

Electronic Voting Research Papers in Web of Science: A Bibliometric Analysis

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Abstract: Purpose - The main aim of the paper is to investigate and recognize trends in Electronic Voting research at an international level. **Design/methodology/approach** - Retrieval of the data was from the database of Web of Science on the topic Electronic Voting that covered the period from 1988- 2020 to identify useful contributions that have been produced and published in the respective field. A total of 994 data records were retrieved from the database. Several trends predominating in Digital Voting research including well known contributing countries, adopted patterns of the authorship, the degree of co-authorship, cross-country co-authorship, prominent sources for research publication, recognition of research in course of citation trends like average citation per year, top-cited papers, citations received/citations per paper, etc. were discovered by analysis of the data. **Findings**—There have been constructive growth in the literature since 1988 as revealed by the analysis. As evident from the analysis, half of the research output was contributed by the five countries – USA, England, China, Spain, and Germany with a total of 491 journals published. When it comes to the effectiveness of the papers, Denmark leads with a PEI of 4.87. It is followed by Canada with PEI of 4.60 and Scotland with PEI of 2.80. Most of the journals belong to Computers Science and Political Science categories of Web of Science. Also, the number of times these papers are cited per year is increasing rapidly for the given duration. This shows there is an increase in research in the field of Digital Voting. COVID-19 pandemic can be made accountable for the irregularity in the trend in 2020 that has halted the research in the field. On performing linear regression, it was observed that we can expect positive growth in the number of citations in the coming years.

Keywords-Electronic Voting, e-Voting, Digital Voting, Bibliometrics, Web of Science

Introduction

Since the 1st paper was published by Kassicieh SK; Kawaguchi GH and Malczynski L in 1988, there has been a swift increase in the number of published papers with the highest of 77 being published in 2009 followed by 73 in 2019. This could solely be because of the advancements in Information and Communication Technology since 1988 (Gochhait, 2011). More powerful and portable devices have paved a way for the growth of new methodologies in various domains.

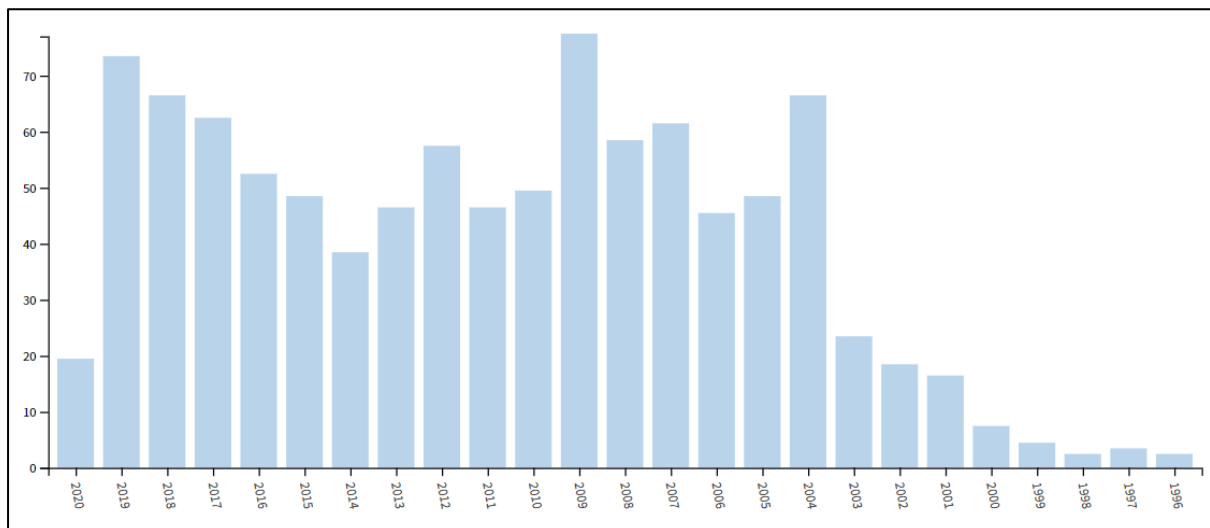
Voting is the most important aspect of a democratic country. India is the most populous democratic country in the world with a population of 1.3 billion. In the Lok Sabha elections of 2019, approximately 911 million people were eligible to vote, and the overall voter turnout was over 67 percent which is much higher as compared to previous elections. It also witnessed the highest ever participation by women voters.

