Graph-based Approach for Motion Capture Data Representation and Analysis

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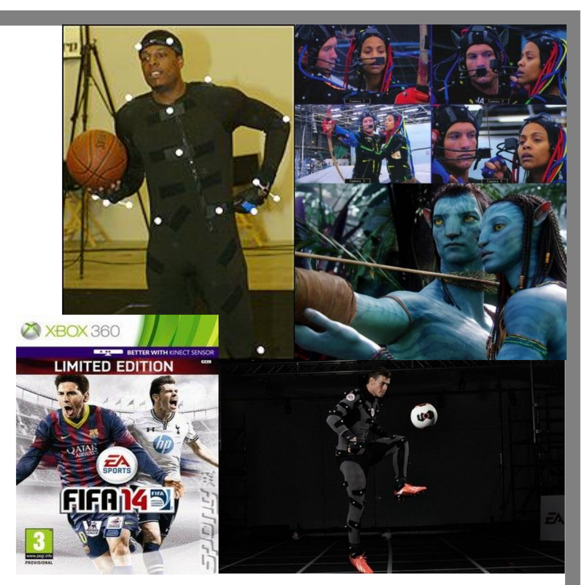
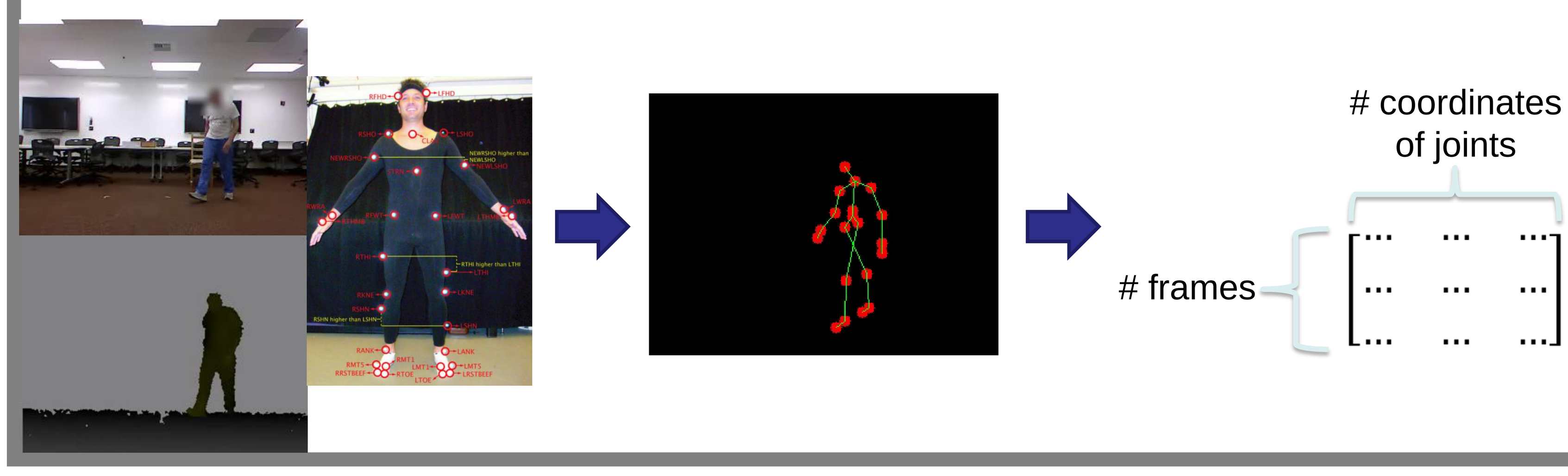
Motion Capture?



- Sample & record motions of humans
- Represent as 3D data
- Applications in various fields:
  medicine, film, animation, video gaming, sports,…
- Tracking coordinates of body joints



Problem Formulation

❑ Research Problem

- Next steps: classification, recognition, synthesis, …
- Finding a good feature space to represent would be good

❑ Proposed Solution

- Modeling human skeleton as a fixed undirected graph
- Projected motion between frames as the graph signals onto the graph Laplacian
- This could provide an Fourier interpretation of the graph signals.

Discussions

- ❑ Structure of basis vectors changed with graph formulation
- ❑ 2 ways to formulate graph: natural skeleton or with motion of interest
- ❑ Bilateral symmetric basis vectors reveal the bilateral coordination
- ❑ 90% energy explained by first few basis vectors - good preprocessing for dimensionality reduction
- ❑ Construct a more "symmetric" basis to accommodate symmetric motion

Conclusions and Future Work

- ❑ Provide a new representation for MoCap data and provide a good alternative processed data to the following analysis step
- ❑ Basis vectors are easy to interpret and can be designed to accommodate specific motion of interests or skeletal structure
- ❑ Find a more systematic methodology to formulate the graph, especially the edge weight selection

Reference: J.-Y. Kao, A. Ortega, S. S. Narayanan, "Graph-based Approach for Motion Capture Data Representation and Analysis", In Proceedings of IEEE International Conference on Image Processing, pp. 2061-2065, Oct. 2014

Proposed Method

❑ Graph Signals

Signal defined on an arbitrary graph $G = (V, E)$

$$graph\ signal\ \boldsymbol{x} = \begin{bmatrix} x_1 \\ \vdots \\ x_N \end{bmatrix}$$

Above is a one-dimensional graph signal.

