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Looking Over the Research Literature on Software Engineering from 2016 to 2018

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Abstract

This paper carries out a bibliometric analysis to detect (i) what is the most influential research on software engineering at the moment, (ii) where is being published that relevant research, (iii) what are the most commonly researched topics, (iv) and where is being undertaken that research (i.e., in which countries and institutions). For that, 6,365 software engineering articles, published from 2016 to 2018 on a variety of conferences and journals, are examined.

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1. Introduction

The primary goal of this paper is to provide guidance on the vast literature on software engineering that it is being published nowadays. In particular, it targets the following Research Questions (RQs) for the period 2016-2018 (i.e., the last three years):

- RQ1: What articles are the most impacting?
- RQ2: Where have those articles been published?
- RQ3: What are the upward research trends?
- RQ4: Which countries and institutions are playing the principal role?

In 2007, Kitchenham and Charters published an influential technical report proposing some guidelines about how to perform systematic software engineering reviews, covering *surveys*, *systematic literature reviews*, *systematic mapping studies*, and *meta-analyses*. These guidelines were extended in Wohlin et al.'s book [1], and many software engineering reviews have applied them successfully, for instance, [2, 3, 4].

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Nevertheless, the review strategies mentioned above work for small-to-medium literature samples of a few hundreds of articles. In contrast, this paper analyzes 6,365 documents gathered from Elsevier's Scopus. To do so, it uses *bibliometric techniques*, which have already proven their usefulness in the software product line domain by analyzing thousands of papers automatically [5].

This article is organized in three sections. Section 2 describes the methodology and tools we have used to undertake the literature review. Section 3 presents the main results of our analysis: Subsection 3.1 summarizes the most influential papers and publication sources (conferences and journals); Subsection 3.2 identifies some hot topics; and Subsection 3.3 presents the most prolific countries and research institutions. Finally, Section 4 gives some concluding remarks.

2. Materials and methods

2.1. Document sample

In order to obtain a representative *sample* of the software engineering literature *population* for the last three years, our corpus is composed of the Scopus records for all the documents published from 2016 to 2018 in the following **journals**: (i) Automated Sw. Eng., (ii) IEEE Sw., (iii) IEEE Trans. on Sw. Eng., (iv) IEICE Trans. on Information and Systems, (v) IET Sw., (vi) Information and Sw. Tech., (vii) Innovations in Systems and Sw. Eng., (viii) Int. Journal of Sw. Eng. and Its Applications, (ix) Int. Journal of Sw. Eng. and Knowledge Eng., (x) Int. Journal on Adv. Science Eng. and Information Tech., (xi) Empirical Sw. Eng., (xii) Sw. and Systems Modeling, (xiii) Sw Practice and Experience, (xiv) Sw. Quality Journal, (xv) Theoretical Computer Sci.; and **conference proceedings**: (i) APSEC: Asia Pacific Sw. Eng. Conf. (APSEC) (ii) ASE: IEEE ACM Int. Conf. on Automated Sw. Eng., (iii) COMPSAC: Int. Computer Sw. and App. Conf., (iv) ESEM: Int. Symposium on Empirical Sw. Eng. and Measurement, (v) FSE: ACM SIGSOFT Symposium on the Foundations of Sw. Eng., (vi) ICODSE: Int. Conf. on Data and Sw. Eng., (vii) ICSE: Int. Conf. on Sw. Eng., (viii) ICSME: IEEE Int. Conf. on Sw. Maintenance and Evolution, (ix) ICST: IEEE Int. Conf. on Sw. Testing Verification and Validation, (x) ISSRE: Int. Symposium on Sw. Reliability Int., (xi) JCSSE: Int. Joint Conf. on Computer Sci. and Sw. Eng., (xii) MOBILESoft: Int. Conf. on Mobile Sw. Eng. and Systems, (xiii) MODELSWARD: Int. Conf. on Model Driven Eng. and Sw. Dev., (xiv) MSR: IEEE Int. Working Conf. on Mining Sw. Repositories, (xv) QRS: IEEE Int. Conf. on Sw. Quality Reliability and Security Companion, (xvi) RE: IEEE Int. Requirements Eng. Conf. (xvii) SEAA: EUROMICRO Conf. on Sw. Eng. and Adv. App.

The corpus is available at:

<https://github.com/rheradio/SwEngScopus2016-18>

2.2. Analysis tools

The document sample was analyzed using the following R packages:

- `bib2df` [6] to parse the Scopus data (in Bibtex format) to an R data frame.
- `tidyverse` [7] for processing the corpus.
- `wordcloud` [8] for identifying the most common article keywords (see Figure 1).
- `ggplot2` [9] for obtaining a visual representation of the countries whose research institutions are the most prolific (see Figure 2).

