


Bibliometric analysis of 50 years of IEEE Industrial Electronics Society publications

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Abstract—Tertiary education increasingly relies on publications. Arguably, Ph.D. work is also increasingly produced within larger teams or with more extensive collaborations. As way to obtain an objective measure of this trend, this manuscript examines authorship trends in IEEE Industrial Electronics Society (IEEE-IES) publications for the 50-year period from 1963 to 2012. We emphasize the trends related to the number of authors and pages per publication. In order to identify several bibliometric indicators, we have analyzed 34,409 entries from IEEE-Xplore digital library for IEEE-IES publications.

We provide results for two different sets of publications. Firstly, we present evidence that the number of authors and the number of pages of articles in the IEEE Transactions in Industrial Electronics (TIE) for the 50-year period are increasing per decade an average of +0.42 authors and +0.87 pages, respectively. Secondly, we provide evidence that the number of authors per article in 14 publication venues for the 25-year period from 1988 to 2012 are increasing per decade an average of +0.375 authors.

Index Terms—scientific authorship, number of authors, scientific publication, tertiary education, industrial electronics

I. INTRODUCTION

In science, a published article is the primary means where new work is publicly made available. Career progression and academic promotion are greatly influenced by authorship. Only those that contribute intellectually to the completion of the respective research can claim authorship. According to Bennett and Taylor [1], the benefits of authorship are numerous and include (1) Contribution to the progress of science; (2) Personal sense of achievement; (3) Evidence of an individual's professional reputation; and (4) Creation of currency for academic appointment, promotion, research funding, and entry to professional bodies.

According to Greene [2], until about 1920, the predominant tradition in science was sole authorship. The dominant situation until 1973 in industrial electronics was also sole authorship, as this manuscript shows. However, there is a general trend in multiple authorship [3] that is also occurring in the industrial electronics domain. Modern research is becoming very specialized in many disciplines and demands several skills and competencies in methodologies, analysis capabilities, computer tools, statistics, and mathematics, as well as intense knowledge of a field. It is very difficult for a single researcher to master all these issues alone and

consequently most research work is currently developed by teams. Articles in some fields already exhibit a very large number of authors. For example, the articles [4] and [5] are co-authored by 2,926 and 972 authors, respectively.

As widely accepted, papers presented at conferences can lead to the creation of journal articles [6]. Some studies are available allowing partial analysis of the technical and publication activities of the Institute of Electrical and Electronics Engineering (IEEE), as in [7], where IEEE is identified as the most influential academic publisher in engineering. The analysis was conducted based on a database of periodicals and conference proceedings published by the IEEE between 1980 and 2008, comprising approximately 0.36 million periodical articles and 1.14 million conference articles. However, to the best of our knowledge, there are no other studies analyzing publications trends in industrial electronics.

It is also arguable that tertiary education, namely publications produced by Ph.D. students (as well as by M.Sc. students in a small degree), is a major source of contributions for authorship. In this sense, analyzing the evolution and trends for publications in a specific area gives firm indications about the evolution and trends associated with Ph.D. and M.Sc. students publication production in that area.

This study examines trends in authorship, especially those related to the number of authors and the number of pages of scientific articles in the Industrial Electronics Society (IEEE-IES). We collected and processed 34,409 entries from 11 conferences and 3 journals, for the period 1963–2012.

The rest of the paper is organized as follows: Section II presents the method that we have used to collect and analyze data. Section III describes our findings, providing individual analysis for the 50-year publication period of the IEEE Transactions on Industrial Electronics (TIE), as well as for the last 25 years of IEEE-IES publications for a group of selected journals and conferences. Section IV presents the conclusions, proposing possible changes in the authorship credit system.

II. METHOD

This study includes articles published in conferences and journals, since both types are prestigious in the IEEE-IES.

