Unfolding Models for Asymmetric Dissimilarity Data With External Information Based on Path Structures

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ABSTRACT
This article contains asymmetric dissimilarity data which is observed in various situations. In asymmetric dissimilarity data, dissimilarity from subject i to j and from subject j to i are not the same necessarily. Asymmetric multidimensional scaling (AMDS) is a visualization method for describing the asymmetric relations between subjects, given asymmetric dissimilarity data for subjects. It is sure that AMDS is a useful tool for interpreting the asymmetric relation, however, existing AMDS cannot be considered for the external information, even if the external information of the same subjects for the asymmetric dissimilarity data is given. If the estimated coordinates can be interpreted from the loading matrix for the external information like principal component analysis (PCA), the AMDS become more useful. This is because we can interpret the relation between the estimated asymmetries and the factors of the external information on the low dimensions. In this article, we proposed new AMDS with external information. In addition to that, the proposed method can consider the path structure for variables like SEM.

KEYWORDS
Asymmetric Multidimensional Scaling (AMDS), GSCA, Slide-Vector Model, Unfolding Model

1. INTRODUCTION
Asymmetric dissimilarity data is data such that dissimilarity from subject i to subject j and dissimilarity from j to i are not the same necessarily. If the value of the dissimilarity from i to j is larger than that from j to i, we consider that the dissimilarity from i to j is relatively far comparison with from j to i. There are various situations such that asymmetric dissimilarity data is observed. For example, brand switching data is observed as an asymmetric similarity data in marketing domains. In the brand switching data, the element from brand i to j indicates frequency of buying brand j after buying brand i for customers. To reveal the competitive relations among brands, Asymmetric Multidimensional Scaling (AMDS) is applied to the brand switching data (e.g. Okada and Tsurumi, 2012), where AMDS is visualization method for the asymmetric relations for subjects. In usually, brand switching data is generated from POS data. Therefore, we can usually get the multivariate data as external

DOI: 10.4018/IJSI.2018070104

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information for the same subjects along with the brand switching data from the POS data. However, in such the situation, ordinal AMDS provide only the interpretation of asymmetric relations, not the relation between the asymmetries and the external information. If the estimated axes in AMDS can be interpreted as those in Principal Component Analysis (PCA), the visualization result is very useful. Therefore, we propose new AMDS with external information.

Several models of AMDS have been proposed (Borg and Groenen, 2005; Chino, 1978, 1990, 2012; Chino and Shiraiwa, 1993; Harshman, 1978; Harshman et al., 1982; Kiers and Takane 1994; Krumhansl, 1978; Loisel and Takane (2011); Okada and Imaiuzumi, 1984, 1987, 1997; Rocci and Bove, 2002; Saito and Yadohisa, 2005; Yadohisa and Niki, 1999). Chino (2012) classify these models into groups. In Unfolding type models among these models (Constantine and Gower, 1978; De Leeuw and Heiser, 1982; Gower, 1977; Zietlman and Heiser, 1993, 1996), each subject on the estimated low dimensions can be described by two different coordinates to represent the asymmetric relation. There are two kinds of Unfolding type models such as Unfolding and slide-vector model. The slide-vector model is considered as a parsimonious model of Unfolding model. The advantage of these methods is that it is easy to interpret the asymmetric relations in Euclidean space. In this paper, we propose new AMDS with external information based on path structures. Given asymmetric dissimilarity data, the multivariate data for the same subjects and path structure, the proposed method provide the low dimensions such that asymmetric relations and each axis can be interpreted like PCA or Generalized Structured Component Analysis (GSCA) (Hwang and Takane, 2004). For the image of the proposed method, see Figure 1. Therefore, the proposed method can reflect the assumption of researchers through the path structure. This is the advantage of the proposed method.

The rest of this paper is organized as follows. In section 2, the model of the proposed method is described. Especially, these proposed methods based on Unfolding and slide-vector model are introduced, respectively. In addition to that, the example of how to interpret the results is also shown. In section 3, the objective function and the algorithm of the proposed method are described to estimate these parameters. In section 4 and 5, the results of numerical example and real example are shown, respectively. Finally, the conclusion is provided in section 6.

![Diagram of AMDS with external information based on path structure](image-url)
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