Research on the Functions of Mainstream Meta-Analysis Software and Their Extended Applications in Domain Knowledge Discovery*

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Abstract

Objective: To assess the future development trends of Meta-analysis and provide guidance for domain knowledge discovery based on Meta-analysis.

Methods: Systematically compare the features of commonly used international Meta-analysis software and their differences in computational, graphical, and other functions, and propose the essential characteristics that Meta-analysis tools suitable for domain-specific knowledge discovery should possess, using the resources and environmental sciences domain as an example.

Results: Through analysis of specific domains, a basic framework is conceptualized for developing a literature synthesis and integration tool featuring a standardized user interface, simplified computational procedures, accurate analysis results, and accessibility to general users.

Limitations: The proposed concept has not been systematically implemented through platform construction to fully validate its feasibility; some inherent weaknesses of Meta-analysis, such as the "apples and oranges" problem, cannot be effectively resolved in domain knowledge discovery based on Meta-analysis.

Conclusion: It is necessary to construct a platform for domain knowledge discovery based on Meta-analysis to guide the extended application of domain literature knowledge discovery.

Full Text

Research on the Functions of Mainstream Meta-Analysis Software and Their Extended Applications in Domain Knowledge Discovery*

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Abstract: [**Objective**] To investigate and judge the future development trends of meta-analysis, and to provide reference for domain knowledge discovery based on meta-analysis. [**Methods**] The characteristics and differences in functions such as computation and graphing of commonly used international meta-analysis software were sorted out and compared. Taking the discipline of resources and environmental science as an example, the basic features that a meta-analysis tool suitable for knowledge discovery in specific domains should possess were proposed. [**Results**] Through analysis of specific domains, the basic conception was developed for a literature-integrated tool with a standardized operation interface, simple computational steps, accurate analytical results, and orientation toward the general public. [**Limitations**] The proposed idea has not yet been systematically implemented through construction of a platform, and its feasibility has not been fully verified; inherent weaknesses of meta-analysis, such as the "apple and orange" problem, cannot be effectively resolved in domain knowledge discovery based on meta-analysis. [**Conclusion**] A platform for domain knowledge discovery needs to be built on the basis of meta-analysis, so as to guide the extended application of domain literature knowledge discovery.

Keywords: meta-analysis; knowledge discovery; software comparison; resources and environment
Classification number: G250

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1 Introduction

As a literature-integrated method that combines qualitative and quantitative approaches, the basic idea of meta-analysis emerged in the 1930s. The generally accepted definition of meta-analysis was proposed by Fleiss et al.[1], namely that meta-analysis is a class of statistical methods used to compare and synthesize research conclusions obtained for the same domain problem. Whether the conclusions obtained through comparison and synthesis are meaningful depends on whether these studies satisfy specific conditions. Meta-analysis has played an important role in domain knowledge discovery. However, existing meta-analysis research in the field of library and information science has mainly relied on manually implemented operational procedures, has rarely been realized with the aid of software, lacks a macroscopic grasp of the process of knowledge discovery in the library and information "big environment," and has not formed a process-oriented data-processing method or platform design. In view of this point, the authors intend to compare and analyze existing meta-analysis software and tools that can be used for reference in the field of library and information science. At the same time, they propose the development of a meta-analysis tool for domain knowledge discovery, which has a certain necessity and feasibility for promoting knowledge services in library and information science.

At present, domestic and international research on the issue of domain knowledge discovery mainly conducts specific knowledge mining for particular disciplinary domains and explains its specific implementation methods. There is a lack of macroscopic process grasp of knowledge services in the library and information "big environment"; traditional meta-analysis software has not been applied to domain knowledge discovery, and no meta-analysis platform suitable for specific domains has been developed. Benites et al.[2], through association-rule mining of inter-ontology and intra-ontology relations, discovered relationships among different biological ontologies or within parts of a single ontology, thereby providing users with new biological knowledge. Moreno et al.[3] constructed a specific biomedical ontology for Alzheimer's disease and promoted research on disease mechanisms through modeling. Tseng et al.[4], based on gene-chip data and the conceptual hierarchy of gene ontology, proposed a new data-mining method to explore multi-level gene association rules, thereby discovering hidden multi-level gene association rules. On the basis of existing research results, the authors conduct a comparative study of current mainstream meta-analysis software oriented toward domain knowledge discovery, and accordingly put forward a conception for developing meta-analysis software suitable for knowledge discovery in specific domains.

2 Comparison of the Basic Characteristics of Mainstream Meta-Analysis Software

With the continuous popularization of meta-analysis methods, meta-analysis software has also increasingly···

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Review and Evaluation

Zhao Duoyang and Zeng Xian 涛 et al.[5] compared the characteristics and functions of 11 online meta-analysis software packages. By comparing the basic features, functions, and calculation results of the software, they found that no single package simultaneously had both strong computational capability and graphing functions. Considering the extended application of meta-analysis in the discipline of resources and environmental science, meta-analysis is divided into five categories, and the basic characteristics of each software package in implementing different types of meta-analysis are compared, as shown in Table 1.

