Motion Graphs for Character Animation

Parag Chaudhuri

Indian Institute of Technology Bombay

Research Promotion Workshop on
Introduction to Graph and Geometric Algorithms
Thapar University
Patiala
October 30, 2010

Outline

The Need for Motion Data

Character animation is about movement.

The Need for Motion Data

Creating plausible movement requires a lot of skill and time.

Source: Sintel, The Durian Open Movie Project

The Need for Motion Data

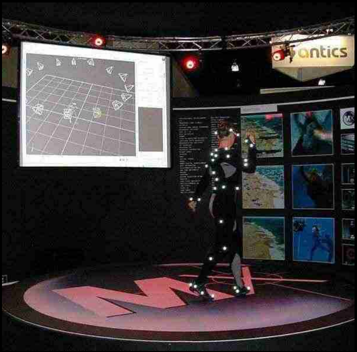
How difficult can it be - it is only one character...

The Need for Motion Data

...then imagine a thousand or a million!

The Need for Motion Data

Capture movement of performers and use it in animation.



Using Motion Data

- Problems
  - Captured data can be voluminous.
  - Processing data motion data is intensive.
  - Capturing all possible motion is impossible.
  - Motion Capture is expensive and cumbersome.
- Solutions
  - Organize and represent data.
  - Combine data intelligently to synthesize new motion.
  - Simulate physics to dynamically generate new motion.

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Outline

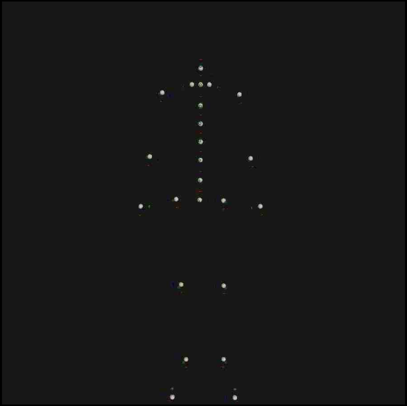
Character Representation

A layered representation for the character

Source: Model courtesy MIRALab

Character Representation

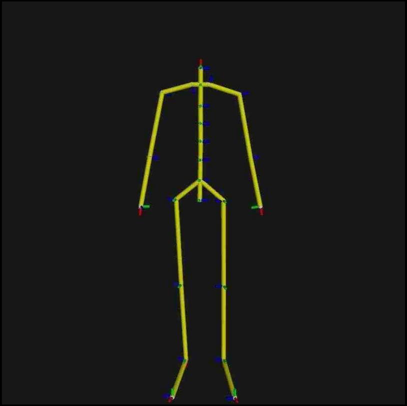
A set of *joints* with fixed degrees of freedom...



Source: Model courtesy MIRALab

Character Representation

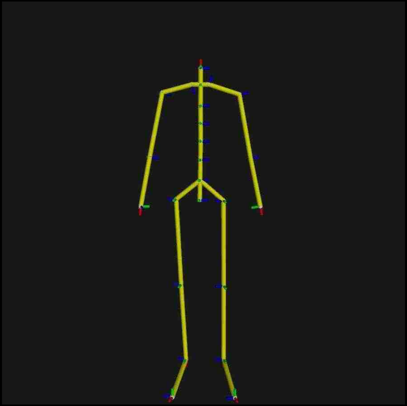
...joined with rigid links or bones form the skeleton of the character.



Source: Model courtesy MIRALab

Character Representation

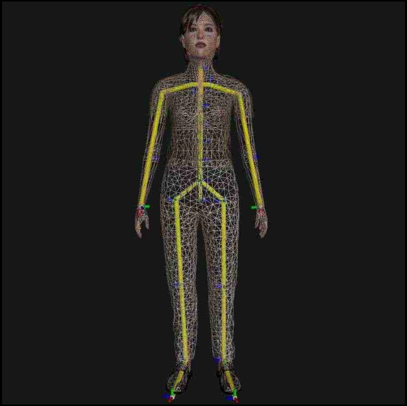
This forms a rooted tree of rigid transformations.



Source: Model courtesy MIRALab

Character Representation

Layered on top of this is a triangle mesh of the character's *skin*.



