Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

Alternating Least Square Method for Decomposing Dance Golek Menak Tensor Data

To cite this article: Joko Sutopo 2018 *J. Phys.: Conf. Ser.* **1090** 012057

Alternating Least Square Method for Decomposing Dance Golek Menak Tensor Data

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Abstract. Golek Menak Dance rhythms a body structure that is motion and geometric patterns that can be presented in the form of a vector, matrix and tensor. In this study the data obtained from the catcher dance Kinect sensor in the form of Bio Vision Format Hierarchy (BVH), which is a geometric data consisting of coordinate geometry (x, y, z), time as well as reinforcing the position of the body (skeleton). The motion data is compiled into a data tensor matrix decomposition process is then performed for a feature that can be obtained will be processed in motion classification. Alternating Least Square (ALS) methods are used in the data decomposition tensor.
Keywords: Golek Menak Dance; Alternating Least Square; Decomposition; Tensor data.

1. Introduction

Golek Menak Dance, which sometimes called Beksan Golek Menak is an adaption of Golek Menak puppet [1,2]. Such dance motion can be understood as motion reality which represents esthetic element and gesture movement with specific meaning [3]. Dance movement happen on the whole of body intellectually, emotionally and physically [4].

When the dance movement is happening, there is a dance element has a relation to the rhythm structure of the whole body movement pattern [3,5]. Symbol system has a closeness with art dance inside of the presentation likes motion, costume and makeup [6]. Estimating the dancer motion can be complicated which till now it is rare and not studied anywhere. Also, the dancer motion consists of array multidimensional data which needs adequate computation approach. This means that which need decomposition and normalization process in order the dance moves can be estimated. Also, since dance motion is a multidimensional array, therefore, decomposition of the dance motion data will result in high order tensor data which need to be resolved. Therefore, this study proposes an alternative method to estimate the dancer body through decomposition and normalization the dancer motion data.

2. Rudimentary

A tensor is the general form of scalar and vector [7]. Tensor has a geometric relation between vector operations, scalar in an array multidimensional process [8]. When the coordinate axis is rotated, the components change following new coordinate transformation; it is an analogue format with vector transformation. Therefore, a vector with a 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 [9].

Decomposition tensor is a method with a purpose to divide body movement horizontally and vertically [10], by combining the relation on each node. Decomposition tensor is a process of the departed frame from digital images into a smaller frame representing the components of the digital images [11]. When the digital images are divided into a smaller subsystem, it will result in different computation process, and different data consisted of complex matrices [12]. Some scholars have proposed a new approach to compute such complex matrices with a 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 [6,10].
On CP approach, a tensor X can be defined as equation 1. It contains A, B, C column, and λ which representing a component of factor matrix [1]. In geometric space, the R rank tensor has three types, e.g., Product Khatri-Rao (⨀), Kronecker Product (⊗) and Hadamard Product (*) [2]. Product Khatri-Rao (⨀) is used for dot estimation of vector dot calculation, Kronecker Product (⊗) is to measure and analyse the vector cross calculation, and Hadamard Product (*) is used for improving the quality of the matrices arrangement [13]. In our study, a combination of the three types is representing the tensor rule of CP tensor as in equation 2 to estimate the dancer motion [4,5].

$$\mathrm{X} \approx [\![\lambda; \mathrm{A}, \mathrm{B}, \mathrm{C}]\!] = \sum_{\lambda} \lambda_r \mathrm{a}_r \circ \mathrm{b}_r \circ \mathrm{c}_r \quad (1)$$

Since dance motion is a multidimensional array, therefore, decomposition of the dance motion data will result in high order tensor data [7,14]. Therefore, to minimise the tensor data into simplified matrices and vectors, it needs to divide the multidimensional array into component A, B, and C. A represented the dancer body, B representing the background and C representing colour pixel [11]. The decomposition form of A, B, C is estimated with equation 2, 3 and 4.

