The role of gender in the International Conference on Pervasive Computing and Communications

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The International Conference on Pervasive Computing and Communications (IEEE PerCom) is a CORE 2021 A* conference (top 7% of ranked venues) that aims to present scientific advances in a broad spectrum of technologies and topics in ubiquitous/pervasive computing, including wireless networking, mobile and distributed computing, sensor systems, ambient intelligence, and smart devices. During the last couple of years, the PerCom organization committee has successfully included many prestigious female researchers to submit, participate, and organize the conference. However, there is still work to do and to help the progress, this article analyses the history of the conference from a gender perspective. This article goes through accepted articles of the last 20 years of the PerCom conferences, showing that even if the role of female authors, in general, has increased, more first and leading female researchers should still be welcomed in the community. Through this analysis, this article aims to highlight the role of gender in the conference program and seeks to find trends and possible improvements to achieve a broader gender balance in pervasive computing.

KEYWORDS

pervasive computing, ubiquitous computing, mobile computing, gender, women

1. Introduction

It is estimated that the partition of the female researchers in computer science is approximately between 15 and 30% (Frachtenberg and Kaner, 2022), which is in one of the worst ratios even among the other STEM fields (Holman et al., 2018; Wang et al., 2021). Some recent bibliographic studies end up even slower numbers, giving only 10% on average for female authorship (Mattauch et al., 2020; Frachtenberg and Kaner, 2021). However, most studies suggest that there is an increasing trend in female participation and authorship over years—even if it is growing slowly. For example, among the prestigious ACM conferences between 1967 and 2007, 10–44% of authors were female with an increasing trend (Cohoon et al., 2011). However, variation between the sub-fields in computer science has been reported to be still considerable. Female authors have been seen as more active in the stereotypical "soft" side of the field, including human-computer interaction, management, design, and other areas involving

human factors. Men, on the other hand, dominate stereotypical "hard" sub-fields of algorithms, reliability, and performance (Cohoon et al., 2011).

Interestingly, pervasive and ubiquitous computing are fields that combine certain sides of both "soft" and "hard" computer sciences. Wherever there are traditionally appreciated large-scale field studies involving real users, there is also a strong consensus on performing measurable data analytics, applying the latest algorithmic inventions, and bringing together various sub-fields inside computer science. There are two key conferences (among various other venues, journals, and workshops) that can be immediately named in the field of pervasive and ubiquitous computing: the International Conference on Pervasive Computing and Communications (IEEE PerCom) and the ACM International Joint Conference on Pervasive and Ubiquitous Computing (ACM UbiComp). Together, they represent also the two key publisher-community organizations in computer science. Both have also immersive history, UbiComp running from 1999 and PerCom since 2003. Both conferences have a strong commitment to their respective and host organizations' equality, diversity, and code of conduct statements. They are also well-established in their practices for aiming to increase female participation, including inviting diverse technical program and organization committees, involving prestigious female keynote speakers, and hosting the N2Women (Networking Networking Women[1]) networking event yearly.

Considering this history, it is indeed of substantial importance to find numerical evidence for the success of these efforts to develop female participation in pervasive and ubiquitous computing. For some reason, ACM UbiComp was not considered in a study by Cohoon et al. (2011) that highlighted female participation in some other major ACM conferences 10 years ago. In a more recent study in Bonifati et al. (2022) focus on female presentation in database community. They are able to conclude with very similar results to Cohoon et al. 10 years ago: the presentation of female authors is slowly increasing, but women are still an underrepresented group in computer science. Similarly, there is variation between conferences, again female researchers are more prominent in human factor-related areas than strictly technical fields.

This article focuses on finding the trends in female authorship in pervasive and ubiquitous computing. For simplicity of the research work, the focus is given only to the IEEE PerCom community, where the author is an active member. However, in the future, a comparison between these two conferences would indeed provide additional insights. The research questions and/or hypotheses this article focuses on are:

1. If and how much female researchers are underrepresented in the IEEE PerCom community?
2. Can we see any prominent trends in female authorship inside the community when analyzing female first authors and leading authors, or female authors in general?
3. Can we identify if there are an underlying stereotypical distribution of research topics inside the community, as reported in the previous work from other computer science fields? i.e., female researchers focusing on more human factors than corresponding male researchers?