We have decided to use publications available in the IEEE-Xplore digital library, since it provides a wide coverage of the bibliographic information of IEEE-IES journals and proceedings of conferences, symposia, and workshops. Although some automatic means to download the data exist, e.g. [8], we obtained the data for the study on October 11, 2013, by manually searching and downloading the entries related to IEEE-IES. The complete list of journals and proceedings is listed in the appendix. As IEEE-IES has been sponsoring a large number of events, only those series of events where IES is the sole financial sponsor (other than local organizers) were considered. We hereafter designate this collection of bibliographic entries as IES-Xplore.

38,965 bibliographic entries, published from 1963 until 2012, in the IEEE-IES publications were downloaded. All the entries were automatically processed and analyzed with a software program (written in Ruby¹) and the ones that were not related to scientific articles were withdrawn. This set includes entries with no authors (e.g., lists of reviewers and program committees), editions of proceedings, editorials, prefaces, acknowledgments, messages from the editors, forewords, special issue introductions, introductions to in honor/in memoriam issues, tributes, obituaries, errata, corrigenda, book reviews, comments to articles, and their replies. We decided also to ignore the entries that have less than 4 pages. In this group, we typically can find editorials, invited papers, posters, tool papers, workshop summaries, and similar short contributions that are not regular scientific articles. Despite our efforts to make a comprehensive evaluation of the processed information, it is possible that some entries were not correctly filtered, due to different designations or spellings; we believe that these situations are relatively small and should not affect the overall results in a significant measure. A total of 4,556 entries have been rejected, representing around 11.7% of the original sample. So, IES-Xplore contains 34,409 entries related to industrial electronics articles.

In total, 6,252 journal articles (18.2%) and 28,157 conference articles (81.8%) were processed, whose annual distribution is depicted in Figure 1. All the articles until 1987 were published only in one journal (TIE). This situation gives a relatively low number of published articles, with a maximum of 85 in 1975. There is a significant growth in the number of published articles, especially in the period of 2003–2006, in accordance with the conclusions presented by Larsen and von Ins [9] and Fernandes [10]. In total, the study includes 14 venues: 3 journals and 11 conferences. The complete list of journals and conferences is listed in the appendix.

Table I shows the number of articles that exist with a given number of authors. It illustrates that there are 10,000+ 3-author articles and almost 10,000 2-author articles. In total, the big majority of the articles have up to 5 authors, since articles with 6+ authors represent a small fraction of the total.

¹<https://www.ruby-lang.org/en>

III. RESULTS AND DISCUSSION

In this section, we provide results for two different scenarios. The first one, described in subsection A, analyses the publications in TIE for a 50-year period (1963–2012). The second scenario, presented in subsection B, is related to the publications for all IEEE-IES, either in journals or conferences, for a 25-year period (1988–2012).

A. Results for TIE; 50 years (1963–2012)

TIE, being the flagship journal of the IEEE-IES for more than fifty years, is the major long-term repository of papers generated within IEEE-IES. According to IES-Xplore, TIE was launched in 1963 (under the title IEEE Transactions on Industrial Electronics and Control Instrumentation between 1963 and 1981) and has been adequately reflecting the evolution of IEEE-IES itself. In total, 5,768 articles were published in TIE in the 1963–2012 period.

After a period with irregular publication schedule between 1963 and 1970, where the number of issues per year varies from 1 to 6, TIE had a long period from 1971 to 1989 where four issues have been published per year. Between 1990 and 2007, the number of issues was increased to six per year, and sustainably moved to twelve issues per year from 2008 onwards.

Figure 2 shows the evolution of the number of articles published per year, where one may identify several plateaus. Roughly, one may associate the period from 1963 to 1972 as an establishment period with a low number of published articles. The first plateau, roughly associated with the period between 1973 and 1997, has the number of published articles below 100 each year. The second plateau, associated with a number of published articles in the range between 100 and 200 articles per year, comprises the period from 1998 to 2006, followed by a big increase in 2007, corresponding to more than 300 articles. Finally, in the third and current plateau, including years from 2008 onwards, the number of published articles in each year is higher than 400. While the figures in the last plateau are directly correlated with the number of published issues per year, the period from 1990 to 2007, where TIE published six issues per year, has contributed to the first and the second plateaus.

