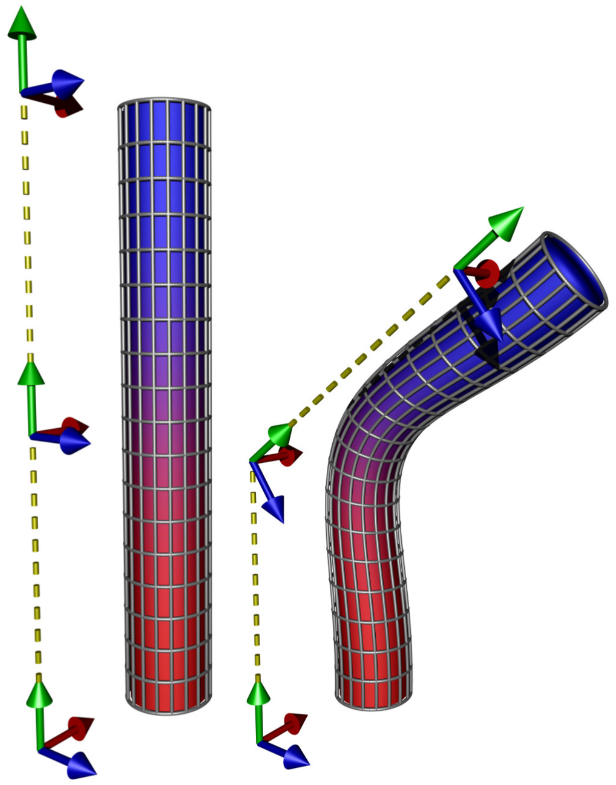
$$p = (0.5\, \mathrm{M}_1 + 0.5\, \mathrm{M}_2)\, p^0$$



Can be generalized to arbitrary interpolation between two bones

$$p = \alpha\, p_{|b1} + (1-\alpha)\, p_{|b2} = (\alpha \mathrm{M}_1 + (1-\alpha)\, \mathrm{M}_2)\ p^0$$

α: skinning weights



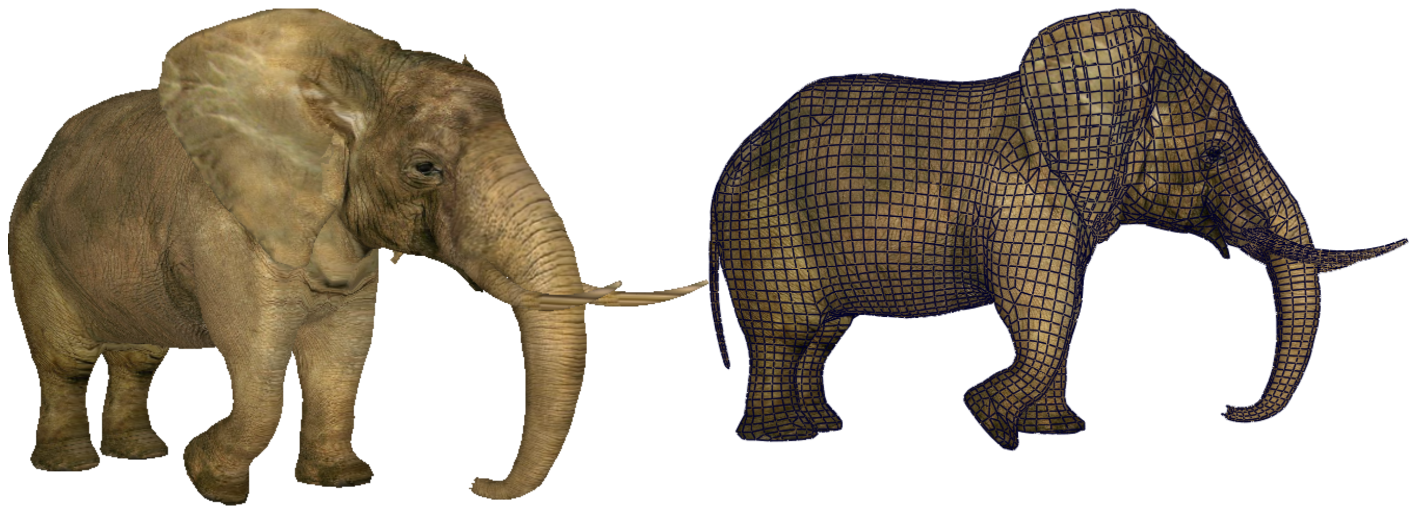
Can be generalized to any number of bones

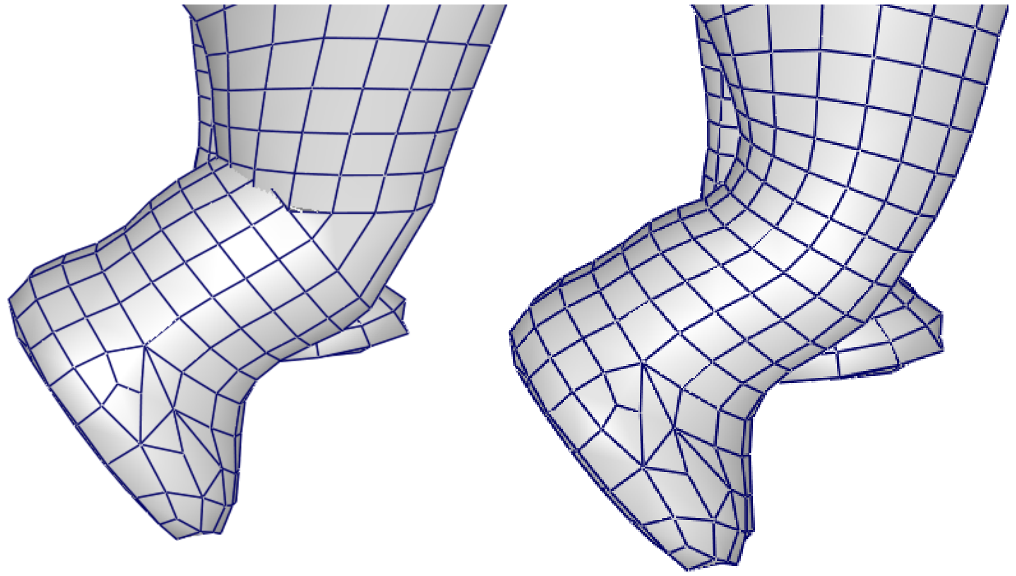
$$p = \sum_{k=0}^{N-1} \alpha_k\, p_{|bk} = \left(\sum_{k=0}^{N-1} \alpha_k\, \mathrm{M}_k \right) p^0 \ , \quad \sum_k \alpha_k = 1$$

Smooth skinning - Summary

$$p = \left(\sum_{k=0}^{N-1} \alpha_k \, \mathrm{M}_k \right) p^0 = \left(\sum_{k=0}^{N-1} \alpha_k \; \mathrm{T}_k \, (\mathrm{T}_k^0)^{-1} \right) p^0$$

$\forall k \,, \;\; \alpha_k \in [0, 1]$, and $\sum_{k=0}^{N-1} \alpha_k = 1$





The current **standard** for almost all articulated character deformations

- Intuitive deformation
- Controlable shape (*through weights*)
- Fast to compute (GPU compatible)
  matrix average, multiplication matrix-vector

$\Rightarrow$ Heavily used in Animation cinema & Video Game

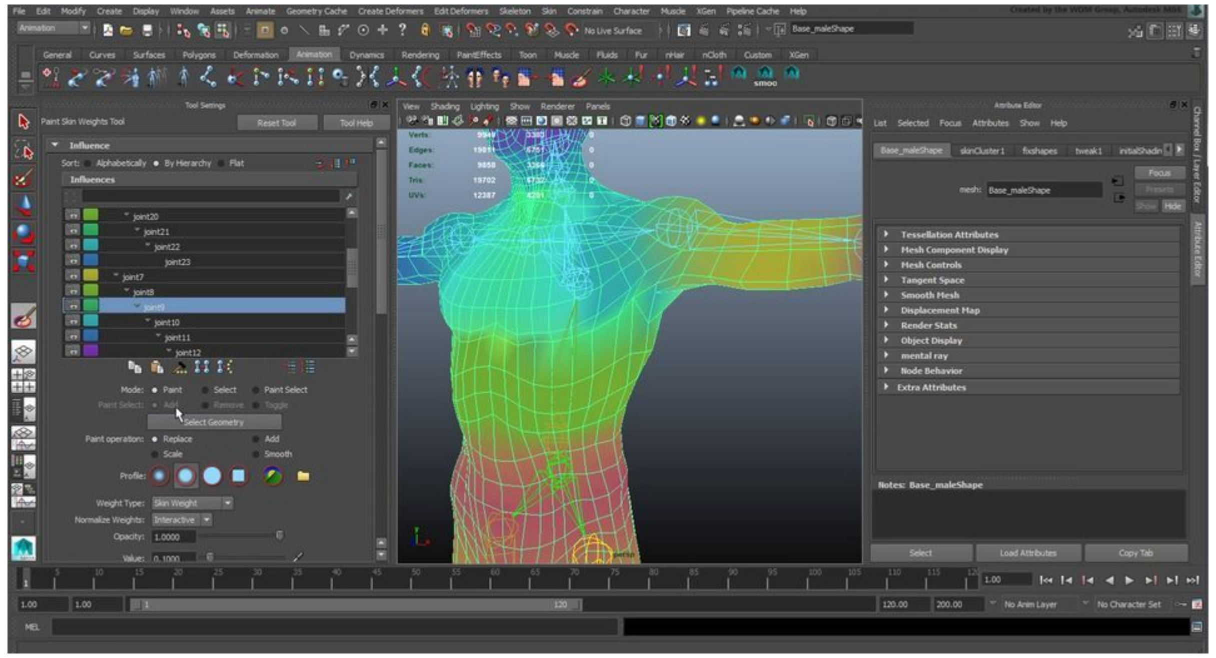
[Joint-Dependent Local Deformations for Hand Animation and Object Grasping. Nadia Magnenat-Thalmann, Rochard Laperière, Daniel Thalmann. Graphics Interface, 1988]

[Over My Dead, Polygonal Body. Jeff Lander. Game Developer Magazine, 1998]

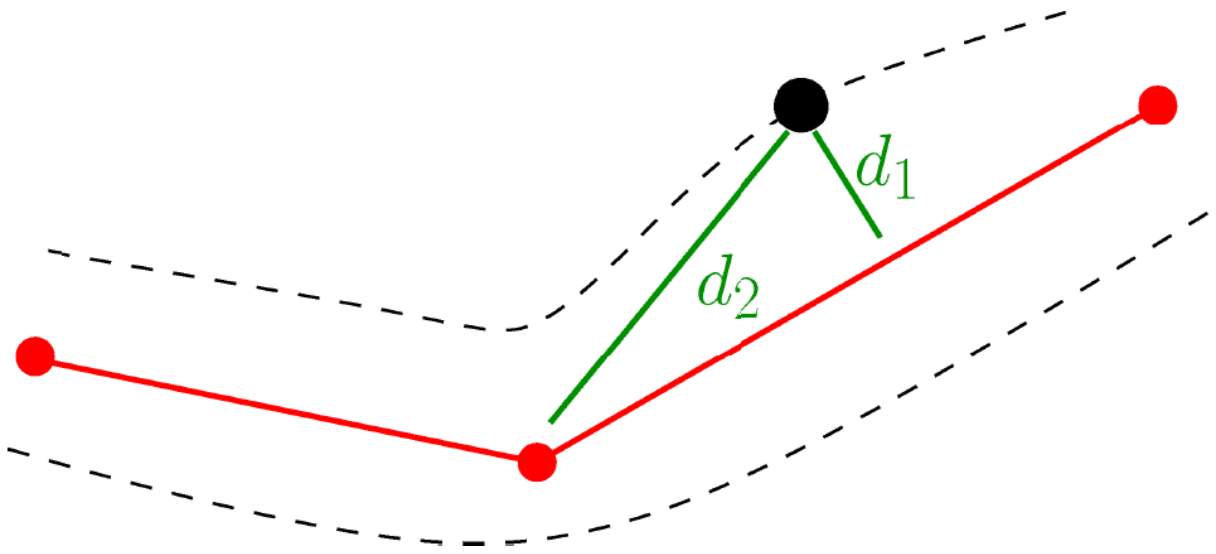
Skinning weights

How to generate skinning weights ?

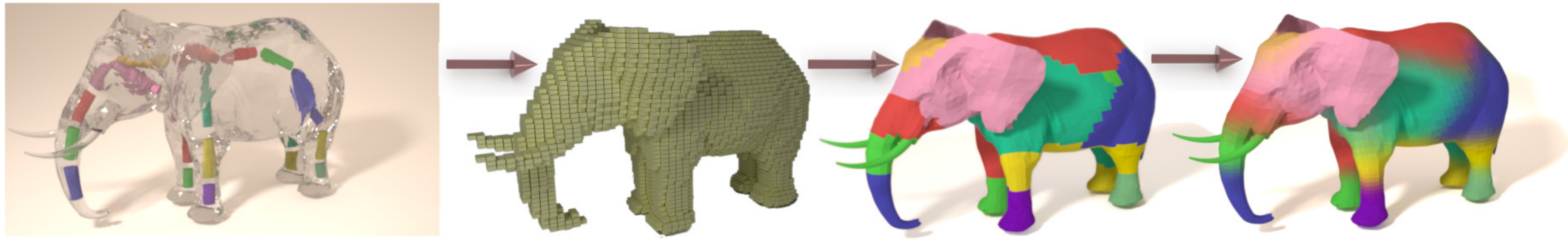
- Paint them manually
- Automatic computation



ex. Using cartesian distances: $\alpha_1 = d_1^{-1}/(d_1^{-1} + d_2^{-1})$



Or using diffusion on the volume/surface



Rigging: Associating bones and skinning weights (or any animation handle) to mesh parts

Skinning: File Format

- Unfortunately few standard open format to store skinning animation data
  - Main open format: Collada (XML), glTF (JSON)
  - Common software related formats: FBX, Blend, 3DS, ...

krissie Maya 7.0 | ColladaMaya v2.04 | FCollada v1.14 Collada Maya Export Options:
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.json

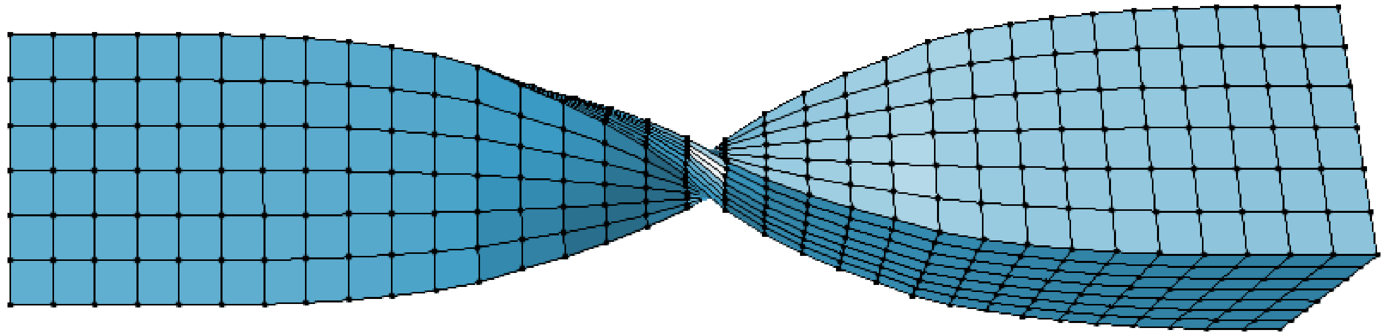
Linear Blend Skinning - Limitations

- Non-trivial rigging settings
- Artifacts for large rotations: Candy wrapper, Collapsing ellbow

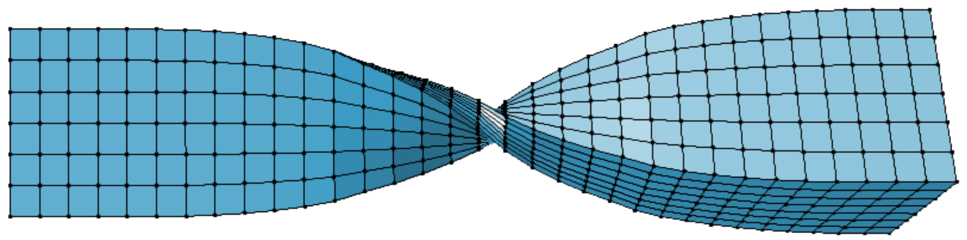
Candy wrapper

Collapsing elbow

Linear blending between rigid transformation matrices



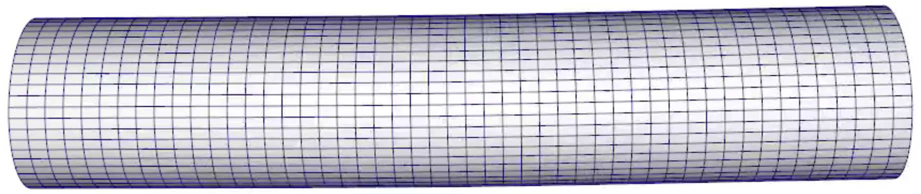
Skinning improvement



Avoid linear blending b/w affine transform matrices

First idea: Split rigid transformation matrices in
- rotation part: blend using quaternions (solve candy wrapper)
- translation part: blend linearily

But doesn't work for general deformation: Arbitrary center of rotation
Rotation and translations are treated separately



Possibility to compute an optimal center of rotation at each frame

[Spherical Blend Skinning: A Real-time Deformation of Articulated Models. L. Kavan, J. Zara. I3D 2005.]

Skinning improvement: Dual Quaternion

Second idea: Use of **dual quaternion**

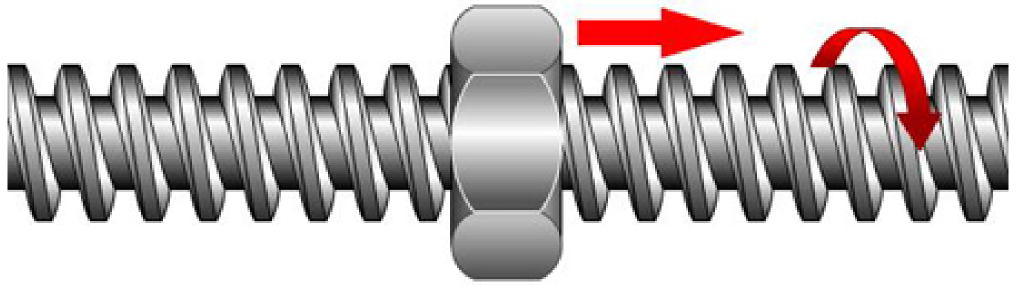
$\hat{q} = q_0 + \epsilon\, q_\epsilon$, ϵ dual element.

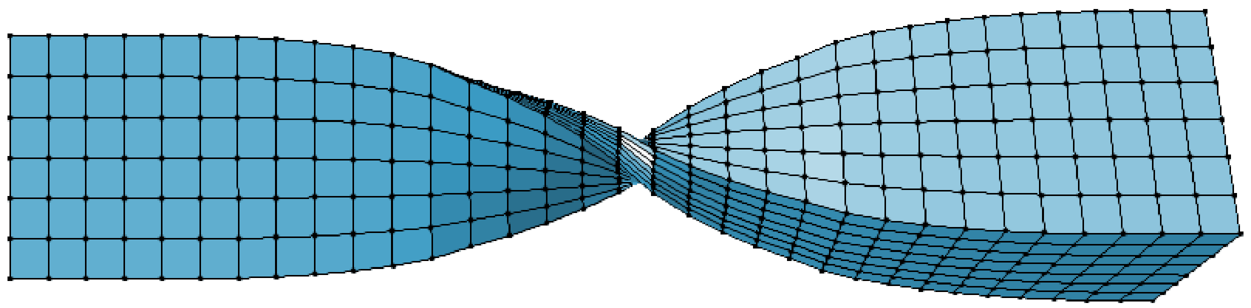
Dual quaternion = generalization of quaternion to handle *rigid transformation*

Rotation + translation

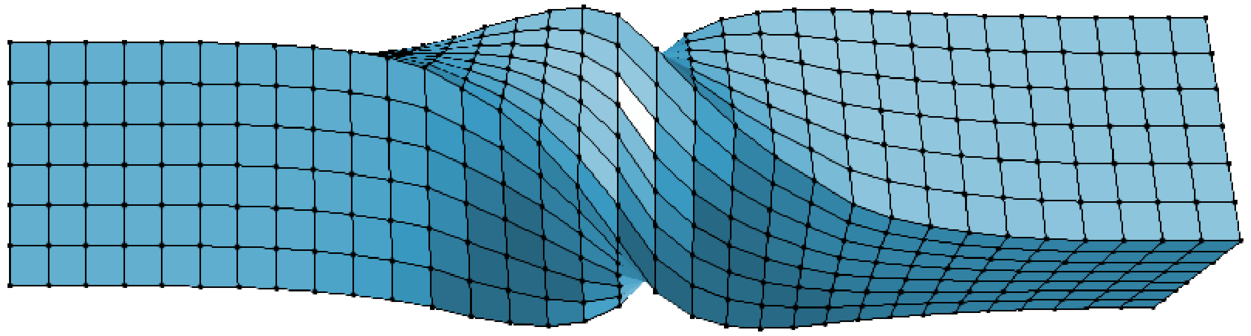
Unit dual quaternion models rigid transformation as **screw motions**

= *rotation about an axis followed by a translation in the direction of this axis*





$\Rightarrow$



LBS *DQS*

Dual number and dual quaternion

Dual number $a = a_0 + \epsilon a_\epsilon$

Dual element ϵ is nilpotent : $\epsilon \neq 0, \epsilon^2 = 0$

ϵ commonly used to model infinitesimal quantity (ex. automatic differentiation)

Dual quaternion $\hat{q}$ = Generalization of quaternion to dual numbers

$\hat{q} = q_0 + \epsilon\, q_\epsilon$

- q_0: pure rotation component
- q_ϵ: encodes translation component (dual part)

Given a unit quaternion q_0, and a translation $t = (t_x, t_y, t_z)$, the associated unit dual quaternion is

$$\boxed{\hat{q} = q_0 + \frac{\epsilon}{2}\, q_t\, q_0} \quad q_t = (t_x, t_y, t_z, 0)$$

Unit dual quaternion ($\|\hat{q}\| = 1$) describe the set of rigid transformation as screw motion.

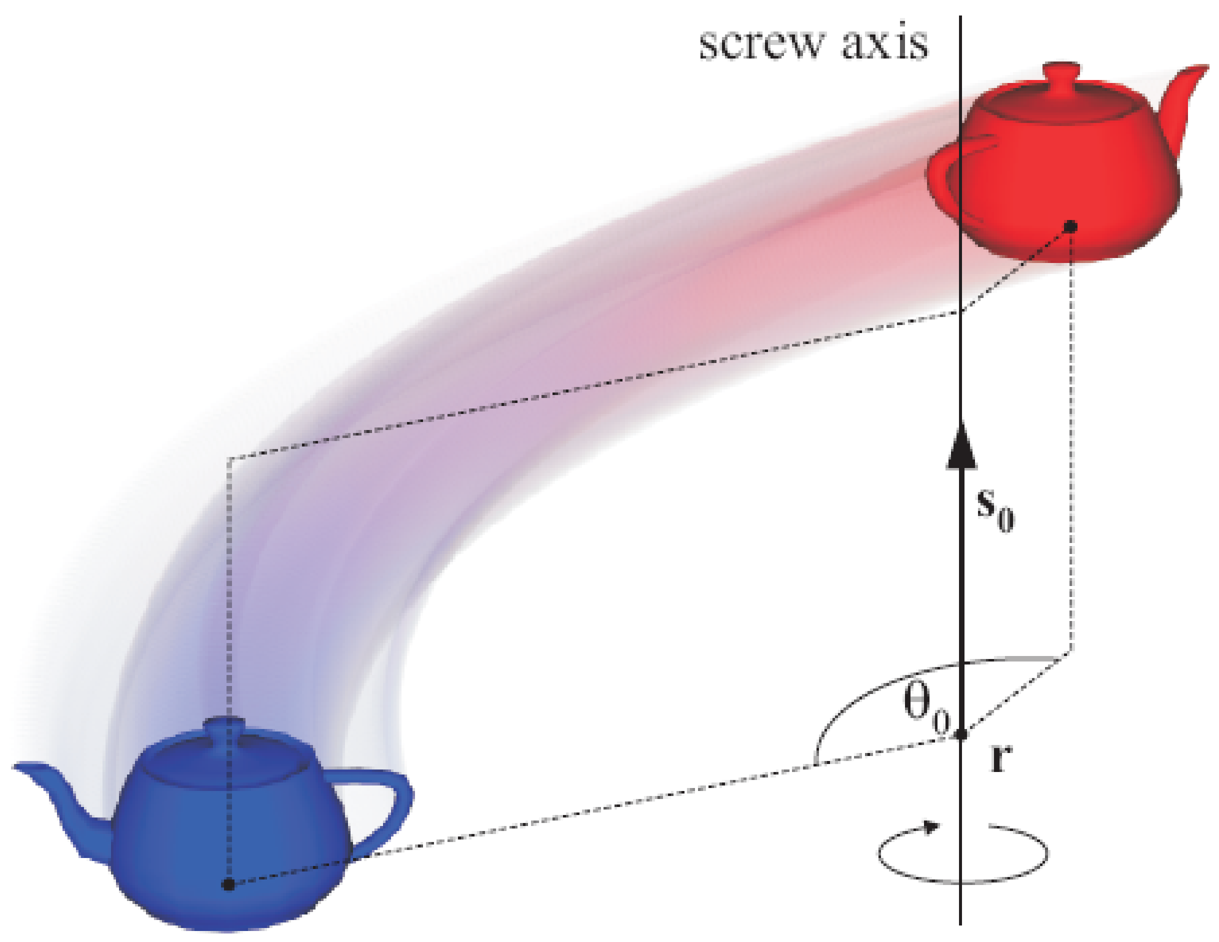
Axis-angle representation with dual quaternion

Similarly to quaternion: "angle/axis" correspondance

- $\hat{q} = \cos(\hat{\theta}/2) + \hat{n}\ \sin(\hat{\theta}/2)$

- $\hat{\theta} = \theta_0 + \epsilon\theta_\epsilon$
  - θ_0: angle of rotation
  - $\theta_\epsilon = t \cdot n_0$: quantity of translation along n_0

- $\hat{n} = n_0 + \epsilon\, n_\epsilon$
  - n_0: axis of rotation
  - $n_\epsilon = \frac{1}{2}\left((n_0 \times t)\, cotan(\theta_0/2) + t\right) \times n_0$: called the moment of the rotation axis.



