Training Objectives for Medical Informatics Professionals and the Construction of Knowledge Ecosystems: Postprint

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Abstract

[Purpose/Significance] In the context of the current big data environment and the demand for knowledge services in the field of medical intelligence, this study explores the cultivation objectives for medical intelligence professionals and the construction of a knowledge ecosystem. [Method/Process] First, from the perspective of knowledge services provided by medical intelligence personnel, we investigate the capability cultivation objectives of analyzing user needs from multiple perspectives, achieving multi-level matching between user needs and resources, and providing knowledge services through multiple channels. Subsequently, based on the constituent elements and operational mechanisms of the knowledge ecosystem, we construct a knowledge ecosystem encompassing the professional curriculum system, teaching practice platform, and educational incentive mechanism for the medical intelligence talent cultivation model, from three distinct perspectives: knowledge resources, knowledge service activities, and knowledge innovation activities. Finally, using the curriculum system reform, teaching practice platform establishment, and knowledge innovation activity cultivation plan implemented in the medical informatics major at Jilin University as a case study, we analyze the role of the knowledge ecosystem in the cultivation process of medical intelligence professionals. [Results/Conclusion] This study constructs innovation capability-driven cultivation objectives for medical intelligence professionals and a knowledge ecosystem, thereby promoting the application of intelligence research theories and methods in the field of medical intelligence.

Full Text

Construction of Training Objectives and Knowledge Ecosystem for Medical Intelligence Talents

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Abstract

[**Purpose/Significance**] Based on the demand for knowledge services in the field of medical intelligence under the current big data environment, this study explores the training objectives for medical intelligence talents and the construction of a knowledge ecosystem. [**Method/Process**] First, from the perspective of medical intelligence personnel providing knowledge services, the study explores the cultivation objectives of abilities including multi-angle analysis of user needs, multi-level matching of user needs and resources, and multi-channel provision of knowledge services. Then, according to the constituent elements and operational mechanisms of the knowledge ecosystem, it constructs a knowledge ecosystem for the medical intelligence talent training model from three perspectives: knowledge resources, knowledge service activities, and knowledge innovation activities, encompassing the professional curriculum system, teaching practice platform, and educational incentive mechanisms. Finally, taking the curriculum system reform, teaching practice platform establishment, and knowledge innovation activity training program of the medical informatics major at Jilin University as examples, the study analyzes the role played by the knowledge ecosystem in the training process of medical intelligence talents. [**Result/Conclusion**] The research constructs the objectives and knowledge ecosystem for medical intelligence talent cultivation driven by innovation capabilities, promoting the application of information science research theories and methods in the field of medical intelligence.

Keywords: healthcare big data; medical intelligence; knowledge ecosystem; knowledge service; talent cultivation

1 Research Status at Home and Abroad

With the extensive application of healthcare big data value in government decision-making, clinical diagnosis and treatment, public health surveillance, and medical scientific research, the demand for medical intelligence talents has increased significantly, drawing greater attention to the methods and current deficiencies in cultivating their intelligence analysis capabilities, logical thinking,

and innovative abilities [4]. The rapid changes in health information technology and the growing dependence of healthcare on information technology have led to a continuous increase in demand for medical intelligence analysis talents with interdisciplinary knowledge backgrounds [5-6]. The professional positioning, employment channels, teaching concepts, and teaching methods at the undergraduate stage lay the foundation for the accumulation of knowledge and skills for students majoring in medical intelligence-related fields.

In international medical informatics education research, the German Association for Medical Informatics, Biometry and Epidemiology (GMDS) [7] and the International Medical Informatics Association (IMIA) [8] have successively proposed talent models for the undergraduate stage of medical intelligence, promoting the construction of medical intelligence curriculum systems. Scholar R. Röhrig et al. proposed that the training objectives for undergraduate medical intelligence talents should focus on cultivating medical information processing capabilities in seven domains, including medical record and information processing, medical classification and terminology, and medical information systems, with relatively greater emphasis on information literacy in the medical field [9]. In foreign medical intelligence undergraduate education, both offline courses and large-scale online courses such as MOOCs are offered [10]. Eta S. Berner et al. designed a method for determining student course selection based on assessment data to ensure that students can acquire skills for future job positions through on-campus courses [11].

