Recent Advances in the Study of Ancient Books on Traditional Chinese Medicine

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Abstract

The ancient books on traditional Chinese medicine (TCM) are the source of knowledge for TCM physicians. Therapeutic principles and therapeutic methods for healing many diseases are recorded in these ancient TCM books, providing a huge number of references for modern TCM physicians on conducting diagnosis and administering treatment for different diseases. The ancient TCM books can be dated back thousands of years, and this vast knowledge is recorded in different medical books in the form of text. However, it is difficult to systematically assimilate much information in ancient TCM books. At present, many researchers are applying advanced analytical techniques to analyze the text data in the ancient TCM books. Advanced techniques that have been applied include database construction, cognitive linguistic analysis, fuzzy logic, data mining, and artificial intelligence (AI) technology. There are different characteristics in these advanced analytical techniques. In this study, we comprehensively review recent advances in these techniques applied to the study of ancient TCM books. Furthermore, as AI technology is increasingly utilized in the medical field as well as in the study of ancient TCM books, we also review the application of AI technology to the study of ancient TCM books.

Keywords: Advanced analytical techniques, ancient books, recent advances, traditional Chinese medicine

Advanced Analytical Techniques in the Study of Ancient Traditional Chinese Medicine Books

Database construction

The digitization of ancient traditional Chinese medicine (TCM) books has made it very convenient for users to find, read, and utilize these books. At present, all major TCM colleges and universities have established databases of ancient TCM books. The data in these databases are sourced primarily from the university’s library collections, such as the database of the library of the China Academy of Chinese Medical Sciences and the database of ancient books of the Nanjing University of Chinese Medicine. Several commercial organizations have also participated in the construction of databases of ancient TCM books and literature. For example, the classics of TCM has collected nearly one thousand ancient TCM books, and a special edition of TCM has been set up in the electronic version of the Si Ku Quan Shu (Complete Library of the Four Branches of Literature). The important processes in database construction for ancient TCM books and literature include metadata processing, associating pictures with texts, digitalization processing, construction of a service platform, and copyright protection. Among these processes, the standardization and normalization of data processing are essential to guaranteeing the quality of the database construction.

An important objective of database construction for ancient TCM books is the mining and analysis of tacit knowledge in ancient books to develop the TCM culture and serve the mass of TCM practitioners. However, the utilization ratio of the databases is still low due to the sheer volume and level of disorganization of the content in the databases of ancient TCM books and the lack of effective analytical tools.

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Cognitive linguistic analysis

In ancient TCM books, the expression of many common terms changed along with changes in the language environment. For example, there are several descriptions of anorexia, such as “Na Cha,” “Yan Shi,” “Bu Yu Yin Shi,” “Na Gu Bu Jia,” “Na Dai,” “Shi Yu Bu Zhen,” and “Yin Shi Wu Wei.” All these descriptions have essentially the same pathogenesis of the disease. Thus, these days, physicians understand these terms uniformly as anorexia while studying. The TCM language originated from thousands of years of development of the ancient texts, which means that the ancient TCM books were significantly influenced by the evolution of ancient Chinese language. Due to this characteristic, it is no surprise that so many TCM physicians think it is difficult to read ancient TCM books. The TCM language was also heavily influenced by the development of ancient Chinese philosophy, and there is a large amount of philosophical terminology in the TCM theoretical system, such as yin and yang and the five elements. Furthermore, during the thousands of years of development of TCM theory, very many famous scholars wrote books to increase the richness of TCM theory, which also increased the complexity and ambiguity of TCM vocabulary. Consequently, cognitive linguistic analysis has increasingly been applied to the TCM study in recent years.

Cognitive linguistics not only studies the influence of human cognition on language but also explores how language, in turn, influences human cognition on a global scale. It is a discipline that researches the relationship between the universal laws of language and the rules of human cognition. Research and application of cognitive linguistics to ancient TCM books explains the construction process of the concepts of TCM etiology and pathogenesis, deepens the understanding of TCM concepts, language, and theory, and also provides a basis for the semantic analysis of ancient TCM books. In a study of Gao, the source domains of the Primordial Qi, the Nutritive Qi, the Defensive Qi, and the Pectoral Qi were found through exploring the cognitive linguistics of the human body’s Qi. Mapping relationships between the source domain and the target domain were built using cognitive linguistics, and these revealed that the concept of the Primordial Qi in the target domain was more similar or identical to the concept of the “embryo” in the source domain. The Nutritive Qi and the Defensive Qi have the characteristics of “barracks” and “garrison,” respectively. The Pectoral Qi takes clan “leader” as its source domain because of the similarity to clan and temples.