Convert dual quaterion to rotation/translation

Given a non-unit dual quaternion as input $\hat{q}' = q'_0 + \epsilon q'_\epsilon$

How to compute the components of $\hat{q}' / \|\hat{q}'\| = \hat{q} = q_0 + \epsilon q_\epsilon$?

Express the parameterization in rotation-translation:

$$\hat{q} = q_0 + \frac{\epsilon}{2} q_t \, q_0 \,, \quad q_t = (t_x, t_y, t_z, 0)$$

First, normalize the non dual component: $\hat{q}' / \|q'_0\|$

$$\Rightarrow \boxed{q_0 = q'_0 / \|q'_0\|}$$

Second, enforce the parameterization of the dual component: $\frac{1}{2} q_t \, q_0 = q'_\epsilon / \|q'_0\|$

$$\Rightarrow \boxed{q_t = 2 \, q'_\epsilon \, q_0^\star / \|q'_0\|}$$

Dual Quaternion Skinning (DQS)

1- Encode rigid transformation (q^i, t^i) into dual quaternion

$$\hat{q}^i = q_0^i + \frac{\epsilon}{2} q_t^i\, q_0^i\,, \quad q_t^i = (t_x^i, t_y^i, t_z^i, 0)$$

2- Compute blending in the dual quaternion space (ScLERP)

$$\hat{q}' = \sum_i \omega_i\, \hat{q}^i = q_0' + \epsilon\, q_\epsilon'$$

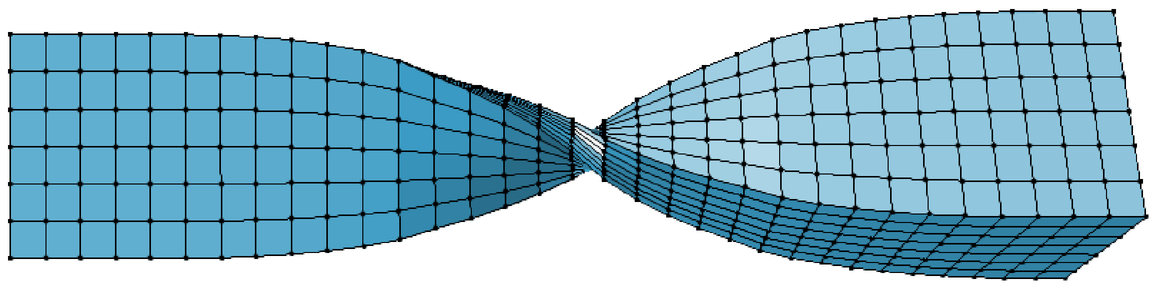
3- Extract components (q, t) from $\hat{q}'$

- $q = q_0' / \|q_0'\|$
- $(t_x, t_y, t_z, 0) = 2\, q_\epsilon'\, q^\star$

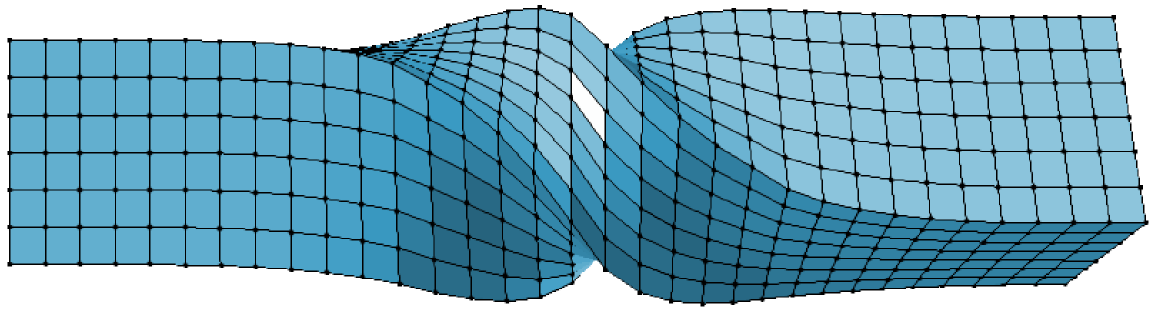
$q^\star$: conjugate of q.

4- Apply finaly the transformation (q, t) to position p_0

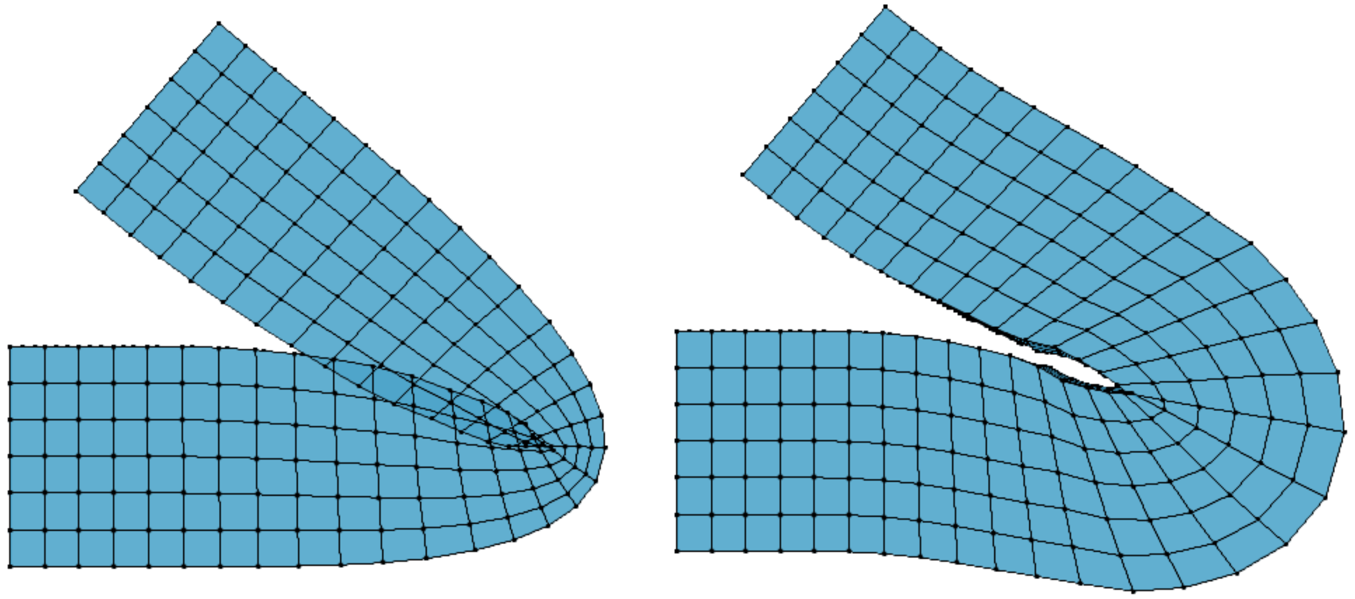
[Skinning with Dual Quaternions. Kavan et al. I3D, 2007]



LBS



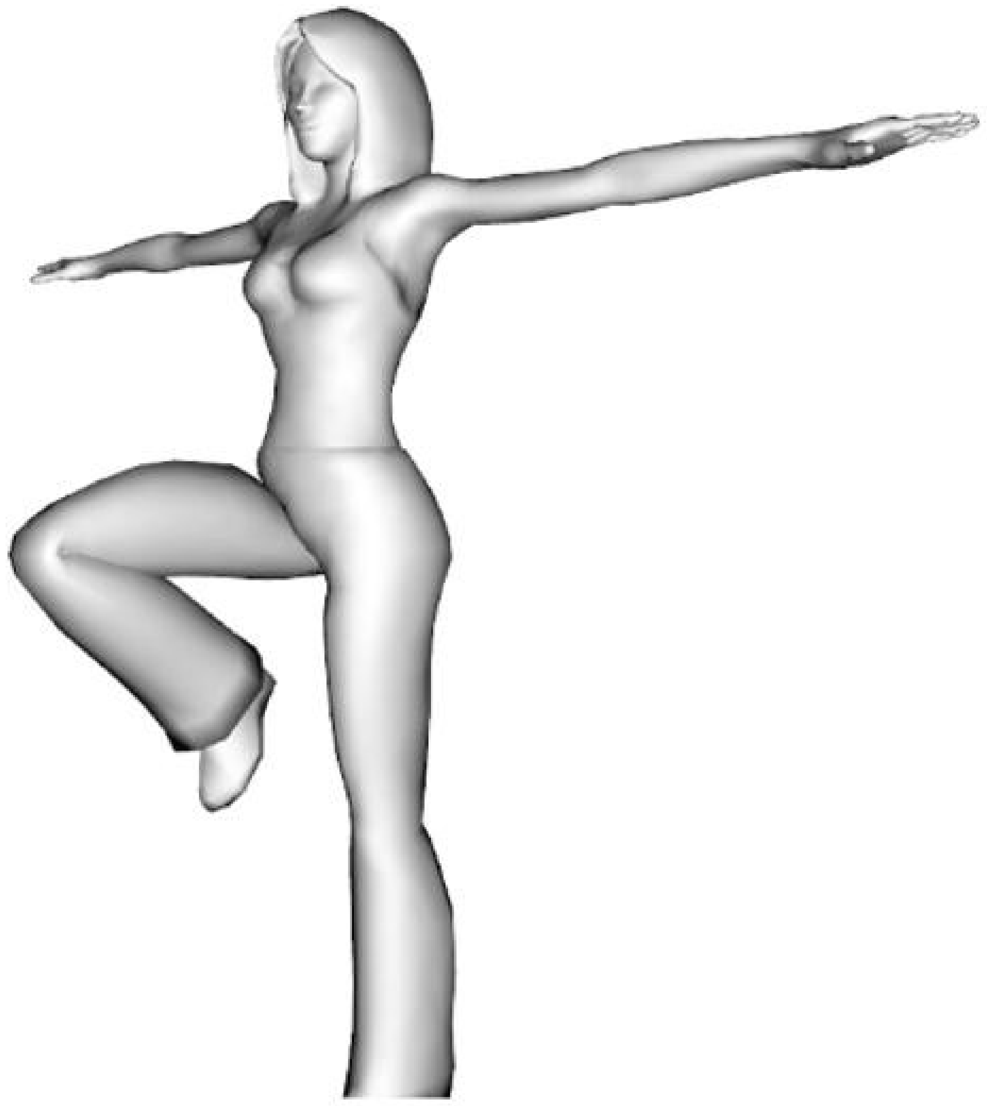
DQS



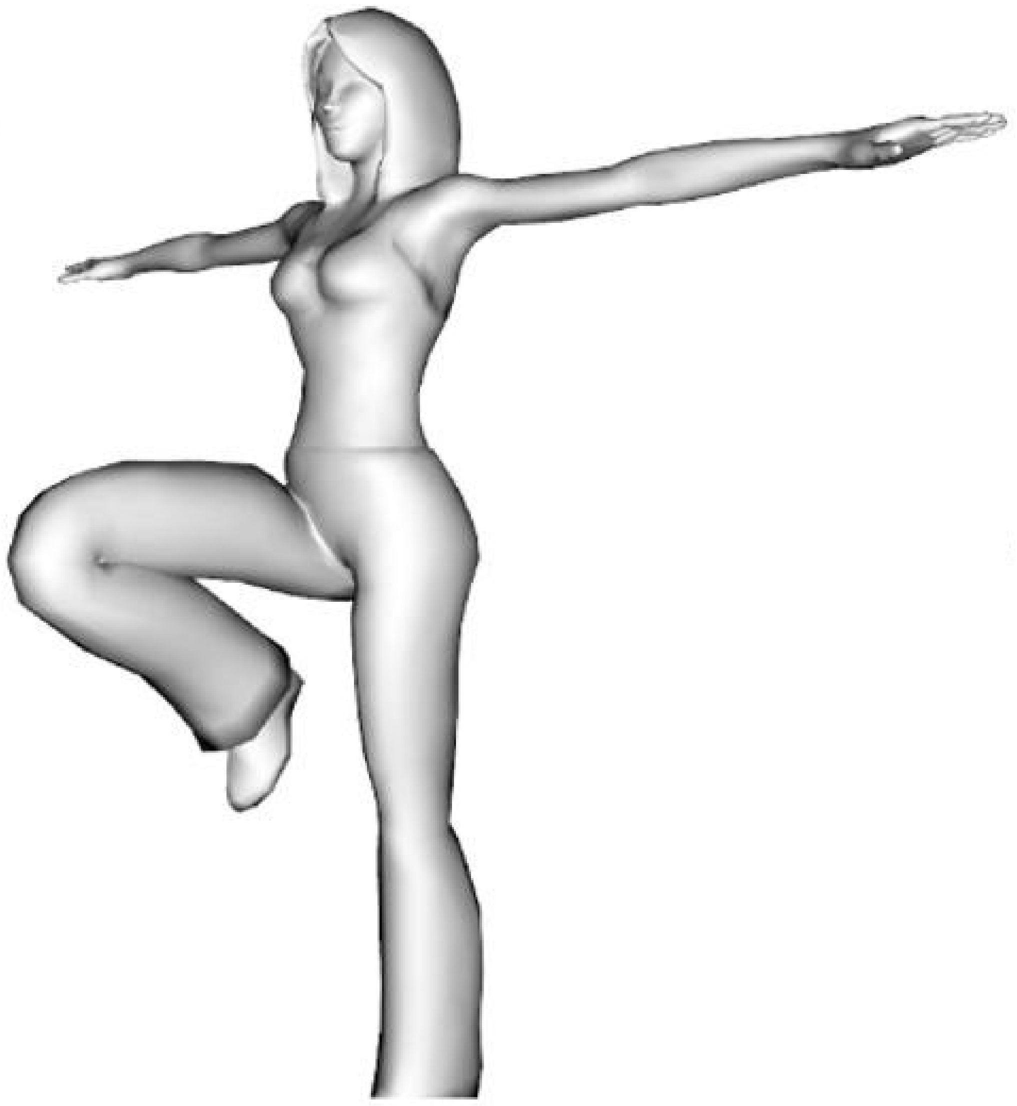
LBS DQS

Dual Quaternion VS LBS

- Dual quaternion
  - (+) Fully solves *candy wrapper* artifact
  - (+) Almost as efficient as LBS
  - (-) May create artificial/unwanted bulge
    - *Not always prefered to LBS*
    - *Both solutions (LBS, DQS) are proposed in standard tools*



LBS



DQS

Character Animation

Skeletal Animation

Skeleton structure

Characteristics

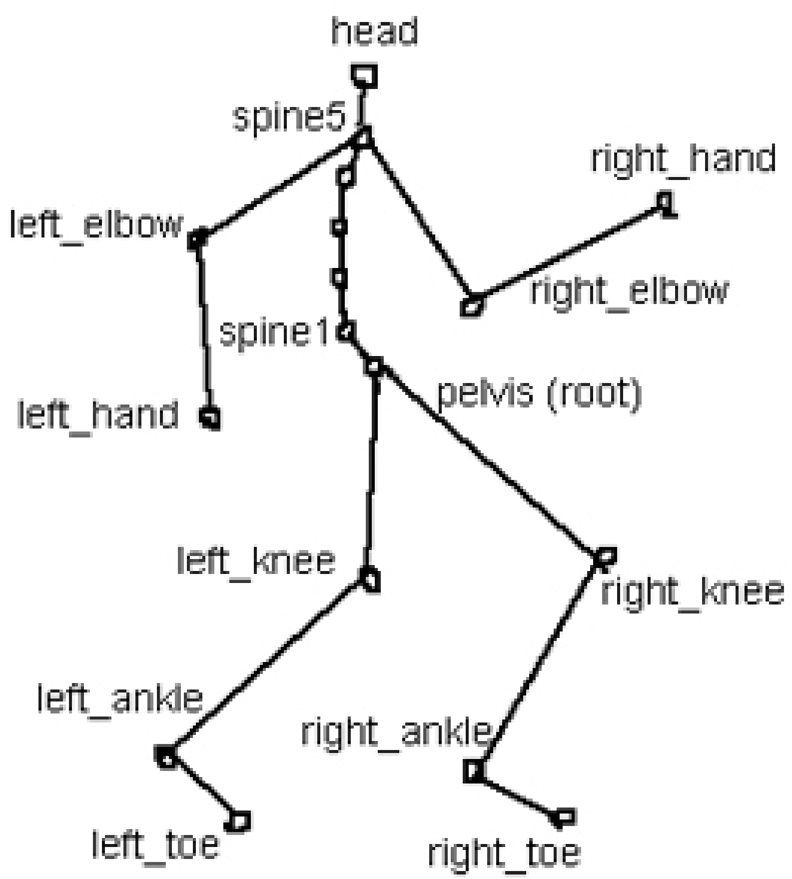
- Hierarchical representation

  All children follow the transformation of the parent

  Need to define a root: usually at the hips/pelvis

- Convenient to express relative transformation with respect to the paren

  ex. Ankle is at 20° *w/r knee*



Converting local to global frames/joint coordinates

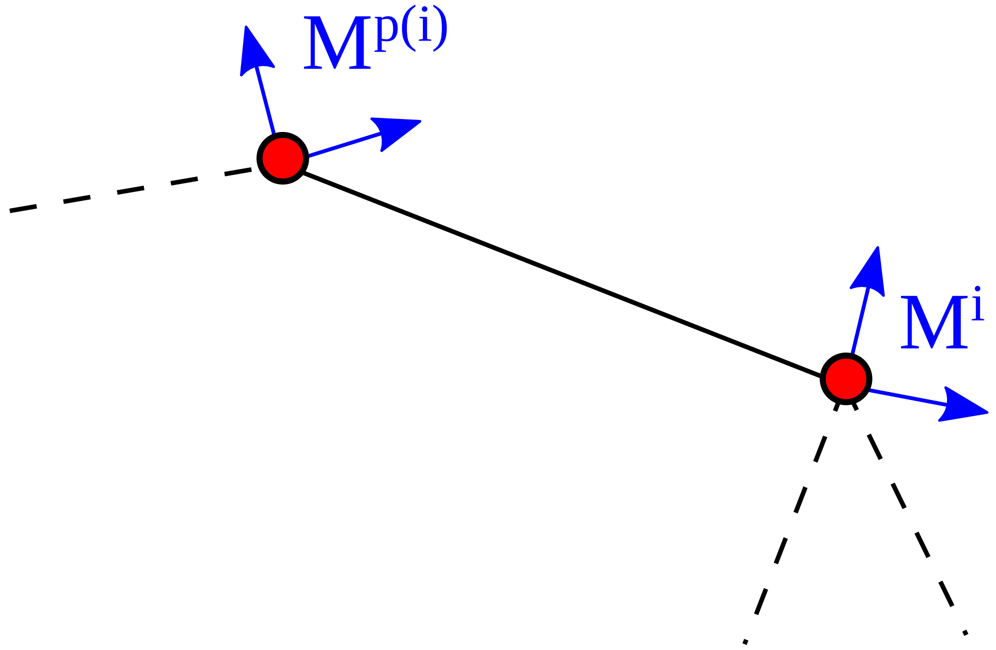
- With 4x4 matrices M

$$M^i_{global} = M^{p(i)}_{global}\ M^i_{local}$$

- With translation t, rotation R

$$R^i_{global} = R^{p(i)}_{global}\ R^i_{local}$$

$$t^i_{global} = t^{p(i)}_{global} + R^{p(i)}_{global}\ t^i_{local}$$



Encoding hierarchical skeleton

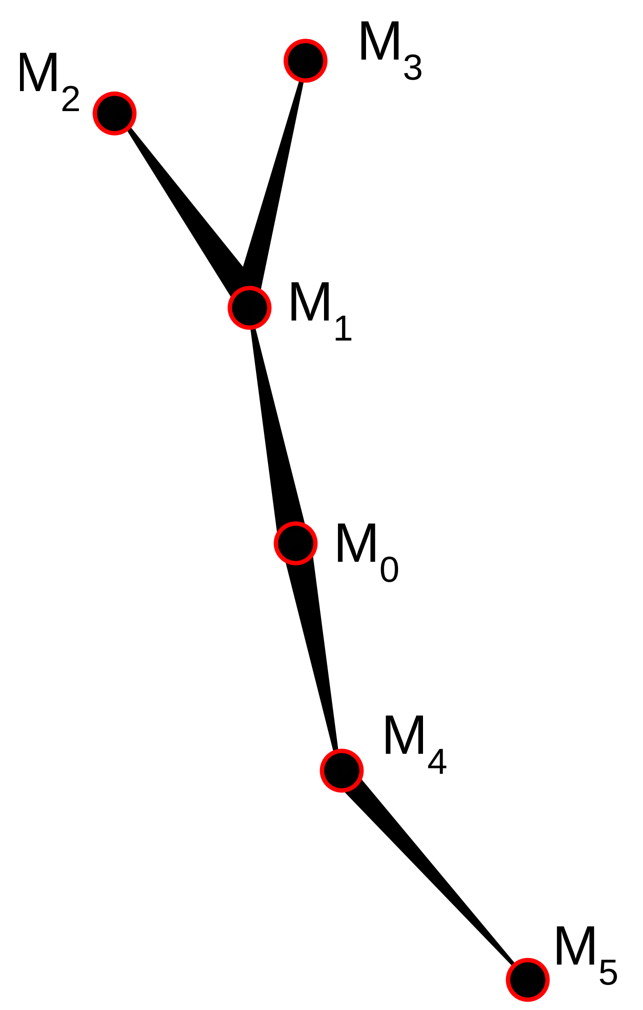
- Simplest encoding based on index within vector

```
Geometry=[M0, M1, M2, M3, M4, M5]
Parent = [-1,0,1,1,0,4]
```

- Convert local coordinates to global coordinates

```
local (Geometry)  <- std::vector of rotation (r), translation (p)
global (Geometry) <- std::vector of rotation (r), translation (p)

global[0] = local[0];
for(size_t k=1; k<N; ++k)
{
    int parent = Parent[k];
    global[k].r = global[parent].r * local[k].r;
    global[k].p = global[parent].r * local[k].p + global[parent].p;
}
```

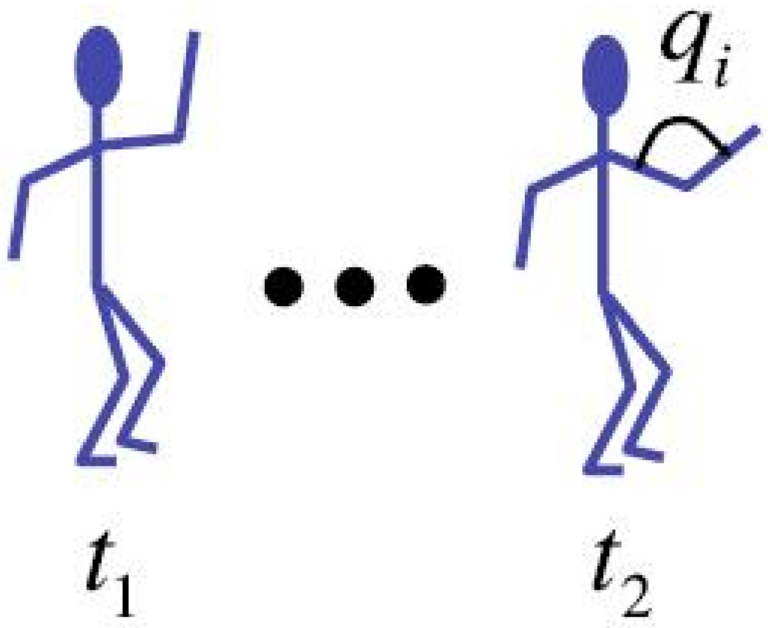


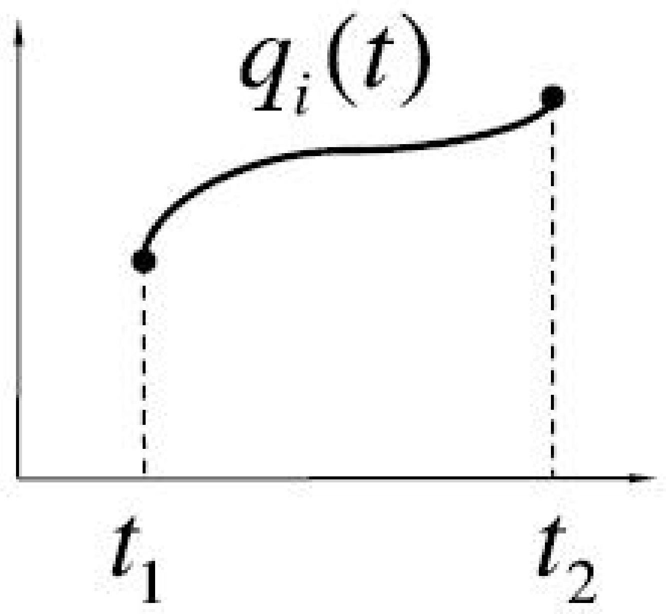
Forward kinematics

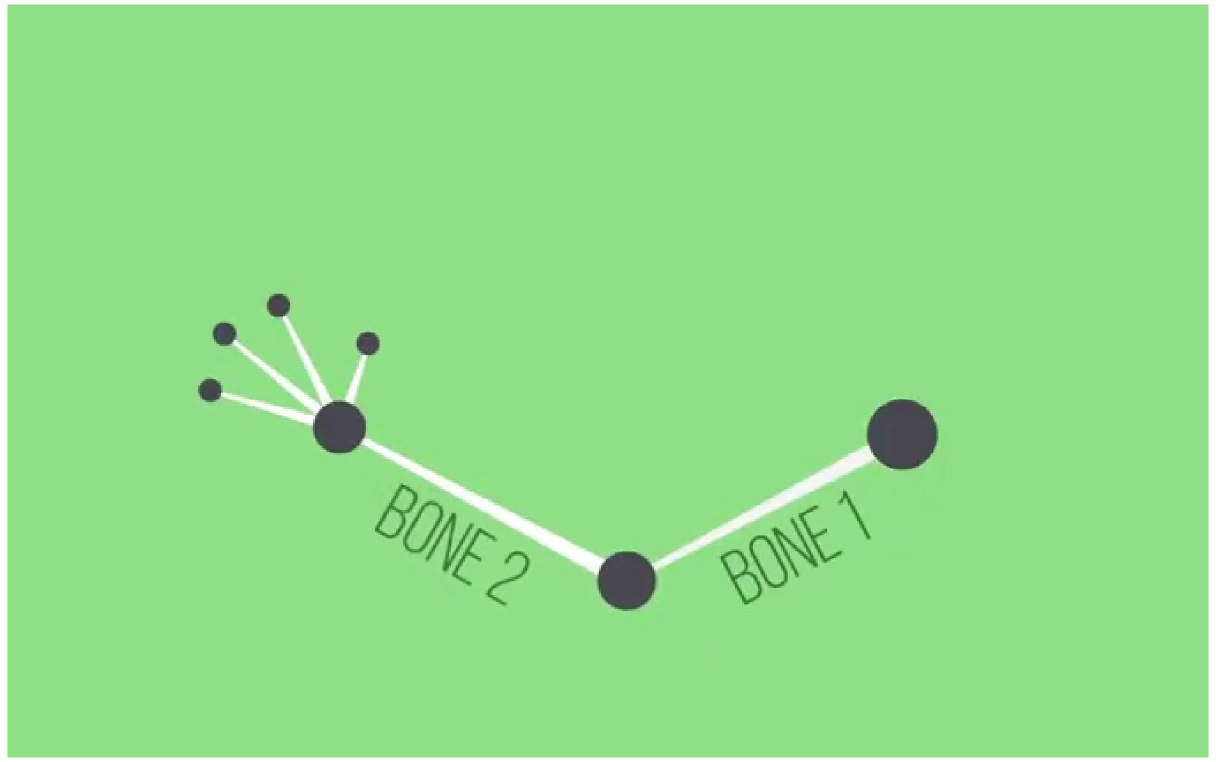
FK - **F**orward **K**inematics

- Each join angle is set manually
- Adapted to set orientation of specific parts
- Interpolate rotations during animation