Table 1 Basic characteristics of commonly used meta-analysis software

Basic attribute	Type of meta-analysis	Software name
Programming software—free	Almost all meta-analyses	R
		BUGS
		JAGS
		Stan
	Meta-analysis of binary data and continuous data	Meta-Stat
		EasyMA
Programming software—paid	Almost all meta-analyses	Stata
		Excel
		SAS
		MATLAB
		SPSS
Non-programming software—free	Meta-analysis of indirect comparisons	ITC
	Meta-analysis of binary data, diagnostic studies, and continuous data	Meta-Analyst
	Meta-analysis of binary data, diagnostic studies, and single-group rates	Meta-DiSc
	Meta-analysis of evidence from randomized controlled trials with direct comparisons of binary and continuous data	TSA

Basic attribute	Type of meta-analysis	Software name
	Meta-analysis of binary and continuous data, indirect comparisons, and network meta-analysis	GeMTC
		ADDIS
	Meta-analyses other than indirect comparisons and network meta-analysis	RevMan
		MIX
Non-programming software—paid	Quantitative meta-analysis mainly used in ecology	Meta-Win
	Meta-analyses other than indirect comparisons and network meta-analysis	CMA
		StatsDirect

(1) Meta-analysis of a single rate. In medicine, this is commonly used to explore prevalence, detection rates, awareness rates, and case-fatality rates. The characteristic of this type of data is that there are only the number of events in a single group and the total number of observations, with no control group. At present, there are already domestic literature introductions for Stata software[6], R software[7], and RevMan software[8].

(2) Meta-analysis of simple P values. When the included studies provide only P values, the required data cannot be calculated according to the calculation methods in the *Cochrane Handbook for Systematic Reviews of Interventions*[9]. When synthesis is needed in practice, one may consider combining only the P values.

(3) Cumulative meta-analysis. Cumulative meta-analysis refers to treating research data as a continuous unified whole and, according to the chronological order in which studies were conducted, promptly incorporating newly emerging studies into the original data[10].

(4) Network meta-analysis (Network Meta-analysis, NMA). In recent years, both its methodology and production software have developed rapidly[11-13]. Compared with traditional meta-analysis, because NMA includes many interventions, a large amount of data, and complex internal structures, its dependence on software is more pronounced[14]. Although several software packages can currently implement NMA, there is still no software that can independently and comprehensively perform NMA cal-

culations and graphing[15]; multiple software packages must be used in combination.

(5) Meta-regression analysis. Meta-regression analysis is used to evaluate the magnitude and sources of heterogeneity among studies. It is mainly conducted through the combination of effect sizes for multiple factors, and when the number of studies included in the meta-analysis is 10 or more[10].

By searching CNKI, Web of Science, and other websites, methods such as analyzing the software used in published meta-analysis literature were applied. Ultimately, 22 software packages were included; their basic characteristics are detailed in Table 1, and the author focuses on analyzing 11 commonly used packages, as shown in Table 2. Among the 22 software packages, the general-purpose programs for meta-analysis include Stata, R, SAS, Excel, SPSS, BUGS (including WinBUGS and OpenBUGS), and MATLAB[16].

Table 2 Comparison of 11 commonly used meta-analysis software packages

Category	Function / item	Stata	R	Excel	SAS	MATLAB	RevMan	MIX	CMA	Meta-Win	MA	MD
Software grade	Basic level						√		√		√	
	Advanced level					√		√		√		√
	Professional level	√	√	√	√							
Data format	Importable data	√	√	√	×	√	×	√	√	√	√	√
	Multiple data formats	√	√	√	√	√	√	×	√	√	×	×
Variable type	Dichotomous variables	√	√	√	√	√	√	√	√	√	√	×
	Continuous variables	√	√	√	√	√	√	√	√	√	√	×
Analysis type	Analysis of rates	√	√	√	×	√	√	√	√	×	√	√

Category	Function / item	Stata	R	Excel	SAS	MATLAB	RevMan	MIX	CMA	Meta-Win	MA	MD
	Simple *P*-value analysis	√	√	√	√	√	×	×	√	√	×	×
	Cumulative meta-analysis	√	√	√	√	×	×	√	√	√	√	×
	Network meta-analysis	√	√	√	√	×	×	×	×	×	×	×
	Meta-regression analysis	√	√	√	√	×	×	×	√	√	√	√
Heterogeneity test	P	√	√	√	√	√	×	×	×	×	×	×
	Q	×	×	√	√	√	√	√	√	√	√	√
	I^2	×	×	√	√	√	√	√	√	×	√	√
Publication bias test	Begg's test	√	√	√	√	√	×	×	×	√	×	×
	Egger's test	√	√	√	√	√	×	×	√	×	×	×
Meta-analysis model	Fixed-effects model	√	√	√	√	√	√	√	√	√	√	√
	Random-effects model	√	√	√	√	√	√	√	√	√	√	√
	Mixed-effects model	√	√	√	√	√	×	×	√	×	√	√
Graphing function	Forest plot	√	√	√	√	√	√	√	√	√	√	√
	Funnel plot	√	√	√	√	√	√	√	√	√	√	×

Category	Function / item	Stata	R	Excel	SAS	MATLAB	RevMan	MIX	CMA	Meta-Win	MA	MD
	L' Abbé plot	√	√	√	√	×	×	√	×	×	×	×
	Star plot	√	√	√	√	×	√	×	×	√	√	×

(Note: √ indicates that the software has this function; × indicates that it does not, meaning that the function has not yet been developed in the software or that no one has yet explored it.)

Each software package has its own distinctive style, but also has certain shortcomings. Except for the general-purpose software Excel, none of the other software packages has a Chinese version. RevMan is highly usable and can integrate statistical computation with systematic evaluation, but its interface is complex and its flexibility is poor. Stata is powerful and can implement many types of meta-analysis, but it is complicated to operate and requires calling the corresponding commands and writing programs[^{17}]. The SAS and SPSS systems are large and structurally complex, lack fixed modules, are difficult for non-statistics professionals to use proficiently, and genuine versions are expensive and difficult to obtain[^{18}]. SAS, SPSS, and MATLAB are not as user-friendly as Stata and R for meta-analysis, and they are more difficult to learn, so their user communities are relatively small. Therefore, the authors will compare and summarize existing meta-analysis software in order to develop a set of meta-analysis software applicable to multiple disciplines and capable of implementing multiple functions.