3. Results

The following sections summarize the main results of our analysis. In particular, Section 3.1 answers Research Questions RQ1 and RQ2 (what papers are the most impacting, and where have they been published?); Section 3.2 deals with RQ3 (what topics should be considered trendy?), and Section 3.3 answers RQ4 (which countries and institutions are playing the principal role?).

3.1. Hot Papers (RQ1 and RQ2)

Table 1 summarizes the papers that, according to the information provided by Scopus on July 23rd, 2019, were in the 99th citation percentile of their corresponding year. Most influential papers have been published in a few sources: the International Conference on Software Engineering - ICSE (16.67% of the papers in Table 1), and the journals Empirical Software Engineering (16.67%), Information and Software Technology (16.67%), IEEE Transactions on Software Engineering (15.15%), and IEEE Software (10.61%).

2016		2017		2018	
Article	#Citations	Article	#Citations	Article	#Citations
<i>Mechtaev et al.</i> [10]	111	<i>Tantithamthavorn et al.</i> [11]	67	<i>Morschheuser et al.</i> [12]	24
<i>Gu et al.</i> [13]	87	<i>Bröring et al.</i> [14]	61	<i>Dingsoyr et al.</i> [15]	24
<i>Wang et al.</i> [16]	84	<i>Xuan et al.</i> [17]	57	<i>Panichella et al.</i> [18]	21
<i>Tantithamthavorn et al.</i> [19]	80	<i>Beller et al.</i> [20]	55	<i>Falessi et al.</i> [21]	21
<i>Sajjani et al.</i> [22]	74	<i>Kitchenham et al.</i> [23]	50	<i>Leemans et al.</i> [24]	16
<i>Stol et al.</i> [25]	72	<i>Taivalsaari et al.</i> [26]	44	<i>Taibi et al.</i> [27]	15
<i>White et al.</i> [28]	71	<i>Groen et al.</i> [29]	40	<i>García et al.</i> [30]	14
<i>Ye et al.</i> [31]	71	<i>Munaiah et al.</i> [32]	35	<i>Kula et al.</i> [33]	14
<i>Zhang et al.</i> [34]	71	<i>Jongeling et al.</i> [35]	35	<i>Chen et al.</i> [36]	14
<i>Xia et al.</i> [37]	64	<i>Lu et al.</i> [38]	34	<i>Bennin et al.</i> [39]	13
<i>Villarroel et al.</i> [40]	64	<i>Le et al.</i> [41]	34	<i>Palomba et al.</i> [42]	13
<i>Sorbo et al.</i> [43]	63	<i>Jing et al.</i> [44]	33	<i>Calefato et al.</i> [45]	13
<i>Segura et al.</i> [46]	61	<i>Borges et al.</i> [47]	33	<i>Di Nucci et al.</i> [48]	13
<i>Kosar et al.</i> [49]	59	<i>Fernández et al.</i> [50]	31	<i>Tantithamthavorn et al.</i> [51]	12
<i>LaToza et al.</i> [52]	59	<i>Hoda et al.</i> [53]	30	<i>Szarnyas et al.</i> [54]	12
<i>Alves et al.</i> [55]	58	<i>Yang et al.</i> [56]	29	<i>Herbold et al.</i> [57]	12
<i>Gousios et al.</i> [58]	55	<i>Beller et al.</i> [59]	29	<i>Tong et al.</i> [60]	12
<i>Hilton et al.</i> [61]	53	<i>Ciurumelea et al.</i> [62]	29	<i>Hosseini et al.</i> [63]	12
<i>Maalej et al.</i> [64]	52	<i>Zhang et al.</i> [65]	29	<i>Hadar et al.</i> [66]	12
<i>Treude et al.</i> [67]	51	<i>Sadeghi et al.</i> [68]	28	<i>Hosseini et al.</i> [69]	12
-	-	-	-	<i>Hadar et al.</i> [70]	12
-	-	-	-	<i>Honghao et al.</i> [71]	11
-	-	-	-	<i>Amritanshu et al.</i> [72]	11
-	-	-	-	<i>Calefato et al.</i> [73]	11
-	-	-	-	<i>Vallon et al.</i> [74]	11
-	-	-	-	<i>Carvalho et al.</i> [75]	11

Table 1. Top 1% cited papers per year.

3.2. Hot Topics (RQ3)

The word-clouds in Figure 1 represent the most repeated *keywords* in the articles published in 2016, 2017, and 2018. According to the figure, three upward trends can be identified:

- Researching on open-source software: see the keywords “open-source software”, “open systems”, and “open-source projects”.
- The application of artificial intelligence techniques to software engineering: see the keywords “deep learning”, “artificial intelligence”, “learning systems”, “learning algorithms”, “genetic algorithms”, “natural language processing”, and “classification of information”.
- Undertaking empirical software engineering: see the keywords “empirical studies”, “empirical software engineering”, “benchmarking”, and “mining software repositories”.



