Analysis of the Current Status and Recommendations for Knowledge Fusion Research: Postprint

Authors: Li Guangjian, Chen Yu

Date: 2023-07-26T00:00:00+00:00

Abstract

[Purpose/Significance] As human society transitions from the information society to the post-information era, it is undergoing a fundamental shift from "information" to "intelligence." Under the dual influence of big data environments and artificial intelligence technology development, knowledge fusion serves as a critical link in the processes of knowledge-ization and intelligence-ization, providing important theoretical and technical support for improving knowledge services, intelligent services, and fostering advanced forms of intelligence. Conducting a survey of knowledge fusion from a pan-disciplinary perspective expands the research horizon and offers valuable insights for comprehensively explaining the current state of knowledge fusion research and constructing a unified theoretical research framework. [Method/Process] This paper employs a literature analysis method combining quantitative and qualitative approaches to analyze the current state of knowledge fusion research from different disciplinary perspectives, and to summarize the main research content and issues of concern regarding knowledge fusion across disciplines, factors involved in knowledge fusion, application scenarios of knowledge fusion, etc. [Results/Conclusions] Knowledge fusion research belongs to a multi-interdisciplinary field with blurred conceptual boundaries and dispersed research areas; a unified research framework has not yet been formed. Through literature investigation and based on a comprehensive summary of previous knowledge fusion research achievements, this paper delineates research orientations for knowledge fusion and proposes well-founded recommendations for knowledge fusion research.

Full Text

Preamble

Analysis and Suggestions on Knowledge Fusion Research
Li Guangjian, Chen Yu
Department of Information Management, Peking University, Beijing 100871

Abstract

[**Purpose/Significance**] As human society transitions from the information society to the post-information era, it is experiencing a leap from "information" to "intelligence." Under the dual influence of big data environments and artificial intelligence technology development, knowledge fusion serves as a critical link in the processes of knowledge capitalization and intelligence, providing important theoretical and technical support for improving knowledge services, intelligent services, and fostering advanced forms of intelligence. Conducting a comprehensive, multidisciplinary investigation of knowledge fusion research expands its research horizons and offers a reference for fully explaining the current state of knowledge fusion studies and constructing a unified theoretical framework.

[**Method/Process**] This paper employs a combined quantitative and qualitative literature analysis method to examine the current state of knowledge fusion research from different disciplinary perspectives, summarizing the main research contents and concerns of knowledge fusion across disciplines, the factors involved in knowledge fusion, and its application scenarios.

[**Result/Conclusion**] Knowledge fusion research is a highly interdisciplinary field with fuzzy conceptual boundaries and scattered research domains, and has not yet formed a unified research framework. Based on a comprehensive review of previous knowledge fusion research outcomes, this paper delineates the research orientations of knowledge fusion and proposes reasonable suggestions for future research.

In big data environments, multiple disciplines are accumulating various forms of multi-source knowledge, making knowledge fusion a crucial research topic. Compared with knowledge from a single source, fused knowledge possesses greater dimensionality and breadth, offering different perspectives for observing, comparing, and understanding the same problem. Applying the concepts, theories, methods, technologies, and models of knowledge fusion enables the integration of multi-source knowledge, generating new knowledge, enriching its content and hierarchy, improving its credibility, constructing more complete knowledge systems, providing more comprehensive, precise, and intelligent knowledge services, and promoting improved decision-making [1]. Knowledge fusion is a multidisciplinary research field, with computer science, library and information science, management science, education, economics, and engineering technology all studying it from different angles. Due to this interdisciplinary nature and its rich connotation and extensive extension, no unified definition has yet been formed. Therefore, conducting knowledge fusion research from a comprehensive disciplinary perspective is significant for expanding its research horizons, explaining its full landscape, and forming a unified theoretical framework.

2. Current Status Analysis of Knowledge Fusion Research

2.1 Data Sources and Research Methods

A cross-database search was conducted in CNKI, covering four databases: master's theses, doctoral dissertations, journals, and domestic conferences. Using the search query "subject = knowledge fusion," 988 results were obtained.