2.1 Programming software

According to whether programming is required, meta-analysis software can also be divided into programming software and non-programming software. Programming software includes Stata, R, Excel, SAS, MATLAB, Meta-Stat, BUGS, JAGS, Stan, EasyMA, and SPSS; the rest are non-programming software.

Stata simultaneously has the characteristics of data management, statistical analysis, graphing, matrix computation, and a programming language[^{19}]; its operating systems also include Linux and Mac[^{20}]. Applications of Stata in meta-analysis have gradually been developed, and it can implement multiple analytical functions[^{21}]. R software completes meta-analysis through corresponding packages; among them, the Metafor package is the only package among R meta-analysis packages that can perform fitting operations for mixed-effects models[^{22}]. Excel has relatively strong database editing and statistical-analysis capabilities as well as convenient graphing functions[^{23}]. Implementing meta-analysis in Excel has gradually received attention, and foreign scholars have carried out some explorations[^{24}]. In China, Wang Fengjuan[^{25}] used Excel' s statistical functions to write Excel calculation programs and found that Excel software, when used for meta-analysis, has the characteristics of accuracy, convenience, stability, and extensibility.

Review and Evaluation

SAS (Statistical Analysis System) software has comprehensive functions for data access, data management, data analysis, and data presentation[^{26}], and can flexibly process various kinds of data through different coding approaches[^{27}]. The macros of SAS software can reduce the amount of input text and modularize programs[^{28}]. Hedges et al.[^{29}-30] used SAS software to develop a set of programs for calculating statistical power in meta-analysis; Cafri et al.[^{31}] jointly developed the MetaPower macro in 2009, specifically for calculating statistical power in meta-analysis. MATLAB software is widely used in fields such as mathematics, medical statistics, and mathematical simulation. Hu Xiaogang et al.[^{32}] wrote a program based on MATLAB for implementing meta-analysis of a single rate; nonprofessionals need only replace the data to implement it conveniently. Shang Jing et al.[^{33}] verified, through example analysis, the feasibility and effectiveness of using MATLAB programs to obtain results for meta-analysis of a single rate, and completed tests for heterogeneity and publication bias. Huang Qingshui et al.[^{34}], based on MATLAB software and according to diagnostic tests, carried out numerical statistical inference using the SROC curve method for systematic evaluation.

2.2 Non-programming software

RevMan (Review Manager) software has been widely used in systematic reviews. RevMan is the only meta-analysis software that can import data into GRADEprofiler software for evidence-quality grading[^8]. CMA (Comprehensive Meta-Analysis) software is professional software for meta-analysis. The data and calculated results entered in its results can be displayed in different colors; it can generate high-definition images, allows adjustment of color, layout, and font, and can be converted into Word or PPT formats[^{35}]. Meta-Analyst (MA) can conduct meta-analyses of dichotomous and continuous variables and of diagnostic tests; in addition, it can perform meta-analysis of single rates, cumulative meta-analysis, and sensitivity analysis by excluding individual studies[^{36}]. MetaWin is a quantitative meta-analysis software package designed mainly for ecologists. Gurevitch published the first monograph on meta-analysis in ecology and, in collaboration with others, released the MetaWin software package in 1997; however, MetaWin can perform only quantitative meta-analysis[^{37}]. Meta-DiSc (MD) is specialized software for meta-analysis of diagnostic tests[^{38}]. It can be used for meta-analysis in the evaluation of multiple diagnostic or screening tests, employing multiple calculation methods for meta-analysis[^{39}], and has now been applied or cited in papers in many high-level journals[^{40}-42].

3 Comparison of Meta-analysis Software Functions Oriented Toward Knowledge Discovery

The authors compare the strengths and weaknesses of 11 commonly used software packages in terms of basic functions such as computational functions and graphing functions. To further apply meta-analysis software to knowledge discovery, on the basis of these basic functions, the authors further compare the application functions of 11 mainstream meta-analysis software packages in knowledge discovery, so as to promote the application of quantitative tools in the field of knowledge discovery.

3.1 Comparison of basic functions

The strengths and weaknesses of 11 commonly used software packages are compared in terms of computational functions and graphing functions, as shown in Table 3.

(1) Computational functions

Computational capacity is one of the most basic elements of statistical software. With continuous innovation in meta-analysis methodology, differences arising from the software itself and from the incorporation of the latest methods have given currently available software their own distinctive features. The authors conduct a comparative analysis of different characteristics of meta-analysis, such as fixed-effect models and random-effects models[^{43}]. For meta-analysis of rates, Stata, R, RevMan, and others can all be used. Stata is often used for cumulative meta-analysis; because R has rich program packages, it is often used for network meta-analysis. In addition, different software packages each have advantages and disadvantages. RevMan is highly usable and can integrate statistical analysis with the writing of systematic reviews, but it can only judge visually from a funnel plot whether publication bias exists and cannot quantitatively analyze the magnitude of publication bias[^{19}]. R has relatively comprehensive functions: in addition to meta-analysis of rates, it can also perform meta-regression and so on, but programming is required. Although Stata is currently one of the most highly recommended software packages for meta-analysis, it has no fixed module for meta-analysis of a single rate. While R, Stata, and SAS have the ability to operate independently, they can not only flexibly call external software but also be conveniently called by external software. Because of differences in use pathways, these software packages also differ in the methodologies commonly used in meta-analysis. For example, in network meta-analysis, Stata uses its own computation with the `metareg` and `mvmeta` modules[^{44}], whereas calls to external software commonly use WinBUGS; when called by external software, implementation can be achieved through R software or SAS software.

