



Motion for Computer Animation

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Outline

- A brief history of computer animation
 - (animation appreciation) – Video!
- Techniques for creating motion
 - (an overview) – Video!
- Motion retargetting and spacetime
 - (what I do) – Video!
- Graphics and Animation at UW CS

Goals

- Give you some idea of what Computer Animation is about
- Give you some idea of where (some of) the hard problems are
- Give you an idea of what I do
- Show some fun video

Caveats

- This talk is skewed toward 3D Animation for film and video
- That ignores lots of interesting stuff
 - 2D and image effects
 - Games, Visualization, Simulation, ...
- Focus on character animation
 - Over-emphasize my heroes

Timeline



- Phases of the history of animation

Pioneer Days (pre-1980s)

- What was happening:
 - Early pioneers (in research labs) started making movies with computers
- General Story:
 - It was hard to make pictures with computers, but people did it anyway
- Why it ended:
 - Computer Animation becomes feasible

Early Days (early to mid-1980s)

- What was happening:
 - Computer animation in film and video
- What it looked like:
 - Computer graphics
 - Things computers could draw well
 - Chrome! Flying Logos!

Early Days (early to mid-1980s)

- Notable examples:
 - TRON ('82), The Last Starfighter ('84)
 - Many TV spots and commercials
- What it looks like today:
 - Quaint
- Why it ended
 - AUDIENCES grew more savvy

A critical moment in history...



Luxo Jr.
Pixar, 1986
J. Lasseter (dir)

- First computer animation nominated for an Academy Award
- Notable character animation
It's the motion! (well, it looks good too)

Computer Animation Comes of Age (late 80s – mid 90s)

- Computer Animation not just for computer animation's sake



Beauty and the Beast, 1991



Jurassic Park, 1993

Glory Days of Computer Animation

- What will they do next?
- Notable examples
 - Tin Toy '88 (and other Pixar Shorts)
 - Terminator 2 '91
 - Beauty and the Beast '91
 - Jurassic Park '93
 - ... more and more and more ...

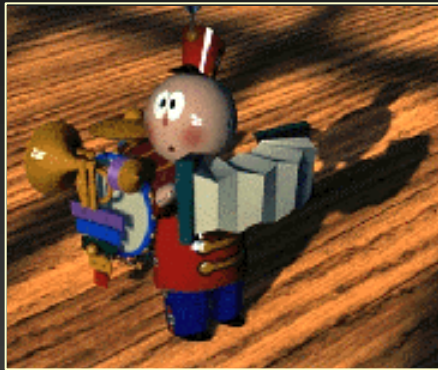
Another important film...



Toy Story
Pixar, 1995
J. Lasseter (dir)

- Feature length, 3D animated film
- Financially and artistically successful
- Everybody wants to copy

Why is Toy Story Different?



Tin Toy
1988



Toy Story
1995

- Same basic technology as shorts
- Different magnitude of problems
 - How to deal with all the bits!
- Must hold attention for 90 minutes

End of the Glory Days?

- Glory is for good films, not cool effects
 - Not just animation for animation's sake
 - Hackers are not the heroes anymore
- Technology is generally available.
 - (Kindof)
- Artistic factors drive

Toy Story++

- More and more animated films
- Greater levels of complexity
 - Antz, Bugs Life, Toy Story 2, ...
- New artistic styles and possibilities
 - Tarzan, Prince of Egypt, ...
- Current state of the art

The Post-Modern Era ('97- ...)

- Don't believe your eyes!
 - Anything is possible!
 - Seamless integration of CG and real
- Some landmarks
 - Titanic '97
 - What Dreams May Come '98
 - The Mummy, Phantom Menace '99

How do you do it?



- “Typical” or Traditional pipeline
- Divides tasks
- Variants exist

Design



- One of the most important pieces
- Deciding what animation is to be made

Modeling



- What are the objects?
- What do they look like?

Animation



- Animate: to bring to life
- Making things move

Lighting



- Making choices in how things look
 - Term is a “Pixarism”
- Catch-all for lots of appearance design

Rendering



- Let the computers color the pixels

Post-Production



- Put the pictures into final form

Why focus on motion?

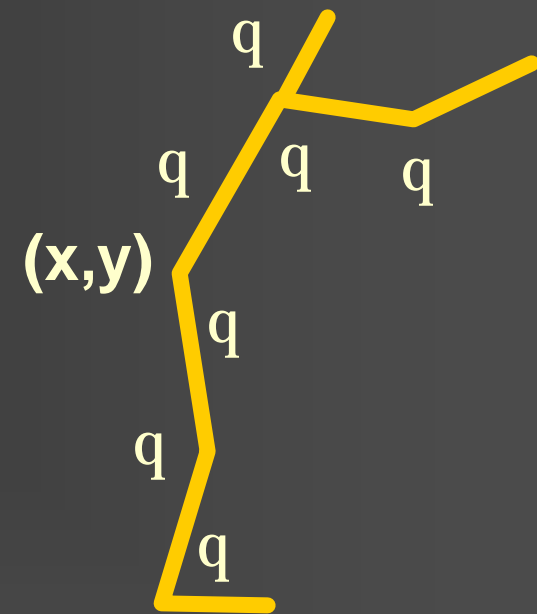
- It is the heart of animation
- It's the most unique aspect of animation
- It's the thing we have the least experience with
- It's the thing I am most interested in

What is a motion?

