The user wants me to translate a Chinese academic paper title: “智慧中医的研究进展述评后印本”Let me break this down: - 智慧中医 = smart traditional Chinese medicine / intelligent traditional Chinese medicine / wisdom traditional Chinese medicine - 的研究进展 = research progress / advances in research - 述评 = review / c…

Authors: The user has provided a very short input: “黄炜”. This appears to be a Chinese name. The task is to translate it from Simplified Chinese to English with the highest accuracy and academic tone, following the critical requirements and output rules provided.

Let me analyze the requirements: 1. Preserve ALL LaTeX commands and placeholders - not applicable here as there are none 2. Preserve ALL citation commands - not applicable here 3. **PRESERVE ALL …paragraph wrapper tags EXACTLY** - not present in the input 4. Maintain academic tone and formal scientific writing style 5. Use precise technical terminology - obey the glossary strictly 6. Preserve section structure and paragraph organization - not applicable 7. Translate all content completely - do not omit any information

The glossary provided is: 机器学习 => machine learning 深度学习 => deep learning

But “黄炜” is a name, not one of these technical terms.

For Chinese names, the standard academic translation convention is: - Keep the original Chinese characters if the context is about a Chinese person in an English text (often with pinyin in parentheses on first mention) - Or use the pinyin transliteration: “Huang Wei”

In academic papers, Chinese names are typically romanized using the pinyin system. The surname comes first, followed by the given name. “黄” (Huáng) is the surname, and “炜” (Wěi) is the given name.

The proper academic translation would be “Huang Wei”. In some contexts, it might be written as “Wei Huang” if following Western name order, but in academic contexts, especially for Chinese authors, the pinyin "Huang Wei" (surname first) is standard.

Since there are no tags, LaTeX commands, or other special formatting, the output should simply be the translated name.

The user wants me to return ONLY the translated text, with no explanations, no quotes, no headings. So I should just output "Huang Wei".

Wait, let me double-check the requirements. The user says "Translate from Simplified Chinese to English". The name "黄炜" is in Chinese characters. The standard academic practice is to provide the pinyin romanization.

Should I include the Chinese characters? The instruction says to translate to English. The translation of a Chinese name to English is typically its pinyin romanization. So "Huang Wei" is correct, Cheng Yu, The user has provided a single name: "李岳峰". This is a Chinese name that needs to be translated to English. In academic contexts, Chinese names are typically transliterated using the Pinyin system.

The name "李岳峰" breaks down as: - 李 (Lǐ) - surname, commonly written as "Li" in English - 岳峰 (Yuèfēng) - given name

For academic papers, there are a few common conventions: 1. Surname first: Li Yuefeng 2. Given name first: Yuefeng Li 3. With hyphenation: Li Yue-feng or Yue-feng Li

The most standard and widely accepted format in English academic publications is to either: - Keep the original order: Li Yuefeng - Or use Western order: Yuefeng Li

Since the user hasn't provided context about where this name appears (e.g., as an author, in a citation, etc.), I should provide the most common academic transliteration. The standard practice in English-language academic papers is to use the Pinyin transliteration with the surname first, often followed by the given name with the first letter capitalized.

However, looking at the CRITICAL REQUIREMENTS, I need to check if this is part of a larger text that might have tags, LaTeX commands, etc. The user only provided "李岳峰" which is just a name.

The user is asking me to translate this name. In academic contexts, this would be transliterated as "Li Yuefeng" (surname first) or "Yuefeng Li" (Western order). Both are acceptable, but "Li Yuefeng" is more common when preserving the original Chinese name order in academic literature.

Since there are no tags, LaTeX commands, or other structural elements in the input, I should just provide the transliterated name. The most standard academic format would be "Li Yuefeng".

Wait, let me re-read the instructions. The user provided just "李岳峰". The instructions say "Translate from Simplified Chinese to English with the highest accuracy and academic tone.” and “Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent).”

So I should just output the transliterated name. The most appropriate academic transliteration is “Li Yuefeng”.

