Data-driven synthesis based on Motion Graphs

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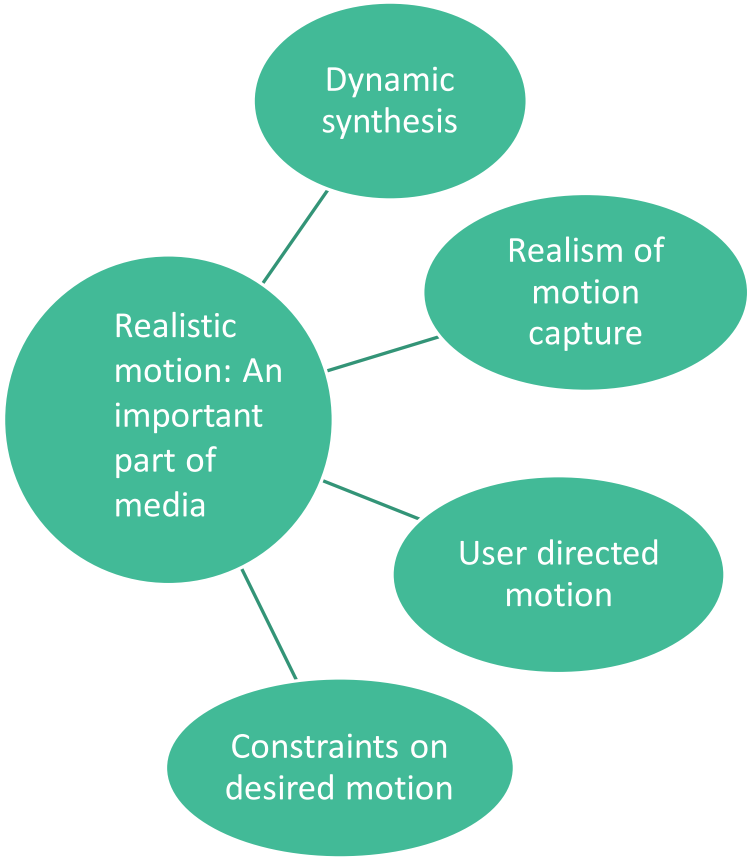
Contents

Motivation


Dynamic synthesis
Realism of motion capture
Realistic motion: An important part of media
User directed motion
Constraints on desired motion

Overview:

Detect candidate transitions
- Identify similar clips
- Compute difference in poses

Create transitions
- Straightforward blending
- Join motion seamlessly

Create motion graphs
- Directed graph
- Reassemble motion clips

Motion synthesis
- Graph walk
- Select sequence of nodes

Motion capture data

Figure 1.(a)

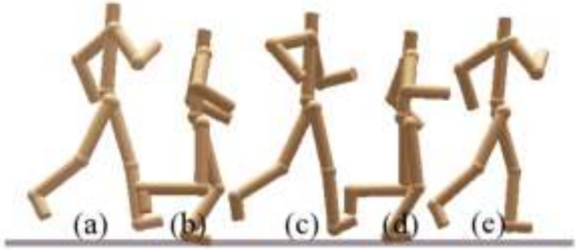


Figure 1.(b)

Sampling root position and joint rotation parameters

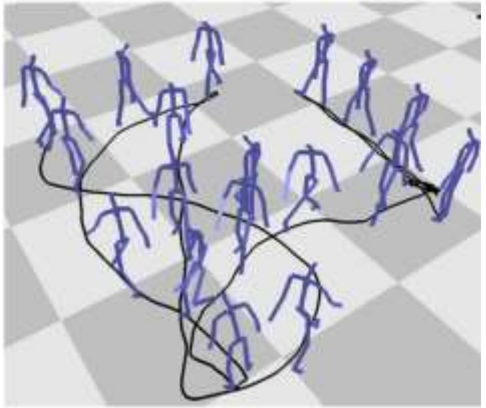


Figure 1.(c)

Figure 1.(d)

Figure 1.(a)- (d) : Example motion clips

Identify similar clips:

How to detect similarity?

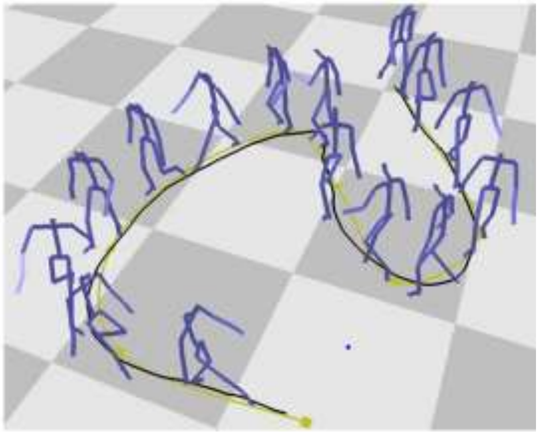


Figure 2.(a)

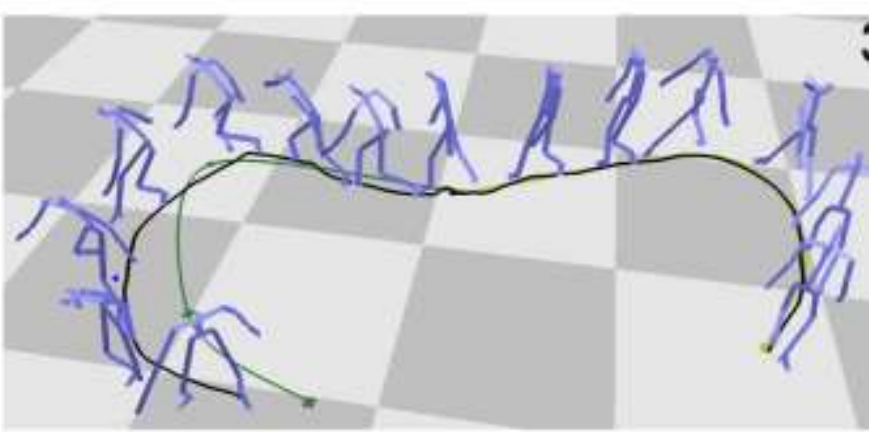


Figure 2.(b)

Figure 2.(a),(b) : Example motion clips

Identify similar clips:

How to detect similarity?

