Journal of Computer Information Systems

ISSN: 0887-4417 (Print) 2380-2057 (Online) Journal homepage: https://www.tandfonline.com/loi/ucis20

Computer Science in ASEAN: A Ten-Year Bibliometric Analysis (2009–2018)

Jun-Jie Hew, Voon-Hsien Lee, Keng-Boon Ooi & Binshan Lin

To cite this article: Jun-Jie Hew, Voon-Hsien Lee, Keng-Boon Ooi & Binshan Lin (2019): Computer Science in ASEAN: A Ten-Year Bibliometric Analysis (2009–2018), Journal of Computer Information Systems, DOI: 10.1080/08874417.2019.1601538

To link to this article: https://doi.org/10.1080/08874417.2019.1601538

Published online: 20 May 2019.

JOURNAL OF COMPUTER INFORMATION SYSTEMS
https://doi.org/10.1080/08874417.2019.1601538

Computer Science in ASEAN: A Ten-Year Bibliometric Analysis (2009–2018)

Jun-Jie Hew [a], Voon-Hsien Lee [a], Keng-Boon Ooi [b], and Binshan Lin [c]

[a]Universiti Tunku Abdul Rahman, Kampar, Malaysia; [b]UCSI University, Kuala Lumpur, Kuala Lumpur, Malaysia; [c]Louisiana State University, Shreveport, LA, USA

ABSTRACT

The growth of a country is heavily depending on its investment over science and technology. In fact, the progress in computer science research serves as a vital factor in the development of a country. Interestingly, despite that the Association of Southeast Asian Nations (ASEAN) is located near each other, they do not share a similar level of ICT development, which leads to a digital divide among them. Thus, it is crucial to bibliometrically evaluate and compare the computer science research output over the latest decade (i.e., 2009 to 2018) among these countries. With the data gathered from the Web of Science, this study seeks to uncover the research focus of all ASEAN countries over the latest decade by analyzing the author keywords. Majority of the ASEAN was having a different research focus, explaining the varied levels of ICT development. Practical and theoretical implications are then offered accordingly.

KEYWORDS

Computer science; ASEAN; digital divide; bibliometric; Web of Science

1. Introduction

Computer science, a research discipline that combines science and engineering,[1] has been widely regarded as a key research field in the world for a few decades.[2] Generally, computer science refers to "the study of phenomena surrounding computers"[3] and is classified as a science.[4] In the words of Uddin and Singh,[5] the progress in computer science is deemed as a vital factor for the development of a country. As discovered by Hoonlor et al.,[6] research grants are essential for maintaining research momentum and scholars' interest in the field of computer science. Certainly, a country's research focus is highly related to its government's policies on technological development and innovation, as scholars fund their research through the research grants provided by the government.[7] Hence, the growth of a country is heavily depending on its investment over science and technology. This is especially true for the Association of Southeast Asian Nations (ASEAN) countries,[8] which consist of Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar (Burma), Philippines, Singapore, Thailand, and Vietnam. According to the ICT Development Index,[9] these ASEAN countries have diversified levels of ICT development. Singapore's development level is slightly above the average of developed countries, while the development levels of Brunei, Malaysia, and Thailand are marginally higher than the world average. Rest of the ASEAN countries (i.e., Cambodia, Indonesia, Laos, Myanmar (Burma), Philippines, and Vietnam) are considered as developing countries in terms of ICT development. The varied levels of ICT development, as discovered by Doong and Ho,[10] cause the digital divide. As noted by Chang et al.[11] and Rao[12], the digital divide among the developing and developed countries is a critical phenomenon that could threaten a country's economy and social development. Certainly, the countries that are advanced in ICT could enjoy social and economic advantages.[13] Therefore, it is important and timely to bibliometrically evaluate the research output of computer science over the latest decade (i.e., 2009 to 2018) among the ASEAN countries in order to assess if the ASEAN countries are having different policies on technological development and innovation, hence a different focus of research.

The bibliometric analysis method has been widely adopted by scholars across various research disciplines to uncover knowledge structure and development of research by examining the published written articles.[14–16] As opined by Lee and Hew,[17] both the quantity and quality of a research discipline could be bibliometrically evaluated by valuing the numbers of publications and the citations received respectively. This particular type of analysis method is powerful to handle a large number of articles in a comprehensive and objective manner as compared to the traditional literature review method.[14,18] Hence, it serves as an ideal method in comprehending the status quo of a research discipline.[19]

Albeit several studies have bibliometrically evaluated the discipline of computer science, these studies have a number of deficiencies. For instance, based on the data collected from the INSPEC database, Guan and Ma[2] compared the research performance in computer science of four major Western countries and two Asian countries. A comparison between Western and Asian countries seems to be unfair as Western countries are native speakers of English, an international language of academic publication.[20] Following that, Ma et al.[21] attempted to evaluate the scientific research competitiveness of world universities in computer science. As their subjects were highly cited universities that have published at least 100 articles in the field of computer science, the universities that could not fulfill the conditions were omitted from their study, hence creating a biased evaluation. In the same vein, as

CONTACT Binshan Lin binshan.lin@lsus.edu Business School, Louisiana State University, Shreveport, USA

Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/ucis.

conducted by Abrizah and Wee[22], Bakri and Willett[23], Franceschet[1], and Singh et al.[24], an evaluation of a single country's computer science research output is narrow, insufficient, and biased too. The same goes to Lin et al.[25], who have only evaluated 11 leading computer science journals. Recognizing these limitations, Uddin and Singh[5], together with Fiala and Willett[26], bibliometrically analyzed the computer science research output among the South Asian Association for Regional Cooperation (SAARC) and Eastern Europe countries respectively. By comparing several countries within the same region, their methodology is believed to have developed rigorously. Nonetheless, a comparison between the ASEAN countries in terms of computer science research output is rare thus far.

