

# Animation by Adaptation

## Tutorial 2: Motion Editing



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# Outline

## Talk #1: Basics

- ✍ What is character animation?
- ✍ How do we represent motion?
- ✍ Where does motion come from?
- ✍ What is Motion Adaptation about?

## Talk #2: Problems in Motion Adaptation

- ✍ Constraint-based Motion Adaptation
- ✍ Spacetime and PFIK+F approaches
- ✍ Lurking Issues
- ✍ Online problems



# Where we left off...

- ✍ I want to make animation
  - ✍ But I'm not an Artist!
- ✍ Motion is the central problem
- ✍ Motion is a map from time to pose
  - ✍ Articulated figures / rotations
- ✍ Several ways to create it
- ✍ But how to modify it...



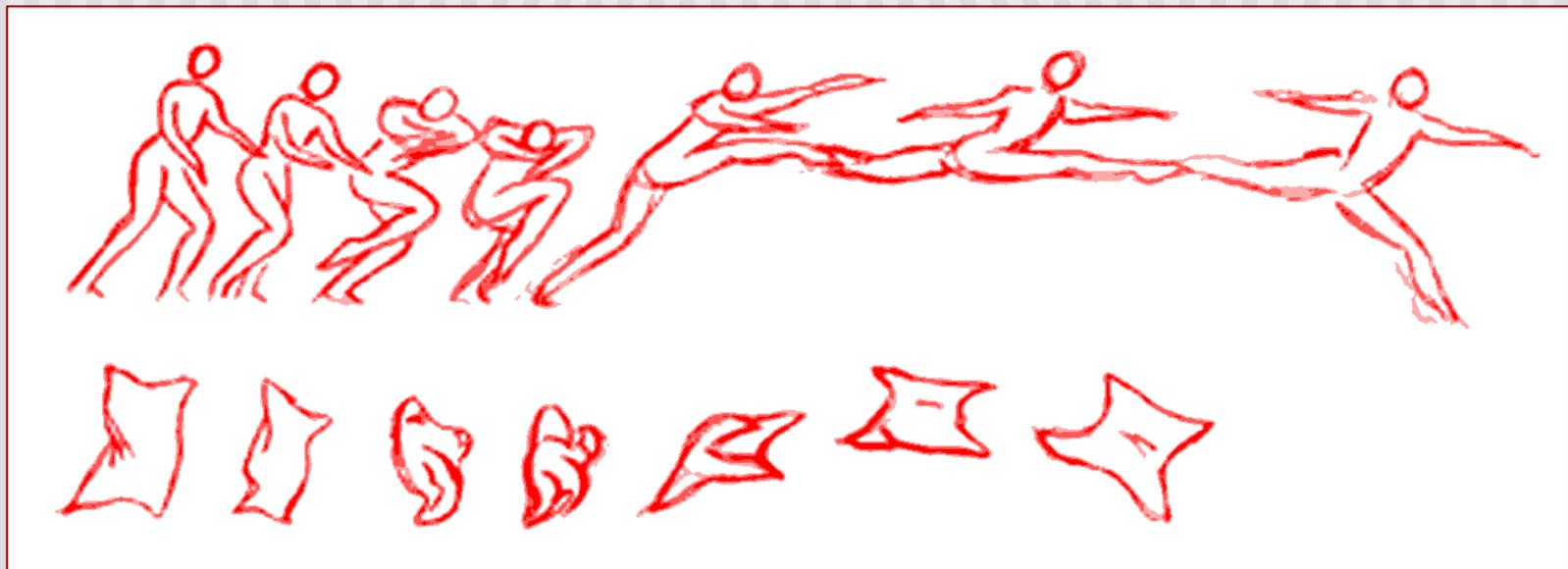
# Why change a perfectly good motion?

- ✍ Animation: bring something to life
  - ✍ means we want to change *something* about the performance
- ✍ Actor vs. character
- ✍ Restrictions of realism
- ✍ Performers aren't perfect
- ✍ Need for usable data (loops, reference poses, ...)
- ✍ Studio is not virtual world
- ✍ Motion re-use
  - ✍ sometimes we are stuck with what we have

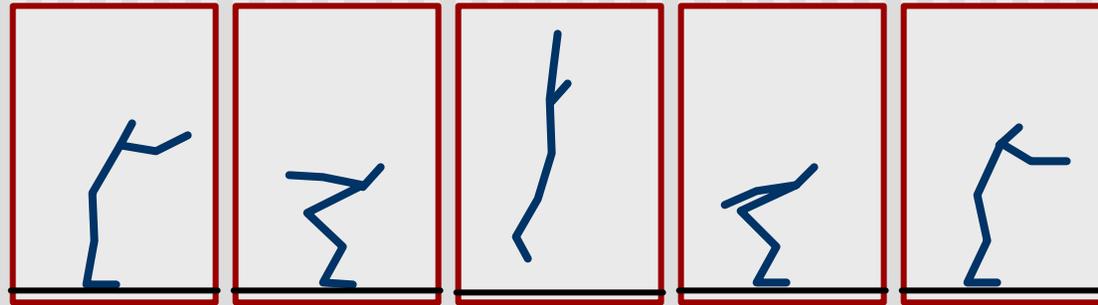


# The Plan...

- ✍ Create animation by re-use
- ✍ Easier to beg, borrow, steal, buy, ...

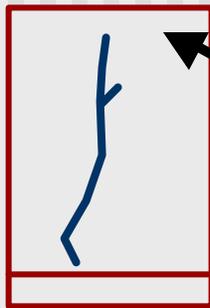


# The Challenge...

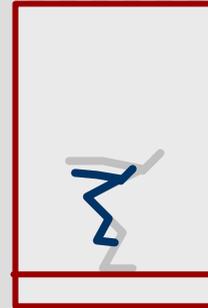


Specific Action

Specific Character



hand is  
not here



different sized  
character  
doesn't fit

***Edit*** motion to  
meet new needs

***Retarget*** motion to  
new character



# Motion Editing

- ✍ Once you have the motion, now what?
- ✍ Change something about a motion
  - ✍ Character
  - ✍ Environment
  - ✍ Mood
  - ✍ Action
  - ✍ ...



# Properties of Motion

What do we change? What do we preserve?

