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Graph-based Approach for Motion Capture Data Representation and Analysis

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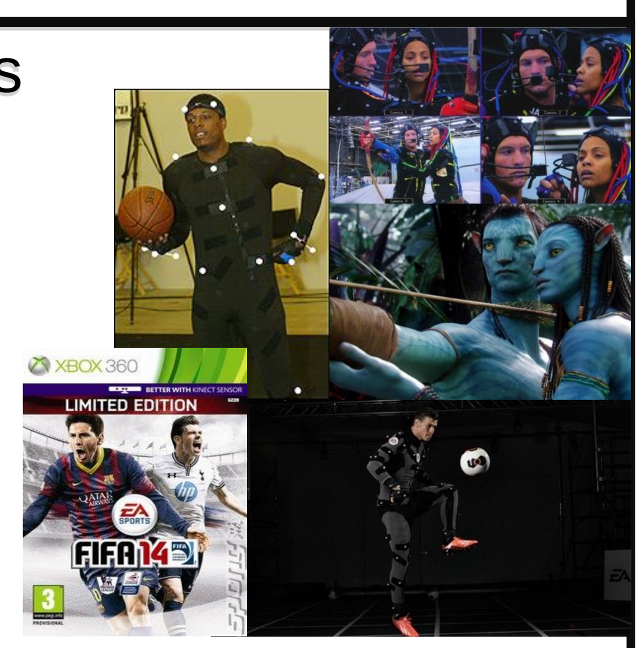
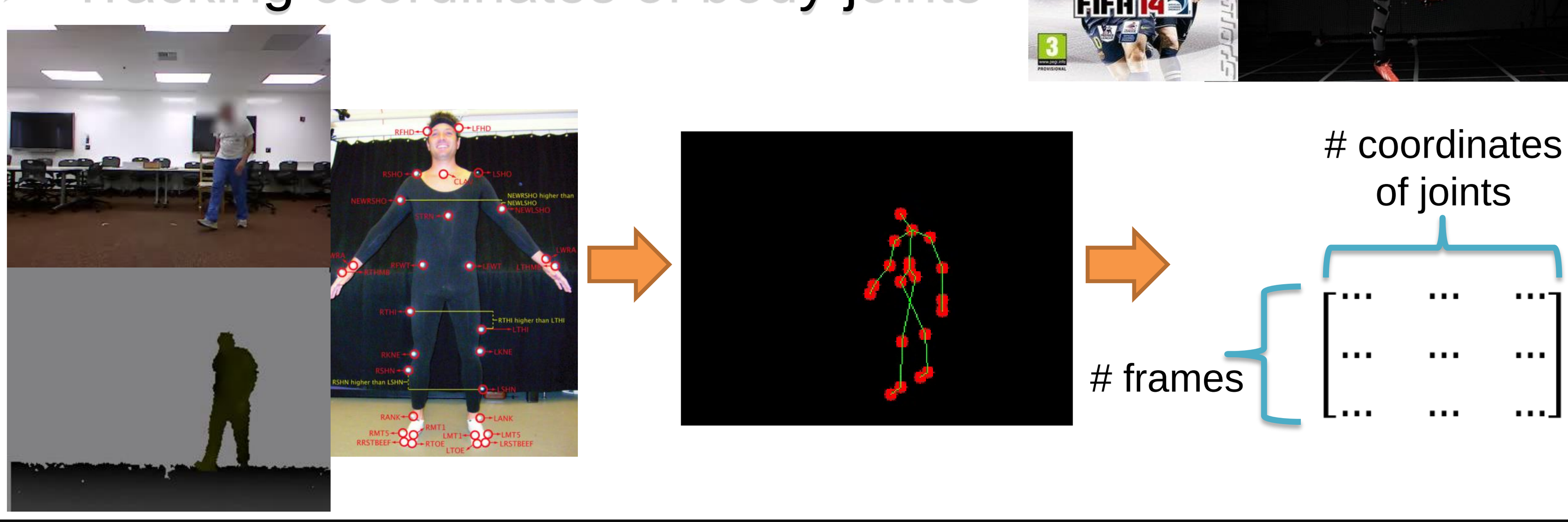
Motion Capture?

