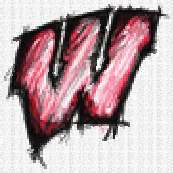
Animation by Example: Parametric Approaches



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Review of Lectures 1-3

- Represent Humans by Skeleton
- Create Motions by Motion Capture
  - Record specific movements
- Motions as vector-values signals
- Blends to combine similar motions
- Transitions by blending
  - Only for similar motions

The Challenge

- High Quality, Expressive Motion
  - Need motion capture (examples)
- Flexible, long-running, controllable
  - Need synthesis
- Synthesis from Examples!

Survey of Techniques

Flexibility:

- Link motions to make sequences
  (last lecture)
- Blend motions to gain control
  (this lecture)

Survey of Projects

- Motion Graphs
  - Link motions to make long sequences
- Snap Together Motion
  - Synthesis for interactive systems
- **Match Webs**
  - Find related motions in a database
- **Registration Curves**
- **Parametric Families**
  - Combine motions to make spaces
- Plus some others…

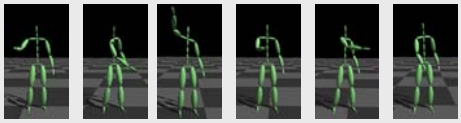
Work with Lucas Kovar, Hyun Joon Shin, …

Review: Concatentative Approaches

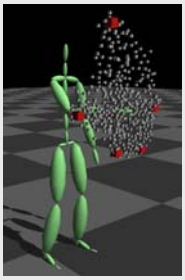
- Find motions that transition
  - Ending is similar to begininh
- Sequence existing motions
- Always play pieces of database or transition

Limitations of Motion Graphs

- Graphs provide discrete choices
- Use pieces of the database
- Can't capture ALL examples
- Synthesize new motions between example by blending

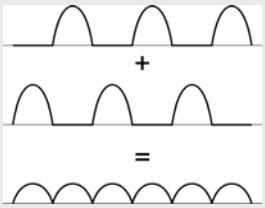


Motions Between examples



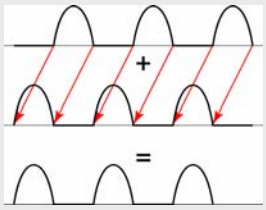
Blending requires similar motions

- Must be similar over entire clip



Align similar frames

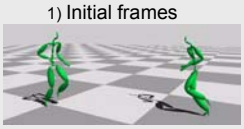
- Find matching frames
- Create timewarp
- Make motions similar



What is a similar frame?

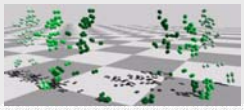
- Factor out invariances and measure

1) Initial frames



2) Extract windows

3) Convert to point clouds

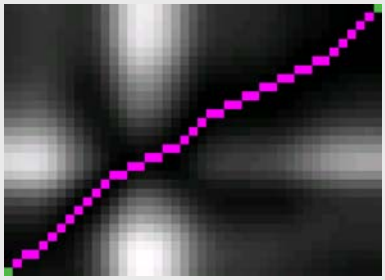


4) Align point clouds and sum squared distances

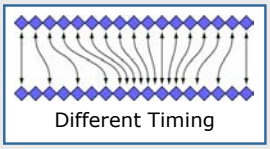
Optimal Timewarping

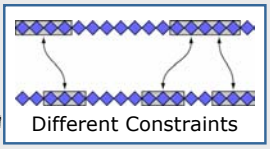
- Every frame matches its best correspondence
  - Dynamic timewarping
- Provides a time mapping
  $t' = f(t) \quad f : R \rightarrow R$
- Place restrictions on mapping
  - Monotonically increasing
  - Slope limits

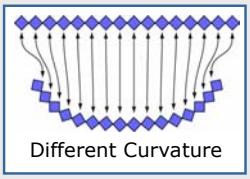
Dynamic Timewarping



Blending requires similar motions







Registration Curves

- Encode the relationships between *similar* motions

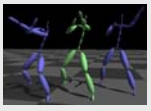
  (video of pair blending apps)

If we have a big database…

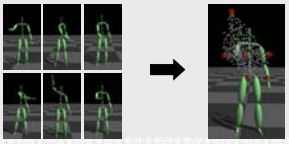
- How do we find similar motions?
- How do we use several examples?

Parameterized Motions

Blend captured motions to make new ones.



Create a natural parameterization for intuitive access to these new motions.



Adapting to Large Data Sets

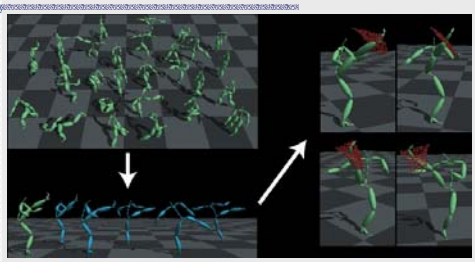
Previous: small, "contrived" data sets (e.g., Rose et al. '98, '02).

(Kovar and Gleicher '04): Adapt parameterized motions to large data sets

- Automatically find and extract examples
- Automated blending (K&G '03)
- Accurate and stable parameterization

Input: database + one example + parameterization function

Motion Families



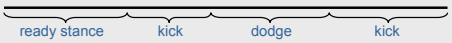
Database-> Controllable Clip

Motion Families

- Match Webs
  - Search for similar motions
- Registration
  - Align motions for blending
- Parameterization
  - Define useful controls
- Sampling
  - Improve nearest neighbor interpolation

Finding Motions

Example motions are buried in longer motions.



