Reconstruction and Applied Research of the Information Science Transformation Theory Model: Postprint

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Abstract

[Purpose/Significance] By reconstructing the transformation theory model of intelligence science, this study attempts to explore the laws of mutual coupling and evolution among the constituent elements of the transformation model, aiming to improve and expand the transformation theory and its applications.

[Method/Process] Employing literature research and content analysis methods, this paper redefines the five elements of data, information, knowledge, intelligence, and wisdom, and constructs a more refined spiral transformation model based on existing transformation models.

[Results/Conclusion] Through the construction of the spiral transformation model, it not only clarifies the transformation processes and methods among the relevant elements of the model, but also extends the application scope of transformation theory to domains such as think tank construction, smart cities, and competitive intelligence.

Full Text

Preamble

Research on Model Reconstruction and Application of Transformation Theory in Information Science

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Abstract

[Purpose/Significance] This paper reconstructs the transformation theory model in information science to explore the coupling and evolution patterns among model components, aiming to improve and expand transformation theory and its applications. [**Method/Process**] Using literature research and content analysis methods, we redefine five elements—data, information, knowledge, intelligence, and wisdom—and construct a more comprehensive spiral transformation model based on existing models. [**Result/Conclusion**] The spiral transformation model not only clarifies the transformation processes and methods among related elements but also extends the application scope of transformation theory to think tank construction, smart cities, and competitive intelligence.

Keywords: Information Science; Transformation Theory; Spiral Model; Think Tank
Classification: G250

Introduction

The "Three Dynamic Theories"—ordering theory, transformation theory, and fusion theory—constitute the foundational framework of information science [1]. For years, research on these theories in China has disproportionately focused on information ordering theory, with inadequate attention to transformation and fusion theories. This imbalance has led to convergence and assimilation between information science, library science, and information management [2].

Transformation theory differs from information chain theory, which primarily discusses relationships and transformation outcomes among elements such as data, information, knowledge, and intelligence [3] while neglecting to explain transformation processes, conditions, and methods. Transformation theory addresses this deficiency by focusing on inter-element relationships and transformation processes, explicitly describing the methods and conditions involved.

Domestic literature on transformation theory remains relatively scarce, with early research concentrating primarily on conceptual definitions and interrelationships among elements. Recent years have witnessed increased attention to this area. For instance, Zheng Yanning and Hua Bolin analyzed relationships among data, information, knowledge, and intelligence through case studies, constructing a linear transformation model with knowledge as the thread throughout the process [4]. Liu Li and Wang Cuiping proposed a triangular transformation model based on data, information, and intelligence [5]. Guo Hua and colleagues examined interrelationships and mechanisms among data, information, knowledge, and intelligence elements, developing a more comprehensive logical transformation model [6]. International research on transformation theory emerged earlier and achieved greater comprehensiveness. R. L. Ackoff systematically supplemented and refined the DIKW hierarchy (incorporating data, information, knowledge, intelligence, and wisdom into a pyramidal system) [7]. J. Rowley added information systems and knowledge management content to the DIKW hierarchy [8]. A. Liew emphasized wisdom's role in the DIKW model, modifying it into the DIKIW model [9].

The big data era and the development of information science have heightened awareness of analyzing and utilizing data, information, and related elements, making transformation theory research a focal point. Big data challenges society not only in rapidly extracting valuable information from massive datasets but also in strengthening big data technology R&D and application to seize developmental frontiers. Transformation theory research aligns perfectly with these societal demands. For example, it can better support "new-type" think tank construction by providing massive data support and high-quality intelligence assurance, thereby enabling superior think tank services. Therefore, information science and related disciplines should strengthen theoretical and applied research on transformation theory to address big data challenges and promote societal development.

2. Analysis of Existing Transformation Models

Existing transformation models fall into two categories: linear transformation models and pyramid transformation models. Linear models demonstrate parallel and inclusive relationships among elements through sequential transformation, while pyramid models exhibit progressive and inclusive relationships through hierarchical structures.