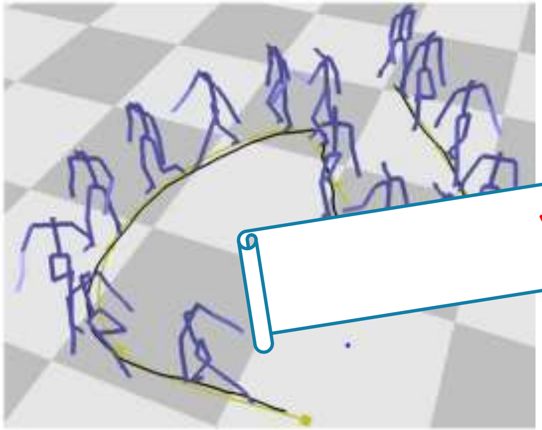


Figure 2.(a)

Vector norms

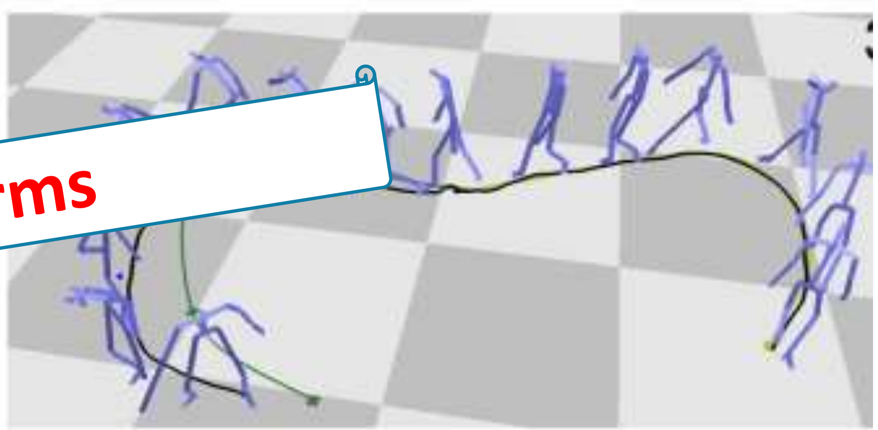


Figure 2.(b)

Figure 2.(a),(b) : Example motion clips

Identify similar clips:

But do vector norms work?

Problems:

- Fail to account for meanings of parameters

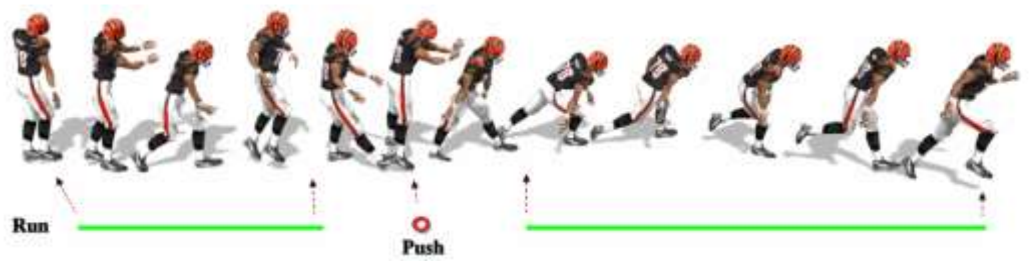


Figure 3 : Example motion clips

Figure 4 : Example motion clips – Rotating Ballerina

Identify similar clips:

But do vector norms work?

Problems:

- Fail to account for meanings of parameters
- Motion defined only up to a rigid 2D co-ordinate transformation

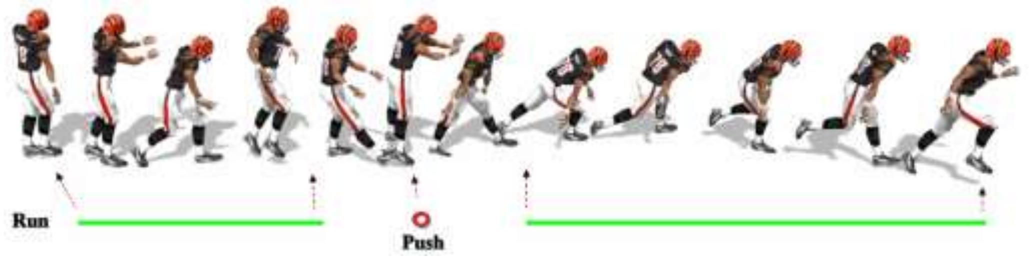


Figure 3 : Example motion clips

Figure 4: Example motion clips – Rotating Ballerina

Identify similar clips:

But do vector norms work?

Problems:

- Fail to account for meanings of parameters
- Motion defined only up to a rigid 2D co-ordinate transformation
- No information about joint velocities, accelerations

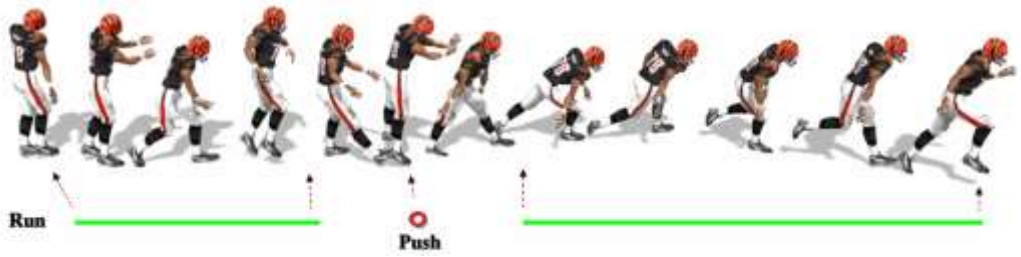


Figure 3: Example motion clips

Figure 4: Example motion clips – Rotating Ballerina

Metric driven by point cloud

Figure 5: Point cloud created by motion

Metric driven by point cloud

- Use window of frames- create point cloud
- Windows before and after the frames to be compared(Ai and Bj)
- Measure closeness of frames of animation
- Primary advantage : Incorporates derivative information
- User-defined 'k'

Figure 6: Point cloud created by motion

Figure 7 : Two example motion clips

Error Metric:

Distance between two frames Ai,Bj

$$D(A_i, B_i) = \min \sum_i w_i \; || p_i - T_{\theta, x_{0,} z_0} p_i' ||^2$$

Where,

- p_i and p_i' = points in the two point clouds
- w_i = weights
- T () = linear transformation matrix
- I = index in point cloud