Source: Model courtesy MIRALab

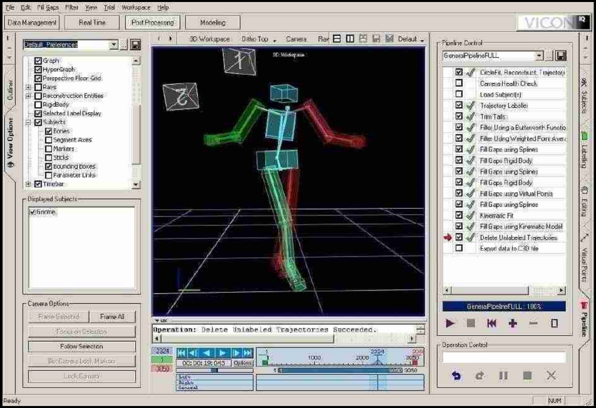
Character Representation

When the skeleton moves, the skin moves along.

Source: Model courtesy MIRALab

Motion Representation

Motion data is typically captured in the form of joint trajectories



Source: Vicon IQ

Motion Representation

Motion data is typically captured in the form of joint trajectories

Motion Representation

It is stored in one of many standard formats

```
HIERARCHY
ROOT Hips
{
        OFFSET  0.00    0.00    0.00
        CHANNELS 6 Xposition Yposition Zposition Zrotation Xrotation Yrotation
        JOINT Chest
        {
                OFFSET   0.00    5.21    0.00
                CHANNELS 3 Zrotation Xrotation Yrotation
                JOINT Neck
                {
                        OFFSET   0.00    18.65   0.00
                        CHANNELS 3 Zrotation Xrotation Yrotation
                        JOINT Head
                        {
                                OFFSET   0.00    5.45    0.00
                                CHANNELS 3 Zrotation Xrotation Yrotation
                                End Site
                                {
                                        OFFSET   0.00    3.87    0.00
                                }
                        }
                }


MOTION
Frames:    2
Frame Time: 0.033333
      8.03     35.01    88.36    -3.41     14.78    -164.35   13.09    40.30    -24.60
      7.88     43.80    0.00     -3.61     -41.45   5.82      10.08    0.00     10.21
      97.95    -23.53   -2.14    -101.86   -80.77   -98.91    0.69     0.03     0.00
      -14.04   0.00     -10.50   -85.52    -13.72   -102.93   61.91    -61.18   65.18
      -1.57    0.69     0.02     15.00     22.78    -5.92     14.93    49.99    6.60
      0.00     -1.14    0.00     -16.58    -10.51   -3.11     15.38    52.66    -21.80
      0.00     -23.95   0.00
      7.81     35.10    86.47    -3.78     12.94    -166.97   12.64    42.57    -22.34
      7.67     43.61    0.00     -4.23     -41.41   4.89      19.10    0.00     4.16
      93.12    -9.69    -9.43    132.67    -81.86   136.80    0.70     0.37     0.00
      -8.62    0.00     -21.82   -87.31    -27.57   -100.09   56.17    -61.56   58.72
      -1.63    0.95     0.03     13.16     15.44    -3.56     7.97     59.29    4.97
      0.00     1.64     0.00     -17.18    -10.02   -3.08     13.56    53.38    -18.07
      0.00     -25.93   0.00
```

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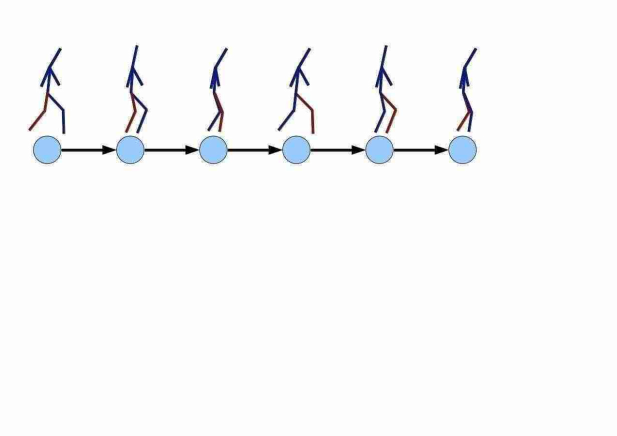
- Character and Motion Data
  - Character Representation
  - Motion Representation
- Motion Graphs
  - Idea
  - Construction
  - Generating Motion
- More Motion Graphs
- Conclusions