- 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

Future Work

- Find a more systematic methodology to formulate the graph, especially the edge weight selection

Proposed Method

- **Graph Signals**

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

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

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 $\mathcal{L}$: $\sigma(G) = \{\lambda_1, \lambda_2, \dots, \lambda_N\}$
  - Properties:

① $\mathcal{L}$ is semi-definite (+)

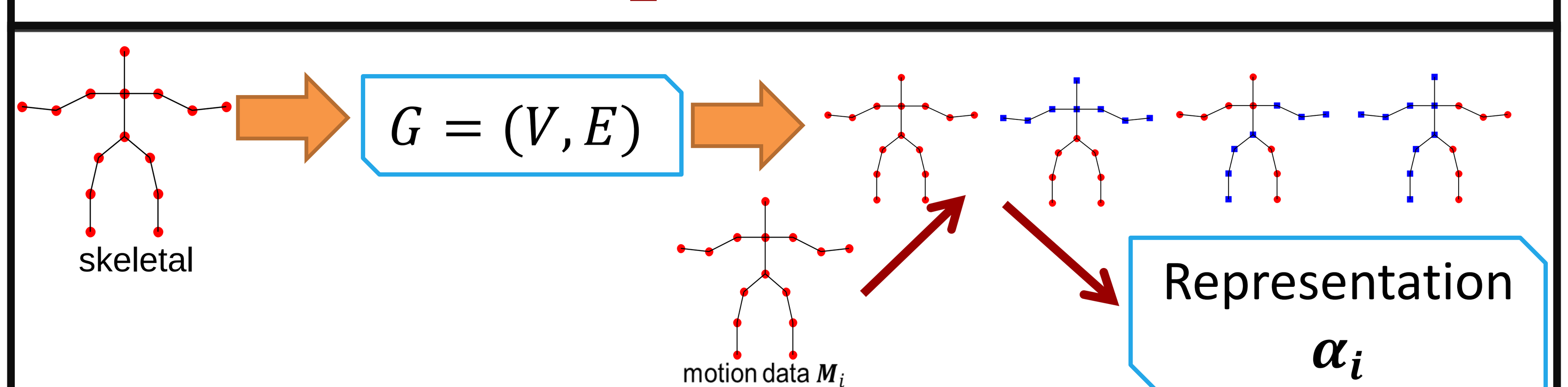
② $\{\boldsymbol{u}_{\mathrm{k}}\}_{\mathrm{k=1:N}}$ can form a basis for $\mathcal{R}^{\mathrm{N}}$

