Research on Description Models and Construction Methods for Science and Technology Resources (Postprint)

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Abstract

[Purpose / Significance] Scientific and technological innovation constitutes a critical pathway for China' s development, necessitating the sharing of scientific and technological resources and collaborative innovation. The sharing of scientific and technological resources represents a systematic engineering endeavor that requires the establishment of description models for scientific and technological resources, upon which integration, evaluation, and sharing of such resources can be conducted.

[Method / Process] This paper proposes a structural framework for scientific and technological resource description models, encompassing: scientific and technological resource classification models, metadata models, ontology models, knowledge element models, graph models, among others. Scientific and technological resources herein include knowledge, data, products, talent, software, hardware, and other resource types. This paper elaborates on the characteristics and functions of scientific and technological resource description models, and presents methodologies for their establishment.

[Results / Conclusions] The primary contributions of this paper are: Through the standardization of scientific and technological resource description models, facilitating the integrated sharing of different types of scientific and technological resources; Through integrated research on various types of description models for scientific and technological resources, forming a systematic architecture for scientific and technological resource description models, thereby providing a holistic solution for the comprehensive and systematic description of scientific and technological resources and helping to address the challenges in sharing such resources; Proposing methodologies for establishing scientific and technological resource description models, characterized by the utilization of new-generation information technology for crowdsourced model building and the employment

of big data intelligent analysis techniques in the process of describing scientific and technological resources to establish and optimize these models.

Full Text

Preamble

Research on Description Models and Establishment Methods for Scientific and Technological Resources

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Abstract

[**Purpose/Significance**] Scientific and technological innovation is a critical pathway for China' s development, requiring the sharing and collaborative innovation of scientific and technological resources. Sharing scientific and technological resources is a systematic project that necessitates establishing description models for these resources as a foundation for integration, evaluation, and sharing. [**Method/Process**] This paper proposes a structural framework for scientific and technological resource description models, including: classification models, metadata models, ontology models, knowledge element models, and graph models for scientific and technological resources. These resources encompass knowledge, data, products, talent, software, hardware, and other categories. The paper elaborates on the characteristics and functions of these description models and presents methods for their establishment. [**Result/Conclusion**] The main contributions of this paper are: (1) Standardizing description models facilitates the integrated sharing of different types of scientific and technological resources; (2) Through integrated research on different types of description models, we form a systematic architecture that provides a holistic solution for comprehensive description, helping to solve the difficult problem of resource sharing; (3) We propose establishment methods that leverage new-generation information technologies, relying on crowdsourced model building and intelligent big data analysis of the description process to create and optimize these models.

Keywords: scientific and technological resources; scientific and technological resource description model; model establishment method; scientific and technological resource sharing; knowledge graph
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1 Introduction

In his speech at the 19th Academician Conference of the Chinese Academy of Sciences and the 14th Academician Conference of the Chinese Academy of Engineering, General Secretary Xi Jinping pointed out that several prominent issues remain to be resolved in the reform of the science and technology system, primarily that the overall efficiency of the national innovation system is not strong enough, and the problems of dispersion, duplication, and inefficiency in scientific and technological innovation resources have not been fundamentally solved.

Standardized, rational, and scientific description methods for scientific and technological resources represent one effective approach to addressing these issues of dispersion, duplication, and inefficiency. Such methods enable the standardization of scientific and technological resources from different perspectives, effectively supporting their integration, evaluation, and sharing. Scientific and technological resources include diverse types such as knowledge, data, products, talent, software, and hardware. While considerable research and application have been conducted in this area, several deficiencies and further needs remain: (1) Existing research primarily focuses on describing different types of resources separately, lacking unified description across types, which hinders unified search and integration. For example, knowledge graphs have been extensively studied, but research on scientific and technological resource graphs that include data, products, talent, software, and hardware remains scarce. A search for "scientific and technological resource graph" as a subject term in CNKI yields zero results, while "knowledge graph" yields 10,542 results. (2) Researchers have separately studied classification models, metadata models, ontology models, knowledge element models, and knowledge graphs for some resources, with several national standards already established. Wang Zhiqiang and Yang Qinghai argue that the process of open sharing of scientific and technological resources has generated a vast number and wide variety of standards and specifications, which have played important roles in promoting resource construction but also face issues such as lack of overall top-level design and absence of a unified standardization framework. There is a need for further integrated and unified research on these models for application in scientific and technological resource description. (3) While systematic methods already exist for describing knowledge resources, these need to be extended to other types of scientific and technological resources. This research addresses these issues, contributing to the standardization of description methods and helping to solve the difficult problem of sharing scientific and technological resources.

