COLLNET Journal of Scientometrics and Information Management

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tsim20

A bibliometric analysis of artificial intelligence publications from 1991 to 2018

Yuh-Shan Ho & Ming-Huang Wang

To cite this article: Yuh-Shan Ho & Ming-Huang Wang (2020) A bibliometric analysis of artificial intelligence publications from 1991 to 2018, COLLNET Journal of Scientometrics and Information Management, 14:2, 369-392, DOI: 10.1080/09737766.2021.1918032

To link to this article: https://doi.org/10.1080/09737766.2021.1918032

Published online: 04 Jun 2021.

COLLNET Journal of Scientometrics and Information Management
ISSN : 0973 – 7766 (Print) 2168 – 930X (Online)
Vol. 14(2) December 2020, pp. 369–392
DOI : 10.1080/09737766.2021.1918032

Taylor & Francis
Taylor & Francis Group

A bibliometric analysis of artificial intelligence publications from 1991 to 2018

Yuh-Shan Ho
Ming-Huang Wang

This study aimed to analyze the characteristics of artificial intelligence-related publications in Science Citation Index Expanded (SCI-EXPANDED) from 1991 to 2018. The analyzed aspects covered distribution of annual publications, citations per publication, journals, Web of Science categories, countries, institutions, as well as research foci and their trends. A total of 13,251 artificial intelligence-related articles were found. Articles were published in a wide range of journals and Web of Science categories. The United States took the lead position in total, single country, international collaboration, and first, corresponding, and single author articles as well as citations per publication among 119 countries. Chinese Academy of Sciences in China, Islamic Azad University in Iran, and Massachusetts Institute of Technology (MIT) in USA were the three most productive institutions. MIT had higher citations per publication. An international collaborative article by authors from Canada, the United States, and Switzerland was the most frequently cited article with the most total citations from Web of Science Core Collection since publication through the end of 2018. Results from word cluster analysis showed that models, neural networks, learning, and prediction were the most popular topics and features, classification, and optimization might be focus in artificial intelligence research.

Keywords: *AI, Neural networks, Hybrid, Machine learning, Support vector machine.*

Yuh-Shan Ho *
Ming-Huang Wang
Trend Research Centre
Asia University
No. 500, Lioufeng Road
Wufeng
Taichung County 41354
Taiwan, R.O.C.

ysho@asia.edu.tw

* Corresponding Author

1. Introduction

In the early 1960s, *A Concise Bibliography of the Literature on Artificial Intelligence: Project 4610, Task 46104* [1] was recommended by Shubik [2] as an earlier significant

bibliography on artificial intelligence. In an article entitled "Steps toward artificial intelligence", a guest editor of *Journal of the American Statistical Association*, Harry T. Larson, noted artificial intelligence is at the center of extensive computer research, design, and application. This field is in its starting transient, characterized by many varied and independent efforts [3]. In this article, Marvin Minsky proposed that "The problems of heuristic programming - of making computers solve really difficult problems - are divided into five main areas: Search, Pattern-Recognition, Learning, Planning, and Induction." [3]. Earlier application of artificial intelligence can be found in the period between 1969 and 1983. Stanford University reported a series study about applications of artificial intelligence for chemical inference [4-8]. In the same period, an artificial intelligence approach to computer assisted instruction was investigated [9-11]. Garfield also presented using computers to think about thinking [11-12]. "Future paths for integer programming and links to artificial intelligence" [14]was the most impactful article published before the 1990s in the artificial intelligence-related field. Glover concluded that some promising directions could be a framework to link the perspectives of artificial intelligence and operations research which may elaborate innovations of models and methods in the future [14].

Applications of artificial intelligence research have been published in wide areas, including computer science [15-16], engineering [17-18], chemistry [4,19], and medicine [20,21].

The aim of this study is to identify and examine the artificial intelligence-related publications in the SCIEXPANDED database from 1991 to 2018. The study covers characteristics of publication outputs, articles published in Web of Science categories, journals and contributing institutions and countries. High impact articles in the most recent year and research foci were also discussed.

2. Methodology

The data reported in this study were retrieved from the online version of Science Citation Index Expanded (SCI-EXPANDED), the Clarivate Analytics (formerly known as the Thomson Reuters and the Institute for Scientific Information) Web of Science Core Collection database (updated on July 05, 2019). Search topic included "artificial intelligence" and "artificial intelligences" (including title, abstract, author keywords, and *KeyWords Plus*) within the publication years from 1991 to 2018. *KeyWords Plus* supplies additional search terms extracted from the titles of articles cited by authors in their bibliographies and footnotes in the ISI (now Clarivate Analytics) database, and substantially augments title-word and author-keyword indexing [22]. This resulted 16,118 documents as artificial intelligence related publications. Those documents only found by *KeyWords Plus* are more likely to be unrelated to the "artificial intelligence" [23]. Ho's group firstly proposed the "front page" filter [24-26] - which covers only documents with searching keywords in their "front page," including only the title, abstract, and author keywords; this filter might avoid introducing unrelated publications for analysis [24]. Finally, 15,510 documents (96% of 16,118 documents) were defined as artificial intelligence research publications. The full record of

SCI-EXPANDED and the number of citations in each year for each document were checked and downloaded into Microsoft Excel 2016 and additional coding was manually performed [26,27]. The journal impact factors (IF_{2018}) were taken from the Journal Citation Reports (*JCR*) published in 2018.

Affiliations of authors in England, Scotland, Northern Ireland, and Wales were regrouped as one group under the heading of United Kingdom (UK). Affiliations of authors in Hong Kong prior to 1997 were included under the heading of China [28]. Czechoslovakia was checked and re-classified under the heading of either Czech Republic or Slovakia [29]. Yugoslavia was checked and re-classified under the heading of either Serbia [30], Slovenia [31], or Serbia Monteneg (Serbia and Montenegro) [30]. The USSR (Union of Soviet Socialist Republics) was checked and re-classified under the heading of Russia [32], Ukraine [30], or Kazakhstan. Neth Antilles (Netherlands Antilles) and Fr Polynesia (French Polynesia) were re-classified under the heading of Netherlands and France respectively. Similarly, Acad Sci USSR (the Academy of Sciences of the USSR) was also reclassified as being Russian Acad Sci (the Russian Academy of Sciences) [30].

In the Web of Science database, the corresponding author was designated as the "reprint author"; this study instead used the term "corresponding author" [33]. In a single author article where authorship was unspecified, the single author was both first author and corresponding author. Similarly, for a single institution article, the institution was classified as both the first author's institution and the corresponding author's institution [29]. Only the first corresponding author was considered in this study.

To investigate the citations received by the artificial intelligence-related publications, we used four indicators:

C_0: the number of citations from the Web of Science Core Collection in publication year [34].

C_{year}: the number of citations in a particular year. C_{2018} means the number of citations in 2018 [35].

TC_{year}: the total number citations since publication to the end of the most recent year. In this study this is 2018 (TC_{2018}) [36,37].

CPP_{year}: citations per publication ($CPP_{2018} = TC_{2018}/TP$) [35,38].

3. Results and Discussion

3.1 *Document type and language of publication*

The distribution of document types at the Web of Science has been analyzed in numerous medical related topics [39,40]. In recent years, Ho's group presented idea of TC_{year}; that is, number of citations from Web of Science Core Collection since publication to the end of the most recent year [36,37]. This indicator makes total citations to be a constant as a scientific result which can be repeated and checked. In addition, citations per publication ($CPP_{2018} = TC_{2018}/TP$) can be a scientific result [26]. A relationship between document type and citations per publication was also proposed [39-41]. Table 1 shows characteristics of 21 document types, including 13,251 articles (85% of the 15,510 documents) with number

of authors per publication (*APP*) of 3.3 which is less than that of data papers, meeting abstracts, corrections, retracted publications, and reviews. Document of review had the highest CPP_{2018} of 47 which was higher than articles (CPP_{2018} = 14). The classic reviews entitled "Perceptual symbol systems" [21] with TC_{2018} of 2,822 and "Intelligent agents: Theory and practice" [42] with TC_{2018} of 2,278 are good example to reach the highest CPP_{2018} in review in SCI-EXPANDED.

