Methods and Practice of Disciplinary Frontier Analysis: A Case Study of Peking University Library (Postprint)

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Date: 2023-04-01T00:00:00+00:00

Abstract

[Purpose/Significance] By comparing existing frontier analysis methods and practices, this study systematically examines and summarizes the advantages, disadvantages, and effectiveness of commonly employed frontier analysis methods, clarifies the concept of disciplinary frontiers, and explores the development of multi-source data-based disciplinary frontier analysis services in libraries. [Method/Process] Through literature review and case investigation, employing methods such as comparative analysis and case study, we compare the methodologies and outcomes of existing frontier analysis reports, with particular focus on Peking University Library' s "Frontiers of Scientific Research at Peking University" and "Frontiers of Research in Chinese Universities" as case studies, to introduce the connotation, characteristics, indicators, and research methodologies of multi-source data-based disciplinary frontier analysis services in university libraries, thereby providing a reference for such services. [Results/Conclusion] University libraries' disciplinary frontier analysis services should precisely align with disciplinary development needs, acquire and mine data from multiple sources and dimensions, comprehensively apply various frontier analysis methods, identify research fields and directions where each discipline holds competitive advantages, evaluate and assess future development trends in disciplinary research, and provide references for the strategic planning and resource allocation of first-class discipline construction.

Full Text

Preamble

Methods and Practices of Discipline Frontier Analysis: A Case Study of Peking University Library

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Abstract: *[Purpose/Significance]* By reviewing and comparing existing frontier analysis methods and practices, this paper summarizes the advantages, disadvantages, and effectiveness of commonly used approaches, clarifies the concept of discipline frontiers, and explores library services for discipline frontier analysis based on multi-source data. *[Method/Process]* Through literature and case studies using comparative and case analysis methods, this paper compares existing frontier analysis reports and their methodologies, focusing on Peking University Library' s *Peking University Science Research Frontiers* and *Chinese University Research Frontiers* as case studies. It introduces the connotation, characteristics, indicators, and research methods of discipline frontier analysis services in academic libraries based on multi-source data, providing references for other university libraries. *[Result/Conclusion]* University library frontier analysis services should precisely target discipline development needs, acquire and mine data from multiple sources and dimensions, comprehensively apply various frontier analysis methods, identify competitive research fields and directions for each discipline, and evaluate future development trends to provide references for first-class discipline construction planning and resource allocation.

Keywords: frontier analysis; frontier report; discipline research frontier; hotspot analysis; co-word analysis
Classification Number: G250
DOI: 10.13266/j.issn.0252-3116.2020.16.005

Analyzing research frontiers across disciplines in Chinese universities holds significant strategic importance. The 19th Party Congress Report [1] states that "innovation is the primary driving force for development and strategic support for building a modernized economy. We must aim at the frontiers of world science and technology, strengthen basic research, and achieve major breakthroughs in forward-looking basic research and leading-edge original achievements." The State Council' s *Overall Plan for Promoting the Construction of World-Class Universities and First-Class Disciplines* [2] proposes that universities should "elevate the level of basic research, strive to become parallel runners or even pacesetters at international academic frontiers, and strengthen research on strategic, global, and forward-looking issues to enhance capabilities for solving major problems and original innovation."

The concept of "research frontiers," first introduced in 1965 [3], has attracted widespread attention in recent years. Literature surveys reveal that scholars and institutions interpret the concept of discipline frontiers differently. Scholars such as H. Small [4], O. Persson [5], E. Garfield [6], and S.A. Morris [7] define research frontiers from the perspective of citation relationships, while J. Kleinberg [8], C. Chen [9], Huang Xiaobin and Wu Gao [10], Chen Shiji [11], and Zhang Huirong [12] define them through burst terms, research hotspots, and emerging themes in papers.

In practice, Clarivate Analytics and the Chinese Academy of Sciences (CAS) Library have jointly published the annual *Research Frontiers* report since 2014, defining research frontiers as clusters of highly cited core papers and their citing papers based on co-citation relationships. The EU Agency for Network and Information Security' s frontier report on privacy and data protection defines frontiers as research hotspots. These examples demonstrate that clarifying the status and distribution of discipline frontiers, identifying universities' competitive advantages in basic research directions, and forming annual dynamic analyses to assess future trends constitute the core value of discipline frontier analysis services provided by university libraries to support discipline construction and development strategies.

1. Research Background and Current Situation Analysis

1.1 The Concept of Discipline Frontiers Needs Clarification

The concept of discipline frontiers, first introduced by D.J. Price in 1965 [3], requires urgent clarification in both theory and practice. Different scholars and institutions understand this concept differently. In practice, various organizations have published frontier reports using different perspectives, data sources, and analytical methods, revealing divergent definitions of "frontiers." Notable examples include the *Research Frontiers* jointly published by CAS and Clarivate since 2014 [32], the *Global Engineering Frontiers 2018* released by the Chinese Academy of Engineering' s Strategic Consulting Center and Clarivate [33], McKinsey' s AI frontier report [34], and UNEP' s environmental frontier reports [35, 36] (see Table 1).