2.1 Linear Transformation Models

The traditional linear transformation model can be represented as: data → information → knowledge → intelligence. This model enjoys widespread recognition among scholars. W. P. Timothy described it as "collecting data → aggregating data to obtain information → deeply analyzing information to obtain knowledge → activating knowledge to obtain intelligence → applying intelligence to form decisions → executing decisions to create value" [10]. A. Debons conceptualized it as: events → symbols → data → information → knowledge → wisdom [11]. Domestic scholars Zheng Yanning and Hua Bolin proposed that knowledge, as the cornerstone of the entire transformation process, should permeate the entire process rather than serve as a single stage [4], as shown in [Figure 1: see original paper].

2.2 Pyramid Transformation Models

In traditional pyramid structures (see [Figure 2: see original paper]), data forms the foundation for generating information, occupying the bottom and broadest layer. Intelligence resides at the pyramid's apex—the narrowest layer—reflecting its high value. R. L. Ackoff's refined DIKW hierarchical model [7] and A. Liew's DIKIW model [9] exemplify pyramid models in transformation theory.

I. Tuomi proposed an inverted pyramid model (see [Figure 3: see original paper]), challenging the traditional hierarchy. In this model, data occupies the top while knowledge resides at the bottom. Tuomi argued that data's scope is smaller than information's, and information's smaller than knowledge's, with knowledge serving as a prerequisite for information and data [12]. In the inverted model, data does not become information by adding meaning. Conversely, information only becomes data when processed into machine-manipulable form that increases its value.

2.3 Critical Assessment of Existing Models

Both linear and pyramid models demonstrate inclusive and progressive relationships among elements but suffer from rigid structures and strict hierarchical constraints. They only consider transformations between adjacent elements, ignoring the possibility of skip-level transformations—for example, data directly transforming into intelligence without passing through information and knowledge. Additionally, while the inverted pyramid model mentions that elements can undergo reverse transformation under specific conditions, it rarely describes the reverse transformation process or methods. Furthermore, model elements lack unified conceptual boundaries, with mutual inclusion making boundary definition difficult. These fuzzy boundaries vary significantly depending on perspective and standpoint. Therefore, whether traditional linear or pyramid models can accurately represent logical and transformational relationships among elements remains questionable. Based on existing models, this paper reconstructs a new model to explore coupling relationships and evolution patterns among elements, proposing multifaceted applications of transformation theory in the big data environment.

3. Defining Model Construction Elements

Existing information science transformation models typically include data, information, knowledge, or intelligence. To create a more comprehensive model, this reconstruction adds "fact" and "wisdom" as supplementary elements. Facts serve as the foundation of academic research—all subsequent elements including data and information originate from facts. As society gradually transitions from the information age to an intelligent and wisdom era, research on intelligence and wisdom elements will diversify, necessitating the inclusion of wisdom.

As an interdisciplinary field, information science lacks unified definitions for elements like data, information, and knowledge. Definitions vary across domains and relate to scholars' historical contexts and environments. For example, Shangguan Jingchang et al. interpreted data, information, and knowledge from philosophical, artificial intelligence, and knowledge management perspectives [13]. Qian Xuesen proposed in 1983 that "intelligence is activated, vitalized knowledge, or spiritual wealth, or something extracted from materials" [14].

A fact represents the actual situation of matters [15], including things, events, and states—objectively existing objects and phenomena that form the foundation for studying all subsequent elements like data, information, and knowledge. Facts possess universality, broad applicability, and fundamentality.

This paper selects definitions of data, information, knowledge, intelligence, and wisdom from domestic and international scholars to comprehensively understand each element (see).

Based on scholars' definitions, we propose:

(1) Redefinition of Data. Data represents concrete manifestations of the physical world—encoded, serialized, and digitized forms that describe and observe the objective world, i.e., specific representations of facts. Specific forms include text, images, and symbols representing objective attributes of objects or events. Generally, individual data points lack inherent meaning.

