

*Fall 2017*

## CSCI 420: **Computer Graphics**



## 11.2 Computer Animation



Hao Li

<http://cs420.hao-li.com>

# Overview

## Animation Production

### Rigging

- Procedural
- Skeletal
- Anatomical

### Posing

- Forward Kinematics
- Inverse Kinematics
- Advanced Methods (Style-Based IK + MeshIK)

### Animation

- Keyframe Animation
- Motion Capture
- Physics-Based Character Animation



# Animation Production

1. Story Board
2. Conceptual Art
3. Recording
4. Modeling
5. Rigging
6. Set Dressing
7. Layout
8. Animation
9. Special Effects
10. Shading
11. Lighting
12. Rendering

# Animation Production

1. **Story Board**
2. Conceptual Art
3. Recording
4. Modeling
5. Rigging
6. Set Dressing
7. Layout
8. Animation
9. Special Effects
10. Shading
11. Lighting
12. Rendering



# Animation Production

1. **Story Board**
2. Conceptual Art
3. Recording
4. Modeling
5. Rigging
6. Set Dressing
7. Layout
8. Animation
9. Special Effects
10. Shading
11. Lighting
12. Rendering





# Animation Production


1. Story Board
2. **Conceptual Art**
3. Recording
4. Modeling
5. Rigging
6. Set Dressing
7. Layout
8. Animation
9. Special Effects
10. Shading
11. Lighting
12. Rendering

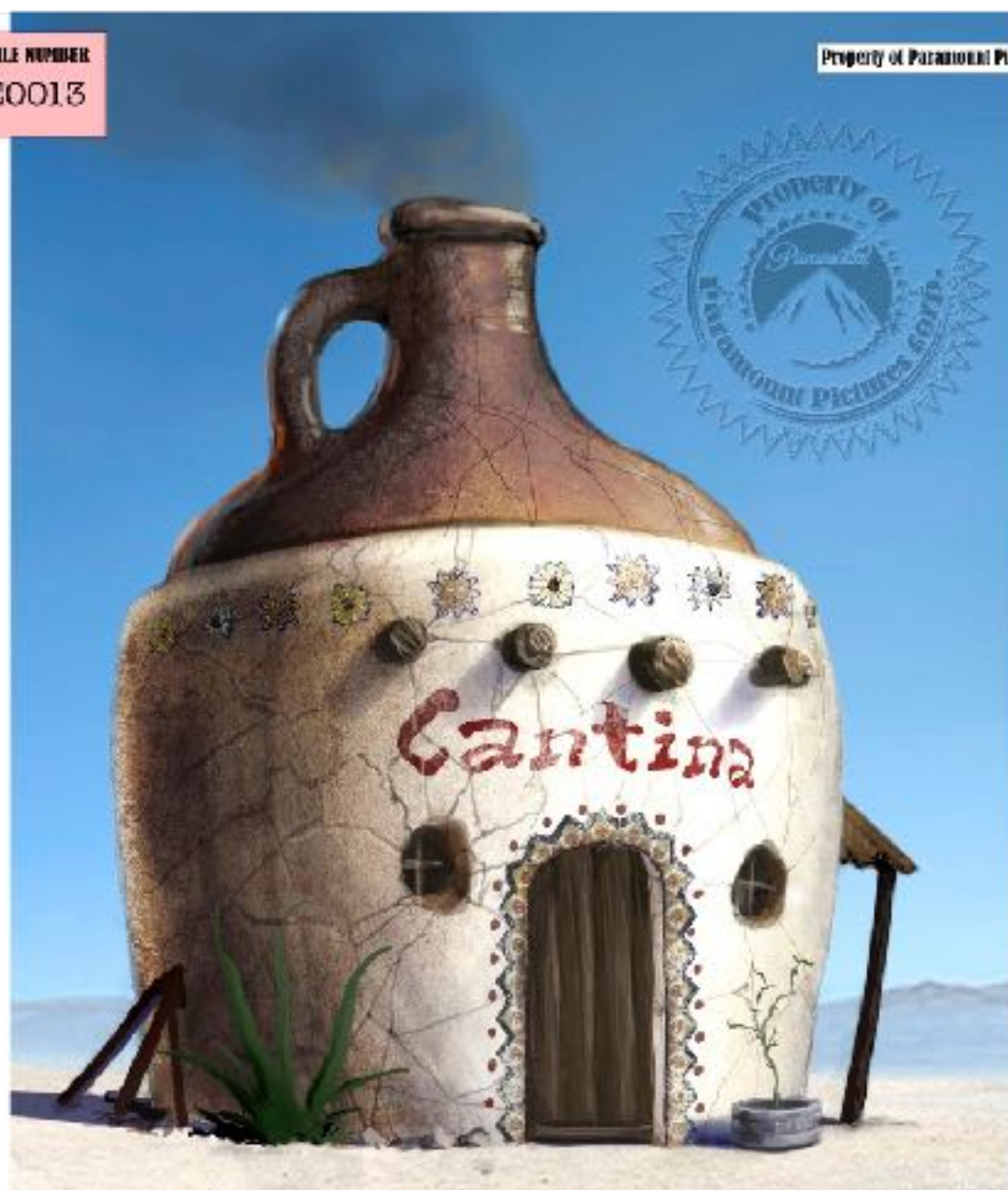



# Concept Art

**FILE NUMBER**  
E0013

Property of Paramount Pictures





<b>Location #</b>	LOC-06	<b>Set #</b>	SET-039-EXT
<b>Description</b>	Cantina		<b>APPROVAL STATUS</b> REFERENCE ONLY <input type="checkbox"/> ROUGH <input type="checkbox"/> FINAL <input checked="" type="checkbox"/>
		<b>Approval Date</b>	<b>Approval Signature</b>
		10/20/08	
<b>NOTES</b> NEW SET NUMBER - PLEASE REPLACE			





**APPROVAL STATUS**

☐ Ref. Only
 ☐ WIP
 ☐ Final

**APPROVAL DATE:**

**APPROVAL STATUS:**

☐ Ref. Only
 ☐ WIP
 ☐ Final

**APPROVAL DATE:**

variations)



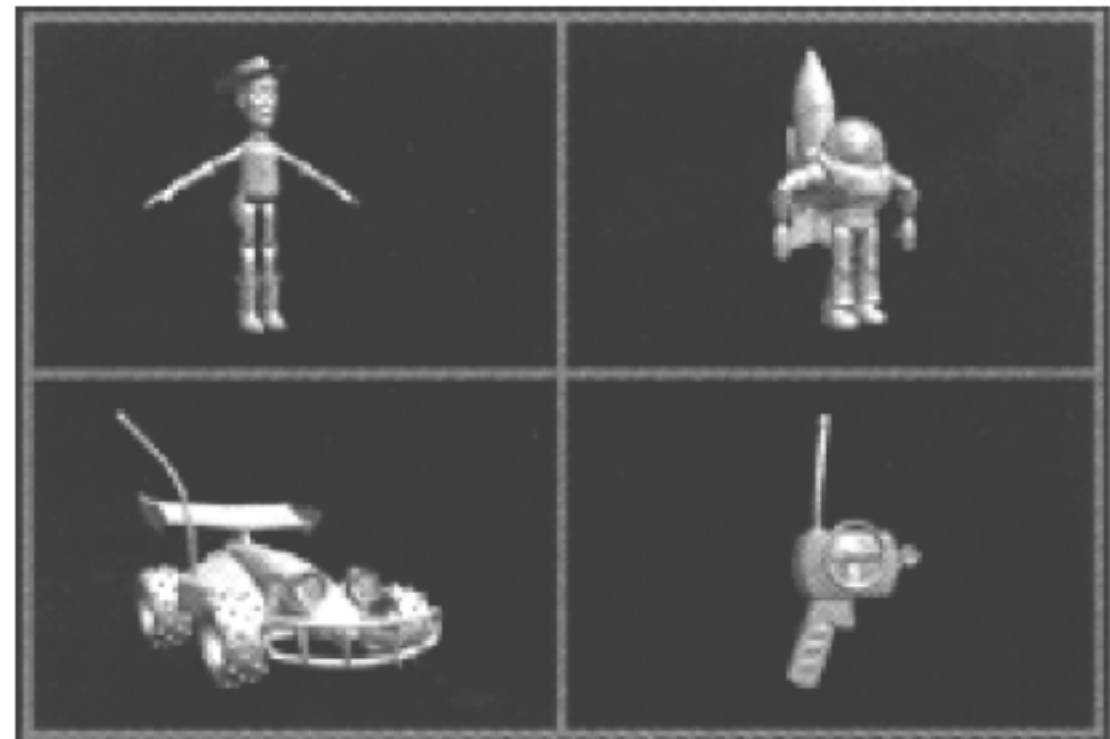
# Animation Production

1. Story Board
2. Conceptual Art
3. **Recording**
4. Modeling
5. Rigging
6. Set Dressing
7. Layout
8. Animation
9. Special Effects
10. Shading
11. Lighting
12. Rendering



# Animation Production

1. Story Board
2. Conceptual Art
3. Recording
4. **Modeling**
5. Rigging
6. Set Dressing
7. Layout
8. Animation
9. Special Effects
10. Shading
11. Lighting
12. Rendering



# Modeling

The creation of a 3D computer-generated asset, be it hard surface (planes, trains, automobiles) or organic (davy jones, dementors, or digital humans).



# Hard Surface Modeling

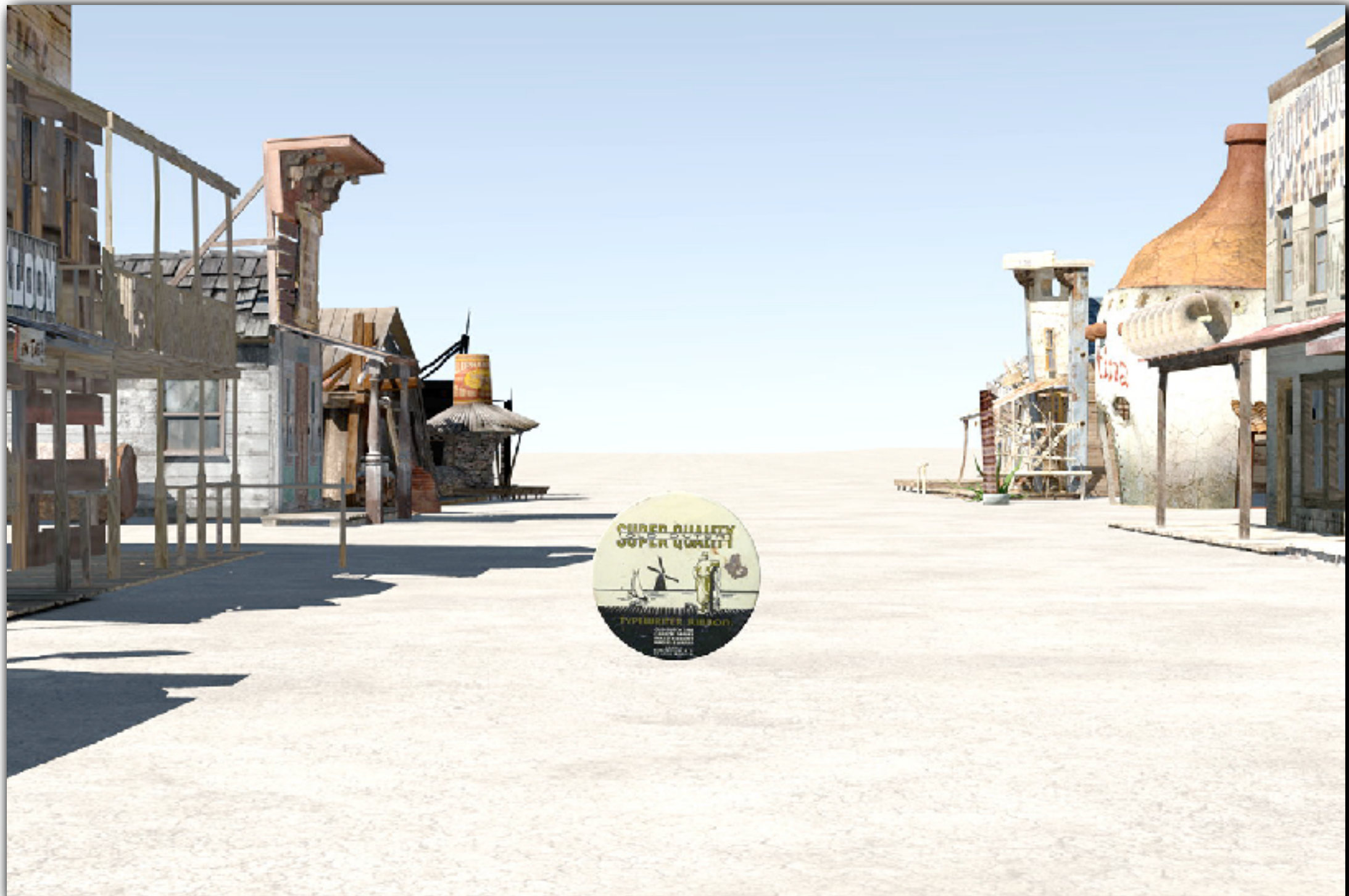
Rango: The town of Dirt...





# Hard Surface Modeling

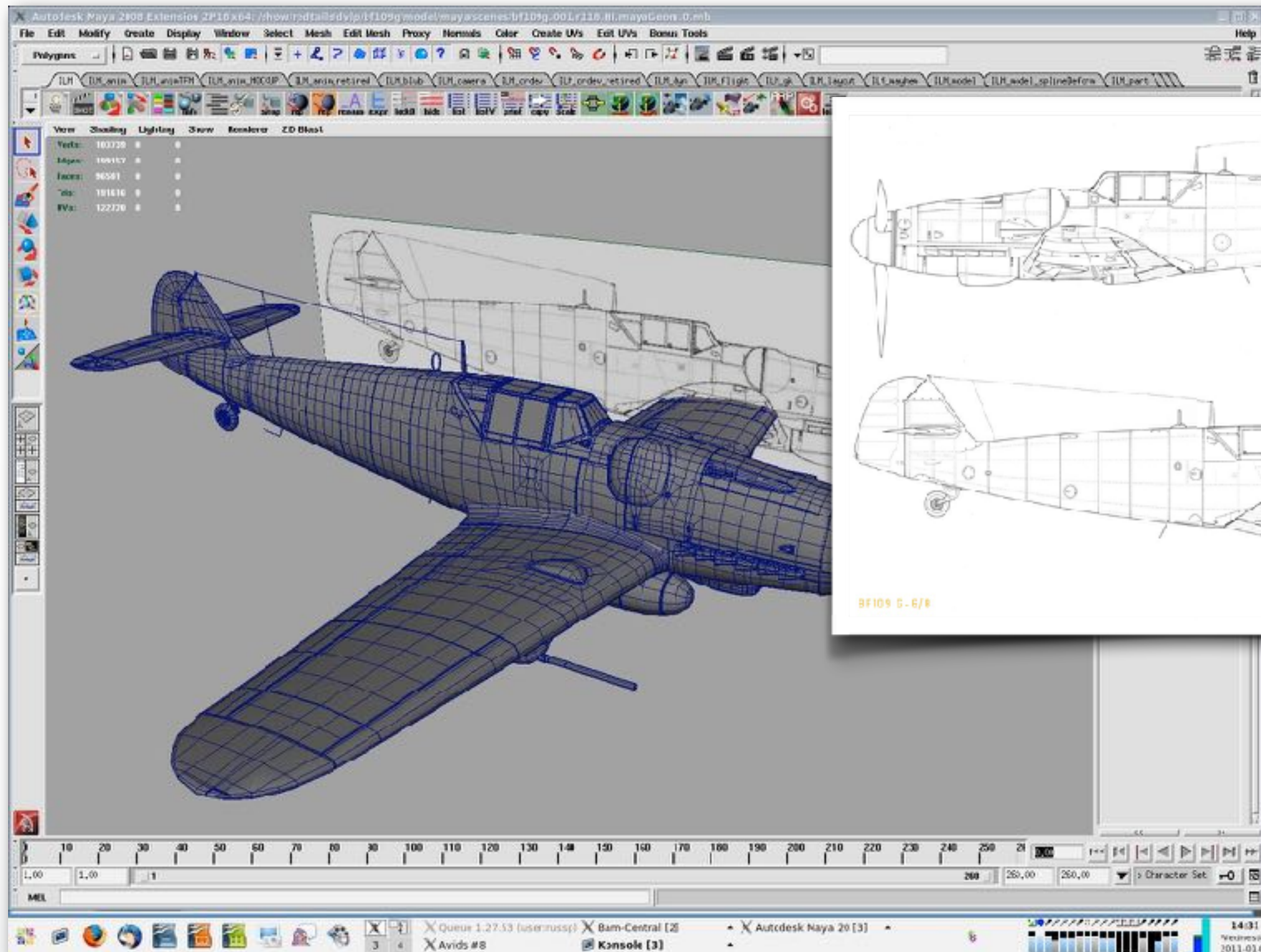
... and all the assets





# Hard Surface Modeling

Modeling in Maya using reference images...



# Hard Surface Modeling

final asset

Y C G M R B

INDUSTRIAL  
LIGHT & MAGIC

*redtails*

Shot: bf109g

CG COMP - Take 85

Date: Sep 08 2010 03:10:57

PTS #: CGRED-06596

artist: davew, td: davew; HDR.bf109g bf109g.td.generic1.v33.7.zshot bf109g.turntable.0.ct; Generic 1  
variation w Gregs latest paint

Frame Range: 1-260





# Creature Modeling

Rango: From Artwork to Maquette to Final Asset

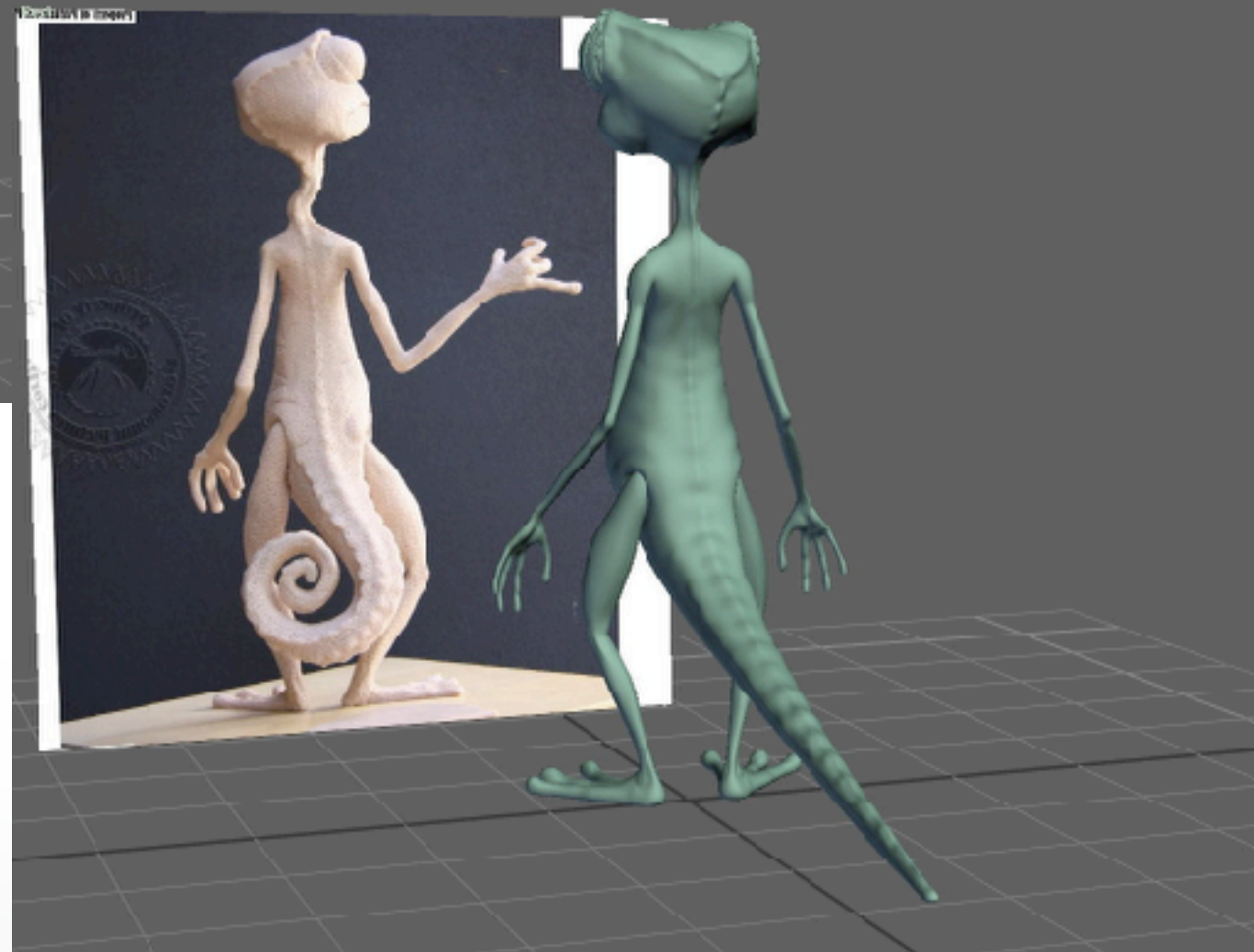




# Creature Modeling

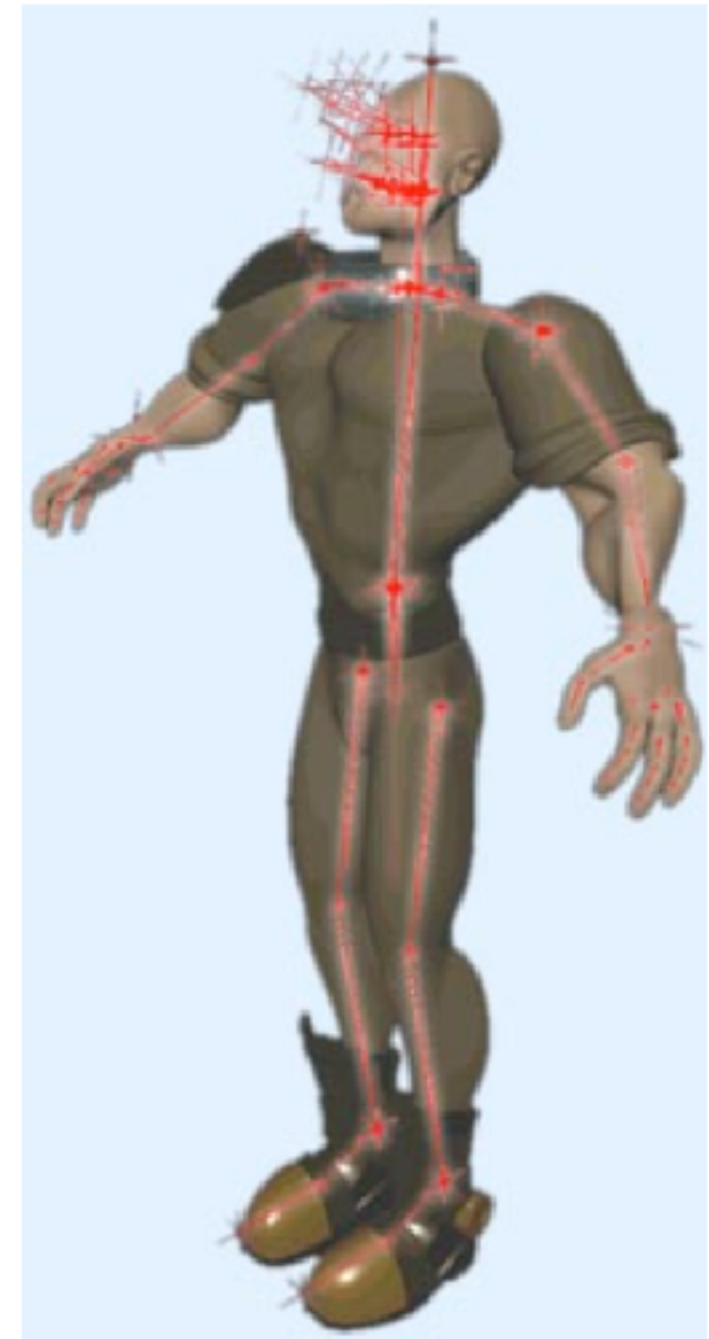


From Rango:  
Modeling Using The Maquette  
(Back Revisions)



# Animation Production

1. Story Board
2. Conceptual Art
3. Recording
4. Modeling
5. **Rigging**
6. Set Dressing
7. Layout
8. Animation
9. Special Effects
10. Shading
11. Lighting
12. Rendering





# Creature Setup

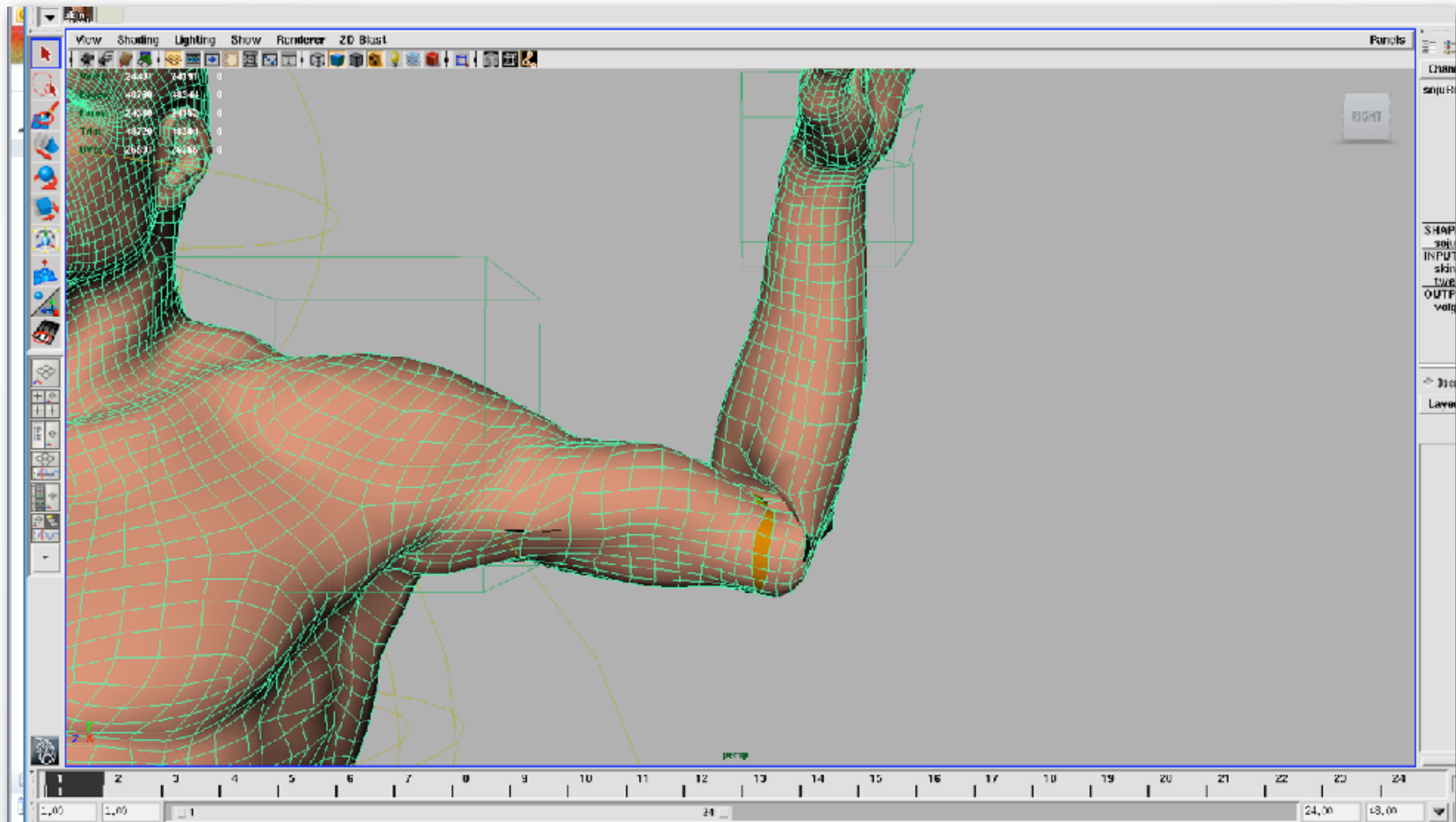
The process of preparing a creature for animation, including creature rigging, skinning, and simulation setup for things such as hair, feathers, flesh, muscles, and, in some cases, tentacles.

