# Animation by Example

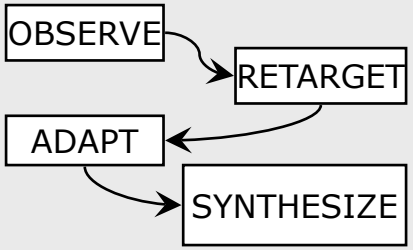
Michael Gleicher
and the UW Graphics Group
University of Wisconsin- Madison
www.cs.wisc.edu/~gleicher
www.cs.wisc.edu/graphics

# Animation from Example?

- Animation is useful!
  - Expressive, powerful, communicative, …
  - Video, film, virtual environments, games, …
- Motion is hard!
  - Subtle, difficult to characterize, …
  - Lots of data, …
- Good motion is precious!

**If we can’t get new motions, we need to make use of existing ones!**

# Talk Roadmap




**Animation from Observation:**

How do we get good motions?

**Motion Retargetting:**

How do we use (and re-use) motions?

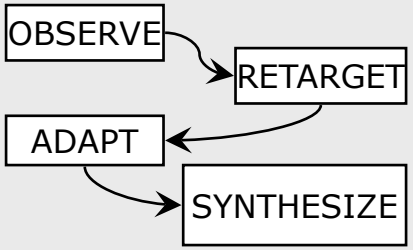
**Animation by Adaptation:**

Can we be adept enough at changing motion that re-use really is an option?

**Animation by Example:**

Can we synthesize new motions based on what we've seen already?

# Research Roadmap




**Animation from Observation:**

Motion Capture 1998-2000

**Motion Retargetting:**

Motion Retargetting 1998

Constraint Editing 1997-2000

**Animation by Adaptation:**

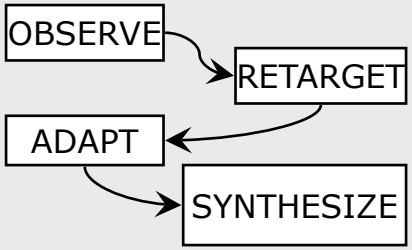
Path Editing 2001, 2003

Footskate Cleanup 2002

**Animation by Example:**

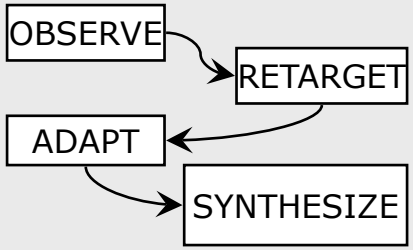
Motion Graphs, 2002, 2003, …

# Cut to the chase…
# An Example



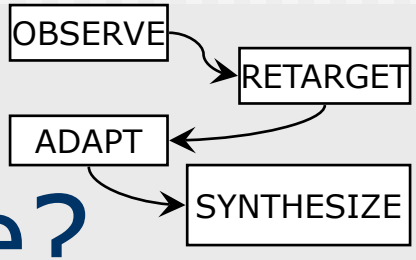

- How do you make a character sneak around?

- Start with some captured motion of a person sneaking around
- Synthesize a new motion of a character "sneaking" somewhere else




# Show sneak video

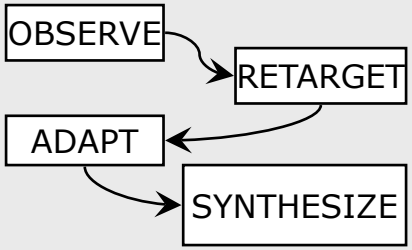
I have no idea why video doesn’t work well in Powerpoint
Play SNEAK.AVI now




# What did you just see?

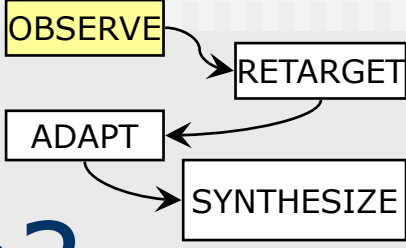
- Small amount of example motion
- Examples of what I want
  - Actions
  - Quality
- Character did something different
  - New path
- Character did it the same way
  - Preserves “style” and “quality”

# How to make a Character "Sneak"?



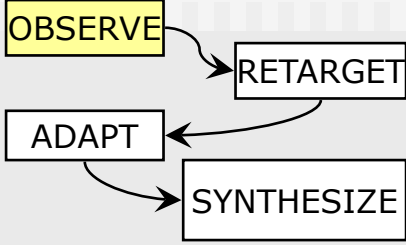

- What is sneaking?

- Hard to define mathematically
- Abstract qualities matter
  - Style, mood, realism, …
- Details matter
  - Feet not sliding on the floor
  - Subtle gestures




# Computer Animation 101:
# How do we get motion?

- Create it manually (keyframing)
  - Common method used for film
  - VERY talent and labor intensive
- Synthesize it by procedural methods
  - Physical simulation, or ad-hoc methods
  - Can’t get exactly what you want
- Capture it from a performer
  - ~~Motion Capture~~
  - Animation from Observation



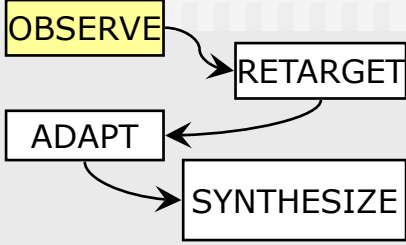

# Motion Capture

**Observations**

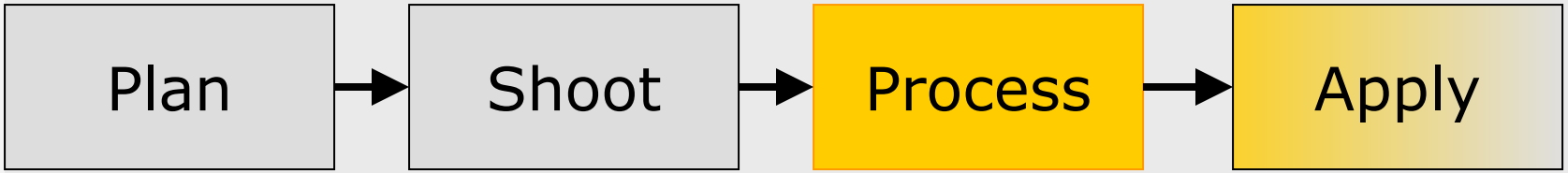
**Computationally Tractable Representations**

Note:

Motion capture means capturing the motion, not the process of Animation by Observation!