Domestic scholars have found obvious differences between China and foreign countries in training objective positioning, curriculum design, and training levels through comparative studies [12]. By drawing on training programs and combining them with the current situation where China's medical intelligence undergraduate curriculum system is disconnected from practical needs and courses fail to integrate well, suggestions have been made to reform and design the curriculum system, teaching staff, and teaching models [20]. Cao Gaofang of Binzhou Medical College investigated universities in Shandong offering medical intelligence-related undergraduate education and found problems such as uncertain talent training objectives, unreasonable curriculum design, and relatively weak practical teaching [21].

The current research status at home and abroad shows that all sectors of society have an urgent need for medical intelligence analysis talents, but the results of talent training cannot meet current social demands. Reflecting on the current situation of medical intelligence talent training at the undergraduate stage, relevant discussions mainly focus on research of curriculum systems, teaching systems, and teaching methods, with fewer studies on training objectives and knowledge systems with interdisciplinary backgrounds for medical intelligence talents at the undergraduate stage. There is a lack of discussion on the dynamic balance process of multi-domain knowledge sources in student learning, including absorption, acceptance, self-organization, and innovative practical application. Therefore, in response to the superficial and unsystematic nature of

current medical intelligence talent knowledge system training, this study plans the training objectives for medical intelligence-related majors and constructs an interdisciplinary knowledge ecosystem. By utilizing the dynamic balance of knowledge flow, value flow, and material flow in the medical intelligence knowledge service process, it promotes medical intelligence talents' ability to organize multi-source heterogeneous medical big data knowledge resources for knowledge discovery and to provide knowledge services for different scenarios and collaborative environments.

2 Training Objectives for Medical Intelligence Talents

The intelligence analysis activities of medical intelligence analysts are the key link connecting knowledge resources and knowledge demanders, and their abilities in knowledge discovery and knowledge services directly affect the utilization effectiveness of medical intelligence. Based on the current healthcare big data environment, Professor Ma Feicheng proposed a mechanism for achieving medical intelligence knowledge services oriented toward smart health, pointing out that medical intelligence analysts need to be able to keenly identify user needs and possess the capabilities to construct demand semantic networks, match user needs with public health knowledge base resources, and provide knowledge services from different dimensions and levels [22]. Therefore, the competency training objectives for medical intelligence personnel are to cultivate students' ability to analyze user needs from multiple angles, their ability to match user needs with target resources at multiple levels, and their ability to provide knowledge services through multiple channels.

2.1 Cultivating the Ability to Analyze User Needs from Multiple Angles User need identification and semantic modeling are prerequisites for providing targeted knowledge services and can avoid the distress of information overload for users, representing a key focus and hotspot in knowledge service activity research. The knowledge service targets of healthcare big data include medical and health administrators, clinical medical staff, medical researchers, patients, and the general public. The content of knowledge needs emerges, develops, and changes under different times and environments, and may even intersect. These needs may be statistical yearbook analysis results for solving current policy management problems, treatment plans for difficult and complicated diseases, or patients' needs for specific medical knowledge. In the face of diverse knowledge needs from different knowledge demanders, complex demand problems need to be decomposed into fine-grained layers, analyzing the content, depth, and urgency of users' knowledge needs, and organizing multi-source heterogeneous knowledge and knowledge carriers into a whole or even a more complex knowledge network. Demand analysis is the starting point for medical intelligence analysts to provide intelligence services. There are multiple ways to identify user needs: analyzing knowledge needs through established real challenges in users' work fields, such as inferring the needs of medical and health supervision departments to formulate regulatory policies based on current drug

quality problems; analyzing the cognitive situation of knowledge demanders to speculate on required knowledge content, such as distinguishing the level of professional knowledge provided when doctors versus the general public are the knowledge demanders; and analyzing users' interactive behaviors to extract information needs subjectively expressed by users, including workflow docking, social activities, and information retrieval behaviors.

