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A SCIENTOMETRIC ANALYSIS OF THE EMERGING TOPICS IN GENERAL COMPUTER SCIENCE

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ABSTRACT

Citations have been an acceptable journal performance metric used by many indexing databases for inclusion and discontinuation of journals in their list. Therefore, editorial teams must maintain their journal performance by increasing article citations for continuous content indexing in the databases. With this aim in hand, this study intended to assist the editorial team of the Journal of Information and Communication Technology (JICT) in increasing the performance and impact of the journal. Currently, the journal has suffered from low citation count, which may jeopardise its sustainability. Past studies in library science suggested a positive correlation between keywords and citations. Therefore, keyword and topic analyses could be a solution to address the issue of journal citation. This article described a scientometric analysis of emerging topics in general computer science, the Scopus subject area for which JICT is indexed. This study extracted bibliometric data of the top 10% journals in the subject area to create a dataset of 5,546 articles. The results of the study suggested ten emerging topics in computer science that can

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be considered by the journal editorial team in selecting articles and a list of highly used keywords in articles published in 2019 and 2020 (as of 15 April 2020). The outcome of this study might be considered by the JICT editorial team and other journals in general computer science that suffer from a similar issue.

Keywords: Scientometrics, scientometric analysis, bibliometrics, citation analysis, research trends.

INTRODUCTION

Journals are an essential source of information and knowledge for scientific studies that make a pool of literature content. Each journal has its editorial team that receives article submission from authors and selects suitable reviewers for the peer-review process. The selected reviewers of the articles provide an evaluation report of the suitability of the submitted articles to be published by the journal based on their area of expertise. This process ensures that the journals publish articles that meet scholarly standards. The number of journals keeps increasing from time to time, which causes massive articles found in the literature with different quality and standard. Therefore, many institutions and researchers have proposed journal evaluation metrics to facilitate researchers in identifying the acceptable quality of research articles as well as journals. Examples of the evaluation metrics are the Journal Impact Factor by Clarivate Analytics and CiteScore by Scopus, which are the major indexing databases. These evaluation metrics provide guidelines to researchers on the acceptable standard of scholarly content. Journal performance also reflects the reputation and achievement of the publishers or institutions.

One of the standard journal performance metrics is the citation counts of articles published by a journal (Moed & Van Leeuwen, 1995) that could serve as a quality indicator (Cole & Cole, 1971). The number of citations has been an acceptable journal performance metric since 1971 based on the evaluation study of sociological research by Cole and Cole (1971). Indexing databases normalise the number of citations with the corresponding number of articles that the journal published in a specific period to obtain accurate and unbiased metrics. The total number of citations is still relevant and useful to date. Prominent indexing databases such as Scopus and Clarivate (formerly known as ISI) used it as one of the performance metrics to determine inclusion or discontinuation of journals from their lists. The indexing databases annually re-evaluate the number of citations received by the journals along with other metrics such as publication concern and discontinue indexing the low-performing journals (Krauskopf, 2018). The purpose of the re-evaluation is to maintain active and performing journals in their databases. The indexing databases will update their list of discontinued journals on their website. For example, Scopus published a list of discontinued journals that can be accessed fromhttps://www.elsevier.com/__data/assets/excel_doc/0005/877523 Discontinued-sources-from-Scopus.xlsx. The list contains 572 journals that had been discontinued since 2009 (as of 20 February 2020). Scopus discontinued 166 journals due to citation-related metrics such as low citations as compared to peer journals in the same subject field and high self-citation rate. The discontinued list denotes the possibility of a journal content that will not be indexed by the indexing databases when it could not reach the minimum number of citations in a year. Therefore, improving journal performance through citation count is necessary for the editorial team of journals listed in the indexing databases.

With this aim in hand, this study intends to support the needs for improving the performance of the Journal of Information and Communication Technology (JICT) published by Universiti Utara Malaysia Press (http://www.jict.uum.edu.my). The journal published its first issue in 2002 and was further indexed in Scopus's general computer science subject area in 2011. In analysing the performance of JICT, the 2018 Scopus CiteScore metrics ranked the journal as number 113 of 206 journals in the general computer science with CiteScore of 0.9, which positions it in the third quartile of the subject area. Looking at the individual articles published by the journal, a study conducted by Shehab, Khader, and Laouchedi (2018) received the highest citations of 23, followed by Hussain, Hashim, Nordin, and Tahir (2013) with 21 citations. Other studies such as those written by Hassan, Nasir, Khairudin, and Adon (2017), Jnr, Majid, and Romli (2018), and Yusuf-Asaju, Dahalin, and Ta'a (2018) had citations above ten, respectively. To date, 27% of the 141 articles published in JICT received no citations. The overall journal achievement is relatively low as compared to other new journals in the same subject area. Due to this condition, the journal editorial team works continuously to improve the impact of the journal, especially in increasing the journal's citations in the coming years.

The number of citations received by an article is evidence of how frequent the content of the article is referred by other researchers in the field (Pechlaner, Zehrer, Matzler, & Abfalter, 2004). Consequently, it demonstrates the overall journal's performance in publishing relevant scientific studies for research literature content. In scientific research, new topics and concepts evolve over time; therefore, studying such topic evolution is necessary to ensure the relevancy and effective dissemination of scientific research output (He et al., 2009). On the other hand, topic evolution studies suggested that the temporal dimension is a significant feature for literature content (Yan, Tang, Liu, Shan, & Li, 2011). In other words, new topics of study in a particular field emerge and adapt in the literature content over time, while some topics are obsolete. The computer science discipline is a fast-growing field of study where many new topics evolve and emerge within a short time (Hazra, Singh, Goyal, Adhikari, & Mukherjee, 2019). Therefore, there is a need for the

JICT editorial team to identify the current topics in computer science so that the journal can publish relevant articles that could attract other researchers' attention in referring to the published content. Eventually, it can increase the journal's citation.