## High Level Properties

Describe motion in abstract terms

Make it angrier!

But keep the graceful dignity.



**The art of motion editing  
is crossing this chasm.**

## Low Level Properties

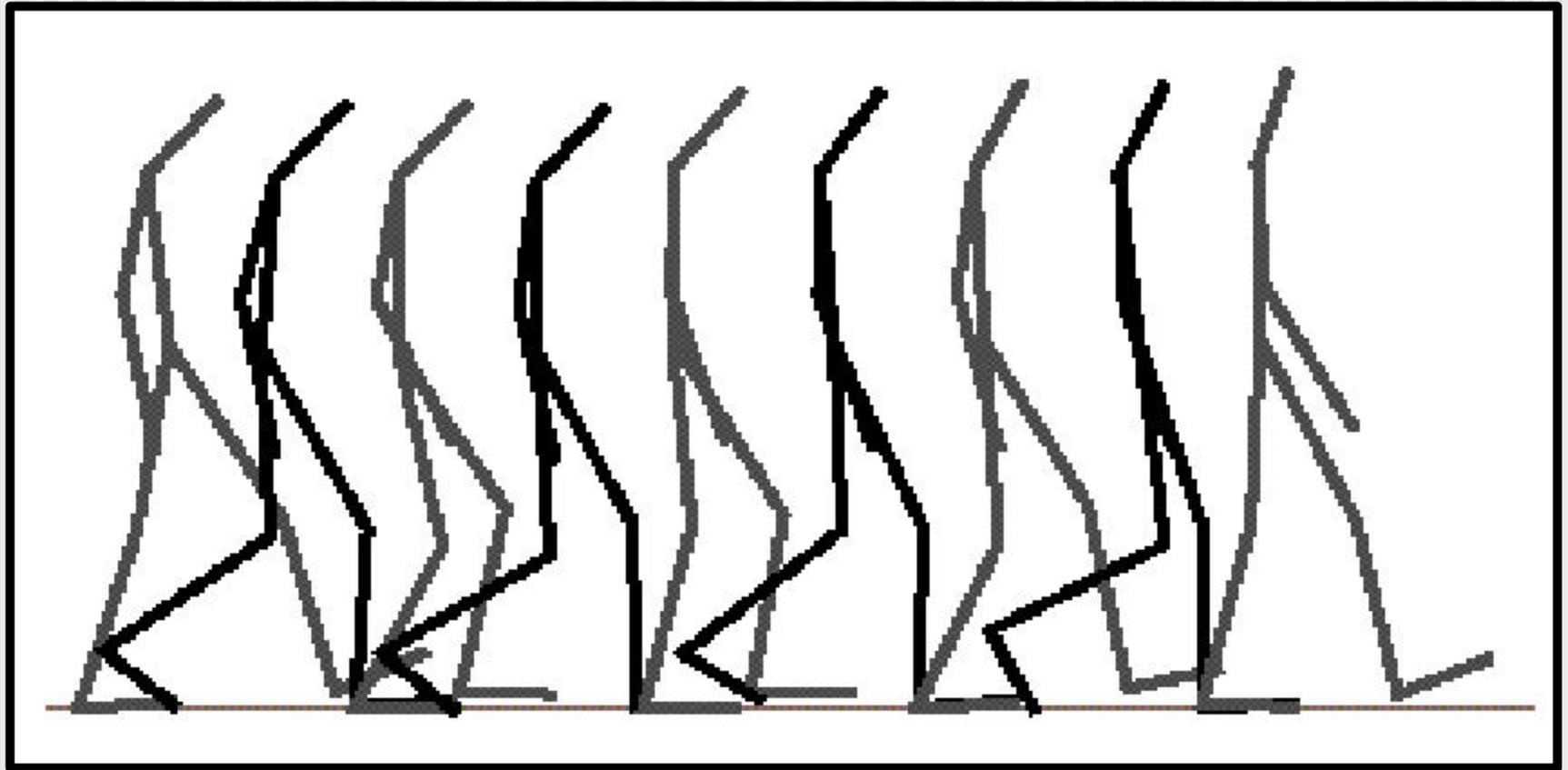
Have to control small details

Poses, joint angles, timing, ...

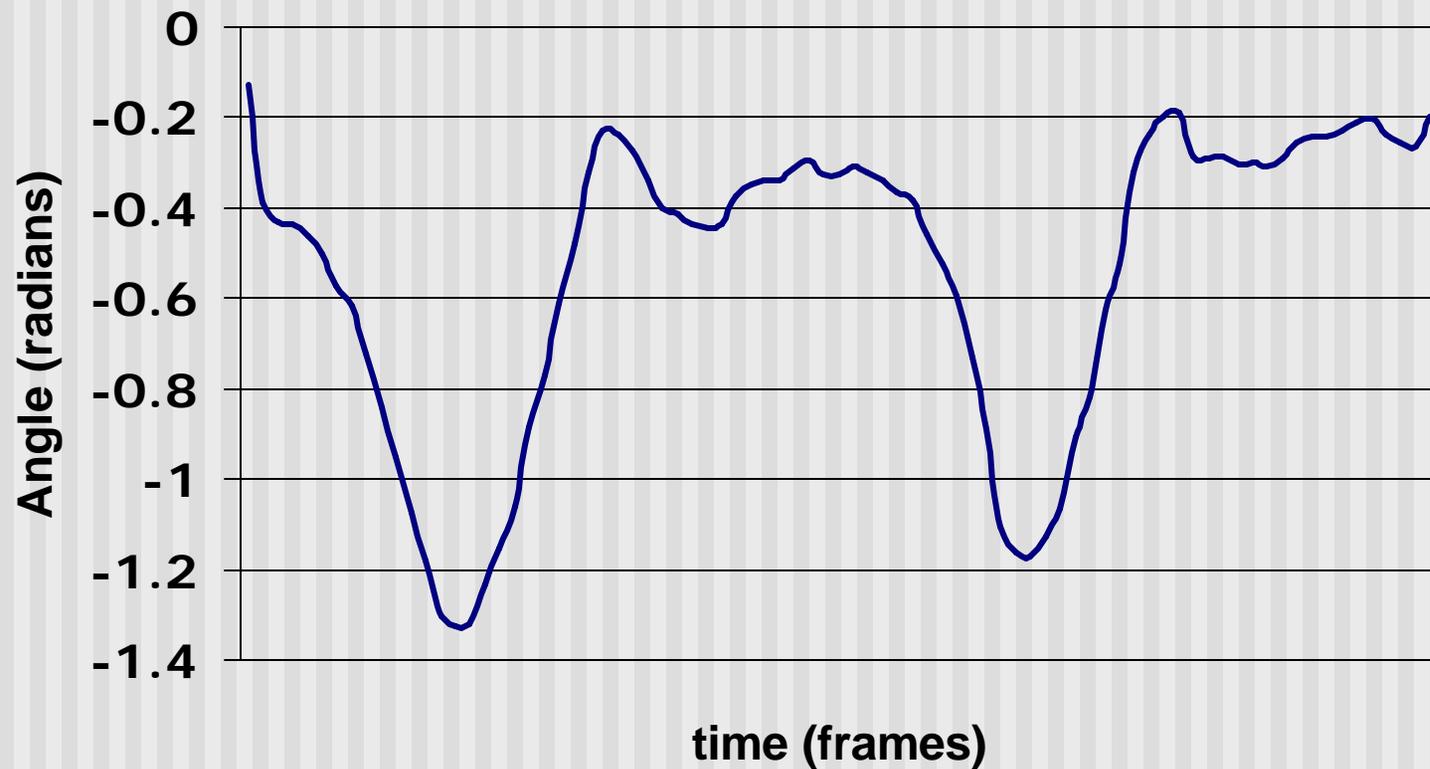
Not how we talk about motions.