The study employed a combined quantitative and qualitative literature analysis approach. Quantitative analysis included: (1) statistical description of the temporal and disciplinary distribution of literature; and (2) co-occurrence network analysis based on keywords from abstracts. The abstracts were segmented and matched with a keyword list to generate a keyword list for all articles, followed by construction of a co-word network diagram where node attributes represented keyword frequency and edge attributes represented co-occurrence counts. The network was then clustered using the Modularity Class algorithm in Gephi software, which identifies networks with dense connections within modules but sparse connections between them. Qualitative analysis primarily involved content analysis, examining literature content individually and interpreting the status of knowledge fusion research across disciplines in conjunction with quantitative results.

2.2 Quantitative Analysis of Knowledge Fusion Research

2.2.1 Annual Distribution of Papers Statistical analysis of publication years for the 988 relevant articles is shown in Figure 1 [Figure 1: see original paper]. The figure reveals an approximately exponential growth trend in publications on knowledge fusion, with high growth rates maintained in recent years except for a slight decline in 2014. The growth rates for 2015 and 2016 were 33.82% and 43.96%, respectively, with annual publications exceeding 100 papers starting in 2016. By July 9, 2018, 64 papers had already been published, indicating growing scholarly attention to knowledge fusion.

2.2.2 Disciplinary Distribution of Papers Using document classification numbers as a reference and combining them with content analysis, the domestic knowledge fusion research is found to concentrate primarily in five disciplinary areas after excluding categories with small quantities: computer science, library and information science, engineering technology, economics and management, and education. The specific distribution is shown in Figure 2 [Figure 2: see original paper].

2.3 Content Analysis of Knowledge Fusion Research

Based on basic statistics, co-word network analysis was conducted on relevant papers from the past five years in computer science, library and information science, engineering technology, economics and management, and education to summarize the main contents and key issues of knowledge fusion research in each field.

Overall, knowledge fusion research in computer science and engineering technology is technology- and application-oriented, though with different emphases. Library and information science research highlights social and user-oriented attributes while applying technology. Economics and management research focuses on how to appropriately apply management methods to enhance knowledge value. Education research examines the role of knowledge fusion in individual cognitive processes.

2.3.1 Knowledge Fusion Research in Computer Science Figure 3 [Figure 3: see original paper] shows the co-word network diagram for the computer science field based on paper keywords. Overall, apart from traditional data fusion and information fusion research, recent knowledge fusion studies in computer science concentrate on two aspects: (1) knowledge fusion theories, techniques, and applications based on knowledge engineering; and (2) knowledge fusion theories, techniques, and applications in Internet and big data environments.

The concept of knowledge engineering was proposed by American computer scientist Feigenbaum in 1977, referring to the use of artificial intelligence principles and methods to provide solutions for application problems requiring expert knowledge. Properly employing expert knowledge acquisition, representation, and reasoning processes constitutes an important technical issue in designing knowledge-based systems [3]. Knowledge engineering studies how to use computers to solve problems of knowledge acquisition, representation, organization, management, and utilization, aiming to standardize and formalize knowledge and seek optimal procedural steps for knowledge computation to enable computer operations on knowledge [4-6]. Current understandings of knowledge engineering research content vary, but generally it includes three subcategories: knowledge measurement, knowledge reasoning, and knowledge fusion [7]. Thus, knowledge fusion is a key technology in knowledge engineering, focusing on integrating multi-source knowledge into new knowledge to improve its connotation, hierarchy, and confidence level, helping decision-makers make more efficient and accurate judgments. Knowledge fusion algorithms are therefore critical technologies directly affecting fusion effectiveness [8]. Existing research on knowledge fusion methods in computer science includes both traditional data/information fusion methods and their extensions, as well as artificial intelligence-based fusion methods. Traditional methods include classical probability reasoning, Bayesian reasoning, Bayesian convex set theory, D-S evidence theory, Kalman filtering, fuzzy logic, rough sets, wavelet transforms, and information theory methods. AI-based methods include cluster analysis, neural networks, and support vector machines [9].

