Scientific Convergence and Divergence in Visualization and Visual Analytics

Jiangen He[1]

[1]School of Information Sciences, The University of Tennessee, Knoxville, TN, USA

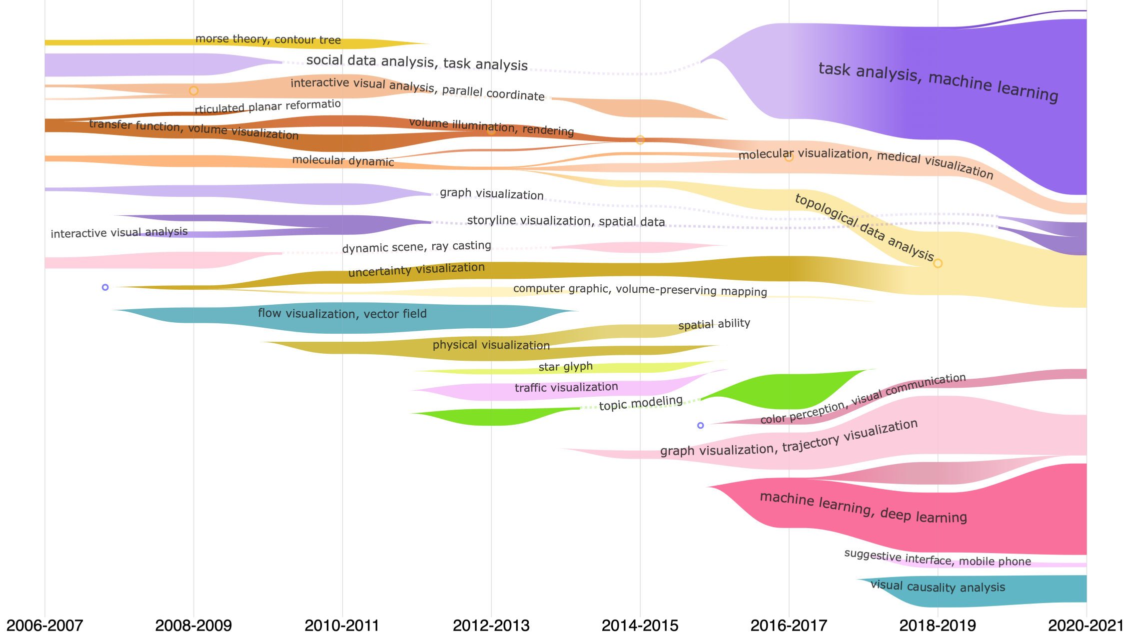

Figure 1: *A Visualization of the Scientific Evolution in Visualization Research.*

Abstract

We present preliminary results of a visualization tool designed to visualize scientific evolution by using scientific publication data, especially convergence-divergence processes. It aims to increase the efficiency and accuracy of our understanding of scientific knowledge in a certain field with limited domain knowledge. We visualized 2,435 papers published in IEEE VIS and EuroVis to demonstrate the tool and provide a big picture of the scientific evolution in the visualization community.

CCS Concepts

• ***Human-centered computing*** → ***Visual analytics; Visualization toolkits;***

1. Introduction

When scrutinizing the scientific growth of a specific research field in its details, the detailed mechanism underlying global growth is complex. Different research areas coexist within a field. The contributions to the global growth made by different areas may vary greatly. Meanwhile, the contribution of each area changes over time, because research areas within the field are growing and shrinking, new areas are emerging [US10], and areas remained dormant for a long period may get an explosive growth which can be associated with internal as well as external causes. The temporal relations among research areas are also complex. Science may grow as the growth pattern of a tree, branching out in ever more new

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twigs. Namely, a research area may evolve into two or more areas over time. Moreover, in light of the theory of structural holes, work bridging previously disjoint areas of knowledge are with high novelty. If further studies enhance the novel connection continuously, a new area may emerge or the intellectual base of an area gets updated by 'absorbing' knowledge from another area. Uncovering the detailed dynamics of science provides a broad picture of science development with context which has significant practical implications for us to identify the dynamic structure, growth points, and transformative discoveries as well as presage paradigm shifts and emerging trends in science.