2 Structural Framework of Scientific and Technological Resource Description Models

Scientific and technological resource description serves as a "profile" of resources, representing their classification and organization to help users quickly search for needed resources, understand their main content, facilitate rapid integration among resources, and resolve issues of inconsistent data formats and inconsistent descriptions of the same concept. [Figure 1: see original paper] illustrates the structural framework of scientific and technological resource description models, while [Figure 2: see original paper] shows the relationships among these models.

The sub-models within the scientific and technological resource description model are defined as follows: The classification model describes classification information to help locate needed resources; the metadata model describes main data formats to enable rapid integration; the ontology model provides normative descriptions to accurately and comprehensively locate resources; the knowledge element model briefly describes resource content for quick understanding; and the graph model briefly describes relationships among concepts to support resource search and inference.

In technological innovation and other scientific work, multiple types of resources often need to be integrated. For example, a research task may require competent R&D personnel (selected from talent resources), product resources related to the task (referencing similar products to improve efficiency), knowledge resources (such as product principles, manufacturability, assembly, and maintainability knowledge), data resources (such as historical usage and maintenance data for similar products), software resources (computer-aided software to assist R&D), and hardware resources (such as experimental equipment and testing instruments).

3.1 Definition of Scientific and Technological Resource Classification Models

A scientific and technological resource classification model groups resource information with certain attributes or characteristics and distinguishes different categories through these attributes. Based on different resources and requirements, classification models can be divided into two types: (1) Tree-structured classification models, which use numeric or alphabetic forms to uniformly classify and code resources according to general principles and methods. These models are hierarchical and systematic, capable of determining the position and relationships of any resource within the system. Also known as classification coding systems, classification catalogs, or identification systems, they are similar to existing coding systems such as those for manufacturing informatization service platforms, networked manufacturing resources, and enterprise information classification. Specific standards already exist for process classification coding and part classification coding.

Tree-structured models first perform basic classification according to the nature of resources. presents existing classification theories for scientific and technological resources, demonstrating their diversity. The national standard "GB/T 32843-2016 Scientific and Technological Resource Identification" provides an identification method that constitutes a tree-structured classification model, as shown in [Figure 3: see original paper]. However, this approach has a drawback: the same resource (e.g., a scientific document) receives different identifiers from different registration agencies. Without considering these agencies, establishing unified identifiers for numerous resources becomes extremely difficult.

(2) Keyword-structured classification models, which use keywords or tags to characterize resource attributes or features. These are often created by the public and thus called folksonomies. Such systems are well-suited for resource sharing on the Internet. compares the two classification models.

The primary issue with keyword-structured models is their high randomness and weak standardization, significantly increasing the difficulty of searching or matching resources. However, in Internet environments, as the number of keyword/tag users increases, this randomness decreases substantially. If resource publishers use overly arbitrary or non-standard keywords/tags, their resources become difficult to search and utilize, defeating the purpose of publication. Similarly, if searchers use non-standard terms, they struggle to find desired resources. Eventually, for the same resource, people tend to adopt consistent keywords/tags.

3.2 Requirements for Scientific and Technological Resource Classification Models

The requirements for classification models include: (1) Supporting unified and effective organization, management, and sharing services; (2) Establishing hierarchical standards to support resource openness and sharing; (3) Possessing standardized and normalized characteristics to support supply-demand matching; (4) Enabling rapid location of needed resources to facilitate sharing.