A characteristic that has been evolving along these five decades is related with the number of authors per article. As can be concluded from Table I and Figure 3(a), the most common number of authors per TIE article is two, which in conjunction with the 3-author articles represent almost 60% of the total. In particular, approximately one third of the TIE articles have 2 authors. If we consider articles up to 5 authors, the percentage is bigger than 95%. Articles with 8 or more authors represent less than 1%.

Figure 4 shows for different 5-year periods, the percentages of articles published in TIE (1963–2012) for different number of authors (1, 2, 3, 4, 5, 6, and 7+). We can say that the percentages of 1-author articles are regularly decreasing. The percentages of 2- and 3-author articles, after an initial

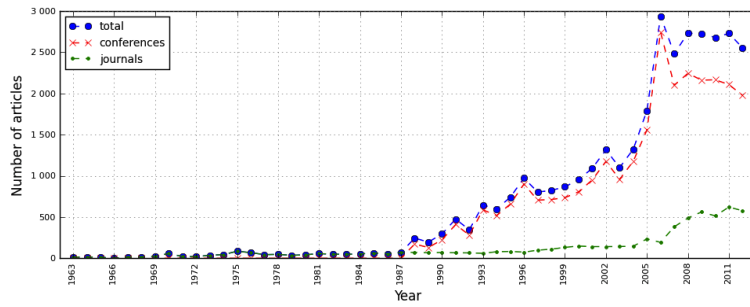


Figure 1. Number of articles published in IES-Xplore publications (1963–2012), per year.

Table I

PERCENTAGES OF ARTICLES FOR DIFFERENT NUMBER OF AUTHORS IN IES-XPLORE (1963–2012), TIE FOR DIFFERENT NUMBER OF AUTHORS (1963–2012), AND IES-XPLORE (1988-2012). THE COLUMNS ARE NUMBER OF AUTHORS (#AUTH); NUMBER OF ARTICLES CONSIDERED IN THIS STUDY FOR EACH NUMBER OF AUTHORS (#ARTIC); PERCENTAGE OF THE ARTICLES FOR EACH NUMBER OF AUTHORS WITH RESPECT TO THE TOTAL NUMBER ARTICLES (%); AND THE CUMULATIVE PERCENTAGE OF THE ARTICLES, I.E., THE PERCENTAGE OF THE ARTICLES WITH AT MOST THE NUMBER OF AUTHORS IN THAT ROW (CUM%).

#auth	IES-Xplore 1963–2012			TIE 1963–2012			IES-Xplore 1988–2012		
	#artic	%	cum%	#artic	%	cum%	#artic	%	cum%
1	2 706	7.9	7.9	632	10.9	10.9	2 364	7.1	7.1
2	9 294	27.0	34.9	1 819	31.6	42.5	8 901	26.6	33.7
3	10 240	29.8	64.7	1 592	27.6	70.1	10 053	30.1	63.8
4	6 903	20.1	84.8	1 000	17.3	87.4	6 857	20.5	84.3
5	3 152	9.2	94.0	473	8.2	95.6	3 138	9.4	93.7
6	1 322	3.8	97.8	169	2.9	98.5	1 320	3.9	97.6
7+	792	2.2	100.0	83	1.5	100.0	789	2.4	100.0
TOTAL	34 409	100		5 768	100		33 422	100	