(+) Generates curved trajectory naturally

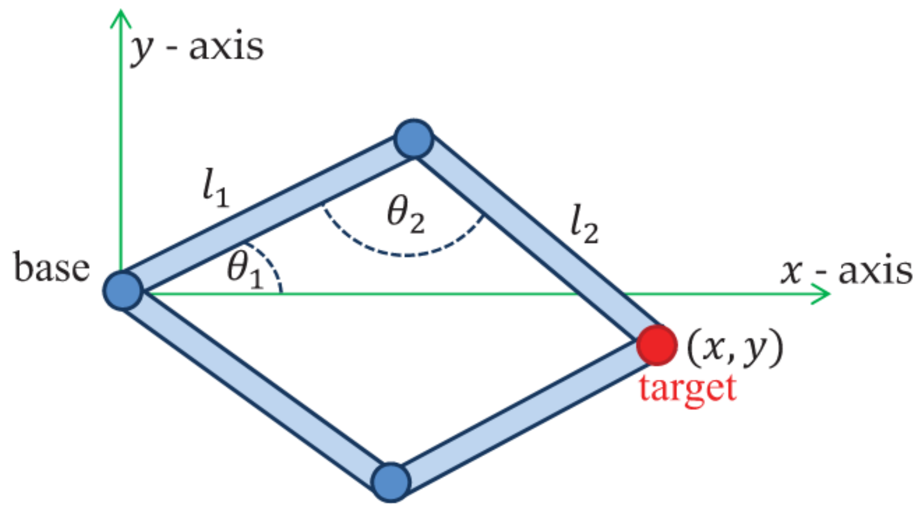






MiloScerny Animation

Inverse Kinematics

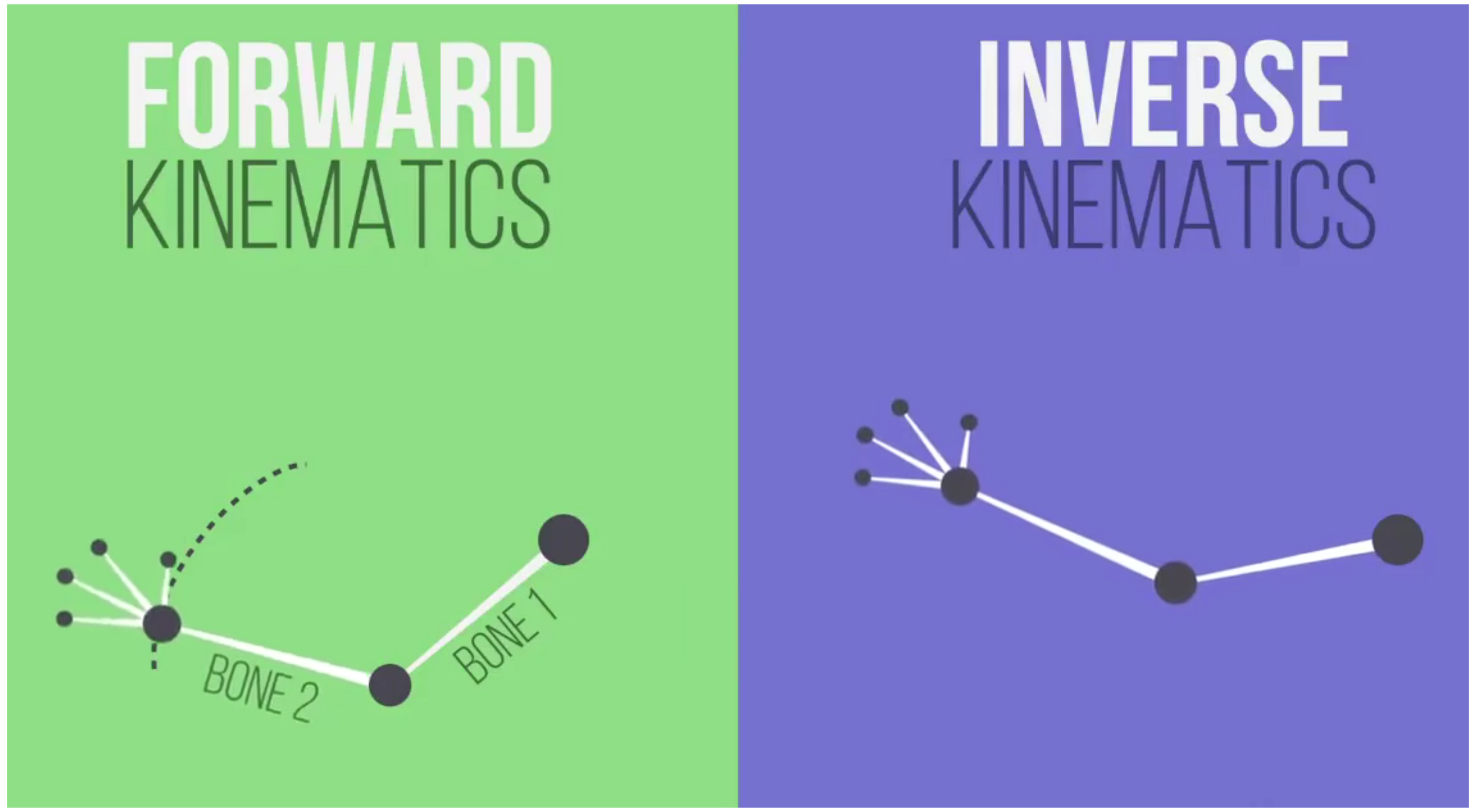


IK: **I**nverse **K**inematics

- Describe position (/and orientation) of *end-effectors* (contact, walking, etc)
- Compute joint angles reaching this position

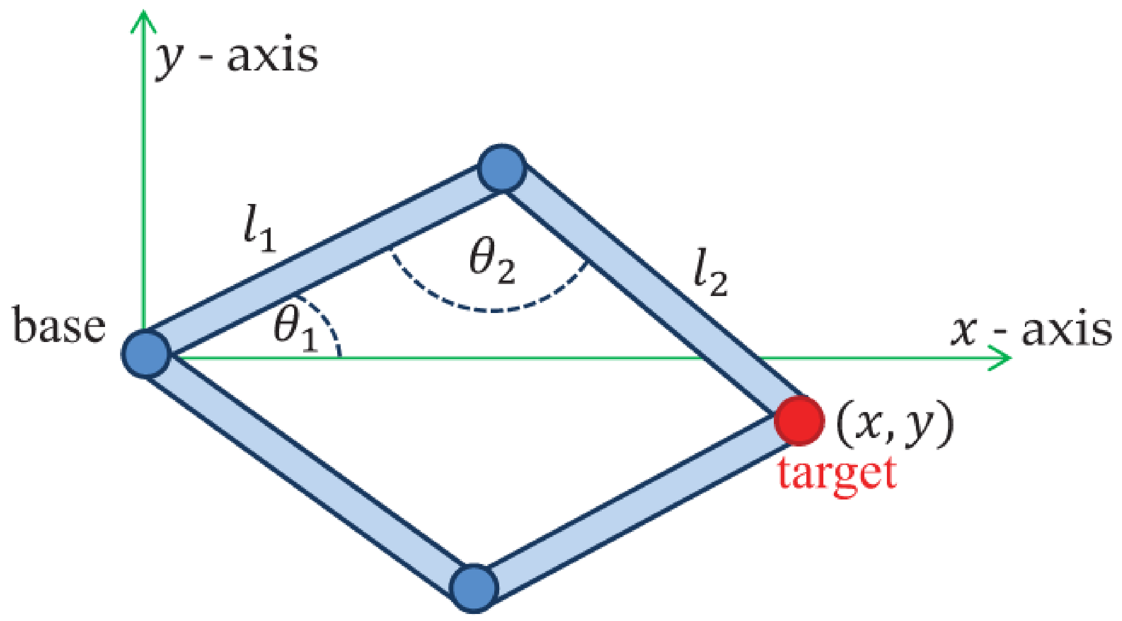
$$p_k = p_0 + \sum_{i=0}^{k-1} l_i \; R_i \, u_i$$

R_i can be expressed with various rotation parameters (Matrices, Euler angles, axis/angle, quaternions, etc)



MiloScerny Animation

IK Example with two bones



[Inverse Kinematics Techniques in Computer Graphics: A Survey. A. Aristidou et al. STAR EG. 2017.]

In general the general case $p_k = f(\theta_i)$

- Look for $\theta_i = f^{-1}(p_k)$
- f is a non linear function
- There may exists multiple solutions (or none)
- Solutions may exhibits discontinuities
- Closed form solution are not available

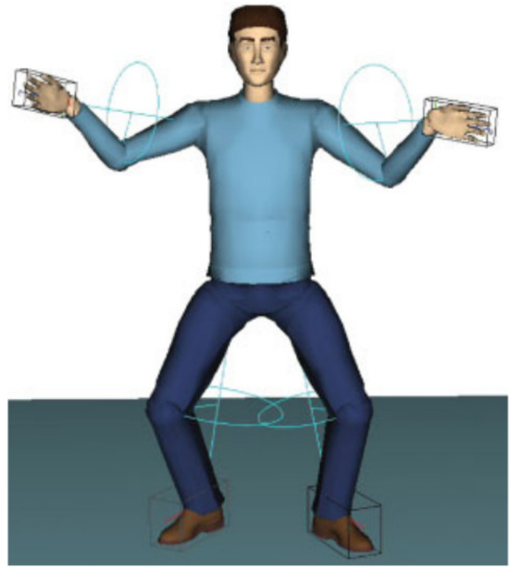
Two solutions defined by

$$\cos(\theta_1) = \frac{l_1^2 + x^2 + y^2 - l_2^2}{2l_1\sqrt{x^2+y^2}}$$

$$\cos(\theta_2) = \frac{l_1^2 + l_2^2 - (x^2+y^2)}{2l_1 l_2}$$

Some attempts for explicit solutions in specific cases

[Real-Time Inverse Kinematics Techniques for Anthropomorphic Limbs. D. Tolani et al. Graphical Models, 2000.]
[Analytical inverse kinematics with bodyposture control. M. Kallmann. Comp. Anim. & Virt. Worlds, 2008]



IK: Numerical methods

Numerical inversion of $p = f(\theta), \theta = (\theta_0, \cdots, \theta_{N-1})$.

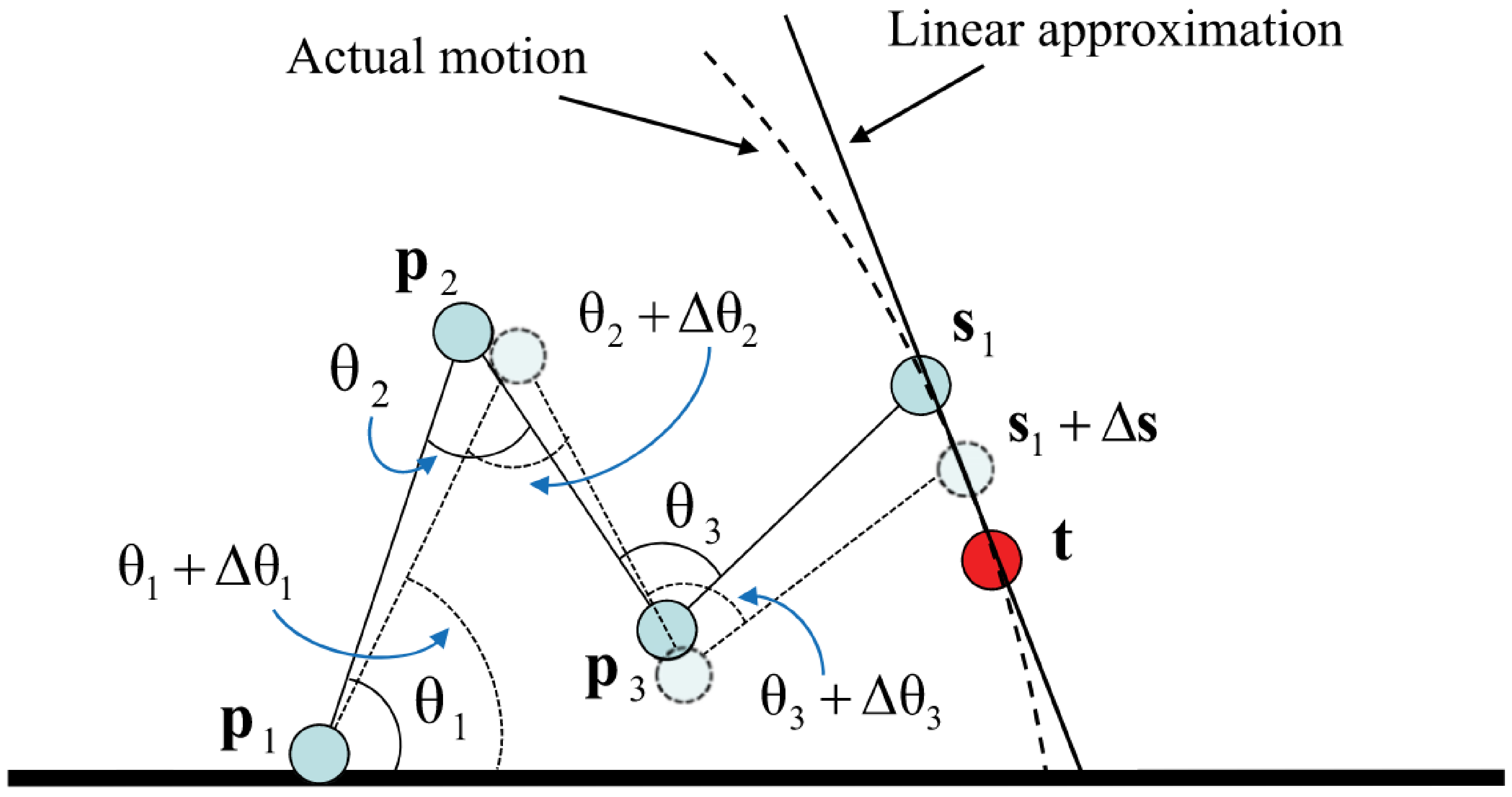
Consider small step size $p \to p + \Delta p$

$$\Delta p \simeq \underbrace{\left(\frac{\partial f}{\partial \theta}\right)}_{\text{J}} \Delta\theta$$

J - Jacobian matrix.

$\to$ Not square ($3 \times N$), not invertible.

Unknown > # constraints



IK: Numerical methods

Several possible approaches to solve $\mathrm{J}\,\Delta\theta = \Delta p$

- Pseudo Inverse

  $\Delta\theta = J^+\ \Delta p$, with $\mathrm{J}\mathrm{J}^+ = \mathrm{I}$

  $\mathrm{J}^+ = \mathrm{J}^T\left(\mathrm{J}\,\mathrm{J}^T\right)^{-1}$

- Can also be computed using SVD: $\mathrm{J}^+ = \mathrm{V}\Sigma^+\,\mathrm{U}^T$

  $\Sigma_{ii} = \sigma_i, \Sigma^+_{ii} = 1/\sigma_i$ if $\sigma_i \neq 0, 0$ otherwise.

- Adding damping to compensate for singularities

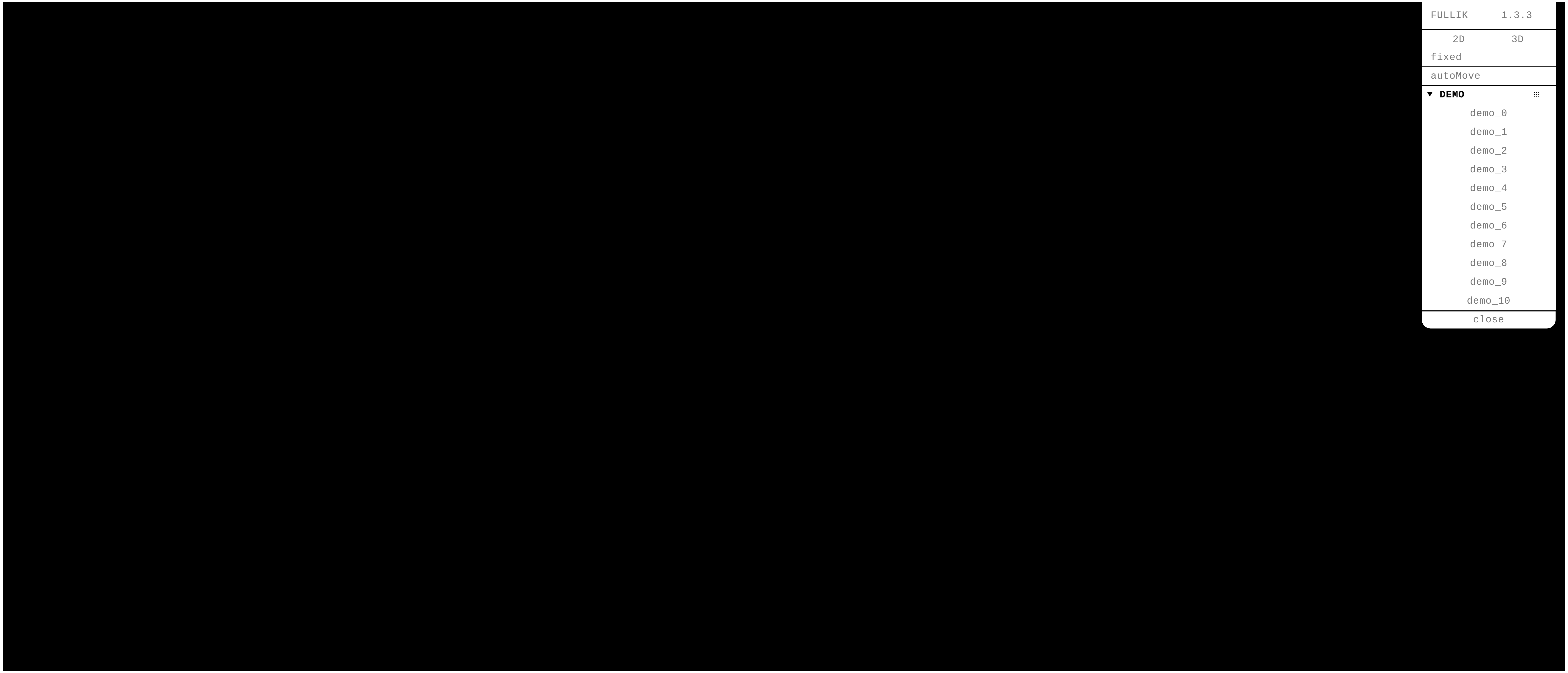
  $\Delta\theta = \mathrm{J}^T\left(\mathrm{J}\,\mathrm{J}^T + \lambda^2\,\mathrm{I}\right)^{-1}\ \Delta p$

- Using Newton's methods

[Inverse Kinematics Techniques in Computer Graphics: A Survey. A. Aristidou. STAR EG 2017]

Inverse Kinematics

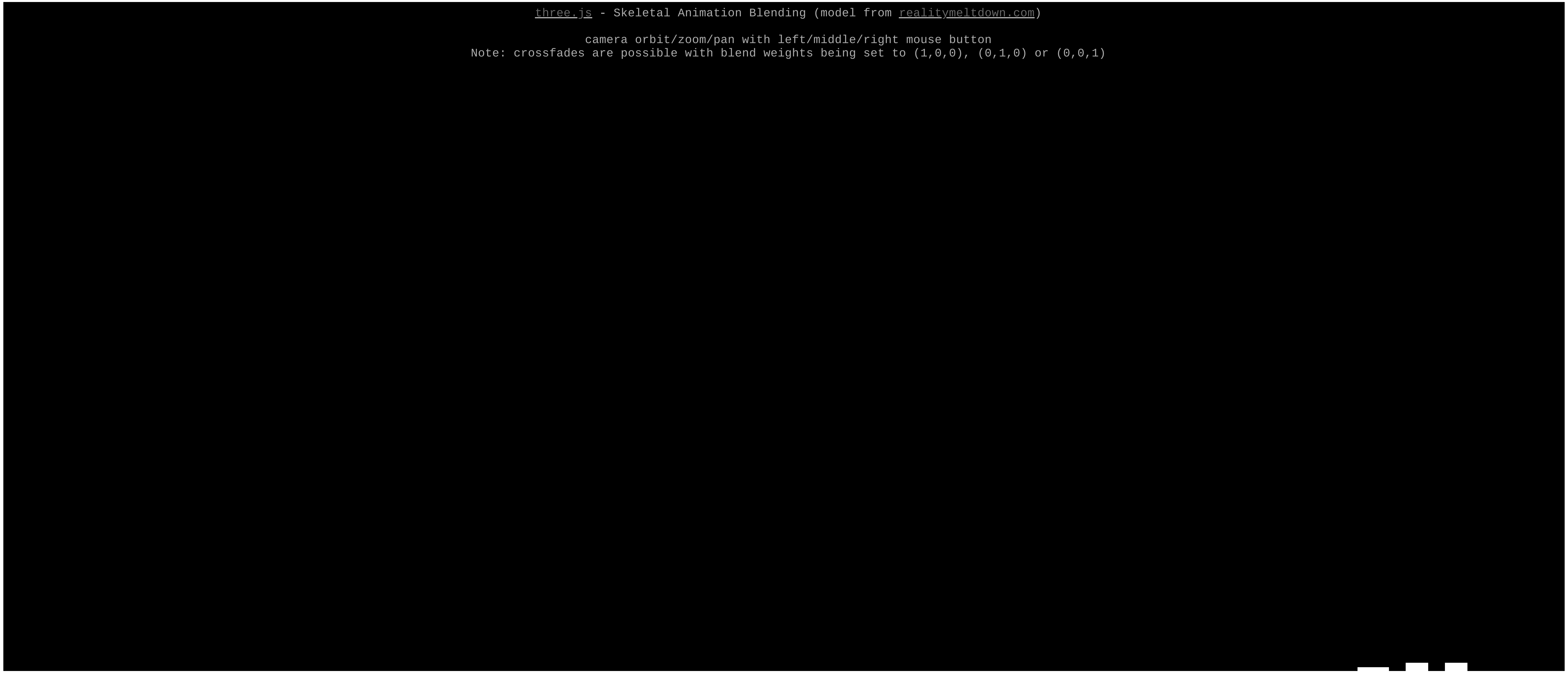
Example



Synthesizing and controling skeleton animation

Blending skeleton animation

Pre-store several looping animation
Blend between animation for transition



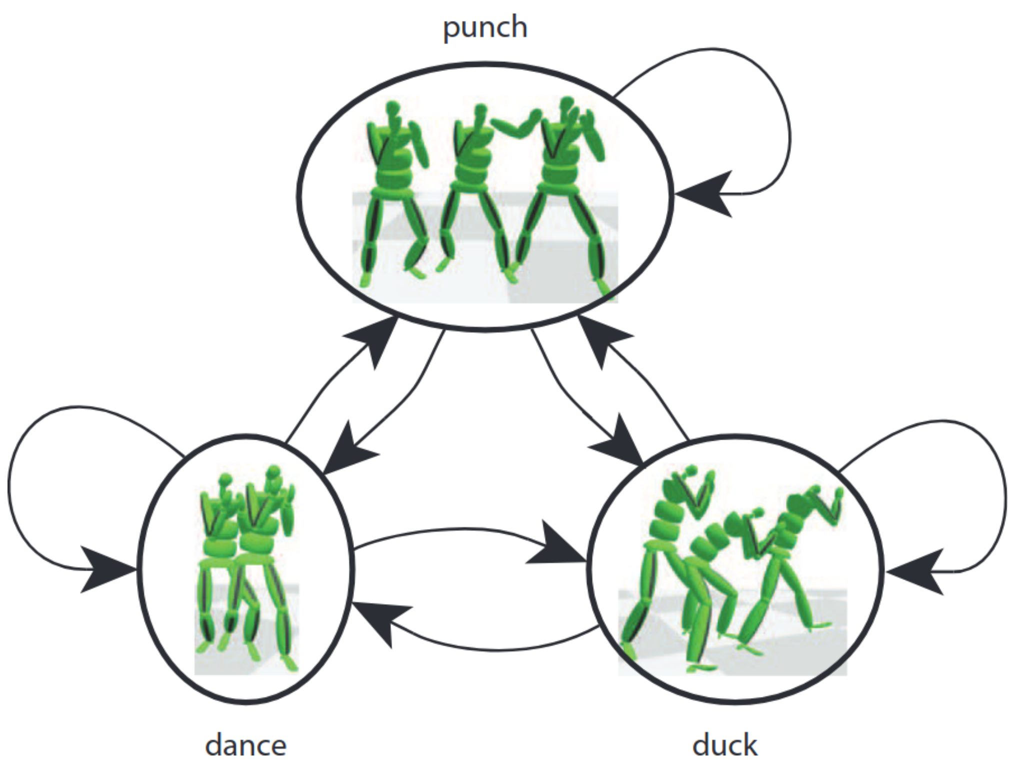
Motion graphs

Also called Move Trees (highly used in video games)

