

A Comparison of Knowledge Domain Visualization Approaches

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Introduction

- ▶ Knowledge domain visualization is concerned with the construction of maps that depict the structure and evolution of a scientific field.
- ▶ We propose a new approach for constructing so-called concept maps, a special type of domain map that gives an overview of a scientific field by visualizing the associations between the field's main concepts.
- ▶ The proposed approach is an alternative to the multidimensional scaling approaches that are typically taken in the literature on knowledge domain visualization.

Concept map

- ▶ A knowledge domain map that visualizes the associations between concepts in a scientific field.
- ▶ Concepts are positioned in such a way that the distance between two concepts reflects the strength of the association between the concepts.
- ▶ Concepts that are strongly associated are located close to each other.
- ▶ Can be used
 - ▶ to obtain an overview of a scientific field, and
 - ▶ to support the discovery of unknown associations between concepts.

Construction of a concept map

Two-step approach

1. Calculate associations between concepts based on co-occurrences in a corpus of scientific texts.
2. Position concepts in a low-dimensional space based on the associations.

Step 2 is typically performed using multidimensional scaling (MDS). We propose to use an alternative to MDS called VOS, which is an abbreviation for *visualization of similarities*.

Step 1: Calculation of associations between concepts

Estimated probability of occurrence of concept i

$$\blacktriangleright p_i = \frac{c_{ii}}{m}$$

Estimated probability of co-occurrence of concepts i and j

$$\blacktriangleright p_{ij} = \frac{c_{ij}}{m}$$

Estimated probability of co-occurrence of concepts i and j under the assumption that occurrences of concept i are independent of occurrences of concept j

$$\blacktriangleright p_{ij}^* = p_i p_j$$

Association strength of concepts i and j

$$\blacktriangleright a_{ij} = \frac{p_{ij}}{p_{ij}^*} = \frac{m c_{ij}}{c_{ii} c_{jj}}$$

Step 2: Positioning of concepts in a low-dimensional space

VOS

- ▶ The objective of VOS is to provide a low-dimensional visualization in which objects are located in such a way that the distance between any pair of objects reflects their similarity as accurately as possible.
- ▶ An alternative method to MDS.

Constrained optimization problem

- ▶ Minimize

$$E(\mathbf{X}; \mathbf{S}) = \sum_{i < j} s_{ij} \|\mathbf{x}_i - \mathbf{x}_j\|^2 \quad (1)$$

subject to

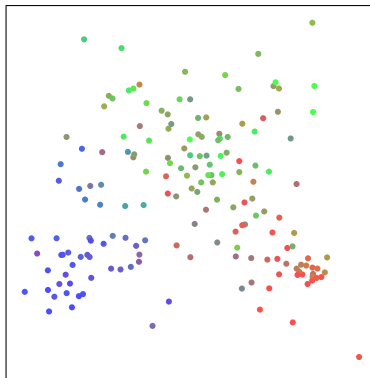
$$\sum_{i < j} \|\mathbf{x}_i - \mathbf{x}_j\| = 1 \quad (2)$$

Experiments

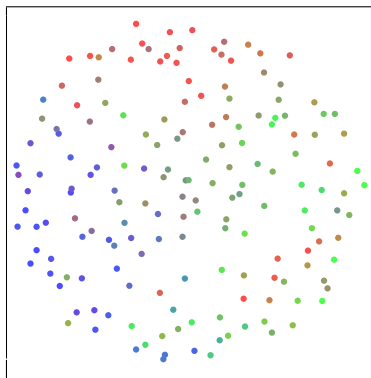
- ▶ The objective is to perform an experimental comparison between VOS and MDS.
- ▶ Both methods are used to construct a concept map based on the abstracts of the 1,687 papers that have been accepted for presentation at the 2006 IEEE World Congress on Computational Intelligence.

Concept maps constructed using VOS and MDS

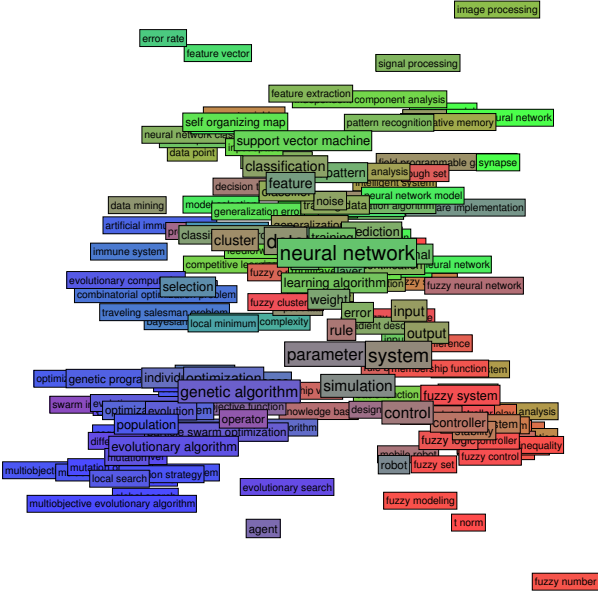
VOS



Ordinal MDS (PROXSCAL)



Concept map constructed using VOS



Precision-recall comparison between VOS and MDS

For a given concept i , the n concepts with the highest association strengths with concept i are considered relevant. Next, concepts are selected based on their proximity to concept i in a concept map. For different numbers of selected concepts, the precision and recall are calculated.

Precision

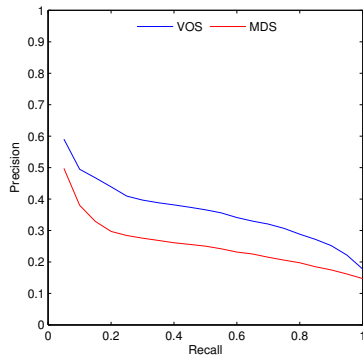
- ▶ Proportion of the selected concepts that are relevant.

Recall

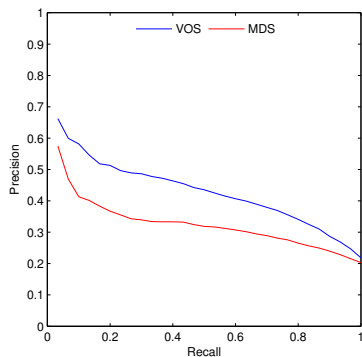
- ▶ Proportion of the relevant concepts that are selected.

Precision-recall graphs

20 relevant concepts



30 relevant concepts



- Based on precision-recall, VOS outperforms MDS.

Conclusions

- ▶ VOS and MDS have been compared experimentally in the following two ways:
 - ▶ Comparison of concept maps by human experts.
 - ▶ Comparison of concept maps based on precision-recall graphs.
- ▶ Both ways of comparing VOS and MDS indicate that associations between concepts are better reflected in the concept map constructed using VOS than in the concept map constructed using MDS.

References

Description and analysis of VOS

- ▶ N.J. van Eck and L. Waltman. VOS: a new method for visualizing similarities between objects. Technical Report ERS-2006-020-LIS, Erasmus University Rotterdam, Erasmus Research Institute of Management, 2006.

Application of VOS to the visualization of associations between concepts based on co-occurrence data

- ▶ N.J. van Eck, L. Waltman, J. van den Berg, and U. Kaymak. Visualizing the WCCI 2006 knowledge domain. In *Proceedings of the 15th IEEE International Conference on Fuzzy Systems*, 2006. Accepted for publication.

Related poster presentation

For a more detailed description of VOS and an analysis of the relationship between VOS and MDS, please visit the poster presentation *VOS: A New Method for Visualizing Similarities between Objects* by Ludo Waltman.