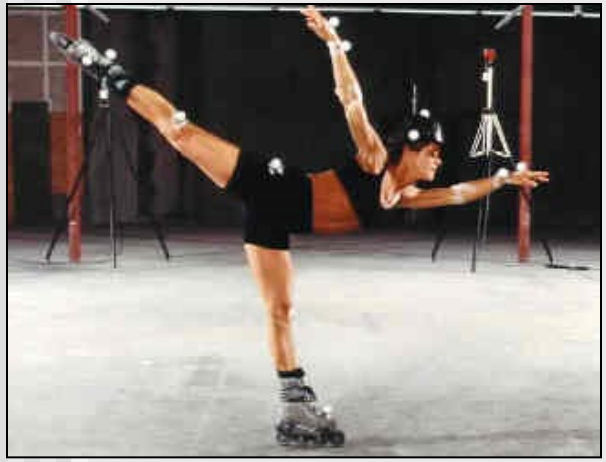

# Mocap Pipeline
## (Animation from Observation)

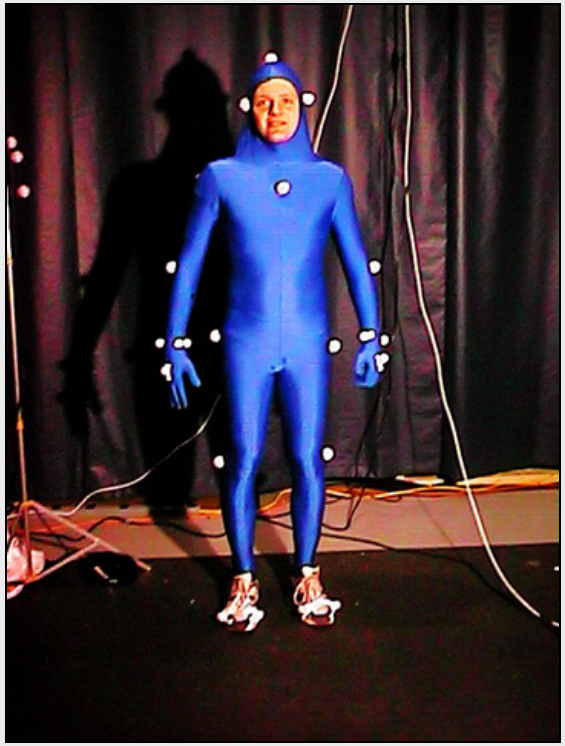


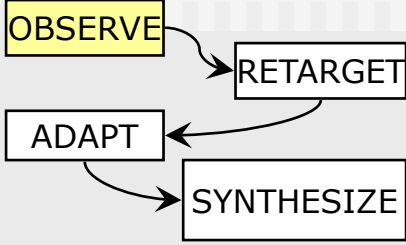

- It's more than just pointing cameras at somebody!
- Getting the observations is just one part of the process
- All examples I will show are from optical motion capture

# Motion Capture Technology: Optical Tracking

- Use markers and special cameras
- Tracking + Math








# Processing Pipeline

Raw Data

identify

clean

cleanup

Clean Marker Data

Solve to Skeleton

Clean Skeletal Data

Define Character

Define Character Controls

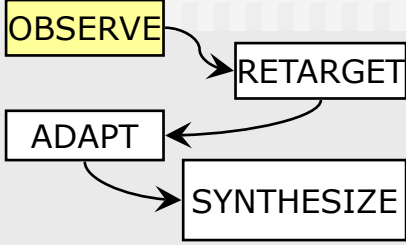
Define Skeleton

Application

Animation Data

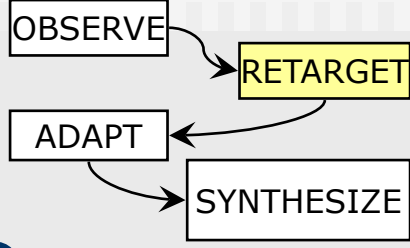
Retargeting& Control Mapping

Clean Skeletal Data




# Why Edit Motion?

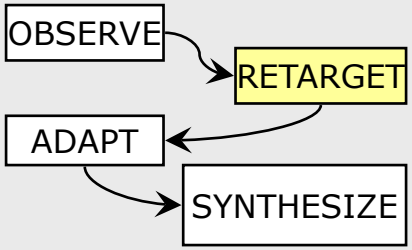
- What you get is not what you want!
- You get observations of the performance
  - A specific performer
  - A real human
  - Doing whatever they did
  - With the noise and “realism” of real sensors
- You want animation
  - A character
  - Doing something
  - And maybe doing something else…




# The General Challenge

- Get a specific motion
  - From capture, keyframe, …
  - Specific character, action, mood, …
- Want something else
- But need to preserve original
  - But we don’t know what to preserve
  - Can’t characterize motion well enough*

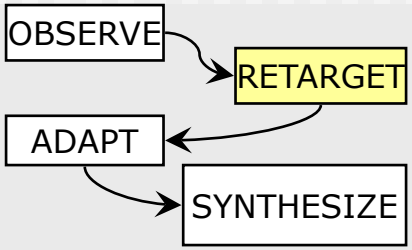
*This is a working assumption of my research.
I’d love to be proven wrong.