Electronic voting is a kind of a computer-enabled voting system under which voters take the aid of computers to make their selections. The voters usually choose with the aid of buttons, although provisions for voters with visual disabilities can be made by providing audio interfaces. Electronic voting is composed of four basic steps of an election process. The first step is the ballot composition in which the voters make decisions of the candidate to vote. The second step is ballot casting in which

voters present their ballots in the voting booth. Then comes ballot recording in which a system registers and stores the submitted ballots. The final step is tabulation, under which vote-counting is performed. Ballot recording, tabulation, and casting are mainly done through computers even if the voting systems are not, strictly speaking, electronic or digital. Electronic voting in the strict sense is a system in which computers are used in the initial step of ballot composition (or choosing) (Peralta, 2016).

Bibliometrics is an analysis technique that is concerned with nature and how the data is quantitatively displayed. It is a highly adaptable and functional technique that could be used to test, blend and analyse both non-printed and printed collection of data (Harande et al., 2013). Bibliometrics can be defined as the implementation of statistical and mathematical methods to quantify scholarly publications' research output (Mattsson, 2008). The bibliometric examination is an important catalyst for the scientific network since it offers methods to break down science and innovation proceedings (Okubo, 1997). In addition, they provide an idea about the co-relations among analysts and research regions through the joint publications statistical investigations and citations (Mingers et al., 2015). Usually, the bibliometric investigation yields patterns of publication, trends in authorship, prime journals, citations, and other parameters (Hazarika et al., 2003). Likewise, the main purpose of this analysis is to use bibliometric indices to analyse the research performance of electronic voting.

Figure 1. The number of papers published each year on E-Voting (Source: Web of Science)



Literature Review

There have been very few bibliometric studies carried out in the field of elections using technologies but they are mainly focused on a particular technology. In the paper published by Savaget, Paulo; Chiarini, Tulio; Evans, Steve on Empowering political participation through artificial intelligence in June 2018 (Savaget et al., 2018), they conducted a bibliometric analysis on a sample of 721 publications and found out that there has been a surge in the number of publications since 2015 and a majority of the authors are from the USA. Another bibliometric research was conducted on the evolution of sentiment analysis by Mantyla, MV; Graziotin, D; Kuutila, Min February 2018 (Mantyla et al., 2018). They emphasized the increased use of sentiment analysis to evaluate customers' behavioural patterns (Gochhait, Tripathy, and Almedia, 2014). Also, there has been an improvement in the use of analysis using sentiments by political parties to understand their standing before the election. They conducted the bibliometric research using the Scopus search engine and found that the number of papers being published in Scopus on this topic is increasing rapidly every year.

COVID-19 pandemic has paved a wave for the digital transformation in every industry of the world. People are looking out for alternative digital opportunities over the traditional one. Social distancing is a new norm and has opened up an opportunity for new ideas to develop. With a population of 1.3 billion, India is considered to be the biggest democratic country in the world. In the 2020 Lok Sabha elections, about 911 million people cast their votes by physically visiting their local voting centers (Jain, 2019). The day of voting was closed for major economic activities. People visited in masses to the centers to cast their votes. Considering the current pandemic situation, it will be beneficial to make the voting process digital where voters can cast their votes from their homes or their workplaces. This will not only ensure social distancing but will also help the economy to remain unaffected on that day. Currently, there are many digital voting options available in the market. Many countries such as India itself has adopted e-voting technology. The only drawback in the Indian voting systems is the EVMs that are installed in the centers. EVMs are just a replacement of paper ballots and the people will have to visit their centers to cast their votes.

Objectives

The principal aim of this analysis is to identify the growth of Electronic Voting literature published in the years 1980-2020 as per the Web of Science database and carry out a qualitative and quantitative evaluation by analysing various characteristics of research performances such as citations, authorship pattern, country-wise analysis, growth of publications, highly cited journals, degree of collaboration, co-authorship patterns, collaborative index, collaborative coefficient, ACPP, etc.

Design/methodology/approach

The data of the study were retrieved from the database of Web of Science covering the core collection series during the period from 1980- 2020. A total of 994 records were retrieved using the terms "electronic voting" or "e-voting" or "digital voting". The analysis was focused only on research papers, reviews and conference proceedings papers. The data was analysed further to identify different trends dominating Electronic Voting research including authorship pattern, most productive countries, collaboration degree, most cited papers, etc.