However, there are also some shortcomings in cognitive linguistic analysis. The main one is that its research and application is mostly based on a single statement, making it challenging to perform a systematic analysis of massive amounts of text data.

Fuzzy logic

There are a lot of fuzzy words in the TCM vocabulary, such as “Hou (thickness)” and “Bo (thiness),” which describe the tongue coating, and “Hong (full pulse)” and “Xi (thready pulse),” which describe the pulse. Many words have no clear definition, and their properties and state appear fuzzy. Fuzzy logic is a mathematical method based on the observation that people make decisions based on inaccurate information by establishing fuzzy mathematical models or sets to represent fuzzy information. Fuzzy mathematical models have been applied to TCM theory research by many scholars. For example, Peng et al. used the classification of tongue-coating color in patients with chronic hepatitis B as an example and applied fuzzy logic to provide a way for computers to understand the fuzziness of human language and human thinking, which then assisted TCM practitioners in carrying out a diagnosis of tongue color. Tan and Yao explored the English translation of fuzzy words in the Yellow Emperor’s Internal Classic, with the fuzziness in TCM regarding the polysemy, metaphors, euphemisms, and imaginary numbers constituting four aspects. Using a fuzzy statistical model, Li et al. obtained the fuzzy membership of the skin index to the constitution and realized fuzzy optimization classification of TCM physique with a multi-attribute skin index. However, as a mathematical method, fuzzy logic analysis cannot handle text directly. Thus, the use of fuzzy logic requires that the text be processed in advance, such as text digitization and data standardization. The text processing process involves a tremendous amount of work analyzing the massive text data in ancient TCM books. However, where it is required, fuzzy logic analysis is an effective method for classifying the fuzzy words in TCM language.

Data mining

Data mining is the process of extracting hidden, previously unknown, and potentially useful information and knowledge from a large number of incomplete random data. The data mining technique not only conducts searching and analysis of the data but also excavates potential relationships among the data. The application of data mining undoubtedly gives new impetus to the study of ancient TCM books and plays a vital role in further study of ancient TCM books.

To date, data mining of ancient TCM books has primarily focused on the study of ancient medical records and prescriptions, and the most commonly used methods for mining include frequency statistics, cluster analysis, factor analysis, correspondence analysis, and association rules. Many scholars utilize this tool for exploring the principles of drug compatibility, correlations between drugs and syndromes, correlations between diseases and syndromes, and then summarize the regularities of diagnoses and treatments of diseases. Huang analyzed the relationship of abnormal stool and urine abnormalities in the Treatise on Febrile Diseases, and Gao and Jia researched the principles of diagnosis and treatment in the ancient books and medical records when Ying Qi (Nourishing Qi) and Wei Qi (Defensive Qi) got impaired.
Multiple methods of analysis and mining have been applied in relevant studies, and the full-text database of ancient TCM books has also been analyzed from different perspectives as comprehensively as possible. However, the fuzziness and complexity of TCM language make data mining reliant on manual processing, which restricts its application in the analysis of ancient TCM books.

