ISASE 2019

Consideration on Transformation Matrix Clarifying Relationships between Impression Factors of Multimedia Data

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Abstract: This paper gives some considerations on a transformation matrix of the factor loading matrixes obtained through factor analysis often used in affective engineering. A transformation matrix transforms a factor loading matrix to another, and vice versa. It represents the relationship of two sets of factors. This paper tries to clarify accuracy and interpretation of the transformation matrix. Accuracy is theoretically explained. Interpretation is demonstrated by using an example.

Keywords: *Factor Analysis, Multimedia data, Factor Loading Matrix, Transformation, Matrix*

1. INTRODUCTION

In recent years, there are opportunities to watch and listen to much multimedia data such as pictures, sounds, and moving pictures. Multimedia data give various impressions to human beings. For example, pictures of clear stream give us freshness and clearness. Human impressions are tried to be clarified [1 - 15]. In these studies, the semantic differential (SD) method is often used in measuring the degree of impression [1 - 15]. The SD method is the technique which uses subjective ratings of an idea, concept, or object by means of scaling opposite impression words in order to study connotative meaning [16] [17]. We also use the SD method in investigating the effects because subjects could more precisely catch the meaning of the impression words by using pairs of impression words than single words.

In the SD method, the number of the impression word pairs may reach around a hundred. The factor analysis is usually applied to the scores obtained through the SD method to obtain potential factors underlying the phenomena observed [1 - 15]. By using the factor analysis, we can obtain a factor loading matrix and a factor score one. The factor loading matrix represents the relationships between the impression word pairs used and the factors obtained. The factor score matrix represents the score of targets in the space represented by the factors. It is shown that the impression given by multimedia data can be represented by several factors [2] [3] [4].

We usually interpret the phenomena observed by using the factors obtained. By comparing two sets of factors, which are obtained through two different but related experiments, the differences between the subjects and/or the settings of experiments are explained. Nationality [7] [12], motif of paintings [8], visual and sensory touch [9], calligraphic styles [10], personality [13], and mood [14] [15] were compared. Here, the difference of two sets of evaluation results is qualitatively examined. For example, it was concluded that Chinese males are more affected by the factor "Naturalness" than Japanese males [4]. However, it is hard for these sets of data to be treated in an information system because the mappings of the impressions of these multimedia data were not quantitatively clarified. The method clarifying these mappings quantitatively is required.

The statistical difference with a significance level is used as an approach to quantitatively clarify the difference in the impression. However, it is inadequate for practical consideration. In the method for using statistical difference, we only obtain the fact that there is a statistical difference or not. In order to practically use the difference in impression, it is necessary to clarify quantitatively the "degree" of coincidence between the impression factors.

Maeda *et al.* proposed a method of transforming a factor score matrix to another one by using a transformation matrix in order to cooperate multiple video retrieval systems based on impression [18] and to clarify the cultural difference of the impression [19]. They showed the potentiality that the components of the transformation matrix may represent the relationships between two sets of the impression factors. Although they used two examples in explaining the power of the transformation matrix, the characteristics of the transformation matrix are not shown.

This paper tries to give some considerations on accuracy and interpretation of the transformation matrix. It is shown that the transformation through this matrix is a kind of approximation. It is also shown that the transformation matrix may rotate the impression space, and map the factors of a data set to those of another one.

The remainder of the paper is organized as follows. Section 2 describes the related works describing the problem of the current analysis. Section 3 describes the method of deriving a transformation matrix, and shows an example. Section 4 gives considerations on accuracy and interpretation. Finally, Section 5 concludes the paper.

2. RELATED WORKS

Yang *et al.* elaborated the similarities and differences of impression of pictures between Japanese and Chinese [4]. The impression evaluation experiment showed the main factors of Chinese males are the same as those of Japanese males. Yang *et al.* also revealed the following differences:

- Compared with Chinese males, Japanese males are easily affected by the factors “Potency” and “Activity.”
- In comparison with Japanese males, Chinese males are more affected by the factor “Naturalness,” that is, Chinese males pay more attention to the natural sense.

These are qualitatively described. Degrees of relationships were not quantitatively described.

