DIMACS Student Initiated Research Project Report

TITLE:

TENSOR ANALYSIS FOR GAIT

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Motivation:

This project is the extension of my previous work which analyse gait image sequences and identified different person from the gait stye in variant factors of variant speed of gait image sequence. At that time, I analyzed gait image sequence by separating gait image sequence into gait style factor and gait content factor using bilinear model[1]. At that time, we just analyzed two factors, gait style and gait content, even though there exist more variant factors. All factors which is not dependent on gait style, which is the characteristics of individual gait motion, counted as gait contents. Even though we got some interesting result based on these two component analysis[2], we expect that we can get better recognition rate if we analyze it in multiple factors. This project is generalization of previous two factor analysis to multiple factors using tensor analysis.

In addition to that we expect good representation and query for data mining after multiple factor analysis. Data set of the whole image is huge and it makes difficult to analyze and query the data set. If we can represent the whole image stream data set by combination of separate factors and represent each factors with feature vectors in low dimension, it will help us data analysis and mining. For example, if we have one person gait pose image and the other person gait image in different view and different gait pose, and we want to find the same gait pose of the other person, we can find proper images by comparing feature vectors in the data set similar to the first person *gait pose feature vector* and *view feature vector* and the second person *person feature vector*. As we have separate feature vectors for each component we can extract proper information using lower dimensional vector comparison. This feature vector also help human indentification or other classification problem.

Approach:

I analyzed gait image streams with different views and walking styles for different persons. I implemented multilinear singular value decomposition(SVD) [3] in Matlab, which is applied recently for face image analysis[4], to find out separable multiple factors in gait image sequence data set. The difference of face image and gait image sequence is from the dynamics of gait motion and gait image sequences usually have multiple cycles. I used CMU MoBo database[5] for the analsis of gait image sequence for several different factors: view, person and pose.

Experimental Result:

Three person gait image sequences with three different views are selected from CMU Mobo database. Five gait poses are resampled from gait cycles to get well aligned data [2]. Figure 1 is an example of silhouette images for a person gait sequence of a cycle. This figure shows five poses, which is the result of resampling. Figure 2 shows three different views for the person gait sequences. We used side view, front view and intermediate view between side and front view. We represented the silhouette image based on signed distances to stabilize the computation in the analysis.