# Three Problems

- Where does X live in the data?
  - Where X ∈ {style, personality, emotion, …}
  - The things to keep or add
- Small artifacts can destroy realism
  - Eye is sensitive to certain details
  - Amazing what you can't get away with
    - See Kovar, Schreiner and Gleicher, SCA '02
    - Discussed later in this talk
- How to *specify* what you want

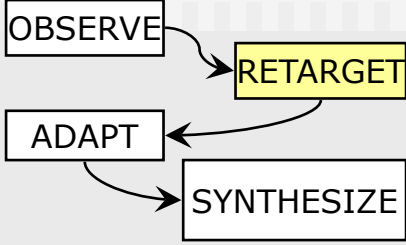
# How do we handle these problems?




- Don't know which details are important!
- Must preserve ALL details
  - Since you don't know what is important
- Need to understand artifacts better

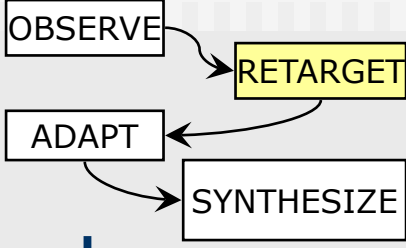
**Motion Capture Animators are conservative:**

**Want *excess* precision just in case!**



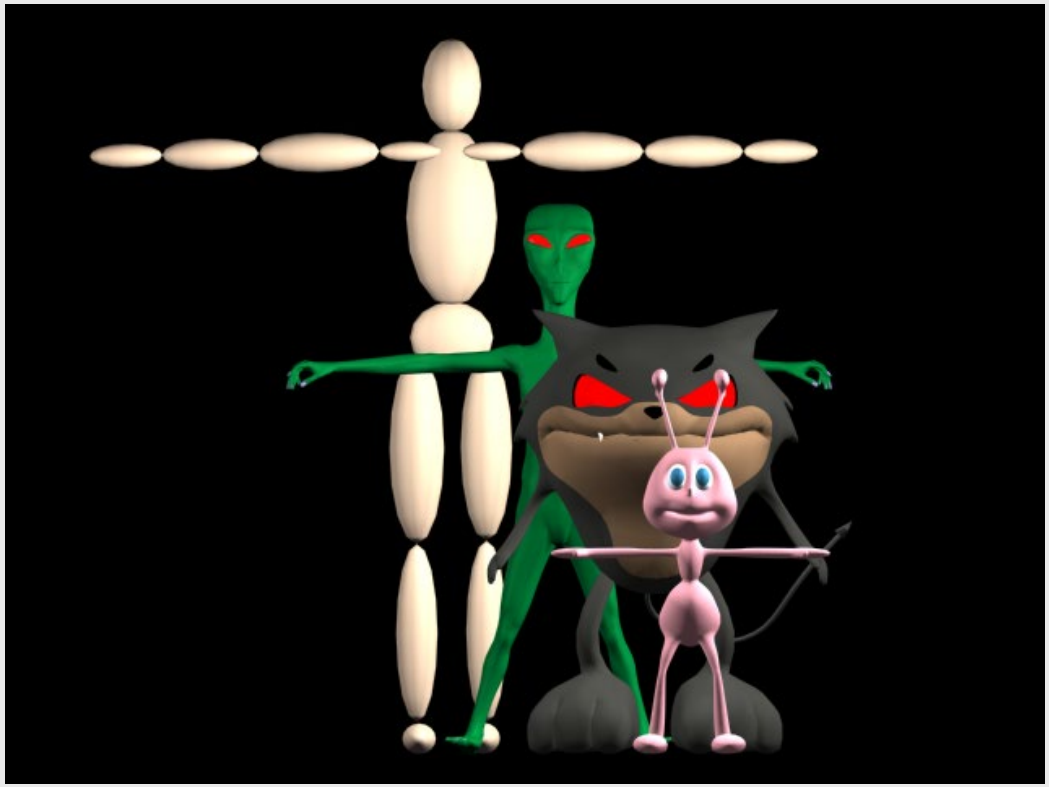

# Another Approach
# Constraint-Based Motion Editing

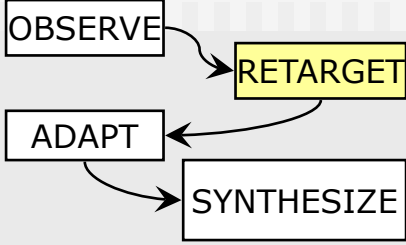
- Identify specific details in motions that must be preserved
  - ***Constraints*** such as footplants
- Make conservative changes to motions
  - Things that generally don't cause problems
  - Add low frequencies
  - Blends with similar motions
- Re-establish constraints (solve)
  - Avoid creating new artifacts




# A concrete example…
# Retargetting Motion to New Characters

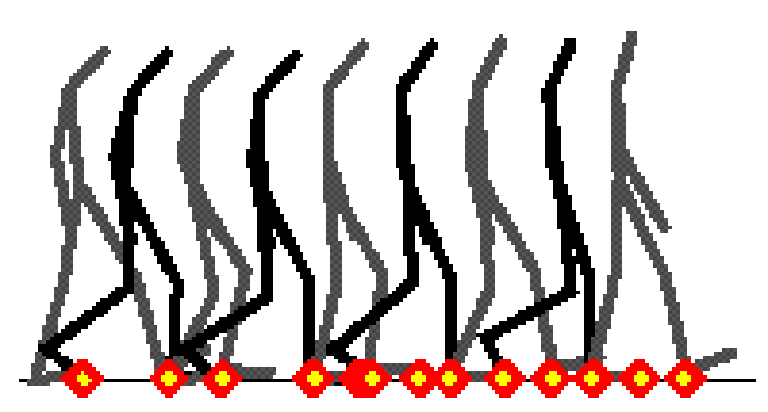
- Goal: one motion, a cast of characters
- Focus on similar structure



