Multi-dimensional Graph Signal Processing for Time Series Analysis

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Introduction

➢ **Research Problem :**

Given estimated human skeleton coordinates from video, we would like to classify individuals into Parkinson's patients and non-Parkinson's people based on their observed motion while performing specific tasks.

➢ **Proposed Solution :**

We modeled human skeleton as a fixed undirected graph. Based on spectral graph theory, we projected motion between frames (as the graph signals) onto the graph Laplacian, which could provide an Fourier interpretation of the graph signals.

Motivation

➢ **Graph Signals**

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

$graph\ signal\ x=[x_1\ x_2\ \ldots\ x_N]$

Above is a one-dimensional graph signal.

➢ **Spectrum of Graphs**

- Adjacency matrix **A**, degree matrix **D**
- Normalized Graph Laplacian Matrix $\mathcal{L}=I-D^{-1/2}AD^{-1/2}$
- Eigenvectors of $\mathcal{L}: U=\{u_k\}_{k=1:N}$
- Eigenvalues of $\mathcal{L}: \sigma(G)=\{\lambda_1,\lambda_2,\ldots,\lambda_N\}$
- Properties

① Matrix $\mathcal{L}$ is semi-definite (+)

② $\{u_k\}_{k=1:N}$ 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.*

System Architecture

① Construct an undirected graph for human skeleton, with joints as vertices and connections as edges.

② Pre-process the coordinates of each joints in each frame to get the three-dimensional graph signals

→ project difference between frames onto the movement direction of the whole task

③ Project the produced graph signals onto the graph Laplacian matrix

④ Calculate certain defined metrics

→ e.g. average magnitude of projection

⑤ Comparison, interpretation and classification

Preliminary Results

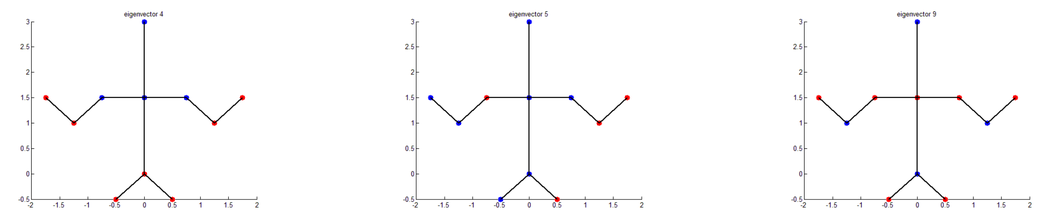


Figure : Three eigenvectors out of totally eleven eigenvectors. Eigenvectors 4 and 9 are bilaterally symmetric in colors (signs) while eigenvector 5 is not.

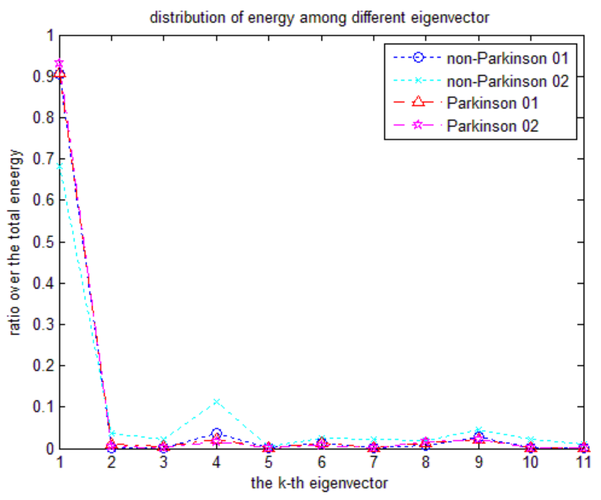
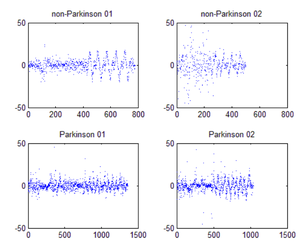
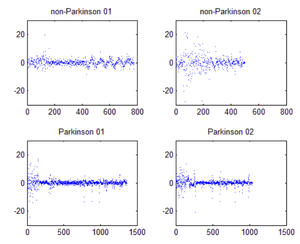


Figure : The magnitude of projection onto different eigenvectors.



(a) magnitude of projection on eigenvector 4



(b) magnitude of projection on eigenvector 5

➢ Observing the magnitude of projection among different eigenvectors, we can find that the magnitude of projection has obvious signals (corresponding to the times motion being conducted) only for some eigenvectors

➢ We find that those eigenvectors which are bilaterally symmetric in colors usually possess higher magnitude in projection vectors. More obvious signals can be observed in the projection.

➢ This provides an interpretation that the motion conducted by human body has a trend to be bilaterally symmetric.

➢ Two possible applications:

① Classification : provide features to help classify different motions

② De-noising : eliminate the components in the non-symmetry eigenvectors

Related Research

David I Shuman, Sunil K. Narang, Pascal Frossard, Antonio Ortega, Pierre Vandergheynst
"Signal processing on graphs : extending high-dimensional data analysis to networks and other irregular domains"
in IEEE Signal Processing Magazine

Henning Hamer, Konrad Schindler, Esther Koller-Meier, Luc Van Gool
"Tracking a Hand Manipulating an Object"
in IEEE ICCV, October 2009

Kohn, B., Nowakowska, A., Belbachir, A.N.
"Real-time body motion analysis for dance pattern recognition"
in 2012 IEEE CVPRW, June 2012

Conclusion and Future Work

➢ Proposed a design to process and analyze position data of human motions in terms of graph based approach

➢ Future Work :

① Acquire more interpretation in specific body parts.

② Establish a different basis according to the targeted motion.