In Internet and big data environments, computer technologies adapted for big data storage, processing, and analysis have emerged, making this research focus on multi-source heterogeneous data from the Web as primary sources. Unlike knowledge engineering-based knowledge fusion, this research pays special at-

tention to publicly available, dispersed, heterogeneous, and fragmented data containing multi-source, heterogeneous, semantically diverse, and dynamically evolving knowledge [10-11]. Beyond continuously adapting knowledge engineering content for big data fusion needs, new technical challenges have arisen, including: (1) the challenge of dynamic data streams—previous data processing methods, whether rule-based or learning-based, assumed static data with constant volume and characteristics, making them unsuitable for big data knowledge fusion; (2) the challenge of fragmented Internet knowledge—fragmentation increases difficulty in identifying entities and relationships, requiring solutions for knowledge abstraction, modeling, relationship inference, deep knowledge discovery, and universal mechanism analysis rather than simple "patching together"; and (3) the challenge of cross-data-type fusion—big data knowledge fusion must fully consider diverse data types and structures, including text, audio, video, images, and geographic information, requiring seamless integration of different data sources.

In summary, knowledge fusion research in computer science has a clear technology orientation, focusing on theories, methods, and technologies for implementing knowledge fusion.

2.3.2 Knowledge Fusion Research in Engineering Technology Figure 4 [Figure 4: see original paper] shows the co-word network diagram for the engineering technology field. Knowledge fusion application in fault diagnosis represents a distinctive feature of engineering technology research, typically using "hard data" as fusion subjects. With the rise of knowledge engineering, research scope has expanded further, notably in product development and design. The frequent appearance of keywords such as knowledge base, knowledge representation, neural networks, and kernel functions indicates that "soft data" processing methods and technologies are gradually gaining attention in engineering technology.

Product development and design are intelligent activities requiring extensive knowledge. Computer-aided design supported by knowledge base systems has become a new approach, known as Intelligent Computer-Aided Design (ICAD) [14]. According to modern innovation design theory, product design innovation is a knowledge fusion process that must fully utilize explicit and implicit knowledge. Multi-source knowledge related to industrial product design includes: (1) existing knowledge; (2) market information; (3) digital simulation and virtual reality; (4) physical model testing; (5) prototype testing; and (6) performance of existing products (user feedback), covering both meta-knowledge and domain knowledge [15]. A key characteristic of knowledge fusion-based product design is knowledge reuse, with the fundamental principle being incremental acquisition of analytical expert knowledge to automate simulation analysis workflows. Knowledge fusion technology can be applied to industrial product design processes related to vehicles [16], engines [15], spacecraft [17], and aviation equipment [18], representing a frontier and development trend in industrial design.

Improving reliability of large complex equipment, production processes, and large systems to prevent faults has always been a concern in engineering technology. Computer and AI technologies have enabled intelligent fault diagnosis [19]. Intelligent fault diagnosis comprehensively utilizes physical information about operational states and various expert knowledge, organically fusing data, information, and knowledge to form comprehensive evaluations of system operation and fault conditions for intelligent maintenance decisions. Actual fusion diagnosis systems include data fusion, knowledge fusion, data-to-knowledge fusion (data mining), and knowledge-to-data fusion (data association) as an organic whole [20]. Diagnostic methods include qualitative and quantitative model-based approaches and AI-based methods, with the latter typically using neural networks and focusing on expert and case knowledge fusion. Current research often combines these methods, with applications in thermal power [21], aerospace [22], metallurgical and chemical engineering [23], and mechanical engineering [24].

Knowledge fusion research in engineering technology is application-oriented, overlapping with computer science in technical methods but emphasizing practical application to solve specific production problems. It is closely tied to application scenarios, exhibiting strong practicality and specialization.

2.3.3 Knowledge Fusion Research in Library and Information Science
Figure 5 [Figure 5: see original paper] shows the co-word network diagram for library and information science. The research themes cover a broad range, featuring both disciplinary characteristics and extensive overlap with computer science, management, and communication studies. However, content analysis reveals significant differences from computer science and engineering technology research.

According to J. Llinas [25], knowledge fusion objects include “hard data” (well-structured, machine-understandable signal data from sensors and detectors representing physical states) and “soft data” (unstructured natural language data like articles, web pages, and social media, or structured data entered by humans). While computer science and engineering technology research both data types, library and information science research has been implicitly limited to “soft data” from the outset, aiming to “acquire, match, integrate, and mine knowledge from numerous dispersed, heterogeneous resources to obtain valuable or implicit new knowledge and provide knowledge services for solving domain problems” [26].