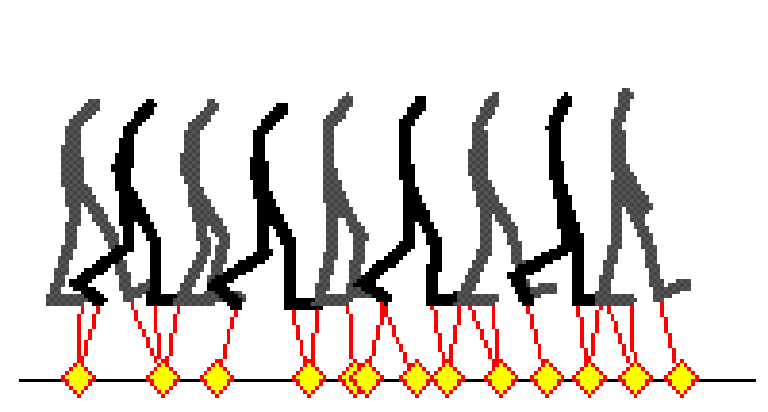


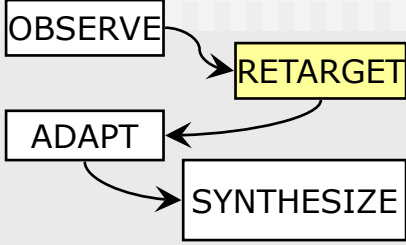

# Retargetting Recipe

1. Define Constraints



2. Apply to new character

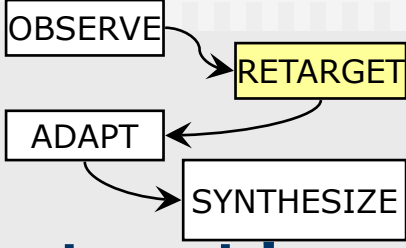





# Retargetting Recipe

3. Approximate Answer

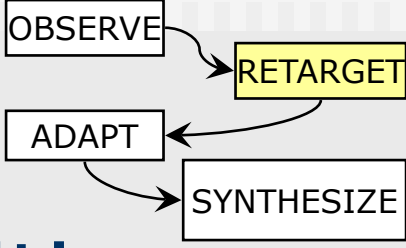
4. Solve constraints (band-limited adaptation)




# The trick…
# Temporal artifacts are important!

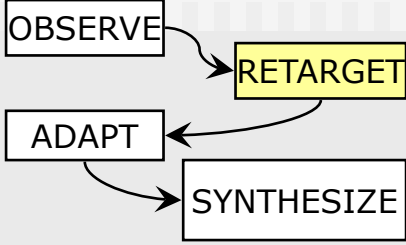
- Can’t add snaps
- Can’t add pops or wobbles or …