3.3 Establishment Methods for Scientific and Technological Resource Classification Models

(1) Tree-structured classification model establishment. This paper focuses on enterprise and platform-level classification models, as international and national models are too broad to meet specific needs. We reference classification systems such as the Chinese Library Classification, GB/T 32843-2016, and the International Patent Classification (IPC) for extension. For knowledge resources, GB/T 23703.7-2014 provides guidance. Detailed categories can reference existing standards—searching the national standards information platform yields numerous relevant classification standards. Tree-structured systems should be compiled by domain experts following principles of scientific rigor, systematicity, extensibility, and compatibility, with expert participation whenever possible. As resource content and concepts evolve constantly, classification models require continuous maintenance. Alternatively, mapping tables in coding search systems can unify searches across different period models, solving traditional models' difficulties in modification and flexibility. Building Internet-based platforms for classification model establishment, maintenance, and application can enhance flexibility and maintainability.

(2) Keyword-structured classification model establishment. This primarily employs folksonomy, where keywords/tags are user-selected. Keywords are natural language vocabulary appearing in titles, abstracts, and texts that express document themes and serve as search entries. Tags are brief descriptions added by users to facilitate searching without relying on fixed categories. The main challenge is establishing keyword/tag norms. This can be achieved through self-organizing optimization, where platforms provide environments that promote this process. For instance, when users input keywords/tags, platforms can prompt whether they are commonly used and intelligently recommend popular ones based on resource characteristics. Keywords/tags can be optimized using ontology models to improve search accuracy and recall, as detailed in Section 5.

4 Scientific and Technological Resource Metadata Model and Establishment Methods

4.1 Definition of Scientific and Technological Resource Metadata Model

Metadata standardizes the dimensions of resource description space, representing "data about data" that describes resource content, coverage, quality, management methods, ownership, and provision methods. Various definitions exist: data about data; data defining and describing other data; data about data elements (including descriptions), ownership, access paths, rights, and volatility; data describing data and its environment; data describing IoT data and related information; and structured data describing scientific and technological reports for retrieval, management, use, and preservation. This definitional multiplicity demonstrates the difficulty of establishing unified metadata.

Scientific and technological resource metadata includes name, type, publisher, publication date, location, keywords, etc. Different resources (knowledge, data, talent, products, software, hardware) have corresponding metadata models, some already standardized.

4.2 Requirements for Scientific and Technological Resource Metadata Model

Different people often define description space dimensions differently, causing integration and search difficulties. Metadata enables unified and standardized description, facilitating organization, integration, retrieval, discovery, and management. The number of metadata elements should balance completeness and usability—too many elements are inconvenient, while too few provide incomplete description. Correlation analysis can remove redundant elements, while importance evaluation can eliminate less valuable ones. The quantity also depends on informatization levels, with higher levels accommodating more elements.

4.3 Establishment Methods for Scientific and Technological Resource Metadata Model

(1) Reference existing metadata models. Investigate and collect as many existing metadata models as possible to establish a reference library. Searching the national standards platform yields numerous relevant standards, such as GB/T 36478.3-2019 for IoT information exchange, GB/T 38154-2019 for product traceability, and GB/T 30523-2014 for scientific and technological platform resource core metadata.

(2) Select appropriate metadata from the reference library. If too many elements exist, correlation analysis removes highly correlated pairs; importance evaluation eliminates less valuable elements. The final quantity should consider description completeness, feature identifiability, and classification capability. Core metadata is defined as the minimal set describing the most basic information, including Chinese and English names, publisher, publication date, location, knowledge element, keywords/tags, identification code, standard ontology, and associated metadata element sets.

(3) Metadata types can be determined through expert consultation, big data analysis, or a combination of both. Standards for metadata establishment can reference GB/T 30522-2014 and GB/T 26499.3-2011.