**Artificial intelligence technology**

In recent years, the rapid development of artificial intelligence (AI) technology has brought fresh vitality to the efficient utilization of ancient TCM books through the efforts of many scholars. For example, Ji et al.\(^{[23]}\) analyzed the composition of ancient TCM prescriptions for the treatment of diabetes with the application of an association rule mining algorithm. This algorithm is a machine learning algorithm that searches for the association rules among massive amounts of data. Ji et al. summarized 93 high-frequency drugs and 187 high-frequency drug pairs and excavated the characteristics and rules of ancient TCM formulas for treating diabetes. Yang\(^{[26]}\) used the support vector machine (SVM) algorithm to extract knowledge from unstructured TCM texts and applied the clustering method to explore the potential connections among prescriptions to realize the storage and organization of knowledge in a structured form, recognizing more effectively useful knowledge from massive digital resources to serve the users. Li et al.\(^{[27]}\) regarded ontology as a method for allocating knowledge, expressed the relationships among concepts with formal language, and then constructed a prototype of semantic retrieval system based on domain ontology, which improved the recall ratio and precision ratio of a database of ancient TCM books and literature. Compared with the Western medicine field, the application of AI technology in the TCM field, especially in ancient TCM books, is still in its infancy. There is still a large room for improvement in AI. However, the successful application of related technologies in the field of Western medicine has also indicated the direction of the AI analysis of ancient TCM books.

**Application of Artificial Intelligence Technologies in the Study of Ancient Traditional Chinese Medicine Books**

At present, certain achievements have been realized in the medical field through the application of AI technologies. Relatively mature AI techniques include machine learning algorithm, deep learning algorithm, and knowledge graph.

**Machine learning algorithm**

The machine learning algorithm is a branch of AI. It is a set of programs that adjust themselves to perform better as they are exposed to more data, making it able to effectively analyze data even when the internal mechanism is not very clear.\(^{[28]}\) At present, traditional machine learning algorithms have conducted some mature applications in the medical field. For instance, SVMs are used in the diagnosis of diseases such as breast cancer\(^{[29]}\) and Alzheimer’s disease;\(^{[30]}\) disease outcomes have been predicted with the application of big data on health care;\(^{[31]}\) medical data have been efficiently classified to support decision-making by medical practitioners.\(^{[32]}\) Related technologies have also been utilized in the field of Chinese medicine, such as the classification of tongue pictures\(^{[33]}\) or physique analysis\(^{[34]}\) and data processing of medical records.\(^{[35]}\) In recent years, deep learning algorithms have achieved enormous development based on machine learning, which has been attributed to advancements in computer hardware and the completeness of large-scale data sets.

**Deep learning algorithms**

Numerous successful applications of deep learning technology in the medical field have been published successively in the top journals of medicine, such as JAMA and Nature. For example, Gulshan et al.\(^{[36]}\) created an automatic detection algorithm for diabetic retinopathy and diabetic macular edema in retinal fundus photographs, which revealed that the algorithm based on deep machine learning possessed high sensitivity and specificity for detecting inductive diabetic retinopathy through the evaluation of diabetic retinal fundus photos. Esteva et al.\(^{[37]}\) trained a deep convolutional neural network with a dataset of 129,450 clinical images, and the results showed that the system’s accuracy for detecting malignant melanoma was comparable to that of trained dermatologists. Furthermore, deep learning algorithms require less manual intervention than traditional machine learning algorithms.

In summary, the primary applications of deep learning technology in the medical field are as follows: the convolutional neural network is primarily used for data processing in medical imaging, the cyclic neural network is chiefly employed in processing the data in electronic patient records, and autocoder and deep belief net can be utilized on data from both medical imaging and electronic cases.\(^{[38]}\) For the analysis of ancient TCM books, deep learning technology can be used to classify the text data or construct a structured mapping of the text on a large scale with high efficiency. It is a promotion of the machine learning algorithm. However, the application of deep learning algorithms in the TCM field is still in its initial stage. Up to now, the main obstacles are the fuzzy descriptions in TCM theory and the absence of objective evaluation indicators, making it difficult for deep learning algorithms to identify information accurately.

**Knowledge graph**

The knowledge graph is an AI technique based on semantic analysis that develops rapidly in recent years. It is a semantic network that describes objective entities, concepts, and the relationships between them in the real world.\(^{[39]}\) With full use of visualization technology, a knowledge graph can not only describe the resources and carriers of knowledge but also analyze and illustrate the connections among knowledge nodes. Google launched its knowledge graph in May 2012, which added semantic analysis technology to the traditional keyword-based search technology and significantly enhanced
the information value returned by Google Search.\textsuperscript{[40]} The knowledge graph is a map-based method of knowledge representation and organization. A semantic network is the core component of the knowledge graph, in which nodes represent domain concepts, and edges represent semantic relationships among concepts. The knowledge graph utilizes the semantic network as the “skeleton” for the collection and systematic distribution of scattered domain knowledge and realizing the functions of knowledge retrieval, knowledge display, and knowledge service.