Detecting candidate transitions:

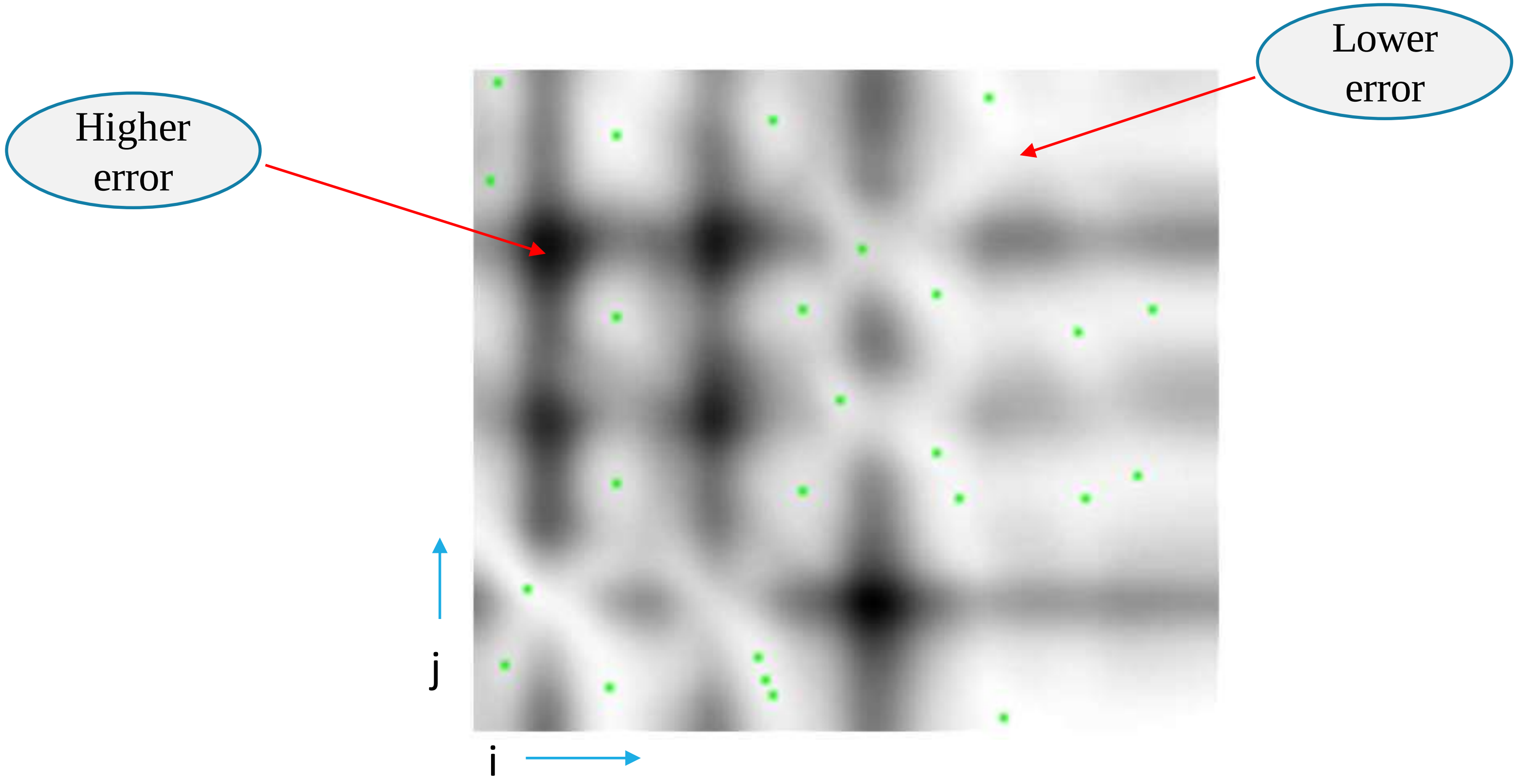


Figure 8 : Example error function for two motions

Detecting candidate transitions:

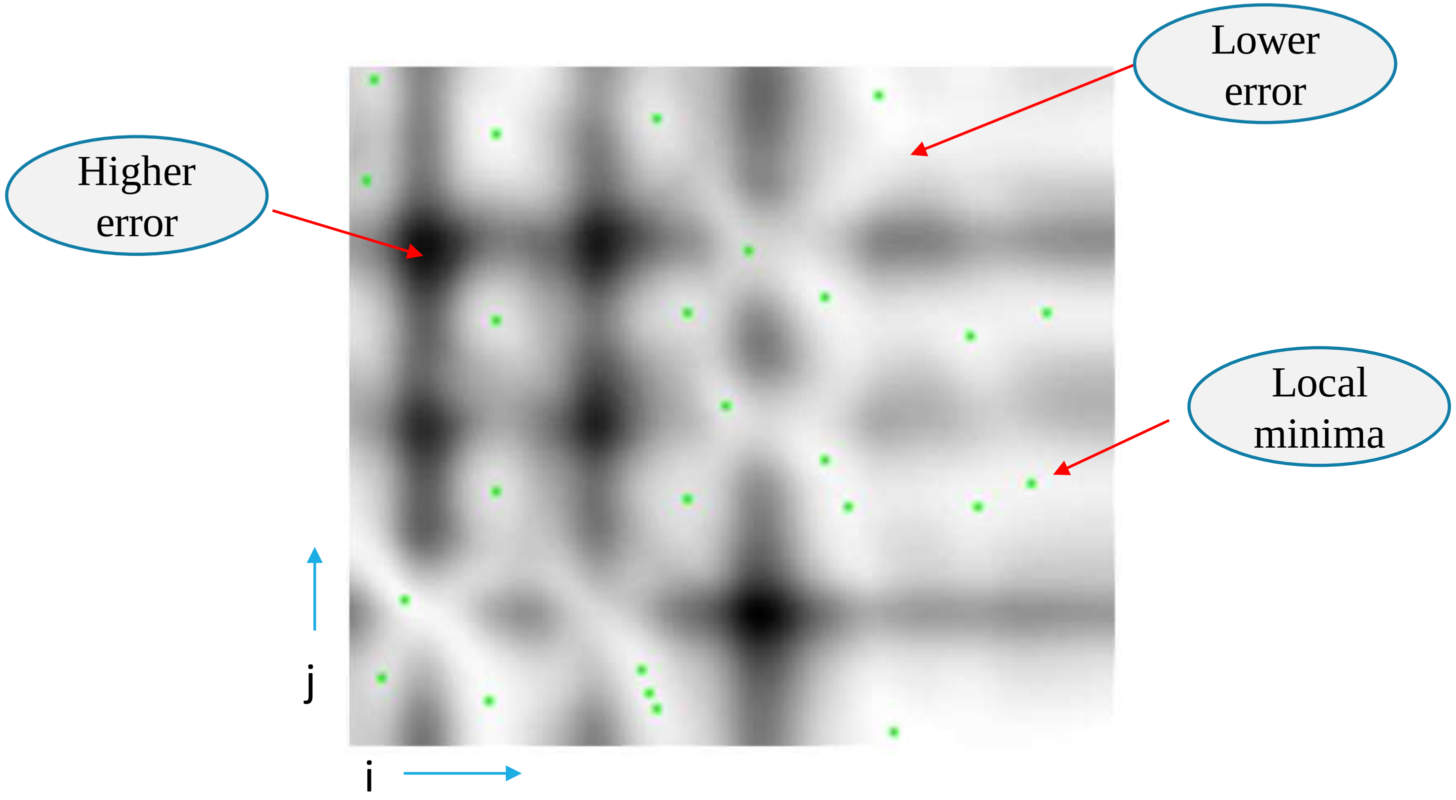


Figure 9 : Example error function for two motions

- Local minima ➡ Most opportune transition
- Choose based on a threshold
- User likes to pick this threshold

Selecting transition points

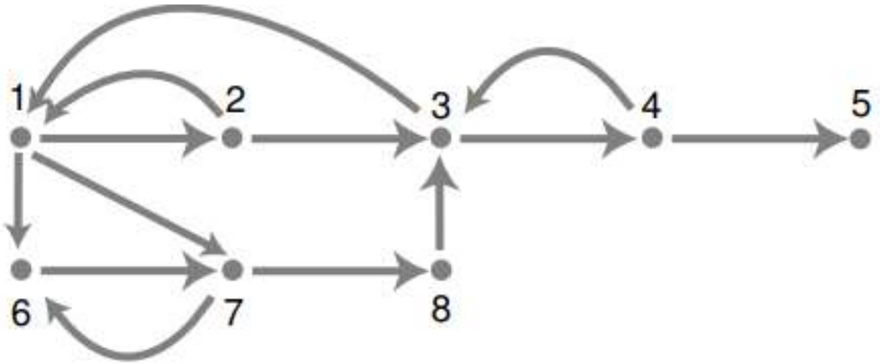
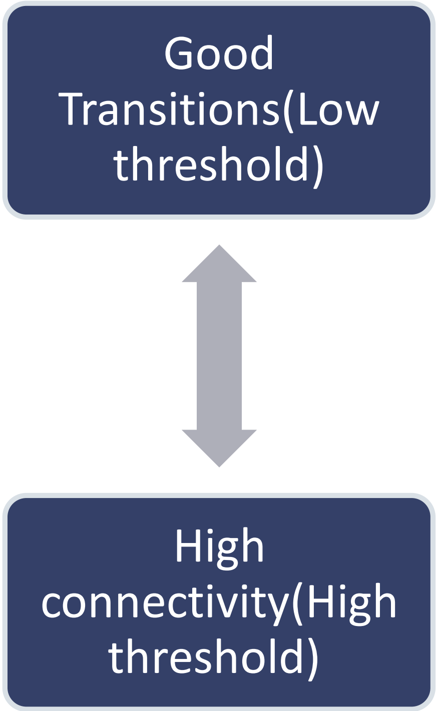


Figure 10 : A simple motion graph

Figure 11: Two example motion clips



Creating transitions : If D(A_i, B_j) meets threshold

- Blend two window of frames
- Ai to Ai+k-1with frames Bj-k+1 to Bj
- Simple linear interpolation on root positions
- Spherical interpolation on joint rotations

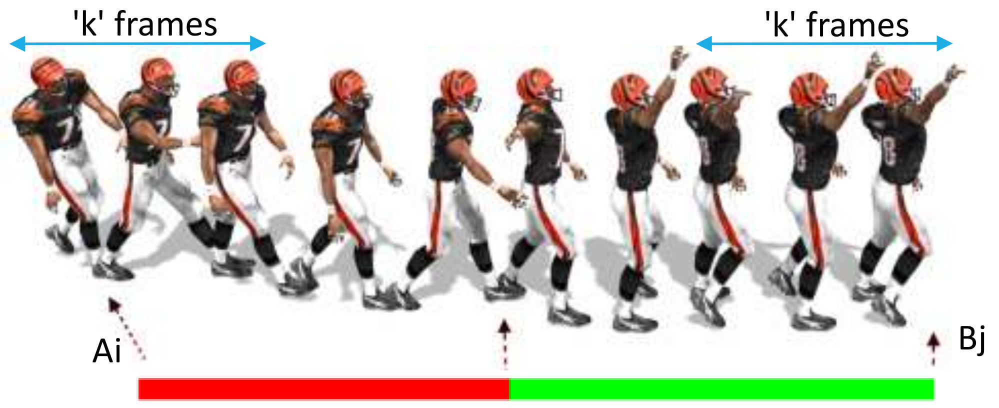


Figure 12: Two example motion clips

Creating transitions : If D(A_i, B_j) meets threshold

Steps:

1. Aligning 2D transformation to motion B
2. On frame p of transition(0≤p<k),

$$R_p = \alpha(p) R_{A_{i+p}} + [1 - \alpha(p)]\, R_{B_{j-k-1}}$$

$$q_p^i = slerp(q^i_{A_{i+p}}, q^i_{B_{j-k+1+p}}, \alpha(p))$$

- where,
  - R_p = Root position on frame *p* of transition
  - q_p^i = Rotation of the i^{th} joint P^{th}
  - R_{A_i} = Root position on frame A_i in motion A
  - R_{B_i} = Root position on frame B_i in motion B

Prevent feet sliding !!!