Data Analysis

Country Wise Analysis

Spanning 32 years of electronic voting research, table 1 shows the breakdown of PEI of different countries. It is found that the USA has contributed to a maximum number of papers (184) with 2774 citations, followed by England (107 papers) with 1071, China (79 articles) with 594 citations. Together the USA, England, China, Spain and Germany have contributed to a total of 491 which is about 50% of world output. An attempt was made to classify the most cited countries' Publication Performance Index.

PEI measures the quality of a research (Guan and Ma, 2007). PEI is calculate by using the formula:

$$PEI = \frac{TNC_i/TNC_t}{TNP_i/TNP_t}$$

TNC_t= A complete number of citations of all countries.

TNP_t= A complete number of papers of all countries.

TNC_i= A complete number of citations of the country i.

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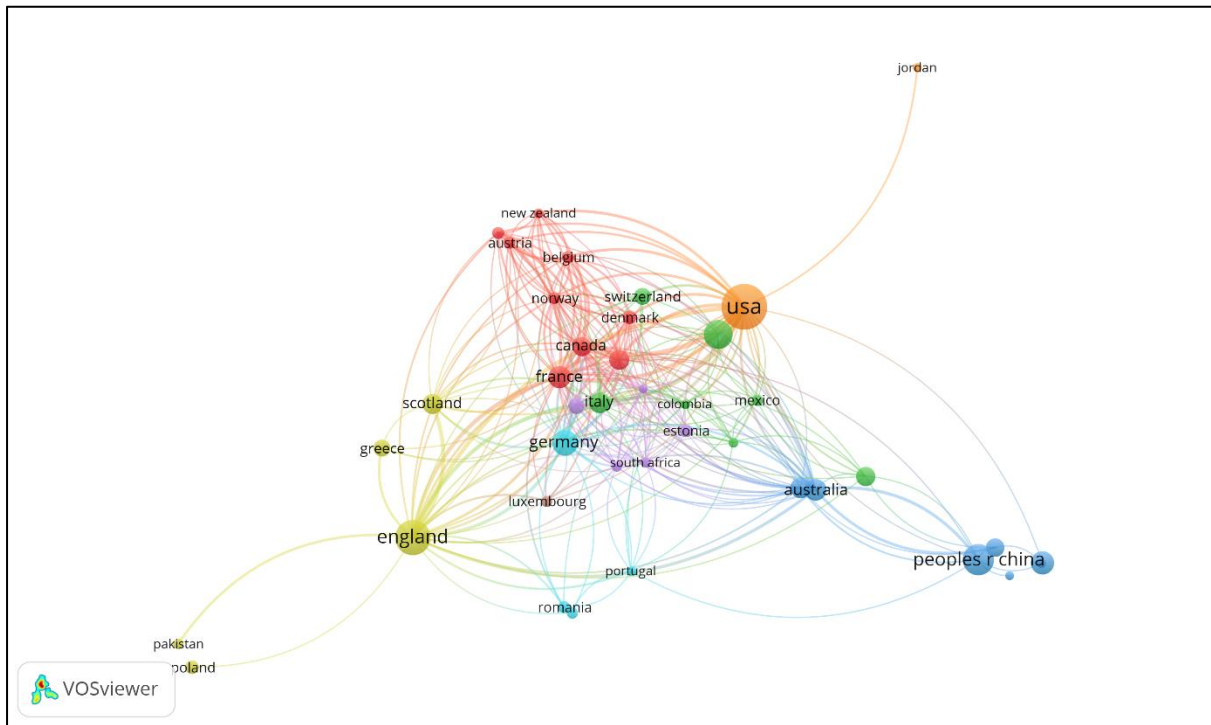
The PEI value of more than 1 shows a greater impact of publication than the research efforts devoted to it. There are 15 countries that have the PEI of more than 1 which means that their publications have more impact. Denmark had the highest PEI (4.87) followed by Canada with 4.06, Scotland with 2.80. A PEI of less than 1 means publication has less impact than efforts devoted to its publication. As is observed from the table, 11 countries have less than 1 PEI which means that their publication doesn't have a greater impact.