Library and information science knowledge fusion research can be categorized into two types: (1) studies on methods, techniques, algorithms, and applications, which align with general computer science methods but address specific knowledge service needs in library and information science; and (2) studies on knowledge fusion architecture frameworks, which are more abstract and macro-level than system-oriented frameworks in computer science and engineering, exemplified by research from Zhang Xinyuan et al. [27], Tang Xiaobo et al. [28],

and Wang Yuefen et al. [29]. These frameworks provide theoretical foundations for optimizing knowledge fusion architectures for specific needs.

Both types of research exhibit strong social/user orientation, a characteristic determined by the discipline's nature. While studying theories, technologies, and applications of knowledge fusion, library and information science research fundamentally aims to meet human knowledge needs using "soft data" sources like literature and web data, rather than focusing on machine intelligence using "hard data" as in engineering.

2.3.4 Knowledge Fusion Research in Economics and Management
Figure 6 [Figure 6: see original paper] shows the co-word network diagram for economics and management. Research in this field primarily focuses on knowledge integration and management in various organizations, emphasizing the value of knowledge as a dynamic capital form resulting from human labor [31].

In the knowledge economy era, planning and managing knowledge creation and application has become central to innovation in knowledge-intensive organizations such as enterprises, universities, and research institutions, making knowledge fusion key to enhancing innovation capacity [32]. In enterprises, knowledge has gradually replaced other assets as the most important resource for creating core competencies and improving performance, with competitive advantages stemming from knowledge fusion rather than single knowledge sources [33]. Research focuses on organizational knowledge fusion models, mechanisms, effects, and capabilities, addressing how to effectively fuse individual tacit knowledge, explicit knowledge, behavioral knowledge, and external beneficial knowledge to achieve organizational knowledge accumulation, complete innovation tasks, improve performance, and promote development [34-40].

Enterprise mergers and acquisitions best illustrate the importance of knowledge fusion. Knowledge integration in post-merger enterprises typically involves three stages: knowledge protection, knowledge transfer, and knowledge fusion with collaborative innovation, with the latter being the ultimate goal [41-43]. Explicit knowledge fusion relies on organizational learning mechanisms through knowledge matching and reconstruction rather than simple combination. Tacit knowledge fusion occurs primarily through dialogue, where acquiring the other party's tacit knowledge and integrating it with existing knowledge systems creates new knowledge.

Economics and management knowledge fusion research is management-oriented, based on theories such as knowledge-based view, knowledge management, knowledge transfer [42], social exchange theory, and planned behavior theory [44]. Application research involves knowledge maps and knowledge management systems [45-47], focusing on using tools and technologies to accomplish management tasks rather than technical implementation.

2.3.5 Knowledge Fusion Research in Education Figure 7 [Figure 7: see original paper] shows the co-word network diagram for education. Research focuses on theory and practice in teaching and learning, roughly divided into three aspects: teaching methods and models, educational reform, and university research and team building (the latter overlapping with economics and management themes).

Teaching method research aims to improve teaching and learning efficiency. In classroom instruction primarily involving declarative knowledge, multi-source knowledge fusion enriches and expands content, stimulating interest and innovation. In teaching procedural knowledge, the focus is on solving "what to do" and "how to do it" problems, emphasizing the fusion of theoretical and practical knowledge.

Educational technology is another hotspot. The "deep fusion" concept of information technology and education seeks effective pathways for structural educational transformation. The TPACK (Technological Pedagogical Content Knowledge) framework integrates content knowledge (CK), pedagogical knowledge (PK), and technology knowledge (TK) to improve knowledge construction in teaching activities [49].

Curriculum and major reform is important in vocational, adult, and higher education. With growing demand for interdisciplinary talents, many institutions are establishing interdisciplinary majors that fuse multi-disciplinary knowledge into curriculum systems to cultivate versatile, well-grounded, practice-oriented talents [50-51].

Education knowledge fusion research differs from other fields in its focus on individuals' (learners') processes of acquiring new knowledge through environmental interaction and integrating it into personal knowledge systems, optimizing this process to promote knowledge absorption. This is essentially a cognitive process, making education knowledge fusion research cognition-oriented.

3. Suggestions for Knowledge Fusion Research

The analysis shows knowledge fusion research is interdisciplinary with different orientations. Each discipline studies knowledge fusion from its own perspective, constrained by its traditions. Comprehensive understanding requires a multidisciplinary approach. Library and information science has shown increasing interest in knowledge fusion research, reflecting both disciplinary development needs and growing demand for "soft data" knowledge fusion that previous research could not satisfy. Based on this understanding, we propose the following suggestions for knowledge fusion research in library and information science.