What makes *this* walk *this* walk?



# Quiz: Name That Motion!



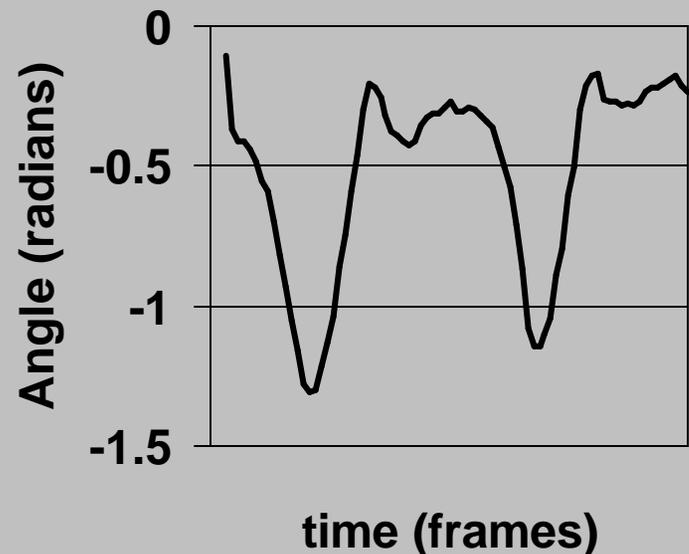
# A Motion Curve

- ✂ Where's the "Mike"?
- ✂ Where's the sad?
- ✂ Where's the walk?
- ✂ Where's the no skate?

How can we preserve (or alter) these properties if we can't see them?



**Motion Curve:  
Left Knee from Walk**



# 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)



# What kinds of constraints

## Geometric

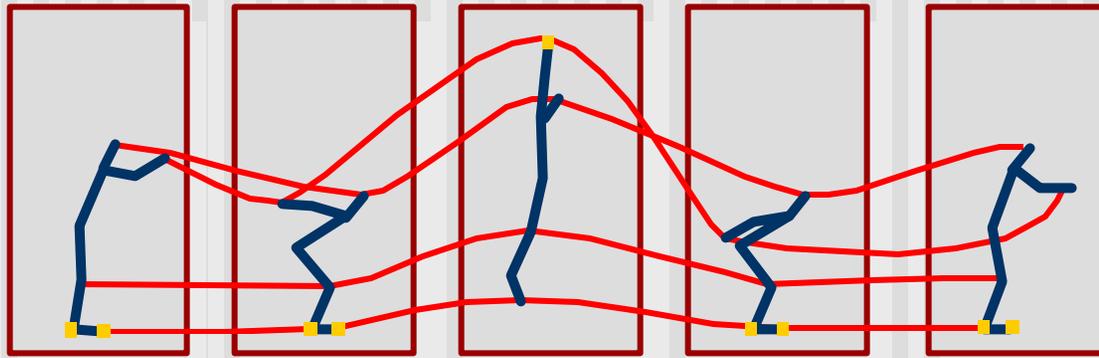
-  At some instant, something must be true
-  Foot on floor, hand on doorknob, no self-intersection, ...

## Temporal

-  Don't introduce discontinuities
-  Preserve momentum



# Spacetime Constraints



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



# Spacetime Basics

- ✍ Find  $\mathbf{m}(t)$ 
  - ✍ A variational problem
- ✍ Such that a metric is optimized
  - ✍ Minimize  $g(\mathbf{m}(t))$ , typically an integral
- ✍ Subject to the constraints being met
  - ✍ Of the form  $\mathbf{c}(\mathbf{m}(t_i)) = k$
  
- ✍ Represent  $m(t)$  as B-Spline
- ✍ Use Sequential Quadratic Programming



# "Original Spacetime"

*Witkin and Kass, SIGGRAPH '98*

- ✍ Attempt to synthesize physically correct motions
- ✍ Metric: minimize energy usage
- ✍ Constraints
  - ✍ Obey Newton's laws
  - ✍ Initial and Final Poses



