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A case study about FWI

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A citation network analysis on diffusion of technologies to other fields: A case study about FWI

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Summary

In recent years, the rapid changes in social trends and technologies, such as digital transformation and energy transition, have had a large impact on many industries. Future forecasts and exploration of potential values become indispensable for dealing with such changes and achieving the success of novel research and/or business. In this paper, we discuss an approach to evaluate the diffusion of innovative technologies to other fields using the network data in academic articles citing a review paper. This study provides a case study of full waveform inversion as an example in exploration geophysics to demonstrate the effectiveness of the approach by using the Web of Science database. This analysis enables us to forecast the trend of technologies by analyzing the diffusion of the other technologies as well as full waveform inversion.

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Introduction

In recent years, the rapid changes in social trends and technologies, such as digital transformation and energy transition, have had a large impact on many industries. Future forecasts and exploration of potential values become indispensable for dealing with such changes and achieving the success of novel research and/or business. The literature has presented several forecast frameworks, including scenario planning (e.g., [1]) and technology roadmapping (e.g., [2]), for future forecasts and exploration. Some investigation and information gathering are usually required in the process of these frameworks. One of the challenges in such investigations is to effectively find significant information not only in the area of our expertise but also in other fields. The information from other fields would also be important for future forecasts, especially technological forecasting. This is because atypical knowledge, as well as conventional knowledge, are key factors in the realization of innovation [3]. Therefore, information gathering in huge data on other fields plays an important role in innovation and future forecasts.

This study focuses on network analysis as one of the approaches to address this issue and effectively estimate the change in technologies. Network analysis is a methodology to investigate various structures through networks and graph theory. It has been widely exploited in many areas. For example, several theoretical models to describe innovation dynamics have been presented by utilizing network theory with the so-called urn model [4] or the random-walk model [5]. Moreover, the previous studies proposed citation network analyses using academic paper data and patent data to predict future trends of technologies (e.g., [6]). Mejia and Kajikawa (2020) estimated the emerging topics in energy storage using a large-scale analysis of academic papers and patents [6]. In this paper, we discuss a method to forecast the trend of technologies by analyzing the diffusion of key technologies to other fields using citation networks in an academic review article. Since the bibliographic analysis for exploration geophysics in previous studies [7-8] focused on the information, including texts, aside from citation, this paper provides a case study of full waveform inversion (FWI), which has been the most successful technology in the exploration geophysics in last decades.

Method

Here, we present a method to analyze the diffusion of key technologies to other fields and industries, as illustrated in Fig. 1. We pay attention to the similarity between the phenomenon of this diffusion and the citation of academic review papers. This method investigates journal research categories of the academic papers citing a review paper at each time step (see Fig. 1). We analyze the effect of diffusion for the review paper by the feature of these journal categories in each time step.

This analysis is conducted by using the Web of Science (WoS) database, which presents data about academic article information, including citations, provided by Clarivate. Since WoS sets journal categories of research fields for each journal, we utilize these journal categories for this analysis. For example, while the journal “Geophysical Prospecting” has one journal category “Geochemistry Geophysics” in WoS, the journal “IEEE Geoscience and Remote Sensing Letters” has four journal categories “Engineering Electrical Electronic”, “Geochemistry Geophysics”, “Imaging Science Photographic Technology”, and “Remote Sensing” in WoS.

An example on FWI

Here, we provide a case study to discuss the effectiveness of the analysis proposed above. The case study uses a review paper on FWI [9] written by Virieux and Operto (2009). This review article would be the most cited paper in the papers published in the area of exploration geophysics last decades. The number of citations for this paper [9] in WoS and Google Scholar is 1569 (see Fig. 2) and 3524, respectively (as of 9th February 2023). Fig. 2 shows that the number of citations and journal categories for the papers citing [9] is approximately increasing.

We exploited the citation data of the papers citing [9] from 2011 to 2022 for the diffusion analysis on FWI. Fig. 3 presents the time variations in the number of citations for the top 10 WoS categories of the papers citing [9]. Naturally, the journal category with the highest number of citations from 2011 to 2022 is “Geochemistry Geophysics” (see Fig. 3 (a)), which is the same journal category as that of [9]. We can also see that the number of citations in several journal categories, such as “Engineering Electrical

Electronic", "Imaging Science Photographic Technology" and "Remote Sensing", has rapidly increased since 2020, as shown in Fig. 3 (b). Therefore, this result indicates that FWI was developed inside the original field of "Geochemistry Geophysics" from 2011 to 2019 and then has spread to other fields. We also conducted a co-citation analysis to examine the detail of the diffusion on FWI using Visualization of Similarities (VOS) [10] viewer software. Co-citation is the frequency with which two articles are cited together by other articles. Fig. 4 illustrates the results of co-citation analysis for the journals citing [9] from 2011 to 2019 and from 2020 to 2022. The co-citation network from 2020 to 2022 has more nodes and links than that from 2011 to 2019, although the number of the papers citing [9] from 2011 to 2019 and from 2020 to 2022 is 1153 and 988, respectively. When we carefully observe these results, we notice that in recent years FWI has been employed for applications in ultrasonics, ground penetrating radar, hydrology, carbon capture and storage, etc. Hence, the results of the co-citation analysis would support the validity of the presented citation network analysis on the diffusion of technologies.