$$\mathrm{A}^{\mathrm{T}} = (\mathrm{B} \odot \mathrm{C})^{\dagger} \mathrm{T}_{\mathrm{JKxI}} \stackrel{\mathrm{def}}{=} \mathrm{f}_{\mathrm{A}}(\mathrm{B}, \mathrm{C}) \quad (2)$$
$$\mathrm{B}^{\mathrm{T}} = (\mathrm{C} \odot \mathrm{A})^{\dagger} \mathrm{T}_{\mathrm{KIxJ}} \stackrel{\mathrm{def}}{=} \mathrm{f}_{\mathrm{B}}(\mathrm{C}, \mathrm{A}) \quad (3)$$
$$\mathrm{C}^{\mathrm{T}} = (\mathrm{A} \odot \mathrm{B})^{\dagger} \mathrm{T}_{\mathrm{IJxK}} \stackrel{\mathrm{def}}{=} \mathrm{f}_{\mathrm{C}}(\mathrm{A}, \mathrm{B}) \quad (4)$$

Where A, B and C are quadratic forms of the Alternating Least Squares (ALS) structure. The solution for finding components A, B and C are represented in Tensor mode, where A_1 is the first mode, A_2 is the second mode, and the third mode A_3 [15,16] is presented in equations 5, 6 and 7.

$$A \leftarrow A_1(C \odot B)(C^t \mathrm{C} * B^t \mathrm{B})^{-1} \quad (5)$$
$$\mathrm{B} \leftarrow A_2(C \odot A)(C^t \mathrm{C} * A^t \mathrm{A})^{-1} \quad (6)$$
$$\mathrm{C} \leftarrow A_3(B \odot A)(B^t \mathrm{B} * A^t \mathrm{A})^{-1} \quad (7)$$

When the A, B and C are moving rotationally, there is a pseudo inverse implemented to each component. It is estimated with $\mathrm{M}_A^{\dagger}, \mathrm{M}_B^{\dagger}, \mathrm{M}_C^{\dagger}$, as the pseudo-inverse of A^{T}, B^{T} and C^{T} are expressed by equations 8 and 9.

$$\mathrm{M}_A^{\dagger} \otimes \mathrm{M}_B^{\dagger} \otimes \mathrm{M}_C^{\dagger} = \mathrm{M}^{\dagger} \quad (8)$$
$$\mathrm{M}^{\dagger} = (\mathrm{M}^{\mathrm{T}}\mathrm{M})^{-1}\mathrm{M}^{\mathrm{T}} \quad (9)$$

The $\mathrm{M}^{\dagger}$ will result in a specific value which so-called the solution of Alternating Least Square (ALS) on the dance motion system with the primary function of the normalization method [17].

3. Proposed Method

Stages during the research are (1) motion capture; (2) classification and extract data; (3) data tensor X, Y, Z making; (4) decomposition and normalisation of motion dance tensor; (5) presenting data [9]. In the data extraction process, the data are extracted from the dataset using the BioVision Hierarchical (BVH) data. It is so-called data tensor X, Y, Z representing the decomposition and normalization of motion dance [10]. The flowchart of this research is given in Figure 1.

3.1. Motion Capture

On this step, the characteristic motion models are captured from the real Golek Menak dancer by sensor Kinect to get visual motion dance data. On motion capturing process [8], the appropriate set of calibration to adaptability position on motion capture process is needed. This calibration will determine the result of the captured motion data [12].

3.2. Data Classification and Extraction

The resulting capture of the whole motion dance is saved into BVH file format. Following [18] It is then conducted the classification of data sample for about ten motion dance sample which consisted 5 Jogetan motion and 5 Sabetan motion as presented in Figure 2. Based on the obtained data sample, the data extraction of the BVH file structure is conducted to estimate the X, Y, X matrix tensor which following [19].

3.3. Data Tensor X, Y, Z Making

The data tensor X, Y, Z making is the dimensioning process can be restructured from the tensor matrix of BVH file [20]. Motion dance processing is conducted by constructed multidimensional matrix or X, Y, Z, and tensor data to normalise the dance motion data based on the relation of each node to get the convergent optimum score.