Web of Science document type of article was used for further analysis because they represented the majority of document types that also included whole the research hypothesis, methods and results [43]. Seventeen languages were found; only one article was published in a multi-language journal (*Strojniski Vestnik-Journal of Mechanical Engineering*) by Slovene and English. English (12,986 articles; 98% of 13,251 articles; CPP_{2018} = 14) was the most used language, followed distantly by Spanish (59; 0.45%; CPP_{2018} = 1.9), German (49; 0.37%; CPP_{2018} = 1.4), French (47; 0.35%; CPP_{2018} = 1.6), Portuguese (40; 0.30%; CPP_{2018} = 3.5), Polish (18; 0.14%; CPP_{2018} = 1.3), Chinese (10; 0.075%; CPP_{2018} = 3.1), and Japanese (10; 0.075%; CPP_{2018} = 0.80). Others languages also used in artificial intelligence-related articles, such as Russian (8 articles), Croatian (7), Turkish (6), Rumanian (3), Italian (2), Korean (2), and one for each of Czech, Slovene, and Ukrainian, respectively. An article entitled "Applications of artificial intelligence in organic chemistry. XVII. New programs in the SISTEMAT project" [44] published in *Spectroscopy-An International Journal* by French had the highest TC_{2018} of 21 in 265 Non-English articles.

3.2 *Characteristics of publication outputs*

In recent years, Ho's group proposed a relationship between total number of articles in a year (*TP*) and their citations per publication ($CPP_{2018} = TC_{2018}/TP$) by the years in a research field as a unique indicator for research topics, for example Ebola [45], dengue [32], bioaccumulation [46], wind tunnel [47], and distributed control [48]. The annual number of artificial intelligence-related articles in SCI-EXPANDED was counted and is displayed in Fig. 1. The number of articles fluctuated slightly with an increase from 303 articles in 1991 to 628 articles in 2015. After that a dramatic sharply increased from 2016 to 2018. The highest CPP_{2018} was 32 in 2001, followed by 26 in 1995. Impact of papers in a research field has been compared with the number of times any paper is cited in other publications from Web of Science Core Collection [49,50]. In general, citation frequency is highly correlated with the length of time since publication and newly published papers require time to accumulate citations [51]. Based on Fig. 1, it takes *CPP*s about a decade to reach a plateau. It has been reported that highly cited articles in Taiwan [50], articles published in *Journal of Membrane Science* [41], and dengue-related articles in the Science Citation Index Expanded [32].also took about one decade to reach a plateau. It might be concluded that to evaluate impact of papers, at least ten years is needed for a good assessment of their active life [26]. In order to verify this 10-year lag, Chuang and Ho concluded that regardless of the year of data, they all showed approximately a 10-year period between the time of data collection and the peak output of highly cited papers [50]. To emphasize this point, a total of 10,632 artificial intelligence articles (80% of 13,251 articles) had no citations in the publication year

($C_0 = 0$). However, with an increasing number of journals in Web of Science Core Collection, articles have had higher citations in the publication year in recent years [34]. Furthermore, among the top 100 articles in C_0, only 7.3% and 26% of them were among the top 100 articles in TC_{2018} and C_{2018} respectively. Using a 5-year time-span as the assessment period might not reflect the true impact of a paper [50].

3.3 *Research areas, Web of Science categories and journals*

In this context, 13,245 artificial intelligence articles with information of Web of Science research areas were published in 135 research areas. In total of 9,360 articles (71% of 13,245 articles) were in research areas of computer science (6,477 articles; 49%) and engineering (4,762; 36%) followed by operations research and management science (901; 6.8%), automation and control systems (643; 4.9%), mathematics (579; 4.4%), science and technology - other topics (574; 4.3%), materials science (484; 3.7%), chemistry (442; 3.3%), environmental sciences and ecology (409; 3.1%), and physics (366; 2.8%). In Web of Science Core Collection, documents can be in two or more research areas, thus the sum of all percentages was higher than 100%. A comparison of the development trends of the top six Web of Science research areas published 100 or more artificial intelligence articles in 2018 is shown in Fig. 2. All the six research areas had an increasing trend after 2016. Research areas of engineering and computer science had a sharply increased trend in last three years.

In last decade, distribution of Web of Science categories were investigated to understand interaction among categories in research topics [33]. Research trends among Web of Science categories were proposed in medical related fields; for example, stem cell [52], Japanese lung cancer [43], Ebola [45], and dengue [26]. A total of 13,245 artificial intelligence articles with journal category information in SCI-EXPANDED were published in journals listed in 215 Web of Science categories including 177 in SCI-EXPANDED. Seven Web of Science categories such as green and sustainable science and technology (35 journals in SCI-EXPANDED; 6 journals in SSCI), history and philosophy of science (62; 46), public, environmental and occupational health (185; 162), psychiatry (146, 142), rehabilitation (65, 69), nursing (120, 118), and substance abuse (19, 35) can be also found in SSCI. Web of Science category of allergy in SCI-EXPANDED published no artificial intelligence-related article.

In total 6,477 articles (49% of 13,245 articles published in journals with Web of Science category) were published in seven computer science related categories including artificial intelligence computer science (3,770 articles; 28% of 13,245 articles), information systems computer science (1,209; 9.1%), interdisciplinary applications computer science (1,205; 9.1%), theory and methods computer science (1,039; 7.8%), software engineering computer science (694; 5.2%), cybernetics computer science (333; 2.5%), and hardware and architecture computer science (262; 2.0%). Except the categories of computer sciences, category of electrical and electronic engineering ranked second with 2,170 articles (16%) followed by operations research and management science (901 articles; 6.8%), automation and control systems (643; 4.9%), multidisciplinary engineering (623; 4.7%), civil engineering (539; 4.1%), manufacturing engineering (4943; 3.7%), environmental sciences (367; 2.8%), energy and fuels (360; 2.7%), telecommunications (358; 2.7%), and multidisciplinary materials

science (350; 2.6%). It should be pointed out that journals could be classified in two or more categories in Web of Science. For example, *Expert Systems with Applications* was listed in categories of artificial intelligence computer science, electrical and electronic engineering, and operations research and management science; thus, the sum of all percentages was higher than 100% [53]. A comparison of the growth trends of the top five Web of Science categories with 1,000 or more articles in artificial intelligence research is shown in Fig. 3. Artificial intelligence computer science was the top category in annual number of articles published from 1991 to 2017 while electrical and electronic engineering was top in 2018. The annual number of articles in electrical and electronic engineering had an obviously increased trend in last three year. Similarly, an increased trend in 2018 can be also found in information systems computer science. Publications in theory and methods computer science were active from 2004 to 2006, with a sharp drop-off after 2006 but increased again in last three years.

In total 13,251 artificial intelligence-related articles were published in 3,111 journals including 2,436 listed in SCI-EXPANDED in 2018. In total 675 journals were not listed in SCI-EXPANDED in 2018. According to Bradford's Law of Scattering [54], the journals were sorted in descending order in terms of number of articles, and then divided into three "zones". Zone one represents the most productive one-third of the total articles, with 84 journals (2.7% of 3,111 journals). Zone two represents the next most productive one-third of total articles, with 447 (14%) journals, and Zone three represents the least productive one-third of total articles with 2,580 (83%) journals. The number of journals was approximately $1 : n : n^2$ (1 : 5.3 : 31), following Bradford's law. The 84 most productive journals were the Bradford's core journals. The number of Bradford's core journals in artificial intelligence study was much greater than wide research fields, for example 48 core journals in risk assessment [55], 11 journals in proteomics [56], 11 journals in pluripotent stem cell [29], eight journals in desalination [57], three journals in Ebola [45], and nine journals in corporate governance [58]. Distribution of the top 20 productive journals were listed in Table 2. *Expert Systems with Applications* (IF_{2018} = 4.292) published the most articles with 373 articles (2.8% of 13,251 articles). Fifteen of the top 20 journals listed in the category of artificial intelligence computer science. Four journals were listed in category of electrical and electronic engineering. The percentage of the top productive journal in artificial intelligence research was not high with only 2.8%, which indicates the breadth of article distribution as well as the broad interest in artificial intelligence from various research angles of computer science, engineering, operations research and management science, automation and control systems, mathematics, and science and technology - other topics. This phenomenon also appears in other research areas, such as *Human and Ecological Risk Assessment* (3.0%) in articles related to risk assessment [55], *Water Research* (4.2%) in papers concerning drinking water [59], and *British Medical Journal* (4.3%) on homeopathy research [60]. The journals with the highest IF_{2018} was *Nature Reviews Drug Discovery* (IF_{2018} = 57.618) with one article, followed by *Nature* (IF_{2018} = 43.070) with ten articles, *Science* (IF_{2018} = 41.037) with nine articles, *Nature Materials* (IF_{2018} = 38.887) with one article, and *Cell* (IF_{2018} = 36.216) with one

article. However, the most frequently cited article with TC_{2018} of 2,864 was published in *IEEE Transactions on Information Theory* with IF_{2018} of 2.679.