# Rigging & Enveloping

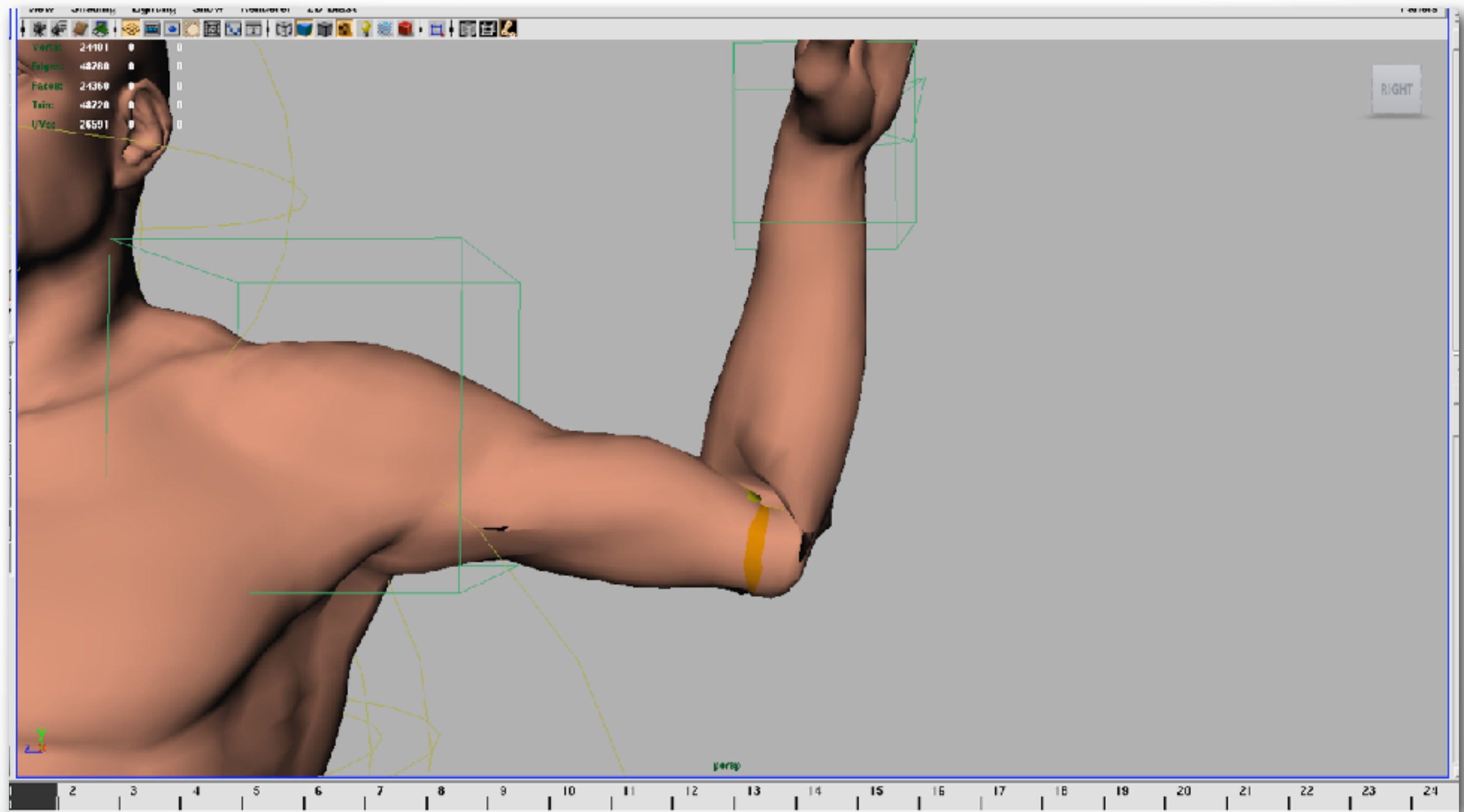


Copyright © 2013  
All rights reserved.  
No part of this  
publication may be  
reproduced or  
transmitted in any  
form or by any  
means, electronic  
or mechanical, including  
photocopying, recording,  
or by any information  
storage and retrieval  
system, without  
permission in writing  
from the publisher.

# Rigging & Enveloping



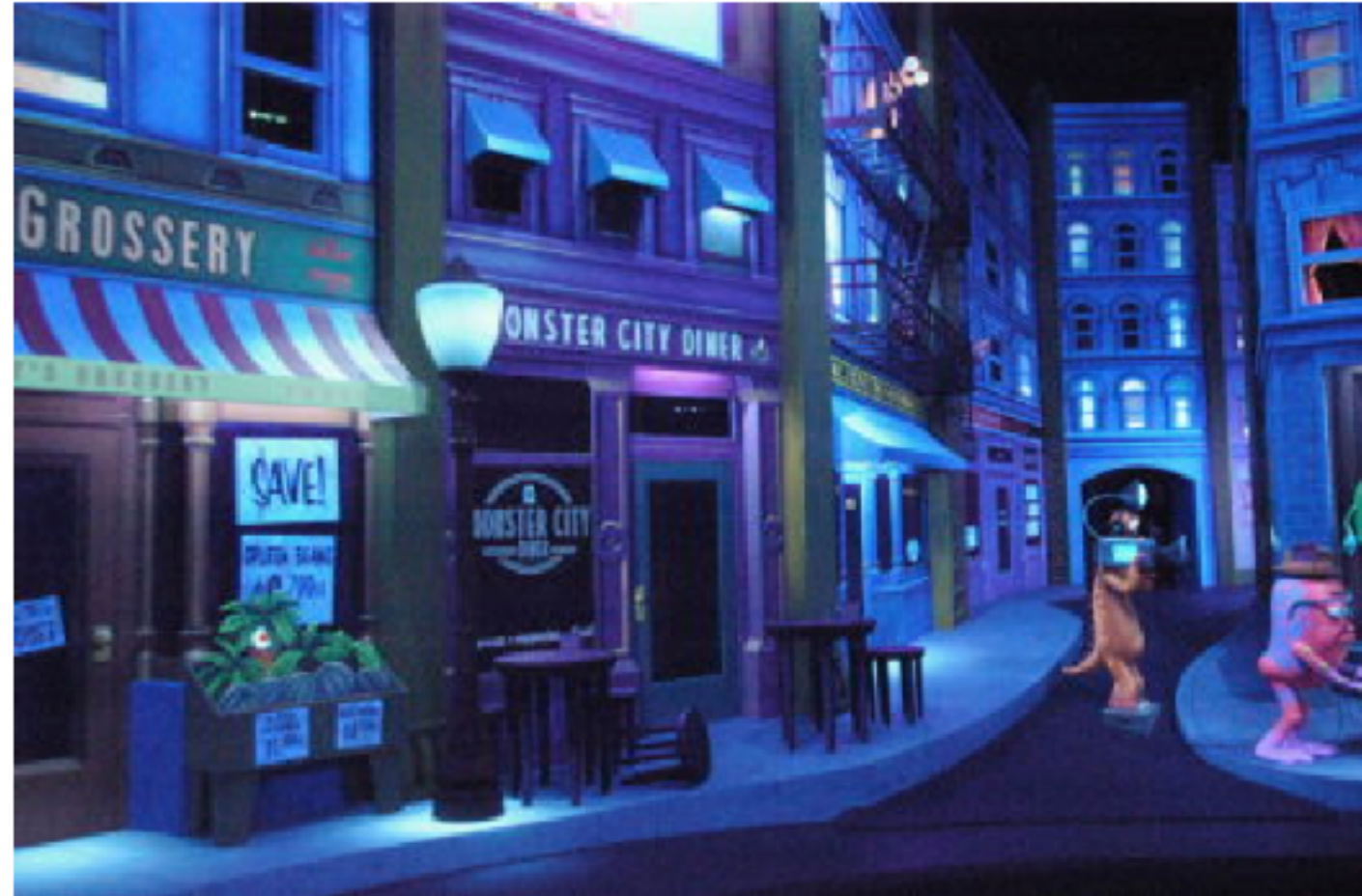
# Rigging & Enveloping





# Animation Production

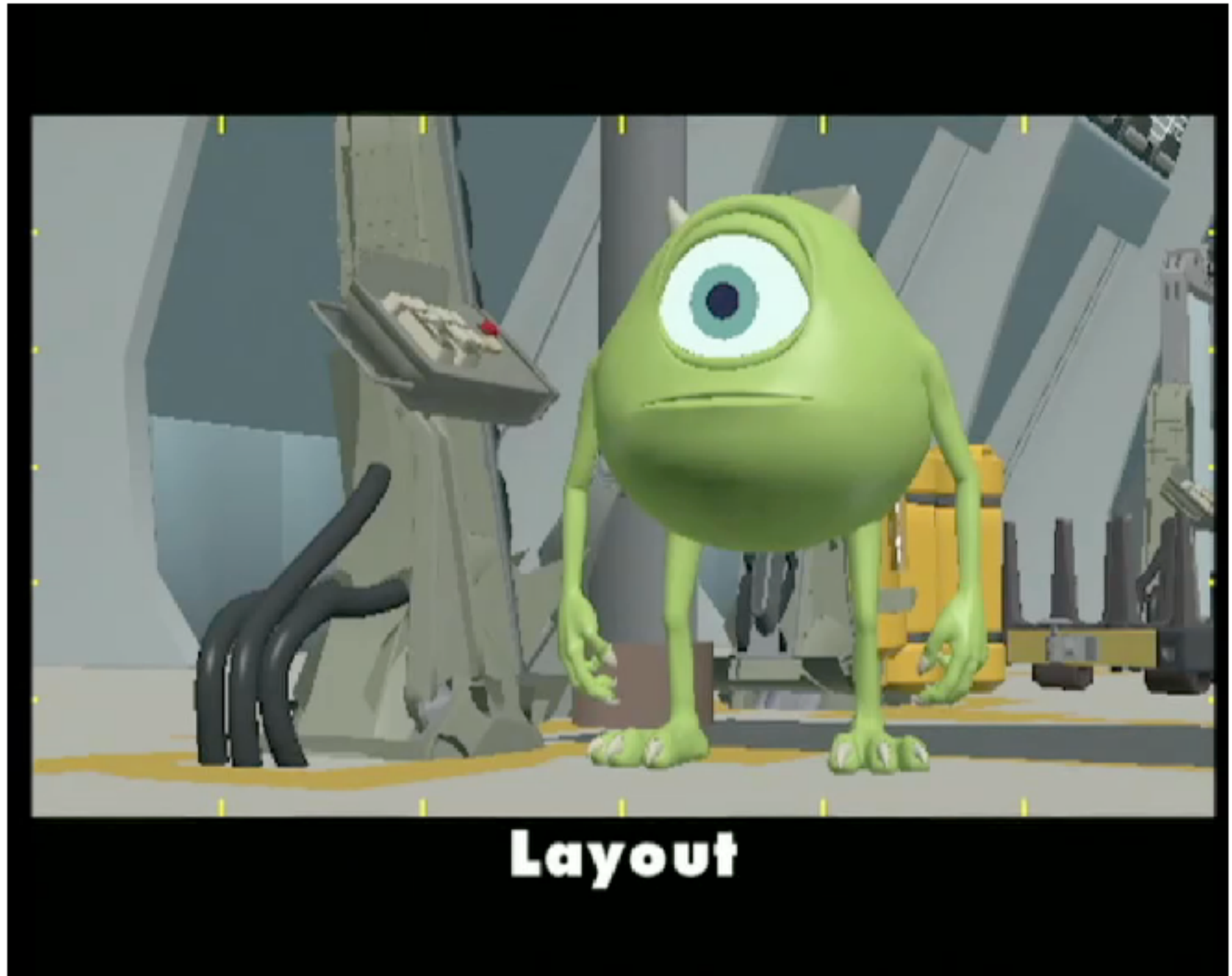
1. Story Board
2. Conceptual Art
3. Recording
4. Modeling
5. Rigging
6. **Set Dressing**
7. Layout
8. Animation
9. Special Effects
10. Shading
11. Lighting
12. Rendering





# Animation Production

1. Story Board
2. Conceptual Art
3. Recording
4. Modeling
5. Rigging
6. Set Dressing
7. **Layout**
8. Animation
9. Special Effects
10. Shading
11. Lighting
12. Rendering



# Mathmove & Layout

**Matchmove:** The process of replicating the real set, camera, and camera movement in a CG world so that 3D assets can be integrated with the live action plate.

**Layout:** The process of integrating camera matchmoves and “new” CG camera moves to create a framework for a sequence, including manipulating 2D and 3D elements and environment.



# Mathmove & Layout



Matching camera move from original background plate





# Mathmove & Layout

... allows adding cg elements to the shot

083\_SH\_230\_v11895

ILM

12-08-07





# Mathmove & Layout

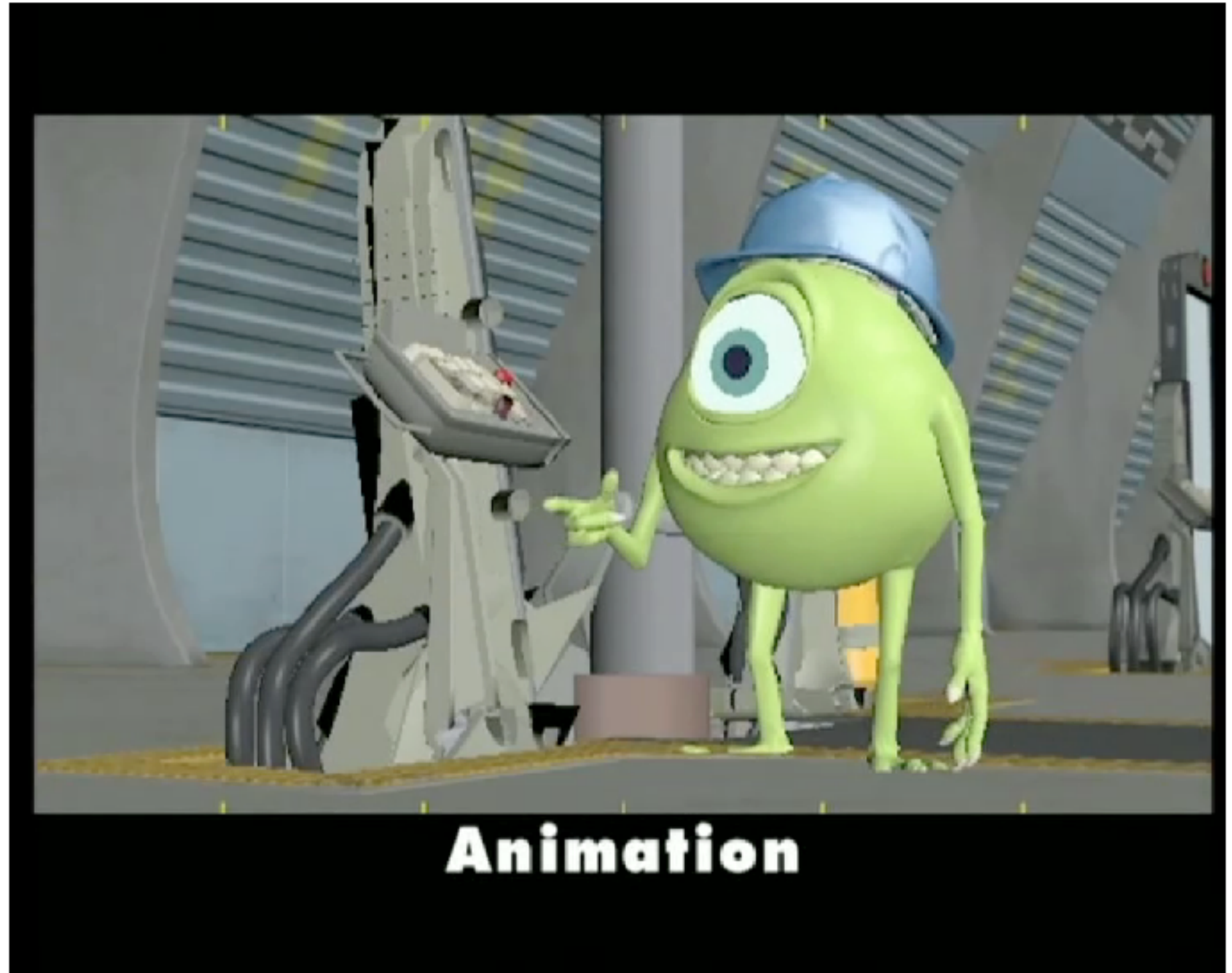


Using placeholder geometry...



# Animation Production

1. Story Board
2. Conceptual Art
3. Recording
4. Modeling
5. Rigging
6. Set Dressing
7. Layout
8. **Animation**
9. Special Effects
10. Shading
11. Lighting
12. Rendering



# Animation

Rango: Character Walking Tests





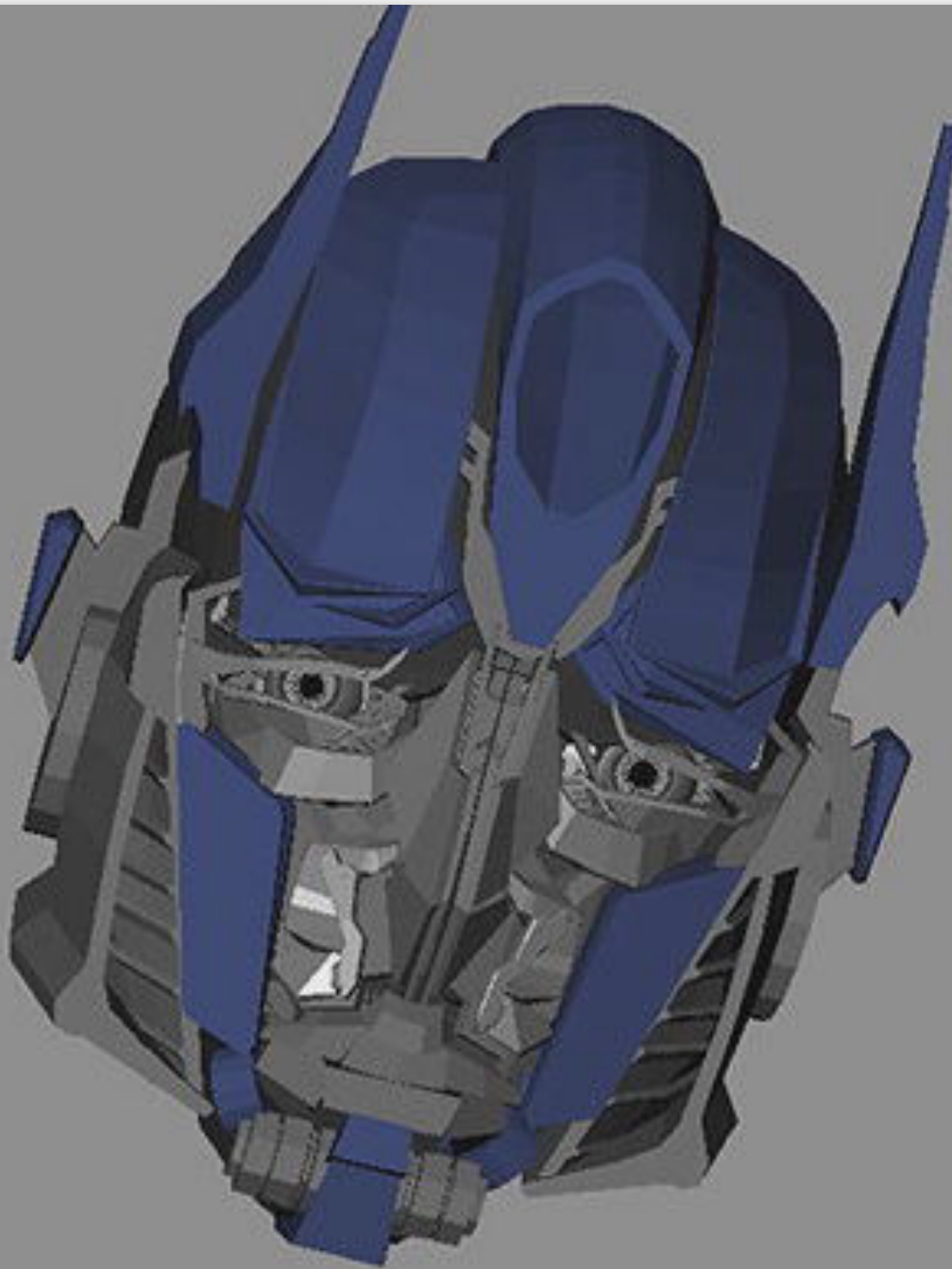
# Animation

## Transformers: Facial Animation Tests



# Animation

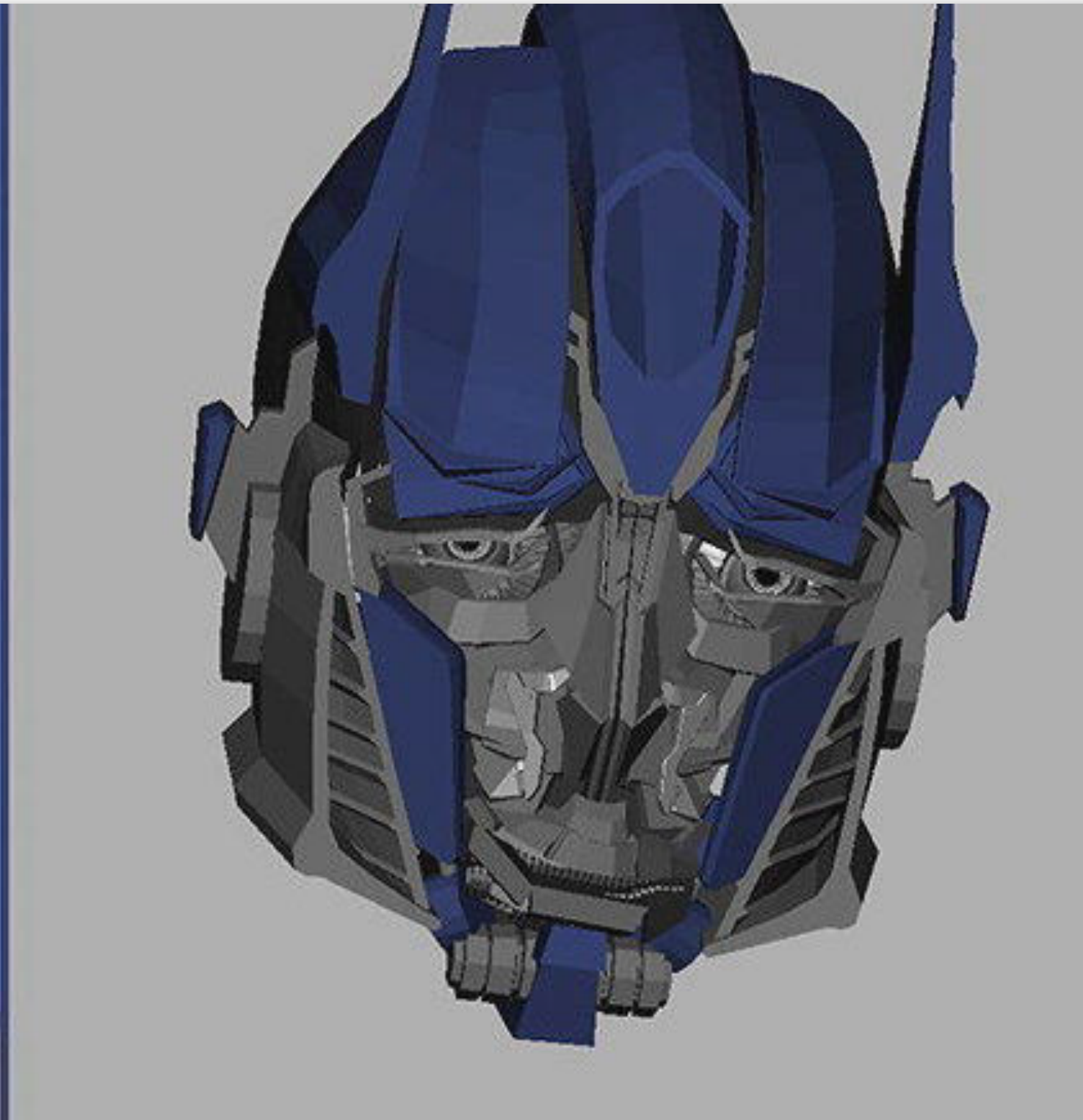
## Transformers: Facial Animation Tests





# Animation

## Transformers: Facial Animation Tests





# Animation Production

1. Story Board
2. Conceptual Art
3. Recording
4. Modeling
5. Rigging
6. Set Dressing
7. Layout
8. Animation
9. **Special Effects**
10. Shading
11. Lighting
12. Rendering