- Animated Character
- Pose or Configuration
 - parameters in a vector

$$\mathbf{p} \in \mathcal{R}^n$$

- Examples are articulated figures (humans)
 - trees of rigid links
 - center + joint angles
 - nothing specific about methods



$$\mathbf{p} = \{\mathbf{x}, \mathbf{y}, q_1, q_2, q_3, \dots\}$$

Three main ways to make motion

- Create it by hand
- Compute it
- Capture it from a performer

- Re-use an existing motion
 - (don't make it at all)

Creating Motion by Hand: Keyframing

- Skilled animators place “key” poses
 - Computer “in-betweens”
- Requires incredible amounts of talent
 - But can be done extremely well

Verdict: Produces the highest quality results, at a very high cost

Computing Motion: Procedural and Simulation

- Define algorithms to create motions
- Ad-hoc rules, or simulate physics
- Physics provides realism
- But how do you control it?

Verdict: Good for secondary effects, not for characters (yet)

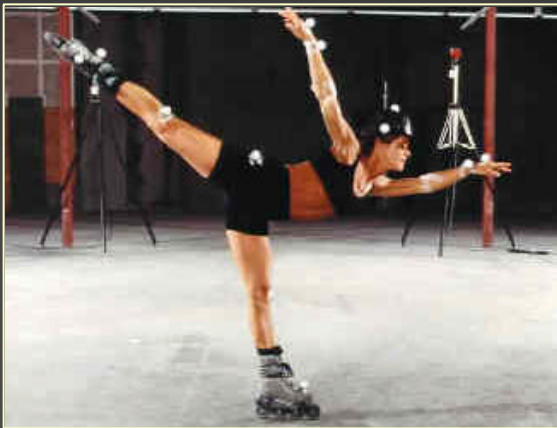
Motion Capture and Performance Animation

- Use sensors to record a real person
- Get high-degree of realism
 - Which may not be what you want...
- Possibility for real-time performance

Verdict: Good for realistic human motions. Scary to animators.

Motion Capture Technology: Optical Tracking

- User markers and special cameras
- Tracking + Math



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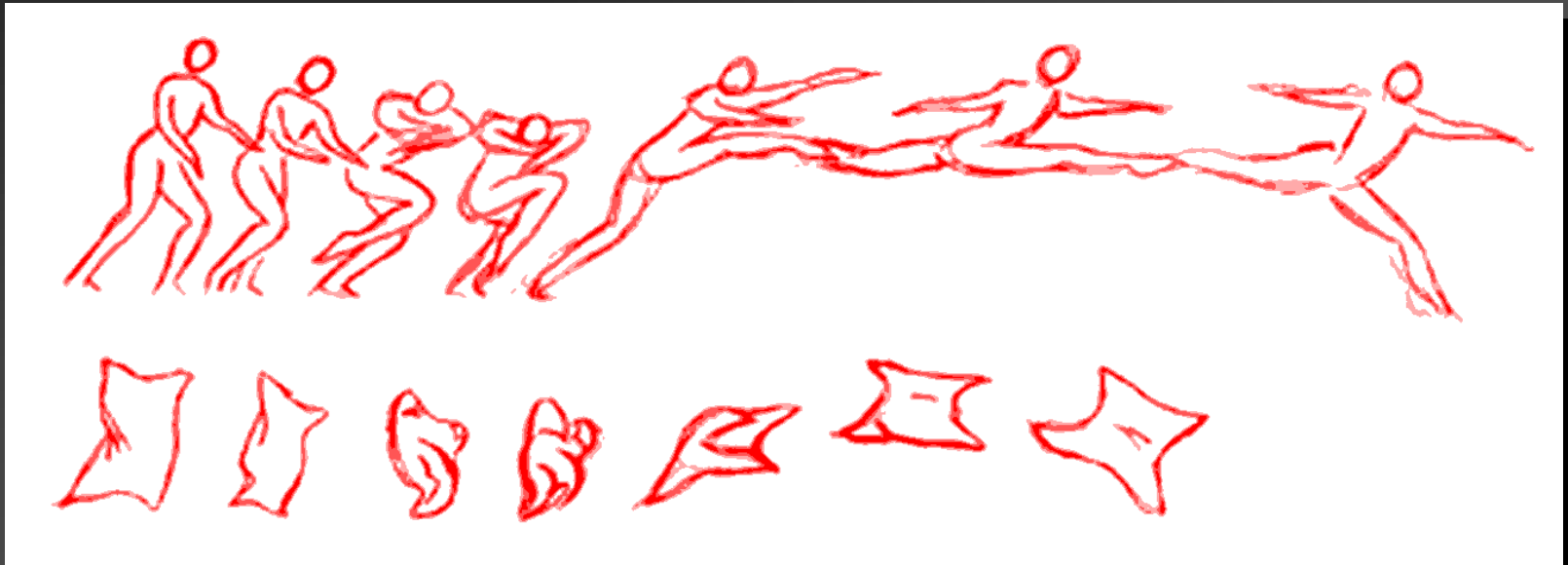
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Motion Capture Technology: Video