Strategy: search for motion segments similar to a query.

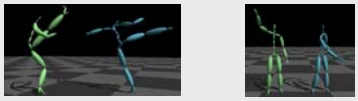
Why It Is Hard to Find Motions

- Motions can be different lengths.

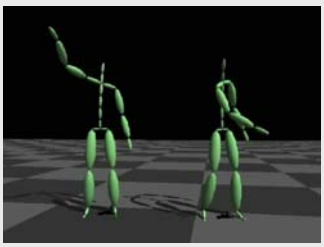
- Complicated distance metrics

$$D(F,F') = \min_{\theta,x_0,z_0} \sum_i \| p_i - T(\theta,x_0,z_0) p_i' \|^2$$

- Logically similar ≠ numerically similar.

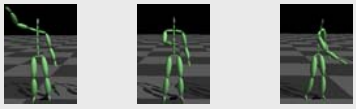


Similar?



Search Strategy

Find "close" matches and use as new queries.



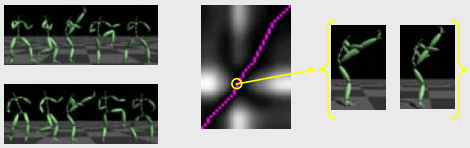
One search may involve many queries.

Precompute potential matches for interactivity.

Computing Distance Between Motions

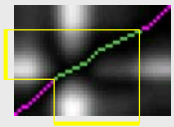
Distance between corresponding frames (in the best time warp)

- Factors out timing differences
- Allows arbitrary distance metrics for frames

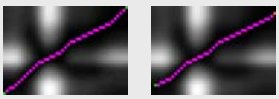


Precomputing Matches: Insights

Any subset of an optimal path is optimal.

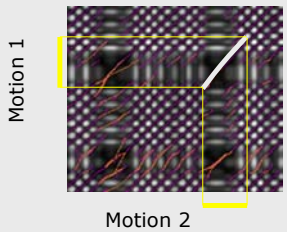


Optimal paths are redundant under endpoint perturbation.



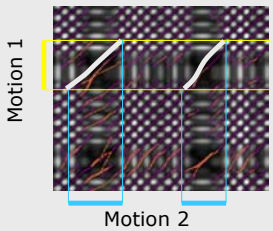
Precomputing Matches: Match Webs

Compute a grid of distances between pairs of frames and find long, locally optimal paths.



Precomputing Matches: Methods

At run time, intersect queries with the match web to find matches.



Search Results

- 37,000 frame data set with ten different kinds of motions.
- 50 minutes to compute match web
- 21MB on disk
- All searches (up to 97 matches) in ≤ 0.5s
- Manual verification of accuracy

Natural Parameterizations

Blend weights offer poor controls

We need more natural parameters.

$g(M) = p$

motion — parameters

reaching	hand position at apex
turning	change in hip orientation
jumping	max height of center of mass

From Parameters to Blend Weights

It is easy to map blend weights to parameters.

$$f(\mathbf{w}) = g(\underbrace{w_1\mathbf{M}_1 \oplus \ldots \oplus w_n\mathbf{M}_n}_{\text{blend}}) = \mathbf{p}$$

blend weights — parameters

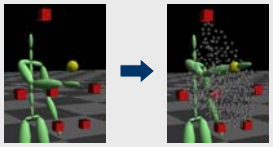
But we want $w=f^{-1}(p)$!

This has no closed form solution!

Building Parameterizations

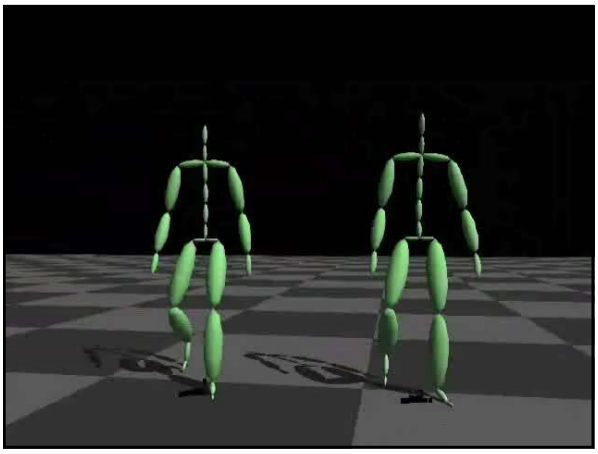
Given samples (p,w), we can approximate f^{-1} with k nearest neighbor interpolation.

Accuracy: create new blends to get additional



Require "reasonable": $\sum_i w_i = 1$

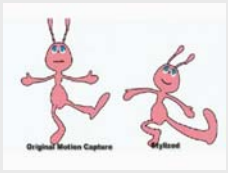
$-\varepsilon \le w_i \le 1+\varepsilon$



A Driving Application

Other uses of examples…

- Stylization by Example



- Artist provides example frames

w/Xin Li, Harry Shum, MSR China

- Skinning by Example

- Sample character rigs to build skins

(w/Alex Mohr – now Pixar)

Summary

- Obtain clips with motion capture
- Gain control and flexibility with Synthesis by Example
  - Concatenation
  - Parametric

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.
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