2. Materials and methods

2.1. Dataset

The data consists of all accepted articles of the International Conference on Pervasive Computing and Communications (IEEE PerCom), from its beginning in 2003 to 2022 when the conference celebrated its twentieth anniversary. For limiting the dataset, only accepted main track (full and concise) articles were considered. The conference also includes yearly various workshops, demonstrations, Ph.D. forum posters, and work-in-progress papers, which were not included for the sake of the number of articles. The limitation was also motivated by the fact that the PerCom main track is the most competed part of the conference, where only 15–20% submitted articles are accepted yearly.

The dataset includes publicly available information about the accepted articles, including the title of the article, the full names of the authors, and the year of the conference where the work was presented. The data sources used to collect this information were the IEEE Explore database[2] and the PerCom websites[3] from the years accepted article information is available. All the PerCom conferences have their proceedings in the IEEE Explore database. Requesting the title and author information does not require an IEEE subscription or membership. The data were fetched from these sources by hand. In total, the data entries consist of 610 items.

2.2. Delivering the gender

In this article, the gender of each author is delivered by following the next procedure. If the name is a traditional (usually western) female name, the author is considered female. If the name is such that can be used for any gender, does not associate with a specific gender, or is rare enough to be unsure, the person behind the name is found out *via* Google Search. In most cases, researchers have a website, either personal or

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1 https://n2women.comsoc.org/

2 https://ieeexplore.ieee.org/Xplore/home.jsp

3 https://www.percom.org/

institutional, with a biography that specifies also the English pronouns they are using. If the pronoun is "she," the author is considered female. There were no cases met where the author would have preferred a neutral pronoun "they" or equivalent, so the situation of these authors did not need to be solved (if so, compounding non-binary authors with female authors would have to be considered). In rare cases, the pronouns could not be found (for example, the author has no website for some reason or other) whenever the name was considered female or male based on the online name finder[4] and if not found, a general Google search -based consensus.

Any type of method of delivering the gender of the authors does not come without limitations. This work of finding the authors' genders was all done manually by hand, so it is prone to human error. However, even the automated methods of inferring names include biases (Karimi et al., 2016). Identification of the international names that are not gender-specific is prone to incorrect categorization and pronouns used publicly for professional websites may not reflect the true identity of the gender, being a more complex phenomenon than a simple two-class category.

2.3. Authorship definitions

This work considers three categories of authorship: if there is a female author at all, if the first/main author is a female, and if the last/leading author is a female. This diversion is already used in some previous studies (Bonifati et al., 2022). First, overall authorship, i.e., if there is at least one female in the group of authors for the given article. These articles are considered in the *total* number of articles with female authors, subsequently in this work. Please note that even if there is more than one female author, the article is counted only once.

Second, the *first author* is simply defined as the first name of the author list provided. In the PerCom community, there is a tradition that the first author contributed most significantly, holds the correspondence, and usually also presents the work at the conference. Third, the *lead author* is considered the last author of the article. In the PerCom tradition, this place is usually reserved for the group leader, professor, or the person who takes the most senior position in the work and has the highest responsibilities for the presented results. All-female authored articles (single or several authors) were almost non-existing, thus they are not considered as a single group.

2.4. Ethical considerations

The data utilized in this work is collected from publicly available databases, such as IEEE Explore and conference

websites, and the author's personal/institutional websites. There is no information that would not have been publicly available, and for sake of combining such information in this work, no individual authors, their gender, or affiliation, are discussed or revealed. The IEEE PerCom steering committee has been made aware of the ongoing study, but it has not influenced the data collection, methodology, or results. The data management and processing pipelines are subject to the University of Oulu Internal Ethical Board, and follow the ethical guidelines of the Finnish National Board on Research Integrity (TENK).
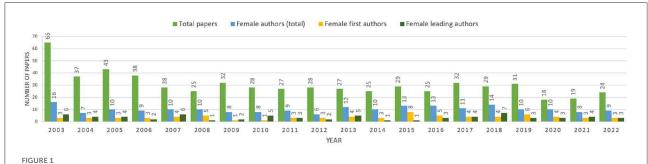
3. Results