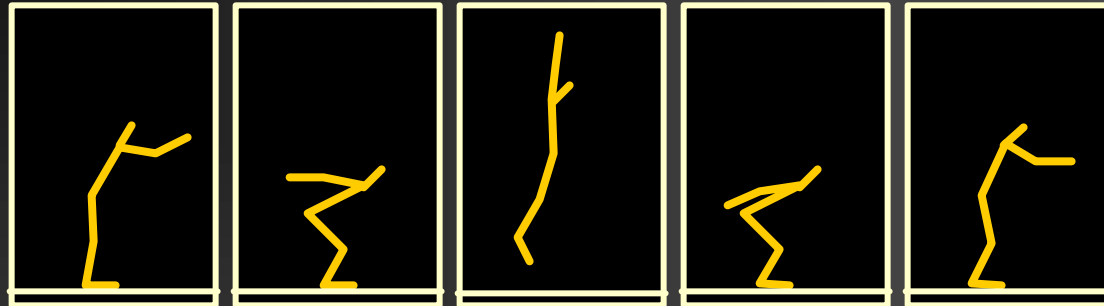
- An interesting and open problem...
- Limited information
 - But seemingly enough
- Problem can be arbitrarily hard
 - Or easy – if you make assumptions
- Video is surprisingly bad

So now you have motion...