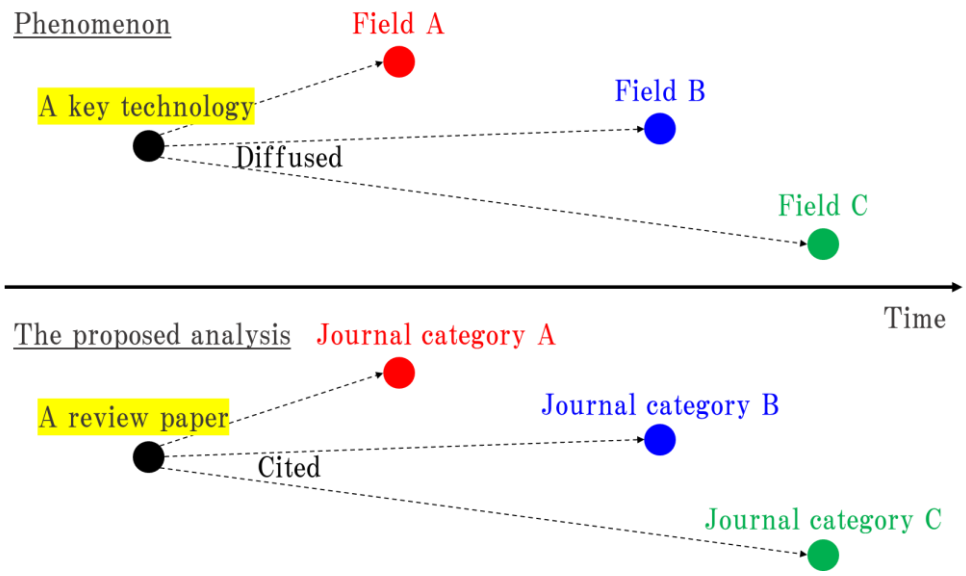
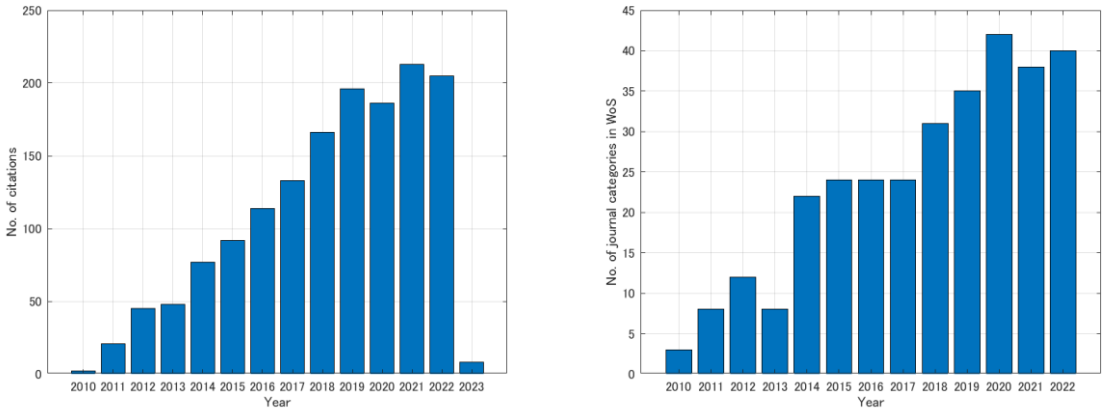


Figure 1 *Comparison between technological diffusion to other fields and the proposed analysis.*



(a) *(b)*

Figure 2 *The time variation in the number of (a) citations (as of February, 9 2023) for [9] and (b) the number of journal categories for the papers citing [9].*