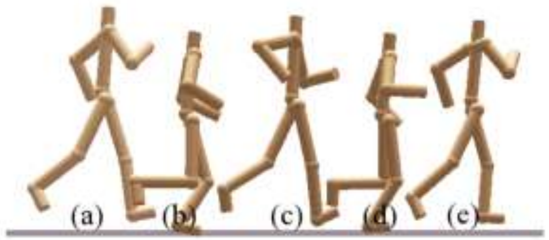


Figure 13: Example motion clip-Human walking

Creating transitions : If D(A_i, B_j) meets threshold

Steps:

1. Aligning 2D transformation to motion B
2. On frame p of transition(0≤p<k), linearly interpolate the root positions and perform spherical linear interpolation on joint rotations
3. Blend weight:

$$\alpha(p) = 2\left(\frac{p+1}{k}\right)^3 - 3\left(\frac{p+1}{k}\right)^2 + 1,\ -1 < p < k$$

- Conditions :
  - $\alpha(p) = 1, p \leq -1$
  - $\alpha(p) = 0, p \geq \mathrm{k}$
  - C1 continuity

Motion graphs

- Arrange clips in directed graph
- Key components:
  - **Dead ends**: not part of any cycle
  - **Sinks**: low connectivity
  - **Strongly connected components**: nodes part of many cycles
- Incoming label doesn't match outgoing label

