Journal of Engineering and Applied Sciences 13 (Special Issue 7): 5630-5635, 2018
ISSN: 1816-949X

The Normalization of Golek Menak Dance Motion on Decomposition Tensor Using Canonical Parafac Alternating Least Square (CP-ALS) Method

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Abstract: Dance motion is a rhythmic structure which can be represented by digital pattern of body movement and estimated by mathematic term of vector, matrix and tensor data. Our study proposed estimation method through tensor decomposition and normalization process and increase the efficiency of estimation by combining tensor rule and CP-ALS method. The methods are applied in the detection of Golek Menak motion dance. The tensor data are processed in BioVision Hierarchical (BVH) matrix to estimate the whole structure of the dance motion for normalization process. Our study result showed that the quality of tensor data can be improved after the normalization and the matrix decomposition are processed to estimate the dance motion.

Key words: Decomposition, normalization, BVH, dance, motion, pose

INTRODUCTION

Golek Menak Dance which sometimes called as Beksan Golek Menak is an adaption of Golek Menak puppet (Nurhayati and Andayani, 2015). Such dance motion can be understood as motion reality which represents esthetic element and gesture movement with certain meaning (Hadi, 2016). Dance movement happen on the whole of body intellectually, emotionally and physically (Saearani and Cahyono, 2016).

When the dance movement is happening, there is dance element has relation with rhythm structure of the whole body movement pattern (Hendro, 2012; Hadi, 2016). Symbol system has closeness with art dance inside of the presentation likes motion, costume and make up. Estimating the dancer motion can be complicated which till now it is rare and not studied anywhere. In addition, the dancer motion are consisted of array multidimensional data which needs adequate computation approach. This means that which need decomposition and normalization process in order the dance motion can be estimate. In addition, since, dance motion is multidimensional array, therefore, decomposition of the dance motion data will result to high order tensor data which need to be resolved. Therefore, this study proposed a method to estimate dancer body through decomposition and normalization the dancer motion data.

Literature review: Basically, tensor is general form of scalar and vector (Schouten, 2013). Tensor has geometric relation between vector operations, scalar in an array multidimensional process (Xiao *et al*., 2015). When the coordinate axis is rotated, the components change following new coordinate transformation, it is an analog format with vector transformation. Therefore, a vector with single subscript on the component is tensor rank 1. A tensor have rank n will have n subscript, therefore, the tensor matrix can be represented by R-rank tensor (Dai *et al*., 2014).

Decomposition tensor is a method with a purpose to divide body movement horizontally and vertically (Guo *et al*., 2016) by combining the relation on each node. Decomposition tensor is process of departed frame from digital images into smaller frame representing the components of the digital images (Kopriva *et al*., 2014). When the digital images are divided into smaller subsystem, it will result to different computation process and different data consisted of complex matrices (Adolphs *et al*., 2016). Some scholars have proposed a new approach to compute such complex matrices with certain tensor rule which so-called Candecomp/Parafac (CP). Inside of CP Model, matrix-based tensor data is formed from factors matrix which so-called Alternative Least Square (ALS) method (Guo *et al*., 2016).

On CP approach, a tensor X can be defined as Eq. 1. It contains A-C column and λ which representing component of factor matrix. In geometric space, the R rank tensor has three types, e.g., product Khatri-Rao ($\odot$), Kronecker product ($\otimes$) and Handamard product (*) (Nurhayati and Andayani, 2015). Product Khatri-rao ($\odot$) is used for dot estimation of vector dot calculation, Kronecker product ($\otimes$) is to measure and analyze the

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vector cross calculation and Handamard product (*) is used for improving the quality of the matrices arrangement. In our study, combination of the three types is representing the tensor rule of CP tensor as in Eq. 2 to estimate the dancer motion (Hendro, 2012; Saearani and Cahyono, 2016):

$$x = [\![\lambda; A, B, C]\!] = \sum_{\lambda} \lambda_r a_r \circ b_r \circ c_r \qquad (1)$$