Du *et al.* compared the cultural difference of the influence on the impression by images having different resolutions [12]. They conducted subjective experiments with Japanese and Chinese participants. They obtained three factors from the experimental results for both of Japanese and Chinese participants. As the three factors obtained from the Japanese results corresponded to those obtained from Chinese ones, the factors could be compared with each other. They placed factor scores of each of two factors for Japanese and Chinese results in two-dimensional space. As the distribution of the factor scores of the second and the third factors of Japanese people is quite different from that of Chinese ones, Du *et al.* concluded there are some cultural differences in the third factor named “Naturalness.”

Although this comparison uses factor scores, which are quantitative values, the comparison is said to be qualitative. This is because the difference of the distributions is neither quantitatively calculated, nor used in the comparison.

3. TRANSFORMATION MATRIX

3.1 Method of Deriving Transformation Matrix

Let a matrix of p variable data (impression word pairs) of n observation targets (pictures, sounds and moving images) be the matrix Z of experimental data. Let F be an n-by-m matrix of factor scores. Let A^T be a p-by-m transpose matrix of factor loadings. Let E be an n-by-p matrix of residuals. Then the factor analysis is represented in Equation (1).

$$Z = FA^T + E \qquad (1)$$

The matrixes F and A are obtained so that m is as small as possible, and E is sufficiently small. Potential factors are obtained by using m sufficiently smaller than p, which is the number of variables.

As a residual matrix E is small and negligible, matrix E in Equation (1) can be omitted to obtain Equation (2). The matrixes Z_1, F_1 and A_1 are the experimental data, the factor score matrix, and the factor loading matrix in a study, respectively. The matrixes Z_2, F_2 and A_2 are the experimental data, the factor score matrix and the factor loading matrix in another study, respectively.

$$\begin{cases} Z_1 = F_1 A_1^T \\ Z_2 = F_2 A_2^T \end{cases} \qquad (2)$$

Assume that the matrix A^T can be expressed in Equation (3) by using a matrix P, which transforms the factor loading matrix [18]. The transformation matrix P (P^{-1}, respectively) is obtained in Equation (4) (Equation (5)) by using Equations (2) and (3).

$$A_2^T = PA_1^T \qquad (3)$$

$$P = F_2^+ Z_2 Z_1^+ F_1 \qquad (4)$$

$$P^{-1} = F_1^+ Z_1 Z_2^+ F_2 \qquad (5)$$

In Equation (4), the order of the data, the impression word pairs and the factor names may be exchanged so that these correspond to each other. As Z and F are not a square matrix of order n, the Moore-Penrose generalized inverse matrix [21] is used for F_2^+ and Z_1^+ of a matrix P, and F_1^+ and Z_2^+ of a matrix P^{-1}.

3.2 Example of Transformation Matrix

Two sets of examination scores of Japanese, Social studies, Mathematics, Sciences, and English are used for explaining the transformation matrix. These are called Score Set 1 (SS1) and Score Set 2 (SS2), respectively. SS1 includes seven students’ scores [22], while SS2 includes twenty ones [23].

The factor loading matrix obtained from SS1 (SS2, respectively) is shown in Table 1 (Table 2). Two factors

Table 1 Factor loading matrix of Score Set 1

Subject	Factor 1	Factor 2
Mathematics	0.0	0.997
Science	-0.188	0.967
Japanese	0.871	0.0
English	0.997	0.0
Social	0.989	0.0

Table 2 Factor loading matrix of Score Set 2

Subject	Factor 1	Factor 2
Mathematics	0.0	0.995
Science	0.282	0.627
Japanese	0.804	0.145
English	0.688	0.428
Social	0.901	0.112

are obtained. The first factor is considered as the one for humanities, while the second one is considered as the one for sciences for both sets of scores.

The transformation matrix P obtained by Equation (4) is as follows:

$$P = \begin{bmatrix} 0.826 & 0.215 \\ 0.284 & 0.874 \end{bmatrix} \quad (6)$$

The values of diagonal elements are large, while those of the others are small. This means that both factors of both score sets correspond well each other.