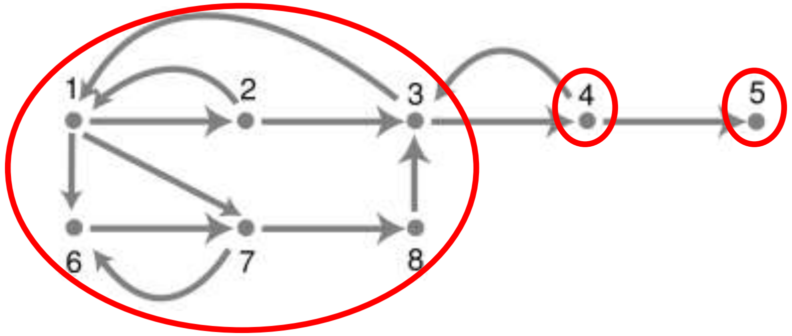


Figure 14 : A simple motion graph

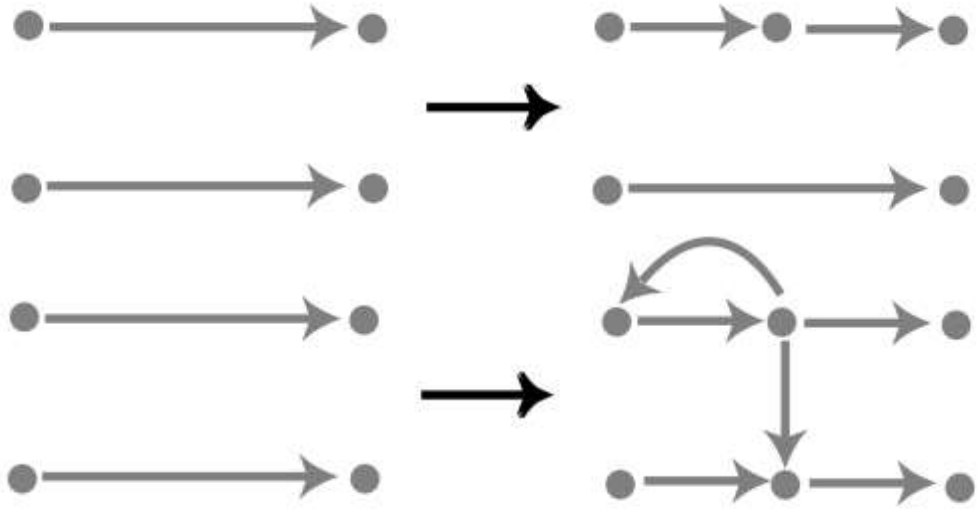


Figure 15 : Motion graphs built from initial clips

Motion graphs

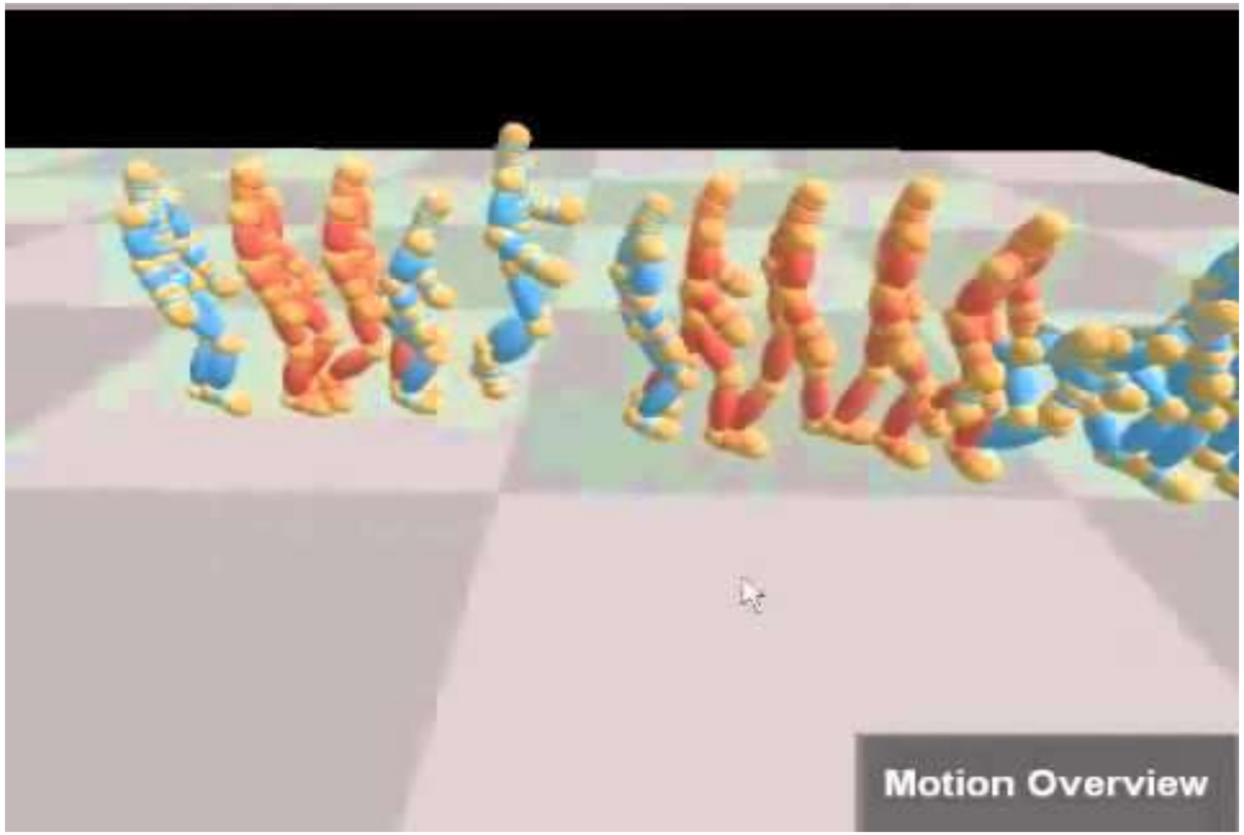


Figure 15 : Example of motion synthesis with interpolated frames

Motion extraction:

- Searching for motion ⟷ Optimizing graph walks
- Suitable metric to extract frames
- Metric used is Scalar error function : g(w,e) - Conforming to user specifications
- Total error :

$$f(w) = f([e_1, e_2, \ldots.., e_n]) = \sum_{i=1}^{n} g([e_1, e_2, \ldots.., e_n]), e_i$$

- Branch and bound to reduce number of graph walks

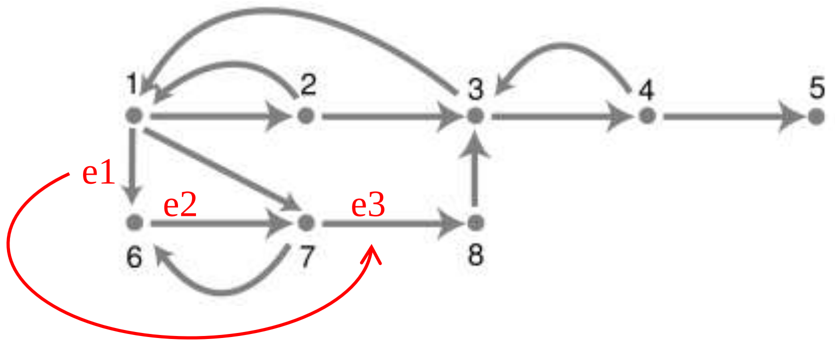


Figure 16: A simple motion graph

Motion extracted depends on 'g' !

Given starting node *N*, target edge *e,* and a transformation T'

Graph walk presenting the same result

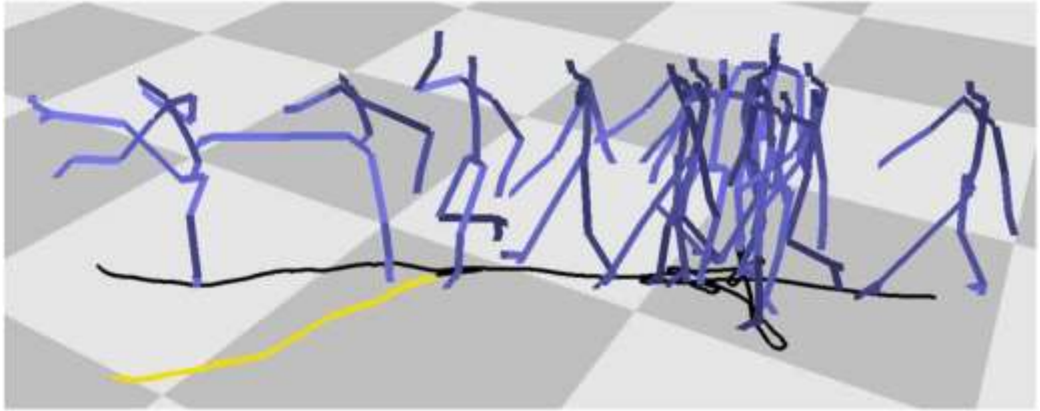


Figure 17: A generated motion using motion graph with position and orientation difference as a metric

- Key requirements in *g:*
  - Guidance through motion
  - Not be too restrictive

Path Synthesis

- Error metric – Distance between points in path
  - Given path – P and actual path P'

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

  - Where,
    - i – frames in edge
    - e_i – i^{th} frame of edge
    - $s(e_i)$ - arc length at e_i
  - Halting condition: current total length of P' ≥ length of P

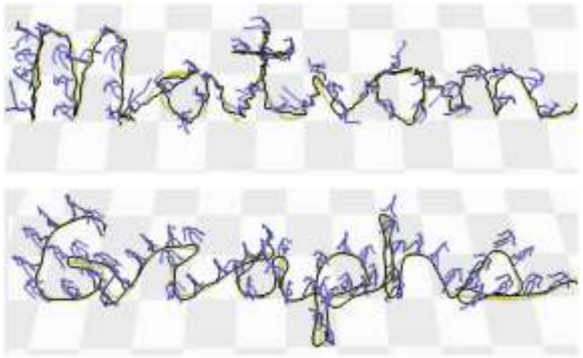


Figure 18: A generated motion using path synthesis algorithm

Character accumulates zero error by standing still

Path synthesis- with descriptive labels

- All generated motion of single type
- Confine search to relevant sub graphs
- Mixed labels on parts of path : Distinct labels for adjoining parts of path