(2) Redefinition of Information. Information is contextualized, ordered data with purpose and relevance. Information functions similarly to data but is more compact and practical.

(3) Redefinition of Knowledge. Knowledge is specialized information existing in the human brain, emphasizing empiricism and evidence, possessing transferability and accumulability, and aiming to create value.

(4) Redefinition of Intelligence. Intelligence is valorized, purposeful, and effective knowledge obtained by mining and screening information and processing it with knowledge. Intelligence's fundamental function is to serve decision-making, possessing speculative and wisdom-like characteristics.

(5) Redefinition of Wisdom. Wisdom is the spiritual product of long-term accumulation from humanity's discovery of knowledge about the world, possessing cohesion and foresight. Wisdom represents the highest spiritual pursuit in philosophy and serves as a catalyst for innovation in the physical world.

4. Construction of the Spiral Transformation Model

Addressing existing models' limitations, this paper reconstructs the transformation model by proposing a spiral transformation model (see [Figure 4: see original paper], [Figure 5: see original paper]). The reconstruction emphasizes elements' intelligence and value, adding fact and wisdom to create a more comprehensive model and incorporating reverse transformation to present both forward and inverse transformation patterns.

Fact, due to its universality and fundamentality, resides at the model's tail end, while wisdom, reflecting foresight and inclusiveness, occupies the apex. Data is extracted from facts, data is filtered into information, information is summarized into knowledge, knowledge is activated into intelligence, and intelligence, as the crystallization of knowledge, "transforms knowledge into wisdom" to become the final stage of forward transformation. Due to reverse transformation's existence, intelligence can revert to knowledge, information, or data; knowledge can transform into information; and information can transform into data.

The spiral structure is a special and magical form, appearing in everything from spirochetes and DNA to screws, spiral staircases, tornadoes, and even galaxies.

Spiral structures feature revolution as linear progression, while central cross-sections of tornado-like spiral structures resemble triangles or inverted triangles. Therefore, the proposed spiral model maintains close connections with existing linear and triangular transformation models. Specifically, the spiral transformation model comprises multiple transformation processes forming a spiral curve, consistent with the parallel relationships in linear models. Additionally, both forward and inverse modes can amplify effects from one element (e.g., data) to others (e.g., information, knowledge, or intelligence) through progression and deepening, corresponding to triangular and inverted pyramid model characteristics.

Compared with A. Liew's DIKIW model, this model features more comprehensive elements, more complete transformation trends, and a spiral structure forming a self-feedback circulatory system where elements mutually influence and promote each other, enabling continuous self-renewal.

4.1 Element Coupling Relationships

4.1.1 Coupling Between Data and Information Data represents attribute symbols of objects or events, reflecting objective facts. Through ordering, correlation, and purpose-driven processing or analysis that establishes relationships, data becomes information, with the goal of increasing usefulness. For example, "13511111111" is meaningless data as unordered numbers, but when contextualized as "13511111111 is XX's phone number," it becomes information. Hua Bolin et al. proposed effective methods for data-to-information transformation: contextualization, validation, normalization, subdivision, and refinement [18]. J. W. Osborne used computers to collect, classify, and valorize data, thereby transforming it into information [19]. With computer science development, data mining technologies including effective algorithms and analytical methods have made massive data-to-information transformation a reality.

Data serves as both the foundation and result of information, while information can also reverse-transform into data—consistent with I. Tuomi's inverted pyramid model. Captured and stored information can be processed into data through compilation and analysis, reconstructing images or symbols of past events. The most common application of information-to-data reverse transformation appears in QR codes and barcodes, where images (data) store massive information accessible through scanning.

4.1.2 Coupling Between Information and Knowledge Knowledge is internalized information; information is externalized knowledge. Compared with information, knowledge emphasizes experience and possesses transferability and accumulability, expressed as "information + experience = knowledge." The knowledge acquisition process involves understanding and interpreting information; expressing mastered knowledge produces information. For example, books represent massive information. Reading books involves processing this information, which readers can gradually transform into knowledge through comprehension. Conversely, when scholars write books, they summarize their knowledge but output it in information form.