The construction of a medical knowledge graph is a research focus in the field of AI at the moment. IBM’s Watson Research Center has established a knowledge graph for analyzing large-scale unstructured medical information to identify drug-to-drug interactions.\textsuperscript{[41]} Sang et al.\textsuperscript{[42]} proposed a recurrent neural network method based on a biomedical knowledge graph, which could explore potential drugs by mining published biomedical literature. Bean et al.\textsuperscript{[43]} achieved the prediction of adverse reactions by establishing a knowledge graph of drugs. Compared to various machine learning algorithms, the knowledge graph has powerful data description capabilities, which can discover and predict new knowledge through knowledge fusion and knowledge reasoning. Exploration and actual construction of knowledge graphs have also been conducted in the TCM field. Yu et al.\textsuperscript{[44]} put forward a framework for the construction of a large-scale TCM knowledge graph for the China Academy of Chinese Medical Sciences. Jia et al.\textsuperscript{[45]} investigated the data sources, research content, and application prospects for constructing the TCM knowledge graph.

There is an easy way to understand the knowledge graph in the context of Chinese medicine: the diagram of the five elements commonly used in TCM theory is a type of knowledge graph, as shown in Figure 1. This figure clearly illustrates the allelopathy among the five elements and the relationships between the five elements and the syndromes. The knowledge graph has the advantage of avoiding obscure language and facilitating systematic understanding and acquisition of knowledge. However, the construction of a knowledge graph requires the text data to be structurally distributed. As the text data in ancient TCM books are barely structurally distributed, research on the construction of a large-scale TCM knowledge graph is still at the exploratory stage. In conclusion, the technology of the knowledge graph provides a method of extracting structured knowledge from massive volumes of texts and images. It is becoming the core driving force for the development of AI in Chinese medicine.

A Study Protocol for Analyzing Ancient Traditional Chinese Medicine Books with Artificial Intelligence Technologies

Based on the characteristics of the ancient TCM books, we propose a study protocol for analyzing the ancient TCM books with AI technologies. There are three main steps, as shown in Figure 2: (1) a database of the ancient TCM books will be constructed; (2) fuzzy logic modeling and cognitive linguistic analysis will be used to analyze the semantics based on the electronic database; (3) a deep learning algorithm with fuzzy logic will be used to extract knowledge entities and their relationships from the ancient books; and (4) a knowledge graph will be drawn and knowledge fusion, knowledge reasoning, and semantic search will be applied to analyze the diagnosis and treatment principles in TCM.

The AI technologies may provide a new method for highly efficient use of the medical resources in the ancient TCM books. Furthermore, a semantic integration service with knowledge-centered resources may also be formed, providing high-value references for TCM research on the diagnosis and treatment of diseases.

In this protocol, the most challenging thing is how to combine fuzzy logic modeling with deep learning algorithms. To solve this problem, the fuzzy mathematical model should be applied first before the deep learning process, as shown in Figure 3. The processed data of the database, which is the input layer, should go through the fuzzy layer first. The output of the fuzzy layer will then be used as the input for deep learning instead of the original data. After continuous iteration optimization, the output of deep learning will be the last result. The deep learning should begin with high-quality small sample data that has been fully standardized. As a character is the smallest semantic unit of the Chinese language, this algorithm will use a single Chinese character structure to capture character-level features.

Conclusion

This study reviewed recent advances in the study of ancient TCM books. It can be seen that advanced analysis techniques for text data, such as database construction, cognitive linguistic analysis, and data mining, present certain advantages for summarizing and organizing the principles of diagnosis and
Recent advances in the study of TCM ancient books

As deep learning and the knowledge graph are increasingly and more extensively applied in the medical field, excavating the essence of the knowledge in the ancient TCM books is of great significance. The knowledge graph is an AI technology based on semantic analysis, making it very suitable for processing and analyzing text data. These AI techniques are thought to be efficient in processing the data in the ancient TCM books and mining the most valuable medical information from the vast amount of knowledge resources in ancient TCM books.

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Conflicts of interest
There are no conflicts of interest.