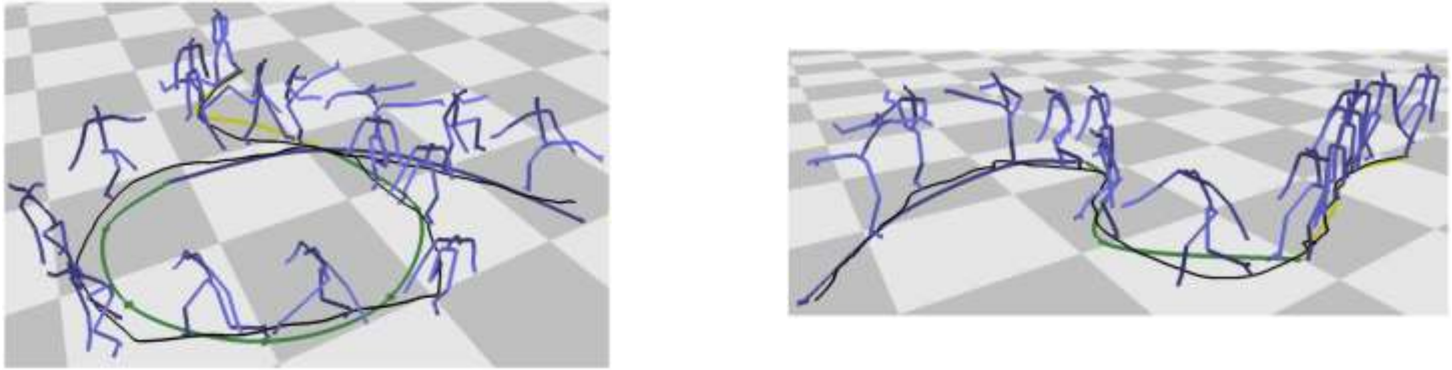


Figure 19: Motions generated with different labels on different parts of the path

Final Synthesized motion

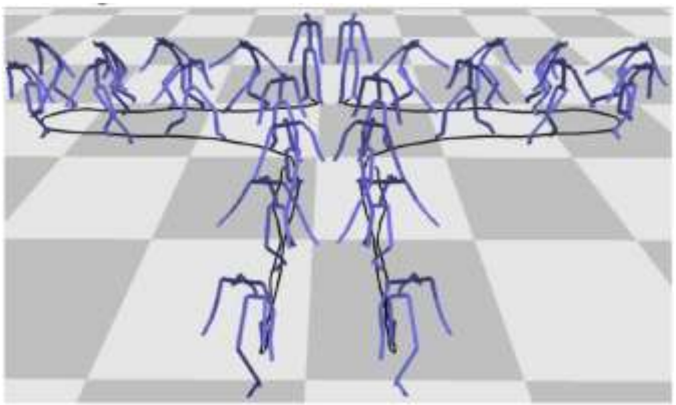


Figure 20 : Original motion clip and its reflection

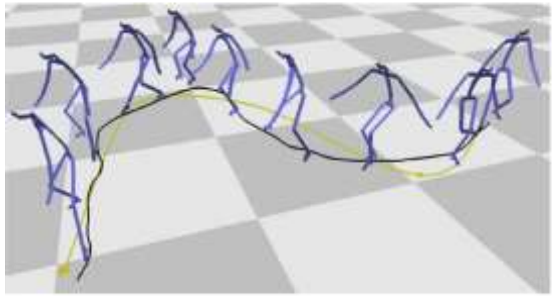


Figure 21 : Motions generated with path synthesis algorithm

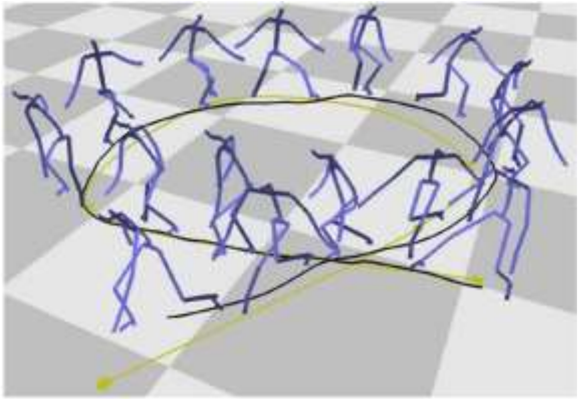


Figure 22: Motions generated with path synthesis algorithm

Final Synthesized motion

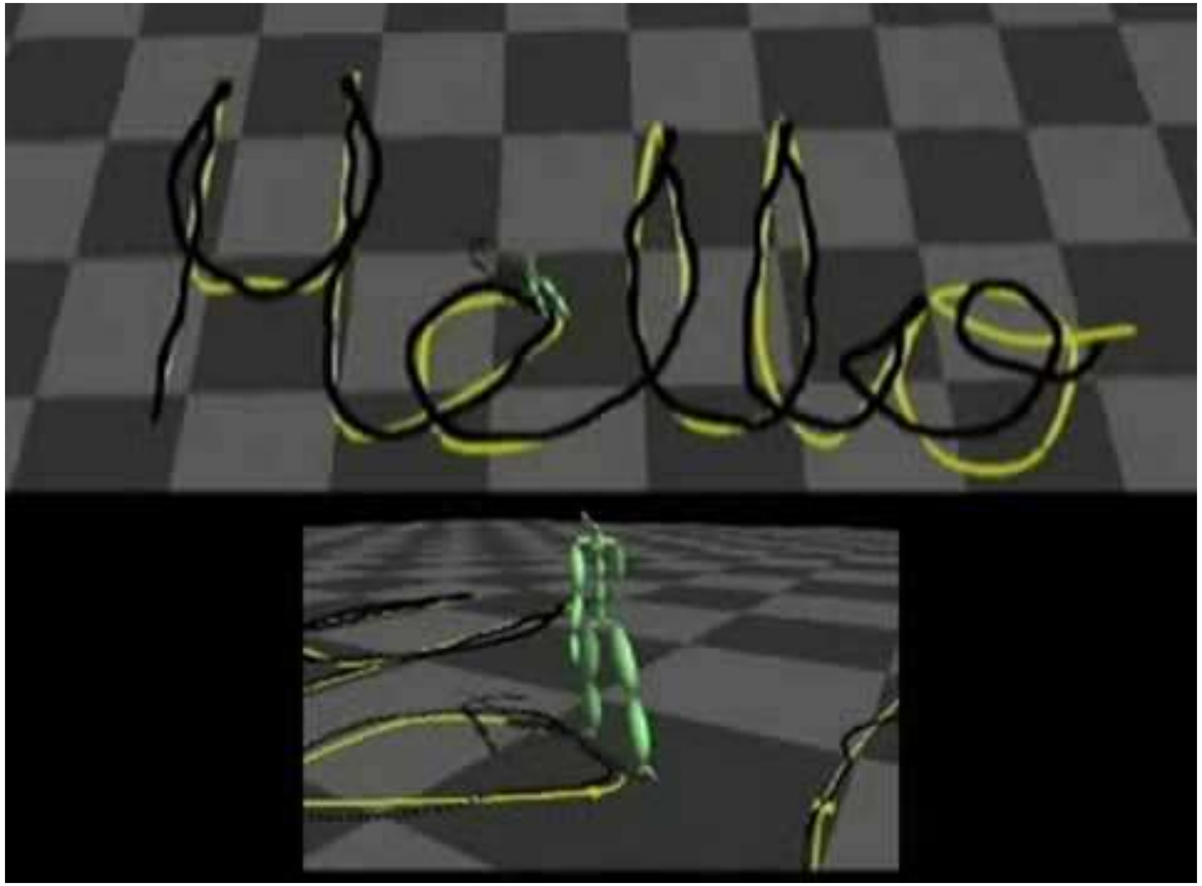


Figure 23 : Results: Motion generated with Kovar et al.. 2002 algorithm

Applications

- **Interactive control:** User control over character
- **High-Level Key Framing:** define subsections with required action types
- **Motion Dumping:** Animate non-player characters and interactive environments
- **Crowds:** Practical tool for crowd generation