(2) Graphing functions

Whether software has the ability to draw high-quality graphics has also become one of the indicators for measuring software quality, functionality, and operability. Meta-analysis often requires drawing the following four types of figures: forest plots, funnel plots, L' Abbé plots, and star plots. These four types of figures carry different information and play different roles in meta-analysis. Stata, R, Excel, and SAS can draw all four types of figures; the resulting graphs are relatively aesthetically pleasing, but programming is needed for auxiliary adjustment, and the implementation process is relatively complex. CMA, MetaWin, Meta-Analyst, Meta-DiSc, and other software specifically designed for meta-analysis each have their own emphasis in graphing functions, and their operation is flexible and simple.

3.2 Comparison of applications in knowledge discovery

Knowledge discovery has been application-oriented from the outset; this characteristic highlights the importance of knowledge-discovery software—the bridge between the theory, technology, and applications of knowledge discovery—and of tools. With the continuous innovation and development of knowledge discovery and data-mining theories and technologies, knowledge-discovery software and tools have continually ⋯

Table 3 Comparison of the Functions of Commonly Used Meta-Analysis Software

Software name	Computational functions: advantages	Computational functions: disadvantages	Graphing functions: advantages	Graphing functions: disadvantages
Stata	Great freedom; comprehensive and rich functions; achieves coordination between ease of use and functionality	The fixed module for single-proportion meta-analysis is not easy to use	Comprehensive graph types; the graphs produced are simple and clear	Graphs are not sufficiently attractive; graph adjustment requires programming and is not flexible enough

Software name	Computational functions: advantages	Computational functions: disadvantages	Graphing functions: advantages	Graphing functions: disadvantages
R	Comprehensive and rich functions; for network meta-analysis, it has the most methods, the most flexible presentation, and the most complete functions	Programming is complex and difficult, with relatively high requirements for users	Graphs are relatively refined and comprehensive	Graphing and analysis are independent of each other; users must define the types of graphs to be generated themselves
Excel	Very high freedom; comprehensive and rich functions	The statistical-analysis programming process is complex, and quantitative evaluation of publication bias has not yet been implemented	Graph types are comprehensive, refined, and easy to adjust	The data preprocessing required for graphs is mostly completed manually, and formula editing is not intuitive
SAS	Very high freedom; comprehensive and rich functions; programs are easy to read and facilitate modification, transplantation, and reuse; often used for network meta-analysis	Programming is complex and difficult, with relatively high requirements for users	Graphing is flexible, and the graphs produced are very attractive	The template language behind the graphs is large and difficult to use, making advanced functions hard to master

Software name	Computational functions: advantages	Computational functions: disadvantages	Graphing functions: advantages	Graphing functions: disadvantages
MATLAB	Very high freedom; the computational accuracy of results can be controlled freely; often used for single-proportion meta-analysis; computational accuracy can be freely controlled through programs; compatibility with other languages is excellent; often used for single-proportion meta-analysis	Programming is complex and difficult, with relatively high requirements for users	Powerful graphing functions; the graphs produced are more attractive than those of similar software	Graph adjustment requires programming and is not flexible enough

Software name	Computational functions: advantages	Computational functions: disadvantages	Graphing functions: advantages	Graphing functions: disadvantages
RevMan	Highly usable, relatively common, and easy to learn	Cannot quantitatively analyze the magnitude of publication bias; cannot perform meta-regression analysis, cumulative meta-analysis, diagnostic analysis, etc.	Exported images require little retouching	Functions are single-purpose; cannot create L' Abbé plots; forest plots have certain problems in display; the interface and operation are complicated and prone to errors
MIX	Mainly embedded in Excel to implement meta-analysis; simple to operate	Lacks flexibility; cannot perform high-level analyses such as large-scale data analysis and bivariate analysis	Rich variety of graph types	Graphs are not sufficiently attractive and lack flexibility
CMA	Statistical software specifically for meta-analysis; requires no programming; more flexible and easy to operate	Cannot perform diagnostic analysis, etc.	Images are clear and attractive; color, layout, and fonts can be adjusted and converted into Word or PPT formats	Graph types are limited

Software name	Computational functions: advantages	Computational functions: disadvantages	Graphing functions: advantages	Graphing functions: disadvantages
Meta-Win	Specialized for ecology researchers to conduct quantitative meta-analysis; simple to operate and relatively complete in functions; can perform resampling tests	Cannot set research-quality weights for effect sizes; cannot perform qualitative meta-analysis	Rich variety of graph types	Graphs are not sufficiently attractive and lack flexibility
Meta-Analyst	Statistical software specifically for meta-analysis; requires no programming; more flexible and easy to operate	Dedicated to binary variables, continuous variables, and diagnostic analysis; lacks other functions	Rich variety of graph types	Graphs are not sufficiently attractive and lack flexibility

Software name	Computational functions: advantages	Computational functions: disadvantages	Graphing functions: advantages	Graphing functions: disadvantages
Meta-DiSc	Specialized for diagnostic-test meta-analysis; supports visual-window operation; among current non-programming software, it is the best software for diagnostic meta-analysis	Lacks flexibility; cannot perform high-level analyses such as large-scale data analysis and bivariate analysis	Can generate forest plots, ROC planes, and SROC curve graphs	Graphs are not sufficiently attractive and lack flexibility

···is gradually becoming more widespread and more complete, and users' needs are also continuously increasing. Each knowledge-discovery task has numerous implementation technologies and methods, mainly including inductive learning methods, statistical-analysis methods, machine-learning methods, fuzzy-theory methods, database technologies, visualization technologies, etc.[45] In a specific knowledge-discovery task, the characteristics of the data object determine the choice of mining algorithm and thus determine the effectiveness of knowledge discovery; therefore, it is necessary to evaluate the applicability of specific implementation algorithms.