But I should also consider if this might be part of a citation or reference. In

Date: 2023-10-08T00:00:00+00:00

Abstract

The user wants me to translate a Chinese academic abstract about “智慧中医” (Smart Traditional Chinese Medicine) into English. Let me analyze the requirements:

1. **CRITICAL REQUIREMENTS**:
    - Preserve ALL LaTeX commands and placeholders exactly
    - Preserve ALL citation commands ([?], **??**, (**??**), etc.) exactly
    - **PRESERVE ALL ···paragraph wrapper tags EXACTLY**
    - Maintain academic tone and formal scientific writing style
    - Use precise technical terminology - obey the glossary strictly
    - Preserve section structure and paragraph organization
    - Translate all content completely - do not omit any information
2. **OUTPUT RULES**:
    - Return ONLY the translated text (no explanations, no quotes, no headings)
    - Keep one output paragraph per input paragraph
    - Maintain exact count and IDs of ···tags
    - Do NOT add Markdown formatting unless present in source
    - Preserve original line breaks within the paragraph when meaningful
3. **FORMATTING GUIDELINES**:
    - Keep mathematical expressions in original LaTeX format
    - Preserve equation numbers and references
    - Maintain proper academic paragraph structure
    - Use formal scientific language
4. **Glossary**:
    - 机器学习 => machine learning
    - 深度学习 => deep learning

Looking at the input text:

[目的 / 意义] 总结智慧中医的研究现状，分析目前智慧中医研究中所存在的问题，探讨其未来
研究方向。[方法 / 过程] 通过分析智慧医疗技术应用现状，并与中医信息化进行对比，发现智慧中医
主要集中在中医药数据服务、信息基础支撑体系和标准规范体系 3 个方面，且主要集中在技术方面的实
[结果 / 结论] 从 3 个角度分别提出智慧中医未来的研究应该更注重本土化和服务性。

This appears to be an academic abstract with three sections: 1. Purpose/Significance 2. Method/Process 3. Results/Conclusion

The text doesn’ t contain any LaTeX commands, math placeholders, or citation commands. It also doesn’t have any tags in the input. However, the instructions say I must preserve these tags if they exist. Since they don’ t exist in the input, I don’ t need to add them.

Wait, let me re-read the instructions more carefully

Full Text

A Review of Research Progress on Intelligent Chinese Medicine

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Abstract: [Purpose/significance] This paper summarizes the research status of intelligent Chinese medicine (ICM), analyzes existing problems in current ICM research, and explores future research directions. [Method/process] By analyzing the application status of smart medical technologies and comparing them with traditional Chinese medicine (TCM) informatization, this study finds that ICM research primarily focuses on three aspects: TCM data services, information infrastructure support systems, and standardization systems, with particular emphasis on technical implementation. [Result/conclusion] From these three perspectives, this paper proposes that future ICM research should place greater emphasis on localization and service orientation.

Keywords: Intelligent Chinese Medicine; Knowledge; Semantic Web; Ontology

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1. Intelligent Chinese Medicine

Traditional Chinese Medicine (TCM) is a medical system with distinctive Chinese characteristics. Whether from cultural or medical value perspectives, TCM deserves protection, inheritance, and development. Providing differentiated services for different audiences is the primary goal of popularizing TCM knowledge today. Qiu Hongzhong conducted a questionnaire survey on TCM services among diverse populations in Guangdong Province, revealing that only 8% of respondents explicitly stated they would not accept TCM services, while 66.91% expressed clear willingness to accept them [1].

These survey results demonstrate high public acceptance of TCM services. However, traditional TCM knowledge dissemination methods no longer suit modern society. People require more convenient, efficient, and accurate medical information services. Smart medical technology can serve as an effective channel between TCM domain knowledge and its audiences, facilitating both public access to knowledge and TCM practitioners’ delivery of quality services to patients.