1.2 Multi-Source Data Fusion is the Trend in Frontier Identification

Currently, discipline frontier identification follows three main paths:

(1) Expert identification. Domain experts comprehensively review literature in specific disciplines, combining their academic expertise to analyze development status and future trends. Alternatively, institutions use expert surveys or consultation meetings with Delphi methods to synthesize expert opinions into frontier prediction reports. While this approach relies heavily on experts' levels and subjectivity, limiting speed, efficiency, and accuracy, it remains an important method for identifying and forecasting S&T development by leveraging expert wisdom and accumulated experience. For example, CAS' s annual *Research Frontiers* combines big data statistics with expert validation, and the *2019 Top Ten Academic Hotspots in Chinese Humanities and Social Sciences* released in January 2020 also integrates big data analysis with expert review.

(2) Bibliometric approach. This method tracks literature characteristics when new developments emerge in a field, mining the internal knowledge structure to detect patterns and identify trends. In 1965, Price [3] defined research frontiers as recently published and highly cited documents, initiating bibliometric exploration. Subsequent scholars like Small [4], Persson [5], Garfield [6], and

Morris [7] expanded this concept through citation-based identification. J. Law [13] explored co-word analysis for detecting hot topics in 1988, while others examined text-based methods: Kleinberg [8] proposed burst detection algorithms considering term frequency density, Chen [9] defined frontiers as clusters of emerging dynamic concepts, and A. Aris [14] identified new disciplinary themes as frontiers.

Bibliometric methods include: citation-based analysis (direct citation, co-citation, and bibliographic coupling); text-based detection (term frequency, co-word analysis, burst detection, knowledge discovery from non-related literature, and probabilistic topic modeling); and integrated citation-text analysis. Method suffers from time lag between publication and citation. Method overcomes this lag but lacks semantic clarity since terms may have different meanings in different contexts. Due to these limitations, many scholars combine methods to compensate for weaknesses [15, 16].

Despite limitations, bibliometrics remains mainstream. Recent studies include: Zheng Yanning [17] on co-word analysis (keyword co-occurrence) in 2016; M. Li [18] improving co-word methods with ARM-KM models in 2017; T. Zhang [19] using co-word and co-citation for medical big data frontiers in 2018; J. Hou [20] using co-citation for information science; Liang Li [21] advocating method combination; V. Aryadoust [22] applying co-citation to eye-tracking research in 2019; and Chen Xue [23] using co-word analysis for library and information science.

(3) Multi-source data analysis in big data environments. Scholars increasingly explore multi-source data for more comprehensive frontier identification: Two-source approaches using patents and papers [24-26], planning documents and funding data [27], or funding and paper data [28]; Three-source approaches using citations, downloads, and altmetrics [29]; Multi-source approaches using up to seven document types (patents, papers, dissertations, conference papers, books, funding data, industry reports) [30]; and Four-source approaches using papers, patents, planning documents, and funding data [31].

However, existing multi-source fusion primarily uses achievement data, rarely incorporating user behavior data, and fusion methods are mostly topic-based. This emerging field requires further exploration in data source selection and fusion depth.

1.3 Libraries Will Become Important Actors in Frontier Development

With increasing national innovation strategy demands and upgraded intelligence analysis services, libraries have begun providing discipline frontier analysis within research support and evaluation frameworks. Representative examples include Peking University Library' s *Peking University Science Research Frontiers (2018 Edition)* [37], Shanghai Jiao Tong University Library's topic tracking services, and Southeast University Library' s consulting services.

Table 1 summarizes major frontier analysis methods and reports, showing that existing reports are published by professional institutions or consulting companies, not targeted at specific users, and vary significantly in scope, perspective, and methodology. Libraries are well-positioned to address these gaps.

2. Methods and Framework for Discipline Frontier Analysis

2.1 Basic Concept of Discipline Frontiers

Theoretically, the concept of discipline frontiers is evolving and often used interchangeably with research frontiers, scientific frontiers, emerging topics, emerging trends, and research hotspots. In practice, analyzing various frontier reports reveals different definitions, frequently mixing hotspots with frontiers. For example, ESI defines Hot Papers as those published in the last two years and cited in the top 0.1% of their field in the last two months, while Research Fronts are clusters of highly cited papers identified through co-citation relationships over a 10-year span, with 2-50 core papers per cluster [32].

Analysis shows clear distinctions: hotspots focus on "heat" and reveal high-visibility existing achievements, while frontiers emphasize "connections" and identify potentially influential themes through research trajectory analysis. The relationship between these concepts is illustrated in Figure 1 [Figure 1: see original paper].