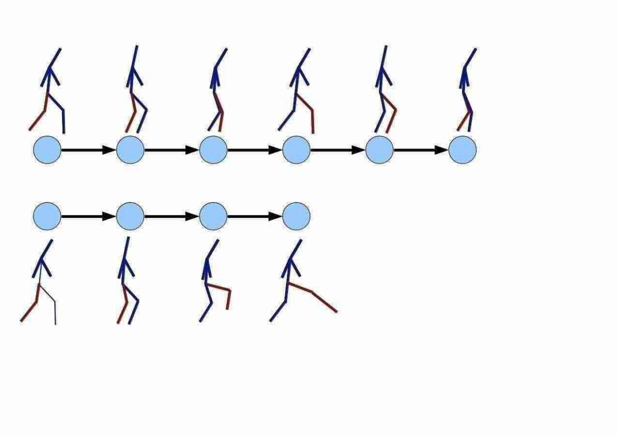
Idea

Every motion clip is a graph. Vertex $\sim$ pose, Edge $\sim$ transition frames.



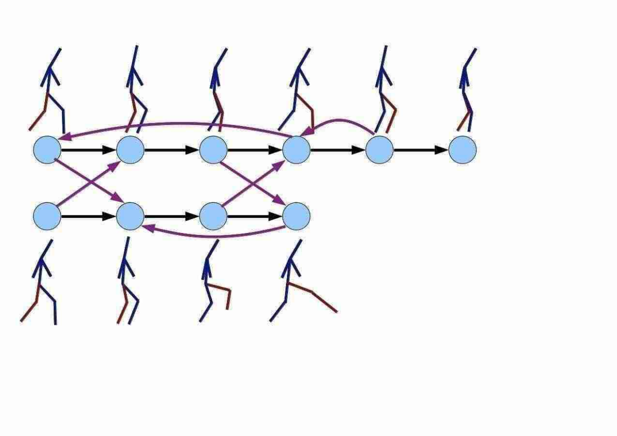
Idea

There are many such clips in a motion database.



Idea

Find similar poses between clips. Add transitions between them.



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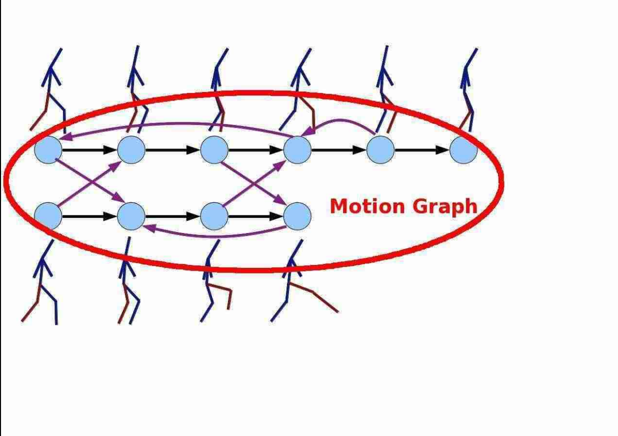
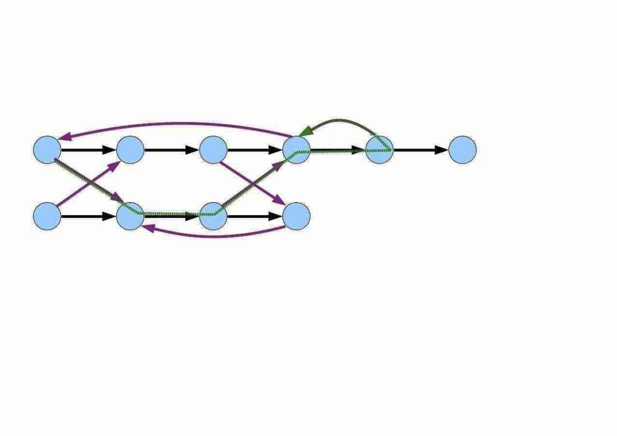