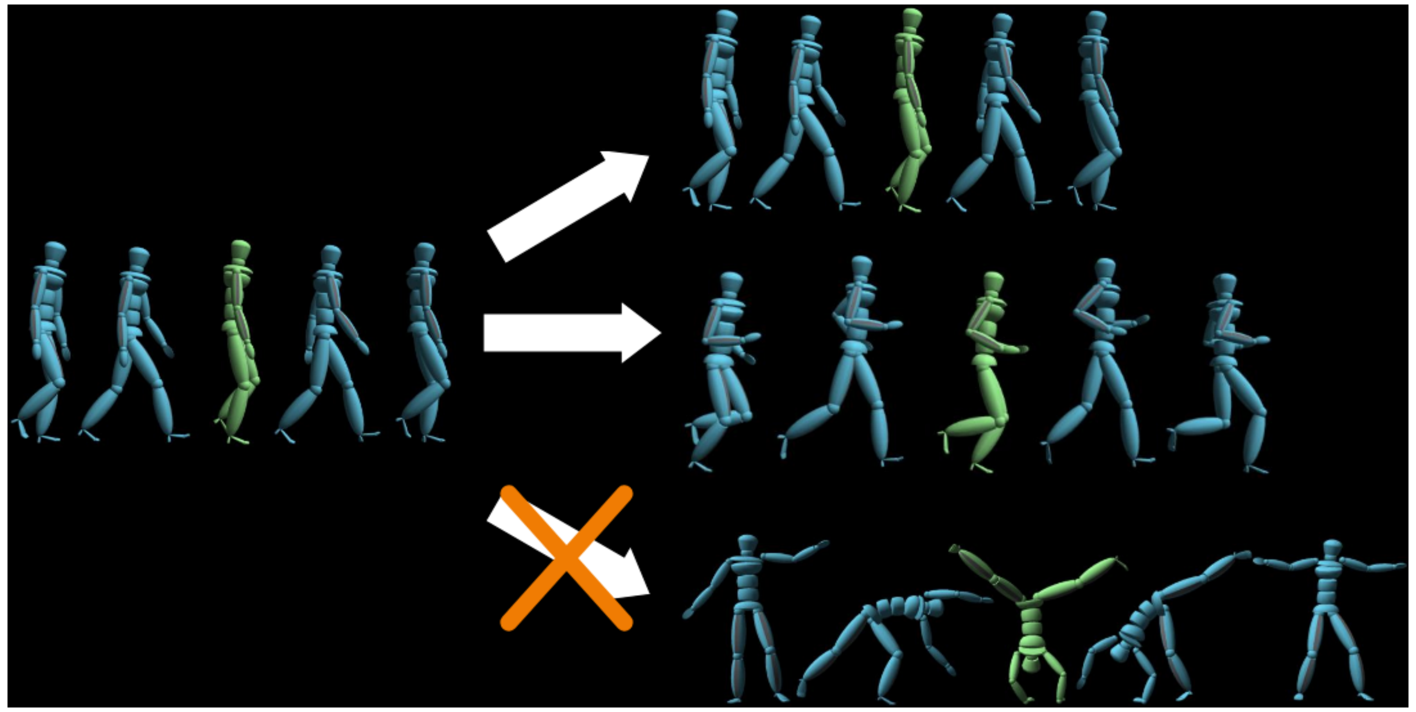
- Stores multiple precomputed animation

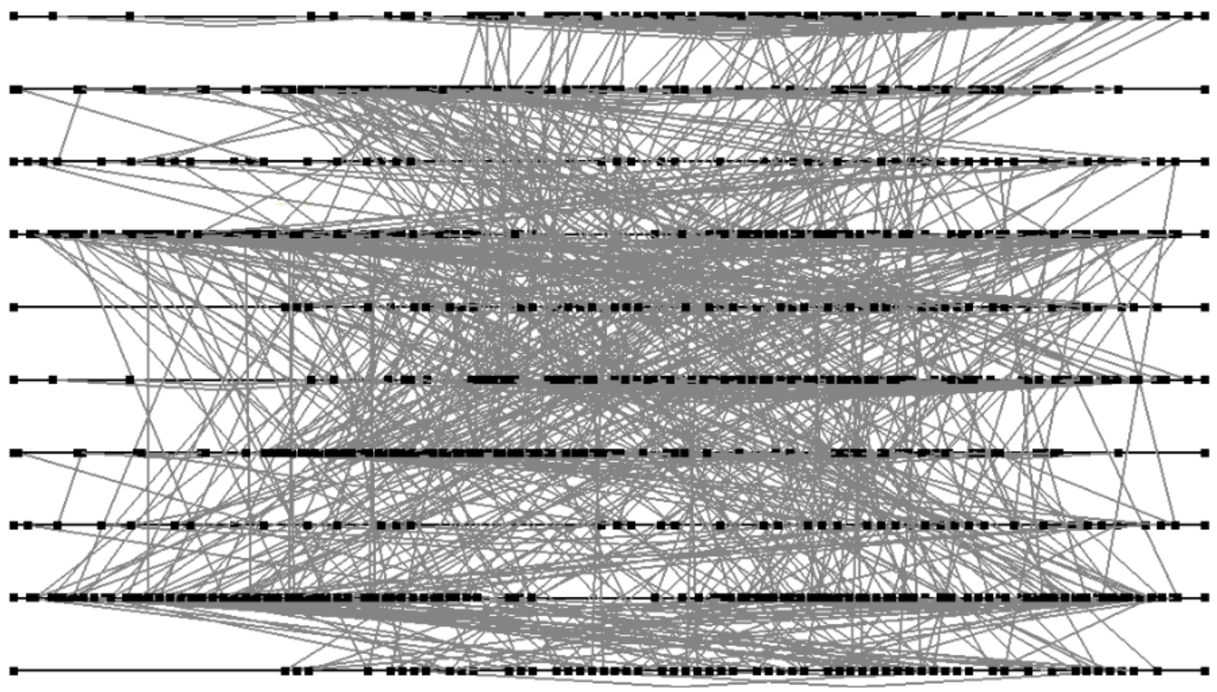
  Manually design, motion capture, etc

- Find optimal transitions between different motions



- *[Mizuguchi et al., Data driven motion transitions for interactive games, EG short paper, 2001]*
- *[Kovar et al., Motion Graphs, ACM SIGGRAPH 2002]*
- *[Heck and Gleicher, Parametric Motion Graphs, ACM SIGGRAPH 2007]*





Controlers

Mix between predefined motions and physics → allow user perturbations

1 - Define target $(\theta_{target}(t), \theta'_{target}(t))$

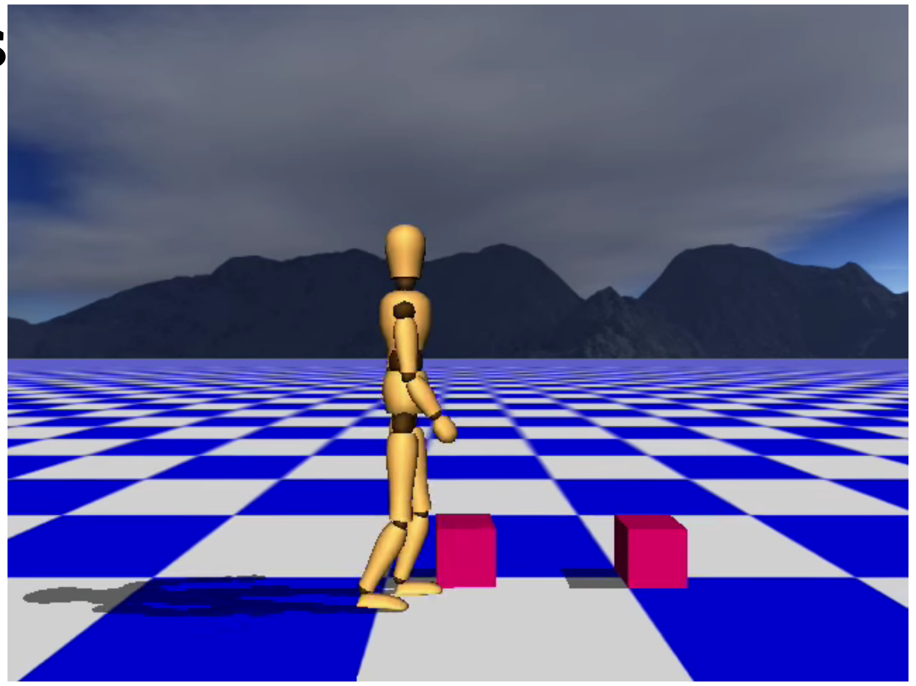
pre-defined finite state machine (Gait model)

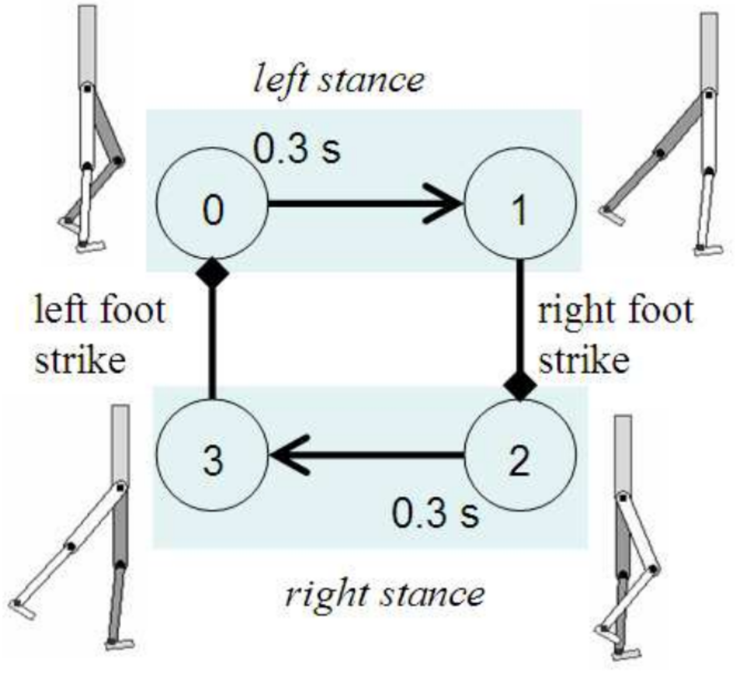
2 - Add user perturbation to the current state

3 - Use proportional derivative controlers to compute joint torque τ

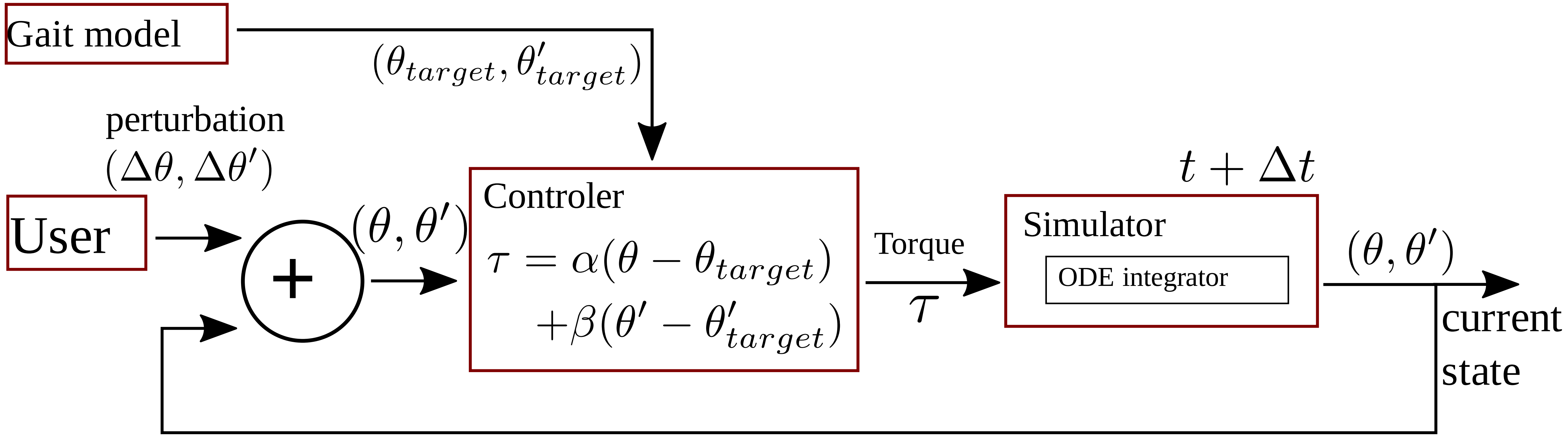
4 - Integrate torque using rigid body simulator

5 - Iterate





Gait model

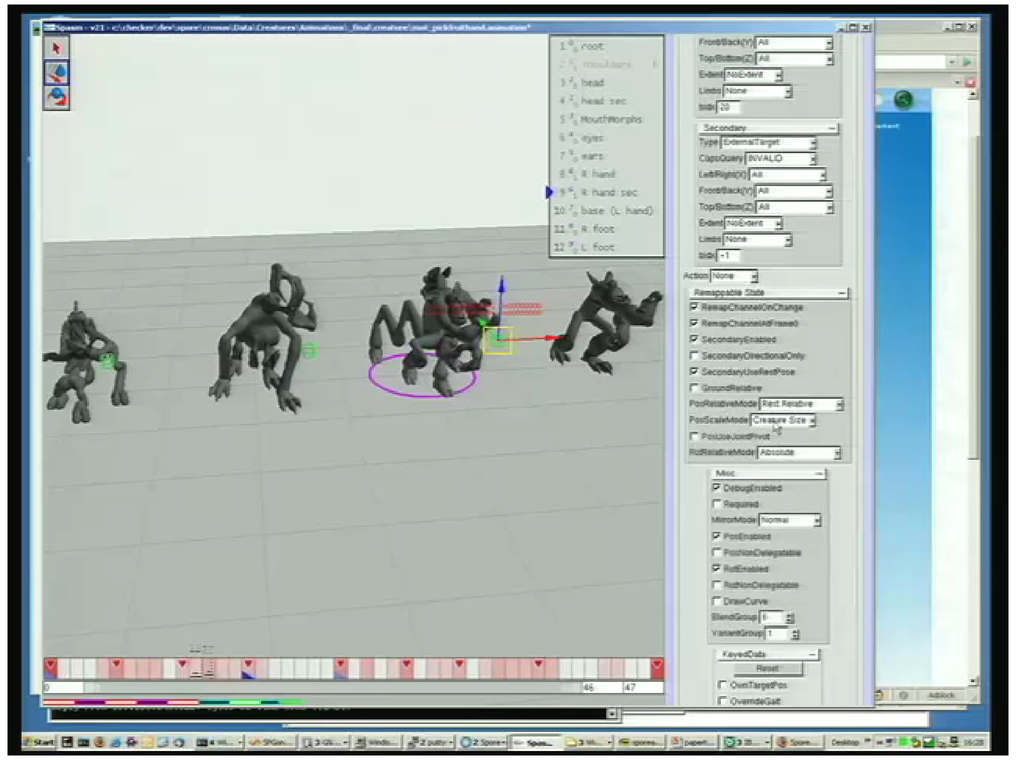


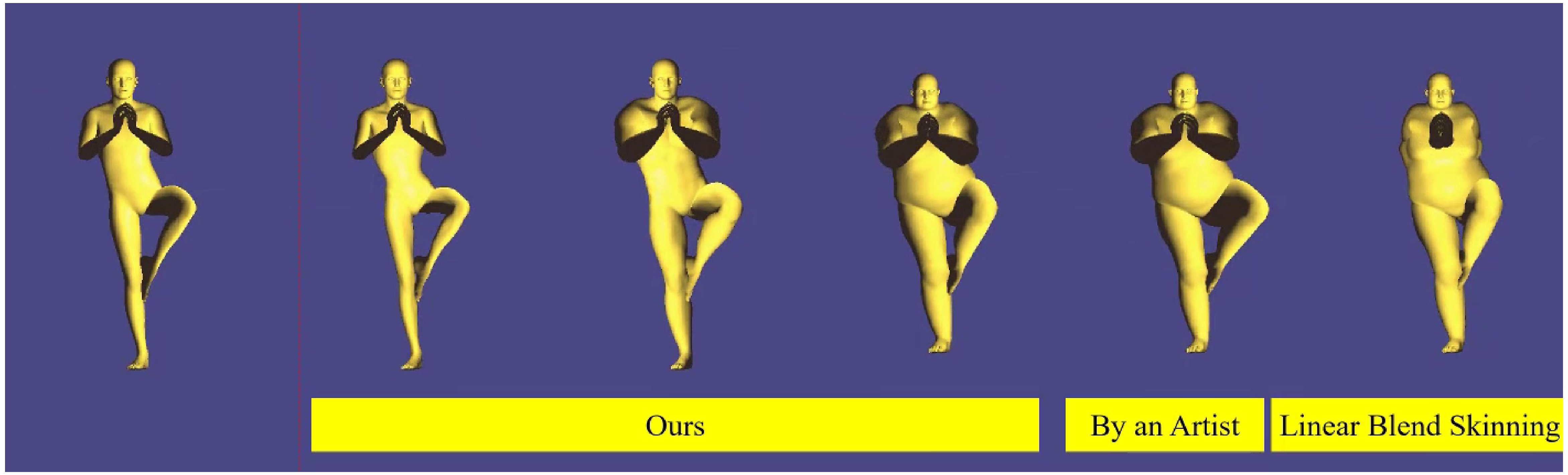
[M. Raibert and J. Hodgins. Animation of Dynamic Legged Locomotion, ACM SIGGRAPH 2001]

[K. Yin et al., SIMBICON: Simple Biped Locomotion Control, ACM SIGGRAPH 2007]

Motion transfert

- Local coordinates mapping from skeletal motions
  - [C. Hecker et al., Real-time Motion Retargeting to Highly Varied User-Created Morphologies, SIGGRAPH 2008] (Spore)
- Including shape morphology
  - [Z. Liu et al., Surface based Motion Retargeting by Preserving Spatial Relationship, MIG 2018]

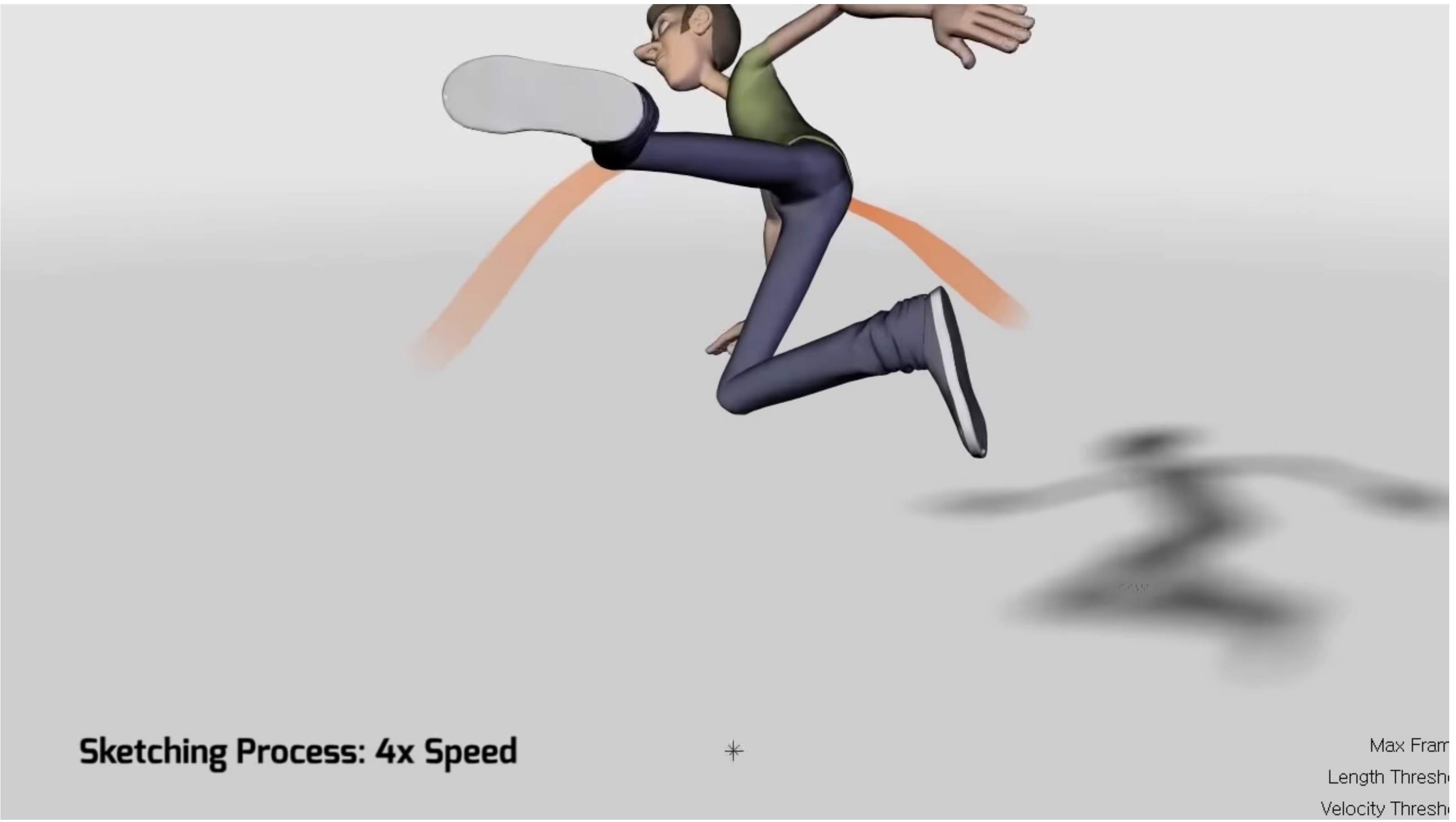




Animation design

Based on the *Line of Action*

- [Guay et al., The Line of Action: an Intuitive Interface for Expressive Character Posing, ACM SIGGRAPH Asia 2013]
- [Guay et al., Space-time sketching of character animation, ACM SIGGRAPH 2015]
- [Choi et al., SketchiMo: Sketch-Based Motion Editing for Articulated Characters, ACM SIGGRAPH 2016]



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Automatic synthesis of skeletal animation

Seminal works

- [Evolving Virtual Creatures. Karl Sims. SIGGRAPH 1994]

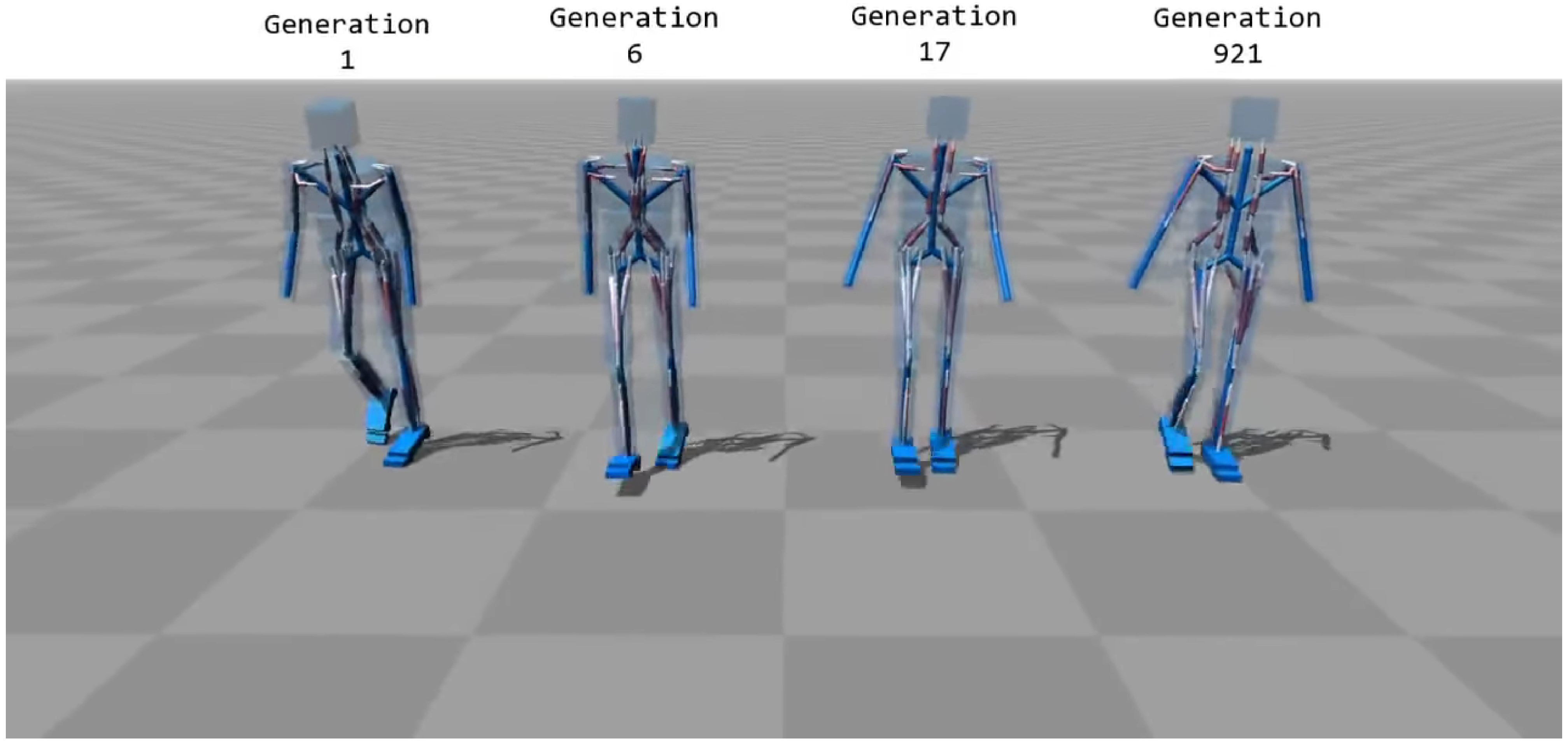
- [Automated Learning of Muscle-Actuated Locomotion Through Control Abstraction. Radek Grzeszczuk and Demetri Terzopoulos. SIGGRAPH 1995]

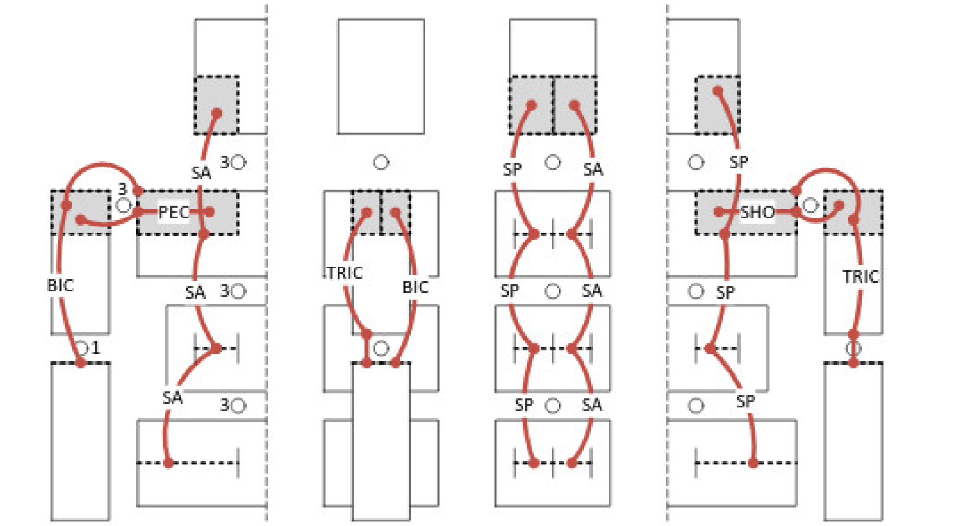
- *Optimization toward objective function coupled with rigid bodies simulations*
- *Morphological variation from genetic algorithm*

Optimizing muscle activation

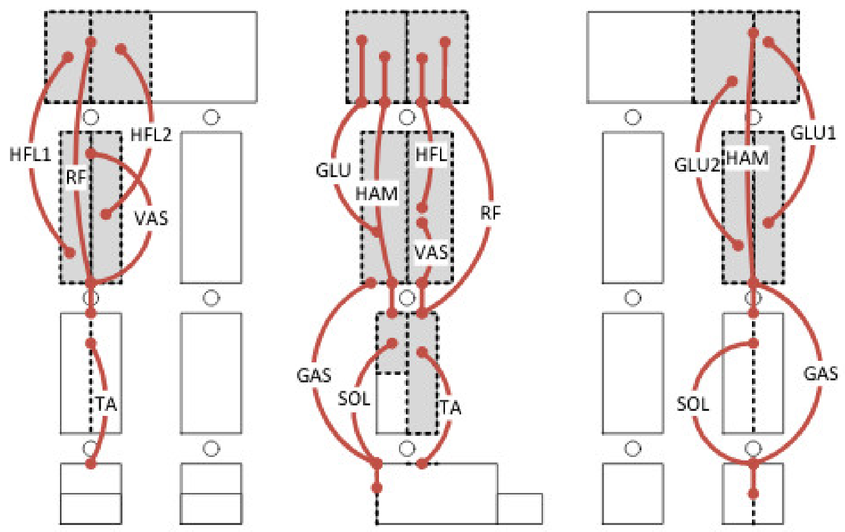
- Take into account simple biomechanical model
- Optimize sequence of activation via reinforcement learning

[Flexible Muscle-Based Locomotion for Bipedal Creatures, T. Geijtenbeek et al. SIGGRAPH Asia 2013.]