Temporal analysis and visualization are routinely used in science mapping techniques and tools to identify and present structural and temporal patterns of science development with key entities [Che06, vEW10, ML17, FHKM16]. Typically, a series of chronologically sequential observations are made to model the scientific dynamics and a temporal visualization view is used to depict the dynamics. Although the modeling and visualization methods are various, these studies aim to analyze the evolution of science across different periods of time. However, the existing methods of modeling dynamics do not characterize the detailed dynamics adequately, since some critical relations are not identified. The visualizations do not provide clear patterns with broad context due to overlaps and crossings of visual elements.

In this poster, we present preliminary results of a new science mapping tool called *SciEvo* which aims to identify, track, and visualize the detailed dynamics in scientific evolution from a scientific article collection. We collected full papers in the proceedings of *IEEE Visualization Conference* and *Eurographics Conference on Visualization* in recent 16 years (2006-2021) to demonstrate the tool and depict a big picture of the scientific evolution in the visualization community.

2. Methods

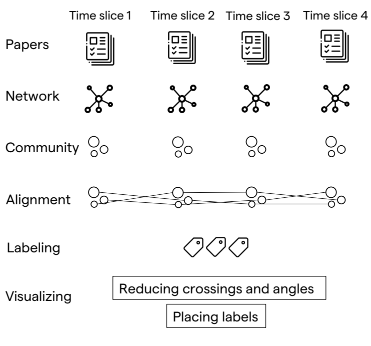

Figure 2: *An overview of the methods for identifying and visualizing scientific evolution.*

The overview of our method is depicted in Figure 2. Initially, an individual co-citation network is derived from articles from each time slice. Then, cited references are grouped into intellectual bases by detecting co-citation network communities and each citing article is mapped into a corresponding intellectual base(s), and citing articles mapped in the same intellectual base comprise a research front. To track the evolution of research fronts and identify the temporal relations among research fronts, we match the set of intellectual bases at succeeding time steps with each other. For each research front, i.e., a group of articles reporting on the same topic over time, We identify critical entities, including articles, references, and authors, by using various metrics. The nature of a research front is characterized by extracting salient noun phrases from titles and abstracts. To convey such complex results, we present a visualization technique based on a river system metaphor wherein river channels are constructed by intellectual bases and the quantity of water filling the channels is decided by the number of publications of the corresponding research front. Methods of crossing reduction and force-directed simulation are used in the layout of visual flows to improve the clarity of visualization.

3. Results and Conclusion

The visualization paper dataset consists of 2,435 full papers published in *IEEE VIS* and *EuroVIS* from the Web of Science Core Collection. The entire time interval of 2006 to 2022 was divided into eight three-year slices. Eight corresponding networks were constructed for each slice. The link threshold was set as 10%, which means links with a weight that is larger than the 90% links were included in the analysis. Communities were detected for each network and only communities with at least three papers remained for further analysis. The visualization of the paper dataset generated by *SciEvo* is shown in the Figure 1 where the evolving patterns of 27 research topics were visualized. The 27 research topics were grouped into 15 groups by network community detection based on their relationship with each other. Research topics in the same group are with the same hue but different saturation.

Overall, more convergence and divergence examples can be found in scientific visualization research than information visualization and visual analytics research. We can also see more convergence patterns than divergence ones in the evolution. For example, research in "molecular visualization, medical visualization" combined knowledge from various topics. It combined knowledge from "volume illumination, rendering" and "molecular dynamics". Some divergence patterns are also depicted in the Figure 1: "computer graphic, volume-preserving mapping" split from "uncertainty visualization".

Some research topics that were well studied in the past did not have much new publication in recent years, such as "morse theory, contour tree" and "flow visualization, vector field". Some research topics emerged and decayed in a relatively short period, such as "star glyph" and "traffic visualization". We also can observe some emerging topics in most recent years, such as "visual causality analysis" and "color perception". The most salient ones are "task analysis, machine learning" and "machine learning, deep learning". It is interesting to see the connection between recent research in "task analysis, machine learning" and "social data analysis, task analysis". From the preliminary result, we can build a quick understanding of scientific knowledge in a certain field without much domain knowledge. However, modeling and visualization of scientific evolution can be improved.

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