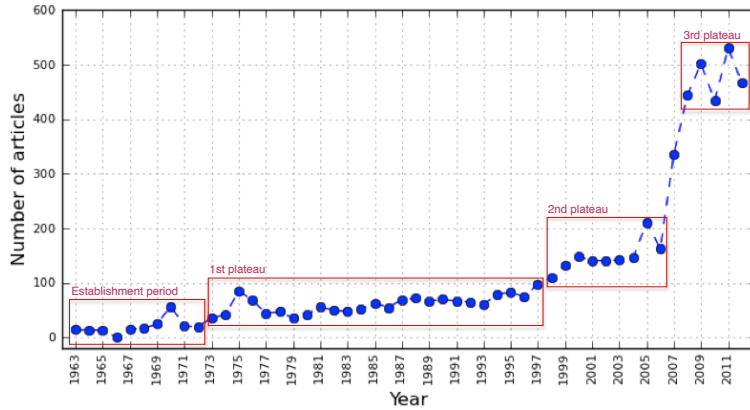


Figure 2. Evolution of the number of articles published per year in TIE (1963–2012).

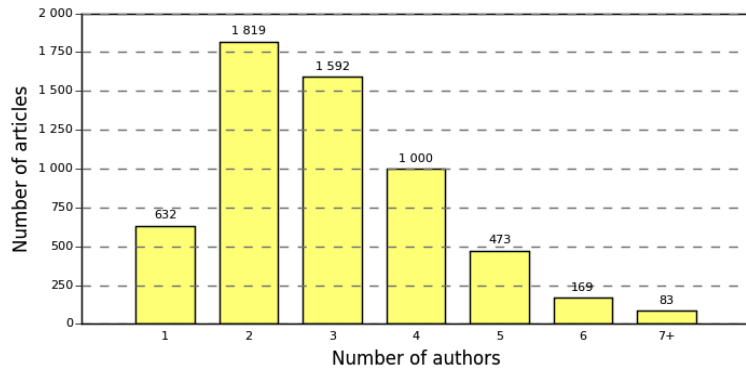
growth, are also diminishing in the last years. Contrarily, the percentages for 4+-author articles are (still) increasing.

We have also calculated the average number of authors for articles in TIE, in a yearly basis. For instance in 1963, there are 11 1-author articles, two 2-author articles, and one 3-author article. This corresponds to an average of 1.29 authors per article in 1963. In 2012, the value is 3.42. Figure 5(top) shows the results for this metric, which grows very smoothly along the timeline. Based on the Ordinary Least Squares method, we can say that from 1963 until 2012, there is an average growth of +0.42 authors in every decade, as given by the linear approximation depicted in Figure 5(top). Stated in a different way, we can say that on average, every 23.8 years all articles get an additional author. These results are in line with previous studies authored by the first author for computer science [10]

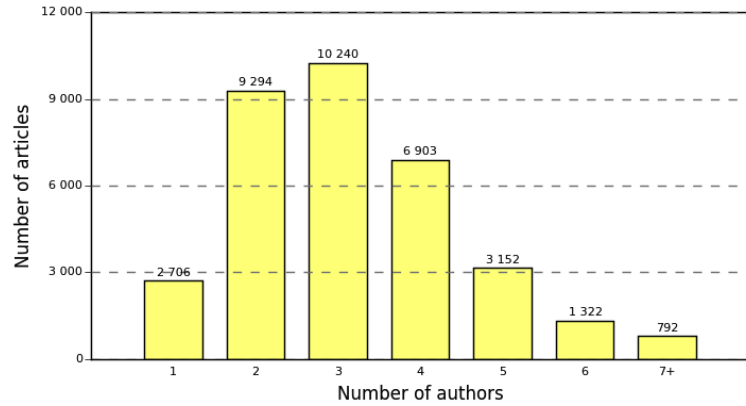
and software engineering [11].

We also observe, from Figure 5(bottom), that the maximum number of authors, per year, tends to grow, although the tendency is a bit erratic. From 1996, this value is constantly greater than or equal to 6. The article written by Garcia et al. [12] lists 12 co-authors, which is the maximum for TIE.