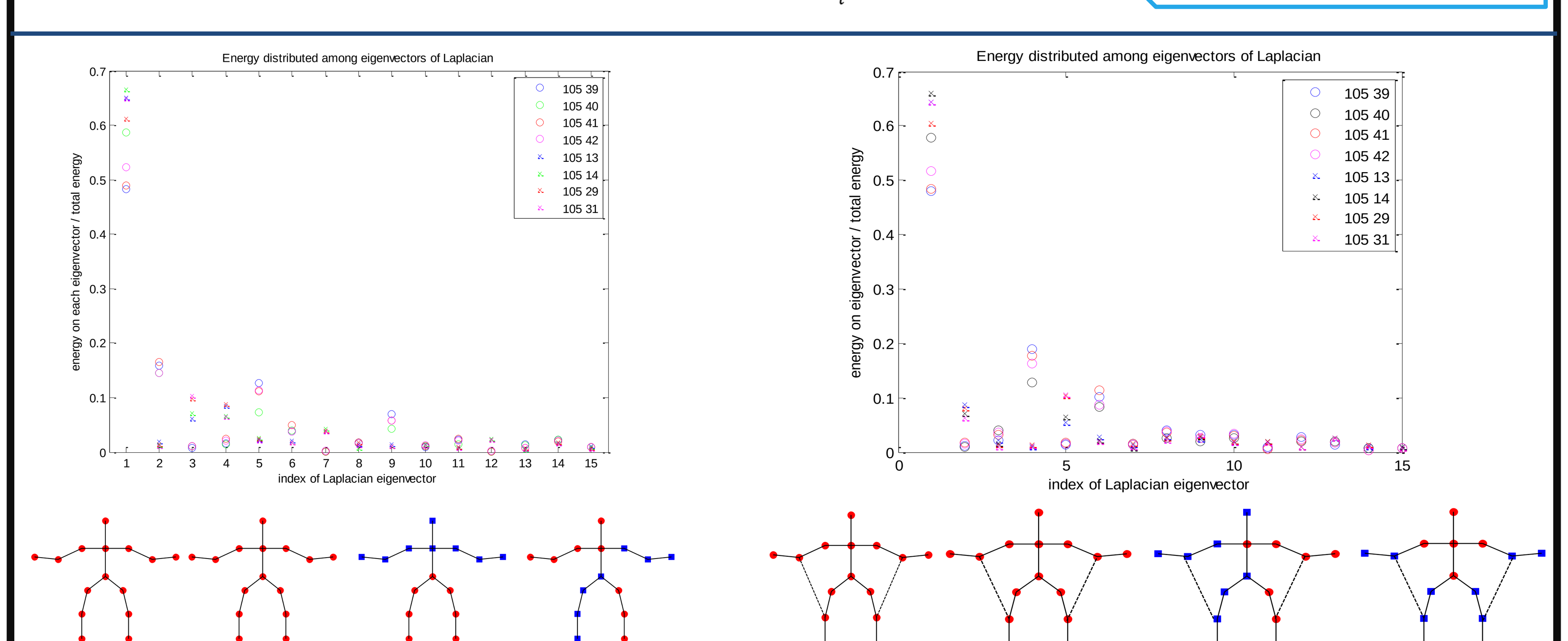
③ $\{\lambda_{\mathrm{k}}\}_{\mathrm{k=1:N}}$ is called the spectrum of graph G

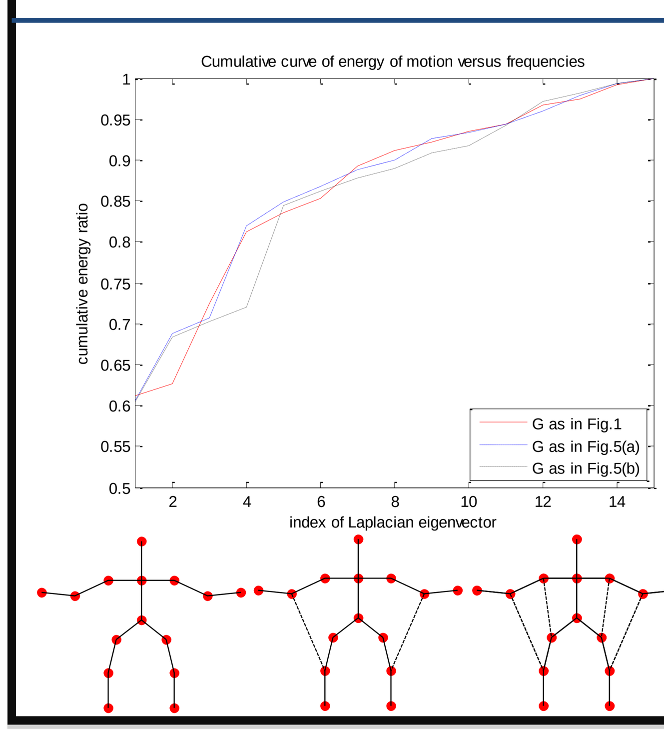
→ *Eigen-pair system $\{(\lambda_k, u_k)\}$ provides Fourier interpretation for graph signals.*

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

Experiments







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

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

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