2.2 Cultivating the Ability to Match User Needs with Information Resources at Multiple Levels The process of matching user needs with information resources involves integrating, ordering, and organizing dispersed multi-source heterogeneous information resources and extracting knowledge closely related to user needs. The sources of healthcare big data include medical literature data, social media health websites, and electronic medical record data, with manifestations including structured data, unstructured data, and features where structured and unstructured data coexist, such as numerical data from laboratory tests, text data from medical record descriptions, and image data from ECGs and color ultrasounds, posing numerous challenges to the knowledge matching process. The information resource matching ability of medical intelligence analysts is reflected in their understanding of the motivation for matching needs and resources, method selection, and strategy design. The matching process is a value creation process that transforms noisy information from chaotic disorder to ordered value. First, it is necessary to clarify the structural and content characteristics of multi-source data, then construct methodological strategies for multi-source heterogeneous data fusion, design data feature extraction, fusion theoretical mechanisms, and fusion methods to promote multi-dimensional deep fusion of multi-source heterogeneous data. This process requires medical intelligence analysts to eliminate interference from ambiguity, uncertainty, incompleteness, and inconsistency in multi-source heterogeneous information resources to achieve structural fusion at the representation layer, relational fusion at the logical layer, and content fusion at the semantic layer for data with different association granularities. Then, based on information fusion, it further analyzes the relevance between needs and information resources, reveals the relationships between problem and user need elements and attributes, and achieves multi-layer fusion of user knowledge needs and information resources in terms of association granularity, association degree, and association depth.

2.3 Cultivating the Ability to Provide Knowledge Services Through Multiple Channels With the continuous changes in knowledge needs in the healthcare big data environment, and the diversity of work forms of medical knowledge service demanders, single knowledge service provision methods are difficult to apply to medical intelligence knowledge service needs. It is necessary to stimulate the innovative service spirit of medical intelligence analysts and cultivate their ability to provide knowledge services to users through multiple channels. The channels for providing knowledge services are bridges linking

knowledge, knowledge service providers, and knowledge service demanders. The effectiveness of these hubs is the comprehensive result of knowledge service methods, knowledge representation forms, and knowledge service implementation paths. Knowledge service methods can be either question-and-answer consultation services or proactive services that actively recommend potentially needed knowledge to users. The representation forms of knowledge provided during the service process are not limited to text but can also be knowledge graphs, social network relationship graphs, and spatiotemporal distribution maps. The implementation paths of knowledge services can be directly providing relevant knowledge retrieved from knowledge bases to users, such as clinical diagnostic gold standards, medication methods, routes of administration, and infectious disease surveillance indicators; processing retrieved multi-source heterogeneous information into information units, such as specific medication plans for special populations; or using real-time interactive methods to continuously update the intentions of knowledge demanders through communication and dynamically adjust knowledge provision plans to improve knowledge service satisfaction. The provision channels for knowledge services require medical intelligence personnel to master existing methods and develop more flexible and adaptable approaches on this basis, making innovation capabilities particularly important for medical intelligence talents.

3 Construction of Knowledge Ecosystem for Medical Intelligence Talents

The big data era has driven the iteration and optimization of theories, methods, and problems in intelligence research, and the resulting transformation has expanded research paradigms. Medical intelligence analysis activities represent the extension of intelligence science's "grand intelligence concept" to information analysis in the healthcare big data field. The knowledge service activities of medical intelligence talents are embedded in the knowledge ecosystem, involving three elements related to healthcare big data: knowledge resources, knowledge service activities, and knowledge innovation activities [23,24]. The data flow, information flow, and knowledge flow among these three elements orderly connect the carriers of medical intelligence knowledge, the ontology of knowledge, and the demanders of knowledge, highlighting the correlation between internal data and the external environment during the knowledge service activity process. Therefore, discussing the knowledge ecosystem of medical intelligence analysis talents can accelerate the flow of healthcare big data knowledge resources, thereby driving value creation, innovating knowledge dissemination, and promoting the application of intelligence research theories and methods in medical data, ultimately transforming more new knowledge into productivity.

