Transformation and Development of Security Informatics in the Big Data Environment (Postprint)

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Abstract

[Purpose/Significance] In the era of big data, big data constitutes the objective environment faced by security informatics. Therefore, it is essential to explore the transformation and development of security informatics in the big data environment. [Method/Process] From a disciplinary perspective and focusing on the top-level design of security informatics in the big data environment, this study employs theoretical speculation and comparative analysis methods to sequentially examine the transformation and development of research resources, research tasks, disciplinary attributes, methodology, and research content of security informatics in the big data environment. [Results/Conclusion] The study finds that big data can expand and deepen the disciplinary research resources and tasks of security informatics, and strengthen its interdisciplinary and comprehensive attributes as well as its science and engineering characteristics. In the big data environment, the innovation of security informatics methodology must address three aspects: research paradigm, thinking, and specific methods. Simultaneously, big data will permeate and integrate into traditional security informatics research content, giving rise to a series of new research topics in security informatics.

Full Text

Change and Development of Safety & Security Intelligence Science in the Big Data Environment

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Abstract: [**Purpose/Significance**] In the era of big data, big data represents the objective environment facing safety & security intelligence science.

Therefore, exploring the transformation and development of safety & security intelligence science within this environment is essential. [**Method/Process**] From a disciplinary perspective and focusing on top-level design for safety & security intelligence science in the big data environment, this paper employs theoretical speculation and comparative analysis to systematically examine the evolution and development of research resources, research tasks, disciplinary attributes, methodology, and research content. [**Result/Conclusion**] The study reveals that big data can expand and deepen the disciplinary research resources and tasks of safety & security intelligence science, while strengthening its interdisciplinary comprehensive nature and scientific/engineering characteristics. In the big data environment, methodological innovation must proceed along three dimensions: research paradigm, research thinking, and specific methods. Simultaneously, big data will permeate and integrate with traditional research content, generating a series of new research topics.

Keywords: Safety & Security Intelligence; Safety & Security Intelligence Science; Big Data; Top-level Design
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Humanity has entered the era of big data. As a new mindset, concept, technology, and tool, big data captures the explosive growth and rapid expansion of data, profoundly influencing human production and life while powerfully driving new scientific developments and breakthroughs [1-2]. Currently, the convergence of big data with various disciplines is unstoppable and unavoidable, and significant transformations across disciplines are already emerging on this convergent stage. In the big data era, various types of safety and security data and information are increasing exponentially, and such data constitutes a valuable resource for safety & security intelligence science [3]. Consequently, big data's impact on safety & security intelligence science will be more direct and profound. For instance, in the big data environment, the development of safety & security intelligence science faces both opportunities (such as increasingly rich research resources) and severe challenges, including the critical problem of "data lost" (where useless safety data and information proliferate while valuable safety & security intelligence is lacking) [3]. Therefore, big data will trigger transformations in safety & security intelligence science, making it imperative to clarify the discipline's overall change and development framework in this new environment to avoid detours in its advancement.

Thus, the development and innovation of safety & security intelligence science in the big data era represent urgent challenges that researchers must address. However, specialized research on this issue remains scarce in the academic community, necessitating focused investigation into the transformation and development of the discipline in the big data era. Fortunately, in recent years, intelligence science and safety science—as the two parent disciplines of safety & security intelligence science—have begun to address their own transformations and developments based on big data [3-5], and these findings offer important

reference value. For example, Dong Ke and Qiu Junping [6] argue that big data will trigger important transformations in the principles, methods, and practices of intelligence science; Pang Na [7] proposes that cognitive intelligence science represents a new opportunity for intelligence science development (particularly intelligence analysis) under the big data background; Wang Bing and Wu Chao [8] present conceptual frameworks for adjusting the safety science disciplinary system based on safety big data; and Q. Ouyang et al. [9] analyze the impact of big data on safety science research.