# Creature Sim

Rango: Cloth Examples

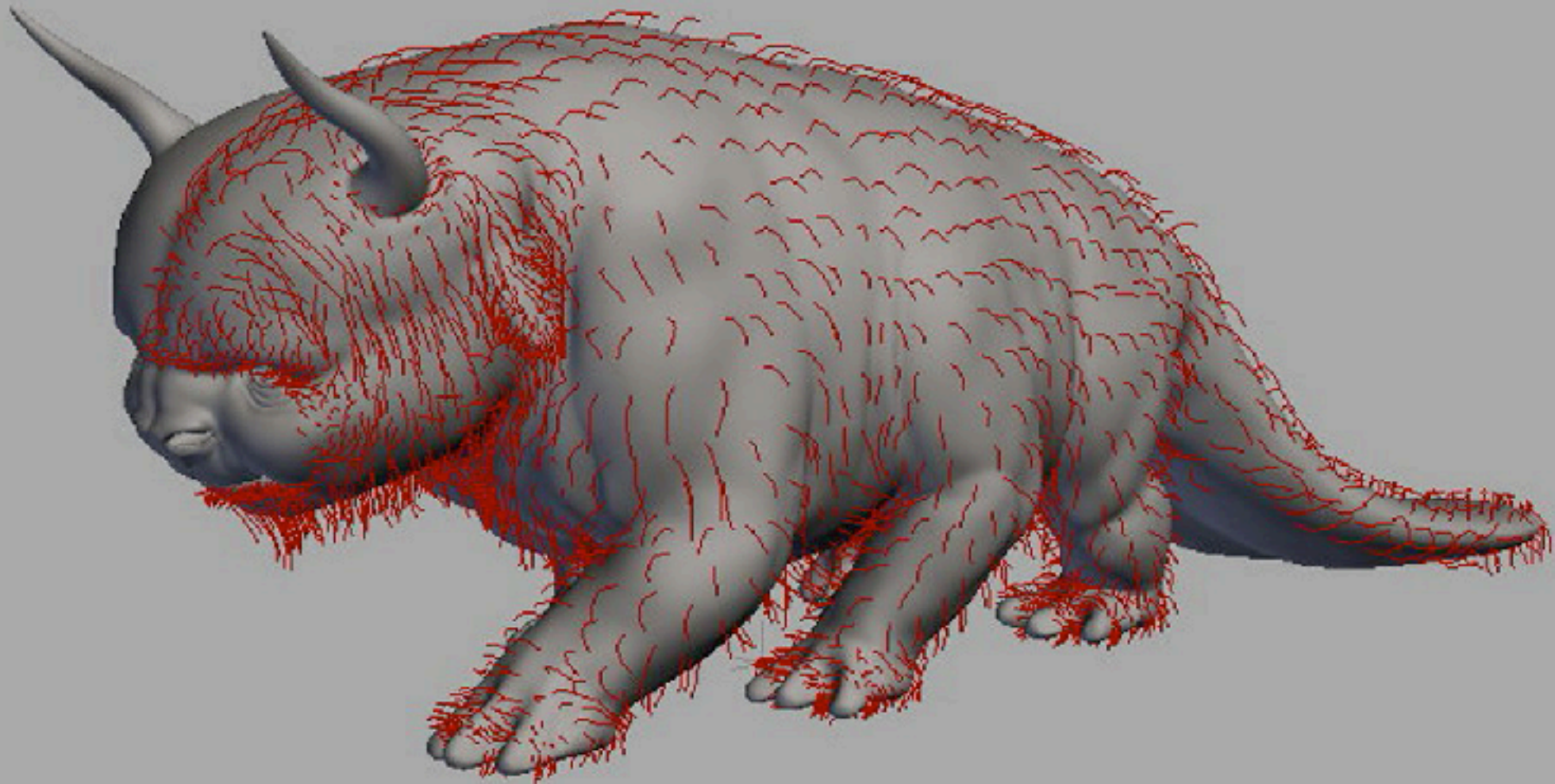
Rest





# Creature Sim

The Last Airbender: Hair Examples





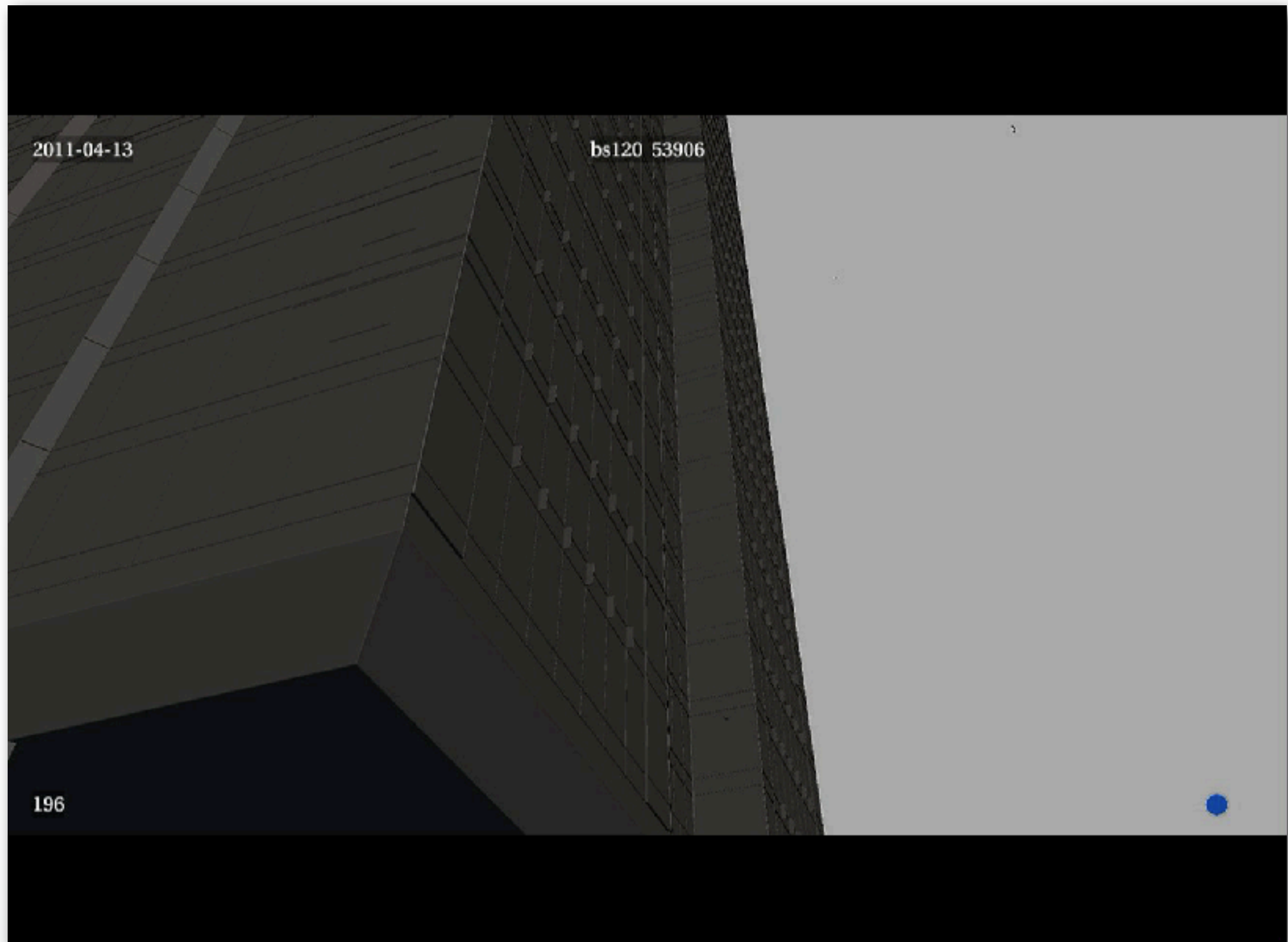
# Creature Sim

Flesh



# Creature Sim

... and also rigids



# Creature Sim

when things go wrong ;-)





# FX Sim

The process of applying forces (such as mass, velocity, and gravity) to particles and rigid bodies to animate items such as dust, wind, rain, fire, and smoke.

# FX Sim

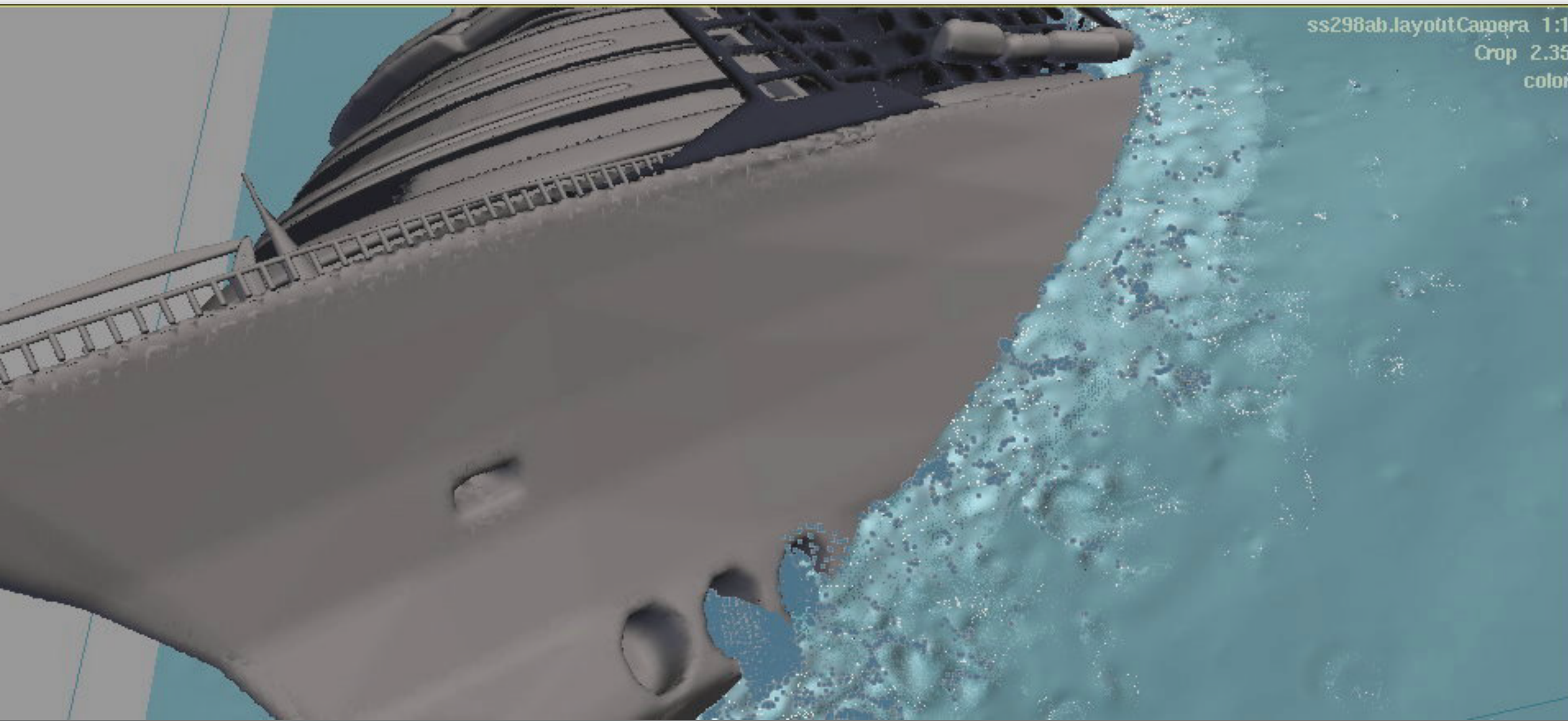
## Harry Potter 6: Fire Simulations





# FX Sim

## Poseidon: Water Simulations





# FX Sim

## Poseidon: Water Simulations

ss298ab FNPOS-06928

1001



Apr 12 2006 - FINAL



# FX Sim

## Poseidon: Water Simulations



# Animation Production

1. Story Board
2. Conceptual Art
3. Recording
4. Modeling
5. Rigging
6. Set Dressing
7. Layout
8. Animation
9. Special Effects
10. **Shading**
11. Lighting
12. Rendering





# Animation Production

1. Story Board
2. Conceptual Art
3. Recording
4. Modeling
5. Rigging
6. Set Dressing
7. Layout
8. Animation
9. Special Effects
10. Shading
11. **Lighting**
12. Rendering



# Lighting & Rendering

**Lighting:** The process of creating lights, assigning them attributes (color, intensity, direction, etc) and applying them in a scene to interact with CG assets.

**Rendering:** Calculating the effect of light on objects in a CG scene from the point of view of the camera, and creating a rendered element.



# Lighting & Rendering

Final shot is composed of several render passes



# Lighting & Rendering

Render Pass: Ironman & Warmachines





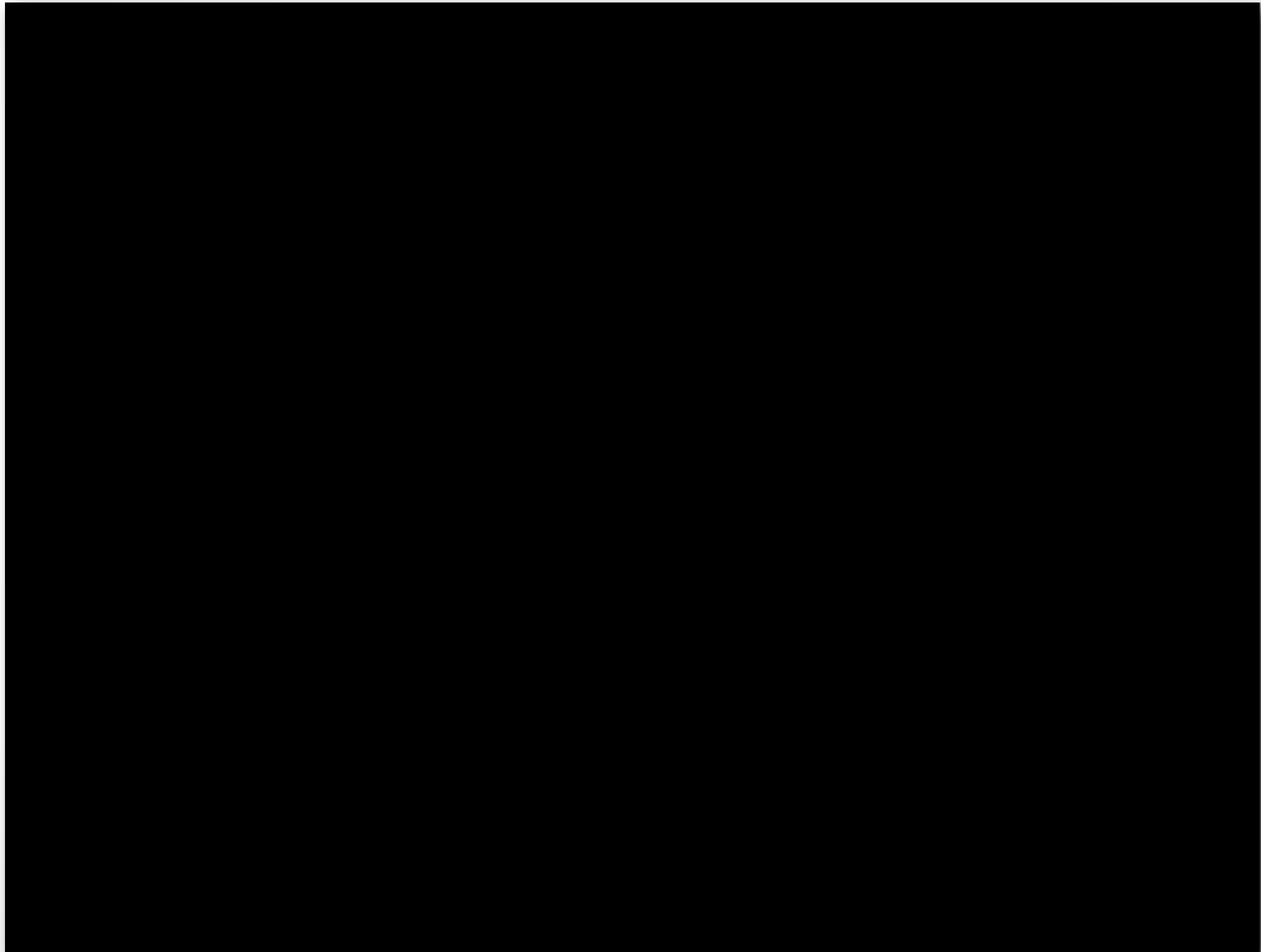
# Lighting & Rendering

Render Pass of Army Drones



# Lighting & Rendering

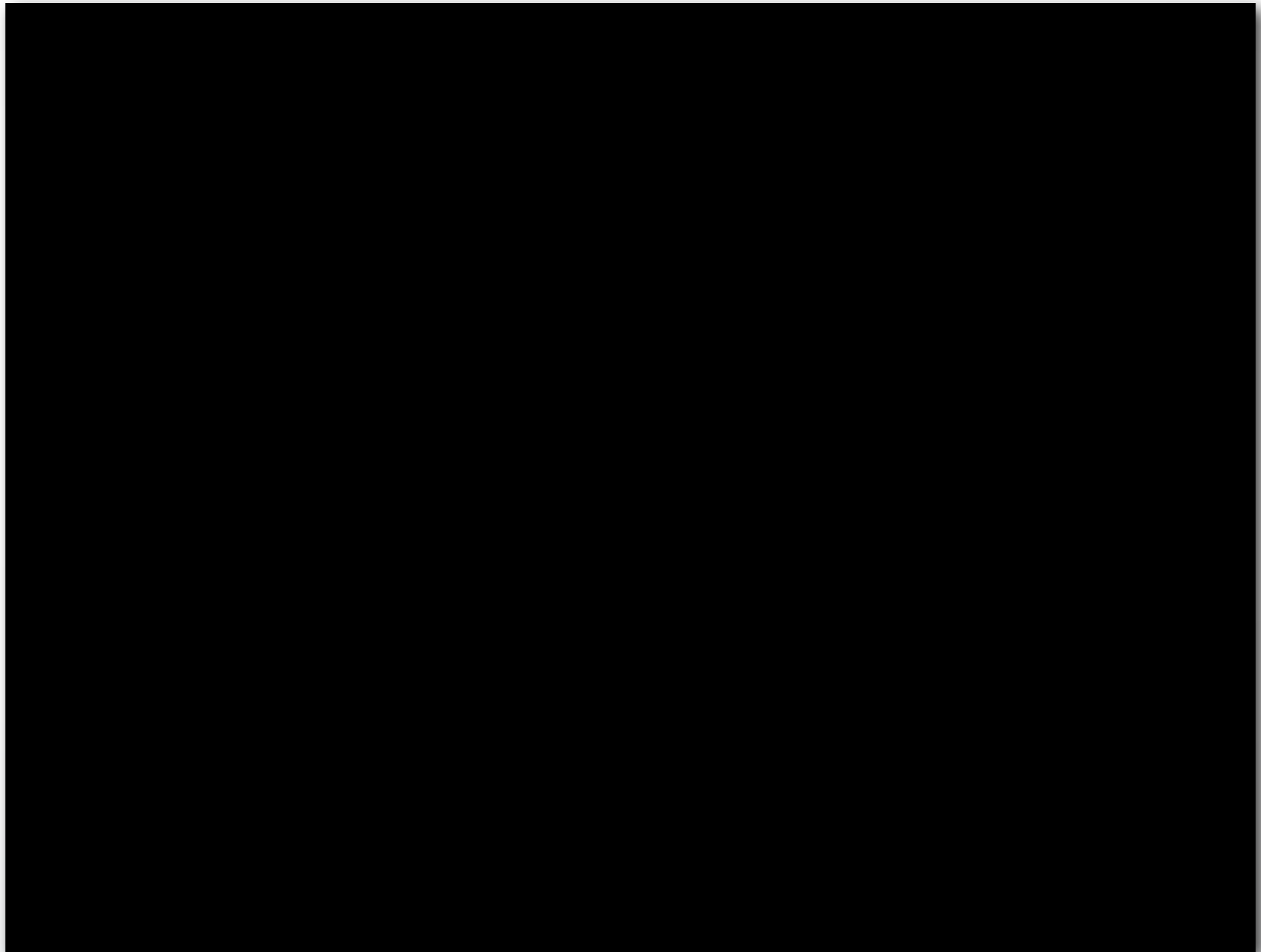
Render Pass of Marine Drones





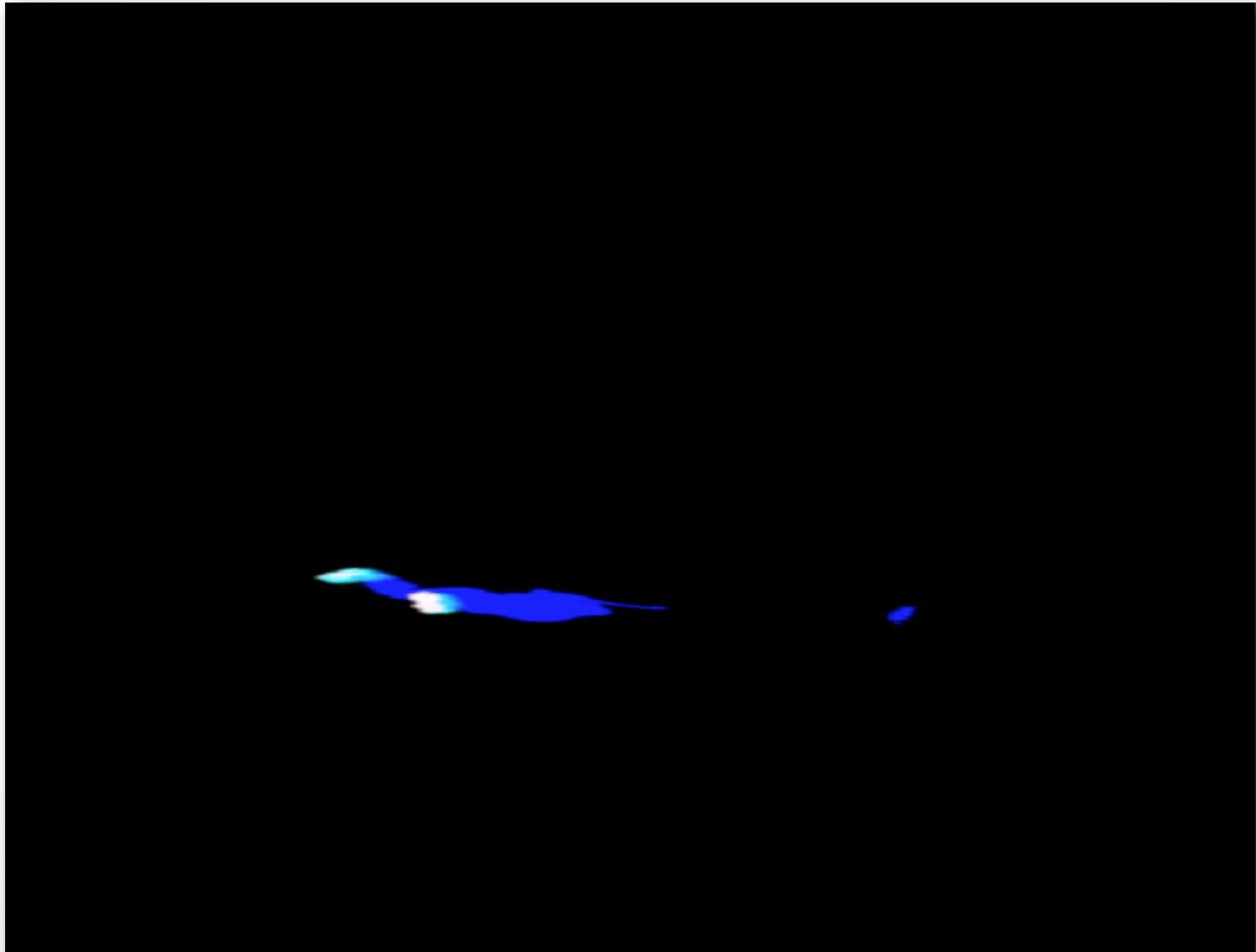
# Lighting & Rendering

Render Pass of Navy Drones



# Lighting & Rendering

## Render Pass of Shadows





# Lighting & Rendering

Render Pass of Cherry Blossom Simulation



# Lighting & Rendering

Can you spot the passes in the final shot...