# Spacetime Motion Editing

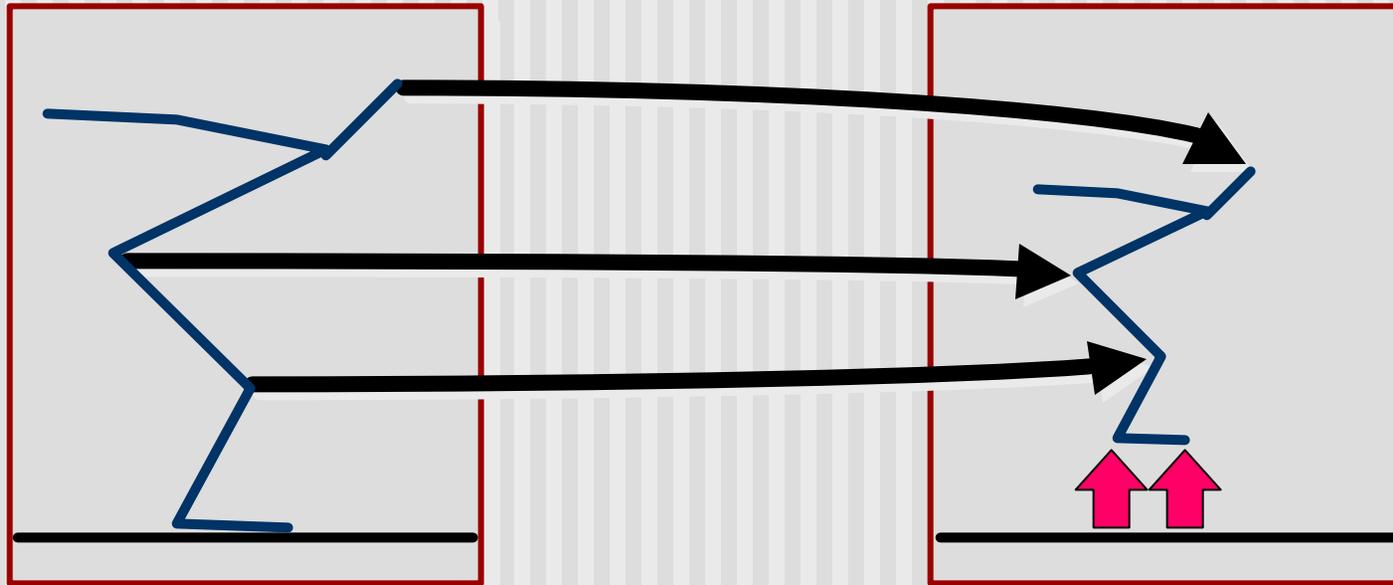
*Gleicher '97, '98*

- ✍ Make tractable for complex motions
- ✍ Solve for changes to motions
  - ✍  $\mathbf{m}(t) = \mathbf{m}_o(t) + \mathbf{d}(t)$ , find  $\mathbf{d}(t)$
- ✍ Pick form of  $\mathbf{d}(t)$  to create temporal constraints (band-limited)
- ✍ Objective selected for ease of solution
- ✍ Modified SQP, non-linear least squares