In the big data era, innovation in safety & security intelligence science based on big data undoubtedly represents the future development path, and the overall framework for the discipline's transformation and development serves as a guiding beacon. Consequently, top-level design constitutes the primary task for current research in safety & security intelligence science. From the perspective of science of science, a discipline's fundamental questions (such as research objects and disciplinary attributes) directly determine its overall system construction and development. Therefore, accurate positioning of these fundamental questions is key to top-level design. Accordingly, this paper examines the transformation and development of five basic issues in safety & security intelligence science—research resources, research tasks, disciplinary attributes, methodology, and research content—from a disciplinary perspective, focusing on top-level design in the big data environment and employing theoretical speculation and comparative analysis to provide a basis and guidance for research and development.

2. Expansion and Deepening of Research Resources and Tasks

By definition, the research object of safety & security intelligence science is safety & security intelligence [4]. From the perspective of disciplinary legitimacy, safety & security intelligence science constitutes an independent discipline distinct from others precisely because it has a uniquely defined research object: safety & security intelligence. In other words, all research and practice in the field must be based on this resource; research and practice without it would be like "water without a source, a tree without roots." Therefore, safety & security intelligence represents the direct research resource of the discipline.

Delving deeper into the question of "where does safety & security intelligence come from?" leads to the issue of indirect research resources. According to the linear safety information chain ("safety facts → safety data → safety information → safety & security intelligence") [3,10], safety & security intelligence is the product of processed and analyzed safety information. Thus, although the direct research resource is safety & security intelligence, its origin in safety information means that safety information constitutes the indirect research resource. Consequently, the "transformation of safety information into safety & security intelligence" represents one of the discipline's important research tasks [4]. In summary, traditional understanding holds that the direct research resource is

safety & security intelligence, the indirect resource is safety information, and a core task is studying how to transform safety information into safety & security intelligence.

In the big data era, various types of safety data have increased dramatically, exhibiting prominent big data characteristics and forming a vast and rich resource. Indeed, safety data represents the most extensive and important resource for safety science research and practice in the big data era, urgently requiring deep exploration and utilization [9-10]. Can safety data resources become research resources for safety & security intelligence science? The answer is affirmative: according to the linear safety information chain [3,10], safety data encompasses more than safety information, which in turn encompasses more than safety & security intelligence. Non-information portions of safety data can be processed into safety information, and non-intelligence portions of safety information can be further processed into safety & security intelligence. In essence, safety information serves merely as an "intermediary" in the transformation from data to intelligence, with safety data representing the most fundamental, essential, and original resource (the root resource) for producing safety & security intelligence. Thus, safety data constitutes the root research resource of safety & security intelligence science.

In the big data era, however, the linear safety information chain can no longer fully represent the transformation relationships among safety data, safety information, and safety & security intelligence. Regarding transformation pathways, in addition to indirect conversion ("data → information → intelligence" [11]), advances in data extraction, mining, and fusion technologies enable direct transformation from data to intelligence [12]. Building upon the traditional linear model, Liu Li et al. [12] proposed a triangular conversion model of "data—information—intelligence." Similarly, in the big data environment, safety data can be directly transformed into safety & security intelligence. Moreover, from a quantitative perspective, the relationship is: safety data > safety information > safety & security intelligence. Based on this, we propose a transformation model among the three elements in the big data environment (see Figure 1 [Figure 1: see original paper]). As shown in Figure 1, research tasks in safety & security intelligence science must also expand and deepen, focusing not only on "how to transform safety information into safety & security intelligence" but also on "how to directly transform safety data into safety & security intelligence" and "how to transform safety data into safety information and ultimately into safety & security intelligence."

In summary, the research resources and tasks of safety & security intelligence science have broadened in the big data environment. However, it must be emphasized that research objects differ from research resources and tasks: although the latter have expanded, the discipline's research object remains safety & security intelligence, with the ultimate goal of obtaining high-quality intelligence.

3. Changes in Disciplinary Attributes

3.1 Enhanced Interdisciplinary Characteristics

The big data era has given rise to a new discipline: data science. As a field specifically dedicated to studying data, data science has entered a fast track of development and gradually become a pillar discipline leading innovation across various fields [13]. In the big data environment, since safety data has become an important research resource and the transformation tasks mentioned above have become central research missions, data science will inevitably become a core supporting discipline for safety & security intelligence science research, development, and innovation.