3.1. Gender in accepted articles

Out of 610 accepted articles during 20 years of PerCom, 203 had at least one female author (33%). This number alone bases it in the high end of the reported 10–44% of computer science conferences in Cohoon et al. (2011). In comparison to newer studies, average in computer systems was reported to be only around 10% in Frachtenberg and Kaner (2022) and 30–70% in database research reported in late 2021 (Bonifati et al., 2022). The distribution of the number of the PerCom articles over the years is illustrated in Figure 1.
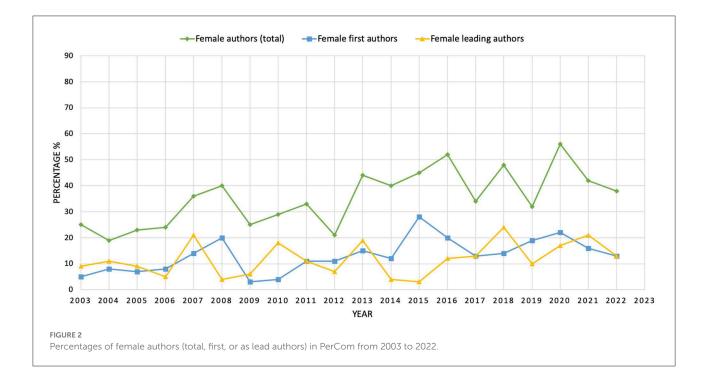
PerCom gained its highest female presentation, 56% in 2020, just before the COVID-19 pandemic (the articles for the next year's conference are submitted around September the previous year, i.e., those accepted for the 2020 conference were ready for evaluation in September 2019). In 2021, the number of accepted articles with female authors was 42% and in 2022 only 38%. Even if the COVID-19 pandemic has reportedly affected negatively, especially to the careers of the female researchers (Inno et al., 2020; Deryugina et al., 2021), there is, unfortunately, no quantitative or qualitative evidence in the data that this was the case with the PerCom conference specifically.

The distribution of the articles with female first and lead authors can also be seen in Figure 1. Please note that the amount of any female author always includes both cases of first or lead female author, thus being higher by definition. Out of 610 articles total, 73 had a female first author (11.9%) and 69 had a female lead author (11.3%). In comparison to the database field where the numbers have been reported similarly (Bonifati et al., 2022), the average for female first authors varies between 12 and 25% and female lead authors between 15 and 25%. It is noteworthy that even if the number of overall female-authored articles is higher in PerCom than in some other conferences (e.g., in systems research) and equal to, for example, the database field, the number of first and lead female authors is hindering behind significantly.

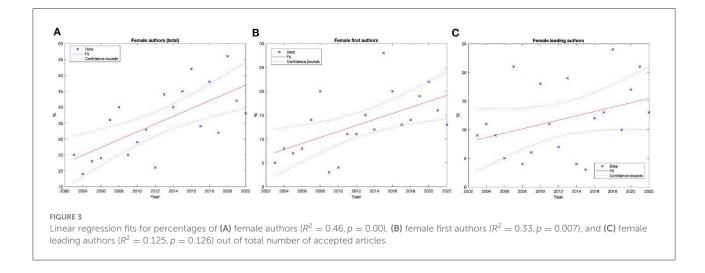---

4 https://gendernamefinder.com/

FIGURE 1
Number of accepted articles in PerCom from 2003 to 2022, and distribution (absolute numbers) of female-authored articles, female first authors, and female lead authors.

FIGURE 2
Percentages of female authors (total, first, or as lead authors) in PerCom from 2003 to 2022.

3.2. Gender trends in authorship

By hypothesis, it is expected that when awareness of gender equality and more equal opportunities arise, also the number of female researchers should increase over time somewhat linearly. Some long-term studies have already supported such a hypothesis (Cohoon et al., 2011) even if the speed of the development seems to be, indeed, slower than one would expect. To analyze the authorship trends in the PerCom conference, the absolute numbers of female authors are converted into percentages of all accepted articles of the corresponding year. Please note that PerCom has no hard limit on how many articles should be accepted yearly, and the number has varied drastically from the beginning of the conference, from approximately 40 articles to the current 20 articles per year.

The percentages of female authors (total, first, or as lead authors) in PerCom from 2003 to 2022 are shown in Figure 2. An overall glance at the trends as well as the removal of the seasonal variation (i.e., removing the polynomial trend from the data series of the total female authors) supports the hypothesis of a possible linear trend. Thus, the data series can be fitted with the linear regression model ($y \sim 1 + x1$). Figure 3 shows the results of the regression analysis, for each category (all female authors, female first authors, and female lead authors), correspondingly.