# Basic Idea 1: Constraints

**Exact parameter values may not be important**



**Geometric constraints often are important**



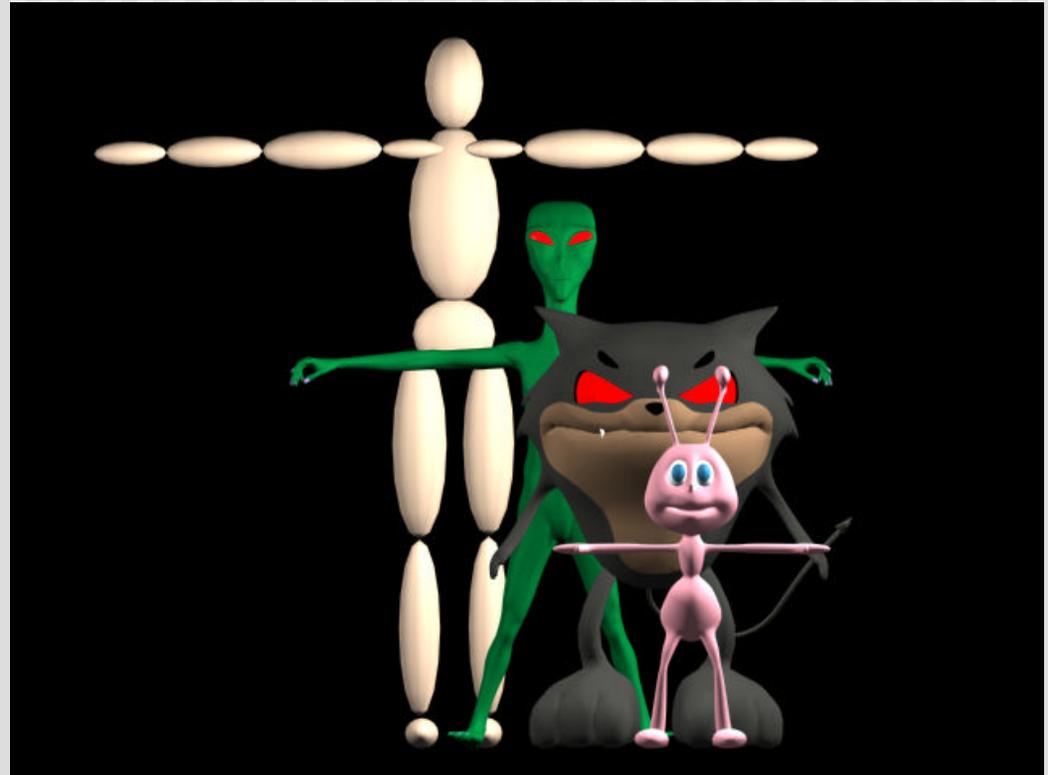
# Basic Idea 2: Frequency Content

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

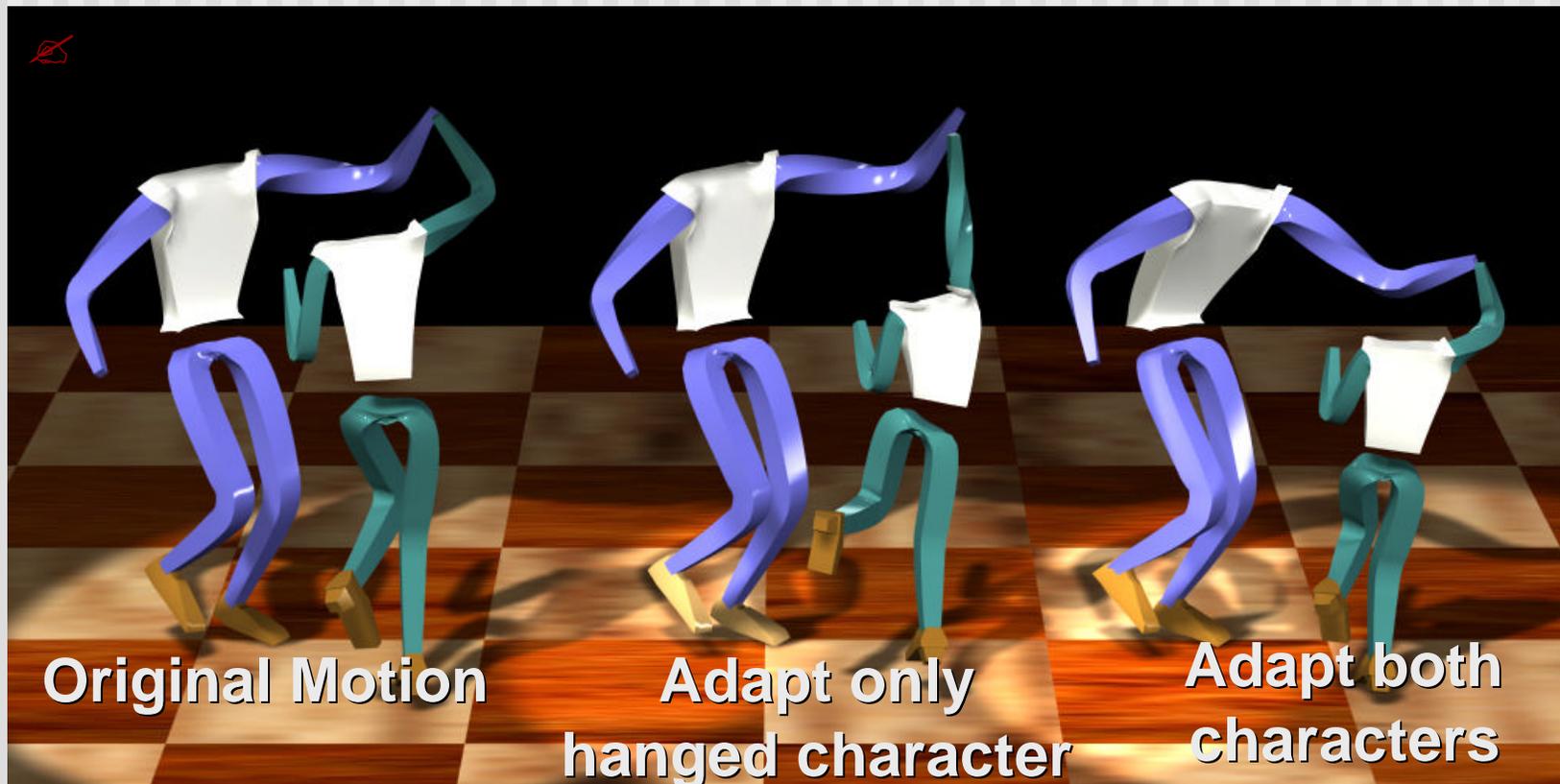


# Retargetting Motion to New Characters

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



# What properties to preserve? What is "important"?



- More change to pose, less change to motion

# Retargetting Recipe

1. Define Constraints



2. Apply to new character



# Retargetting Recipe

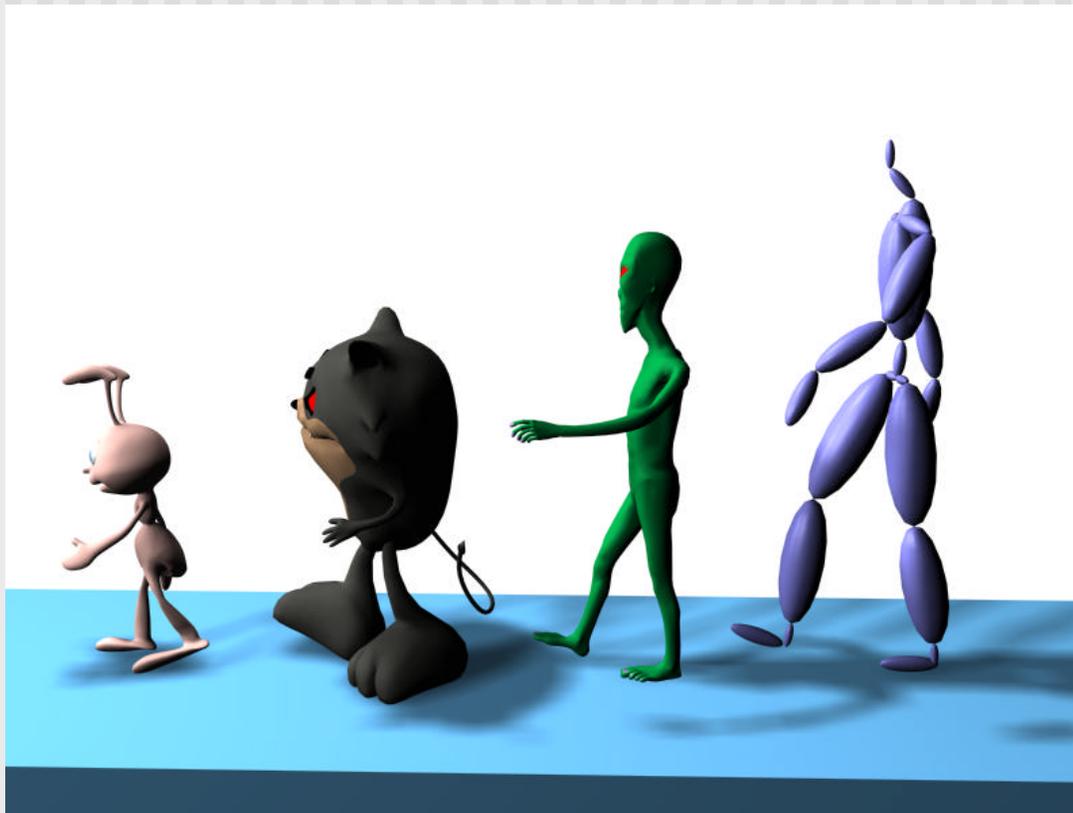
3. Approximate Answer



4. Solve constraints  
(band-limited adaptation)



# Retargetting Results



# Want Better Results? Devise Better Constraints!

- ✍ Self-intersection
- ✍ Higher-level properties
  
- ✍ Style ?????
- ✍ Form ?????
- ✍ ?????