To truly realize this core supporting role, the integration of data science with safety & security intelligence science must transcend superficial or conceptual levels and achieve complete fusion into research and practice. Consequently, the disciplinary foundation of traditional safety & security intelligence science will shift, with data science becoming one of its important pillar disciplines. From the perspective of disciplinary formation principles and pathways, traditional safety & security intelligence science emerged from the direct intersection of intelligence science and safety science [4,14], indicating that interdisciplinary characteristics have always been typical attributes. In the big data environment, data science will integrate with traditional safety & security intelligence science to form a new discipline, as shown in Figure 2 [Figure 2: see original paper].

As illustrated in Figure 2, at the macro level, the new safety & security intelligence science results from the organic integration of three disciplines: intelligence science, safety science, and data science. Since data science itself is an interdisciplinary field (primarily involving mathematics, statistics, and computer science) [13], the new discipline's interdisciplinary attributes will be further strengthened compared to its traditional form. From a micro perspective, the new discipline can also be viewed as the product of intersecting traditional safety & security intelligence science (the product of intelligence and safety sciences), safety statistics (the product of safety and data sciences), and new intelligence science (the product of intelligence and data sciences).

3.2 Highlighted Science and Engineering Characteristics

Similar to the nature of intelligence, safety & security intelligence and intelligence activities are fundamentally social phenomena [4]. Since analyzing and explaining social phenomena primarily relies on social science theories and methods, and since safety & security intelligence is the discipline's research object, the discipline's inherent social attributes determine that it should be a social science [4,14]. Furthermore, serving and supporting safety management (which belongs to the social science category) represents the central goal of safety & security intelligence science [6], further emphasizing its social science characteristics. Therefore, traditional safety & security intelligence science possesses strong social science features. Although traditional research occasionally em-

ployed theories, methods, and means from science and engineering (including natural and engineering sciences), these played only auxiliary supporting roles [4,14] without fundamentally altering the discipline's social science nature.

As safety & security intelligence science enters the big data era, its research resources will inevitably shift toward safety data, with obtaining safety & security intelligence from massive data resources becoming a core research task. Consequently, data science theories, methods, and means will become one of the discipline's dominant approaches. Since data science is a typical science and engineering discipline (its characteristics are explained in Table 1 [13,16-17]), these changes will inevitably highlight the science and engineering features of safety & security intelligence science. In other words, in the big data environment, the discipline will exhibit increasingly prominent science and engineering characteristics, as detailed in Table 1.

Moreover, as shown in Table 1, applicability constitutes an important disciplinary feature of data science. For safety & security intelligence science in the big data environment, specialized data science theories, technologies, and methods tailored to the field should be developed to address the 困境 (dilemma) where traditional research cannot effectively utilize safety data resources due to missing or outdated science and engineering thinking, methods, and technologies. In summary, data science theories, methods, and means (particularly big data technologies and methods) will improve existing safety & security intelligence research methods, forming new research approaches that can fully leverage the unique advantages of science and engineering theories and methods. Only through such improvements can big data-driven safety & security intelligence science achieve rapid development.

4. Methodological Innovation

In the big data era, big data is driving methodological innovation across disciplines, and it will profoundly influence the methodology of safety & security intelligence science. To integrate big data into the discipline and unleash its enormous value, methodological innovation must precede practice—that is, the discipline's methodology must be reformed to meet the needs of research, development, and practice in the big data environment. Generally, methodological innovation should proceed along three dimensions: "one major paradigm (data-intensive research paradigm), three ways of thinking (interdisciplinary thinking, big data thinking, and broad safety & security intelligence perspective), and five methods (data science methods, big data technologies and methods, interdisciplinary methods, meta-synthesis, and complexity science methods)," as specifically analyzed and demonstrated in Table 2 .

presents the detailed analysis and justification for methodological innovation in safety & security intelligence science within the big data environment. The framework emphasizes adopting a data-intensive research paradigm, cultivating interdisciplinary thinking (particularly across science/engineering and hu-

manities/social sciences), embracing big data thinking (including whole-sample thinking, correlation thinking, and fault-tolerance thinking), and developing a broad safety & security intelligence perspective. The five key methods include data science methods, big data technologies, interdisciplinary approaches, meta-synthesis for multi-source data fusion, and complexity science methods to address the discipline's emerging challenges.