Figure 2: Number of papers and citation for different countries

| Sr. No. | Country | Total Papers | Total Citations | PEI |
|---------|-----------------|--------------|-----------------|------|
| 1 | Denmark | 13 | 521 | 4.87 |
| 2 | Canada | 28 | 1061 | 4.60 |
| 3 | Scotland | 31 | 714 | 2.80 |
| 4 | Norway | 10 | 218 | 2.65 |
| 5 | France | 42 | 907 | 2.62 |
| 6 | Ireland | 11 | 226 | 2.50 |
| 7 | Austria | 11 | 217 | 2.40 |
| 8 | Netherlands | 31 | 594 | 2.33 |
| 9 | Belgium | 11 | 196 | 2.16 |
| 10 | USA | 184 | 2774 | 1.83 |
| 11 | Germany | 52 | 677 | 1.58 |
| 12 | Italy | 35 | 404 | 1.40 |
| 13 | Australia | 37 | 417 | 1.37 |
| 14 | England | 107 | 1071 | 1.22 |
| 15 | South Korea | 26 | 214 | 1.00 |
| 16 | Japan | 36 | 277 | 0.93 |
| 17 | Greece | 21 | 160 | 0.93 |
| 18 | Taiwan | 45 | 341 | 0.92 |
| 19 | Peoples R China | 79 | 594 | 0.91 |
| 20 | Estonia | 12 | 81 | 0.82 |
| 21 | Brazil | 19 | 103 | 0.66 |
| 22 | Romania | 10 | 53 | 0.64 |
| 23 | India | 29 | 111 | 0.46 |
| 24 | Switzerland | 22 | 84 | 0.46 |
| 25 | Poland | 13 | 43 | 0.40 |
| 26 | Spain | 69 | 84 | 0.15 |

On analysing the co-authorship contribution from different countries using VOSViewer, it was observed that the USA is the country with the highest linkages of 128 with other countries. After the USA, England has the second-highest co-authorship linkages with a total link strength of 109 and Canada is the third highest with a total link strength of 81. Please refer to the below figure. It is a clear indication that the USA is leading the world when it comes to research in the field of e-Voting.

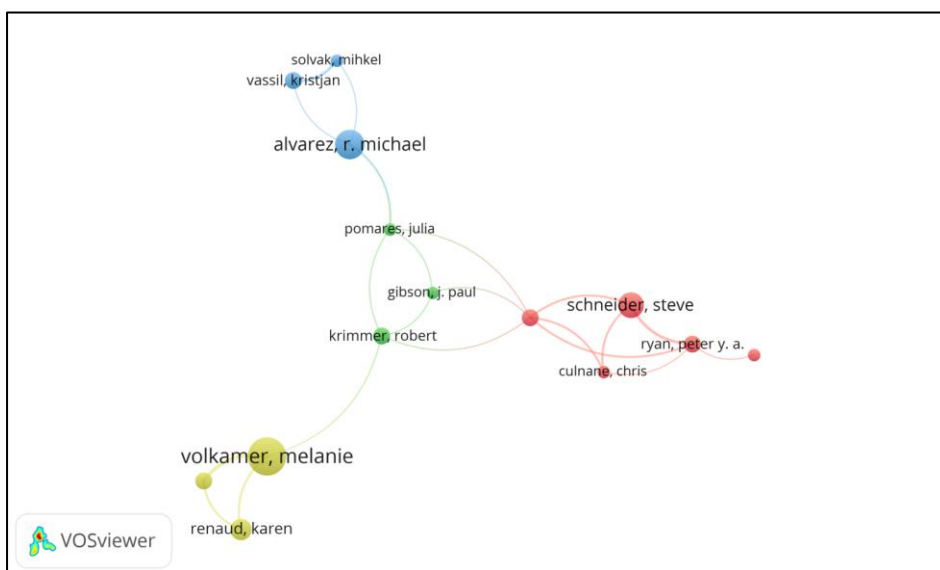
Figure 3: Co-authorship contribution from different countries



Cluster Analysis of Co-Authorship based on the number of papers cited and published

Using VOSViewer for data analysis with the criteria of a minimum of three papers published and three papers cited for the authors, four clusters were formed with a total of 21 linkages. The strongest link strength was found out to be of the cluster formed by the co-authorship of Volkamer, Melanie; Budurushi, Jurlind and Renaud, Karen. Volkamer, Melanie being the strongest co-authorship published nine documents and was cited in 22 documents making it the biggest contributor in the research.