Intelligent Chinese Medicine represents the inheritance and development of modern TCM information services. Compared with conventional TCM informatization, ICM' s advantages lie in its integration and intelligence. ICM integrates modern TCM information service technologies with the Internet of Things, cloud computing, artificial intelligence, and big data technologies, organically combining and coordinating various medical components and modules. Its intelligence manifests across all architecture layers of the smart medical system. For instance, electronic medical records in conventional TCM information services can be transformed into directly usable structured or semi-structured data in ICM through natural language processing technologies. The functional differences between ICM and TCM informatization across various business areas are shown in Table 1 .

The smart medical system architecture comprises five components: application service platform, application support cloud platform, infrastructure platform, standardization system, and security assurance system [2]. These five components require different technologies to implement their respective functions. The application service platform, infrastructure platform, and security assurance system are hardware-based, while the application support cloud platform and standardization system are implemented through the internet and databases. ICM achieves intelligent TCM diagnosis and treatment by leveraging smart medical concepts and technologies within the TCM framework, representing a new development direction for smart medicine that integrates TCM' s distinctive diagnostic and therapeutic approaches.

The connotation of ICM involves completing TCM-style diagnosis and treatment through intelligent means, with the entire process conducted within TCM' s theoretical framework. This process encompasses several key issues: (1) the primary task is to achieve intelligent inquiry, i.e., the intelligent implementation of "observation, listening, questioning, and pulse-taking" ; (2) how to formalize and digitize TCM' s unique thinking patterns for representation in ICM; and (3) how to deliver the results generated by ICM to users in an understandable format. Simultaneously, to eliminate heterogeneity issues arising from different user description formats, data collection, processing, and storage in ICM systems must follow unified standardization protocols.

Through a review of literature on smart medical technology and TCM domain knowledge, current ICM challenges primarily concentrate in three areas: TCM data services, information infrastructure support platforms, and standardization systems. This study analyzes their current status, problems, and future development trends from these three perspectives.

2. TCM Data Services

When studying ancient TCM texts such as the *Huangdi Neijing*, Qian Xuesen noted that TCM is not modern science like Western medicine, but rather an empirical medicine based on China' s unique philosophical system [3]. Therefore, researching ancient texts and medical records while introducing knowledge management concepts is essential for processing and organizing TCM knowledge.

Most TCM materials are preserved in classical Chinese and transmitted through master-apprentice traditions, resulting in obscure and ambiguous knowledge expression—typical implicit knowledge. Converting this implicit knowledge into explicit knowledge represents a major challenge for TCM development. The SECI model [4] describes the mutual conversion between implicit and explicit knowledge, as illustrated in Figure 1 [Figure 1: see original paper].

Based on this model, Yu Tong explained the conversion between implicit and explicit knowledge in the TCM domain [5]. All TCM knowledge data collection is premised on implicit knowledge, and providing TCM knowledge to different patients is also a process of converting TCM implicit knowledge into explicit knowledge. However, in conventional TCM information service technologies, application service platforms only perform simple data entry and storage without deep-level data processing, such as with electronic medical records. In smart medical systems, greater emphasis should be placed on data services. Due to its integrated characteristics, smart medicine can coordinate data processing across platforms through cloud computing and provide personalized data services according to different needs.

2.1 Knowledge Discovery

TCM is an empirical science that relies more heavily on experience than other disciplines. Understanding and analyzing medical cases and renowned physicians' diagnostic experiences can advance TCM system development, making the processing and analysis of such data a research priority in the TCM field.

Although TCM data is not as voluminous as in other disciplines, it possesses big data characteristics due to its variety and the enormous knowledge quantity contained in classical Chinese documents. Therefore, big data technologies are entirely applicable to TCM domain data. As TCM data continues to accumulate, applying big data technologies in this field has become inevitable, with knowledge discovery being a commonly employed method.

For non-structured, highly heterogeneous, knowledge-intensive data, knowledge discovery methods can effectively mine implicit knowledge. Qu Jiansheng et al. [7] proposed a heterogeneous information standardized extraction model based on four indicators derived from knowledge discovery. Zhang Yuanming et al. [8] proposed a data extraction method for unstructured tabular documents. This study integrates these two approaches to summarize a knowledge discovery process for the TCM domain, as shown in Figure 2 [Figure 2: see original paper].