A comparative analysis of the application of 11 commonly used meta-analysis software packages in knowledge discovery found that only five general-purpose meta-analysis software packages—Stata, R, Excel, SAS, and MATLAB—have some applications in knowledge discovery, whereas software specifically designed for meta-analysis is less often applied to knowledge discovery (see Table 4). In knowledge discovery, meta-analysis software mainly implements quantitative statistical-analysis functions. The basic process of knowledge discovery includes word-frequency statistics for words, phrases, and thematic concepts in the literature, semantic filtering, and co-word clustering analysis. Although statistical tool software used for knowledge discovery, such as SAS and SPSS, has already become quite mature, there are still very few software tools required for the entire knowledge-discovery process, and these software packages often can implement only a single process and complete only one link in knowledge mining. At present, there is still no free software that guides users through the complete knowledge-discovery process. Moreover, the process is relatively complex and has not yet become widespread in scientific research. The knowledge-discovery process is an area that information professionals should actively explore. Information researchers can combine knowledge from information science and statistics···

Review and Evaluation

Table 4 Applications of Typical Meta-Analysis Software in Knowledge Discovery

Software name	Applications in knowledge discovery	
	Technical methods	Functions implemented
Stata	Techniques such as decision trees, multiple regression, and neural networks.	General-purpose data-mining software.
R	Multivariate statistical analysis methods such as correlation analysis, multidimensional scaling analysis, principal component analysis, factor analysis, and cluster analysis.	Clustering, word-cloud generation, and other text-mining visualizations. Open R repositories for literature data mining can implement such functions as literature retrieval, construction of co-occurrence matrices, and partial visualization, facilitating analysis of the correlations among subject terms.
Excel	Frequency analysis, i.e., word-frequency statistics for individual words, phrases, and thematic concepts.	Researching the content and research hotspots of a discipline; often combined with TDA for text mining and visualization, or integrated with other tools. Macros can implement functions such as text extraction.

Software name	Applications in knowledge discovery	
SAS	Techniques such as decision trees, multiple regression, and neural networks; co-citation clustering analysis and multidimensional scaling analysis of keywords/subject terms/patent IPC technical terms and highly cited references.	General-purpose data-mining software; it can also be integrated with SAS data warehouses and OLAP to achieve "end-to-end" knowledge discovery, from submitting data, grasping data, to obtaining answers and visualization.
MATLAB	Multivariate statistical analysis methods such as correlation analysis, multidimensional scaling analysis, principal component analysis, factor analysis, and cluster analysis; calculations such as term co-occurrence and transformation of document co-citation Ochiai dissimilarity matrices.	Implements data-mining functions such as association analysis, classification analysis, cluster analysis, and automatic prediction, as well as knowledge visualization.

Knowledge: content-analysis methods and Meta-analysis methods are used to explore the process of knowledge discovery and to discuss this field.

As can be seen from Table 4, under specific circumstances some software can be used to complete certain knowledge-discovery functions, such as data mining. Examples include MATLAB' s neural-network toolbox and some other statistical software. However, the design objectives of these software packages themselves are not knowledge discovery. Although these mainstream Meta-analysis software packages have, to a greater or lesser extent, certain shortcomings in knowledge discovery and have not yet been widely recognized by researchers, their powerful data-analysis functions give them broad prospects for promotion in future scientific development and will greatly promote scientific progress.

4 Case Analysis of Meta-Analysis Software Suitable for Domain Knowledge Discovery

Through a multidimensional comparison of existing Meta-analysis software, it can be seen that a good knowledge-discovery-oriented tool should be able to connect with as many database management systems and other types of data sources as possible. At the same time, it should also be able to integrate with other software tools, such as query tools and visualization tools. To promote the application of knowledge discovery across multiple disciplines, the author takes resource and environmental science as an example, integrates the advantages and disadvantages of existing Meta-analysis tools, and identifies the basic characteristics of Meta-analysis tools in resource and environmental science, so as to guide the extended implementation of Meta-analysis software for knowledge discovery in multiple domains.

4.1 Current Application Status in Knowledge Discovery in Resource and Environmental Science

The main data types in resource and environmental science are not binary classified controlled data. Its research form involves two-dimensional positioning in the temporal and spatial domains and has distinctive longitude–latitude characteristics. Therefore, the extension of Meta-analysis methods in this discipline has unique significance.