- Need to look at durations of motion

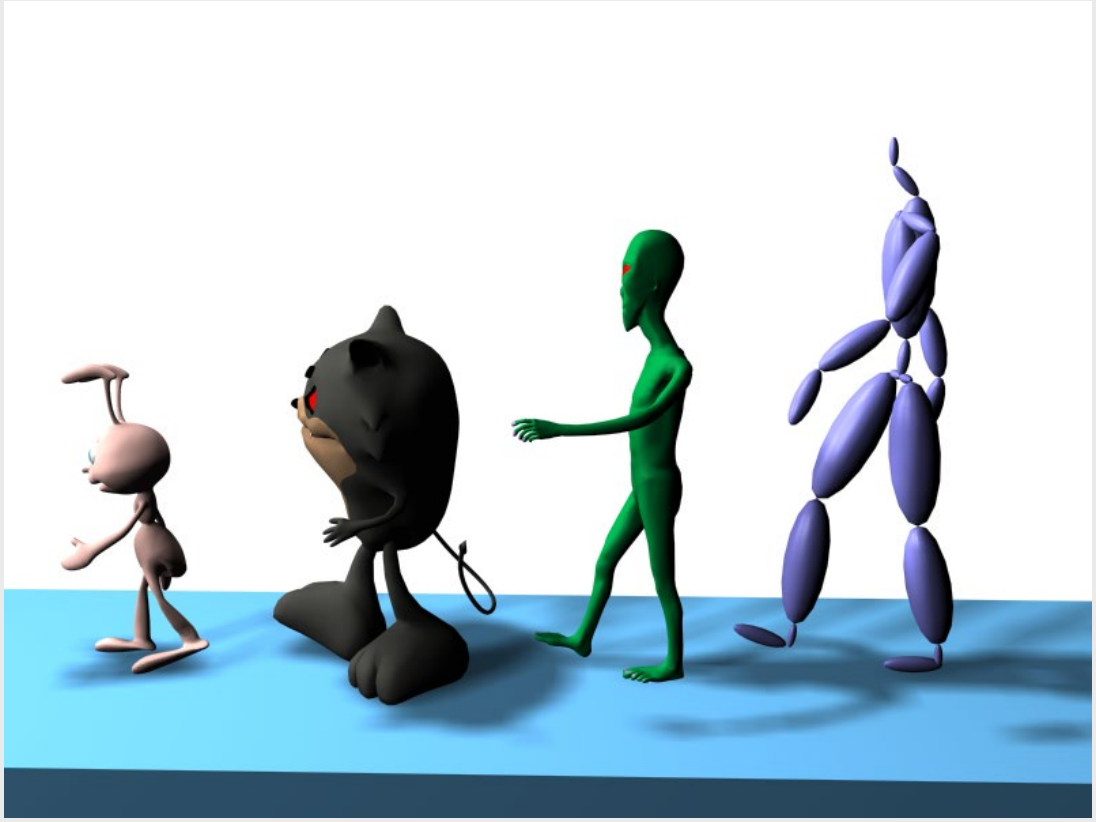



# Constraint Solutions for Editing

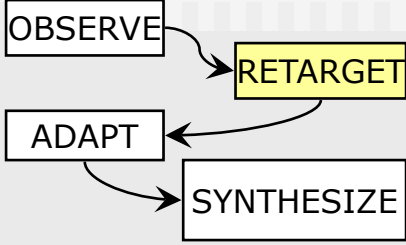
- Spacetime (single, large, non-linear optimization)
  - Gleicher ’97, Gleicher ’98, Popovic and Witkin ’99
- Hierarchical Splines
  - Lee and Shin ’99
- IK + Filter
  - Gleicher ’00
- Importance-Based
  - Shin Lee Gleicher Shin ’01
- IK + Blending
  - Kovar Schreiner Gleicher ’02




# Retargetting Results



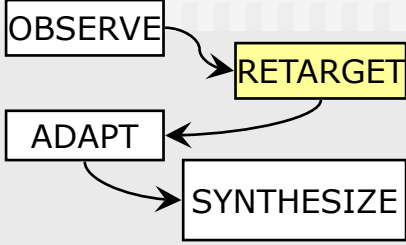
- Play retarget.avi




# Why is this good?

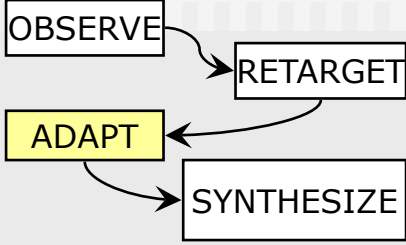
- Found motion + found character
- Overall quality of the motion preserved
- Makes interesting animation
  - New characters move like performer

- Complete pipeline
  - Character mapping




# What's wrong?

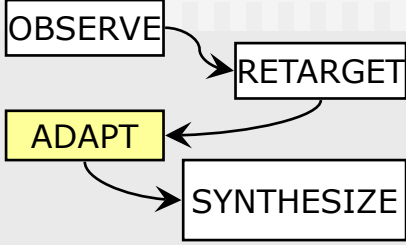
- Character not considered
  - How would the character do this?
  - Simple mapping methods
- Non-linear optimization is a pain
- Results could be better
  - Small details not right
  - Some "big" details ignored
- Controls are too low level
- Clip in, Clip out




# Towards a general paradigm…
# Animation by Adaptation

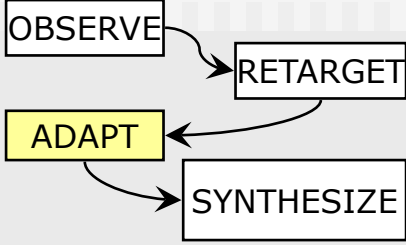
- Need a fast and easy way to deal with the most important constraints
  - Footskate Cleanup
- Need ways to deal with motion at a high-level
  - Path Editing and Motion Tiles
  - Synthesis-based on description
- Need to get beyond clips

# Footskate Cleanup



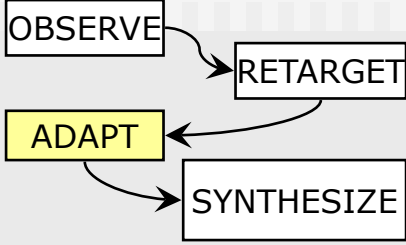

Kovar, Schreiner, Gleicher ’02

- Address the most common constraint
- Footplants are the primary connection between character and world
- Problems are very noticeable



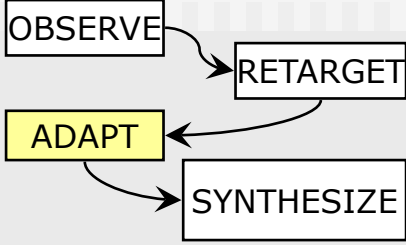

# Goals of our method

- Precise: Footplants enforced exactly
- Unobtrusive: Avoid adding noticeable new artifacts
- Simple and efficient: No nonlinear optimizations
- Local: Only a small neighborhood needed to solve each frame
- Fast and Reliable: closed form math



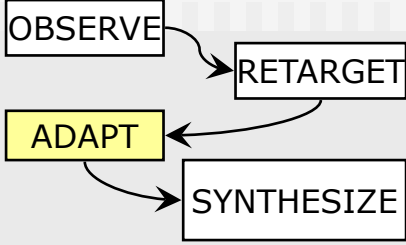

# Key insights

- Some things are noticeable
  - Small amounts of footskate
  - The addition of discontinuities
  - Unnatural accelerations of limbs
- Some things are not noticeable
  - Low frequencies added to motions
  - Small amount of limb stretch



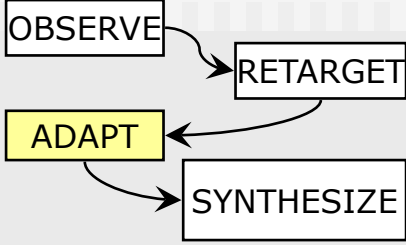

# Basic Idea

- Place foot to meet constraints
  - Adjust leg to meet ankle
- Make sure body is close enough
  - Need to be close enough to both feet
- Adjust leg angles
  - Standard single-limb inverse kinematics
- Blend results onto free frames
  - Avoid discontinuities at constraint switches