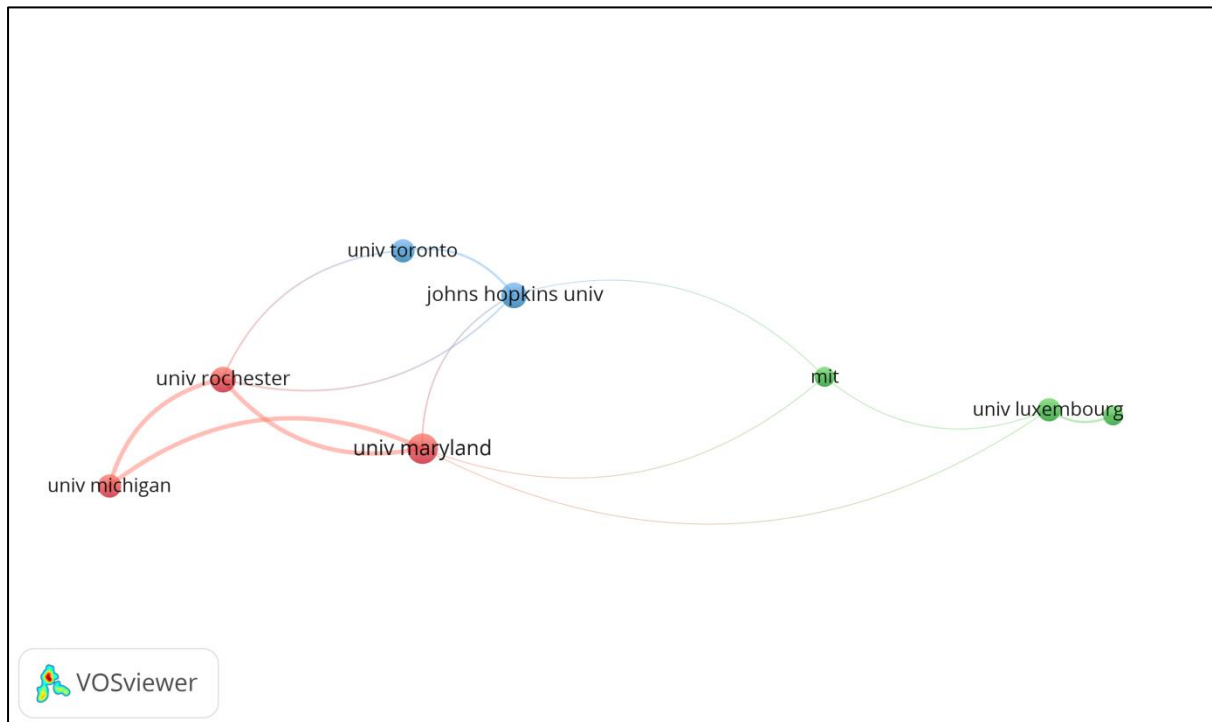
Figure 4: Co-Authorship based on the number of papers cited and published



And while analysing the organizations to which these authors belong, we have filtered out those organizations that have published less than 8 documents and have been cited for less than 10 times,

we have got eight organizations with three clusters and 12 linkages. The strongest cluster is of the University of Maryland, the University of Rochester and the University of Michigan with the University of Maryland contributing the most to research in the field of e-Voting.