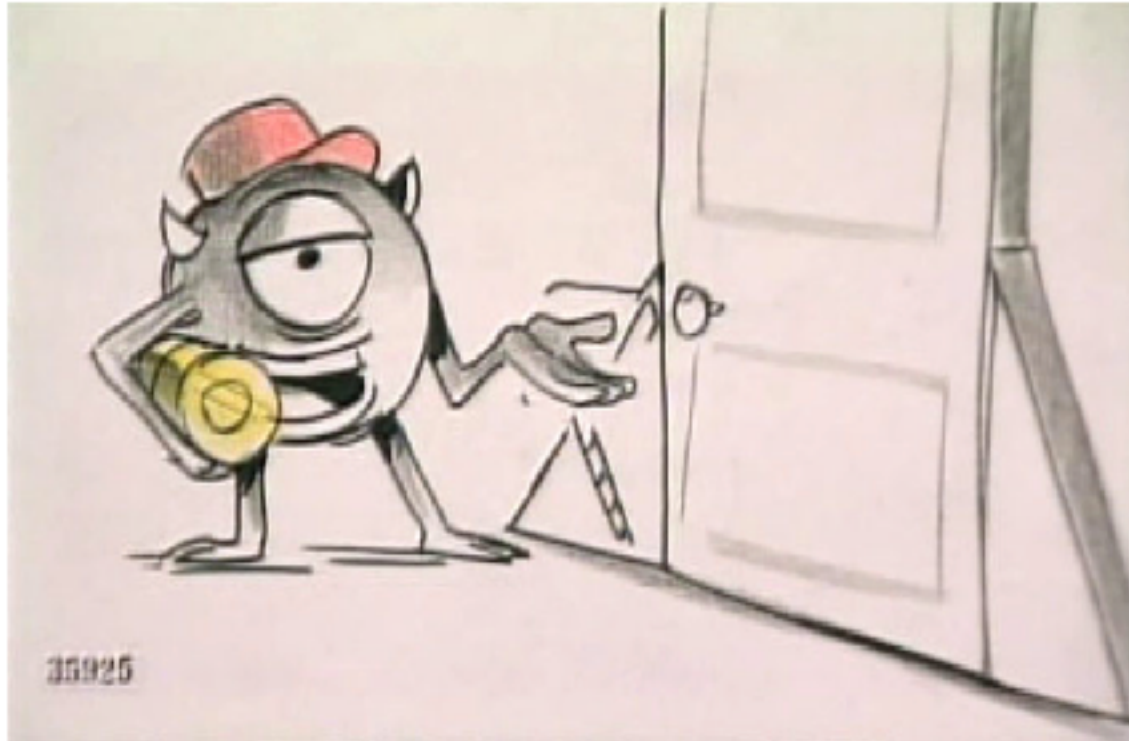


# Animation Production

1. Story Board
2. Conceptual Art
3. Recording
4. Modeling
5. Rigging
6. Set Dressing
7. Layout
8. Animation
9. Special Effects
10. Shading
11. Lighting
12. **Rendering**



# Animation Production



Story



Layout



Animation



Final Rendering



# Overview

## Animation Production

### Rigging

- Procedural
- Skeletal
- Anatomical

### Posing

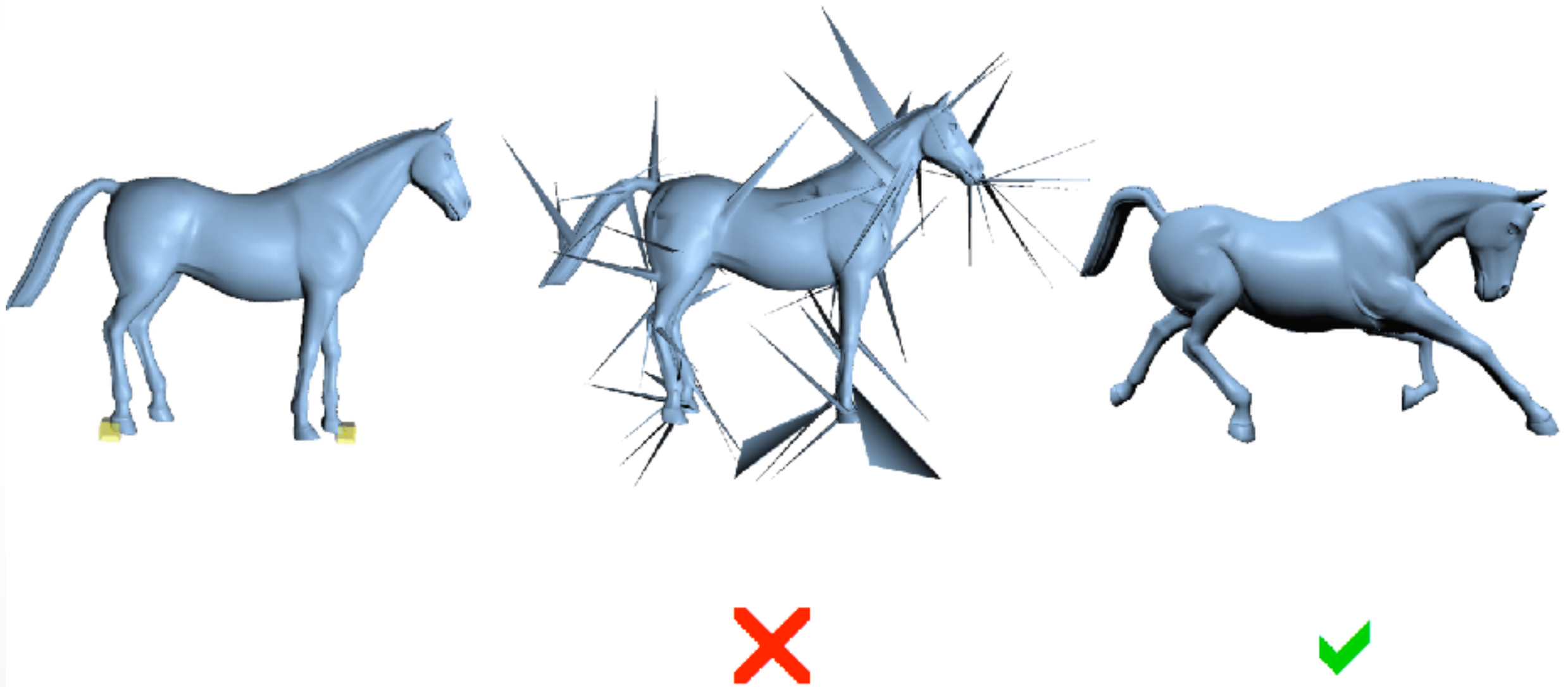
- Forward Kinematics
- Inverse Kinematics
- Advanced Methods (Style-Based IK + MeshIK)

### Animation

- Keyframe Animation
- Motion Capture
- Physics-Based Character Animation

# Rigging

- Parameterize meaningful deformations





# Rigging

- Augment character with controls to easily change its pose, create facial expressions, bulge muscles, etc.
- Rigging is like the strings on a marionette.
- Capture space of meaningful deformations.
- Varies from character to character.

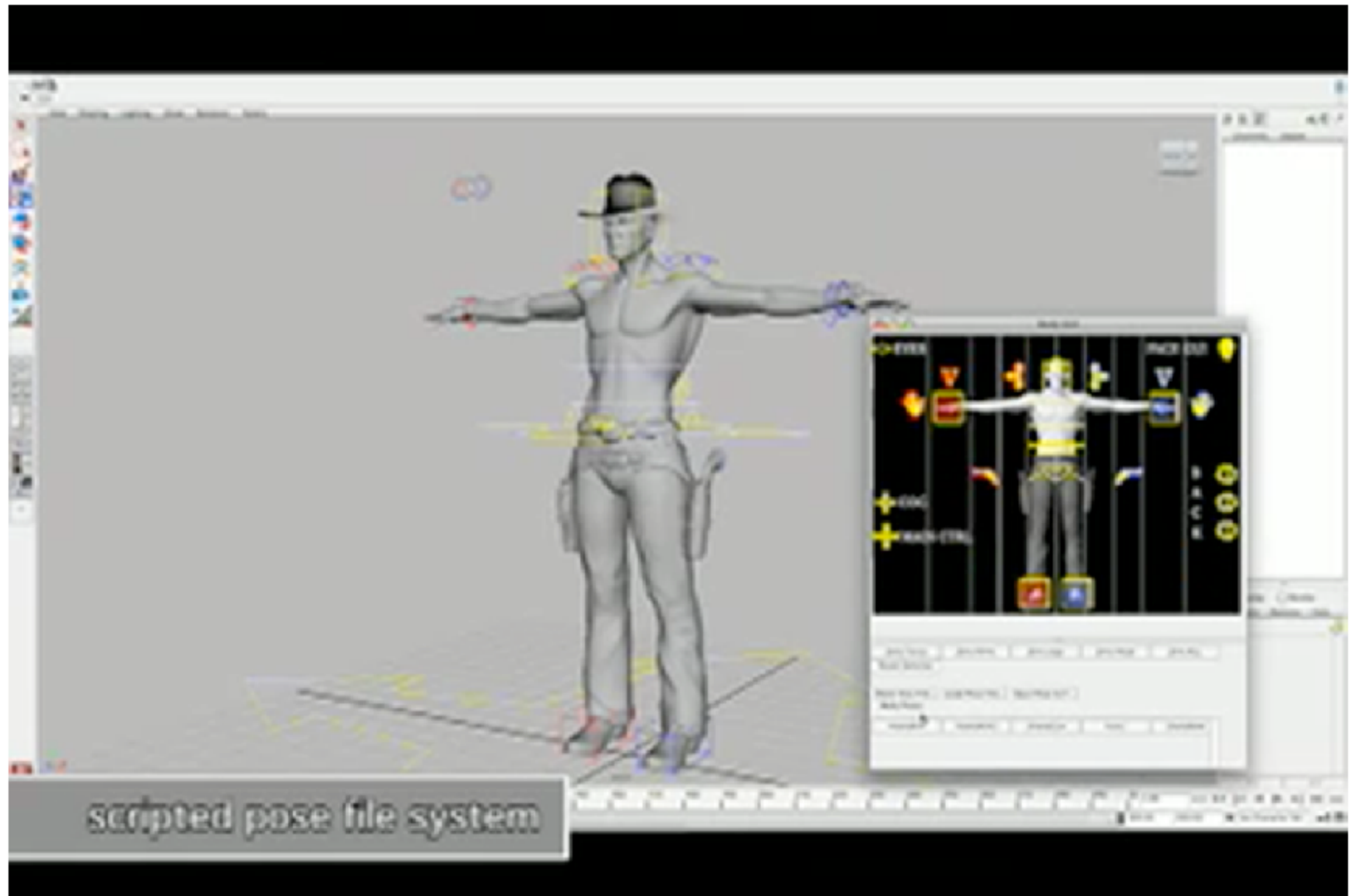


# Rigging

- Extremely important:
  - Determines final shape of the character
  - Quality of rigging deformations has large influence on quality of animation itself
  - Must encode every deformation animator needs to tell the story
- Expensive:
  - Manual effort
  - Both artistic and technical training

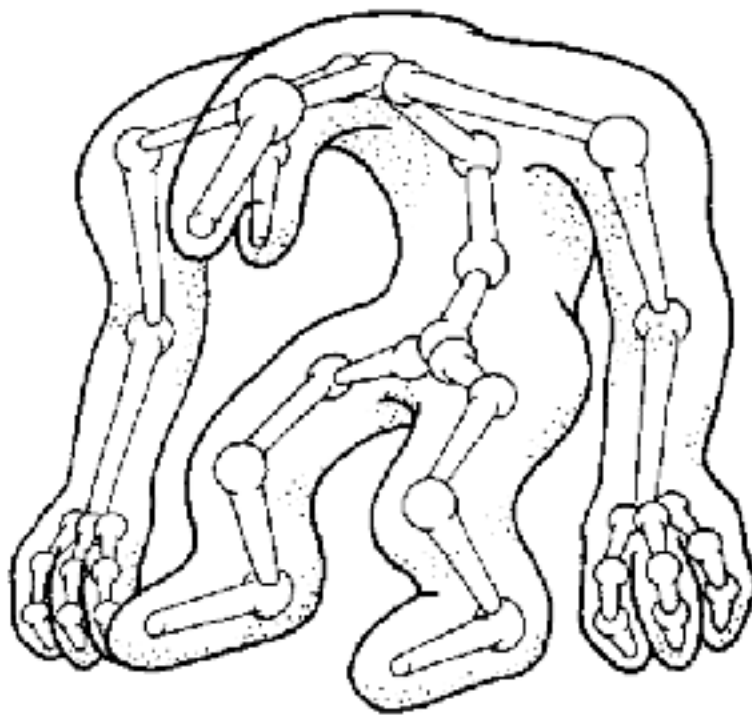
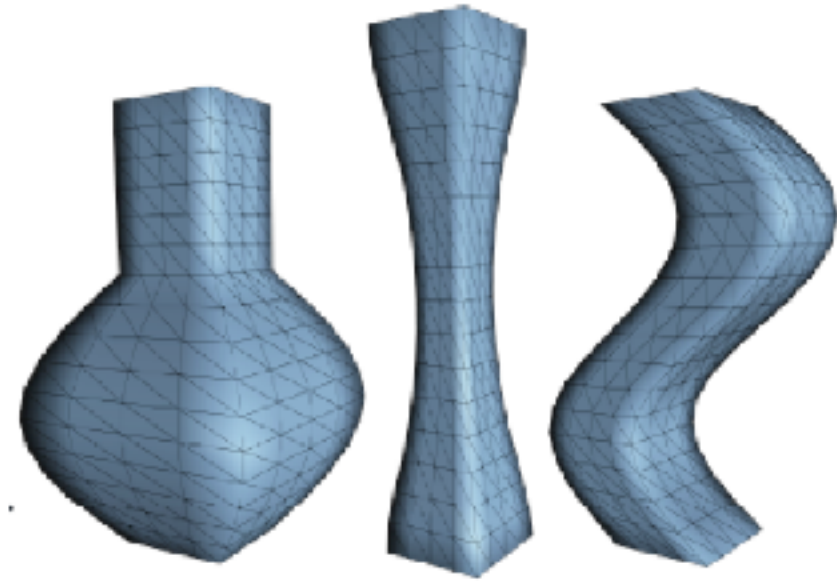


# Rigging



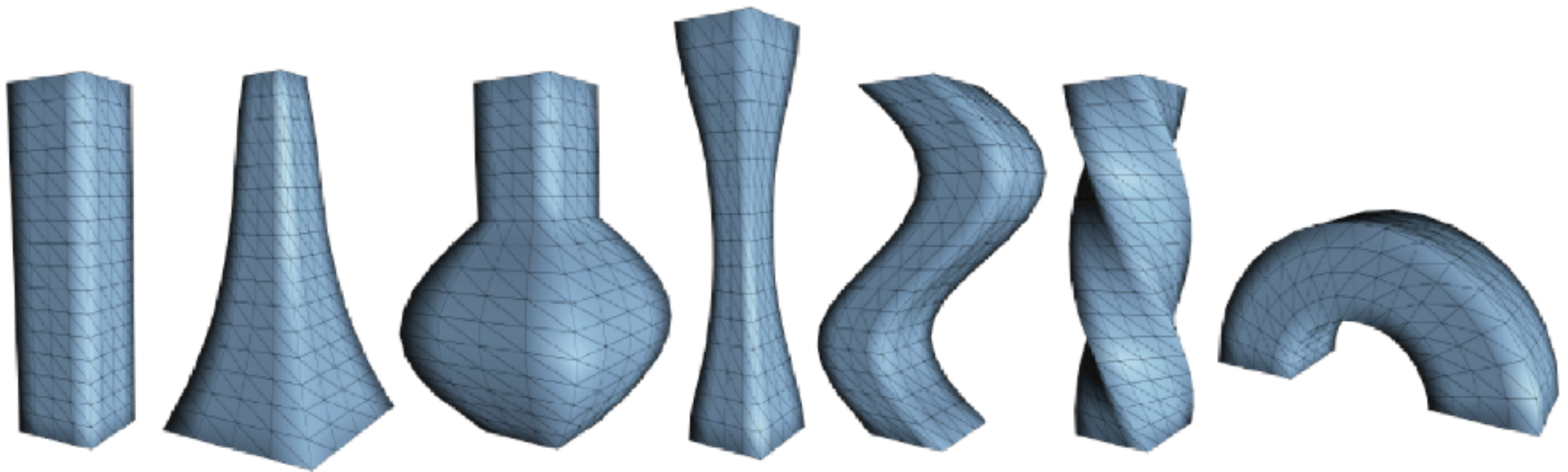
# Types of Rigging

- Procedural Rigging
- Skeletal Rigging
- Anatomical Rigging



# Non-Linear Deformation

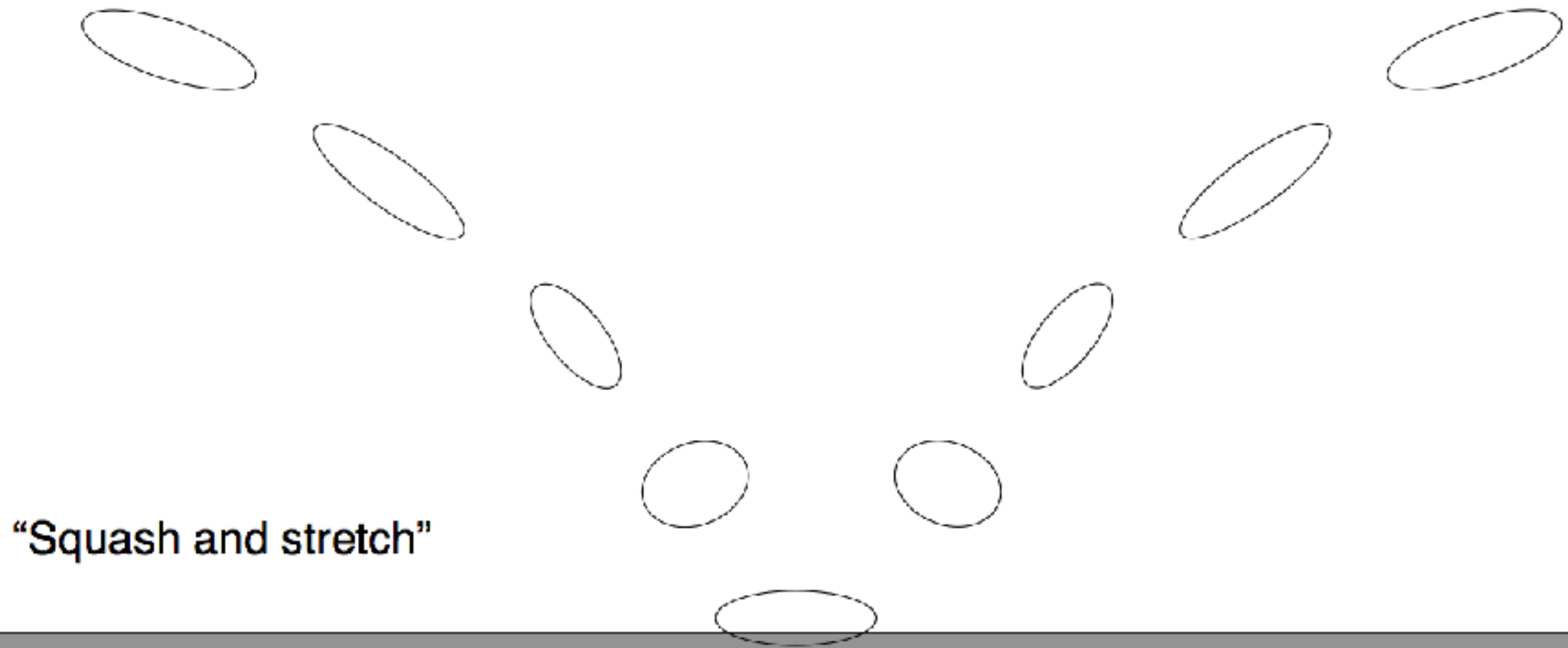
- Barr's "global and local deformations."
- Non-linear deformations for bends, twists, tapering, bulges, etc.



Al Barr. Global and Local Deformations of Solid Primitives. SIGGRAPH 1984.