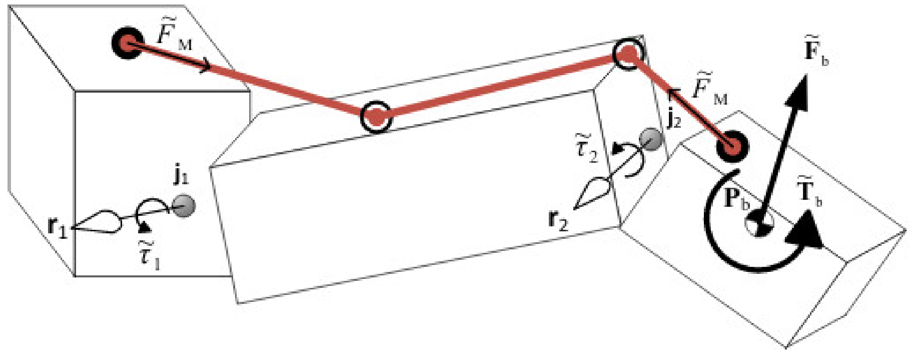




(a) Humanoid upper-body model: front, side arm, side body, and back.



(c) Humanoid lower-body model: front, side and back.

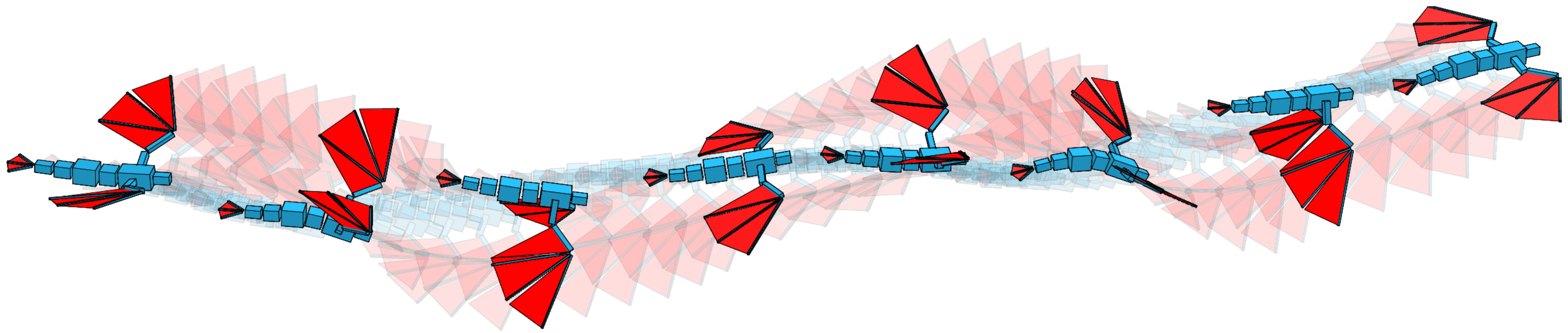


Use of deep learning

Deep reinforcement learning for complex optimization

Learn muscle activation

[Won et al. How to Train Your Dragon: Example-Guided Control of Flapping Flight, ACM SIGGRAPH Asia 2017]



Deep learning for real-time motion control

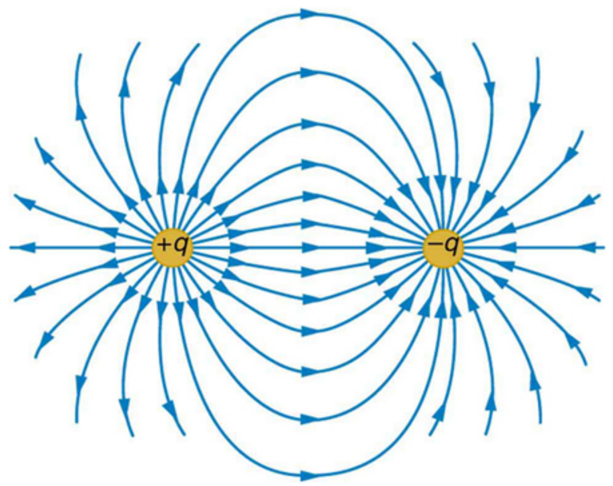
Learn phase of the motion cycle.

Use large data base of motion capture data

[Holden et al., Phase-Functioned Neural Networks for Character Control, ACM TOG 2017]

Animating crowds of characters

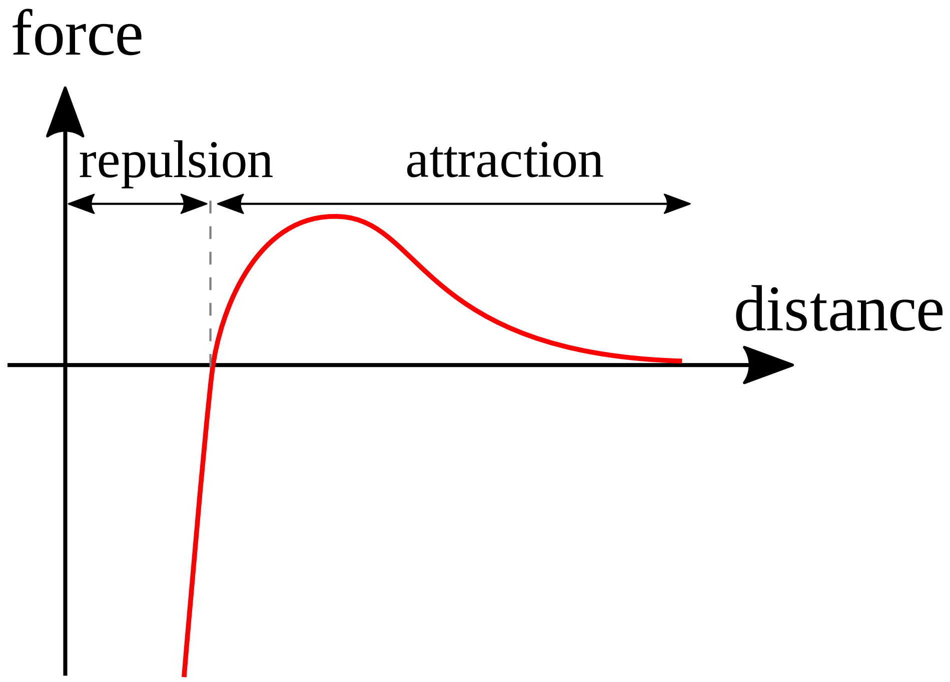
Interaction between particles



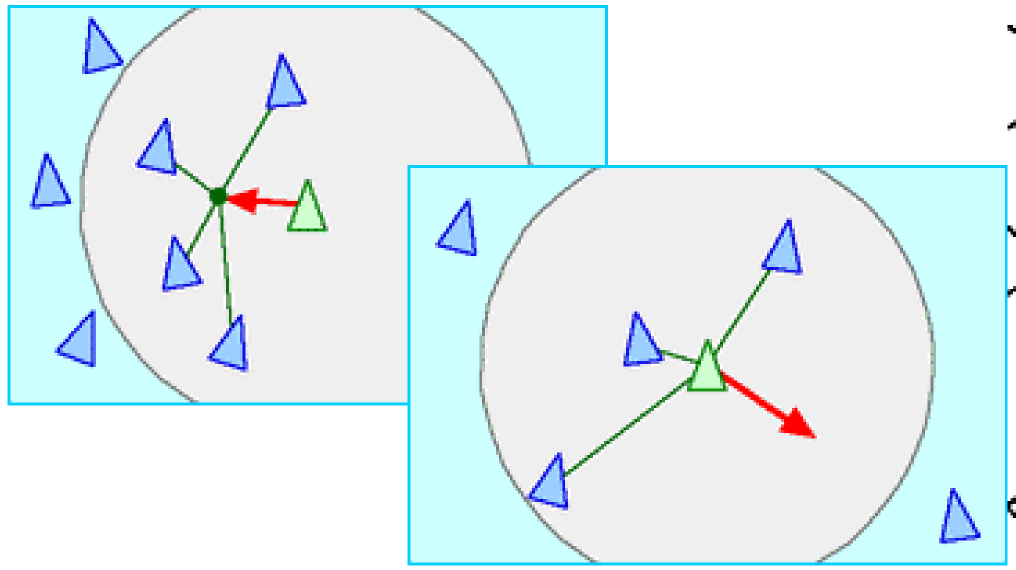
Interaction as **force field** (interact at distance)

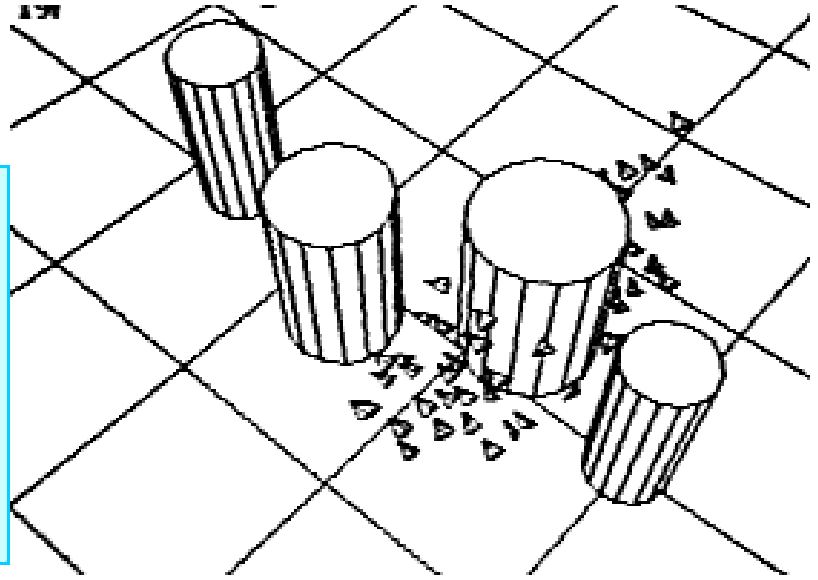
Example of usage

- Models crowd of life-like characters at large scale
  Inspired from physics particles forces (ex. Lennard-Jones potential)
  Attraction at *long-range*
  Repulsion at *short-range*



- First model: **Boids** Craig Reynolds 1987
- Extended later to human crowd modeling





Boids Model

Introduced by

[Craig Reynolds. Flocks, Herds, and Schools: A Distributed Behavioral Model, SIGGRAPH 1987]

[Craig Reynolds. Steering Behaviors For Autonomous Characters. Proceedings of Game Developers, 1999]

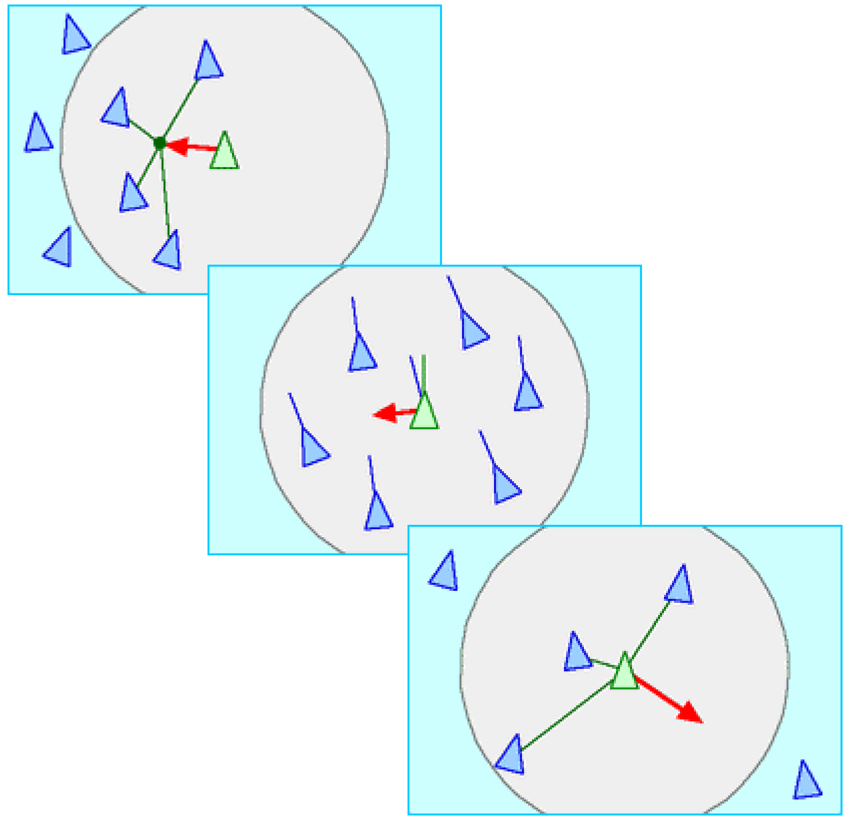
A boid is defined by its

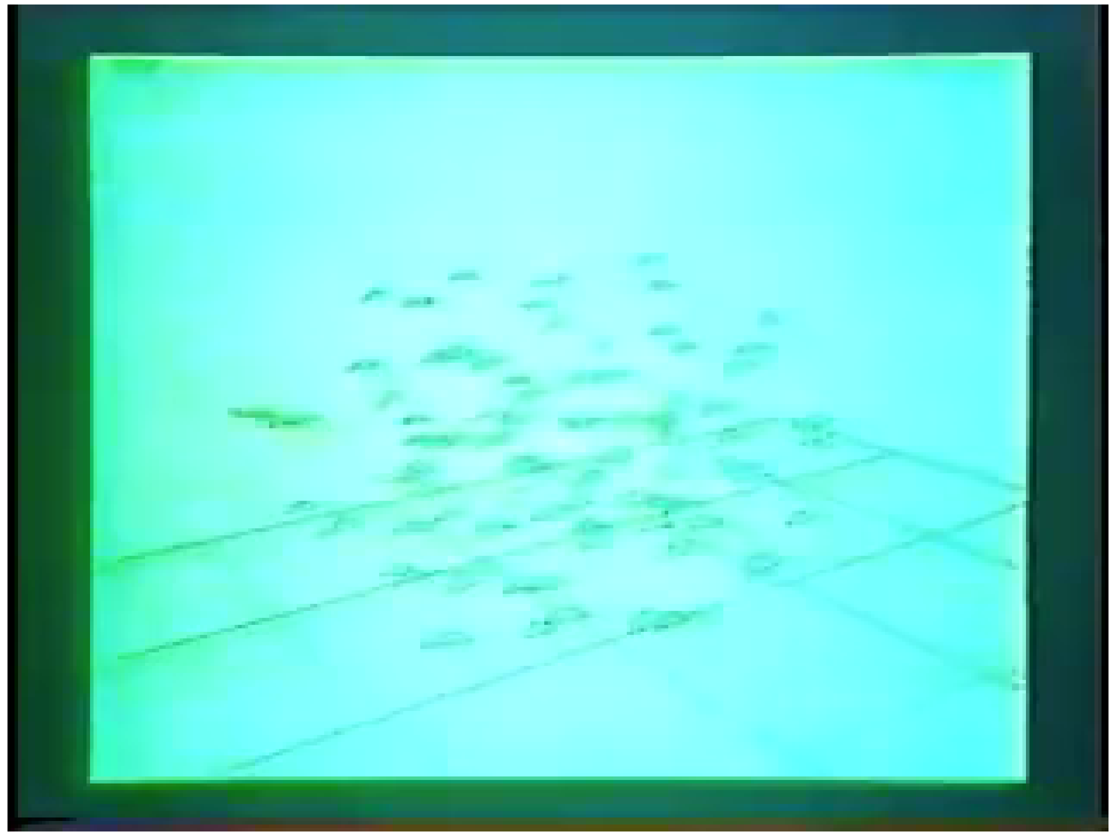
- Position
- Speed
- Forces acting on it

Three basic local *steering behaviors* to model flocks

- **Cohesion** between local particles
- **Alignment** between local particles
- **Separation** between too close particles

=> Leads to emerging global behaviors.





Original video in 1986 (C. Reynolds)

Boids Model - Basic model.

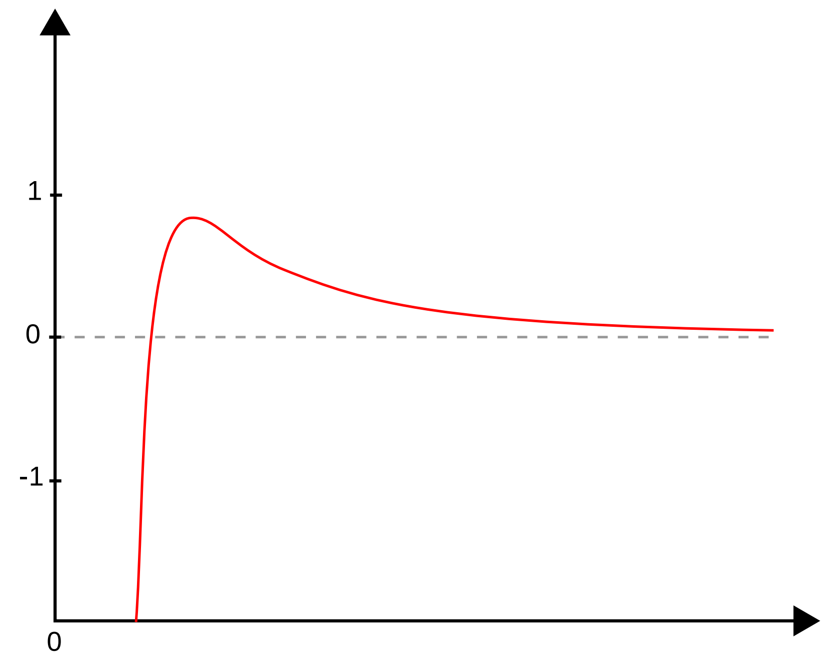
- Set random initial position/speed to N particles.

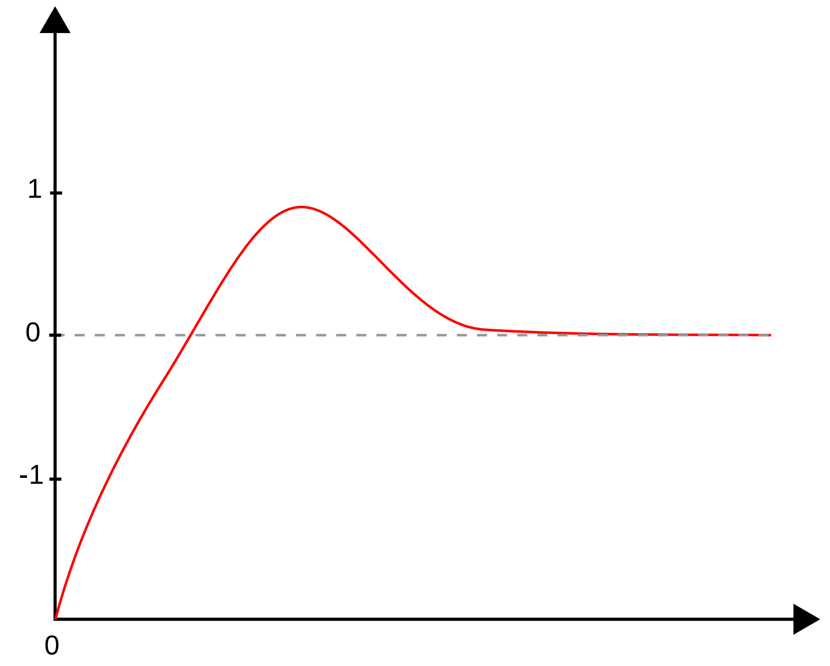
- Set attraction/repulsion force depending on pairwise distances

$$F(p_i) = \sum_j f(\|p_j - p_i\|) \frac{p_j - p_i}{\|p_j - p_i\|}$$

Example

- Inverse of distance $f(x) = \frac{\alpha_1}{x^2} - \frac{\alpha_2}{x^4}$
- Exponential/Gaussian $f(x) = \alpha_1 \exp\left(-k\left(\frac{x - x_0}{x_0}\right)^2\right) - \alpha_2 \exp\left(\frac{x}{x_0}\right)$





- Integrate position and speed through time

$$v^{t+\Delta t}(p_i) = v^t(p_i) + \Delta t\ F(p_i^t)$$
$$p^{t+\Delta t}(p_i) = p^t(p_i) + \Delta t\ v^{t+\Delta t}(p_i)$$

Boids Model - Complexity.

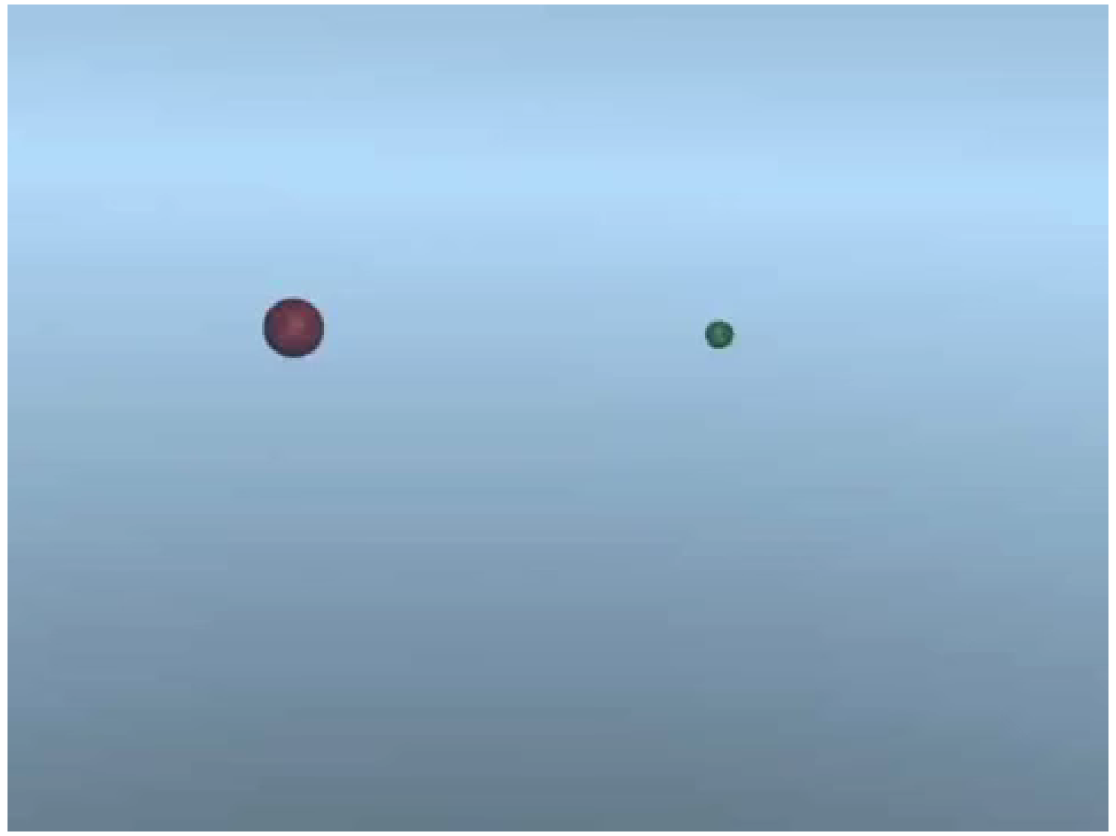
Trivial implementation:

```
struct particle { vec3 p, v, f; };

std::vector<particle> boids;

// Initialize N boids ...
// ...

// compute pairwise force
for(int i=0; i<N; ++i)
{
    for(int j=0; j<N; ++j)
    {
        if( i!=j )
        {
            const vec3& pi = boids[i].p;
            const vec3& pj = boids[j].p;

            boids[i].f += force( norm(pi,pj)) / (pi-pj)/norm(pi-pj);
        }
    }
}

// integration
for(int i=0; i<N; ++i)
{
    boids[i].v = boids[i].v + dt * boids[i].f;
    boids[i].p = boids[i].p + dt * boids[i].v;
}
```

- What is the complexity (wrt. N) of this algorithm ?
- Can you think of a way to be more efficient for large N ?