Figure 3A shows that the female authorship in general is in upward trend—steady, but not fast, with statistical significance ($R^2 = 0.46, p = 0.00$). The trend of female first authors is also increasing but less steadily ($R^2 = 0.33, p = 0.007$, see Figure 3B) than the female authors in general. However, the role of leading female authors has not significantly changed from the past 20 years ($R^2 = 0.125, p = 0.126$) as seen in Figure 3C. Even if more

FIGURE 3
Linear regression fits for percentages of **(A)** female authors ($R^2 = 0.46$, $p = 0.00$), **(B)** female first authors ($R^2 = 0.33$, $p = 0.007$), and **(C)** female leading authors ($R^2 = 0.125$, $p = 0.126$) out of total number of accepted articles.

female authors have been attracted to the PerCom community, they take the role of "junior" positions either as first authors or somewhere in the middle of the author list. However, it is noteworthy that there are several "mid-term" female professors in the field, which may lead to a situation where the first name is reserved for a more mature male professor even if the "second last" position included tasks of a leading author. These cases are not analyzed in this article, simply because either the PerCom articles or IEEE database list the roles or responsibilities of the authors.

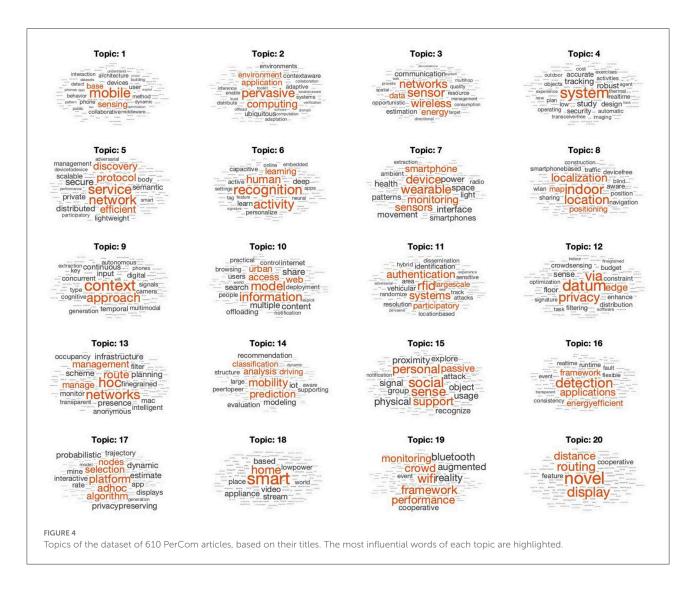## 3.3. Gender and research topics

Computer science and other STEM fields are not free of gender stereotypes (Thébaud and Charles, 2018). These include traditional stereotypes like "men are strong and competent" and "women are softer and more human-oriented." Luckily, there are already arguments that the stereotype of men being more intelligent than women has already started to vanish (Eagly, 2018). Even if different personalities and skill sets are required in computer science, it can be harmful to analytical women and more emotional men to be subject to such stereotypes during hiring processes (Thébaud and Charles, 2018), when choosing a graduate or postgraduate program (Ertl et al., 2017), and other occurrences also in research. The stereotypes have been linked to the shortage of women in the technical and other STEM fields, mainly through students' and kids' tendency of choosing other fields over STEM under the biased image of the field (Piatek-Jimenez et al., 2018).

The stereotypes in the research field of computer science can be, on a general level, summarized as the tendency of women to focus on areas involving human-factors whereas male researchers are seen to success in more technical topics (Cohoon et al., 2011). To analyze this in the context of the

PerCom conference, we take a look at the titles of the published articles. The hypothesis that can be considered here is that the titles should be possible to organize into groups through topic modeling. These groups, when later analyzed with authors' gender information, should show if certain research topics are, indeed, more prominent among the female researchers than their male counterparts.

The topic modeling algorithm chosen is a commonly known Dirichlet allocation (LDA). The pipeline of the LDA analysis is to choose the representative words among the article titles and then associate the words with characterizing topics. As a result, an approximation is given that how important each topic is for a certain title. The preprocessing of the article titles involves a standard procedure of lowering all the cases and then removing any punctuation (including colons and hyphens), words <2 characters, and so-called stop-words (including prepositions and conjunctions). For the LDA hyper-parameter training (i.e., how many topics should be expected), goodness-of-fit is calculated by the perplexity of a held-out set of items i.e., the article titles. The hyper-parameter training finishes (i.e., ends with the lowest perplexity) with approximately 20 topics being an optimal number for this dataset.