The present study aims to address the issue of JICT's low citation count, as described in the previous paragraph. Therefore, the researchers conducted a scientometric analysis to identify emerging topics in computer science. It is a quantitative study to analyse the literature and reveal trends in specific areas or disciplines (Wang, Xue, Zhao, & Wang, 2018). The objective of the study is to analyse the emerging topics and trends of scientific research in general computer science, which can be used by the JICT editorial team in selecting up-to-date studies for publication. It can help the team to select the trending research topics and thus avoid obsolete studies that receive no attention from the researchers in the discipline. The next section describes the methodology in conducting the scientometric analysis, followed by the results of the study. Finally, the last section summarises the results and discusses future works.

METHODOLOGY

This section presents the overall process and procedure in conducting the scientometric analysis covering the research questions, the methods and tools used for the study, the source of data and dataset construction as well as the procedure for selecting the samples for the study.

Research Questions

The main objective of this study is to analyse the emerging topics and trends of scientific research in general computer science. Therefore, the study formulated the following research questions (RQ) to guide its implementation and analysis:

RQ1 – What are the emerging topics in general computer science?

RQ2 – What are researchers' areas of interest in general computer science?

RQ3 – What are the characteristics of the most recent impactful scientific research in general computer science?

Methods and Tools

The generic process of conducting a scientometric analysis comprises four stages, namely (1) metadata extraction; (2) data pre-processing; (3) data processing and analysis; and (4) result visualisation (Qasim, 2017). Figure 1 illustrates the process and the tools in conducting this study. The software tools used in the study include Microsoft Excel, R Studio, Orange 3.25.0, and IBM SPSS 25. The study derived the bibliometric data from Scopus.

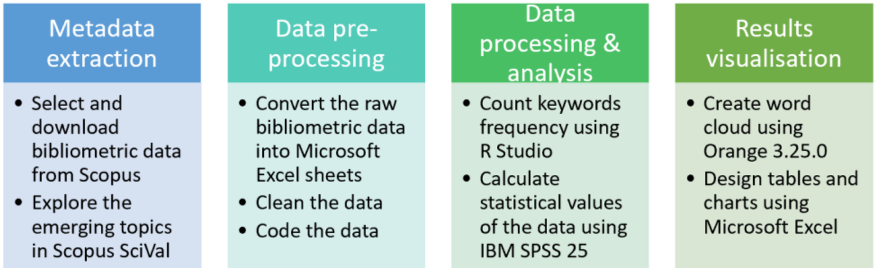

Figure 1. *The process of conducting the scientometric analysis.*

Data and Dataset

The bibliometric data comprised the authors, title, journal title, year of publication, volume, issue, page number, cited by, author keywords, indexed keywords, and types of article. The study omitted other bibliometric data that were irrelevant to the analysis. In Scopus, the computer science discipline encompassed 13 subject areas as listed in Table 1. As of 15 April 2020, Scopus indexed 1,922 journals in the computer science discipline. This number did not include book series, conference proceedings, and trade reports.

Table 1

Number of journals in computer science subject area

Computer Science Subject Area	Number of Journals
Artificial Intelligence	202
Computational Theory and Mathematics	146
Computer Graphics and Computer-Aided Design	86
Computer Networks and Communications	341
Computer Science (miscellaneous)	66
Computer Science Applications	668
Computer Vision and Pattern Recognition	90
General Computer Science	***277***
Hardware and Architecture	170
Human-Computer Interaction	119
Information Systems	319
Signal Processing	118
Software	397
Total	**1,922**

JICT is listed in Scopus's general computer science subject area together with other 276 journals. The subject area reflects its name where it contains multidisciplinary journals that reported studies in a combination of computer science with other disciplines. This includes mathematics, education, engineering, law, business, management and accounting, social sciences, architecture, linguistics, library studies, agriculture, biological sciences, and history. This study utilised the Scopus data from the general computer science subject area in creating a dataset of articles to identify the emerging topics. The dataset contained bibliometric data of 5,546 articles published by 24 journals. These articles were published in 2019 up until 15 April 2020. The following subsection describes the selection procedure for the dataset.

Selection Procedure

The following selection rules have been applied in the analysis when creating the dataset:

1. Selecting the top 10% of journals in the general computer science subject area. Table 2 lists the selected journals and publishers.
2. Limiting the type of publication to journals only. The study has excluded other types of publications, such as conference proceedings, book series, and trade publications.
3. Limiting the journal articles published in 2019 and 2020 (as of 15 April 2020). The study has excluded other years.