Boids Model - Usage and limitations

- Well adapted to flocks (birds, fishes - looking behavior)
- Display particles using 3D animated model



Additional behaviors

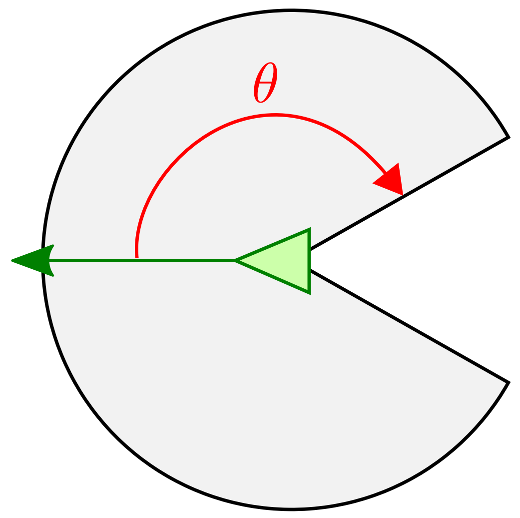
- Objective position/speed value
- Constraints: Obstacle avoidance, limited velocity
- Pursue and evade target/other particles - follow the leader, predators, etc.

- *Is collision between particles possible ?*
- *Human displacement are mostly guided by vision, what key element is missing in the basic boids force-based model ?*

Boids Model - Extensions

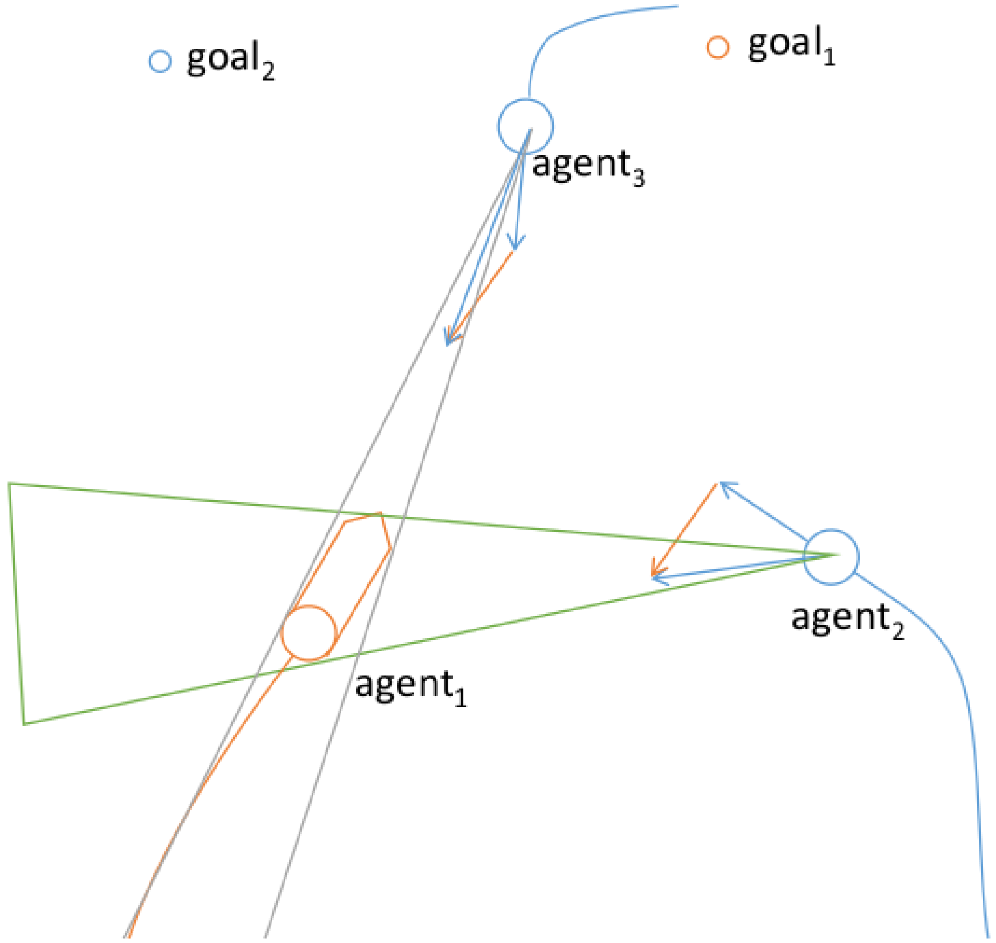
Improving force computation

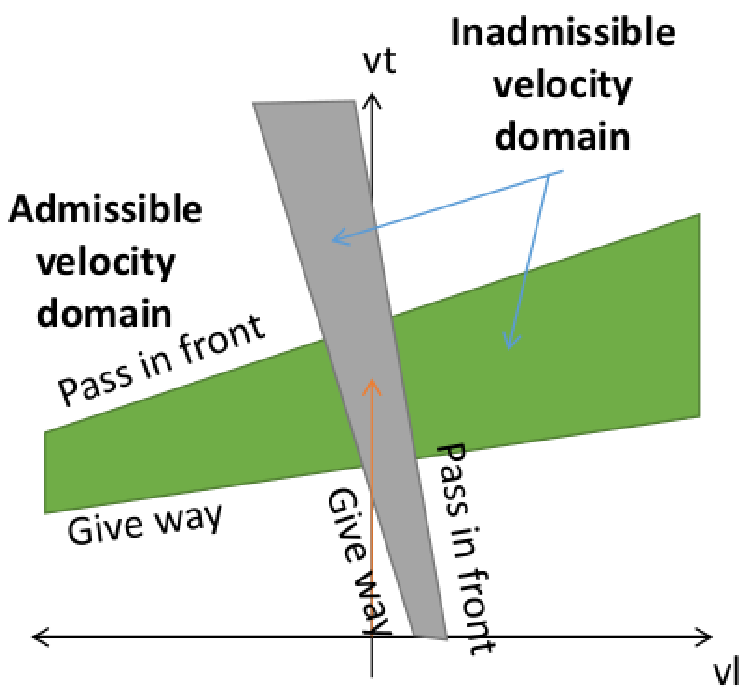
- Vision-based force computation (angle, speed) : limited view angle



Improving collision avoidance

- Velocity-based





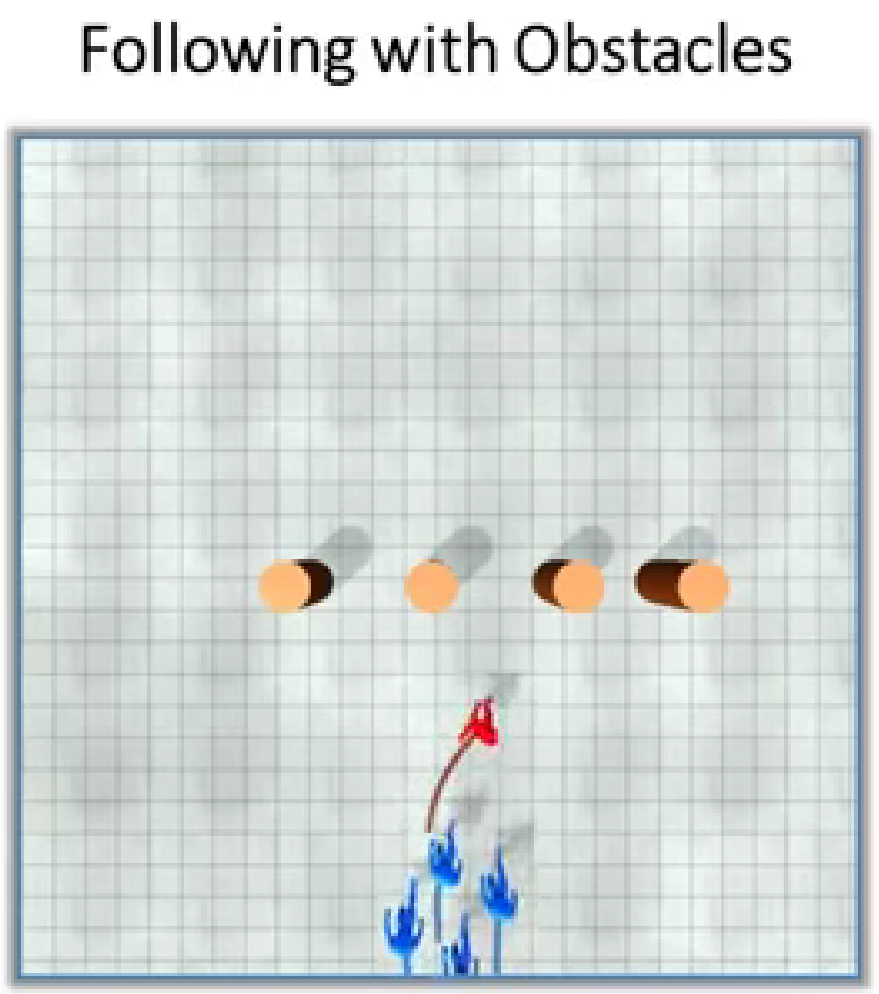
[Experiment-based Modeling, Simulation and Validation of Interactions between Virtual Walkers. J. Pettré et al. SCA 2009]

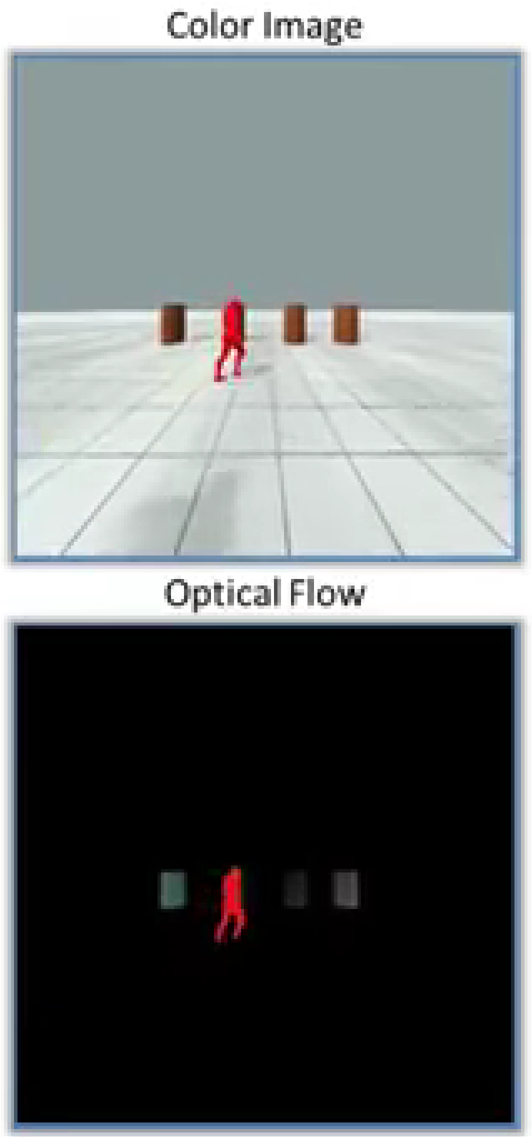
Vision based displacement

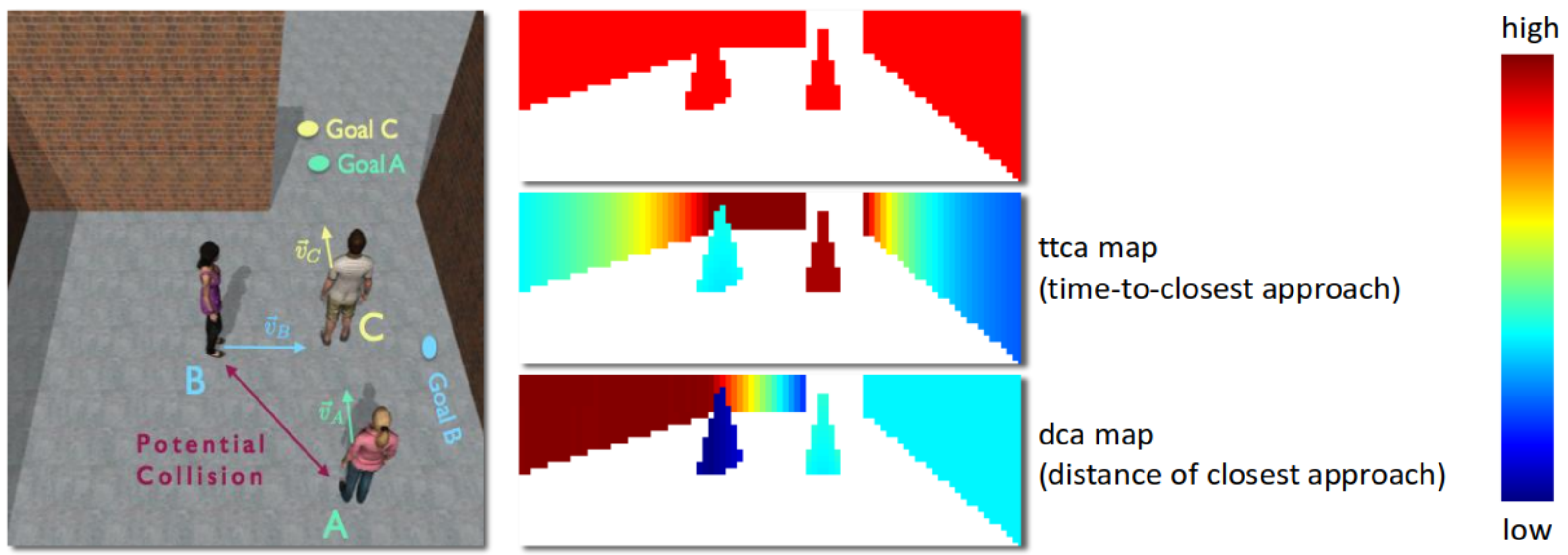
Render vision for each individual agent

- Compute optical flow u.
- Obstacles are approaching when $div(u) > 0$

Best results, but high computational cost.







[A Synthetic-Vision Based Steering Approach for Crowd Simulation. J. Ondrej et al. SIGGRAPH 2010]

[Character navigation in dynamic environments based on optical flow. A. Lopez et al. EG 2019]

Example of crowd simulation software

Golaem

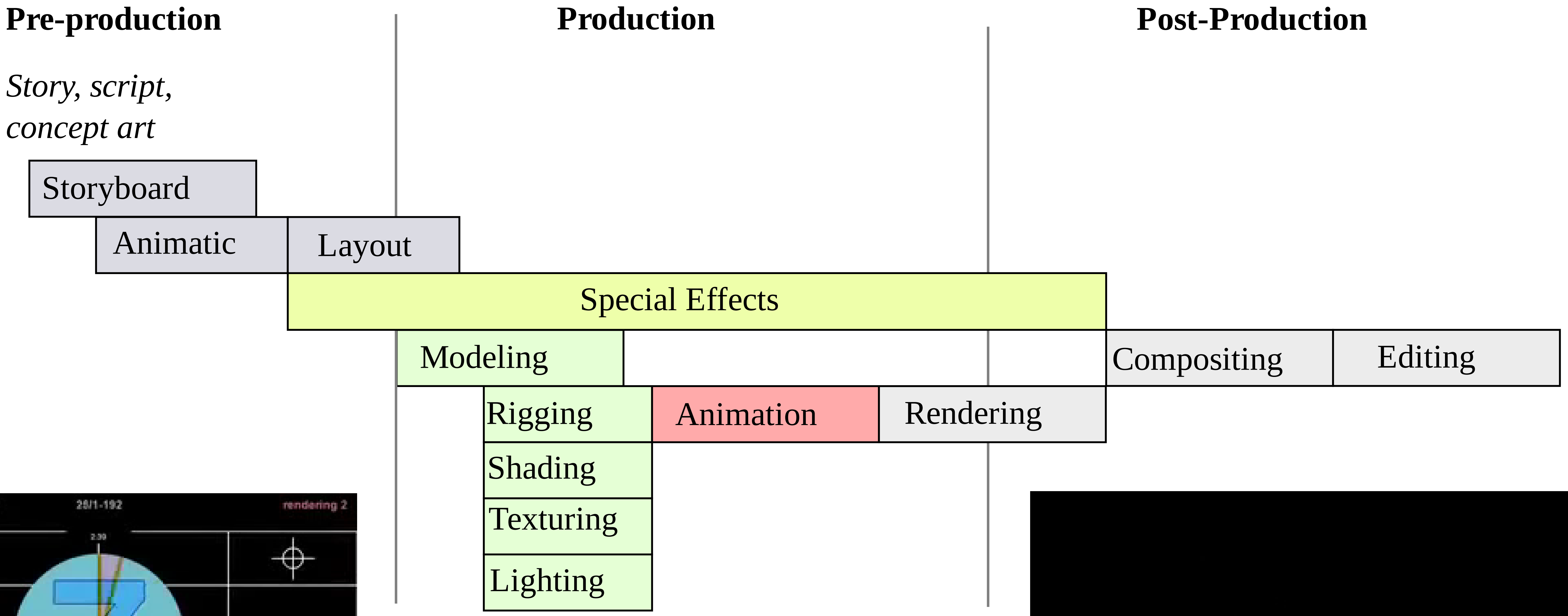
In Rennes

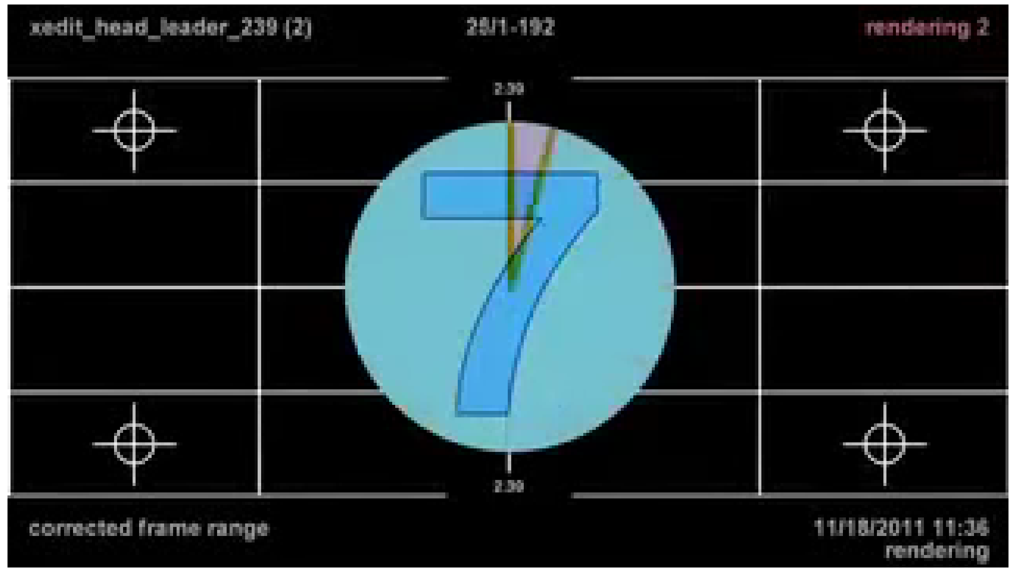
Production Pipeline

Case of Animation Cinema production

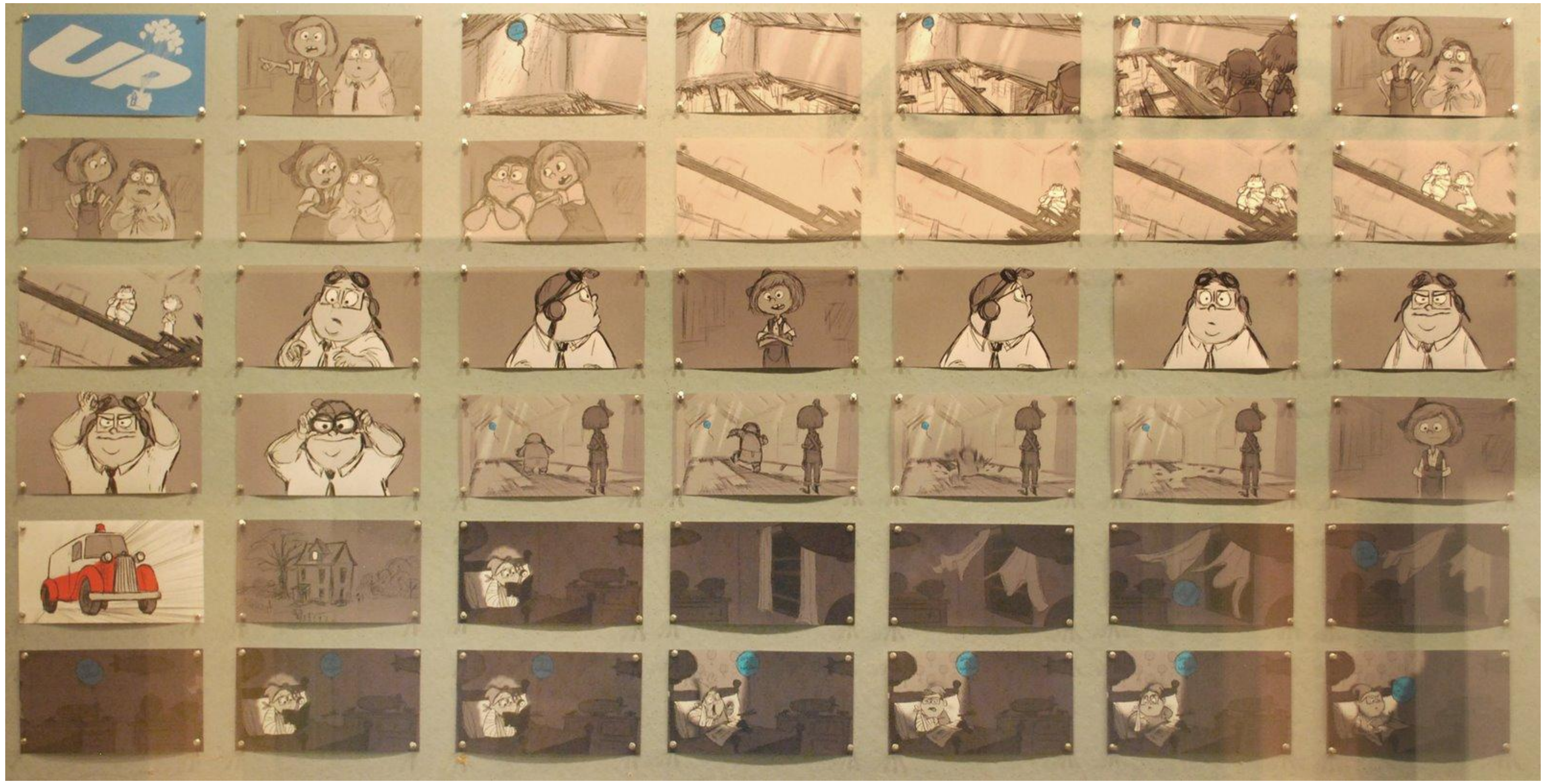
Production Pipeline

Fundamental structure for VFX/animation movie production.





Story-board



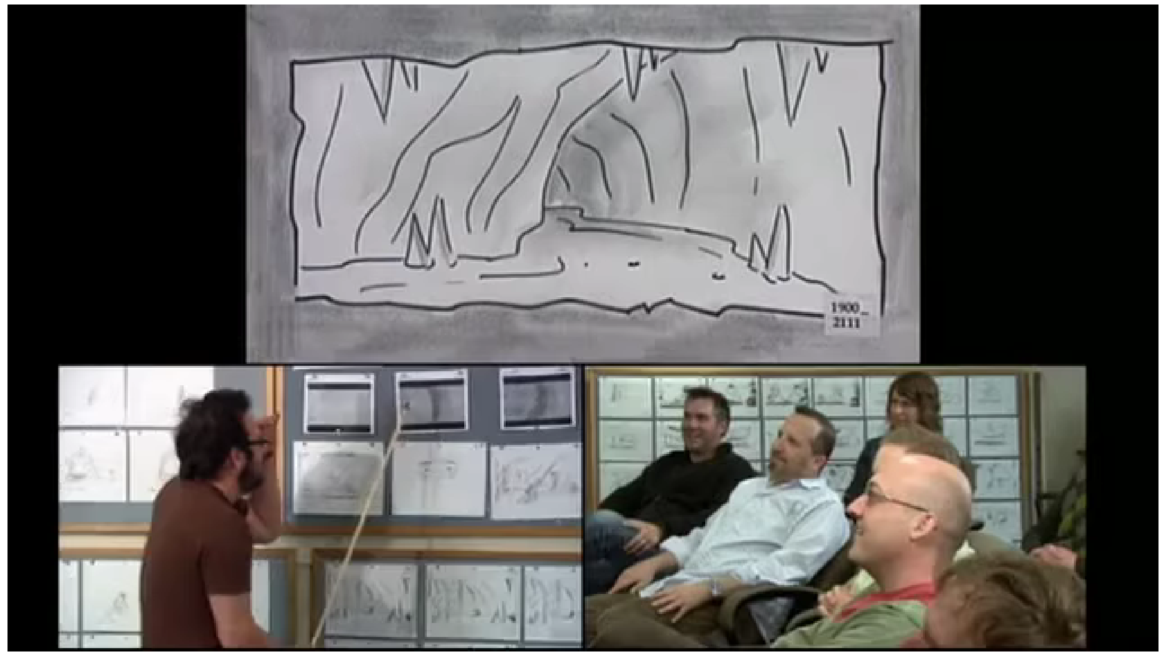
Few 2D drawings: express the story

Before mostly non-technical - artistic/creative based
Curently Strong increase of Storytelling-related researches in CG
ex. Disney Research Studios, Anima team at Inria

Animatic

≃ Animated story-board, Various format

Rough sense of timing, visual, action: details not necessarily followed precisely in the final version.



Layout: Moving into 3D

1st step: Rough 3D modeling and placement of

- Camera: visual field, perspective

  3D much more constrained than 2D drawings

- Shape volumes, continuity

  No details: face, etc.