Although the ASEAN countries are located near each other geographically, their ICT development levels are dissimilar. Hence, it would be interesting to evaluate and compare the computer science research output of these countries bibliometrically over the latest decade. Specifically, this study aims to discover the research focus of all ASEAN countries and to ascertain the research focus that was able to garner more citation counts over the latest decade. Practically, a higher citation count generally means the work is trending and influential.[27,28] The policymakers could, therefore, adjust their policy on technological development and innovation accordingly in order to further advance their country in terms of computer science research, which is deemed as a vital factor in the development of a country[5] and its ICT development level.[24] Eventually, the digital divide among the ASEAN countries shall be bridged. Theoretically, different from the past studies that have bibliometrically evaluated the discipline of computer science, this study evaluates and compares the computer science research output between the ASEAN countries. Thus, this study expects to fill a gap that is considered urgent right now and subsequently makes suggestions to ASEAN scholars on the topics that they could have possibly overlooked.

In this study, the rest of the sections are organized in the following manner. The methodology employed would be discussed in detail, followed by the results and discussion, future research directions, and lastly a conclusion.

2. Methodology

This study utilized the Web of Science database, which consists of more than 15,000 journals and 50,000,000 articles in total, to obtain the relevant data for further analysis.[19] As compared to other databases (e.g., Scopus and Google Scholar), the Web of Science database indexes the highest quality articles.[29] During the initial search, we discovered that not every ASEAN country has published Web of Science indexed computer science articles. For such reason, Brunei, Cambodia, Laos, and Myanmar (Burma) were excluded from the later search. In order to capture the relevant data, a query command (CU = (INDONESIA OR PHILIPPINES OR THAILAND OR SINGAPORE OR VIETNAM OR MALAYSIA)) was entered under the advanced search function. Moreover, several filters were applied at this stage. Firstly, only journal articles were selected. Secondly, only the journal articles written in English were selected. Thirdly, given that computer science is a fast-changing research discipline and new research focus will emerge constantly within this discipline,[30] the time span was limited to the latest decade (i.e., 2009 to 2018). Fourthly, only the articles indexed to Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), and Arts & Humanities Citation Index (AHCI) were included. Lastly, following Abrizah and Wee[22], only articles that are captured under the Web of Science categories of "Computer Science Theory Methods", "Computer Science Interdisciplinary Applications", "Computer Science Artificial Intelligence", and "Computer Science Information Systems" were selected.

During the data collection stage, a few popular bibliometric indicators, namely publication counts, total citation counts, average citations per item, and h-index were extracted from the results.[1,19,29] VOSviewer 1.6.10 was then used to calculate the frequency of author keywords occurrences from the data collected.[31] Developed by van Eck and Waltman,[32] VOSviewer is a powerful software that could handle a large number of items or data extracted from well-known databases such as Scopus and Web of Science. Apart from being capable of calculating the author keywords occurrences from a large amount of data extracted, VOSviewer could help in constructing and visualizing bibliometric networks based on the results obtained.[33]

3. Results and discussion

Following the criteria set, the search returned a total of 14,057 articles. As shown in Table 1, the publication counts of all ASEAN countries were mostly increasing throughout the years. Singapore was leading in terms of publication counts over the years and in terms of total publication counts, followed by Malaysia. These two countries together accounted for 80.27% of the total number of publication counts. Thailand was ranked third in terms of publication counts, followed by Vietnam,

Table 1. The publication counts over the last decade.

Year	Singapore	Malaysia	Thailand	Vietnam	Indonesia	Philippines	
2009	439	114	87	16	12	9	
2010	525	175	79	26	14	10	
2011	625	248	116	35	22	11	
2012	679	340	136	47	28	10	
2013	741	349	130	69	22	10	
2014	799	462	130	110	25	8	
2015	862	499	128	117	23	8	
2016	871	482	143	154	35	12	
2017	890	567	165	191	63	17	
2018	974	642	176	280	85	15	
Total	*7,405*	*3,878*	*1,290*	*1,045*	*329*	*110*	*14,057*
Percentage	*52.68%*	*27.59%*	*9.18%*	*7.43%*	*2.34%*	*0.78%*	*100%*

Indonesia, and the Philippines. It is also interesting to note that Thailand was leading ahead of Vietnam from 2009 to 2015, while Vietnam took the lead from 2016 onwards.

As reported by Waltman,[34] the total number of citations received is one of the size-dependent indicators, which means that the number of citations is highly influenced by the number of publications. This is true in Table 2, which shows the citation counts received by all the ASEAN countries within the latest decade are positively correlated to the number of publications. Singapore tops the list with 122,694 total citations received, followed by Malaysia, Thailand, Vietnam, Indonesia, and the Philippines. Similar to Table 1, Singapore and Malaysia have accounted for about 88.02% of the total citations received by all countries. In order to discover the true citation impact of a country and to have a like to like comparison, a size-independent indicator, namely average citations per item[34], is included in Table 2. It is interesting to see that although Malaysia has a significantly higher amount of publications than Thailand, Vietnam, Indonesia, and the Philippines, its average citations per item did not deviate too far from the rest. The same goes to its h-index. Moreover, it is surprising to see that Philippines was ranked third in terms of average citations per item. This result is believed to have a connection with the research focus of these countries, hence attracting a different amount of citations. Thus, in order to discover their research focus, an author keywords analysis was conducted via the VOSviewer 1.6.10.

Figure 1 pictures while Table 3 showcases the author keywords analysis among the ASEAN countries at the country level based on the results obtained from VOSviewer 1.6.10. A relative measure (i.e., the percentage of author keywords occurrences) was used instead of the absolute measure (i.e., the number of author keywords occurrences) obtained from the VOSviewer 1.6.10. This is to ensure the comparison between countries is on a like to like basis. The percentage of author keywords occurrences is calculated by dividing the number of author keywords occurrences by the total publication counts of a particular country. For every country, only the top five author keywords with the highest occurrence were included. Generally, a high percentage of author keywords occurrences for a particular keyword indicates that there is a large proportion of articles carrying that author keyword.