3.1 Strengthen Interdisciplinary Research

The five orientations of knowledge fusion research demonstrate its strong interdisciplinary characteristics. Technology-oriented research focuses on theories,

frameworks, systems, processes, algorithms, and evaluation, providing technical foundations. Application-oriented research applies technical theories to practical scenarios, accumulating experience for system design and development. User-oriented research targets social needs to realize knowledge fusion's social value. Management-oriented research ensures orderly, healthy development of knowledge fusion processes. Finally, cognition-oriented research focuses on individuals in knowledge fusion, constituting its philosophical and epistemological foundation and logical starting point.

A complete knowledge fusion theoretical system requires all these orientations. Current library and information science research has drawn heavily from computer science but less from other orientations. We should broadly absorb beneficial results from different disciplines. Library and information science has natural connections with background disciplines of different orientations and can relatively easily integrate their achievements. Additionally, library and information science professionals, through their information analysis work, may have deeper insights into knowledge fusion's distribution, hotspots, and trends than experts in other fields.

3.2 Construct a Unified Knowledge Fusion Theory

Knowledge fusion research has gained prominence in academia (except education) due to big data development. While e-commerce, military security, remote sensing, and management science have achieved practical results, theoretical research remains scarce, scattered, and lacking systematicness and hierarchical unity. This makes it difficult to explain phenomena or guide practice. A unified theoretical framework is urgently needed to absorb and accommodate related research, enabling different concepts to be both distinct and interconnected within the system.

As a relative newcomer, library and information science should contribute to this effort. It has inherent advantages: strong foundations in user needs research can clarify big data era knowledge fusion requirements; its applied nature and extensive use of information technology, automation, management science, and education concepts facilitate integration of different orientations; and preliminary research on concepts, supporting theories, frameworks, and methodologies under big data environments has already begun.

3.3 Strengthen Applied Research

Knowledge fusion applications in mechanical manufacturing, industrial design, and automation using "hard data" are relatively mature, but "soft data" applications remain underdeveloped due to technical challenges from acquisition to service delivery and unclear mechanisms of user knowledge absorption. These problems can be solved through application-driven approaches.

On one hand, library and information institutions possess rich knowledge resources, providing experimental platforms for "soft data" knowledge fusion. The

combination of technology and resources is essential for applications, as demonstrated by digital library construction. “Soft data” knowledge fusion represents the development trend, and library and information science-based research is necessary. On the other hand, library and information science has entered the knowledge services era, where services are based on capabilities to search, organize, analyze, and reorganize information and knowledge, integrating into users' problem-solving processes. This analysis, reorganization, and integration is essentially knowledge fusion, making applied research both a requirement and prerequisite for knowledge services.

As society enters the big data era, the world seems digitized except for the human brain—the only remaining “analog device” for which big data provides environmental preparation. Knowledge's discrete distribution and tendency toward concentration require knowledge fusion to organically bind fragmented knowledge. The existence of tacit and implicit knowledge, along with its enormous representational and mining value, increases knowledge fusion's complexity and necessity. As a key link in enhancing decision support and knowledge service intelligence, knowledge fusion will spawn new intelligence forms like super-intelligence and fusion intelligence, making it a crucial research topic. This paper summarizes five orientations of knowledge fusion research and proposes issues warranting attention in library and information science, hoping to stimulate further discussion among colleagues.

References

[1] Liu Xiaojuan, Li Guangjian, Hua Bolin. Knowledge fusion: Concept analysis and definition[J]. Library and Information Service, 2016, 60(13): 13-19.
[2] Zhao Rongying, Zhang Xinyuan. Research on the impact of big data environment on knowledge fusion[J]. Journal of Intelligence, 2017, 36(9): 878-885.
[3] Tong Tianxiang. Artificial intelligence and the Nth generation computer[J]. Philosophical Research, 1985(05): 12-20.
[4] Frederick H, Huang Xiangxi, Qiu Dihong. Overview of knowledge engineering[J]. Computer Science, 1986(3): 1-17.
[5] Tang Huaikun. Research on communication engineering design expert system based on knowledge engineering[J]. Communication and Information Technology, 2018(4): 21-25.
[6] Shi Zhongzhi, Yang Zhicheng, Fang Jianmei. Knowledge engineering[J]. Chinese Journal of Computers, 1986(4): 241-248.
[7] Wang Yu. Research on key technologies of knowledge measurement, reasoning and fusion in knowledge engineering[D]. Shanghai: Fudan University, 2004.
[8] Zhou Fang, Wang Pengbo, Han Liyan. Multi-source knowledge fusion processing algorithm[J]. Journal of Beijing University of Aeronautics and Astronautics, 2013, 39(1): 109-114.
[9] Xiao Bin, Duan Chengxian, Yan Gaowei. Overview of multi-sensor information fusion and its application in industry[J]. Computer Development & Applications, 2007, 20(10): 27-29.