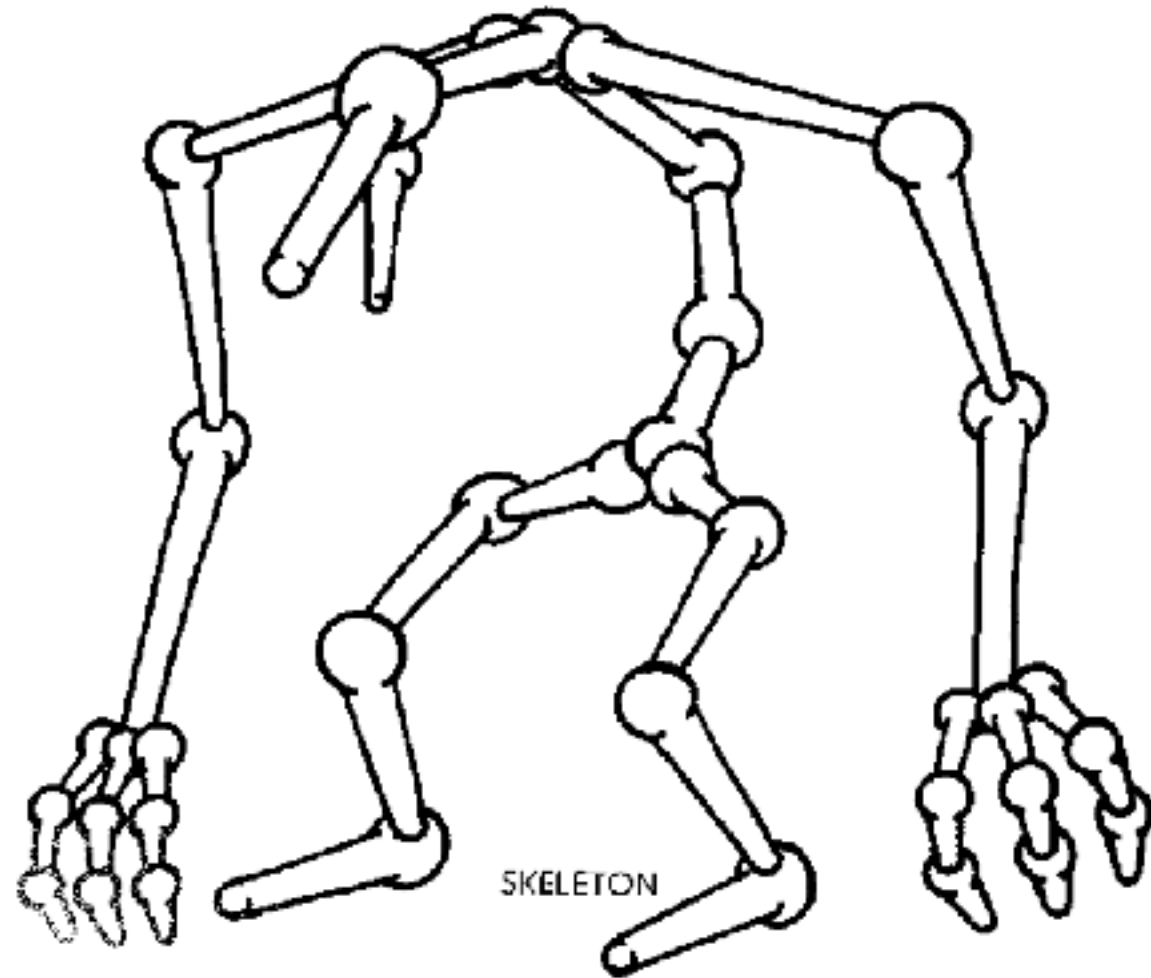


# Non-Linear Deformation



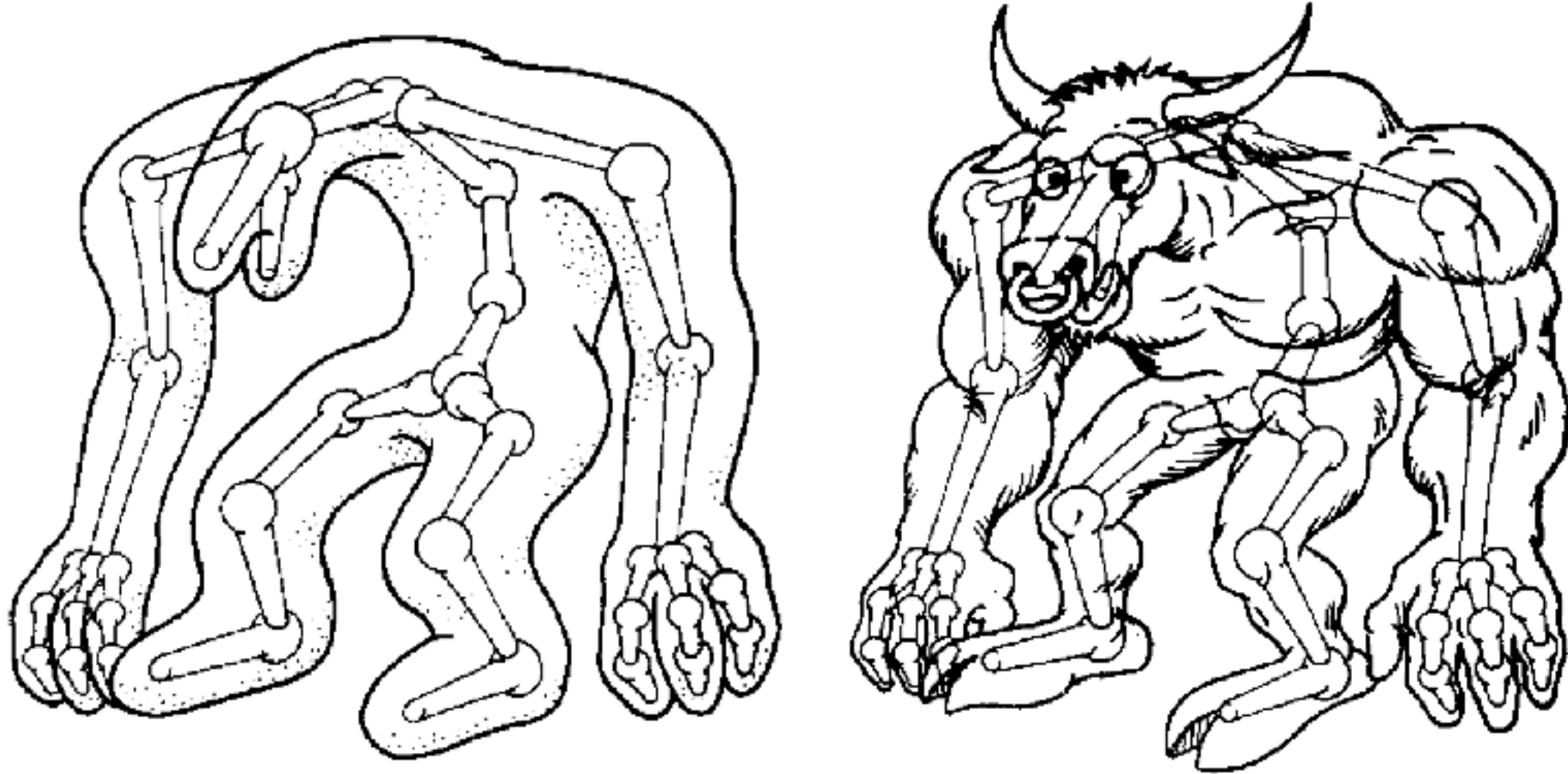
# Skeletal Rigging

- Parameterize character deformation with a skeleton.
- Approximate actual skeleton of the character.



# Skeletal Rigging

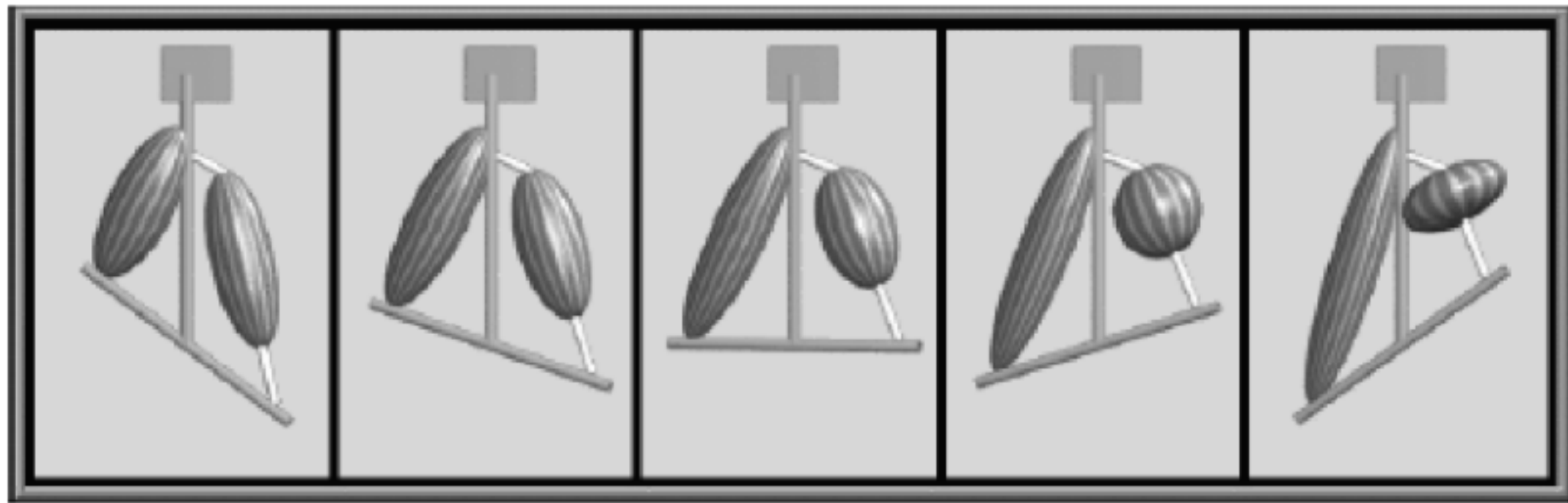
- Then add skin on top.





# Anatomical Models

- Muscles are attached to bones, sometimes with tendons as well
- The muscles contract in a volume preserving way, thus getting wider as they get shorter

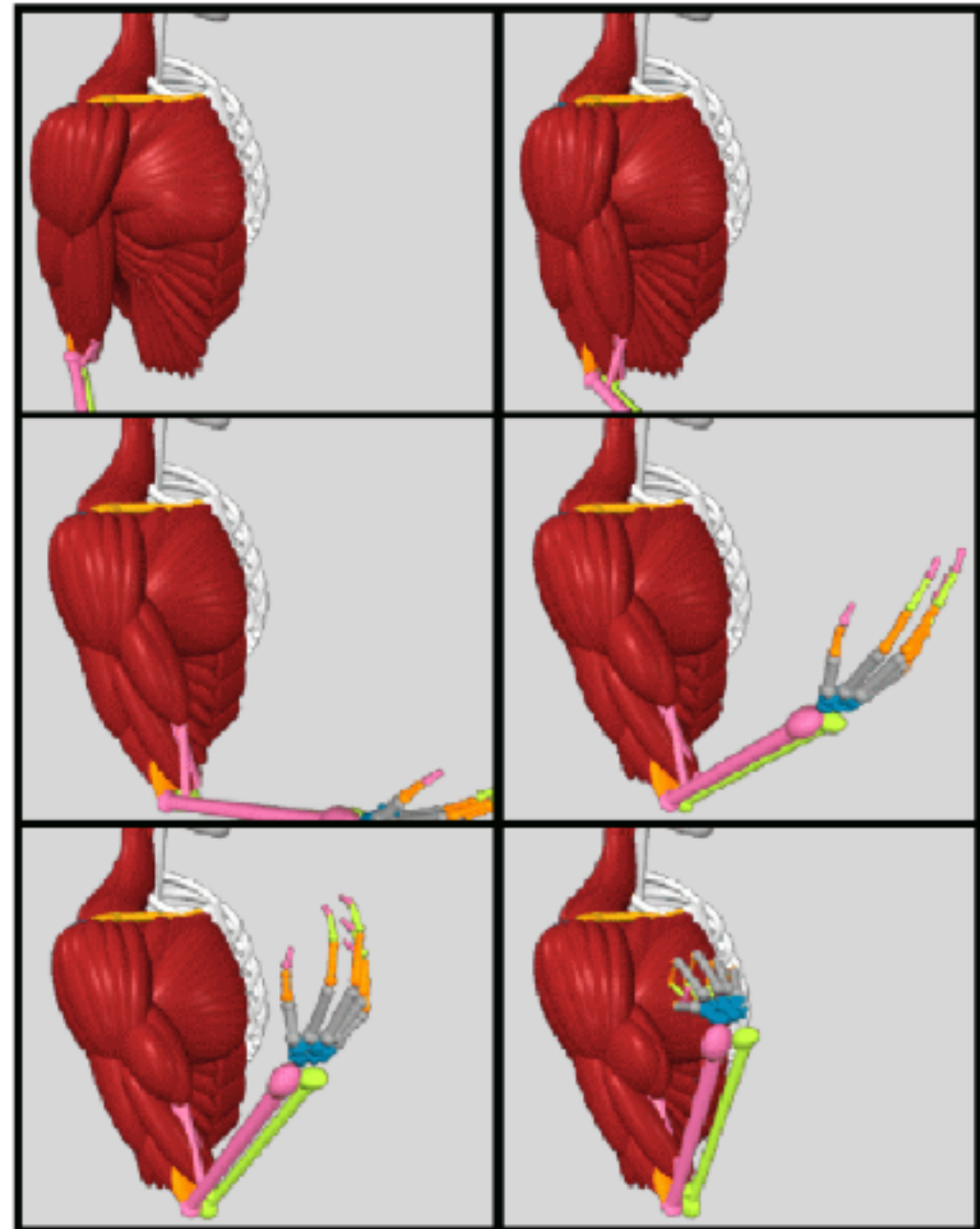


# Anatomical Models

Complex musculature built up from lots of simple primitives.

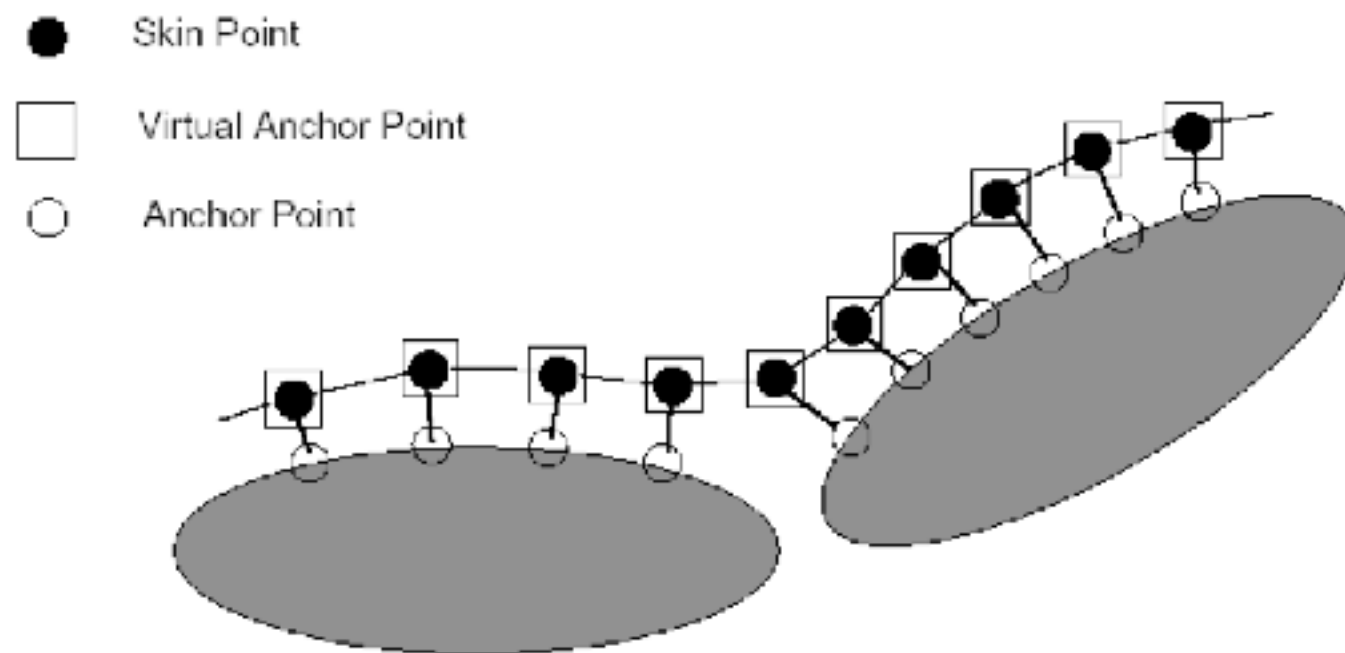


Anatomy-Based Modeling of the Human Musculature. Scheepers et al.  
SIGGRAPH 1997.



# Anatomical Models

- Skin can be attached to the muscles with springs/dampers and physically simulated with collisions against bone & muscle

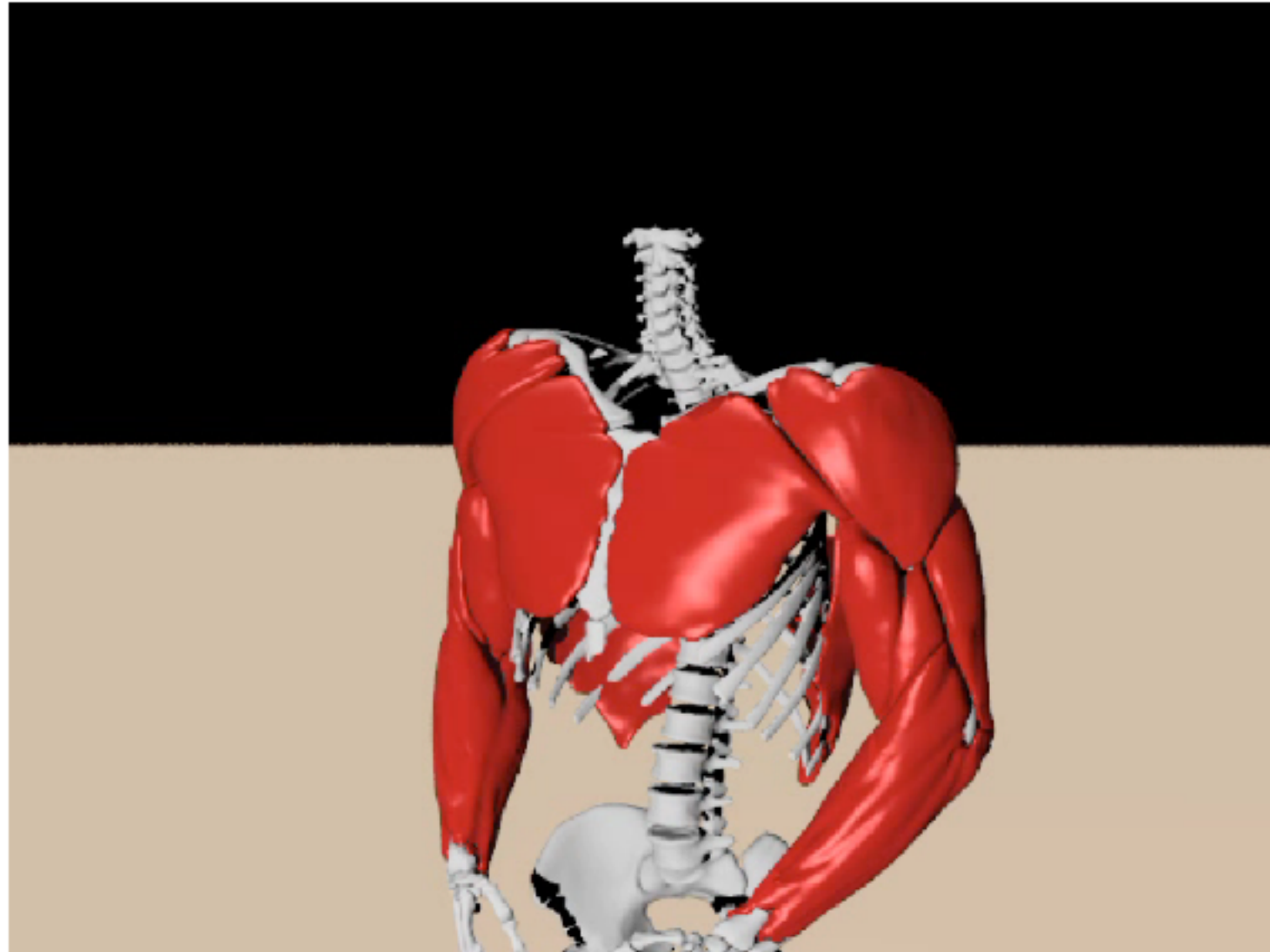


Anatomically based modeling, Wilhelms  
& Van Gelder, 1997





# Anatomical Models



J. Teran, E. Sifakis, S. Blemker, V. Ng Thow Hing, C. Lau and R. Fedkiw, Creating and simulating skeletal muscle from the Visible Human Data Set, IEEE Transactions on Visualization and Computer Graphics, 11, 2005

# Overview

## Animation Production

### Rigging

- Procedural
- Skeletal
- Anatomical

### Posing

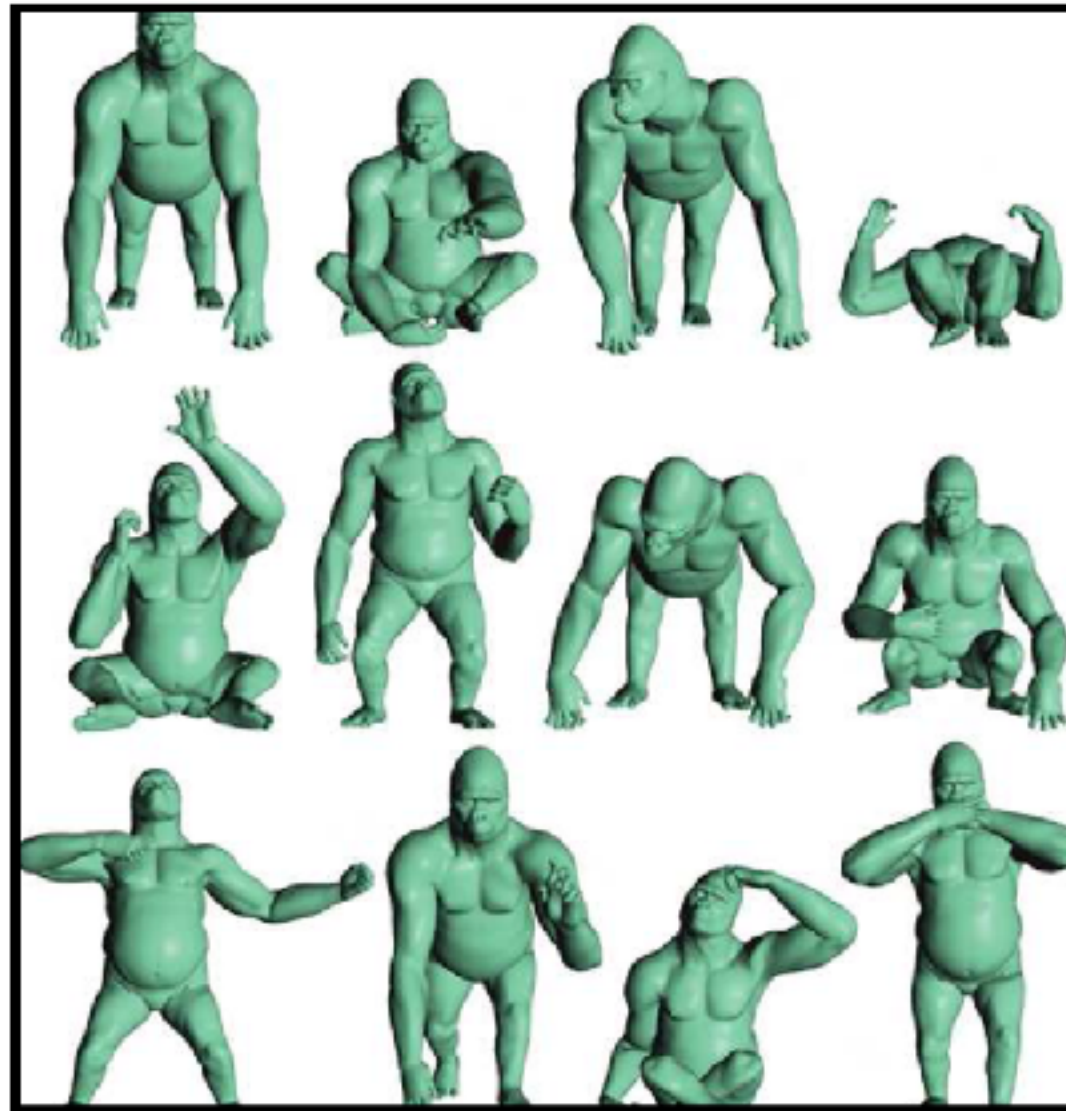
- Forward Kinematics
- Inverse Kinematics
- Advanced Methods (Style-Based IK + MeshIK)

### Animation

- Keyframe Animation
- Motion Capture
- Physics-Based Character Animation

# Posing

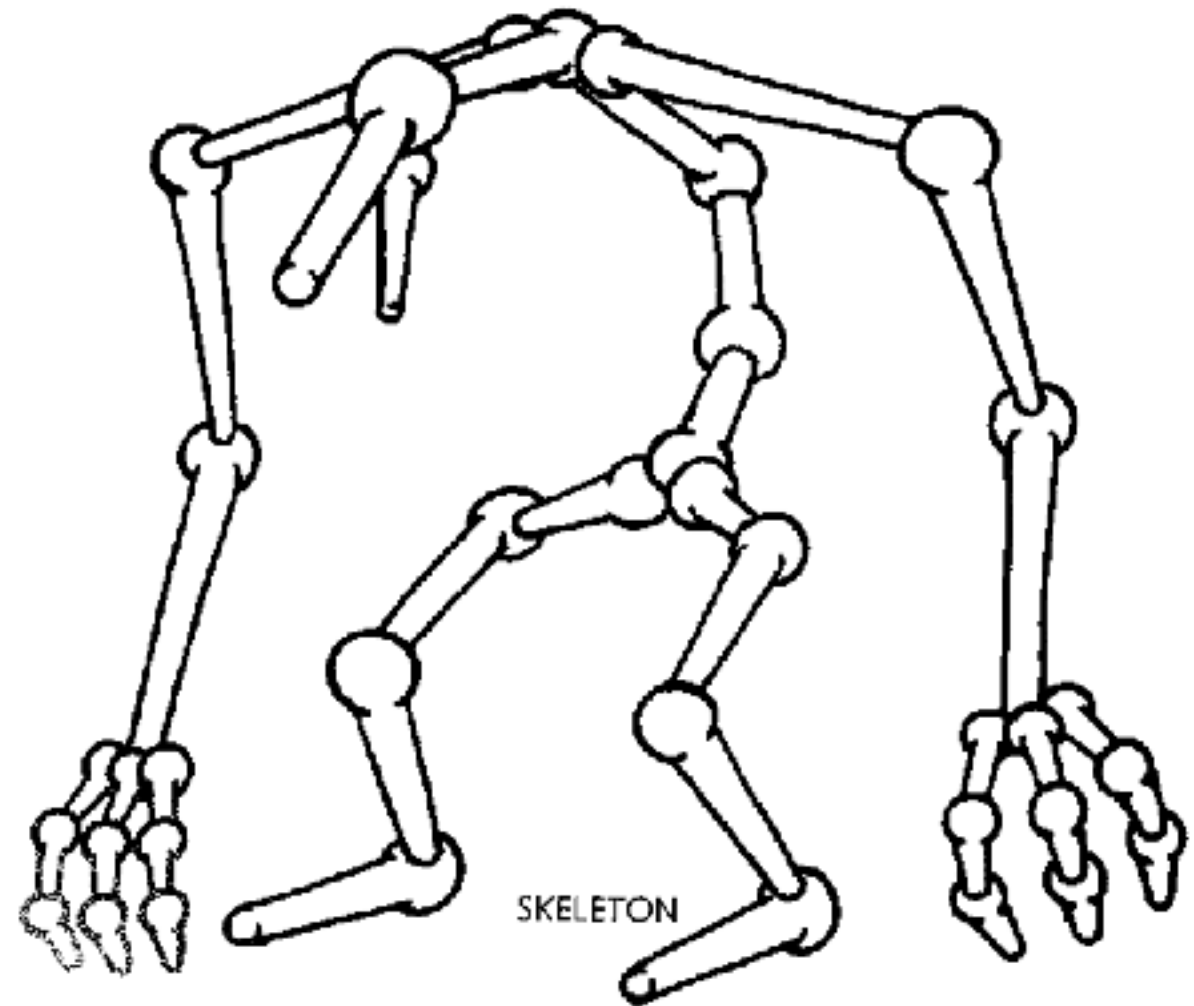
- Use the rigging controls to put the character into a given pose.