From Figure 1 and Table 3, two interesting points were noted. Firstly, some author keywords were only associated with a particular country. This could mean that the country has placed a heavy weight on that particular research focus. Among the author keywords, "algorithms", "deep learning", "experimentation", "performance", and "security" were only associated with Singapore; "thailand" was only associated with Thailand; "cognitive radio", "differential evolution", "energy harvesting", "feature selection", "fuzzy clustering", "machine learning", and "wireless sensor networks" were only associated with Vietnam; "fuzzy logic", "indonesia", "molecular docking", and "qos" were only associated with Indonesia; "complex systems", "membrane computing", and "spiking neural p systems" were only associated with the Philippines. Rest of the keywords (i.e., "artificial neural network", "classification", "clustering", "data mining", "genetic algorithm", "optimization", "particle swarm optimization", and "support vector machine") were associated with more than one countries. Secondly, a great proportion of the articles published by the authors in Singapore, Indonesia, and the Philippines carried the author keywords that were associated with their respective countries only. For instance, "algorithms", an author keyword that was associated with Singapore only, has 1.89% author keywords occurrences. This percentage is the highest among the other author keywords in Singapore, while the other ASEAN countries have 0% author keywords occurrences for that particular keyword. The same goes to the "fuzzy logic" for Indonesia (2.74%) and "membrane computing" for the Philippines (5.45%).

Table 2. Citation counts received.

	Singapore	Malaysia	Thailand	Vietnam	Indonesia	Philippines	Total
Total publication counts	7,405	3,878	1,290	1,045	329	110	14,057
Total citation counts (%)	122,694 (67.87%)	36,421 (20.15%)	10,552 (5.84%)	7,508 (4.15%)	2,698 (1.49%)	915 (0.51%)	180,788
Average citations per item	16.57	9.39	8.18	7.18	8.2	8.32	
h-index	121	61	42	38	27	16	

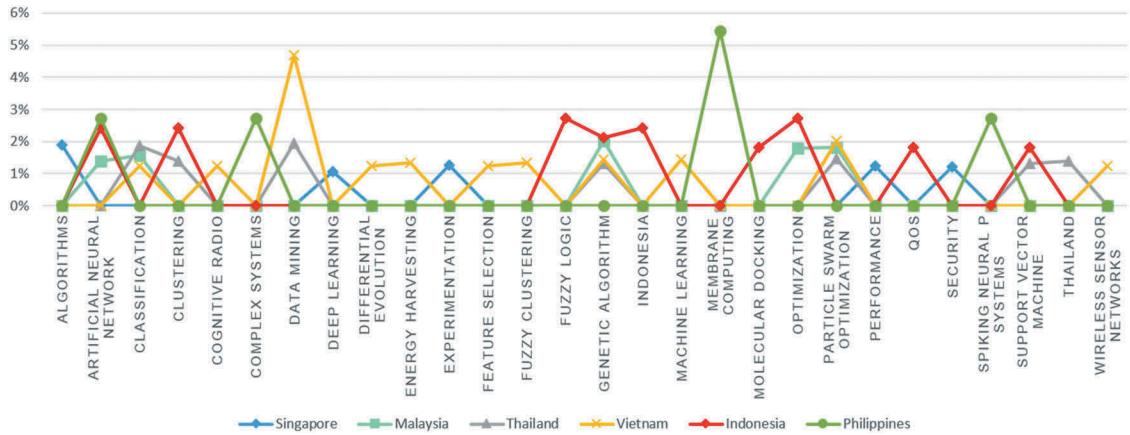

Figure 1. Author keywords analysis among the ASEAN countries.

Table 3. Author keywords analysis among the ASEAN countries.

Author keywords	Singapore	Malaysia	Thailand	Vietnam	Indonesia	Philippines
algorithms*	1.89%	-	-	-	-	-
artificial neural network	-	1.39%	-	-	2.43%	2.73%
classification	-	1.57%	1.86%	1.24%	-	-
clustering	-	-	1.40%	-	2.43%	-
cognitive radio*	-	-	-	1.24%	-	-
complex systems*	-	-	-	-	-	2.73%
data mining	-	-	1.94%	4.69%	-	-
deep learning*	1.05%	-	-	-	-	-
differential evolution*	-	-	-	1.24%	-	-
energy harvesting*	-	-	-	1.34%	-	-
experimentation*	1.26%	-	-	-	-	-
feature selection*	-	-	-	1.24%	-	-
fuzzy clustering*	-	-	-	1.34%	-	-
fuzzy logic*	-	-	-	-	2.74%	-
genetic algorithm	-	2.01%	1.32%	1.44%	2.13%	-
indonesia*	-	-	-	-	2.43%	-
machine learning*	-	-	-	1.44%	-	-
membrane computing*	-	-	-	-	-	5.45%
molecular docking*	-	-	-	-	1.82%	-
optimization	-	1.78%	-	-	2.74%	-
particle swarm optimization	-	1.81%	1.47%	2.01%	-	-
performance*	1.24%	-	-	-	-	-
qos*	-	-	-	-	1.82%	-
security*	1.20%	-	-	-	-	-
spiking neural p systems*	-	-	-	-	-	2.73%
support vector machine	-	-	1.32%	-	1.82%	-
thailand*	-	-	1.40%	-	-	-
wireless sensor networks*	-	-	-	1.24%	-	-

Notes:
1. 0% author keywords occurrences are denoted by "-".
2. * denotes the exclusive author keywords for a country.

It appears that the majority of ASEAN countries are having a varied policy on technological development and innovation, hence a different focus of research and ICT development. A significant digital divide is noticed between Singapore and other ASEAN countries. While others were working on the general "artificial neural network", Singapore is already studying on "deep learning", an emerging subfield of "artificial neural network".[35,36] Besides, among the ASEAN countries, Malaysia was the only country that did not have any association with any of the exclusive author keywords. The same happens to Thailand if "thailand" were to be disregarded as a meaningful author keyword. The result implies that the authors from Malaysia and Thailand were generally working on the topics that other ASEAN countries were working on. This perhaps could explain why their average citations per item did not deviate too far from the other ASEAN countries (except Singapore) although their publication counts were significantly higher. As noted by Tahamtan et al.,[37] a novel research focus shall gain a higher citation count. Thus, the citation counts of a common research focus could be easily diluted as many are working on the same topic. Similarly, if the authors within a country are pursuing the same novel research focus, hypothetically this shall help the country to gain more citation counts, which seems to be supported by the results. This should explain why Indonesia and Philippines have impressive average citations per item even when their publications counts were only accounted for 3.12% of the total ASEAN publication counts.

