Fast Skeleton Estimation from Motion Capture Data using Generalized Delogne-Kåsa

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Synopsis

- Purpose
- Motion Capture
- Skeleton Formation
- Closed Form Solution
- Conclusion

Purpose

- Draw an articulated framework of solid segments connected by joints.
- Fastest possible solution from motion capture data

Motion Capture

- Magnetic Trackers
  - Position and Orientation
- Marker Reflectors
  - Position if in view
- Figure Tracking
  - Computer vision and image analysis

Motion Capture Session

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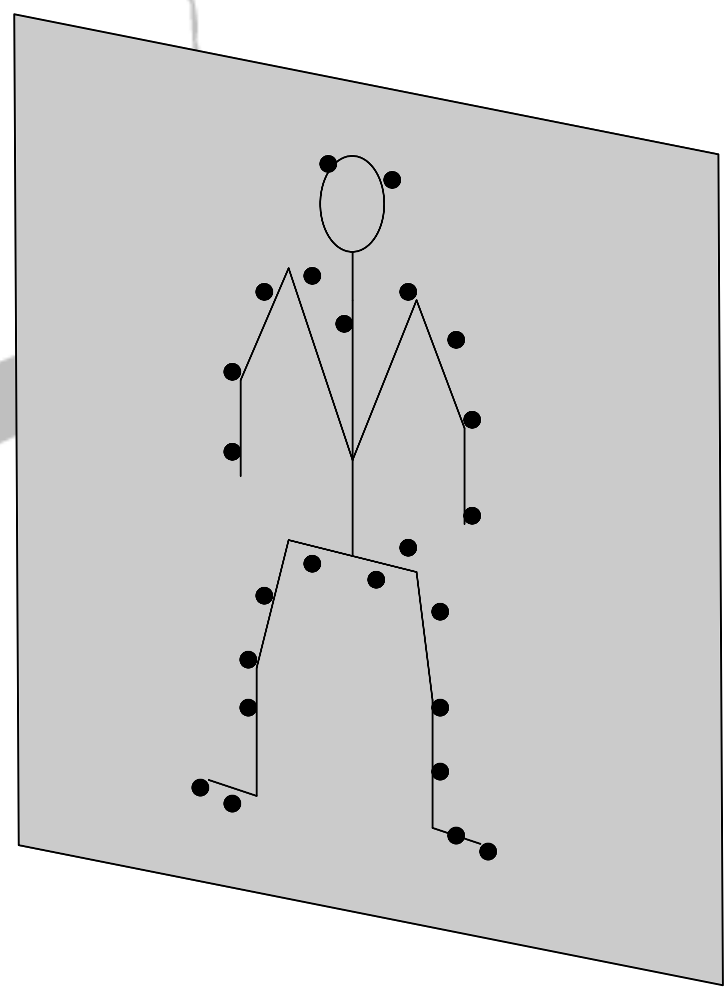
Producing a Skeleton

- Single Time Frame
  - Produce position, size and orientation of each segment
  - Markers are fixed 3D positions on segment
  - Orientation is included with magnetic trackers
  - Draw lines between rotation points

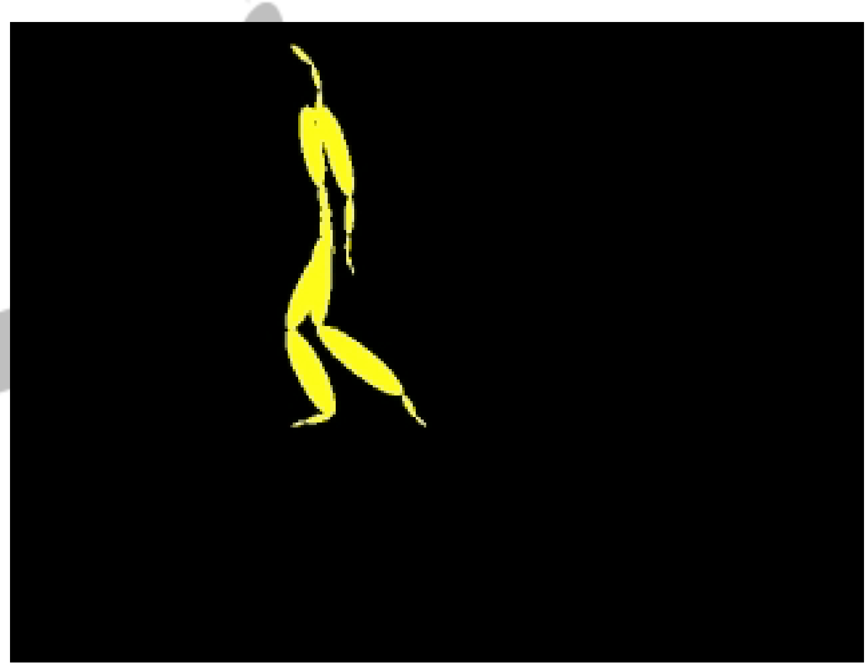
Time Slice



Inverse Kinematics

- What joint angles are needed to get to next position and orientation?
- Good for filling in large frame gaps
- Sometimes more than one answer