# Forward Kinematics

- Given the joint angles, find the position of the “end effector” (ie, hand)
- Problem: unintuitive

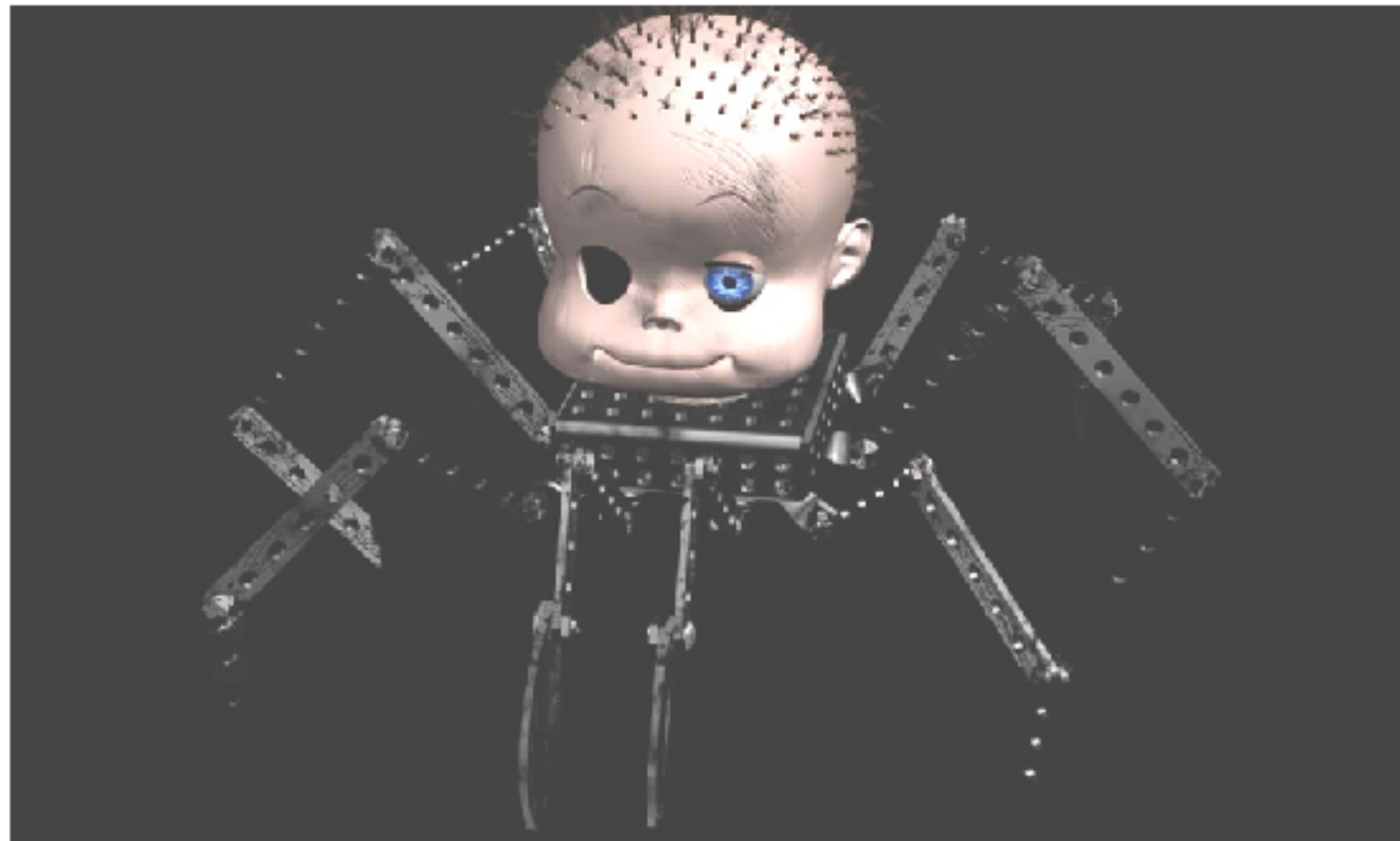


# Inverse Kinematics

- Given the end effector position, find the joint angles.
- Goals
  - Keep end of limb fixed while body moves
  - Position end of limb by direct manipulation
  - (More general: arbitrary constraints)

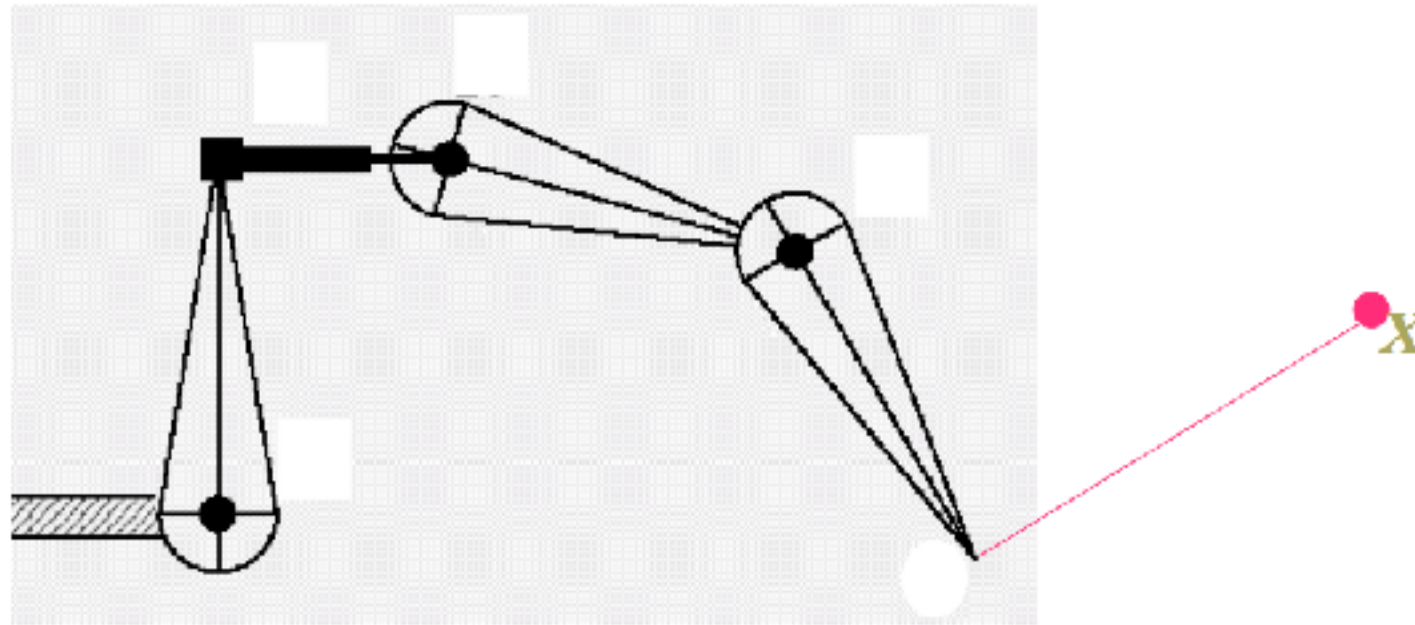
# Three-link IK

- Can be solved with trigonometry
  - Extra parameter for choice of solution
  - Joint limits



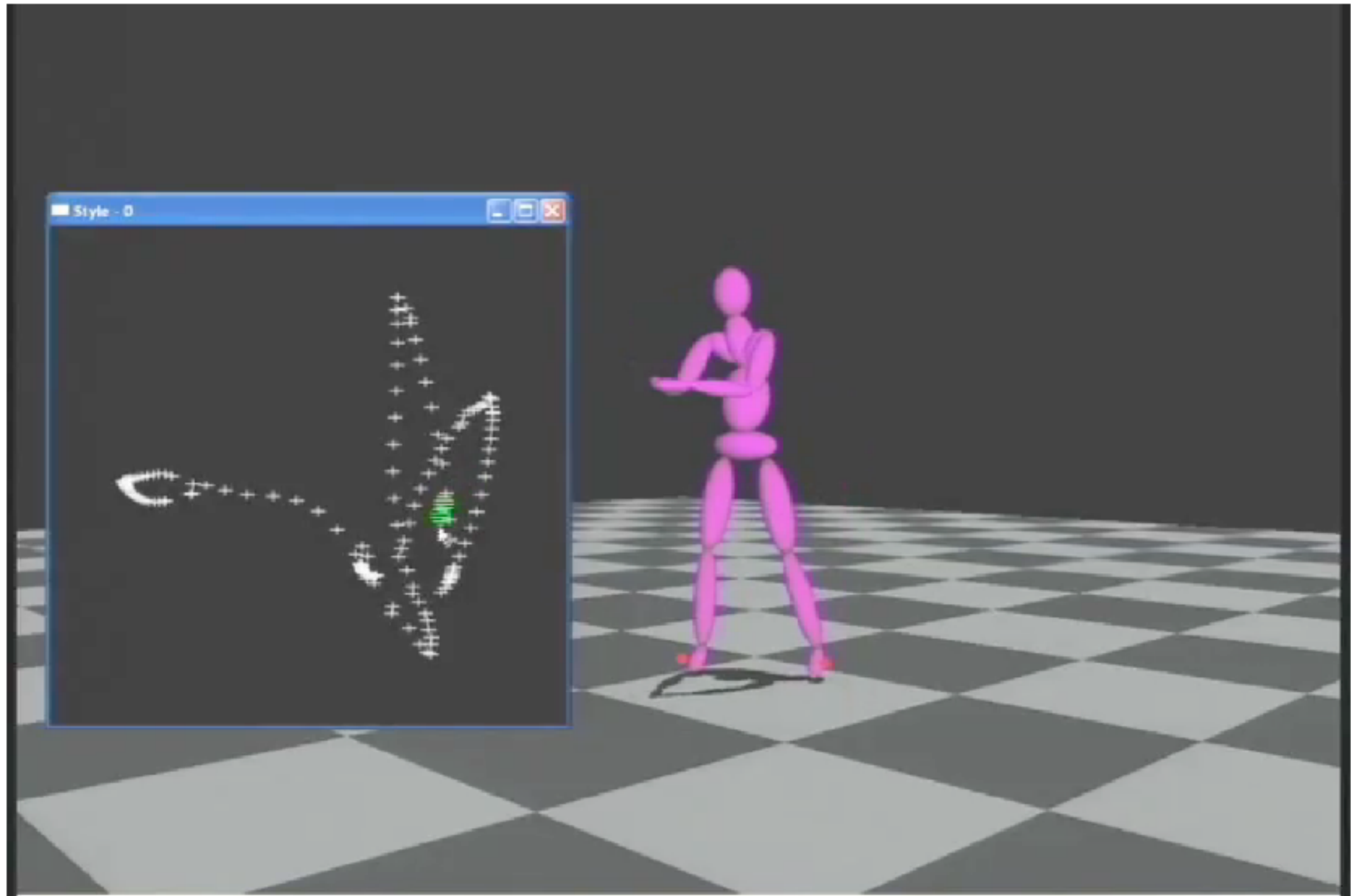


# General N-link IK



- want  $f(\theta) = X$ 
  - $\theta$  is a vector of N link parameters (angles, extensions)
  - $f(\theta)$  is the position of the endpoint (2D coordinates)
  - $X$  is the position of the target (2D coords)
- Given  $X$ , find  $\theta$

# Style-Based IK



# Overview

## Animation Production

### Rigging

- Procedural
- Skeletal
- Anatomical

### Posing

- Forward Kinematics
- Inverse Kinematics
- Advanced Methods (Style-Based IK + MeshIK)

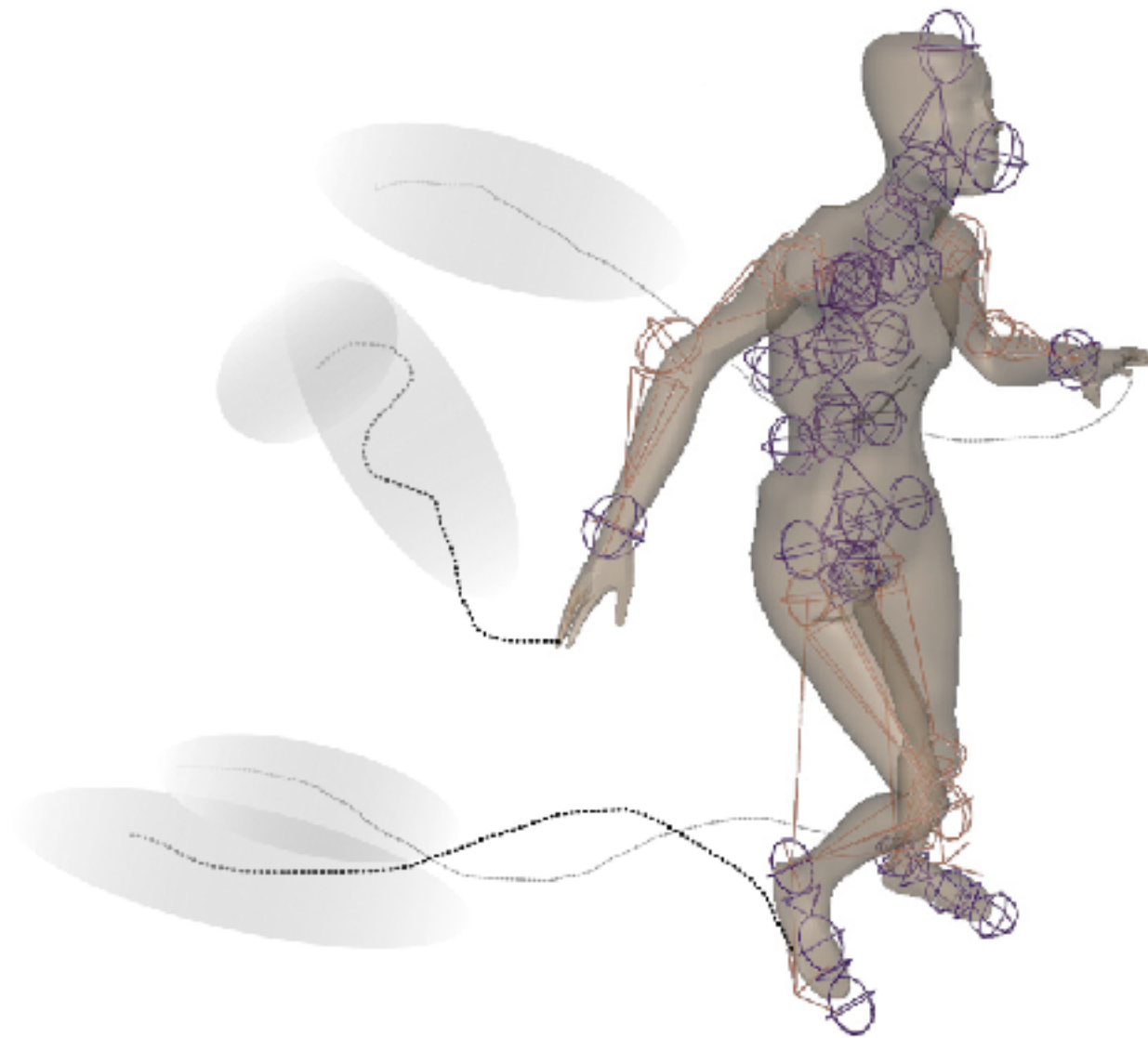
### Animation

- Keyframe Animation
- Motion Capture
- Physics-Based Character Animation



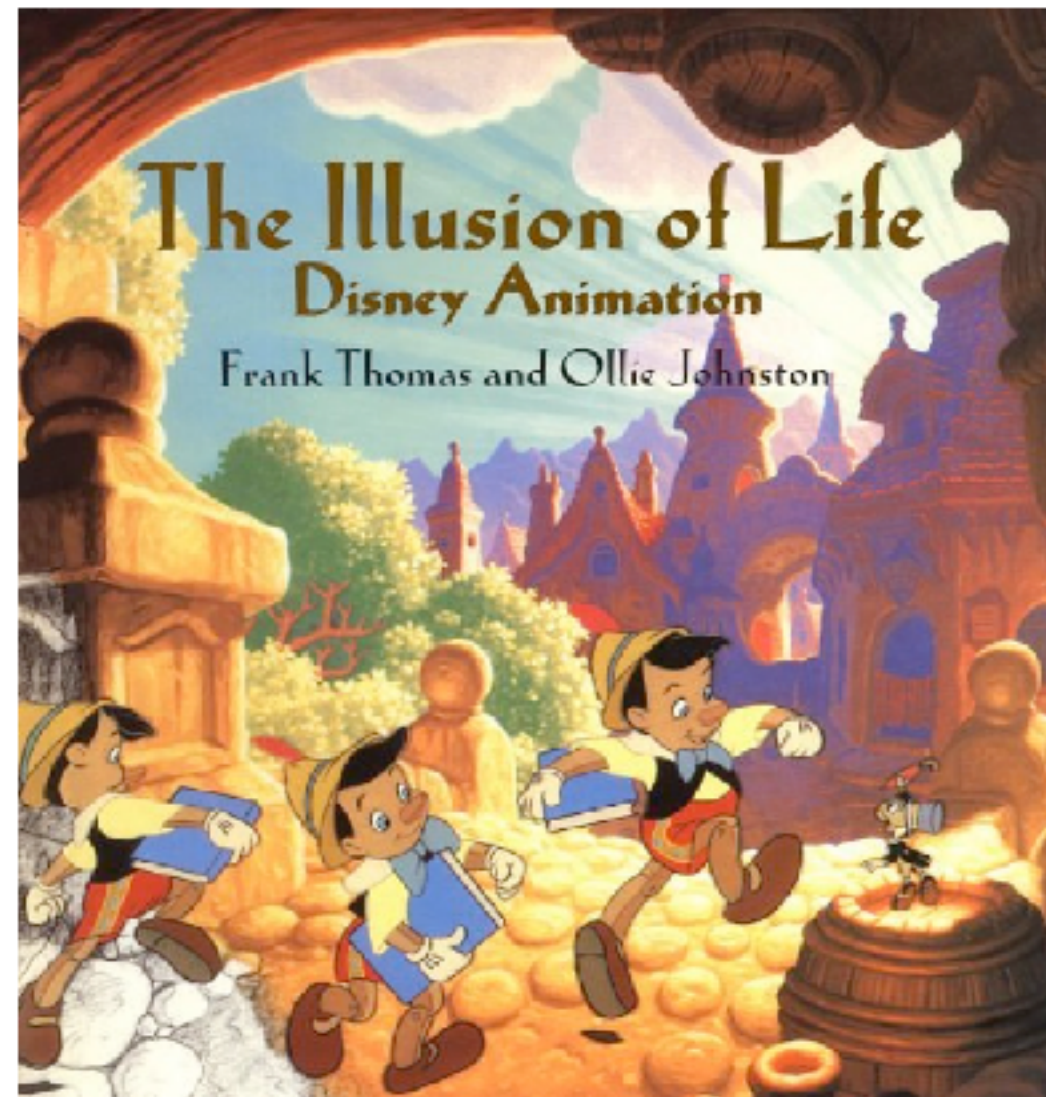
# Animation

- Change the rigging parameters over time to generate continuous movement.