Since, dance motion is multidimensional array, therefore, decomposition of the dance motion data will result to high order tensor data (Schouten, 2013; Kolda and Mayo, 2014). Therefore, to minimize the tensor data into simplified matrices and vectors, it needs to divide the multidimensional array into component A-C. A represented the dancer body, B representing the background and C representing color pixel (Kopriva *et al*., 2014). The decomposition form of A-C are estimated with Eq. 2-4:

$$A^T = (B \odot C)^{\dagger} T_{JKXI} \overset{def}{=} f_A(B, C) \qquad (2)$$

$$B^T = (C \odot A)^{\dagger} T_{KIXJ} \overset{def}{=} f_B(C, A) \qquad (3)$$

$$C^T = (A \odot B)^{\dagger} T_{IJXK} \overset{def}{=} f_C(A, B) \qquad (4)$$

When the A, B and C are moving rotationally, there is a pseudo invers implemented to each component. It is estimated with $M_A^{\dagger} M_B^{\dagger} M_C^{\dagger}$ as pseudo invers of A^T, B^T and C^T:

$$\begin{aligned} M_A^{\dagger} \otimes M_B^{\dagger} \otimes M_C^{\dagger} &= M^{\dagger} \\ M^{\dagger} &= (M^T M)^{-1} M^T \end{aligned} \qquad (4)$$

The M^+ will result to specific value which so-called the solution of Alternating Least Square (ALS) on the dance motion system with the main function for normalization method (Pitas, 2016).

MATERIALS AND METHODS

Stages during the research are: motion capture, classification and extract data, data tensor X-Z making, decomposition and normalization of motion dance tensor, presenting data (Dai *et al*., 2014). In the data extraction process, the data are extracted from dataset using the Bio Vision Hierarchical (BVH) data. It is so-called data tensor X-Z representing the decomposition and normalization of motion dance (Guo *et al*., 2016). The flowchart of this research is given in Fig. 1.

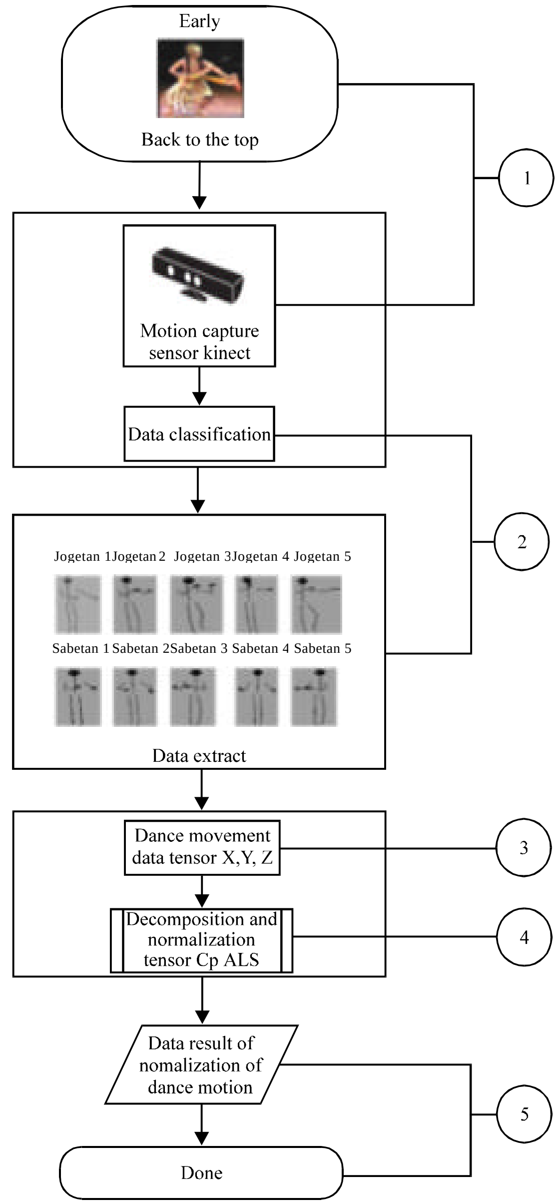

Fig. 1: Research's flowchart

Motion capture: On this step, the motion characteristic models are captured from the real Golek Menak dancer by sensor kinect to get visual motion dance data. On motion capturing process (Xiao *et al*., 2015), the appropriate setting of calibration to adaptability position on motion capture process is needed. This calibration will determine the result of the captured motion data (Adolphs *et al*., 2016).