Table 2

Top 10% journals in general computer science (based on 2018 CiteScore metrics)

Journal	2019-2020 Documents	Publisher
IEEE Transactions on Smart Grid	679	IEEE
ACM Computing Surveys	185	ACM
Computer Science Review	20	Elsevier
Swarm and Evolutionary Computation	266	Elsevier
Computers and Education	349	Elsevier
Computers in Industry	167	Elsevier
Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery	80	Wiley-Blackwell
European Journal of Operational Research	1,192	Elsevier

(continued)

Journal	2019-2020 Documents	Publisher
IEEE Access	0	***IEEE***
Foundations and Trends in Databases	0	***Now Publishers Inc.***
Computers and Industrial Engineering	947	Elsevier
Computers and Security	333	Elsevier
Computers and Operations Research	369	Elsevier
Human-centric Computing and Information Sciences	54	Springer Nature
Engineering	204	Elsevier
International Journal of Bio-Inspired Computation	47	Inderscience
ACM Transactions on Computer Systems	9	ACM
ACM Transactions on Knowledge Discovery from Data	85	ACM
International Journal of Computational Intelligence Systems	116	Atlantis Press
ACM Transactions on Computing Education	50	ACM
International Journal of Health Geographics	40	Springer Nature
SIAM Journal on Computing	59	Society for Industrial and Applied Mathematics
Computer Science Education	27	Taylor & Francis
Information Technology and Tourism	41	Springer Nature
Computational Intelligence and Neuroscience	173	Hindawi
Construction Innovation	54	Emerald

Table 2 shows the top 10% of journals listed in general computer science based on the Scopus 2018 CiteScore metrics. Scopus had discontinued indexing a journal named Foundations and Trends in Databases in 2018. The contents of 2019 and 2020 of this journal were no longer available in Scopus; therefore, this journal did not have any articles included in the dataset. On the other hand, IEEE Access published 17,379 articles in 2019 and 4,769 articles in 2020 (as of 15 April 2020) and made a total of 18,148 articles for both years. This number was three times higher than the other 24 journals that had published in the same period. The articles published by IEEE Access can make a separate dataset. For this reason, the present study has excluded the journal from the dataset.

ANALYSIS AND RESULTS

This section elaborates the findings of the scientometric analysis conducted for this study. The study calculated the descriptive statistics of the dataset. The citations' mean and standard deviation of the 5,546 articles were 2.46 and 5.283, respectively. On the other hand, the mean for the number of authors and indexed keywords was 4.66 and 13.55, respectively. This section contains three subsections based on the three defined RQs.

What are the emerging topics in computer science?

The study used SciVal, a Scopus tool for analysing research performance in identifying the emerging topics in computer science. The tool discovered 37 newly emerged topics for 2019 in the whole world. The SciVal algorithm identified the emerging topics based on a remarkable growth of published articles in certain areas between 2014 and 2018 that have attracted funding from various agencies. The computer science discipline has ten emerging topics; the highest number of emerging topics as compared to other disciplines. Table 3 lists the emerging topics in computer science from the existing ones, the number of articles in the identified new topics, the value of field-weighted citation impact, and the prominence percentile of the topics. Field-weighted citation impact represents "*the ratio of the total citations actually received by the denominator's output, and the total citations that would be expected based on the average of the subject field*" (Scopus Support Center, 2019). Prominence percentile shows the rank of the topics that combined three metrics, including citation counts, views counts, and CiteScore (Elsevier, 2020).

Table 3

Emerging topics in computer science based on SciVal (as of 15 April 2020)

Emerging topics in computer science	Number of articles	Field-weighted citation impact	Prominence percentile
Models→Computer vision→Deep generative	3310	3.91	99.829
Convolution→Particle accelerators→Convolutional neural network accelerator	2505	3.50	99.604
Models→Computational linguistics→Neural machine translation	1935	3.09	98.337

(continued)

Emerging topics in computer science	Number of articles	Field-weighted citation impact	Prominence percentile
Face recognition→Neural networks→Labelled faces in the wild dataset	895	3.19	98.081
Cloud computing→Tensors→Deep computation	131	4.42	96.356
Neural networks→Convolution→ Unsupervised learning	218	3.73	94.055
Students→Research→Learning media	262	3.71	91.536
Internet→Network security→ Distributed denial-of-service attacks	135	2.79	90.810
Sensor nodes→Genetic algorithms→Wireless sensor networks	125	5.82	90.525
Applications→Internet→Wireless network	103	2.36	88.119

A closer look into the ten emerging topics in computer science listed in Table 3 revealed that those topics were the subfields of artificial intelligence techniques and computer networks. In detail, topics such as “deep generative”, “convolutional neural network accelerator”, “neural machine translation”, “labelled faces in the wild dataset”, “deep computation”, and “unsupervised learning” were the emerging topics related to artificial intelligence techniques. On the other hand, “wireless network”, “wireless sensor networks”, and “distributed denial-of-service attacks” were the emerging topics related to computer network. Nevertheless, “learning media” is a multidisciplinary topic related to education and computer science.

What are the recent researchers’ areas of interest in general computer science?

The study answered this RQ by analysing the keywords in the 5,546 articles of the dataset to obtain the researchers’ areas of interest in general computer science. Scopus provided two types of keyword, namely author keyword and indexed keyword. Author keywords are the keywords defined by authors in the articles. The study used R Studio to perform a frequency count on the keywords in the dataset. The study removed the hyphen in the keyword phrase to maintain data consistency for the frequency count. The dataset yielded a total of 25,849 author keywords. The keyword length differed, covering from one to a maximum of 11 words. As stated earlier, each article in the dataset had an average of 4.66 author keywords. 2-word phrase was the highest with 12,550 keywords. This was followed by 3-word and 1-word phrases with 6,328 and 4,602, respectively. Table 4 lists the size or length of the keyword with its frequency. This study found that an article by Li and Chen (2020) had 11 words for representing a keyword phrase. It is “two-area four-machine and 16-machine 68-bus power system”.