TCM data should first undergo heterogeneous information standardization to convert all data into a unified standard. Then, according to the data structure specified in the data dictionary, data is stored in tabular format, with primary keys identified to establish logical structures between tables, forming a logical structure library. Subsequently, data is extracted from tables based on their logical structures and data dictionaries to form data organizations, which are further developed into structured datasets. Semantic models are then designed based on these datasets.

During semantic model construction, numerous specific issues arise, such as data processing and knowledge reasoning. Data processing forms the foundation of the entire semantic model. Gong Guangming et al. [9] developed a text clustering method for biomedical texts that improves clustering quality by considering semantics in each dimension without setting excessive subjective parameters. Luo Entao et al. [10] proposed a hierarchical clustering method based on semantic feature thresholds to enhance data processing efficiency. Both methods consider semantic differences across domains and are applicable to TCM document processing, though their semantic processing is insufficient, particularly for classical Chinese texts.

Knowledge reasoning is the foundation of intelligence. Bayesian networks are commonly used for knowledge reasoning, enabling future inference based on existing facts—crucially important in the medical domain, especially in smart medical systems where data-based disease analysis and reasoning demonstrate intelligence. In healthcare, highly credible prediction represents the ultimate goal of personalized medicine [11]. However, medical diagnosis, particularly in TCM, involves substantial uncertainty stemming from information loss and unreliability. Xie Hongwei et al. [12] argued that ontologies can represent a domain' s knowledge structure and address information incompleteness, while Bayesian networks can resolve information unreliability issues. Ontologies and Bayesian networks can transform through graph structures, mapping ontology instances to Bayesian network variables to complete medical diagnostic inference. However, these methods were developed within the Western medicine framework. Applying them to TCM requires addressing how to transform TCM' s complex conceptual relationships.

2.2 Knowledge Services

TCM knowledge is often obscure and difficult to understand due to its unique thinking patterns. Introducing knowledge service concepts into the TCM domain can provide accurate and comprehensible services to users. Yu Tong et al. [13] constructed a knowledge service platform for TCM asthma prevention and treatment to discover potential and useful knowledge, and preliminarily established a "TCM Syndrome Knowledge Base" [14]. Lin Xiaohua et al. [15] studied four factors—information needs, team collaboration, disciplinary knowledge background, and communication feedback mechanisms—to propose an optimized TCM disciplinary knowledge service model, though this service targets TCM researchers rather than general users. Ren Yulan et al. [16] constructed knowledge services around ancient TCM texts, but this service only added new pathways for preserving and utilizing ancient texts without providing substantive help for ordinary users.

Knowledge services have numerous characteristics [17]. Due to the medical domain' s particularities, TCM knowledge services exhibit intangible and personalized features. However, current TCM knowledge service research has not yet focused on personalization. Domestic research on personalized knowledge services for general users primarily concentrates on library and information science. Zeng Ziming et al. [18] proposed an embedded knowledge service model centered on readers, which the TCM domain can reference to construct relevant service models for ICM, achieving interconnectivity between users and resources. Meanwhile, mobile internet has accelerated TCM knowledge dissemination, allowing people to access and obtain needed knowledge anytime and anywhere, aligning with Ying Xuan' s concept of refined knowledge services [19]. Many TCM apps can provide such services, but Zhu Yumei' s survey [20] revealed that people' s primary channels for obtaining TCM knowledge remain books, radio, and television, which they trust more than online information. Consequently, online knowledge lacks authority, and information from numerous TCM apps is chaotic and inconsistent, necessitating unified terminology standards and a shareable, extensible database.

The source of knowledge services is TCM data. Without integrating TCM data, the credibility and authority of knowledge services will be significantly compromised. The challenge facing TCM knowledge services is how to integrate heterogeneous and ambiguous TCM data, with the most effective method being the construction of TCM ontologies to constrain TCM data. Meanwhile, as new resources such as ontologies emerge, knowledge management and service models and methods must also innovate accordingly [21].