❑ Spectrum of Graphs

- Adjacency matrix $\boldsymbol{A}$, degree matrix $\boldsymbol{D}$
- Normalized Graph Laplacian Matrix $\boldsymbol{\mathcal{L}} = \boldsymbol{I} - \boldsymbol{D}^{-1/2}\boldsymbol{A}\boldsymbol{D}^{-1/2}$
- Eigenvectors of $\mathcal{L}$: $\boldsymbol{U} = \{\boldsymbol{u}_k\}_{k=1:N}$
- Eigenvalues of $\mathcal{L}$: $\boldsymbol{\sigma}(\boldsymbol{G}) = \{\boldsymbol{\lambda}_1, \boldsymbol{\lambda}_2, \dots, \boldsymbol{\lambda}_N\}$
- Properties:

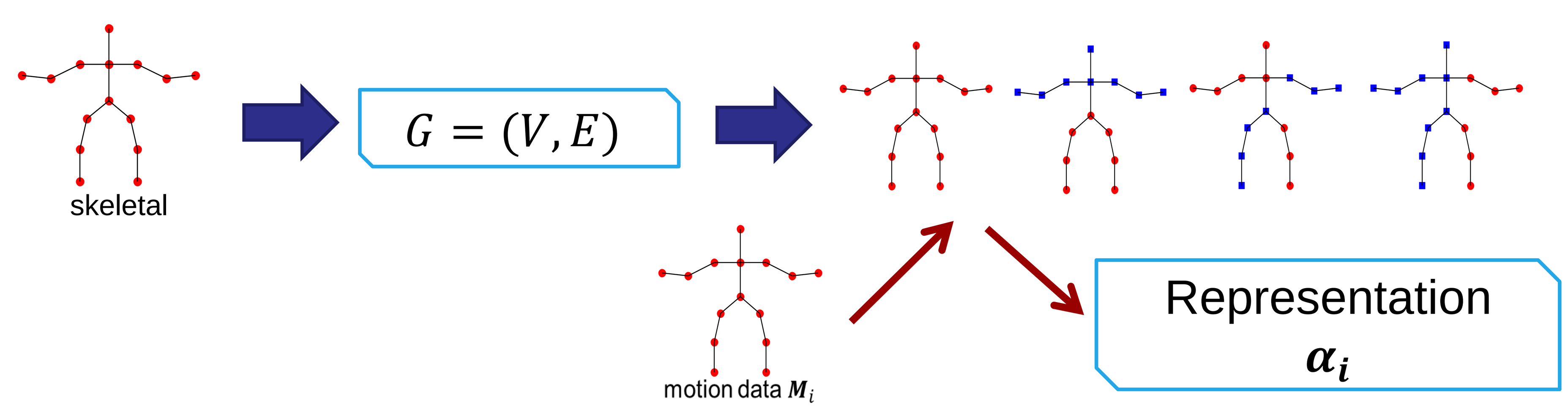
① $\mathcal{L}$ is semi-definite (+)
② $\{\boldsymbol{u}_k\}_{k=1:N}$ can form a basis for $\mathcal{R}^N$
③ $\{\lambda_k\}_{k=1:N}$ is called the spectrum of graph G