Nevertheless, the average citations per item of Vietnam remained the lowest among the ASEAN countries despite their impressive number of exclusive author keywords. In order to answer this query, this study has further analyzed the author keywords for each ASEAN country at the author level. As such, the top ten most productive authors (based on their publication counts) were obtained from the search results. Table 4 displays the top ten most productive authors who are affiliated with the ASEAN countries. Given that some of the authors were sharing the same amount of publication counts, more than ten authors might be listed for some countries. In addition to the publication counts, the citation counts, h-index, and average citations per item are shown to complement the influence of each author. It is easily noticeable that the majority of authors in Singapore have received a massive amount of citation counts throughout the latest decade as compared to other ASEAN countries. In contrast, the majority of the authors who are affiliated with Malaysia and Thailand did not receive a great number of citation counts in spite of their noteworthy publication counts.

Subsequently, all the data of these top authors were captured and analyzed by the VOSviewer 1.6.10, so as to capture and count the author keywords occurrences among them. Only the top five highest occurring author keywords that could match with the author keywords at the country level were included. The results obtained for each country are drawn in Figure 2 and detailed in Table 5. Similar to the author keywords analysis at the country level, a relative measure (i.e., the percentage of author keywords occurrences) was used. The percentage is calculated by dividing the author keywords occurrences at the author level by the total author keywords occurrences at the country level.

Clearly, the results suggest that the top authors of Singapore were following their country's research focus. These top authors have contributed 43.59% toward the total publication counts of "deep learning", 34.41% toward "experimentation", 27.86% toward "algorithms", and 23.91% toward "performance".

Table 4. The most productive authors of ASEAN countries.

Authors	Last known affiliation	Publication counts (Ranking)	Citation counts (Ranking)	h-index (Ranking)	Average citations per item (Ranking)
Singapore					
Acharya UR	Ngee Ann Polytechnic	**122 (2)**	2,966 (6)	32 (2)	24.31 (8)
Chua TS	National University of Singapore	75 (7)	1,978 (8)	26 (5)	26.37 (6)
Deng RH	Singapore Management University	76 (6)	853 (10)	14 (9)	11.22 (10)
Li XL	Agency for Science, Technology and Research	72 (8)	3,146 (5)	27 (4)	**43.69 (3)**
Lin WS	Nanyang Technological University	**121 (3)**	**3777 (3)**	**32 (2)**	31.21 (4)
Niyato D	Nanyang Technological University	72 (8)	3,510 (4)	27 (4)	**48.75 (2)**
Suganthan PN	Nanyang Technological University	90 (4)	**7844 (1)**	**36 (1)**	**87.16 (1)**
Wang M	National University of Singapore	68 (10)	1,986 (7)	22 (6)	29.21 (5)
Wang Y	National University of Singapore	84 (5)	683 (11)	15 (8)	8.13 (11)
Yan SC	National University of Singapore	**167 (1)**	**4320 (2)**	**30 (3)**	25.87 (7)
Zhang J	Singapore National Eye Center	71 (9)	956 (9)	20 (7)	15.17 (9)
Malaysia					
Abdullah AH	Universiti Teknologi Malaysia	**38 (3)**	250 (11)	8 (7)	6.58 (11)
Abdullah S	Universiti Kebangsaan Malaysia	29 (8)	467 (7)	**13 (3)**	16.1 (4)
Anuar NB	Universiti Malaya	28 (9)	**825 (3)**	**13 (3)**	**29.46 (3)**
Gani A	Universiti Malaya	**45 (2)**	**1383 (1)**	**16 (1)**	**30.73 (2)**
Hussain A	Universiti Kebangsaan Malaysia	32 (5)	209 (12)	9 (6)	6.53 (12)
Isa NAM	Universiti Sains Malaysia	**45 (2)**	579 (5)	**15 (2)**	12.87 (7)
Ismail M	Universiti Kebangsaan Malaysia	30 (7)	54 (14)	5 (9)	1.8 (14)
Kendall G	University of Nottingham Malaysia	27 (10)	313 (9)	10 (5)	11.59 (8)
Loo CK	Universiti Malaya	**45 (2)**	197 (13)	8 (7)	4.38 (13)
Ooi KB	UCSI University	29 (8)	**1026 (2)**	**16 (1)**	**35.38 (1)**
Othman M	Universiti Putra Malaysia	**51 (1)**	479 (6)	11 (4)	9.39 (9)
Seera M	Swinburne University of Technology Sarawak	31 (6)	279 (10)	7 (8)	9 (10)
Selamat A	Universiti Teknologi Malaysia	34 (4)	449 (8)	**15 (2)**	13.21 (6)
Shamshirband S	Universiti Malaya	**45 (2)**	685 (4)	**15 (2)**	15.22 (5)
Thailand					
Bureerat S	Khon Kaen University	14 (7)	158 (6)	**8 (2)**	11.29 (5)
Chamnongthai K	King Mongkuts University of Technology Thonburi	13 (8)	32 (16)	3 (6)	2.46 (16)
Dailey MN	Asian Institute of Technology	18 (4)	**251 (3)**	**7 (3)**	**13.94 (2)**
Gleeson MP	Kasetsart University	10 (10)	119 (8)	6 (4)	11.9 (4)
Haddawy P	Mahidol University	15 (6)	108 (9)	6 (4)	7.2 (11)
Hannongbua S	Chulalongkorn University	**35 (1)**	**427 (1)**	**12 (1)**	**12.2 (3)**
Kumam P	King Mongkuts University of Technology Thonburi	16 (5)	70 (13)	6 (4)	4.38 (15)
Lursinsap C	Chulalongkorn University	**26 (2)**	177 (5)	**8 (2)**	6.81 (12)
Makhanov SS	Thammasat University	14 (7)	66 (14)	5 (5)	4.71 (14)
Nantasenamat C	Mahidol University	11 (9)	119 (8)	**7 (3)**	10.82 (6)
Ngamroo I	King Mongkuts Institute of Technology Ladkrabang	11 (9)	89 (11)	5 (5)	8.09 (8)
Pathumnakul S	Khon Kaen University	10 (10)	61 (15)	6 (4)	6.1 (13)
Phusavat K	Kasetsart University	15 (6)	183 (4)	**7 (3)**	**12.2 (3)**
Prachayasittikul V	Mahidol University	11 (9)	119 (8)	**7 (3)**	10.82 (6)
Ruangpornvisuti V	Chulalongkorn University	11 (9)	101 (10)	5 (5)	9.18 (7)
Rungrotmongkol T	Chulalongkorn University	**20 (3)**	**402 (2)**	**12 (1)**	**20.1 (1)**
Sriboonchitta S	Chiang Mai University	18 (4)	138 (7)	**7 (3)**	7.67 (9)
Theeramunkong T	Thammasat University	15 (6)	27 (17)	3 (6)	1.8 (17)
Wolschann P	Chulalongkorn University	10 (10)	76 (12)	5 (5)	7.6 (10)
Vietnam					
Anh HPH	Ho Chi Minh City University of Technology	9 (10)	19 (20)	2 (10)	2.11 (23)
Bui LT	Le Quy Don Technical University	10 (9)	45 (15)	3 (9)	4.5 (15)
Ho TB	John von Neumann Institute	10 (9)	39 (17)	2 (10)	3.9 (19)
Hoa NV	Ton Duc Thang University	9 (10)	67 (10)	6 (6)	7.44 (10)
Hoang ND	Duy Tan University	14 (7)	139 (7)	9 (4)	9.93 (8)
Le B	Ho Chi Minh City University of Science	27 (4)	**313 (3)**	**10 (3)**	11.59 (6)
Le T	Ton Duc Thang University	14 (7)	149 (6)	8 (5)	10.64 (7)
Long HV	People's Police University of Technology and Logistics	9 (10)	106 (8)	6 (6)	11.78 (5)
Ngo LT	Le Quy Don Technical University	9 (10)	49 (13)	3 (9)	5.44 (13)
Nguyen LTT	Ton Duc Thang University	11 (8)	106 (8)	6 (6)	9.64 (9)
Nguyen MT	Thai Nguyen University of Technology	9 (10)	35 (18)	4 (8)	3.89 (20)
Nguyen NT	Tay Nguyen University	18 (5)	77 (9)	5 (7)	4.28 (17)
Nguyen TH	Duy Tan University	10 (9)	44 (16)	4 (8)	4.4 (16)
Nguyen TS	Tra Vinh University	16 (6)	56 (11)	5 (7)	3.5 (21)
Nguyen TT	Ton Duc Thang University	**31 (3)**	203 (5)	8 (5)	6.55 (11)
Nguyen VD	Nong Lam University	9 (10)	8 (21)	2 (10)	0.89 (24)
Nguyen VH	Hanoi University of Science & Technology	9 (10)	203 (5)	4 (8)	**22.56 (2)**
Son LH	Vietnam National University Hanoi	**43 (2)**	**631 (1)**	**15 (1)**	**14.67 (3)**
Truong TK	Ton Duc Thang University	9 (10)	236 (4)	6 (6)	**26.22 (1)**
Vinh PC	Nguyen Tat Thanh University	10 (9)	26 (19)	3 (9)	2.6 (22)
Vo B	Ton Duc Thang University	**46 (1)**	**551 (2)**	**14 (2)**	11.98 (4)
Vo NS	Duy Tan University	9 (10)	47 (14)	4 (8)	5.22 (14)
Vu H	Hanoi University of Science and Technology	11 (8)	44 (16)	4 (8)	4 (18)
Zelinka I	Ton Duc Thang University	9 (10)	52 (12)	3 (9)	5.78 (12)