# Collision Constraints



✎ Get your hands out of your pockets!



# Constraints don't fix everything...

System does well

This arm doesn't go through the body, but...



# Other Editing Tricks

- ✍️ Constraint-based Editing

- ✍️ Motion Path Editing

  - ✍️ Abstract the “path” of a motion

  - ✍️ Alter the path, preserve details of the motion



# Wins and Losses of Spacetime

- ✍ Fast, practical
  - ✍ Linear complexity?
- ✍ Solves real problems
- ✍ Flexibility in:
  - ✍ Spatial Constraints
  - ✍ Objective Functions ?
  - ✍ Temporal Constraints ?
- ✍ Widely applicable
- ✍ Nice results
- ✍ Hard to implement
- ✍ Poor integration
- ✍ Off-line
- ✍ No guarantees
- ✍ Spatial constraints not enforced
- ✍ Flexibility not exploited
- ✍ Rely on constraints



# Is there an alternative?

- ✍ Need to deal with spatial and temporal constraints
- ✍ Don't want the messiness of "whole motion" computation
- ✍ Handle spatial and temporal constraints separately!



# Per-Frame IK + Filter (PFIK+F)

- ✍ IK per frame to solve spatial constraints
  - ✍ But this messes up temporal constraints
- ✍ Filter changes to enforce temporal constraints
  - ✍ But this messes up spatial constraints
- ✍ Iterate until converges, or ...



# PFIK+F vs. Spacetime

- ✍ Fast, practical ✍ Yes! (requires fast IK)
- ✍ Solves real problems ✍
- ✍ Flexibility in: ✍ Yes!
  - ✍ Spatial Constraints
  - ✍ Objective Functions (?) ✍ (depends on IK)
  - ✍ Temporal Constraints (?) ✍ (depends on IK)
- ✍ Widely applicable ✍ (limited, unexplored)
- ✍ Nice results ✍ Yes!
  - ✍ Um, it's a matter of taste, and IK quality



# PFIK+F vs. Spacetime

- ✍ Use standard pieces!
- ✍ Use standard pieces!
- ✍ Choice in which last
- ✍ Solve spatial constraints last
- ✍ Need good IK
- ✍ Hard to implement
- ✍ Poor integration
- ✍ Off-line
- ✍ No guarantees
- ✍ Spatial constraints not enforced
- ✍ Flexibility not exploited
- ✍ Rely on constraints



# My PFIK+F solver

- ✍ Use pieces I have lying around
- ✍ Non-linear optimizing solver for IK
- ✍ FIR linear filters for temporal constraints
- ✍ Propagation of results for temporal coherence

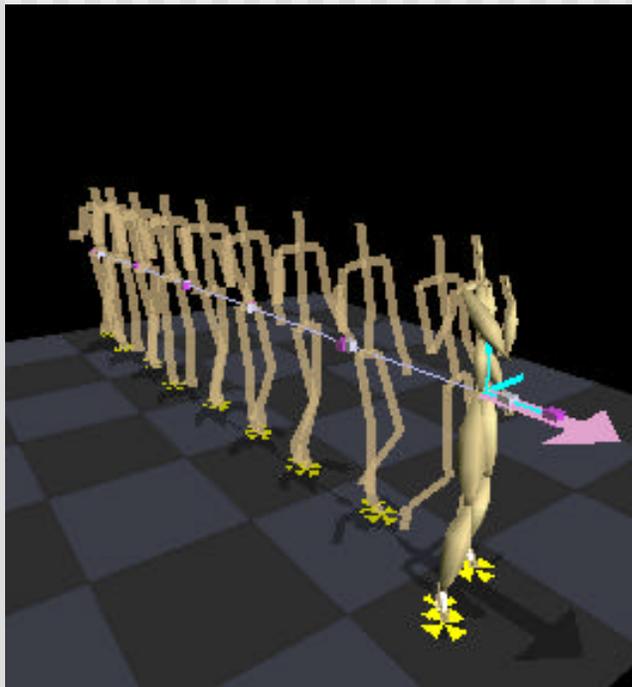


# Downsides of PFIK+F?

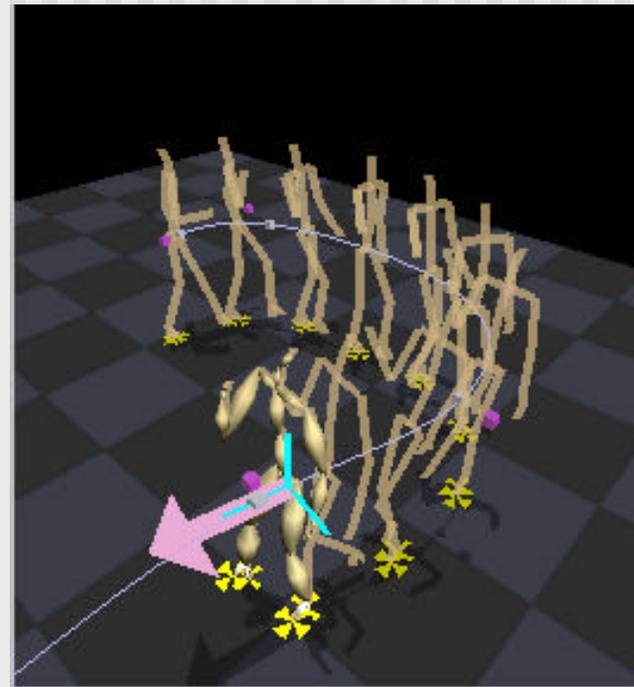
- ✍ No global decisions
  - ✍ Doesn't handle "don't cares" as well
  - ✍ Order dependence
  - ✍ No interframe constraints
- ✍ Reliance on quality of IK solver
- ✍ Not necessarily faster (or slower)