Table 4

The number of author keywords derived from the dataset

Size	Frequency
1-word	4,602
2-word	12,550
3-word	6,328
4-word	1,792
5-word	416
6-word	114
7-word	32
8-word	8
9-word	3
10-word	3
11-word	1
TOTAL	**25,849**

For the 1-word phrase size, “scheduling” had the highest frequency with 135 times of occurrence in the dataset, followed by “optimization”, and “heuristics” with 83 and 63, respectively. Table 5 shows the frequency (F) of the keywords found from the dataset for 1-word, 2-word, and 3-word. The highest frequency for 4-word length keyword was mixed-integer linear programming with 44 occurrences. The occurrences of 5-word, 6-word, 7-word, 8-word, 9-word, and 10-word were not too frequent; therefore, the study omitted those keywords from further analysis. For 2-word, “machine learning”, “game theory”, and “combinatorial optimization” were the top three author keywords. On the other hand, “supply chain management”, “data envelopment analysis”, and “multi-objective optimization” were the top three 3-word author keywords.

Table 5

The top 50 keywords for 1-word, 2-word, and 3-word length

1-word		2-word		3-word	
Keyword	**F**	**Keyword**	**F**	**Keyword**	**F**
scheduling	135	machine learning	142	supply chain management	122
optimization	83	game theory	96	data envelopment analysis	99
heuristics	63	combinatorial optimization	82	multi objective optimization	58
metaheuristics	54	deep learning	79	interactive learning environments	52
simulation	54	integer programming	73	improving classroom teaching	50
microgrid	53	teaching/learning strategies	67	internet of things	40
logistics	48	robust optimization	65	mixed integer programming	40
pricing	48	stochastic programming	57	particle swarm optimization	39
routing	48	demand response	55	media in education	35
security	45	smart grid	55	computer mediated communication	27
classification	41	genetic algorithm	53	vehicle routing problem	27
inventory	40	industry 4.0	52	branch and bound	26
transportation	39	big data	49	branch and price	24
blockchain	38	data mining	49	group decision making	23
uncertainty	37	cloud computing	47	human computer interface	22
finance	35	pedagogical issues	44	systematic literature review	22
sustainability	30	differential evolution	41	ant colony optimization	21
clustering	28	dynamic programming	39	branch and cut	21
energy	27	artificial intelligence	38	multiple objective programming	21
privacy	27	health services	36	post secondary education	21

(continued)

1-word		2-word		3-word	
Keyword	**F**	**Keyword**	**F**	**Keyword**	**F**
location	26	distributed control	30	many objective optimization	20
makespan	25	evolutionary algorithm	30	decision support systems	19
maintenance	24	vehicle routing	30	demand side management	18
survey	24	risk management	29	distributed energy resources	18
cybersecurity	23	decision analysis	28	multiple criteria analysis	18
heuristic	23	local search	28	cyber physical systems	17
manufacturing	23	literature review	27	markov decision process	17
microgrids	23	cooperative/ collaborative learning	25	variable neighborhood search	17
forecasting	22	electric vehicles	25	approximate dynamic programming	15
remanufacturing	22	elementary education	24	big data analytics	15
networks	21	energy storage	24	productivity and competitiveness	15
analytics	20	feature selection	24	monte carlo simulation	14
malware	20	network security	24	optimal power flow	14
efficiency	19	tabu search	24	statistical process control	14
iot	19	project scheduling	23	discrete event simulation	13
matheuristic	18	supply chain	23	natural language processing	13
queueing	18	cyber security	21	model predictive control	12
decomposition	15	project management	21	supply chain coordination	12
marketing	15	benders decomposition	20	cyber physical system	11
resilience	15	evolutionary computation	20	deep neural network	11
review	15	linear programming	20	multi agent systems	11
packing	14	secondary education	20	artificial neural networks	10

(continued)

1-word		2-word		3-word	
Keyword	**F**	**Keyword**	**F**	**Keyword**	**F**
authentication	13	swarm intelligence	20	large scale optimization	10
consensus	13	distribution network	19	phasor measurement units	10
learning	13	electric vehicle	19	support vector machine	10
ontology	13	stochastic optimization	19	traveling salesman problem	10
robustness	13	droop control	18	wireless sensor networks	10
fairness	12	revenue management	18	artificial bee colony	9

The information in Table 5 listed the keywords based on the keyword size or length. The combined keywords of multiple lengths were sorted descendingly as in Table 6. The top three author keywords in general computer science were "machine learning", "scheduling", and "supply chain management". Other author keywords included "data envelopment analysis", "game theory", "optimization", "combinatorial optimization", "deep learning", "integer programming", "teaching/learning strategies", "robust optimization", and "heuristics". Figure 2 shows the word cloud of the author keywords.

Table 6

Author keywords with more than 50 occurrences

Keywords	F
machine learning	142
scheduling	135
supply chain management	122
data envelopment analysis	99
game theory	96
optimization	83
combinatorial optimization	82
deep learning	79
integer programming	73
teaching/learning strategies	67
robust optimization	65

(continued)

Keywords	F
heuristics	63
internet of things (iot)	59
multi objective optimization	58
stochastic programming	57
demand response	55
smart grid	55
metaheuristics	54
simulation	54
microgrid	53
genetic algorithm	53
industry 4.0	52
interactive learning environments	52
improving classroom teaching	50

Figure 2. *The word cloud of the author keywords.*

The study also analysed the indexed keyword of the 5,546 articles in the dataset. Scopus also allowed "indexed keywords" for articles included in its database that are chosen by content suppliers. The keywords are standardised based on public vocabularies (Scopus Support Center, 2020). Scopus did not influence both the author and indexed keywords as third parties determined them. Indexed keywords appear in various categories. Engineering and technology articles have three types of indexed keywords, namely "engineering controlled terms", "engineering uncontrolled terms", and "engineering main heading". Figure 3 shows an example of indexed keywords for an article written by Kong et al. (2019) as displayed in the Scopus website. Other types of indexed keywords include "GEOBASE Subject Index", "EMTREE Medical Term", "Regional Index", and "Medical Subject Heading".