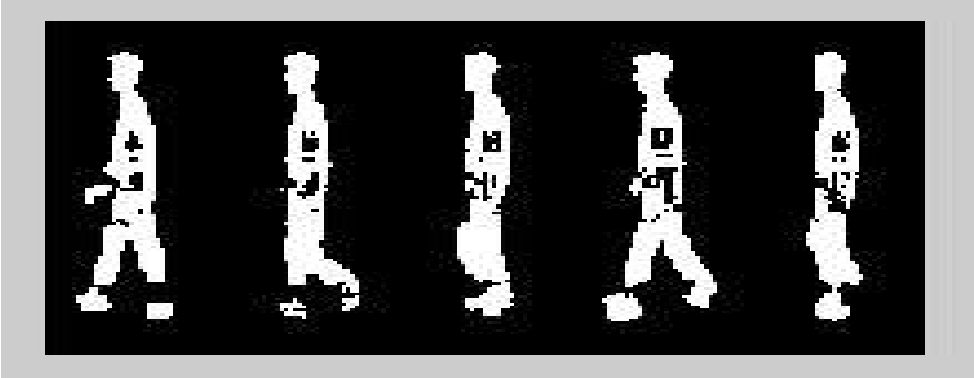

Figure 1 Silhouette Gait Image of Sequences

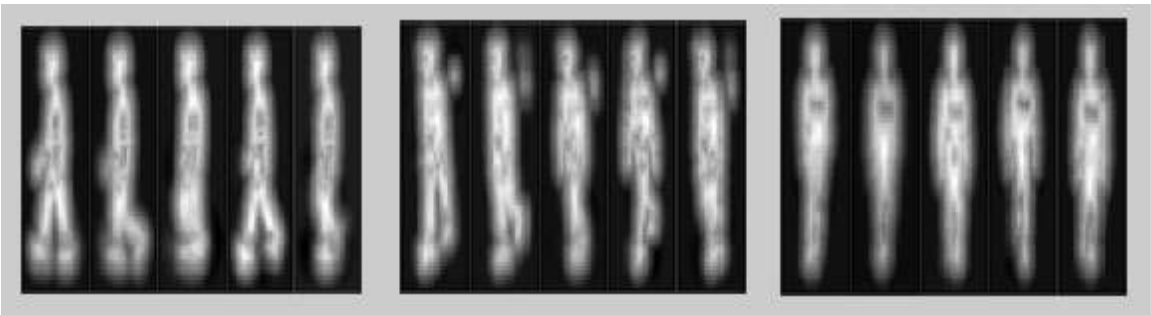

Figure 2 Gait sequence image of 3 different views

We analyzed the data set using fourth-order multilinear tensor analysis.

$$D = Z \times_1 U^{person} \times U^{view} \times U^{pose} \times U^{pixel}$$

, where D is tensor for the original data collection with dimension $3 \times 3 \times 5 \times 1500$, Z is core tensor with same dimension as D, U^{person} is unitary matrix for person factor with 3×3 dimension, U^{view} is unitary matrix for view factor with 3×3 dimension, U^{pose} is unitary matrix for pose factor with 5×5 dimension, and U^{pixel} is unitary matrix for pixel factor with 1500×1500 dimension.

Figure 3,4, 5 and 6 shows analyzed basis vectors for each components, which are row vector in each unitary matrix of tensor analysis. Each person basis vector and view basis vector are represented by three components. For pixel basis, 1500 dimensional vector are reshaped to be able to interpret as image basis. Just frist 50 baiss are shown. In the analysis first few number of basis are important basis vectors, whose sigular values are not close to zero. In this experiments, first 45 basis are important basis for pixel basis.