Wen Youkui and Xu Guohua noted that knowledge systems with selectivity, transformability, and utility enable information-knowledge conversion; information can regenerate within knowledge systems given sufficient sampling during conversion [20]. Long Guohua et al. proposed that under knowledge structure frameworks, information interaction can directly generate knowledge [21]. I. Tuomi designed knowledge management and organizational memory information systems that make personal knowledge's meaning structures focal and structured through cognitive effort, transforming knowledge into information through system processing [22].

4.1.3 Coupling Among Data, Information, Knowledge, and Intelligence The rise of the big data era is inseparable from computer science and technology development. Advanced big data technologies including data collection, preprocessing, storage, and mining increasingly enable data-to-intelligence transformation. For example, Walmart observed massive transaction data and discovered that flashlight sales increase before seasonal hurricanes—and so do Pop-Tart sales. Consequently, the supermarket places Pop-Tarts near hurricane supplies before seasonal hurricanes, increasing profits [23]. This case, like the "beer and diapers" example, illustrates data-to-intelligence transformation. J. Gersh et al. described how analyzing, synthesizing, and annotating datasets extracts effective datasets, achieving data-to-intelligence transformation [24].

Data and intelligence can also transform under specific conditions. For instance, Morse code transmission represents intelligence-to-data transformation, where senders transmit intelligence as data according to agreed sequences or patterns.

H. Garai expressed data-information-intelligence relationships through formulas: data + relevance + purpose = information; information + analysis = intelligence; intelligence + action = effectiveness [25]. Information analysis thus becomes crucial for information-to-intelligence transformation, with main methods including truth-discerning analysis, comparative analysis, subtle-significance analysis, associative analysis, and integrative analysis [26]. Intelligence can also reverse-transform into information through screening, diffusion, recombination, and confidentiality relaxation.

Under specific conditions, knowledge can transform into intelligence through refinement and processing. When intelligence dissemination fails, it can revert to knowledge. The competitive intelligence process represents transformation from data, information, and knowledge to intelligence. Intelligence personnel collect data and information according to management needs, organize and process them into knowledge, then refine and exchange them into intelligence. For example, in corporate competition, "shadow teams" can integrate knowledge management with competitive intelligence, activating knowledge assets to obtain high-value intelligence for strategic decision-making [27].

4.1.4 Coupling Between Knowledge and Wisdom Philosophers understand wisdom more profoundly. Wisdom is a universal, general method for acquiring knowledge—a comprehensive capability integrating multiple elements [28]. Wisdom is based on existing knowledge, representing the ability to analyze and compare information about global issues to find solutions. A. Liew defined wisdom as "knowledge + knowing truth + correct judgment + accomplishing actions" [9]. Wisdom originates from humanity's long-term accumulated knowledge and emerges from its free application [29]. Knowledge is wisdom's prerequisite but not equivalent. Knowledge emphasizes information accumulation and processing, while wisdom focuses on knowledge summarization and application. Knowledge can generally be expressed through language and directly acquired; wisdom is essentially an ability to observe, experience, and apply that cannot be directly acquired. Wisdom acquisition requires a process: based on existing knowledge and experience, through independent thinking and problem-solving, forming personal experiences and insights to transform knowledge into wisdom [30].

4.1.5 Coupling Between Wisdom and Fact Wisdom generation is based on facts, while wisdom existence influences fact development, forming a self-feedback circulatory system. Wisdom results from the joint action of facts, data, information, knowledge, and other elements, representing humanity's high-level summary of facts. Wisdom can guide people to establish systematic, theoretical worldviews and correctly transform the world, thereby influencing fact development. In the current "wisdom era," lacking wisdom means losing the ability to control knowledge and technology, unable to guide human civilization's correct direction.