3.4 *Countries and institutes*

Excluding 152 articles (1.1% of 13,251 articles) without any affiliation information of authors in SCI-EXPANDED, there were 13,099 artificial intelligence articles with author information from 119 countries. Altogether, 10,499 (80% of 13,099 articles) were single country articles from 86 countries and 2,650 (20%) were internationally collaborative articles from 113 countries. Six publication indicators [34,43] such as total publications (*TP*), independent publications (*IP*), collaborative publications (*CP*), first authored publications (*FP*), corresponding authored publications (*RP*), and single authored publications (*SP*) as well as citations per publication (CPP_{2018}) were applied to compare the top 20 countries (Table 3). The top 10 most productive countries published 69% of the 13,099 articles. Nine Asian countries, seven European countries, three American countries, and one Oceania country, were ranked on the top 20 of publications. The most productive African country was Egypt with 88 articles ranked 32th and CPP_{2018} of 9.6. The United States dominated in all six publication indicators and CPP_{2018}. The UK ranked second in *CP* of 554 articles (21% of 2,650 internationally collaborative articles), *SP* of 235 articles (11% of 2,177 single author articles), and CPP_{2018} of 19 while China ranked second in *TP* of 1,523 articles (12% of 13,099 articles), *IP* of 1,053 articles (10% of 10,499 independent articles), *FP* of 1,361 articles (10% of 13,099 first author articles), *RP* of 1,335 articles (10% of 12,883 corresponding author articles). However, China had lower CPP_{2018} of 9.2. A comparison of the growth trends of the top five most productive countries in the most recent year of 2018 is displayed in Fig. 4. Obviously, publications from China grew sharply in last three years and reached 485 articles in 2018. Similarly, The United States and the UK also had sharper trend after 2016. India and Iran ranked 10th and 8th in total articles but ranked 4th and 5th in annual number of articles in 2018.

Number of publications and citations per publication of institutions can be references for evaluating institutions research performance in a field. Of the 13,099 articles with author addresses in SCI-EXPANDED, 6,715 (51% of 13,099 articles) were institute independent articles and 6,384 (49%) were inter-institutionally collaborative articles, including 2,650 (42% of 6,384 articles) international collaborations and 3,734 (58%) national collaborations. The top ten institutions were listed in Table 4. Among these institutions, four of them derived from the United States, two from China, two from Singapore, and one from each of India and Iran, respectively. Chinese Academy of Sciences in China was the most productive institute, and dominated total, inter-institutionally collaborative, first author, and corresponding author articles with CPP_{2018} of 12, while Hong Kong Polytechnic University in China published the most institutionally independent articles and Massachusetts Institute of Technology (MIT) in the United States published the most single author articles. MIT ranked first in CPP_{2018} with 52 followed by Stanford University in the United States with CPP_{2018} of 49. Two of the top ten highly cited articles were published by authors from Stanford University. Islamic Azad University in Iran had the lowest CPP_{2018} of 9.2.

Chinese Academy of Sciences and Indian Institute of Technology had also lower CPP_{2018} of 12 respectively. Furthermore, a bias would appear because the Chinese Academy of Sciences (Chinese Acad Sci) [61] and Indian Institute of Technology (Indian Inst Technol) [57] had numerous branches in different cities. The publications of the institutes were pooled less than one heading; therefore, dividing the publications among the branches would have given different rankings.

3.5 *High impact articles in 2018*

Total number of citations (TC_{2018}) is an indication for an article with high impact or visibility in the research community. Highly cited articles provide an interesting and useful insight into which authors and topics are influencing a research discipline over time [62]. However, an article impact might not be always high since its publication [35]. Therefore, number of citations in the most recent year (C_{year}) of an article was concerned for high impact articles in the most recent year. It was found that the top articles on TC_{year} and C_{year} were never the same [35,63]. The top articles on number of citations in most recent year (C_{year}) might be an indicator to help researchers to understand recent research in a field [26]. The eight most impact articles in 2018 with $C_{2018} > 100$ are shown in Table 5. Three of the eight articles were published in *Nature* ($IF_{2018} = 43.070$), and one in each of *Nature Materials* ($IF_{2018} = 38.887$), *IEEE Transactions on Image Processing* ($IF_{2018} = 6.790$), *Mechanical Systems and Signal Processing* ($IF_{2018} = 5.005$), *IEEE Transactions on Information Theory* ($IF_{2018} = 3.215$), and *International Journal of Human-Computer Studies* ($IF_{2018} = 2.006$) respectively. Five articles were published by authors from the United States, two from the UK, one from each of Belgium, Canada, China, and Switzerland respectively. Only Stanford University published two high impact articles as both first author and corresponding authors. The top cited articles and high impact articles in the most recent year were discussed [26]. Figure 4 shows citation histories of the five articles ranked in the top ten of both the number of citations since its publication to the end of 2018 and number of citations in 2018.

An article entitled "Mastering the game of Go with deep neural networks and tree search" [64] by Silver et al. from Google DeepMind in the UK and Google in the United States, ranked first in C_{2018} and C_0 with 791 and 183 respectively and TC_{2018} ranked 4th with 1,435. The game of Go has long been viewed as the most challenging of classic games for artificial intelligence. Silver et al. presented a new approach to computer Go that uses 'value networks' to evaluate board positions and 'policy networks' to select moves [64]. The classic article [65] by Silver et al. [64] had dramatic increasing of citations after it publication shows the most impactful article in 2018 (Fig. 5) and might keep in a high impact position in artificial intelligence research filed. An article entitled "Highly sensitive flexible pressure sensors with microstructured rubber dielectric layers" [66] by Mannsfeld et al. from Stanford University in the United States also had a sharply increased citation trend.

3.6 *Research foci*

In the last decade, Ho's group proposed distributions of article titles and abstracts, author keywords, and *KeyWords Plus* of different periods to determine research foci and trends [55,67]. These analysis could minimize limitations, such as the incomplete meaning of single words in article title and abstract, small sample size for author keywords, and the indirect relationship between *KeyWords Plus* and the research emphases [68]. The four kinds of words were examined by period to show the rough trends, as well as to minimize the year-to-year fluctuations. Among 13,251 articles, 13,029 articles (98% of 13,251 articles) had records information of article abstracts, 10,316 (78%) articles had author keywords, and 9,032 (68%) articles had *KeyWords Plus*. The 20 most frequently used author keywords of four sub-periods (1991–1997, 1998–2004, 2005–2011, and 2012–2018) are listed in Table 6. The most frequently used author keywords, except for the searching words, "artificial intelligence" and "artificial intelligences", can be divided into three groups according to their appearing features. With this in mind, the three most frequently used author keywords were "neural networks", "fuzzy logic", and "learning". The authors keyword "artificial neural network" ranked 6th with 2.8% of 10,316 articles published from 1991 to 2018. "Artificial neural network" has gained popularity in the last two decades, rising from 83th overall with 0.45% of 1,321 articles published from 1991 to 1997 to 4th overall with 4.2% of 5,134 articles published from 2012 to 2018. Authors used "deep learning" as author keyword in 146 articles since 2015. However, the ranks of author keywords "expert systems" and "expert system", decreased from 2nd and 4th to 43th and 41th respectively.