A different aspect where a consistent growth can be observed is associated with the average number of pages per article. Figure 6(top) clearly presents a growth during the 50-year period, where the average number of pages almost doubled. Based on the Ordinary Least Squares method, we can identify an average growth of +0.87 pages per decade, from 1963 until 2012. For the maximum average number of paper per article per year, Figure 6(bottom) shows that it is roughly twice the average number of paper for the respective



(a)



(b)

Figure 3. Number of articles for different number (1, 2, 3, 4, 5, 6 and 7+) of authors published in (a) TIE (1963–2012) and (b) IES-Xplore (1988–2012).

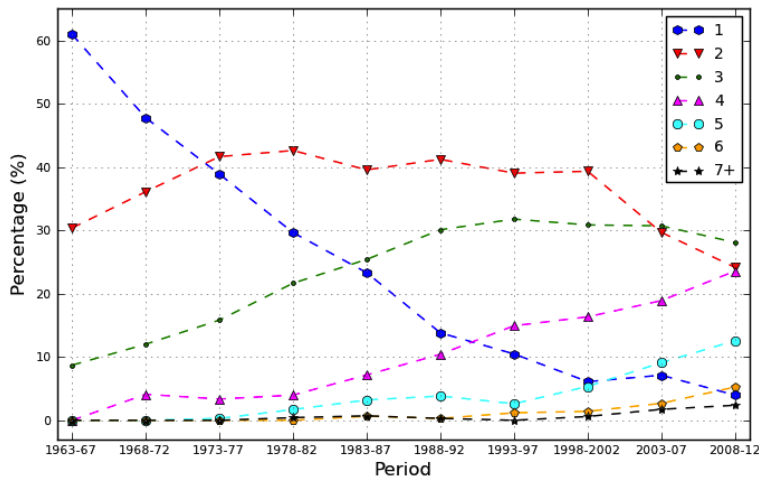


Figure 4. Percentages of articles published in TIE (1963–2012) for different number of authors (1, 2, 3, 4, 5, 6 and 7+) per five-year periods.

year (with an exception for 1983).

Table II presents the number of articles in the Industrial Electronics Magazine (IEMag) and both IES journals, Transactions on Industrial Electronics (TIE) and Transactions on Industrial Informatics (TII), for the period 2005–2012. TIE has, by far, the largest number of articles, 467 in 2012, compared to 92 for TII and 18 for IEMag in the same year. From its start, TII exhibits a relatively steady increase except

for a stagnation between 2006 and 2008 (30, 29, and 28). Since its origin, in 2007, IEMag has published, in each year, a very similar number of papers, always between 16 and 21. Finally, after a sharp increase, from 2006 to 2008, the number of published articles in TIE has oscillated around 500, more precisely between 434 and 531.

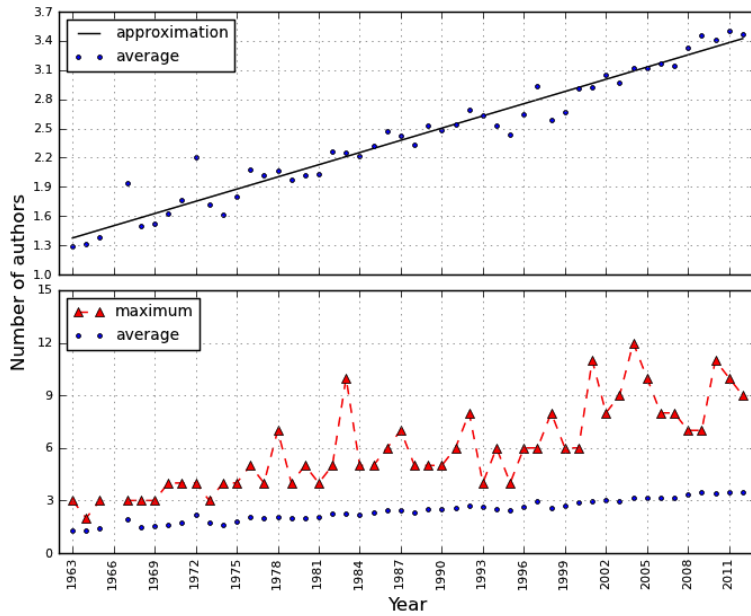


Figure 5. (top) Average number of authors for articles published in TIE (1963–2012), per year. The blue dots show the actual values calculated for each year, while the black line shows the linear approximation for the trend, which provides a growth of +0.42 authors/decade. (bottom) Average and maximum number of authors for articles published in TIE (1963–2012), per year.