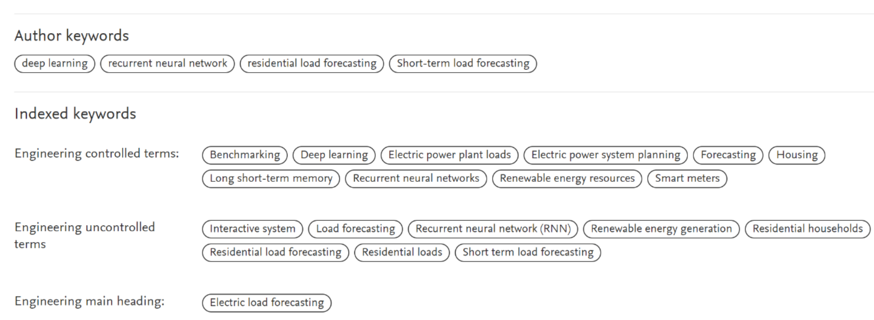

Figure 3. *Examples of indexed keywords for an article written by Kong et al. (2019).*

The study further analysed the frequency of the indexed terms for the 5,546 articles in the dataset. The total indexed keywords for the dataset was 74,045. On average, an article had 13.35 indexed keywords. Chukwusa et al. (2019) had the highest number of indexed keywords with 62 in total. However, 276 articles had no indexed keywords. Table 7 lists the journals of the corresponding articles. The highest number of articles without indexed keywords came from the journal of "Human-centric Computing and Information Sciences". Only two of the articles from the journal included in the dataset had indexed keywords. Nevertheless, this study did not cover the reasons behind the absence of indexed keywords for the articles.

Table 7

The number of articles without indexed keywords and their corresponding journals

Journals	Number of articles without indexed keyword
ACM Transactions on Computing Education	1
Computational Intelligence and Neuroscience	3
Computer Science Education	27
Computers and Education	6
Computers and Industrial Engineering	12
Computers and Operations Research	3
Computers and Security	4
Computers in Industry	5
Engineering	48
European Journal of Operational Research	17
Human-centric Computing and Information Sciences	52
IEEE Transactions on Smart Grid	1
Information Technology and Tourism	41
International Journal of Bio-Inspired Computation	47
International Journal of Health Geographics	2
SIAM Journal on Computing	1
Swarm and Evolutionary Computation	5
Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery	1

The occurrences of indexed keywords in the dataset had been counted. Table 8 lists the top 50 indexed keywords of the articles in the dataset with their frequency. In general, the frequency of the top indexed keywords derived from the dataset was much higher than the author keywords. The size or length of the keywords covered 1-word, 2-word, 3-word, and 4-word. The dataset did not contain keyword size or length more than 5-word. “Integer programming” had the highest frequency with 574 occurrences, followed by “decision making, and “scheduling” with 533 and 458, respectively. Other keywords such as “stochastic systems” and “optimization” appeared 401 times, respectively, in the dataset.

Table 8

Top 50 indexed keywords in the articles

Indexed Keywords	Frequency
Integer Programming	574
Decision Making	533
Scheduling	458
Optimization	401
Stochastic Systems	401
Sales	318
Costs	310
Learning Systems	279
Genetic Algorithm	255
Surveys	229
Students	228
Micro Grid	222
Supply Chains	222
Machine Learning	218
Multiobjective Optimization	218
Commerce	217
Benchmarking	205
Human	192
Evolutionary Algorithms	191
Heuristic Algorithms	190
Manufacture	176
Stochastic Models	171
Game Theory	165
Data Mining	161
Forecasting	161
Supply Chain Management	159
Electric Power Transmission Networks	156
Linear Programming	156
Combinatorial Optimization	154
Artificial Intelligence	153

(continued)

Indexed Keywords	Frequency
Network Security	153
Problem Solving	150
Computational Experiment	149
Algorithm	148
Location	148
Heuristic Methods	146
Neural Networks	146
Learning Algorithms	143
Economic And Social Effects	140
Sensitivity Analysis	138
Teaching/learning Strategy	133
Deep Learning	132
Efficiency	130
Operational Research	130
Computer-Aided Instruction	129
Iterative Methods	129
Profitability	127
Computer Science	125
Investments	125

The study further compared the occurrences of author and indexed keywords that appeared in both categories as listed in Table 9. The keywords "scheduling" and "optimization" were found in the author and indexed keywords with a high number of occurrences. Other keywords such as "forecasting", "location", "efficiency", "metaheuristics", "logistics", "security", and "maintenance" were also found in both types of the keyword. The 1-word size was frequently found in the two types of keywords as compared to the other sizes or lengths.

Table 9

Author and indexed keywords with their frequency

Keyword	F (Author keyword)	F (Indexed keyword)
Scheduling	135	458
Optimization	83	401

(continued)

Keyword	F (Author keyword)	F (Indexed keyword)
Forecasting	22	161
Location	26	148
Efficiency	19	130
Metaheuristics	54	103
Heuristics	63	65
Logistics	48	55
Security	45	55
Maintenance	24	53

The researchers cross-checked the results of this study with JICT articles to compare the author keywords used in the journal. The top five author keywords in 141 JICT articles were "cloud computing" (4), "neural network" (3), "ontology" (3), "particle swarm optimization" (3), and "WCAG 2.0" (3). The number in the brackets denotes the frequency. The study also selected the top 50 JICT articles with the highest citations to understand their keywords. The top ten author keywords were "analytic hierarchy process" (2), "artificial neural network" (2), "biometrics" (2), "cloud computing" (2), "firefly algorithm" (2), "particle swarm optimization" (2), "SMEs" (2), "software engineering" (2), "WCAG 2.0" (2), and "web accessibility" (2). Furthermore, the study searched JICT articles with the top three author keywords in Table 6. The keywords were "machine learning", "scheduling", and "supply chain management". Table 10 summarises the JICT articles that were related to the top three author keywords with their citations. Overall, only three articles mentioned "machine learning" in their abstracts. However, two of them did not list the keyword in the keyword section. For "scheduling", two articles mentioned it in their abstract and keyword section; while one article mentioned "supply chain management" in the title. The analysis suggested that less than 1% of the articles published in JICT had the similar top author keywords listed in Table 6.