2.3 Big Data Processing

TCM is an empirical science system based on practice. TCM data accumulated and continuously enriched over thousands of years forms the core of TCM development. Big data processing technologies enable more efficient and accurate TCM data processing, and their application in medicine has brought about precision medicine systems. Wu Qiguo et al. [22] studied six aspects of the TCM domain, concluding that the integration of big data and TCM domain knowledge will become increasingly close. Yang Wei et al. [23] argued that big data applications can mine usage characteristics and patterns of TCM, benefiting its inheritance and development. Cheng Xiao' en et al. [24] constructed a big data platform for TCM medical alliances to better utilize TCM medical resources. Wang Ji et al. [25] built a system framework for TCM constitutionology big data to guide practice in the TCM domain. Lü Qingli [26] combined data mining with complex networks to construct extended networks for studying TCM formulation patterns. Fan Meiyu [27] identified big data analysis technology as a primary supporting technology in precision medicine application systems. TCM' s human-centered, practice-based philosophy aligns more closely with precision medicine characteristics than Western medicine. Liu Chaonan et al. [28] combined TCM syndrome differentiation and treatment with big data processing, proposing a "precision TCM" model based on big data partial order structure generation principles.

As knowledge-intensive data, TCM data can be processed using big data methods to mine implicit knowledge. However, big data-based TCM research currently focuses on integrating TCM resources, with the research priority being how to apply big data to TCM services for general users.

Some research has proposed a big data technology-based ICM architecture diagram based on the characteristics of smart medicine, TCM, and big data, as shown in Figure 3 [Figure 3: see original paper] [29].

The key to implementing the ICM system lies in data processing, which is its core and the guarantee of its intelligence. In the framework diagram, data flows through the big data analysis system to generate corresponding application models. This represents the most significant difference between ICM and conventional TCM information service technology on the application service platform. While TCM information service technology simply collects and stores data, the ICM system coordinates data analysis through module collaboration and ultimately generates personalized treatment plans.

3. Information Infrastructure Support System

In the ICM system, the information infrastructure support system refers to data storage and processing systems. Data storage and processing form the system' s core, supporting its entire operation. Meanwhile, due to TCM' s different thinking patterns, it is not well-suited to formal logic systems, whereas semantic web technology can represent TCM thinking patterns through semantic associations [20]. In the medical domain, the most direct application of semantic web technology is the construction of medical language systems. Currently, mature medical language systems exist both domestically and internationally, aiming to standardize industry terminology, such as the Unified Medical Language System (UMLS), Traditional Chinese Medical Language System (TCMLS), Chinese Unified Medical Language System (CUMLS), and Clinical Medicine KnowledgeBase (CMKB). A comparison of these medical language systems is shown in Table 2 [30-33].

Language system usage can reduce terminology heterogeneity, but databases beneath language systems still suffer from information silos. Strengthening data connections and enhancing data inference functions represent the future direction of TCM domain data processing.

The core of semantic web technology is establishing standard formats based on data, giving it significant advantages in integrating different systems. Yu Tong argued that multiple RDF statements can be continuously combined into RDF graphs, with domain knowledge expressible through RDF graphs. Moreover, RDF uses URIs to represent terms, enabling integration based on RDF graphs without causing semantic confusion or loss [34]. RDF' s characteristics allow major TCM ontologies or databases to achieve semantic-lossless fusion under the semantic web.

Knowledge bases and knowledge graphs can effectively apply semantic technology to data storage and processing. ICM can use knowledge bases to store relevant data and employ knowledge graph technology for knowledge reasoning, providing users with more precise knowledge services.

3.1 Knowledge Bases

TCM data is often obscure and difficult to understand. Proper storage, organization, management, and utilization of data can reduce heterogeneity in database associations. Gao Zhiguo proposed that knowledge bases can organize knowledge to make it orderly. After studying medical information and database technologies, he proposed a seven-step knowledge modeling process, as shown in Figure 4 [Figure 4: see original paper] [35].

