Expert Systems with Applications 39 (2012) 11303–11311

Contents lists available at SciVerse ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Review

Data mining techniques and applications – A decade review from 2000 to 2011

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ARTICLE INFO

Keywords:
Data mining
Data mining techniques
Data mining applications
Literature survey

ABSTRACT

In order to determine how data mining techniques (DMT) and their applications have developed, during the past decade, this paper reviews data mining techniques and their applications and development, through a survey of literature and the classification of articles, from 2000 to 2011. Keyword indices and article abstracts were used to identify 216 articles concerning DMT applications, from 159 academic journals (retrieved from five online databases), this paper surveys and classifies DMT, with respect to the following three areas: knowledge types, analysis types, and architecture types, together with their applications in different research and practical domains. A discussion deals with the direction of any future developments in DMT methodologies and applications: (1) DMT is finding increasing applications in expertise orientation and the development of applications for DMT is a problem-oriented domain. (2) It is suggested that different social science methodologies, such as psychology, cognitive science and human behavior might implement DMT, as an alternative to the methodologies already on offer. (3) The ability to continually change and acquire new understanding is a driving force for the application of DMT and this will allow many new future applications.

1. Introduction

Data mining techniques (DMT) have formed a branch of applied artificial intelligence (AI), since the 1960s. During the intervening decades, important innovations in computer systems have led to the introduction of new technologies (Ha, Bae, & Park, 2000), for web-based education. Data mining allows a search, for valuable information, in large volumes of data (Weiss & Indurkhya, 1998). The explosive growth in databases has created a need to develop technologies that use information and knowledge intelligently. Therefore, DMT has become an increasingly important research area (Fayyad, Djorgovski, & Weir, 1996).

Of the data mining techniques developed recently, several major kinds of data mining methods, including generalization, characterization, classification, clustering, association, evolution, pattern matching, data visualization and meta-rule guided mining, are herein reviewed. The techniques for mining knowledge from different kinds of databases, including relational, transactional, object oriented, spatial and active databases, as well as global information systems, are also examined. Potential data mining applications and some research issues are discussed.

As an element of DMT research, this paper surveys the development of DMT, through a literature review and the classification of articles, from 2000 to 2011. The various applications of DMT, during that period, are reviewed. This period is especially important, because the Internet was opened to general users, in 2000, and the newly widespread availability of information and communication technology has played an important role, not only in the field of DMT, but also in the development of methodologies for the collection of data from online databases.

The period of interest, for this literature survey, begins in January 2000. In August, 2011, a search was made of the keyword indices on the Elsevier SCOPUS, Springerlink, IEEE Xplore, EBSCO (electronic journal service) and Wiley InterScience online database, for article abstracts containing the phrase, "data mining technique". For the period from 2000 to 2011, 14,972 articles were found. Topic filtering reduced this number to 216 articles, from 159 journals, which were related to the keyword, "Data mining application". Using these 216 articles on DMT applications, this paper surveys and classifies DMT, using nine categories: Neural networks, Algorithm architecture, dynamic prediction-based, Analysis of systems architecture, Intelligence agent systems, Modeling, knowledge-based systems, System optimization and Information systems, together with their applications in different research and practical domains.

The remaining part of the paper is organized as follows. Sections 3–11 present the survey results for DMT methodologies and applications, based on the categories mentioned, above. Section 12 is a discussion of suggestions for the future development of DMT methodologies and their applications. Finally, Section 13 contains a brief conclusion.

2. Trend in data mining techniques

The data collected dates from 2000, until August 2011. The trend for the keywords; Data mining, Decision tree, Artificial

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doi:10.1016/j.eswa.2012.02.063

neural network, Clustering, Association rule, Artificial intelligence, Bioinformatics, Customer relationship, Fuzzy logic, and their applications, are shown in Table 1.

3. Neural networks and their applications

The term, neural network, is traditionally used to refer to a network, or circuit of biological neurons. Modern use of the term often refers to artificial neural networks, which are composed of artificial neurons, or nodes. As well as electrical signaling, other forms of signaling arise from neural transmitter diffusion, which have an effect on electrical signaling. As such, neural networks are extremely complex.