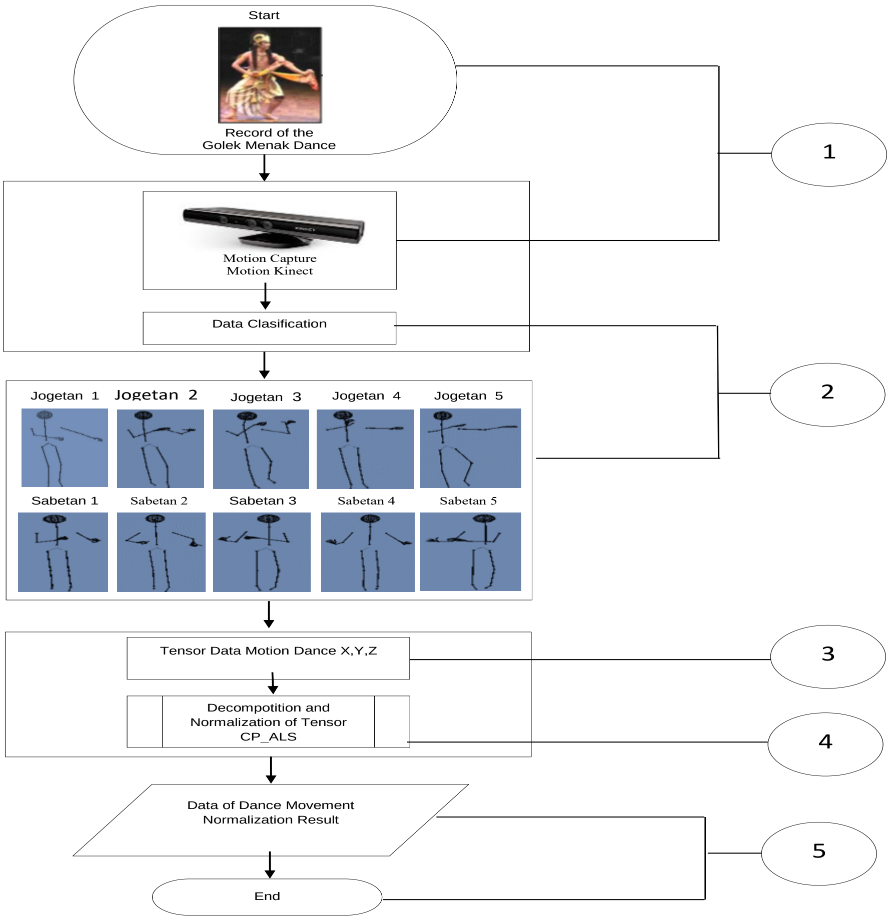

Figure 1. Research's Flow

In the flow diagram of the research in Figure 1 to generate the tensor data X, Y, Z, first performed the capture of the dance Golek terrifying motion capture motion (motion capture) Kinect sensor, which then produces data dance movement. Then from the data of dance movement is done by the classification process for Jogetan motion and Sabetan, which produce classification data. Furthermore from the data classification is done extract data to form data tensor X, Y, Z and then done the process of decomposition and normalization of tensor data by using CANDECOMP/PARAFAC_Alternating Least Square (CP_ALS) method, which then yields a result of normalization of data of dance movement.

3.4. Decomposition and Normalization of Motion Dance Tensor Data

The simplified X, Y, Z data tensor motion dance on decomposition process is conducted by dispersing the parts of tensor into some simple component [21] which divided the motion dance horizontally and vertically [19,22]. The decomposition and normalization of tensor X, Y, Z are represented by Figure 3.

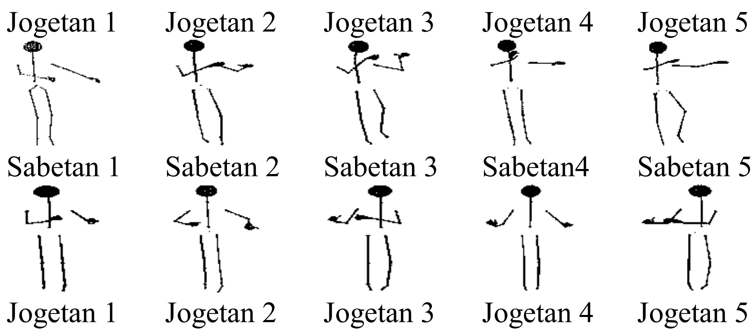

Figure 2. Data extraction process

$\mathrm{CP-ALS}\ (T, 1, M, \epsilon)$
$m \leftarrow 0$
$D1 \leftarrow$ R eigen vector $X_{(1)}$
$D2 \leftarrow$ R eigen vector $X_{(2)}$
$D3 \leftarrow$ R eigen vector $X_{(3)}$