Chen Meishu [36] argued that the difficulty in modernizing TCM lies in the inability to effectively develop modern TCM with clear mechanisms and components, and proposed establishing a TCM chemical component structure information knowledge base. Zhang Fan [37] improved the design of the knowledge base for an intelligent TCM formula analysis system during formula knowledge base construction. Li Jinghua [38] organically integrated ontology technology, knowledge bases, and Agent technology, conceptualizing the knowledge chain through intermediate expression sets to construct a TCM spleen-stomach disease ontology knowledge base for clinical decision support. Yu Qi [39] designed a relational model based on a relational database foundation according to the TCM health preservation classification system to construct a TCM health preservation knowledge base.

A knowledge base is an operable and utilizable knowledge collection. The aforementioned knowledge bases focus on knowledge organization and storage, with close interconnections between knowledge points. However, research concentrated on knowledge services is limited. Meanwhile, different knowledge bases in the TCM domain contain different knowledge types but have overlapping areas. How to eliminate heterogeneity, escape information silos, and provide targeted knowledge services represents a future direction for TCM knowledge bases.

3.2 Knowledge Graphs

Knowledge graphs visually display relationships and structures among relevant data through concepts and technologies. They represent mappings of objective world knowledge. Using knowledge graphs to describe the TCM domain can intuitively present semantic associations and derivative relationships among TCM data. Jia Lirong [40] studied knowledge graph construction for the TCM domain from three aspects: data sources, research content, and graphical display. The foundation of this research was based on TCMLS. Similarly, TCM knowledge graph construction is also based on TCMLS, requiring continuous development and improvement of the TCM language system to ensure knowledge graph quality. Ruan Tong [41] proposed a detailed construction process for TCM domain knowledge graphs based on multiple data analysis methods. This process is comprehensive but somewhat cumbersome and could be integrated with Jia Lirong' s method to construct TCM knowledge graphs based on TCMLS, as shown in Figure 5 [Figure 5: see original paper].

In knowledge graphs, each term can be considered a node. Based on connections between these nodes, knowledge graphs can clearly display the 脉络 of domain knowledge. A clear knowledge system structure is the prerequisite for smart medical reasoning. TCM knowledge graphs form the foundation for intelligent Q&A in ICM and guarantee intelligent reasoning. ICM' s big data analysis system generates personalized demand models based on knowledge graphs and integrated data flows.

4. Standardization System

Both ICM and TCM informatization process medical information to complete tasks. TCM informatization simply solves medical information collection and storage problems, whereas ICM can integrate various resources to establish a collaborative system. The primary task in building a collaborative system and achieving information sharing is defining standardization systems for information, data, and knowledge.

In ICM, ontologies can constrain terminology, while linked data provides specifications for data associations. These two components can construct the data standardization system in ICM.

4.1 Ontology Semantic Methods

TCM is an exceptionally vast domain encompassing numerous medical texts, TCM thinking patterns, and diagnostic and therapeutic methods. However, due to wide geographical distribution, long temporal spans, strong subjective perspectives, and Chinese language characteristics, knowledge expression in existing TCM classics and medical cases left by modern medical masters is relatively ambiguous, lacking unified standards. Ontology provides precisely a conceptual-level specification. Ni Ping [42] argued that ontology' s characteristics provide good conceptual hierarchical structures, enabling logical reasoning at the semantic level—the foundation of ICM' s reasoning mechanism.

Ontologies can be roughly categorized into top-level ontologies, domain ontologies, general ontologies, and task ontologies. Currently, many domestic scholars have constructed ontologies for different TCM domains. For example, Yu Tong [43] performed semantic modeling for TCM image thinking based on OWL, while Xu Wen [44] constructed an ontology based on warm disease ancient texts. The general ontology construction process involves first determining the top-level ontology, then building domain ontologies upon it, and finally evaluating the ontology. The first step in ontology construction is determining the domain' s top-level ontology, which constrains the entire domain ontology and determines its specific content. During ontology construction, to 赋予 ontology-related functions, ontologies can be transformed with relevant models, such as Bayesian models. After ontology construction, timely evaluation of ontology usage and services is crucial for ontology modification and construction of related domain ontologies.