Some applications for neural networks are radial basis function networks, neural classification, Bayesian confidence propagation neural networks, gene regulatory networks, fuzzy recurrent neural networks, neural nets, back-propagation artificial neural networks, Bayesian networks, general regression neural networks and flow networks. The neural network technique and its applications are detailed in Table 2.

4. Algorithm architecture and its applications

Algorithm architecture is expressed as a finite list of well-defined instructions, to calculate a function. Algorithms are used for calculation, data processing and automated reasoning. Simply put, an algorithm is a step-by-step procedure for calculation. A partial formalization of the concept began with attempts to solve the Entscheidungs problem, posed by David Hilbert in 1928.

Some applications that are implemented by algorithms include gap statistic algorithms, chi-square automated interaction detection, models and algorithms, GRASP, OLAP, k-means, Clustering algorithms, decision forest algorithms, classification and regression trees, Euclidean distance, bagged clustering algorithms, fuzzy logic, association rules, C&RT, Apriori algorithms, C5, anomaly-based IDS, clustering, genetic algorithms, CRISP-DM models, thyroid stimulation and SVM. Algorithm architectures and their applications are listed in Table 3.

5. Dynamic prediction based approach and its applications

The dynamic prediction based approach is a mathematical model for stochastic dynamics; used in modeling molecules, but it also finds applications in the stock market, among other areas. The most important feature of Langevin dynamics is the presence of a Gaussian random noise. The principle of temporal locality was widely studied and applied to different domains of computer science by Peter in 1968. It observes that a thread does not access a completely random set of addresses across its transactions.

Some applications which use a dynamic prediction based approach include ophthalmic oncology, vehicle fault diagnosis, grid computing, dyadic wavelet, pre-fetching, fault restoration prediction models, fault prediction models, financial distress prediction models, Vlasov–Maxwell equations, chemical reactivity predictions, real time vehicle tracking, forecasting, anomaly detection, churn prediction, comparative genomics, clinical predictions and predictive models. Table 4 categorizes predictions into read-set predictions and write-set predictions.

6. Analysis of system architecture and its applications

The analysis of system architecture uses a conceptual model that defines the structure, behavior and other aspects of a system. Systems architecture makes use of elements of both software and hardware, which allows the design of composite systems. A good architecture may be viewed as a 'partitioning scheme', or algorithm, which completely partitions all of the system's present and foreseeable requirements into a workable set of clearly bounded subsystems.

Some applications of the analysis of system architecture are semantic analysis, regression analysis, statistical analysis, discriminative analysis, association analysis, penalized discriminative analysis, process parameter analysis, cluster analysis, decision making, decision support systems, consumer behavior analysis, binary logistical regression analyses, M5 model trees, factor analysis, market basket analysis, collaborative filtering, data analysis, decision tree based models, principal component analysis, multi-feature selection, intrusion detection and hem dialysis. These System architectures and their applications are listed in Table 5.

7. Intelligence agent systems and their applications

In the field of artificial intelligence, an intelligent agent system (IAs) is an autonomous entity, which observes and acts upon an environment. Intelligent agents may also learn, or use knowledge to achieve their goals. They may be very simple, or very complex. A reflex machine, such as a thermostat is an intelligent agent, as is a human being, as is a community of human beings working together towards a goal. Russell and Norvig (2003) considered goal-directed behavior as the essence of intelligence and so borrowed the term, "rational agent", from economics.

Some applications for intelligence agent systems include multi-agent systems, complex systems, computer interface design, multiuser database systems, intelligent analysis, manufacturing intelligence, intelligent tutoring systems, support vector machines, program diagnostics systems, supervisory and specialist systems, supervisory and specialist systems, computing intelligence, artificial intelligence and Mahalanobis Taguchi systems. These intelligent agent systems and their applications are detailed in Table 6.

Table 1
2000–2011 DMT keywords trends.