(*Continued*)

Table 4. (Continued).

Authors	Last known affiliation	Publication counts (Ranking)	Citation counts (Ranking)	h-index (Ranking)	Average citations per item (Ranking)
Indonesia					
Herawan T	AMCS Research Center	**8 (1)**	**50 (2)**	**4 (2)**	**6.25 (3)**
Liem AT	Universitas Klabat	**7 (2)**	33 (4)	**4 (2)**	4.71 (4)
Prayogo D	Universitas Kristen Petra	5 (4)	**45 (3)**	**3 (3)**	**9 (2)**
Sari RF	University of Indonesia	5 (4)	5 (5)	1 (4)	1 (5)
Widodo A	Agency for the Assessment and Application of Technology	**6 (3)**	**358 (1)**	**5 (1)**	**59.67 (1)**
Zulvia FE	Universitas Pertamina	5 (4)	2 (6)	1 (4)	0.4 (6)
Philippines					
Adorna HN	University of the Philippines Diliman	**6 (2)**	**43 (3)**	**3 (2)**	**7.17 (3)**
Barrios EB	University of the Philippines Diliman	**5 (3)**	20 (4)	**3 (2)**	4 (4)
Cabarle FGC	University of the Philippines Diliman	**5 (3)**	**47 (2)**	**4 (1)**	**9.4 (2)**
Monterola C	Asian Institute of Management	**8 (1)**	12 (5)	**2 (3)**	1.5 (5)
Tan RR	De La Salle University	**5 (3)**	**107 (1)**	**4 (1)**	**21.4 (1)**

Note: The top three rankings of each category in a country are highlighted in bold.