4.1.6 Skip-Level Transformation Skip-level transformation is not limited to data-to-intelligence or information-to-intelligence (see Section 4.3) but includes data-to-knowledge and fact-to-knowledge transformations. Data-to-knowledge transformation in library and information science is exemplified by bibliometrics. Bibliometrics pioneers observed literature, journals, and author data, established connections, and discovered laws of literature growth and aging, promoting bibliometrics' development. Achieving data-to-knowledge skip-level transformation poses new challenges for computer information technology, requiring data processing through mathematical statistics, artificial intelligence, and knowledge engineering—fields that have laid theoretical and technical foundations for data mining software and knowledge discovery tools.

4.2 Element Evolution Patterns

Transformation model elements exhibit spiral evolution patterns. The spiral shape characterizes transformation trajectories. The spiral model is not track-style cyclical repetition but continuously self-renews and improves, promoting qualitative change. The spiral model shows transformation is not linear progression but evolves from simple to complex, from low-level to high-level spiral development—starting from facts, ascending through transformations, and finally feeding back to promote fact development. Throughout this process, facts undergo multiple element transformations (data, information, knowledge, intelligence), continuously enriching and improving to become wisdom. When this wisdom returns to the starting point through similar processes, it has undergone multiple evolutions and spiral developments. These similar processes ultimately form the entire system's spiral structure.

In spiral development, progress and zigzag nature are dialectically unified. Elements also demonstrate feedback-adaptive evolution patterns. Model elements interconnect, influence, and promote each other, forming a feedback-adaptive system. Element interactions and influences drive the system's continuous advancement, with small adaptive systems composed of two or more elements further propelling the entire adaptive system forward. Under continuous feedback, the system cycles forward, maintaining advanced levels across all elements.

4.3 Transformation Conditions and Evaluation Criteria

Element transformation is influenced by both subjective and objective conditions. Subjective conditions include personal knowledge structure, cognitive ability, innovation capacity, and collaboration skills. These directly affect transformation heights—the richer one's knowledge structure and stronger one's abilities, the higher the possibility of linear and skip-level transformations. Objective conditions include social environment, resource control, and computer technology development level, directly affecting transformation efficiency. Social environments determine resource richness and computer technology availability. Richer data resources and more advanced computer technology increase transformation efficiency. Key computer technologies include mining, induction, processing, recombination, clustering, compilation, and analysis. Transformations primarily occur in information society environments, led by human wisdom and facilitated by information technology.

Different groups can establish different evaluation criteria based on purpose, cognitive level, context, and technical support. Transformation evaluation criteria are not static. This paper proposes one reference criterion: intelligence level. Intelligence level uses element intelligence intensity as a measurement unit to classify transformation elements and serve as a system classification standard. Individual data cannot explain situations or attributes, with the lowest intelligence level approaching 1. Information can represent specific attributes at level 2. Knowledge, as specialized information emphasizing empiricism and evidence, is level 3. Intelligence, serving decision-making with speculative and wisdom-like characteristics, is level 4. Wisdom, as humanity's long-term accumulated spiritual product with cohesion and foresight, has the highest level at 5.

5. Applications of Transformation Theory

As human thinking advances, the dominant force in economic creation has gradually shifted from knowledge to wisdom. The post-knowledge economy era is the wisdom economy era, where wisdom manifests as discovery and innovation—discovering what exists but remains unrecognized, and creating or inventing from nothing [28]. Wisdom's unique characteristics make its importance increasingly prominent. As transformation theory's current final element, "transforming knowledge into wisdom" aligns with human development and common interests. Data, information, knowledge, and intelligence as foundational elements deserve sufficient attention. In the big data era, transformation theory applications have permeated all aspects of society.