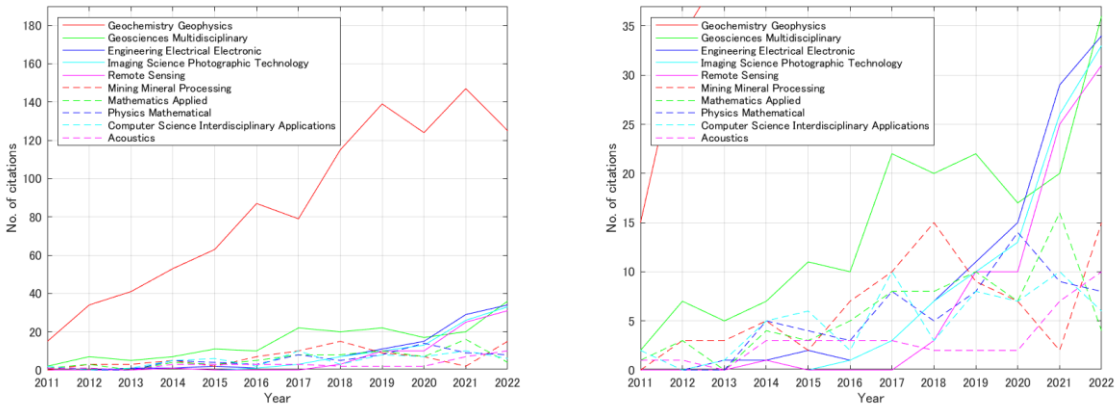


Figure 3 *The time variations in the number of citations for the top 10 WoS categories of the papers citing [9]: (a) the scale of the top 10 and (b) the scale of the top 10 aside from the top 1.*

Conclusions

We discussed an approach to evaluate the diffusion of innovative technologies to other fields using the information in academic articles citing a review paper. This study provides a case study of full waveform inversion as an example in exploration geophysics to demonstrate the effectiveness of the approach by using the Web of Science database. This analysis enables us to forecast the trend of technologies by analyzing the diffusion of the other technologies as well as full waveform inversion. The limitation of this approach is that an appropriate review article with the sufficient number of citations is required to investigate particular technologies.

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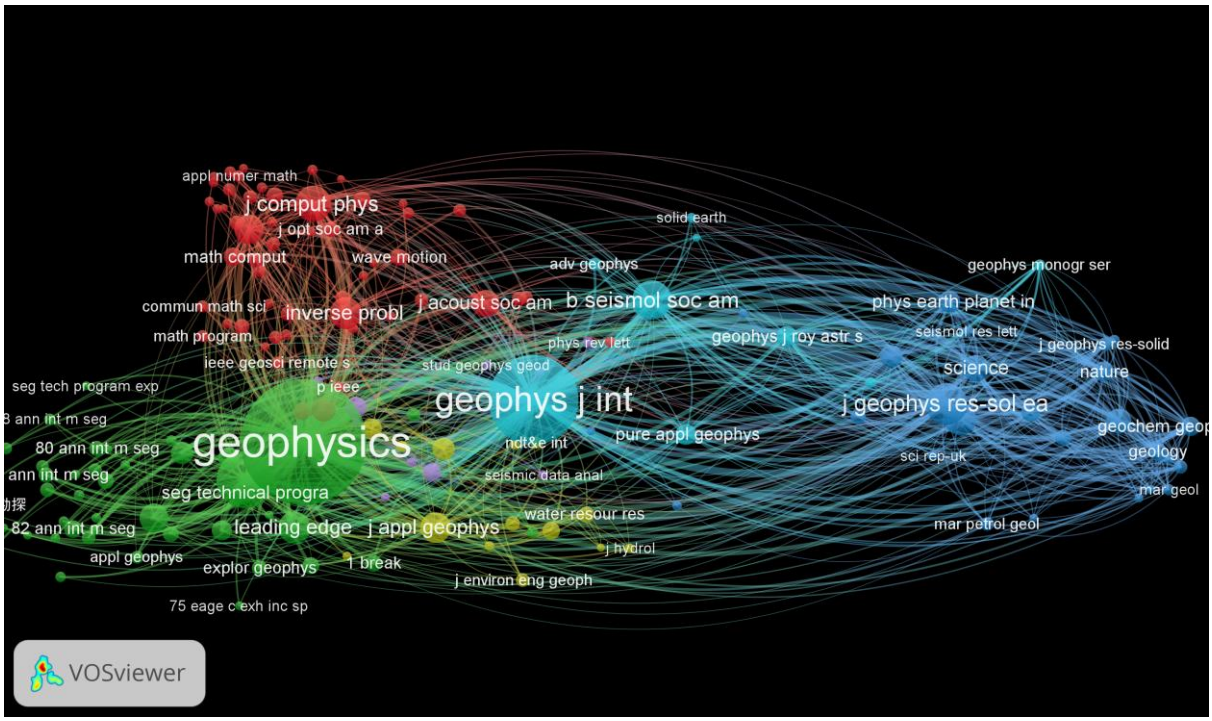
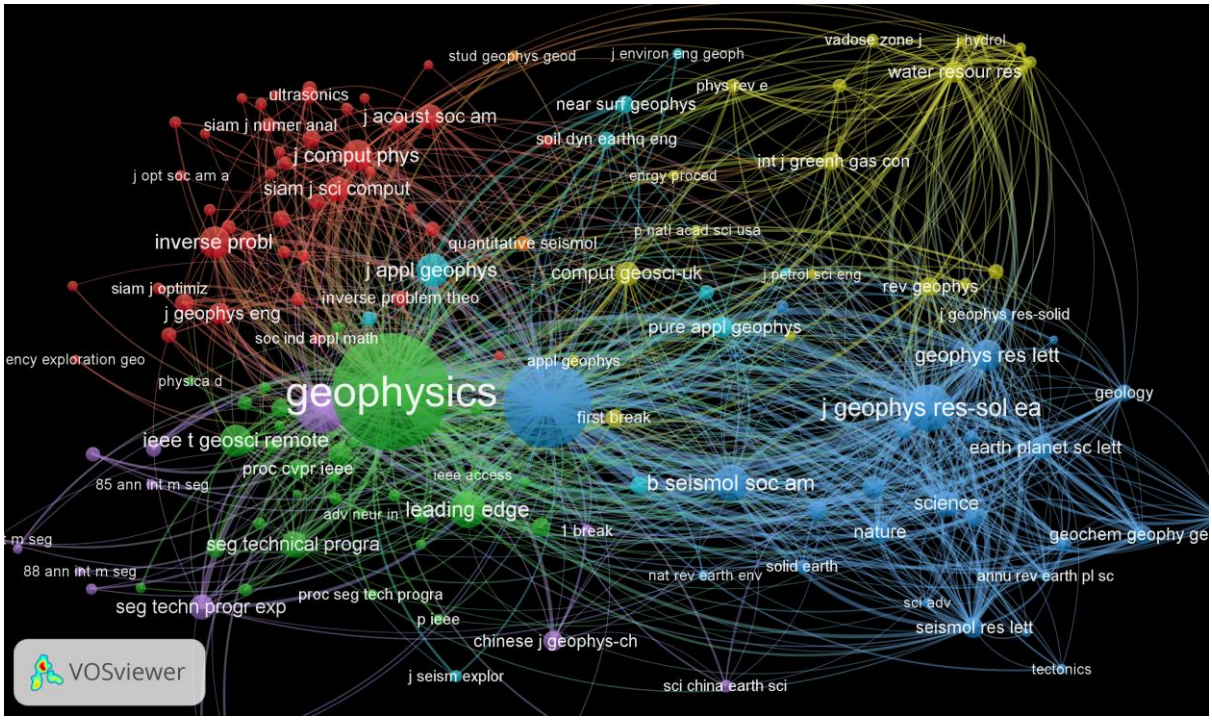
References