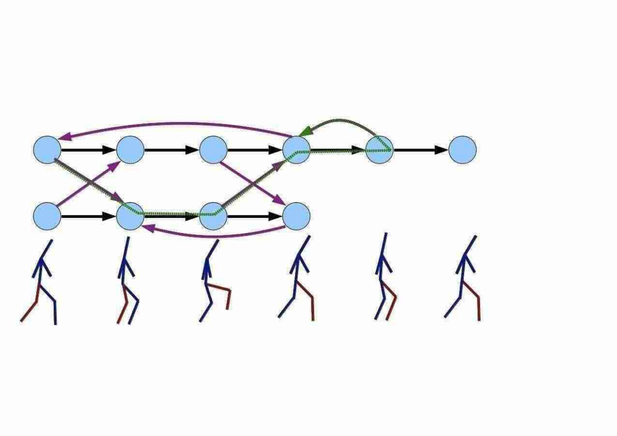
Idea

Now any walk on this graph...



Idea

...generates a new, smooth motion.



Construction

Similarity between poses across clips

- A simple distance measure between joints is a bad idea as some joints have more influence on the pose and they may also be subject to constraints.
- A pose is defined only up to a rigid coordinate transformation. Hence comparing two pose requires identifying compatible coordinate systems.
- A seamless transition must account not only for differences in body posture, but also in joint velocities, accelerations, and possibly higher-order derivatives.

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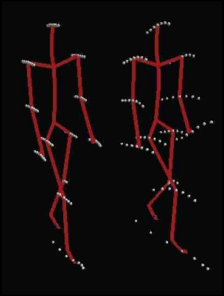
Construction

$$D(P_i, P_j) = \min_{\theta, x_o, z_o} \sum_{k=1}^{n} \omega_k \| p_i^k - T_{\theta, x_o, z_o} p_j^k \|^2$$

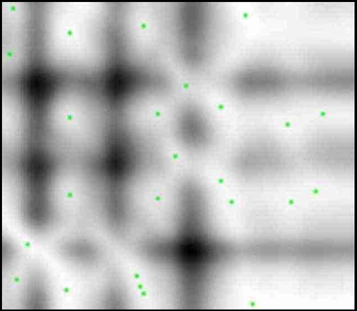


- Compute the distance metric over a window of $2L + 1$ frames centered at P_i and P_j.

Constructing Good Quality Motion Graphs for Realistic Human Animation, Limin Zhaog, PhD Thesis, University of Pennsylvania, 2009.

Motion Graphs, Lucas Kovar, Michael Gleicher and Frédéric Pighin, SIGGRAPH 2002

Construction



- Create transitions between frames for which similarity satisfies a threshold.
- Linear interpolations of translations, Spherical linear interpolations for rotations.
- Prune the graph for dead ends. Retain only the largest strongly connected component.

Motion Graphs, Lucas Kovar, Michael Gleicher and Frédéric Pighin, SIGGRAPH 2002

Generating Motion

- Random walks on the motion graph are not interesting
- So we search for motion that satisfies some objective
- Minimize a function $f(w)$ such that

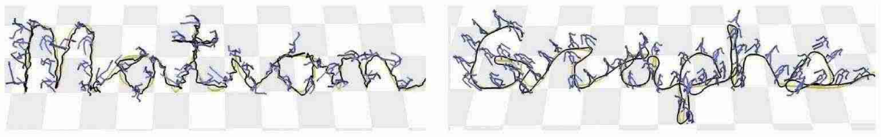
$$f(w) = f([e_1, \cdots e_n]) = \sum_{i=1}^{n} g([e_1, \cdots e_{i-1}], e_i)$$

- where $f(w)$ gives the total path error for a path $w = [e_1, \cdots e_n]$ on the graph
- $g(w, e)$ is a scalar function that gives the additional error when the edge e is added to an existing path w.
- In addition to this we also have a *halting criteria*.

Generating Motion

Path Synthesis - making the character move on a path given by the user

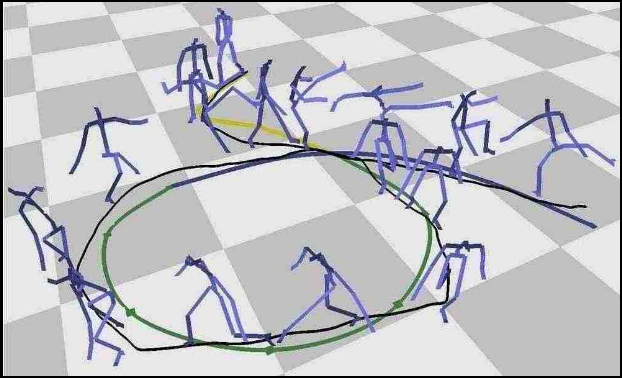
$$g(w, e) = \sum_{i=1}^{n} \| Q'(s(w, e_i) - Q(s(w, e_i) \|^2$$