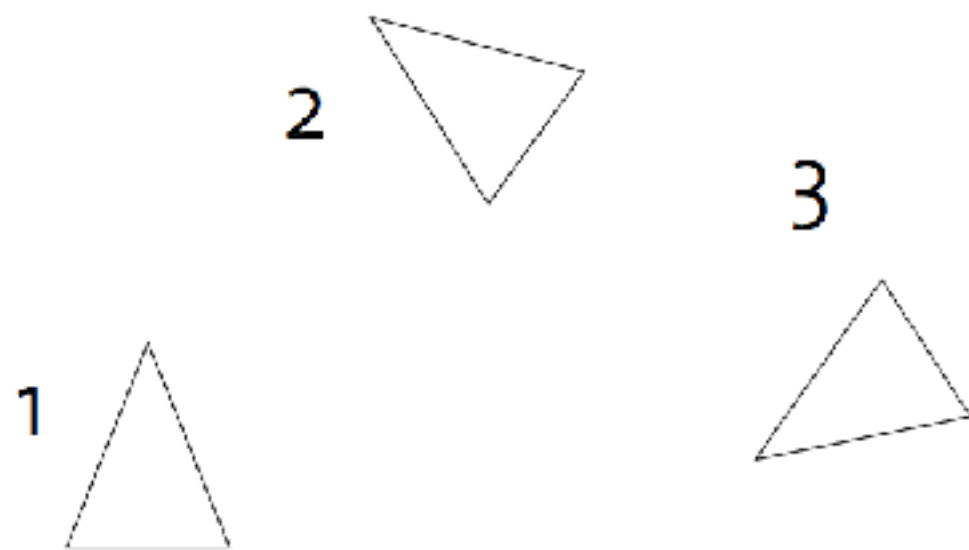


# Keyframe Animation

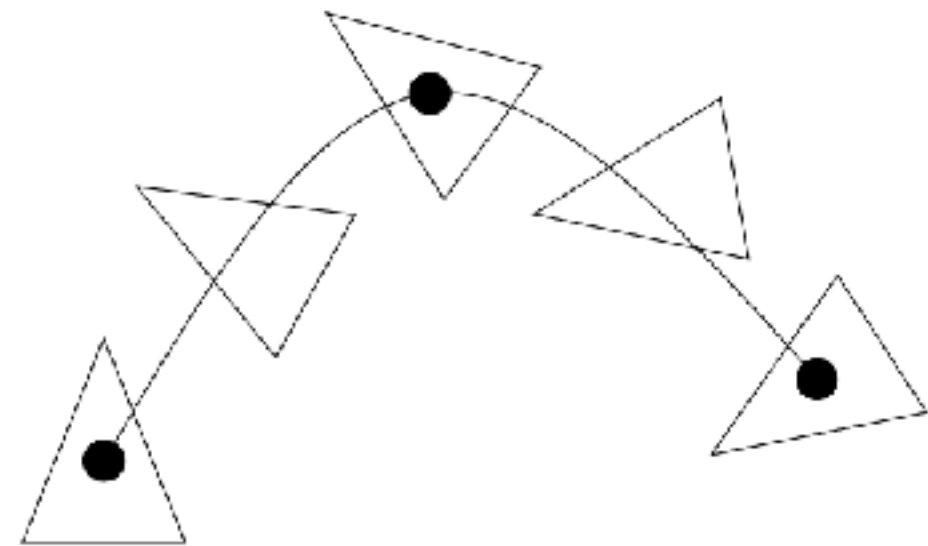
- Traditionally, animator draws character at “extreme” poses
- Fill in in-betweens
- Textbook “Illusion of Life”



# Keyframe Animation



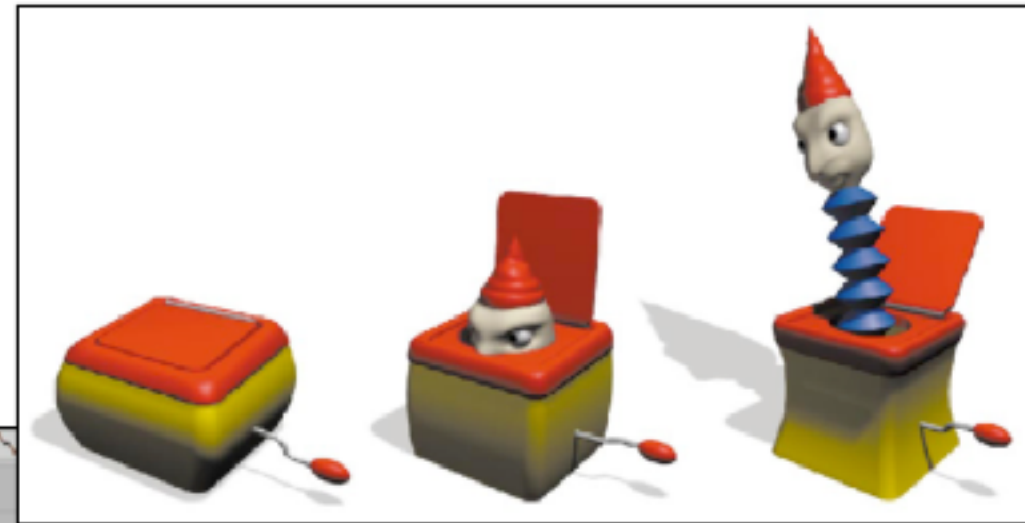
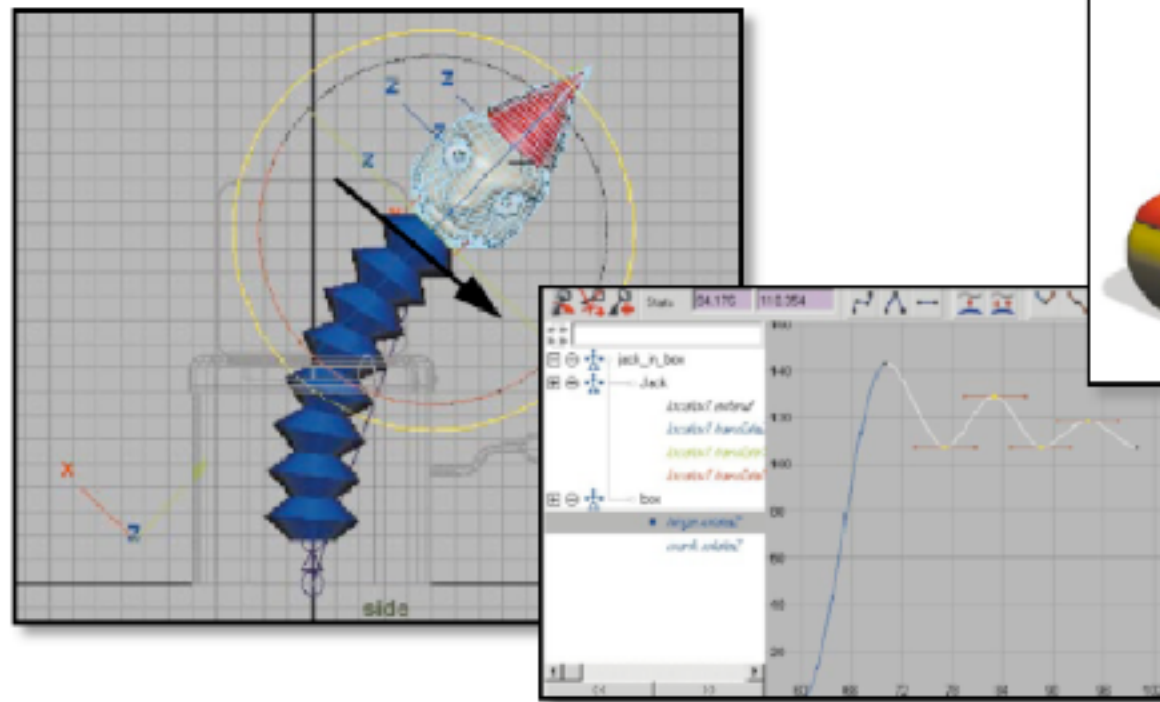
Keyframes



Animation



# Keyframe Animation



*From Learning Maya 2.0*

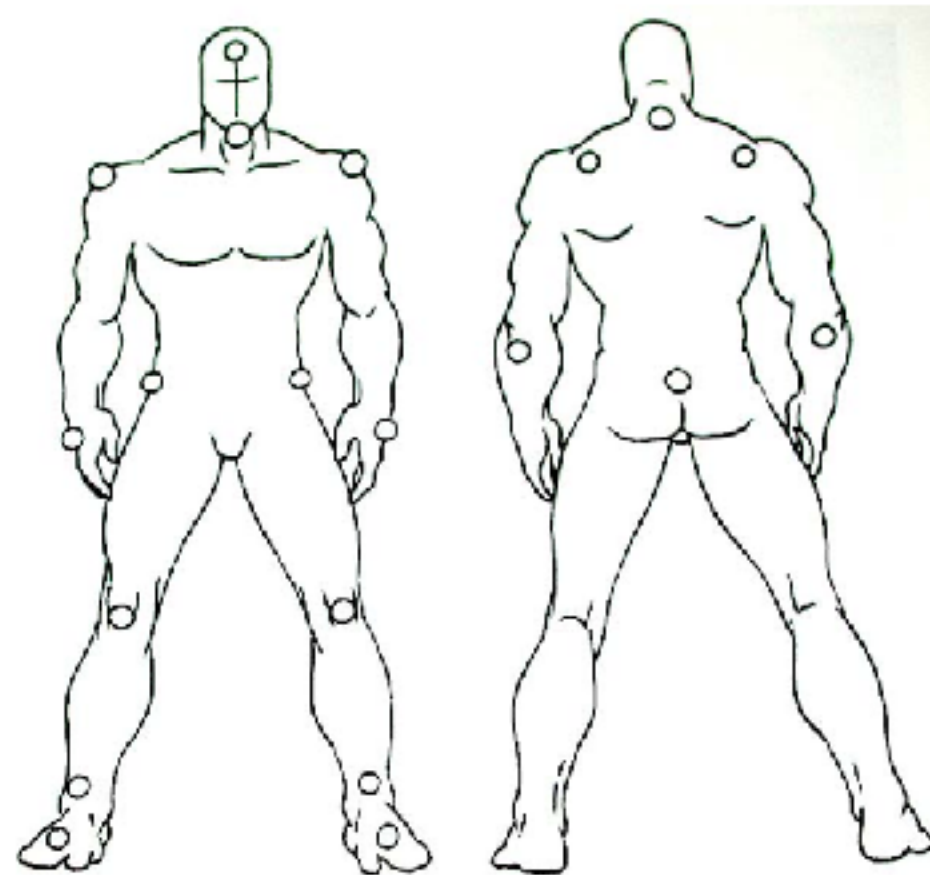
# Keyframe Animation

- Expressive! Gives artist total control
- But labor intensive even for talented artist



# Motion Capture

- More realistic motion sequences can be generated by Motion Capture
- Extract data from real-world people acting out a scene
- Record live action



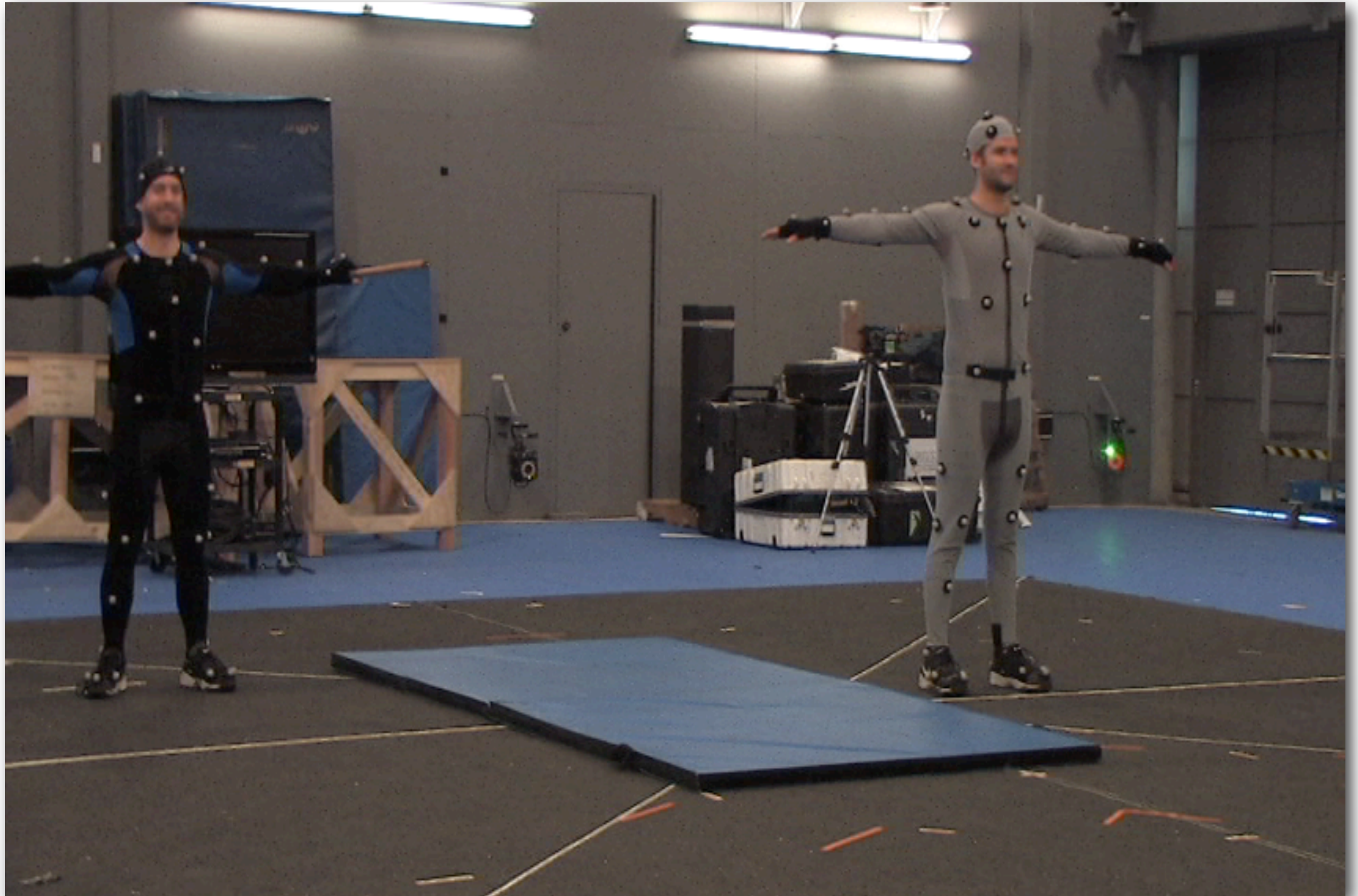


# Optical



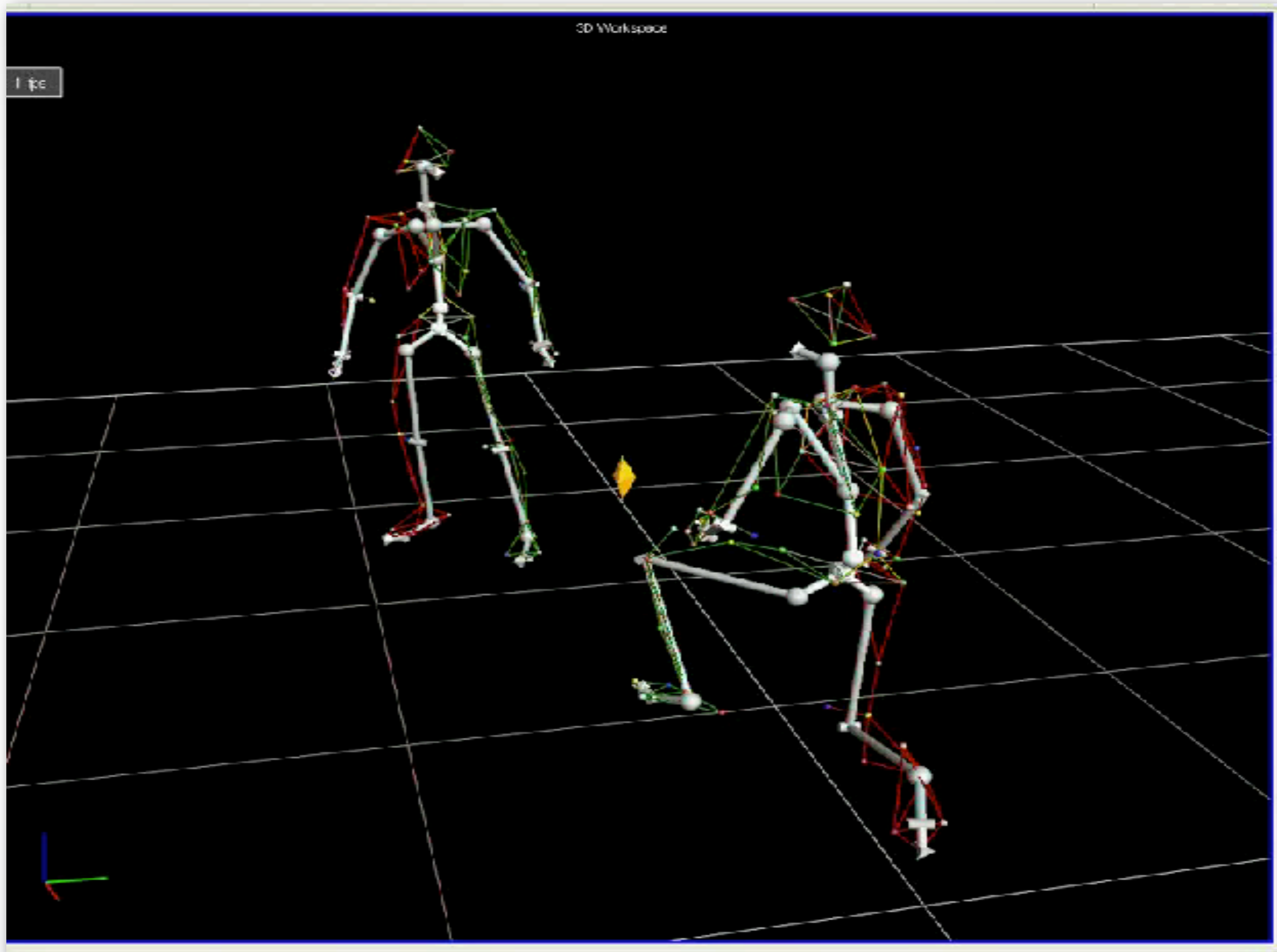
[Images from NYU and UW]

# Motion Capture





# Motion Capture



... becomes Mocap Data



# IMocap

A new technique developed for Pirates of the Caribbean 2 that enabled ILM to capture performance on location while maintaining a relatively small footprint.

# IMocap

114\_NG\_210\_v23334

ILM

03-11-08





# IMocap





# IMocap

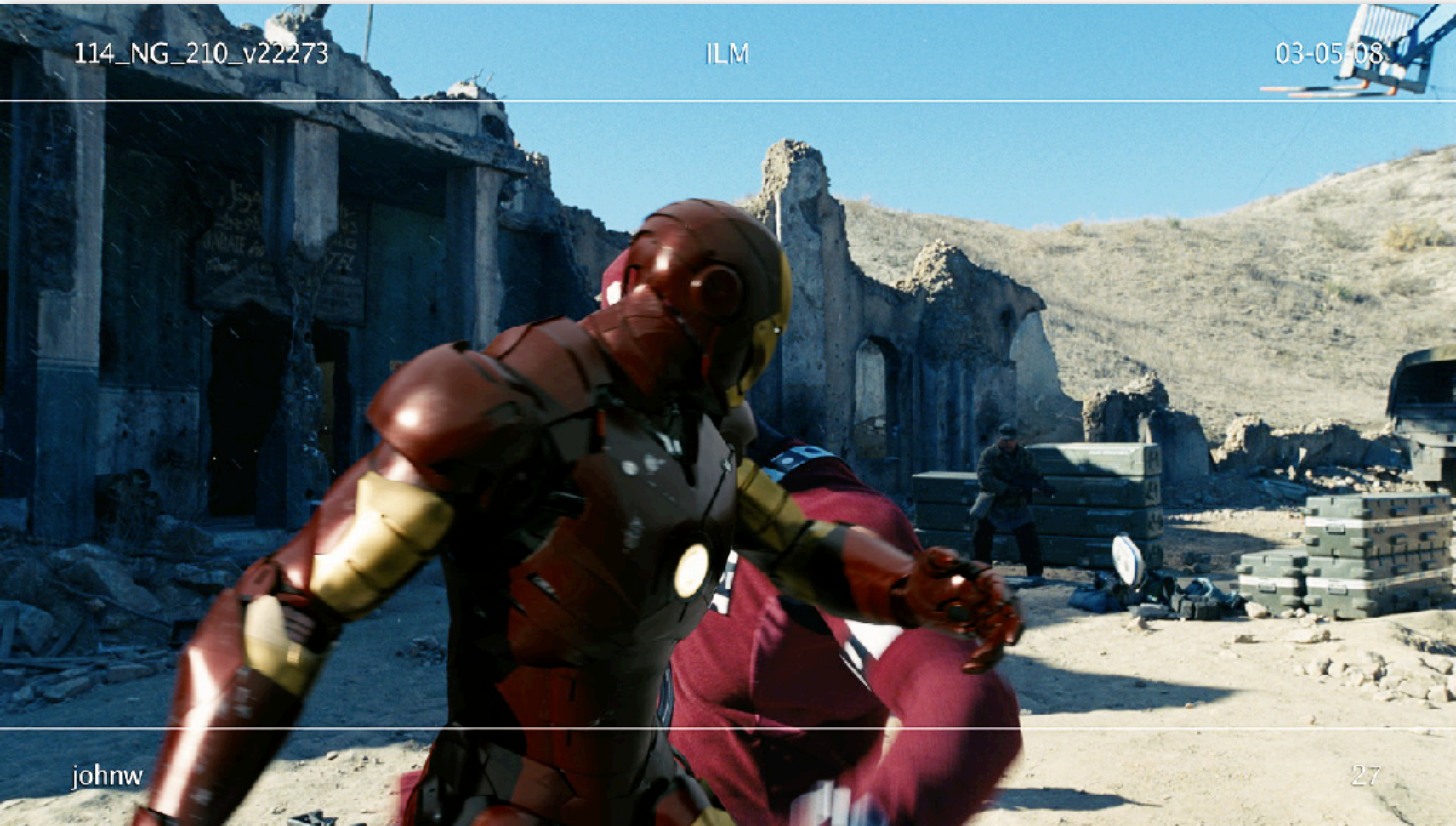
114\_NG\_210\_v22273

ILM

03-05-08

johnw

27





# IMocap

114\_NG\_210\_v24308

ILM

03-20-08



mclemens

48



# Performance Capture





# Head-Mounted Camera



input performance



input video  
with markers



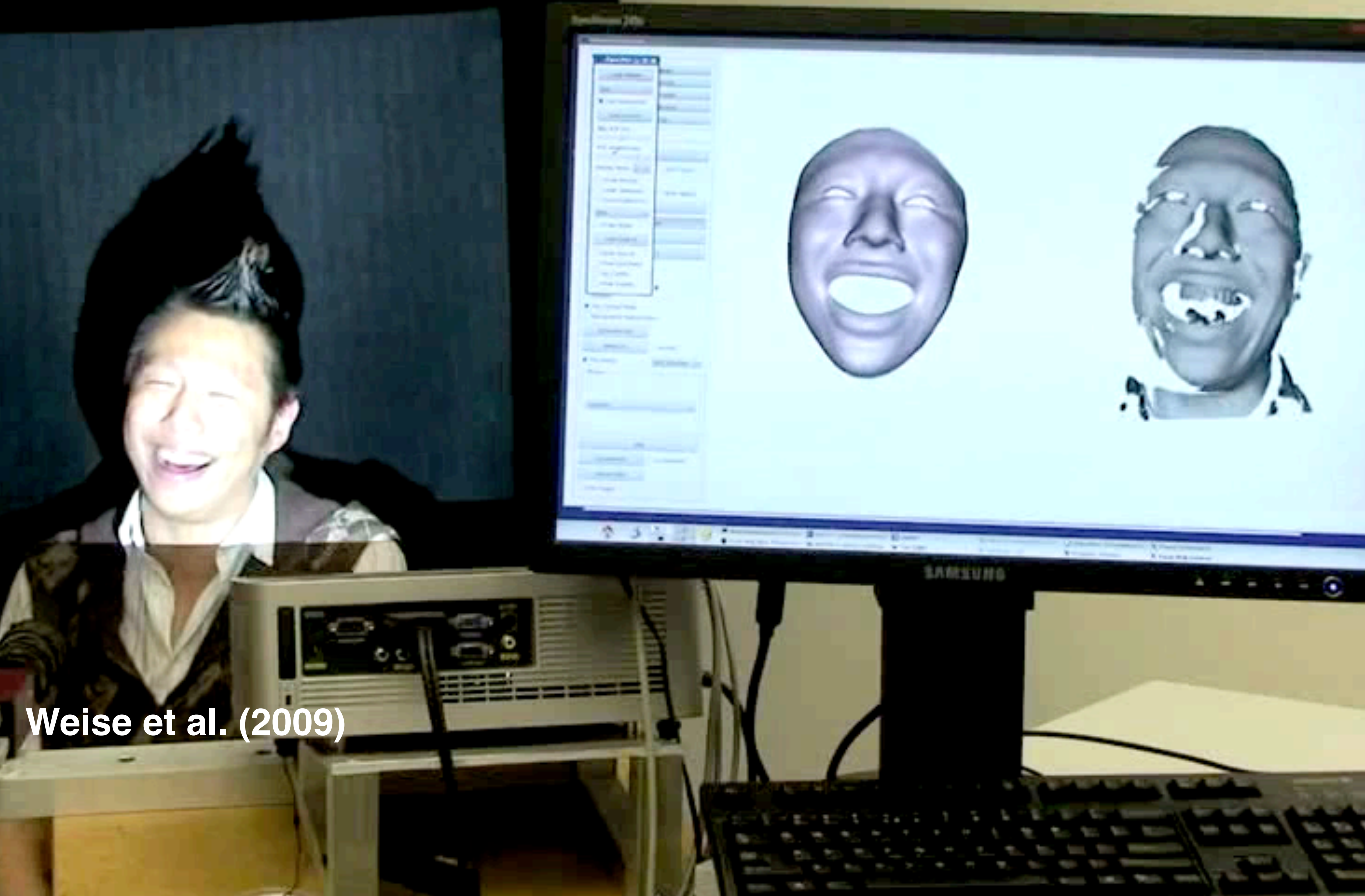
tracking



retargeting

**Bhat et al. (2013)**

# Back in 2009



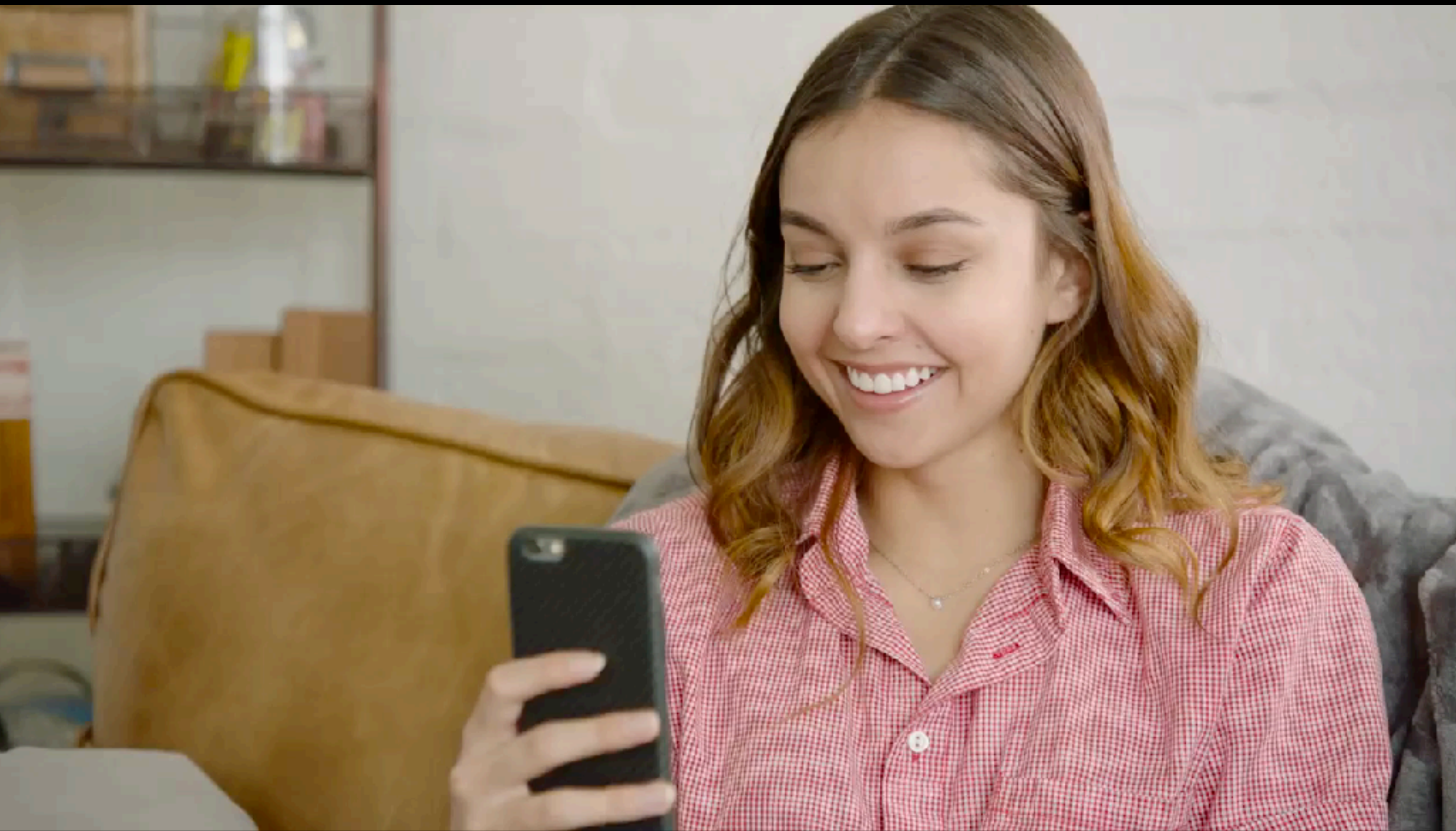
Weise et al. (2009)