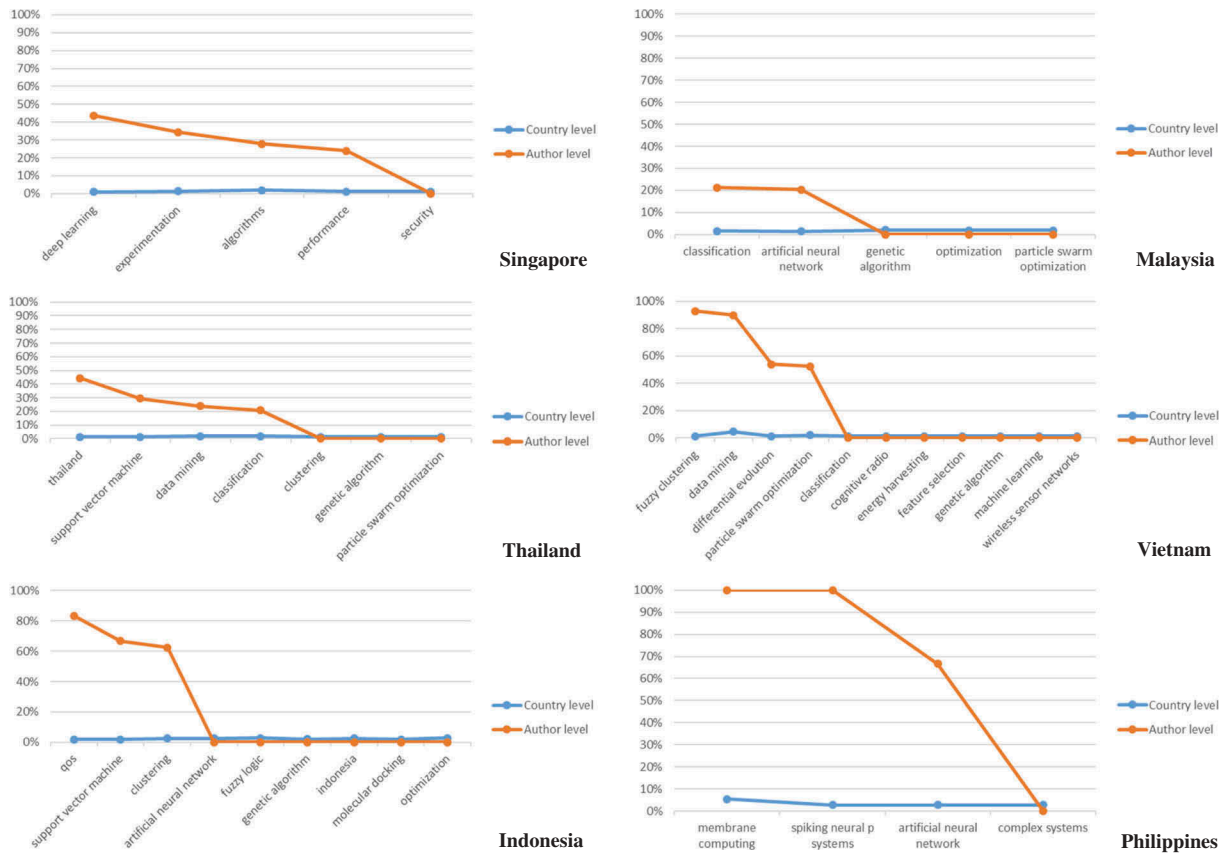

Figure 2. Author keywords analysis among the top authors.

Nevertheless, none of them has concentrated on "security", one of the author keywords that emerged during the author keywords analysis at the country level. In contrast, most of the top authors in other ASEAN countries did not follow their respective country's trends, as their lines are steeper as compared to Singapore in Figure 2. This, perhaps, could explain the exceptional average citations per item of Singapore.

Generally, a higher number of publication counts could always contribute to a greater amount of citation counts.[38] Hence, even if a country has a number of exclusive author keywords, its citation counts would not be impressive if its authors were not pursuing the same goal, and this is especially true for the case of Vietnam.

4. Future research directions

In light of the results, this study has identified several future research directions to the ASEAN computer science scholars and policymakers. Firstly, it is believed that the exclusive author keywords (except for "indonesia" and "thailand") of all ASEAN countries as identified in Figure 1 and Table 3 are currently sparsely researched and novel topics in ASEAN (for e.g., "deep learning", "differential evolution", and "membrane computing"). Working on these topics could definitely attract more citations, provided that the authors are focusing on them and being productive. These areas shall also move the nations to a better ICT development level. Secondly, this study has also identified some common research focuses (for e.g., "artificial neural network",

Table 5. Author keywords analysis at the country and author levels.

Author keywords	Country level	Author level
Singapore		
deep learning	1.05%	43.59%
experimentation	1.26%	34.41%
algorithms	1.89%	27.86%
performance	1.24%	23.91%
security	1.20%	-
Malaysia		
classification	1.57%	21.31%
artificial neural network	1.39%	20.37%
genetic algorithm	2.01%	-
optimization	1.78%	-
particle swarm optimization	1.81%	-
Thailand		
Thailand	1.40%	44.44%
support vector machine	1.32%	29.41%
data mining	1.94%	24.00%
classification	1.86%	20.83%
clustering	1.40%	-
genetic algorithm	1.32%	-
particle swarm optimization	1.47%	-
Vietnam		
fuzzy clustering	1.34%	92.86%
data mining	4.69%	89.80%
differential evolution	1.24%	53.85%
particle swarm optimization	2.01%	52.38%
classification	1.24%	-
cognitive radio	1.24%	-
energy harvesting	1.34%	-
feature selection	1.24%	-
genetic algorithm	1.44%	-
machine learning	1.44%	-
wireless sensor networks	1.24%	-
Indonesia		
qos	1.82%	83.33%
support vector machine	1.82%	66.67%
clustering	2.43%	62.50%
artificial neural network	2.43%	-
fuzzy logic	2.74%	-
genetic algorithm	2.13%	-
indonesia	2.43%	-
molecular docking	1.82%	-
optimization	2.74%	-
Philippines		
membrane computing	5.45%	100.00%
spiking neural p systems	2.73%	100.00%
artificial neural network	2.73%	66.67%
complex systems	2.73%	-

Note: 0% author keywords occurrences is denoted by "-".