  Choice between 3D/2D elements

“MONSTERS UNIVERSITY” Progression Image 1 of 6: STORY
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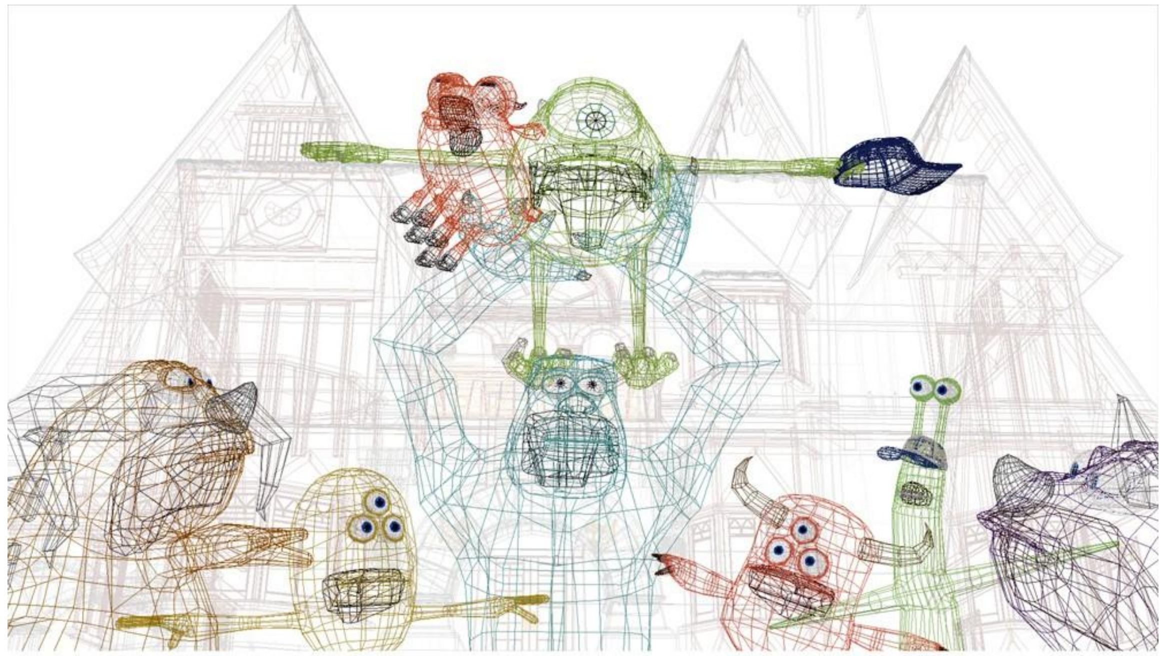

“MONSTERS UNIVERSITY” Progression Image 3 of 6: MODELING
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“MONSTERS UNIVERSITY” Progression Image 4 of 6: LAYOUT
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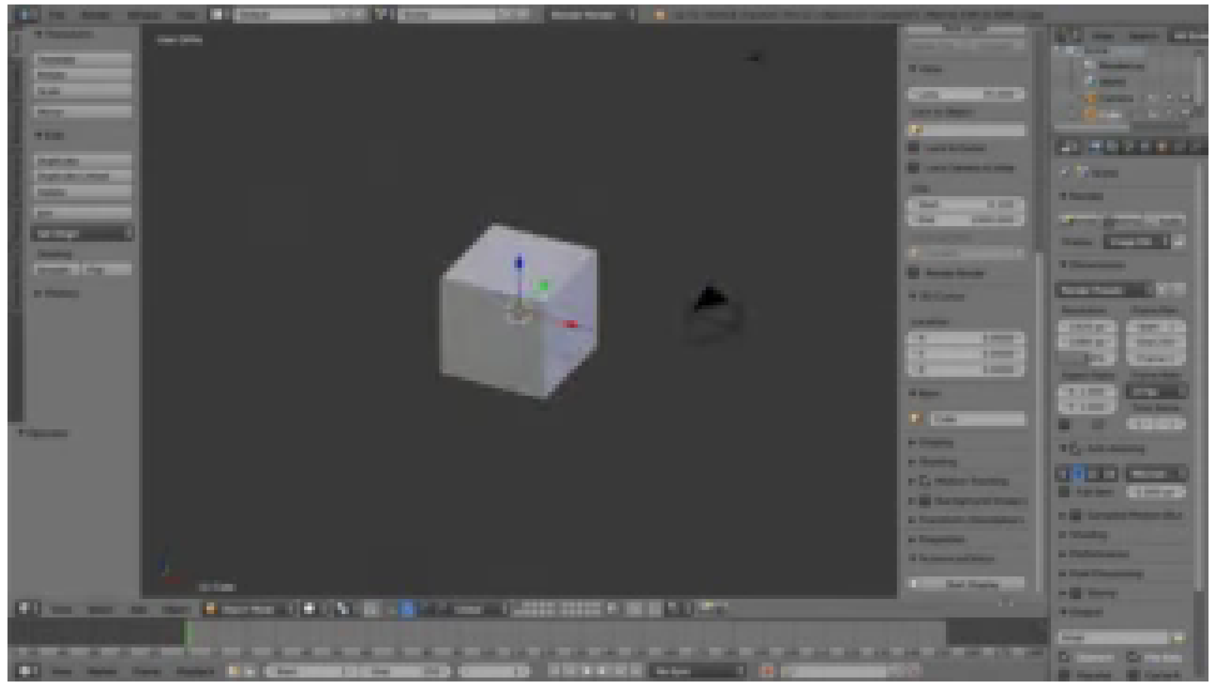
3D Modeling



In production

- Polygonal mesh modeling

  Coarse to fine approach

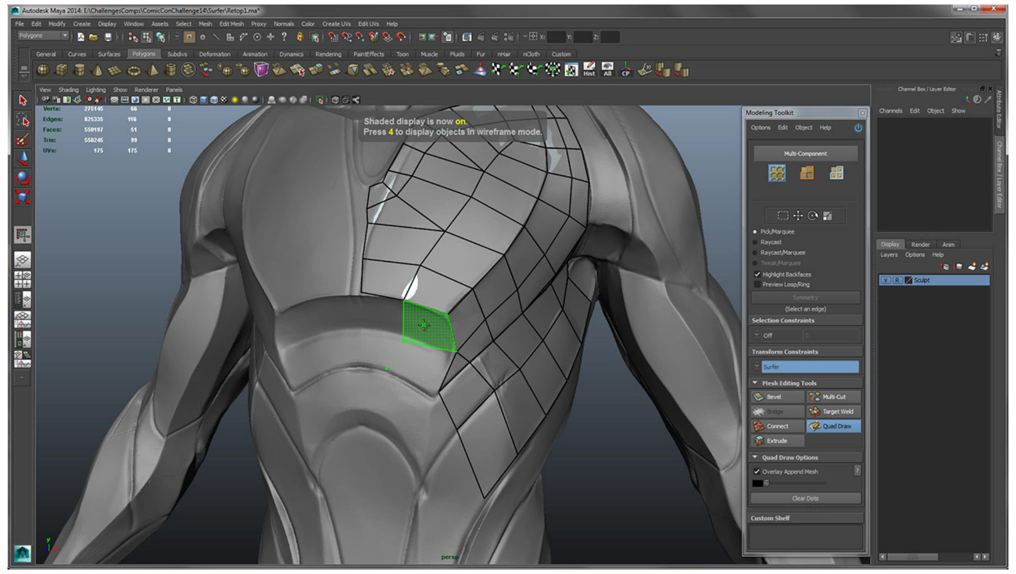
  1. Low res modeling (extrusion)

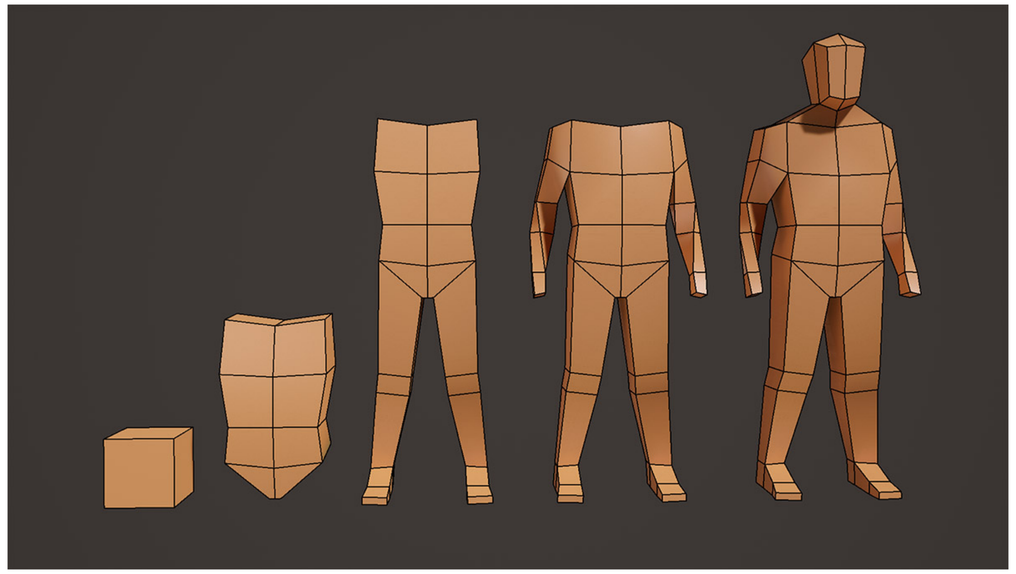
  2. Subdivide, Refine

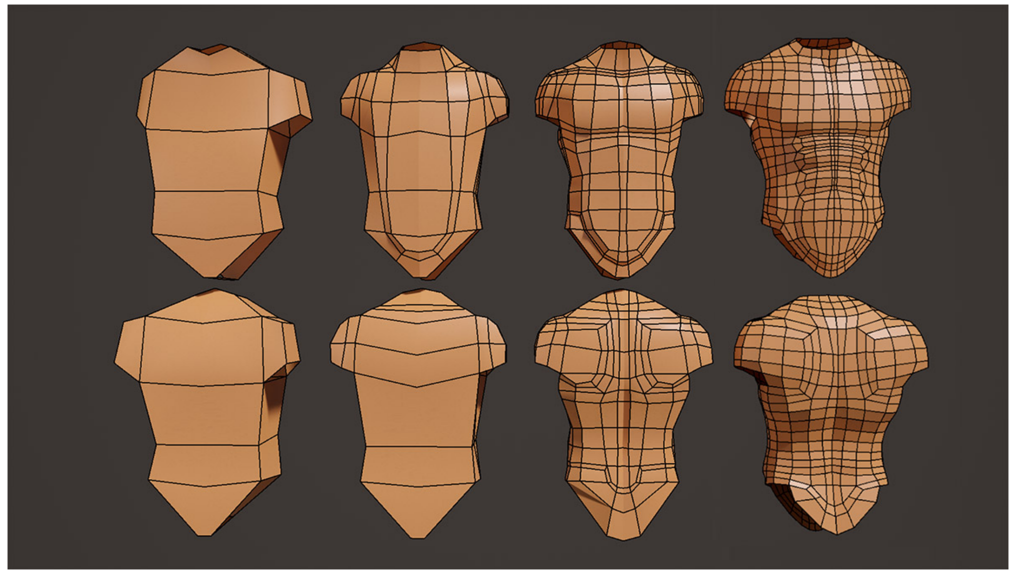
- Parametric (NURBS) modeling

Everything else is "VFX"

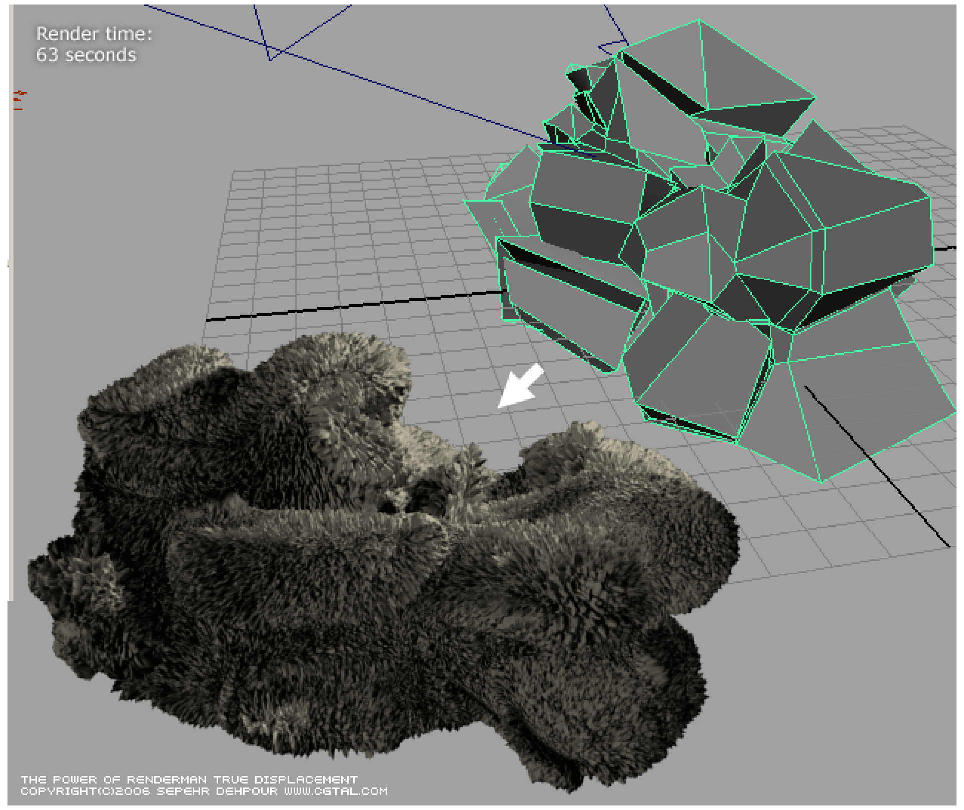
Common tools: Maya, 3DSMax, Cinema4D, Blender, etc.



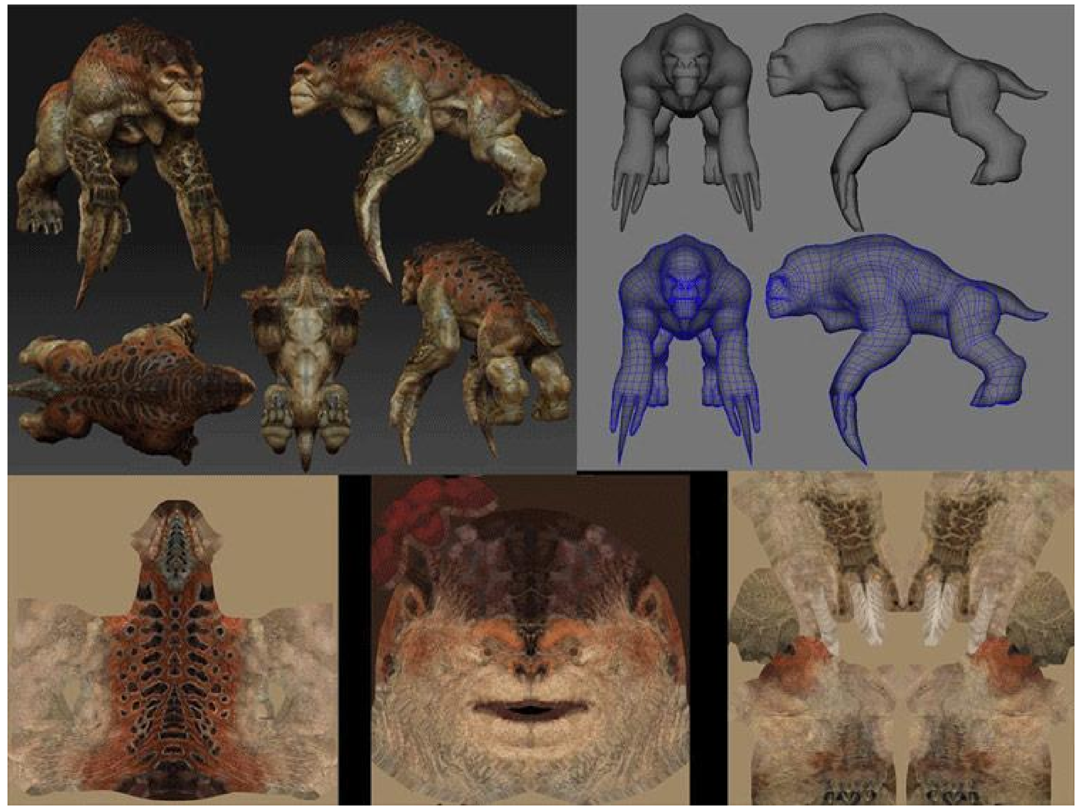




Modeling appearance - Rendering purpose

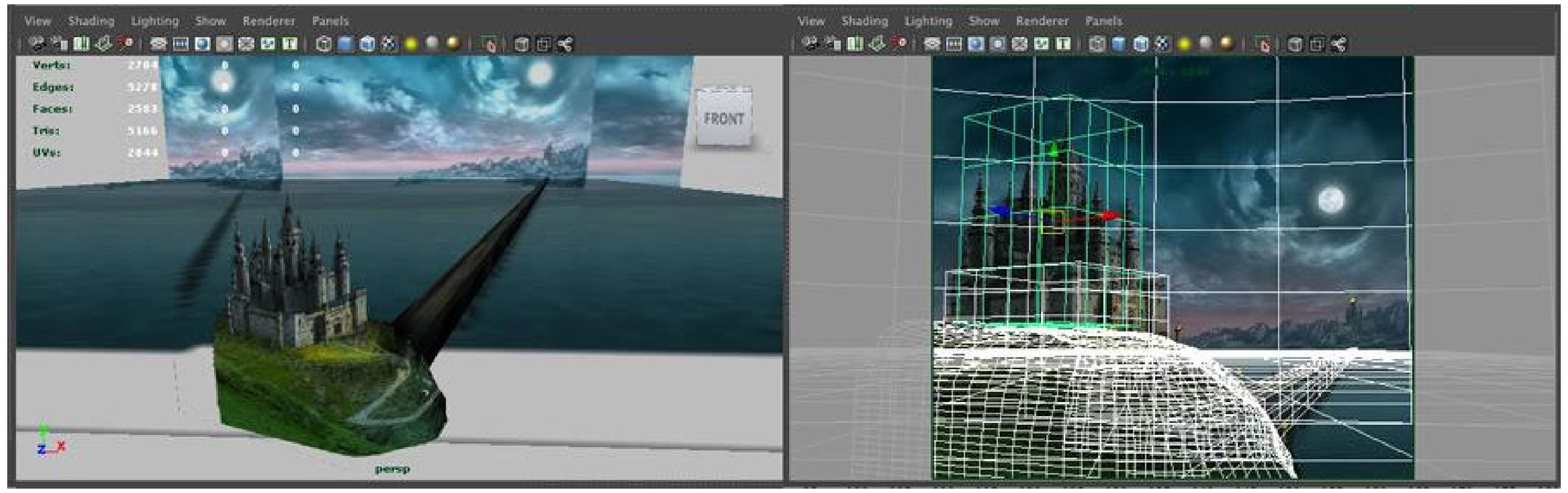


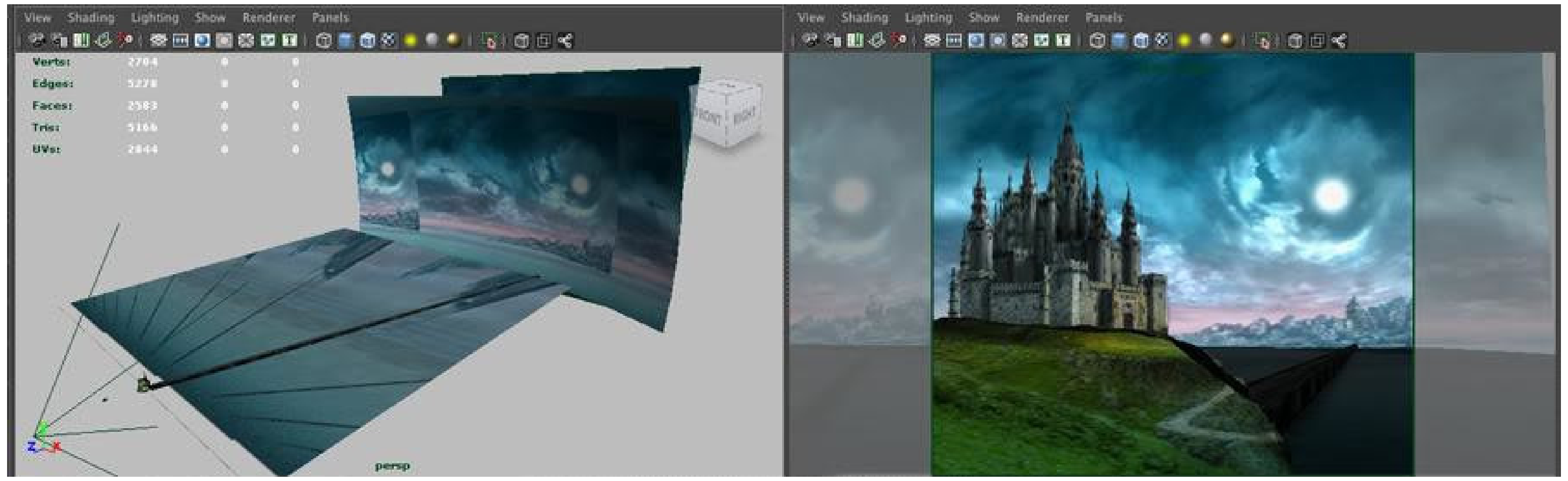
Shading



Texturing

Lighting



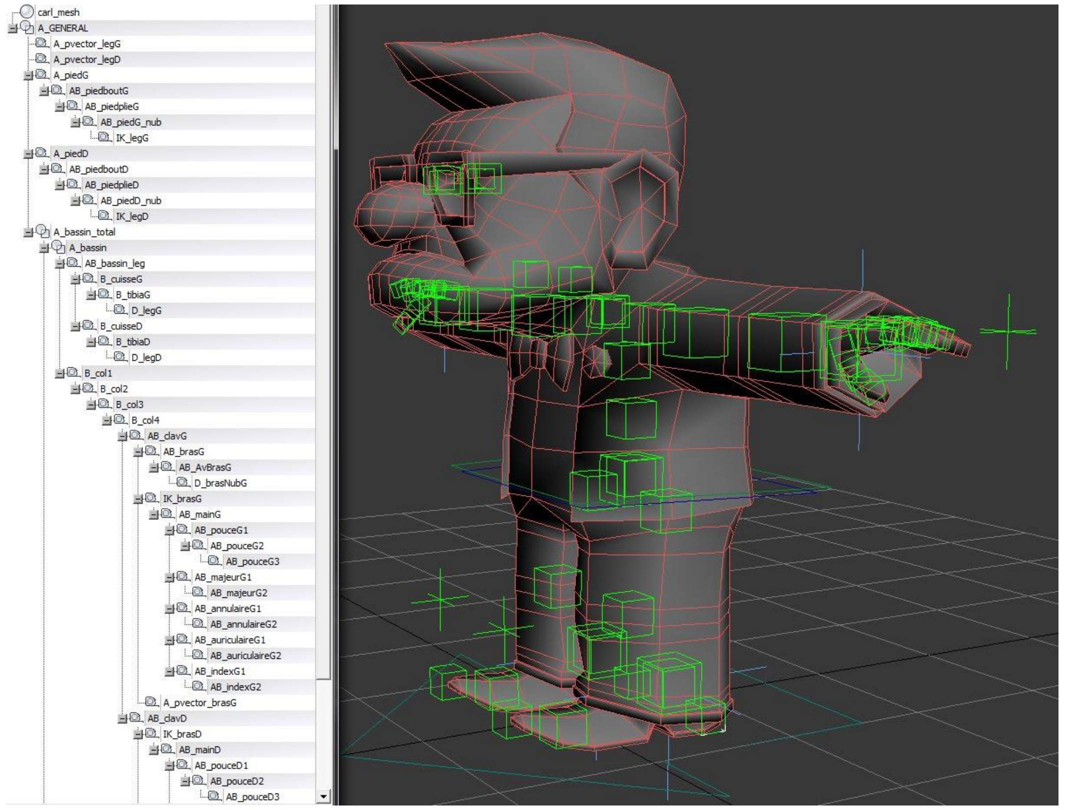


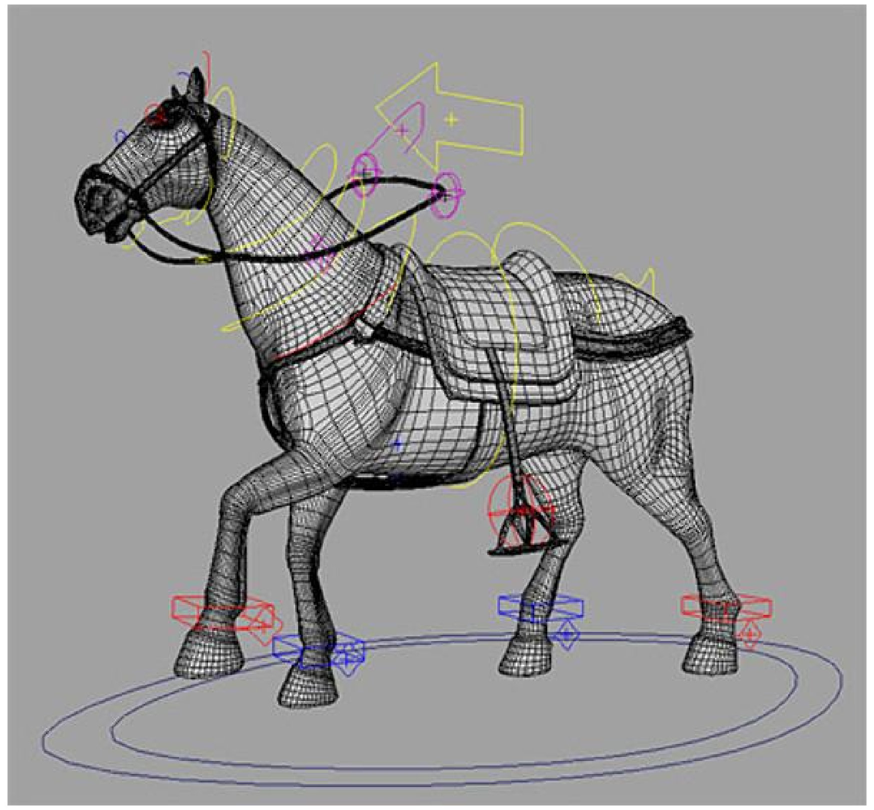
Mate painting

Rigging

Attach deformation handles to the mesh
Each handle (controler) is associated to a deformation - degrees of freedom

Rigging is a technical part
- Python script, Mel (Maya), Lua, etc.