In the 1990s, Meta-analysis methods and tools began to be applied in the field of resource and environmental science. Gurevitch et al.[46] first published the first monograph on Meta-analysis in ecology in 1993 and subsequently released the MetaWin software package for knowledge discovery in ecology. In 1998, Peng Shaolin et al.[47] first introduced the Meta-analysis method into China' s ecological community and used the MetaWin software package for ecological analysis[48-49]. They also applied Meta-analysis to comprehensive studies of controlled experiments, with the purpose of determining whether the treatments in experiments produced positive or negative effects on the experimental objects, as well as the magnitude of the effects; and whether results from different independent experiments under the same topic were consistent and the degree of variation, among other questions[37]. In the field of historical geography, in order to explore the main causes of discrepancies in research on historical climate change, Ge Quansheng et al.[50-54] used temperature-change sequences reconstructed by different authors from historical documents as research data, employed tools such as Excel and MATLAB, and adopted statistical methods including correlation analysis, cluster analysis, and hypothesis testing to conduct quantitative comprehensive analysis of the sequences established by different scholars, thereby achieving the extraction of individual research conclusions and the purpose of knowledge discovery. Taking Beijing as an example, Zhang Xiaojing[55] studied the application of data-mining technology in the field of water resources through SAS, but only used statistical-analysis methods to study the application of data mining in water use and other aspects, without studying knowledge-discovery methods such as neural networks, decision trees, and association rules. Qin Bijun[56] used MATLAB-based BP neural networks to effectively predict carbon emissions from energy consumption. Liu Hanlin[57] adopted the Meta-analysis method and used SPSS and RevMan software to examine the impact of land-reclamation project construction on the marine ecological environment. Zinn et al.[58] used SAS software to conduct a Meta-analysis of the trends and magnitudes of the effects of different management practices in Brazil on soil organic carbon. Zhang Ling et al.[59] used Stata software and applied Meta-analysis and multiple regression analysis.

methods to construct a meta-analytic value-transfer model for ecosystem services in China' s lake and marsh wetlands. Chen Renjie[^{60}] used R software to study the health-hazard characteristics of compound air pollution in China. Jin Xin et al.[^{61}] used R software to conduct a meta-analysis of hygiene indicators for centralized air-conditioning ventilation systems in public places in China in recent years.

Through the integration of software and cases, it can be found that Stata software has achieved relatively good coordination between ease of use and functionality, and is highly powerful in data management and frontier statistical methods[^{62}]. Even so, when conducting knowledge discovery in specific domains —such as resource and environmental sciences—because of their distinctive disciplinary characteristics, these tools still cannot be fully applied. A comprehensive analysis of the current application of these software packages in the resource and environmental field shows that most of them participate only in certain stages of meta-analysis, such as the calculation of combined effect sizes and tests for publication bias; they still cannot fully implement the meta-analysis workflow for knowledge discovery. Therefore, developing a set of meta-analysis software with a standardized interface, simple computational steps, accurate analytical results, and applicability to a broad user base has certain practical significance for meta-analysis users, especially non-statistics professionals.

4.2 Attribute Analysis of Resource and Environmental Sciences

The scope of research in resource and environmental sciences is extremely broad. In terms of the temporal domain, the period during which interactions between human beings and nature are most influential ranges from several decades to several centuries, or even smaller scales. During such periods, human beings invest large amounts of manpower and material resources, and the main line of research unfolds around environmental elements such as the atmosphere, water, vegetation, and soil. From the perspective of the spatial domain, any region —ranging from a single phenomenon to the entire Earth—may be the object of study. At present, the spatial domain of this discipline is developing both in depth and breadth, extending from the fine structure of subsurface media to changes across the whole Earth. Therefore, from the spatiotemporal perspective, resource and environmental sciences proceed across several levels, from regional to global, and employ methods that combine the single and the comprehensive for research[^{63}].

Space and time in the resource and environmental field are two basic characteristics of geographical phenomena[^{64}] and are the two fundamental elements of geospatial analysis[^{65}].

The temporal information of attributes refers to changes in the attributes or geometric characteristics of geographical objects over time[^{66}], which may reflect changes in attribute characteristics. For example, a city' s daily meteorological data are not exactly the same every day, and the air pollution index of a certain place may differ across seasons. Temporal information may also reflect changes in spatial geometric characteristics; for example, the spatial extent of a city differs across decades, and the position of a typhoon changes continuously as time progresses.

The spatial-domain characteristics of attributes mean that the object studied in resource and environmental sciences is the objectively existing Earth system as a whole. It may change independently over time, or it may change simultaneously with time, and it can be located by latitude and longitude coordinates. The spatial distributions of attributes differ at the same time or across different time periods. For example, precipitation varies across different regions in summer; water levels in different reaches of the Yangtze River differ within a single day; and so on. Therefore, the composition of data in the resource and environmental field should be four-dimensional space, namely data D (horizontal X, vertical Y, depth Z, time T)[^{63}].

4.3 Analysis of the Characteristics of Spatiotemporal Visualization

Traditional visual expression of statistical data emphasizes chart analysis and generalized computational analysis, and often ignores or simplifies the spatial distribution characteristics of statistical information. With the development of computer technology, integrating statistical data resources from multiple sources and multiple departments based on geographic spatial data, and using the spatial visualization technology of geographic information systems to express the information contained in statistical data, has become a new pathway for the utilization of statistical data resources[^{67}]. A Geographic Information System (GIS) is a computer system used to collect, simulate, process, retrieve, analyze, and express geospatial data[^{68}]. In geographic information systems, in terms of presentation content, the most commonly used form of spatial information visualization is the map (graphic); in terms of spatial dimensions, it mainly includes two-dimensional visualization and multidimensional dynamic visualization.

Because data in resource and environmental sciences have two-dimensional attributes, they can be intuitively output through spatiotemporal information visualization. For example, in the field of geography, geographic visualization mainly emphasizes visualization of geographical computation and geographic information. Wang Weixing et al.[^{69}] proposed a basic definition of geographic visualization and discussed and analyzed its conceptual characteristics, theoretical foundations, and methods of expression. They argued that geographic knowledge visualization is a new research direction formed by the introduction of knowledge visualization theories, methods, and technologies into the field of geographic research, and concerns the visual expression and analysis of geographic knowledge.