5.1 Application in New-Type Think Tanks

The big data era has made information sources divergent and disordered, flooding networks and social life. Rich data and information sources satisfy new-type think tanks' resource database needs while laying foundations for high-quality service outputs. Rapidly developing computer technologies like data mining, extraction, information analysis, and processing make massive data transformation and information analysis feasible. Since Western countries developed think tank systems earlier and more comprehensively, China should actively learn from foreign experiences while building think tanks with Chinese characteristics. A think tank team working model of "data mining + information processing + experience summarization (knowledge) + intelligence analysis + expert wisdom" will become more efficient, producing intelligent intelligence integrating demand sensitivity, data multiplicity, analytical intelligence, and service embeddability [31]. Applying transformation theory to think tank construction and services can promote resource integration and sharing, enabling intelligent intelligence to serve decision-making more conveniently.

5.2 Application in Smart Cities

Transformation theory plays a crucial role in smart city construction. Smart cities employ highly integrated information technology and comprehensive information resource application as primary means, focusing on government intelligent management innovation, enterprise intellectual service innovation, and public wisdom-based lifestyle innovation [32]. Transformation theory serves as an effective intermediary in smart city construction. In smart city data analysis and processing systems, transformation theory can both expand theoretical components of information technology systems and test system integration and transformation efficiency, providing data collection and information analysis services for smart city development. In smart city knowledge operation centers, expert wisdom combined with professional knowledge and intelligent intelligence can provide urban decision support and personalized customized services, achieving comprehensive data resource analysis and processing for urban management and government decision-making reference. Additionally, transformation theory achievements can promote cross-domain information exchange and data fusion, further advancing smart city information resource sharing mechanism development [33]. Transformation theory applications make smart city construction more intelligent and scientific.

5.3 Application in Competitive Intelligence

Transformation theory plays a significant role in corporate competitive intelligence. The big data era emphasizes data as a strategic factor that enterprises must prioritize, as data can create unlimited value. Big data provides diverse information sources for corporate competitive intelligence, demanding improved data and information analysis capabilities and cloud computing-based competitive intelligence systems. "Shadow teams" as competitive intelligence units promote transformation theory application in corporate competitive intelligence processes. After data collection and information analysis, intelligence teams concentrate intellectual capital to synthesize competitive information for decision services or early warnings, providing companies with intelligent intelligence and creating competitive capital. Meanwhile, data, information, and knowledge openness and sharing have catalyzed the "sharing economy," with intelligence sharing evolving from intelligence data sharing to intelligence service sharing. Transformation theory application in competitive intelligence drives team formation and system improvement, enabling scientific corporate decision-making and development and fostering market economy openness and prosperity.

Conclusion

This paper reconstructs a new transformation model by reviewing information science transformation theory and incorporating the current "intelligent" social environment. The new model adds fact and wisdom elements to existing models and constructs multi-element reverse and skip-level transformations. The model reveals that the entire transformation process follows a spiral trend, forming a self-feedback circulatory system that continuously self-renews and improves in quality and level. However, information science transformation theory should serve practice while practice promotes theory. This model's construction is based solely on transformation theory, with theoretical applications in think tank construction, smart city development, and competitive intelligence yet to undergo empirical research—representing future research priorities. Additionally, the actual impact of computer science methods like data mining and mathematical statistics on transformation efficiency requires verification.

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Author Contributions

Ma Xiaoqi: Provided guidance on research framework and content, and conducted later revisions.
Hao Zhichao: Selected the research topic, collected materials, constructed the overall research framework, and wrote the paper.

English Abstract

Research on Model Reconstruction and Application of Transformation Theory in Information Science

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Abstract: [Purpose/significance] This paper reconstructed the model of transformation theory in information science, and explored the rules of coupling and evolution between elements of transformation model, aiming to improve and expand transformation theory and its application. [Method/process] This paper redefined the five elements of data, information, knowledge, intelligence and wisdom by using literature research method and content analysis method, and constructed a more complete spiral transformation model based on the existing transformation model. [Result/conclusion] By constructing the spiral transformation model, not only the conversion process and conversion methods of model-related elements can be clearly defined, but also the application of transformation theory can be covered in the fields of think tank construction, smart city and competitive intelligence.

Keywords: information science; theory of transformation; spiral model; think tank

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