[10] Zhang Yao, Li Shuyu, Tang Yu. Research on multi-source heterogeneous knowledge fusion algorithm under big data[J]. Computer Technology and Development, 2017, 27(9): 12-16.
[11] Lin Hailun, Wang Yuanzhuo, Jia Yantao, et al. Knowledge fusion method for network big data[J]. Chinese Journal of Computers, 2017, 40(1): 1-27.
[12] Meng Xiaofeng, Du Zhijuan. Big data fusion research: Problems and challenges[J]. Journal of Computer Research and Development, 2016, 53(2): 231-246.
[13] Wu Xindong, He Jin, Lu Ruqian, et al. From big data to big knowledge: HACE+BigKE[J]. Acta Automatica Sinica, 2016, 42(7): 965-982.
[14] Chen Lichao. Knowledge Engineering and Expert Systems[M]. Beijing: Higher Education Press, 2013.
[15] Wu Jingrui, Yang Ling, Zhang Guoyuan, et al. Research on sliding bearing design based on multi-source knowledge fusion[J]. Lubrication Engineering, 2008, 33(8): 80-83, 87.
[16] Chen Ke, Yin Guofu, Zhao Wu. Structure optimization of automobile rear axle differential gear based on knowledge fusion[J]. Advanced Engineering Sciences, 2009, 41(4): 208-212.
[17] He Miao, Chang Haoli, Yang Haicheng. Research on collaborative innovation platform for complex products based on shared intelligence models[J]. Manufacturing Automation, 2008, 31(1): 9-12.
[18] Xiong Qingchun, Chen Cai. Research and implementation of NC machining process information platform based on knowledge fusion[J]. Precise Manufacturing & Automation, 2009(4): 55-58.
[19] Zheng Wei, Dai Jin. Application of multi-sensor information fusion technology in industry[J]. China Electric Power Education, 2007(s3): 172-174.
[20] Zhang Yanduo, Jiang Xingwei, Huang Wenhu. Research on autonomous fault diagnosis technology for space station based on information fusion[J]. Computer Engineering and Applications, 2002, 38(2): 58-60.
[21] Cai Ding. Research on underdetermined gas path fault diagnosis method for gas turbine fusing prior knowledge[D]. Harbin: Harbin Institute of Technology, 2015.
[22] Ge Zhexue, Yang Yongmin, Hu Zheng, et al. Knowledge-based fault fusion diagnosis strategy for helicopter autopilot[J]. China Mechanical Engineering, 2006, 17(4): 338-342.
[23] Yuan Jie, Wang Fuli, Wang Shu, et al. Fault diagnosis method based on D-S fusion hybrid expert knowledge system[J]. Acta Automatica Sinica, 2017, 43(9): 1580-1587.
[24] Wei Shaohua. Research on engine fault diagnosis based on sound intensity knowledge and neural network fusion technology[D]. Nanjing: Nanjing University of Science and Technology, 2006.
[25] Llinas J. Information fusion process design issues for hard and soft information: Developing an initial prototype[M]//Intelligent methods for cyber warfare. New York: Springer, 2015: 129-149.
[26] Tang Xiaobo, Wei Wei. Knowledge fusion: Growth point of knowledge services in big data era[J]. Research on Library Science, 2015(5): 9-14, 8.