Keyword	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
Data mining	1	0	6	5	8	8	12	16	10	16	16	16	114
Decision tree	0	0	1	0	0	2	0	1	2	4	3	4	17
Artificial neural network	1	1	2	1	2	2	2	0	2	4	2	3	22
Clustering	0	0	1	0	0	3	0	1	0	2	1	1	9
Association rule	0	0	0	1	0	0	0	2	1	3	0	1	8
Artificial intelligence	0	0	0	0	0	0	1	0	1	1	2	1	6
Bioinformatics	0	0	0	0	0	0	0	3	0	1	0	0	4
Customer relationship management	0	0	0	1	0	0	0	0	0	0	3	0	4
Fuzzy logic	0	0	0	1	1	0	0	1	0	1	0	0	4
Total	2	1	10	9	11	15	15	24	16	32	27	26	188

Table 2
Neural networks and their applications.

Neural networks applications	Authors
Feed forward neural networks	Trafalis et al. (2002)
Radial basis function networks	Srivastava et al. (2005)
Neural classification	Dutta et al. (2004)
Bayesian confidence propagation neural networks	Cesana et al. (2007)
Gene regulatory networks	Ma and Chan (2007)
Fuzzy recurrent neural networks	Aliev et al. (2008)
Neural nets	Tsai and Chen (2008)
Back-propagation artificial neural networks	Lin et al. (2011)
Bayesian networks	Rivas et al. (2011)
General regression neural networks	Tu et al. (2011)
Flow networks	Zhang and Ramirez-Marquez (2011)

Table 3
Algorithm architecture and its applications.

Algorithm applications	Authors
Gap statistic algorithm	Huang and Lin (2002)
Chi-square automated interaction detection	Rygielski et al. (2002)
Models and algorithms	Lancashire et al. (2005)
GRASP	Ribeiro et al. (2006)
OLAP	Singhal and Jajodia (2006)
K-Means	Adderley et al. (2007)
Clustering algorithms	Balzano and Del Sorbo (2007)
Decision forest algorithms	Hsia et al. (2008)
Classification and regression tree	Qiang et al. (2008)
Euclidean distance	Fan et al. (2009)
Bagged clustering algorithms	Huang et al. (2009)
Fuzzy logic	Jiménez et al. (2009)
Association rule	Shih et al. (2009)
C&RT	Ture et al. (2009)
Apriori algorithms	Chen and Bai (2010)
C5	Marx (2010)
Anomaly-based IDS	Nikolova and Jecheva (2010)
Clustering	Piquer et al. (2010)
Genetic algorithms	Ahn et al. (2011)
CRISP-DM model	Chen and Huang (2011)
Thyroid stimulating hormone	Henderson and Grey (2011)
SVM	Ravisankar et al. (2011)

Table 4
Dynamic prediction based approach and its applications.

Dynamic prediction based applications	Authors
Ophthalmic oncology	Jegelevičius et al. (2002)
Vehicle fault diagnosis	Fong et al. (2003)
Grid computing	Sánchez et al. (2004)
Dyadic wavelet	Yu et al. (2006)
Pre-fetching	Jain (2007)
Fault restoration prediction model	Hwang et al. (2008)
Fault prediction model	Bae et al. (2009)
Financial distress prediction model	Chen and Du (2009)
Vlasov–Maxwell equations	Assous and Chaskalovic (2010)
Chemical reactivity prediction	Borghini et al. (2010)
Real time vehicle tracking	Constantinescu et al. (2010)
Forecast	He et al. (2010)
Anomaly detection	Mahesh et al. (2010)
Churn prediction	Tsai and Lu (2010)
Comparative genomics	Bhramaramba et al. (2011)
Clinical predictions	Gregori et al. (2011)
Predictive model	Li et al. (2011)

8. Modeling and its applications

Modeling, in software engineering, is the process of creating a data model by making descriptions of formal data models, using data modeling techniques. Modeling technology can provide quantitative methods for the analysis of data, to represent, or acquire expert knowledge, using inductive logic programming, or algorithms, so that AI, cognitive science and other research fields are afforded broader platforms for the development of DMT.

Applications of modeling include cost modeling, model-based diagnosis, forest fire proliferation modeling, model output statistics, intonation modeling, XML document modeling, Cox proportional hazard modeling, load damage exponents, polynomials, similar waveforms, simple additive weight, computer numerical control, meta learning and drug utilization. The applications of modeling techniques are listed in Table 7.