In summary, when conducting meta-analysis of knowledge in resource and environmental sciences, it is necessary to consider its spatiotemporal characteristics. On the one hand, because most of the data are non-controlled measurements, traditional data formats such as binary categorical variables and control experiments are no longer applicable. By contrast, cumulative meta-analysis, network meta-analysis, meta-regression analysis, and other methods developed from basic meta-analysis can still be used for the analysis of data in resource and environmental sciences because they are applicable to diverse data types. How to organize and transform the data requires further exploration by researchers. The author believes that, based on the advantages and disadvantages of the software packages above, a fully functional meta-analysis software package applicable to resource and environmental sciences can be developed.

4.4 Design Ideas for Meta-Analysis Software Based on Domain Knowledge Discovery

Through the above analysis, it can be learned that, because data in the field of resource and environmental sciences are presented in spatiotemporal multidimensional forms, there is currently an urgent need to transform existing meta-analysis software or to develop a new comprehensive integrated analysis platform. The author believes that although existing software can perform partial meta-analysis, it is crucial to develop a complete software package for the entire meta-analysis process from data collection to conclusion output. The new software should be guided by geographically oriented empirical research; its basic analysis ⋯

Review and Evaluation

The analysis process is:

(1) Literature acquisition. Based on a given research topic, literature retrieval is carried out through an embedded retrieval system, and the results are promptly stored in a database so as to facilitate subsequent inclusion/exclusion and screening of the literature;

(2) Manual interpretation of the literature. After eliminating heterogeneity arising from human understanding, manual extraction is performed to ensure a certain degree of accuracy. This step requires detailed manual

reading of the literature in preparation for further determining the format of literature extraction;

(3) Customization of the extraction format, customization of task tables, and content extraction. After thoroughly interpreting the literature, the structured format for knowledge extraction is customized and content is extracted;

(4) Machine interpretation and processing. After a certain amount of literature content has been extracted, the computer automatically integrates and synthesizes the extracted content. How to determine statistical methods and how to implement data synthesis by machine are the key issues for the authors' next stage of work;

(5) Generation of integrated conclusions. That is, integrated conclusions under the same topic are formed, and a comprehensive literature-integration report is produced in formats such as PDF, Word, and Excel.

(6) Visualization of geographic information. The geographic information in the integrated conclusions is visualized on the basis of GIS and displayed in two dimensions of time and space.

When conducting Meta-analysis in the discipline of environmental resources, taking into account the characteristics of the literature in this field, the authors believe that the basic characteristics generally possessed by the literature include: title, abstract, keywords, year of publication, publishing journal, authors, etc. These basic items of information can be integrated using statistical methods—for example, analyzing authors' publication output from the perspective of bibliometrics, and analyzing research hotspots through keywords. In addition, for unstructured literature content, knowledge can be extracted, statistically analyzed, and integrated; this process belongs to comprehensive integration in a broad sense. The authors believe that, through standardized constraints, information such as the disciplinary-domain classification, research-area information, timing of the research work, time of the research object, information on the research object, descriptions of research methods, evaluation of research methods, and research conclusions of papers under the same research topic can be extracted, structurally stored, and statistically analyzed, thereby obtaining integrated research conclusions. This process can achieve integration of research conclusions. However, how to extract such information in a structured way so that it has statistical significance, and how to synthesize and statistically analyze it from the algorithmic perspective to form new conclusions or knowledge, are current research difficulties.

4.5 Case Study

Using the discipline of environmental resources as an example, this paper proposes the features that Meta-analysis tools suitable for domain knowledge discovery should possess. In view of the characteristics and functions compared above, the authors will verify them through experiments, so as to demonstrate, more scientifically, reasonably, and convincingly, the practicality and necessity of developing Meta-analysis tools applicable to the environmental resources discipline.

The authors take as a basis the existing domestic quantitative empirical research results on factors influencing water quality in the Huangpu River. Guided by the software-design concept of domain knowledge discovery, they manually implement this systematic processing procedure. The main idea is to conduct comprehensive integrated analysis of the deterioration and improvement of water quality in the Huangpu River under different temporal and spatial conditions over the 35 years from 1977 to 2012, as well as of its influencing factors, determine the main factors affecting water-quality changes in the Huangpu River system, and form comprehensive integrated conclusions.

In the literature-acquisition stage, the databases on the CNKI platform were searched using "Huangpu River" and "water quality" as search terms, with exact searching in titles and keywords. A total of 86 articles published from 1983 to 2014 were retrieved. After manual interpretation, 36 articles that comprehensively introduced the research topic were retained. The established content-extraction template is shown in Table 5. After interpretation and processing, integrated research conclusions were obtained.

Table 5 Information Extraction Template for Meta-analysis of Huangpu River Water Quality

Basic characteristic indicators	Basic qualitative indicators	Influencing-factor characteristic indicators	Research-subject characteristic indicators
Number	Disciplinary field	Year and season	Water-quality status
Literature title	Research area	Water inflow	Water temperature
Author	Research time	Natural factors; precipitation	Dissolved oxygen (DO)
Keywords	Research method	Temperature	Chemical oxygen demand (CODCr)
Publication time	Publication type	Industrial pollution sources	Permanganate index (CODMn)
Journal title	Data source	Human factors; agricultural pollution sources	Five-day biochemical oxygen demand (BOD5)
Author affiliation		Domestic pollution sources	Ammonia nitrogen (NH3-N)

Basic characteristic indicators	Basic qualitative indicators	Influencing-factor characteristic indicators	Research-subject characteristic indicators
		Policy regulations, etc.; policy laws	Total phosphorus (TP)
		Other; other	Main pollutants

(1) The main factors affecting the water quality of the Huangpu River are inflow water, precipitation, temperature, industrial pollution, agricultural pollution, domestic pollution, policies and laws, and mobile-source pollution such as ships. Among them, domestic pollution and upstream inflow have the greatest impact on water quality.