4. CONSIDERATIONS

4.1 Accuracy of Transformation Matrix

A residual matrix E in Equation (1) is omitted to obtain Equation (2) as described above. This causes an error of the transformation matrix. If the residual matrix E is not omitted, Equation (4) becomes Equation (7).

$$P = F_2^+(Z_2 - E_2)(Z_1 - E_1)^+F_1 \quad (7)$$

$$P = (F_2^+Z_2 - F_2^+E_2)(Z_1 - E_1)^+F_1 \quad (8)$$

$$P = F_2^+Z_2(Z_1 - E_1)^+F_1 - F_2^+E_2(Z_1 - E_1)^+F_1 \quad (9)$$

The first term of the right side of Equation (9) becomes the right side of Equation (4) because E_1 is very small compared with Z_1. The second term of the right side of Equation (9) becomes the major part of the error of Equation (4). The residual matrix E_2 is usually very small. This means that all the elements of E_2 are almost zero. Therefore, this term is usually negligible. The similar discussion can be applied to Equation (5).

We use the Moore-Penrose generalized inverse matrix because the matrixes used are not square ones. This matrix is not an inverse matrix, but it works as if it was an inverse matrix. It is proved that the Moore-Penrose generalized inverse matrix minimizes the amount $\|Ax - b\|$ where $x = A^+b$ [21]. When this amount is equal to zero, it can be said that there is no error in some sense. This amount, however, is not guaranteed to be zero. Therefore, there is a kind of error in using this inverse matrix. The result obtained by this inverse matrix is equal to that of the least square error method [21]. This means that this inverse matrix gives us the optimal matrix. Although there may be a kind of error in using this inverse matrix, it is said that using it is the best way.

When we use the transformation matrix, we should note that the transformation based on this matrix is a kind of approximation, and has some error even though it is negligible.

4.2 Interpretation of Transformation Matrix

Here, a transformation matrix is tried to be represented with the product of two matrixes as shown in Equation (10) or Equation (11) by using a rotation matrix R shown in (12).

$$P = RM \quad (10)$$

$$P = NR \quad (11)$$

$$R = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \quad (12)$$

The transformation matrix shown in Equation (6) is used as an example. The matrixes R, M, and N are obtained by trial and error. These are as follows:

$$R = \begin{bmatrix} 0.96 & -0.28 \\ 0.28 & 0.96 \end{bmatrix} \quad (13)$$

$$M = \begin{bmatrix} 0.87 & 0.45 \\ 0.04 & 0.78 \end{bmatrix} \quad (14)$$

$$N = \begin{bmatrix} 0.73 & 0.44 \\ 0.03 & 0.92 \end{bmatrix} \quad (15)$$

The matrix R is the rotation one with an angle of 16.3 degrees. Equation (16) is obtained by substituting (10), and (14) to (3).

$$A_2^T = RMA_1^T = R\begin{bmatrix} 0.87 & 0.45 \\ 0.04 & 0.78 \end{bmatrix} A_1^T \quad (16)$$

The matrix A_1^T (A_2^T, respectively) is the transposed one of the matrix shown in Table 1 (2). The value of the (1, 2) ((2, 2), respectively) element of MA_1^T is calculated by 0.87*-0.188+0.45*0.967 (0.04*-0.188+0.78*0.967). The (1, 2) ((2, 2)) element corresponds to the first (second) factor of the second subject, Science. The first factor of SS2 is obtained from both factors of SS1, while the second one of SS2 is obtained almost only from the second one of SS1 because the value of the first factor is multiplied by 0.04. As for this example, a transformation matrix may map the factors of a data set to those of the other, and rotate the impression space mapped.

5. CONCLUSION

This paper tried to give some considerations on accuracy and interpretation of the transformation matrix. It was shown that the transformation through this matrix is a kind of approximation. It was also shown that the transformation matrix may rotate the impression space, and map the factors of a data set to those of another one.

Although we show an interpretation of a transformation matrix, its application to real data sets is in future work. It is also required to set an extent that we can regard it as a clear difference. This extent may affect the differences in the data set, the number of steps in the SD method, the difference in impression word pairs, and the method of factor analysis.

ACKNOWLEDGMENTS

This work was partially supported by JSPS KAKENHI Grant Number 16K00370.

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