The possible research hotspots related to artificial intelligence could be obtained by word cluster from words in article titles and abstracts as well as author keywords and *KeyWords Plus*. Each word cluster was composed of several supporting words [55,67]. For example, the two words model, modelling, models, and modelling constitute a word cluster for a research focus of "models" including model based, mixed model, mathematical modeling, metamodeling, metamodel, meta model, and metamodelling. Another example, the two words "neural networks" and "neural network" constitute a word cluster for a research focus of "neural networks" including artificial neural networks, artificial neural network, fuzzy neural network, radial basis function neural network, and fuzzy neural networks. "Learning" (TP = 3,004) with supporting words learning, learn, learns, learned, learning-based, machine-learning, E-learning, self-learning, and Q-learning and "prediction" (TP = 2,679) with supporting words prediction, predictions, predict, predicts, predicting, predicted, predictive, predictor, predictors, unpredictable, predictability, predictable, bankruptcy prediction, predictive modeling, and time-series prediction were also the main research focuses. The article number growth trends of the top four most concerned topics in artificial intelligence from 1991-2018 are compared in Fig. 6. Studies on "models", "neural networks", "learning", and "prediction" showed similar trends in that a sharply increased trendline can be found in the last three years especially "models" and "neural networks". The early study of models in artificial intelligence can be found in 1975 [69] by Schiminovich from American Institute of Physics in USA. The classic articles with TC_{2018} of

1,000 or more entitled "Factor graphs and the sum-product algorithm" [70] by Kschischang et al. from Canada, USA, and Switzerland is the most frequently cited with TC_{2018} of 2,864 and the most impact in 2018 with C_{2018} of 203. Similarly, the early study of neural networks in artificial intelligence can be found in 1989 [71]. The main research areas under the heading of neural networks were applications in the managerial applications [72], atmospheric sciences [73], diagnostic techniques for electrical machines [74], medicine [75], and games [64]. For the topic of learning in artificial intelligence, a study of learning control systems and intelligent control systems was reported in 1971 [76]. Related studies were presented including medical related research and energy management [77]. Other research foci of artificial intelligence were optimization (*TP* = 1,984), features (*TP* = 1,606), fuzzy logic (*TP* = 1,579), classification (*TP* = 1,318), genetic algorithms (*TP* = 1,053), expert systems (*TP* = 1,032), hybrid (*TP* = 969), support vector machine (*TP* = 637), and big data (*TP* = 269). Figure 7 shows that "features", "classification", and "big data" might be new research topics in artificial intelligence field. Furthermore, a trend of "expert systems" related topic with 1,032 articles in SCI-EXPANDED was found, decreasing from 1991 to 2018 and reaching 20 articles in 2018.

4. Conclusions

During the period from 1991 to 2018, 15,510 artificial intelligence-related documents were published in 21 Web of Science document types in SCI-EXPANDED. A dramatic increasing of articles has been found since 2016. Artificial intelligence has been concerned in wide fields except for Web of Science category of allergy in SCI-EXPANDED. Artificial intelligence computer science field was the most active. All related articles were also published in a wide range of journals. The United States dominated artificial intelligence research. China and Iran were new productive members in artificial intelligence research but had lower citations per publication. Chinese Academy of Sciences in China published the most articles. Massachusetts Institute of Technology (MIT) and Stanford University had better performance on high impact articles. "Factor graphs and the sum-product algorithm" was the most cited article in the artificial intelligence field. Neural networks and learning were the main research foci. In addition, researchers paid more attention to the topics of optimization, features, classification, support vector machine, and big data in recent years.

Table 1
Document types of artificial Intelligence publications in SCI-EXPANDED

Document type	*TP*	%	*TP**	*AU*	*APP*	TC_{2018}	CPP_{2018}
Article	13,251	85	13,246	43,098	3.3	185,823	14
Proceedings paper	1,569	10	1,568	4,495	2.9	22,930	15
Review	873	5.6	873	2,940	3.4	41,081	47
Editorial material	822	5.3	804	1,799	2.2	2,743	3.3
Meeting abstract	303	2.0	301	1,799	6.0	16	0.053
Letter	86	0.55	83	153	1.8	372	4.3
Book review	41	0.26	40	40	1.0	14	0.34
Note	37	0.24	35	70	2.0	207	5.6
News item	34	0.22	27	29	1.1	35	1.0
Book chapter	21	0.14	21	62	3.0	222	11
Correction	17	0.11	17	62	3.6	33	1.9
Bibliography	12	0.077	12	14	1.2	366	31
Reprint	11	0.071	11	25	2.3	152	14
Biographical-item	10	0.064	9	16	1.8	10	1.0
Addition correction	4	0.026	4	8	2.0	5	1.3
Discussion	4	0.026	4	4	1.0	1	0.25
Software review	3	0.019	3	7	2.3	4	1.3
Data paper	2	0.013	2	14	7.0	2	1.0
Retracted publication	2	0.013	2	7	3.5	24	12
Database review	1	0.0064	1	2	2.0	5	5.0
Retraction	1	0.0064	0	0	N/A	0	0

TP: number of publications; *TP**: number of publications with author information; *AU*: number of authors; *APP*: number of authors per publication; TC_{2018}: the total number of citations from Web of Science Core Collection since publication to the end of 2018; CPP_{2018}: number of citations (TC_{2018}) per publication (*TP*); N/A: not available.

Table 2

Top 20 most productive journals

Journal	*TP* (%)	IF_{2018}	Web of Science category
Expert Systems with Applications	373 (2.8)	4.292	artificial intelligence computer science electrical and electronic engineering operations research and management science
AI Magazine	191 (1.4)	1.316	artificial intelligence computer science
Engineering Applications of Artificial Intelligence	175 (1.3)	3.526	automation and control systems artificial intelligence computer science multidisciplinary engineering electrical and electronic engineering
Artificial Intelligence	146 (1.1)	4.483	artificial intelligence computer science
Kybernetes	102 (0.77)	1.381	cybernetics computer science
IEEE Access	99 (0.75)	4.098	information systems computer science electrical and electronic engineering telecommunications
Minds and Machines	91 (0.69)	1.400	artificial intelligence computer science
Knowledge-Based Systems	88 (0.66)	5.101	artificial intelligence computer science
Applied Artificial Intelligence	84 (0.63)	0.988	artificial intelligence computer science electrical and electronic engineering
Artificial Intelligence Review	79 (0.60)	5.095	artificial intelligence computer science
European Journal of Operational Research	79 (0.60)	3.806	management operations research and management science
Applied Soft Computing	75 (0.57)	4.873	artificial intelligence computer science interdisciplinary applications computer science
Journal of Intelligent Manufacturing	65 (0.49)	3.535	artificial intelligence computer science manufacturing engineering
Neurocomputing	65 (0.49)	4.072	artificial intelligence computer science
Artificial Intelligence in Medicine	64 (0.48)	3.574	artificial intelligence computer science biomedical engineering medical informatics
Information Sciences	64 (0.48)	5.524	information systems computer science
Applied Intelligence	63 (0.48)	2.882	artificial intelligence computer science
International Journal of Advanced Manufacturing Technology	62 (0.47)	2.496	automation and control systems manufacturing engineering
Journal of Experimental & Theoretical Artificial Intelligence	62 (0.47)	2.111	artificial intelligence computer science
Neural Computing & Applications	58 (0.44)	4.664	artificial intelligence computer science

TP: number of articles; IF_{2018}: journal impact factor in 2018.

Table 3
Top 20 most productive countries

Country	*TP*	*TPR* (%)	*IPR* (%)	*CPR* (%)	*FPR* (%)	*RPR* (%)	*SPR* (%)	CPP_{2018}
USA	3,098	1 (24)	1 (21)	1 (34)	1 (19)	1 (19)	1 (31)	23
China	1,523	2 (12)	2 (10)	3 (18)	2 (10)	2 (10)	4 (4.3)	9.2
UK	1,322	3 (10)	3 (7.3)	2 (21)	3 (7.6)	3 (7.7)	2 (11)	19
Spain	832	4 (6.4)	4 (5.4)	5 (10)	4 (5.4)	4 (5.5)	13 (2.1)	11
Canada	604	5 (4.6)	10 (3.0)	4 (11)	8 (3.4)	8 (3.4)	7 (3.8)	18
France	582	6 (4.4)	9 (3.2)	6 (9.5)	9 (3.2)	9 (3.2)	5 (4.2)	13
Italy	567	7 (4.3)	7 (3.4)	9 (8.0)	7 (3.5)	7 (3.5)	8 (3.0)	14
Iran	561	8 (4.3)	6 (3.5)	10 (7.3)	5 (3.8)	5 (3.8)	19 (1.0)	9.9
Germany	545	9 (4.2)	11 (3.0)	7 (8.7)	10 (3.0)	10 (3.0)	3 (4.8)	12
India	534	10 (4.1)	5 (4.0)	14 (4.3)	6 (3.6)	6 (3.6)	14 (1.6)	9.8
Australia	459	11 (3.5)	17 (2.2)	8 (8.6)	15 (2.4)	15 (2.4)	10 (2.4)	12
Taiwan	408	12 (3.1)	8 (3.2)	19 (2.8)	11 (2.9)	11 (2.9)	9 (2.6)	17
Japan	401	13 (3.1)	14 (2.6)	11 (4.7)	14 (2.4)	13 (2.4)	11 (2.4)	9.5
Turkey	377	14 (2.9)	13 (2.6)	15 (3.8)	12 (2.5)	12 (2.5)	11 (2.4)	13
Brazil	374	15 (2.9)	12 (2.7)	17 (3.4)	12 (2.5)	14 (2.4)	20 (0.92)	8.3
South Korea	320	16 (2.4)	15 (2.4)	20 (2.8)	16 (2.1)	16 (2.2)	17 (1.3)	9.4
Poland	298	17 (2.3)	16 (2.2)	25 (2.4)	17 (2.0)	17 (2.0)	6 (4.1)	8.9
Netherlands	226	18 (1.7)	20 (1.0)	13 (4.6)	21 (1.1)	22 (1.1)	15 (1.5)	14
Malaysia	205	19 (1.6)	24 (0.78)	12 (4.6)	20 (1.2)	20 (1.2)	56 (0.092)	11
Singapore	190	20 (1.5)	21 (0.92)	16 (3.5)	22 (1.1)	21 (1.1)	32 (0.51)	16