Table 10

Top three author keywords and JICT articles with citations

Keywords	Title of JICT articles with the keyword listed in the author keyword section	Keyword listed in the keyword section	Year published	Citations (As of 15 April 2020)
machine learning	Bayesian network of traffic accidents in Malaysia	No	2019	0
	Intelligent cooperative web caching policies for media objects based on J48 decision tree and Naïve Bayes supervised machine learning algorithms in structured peer-to-peer systems	Yes	2016	0
	Artificial fish swarm optmization for multilayer network learning in classification problems	No	2012	5
scheduling	Hybrid cat swarm optimization and simulated annealing for dynamic task scheduling on cloud computing environment	Yes	2018	6
	A mixed integer linear programming model for real-time task scheduling in multiprocessor computer system	Yes	2012	0
supply chain management	Supply chain management: A system dynamics approach to improve visibility and performance	No	2011	2

What are the characteristics of the most recent impactful scientific research in general computer science?

In answering this RQ, the study analysed the 5,546 articles in the dataset to identify the impact of the scientific study, indexed keywords, types of articles as well as other attributes such as the top contributors covering the authors, countries, and funding agencies. The top 100 articles with the highest citations were filtered and selected for further analysis of the characteristics mentioned previously. An article by Kong et al. (2019) received the highest citations of 139 (as of 15 April 2020). "IEEE Transactions on Smart Grid" published the article with four author keywords and 19 indexed keywords. Table 11 lists the other highly-cited articles in the dataset and their information. The latest articles included in the Scopus were Rauch, Linder, and Dallasega (2020) (i.e. number 90 of Table 11) and Fantini, Pinzone, and Taisch (2020) (i.e. number 30 of Table 11). The articles received 18 and 28 times of citation, respectively. Both articles were published by "Computers and Industrial Engineering". The impact of the scientific research listed in Table 11 was remarkable as the articles managed to attract a high number of citations in a short period.

Table 11

Top 100 highly-cited articles in general computer science in 2019 (derived from the top 10% journals)

Num.	Authors	Source title	Number of citations	Number of author keywords	Number of indexed keywords
1	Kong et al. (2019)	IEEE Transactions on Smart Grid	139	4	19
2	Zhang, Yao, Sun, and Tay (2019)	ACM Computing Surveys	108	3	15
3	Wang, Chen, Hong, and Kang (2019)	IEEE Transactions on Smart Grid	72	10	21
4	Wu and Liao (2019)	European Journal of Operational Research	64	5	7
5	Zhang, Kou, and Peng (2019)	European Journal of Operational Research	62	5	12
6	Zhang, Dong, Chiclana, and Yu (2019)	European Journal of Operational Research	61	4	11
7	Scherer, Siddiq, and Tondeur (2019)	Computers and Education	60	4	12
8	Jain, Singh, and Rani (2019)	Swarm and Evolutionary Computation	55	3	10
9	Wang and Blaabjerg (2019)	IEEE Transactions on Smart Grid	54	5	19
10	Wang and Blaabjerg (2019)	Computers in Industry	50	5	12
11	Morstyn, Teytelboym, and Mcculloch (2019)	IEEE Transactions on Smart Grid	46	12	29
12	Del Ser et al. (2019)	Swarm and Evolutionary Computation	46	19	19
13	Liang, Weller, Luo, Zhao, and Dong (2019)	IEEE Transactions on Smart Grid	45	5	14
14	Gupta and Deep (2019)	Swarm and Evolutionary Computation	44	4	13
15	Modak and Kelle (2019)	European Journal of Operational Research	41	7	14
16	Abdel-Baset, Chang, Gamal, and Smarandache (2019)	Computers in Industry	37	6	10

(continued)

Num.	Authors	Source title	Number of citations	Number of author keywords	Number of indexed keywords
17	Xu, Zhang, Wen, and Wang (2019)	IEEE Transactions on Smart Grid	36	4	16
18	Awidi and Paynter (2019)	Computers and Education	35	8	12
19	Zhang, Zhang, and Li (2019)	Computers in Industry	34	5	15
20	Opara and Arabas (2019)	Swarm and Evolutionary Computation	34	5	11
21	Huber and Kolar (2019)	IEEE Transactions on Smart Grid	33	4	17
22	Mohammadi, Mehrtash, and Kargarian (2019)	IEEE Transactions on Smart Grid	33	5	21
23	Li, He, et al. (2019)	IEEE Transactions on Smart Grid	31	5	14
24	Mocanu et al. (2019)	IEEE Transactions on Smart Grid	31	5	23
25	Wang, Zhang, Kang, et al. (2019).	IEEE Transactions on Smart Grid	31	5	8
26	Yan, Zhou, Zhang, Yang, and Wu (2019)	IEEE Transactions on Smart Grid	30	4	14
27	Diaz et al. (2019)	ACM Computing Surveys	29	4	9
28	Dizdarević, Carpio, Jukan, and Masip-Bruin (2019)	ACM Computing Surveys	29	5	18
29	Yang, Ye, Lee, Yang, and Peng (2019)	European Journal of Operational Research	29	5	14
30	Fantini et al. (2020)	Computers and Industrial Engineering	28	7	14
31	Huang, Zhang, Yang, Wang, and Kang (2019)	IEEE Transactions on Smart Grid	28	7	22
32	Holzinger, Langs, Denk, Zatloukal, and Müller (2019)	Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery	28	6	11
33	Liu, Wang, et al. (2019)	Engineering	28	5	16