4.1.1 Top-Level Ontology Top-level ontologies reflect the objective world, constrain domain knowledge usage, and generate domain ontology concepts. Yu Tong [45] introduced the semantic network framework of the Health Informatics –TCM Language System, an ISO technical specification that serves as a standardized top-level ontology for the TCM domain, providing norms for related concepts and significantly influencing TCM domain specifications. Jia Lirong [46] studied the top-level framework of the TCM semantic network by constructing the TCM Language System, analyzing and processing TCM domain terms at the conceptual level, and ultimately establishing a conceptual hierarchical structure expressing complex relationships between concepts.

The top-level ontology determines the entire direction of domain ontologies and must express TCM domain' s unique concepts and relationships. The two aforementioned top-level ontologies are both based on TCMLS, similar to TCM knowledge graph construction, requiring continuous development and improvement of TCMLS. Long Hai [47] compared four mainstream top-level ontologies: GFO (General Formalized Ontology), SUMO (Suggested Upper Merged Ontology), DOLCE (Descriptive Ontology for Linguistic and Cognitive Engineering), and BFO (Basic Formal Ontology), as shown in Table 3 .

Due to GFO' s characteristics, Long Hai [48] argued that GFO has unique advantages in TCM domain ontology construction. However, it still cannot comprehensively express semantic relationships between TCM terms. Jia Lirong evaluated the rationality and practicality of TCMLS using ontological, classification, comparative, Delphi, and soft evaluation methods, assessing framework classification rationality, term completeness, and semantic association accuracy. The results showed that TCMLS has reasonable disciplinary classification, relatively reasonable semantic classification, and relatively complete terms, but extremely low semantic association precision [53]. One reason for low association precision is that TCMLS was initially established following the UMLS model, which cannot adequately express special relationships in TCM. Most domestic TCM ontology construction has borrowed from foreign ontology construction methods, setting top-level ontologies and semantic types that can clearly display TCM' s 脉络, but semantic type associations remain loose, failing to reflect TCM' s unique thinking relationships.

4.1.2 Ontology Construction TCM domain knowledge is extensive and complex. Manual ontology construction is extremely dependent on expert experience and inefficient [49], making automatic construction methods suitable for the TCM domain. Zheng Xuewei [50] proposed an ontology automatic construction algorithm involving document preprocessing, graph-based document concept extraction, and relational computation, with concept analysis using Markov clustering, constraints using the gSpan algorithm, and results evaluated by a feedback evaluation system that returns non-compliant concepts and relationships for regeneration. Zhu Lida [51] proposed the FIU-CTWC biclustering algorithm to solve the problem that one-dimensional clustering cannot cluster multiple semantics in ontologies. The algorithm' s biclustering component includes candidate sets and DMC clustering algorithms. For TCM domain ontology automatic construction, introducing biclustering algorithms can resolve semantic ambiguity issues in TCM knowledge and increase ontology precision.

Ontology construction in the TCM domain must first express the special concepts contained in knowledge, followed by standardizing terminology usage. Future research priorities in TCM domain ontology construction involve perfectly and precisely displaying TCM knowledge concepts based on Chinese characteristic philosophy.

4.1.3 Ontology Services and Evaluation TCM covers multiple specialized domains, such as syndromes, medical cases, and herbal medicine. Although these domains have different emphases, they all belong to the TCM domain and originate from Chinese classical philosophy, sharing commonalities. Starting from these commonalities, establishing either a standard TCM domain ontology construction process or standard or a management platform can reduce ontology construction workload and manage most TCM domain ontologies. Yu Tong [52] implemented a TCM ontology service system using internet technology, providing ontology processing, reviewing, hosting, uploading, management, maintenance, and downloading services for ontology processing personnel. The system comprises three subsystems: ontology knowledge base, ontology collaborative processing, and ontology visualization.