REFERENCES
1. Yang Q, Tian S, Ma M. Research and thinking on the construction of ancient literature database of traditional Chinese medicine. China Med Herald 2018;15:119-22.
2. Zhao S, Yang Y, Chen J, Wu T. The Status Quo and Necessity of Digitization of Ancient Chinese Medicine Books. China Market, 2015:191-2.
3. Li Bing, Fu Y, Zhang H, Li B, Wang R, Sun H. The Construction and Service of Ancient Books Database in the Trade of Traditional Chinese Medicine. Western Journal of Traditional Chinese Medicine, 2014,27:85-7.
4. Xue R, Fang Z, Zhang M, Yi Z, Wen C, Shi T. TCMD: Traditional Chinese medicine integrative database for herb molecular mechanism analysis. Nucleic Acids Res 2013;41:D1089-95.
5. Gao C, Zhao B. Review of database about ancient traditional Chinese
medical books. J Chengdu Univ Tradit Chin Med 2012;35:84-7.
6. Hu D, Zhu Q. Problems in digitalization of ancient medical documents and measures for their solution. Chin J Med Lib Inf Sci 2017;26:1-6.
7. Zhu Y. Opportunities and challenges of traditional Chinese medicine ancient books in the era of big data. Chin J Lib Inf Sci Tradit Chin Med 2014;38:12-4.
8. Lu Z, Peng J. Professor Ren Yingqiu talks about learning ancient Chinese. J Tradit Chin Med 1986;3:74.
9. Sun W. Learning Ancient Chinese is an Important Thrust to Enhance the Language and Cultural Attainment of Chinese Medicine Graduate Students. In: Chinese Medicine Association Ancient Chinese Literature Seminar; 2013.
10. Wang L. A Study on the Development of TCM Theory Based on Ancient Chinese Philosophy and the Simulation Method of Doctors’ Thinking. Beijing University of Chinese Medicine; 2011.
11. Cai Z. Outline of research on cultural foundation and theoretical system of traditional Chinese medicine (II)—cultural basis: Research on ancient Chinese ecological philosophy. J Mianjiang Med Univ 2005;26:49-52.
12. Yin P, Pang J. Standardization of Chinese medicine terminology and its hierarchical processing. Chin J Basic Med Tradit Chin Med 2008;12:901-2.
13. Clark A. Whatever next? Predictive brains, situated agents, and the future of cognitive science. Behav Brain Sci 2013;36:181-204.
14. Gao L. A Study of Qi in the Human Body Based on Conceptual Metaphor and Data Mining. Beijing University of Chinese Medicine; 2018.
15. Zadeh L. Toward a generalized theory of uncertainty (GTU) – An outline. Inf Sci 2005;172:1-40.
16. Peng Y, Li H, Shen X. Application of fuzzy logic in tongue diagnosis of traditional Chinese medicine – A case study of classification of moss of chronic hepatitis b by fuzzy logic. J Tradit Chin Med Manage 2013;21:347-8.
17. Tan Z, Yao X. Study on ambiguity translation of the inner canon of Huangdi from the perspective of translation as adaptation and selection. Chin J Basic Med Tradit Chin Med 2018;24:1311-4.
18. Li S, Zhang H, Wang L, Wang X, Dong Y, Meng H. Fuzzy optimization classification model in Chinese medicine constitution of multattribute skin indexes. J Frontiers Comput Sci Technol 2016;10:995-1002.
19. Wu X, Kumar V, Quilran R, Ghosh J, Yang Q, Motoda H, et al. Knowl Inf Syst 2008;14:1-37.
20. Wu X, Zhu X, Wu G, Ding W. IEEE Transact Knowl Data Eng. 2014;26:97-107.
21. Ji M. Study on Compatible Rules and Application Principles of Herbs for Nourishing Yin in Ming-Qing Dynasty Based on Data Mining Technology. Nanjing University of Chinese Medicine; 2016.
22. Wang B, Liu C. Analysis on Prescription Regularity of Damp-Heat by Data Mining. Asia-Pacific Traditional Medicine 2019;164-6.
23. Huang X. Research on the Abnormality and Its Relationship of Treatise on Febrile Diseases Based on Data Mining. Beijing University of Chinese Medicine; 2017.