(continued)

Num.	Authors	Source title	Number of citations	Number of author keywords	Number of indexed keywords
34	Zhang, Sun, et al. (2019)	Engineering	28	7	10
35	Ivanov (2019)	Computers and Industrial Engineering	27	6	13
36	Pamucar, Chatterjee, and Zavadskas (2019)	Computers and Industrial Engineering	27	6	12
37	Zhang, Zhan, Wu, and Alcantud (2019)	Computers and Industrial Engineering	27	4	12
38	Seiti and Hafezalkotob (2019)	Computers and Industrial Engineering	26	6	14
39	Abdel-Baset, Chang, and Gamal (2019)	Computers in Industry	26	4	13
40	Li, Ji, et al. (2019)	IEEE Transactions on Smart Grid	26	5	18
41	Wang, Zhang, Tan, et al. (2019)	IEEE Transactions on Smart Grid	26	6	15
42	Yu, Hou, Lam, and Li (2019)	IEEE Transactions on Smart Grid	26	5	19
43	Boysen, De Koster, and Weidinger (2019)	European Journal of Operational Research	26	4	13
44	Buyya et al. (2019)	ACM Computing Surveys	25	9	16
45	Zeng, Xie, Chen, and Weng (2019)	Swarm and Evolutionary Computation	24	4	19
46	Deng, Benckendorff, and Gannaway (2019)	Computers and Education	23	5	13
47	Long, Ali, Son, Khan, and Tu (2019)	Computers and Industrial Engineering	23	5	9
48	Chen, Chen, et al. (2019)	IEEE Transactions on Smart Grid	23	4	12
49	Zhao and Mili (2019)	IEEE Transactions on Smart Grid	23	6	20
50	Li, Deb, Zhang, Suganthan, and Chen (2019)	Swarm and Evolutionary Computation	23	5	15
51	Wu, Mallipeddi, and Suganthan (2019)	Swarm and Evolutionary Computation	23	12	15
52	Wang, Gu, Liu, Sangaiah, and Kim (2019)	Human-centric Computing and Information Sciences	23	5	1
53	Fu, Chang, Xue, and Yang (2019)	European Journal of Operational Research	23	5	10

(continued)

Num.	Authors	Source title	Number of citations	Number of author keywords	Number of indexed keywords
54	De Giovanni, Karray, and Martín-Herrán (2019)	European Journal of Operational Research	23	5	14
55	Hiermann, Hartl, Puchinger, and Vidal (2019)	European Journal of Operational Research	23	5	19
56	Bélanger, Ruiz, and Soriano (2019)	European Journal of Operational Research	23	4	14
57	Zakir Hossain, Sohel, Shiratuddin, and Laga (2019)	ACM Computing Surveys	22	6	11
58	Sahoo and Mishra (2019)	IEEE Transactions on Smart Grid	22	4	16
59	Shen, Yao, Wen, He, and Jiang (2019)	IEEE Transactions on Smart Grid	22	5	17
60	Yan, Zhang, and Kezunovic (2019)	IEEE Transactions on Smart Grid	22	6	26
61	Zeraati, Hamedani Golshan, and Guerrero (2019)	IEEE Transactions on Smart Grid	22	5	17
62	Zhang, Dehghanian, and Kezunovic (2019)	IEEE Transactions on Smart Grid	22	5	16
63	Osaba et al. (2019)	Swarm and Evolutionary Computation	22	5	15
64	Manavalan and Jayakrishna (2019)	Computers and Industrial Engineering	21	6	14
65	Salih, Zaidan, Zaidan, and Ahmed (2019)	Computers and Operations Research	21	4	14
66	Dehghanpour, Wang, Wang, Yuan, and Bu (2019)	IEEE Transactions on Smart Grid	21	4	18
67	Li, Li, et al. (2019)	IEEE Transactions on Smart Grid	21	5	24
68	Papari, Edrington, Bhattacharya, and Radman (2019)	IEEE Transactions on Smart Grid	21	4	17
69	He, Wang, Yang, He, and Jiang (2019)	European Journal of Operational Research	21	4	12

(continued)

Num.	Authors	Source title	Number of citations	Number of author keywords	Number of indexed keywords
70	Zhang, Cao, and He (2019)	European Journal of Operational Research	21	4	13
71	Selvakumar and Muneeswaran (2019)	Computers and Security	20	4	18
72	Shuai et al. (2019)	IEEE Transactions on Smart Grid	20	4	17
73	Welikala, Dinesh, Ekanayake, Godaliyadda, and Ekanayake (2019)	IEEE Transactions on Smart Grid	20	7	11
74	Cui, Chang, Zhang, Cai, and Zhang (2019)	Swarm and Evolutionary Computation	20	5	7
75	Ma et al. (2019)	Swarm and Evolutionary Computation	20	5	13
76	Peng et al. (2019)	Swarm and Evolutionary Computation	20	5	12
77	Probst, Wright, and Boulesteix (2019)	Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery	20	7	13
78	Liu, Zhou, Ding, Palomares, and Herrera (2019)	European Journal of Operational Research	20	5	11
79	Jie, Yang, Zhang, and Huang (2019)	European Journal of Operational Research	20	5	14
80	Chen, Huang, et al. (2019)	Computers in Industry	19	5	18
81	Kalathil, Wu, Poolla, and Varaiya (2019)	IEEE Transactions on Smart Grid	19	4	18
82	Fan et al. (2019)	Swarm and Evolutionary Computation	19	4	12
83	Suárez, Iglesias, and Gálvez (2019)	Swarm and Evolutionary Computation	19	5	10
84	Reimann, Xiong, and Zhou (2019)	European Journal of Operational Research	19	5	14
85	Spencer, Hoskere, and Narazaki (2019)	Engineering	19	5	16
86	Cleophas, Cottrill, Ehmke, and Tierney (2019)	European Journal of Operational Research	19	4	13