In summary, research frontiers, discipline frontiers, and scientific frontiers share the same connotation, as do emerging topics and emerging trends, and research hotspots, hot papers, and discipline hotspots. Discipline frontiers represent the latest, most advanced, and most promising research themes in scientific research —characterizing the most influential, strategically valuable, and future-oriented research topics and key ideas within disciplines or interdisciplinary fields. Their essence lies in leading-edge achievements and ideas within a research field, which may include both established hotspots with continued potential and emerging trends with strategic value.

2.2 Basic Elements of Frontier Analysis Methods

Different understandings of discipline frontiers lead to different analytical methods. Based on the conceptual foundation, frontier analysis methods should include these essential elements:

(1) Multi-source data analysis. Frontier analysis in big data environments must encompass diverse disciplinary data: journals, conferences, patents, books, research projects/funding, and both achievement data and user behavior data.

(2) Comprehensive application of multiple methods. As analyzed in Section 1.2, each method has strengths and limitations. Comprehensive description of discipline frontiers requires integrated application of various methods to maximize advantages and compensate for weaknesses.

(3) Combination of quantitative and qualitative analysis. Frontier reports should not only depend on bibliometric results but also incorporate expert wisdom. Authoritative frontier reports all involve expert interpretation—reports with data but without expert insight lack longevity.

(4) Forward-looking analysis to guide discipline planning. Frontier analysis should provide dynamic, forward-looking assessments of future research trends to guide discipline layout.

2.3 Framework for Discipline Frontier Analysis

Based on these concepts and elements, the overall framework for discipline frontier analysis is shown in Figure 2 [Figure 2: see original paper]: Data sources including journal papers, patents, user attention data, and funding data; Analysis methods whose results corroborate and complement each other to provide a panoramic description; Extracted results including research hotspots from achievement data, frontiers identified by experts through literature review, and emerging trends that attract user attention despite limited publications; Expert analysis to identify themes with continued influence among hotspots and strategically valuable emerging trends to form discipline frontiers.

Peking University Library' s two reports comprehensively applied various methods. *Peking University Science Research Frontiers* used citation analysis, heat analysis, keyword analysis, and achievement tracking, analyzing high-cited papers by Peking University scholars, top 1,000 downloaded papers, popular search terms, and NSFC funding data. *Chinese University Research Frontiers* used citation analysis, keyword analysis, and heat analysis, examining highly cited clusters in ESI and SciVal-TOP, keyword frequency of core papers, and institutional participation levels.

3. Implementation and Effectiveness

Driven by the "Double First-Class" initiative, Chinese university libraries have pioneered discipline frontier analysis with notable success, exemplified by Peking University Library' s two reports. Completed and released in 2019, these reports mapped the status and distribution of discipline frontiers in Chinese universities and Peking University, identified competitive research fields, evaluated future trends, and aimed to pinpoint potential leadership opportunities to inform "Double First-Class" planning and resource allocation.

3.1 Characteristics of Discipline Frontier Analysis

Both reports demonstrate distinct characteristics: **forward-looking orientation** targeting "Double First-Class" goals; **multi-dimensional analysis** examining literature quantity, content (keywords), impact (citations/downloads), user attention, search behavior, funding data, significance indices, average publication years, growth patterns, and institutional distribution; and **integration**

of quantitative and qualitative analysis combining bibliometrics with expert interpretation of core papers.

3.2 Innovative Value

(1) Precise content services targeting university discipline development. Unlike existing reports focusing on broad research fields, Peking University Library' s reports precisely target university discipline development for forward-looking analysis. Compared to common bibliometric services, frontier analysis not only presents quantitative results but also invites experts to analyze and interpret each frontier through literature review of titles, keywords, and abstracts, validated by discipline specialists. This quantitative-qualitative combination provides deeper value for discipline development.

(2) Integrated data sources, indicator systems, and analytical dimensions. While existing reports often rely on single data sources or methods, Peking University Library' s reports integrate: commercial databases (Web of Science, ESI, Scopus, SciVal, Elsevier e-journals, CNKI); user behavior data (downloads, searches); and diverse data types (papers, keywords, search terms, citation counts, institutional data). The reports redefine some indicators, such as expanding ESI Research Fronts (RF) to Emerging Research Areas (ERA) with three criteria: co-citation with sufficient RF papers (2-12 depending on RF size); sufficient citations to both RF and other papers (double the co-citation threshold); and maximum cosine similarity with any RF paper exceeding 0.05.

For SciVal, the reports select Topics with Prominence_{Percentile} >99% or 90% and top 50% global publication volume, then filter top 20-25 frontiers per discipline by publication volume, total citations, prominence index, growth patterns, etc. The reports also validate findings using institutional search hot terms (see Figure 3 [Figure 3: see original paper]), overcoming single-indicator limitations and enhancing scientific rigor and foresight.