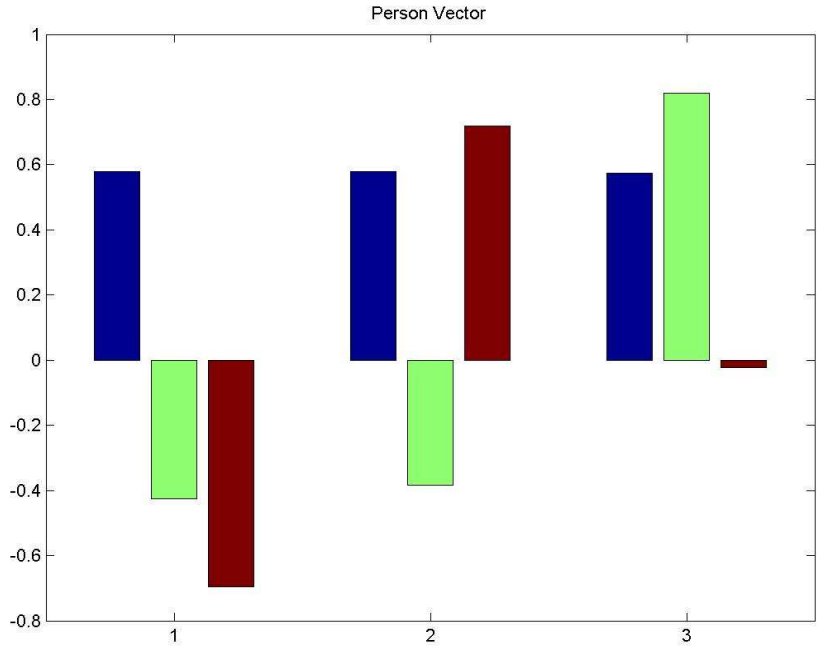

Figure 3 Three Person basis Vectors

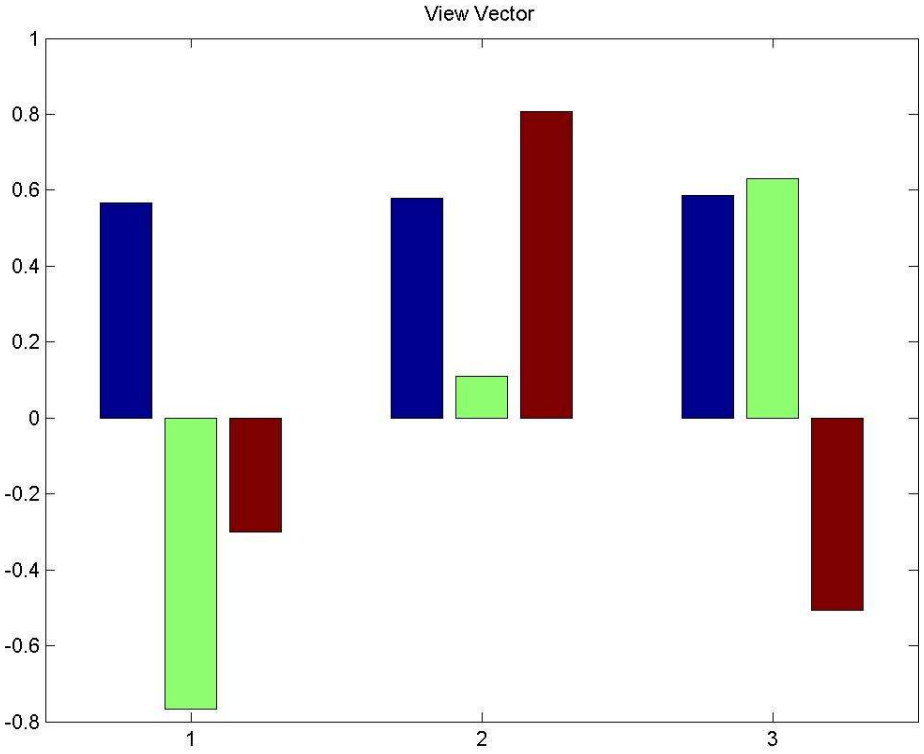

Figure 4 Three view basis vectors

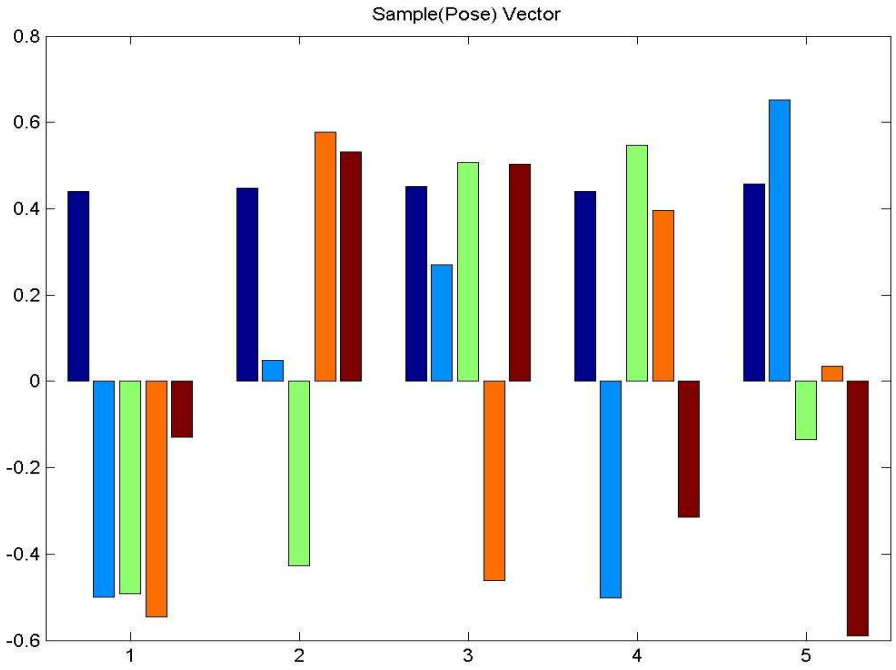

Figure 5 Five pose basis vectors

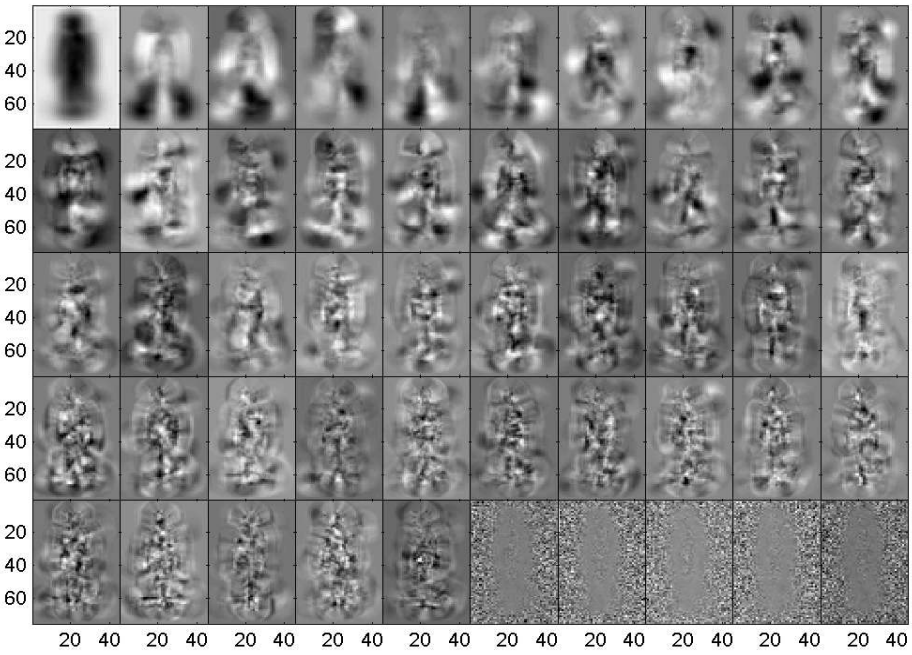

Figure 6 Pixel basis from 1 to 50 among 1500

We also analyzed person factor, which can be used for the identification of individual gait. Figure 7 shows person factor analysis for known view vector and pose vectors. We analized original image sequence and used computed pose vector based on the tensor analysis. We assumed view vector is known. The figure shows that one person style factor is dominant than other two person factors. We can use this person factor for gait recognition. Figure 8 shows the person factor analysis with arbitrary one constant pose vector, which means we did not counted the variant pose factor in gait sequence. Even though this incorrect pose vector, the person factor shows maximum values for the correct person most of the time. This is very promissing result for gait recognition using tensor analysis.

Extension

We applied this tensor analysis for the gait recogntion. We analyzed gait sequences of NIST-USF gait data set. This data set have continuous view variantion as each person walked an ellipsoidal path with pixed camera location. Attached paper explains details of computation of tensor analysis and accumulation of several cycle for gait recogntion and possibility data mining using tensor analysis.

(We plan to submit the paper to the British Machine Vision Conference)