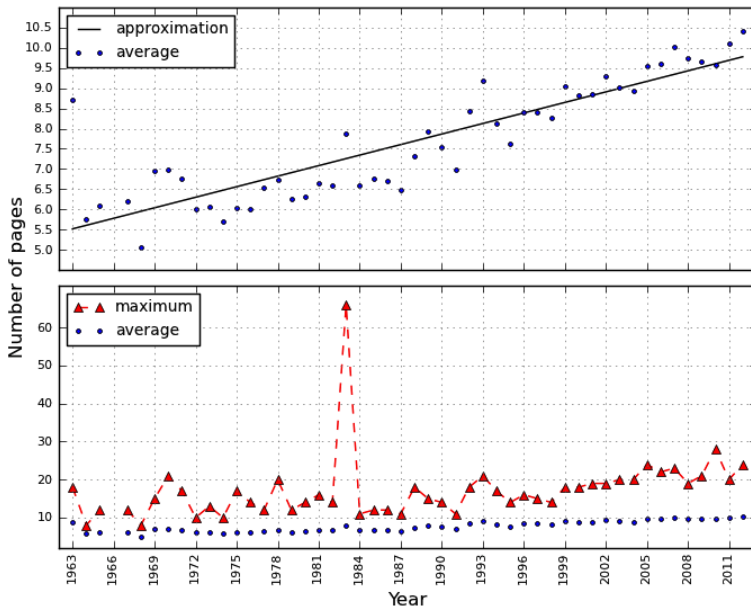


Figure 6. Average and maximum number of pages for articles published in TIE (1963–2012), per year.

Table II
NUMBER OF ARTICLES IN IEMag, TII, TIE (2005–2012).

	2005	2006	2007	2008	2009	2010	2011	2012
IEMag	0	0	17	16	21	17	19	18
TII	24	30	29	28	39	63	71	92
TIE	211	163	336	444	502	434	531	467

B. Results for IES-Xplore; 25 years (1988–2012)

We have analyzed IES-Xplore (which includes 14 IEEE-IES publication venues) for a 25-year period, from 1988 until 2012.

According to Kaynak [13], the first IEEE-IES annual conference was held in 1975, with the acronym IECI'75. This was later on considered as the first edition of IECON, the annual conference of the IEEE-IES. Unfortunately, the articles published within the IEEE-IES annual conference are available

in digital form (at the IEEEExplore repository) only for the year 1988 onwards. Therefore, this manuscript considers only papers from 1998 until 2012. Figure 7 shows the number of published articles, both in conferences and journals. Overall, the number of published articles is increasing along the years, but the period 2003–2006 witnessed a tremendous growth from 1,100 articles (in 2003) to 2,938 (in 2006). The launch of conferences opened more publishing opportunities to the members of the IEEE-IES community, allowing more scholarly material to become available. In total, 33,422 articles were published in IEEE-IES in the 1988–2012 period.

Table I and Figure 3(b) shows the number of articles published in IES-Xplore (1988–2012) for different number of authors. IES-Xplore articles with from 2 to 4 authors dominate the scene, representing 77.2%. Articles with 7+ authors represent less than 2.5% (789/33,422) of the total.

We have calculated the average number of authors for articles in IES-Xplore (1988–2012), in a yearly basis. Figure 8(top) shows the results for this indicator, which generically grows very smoothly along the timeline. The values vary from 2.51 for 1988 to 3.49 in 2012. Based again on the Ordinary Least Squares method, we conclude that from 1988 until 2012, there is an average growth of +0.375 authors in every decade, as given by the linear approximation depicted in Figure 8(top). Thus, on average, all articles get an additional author every 26.7 years.