repeat
$m \leftarrow m + 1$
$D3 \leftarrow X_{(3)}\ (D2 \odot D1)((D2^T D2) * (D1^T D1))^{\dagger}$
Column Normalization D3
$D2 \leftarrow X_{(2)}\ (D3 \odot D1)((D3^T D3) * (D1^T D1))^{\dagger}$
Column Normalization D2
$D1 \leftarrow X_{(1)}\ (D3 \odot D2)((D3^T D3) * (D2^T D2))^{\dagger}$
Column Normalization D1
until $m > M$ atau $\| X - [\![\lambda; A, B, C]\!] \| < \epsilon$
return $\lambda \in \mathbb{R}^R$; $\mathbf{D1} \in \mathbb{R}^{IXR}$; $\mathbf{D2} \in \mathbb{R}^{JXR}$; $\mathbf{D3} \in \mathbb{R}^{KXR}$;
Where That $X \approx [\![\lambda; D1, D2, D3]\!]$

Figure 3. Algorithm for decomposition and normalization of Tensor X, Y, Z

Where D1, D2, D3 represent dimensions of X, Y, Z. in the D3 Normalization, it is obtained from multiplication product of Khatri-Rao D2 and D1, wherein D2T and D1T is multiplication form of Hadamard's product. In D2 Normalization, the component matrix D2 is obtained from the multiplication product Khatri-Rao D3, and D1, wherein D3T and D1T is multiplication form of Hadamard's product [23]. In D1 Normalization, the component matrix D1 is obtained from the multiplication product Khatri-Rao D3, and D2, wherein D3T and D2T is multiplication form of Hadamard's product.

The last result from that solution is obtaining normalization of each component matrix D1, D2, D3 with $X \approx [\![\lambda; D1, D2, D3]\!]$ to estimate component matrix D1, D2 and D3. On the normalization process for finding the optimum solution, it needs to held iteration until reaching the excellent convergent which consisted of matrix component D1, D2, D3. The matrix T is then decomposition which create matrix T1 and being tested [24]. The normalization process used Alternating Least Square (ALS) to make diagonal vector λ for each component matrix D1, D2 and D3, that all is the component of matrix T1. The normalization process is looking for all vectors in an array of vector H as multiplier vector after normalised to find the convergent optimum score that differentiates the Jogetan and Sabetan after estimated with the algorithm in Figure 3.

3.5. Presenting Data

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

4. Result and Discussion

4.1. BVH-Based Structured Data Representing Dance 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 the frame representing the dancer motion in skeleton type. The decomposition and normalization of motion dance tensor have a goal to get tensor data containing X, Y, Z nodes that will decide based on offset score of the captured motion. Offset score is a pure value from the result of motion capture, and the function as the input score of X, Y, Z tensors that is obtained from data extraction of BVH structured file.

BVH structured file (Figure 2) consist of whole joints (e.g., Head, Neck, Chest, Hips, LeftHip, left knee, left ankle, right, right knee, right ankle, left shoulder, left collar, left elbow, left wrist, leftwingers, RightShoulder, RightCollar, right elbow, right wrist, RightFingers) [21]. The whole skeleton component is a skeleton frame representing a 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. The score in each motion dance's matrix element is determined by offset score of the whole motion dance.

$R_x R_y R_z$ Is homogeneous rotation matrix representing the matrix of coordinates contains X, Y, Z composite rotational vector which organised in a vector structure? Hierarchy joint value determines normalization data motion dance on extract data process on the primary hierarchy structure (parent), which is also on the translational motion in a diagonal matrix structure.

For data processing, the value of matrix element of motion dance data is determined by the offset score of the whole motion dance on BVH structure file especially for each joint [25]. The table below shows the offset score of each joint MhipsMLeftHipMRightHipMChest motion dance as presented in Table 1.