Inverse Kinematics Example



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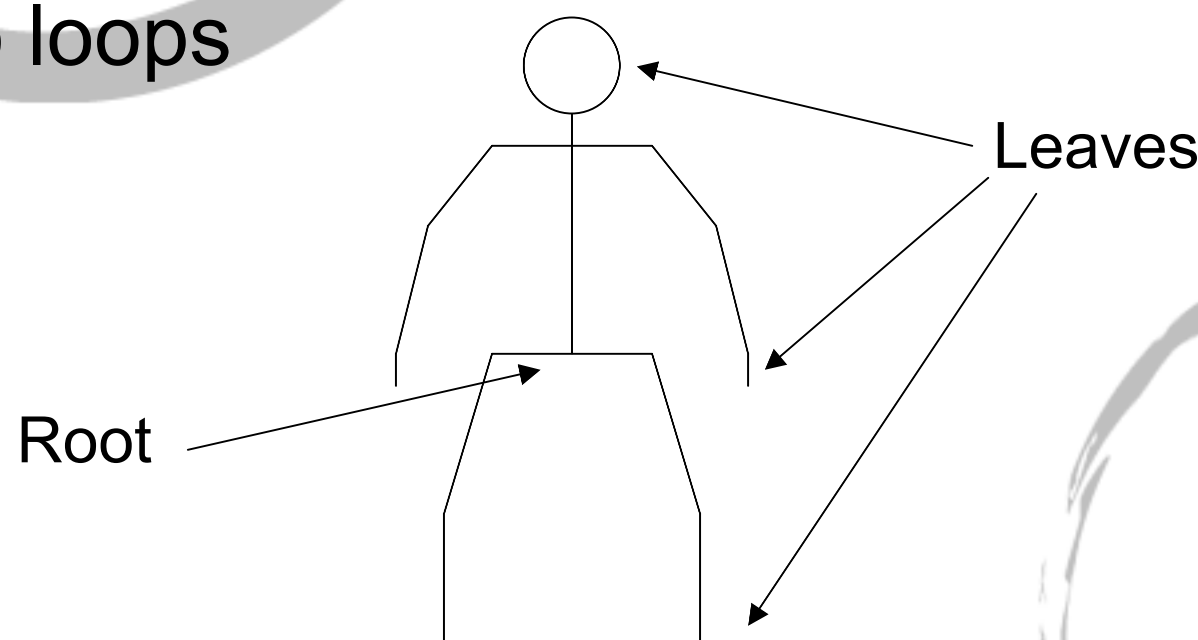
Closed Form Solution

- Find centers of rotation for each segment
- Each frame independently drawn
- No iterations
- Quick solution

Segment Tree

- Root segment usually hips
- Leaf segments hands, head and feet
- No loops



Solve Sphere at Each Joint

- One marker on child produces sphere around joint relative to parent
- Must know orientation of parent
  - 1-3 markers needed or
  - Magnetic trackers

Three Point Orientation

- Three Orthogonal Axes

$$\hat{x} = \frac{\vec{p}_2 - \vec{p}_1}{\left|\vec{p}_2 - \vec{p}_1\right|}$$

$$\hat{z} = \frac{(\vec{p}_3 - \vec{p}_1) \times \hat{x}}{\left|(\vec{p}_3 - \vec{p}_1) \times \hat{x}\right|}$$

$$\hat{y} = \hat{z} \times \hat{x}$$

Two Point Orientation

- Three Orthogonal Axes
- Substitute center of rotation

$$\hat{x} = \frac{\vec{p}_1 - \vec{c}}{\left|\vec{p}_1 - \vec{c}\right|}$$

$$\hat{z} = \frac{\left(\vec{p}_2 - \vec{c}\right) \times \hat{x}}{\left|\left(\vec{p}_2 - \vec{c}\right) \times \hat{x}\right|}$$

$$\hat{y} = \hat{z} \times \hat{x}$$

One Point Orientation

- Three Orthogonal Axes
- Substitute center of rotation and constant axis

$$\hat{x} = \hat{n}$$

$$\hat{z} = \frac{(\vec{p}_1 - \vec{c}) \times \hat{x}}{\left|(\vec{p}_1 - \vec{c}) \times \hat{x}\right|}$$

$$\hat{y} = \hat{z} \times \hat{x}$$

Extra Information

- Center of Rotation is available from previously calculated segment
- Constant Axis is available for segments with near cylindrical motion.