The results of the LDA model fit are given in Figure 4, where each topic is visualized as a word cloud. The highlighted words are those of the highest probability in each topic, and the size of the words corresponds to their probability, too. For reference, the PerCom conferences' predefined topics or themes can be found in the year call for papers[5]. The topics from the LDA model characterize well the PerCom community's interests: mobile sensing (topic 1), sensor networks (topic 3), systems (topic 4), human-activity recognition (topic 6), wearable computing (topic 7), indoor localization (topic 8),

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5 https://www.percom.org/call-for-papers/

FIGURE 4
Topics of the dataset of 610 PerCom articles, based on their titles. The most influential words of each topic are highlighted.
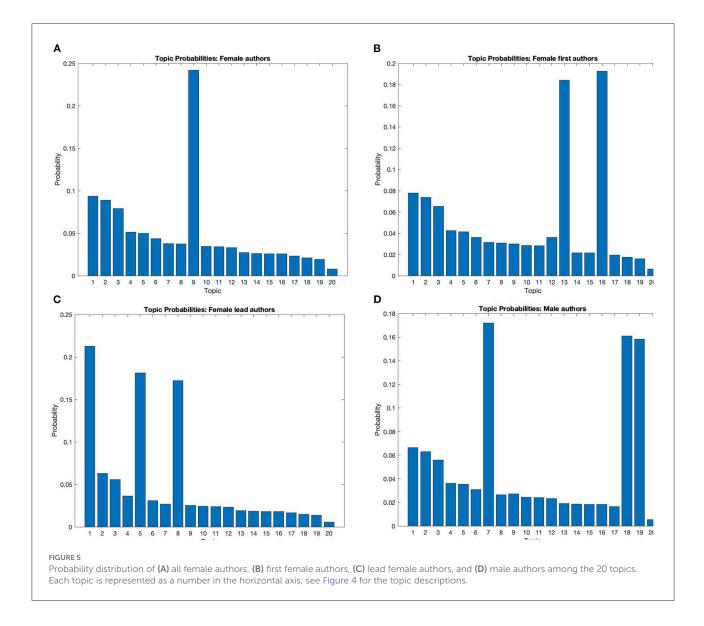
authentication and RFIDs (topic 9), *ad hoc* networks (topic 13), and smart homes (topic 18), to highlight some.

After finding the models, the next step is to associate authors' genders with the topics. This is done by separating the titles into four groups based on their authorship status: a) at least one female author, b) female first author, c) female lead author, and d) only male authors. The results are shown in Figures 5A–D, respectively. The numbers on the x-axis represent the topics given by the LDA model (see Figure 4 for reference) and the y-axis represents the probability of each topic being present in the titles of each group.

Surprisingly enough, the female authors of the PerCom conference seem NOT to follow the stereotype of focusing on research topics driven by human factors (see Figure 5A). The most "female" topic number 9 includes keywords such as "context" and "approach," followed by words such as "digital," "continuous," "multimodal," "signals," and "camera." These topics can be identified as data analytics, sensor data

processing, and in general pervasive and data-driven approaches that are usually highly technical and mathematical. For the female first authors, the most prominent topics are numbers 13 and 16 (see Figure 5B). Topic 13 can be defined by network management, routing, and *ad hoc* networks—all extensively technical keywords. Similarly, topic 16 involves keywords such as "frameworks" and "energy efficient." No human-factors present.

For female leading authors, the leading topics are numbers 1, 5, and 8 (see Figure 5C). Here highlighted are keywords including themes of mobile sensing, protocols and service discovery, and indoor localization. It is noteworthy that due to the small number of female leading authors in general, the results might be biased toward individual professors' research interests. However, they are members of the community.

To compare, the results of the male-only articles are shown in Figure 5D. Here the highlighted topics are numbers 7, 18, and 19. These topics involve keywords indicating wearable

FIGURE 5
Probability distribution of **(A)** all female authors, **(B)** first female authors, **(C)** lead female authors, and **(D)** male authors among the 20 topics. Each topic is represented as a number in the horizontal axis; see Figure 4 for the topic descriptions.

computing and smartphones, smart home, and crowd-sourcing. Especially, research on smartphones and smart homes includes user perspectives i.e., human factors, which is unlikely the stereotypical hypothesis would predict. Thus, it is indeed interesting to conclude that the stereotypical perspectives seem not to play a role in the PerCom community research topics or how to research topics are chosen in general within the community. Indeed, as a personal experience from the technical program committee meetings, the articles are discussed through their overall scientific value instead of the topics they address, as long as those topics are within the PerCom conference's interests that include user experiences and human factors. However, it is possible that because there are other prominent and high-class venues in close reach to the PerCom community (including conferences like UbiComp and CHI, and multiple journals), the most user-focused

or qualitative works do not become submitted to the PerCom conference.