Table 1. Offset values for Joint MhipsMLeftHipMRightHipMChest

Joint	Motion	Offset		
		X	Y	Z
Hips	Jogetan 1	18.8200	24.1040	-233.820
	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

4.2. Decomposition and Normalization of X, Y, Z Tensors

In this study, the tensor data is represented by the T matrix, which is then decomposed to create a T1 matrix and normalized using the Alternating Least Square (ALS) method through the diagonal vector λ for each matrix component D1, D2 and D3. The normalization process is done by finding all the vectors in the 1×114 H dimension vector array in Table 2 simultaneously [26]. Whereas the vector H is the diagonal vectorization of the T1 matrix, as the multiplier vector to obtain the normalization of all components of the T1 matrix.

Table 2. Vector Normalization process

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

The normalized results in Table 3 are obtained from the normalization process to find the optimum solution, by iterating to reach the optimum convergence for the matrix components D1, D2, D3 processed by the algorithm in Figure 3.

Table 3. Normalization result

λ.D1 3x1		λ.D2 50x1		λ.D3 61x1	
1	0.0977	1	0.1439	1	0.1323
2	0.1379	2	0.1418	2	0.1313
3	-0.9856	50	0.1415	61	0.1355

Based on the test result of decomposition and normalization, the convergent optimum score is standard to score for the motion of Golek Menak dance on Jogetan and Sabetan motion from T1 matrix. Normalization score is the way to understand the effect of motion dance on 3-dimension X, Y, Z form. It is suitable for the other study [27] that decomposition and normalization can gain convergent optimum score.

Our study finding is a model which can estimate the digital pattern of dancer body movement through tensor decomposition and normalization approach. It used the tensor rule of CP-ALS method by processing the data from BioVision Hierarchical (BVH) matrix to estimate the whole structure of the dance moves. 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 Hadamard Product (*) to improve the quality of the matrices arrangement. The decomposition of the dancer motion has resulted in three components, e.g., A, B, and C which also used inversely with X, Y, and Z. X represented the dancer body, Y representing the background and Z representing the Color. This means we use A, B, C and X, Y, Z for the same purposes and meaning in this study.

5. Conclusion

Through five processes from motion capture to data decomposition and normalization, until it is presented, our method can process the data into decomposition and normalization process. In the data classification and extraction, we have 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 the optimum convergent result. Finally, our decomposition and normalization approach can process the output data into the converged result to differentiate two types of poses, e.g., Sabetan and Jogetan pose.

Based on the test result of decomposition and normalization, we find that our approach can differentiate both poses since the convergent optimum score is standard to 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 effect of motion dance on 3-dimension of X, Y, 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 of dance moves. Also, our study about the use of the tensor rule of CP-ALS method also can be expanded by combining other tensor rules beside Product Khatri-Rao (⊙), Kronecker Product (⊗) and Hadamard Product (*) in other applications. We also found that the model can be improved by adding other methods such as genetic algorithm, neural network and/other artificial intelligence estimation or expert system which suitable to measure and estimate dancer body through another approach besides tensor rule to differentiate the dancer poses.