Center of Sphere

- Generalized Delogne-Kåsa Method for points on a hypersphere x_i

$$\vec{c} = \bar{x} + \tfrac{1}{2}\mathbf{C}^{-1}\mathbf{S}$$

$$\mathbf{C} = \tfrac{1}{N-1}\sum_{i=1}^{N}\left(x_i - \bar{x}\right)\left(x_i - \bar{x}\right)^T$$

$$\bar{x} = \tfrac{1}{N}\sum_{i=1}^{N} x_i$$

$$\mathbf{S} = \tfrac{1}{N-1}\sum_{i=1}^{N}\left(x_i - \bar{x}\right)\left(x_i - \bar{x}\right)^T\left(x_i - \bar{x}\right)$$

Constant Axis

- Test by condition number or determinant of C

$$|\mathbf{C}| \approx 0$$

- Null vector is axis of cylinder motion
- Center of circle

$$\mathbf{C}\hat{n} = 0$$

$$\vec{c}\,' = \vec{c} + \hat{n}\hat{n}^T\left(\bar{x} - \vec{c}\right)$$

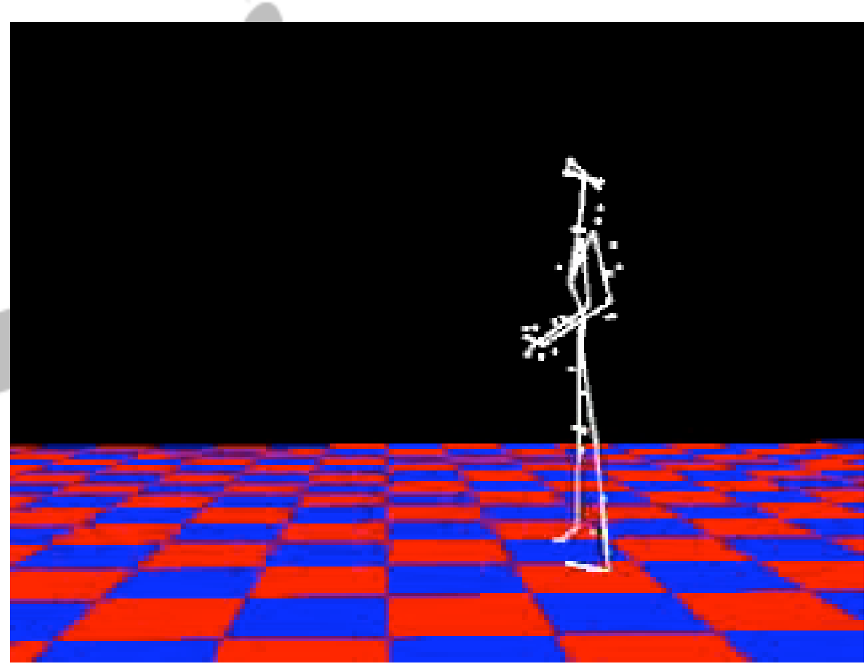
GDK Properties

- Closed form solution for any dimension
- Fastest known 26N
- Cholesky inverse of 3x3 matrix
- Biased when partial coverage of sphere
- As accurate as data $O(\sigma)$

Marker Requirements

- 3 Markers on root segment of tree
- 1-3 Markers on all other segments
- Segments with 1 Marker should have one degree of freedom (e.g.knee,elbow)

Break Dance



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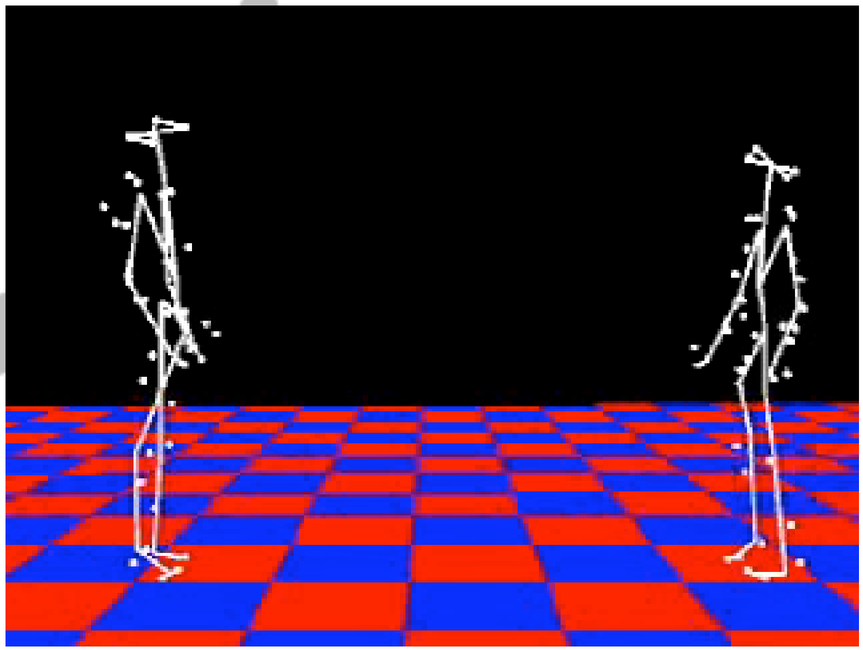
Salsa Dance



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Conclusion

- GDK is fastest available sphere solution 26N
- As accurate as data O(σ)
- 1-3 Marker requirements per segment
- Provides skeleton to attach solid shape

Future Research

- Unbiased version of GDK
- Full analysis of statistical nature
- Condition for acceptable data

Acknowledgments

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