(2) Spatially, the main factors affecting water quality are upstream inflow and emissions from pollution sources along the banks. In order of degree of influence, these are domestic pollution sources, upstream inflow, industrial pollution sources, and agricultural pollution sources.

(3) Temporally, the water quality of the Huangpu River underwent five stages of change between 1977 and 2007. By 2012, the water quality had remained at a normal level, and overall it was in Classes III–V. The seasonal influence on water quality is mainly reflected in the fact that winter water quality is better than summer water quality; the higher the temperature across the four seasons, the worse the water quality. The principal influencing factors are natural factors such as inflow water and water temperature, as well as discharges from industrial, agricultural, and domestic pollution sources. In addition, the implementation of policies and laws can effectively improve water quality, while ship transportation can worsen it.

The specific process of index analysis will not be elaborated here. This is only to illustrate, using resource and environmental science as an example, the feasibility of proposing Meta-analysis tools suitable for the resource and environmental field.

5 Conclusion

By sorting through and comparing the various types of Meta-analysis software commonly used internationally, analyzing the differences among these software packages in terms of their characteristics and functions such as computation and plotting, studying the future development trends of Meta-analysis, summarizing the currently commonly used Windows-based Meta-analysis software, comparing the characteristics of each tool, and taking the field of resource and environmental science as an example, this paper proposes the basic characteristics that Meta-analysis tools suitable for the field of resource and environmental science should possess. The aim is to guide the extended application of Meta-analysis tools in literature-based knowledge discovery in resource and environmental science, and to provide reference and reflection for domain knowledge discovery based on Meta-analysis. However, this paper also has certain limitations: it has not systematically implemented this process by constructing a platform, nor has it fully verified the feasibility of the proposed ideas. Meanwhile, some inherent weaknesses of Meta-analysis cannot be effectively resolved in domain knowledge discovery based on Meta-analysis.

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Liu Hongzhao: designed the research plan, obtained and analyzed the data, and drafted the manuscript;
Qu Jianping: proposed the research topic and research ideas, and revised the final version of the manuscript.

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Using Meta-analysis Software for Domain Knowledge Discovery

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Abstract: [**Objective**] We try to predict the future trends of Meta-analysis methodology, and improve the performance of domain knowledge discovery tasks. [**Methods**] First, we reviewed the features of popular Meta-analysis software, as well as their differences in computing and graphics functions. Second, we designed a Meta-analysis tool for the resources and environment science. [**Results**] We developed a new concept for public oriented Meta-synthesis tool with standardized interface, simplified procedure and accurate results. [**Limitations**] We did not examine the feasibility of the new tool on a working platform, The inherent weaknesses of Meta-analysis cannot be avoided in the domain knowledge discovery. [**Conclusions**] We need to build a platform for the domain knowledge discovery with Meta-analysis technology and then expand its application in literature discovery.

Keywords: Meta-analysis Knowledge discovery Software comparison Resources and environment science

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WebJunction Receives IMLS Funding to Help Small Public Libraries Create Active Learning Spaces

WebJunction is a program group of OCLC Research. It has received a two-year National Leadership Grant from IMLS (Institute of Museum and Library Services), with project funding of US$249,710. The project is titled "Creating Smart Spaces for Small Libraries."

Through cooperation with U.S. township and small-library associations, WebJunction will provide guidance and support for the construction of small libraries, helping them redesign library spaces so as to support broader social participation and learning activities.

"WebJunction believes that learning is a social process, and that learning through concrete practice becomes more effective," said Sharon Streams, director of WebJunction. "With the expert guidance and peer support provided by this project, more community libraries will be able to transform library spaces into social centers for practical learning."

The goals of the project are: to cultivate close social connections among people and make communities stronger; to create library spaces, provide opportunities for active learning, and encourage more exploratory activities; to enable small libraries to make better use of their existing physical spaces in order to adapt to the constantly developing needs and interests of their communities; and to strengthen the core role that libraries play in providing out-of-class learning venues for people of all ages.

Participating libraries will be recommended to adopt principles for space creation, community participation, and human-centered space design. After community engagement, activity planning, and pilot activities, libraries will be able to use a series of initial materials to create a learning space.

This project passed the first round of review for the IMLS National Leadership Grants for Libraries program. The IMLS National Leadership Grants for Libraries program supports a series of projects that can address challenges facing the library and archives fields and use new tools, research findings, models, services, and the like that can be widely replicated, in order to promote practical activities in the library and archives fields. The committee received applications totaling more than US$31 million, and has already approved US$6,339,441 in funding for 20 of the projects.

About WebJunction

As an open learning community, WebJunction provides librarians with a variety of online resources, programming, and learning opportunities. WebJunction is a program group of OCLC Research. It designs and delivers various transformational projects that combine public library services with a series of community needs, such as lifelong education, health care, and a successful economy. Since 2003, more than 70% of public libraries across the 50 states of the United States have participated in WebJunction' s learning projects.

(Translated by: https://www.webjunction.org/news/webjunction/webjunction-imls-smart-spaces-grant.htm)

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

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