TP: total articles, *TPR* (%): total number of articles and the percentage of total articles, *IPR* (%): rank and percentage of single country articles, *CPR* (%): rank and percentage of internationally collaborative articles, *FPR* (%), rank and the percentage of first author articles, *RPR* (%), rank and the percentage of the corresponding authored articles; CPP_{2018}: citations per publication (TC_{2018}/TP).

Table 4

Top 10 most productive institutions

Institute	*TP*	*TPR* (%)	*IPR* (%)	*CPR* (%)	*FPR* (%)	*RPR* (%)	*SPR* (%)	CPP_{2018}
Chinese Academy of Sciences, China	149	1 (1.1)	30 (0.24)	1 (2.1)	1 (0.60)	1 (0.66)	71 (0.18)	12
Islamic Azad University, Iran	128	2 (1.0)	14 (0.36)	2 (1.6)	3 (0.56)	4 (0.50)	192 (0.092)	9.2
Massachusetts Institute of Technology (MIT), USA	101	3 (0.77)	4 (0.57)	4 (1.0)	5 (0.45)	5 (0.44)	1 (1.0)	52
Hong Kong Polytechnic University, China	100	4 (0.76)	1 (0.69)	7 (0.85)	2 (0.59)	2 (0.62)	4 (0.55)	20
Nanyang Technological University, Singapore	94	5 (0.72)	3 (0.58)	6 (0.86)	3 (0.56)	3 (0.57)	26 (0.32)	19
Stanford University, USA	93	6 (0.71)	7 (0.42)	3 (1.0)	9 (0.35)	7 (0.36)	2 (0.92)	49
Indian Institute of Technology, India	81	7 (0.62)	2 (0.60)	17 (0.64)	6 (0.42)	6 (0.42)	71 (0.18)	12
Carnegie Mellon University, USA	75	8 (0.57)	7 (0.42)	10 (0.74)	11 (0.29)	13 (0.28)	3 (0.78)	25
Georgia Institute of Technology, USA	71	9 (0.54)	21 (0.27)	8 (0.83)	26 (0.24)	24 (0.24)	192 (0.092)	18
National University Singapore, Singapore	69	10 (0.53)	9 (0.39)	14 (0.67)	9 (0.35)	8 (0.35)	192 (0.092)	14

TP: total articles, *TPR* (%): total number of articles and the percentage of total articles, *IPR* (%): rank and percentage of single institute articles, *CPR* (%): rank and percentage of inter-institutionally collaborative articles, *FPR* (%), rank and the percentage of first author articles, *RPR* (%), rank and the percentage of the corresponding authored articles; CPP_{2018}: citations per publication (TC_{2018}/TP).

Table 5

The top eight most impactful articles in the most recent year of 2018 in artificial intelligence research with $C_{2018} > 100$

Rank (C_{2018})	Rank (TC_{2018})	Title	Countries	References
1 (791)	4 (1,435)	Mastering the game of Go with deep neural networks and tree search	UK, USA	[64]
2 (540)	12 (677)	Dermatologist-level classification of skin cancer with deep neural networks	USA	[78]
3 (302)	37 (311)	Mastering the game of Go without human knowledge	UK	[97]

Contd...

4 (269)	5 (1,133)	Highly sensitive flexible pressure sensors with microstructured rubber dielectric layers	USA	[66]
5 (203)	1 (2,864)	Factor graphs and the sum-product algorithm	Canada, USA, Switzerland	[70]
6 (141)	6 (726)	ViBe: A universal background subtraction algorithm for video sequences	Belgium	[80]
7 (131)	72 (217)	Deep neural networks: A promising tool for fault characteristic mining and intelligent diagnosis of rotating machinery with massive data	China	[81]
8 (103)	2 (2,159)	Toward principles for the design of ontologies used for knowledge sharing	USA	[82]

C_{2018}: number of citations from Web of Science Core Collection in 2018; TC_{2018}: number of citations from its publication to the end of 2018.

Table 6

The 20 most frequently used author keywords

Author keywords	*TP*	91-18 *R* (%)	91-97 *R* (%)	98-04 *R* (%)	05-11 *R* (%)	12-18 *R* (%)
artificial intelligence	3,907	1 (38)	1 (52)	1 (41)	1 (36)	1 (34)
neural networks	515	2 (5.0)	3 (7.2)	2 (8.7)	2 (6.0)	6 (2.9)
machine learning	444	3 (4.3)	10 (2.1)	8 (2.8)	10 (2.3)	2 (6.2)
learning (artificial intelligence)	323	4 (3.1)	N/A	N/A	64 (0.47)	3 (6.1)
artificial neural networks	311	5 (3.0)	17 (1.4)	6 (2.8)	3 (4.1)	5 (3.0)
artificial neural network	294	6 (2.8)	83 (0.45)	48 (0.66)	8 (2.6)	4 (4.2)
fuzzy logic	286	7 (2.8)	10 (2.1)	4 (3.5)	5 (3.2)	8 (2.5)
neural network	267	8 (2.6)	8 (2.3)	6 (2.8)	4 (3.3)	11 (2.3)
expert systems	239	9 (2.3)	2 (10)	5 (3.2)	17 (1.3)	43 (0.56)
genetic algorithm	227	10 (2.2)	54 (0.68)	13 (1.8)	7 (2.7)	9 (2.5)
genetic algorithms	211	11 (2.0)	14 (1.7)	3 (4.8)	9 (2.5)	21 (1.1)
data mining	195	12 (1.9)	128 (0.30)	16 (1.7)	6 (2.7)	12 (2.0)
optimization	173	13 (1.7)	34 (0.91)	19 (1.5)	11 (1.9)	14 (1.9)
expert system	162	14 (1.6)	4 (5.1)	11 (2.3)	15 (1.3)	41 (0.58)
pattern recognition	147	15 (1.4)	9 (2.2)	12 (1.9)	14 (1.5)	26 (1.0)
deep learning	146	16 (1.4)	N/A	N/A	N/A	7 (2.8)
feature extraction	137	17 (1.3)	177 (0.23)	322 (0.13)	59 (0.51)	10 (2.3)
case-based reasoning	132	18 (1.3)	17 (1.4)	9 (2.4)	12 (1.7)	35 (0.72)
knowledge representation	130	19 (1.3)	7 (3.3)	10 (2.4)	26 (1.0)	54 (0.53)
classification	124	20 (1.2)	29 (1.0)	26 (1.0)	20 (1.2)	16 (1.3)

TP: number of articles; *R*: rank in a period; N/A: not available

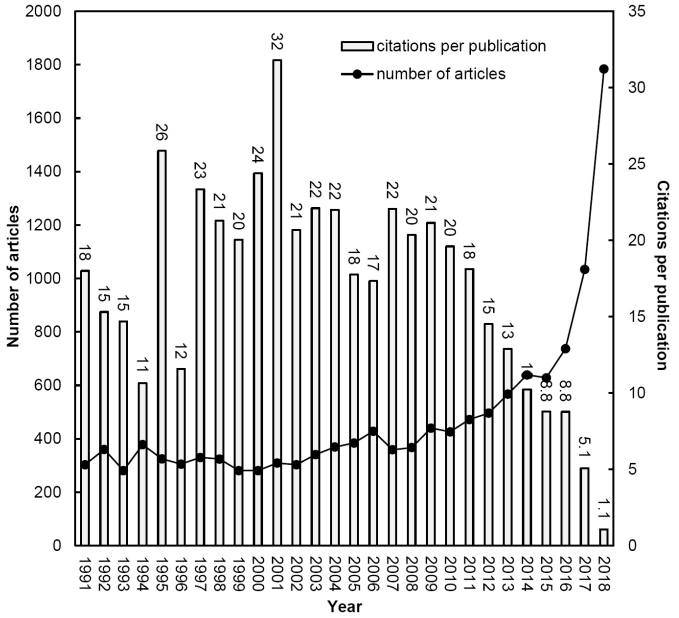

Figure 1

Number of articles and citations per publication by year.