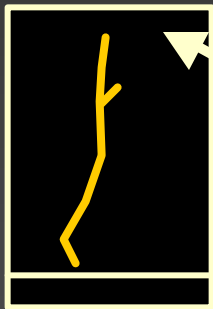
- Transform Motion to new uses



Problem: Motion is Specific



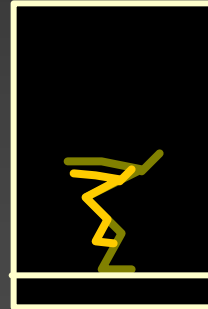
Specific Action



hand is
not here

Edit motion to
meet new needs

Specific Character

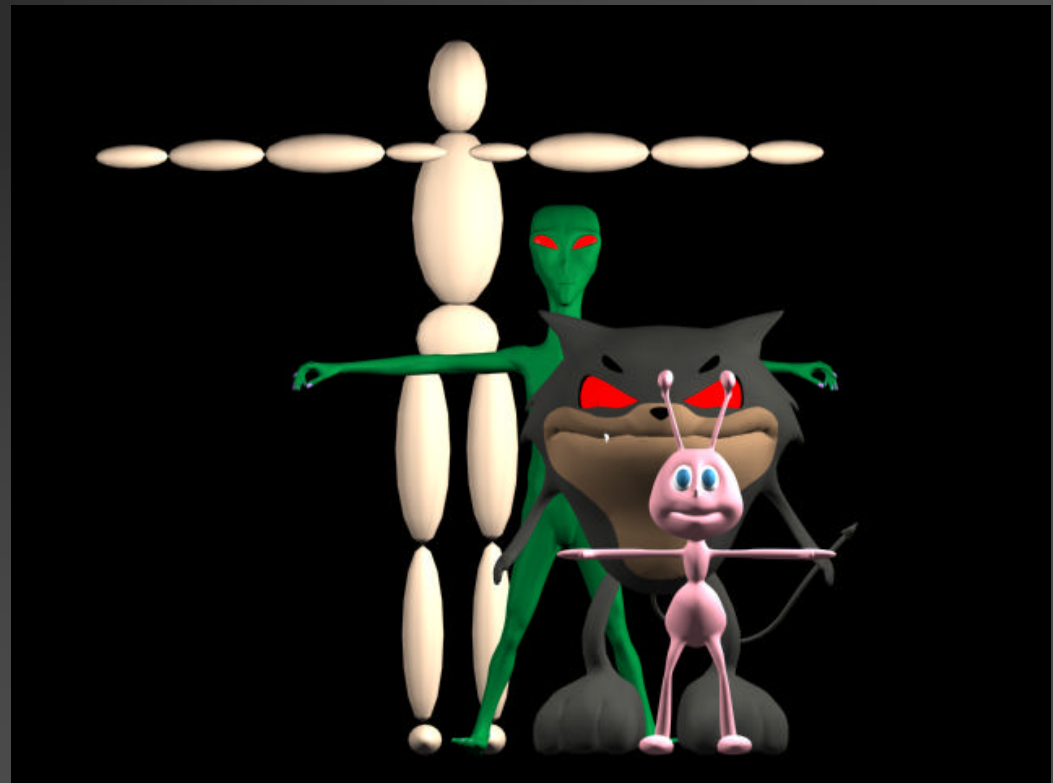


different sized
character
doesn't fit

Retarget motion to
new character

Retargetting Motion to New Characters

- Goal: one motion, a cast of characters
- Focus on similar structure



Transformation Basics

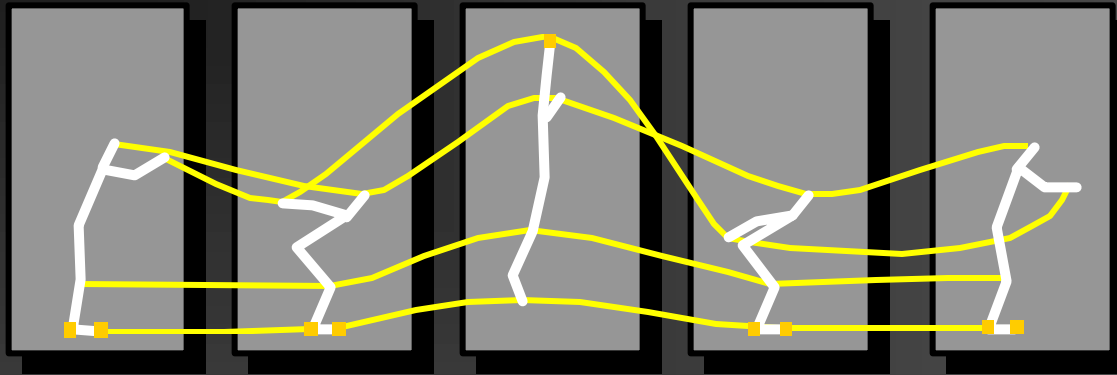
Change what isn't important, retain what is

- Hard to define what is important
 - high-level properties
 - motion specific
- Stick to what's easy to define
 - geometric constraints
 - signal characteristics
 - framework for better metrics later

Transformation as Constrained Optimization

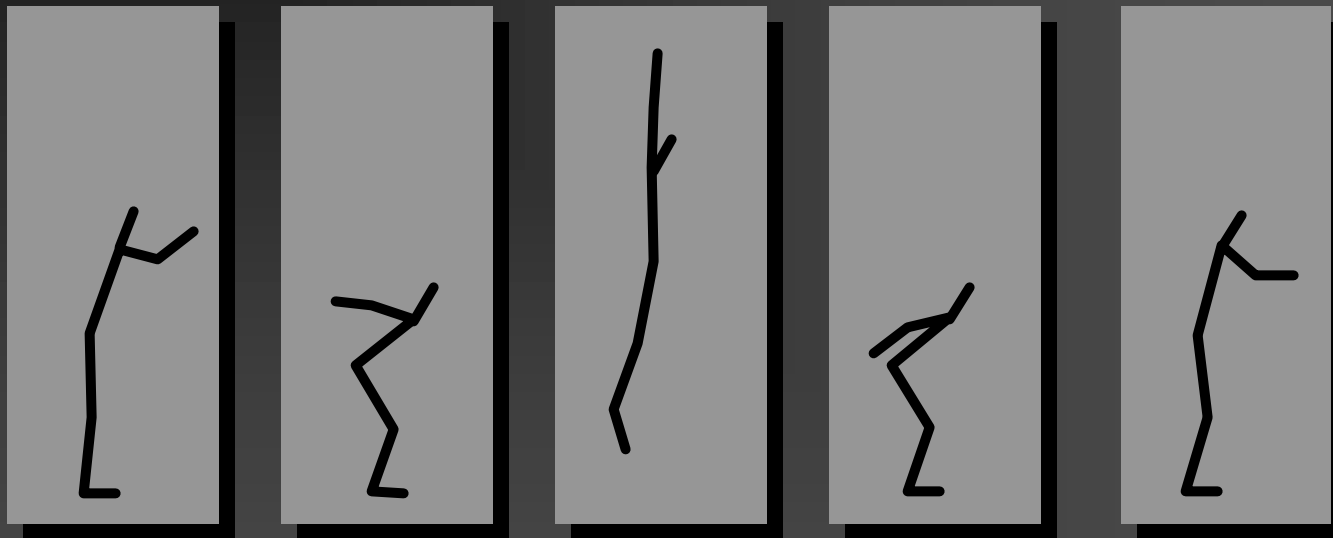
- Find a motion that...
 1. Meets any specific requests
 2. Keeps any specific characteristics of the original
 3. Is as similar as possible to the original
- Naturally posed as constrained optimization
 - subject to meeting the constraints (1 and 2)
 - minimize some objective (3)

Spacetime Constraints



- Consider all constraints simultaneously
 - NOT frame at a time
- Solve for motions
 - “best” motion that meets constraints