Data classification and extraction: The result capture of the whole motion dance is saved into BVH file format. Following Rochani (2014) it is then conducted the

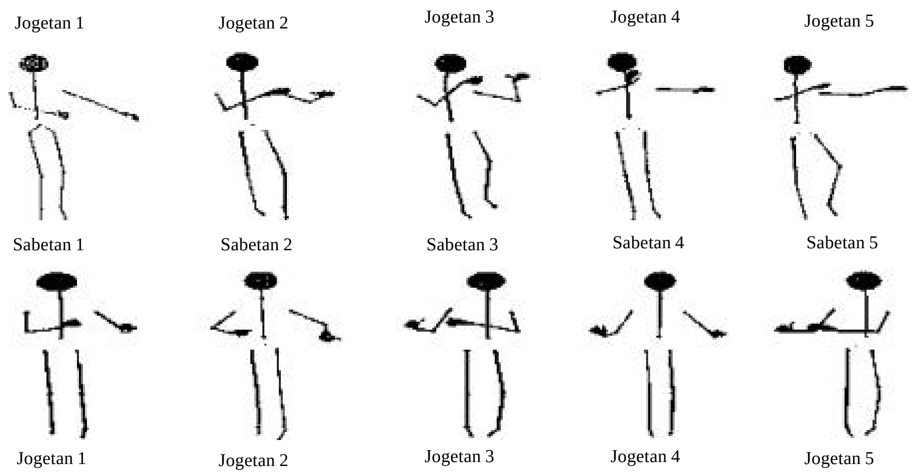

Fig. 2: Data extraction process

classification of data sample for about 10 motion dance sample which consisted 5 Jogetan motion and 5 Sabetan motion as presented on Fig. 2. Based on obtained data sample, the data extraction of BVH file structure is conducted to estimate the X, Y, X matrix tensor which following.

Data tensor X-Z making: The data tensor X-Z making is the dimension process can be restructured from the tensor matrix of BVH file (Vomlel and Tichavsky, 2014). Motion dance processing is conducted by constructed multidimensional matrix or X-Z and tensor data to normalize the dance motion data based on the relation of each node to get the convergent optimum score.

Decomposition and normalization of motion dance tensor data: The simplified X-Z data tensor motion dance on decomposition process is conducted by disperse the parts of tensor into some simple component (Li and Cichocki, 2015) which divided the motion dance horizontally and vertically (Sitharam *et al*., 2018). The decomposition and normalization of tensor X-Z is represented by Algorithm 1.

Algorithm 1; Algorithm for decomposition and normalization of Tensor X-Z:

CP-ALS (T, 1, M, ϵ)
m$\leftarrow$0
D1$\leftarrow$Reigen vektor $X_{(1)}$
D2$\leftarrow$Reigen vektor $X_{(2)}$
D3$\leftarrow$Reigen vektor $X_{(3)}$
repeat
  m$\leftarrow$m+1
  D3$\leftarrow X_{(3)}$ $(D2\odot D1)((D2^TD2)+(D1^TD1))^\dagger$
  nomalization column D3
  D2$\leftarrow X_{(2)}$ $(D3\odot D1)((D3^TD3)+(D1^TD1))^\dagger$
  nomalization column D2
  D1$\leftarrow X_{(1)}$ $(D3\odot D2)((D3^TD3)+(D2^TD2))^\dagger$
  nomalization column D1
until m>M atau $\| x-[\![\lambda; A, B, C]\!] \| < \epsilon$
return $\lambda\in\mathbb{R}^R$; $D1\in\mathbb{R}^{I\times R}$; $D2\in\mathbb{R}^{J\times R}$; $D3\in\mathbb{R}^{K\times R}$
where that $X \approx [\![\lambda; D1, D2, D3]\!]$

where, D1-D3 represents dimensions of X- Z. In the D3 normalization, it is obtained from multiplication product of Khatri-Rao D2 and D1 where in D2T and D1T is multiplication form of Handamard's product. In D2 normalization, the component matrix D2 is obtained of the multiplication product Khatri-Rao D3 and D1 where in D3T and D1T is multiplication form of Handamard's product (Yanuartuti, 2015). In D1 normalization, the component matrix D1 is obtained of the multiplication product Khatri-Rao D3 and D2 where in D3T and D2T is multiplication form of Handamard's product.