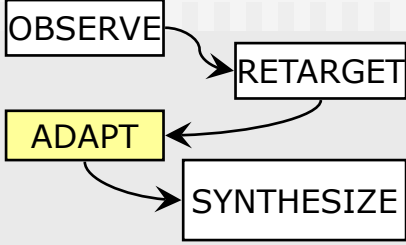

# The Details Matter…

- Get geometric calculations right
  - Continuity when there aren't switches
- Careful when constraints switch
  - Blend foot positions and orientations
  - Blend root position, when possible
- Avoid unnatural accelerations
  - Fast speeds look like discontinuity
  - Just as unnatural




# How to use this

- Editing methods just need to get close
  - Avoid nasty artifacts (high-frequencies)
- Footskate cleanup fixes many important details
- Makes editing methods easier to devise and implement

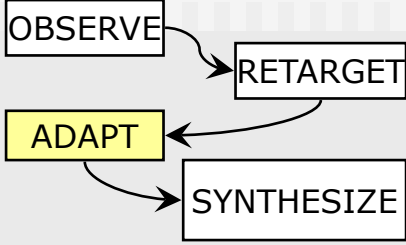



# A useful example:
# Path Editing

Gleicher '01

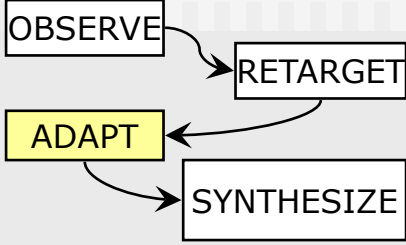
- How to change a straight motion into a curved one (or vice versa)

- Abstract control:
  - Path as an abstraction of the motion
  - Path as a control
- Fit low order polynomial curves (splines)
  - Provides abstraction
  - Provides easy control over large scale
- Factor into path and details



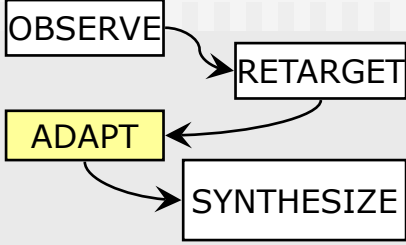

# Path Editing Details

- Need to consider orientation
  - Oriented coordinate system for factoring
- Need to avoid stretching
  - Arc-length parameterization of path
- Easy to do
  - Programming assignment in class!



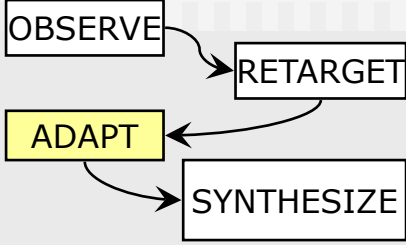

# Path Editing Video

- Show path.avi




# Beyond Paths

- Paths are great for movement
- Fail for location dependent actions
  - Can’t position them (arc-length pulls them)
  - Details of movement connect to path (cusps and sharp turns)
- Solution: add rigid “Tiles”
  - Annotate motions when path editing works



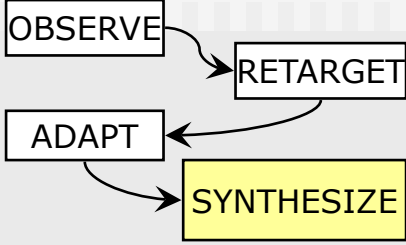

# Motion Tiles

## Selle and Gleicher ’03

- Rigid tiles for “location specific” actions
  - Position and orient them
- Non-stretchable paths to connect them

- Interactive editing paradigm
  - Requires non-linear constraints to preserve arc-length
- Modular footskate cleanup implementation
  - Allows us to have good motions from all of our systyems

# Motion Tiles Video

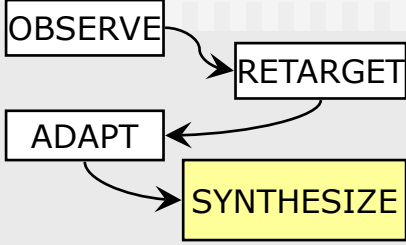



# Getting Beyond Clips

- Want to generate a wider range
- Want more control

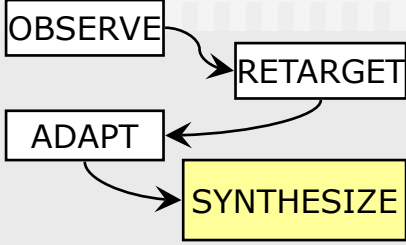
- Applications need streams of motion
  - Dynamically generated
- Applications need “long clips”

# Idea: Put Clips Together




- New motions from pieces of old ones!

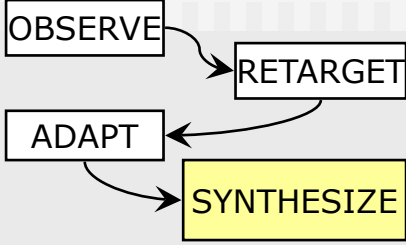
- Good news:
  - Keeps the qualities of the original (with care)
  - Can create long and novel “streams” (keep putting clips together)
- Challenges:
  - How to connect clips?
  - How to decide what clips to connect?