4. Discussion

4.1. About the obstacles

When studying female presentation in computer science, the main question arises what could we do to improve the situation? Various activities have taken place, over the specialized networks such as N2Women and inside the conference committees themselves, especially rising awareness of the female representation in different panels, committees, and reviewer boards, as well as keynote speakers (Martin, 2014). Focusing on the systems research in computer science, Frachtenberg and Kaner (2022) studied the conference factors

and their influence on gender diversity: size of the conference, whether the double-blinded review was applied, diversity in conference organizational roles, and different diversity initiatives. However, they concluded none of these factors influenced significantly the gender ratio. Similarly, Bonifati et al. (2022) did not find an effect on double-blind review over single-blind review even if they had data where the same conference had made the change in their review process. Both works (being from 2022) however concluded, that there is a chance that some of the effects are only visible after the next decade or so, when the current Ph.D. students become leaders of their own labs, for example.

Of course, some obstacles to women's scientific careers are larger than a single conference can fix (Huang et al., 2020). These include, but are not limited to, a higher drop-out rate for various career-related reasons, and fewer resources and changes to building an effective "paper factory" as a senior researcher. Even if being a female may not affect negatively in peer-review process (Tomkins et al., 2017), female professors and senior researchers face a high load of faculty services and teaching (Misra et al., 2012; Roper, 2019) that is immediately away from the productive research time. Huang et al. (2020) conclude that the most pronounced—and also the most worrisome—gender gap is indeed between the most productive authors. Those "leading" researchers should be the role models for the next generations, too (Bettinger and Long, 2005). This is comparable to the results shown on leading authors' increase rate over year: even if there are more female authors and even more female first authors present, the number of leading female authors is barely increasing.

4.2. Concrete actions

To summarize, the PerCom conference seems to be on a positive track in attracting female authors as long as they work together with their male peers. Female-only authored articles are still consistently missing, and the role of female researchers in first and leading authorship positions is still scarce. To address this, more effort should be provided in attracting female Ph.D. researchers to submit as first authors and participate in the conference in general to find the community. Possible concrete actions include an international female junior researcher fellowship aimed to fund participation in the conference. This should complement the N2Women Fellowship that funds only a single (usually female) person to organize the actual N2Women meeting within the conference.

The data utilized in this work is limited to the accepted articles because the names and titles of the submitted but rejected articles remain confidential information. Because PerCom follows the double-blinded peer-review process, it is hard to implicitly guide toward more female-friendly peer-review progress or establish concrete actions in this area. However, it is important to address the situation of the female

professors and research leaders and how they see the PerCom community as a potential publication and discussion forum. For this, a possible concrete action would be to run a questionnaire study to gather the information that is now missing in the data: why do female authors submit or do not submit to the conference? How do they see the atmosphere at the conference? How equality is addressed in practice, and is there unknown obstacles that should be identified and addressed?

The PerCom Diversity, Equity, and Inclusion commitment listed on the website is somewhat generic[6]. It states that "PerCom is committed to providing an equitable and inclusive forum that supports these rights for all" but does not list actions on how equality and inclusive participation are guaranteed. The statement continues: "We want every participant to feel welcome at the conference. We aim to provide a safe, respectful, and harassment-free conference environment for everyone." As usual in these statements, there is an anonymous email that can be addressed if "behavior inconsistent with such principles" is met, but by personal experience, few are confident to send such an email without strong concrete evidence of a serious harassment case. Actions should be taken before the community even has to address such situations. Thus, another concrete action could be to address not only the prevention of clear harassment but also how to provide a positive environment and support equality in everyday actions regarding the community's operations, such as peer-review process, conference attendance, and even after parties. The ending of the COVID-19 pandemic and returning to the "new normal" will provide a great opportunity to address also questions of equality and inclusiveness in conference organization.

4.3. Conclusion

Female researchers are still represented in authorship of the scientific papers in the STEM field, including the IEEE PerCom conference discussed in this paper. In this paper, we have presented that there is an upward trend of female participation in the published articles of the last 20 years of PerCom. This trend is especially prominent when considering female authors in general or female first authors, i.e., young or early-career researchers. However, the trend is not equally strong with leading authors, i.e., among established professors and research leaders. In addition to the trend analysis, we studied if there are underlying stereotypical distribution of research topics inside the community, as reported in the previous work from other computer science fields. Here, we can conclude that the female researchers in the IEEE PerCom community are not focusing on more "soft" human factors than corresponding male researchers, as suggested by similar studies in other fields. Indeed, they are active in various technical topics found in pervasive computing.

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6 https://www.percom.org/percom-diversity-equity-and-inclusion-statement/

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: IEEE Explore.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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