Fig. 1. Most repeated keywords in (a) 2016, (b) 2017, and (c) 2018.

3.3. Principal institutional actors (RQ4)

Figure 2 shows how many articles the research centers of every country have published for the last three years, summarizing on the right the top ten most prolific institutions per year. It is worth noting that the countries whose institutions published most papers were:

- In 2016, USA (23.96% of all the articles published in 2016), China (12.71%) and South Korea (11.25%).
- In 2017, USA (22.37%), China (14.61%) and Canada (9.58%).
- In 2018, USA (23.16%), China (14.38%) and Germany (11.03%).

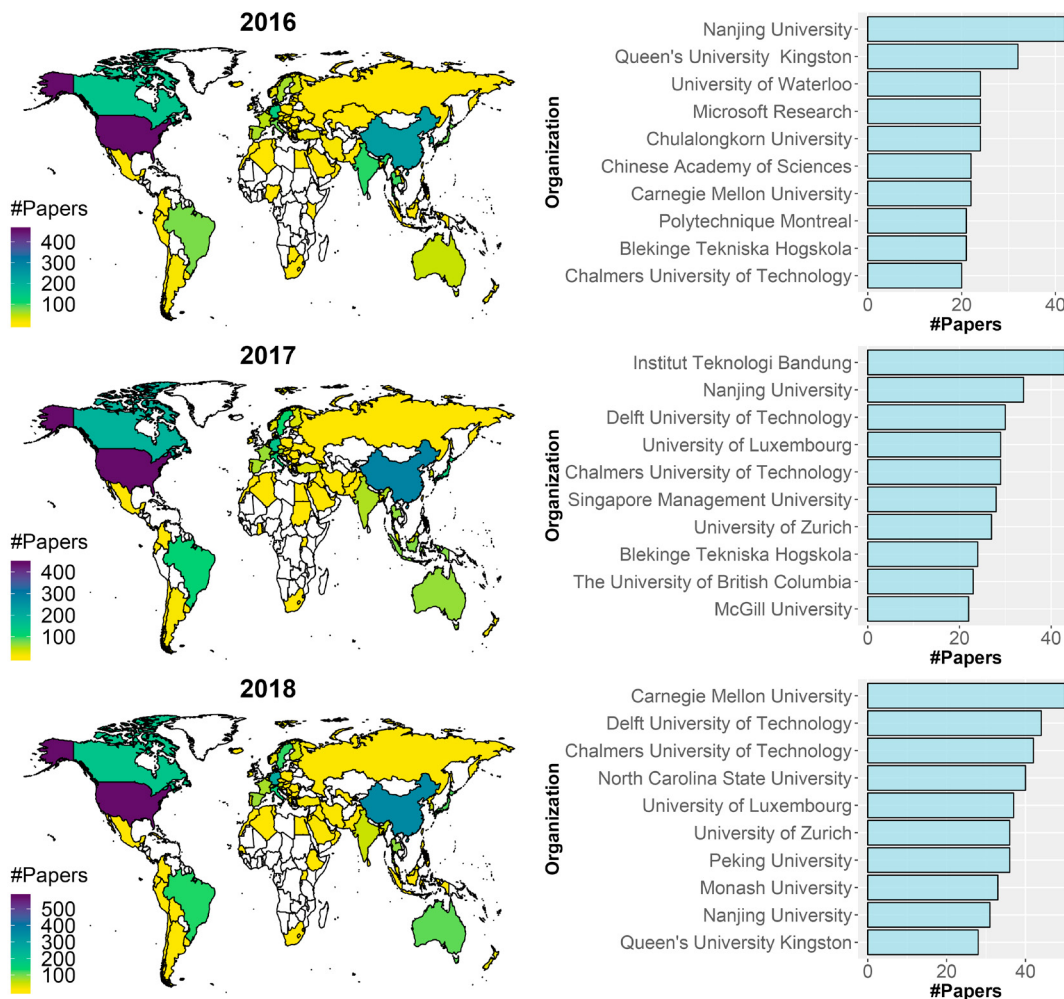


Fig. 2. Most prolific countries and organizations.

4. Conclusions

According to the document sample this paper analyzes, most literature on software engineering is produced in two countries: USA and China, with 23.16% and 13.9% of all published articles on average, respectively. The publication sources of the most influential papers are also rather concentrated: one conference and four journals have published 75.77% of the documents in the top 0.1% citation ranking. Finally, we have detected three hot topics: open-source software, the application of artificial intelligence to deal with software engineering problems, and the importance of performing empirical studies about software development.

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