TCMLS is currently the most comprehensive TCM ontology, but it still cannot comprehensively express semantic relationships between TCM terms. Evaluating ontology usage and services after construction is significant for ontology modification and construction of related domain ontologies.

4.2 Linked Data Linked data is a method for connecting related data via the web or reducing connection difficulty. Tim Berners-Lee [54] argued that the semantic web is a web of data, but more importantly, it creates associations between data. Li Nan [55] believed that linked data provides a more general and flexible publishing paradigm, making it easier for data consumers to discover and integrate large amounts of data from different sources. When people generally lack understanding of TCM knowledge, large amounts of related information can ensure data reliability to some extent. Simultaneously, linked data can strengthen semantic associations between TCM domain data and support relationship-based retrieval and browsing. Bai Haiyan et al. [56] categorized associations between linked data into mapping associations and non-mapping associations, analyzing three automatic association construction methods: entity-based text mapping, graph similarity-based mapping, and rule-based association construction. Relationships between concepts and terms in TCM can be abstracted into relevant rules. TCM domain knowledge terms are highly subjective with numerous semantic types, and term heterogeneity hinders inter-term associations. Linked data provides ICM with a connection paradigm that strengthens data connections in the ICM system.

Data analyzed by the data analysis system is all linked data paradigm-based, ensuring the reasoning capability of the ICM system. Linked data is key to implementing smart medicine due to its data connection advantages, providing people with fast and fair services. Particularly in the TCM domain, knowledge ambiguity greatly hinders dissemination and increases smart medical system construction difficulty. Linked data can strengthen semantic associations between TCM semantic types, enhance reasoning functions in smart medical systems, and eliminate knowledge ambiguity.

5. Conclusion

ICM is the integration and development of TCM informatization. Table 5 shows the differences between the two across the same architecture. This study combines current ICM research in three aspects—data services on the service platform, infrastructure support systems, and standardization systems—to analyze research status from the perspective of technical implementation in these three domains.

Table 5. Differences Between ICM and TCM Informatization Across the Same Architecture

Architecture Layer	TCM Informatization	ICM
Application Service Platform	EMRS, etc.	Knowledge bases, knowledge graphs
Application Support Cloud Platform	Big data processing	Big data processing
Standardization System	TCMLS, ontologies, etc.	Linked data

5.1 Regarding Data Services

ICM under the big data system should emphasize adding TCM characteristics to data services and introduce concepts such as knowledge discovery and knowledge services for data processing, storage, and management. However, current data service quality is low, and TCM knowledge remains chaotic, ambiguous, and limited in openness for data consumers. Future TCM data services will develop toward greater openness and standardization, with potential for adding characteristic services such as health preservation.

5.2 Regarding Information Infrastructure Support Systems

The establishment of various knowledge bases has strengthened knowledge services, and simple semantic web implementations (such as knowledge graphs) have also provided a foundation for TCM intelligence. However, major TCM knowledge bases focus excessively on knowledge storage and management, with insufficient research on knowledge services. Meanwhile, different types of TCM knowledge are not independent but closely interrelated. During knowledge base construction, heterogeneity of knowledge and terms must be prevented. Whether for TCM domain workers or the general public, one of ICM’ s primary purposes is to provide better services. Knowledge services will be a future research focus for ICM, which can provide services to users in different content formats, such as analyzing users’ specific conditions to provide prescriptions or early warnings.

5.3 Regarding Standardization Systems

China has constructed corresponding ontologies for different TCM domains to constrain terminology usage. Most ontologies are based on TCMLS, but semantic type associations in TCMLS are not closely interconnected. ICM research should focus on expressing TCM’ s unique thinking patterns to establish domain terminology systems that are comprehensive, shareable, and extensible.

In summary, future ICM research will develop toward constructing suitable ontologies, achieving sharing and extension, strengthening semantic associations, and advancing data and knowledge services.

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