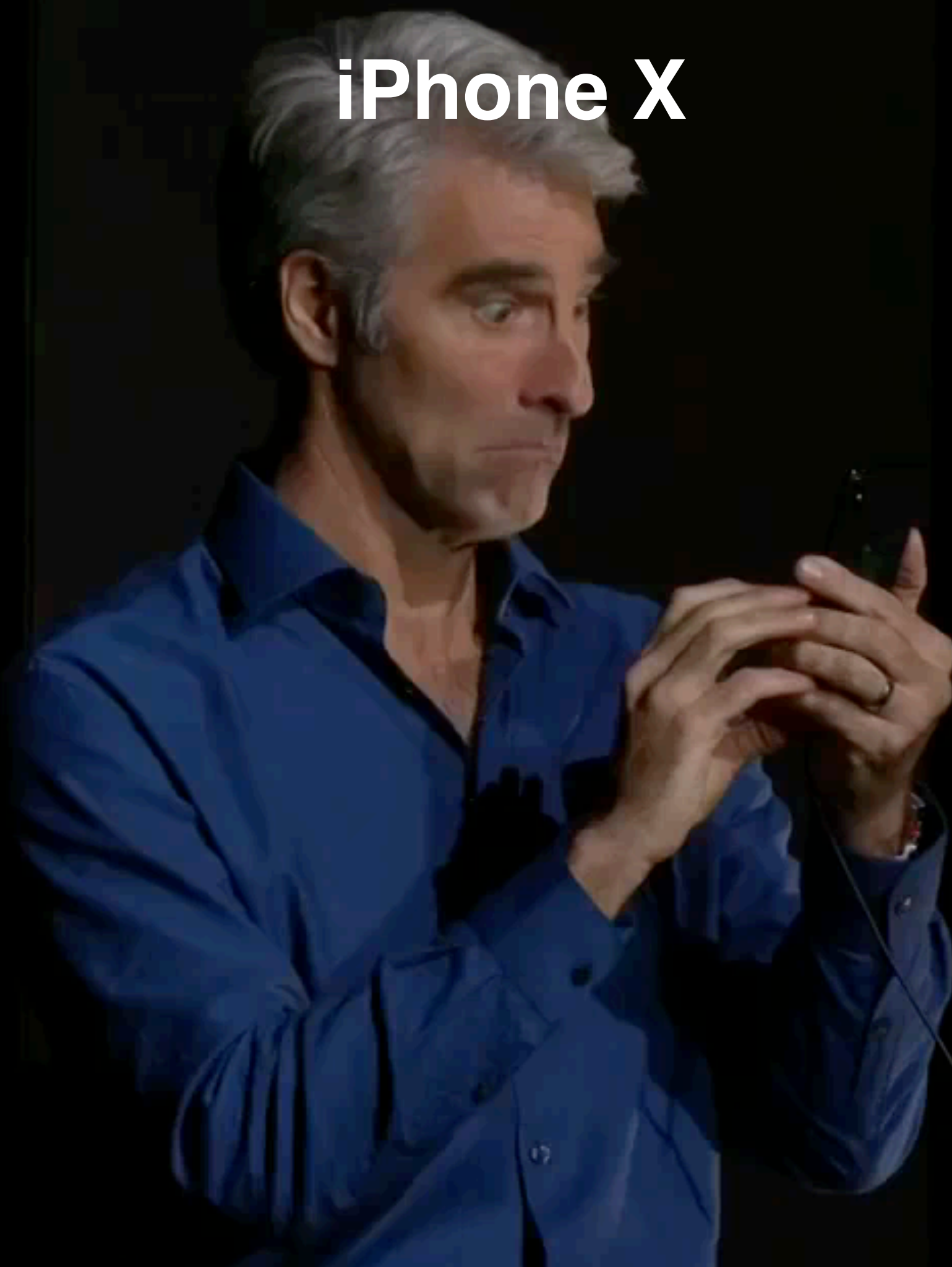
Li et al. (2013)

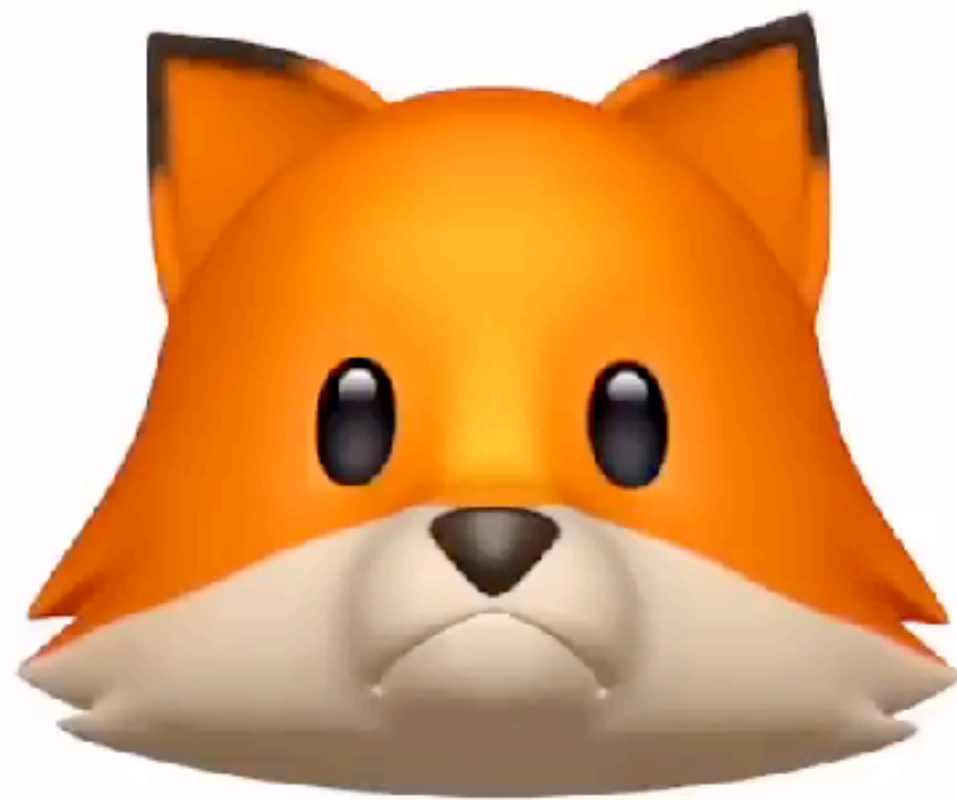




**Snapchat**

iPhone X







# We can capture these...



# Motion Capture???





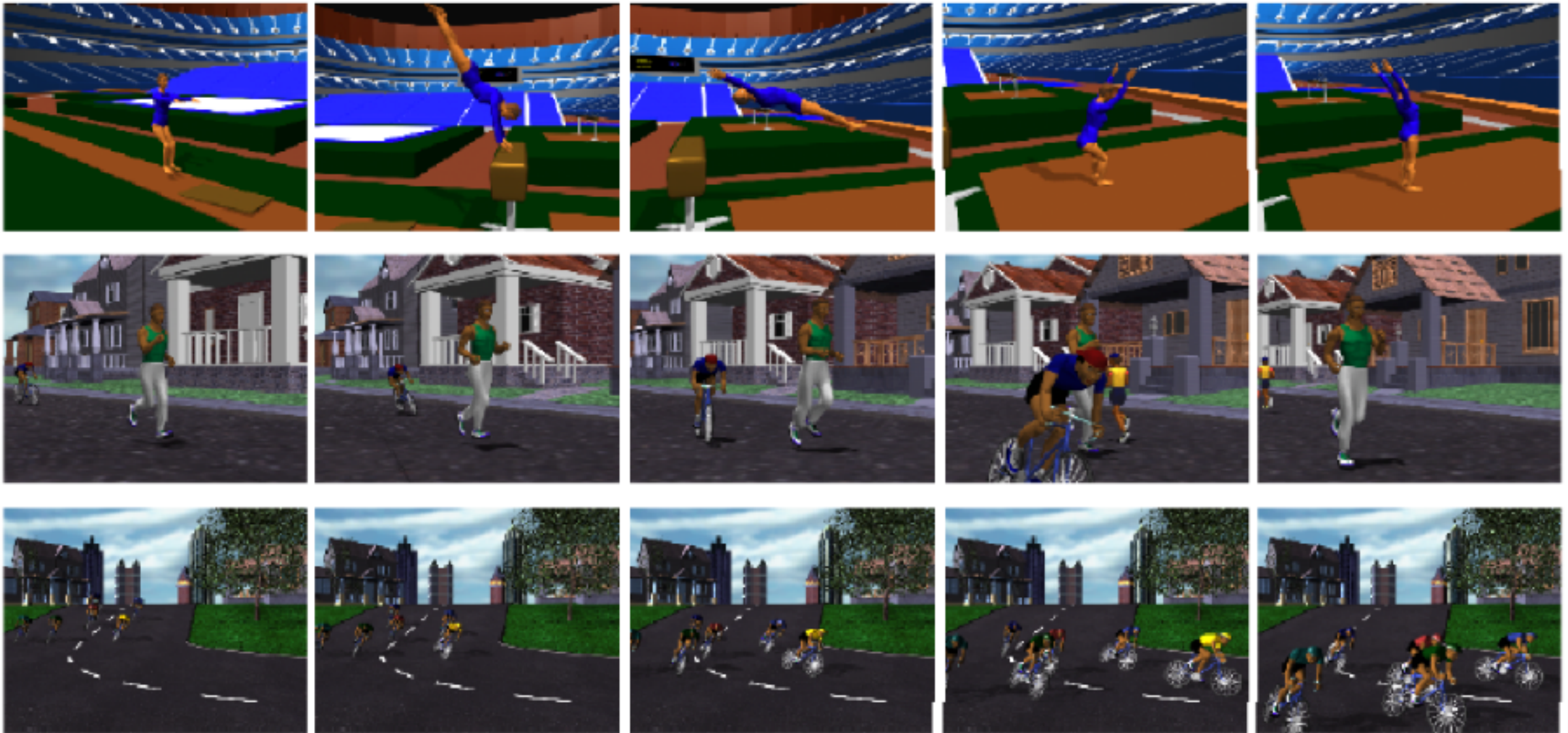
# Physics-Based Character Animation



Olympic Running

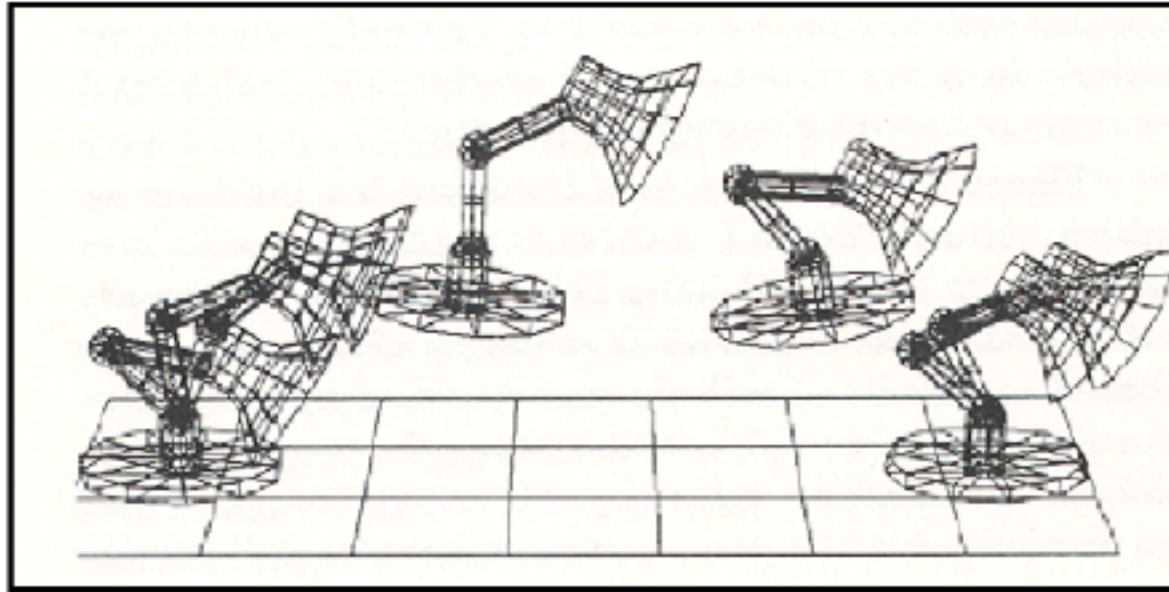


# Physics-Based Character Animation

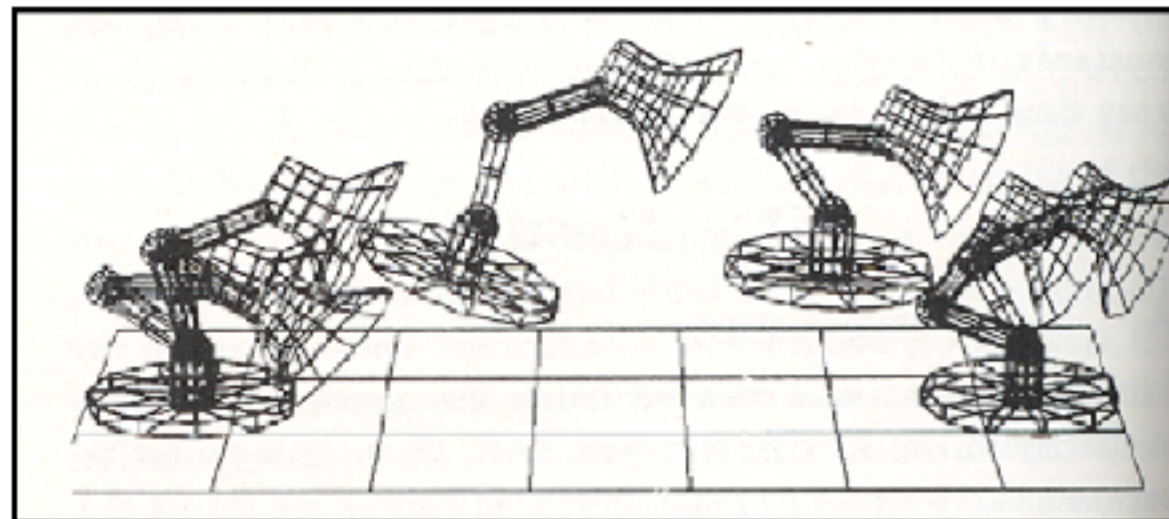


Vaulting, Cycling and Running

# Space Time Constraints



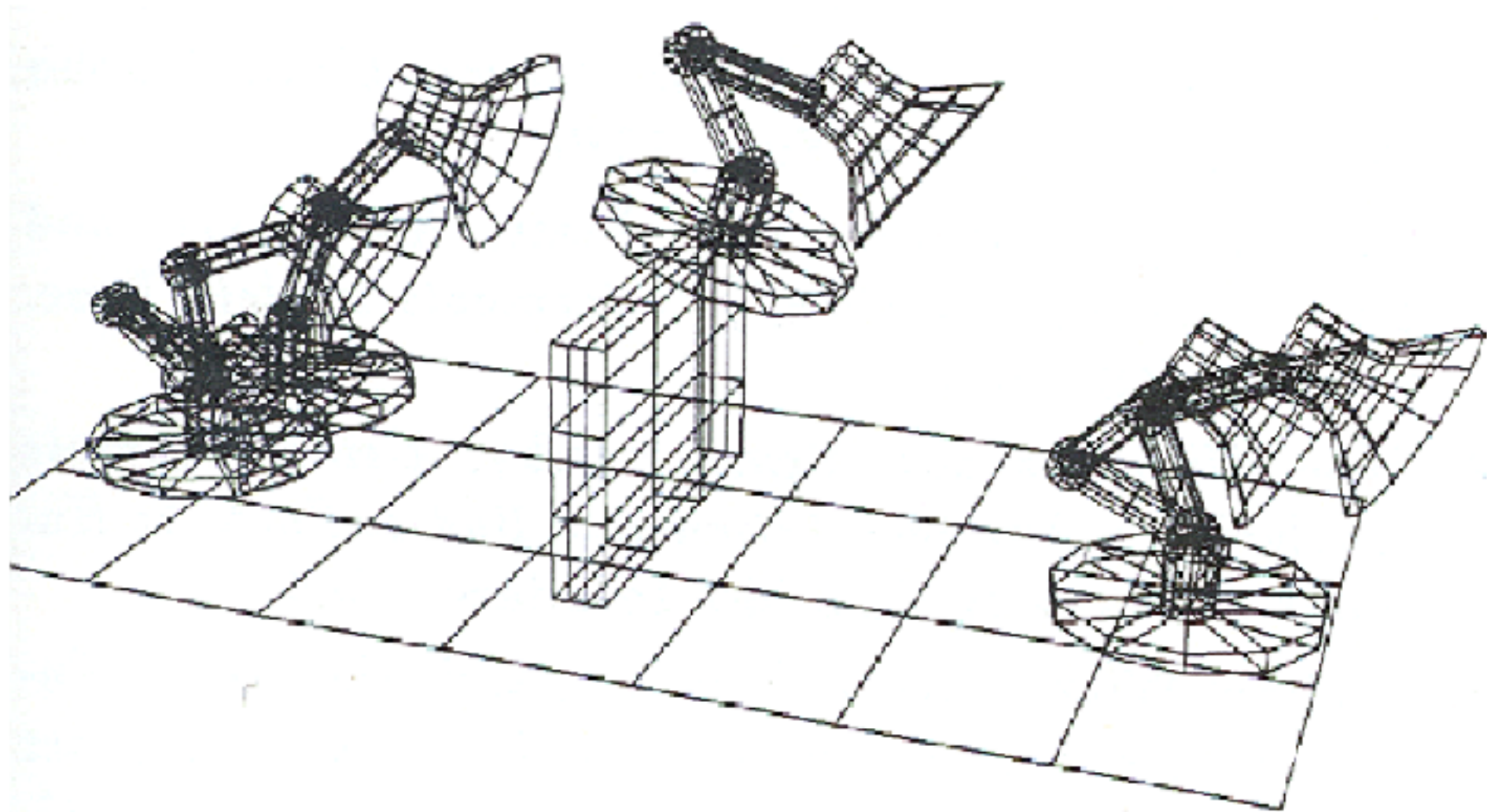
Original Jump



Heavier Base



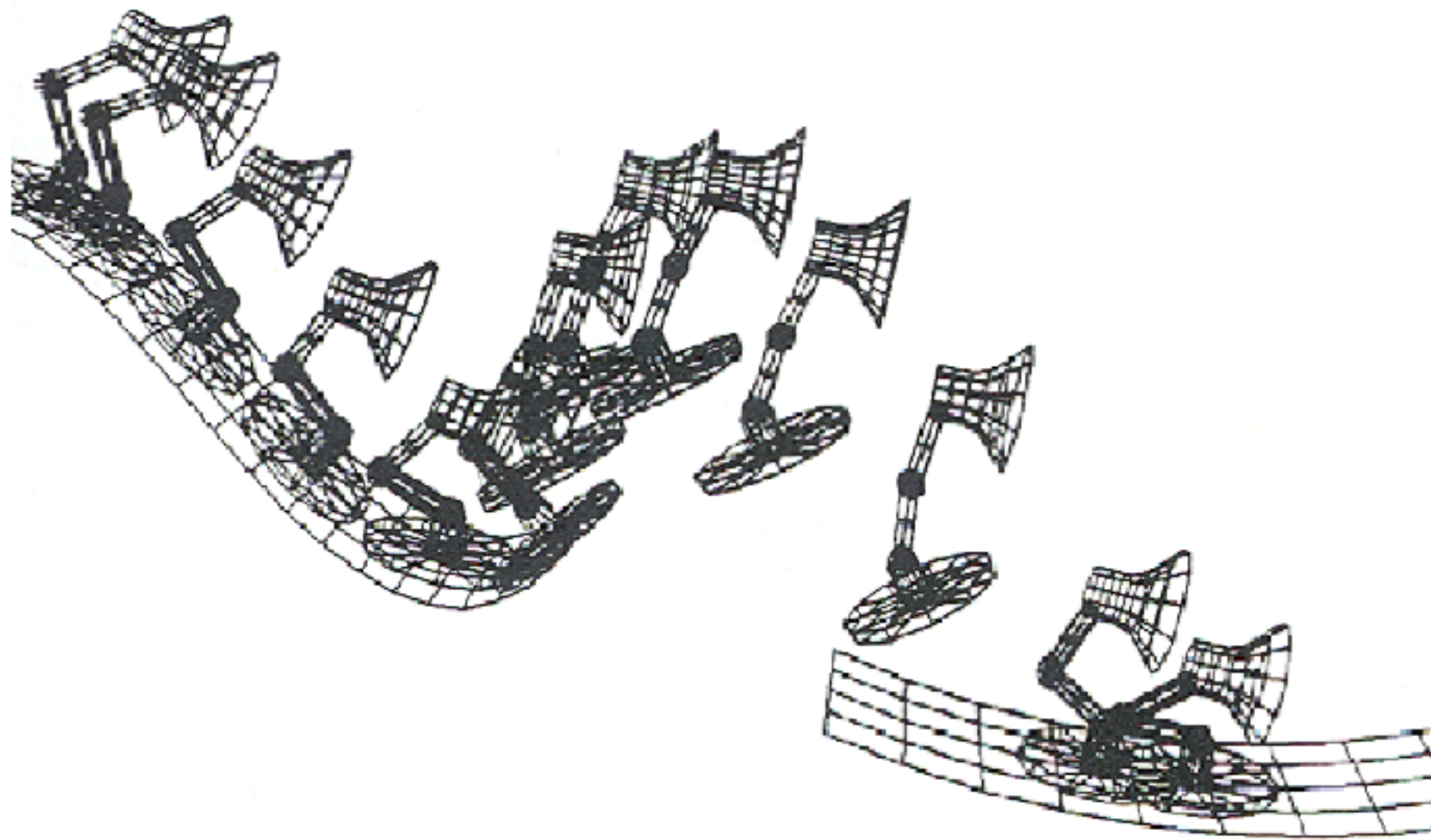
# Space Time Constraints



Hurdle



# Space Time Constraints



Ski Jump

<http://cs420.hao-li.com>

# Thanks!