Animation

In production terminology: Animation = Key-frame animation of the rigged character

Set animation curves on rig controlers

Everything else is VFX

Animating the walk cycle (×40)

Result

Up to 75% of artists production studios are animators

Animation = The key element - higher cost - for production studios

One animator → 1-10 s of animation per day

Animation sub-parts

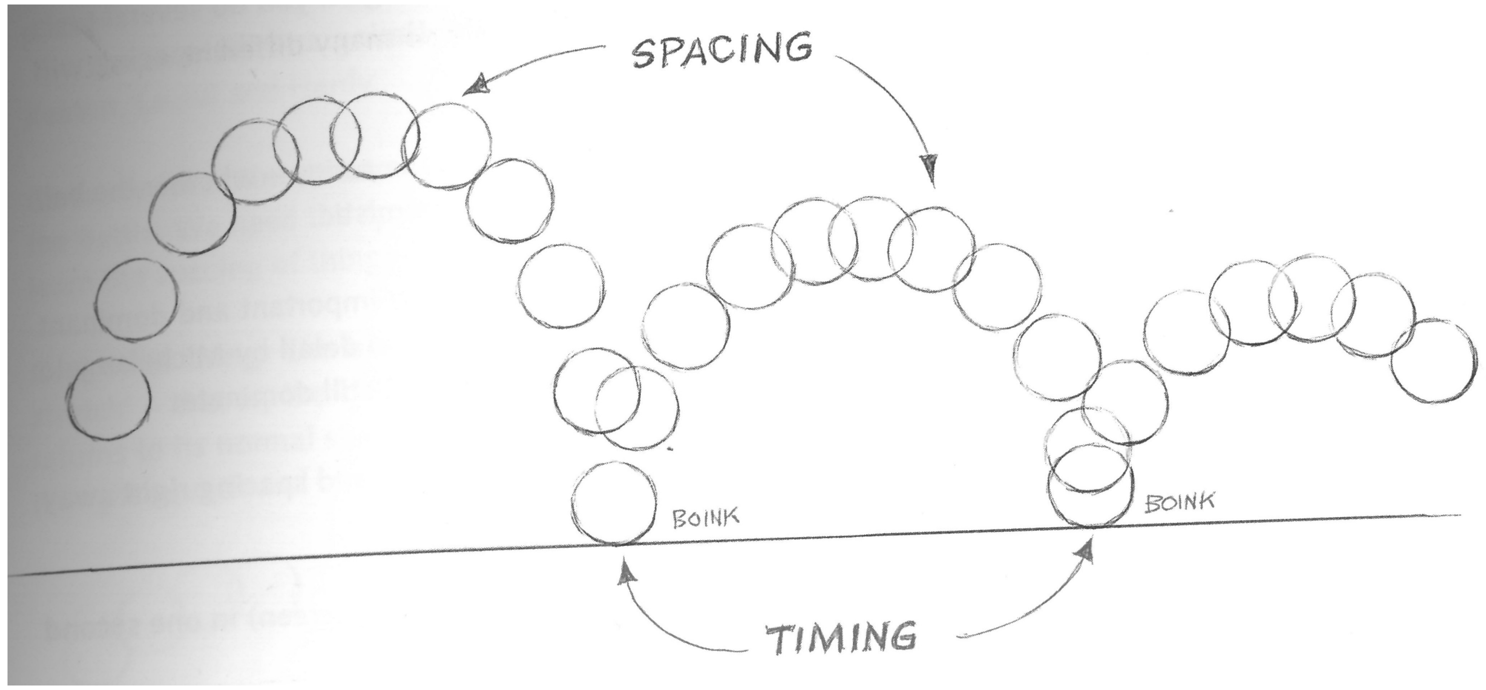
1- **Posing** the *key frames*

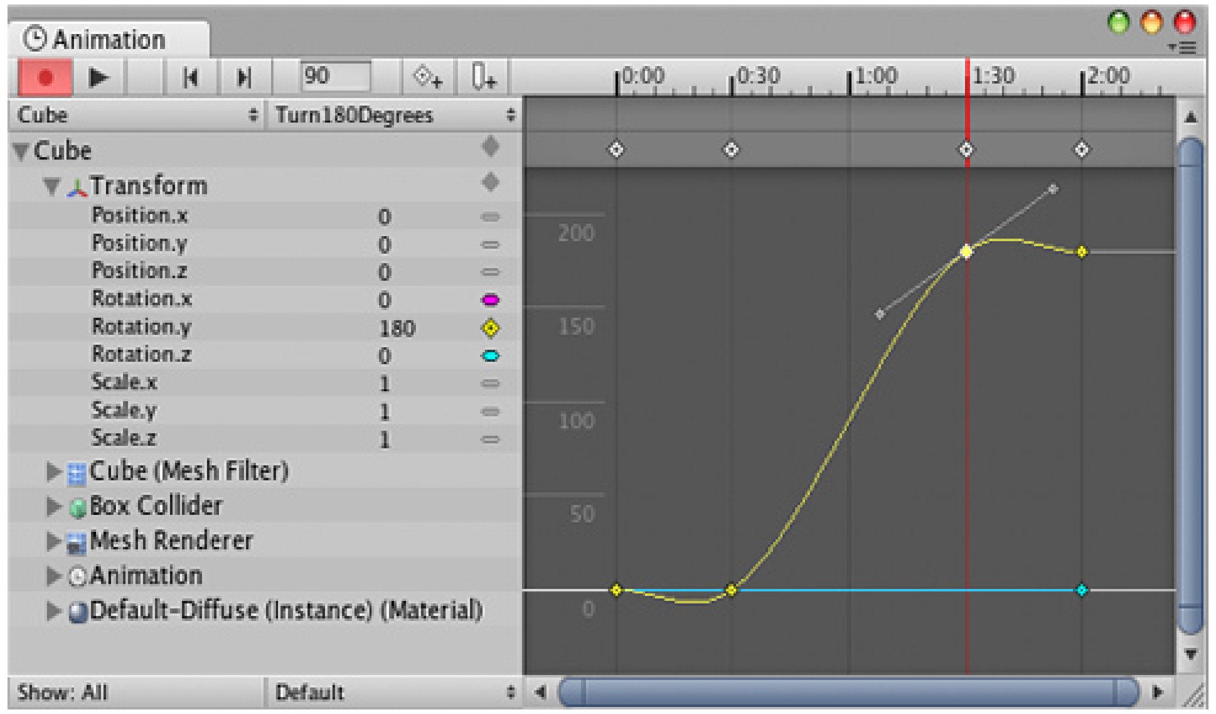
Set the main general posture of the character

*Linked to geometric **character deformation**, time is not involved*

2- **Animating** the in-betweens

- **Timing** : Place key frames at specific times (global length of an action)
- **Spacing** : Speed of the interpolation (dynamic of the action)





Special Effects (VFX)

- Everything which is not handled by traditionnal modeling/rigging/animation
  - *Physics (explosion, fluids, dynamic hairs, cloth, ...), particles systems, complex shape, crowd, etc.*
- Technical R&D part: One element can lead to the development of a dedicated system.
- Main software: Houdini (SideFX)

Post Production

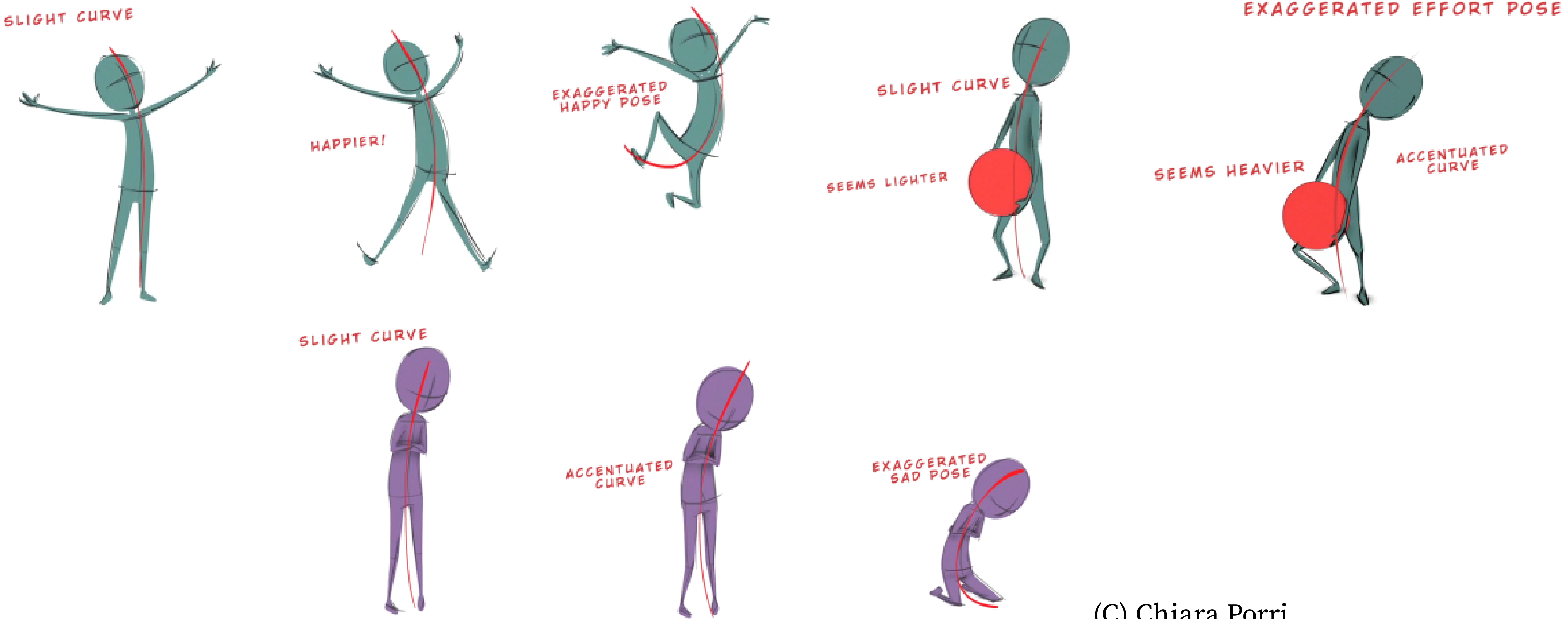
Compositing

- Blend all layers: Rendered and real ones
  - Note: Rendering of color layers but also depth and normals.
- Main software: Nuke (Foundry)

Expressive Animation

Character Animation Posing - Line of Action

- Line of action: *Medial axis* expressing the character pose
- Express *statically* the dynamic of the action
  - Unstable pose ⇒ Dynamic action/motion



(C) Chiara Porri

Principles of animation

- Interpolation between realistic poses isn't enough for expressive animation
- *12 principles of animation* by Disney *Illusion of Life, 1981*

1. Timing
2. Spacing
3. Slow-in, Slow-out
4. Squash & Stretch
5. Anticipation
6. Follow Through
7. Secondary Action
8. Exaggeration
9. Appeal
10. Arcs
11. Staging
12. Straight Ahead/Pose to Pose

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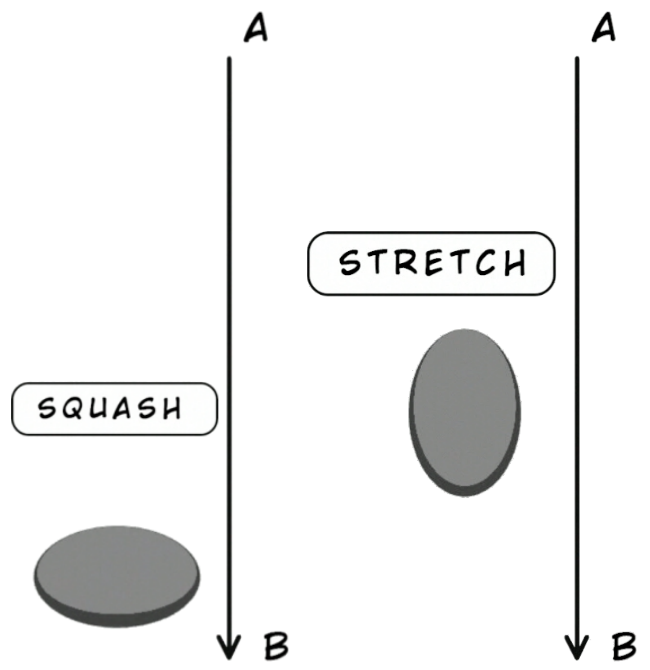
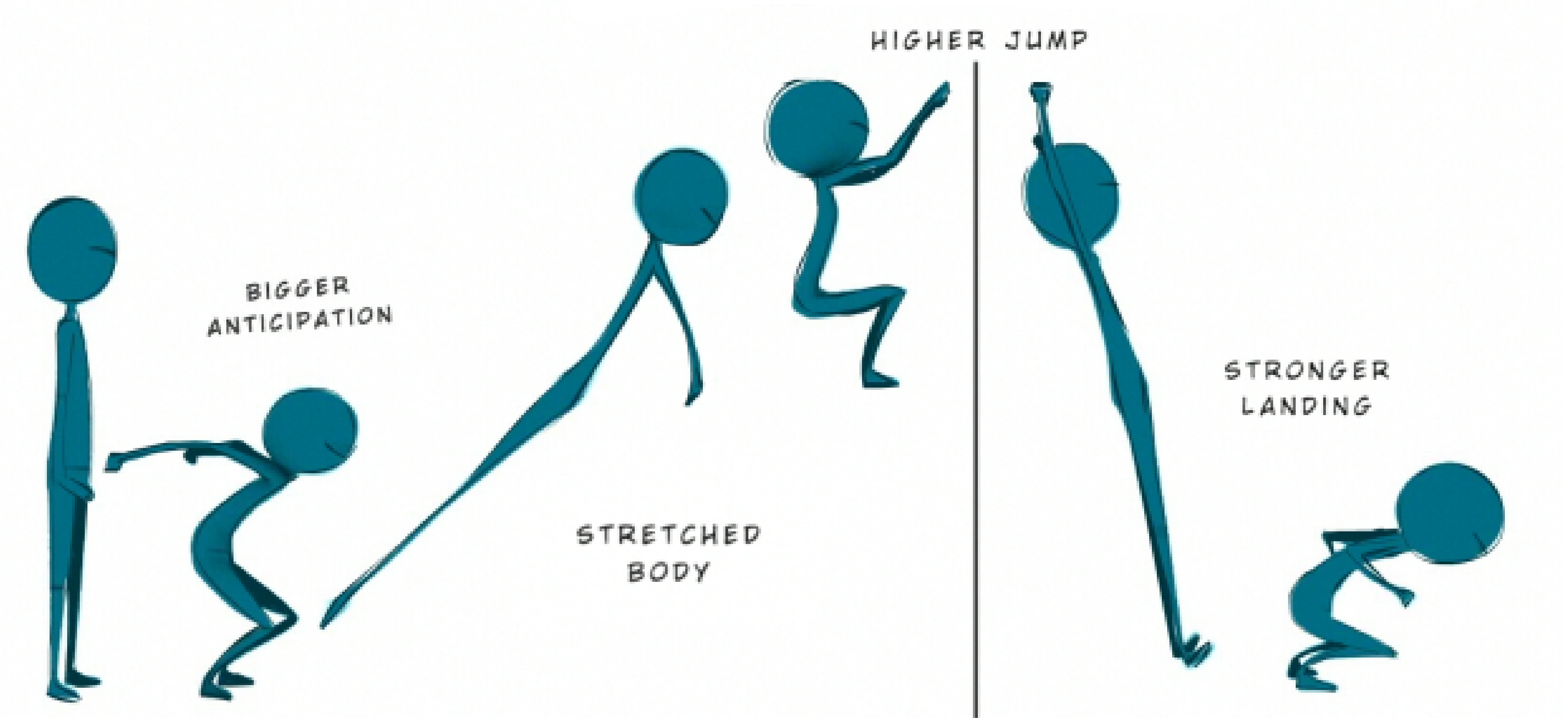
Expressive animation

Squash & Stretch

- Very common in cartoon
- Unrealistic, but surprizingly *plausible*





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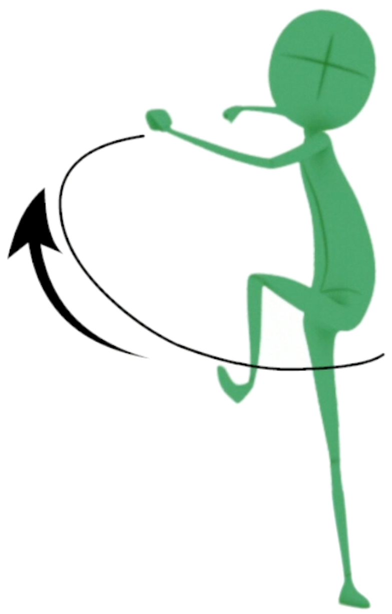
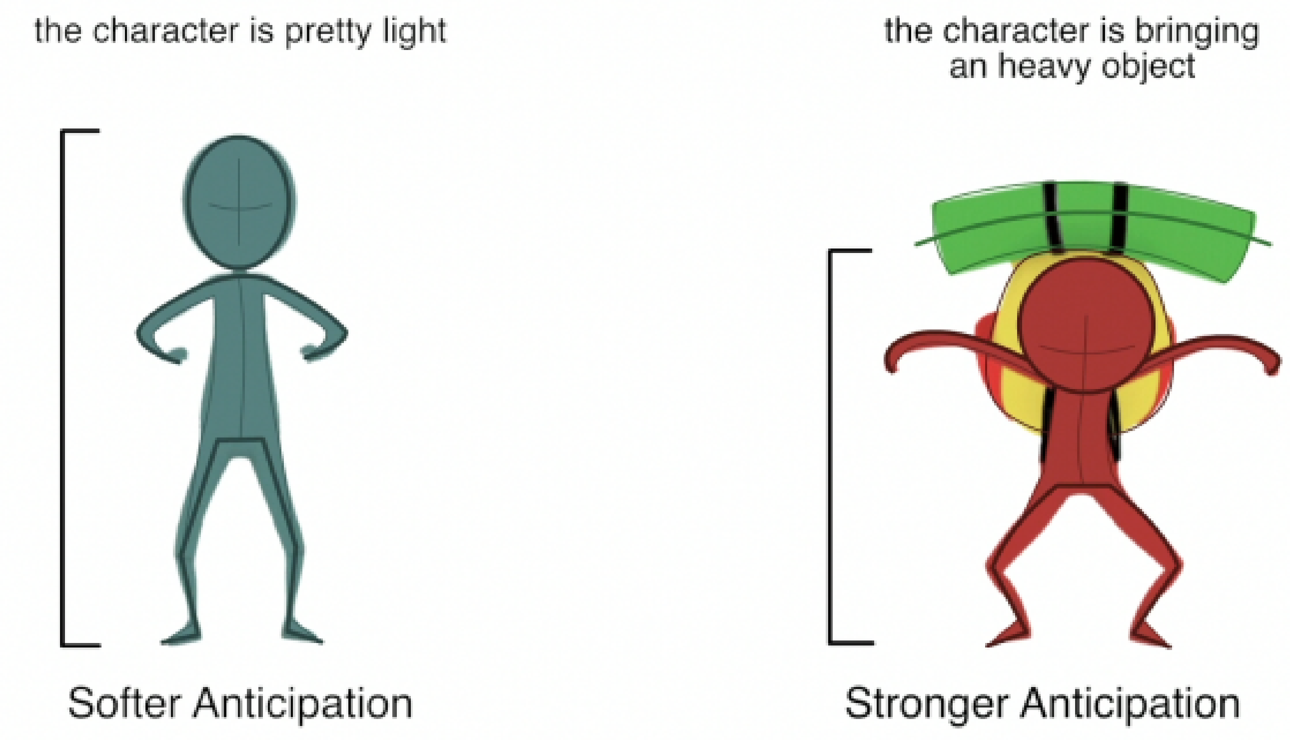
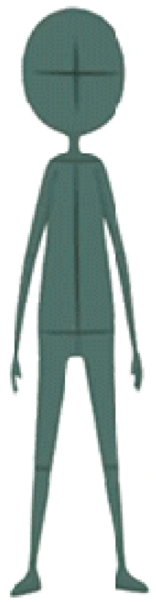
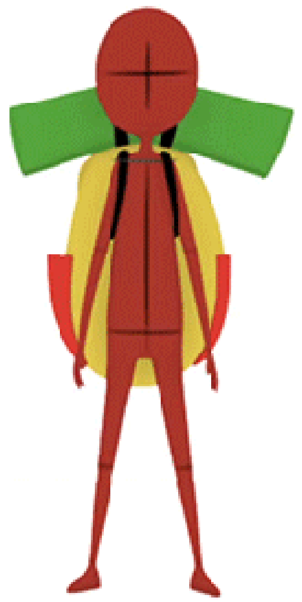
Expressive animation

Anticipation









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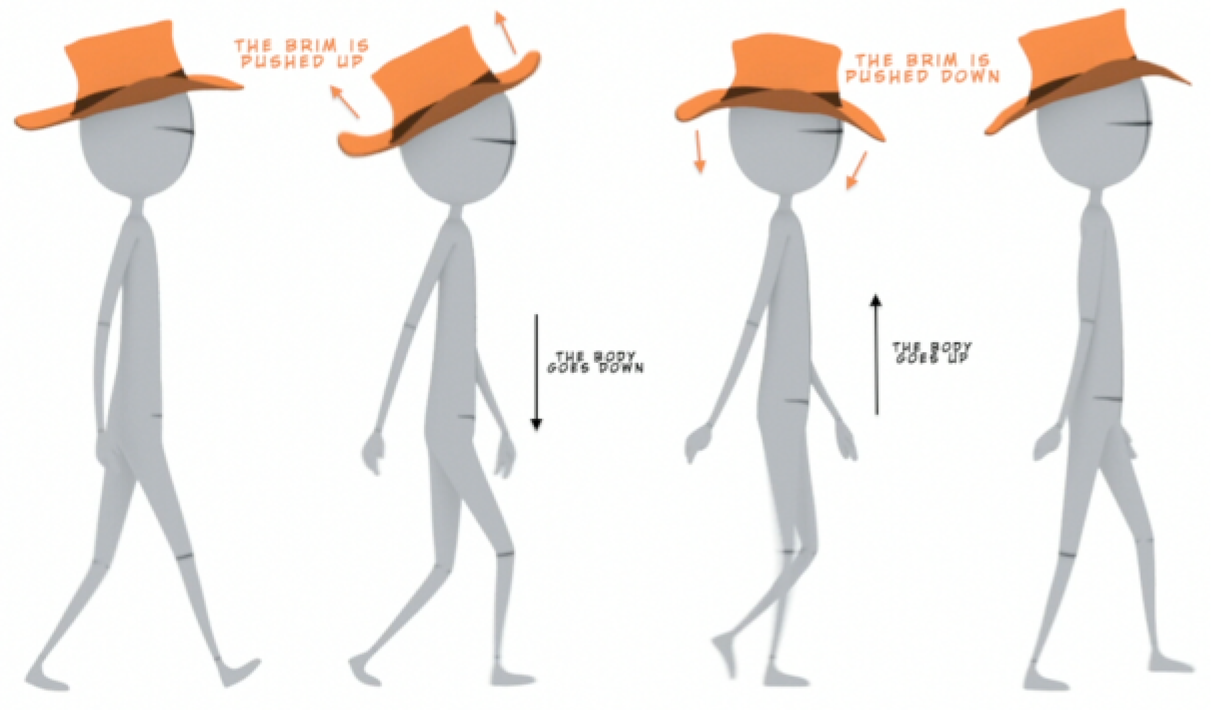
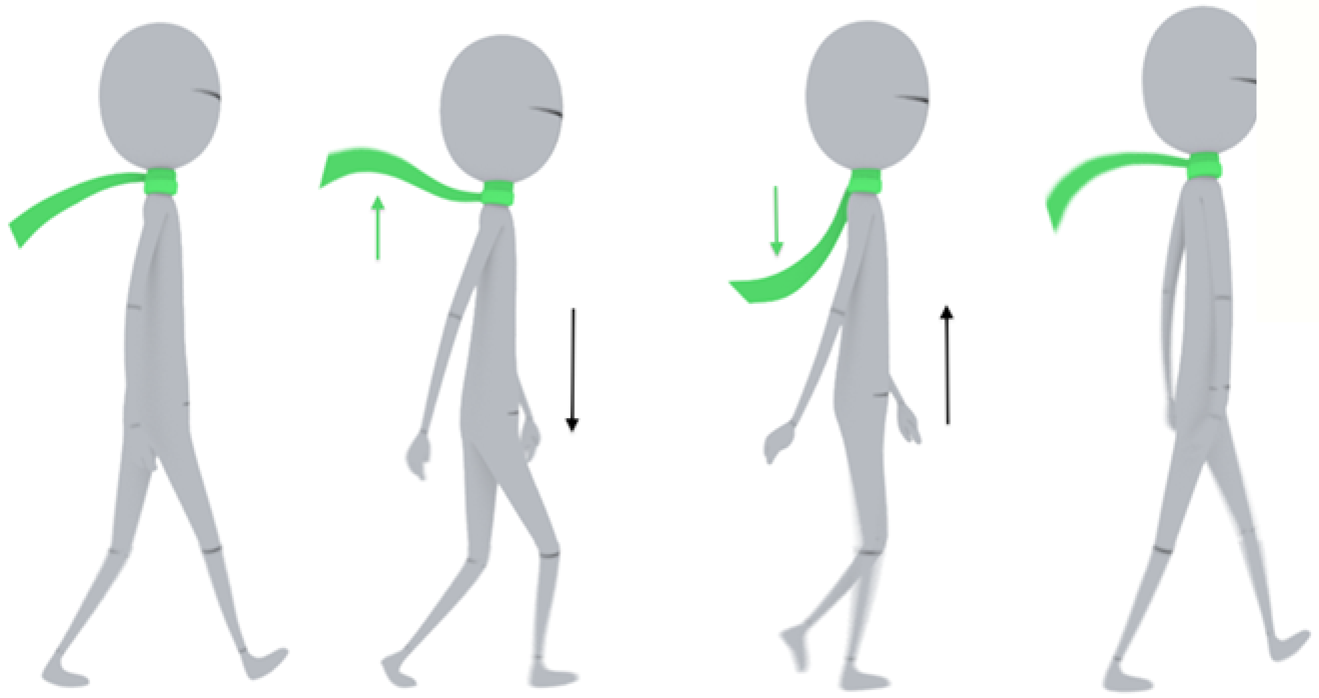
Expressive animation

Follow Through / Secondary motions





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