[27] Zhang Xinyuan, Qiu Junping. Research on knowledge fusion framework under big data environment[J]. Research on Library Science, 2016(8): 66-70, 43.
[28] Tang Xiaobo, Zhu Juan, Yang Fenghua. Research on knowledge fusion framework model under big data environment[J]. Research on Library Science, 2016(1): 32-35, 18.
[29] Wang Yuefen, Cen Yonghua. Research on architecture design of knowledge fusion system in big data era[J]. Digital Library Forum, 2016(10): 16-24.
[30] Zhang Xinyuan, Qiu Junping. Development and analysis of knowledge fusion research in domestic library and information science field[J]. Digital Library Forum, 2016(3): 17-23.
[31] Li Zhigang. Knowledge Management: Principles, Technologies and Applications[M]. Beijing: Publishing House of Electronics Industry, 2010.
[32] Li Li, Xiong Jucheng. Research on knowledge fusion mechanism of innovation alliance based on open technology interface[J]. Science & Technology Progress and Policy, 2015(14): 122-126.
[33] Chen Jing. Research on knowledge integration capability from the perspective of social capital theory[D]. Tianjin: Tianjin University, 2010.
[34] Pan Wei. Research on enterprise knowledge integration based on IDE-SECI model[D]. Changchun: Jilin University, 2015.
[35] Wang Xiaojian, Liu Yanping. Enterprise knowledge management method based on multi-source knowledge fusion[J]. Science Research Management, 2015, 36(8): 77-85.
[36] Wang Yanbo. Micro-level research on cross-organizational networks based on knowledge innovation[D]. Tianjin: Tianjin University, 2011.
[37] Hu Bei, Wang Congying. Research on knowledge fusion and innovation model of high-tech industrial clusters in developing countries based on information fusion[J]. Library and Information Service, 2009, 53(2): 38-43.
[38] Lu Xiaocheng. Research on knowledge chain model of producer services and manufacturing integration[J]. Journal of Intelligence, 2009, 28(2): 117-120.
[39] Liu Xuyou. On the role of knowledge in industrial integration: From the perspective of knowledge sharing[J]. Economist, 2008(9): 11-12.
[40] Zhang Jinle, Zhang Kun. Fuzzy cognitive research on influencing factors of knowledge sharing in military-civilian integration industrial parks in Shaanxi Province[J]. Journal of Northwestern Polytechnical University (Social Sciences), 2014, 34(2): 59-64.
[41] Wang Xiaojie. Research on knowledge integration after overseas mergers and acquisitions of Chinese enterprises[D]. Jinan: Shandong University, 2009.
[42] Yang Wenrui. Research on technology integration and risk of overseas mergers and acquisitions based on knowledge-based view[D]. Shanghai: Shanghai Jiao Tong University, 2007.
[43] Ji Cheng. Research on intellectual capital integration in cross-border mergers and acquisitions[D]. Shanghai: Shanghai Jiao Tong University, 2007.
[44] Yu Ting. Research on individual knowledge integration behavior within university research teams[D]. Harbin: Harbin Normal University, 2016.
[45] Cao Xia, Liu Guowei, Fu Xiangmei, et al. Process mechanism of knowledge

integration based on network perspective and simulation[J]. Studies in Science of Science, 2012, 30(6): 886-894.
[46] Song Xinping, Cheng Shuping, Zhang Haibin, et al. Application analysis of information fusion in large-scale project management and audit[J]. Modern Management Science, 2012(1): 43-46.
[47] Zhou Fang, Han Liyan. Corporate failure discrimination method based on knowledge fusion[J]. Finance and Accounting Newsletter, 2015(3): 61-63.
[48] Li Tao, Zhou Hua. Immunology teaching strategy based on multidisciplinary knowledge fusion[J]. Basic Medical Education, 2015(8): 664-666.
[49] Dai Xiying. Research on mathematics teachers' educational technology knowledge construction based on TPMK[D]. Changchun: Northeast Normal University, 2014.
[50] Zhang Yunfeng, Sun Ken. Collaborative training concept of hydraulic engineering master's education based on knowledge fusion[J]. Journal of North China University of Water Resources and Electric Power (Social Science Edition), 2010, 26(1): 102-104.
[51] Quan Xiaoyan. Research on curriculum design of preschool education major in universities under integrated education background[J]. Teacher Education Forum, 2016, 29(3): 45-50.
[52] Zhang Xiaolin. Toward knowledge services: Seeking growth points for library and information work in the new century[J]. Journal of Library Science in China, 2000(5): 30-35.

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