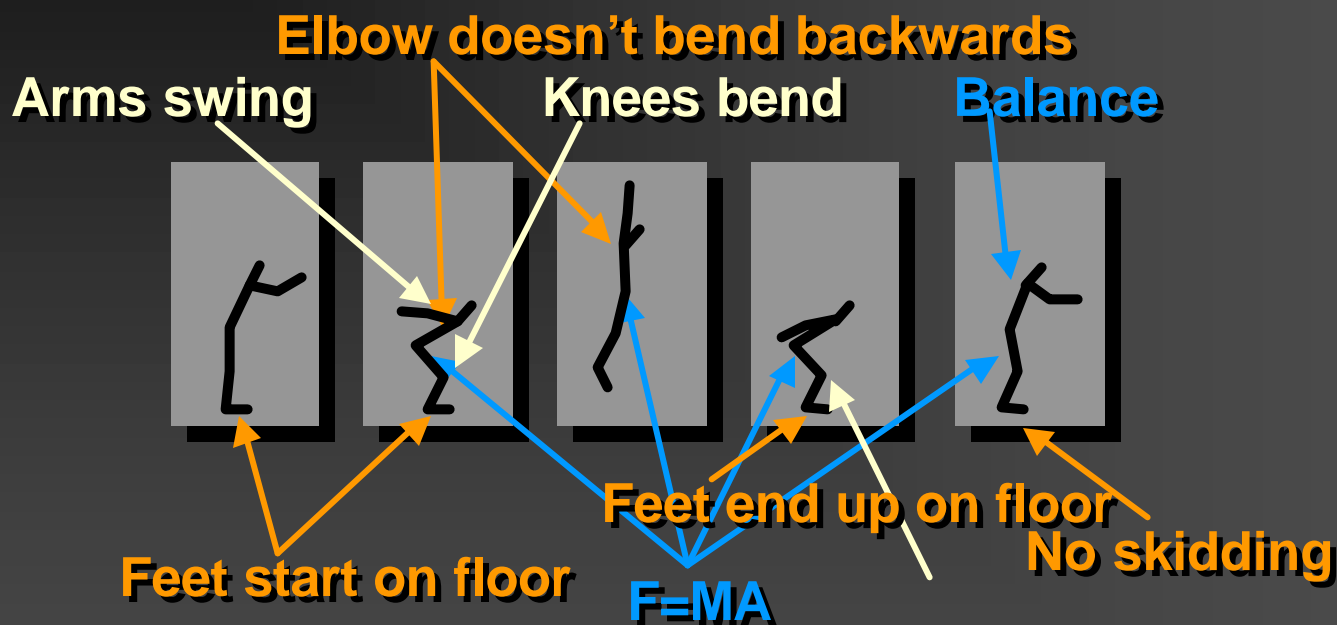
What makes a jump a jump?



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What makes a jump a jump?