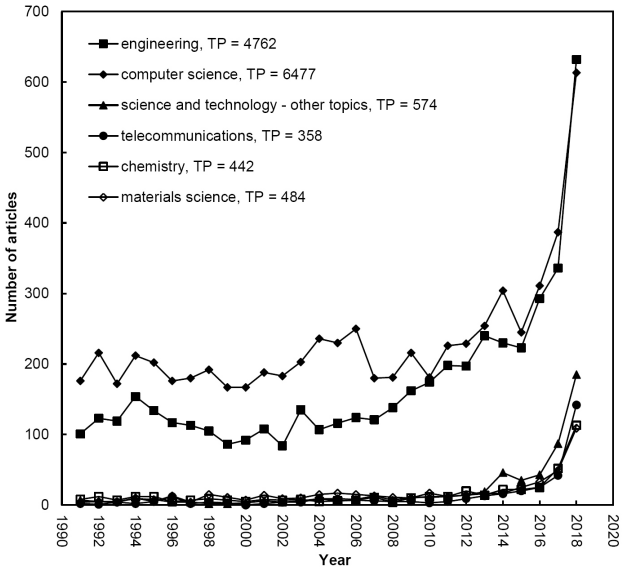

Figure 2

Development of the top six research areas during 1991-2018.

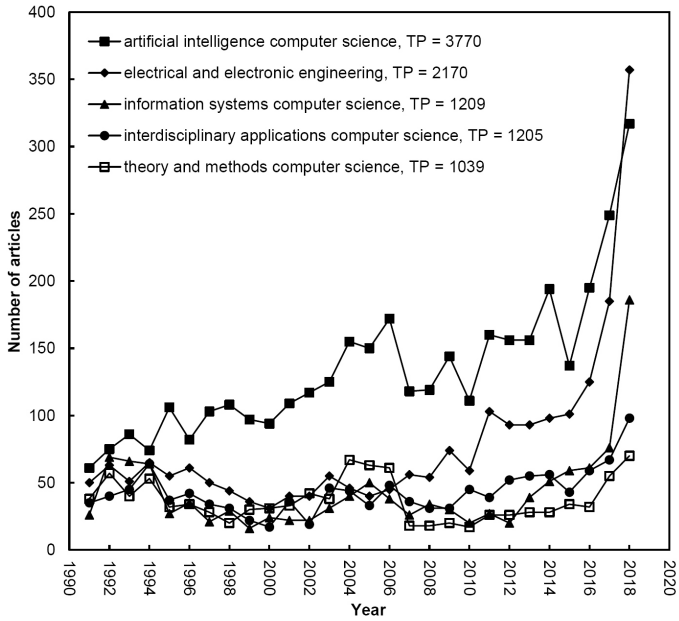

Figure 3

Top five Web of Science categories during 1991-2018.

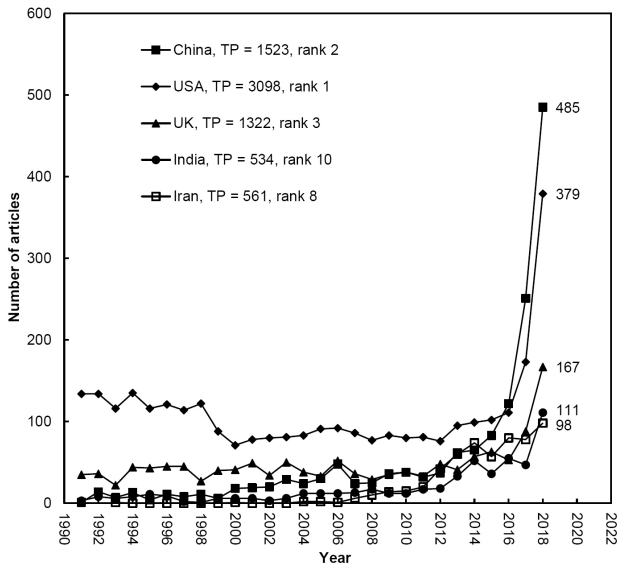

Figure 4

Development of the top five productive countries in 2018.

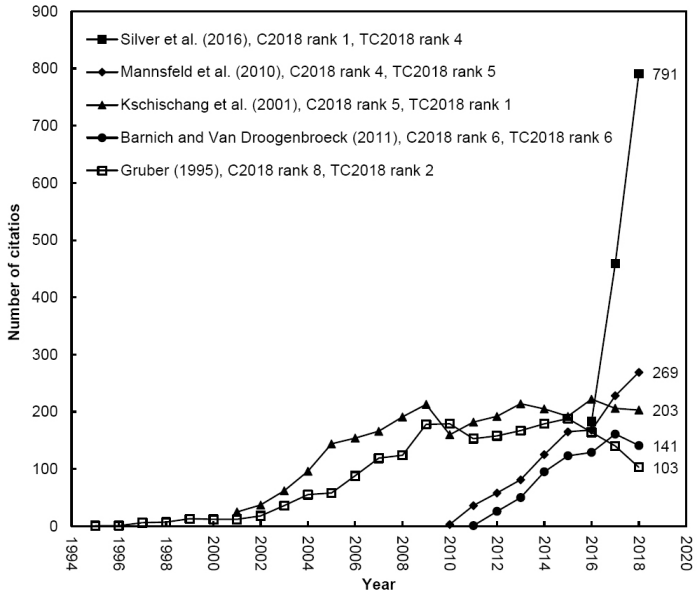

Figure 5

Citation histories of the five articles ranked in the top ten of both the number of citations since its publication to the end of 2018 and number of citations in 2018.

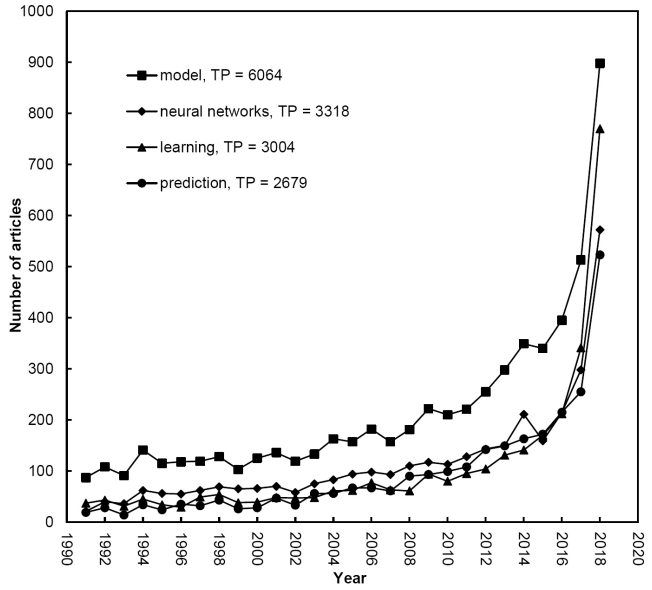

Figure 6

Development of the top four most concerned topics in artificial intelligence from 1991-2018.

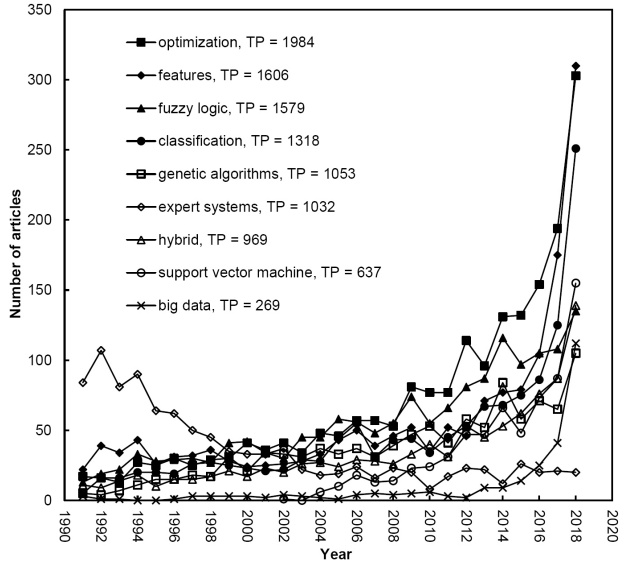

Figure 7

Development of the main research focuses in artificial intelligence from 1991-2018.