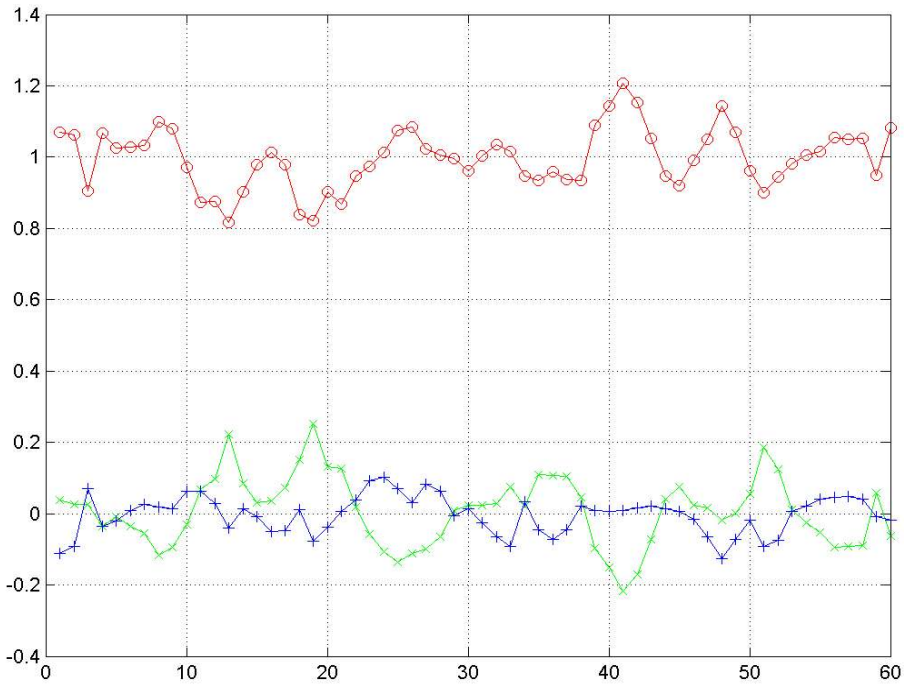

Figure 7 Person Factors for known pose vectors

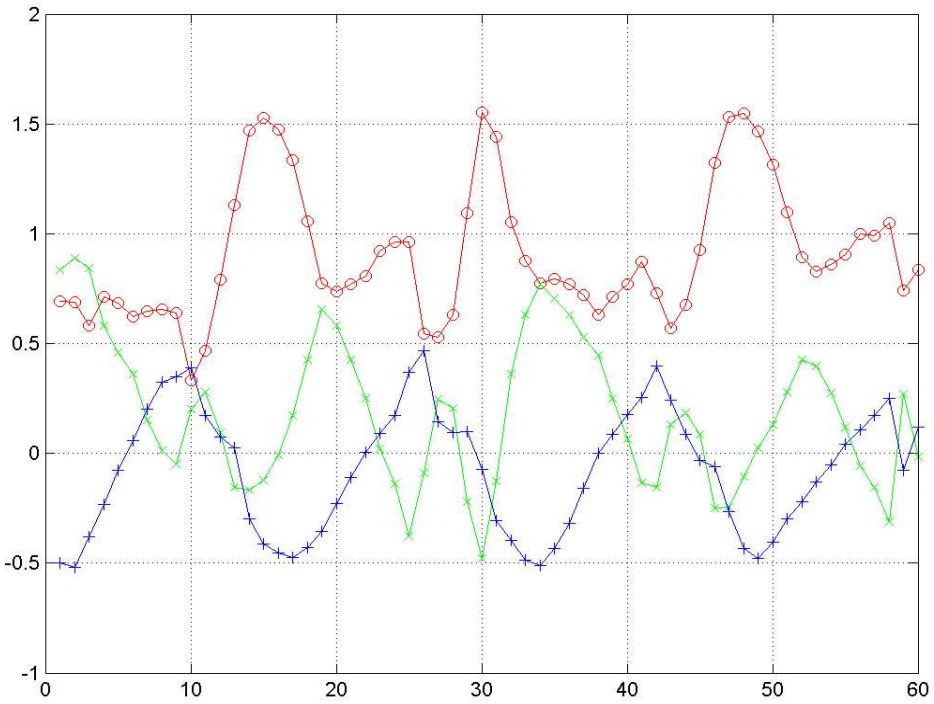

Figure 8Person Factors for unknown pose vectors

- Reference

[1] J. B. Tenenbaum et al., "Separating Style and Content with Biliear Models", Neural Computation, Vol. 12, pp. 1247-1283, 2000

[2] Chan-Su Lee et al. "Gait Recognition Using Low Dimensional Embedding and Biliear Models" accepted to IEEE Automatic Face and Gesture Recognition, 2004

[3] L.D. Lathauwer et al. "A Multilinear Singular Value Decomposition," SIAM J. Matrix Analsis and Applications, Vol. 21, No. 4, pp.1254-1278, 2000

[4] M. Alex et al. "Multilinear Analysis of Image Ensembles: TensorFaces," ECCV2002. pp.447-460, 2002

[5] G. Ralph et al. "The CMU Motion of Body(MoBo) Databse", CMU-RI-TR-01-18, 2001