We also observe, from Figure 8(bottom), that the maximum number of authors, in each year, tends to grow, although the tendency is a bit erratic. From 1998, this value is constantly greater than or equal to 10. The 27-author article written by Silvano et al. [14] is the one with the biggest number of co-authors.

IV. RELATED WORK

The present paper is focused on publications in a specific subfield: the Industrial Electronics Society of the IEEE. Hence, it provides concrete and objective information about trends in that area. To the best of our knowledge there is no similar study of this kind. Yet, there are numerous bibliometric studies based on varied publications domains. Here, we present some articles that provide additional and complementary information about authors and article dimensions.

Canavero et al. [15] compare several IEEE journals regarding impact and diffusion, as well as the academic reputation of journal authors. To that end, the article presents and discusses the relative merit of different metrics. Its main limitation, as pointed out by the authors, is the reliance on citations as a good indicator of the impact of an article.

Franceschini and Maisano [16] complement the work by Canavero et al. [15] by investigating the different citation cultures of the same journals, depending on the sub-field/specialty of interest.

Shirakawa et al. [7] analyze the journal, magazine, and conference proceedings published by the IEEE between 1980 and 2008, namely the transitions in technical innovations from two perspectives: trends within (1) individual countries and (2)

specialized fields represented in IEEE societies. The article presents several results, but no data regarding trends on the number of authors or pages per article. Hence, the present paper provides complementary data.

The article by Barry et al. [17] presents an in-depth study about a single publication, the “Journal of Professional Issues in Engineering Education and Practice”, more specifically about its content and authorship along the previous sixty years. The authors’ objective was to identify the changes in the journal, namely publication rates, citation rates, article subject area trends, keyword usage, author affiliations, impact factor rankings, international collaborations, and scholarship standards. Interestingly, the article does not present results for trends about the number of authors or the number of pages per article.

V. CONCLUSIONS

This manuscript shows that the number of authors of scientific articles in the industrial electronics domain is increasing. This situation is not unexpected, since similar observations exist in other domains [10], [18]–[20]. From a situation in industrial electronics, where 1-author articles were more than 50% of the total, 2-, 3- and 4-author articles dominate nowadays, representing around 80%.

Since the average number of authors of scientific articles is rising, the system of authorship is consequently becoming increasingly inaccurate, in the sense that it becomes more difficult to credit each author for the specific contribution to each article. Therefore, the community should establish an agreed publishing standard to define how to assign the academic contribution to all collaborators of a research project, as proposed by Solomon [21]. We may also follow the suggestions made by Marcos et al. [22], which proposes articles to be explicit about the role/contribution of each involved person.

The increasing number of authors can, somehow benevolently, be seen as a result of extended collaboration, yet many unacceptable and inappropriate forms of authorship do exist: honorary, gift, guest, ghost, and coercive [23]. These authorship forms together with the increasing number of authors are making the notion of author become unreliable as a credit system and thus useless. An author is someone who has made substantive intellectual contributions to a study and is responsible for a component of the work [24]. The scientific community needs the more realistic notion of contributor [25]. The observed growth in the number of authors will imply in the near future new metrics for the productivity of both researchers and institutions, as they tend to work more in cooperation. For instance, some recent proposals suggest new forms of assigning citations to co-authors [26]–[28].

The following are possible causes for the identified increase in the number of authors per paper:

- Additional collaboration at the individual and institutional level;
- The individual evaluations of researchers and institutions that increasingly promotes a “publish or perish” approach;