Motion Graphs, Lucas Kovar, Michael Gleicher and Frédéric Pighin, SIGGRAPH 2002

Generating Motion

Motion Styles



Motion Graphs, Lucas Kovar, Michael Gleicher and Frédéric Pighin, SIGGRAPH 2002

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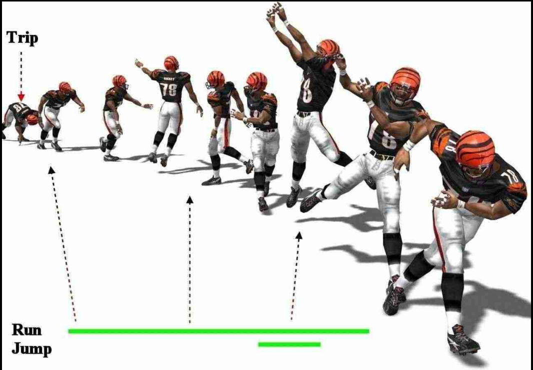
Motion from Annotations

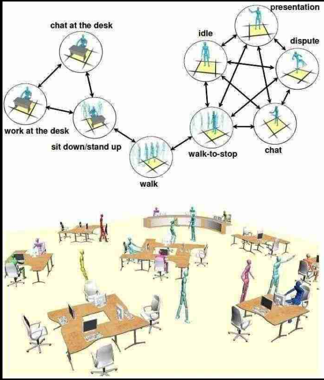
Annotate the motions, paint a time line, search



Motion Synthesis from Annotations, Okan Arikan, David Forsyth, James O'Brien, SIGGRAPH 2003

Motion Patches

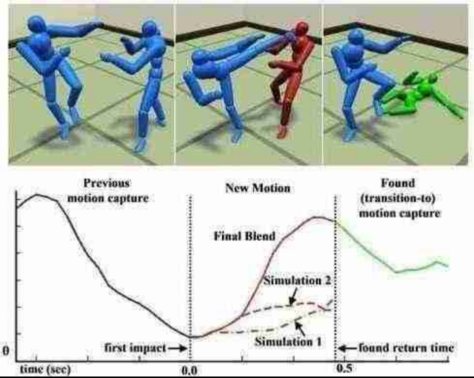
Motion capture motion in patches, graph between patches



Motion Patches: Building Blocks for Virtual Environments Annotated with Motion Data, Kang Hoon Lee, Myung Geol Choi and Jehee Lee, SIGGRAPH 2006

Dynamic Response

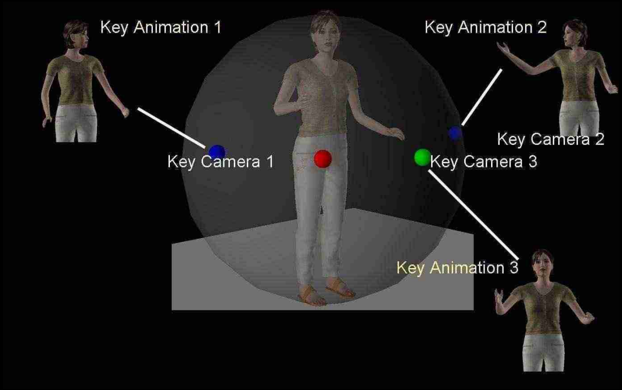
Motion capture motion in patches, graph between patches



Dynamic Response for Motion Capture Animation, Victor Zordan, Anna Majkowska, Bill Chiu and Matthew Fast, SIGGRAPH 2005

Self Adaptive Animation

Transitions driven by camera position



Self Adaptive Animation based on User Perspective, Parag Chaudhuri, George Papagiannakis, Nadia Magnenat-Thalmann, CGI 2008

Outline

Conclusions

- Motion Graphs are very useful in character animation.
- Extensively used for real-time animation synthesis.
- Cutting edge research area in Computer Graphics.
- Future going toward a combination of physics simulation and motion capture.

Thank You