Figure 5: Co-Authorship based on organizations to which authors belong

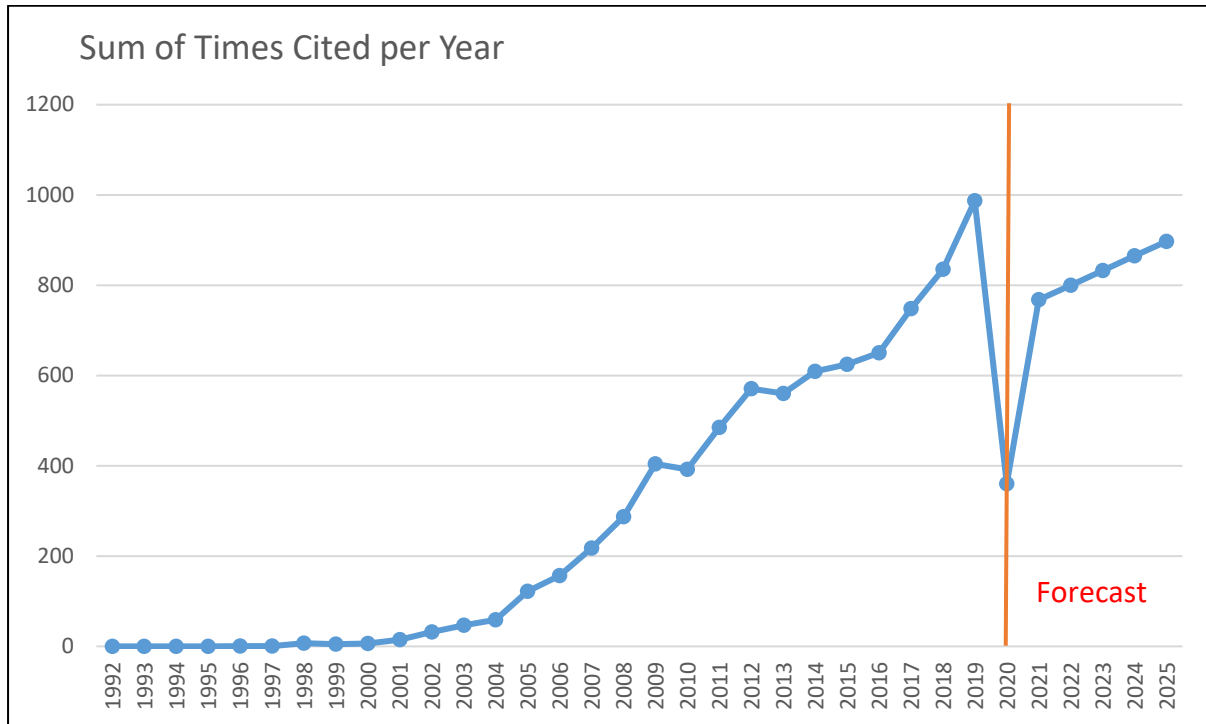


Linear Regression Analysis of number of times the papers were cited per year

It is clearly visible that the number of citations per year is increasing exponentially since 1992. The advancement in technologies is the main reason behind the increase in research in the field of digital voting. There has been an odd trend for the year 2020. This is mainly due to the COVID-19 pandemic that has disrupted the ongoing research in this field.

By performing linear regression analysis on the citation data, it was discovered that the trend is likely to increase in the near future (Please refer to the chart to see the predicted values). Also, the COVID-19 pandemic has paved a way for social distancing and this will lead to an exponential increase in the research on the e-voting. In that case, the values are likely to be increased further than the current predicted values.

Figure 6: Number of times the papers were cited on Electronic Voting (Source – Web of Science)



Core Authors

On enquiring about core authors it was found that co-authorship of Xenakis, A and MacIntosh, A have contributed a maximum number of articles (6) with a total citation of 15 which was followed by Lorimer, Jenny and Hilliard, Alan (5 articles) with 11 citations. On analysing single-authored publications, it was found that Peng, Kun has contributed the maximum number of articles (5) with a total citation of 13 which was followed by Pieters, Wolter (4 articles) with 37 citations.