(4) Establish metadata model standards collaboratively. Given their broad scope and numerous users, a Wiki model can organize widespread participation for proposing and revising standards.

5 Scientific and Technological Resource Ontology Model and Establishment Methods

5.1 Definition of Scientific and Technological Resource Ontology Model

No unified definition of ontology exists. National standards provide various definitions: in big data contexts, ontologies are semantic models constraining subsequent logical models; in computer science, they are models describing a world of object types, attributes, and relationships; they can be expressed as interrelated concepts and definitions similar to thesauri terms (but not terminology standards); they use computer-processable language to describe domains; and in cultural heritage, they integrate heterogeneous, dispersed information sources.

This paper defines scientific and technological resource ontology as: a model that standardizes terminology for the same resource and relationships among different terms.

5.2 Requirements for Scientific and Technological Resource Ontology Model

Different people often use different names and terminology relationships for the same resource, causing integration and search difficulties. Two main problems exist: (1) The same resource may have multiple names, or one name may describe multiple concepts, hindering integration. Solutions include standardization methods like data dictionaries and ontology approaches establishing standard ontologies and associated ontologies. Standard ontologies describe standard terminology for a concept, while associated ontologies describe other terms for that concept. Both are used in searches. (2) The same resource may have multiple conceptual structures, also hindering integration. Ontologies help solve name diversity issues (leading to incomplete, inaccurate search results and integration difficulties) and conceptual structure confusion (causing classification chaos and search/integration problems).

The ontology model facilitates sharing, integration, and services: knowledge resource sharing (unified retrieval, knowledge graph construction, technology roadmaps, knowledge push); talent resource sharing (unified description and search); software resource sharing (unified description/search and integration needs across different development stages and units); and AI systems (establishing logical relationships, implementing inference engines for expert systems and intelligent decision support).

5.3 Establishment Methods for Scientific and Technological Resource Ontology Model

The ontology model includes standard ontologies and associated ontologies, with their relationship shown in [Figure 4: see original paper]. Standard ontology (simplified as "ontology" when unambiguous) represents the standard term in the ontology library (e.g., "computer"), while synonymous ontology represents alternative terms (e.g., "computer" in Chinese context).

Establishment methods include: (1) Understanding business organization and work content to determine the scope of resources needing sharing and ontology requirements; (2) Preliminary selection and trial of ontologies; (3) Collaborative establishment by scientific and technical personnel, with continuous optimization through tracking, statistics, and analysis of usage behavior.

Standard ontologies are similar to terminology concepts and can reference standards like GB/T 10112-2019 and GB/T 13725-2019. Searching the national standards platform yields numerous terminology standards, though most provide limited terms requiring expansion. Associated ontologies, lacking in terminology standards, require significant effort to identify from synonyms and near-synonyms, helping improve search accuracy and recall.

6 Scientific and Technological Resource Knowledge Element and Establishment Methods

6.1 Definition of Scientific and Technological Resource Knowledge Element

A knowledge element is the most core and refined knowledge extracted from scientific and technological resources, often displayed as abstracts or brief introductions. Existing standards define it as: under application requirements, an independent knowledge unit expressing a complete thing or concept that cannot be further divided. Knowledge elements can represent knowledge carriers beyond documents, such as patents, presenting concepts, arguments, demonstrations, and innovation points as the minimal units for knowledge management, evaluation, and discovery.

Scientific and technological resource knowledge elements enable users to quickly understand main characteristics and content, which is difficult with keywords alone. They support rapid construction of knowledge graphs and integration among knowledge elements.

6.2 Requirements for Scientific and Technological Resource Knowledge Element

Knowledge elements primarily consist of: (1) Purpose/Significance: briefly explaining resource requirements and applications (Why). For example, the purpose of a scientific instrument' s detection; (2) Method/Process: briefly explaining establishment and application methods (How). For example, detection principles and accuracy; (3) Result/Conclusion: briefly explaining content and application outcomes (What). For example, specific detection content and results obtainable.