Table 5
Analysis of systems architecture and its applications.

Analysis of systems architecture applications	Authors
Correlation analysis	Lee et al. (2000)
Semantic analysis	Sui and Meng (2001)
Regression analysis	Li et al. (2002)
Statistical analysis	Lu et al. (2005)
Discriminative analysis	Adachi et al. (2006)
Association analysis	Al-Hamami et al. (2006)
Penalized discriminative analysis	Granitto et al. (2007)
Process parameter analysis	Martínez-de-Pisón et al. (2007)
Cluster analysis	Hoontrakul and Sahadev (2008)
Decision making	Ranjan et al. (2008)
Decision support systems	Bâra et al. (2009)
Consumer behavior analysis	Hsieh and Chu (2009)
Binary logistic regression analyses	Jilani et al. (2009)
M5 model trees	Küçüksille et al. (2009)
Factor analysis	Parhizi et al. (2009)
Market basket analysis	Shahrabi and Neyestani (2009)
Collaborative filtering	Kim et al. (2010)
Data analysis	Miranda et al. (2010)
Decision tree based models	Bae and Kim (2011)
Principal component analysis	Bhramaramba et al. (2011)
Multi-feature selection	Chang et al. (2011)
Intrusion detection	Thiruvadi and Patel (2011)
Hem dialysis	Yeh et al. (2011)

Table 6
Intelligence agent systems and their applications.

Intelligence agent systems applications	Authors
Inductive learning systems	Kaichang et al. (2000)
Multi-agent systems	Symeonidis et al. (2003)
Complex systems	Trafalis and White (2003)
Computer interface design	Ye et al. (2003)
Multiuser database systems	Feng and Lu (2004)
Intelligent analysis	Mamčenko and Kulvietiene (2005)
Manufacturing intelligence	Hsieh (2007)
Intelligent tutoring systems	Chen and Chen (2009)
Support vector machines	Mucherino et al. (2009)
Program diagnostics systems	Riquelme et al. (2009)
Supervisory and specialist systems	De Andrade et al. (2010)
Computing intelligence	Chou et al. (2011)
Artificial intelligence	Fiol-Roig and Miró-Julià (2011)
Mahalanobis Taguchi system	Su et al. (2005)

9. Knowledge-based systems and their applications

Knowledge-based systems are artificial intelligent tools that work in a narrow domain, to provide intelligent decisions, with justification. The most common definition of KBS is human-centered, since KBS have their roots in the field of artificial intelligence (AI). They represent attempts to understand and initiate human knowledge, in computer systems (Wiig, 1994).

Knowledge is acquired and represented, using various knowledge representation techniques, rules, frames and scripts. The basic advantages offered by such systems are the documentation of knowledge, intelligent decision support, self-learning, reasoning and explanation. Akerkar and Sajja Priti Srinivas (2009) stated that knowledge-based systems are systems based on the methods and techniques of Artificial Intelligence.

Some applications of knowledge-based systems include learning techniques, auto control techniques, knowledge discovery in databases, knowledge spirals, communication technologies, knowledge measurement, knowledge extraction, knowledge acquisition, knowledge management, knowledge representation, digital libraries and information gain theory data mining. The applications of knowledge-based systems are listed in Table 8.

10. System optimization and its applications

Fermat and Lagrange used calculus-based formulas, for the identification of optima, while Newton and Gauss proposed iterative methods of approaching an optimum. Historically, the original term for optimization was "linear programming", coined by George B. Dantzig, although much of the theory had been described by Leonid Kantorovich, in 1939.

Dantzig published the Simplex algorithm, in 1947, and developed the theory of duality, in the same year. System Optimization refers to the selection of a best element, from some set of available alternatives. In the simplest case, problems in which a real function is maximized, are solved by systematically choosing the values of real or integer variables, from within an allowed set.