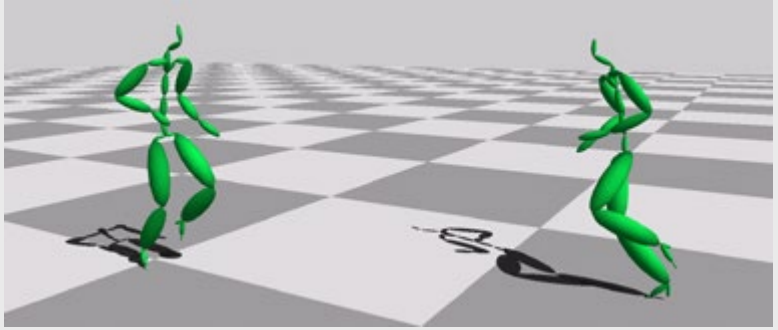

# Connecting Clips
# Transition Generation

- Transitions between motions can be hard
- Simple method work *sometimes*
  - Blends between aligned motions
  - Cleanup footskate artifacts
  - Just need to know when is “sometime”

# Identifying Transition Points

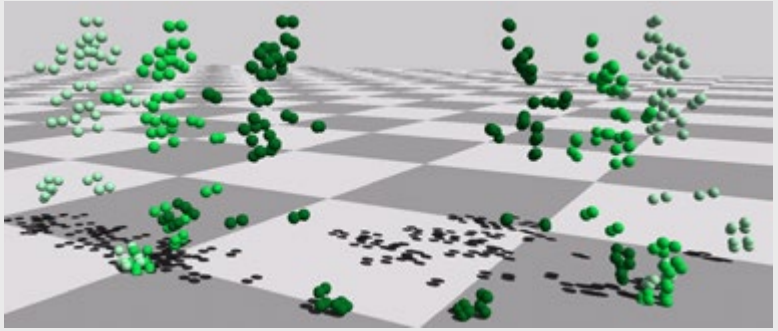



1) Initial frames

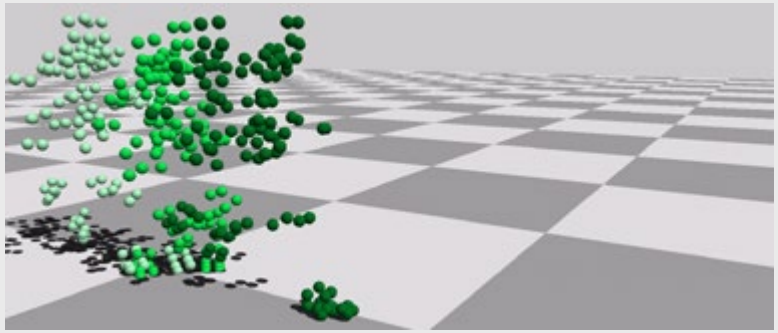


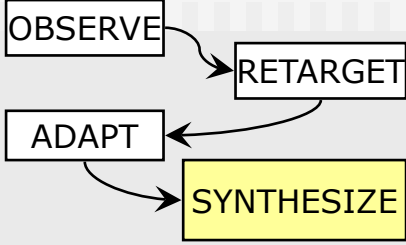
2) Extract windows

3) Convert to point clouds



4) Align point clouds and sum squared distances



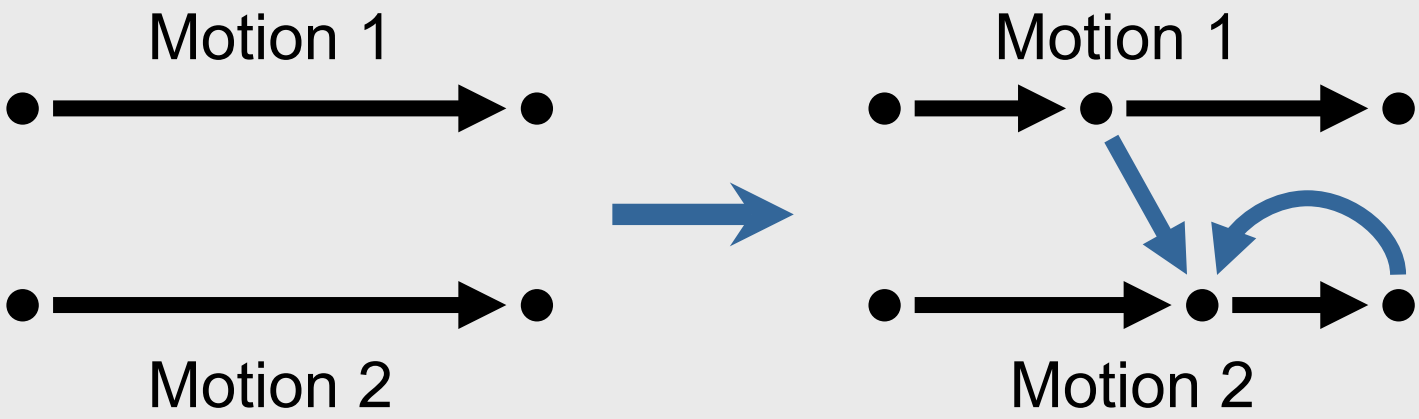


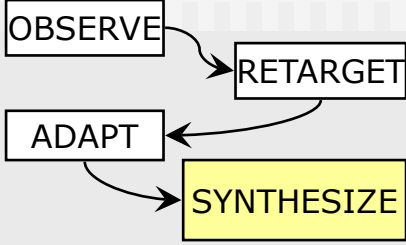

# Motion Graphs

## Kovar, Gleicher, Pighin ’02

Start with a database of motions, each with type and constraint information.