Figure 7: Core authors based on number of papers and total citations

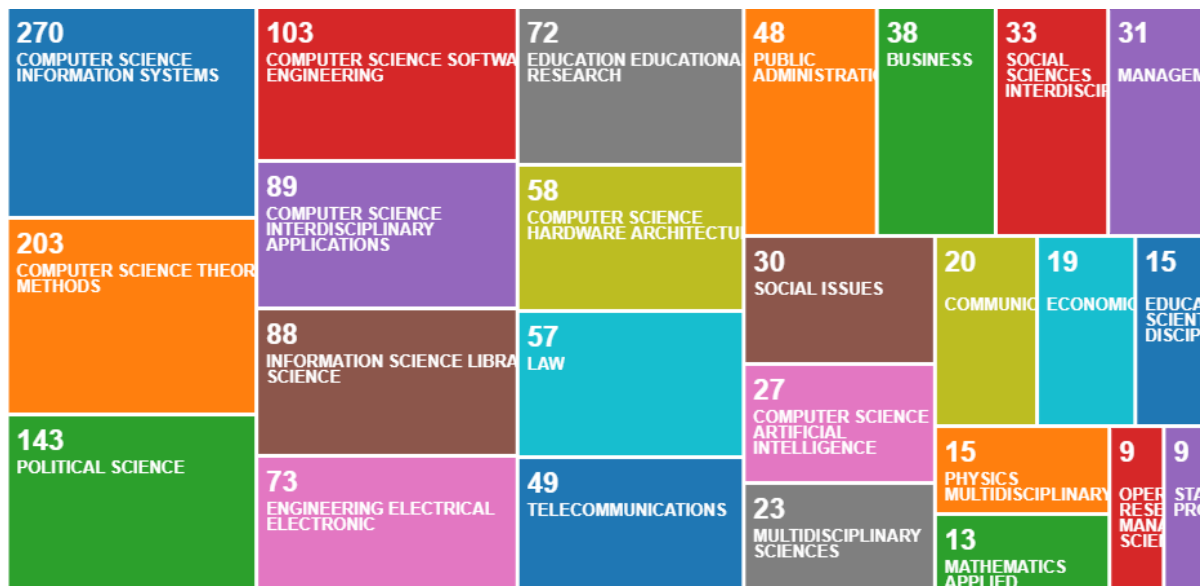
| Sr.No. | Authors | Count of Title | Sum of Total Citations | ACCP |
|--------|------------------------------------|----------------|------------------------|------|
| 1 | Xenakis, A; MacIntosh, A | 6 | 15 | 2.5 |
| 2 | Lorimer, Jenny; Hilliard, Alan | 5 | 11 | 2.2 |
| 3 | Peng, Kun | 5 | 13 | 2.6 |
| 4 | Pieters, Wolter | 4 | 37 | 9.25 |
| 5 | Dill, David L. | 3 | 4 | 1.33 |
| 6 | Gok, Tolga | 2 | 25 | 12.5 |
| 7 | Dini, G | 2 | 26 | 13 |
| 8 | Wu, Tsu-Yang; Tseng, Yuh-Min | 2 | 28 | 14 |
| 9 | SAKO, K | 2 | 30 | 15 |
| 10 | Oostveen, AM; Van den Besselaar, P | 2 | 32 | 16 |

Core Areas

The results of the study show that Computer Science Information is the most researched area in the field of e-Voting. Researchers have published 270 research papers on Computer Science Information

System which was followed by Computer Science Theory Methods (203 papers), Political Science (143 papers), Computer Science Software Engineering (103 papers) and Computer Science Interdisciplinary Applications (89 papers). It is clearly visible that maximum research has been conducted in the Computer Science field and it is followed by the Political Science field.

Figure 8: Category wise paper published on Electronic Voting (Source – Web of Science)



Most Cited Journals

In every field, there are few journals that are the most productive. They produce a majority of research papers. In the domain of electronic voting, there are also core journals which are listed below. It has been found that the top ten journals have contributed to 1882 research papers. The paper titled “A generalisation, a simplification and some applications of Paillier's probabilistic public-key system” has been cited the most with 360 citations. It is followed by “Examining the benefits and challenges of using audience response systems: A review of the literature” (288 citations) and “Increasing interactivity in lectures using an electronic voting system” (268 citations).

Average citation per year indicates the importance of the paper in the domain as it considers the time period from the year the paper got published. The paper that got published recently but has a higher average citation per year indicates it to be more important than the papers that were cited more number of times. It was found that “Guidelines for Family-Centered Care in the Neonatal, Pediatric, and Adult ICU” has the highest average citation per year with a value of 55.5 and is followed by “Treating axial spondyloarthritis and peripheral spondyloarthritis, especially psoriatic arthritis, to target: 2017 update of recommendations by an international task force” with a value of 45.33. Top 10 titles have contributed to more than twenty percent of total citations in the field of electronic voting.