Figure 27 : Interactive motion synthesis

Figure 24 : Randomly walking crowd

Figure 25 : Motion dumping in games

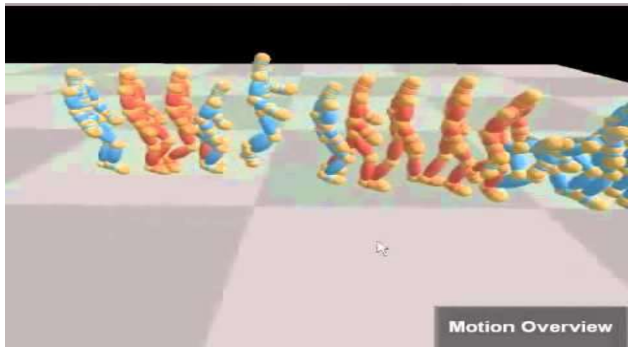
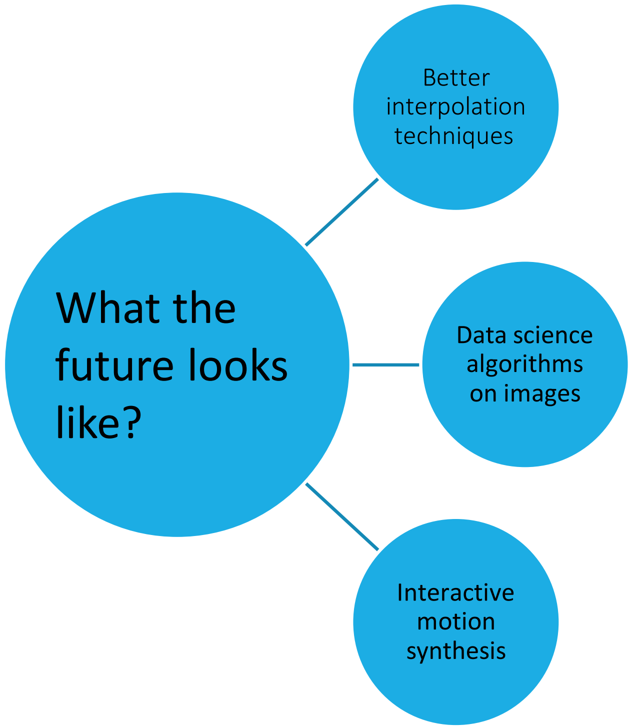


Figure 26 : High level key framing

Conclusion and Future Scope

- Framework for generating realistic, controllable motion
- Encapsulate connections in the database automatically
- Comparing every pair of F frames involves $O(F^2)$
- Major limitation here : Thresholds are user-specified



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Thank you !

References

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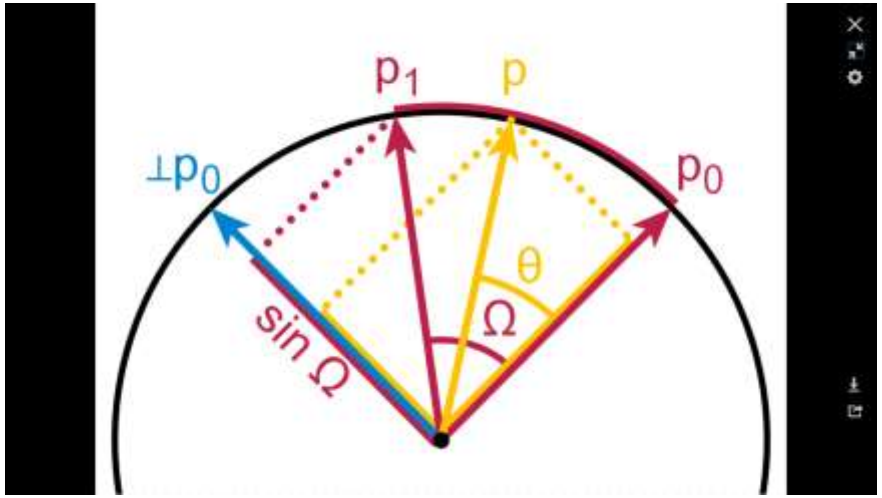
A1. Modified parametric equation in path synthesis

- Character standing still has low error
- Require atleast small progress on each frame
- Use $t(e_i)$ instead of s(e_i)

$$t(e_i) = \max(t(e_{i-1}) + s(e_i) - s(e_{i-1}), t(e_{i-1}) + \gamma_i$$

A2. Slerp

- Shorthand for spherical linear interpolation
- Rotation with uniform angular velocity around a fixed rotation axis



A2. Optimised solution of the metric

$$\theta = \arctan \frac{\sum_i w_i (x_i z'_i - x'_i z_i) - \frac{1}{\sum_i w_i} (\overline{x}\overline{z'} - \overline{x'}\overline{z})}{\sum_i w_i (x_i x'_i + z_i z'_i) - \frac{1}{\sum_i w_i} (\overline{x}\overline{x'} + \overline{z}\overline{z'})}$$

$$x_0 = \frac{1}{\sum_i w_i} (\overline{x} - \overline{x'} \cos(\theta) - \overline{z'} \sin\theta)$$

$$z_0 = \frac{1}{\sum_i w_i} (\overline{z} + \overline{x'} \sin(\theta) - \overline{z'} \cos\theta)$$

where $\overline{x} = \sum_i w_i x_i$ and the other barred terms are defined similarly.