"classification", and "genetic algorithm") in Figure 1 and Table 3. Pursuing these topics might not help in attracting an impressive amount of citation counts as multiple countries are currently looking into them. Thirdly, all the ASEAN countries are urged to follow the world trends in computer science research as identified by Singh et al.[24] By comparing the world trends and ASEAN trends, it was found that the ASEAN countries were hardly following the trends, except for Singapore. For instance, the world is already looking into big data, cloud computing, deep learning (associated with Singapore as an exclusive author keyword), emotion recognition, mobile computing, smart grid, etc. Thus, other than enhancing their current strength by working more on their exclusive author keywords, ASEAN countries should align their focus with the world trends in order to bridge the digital divide. Fourthly, on top of following the existing world trends, ASEAN countries are encouraged to look into several future trends as identified by The IEEE Computer Society.[39] It is believed that in years to come, research on deep learning accelerators,[40,41] assisted transportation,[42] the Internet of Bodies,[43] serverless computing,[44,45] mobile edge computing,[46,47] and so forth would be the key promising research trends. In order to foster these changes of research focus, policymakers of each ASEAN country could play an active role by adjusting their policy on technological development and innovation accordingly in order to encourage their own computer science scholars to work on the research focus that is deemed to be vital in raising their ICT development levels. Ultimately, it is hoped that the digital divide among the ASEAN countries could be bridged.

5. Conclusion

ASEAN countries are geographically and closely located near each other. Nevertheless, these countries do not share the same level of ICT development, hence creating a digital divide among them. All these reasoning make ASEAN an interesting target to research on. Indeed, the results indicated that the research focus of the ASEAN countries in the discipline of computer science was different over the latest decade, suggesting a varied level of ICT development and digital divide among them. Practically, the policymakers, as well as the ASEAN computer science scholars, are urged to focus on the exclusive author keywords in order to attract more citation counts, given that these topics were sparsely researched. Moreover, they should align their focus with world trends and some future trends, so as to further enhance their ICT development levels and bridge the digital divide eventually. Theoretically, this study has filled a research gap in a timely manner by comparing the research output of computer science over the latest decade among the ASEAN countries.

This study possesses two limitations that the scholars could consider to resolve in future. Firstly, this study has solely gathered the data from the Web of Science database, in particular, the SCIE, SSCI, and A&HCI indexes. For future study, scholars could consider looking at other databases such as Scopus and Google Scholar, for the purpose of capturing more research output. Scholars could also consider comparing the author keywords among the databases to see if there is any significant deviation. Secondly, given that this study has only focused on the ASEAN countries, future scholars can consider drawing a comparison between the countries that are located near each other geographically, for example, Asia and the Middle East.

All in all, the computer science research of a country is closely related to its ICT development level, hence computer science scholars should always strive to contribute new knowledge toward this discipline in order to help their nations in moving forward to a better tomorrow.

Funding

This work was supported by the Universiti Tunku Abdul Rahman Research Publication Scheme [grant number UTARRPS/2017/25, vote number 6251/H05].

ORCID

Jun-Jie Hew http://orcid.org/0000-0003-4957-1050
Voon-Hsien Lee http://orcid.org/0000-0002-8723-8219
Keng-Boon Ooi http://orcid.org/0000-0002-3384-1207
Binshan Lin http://orcid.org/0000-0002-8481-302X