Figure 9: Most Cited Journals

| Sr. No. | Authors | Title | Total Citations | Average Citation per Year |
|---------|----------------------------|--|-----------------|---------------------------|
| 1 | Jurik, M; Damgard, I | “A generalisation, a simplification and some applications of Paillier's probabilistic public-key system” | 360 | 18 |
| 2 | Kay, Robin H.; LeSage, Ann | “Examining the benefits and challenges of using audience | 288 | 24 |

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|---|--|---|-----|-------|
| | | response systems: A review of the literature” | | |
| 3 | Draper, SW; Brown, MI | “Increasing interactivity in lectures using an electronic voting system” | 268 | 15.76 |
| 4 | Puntillo, Kathleen A.; Kross, Erin K.; Hart, Joanna; Hopkins, Ramona O.; Franck, Linda S.; Skrobik, Yoanna; Kon, Alexander A.; Scruth, Elizabeth A.; Harvey, Maurene A.; Lewis-Newby, Mithya; Swoboda, Sandra M.; Cooke, Colin R.; Levy, Mitchell M.; Curtis, J. Randall; Davidson, Judy E.; Aslakson, Rebecca A.; Long, Ann C.; Cox, Christopher E.; Wunsch, Hannah; Wickline, Mary A.; Nunnally, Mark E.; Netzer, Giora; Kentish-Barnes, Nancy; Sprung, Charles L.; Hartog, Christiane; Coombs, Maureen; Gerritsen, Rik T.; Azoulay, Elie; White, Douglas B.; | “Guidelines for Family-Centered Care in the Neonatal, Pediatric, and Adult ICU” | 222 | 55.5 |
| 5 | Cain, Jeff; Robinson, Evan | “A primer on audience response systems: Current applications and future considerations” | 165 | 12.69 |
| 6 | Gensler, Lianne S.; Gossec, Laure; Helliwell, Philip; Jongkees, Merryn; Kvien, Tore K.; Inman, Robert D.; McInnes, Iain B.; Maccarone, Mara; Machado, Pedro M.; Ogdie, Alexis; Poddubnyy, Denis; Ritchlin, Christopher; Thio, Bing; Veale, Douglas; de Vlam, Kurt; van der Heijde, Desire; Smolen, Josef S.; Schoels, Monika; Braun, Juergen; Dougados, Maxime; Gladman, Dafna D.; Kavanaugh, Arthur; Landewe, Robert; Mease, Philip; Sieper, Joachim; Stamm, Tanja; de Wit, Maarten; Aletaha, Daniel; Baraliakos, Xenofon; Betteridge, Neil; van den Bosch, Filip; Coates, Laura C.; Emery, Paul; FitzGerald, Oliver; Rudwaleit, Martin; Tanew, Adrian; Molto, Anna | “Treating axial spondyloarthritis and peripheral spondyloarthritis, especially psoriatic arthritis, to target: 2017 update of recommendations by an international task force” | 136 | 45.33 |
| 7 | Liu, JK; Wei, VK; Wong, DS | “Linkable spontaneous anonymous group signature for ad hoc groups” | 126 | 7.41 |

| | | | | |
|----|---|--|-----|------|
| 8 | Delaune, Stephanie; Kremer, Steve; Ryan, Mark | “Verifying privacy-type properties of electronic voting protocols” | 115 | 9.58 |
| 9 | Kennedy, GE; Cutts, QI | “The association between student’s use of an electronic voting system and their learning outcomes” | 102 | 6.38 |
| 10 | MacArthur, James R.; Jones, Loretta L. | “A review of literature reports of clickers applicable to college chemistry classrooms” | 100 | 7.69 |

Conclusion

The paper cited in the journals tries to identify the research trends in the discipline of Electronic Voting during 1988-2020. Based on the data retrieved from the database of Web of Science, authors analysed year-wise publications, most productive countries, most used journals, and authorship pattern journals, etc. There is a positive growth in literature on electronic voting. It is clear that more than half of the research outputs are from the countries USA, England, China, Spain and Germany. Denmark has PEI of 4.87 followed by Canada with PEI of 4.60 and Scotland with PEI of 2.80. Most of the journals belong to Computers Science and Political Science categories of Web of Science. The number of citations is increasing every year. The irregularity in the trend in 2020 is due to the COVID-19 pandemic that has halted the research in the field. On performing linear regression, it was observed that we can expect positive growth in the number of citations in the coming years. Top 10 titles have contributed to more than twenty percent of total citations in the field of electronic voting. The Post COVID-19 era will lead to more research in the field of electronic voting as social distancing will be considered to be a new norm in every domain and industry of the world.

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