Geometric Constraints

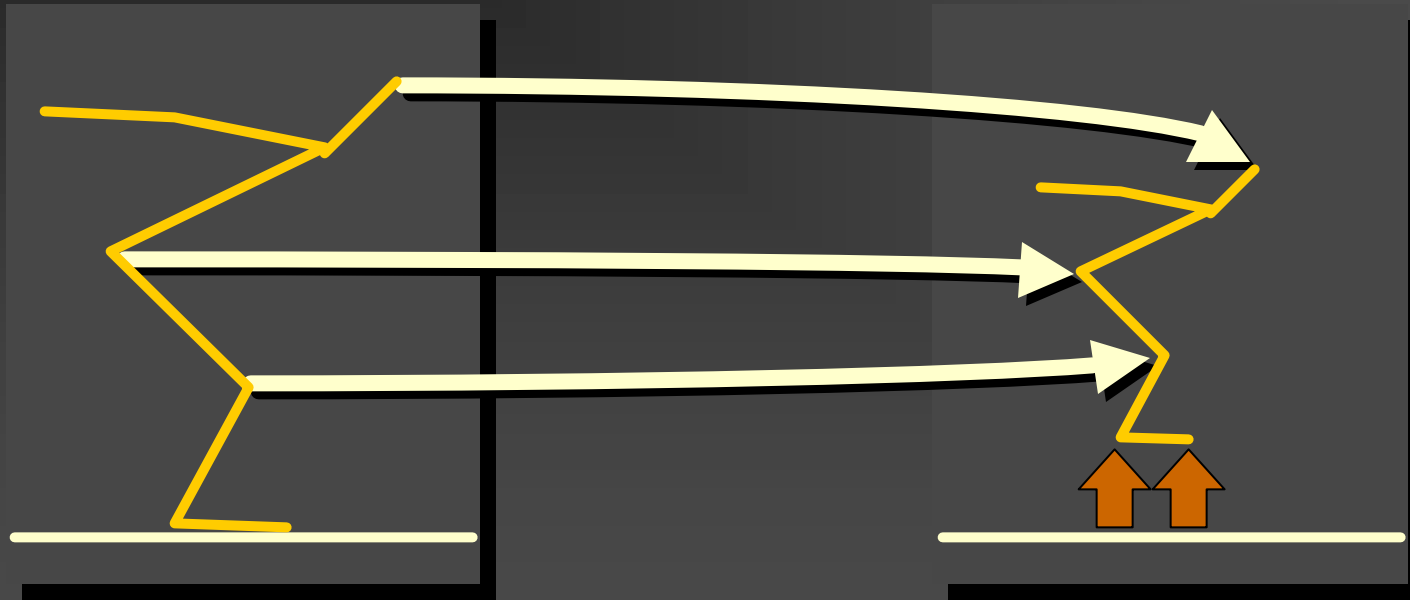
Signal Characteristics

Other Constraints

- implement as constraints
- get from signal matching
- could be added later

Basic Idea 1: Constraints

Exact parameter values may not be important



Geometric constraints often are important

Basic Idea 2: Frequency Content

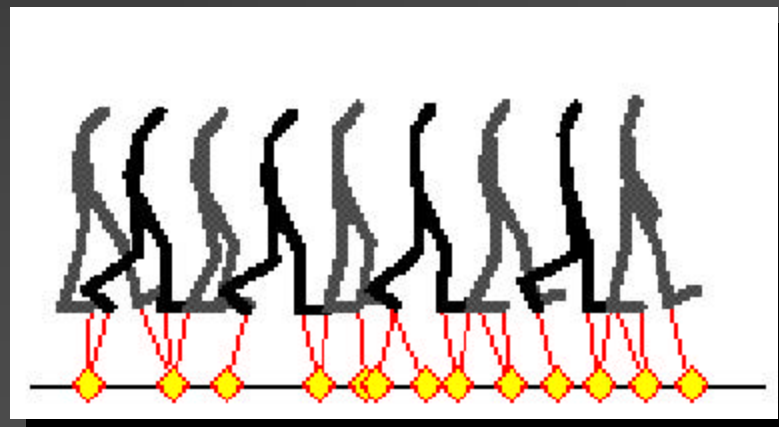
- High frequencies (abrupt changes) are significant and noticeable
- Altering high-frequencies changes motions
- Adaptations should avoid disturbing high frequencies