# The Idea



Original Motion



New Path

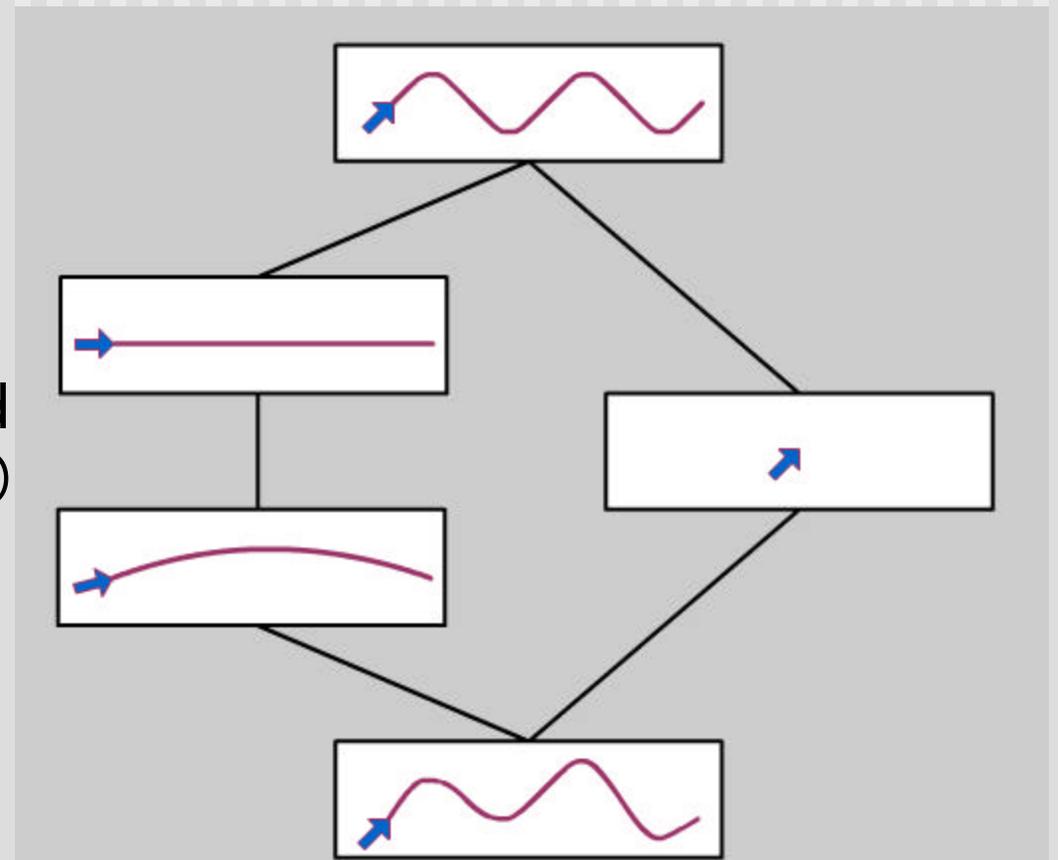


# What is Path Editing?

Factor Motion into  
Path And Detail

Edit Path as Needed  
(use curve editing tools)

Apply Detail to  
new Path



# Why Edit Paths?

*(because previous work can't do it)*

- ✍ Can't Capture All Possibilities
- ✍ Can't Synthesize All Styles
- ✍ Can't Simulate Complex Motions
- ✍ Current Editing Tools Don't Apply
  
- ✍ Need tools for sculpting motion  
INTERACTIVELY!
- ✍ Need easier to implement tools!



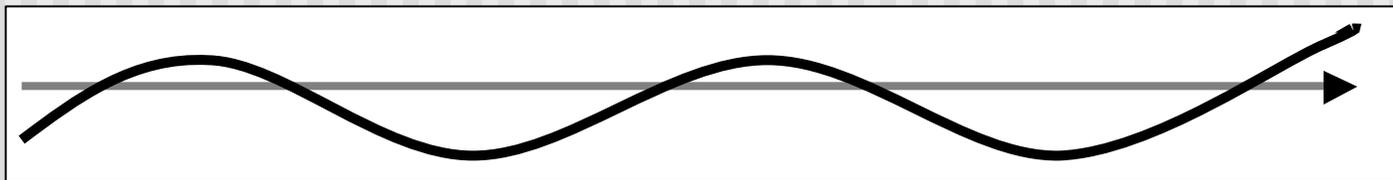
# How to Edit a Path

- ✍ Determine what the path is
  - ✍ Easy to manipulate, conceptual representation
- ✍ Factor motion into path and detail
- ✍ Edit the path
- ✍ Put path and detail back together
- ✍ Clean up the details



# What is a Path?

- ✍ An abstraction of the motion
- ✍ How would you describe it?
  - ✍ Non-exact (straight isn't exactly a line)
- ✍ Open to interpretation
  - ✍ Drunk walking in a straight line?
  - ✍ Walking on a slalom course?



# Orientations

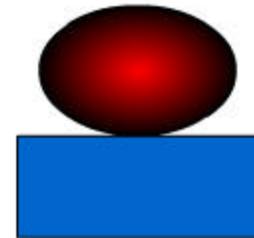
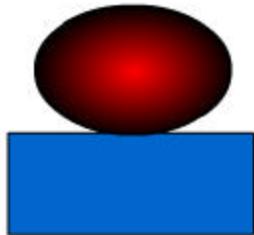
- ✍ Store orientation relative to path
  - ✍ Forward is important
  - ✍ Eastward is less-important
- ✍ Use forward facing frame
  - ✍ not Frenet Frame
  - ✍ Down is Down (gravity is absolute)
  - ✍ No banking
- ✍ Path is a moving co-ordinate system



# Path Editing is just... A Moving Tile on the Floor

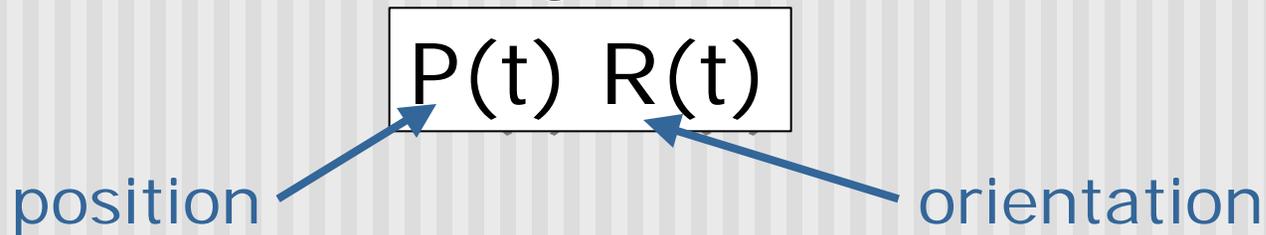
- ✍ Path is a moving floor tile
- ✍ Character moves in place
  - ✍ Small movements, relative to tile