References

[1] Pierce, A. A Concise Bibliography of the Literature on Artificial Intelligence: Project 4610, Task 46104. 1959.

[2] Shubik, M. Bibliography on simulation, gaming, artificial intelligence and allied topics. *Journal of the American Statistical Association* 55, 1960, 736-751.

[3] Minsky, M. Steps toward artificial intelligence. *Proceedings of the Institute of Radio Engineers* 49, 1961, 8-30.

[4] Lederberg, J., Sutherla, G.l., Buchanan, B.G., Feigenba, Ea. Robertso, Av., Duffield, A.M. & Djerassi, C. Applications of artificial intelligence for chemical inference. i. Number of possible organic compounds. Acyclic structures containing C H O and N. *Journal of the American Chemical Society* 91, 1969, 2973-2976.

[5] Masinter, L.M., Sridharan, N.S., Lederberg, J. & Smith, D.H. Applications of artificial intelligence for chemical inference. 12. Exhaustive generation of cyclic and acyclic isomers. *Journal of the American Chemical Society* 96, 1974, 7702-7714.

[6] Carhart, R.E., Smith, D.H., Brown, H. and Djerassi, C. Applications of artificial intelligence for chemical inference. 17. Approach to computer-assisted elucidation of molecular-structure. *Journal of the American Chemical Society* 97, 1975, 5755-5762.

[7] Carhart, RE, Smith DH, Gray NAB, Nourse JG, Djerassi C: Applications of artificial-intelligence for chemical inference. 37. Genoa - a computer-program for structure elucidation utilizing overlapping and alternative substructures. *Journal of Organic Chemistry* 46, 1981, 1708-1718.

[8] Lindley, M.R., Shoolery, J.N., Smith, D.H. & Djerassi, C. Applications of artificial-intelligence for chemical inference. 43. Application of the computer-program genoa and two-dimensional NMR-spectroscopy to structure elucidation. *Organic Magnetic Resonance* 21, 1983, 405-411.

[9] Carbonel. Jr. AI in CAI: An artificial-intelligence approach to computer assisted instruction. *IEEE Transactions on Man-Machine Systems* MM11, 1970, 190-202.

[10] Smith, L.C. Artificial-intelligence applications in information systems. *Annual Review of Information Science and Technology* 15, 1980, 67-105.

[11] Klopman, G. Artificial-intelligence approach to structure activity studies - computer automated structure evaluation of biological-activity of organic-molecules. *Journal of the American Chemical Society* 106, 1984, 7315-7321.

[12] Garfield, E. Artificial intelligence: Using computers to think about thinking. Part 1. Representing knowledge. *Current Contents* 49, 1983, 5-13.

[13] Garfield, E. Artificial intelligence: Using computers to think about thinking. Part 2. Some practical applications of AI. Current Contents 1983, 52:5-17.

[14] Glover, F. future paths for integer programming and links to artificial-intelligence. Computers & Operations Research 13, 1986, 533-549.

[15] Carhart, R.E., Smith, D.H., Brown, H. & Sridharan, N.S. Applications of artificial intelligence for chemical inference. 16. computer generation of vertex-graphs and ring-systems. Journal of Chemical Information and Computer Sciences 1975, 15:124-130.

[16] Bahrammirzaee, A. A comparative survey of artificial intelligence applications in finance: artificial neural networks, expert system and hybrid intelligent systems. *Neural Computing & Applications* 19, 2010, 1165-1195.

[17] Gribov, L.A. Application of artificial-intelligence systems in molecular-spectroscopy. *Analytica Chimica Acta-Computer Techniques and Optimization* 4, 1980, 249-256.

[18] Mellit, A. & Kalogirou, S.A. Artificial intelligence techniques for photovoltaic applications: A review. *Progress in Energy and Combustion Science* 2008, 34:574-632.

[19] Mazaheri, H., Ghaedi, M., Azqhandi, M.H.A. & Asfaram, A. Application of machine/statistical learning, artificial intelligence and statistical experimental design for the modeling and optimization of methylene blue and Cd(II) removal from a binary aqueous solution by natural walnut carbon. *Physical Chemistry Chemical Physics* 19, 2017, 11299-11317.

[20] Hunt, E. Computer simulation: artificial intelligence studies and their relevance to psychology. *Annual Review of Psychology* 19, 1968, 135-168.

[21] Barsalou, L.W. Perceptual symbol systems. *Behavioral and Brain Sciences* 22, 1999, 577-660.

[22] Garfield, E. *KeyWords Plus*: ISI's breakthrough retrieval method. Part 1. Expanding your searching power on Current Contents on Diskette. *Current Contents* 32, 1990, 5-9.

[23] Fu, H.Z. & Ho, Y.S. Top cited articles in thermodynamic research. Journal of Engineering Thermophysics 2015, 24:68-85.

[24] Fu, HZ, Wang, MH, Ho, YS. The most frequently cited adsorption research articles in the Science Citation Index (Expanded). Journal of Colloid and Interface Science 2012, 379:148-156.

[25] Fu, HZ, Ho, YS. Top cited articles in adsorption research using Y-index. Research Evaluation 2014, 23:12-20.

[26] Ho, YS, Fu, HZ: Mapping of metal-organic frameworks publications: A bibliometric analysis. Inorganic Chemistry Communications 2016, 73:174-182.

[27] Li, Z, Ho, YS. Use of citation per publication as an indicator to evaluate contingent valuation research. Scientometrics 2008, 75:97-110.

[28] Fu, HZ, Ho, YS. Comparison of independent research of China's top universities using bibliometric indicators. Scientometrics 2013, 96:259-276.

[29] Lin, CSL, Ho, YS. A Bibliometric Analysis of Publications on Pluripotent Stem Cell Research. Cell Journal 2015, 17:59-70.

[30] Wambu, EW, Fu, HZ, Ho, YS. Characteristics and trends in global tea research: a Science Citation Index Expanded-based analysis. International Journal of Food Science and Technology 2017, 52:644-651.

[31] Tchuifon, DRT, Fu, HZ, Ho, YS. Cameroon publications in the Science Citation Index Expanded: Bibliometric analysis. Revista De Biologia Tropical 2017, 65:1582-1591.

[32] Ho, Y.S., Siu, E., Chuang, K.Y. A bibliometric analysis of dengue-related publications in the Science Citation Index Expanded. Future Virology 2016, 11:631-648.

[33] Chiu, W.T. & Ho, Y.S. Bibliometric analysis of tsunami research. *Scientometrics* 73, 2007, 3-17.

[34] Ho, Y.S. & Kahn, M. A bibliometric study of highly cited reviews in the science citation index expanded (TM). *Journal of the Association for Information Science and Technology* 65, 2014, 372-385.

[35] Ho, Y.S. Top-cited articles in chemical engineering in science citation index expanded: A bibliometric analysis. *Chinese Journal of Chemical Engineering* 20, 2012, 478-488.

[36] Wang, M.H., Fu, H.Z. & Ho, Y.S. Comparison of universities' scientific performance using bibliometric indicators. *Malaysian Journal of Library & Information Science* 16, 2011, 1-19.

[37] Chuang, K.Y., Wang, M.H., Ho, Y.S. High-impact papers presented in the subject category of water resources in the essential science indicators database of the institute for scientific information. *Scientometrics* 87, 2011, 551-562.

[38] Elango, B. & Ho, Y.S. A bibliometric analysis of highly cited papers from India in Science Citation Index Expanded. *Current Science* 112, 2017, 1653-1658.

[39] Hsieh, W.H., Chiu, W.T., Lee, Y.S. & Ho, Y.S. Bibliometric analysis of patent ductus arteriosus treatments. *Scientometrics* 2004, 60:205-215.

[40] Han, J.S., Ho, Y.S. Global trends and performances of acupuncture research. *Neuroscience and Biobehavioral Reviews* 35, 2011, 680-687.