The last result from that solution is obtaining normalization of each component matrix D1-D3 with $x = [\![\lambda; D1, D2, D3]\!]$ to estimate component matrix D1-D3. On normalization process for finding the optimum solution it need to held iteration until reach the optimum convergent which consisted of matrix component D1-D3. The matrix T is then decompositioned which create matrix T1 and being tested (Tang, 2007). The normalization process used Alternating Least Square (ALS) to make diagonal vector λ for each component matrix D1-D3, that all is the component of matrix T1. Normalization process is looking for all vectors in an array of vector H as multiplier vector after normalized to find the convergent optimum score that differentiate the Jogetan and Sabetan after estimated with the algorithm in Algorithm 1.

Presenting data: The last step of decomposition process and normalization data is to process the output data into convergent result of Sabetan and Jogetan motion.

RESULTS AND DISCUSSION

BVH-based structured data representing dancer motion: Focus object on this research is to find the method of dancer motion to be estimated into tensor data and finally the whole node of frame representing the dancer motion in skeleton type. The decomposition and normalization of motion dance tensor has a goal to get tensor data containing X-Z nodes that will decided based on offset score of the captured motion. Offset score is a pure value from the result of motion capture and the function as input score of X-Z tensors that is obtained from data extraction of BVH structured file.

BVH structured file (Fig. 2) consist of whole joints (e.g., head, neck, chest, hips, left hip, left knee, left ankle, right hip, right knee, right ankle, left shoulder, left collar, left elbow, left wrist, left fingers, right shoulder, right collar, right elbow, right wrist, right fingers) (Li and Cichocki, 2015). The whole skeleton component is a skeleton frame representing digital skeleton tensor body. The whole bone can be defined as matrix M with the elements consisted of the whole structure joint on motion dance. Score in each motion dance's matrix element are determined by offset score of the whole motion dance.

$R_xR_yR_z$ is homogenous rotation matrix representing the matrix of coordinates contains X-Z composite rotational vector which organized in a vector structure. Normalization data motion dance on extract data process is determined by hierarchy joint value on main hierarchy structure (parent) which is also on translational motion in diagonal matrix structure.

For data processing, the value of matrix element of motion dance data is determined by offset score of the whole motion dance on BVH structure file especially for each joint (Hasan and Kareem, 2014). Tables show offset score of each joint M hips M left Hip M right Hip M Chest motion dance as presented in Table 1.

Decomposition and normalization of X, Y, Z tensors: In our study, the tensor data are represented by matrix T which then decompositioned to create matrix T1 and normalized with Alternating Least Square (ALS). It gives diagonal vector λ for each component matrix D1-D3. The normalization process is looking for all vectors in an array of vector H with 1×114 dimensions simultaneously (Hidayat, 2005). Whereas vector H is diagonal vectorisation of matrix T1 as the multiplier vector for having normalization solution of all matrix T1 component (Table 2 and 3). On normalization process for finding the optimum solution, need to held iteration until reach the optimum convergent which for matrix component D1-D3 can be process with the algorithm in Algorithm 1.