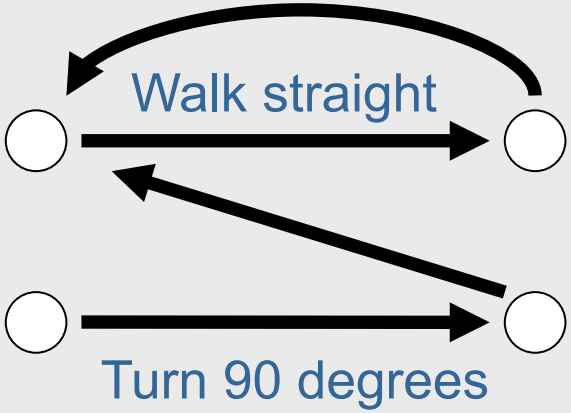
Goal: add transitions at opportune points.






# Motion Graphs

Idea: automatically add transitions within a motion database



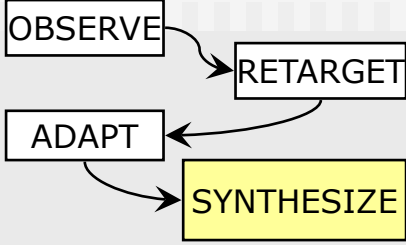

Edge = clip

Node = choice point

Walk = motion

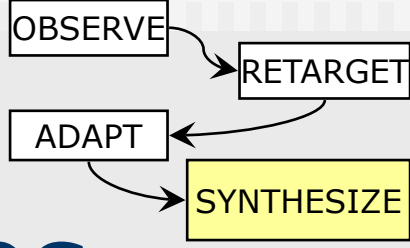
Quality: restrict transitions

Control: build walks that meet constraints



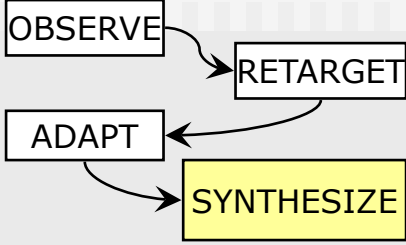

# Using a motion graph

- Any walk on the graph is a valid motion
- Generate walks to meet goals
  - Random walks (screen savers)
  - Search to meet constraints
- Other Motion Graph-like projects elsewhere
  - Differ in details, and attention to detail



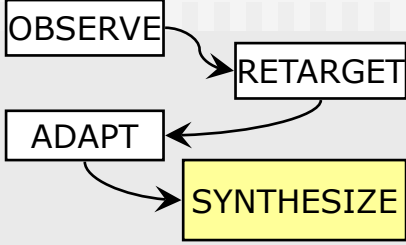

# Motion Graph Examples

- Play pathFit.avi
- Play pathFit-MultiStyle.avi




# What's next…

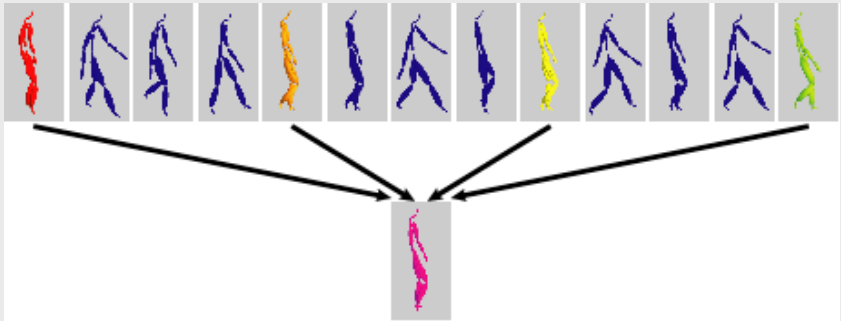
- Better synthesis
  - Self-awareness (what can you do?)
  - Parameterized motions
  - Better goal specifications
  - Low-cost runtimes
- Multiple interacting characters
- Crowds
- Characters

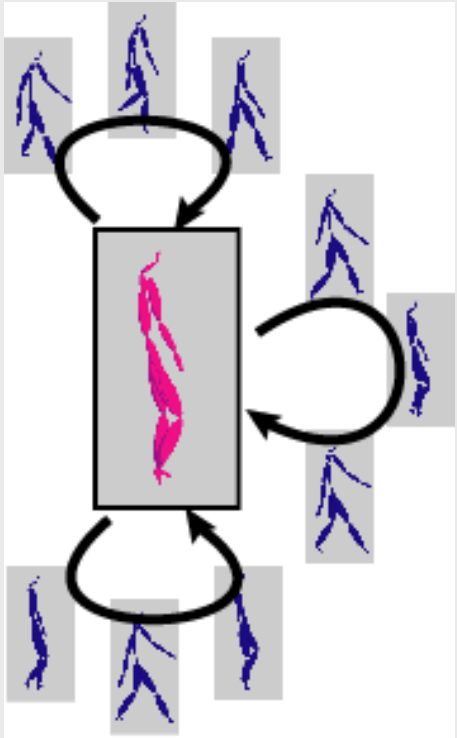



# Snap-Together Motion

## (w/ Hyun-Joon Shin, Andy Jepsen, Lucas Kovar)

- Low-cost/highly controllable runtimes
  - Pre-compute all transitions
  - Contrived graph structures
  - Multi-way transitions are hub nodes
- User guided authoring process





# Crowds

- Aggregate behavior is important
- Individuals are not
  - As long as they are plausible

- Real world example:
  - Feeding of the hounds at Cheverny
  - 90 dogs, kennel master knows them

# Thanks!


- To the UW graphics gang.
- Animation research at UW is sponsored by the National Science Foundation, Microsoft, and the Wisconsin University and Industrial Relations program.
- House of Moves, IBM, Alias/Wavefront, Discreet, Pixar and Intel have given us stuff.
- House of Moves, Ohio State ACCAD, and Demian Gordon for data.
- And to all our friends in the business who have given us data and inspiration.