24. Gao L, Jia C. Research on the compatibility principles of regulating Ying and Wei based on the data of literature of encyclopedia of traditional Chinese medicine. Fujian J Tradit Chin Med 2018;49:47-9.
25. Ji T, Su S, Shang E, Qian D, Tang Y, Duan J, et al. Determining the rules of traditional Chinese medicine on treatment of consumptive thist based on association rules mining. China J Tradit Chin Med Pharm 2016;31:4982-6.
26. Yang Y. A Method of Knowledge Extraction and Association from Unstructured Texts. Zhejiang University; 2010.
27. Li M, Zhou Q, Luo X, Zhu B. Research on the construction of semantic retrieval system of traditional Chinese medicine literature database. Lishizhen Med Materia Med Res 2017;28:2557-9.
28. Jordan MI, Mitchell TM. Machine learning: Trends, perspectives, and prospects. Science 2015;349:255-60.
29. Akay M. Support vector machines combined with feature selection for breast cancer diagnosis. Expert Syst Applications 2009;36:3240-7.
30. Vemuri P, Gunter JL, Senjum ML, Whitwell JL, Kantarci K, Knopman DS, et al. Alzheimer’s disease diagnosis in individual subjects using structural MR images: Validation studies. Neuroimage 2008;39:1186-97.
31. Chen M, Hao Y, Hwang K, Wang L, Wang L. Disease prediction by machine learning over big data from healthcare communities. IEEE Access 2017;5:8869-79.
32. Nguyen T, Khosrovi A, Creighton D, Nahavandi S. Classification of healthcare data using genetic fuzzy logic system and wavelets. Expert Syst Appl 2015;42:2184-97.
33. Hu J, Ding Y, Kan H. Tongue body constitution classification based on machine learning. J Jiamusi Univer (Natural Sci Ed) 2018;36:709-13.
34. Lv Q, Gao Z. Research on application of data mining in TCM Constitution analysis. J Shaanxi Coll Tradit Chin Med 2018;41:93-7.
35. Xiao X. Research on Clinical Symptom Data Elements of Traditional Chinese Medicine Based on Machine Learning. Hunan University of Chinese Medicine; 2018.
36. Gulshan V, Peng L, Coram M, Stumpe MC, Wu D, Narayanaswamy A, et al. Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. JAMA 2016;316:2402-10.
37. Esteva A, Kuprel B, Novoa RA, Ko J, Swetter SM, Blau HM, et al. Dermatologist-level classification of skin cancer with deep neural networks. Nature 2017;542:115-8.
38. Zhang X, Shi Q, Wang B, Wang B, Wang Y, Chen Li, et al. Review of machine learning algorithms in traditional Chinese medicine. Comput Sci 2018;45:32-6.
39. Nickel M, Murphy K, Tresp V, Gabrilovich E. A review of relational machine learning for knowledge graphs. Proce IEEE 2016;104:11-33.
40. Paulheim H. Knowledge graph refinement: A survey of approaches and evaluation methods. Semantic Web 2016;8:489-508.
41. Abdelaziz I, Fokoue A, Hassanzadeh O, Zhang P, Sadoghi M. Largescale structural and textual similaritybased mining of knowledge graph to predict drug–drug interactions. J Web Semant 2017;44:104-17.
42. Sang S, Yang Z, Liu X, Wang L, Lin H, Wang J, et al. GrDeL: A knowledge graph embedding based method for drug discovery from biomedical literatures. IEEE Access 2019;7:8404-15.
43. Bean D, Wu H, Iqbal E, Dzahini O, Ibrahim Z, Broadbent M, et al. Knowledge graph prediction of unknown adverse drug reactions and validation in electronic health records. Sci Rep 2017;7:16416.
44. Yu T, Liu J, Jia L, Zhang Z, Yang S, Liu L, et al. Research on the Construction of Big Knowledge Graph for Traditional Chinese Medicine. China Digital Med 2015;10:80-2.
45. Jia L, Liu J, Yu T, Dong Y, Zhu L, Gao B, et al. Construction of Traditional Chinese Medicine Knowledge Graph. J Med Inf 2015;36:51-3.