Based on the interdisciplinary nature of medical intelligence, this study constructs a knowledge ecosystem for medical intelligence talent training that integrates multi-disciplinary knowledge. From the perspectives of the constituent elements, characteristics, and hierarchy of the knowledge ecosystem, it ana-

lyzes the training process of medical intelligence talents. First, the knowledge ecosystem of medical intelligence is an open and dynamic system under different temporal and spatial environments. Under the regulation of the system's internal and external environments, medical intelligence knowledge service activities promote the knowledge flow, value flow, and material flow within the system. Then, through the interaction of these three flows, they gradually promote the organizational activities of the core elements of the knowledge ecosystem: knowledge resources, knowledge services, and knowledge innovation. Finally, through their exchange and collaborative environment, they form a complex medical intelligence knowledge value network. Corresponding to the three elements of the knowledge ecosystem, the training pathways for medical intelligence talents at the undergraduate stage can achieve the accumulation of multi-channel knowledge resources by integrating multi-domain professional courses and related standards; open diversified practice platforms to enrich the knowledge service activity environment; and establish diversified incentive mechanisms to promote innovation activities. The knowledge ecosystem for medical intelligence talent training constructed in this study is shown in Figure 1 [Figure 1: see original paper].

3.1 Integrating Multi-Domain Professional Courses to Enrich Knowledge Resource Channels Medical intelligence knowledge discovery requires the integration of multi-disciplinary knowledge. Only through interdisciplinary knowledge can intelligence analysis results be more targeted and insightful, and the status analysis results, current development limitations and deficiencies, and discipline development predictions can be more accurate and valuable [25]. The data analysis ability of medical intelligence personnel is reflected in their comprehensive qualities demonstrated in data cleaning, analysis, and visualization tasks or objectives. It is the manifestation of their knowledge reserves and knowledge structures in practical processes and is also an important criterion for identifying, evaluating, and judging researchers' scientific research abilities. Currently, some experts have pointed out the need to formulate new intelligence talent training objectives, build a hierarchical education system in undergraduate, master's, and doctoral curriculum design, and actively expand the directions of scientific and technical intelligence research [26]. Therefore, cultivating medical intelligence personnel's knowledge service abilities and innovative thinking at the undergraduate stage is an important starting point. First, it is necessary to reorganize the professional curriculum system, expand the boundaries of the talent training discipline curriculum system, break through the curriculum system centered on theories and methods of a single discipline, and aim at cultivating intelligent intelligence analysis in multiple fields. Driven by the "4V" characteristics of healthcare big data [27] and using statistical analysis and deep learning methods as means, it enhances the competitiveness of intelligence science research extended to the field of medical intelligence analysis [28]. While expanding the boundaries of intelligence research, it improves the core competitive literacy of medical intelligence analysis personnel in medical intelligence

knowledge services. According to the concept of multi-disciplinary integration, it constructs an interdisciplinary curriculum system integrating intelligence science, medicine, statistics, and computer science, establishing an educational curriculum training system community with "data-information-knowledge-wisdom" as the knowledge chain [29]. While adhering to the essential educational concept of intelligence science, it expands the adaptability of intelligence research paradigms to the multi-dimensional changing characteristics of healthcare big data and explores the application of intelligence research paradigms in the information analysis and knowledge service processes of healthcare big data.

3.2 Building Diversified Practice Platforms to Promote Knowledge Service Activities Knowledge service practice platforms are important conditions for cultivating excellent intelligence analysis talents and stimulating the innovative vitality of knowledge service personnel. Building diversified practice platforms is more conducive to medical intelligence personnel understanding the practical needs of medical-related field staff from different perspectives and meeting the needs of different students' future career development planning. Creating platforms such as inter-university scientific research project cooperation, medical and health institution internships, pharmaceutical enterprise internships, medical intelligence retrieval and novelty search, and medical data mining competitions can break the barriers between closed university talent training and social talent demand, creating more exchange and interaction opportunities between universities, between universities and hospitals, between universities and health supervision departments, and between universities and pharmaceutical enterprises. Embedding the theoretical knowledge students learn in school into the working environment of medical intelligence knowledge demanders, and mastering their working environment, processes, and paths, can create a multi-level open exchange and collaborative innovation medical intelligence knowledge service model, integrating knowledge service activities into all aspects of demanders' work and achieving deep semantic-level integration of knowledge service content, embedding of knowledge service methods in workflows, and fusion of knowledge push timing at work nodes. Based on practice platforms in medical institutions, students can understand hospital workflows and the knowledge needs of doctors, nurses, and administrative personnel in diagnosis and treatment activities; based on practice platforms in health supervision departments, they can understand the elements and decision-making principles considered by management agencies in the macro-coordination of medical institution human, material, and financial resources, providing targeted knowledge support for health supervision managers' auxiliary decision-making; based on practice platforms in pharmaceutical enterprises, students can understand the drug research and development design and adverse drug reaction reporting system operation mechanisms, discovering the knowledge urgently needed by drug research and development workers to conquer disease treatment drugs; based on practice platforms in research institutes, students can participate in scientific research project application, implementation, and conclusion activities, exploring the