(3) Macro-micro combined perspective. The reports employ both macro-level analysis of overall performance and participation, and micro-level analysis of specific frontier topics and institutional distribution. They examine both co-citation-based frontiers and emerging/potential frontiers based on significance indices. This combined perspective makes the analysis both a development barometer and a source of predictive information within specific disciplines.

3.3 Effectiveness Analysis

The *Peking University Science Research Frontiers* report attracted significant attention across campus. Schools including the National School of Development (economics, management), the School of Advanced Agricultural Sciences (economics), and the School of Earth and Space Sciences (geology, environmental science) requested customized reports for sub-disciplines or new discipline proposals. The library' s new perspective earned recognition from academic

units and management, leading to collaborative projects with the university' s academic development office and research department.

The *Chinese University Research Frontiers* report, based on Chinese university discipline structures and data from Clarivate and Elsevier, analyzed 12 disciplinary fields from a frontier perspective. The two data sources provide complementary coverage—ESI frontiers represent recent concentrated research areas, while SciVal frontiers include both emerging interdisciplinary topics and traditional, well-established fields. The report, planned for annual release starting 2018, will serve as a barometer for Chinese university discipline development.

4. Problems and Prospects

4.1 Data Source Limitations and Processing Difficulties

The library attempted to use user attention and search data, but faced constraints: data providers limited availability, format, and flexibility; search platforms had incomplete logs and update issues. Some reports couldn' t use Chinese data, and most lacked humanities/social sciences coverage. Merging and deduplicating different data sources proved difficult due to varying time spans, volumes, and clustering algorithms, with content formats restricted by publishers.

4.2 Analytical Technique and Tool Limitations

The library primarily used SPSS and CiteSpace, whose capabilities depend on data quality and analyst expertise. Due to data limitations, analysis remained at the keyword level, with co-occurrence analysis only reaching "degree centrality." Without professional technical teams for large-scale data merging, cleaning, association, and mining, conclusions often relied on discrete keyword accumulation, resulting in overly broad frontiers that failed to capture distinctive characteristics.

4.3 Lack of Professional Frontier Content Analysis

Frontier interpretation is complex and requires stable, long-term expert teams from various disciplines. Establishing effective organizational mechanisms remains challenging.

To address these issues, future work should introduce more data sources, collaborate deeply with technical teams and discipline experts, and build proprietary databases for data acquisition, cleaning, and normalization. Libraries should develop custom algorithms and employ data mining techniques for independent analysis while establishing stable expert teams. Additionally, data openness should be promoted to provide open access to underlying data for verification and broader utilization.

Conclusion

Library discipline frontier analysis services represent a crucial support for discipline construction. Libraries possess natural advantages: massive information resources, analytical tools, bibliometric methods, and service foundations. While currently more suitable for STEM disciplines, especially emerging and interdisciplinary fields, frontier analysis is increasingly relevant for humanities and social sciences in the big data era. For instance, Peking University' s School of Advanced Agricultural Sciences requested frontier analysis before establishing agricultural economics and management programs. Despite data and technical bottlenecks, library frontier analysis has clear application prospects in universities. Future development should involve deeper collaboration with data and technology companies to advance data construction, particularly for humanities and social sciences, and promote data openness.

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Author Contributions:

Zhang Chunhong: Main framework design, case analysis, and conclusion;
Xiao Long: Framework revision and text editing;
He Fei: Topic positioning and value exploration;
Tang Yong: Framework adjustment, literature review, and comparative analysis of research methods.

The Study of Methods and Practices of Identifying Discipline Re-

search Frontiers—Taking Peking University Library as an Example

Abstract: [Purpose/significance] By reviewing and analyzing the methods and practices, this paper summarized the effects, advantages and disadvantages of identifying discipline research fronts. This paper clarified the concept of the discipline research fronts and explored the development of frontier analysis services based on multi-source data in libraries. [Method/process] Using literature study and case study, this paper explored the studies of identifying discipline research fronts by comparative analysis. Then it took two cases of identifying discipline research fronts of Peking University library as examples, explores the connotation, characteristics, indexes and research methods of discipline research frontier analysis service in university library, which provides reference for the development of the services. [Result/conclusion] The results show that the accurate benchmarking of discipline development needs, diversity of data sources, comprehensive analysis of the source data, and comprehensive application of various methods have been significantly improved the effects of the frontier analysis service in the aspects of clarifying the research fields and research directions of each discipline. Which can help to clearly understand, evaluate and judge the future development trend of the disciplines, and provide a useful reference for the layout and resource investment of the disciplines development.

Keywords: frontier analysis; frontier report; discipline research frontier; hotspot analysis; co-word analysis

Note: Figure translations are in progress. See original paper for figures.