Some applications of system optimization include electrical nerve stimulation, R-peak detection, latent reference individual extraction methods, operation optimization values, vertical partitioning, logistical regression, analytical hierarchy processes, polynomial regression, biogeography based optimization, particle swarm optimization, finite element methods, discrete rough set methods, asymptotic methods and parallel computing. The applications of system optimization techniques are listed in Table 9.

11. Information systems and their applications

Information systems are the products of an academic discipline. They occupy a place between the business world and computer science bridging the business field and the well-defined computer science field that is evolving toward a new scientific area of study. An information system relies on the theoretical foundations of information and computing which allows researchers a unique opportunity to engage in academic studies of various business models and related algorithmic processes that are pertinent to computer science. In general, information systems focus upon the processing of information within organizations (Hoganson, 2001), especially within business enterprises. The products of the process can then be share with society.

Some applications of information systems include patient characteristics, catchment characteristics, mobile databases, self-organizing, feature maps, insurance claims databases, alternating current field measurement, fracture acidizing, latest time sub-series, destination choice, attribute relevance studies, fraudulent financial statements, sequence similarity, case-based reasoning, anthropometric data, regression spines, economic imbalances, medium-voltage customer faults, maintenance and engineering, bank lending, reinforcement learning, supervised learning, arousals, information visualization, customer retention, churn management, pattern discovery, customer relationship management and uniaxial compressive strength. The applications for information systems are listed in Table 10.

Table 8
Knowledge-based systems and their applications.

Knowledge-based systems applications	Authors
Data analysis techniques	Górniak-Zimroz et al. (2005)
Learning techniques	Chun and Park (2006)
Auto control techniques	Li et al. (2006)
Knowledge discovery in databases	Wasan et al. (2006)
Knowledge spiral	Wasan et al. (2006)
Communication technologies	Ko and Osei-Bryson (2006)
Knowledge measurement	Shapira and Youtie (2006)
Knowledge extraction	Sugihara (2006)
Knowledge acquisition	Gajzler (2010)
Knowledge management	Fesharaki et al. (2011)
Knowledge representation	Hoonakker et al. (2011)
Digital libraries	Segura et al. (2011)
Information gain theory data mining	Sudheep et al. (2011)

12. Discussions, limitations, and suggestions

12.1. Discussions

A top-level analysis of data mining technologies must focus on data retention. In early attempts at data mining, the data set was maintained, for future pattern matching. This literature review shows that DMT application and development has diversified, in line with the various authors' backgrounds, expertise, and areas of interest. For this reason, some authors are associated with literature concerning more than one methodology, or application.

It is also true that some techniques have common concepts and types of methodology. For example, dynamic prediction based methods, knowledge-based systems and neural network applications. A few authors are associated with literature concerning different methodologies and applications. This indicates that the development of methodologies is also diverse, in accordance with each author's research interests and areas of interest. This seems to indicate that the development of DMT more expertise oriented.

Furthermore, some applications afford a greater opportunity for the use of different methodologies. For example, neural classification, Bayesian confidence propagation neural networks, gene regulatory networks, fuzzy recurrent neural networks, C&RT, Apriori algorithms, C5, anomaly-based IDS, clustering, genetic algorithms, CRISP-DM models, thyroid stimulation, Vlasov–Maxwell equations, chemical reactivity predictions, real time vehicle tracking, forecast, anomaly detection, churn prediction, knowledge measurement, knowledge extraction, knowledge acquisition, knowledge manage-

Table 7
Modeling and its applications.

Modeling applications	Authors
Language modeling	Chen (2004)
Cost modeling	Popovic (2004)
Model-based diagnosis	Saitta et al. (2005)
Forest fire spreading modeling	Xiao et al. (2006)
Model output statistics	Besse et al. (2007)
Intonation modeling	Escudero-Mancebo and Cardeñoso-Payo (2007)
XML document modeling	Mei and Zhang (2007)
Cox proportional hazard modeling	Pelletier and Diderrich (2007)
Load Damage Exponents	Chen et al. (2008)
Polynomials	Rezania et al. (2008)
Similar waveforms	Vega et al. (2008)
Simple additive weight	Laosiritaworn and Holimchayachotikul (2010a).
Computer numerical control	Laosiritaworn and Holimchayachotikul (2010b)
Meta learning	Radosavljevic et al. (2010)
Drug utilization	Dakheel et al. (2011)

Table 9
System optimization and its applications.