References

[1] Sutopo, J., Susanto, A., Santosa, I., & Adji, T. B. (2015). Feature Reduction of Wayang Golek Dance Data Using Principal Component Analysis (PCA). *Advances in Statistical Methods in Engineering, Science, Economy, Education and Disaster Management*, *1*, 60.
[2] Nurhayati, E., & Andayani, R. D. (2016). Javanese Traditional Menu and Bedaya Dance as the Cultural Tourism Attractions of Magersari and Yogyakarta Kingdom. *HUMANIORA*, *20* (2).
[3] Hadi, Y. S. (2016). The Continuity and Development of the Yogyakarta Style Classical Dance as the Legitimacy of the National Cultural Heritage. *Mudra*, *28*(1).
[4] Saearani, M. F. T. B., & Cahyono, A. (2016). The Inheritance of Malay Palace Dance in Malaysia and Yogyakarta Classical Dance in Indonesia. *Harmonia: Journal of Arts Research and Education*, *16*(1), 75-86.
[5] Martono, H. (2016). Environmental Choreography Enriches the Creation Methods of Dances in Indonesia. *Mudra*, *27*(2).
[6] Sumiati, L. (2016). The Transformation of Jayengrana Dance from the Perspective of Anthony Giddens's Structuration Theory. *TAWARIKH*, *5*(2).
[7] Schouten, J. A. (2013). Ricci-calculus: an introduction to tensor analysis and its geometrical applications (Vol. 10). Springer Science & Business Media.
[8] Xiao, J., Feng, Y., Ji, M., Yang, X., Zhang, J. J., & Zhuang, Y. (2015). Sparse motion bases selection for human motion denoising. *Signal Processing*, *110*, 108-122.
[9] Dai, Y., Li, H., & He, M. (2014). A simple prior-free method for non-rigid structure-from-motion factorization. *International Journal of Computer Vision*, *107*(2), 101-122.
[10] Guo, Y., Tao, D., Cheng, J., Dougherty, A., Li, Y., Yue, K., & Zhang, B. (2016). Tensor Manifold Discriminant Projections for Acceleration-Based Human Activity Recognition. *IEEE Transactions on Multimedia*, *18*(10), 1977-1987.
[11] Kopriva, I., Popovic-Hadzija, M., Hadzija, M., & Aralica, G. (2014). *U.S. Patent Application No. 14/221,017*.
[12] Adolphs, R., Nummenmaa, L., Todorov, A., & Haxby, J. V. (2016). Data-driven approaches in the investigation of social perception. *Phil. Trans. R. Soc. B*, *371*(1693), 20150367.
[13] Schatz, M. D., Low, T. M., Van De Geijn, R. A., & Kolda, T. G. (2013). Exploiting symmetry in tensors for high performance. *arXiv preprint arXiv:1301.7744*.
[14] Kolda, T. G., & Mayo, J. R. (2014). An adaptive shifted power method for computing generalized tensor eigenpairs. *SIAM Journal on Matrix Analysis and Applications*, *35*(4), 1563-1581.
[15] Bader, B. W., & Kolda, T. G. (2006). Algorithm 862: MATLAB tensor classes for fast algorithm prototyping. ACM Transactions on Mathematical Software (TOMS), 32(4), 635-653.
[16] Bhatt, V., & Kumar, S. (2014). A Cas Aided Survey Of CP Decomposition And Rank-1 Approximation Of A 3rd-Order Tensor. Palestine Journal of Mathematics, 3(2).
[17] Kotropoulos, C., & Pitas, I. (2016). Multimedia social search based on hypergraph learning. *Graph-Based Social Media Analysis*, *39*, 215.
[18] Rochani, E. (2014). Fenomena Tari Diskotik Di Era Globalisasi (Sebuah Studi Tentang Perkembangan Tari Di Yogyakarta) (Doctoral dissertation, Universitas Negeri Yogyakarta).
[19] Chen, Y., Liu, Z., & Zhang, Z. (2013). Tensor-based human body modelling. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition* (pp. 105-112).
[20] Vomlel, J., & Tichavský, P. (2014). On the tensor rank of conditional probability tables in Bayesian networks. *arXiv preprint arXiv:1409.6287*.
[21] Li, J., Li, C., & Cichocki, A. (2015). Canonical polyadic decomposition with assistant information for a brain-computer interface. *IEEE Journal of biomedical and health*

informatics.
[22] Sitharam, M., Tarifi, M., & Wang, M. (2016). Combinatorial rigidity of Incidence systems and Application to Dictionary learning. *arXiv preprint arXiv:1603.04109*.
[23] Yanuartuti, S. (2015). Revitalisasi Pertunjukan Wayang Topeng Jati Duwur Jombang Lakon Patah Kuda Narawangsa (Doctoral dissertation, Institut Seni Indonesia Surakarta).
[24] Tang, K.T. (2007). Mathematical Methods for Engineer and Scientists 3. Berlin: Springer.
[25] Hasan, H., & Abdul-Kareem, S. (2014). Static hand gesture recognition using neural networks. *Artificial Intelligence Review*, *41*(2), 147-181.
[26] Hidayat, Robby. 2005. Wawasan Seni Tari, Pengetahuan Praktis Bagi Guru Tari. Malang: Jurusan Seni dan Desain Fakultas Sastra UNIMA.
[27] Sari, Y. (2015). Penerapan Model Kooperatif Dalam Pembelajaran Sejarah Berbasis Nilai Budaya Lokal Untuk Meningkatkan Prestasi Belajar Dan Karakter Siswa Kelas Xi Smk N 8 Surakarta. *Candi*, *9*(1), 73-89.