Table 1: Offset vakues for joint M hips, Mleft hip, M right hip, M chest

	Offset		
Joints/Motions	X	Y	Z
Hips			
Jogetan 1	18.8200	24.1040	-233.8200
Jogetan 2	17.0220	23.5580	-235.0890
Jogetan 3	14.9010	22.6860	-235.8390
Jogetan 4	15.1860	22.4520	-235.4210
Jogetan 5	15.6650	22.6810	-234.6420
Sabetan 1	24.5940	27.4390	-229.3940
Sabetan 2	24.4450	27.7390	-229.2510
Sabetan 3	25.2620	27.4240	-229.7920
Sabetan 4	25.6570	27.7360	-229.8660
Sabetan 5	25.5500	27.6520	-230.2050
Left hip			
Jogetan 1	7.1180	-6.9710	1.7750
Jogetan 2	6.8850	-7.0500	1.8220
Jogetan 3	7.3630	-6.6990	2.5160
Jogetan 4	7.2140	-6.7500	1.9870
Jogetan 5	7.4560	-7.1060	1.6220
Sabetan 1	6.6430	-6.2350	1.3300
Sabetan 2	6.5180	-6.1110	1.2620
Sabetan 3	6.6050	-6.1790	1.3450
Sabetan 4	6.5690	-6.1750	1.2360
Sabetan 5	6.6260	-6.1020	1.3900
Right hip			
Jogetan 1	-7.2790	-6.7400	1.5560
Jogetan 2	-7.3280	-6.8460	1.4920
Jogetan 3	-7.4200	-6.7670	2.0420
Jogetan 4	-7.3890	-6.8800	1.9300
Jogetan 5	-7.5990	-7.0180	1.8870
Sabetan 1	-6.3310	-6.4970	1.5460
Sabetan 2	-6.1820	-6.3510	1.6230
Sabetan 3	-6.2510	-6.4420	1.5820
Sabetan 4	-6.1340	-6.4630	1.5730
Sabetan 5	-6.1770`	-6.5280	1.4470
Chest			
Jogetan 1	0.0000	5.4270	-5.4270
Jogetan 2	0.0000	5.2800	-5.2800
Jogetan 3	-0.0000	5.1320	-5.1320
Jogetan 4	0.0000	5.3340	-5.3340
Jogetan 5	0.0000	5.3960	-5.3960
Sabetan 1	0.0000	5.9070	-5.9070
Sabetan 2	0.0000	5.9270	-5.9270
Sabetan 3	0.0000	5.9090	-5.9090
Sabetan 4	-0.0000	5.8750	-5.8750
Sabetan 5	-0.0000	5.9070	-5.9070

Table 2: Vector normalization process

1	2	3	...	114
0.2439	0.3443	-2.4603	...	0.3382

Table 3: Normalization result

λ.D13×1		λ.D250×1		λ.D361×1	
1	0.0977	1	0.1439	12	0.1323
2	0.1379	2	0.1418	2	0.1313
3	-0.9856	50	0.1415	61	0.1355

CONCLUSION

Based on test result of decomposition and normalization, convergent optimum score is normal score for the motion of Golek Menak dance on Jogetan and Sabetan motion from T1 matrix. Normalization score is the way to understand the effectively of motion dance on

3-dimension X-Z form. It is suitable with the other study (Sari, 2015) that decomposition and normalization can gain convergent optimum score.

Our study finding is a model which can estimate digital pattern of dancer body movement through tensor decomposition and normalization approach. It used tensor rule of CP-ALS method by processing the data from Bio Vision Hierarchical (BVH) matrix to estimate the whole structure of the dance motion. The dancer gesture movement can be estimated following new coordinate transformation to gain tensor matrix represented by R-rank tensor. The CP-ALS work on the basis that the matrix-based tensor data is formed from factors matrix of Alternative Least Square (ALS) by combining the product Khatri-Rao (⊙), Kronecker product (⊗) and Handamard product (*) to improve the quality of the matrices arrangement. The decomposition of the dancer motion has resulted three components, e.g., A-C which also used inversely with X-Z. X represented the dancer body, Y representing the background and Z representing the color. This means, we use A-C and X-Z as same purposes and meaning in this study.

Through five processes from motion capture to data decomposition and normalization, till it is presented, our method can process the data into decomposition and normalization process. In the data classification and extraction, we are successfully conducted the classification to get 5 Jogetan motion and 5 Sabetan motion and then we continue to estimate the X, Y, X matrix tensor and normalize the dance motion data based on the relation of each node to get the convergent optimum score. By combining the three tensor rules, we can obtain normalized matrices with optimum convergent result. Finally, our decomposition and normalization approach can process the output data into converged result to differentiate two types of poses, e.g., Sabetan and Jogetan poses.

RECOMMENDATIONS

Based on test result of decomposition and normalization, we find that our approach can differentiate both poses, since, the convergent optimum score is normal score for the motion of Golek Menak dance on Jogetan and Sabetan motion from T1 matrix. We also found that the normalization score is the way to understand the effectively of motion dance on 3-dimension of X-Z form.

The topic of tensor decomposition will bring advantage for other researchers such as especially for those interested in studying the decomposition and normalization for dance motion. In addition, our study about the use of tensor rule of CP-ALS method also can be expanded by combining other tensor rules beside product Khatri-Rao (⊙), Kronecker product (⊗) and Handamard product (*) in other applications. We also found that the model can be improved by adding other methods such as genetics algorithm, neural network and/other artificial intelligence estimation or expert system which suitable to measure and estimate dancer body through other approach besides tensor rule to differentiate the dancer poses.

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