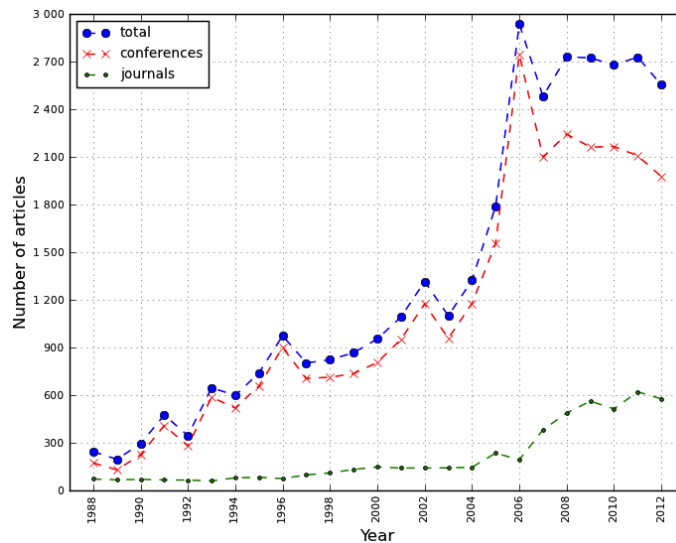


Figure 7. Number of articles published in IES-Xplore (1988–2012), per year, for conferences and journals.

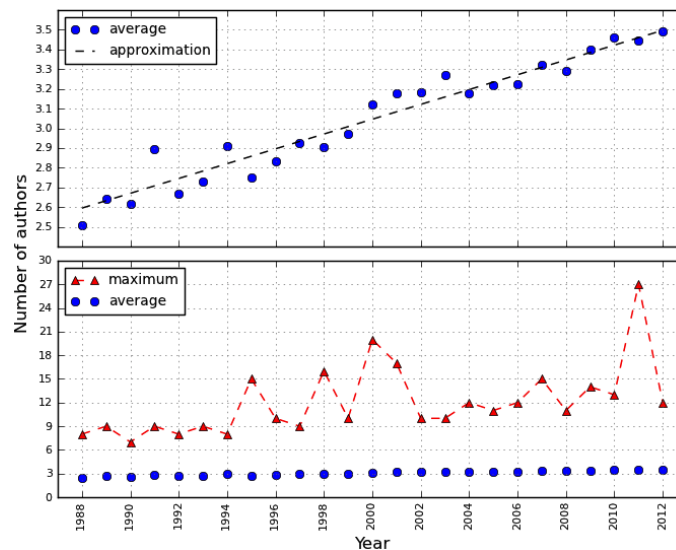


Figure 8. (top) Average number of authors for articles published in IES-Xplore (1988–2012), per year. The blue dots show the actual values calculated for each year, while the dashed black line shows the linear approximation for the trend, which provides a growth of +0.375 authors/decade. (bottom) Average and maximum number of authors for articles published in IES-Xplore (1988–2012), per year.

- The increasing number of young researchers (namely M.Sc. and Ph.D. students) contributing as co-authors.

In our opinion, the research community needs to be aware of the trends and changes in academic authorship. Articles about authorship in industrial electronics are not common; this manuscript is an attempt to provide a comprehensive analysis on IEEE-IES publications over a 50-year period, from 1963 to 2012.

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APPENDIX

List of Journals including the inaugural year: IEEE Transactions on Industrial Electronics (TIE): 1963, IEEE Transactions on Industrial Informatics (TII): 2005, Industrial Electronics Magazine (IEMag): 2007.

List of Conferences including the inaugural year: International Workshop on Advanced Motion Control (AMC): 1993, IEEE International Conference on Digital Ecosystems and Technologies (DEST): 2007, International Conference on Emerging Technologies and Factory Automation (ETFA): 1992, International Conference on Industrial Technology (ICIT): 1996, IEEE International Conference on Mechatronics (ICMECH): 2004, Annual Conference of the

IEEE Industrial Electronics Society (IECON): 1988, IEEE International Conference on Industrial Informatics (INDIN): 2003, IEEE International Symposium on Industrial Electronics (ISIE): 1992, International Conference on Power Engineering, Energy, and Electrical Drives (POWERENG): 2007, IEEE International Symposium on Industrial Embedded Systems (SIES): 2006, IEEE International Workshop on Factory Communication Systems (WFCS): 1995.

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