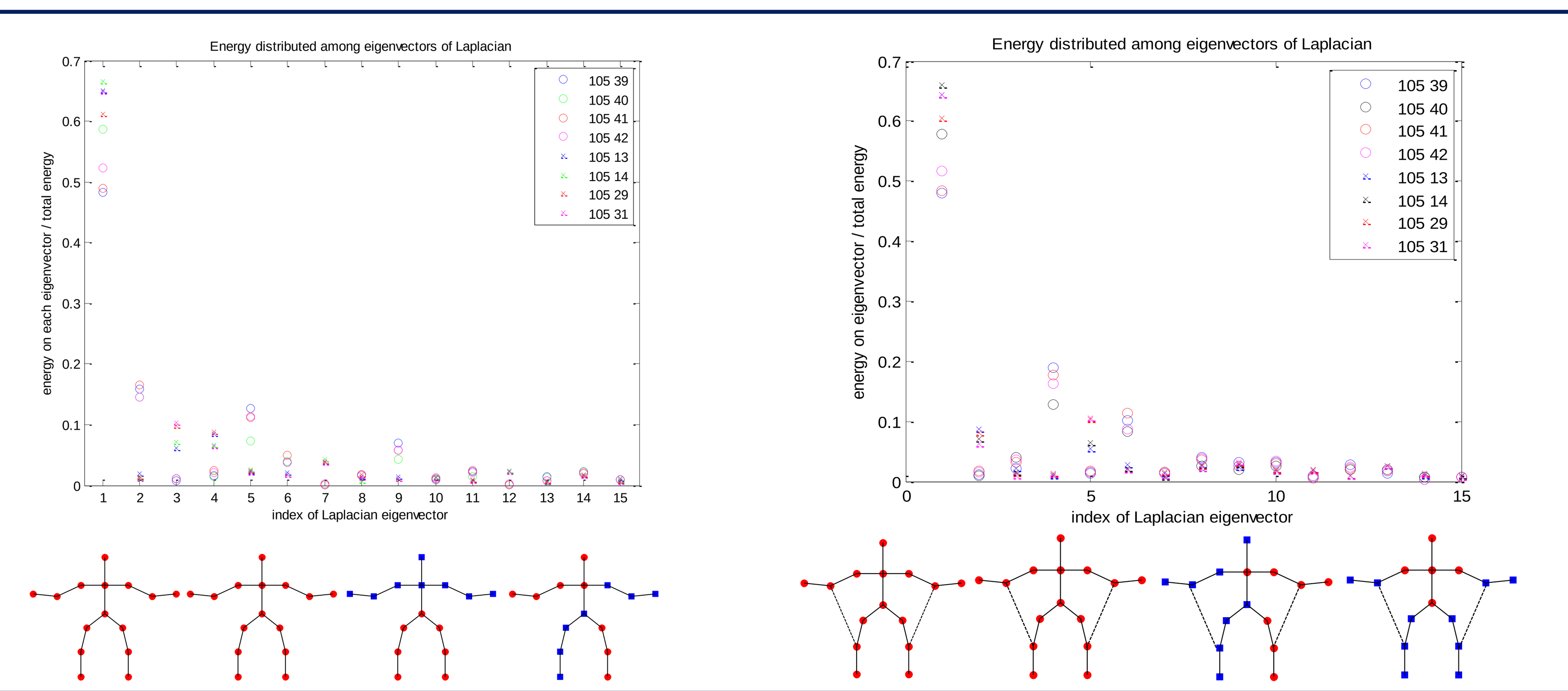
→ *Eigen-pair system $\{(\lambda_k, u_k)\}$ provides Fourier interpretation for graph signals.*

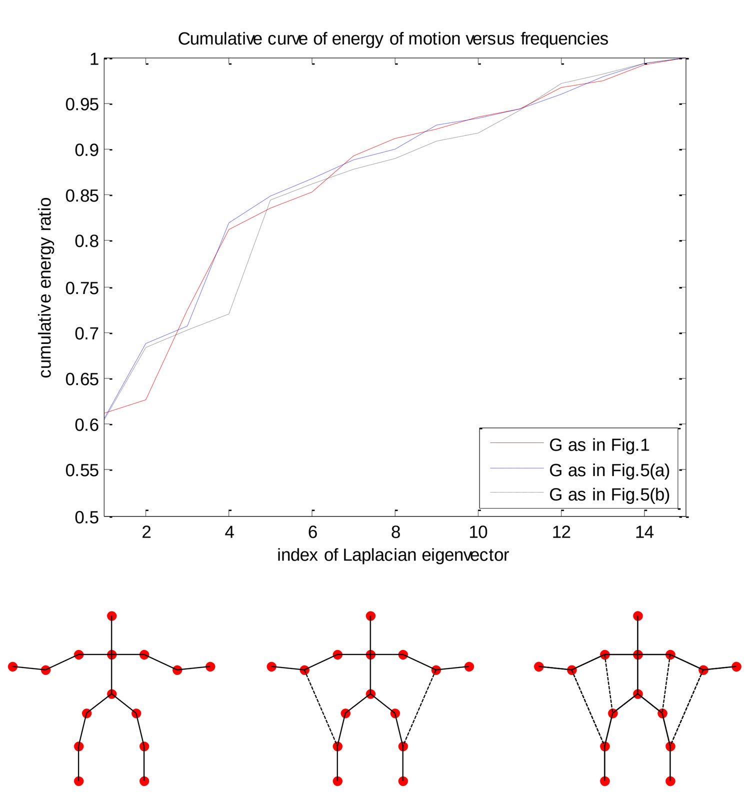
❑ Proposed Representation

- Motion data per frame $\boldsymbol{M}_i \sim \boldsymbol{d} \times 3$
- $\boldsymbol{M}_i = \sum_{k=1}^{d} \boldsymbol{u}_k \boldsymbol{\alpha}_{k,i}^T$, $\boldsymbol{\alpha}_{k,i} = \boldsymbol{M}_i^T \boldsymbol{u}_k$

Experiments







$$symm = \sum_{(i,j)\ \in\ pair\ of\ symmetric\ nodes} \left| \frac{(V(i) - \bar{V})(V(j) - \bar{V})}{Var(V)} \right|$$

PCA	1st dim.	2nd	3rd
	3.8622	3.9818	4.1016
Graph-based	Fig. 1	Fig. 5(a)	Fig. 5b
	5.3236	5.5245	5.4215