(continued)

Num.	Authors	Source title	Number of citations	Number of author keywords	Number of indexed keywords
87	Gan, Lin, Fournier-Viger, Chao, and Yu (2019)	ACM Transactions on Knowledge Discovery from Data	18	5	16
88	Liu and You (2019)	Computers and Industrial Engineering	18	5	11
89	Rahmani and Yavari (2019)	Computers and Industrial Engineering	18	5	16
90	Rauch et al. (2020)	Computers and Industrial Engineering	18	6	9
91	Ucci, Aniello, and Baldoni (2019)	Computers and Security	18	5	17
92	Castelo-Branco, Cruz-Jesus, and Oliveira (2019)	Computers in Industry	18	6	14
93	Li and Shahidehpour (2019)	IEEE Transactions on Smart Grid	18	4	16
94	Yang, Zhang, He, Ren, and Weng (2019)	IEEE Transactions on Smart Grid	18	5	19
95	Liu, Song, and Yang (2019)	European Journal of Operational Research	18	4	12
96	Ding (2019)	Computers and Industrial Engineering	17	5	8
97	Glock, Grosse, Jaber, and Smunt (2019)	Computers and Industrial Engineering	17	7	9
98	Wu, Chang, Cao, and Liang (2019)	Computers and Industrial Engineering	17	5	13
99	Sarkar, Vinay, Raj, Maiti, and Mitra (2019)	Computers and Operations Research	17	6	22
100	Zhao, Wang, and Chu (2019)	Computers in Industry	17	4	17

This study also intended to understand the characteristics of highly-cited articles in general computer science that had recently been published. First, the study looked at the prestigious journals that published the highly-cited articles. “IEEE Transactions on Smart Grid” was identified as the journal with the highest number of highly-cited articles in the dataset. It was also in the first rank of journals in the general computer science subject area based on 2018 CiteScore metrics. In 2018, the journal received a total citation of 10,830, and the number of citation increased to 14,292 in 2019 (this study took place at the time Scopus was yet to publish the 2019 CiteScore metrics; therefore, it used the estimation of data on 9 April 2020). “IEEE Transactions on Smart Grid” is available in Scopus database since 2010 and it has 3,236 indexed articles to date. The editor-in-chief of the journal is Claudio Cañizares from the University of Waterloo, Canada. Table 12 lists other journals that had a good number of highly-cited articles in the dataset.

Table 12

Journals of top 100 highly-cited articles

Journals	Number of articles
IEEE Transactions on Smart Grid	31
European Journal of Operational Research	17
Swarm and Evolutionary Computation	13
Computers and Industrial Engineering	13
Computers in Industry	7
ACM Computing Surveys	5
Computers and Education	3
Engineering	3
Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery	2
Computers and Operations Research	2
Computers and Security	2
Human-centric Computing and Information Sciences	1
ACM Transactions on Knowledge Discovery from Data	1

This study further analysed the type of the top 100 highly-cited articles as listed in Table 11. The number of reviews and research articles in the dataset of highly-cited articles were 14 and 86, respectively. In terms of research funding, 68 studies specified their funding agencies. National Natural Science

Foundation of China funded 42 studies of the highly-cited articles. Authors from China and the United States were the highest with 48 and 30, respectively from the total of 176 authors. Kang, Chongqing (Scopus ID 7402312938) was the highest contributor with four highly-cited articles published in "IEEE Transactions on Smart Grid". The h-index of this author was 42 with 370 published articles and 7,704 citations. His affiliation is Tsinghua University, Beijing, China. The characteristics of the top contributors might indicate vital information on the trend of publishing scientific studies. For example, Chinese authors and funding agencies were found to be the top contributors to the general computer science subject area. A benchmark study using studies published by Chinese researchers could be beneficial to the JICT editorial team so that the specific attributes of their studies can be identified and appropriate strategies can be taken to explore authors from China. Currently, JICT has received massive article submission of authors from India. Therefore, there could be an opportunity to broaden the current coverage of countries by promoting JICT to Chinese institutions.

CONCLUSION

This study aimed to address the issue of JICT's low citations through a scientometric analysis. The study has successfully identified the emerging topics and trends of scientific research in general computer science. The ten emerging topics in computer science as suggested by SciVal could be given priority by the editorial team in selecting article submissions for further peer-review process. Similarly, the top authors and indexed keywords might also be used as the scope of topic for article submissions in the near future. The characteristics of the highly-cited articles provide several new insights to the JICT editorial team on the potential of authors and scientific studies from China. Overall, the results of this study could be used by the JICT editorial team in selecting up-to-date studies for publication. It also helps the team to select the trending research topics and thus avoid obsolete studies that receive no attention from researchers in the discipline. Other journals in general computer science that suffer from the same issue might use the findings of this study to improve their performance and impact of the scientific studies that they publish.

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