References

1. Franceschet M. A comparison of bibliometric indicators for computer science scholars and journals on web of science and google scholar. Scientometrics. 2010;83:243–58. doi:10.1007/s11192-009-0021-2.
2. Guan J, Ma N. A comparative study of research performance in computer science. Scientometrics. 2004;61:339–59. doi:10.1023/B:SCIE.0000045114.85737.1b.
3. Newel A, Simon H. Completer science as empirical inquiry: symbols and search, commun. Acm. 1976;19:113–26. doi:10.1145/360018.360022.
4. Wainer J, Billa C, Goldenstein S. Invisible work in standard bibliometric evaluation of computer science, Commun. Acm. 2011;54:141. doi:10.1145/1941487.1941517.
5. Uddin A, Singh VK. Mapping the computer science research in SAARC countries. IETE Tech Rev. 2014;31:287–96. doi:10.1080/02564602.2014.947527.
6. Hoonlor A, Szymanski BK, Zaki MJ. Trends in computer science research. Commun ACM. 2013;56:74. doi:10.1145/2507771.
7. Wonglimpiyarat J. Government programmes in financing innovations: comparative innovation system cases of Malaysia and Thailand. Technol Soc. 2011;33:156–64. doi:10.1016/j.techsoc.2011.03.009.
8. Research Performance in South-East Asia. Available at https://www.britishcouncil.org/education/ihe/knowledge-centre/partnerships-collaboration/research-performance-seasia.
9. *Measuring the Information Society Report* 2017. Available at https://www.itu.int/en/ITU-D/Statistics/Documents/publications/misr2017/MISR2017_Volume1.pdf.
10. Doong SH, Ho SC. The impact of ICT development on the global digital divide. Electron Commer Res Appl. 2012;11:518–33. doi:10.1016/j.elerap.2012.02.002.
11. Chang Y, Kim H, Wong SF, Park M-C. A comparison of the digital divide across three countries with different development indices. J Glob Inf Manag. 2015;23:55–76. doi:10.4018/JGIM.2015100103.
12. Rao SS. Information systems in indian rural communities. J Comput Inf Syst. 2003;44:48–56.
13. Ziemba E. The contribution of ICT adoption to the sustainable information society. J Comput Inf Syst. 2019;59:116–26.
14. Wang JJ, Chen H, Rogers DS, Ellram LM, Grawe SJ. A bibliometric analysis of reverse logistics research (1992-2015) and opportunities for future research. Int J Phys Distrib Logist Manag. 2017;47:666–87. doi:10.1108/IJPDLM-10-2016-0299.
15. Chen X, Chen J, Wu D, Xie Y, Li J. Mapping the research trends by co-word analysis based on keywords from funded project. Procedia Comput Sci. 2016;91:547–55. doi:10.1016/j.procs.2016.07.140.
16. Pratt JA, Hauser K, Sugimoto CR. Cross-disciplinary communities or knowledge islands: examining business disciplines. J Comput Inf Syst. 2012;53:9–21.
17. Lee VH, Hew JJ. Is TQM fading away? A bibliometric analysis of a decade (2006 – 2015). Int J Serv Econ Manag. 2017;8:227–49.
18. Feng Y, Zhu Q, Lai KH. Corporate social responsibility for supply chain management: A literature review and bibliometric analysis. J Clean Prod. 2017;158:296–307. doi:10.1016/j.jclepro.2017.05.018.
19. Hew JJ. Hall of fame for mobile commerce and its applications: A bibliometric evaluation of a decade and a half (2000–2015). Telemat Informatics. 2017;34:43–66. doi:10.1016/j.tele.2016.04.003.
20. Bocanegra-Valle A. "English is my default academic language": voices from LSP scholars publishing in a multilingual journal. J English Acad Purp. 2014;13:65–77. doi:10.1016/j.jeap.2013.10.010.
21. Ma R, Ni C, Qiu J. Scientific research competitiveness of world universities in computer science. Scientometrics. 2008;76:245–60. doi:10.1007/s11192-007-1913-7.
22. Abrizah A, Wee MC. Malaysia's computer science research productivity based on publications in the web of science, 2000-2010. Malaysian J Libr Inf Sci. 2011;16:109–24.
23. Bakri A, Willett P. Computer science research in Malaysia: a bibliometric analysis. Aslib Proc. 2011;63:321–35. doi:10.1108/00012531111135727.
24. Singh VK, Uddin A, Pinto D. Computer science research: the top 100 institutions in India and in the world. Scientometrics. 2015;104:529–53. doi:10.1007/s11192-015-1612-8.
25. Lin WC, Tsai CF, Ke SW. Correlation analysis for comparison of the citation impact of journals, magazines, and conferences in computer science. Online Inf Rev. 2015;39:310–25. doi:10.1108/OIR-11-2014-0273.
26. Fiala D, Willett P. Computer science in Eastern Europe 1989-2014: a bibliometric study. Aslib J Inf Manag. 2015;67:526–41. doi:10.1108/AJIM-02-2015-0027.
27. Bornmann L. Validity of altmetrics data for measuring societal impact: A study using data from Altmetric and F1000 Prime. J Informetr. 2014;8:935–50. doi:10.1016/j.joi.2014.09.007.
28. Wang J, Alotaibi NM, Ibrahim GM, Kulkarni AV, Lozano AM. The spectrum of altmetrics in neurosurgery: the top 100 "trending" articles in neurosurgical journals. World Neurosurg. 2017;103:883–95. doi:10.1016/j.wneu.2017.04.157.
29. Lee VH, Hew JJ, Loke SP. Evaluating and comparing ten-year (2006-2015) research performance between Malaysian public and private higher learning institutions: A bibliometric approach. Int J Innov Learn. 2018;23:145–65. doi:10.1504/IJIL.2018.089618.
30. Pham MC, Klamma R, The structure of the computer science knowledge network, In International Conference on Advances in Social Network Analysis and Mining, 2010, pp. 17–24. Odense, Denmark.
31. van Eck NJ, Waltman L. Text mining and visualization using VOSviewer. ISSI Newsl. 2011;7:1–5.
32. van Eck NJ, Waltman L. Software survey: vOSviewer, a computer program for bibliometric mapping. Scientometrics. 2010;84:523–38. doi:10.1007/s11192-009-0146-3.
33. van Eck NJ, Waltman L. Citation-based clustering of publications using CitNetExplorer and VOSviewer. Scientometrics. 2017;111:1053–70. doi:10.1007/s11192-017-2300-7.
34. Waltman L. *A review of the literature on citation impact indicators*, J. Informetr. 2016;10:365–91. doi:10.1016/j.joi.2016.02.007.
35. Qiu X, Zhang L, Ren Y, Suganthan P, Amaratunga G, Ensemble deep learning for regression and time series forecasting, In 2014 IEEE Symposium on Computational Intelligence in Ensemble Learning (CIEL), 2014. Orlando, USA.
36. Colyer A. Deep learning in neural networks - an overview. Neural Networks. 2016;61:85–117.
37. Tahamtan I, Safipour Afshar A, Ahamdzadeh K. Factors affecting number of citations: a comprehensive review of the literature. Scientometrics. 2016;107:1195–225. doi:10.1007/s11192-016-1889-2.
38. Parker JN, Allesina S, Lortie CJ. Characterizing a scientific elite (B): publication and citation patterns of the most highly cited scientists in environmental science and ecology. Scientometrics. 2013;94:469–80. doi:10.1007/s11192-012-0859-6.
39. IEEE computer society predicts the future of tech: top 10 technology trends for 2019. Available at https://www.computer.org/press-room/2018-news/ieee-cs-top-technology-trends-2019.
40. Kim LW. DeepX: deep learning accelerator for restricted boltzmann machine artificial neural networks. IEEE Trans. Neural Networks Learn Syst. 2018;29:1441–53. doi:10.1109/TNNLS.2017.2665555.
41. Tsai H, Ambrogio S, Narayanan P, Shelby RM, Burr GW. Recent progress in analog memory-based accelerators for deep learning. J Phys D Appl Phys. 2018;51:1–27. doi:10.1088/1361-6463/aac8a5.
42. Birnbacher D, Birnbacher W. Fully autonomous driving: where technology and ethics meet. IEEE Intell Syst. 2017;32:3–4. doi:10.1109/MIS.2017.3711644.
43. Cocchiarella L. The colors of black: digital computation as a spectrum of knowledge. In: Hemmerling M, Cocchiarella L editors. Informed architecture: computational strategies in architectural design. Cham, Switzerland: Springer International Publishing; 2018. p. 11–18.

44. Pérez A, Moltó G, Caballer M, Calatrava A. Serverless computing for container-based architectures. Futur Gener Comput Syst. 2018;83:50–59. doi:10.1016/j.future.2018.01.022.
45. Vazquez-Poletti JL, Llorente IM, Hinsen K, Turk M. Serverless computing: from planet mars to the cloud . Comput Sci Eng. 2018;20:73–79. doi:10.1109/MCSE.2018.2875315.
46. Roman R, Lopez J, Mambo M. Mobile edge computing, Fog et al.: A survey and analysis of security threats and challenges. Futur Gener Comput Syst. 2018;78:680–98. doi:10.1016/j.future.2016.11.009.
47. Abbas N, Zhang Y, Taherkordi A, Skeie T. Mobile edge computing: a survey. IEEE Internet Things J. 2018;5:450–65. doi:10.1109/JIOT.2017.2750180.