Retargetting Recipe

1. Define Constraints



2. Apply to new character



Retargetting Recipe

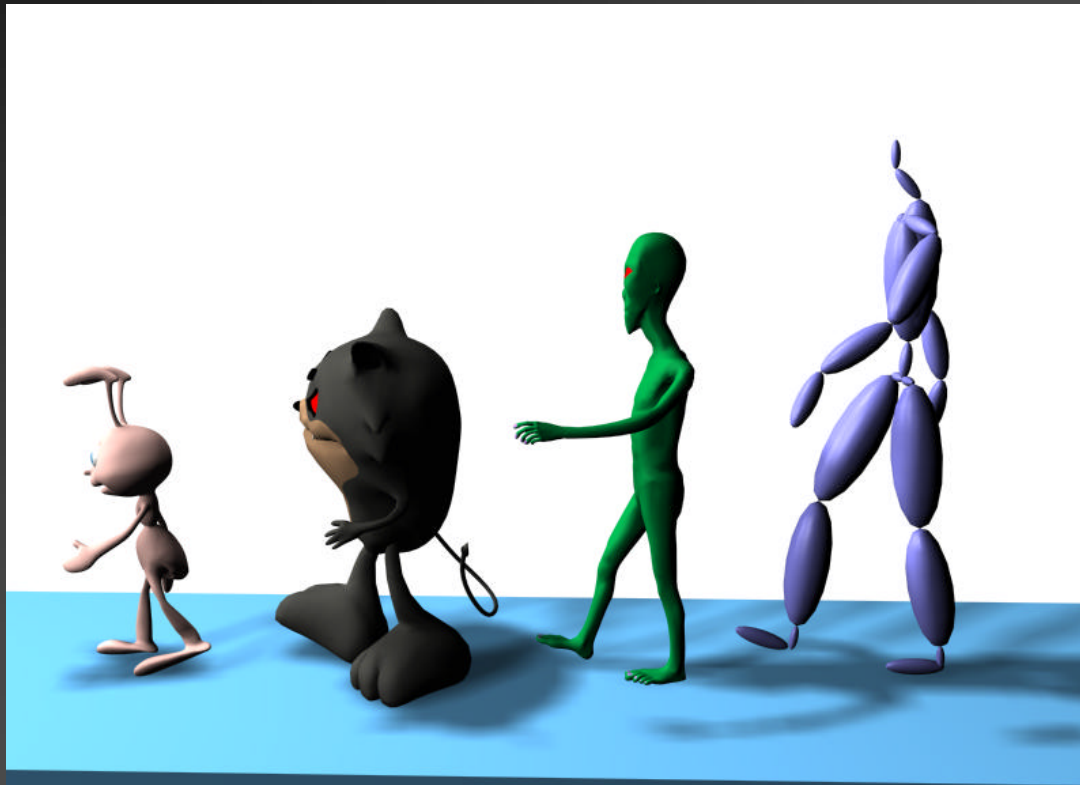
3. Approximate Answer



4. Solve constraints
(band-limited adaptation)



Retargetting Results



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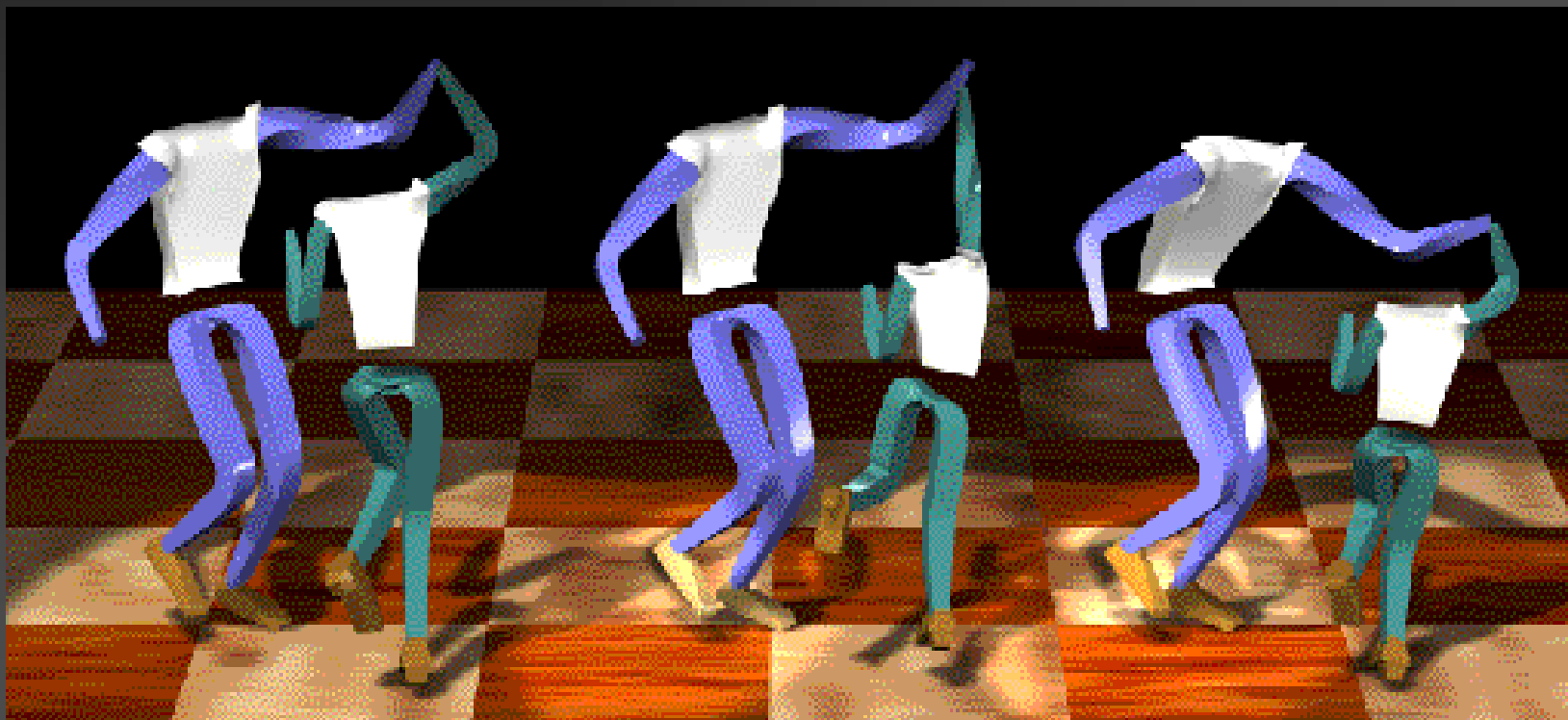
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Some successes

Original
Motion

Adapt Female
Only

Adapt Both

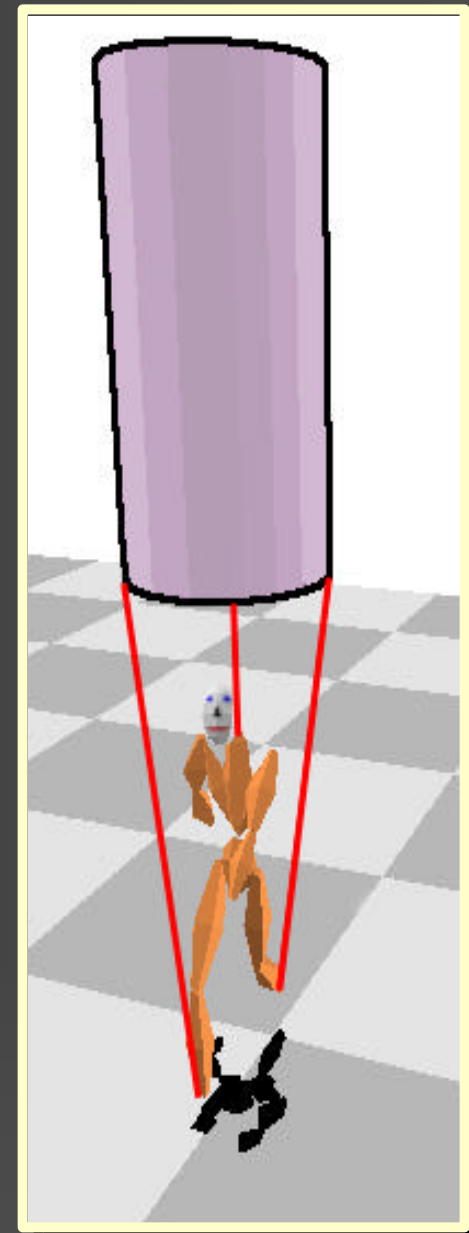


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Characters with Different Structure