6.3 Establishment Methods for Scientific and Technological Resource Knowledge Element

To improve search and utilization efficiency, resources should be described according to the metadata model using standard ontologies.

7 Scientific and Technological Resource Graph and Establishment Methods

7.1 Definition of Scientific and Technological Resource Graph

Knowledge graphs are essentially semantic networks building relationships among entities, formally describing things in the objective world and their interrelationships. Today, they refer to large-scale knowledge bases. In 2012, Google pioneered the concept to enhance search engine understanding and improve search quality and user experience. Since then, knowledge graph research has attracted widespread attention, with their openness, interconnectivity, and semantic processing capabilities laying foundations for knowledge interconnection on the Internet.

Triplets are a universal representation: G=(E, R, S), where E represents the entity set, R the relationship set, and S the triplet set. Basic forms include Entity-Relationship-Entity and Entity-Attribute-AttributeValue. Each entity can be identified by a globally unique ID, each attribute-value pair characterizes intrinsic properties, and relationships connect entities.

The concept of scientific and technological resource graphs extends from knowledge graphs, using various graphical models to display development processes and structural relationships. Through visualization technology, they describe knowledge resources and carriers, mining, analyzing, constructing, drawing, and displaying knowledge and their interconnections, providing comprehensive descriptions of resource relationships.

Examples include: Shanghai AI Public R&D Resource Graph (over 100,000 expert profiles, 300,000+ discipline terms, 100 million+ scientific documents); SciKG (Tsinghua' s computer science knowledge graph linking experts and papers); and gstore (Peking University's graph database supporting massive triplet management).

7.2 Requirements for Scientific and Technological Resource Graph

Resources have certain correlations that can be described through graphs to help quickly search for systematic resources and improve utilization efficiency. For example, data relationships can be completely obtained through data graphs. Graphs enable orderly integration and comprehensive description, facilitating sharing.

7.3 Establishment Methods for Scientific and Technological Resource Graph

The difficulty lies in the massive workload that varies by individual. Transparent and fair methods are needed to incentivize participation, along with big data and collective intelligence methods to improve automation and accuracy. Different experts should be given different weights based on their subfield expertise and research level.

Construction patterns include top-down (defining ontology and schema first, then adding facts) and bottom-up (extracting and analyzing data first, then designing schema). While general knowledge graphs often use bottom-up approaches (e.g., Google' s Knowledge Vault), vertical domain graphs facing complex and unstable business requirements may need top-down methods with industry-specific expertise and high-quality data.

8 Conclusion

Innovation is China' s development strategy, and collaborative innovation requires scientific and technological resource sharing, which in turn necessitates effective, standardized, rational, and scientific description models and establishment methods.

This paper proposes a structural framework for description models that standardizes resources from multiple perspectives, forming an integrated and systematic description that effectively supports integration, evaluation, and sharing: (1) Classification models (primarily tree-structured with keyword-based as supplementary) for large-scale, cross-disciplinary classification; (2) Metadata models unified across resource types for aggregation and sharing; (3) Ontology models addressing name diversity and conceptual structure confusion through standard and associated ontologies; (4) Knowledge elements providing brief descriptions of main content to support graph construction; (5) Resource graphs associating and visualizing various resources to clarify relationships and facilitate search and utilization.

These models provide a relatively standardized, concise, and complete holistic solution, improving integration, evaluation, and sharing capabilities. The proposed establishment methods leverage new-generation information technologies, relying on crowdsourced model building and intelligent big data analysis of the description process. As these models are foundational standards that are numerous and frequently changing, they require open, distributed, parallel, collaborative, and intelligent co-construction methods—open to interested enterprises, with contributors ranked by contribution; parallel to system development; collaborative for resource sharing and improved quality; and intelligent through big data analysis to simplify workload and transparently monitor contributions.

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Author Contributions:
Gu Fu: Analysis of standards and other literature, paper writing;
Liu Yangshengyan: Partial paper writing, literature review;
Gu Xinjian: Proposed overall paper structure, paper revision.

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