[41] Fu, H.Z. & Ho, Y.S. A bibliometric analysis of the Journal of Membrane Science (1976-2010). Electronic Library 33, 2015, 698-713.

[42] Wooldridge, M. & Jennings, N.R. INTELLIGENT AGENTS - THEORY AND PRACTICE. Knowledge Engineering Review 10, 1995, 115-152.

[43] Ho, Y.S., Satoh, H. & Lin, S.Y. Japanese Lung Cancer Research Trends and Performance in Science Citation Index. *Internal Medicine* 49, 2010, 2219-2228.

[44] Emerenciano, V.D., Rodrigues, G.D., Macari, P.A.T., Vesti, S.A., Borges, J.H.G., Gastmans, J.P. & Fromanteau, D.L.G. Applications of artificial-intelligence in organic-chemistry. 17. New programs in the sistemat project. *Spectroscopy-an International Journal* 12, 1994, 91-98.

[45] Pouris, A. & Ho, Y.S. A bibliometric analysis of research on Ebola in Science Citation Index Expanded. *South African Journal of Science* 112, 2016, 83-88.

[46] Lei, J., Fu, H.Z. & Ho, Y.S. A global perspective of bioaccumulation research using bibliometric analysis. *COLLNET Journal of Scientometrics and Information Management* 12, 2018, 327-341.

[47] Mo, Z.W., Fu, H.Z. & Ho, Y.S. Global development and trend of wind tunnel research from 1991 to 2014: a bibliometric analysis. Environmental Science and Pollution Research 25, 2018, 30257-30270.

[48] Zhai, C., Ho, Y.S. A bibliometric analysis of distributed control publications. *Measurement & Control* 51, 2018, 113-121.

[49] Chuang, K.Y. & Ho, Y.S. Bibliometric profile of top-cited single-author articles in the Science Citation Index Expanded. *Journal of Informetrics* 8, 2014, 951-962.

[50] Chuang, K.Y. & Ho, Y.S. An evaluation based on highly cited publications in Taiwan. Current Science 2015, 108:933-941.

[51] Picknett, T. & Davis, K. The 100 most-cited articles from JMB. *Journal of Molecular Biology* 293, 1999, 173-176.

[52] Li, L.L., Ding, G.H., Feng, N., Wang, M.H. & Ho, Y.S. Global stem cell research trend: Bibliometric analysis as a tool for mapping of trends from 1991 to 2006. Scientometrics 80, 2009, 39-58.

[53] Ho, Y.S. Hartley J: Classic articles published by American scientists (1900-2014): a bibliometric analysis. *Current Science* 111, 2016, 1156-1165.

[54] Bradford, S.C. Sources of information on specific subjects. *British Journal of Engineering* 137, 1934, 85-86.

[55] Mao, N., Wang, M.H. & Ho, Y.S. A Bibliometric study of the trend in articles related to risk assessment published in Science Citation Index. *Human and Ecological Risk Assessment* 16, 2010, 801-824.

[56] Tan, J., Fu, H.Z. & Ho, Y.S. A bibliometric analysis of research on proteomics in Science Citation Index Expanded. *Scientometrics* 98, 2014, 1473-1490.

[57] Tanaka, H. & Ho, Y.S. Global trends and performances of desalination research. *Desalination and Water Treatment* 25, 2011, 1-12.

[58] Huang, C.Y. & Ho, Y.S. Historical research on corporate governance: A bibliometric analysis. *African Journal of Business Management* 2011, 5:276-284.

[59] Fu, H.Z., Wang, M.H., Ho, Y.S. Mapping of drinking water research: A bibliometric analysis of research output during 1992-2011. *Science of the Total Environment* 443, 2013, 757-765.

[60] Chiu, W.T. & Ho, Y.S. Bibliometric analysis of homeopathy research during the period of 1991 to 2003. *Scientometrics* 2005, 63:3-23.

[61] Li, J.F., Zhang, Y.H., Wang, X.S. & Ho, Y.S. Bibliometric Analysis of Atmospheric Simulation Trends in Meteorology and Atmospheric Science Journals. *Croatica Chemica Acta* 82, 2009, 695-705.

[62] Smith, D.R. Citation indexing and highly cited articles in the Australian Veterinary Journal. *Australian Veterinary Journal* 2008, 86:337-339.

[63] Ho, Y.S. Classic articles on social work field in Social Science Citation Index: a bibliometric analysis. *Scientometrics* 98, 2014, 137-155.

[64] Silver, D., Huang, A., Maddison, C.J., Guez, A., Sifre, L., van den Driessche, G., Schrittwieser, J., Antonoglou, I., Panneershelvam, V., Lanctot, M., et al: Mastering the game of Go with deep neural networks and tree search. *Nature* 529, 2016, 484-489.

[65] Long, X., Huang, J.Z., Ho, Y.S. A historical review of classic articles in surgery field. *American Journal of Surgery* 208, 2014, 841-849.

[66] Mannsfeld, S.C.B., Tee, B.C.K., Stoltenberg, R.M., Chen, C., Barman, S., Muir, B.V.O., Sokolov, A.N., Reese, C., Bao, Z.N. Highly sensitive flexible pressure sensors with microstructured rubber dielectric layers. *Nature Materials* 9, 2010, 859-864.

[67] Wang, C.C., Ho, Y.S. Research trend of metal-organic frameworks: a bibliometric analysis. *Scientometrics* 109, 2016, 481-513.

[68] Fu, H.Z. & Ho, Y.S. Independent research of China in Science Citation Index Expanded during 1980-2011. *Journal of Informetrics* 7, 2013, 210-222.

[69] Schiminovich, S. Automatic classification of bibliographic data bases: model for cognitive biological processes and artificial intelligence. *Biosciences Communications* 1, 1975, 24-39.

[70] Kschischang, F.R., Frey, B.J. & Loeliger, H.A. Factor graphs and the sum-product algorithm. *IEEE Transactions on Information Theory* 47, 2001, 498-519.

[71] White, R.W. The artificial-intelligence of urban-dynamics: Neural network modeling of urban structure. *Papers of the Regional Science Association* 67, 1989, 43-53.

[72] Tam, K.Y., Kiang, M.Y. Managerial applications of neural networks: The case of bank failure predictions. *Management Science* 38, 1992, 926-947.

[73] Gardner, M.W., Dorling, S.R. Artificial neural networks (the multilayer perceptron): A review of applications in the atmospheric sciences. *Atmospheric Environment* 32, 1998, 2627-2636.

[74] Bellini, A., Filippetti, F., Tassoni, C. & Capolino, G.A. Advances in Diagnostic Techniques for Induction Machines. *IEEE Transactions on Industrial Electronics* 55, 2008, 4109-4126.

[75] Qian, L., Winfree, E., Bruck, J. Neural network computation with DNA strand displacement cascades. *Nature* 475, 2011, 368-372.

[76] Fu, K.S. Learning control systems and intelligent control systems - intersection of artificial intelligence and automatic control. *IEEE Transactions on Automatic Control* AC16, 1971, 70-&.

[77]. Chaouachi, A., Kamel, R.M., Andoulsi, R. & Nagasaka, K. Multiobjective intelligent energy management for a microgrid. *IEEE Transactions on Industrial Electronics* 60, 2013, 1688-1699.

[78] Esteva, A., Kuprel, B., Novoa, R.A., Ko, J., Swetter, S.M., Blau, H.M., Thrun, S. Dermatologist-level classification of skin cancer with deep neural networks. *Nature* 542, 2017, 115-118.

[79] Silver, D., Schrittwieser, J., Simonyan, K., Antonoglou, I., Huang, A., Guez, A., Hubert, T., Baker, L., Lai, M. & Bolton, A. et al. Mastering the game of Go without human knowledge. *Nature* 550, 2017, 354-359.

[80] Barnich, O. & Van Droogenbroeck, M. ViBe: A universal background subtraction algorithm for video sequences. *IEEE Transactions on Image Processing* 20, 2011, 1709-1724.

[81] Jia, F., Lei, Y.G., Lin, J., Zhou, X. & Lu, N. Deep neural networks: A promising tool for fault characteristic mining and intelligent diagnosis of rotating machinery with massive data. *Mechanical Systems and Signal Processing* 72-73, 2016, 303-315.

[82] Gruber, T.R. Toward principles for the design of ontologies used for knowledge sharing. *International Journal of Human-Computer Studies* 43, 1995, 907-928.