System optimization applications	Authors
Electrical nerve stimulation	Tam et al. (2004)
R peak detection	Yu et al. (2004)
Latent reference individual extraction method	Tamechika et al. (2006)
Operation optimization value	Li et al. (2007)
Vertical partitioning	Gorla and Betty (2008)
Logistic regression	Setoguchi et al. (2008)
Analytical hierarchy process	Shen and Chuang (2009)
Polynomial regression	Wi et al. (2009)
Biogeography based optimization	Chandrakala et al. (2010)
Particle swarm optimization	Durán et al. (2010)
Finite element method	Fernández et al. (2010)
Discrete rough set methods	Wan et al. (2010)
Asymptotic methods	Assous and Chaskalovic (2011)
Parallel computing	Jian et al. (2011)

ment and knowledge representation are all topics with different methodologies, which nevertheless implement DMT, for problems that are common to all. These applications represent a major part of DMT development, but many methodologies are used to solve the problems that are specific to them. This would seem to imply that future developments of DMT will be more problem-centered.

In this paper, the articles discussed were sourced from different discipline areas, including computer science, engineering, medicine, mathematics, earth and planetary sciences, biochemistry, genetics and molecular biology, business, management and accounting, social sciences, decision sciences, multidisciplinary, environmental science, energy, agricultural and biological sciences, nursing, materials science, pharmacology, toxicology and pharmaceutics, chemistry, health professions, physics and astronomy, economics, econometrics and finance, psychology, neuroscience, chemical engineering and veterinary, which were all retrieved from the Elsevier SCOPUS, Springerlink, IEEE Xplore, EBSCO (electronic journal service) and Wiley InterScience online database.

Industrial applications of data mining techniques have increased, between 2000 and 2011. Fig. 1 shows the important DMT trends for association rules, genetic algorithms, clustering, artificial neural networks, Apriori algorithms, support vector machines, feature selection, customer relationship management, classification, neural networks and decision trees.

It cannot be concluded that DMT methodologies and applications are not developed in other science fields. However, studies that mention more applications of DMT in different research fields must be published, in order to broaden the scope of DMT, in the academic and practical fields.

12.2. Limitations

This study has some limitations. Firstly, a widespread literature review of DMT and its applications presents a difficult task, because of the extensive background knowledge that is required, when collecting, studying and classifying these articles. Although acknowledging a limited background knowledge, this paper makes a brief review of literature concerned with DMT, from 2000 to 2011 in order to determine how DMT and their applications have developed, in this period. Indeed, the categorization of methodologies and their applications is based on the keyword index and article abstracts, collected for this research. Some other articles may have used similar DMT methodologies in their applications, but may not have a DMT index, so this paper is unaware of these reference sources. Therefore, the first limitation of this article is the author's limited knowledge of this subject. Secondly, although 216 articles from 159 academic journals (five online databases) are cited in this

Table 10
Information systems and their applications.

Information systems/applications	Authors
Patient characteristics	Mylod and Kaldenberg (2000)
Catchment characteristics	Hall et al. (2002)
Mobile databases	Saygin and Ulusoy (2002)
Self-organizing feature map	Chen and Mynett (2003)
Insurance claims database	Chen et al. (2003)
Alternating current field measurement	Kang et al. (2004)
Fracture acidizing	Kang et al. (2004)
Latest time sub-series	Wang and Zhang (2006)
Destination choice	Wong et al. (2006)
Attribute relevance study	Bagui et al. (2007)
Fraudulent financial statements	Kirkos et al. (2007)
Sequence similarity	Zhu and Xiong (2007)
Case-based reasoning	Chun et al. (2008)
Anthropometric data	Lin et al. (2008)
Regression splines	Paul (2008)
Economic imbalances	Andronie and Andronie (2009)
Medium-voltage customer fault	Bae et al. (2009)
Maintenance and engineering	Cruz et al. (2009)
Bank lending	Ince and Aktan (2009)
Reinforcement learning	Kheradmandian and Rahmati (2009)
Supervised learning	Oh et al. (2009)
Arousals	Shmiel et al. (2009)
Information visualization	Neto et al. (2010)
Customer retention	Ranjan and Bhatnagar (2010)
Churn management	Su et al. (2010)
Pattern discovery	Tremblay et al. (2010)
Customer relationship management	Wang et al. (2010)
Uniaxial compressive strength	Tinoco et al. (2011)