knowledge support needed by researchers in discovering scientific frontiers and hot issues, matching research questions and solutions, and assessing the applicability and feasibility of research methods. Conducting multi-angle knowledge demand analysis from diversified practice platforms and then 定向整合 health care big data 中的文献数据、调查报告、统计年鉴、电子病历等，使医学情报的知识服务活动以更精准的落脚点和更灵活的服务方式进行提供。

3.3 Constructing Diversified Incentive Mechanisms to Encourage Knowledge Innovation Activities The conceptual framework of intelligence research has both theoretical research and practical analysis dimensions, and intelligence analysts are the hub linking the two dimensions. Through analytical activities that integrate multi-disciplinary theories and methods to solve practical problems, they constitute the main content of intelligence research activities. Some research suggests that the most fundamental aspect of cultivating innovative talents is the enhancement of knowledge service subjectivity and the cultivation of autonomous and free consciousness; forced education cannot cultivate talents with innovative spirit [30]. Therefore, the stronger and more continuous the endogenous motivation of medical intelligence analysts to participate in knowledge service activities, the more conducive it is to cultivating their proactive service attitude and independent innovation ability, and incentive mechanisms are the link connecting knowledge service willingness and action enthusiasm. Knowledge service incentive mechanisms can both maintain the structural stability of the knowledge ecosystem and stimulate the potential of medical intelligence personnel in knowledge services, promoting medical intelligence knowledge innovation, accelerating output rates, and fostering team collaboration and win-win outcomes. Medical intelligence analysts are the academic subjects of the knowledge ecosystem, but the vast majority are in a state of passively providing knowledge services. Incentive mechanisms that integrate material rewards, spiritual encouragement, and self-identity can alleviate the pressure of knowledge service work while triggering endogenous motivation to participate in knowledge service activities, maintaining the stability and sustainability of the medical intelligence knowledge ecosystem. Thus, incentive mechanisms can guide medical intelligence personnel to establish correct knowledge service awareness, which is conducive to promoting the autonomy and continuity of knowledge service activities. Medical universities and research institutes should expand students' autonomy in scientific research project initiation, human and financial resource management, research question selection, and technical route formulation. Increasing the proportion of projects where students serve as project leaders in scientific research project initiation and granting medical intelligence talents greater independent control and decision-making rights can serve as an opportunity to encourage and motivate the rapid growth of a new generation of medical intelligence talents.

4 Knowledge Ecosystem for Medical Intelligence Talent Training

The undergraduate major of Information Management and Information Systems (Medical Information Management) at the School of Public Health of Jilin University is one of the earliest universities in China to establish an information management major oriented toward the medical and health field. Since the establishment of this major in 1985, it has twice hosted the Medical Information Education Sustainable Development Academic Seminar of the Chinese Medical Association, accumulating considerable teaching 实践经验 in medical intelligence talent training. The reform design of the talent training program in recent years has also incorporated the guiding role of the knowledge ecosystem in the talent training process, offering an interdisciplinary curriculum system and diversified teaching practice platforms, with greater emphasis on knowledge innovation activities in medical intelligence knowledge services. The talent training system of this major takes cultivating medical intelligence talents with a grand information concept as the overall objective and constructs a knowledge ecosystem for medical intelligence talent training that adapts to the development needs of the big data era, comprehensively shaping students' interdisciplinary knowledge backgrounds. Based on the three constituent elements of the knowledge system—knowledge resources, knowledge services, and knowledge innovation—it constructs a multi-domain integrated curriculum system, diversified practical teaching platforms, and multi-mode incentive mechanisms to promote the construction of the medical intelligence talent knowledge ecosystem.