[1] P. J. H. Schoemaker, 1993, “Multiple scenario development: Its conceptual and behavioral foundation”, Strategic Management Journal, 14 (3), 193-213.
[2] R. Phaal et al., 2010, “Roadmapping for Strategy and Innovation: Aligning Technology and Markets in a Dynamic World”, University of Cambridge, Institute for Manufacturing.
[3] B. Uzzi et al., 2013, "Atypical Combinations and Scientific Impact", Science, 342, 468.
[4] F. Tria et al., 2014, “The dynamics of correlated novelties”, Scientific Reports, 4, 5890.
[5] I. Iacopini et al., 2018, “Network Dynamics of Innovation Processes”, Physical Review Letter, 120, 048301.
[6] C. Mejia and Y. Kajikawa, 2020, “Emerging topics in energy storage based on a large-scale analysis of academic articles and patents”, Applied Energy, 263, 114625.
[7] I. Vlad, 2018, “Exploratory analysis of affiliation information in Geophysics articles from 1936 to 2017”, The Leading Edge, 37, 682-686.
[8] T. Eltsovand et al., 2020, “Text Analysis Reveals Major Trends in Exploration Geophysics”, Energies, 13, 4550.
[9] J. Virieux and S. Operto, 2009, “An overview of full-waveform inversion in exploration geophysics”, Geophysics, 74, WCC127-WCC152.
[10] N. J. Van Eck and L. Waltman, 2007, “VOS: a new method for visualizing similarities between objects”, Advances in Data Analysis, 299-306.



(a) 2011-2019



(b) 2020-2022

Figure 4 *Co-citation analysis for the journals citing [9]:(a) from 2011 to 2019 and (b) from 2020 to 2022. Note that the number of the papers citing [9] from 2011 to 2019 and from 2020 to 2022 is 1153 and 988, respectively.*