paper, other academic journals are listed in the science citation index (SCI) engineering index (EI) and the social science citation index (SSCI), as well as other academic journals/ magazines, practical articles and reports that are not included in this survey. These would have provided more complete information about the developments in DMT and their applications. Lastly, non-English publications were excluded from this study. It is believed that research regarding the application of data mining techniques has also been discussed and published in other languages.

12.3. Suggestions

(1) Other social science methodologies. This article's definition of DMT is not complete, because other methodologies, such as social science methodologies, were not included in the survey. However, qualitative questionnaires and statistical methods are a type of research technology that is often used in social studies. For example, cognitive science, psychology and human behavior are used to implement different methods for investigating specific human problems, so other social science methodologies may include DMT in future studies.
(2) Integration of methodologies. DMT is an interdisciplinary research topic, so future development of DMT must be integrated with different methodologies. This integration of methodologies and cross-disciplinary research may offer new insights into the problems associated with DMT.
(3) Change is a source of future ES development. Change, due to social and technical reasons, can either enable, or inhibit ES methodologies and the development of applications. It can be seen that inertia, stemming from the use of routine problem solving procedures, stagnant knowledge sources and reliance on past experience, or knowledge may impede change, with respect to learning and innovation, for individuals and organizations.
Continued creation, sharing, learning and the acquisition of knowledge about different methodologies and applications also plays a key role in ES development.

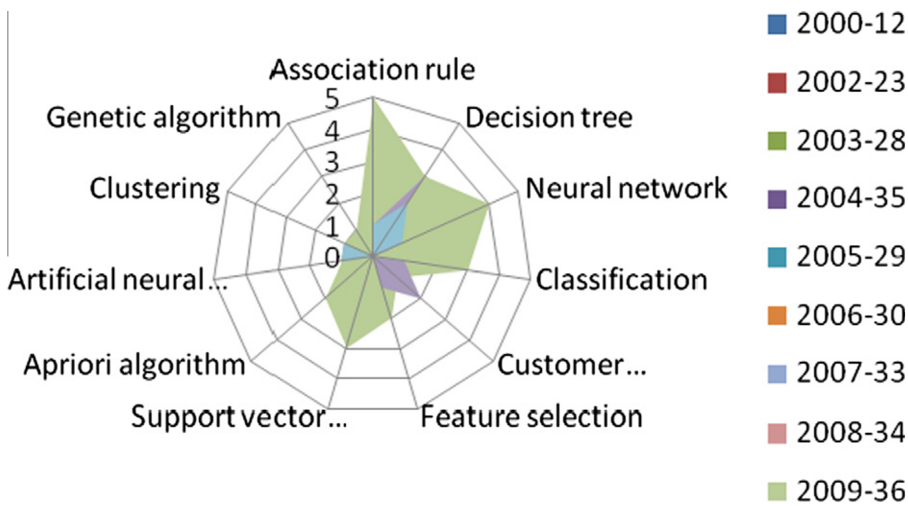

Fig. 1. DMT trend from 2000–2011.

13. Conclusions

This paper presents a review of literature concerned with DMT and its applications, from 2000 to 2011. It used a search of keyword indices and article titles. It is concluded that development of DMT is tending to become more expertise-oriented and that the development of DMT applications is more problem-centered. It is suggested that different social science methodologies, such as psychology, cognitive science and human behavior might use DMT as an alternative methodology. Integration of qualitative, quantitative and scientific methods and the integration of studies of DMT methodologies will increase understanding of the subject. Finally, the ability to continually change and provide new understanding is the principle advantage of DMT methodologies, and will be at the core of DMT applications, in future.

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