Bouncing in a straight line - path is a line

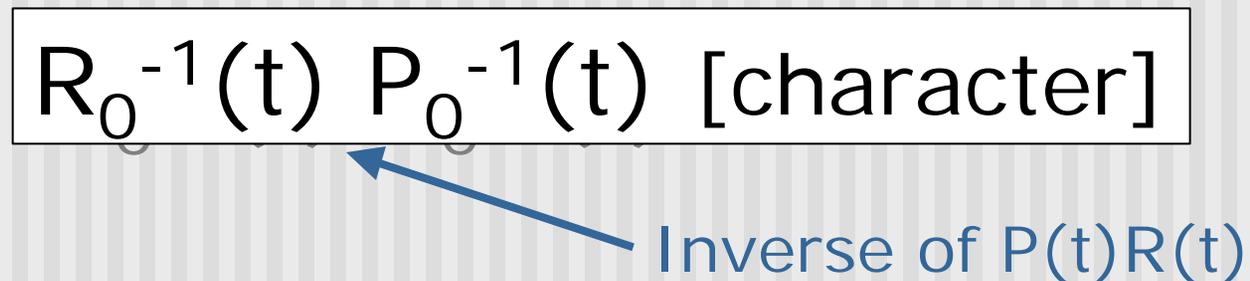


# Path Mathematics...

- ✍ The "Floor Tile" is a moving coordinate system



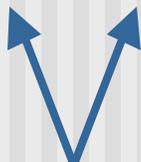
- ✍ Multiply by the inverse to put character into coordinate system

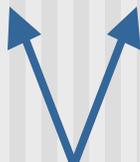


# Wait! Isn't this just...

- ✍ Place some extra transformations above the character's root

$P(t)$   $R(t)$   $R_0^{-1}(t)$   $P_0^{-1}(t)$  [character]

  
New path  
Coordinate  
System

  
Inverse of  
old path  
Coordinate  
System

  
Details of  
motion  
unchanged



# In Practice...

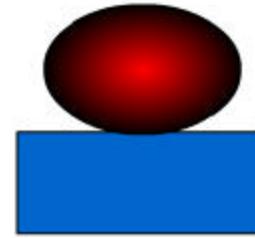
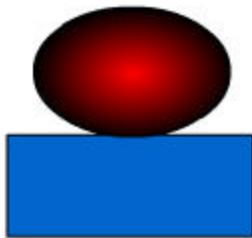
- ✍ Fit “smooth” spline
  - ✍ Uniform, cubic B-Splines
  - ✍ Least-Squares Fit
  - ✍ Sample initial inverses
- ✍ Pick representation for ease of manipulability
  - ✍ Move control points
  - ✍ Direct manipulation by least-squares
- ✍ Doesn't always get a good path



# The Importance of Timing

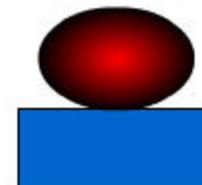
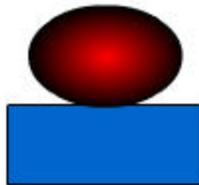
- ✍ Path is temporal AND geometric
- ✍ Timing may not match parameterization

Linear Motion, Non-Linear Timing  
Linear Path, Linear Parameterization

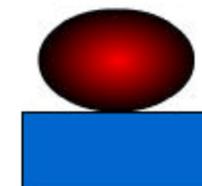
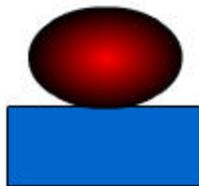


# Closest-point Parameterization

Linear Motion, Non-Linear Timing  
Linear Path, Linear Parameterization



Linear Motion, Non-Linear Timing  
Linear Path, Closest-Point Parameter



# Details:

## Arc-Length Parametrization

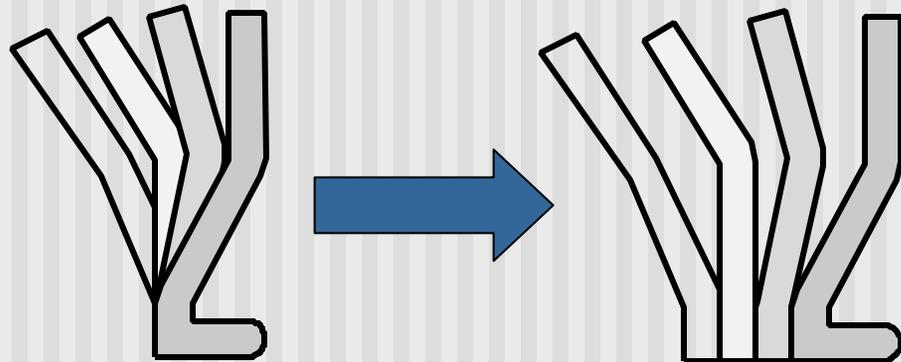
- ✍ Time is fixed (not resampling)
  - ✍ Can't generate new steps!
- ✍ Stretching path may not make sense
- ✍ Keep arc-length the same
  - ✍ (or change it explicitly)



# Details of Motions: Constraints

- ✂ Edits do not preserve geometric constraints

- ✂ Foot skate!



- ✂ Clean up constraints

- ✂ Pick one place per footplant

- ✂ Spacetime solve

- ✂ IK on each frame, then filter



# Animation by Adaptation!

- ✍ Motion editing enables libraries of motion
- ✍ As editing evolve, motion re-use becomes more possible
- ✍ Increasingly practical to create motions by adapting old ones



# What's next?

## *Graphics group projects*

- ✍ Video Motion Capture
- ✍ Stylized rendering
- ✍ Virtual Videography
- ✍ User Interfaces for 3D Applications
- ✍ Visualization



# What's next?

## ***Graphics group projects***

- ✍ Practical issues in Motion Editing
- ✍ Mix-n-match motion
  - ✍ Transitions
  - ✍ Motion Databases
- ✍ Dynamic Applications
- ✍ Automatic Constraint Detection
- ✍ Improved Motion Retargetting



# Thanks!

- ✍ UW Graphics Gang
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