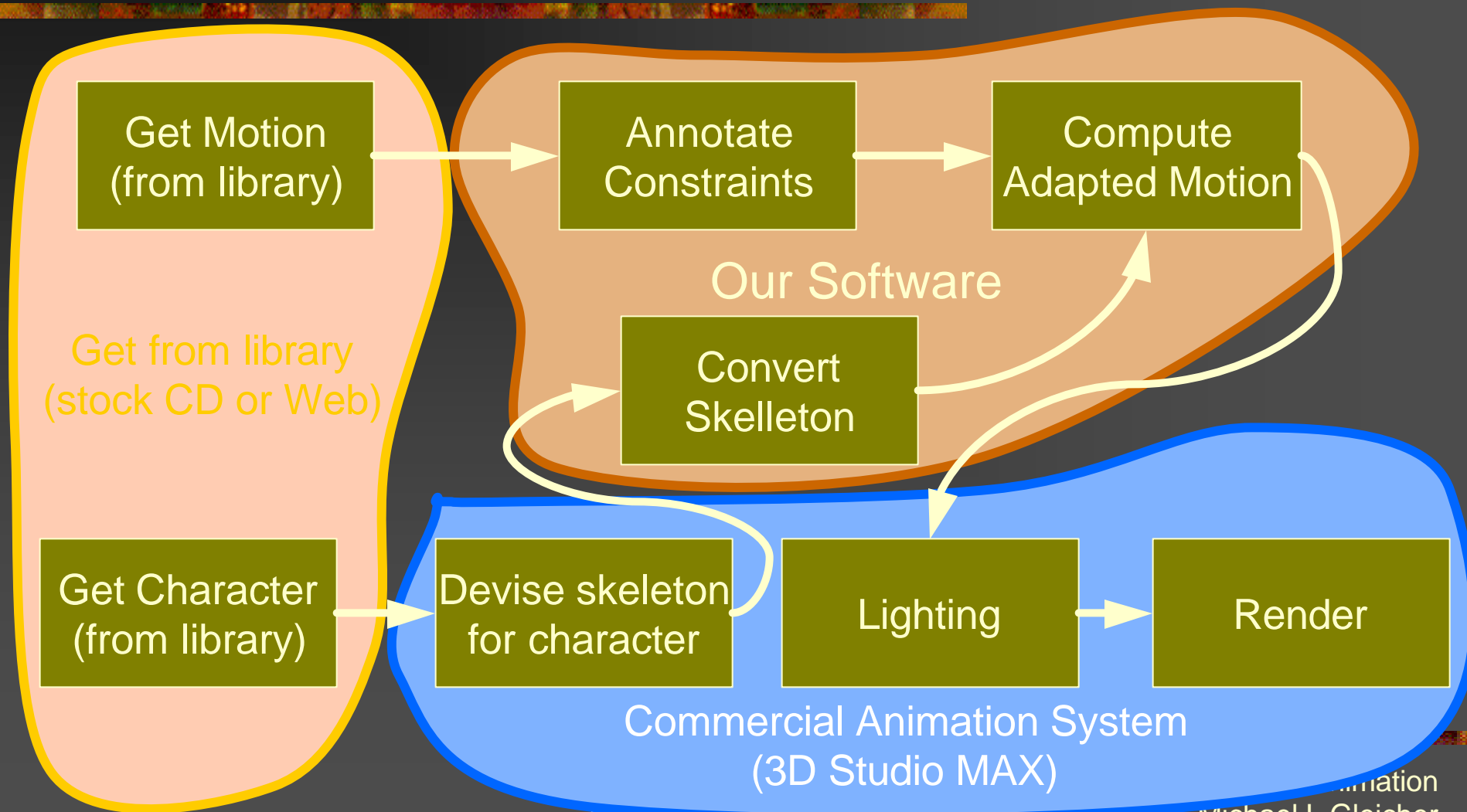
- Creativity vs. Automation
- User defines point correspondences
- Adapt similar structure to same size first
- Different numbers of degrees of freedom
 - least squares (too few)
 - objective (too many)



What does it take to do this?

- Setup and Solve a BIG math problem
 - Non-linear, variational, constrained optimization
- Thousands of simultaneous equations
- Yes, you can do it in real time
 - with some caveats...

How did we do that?



Graphics at UW CS

- Target for growth in the department
- New courses:
 - Introduction to Graphics
 - now taught as CS638, will get new number soon
 - Computer Animation
 - now taught as CS838, will get new number soon
 - Other courses elsewhere
 - Art (comp. anim), ECE (image proc), ...

To Learn More...

- Take Graphics and/or Animation
- Look on the web
 - Hodgkin's motion overview in Scientific American
 - "Why Files" introductory article
 - A lot of stuff is on the 838 Web from last year (access from my home page)