5. Expansion of Research Content

Since big data introduces new changes to research resources, tasks, disciplinary attributes, and methodology, all research content related to or influenced by these aspects will be further enriched. Macroscopically, safety & security intelligence science research covers three levels: upstream (basic disciplinary theory), midstream (applied basic theory), and downstream (specific application practice). As big data's impact on the discipline and its practice is primarily embedded, the overall "upstream—midstream—downstream" framework (detailed in [4]) will not change dramatically. However, big data will permeate and fuse with traditional research content, generating a series of new topics:

(1) Upstream expansion primarily involves theoretical and methodological innovation based on big data, as well as professional education and talent cultivation adapted to the era. Specific research topics include: safety & security intelligence attributes of big data, the value and realization mechanisms of safety big data, disciplinary system reconstruction and development, new research paradigms driven by big data, theories and methods for transforming safety big data into intelligence, integration of big data with the discipline, big data theories and methods oriented toward safety & security intelligence science, comparisons between traditional and big data-era disciplines, and computational and cognitive intelligence theories and methods [7]. In terms of education and talent cultivation, research should address content updates for professional education, data literacy education for professionals, and cultivation of safety big data specialists oriented toward the discipline.

(2) Midstream expansion mainly manifests in three aspects: management, business, and technology. For big data-based management, research should examine the application of big data methods, construction of management systems based on big data technologies, and integration of safety data culture with intelligence culture. For business aspects, topics include: impacts of big data on intelligence work, workflow reengineering and optimization (particularly organic integration of big data workflows with traditional processes), fusion of big data analysis and intelligence analysis, big data-driven decision-making and service systems, intelligence-led smart safety management, smart intelligence work systems, and theories and methods for collecting, analyzing, and fusing multi-source safety data. For technology aspects, research should focus on developing intelligence systems based on big data, and intelligence analysis, mining, and processing technologies utilizing related technologies such as artificial intelligence, deep learning, cloud computing, and machine learning.

(3) Downstream expansion encompasses all application practice fields. Depending on classification criteria, these can be divided into: normal vs. emergency intelligence research; Safety intelligence vs. Security intelligence; social security, information security, resource security, economic security, homeland security, and military security intelligence; and enterprise, social, and national security intelligence. In the big data environment, research must focus on innovating work models in these specific application fields by integrating disciplinary theories with big data methods.

These new research topics urgently require specialized in-depth investigation. Naturally, the listed topics do not exhaust all possibilities, and each can be further expanded and subdivided into sub-topics.

In today's big data era, big data constitutes the objective environment for safety & security intelligence science, bringing tremendous changes and particularly influencing its top-level design. This will undoubtedly usher in a new era for the discipline. While presenting significant opportunities, the big data environment also poses challenges. The discipline must recognize these impacts, adapt to new changes and requirements, and seize development opportunities. This paper has analyzed transformations across five dimensions—research resources, tasks, disciplinary attributes, methodology, and content—clarifying new requirements for top-level design. This study provides a foundation and guidance for research and development in the big data environment. However, given the complexity of this undertaking, this research represents only an initial exploration; we hope colleagues will join us in advancing the discipline's growth in the big data era.

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Abstract: [**Purpose/Significance**] In the era of big data (BD), safety & security intelligence (SI) science is facing an objective environment, that is the BD environment. Therefore, at present, it is the right time to discuss the changes and development of SI science in the BD environment. [**Method/Process**] On the disciplinary level, focusing on the top-level design of SI science in the BD environment, and by using theoretical speculation and comparative analysis methods, this paper analyzed the change and development of research resources, research tasks, disciplinary attributes, methodology and research contents of SI science in the big data environment respectively. [**Result/Conclusion**] Results of this study show that, BD can expand and deepen the disciplinary research resources and tasks of SI science, and can enhance the cross-comprehensive feature and the feature of science and engineering of SI science. In the BD environment, the innovation of the disciplinary methodology of SI science should be innovated from three aspects, namely, the research paradigm, the research thought, and the specific research method. Moreover, BD can permeate and integrate into the traditional research content of SI science, this can propose a series of new research topics of SI science.

Keywords: safety & security intelligence (SI); SI science; big data; top-level design

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