4.1 Multi-Domain Integrated Curriculum System From the perspective of constructing knowledge resource elements of the knowledge ecosystem, the curriculum system design of the Information Management and Information Systems (Medical Information Management) major integrates courses in intelligence science, medicine, and computer science, committed to cultivating composite medical intelligence talents who master medical information management, intelligence analysis, and information system analysis and design methods. The 2018 version of the Information Management and Information Systems major curriculum divides the system into required and elective courses. Required courses include medical courses (pathology, medical immunology, biochemistry, etc.) to establish students' medical knowledge background; intelligence science courses (information analysis and decision-making, medical information retrieval, fundamentals of information management, etc.) to teach principles and methods of information collection, processing, and organization; computer courses (computer networks, JAVA programming, database system principles, etc.) to teach methods for massive data storage and linking; and statistical analysis courses (health statistics, medical statistical software application, probability theory and mathematical statistics, etc.) to teach principles, applicable conditions, and result interpretation of data analysis methods. Elective courses include artificial intelligence fundamentals, health law, medical ethics, operations research, evidence-based medicine, and intellectual property law to help students understand comprehensive knowledge beyond data analysis and processing. The

curriculum design for medical intelligence talents at the undergraduate stage combines required and elective courses to establish students' interdisciplinary knowledge background.

4.2 Diversified Practical Teaching Platforms From the perspective of constructing knowledge service elements of the knowledge ecosystem, efforts are made to develop diversified practical teaching platforms to enhance students' employment opportunities in positions such as medical big data companies, medical intelligence research institutes, medical school libraries, medical and health institution research departments, and journal editorial departments. To improve students' competency in future work positions, the Information Management and Information Systems major has established multiple practical teaching bases both on and off campus. On campus, the Medical Informatics Experimental Teaching Center has been set up to meet the practical operation needs of courses such as medical information retrieval, medical statistics, and hospital information systems. Off campus, undergraduate practical teaching bases have been established in Beijing, Shanghai, Hangzhou, Changchun, and other locations, such as the Library of the Chinese People's Liberation Army General Hospital in Beijing, the Library of the Second Military Medical University in Shanghai, and the Hangzhou Medical Intelligence Research Institute, to train students' abilities in information organization, retrieval, and novelty search of medical intelligence-related materials. The Jilin Provincial Health Statistics Information Center familiarizes students with the reporting, transmission, aggregation, organization, and analysis of statistical yearbook data in medical and health institutions. The information departments and medical record rooms of the First, Second, and Third Hospitals of Jilin University allow students to learn about the operation of hospital information systems, the storage and retrieval of different types of data, and the mining and utilization of healthcare big data. The design of practical teaching platforms for medical intelligence talents at the undergraduate stage combines on-campus and off-campus approaches to meet the development needs of students' different career plans.

4.3 Multi-Mode Incentive Mechanisms From the perspective of constructing knowledge innovation elements of the knowledge ecosystem, the university has collaborated with numerous departments and institutions to organize various project applications, social practices, and scientific research competitions to motivate students to apply their learned medical intelligence knowledge and skills to solve practical problems. Jilin University has carried out multiple independent innovation and entrepreneurship activities, including multiple sessions of the "Internet+" Innovation and Entrepreneurship Competition and the "Undergraduate Innovation and Entrepreneurship Training Program," encouraging undergraduates to serve as project leaders, independently propose research questions, and discuss research backgrounds, current status, and feasibility, thereby training students' scientific research thinking and innovation abilities. Provincial units and departments have

organized multiple skill competitions, such as the "Hangzhou Cup" Novelty Search Skills Competition jointly organized by Jilin University's Medical Informatics major and the Hangzhou Medical Intelligence Research Institute, and the College Student Innovative Technology and Product Design Patent Challenge Competition held in Jilin Province. In addition, national education departments have established multiple international exchange programs, providing students with opportunities to access international frontier theories and technologies in medical intelligence research, such as the Innovative Talent International Cooperation Training Program, the Excellent Undergraduate International Exchange Program, and the International Organization Talent Training Program established by the China Scholarship Council, which select undergraduates to study abroad as visiting students or select outstanding undergraduates to pursue master's degrees abroad, providing pathways for undergraduate students to reach the international stage. The incentive mechanisms for medical intelligence talents at the undergraduate stage, along with the multi-department linkage at the university, provincial, and national levels, jointly promote students' spirit of autonomous learning and innovative practice.

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Fa Hui: Responsible for data collection and paper revision;
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Yang Xinyu: Responsible for literature research.

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