




# An Analysis of the Authorship and Co-authorship Networks of the Brazilian Human-Computer Interaction Conference

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**Abstract:** In Brazil, the Brazilian Symposium on Human Factors in Computing Systems (IHC) gathers the scientific community of researchers interested in the field of Human-Computer Interaction since 1998, being the main Brazilian event in this sub-area of Computing. Over twenty-one editions, the IHC received works from researchers from different regions of the country who, over the years, have been building their own co-authorship relationships with the other authors of the Symposium. In this context, this paper analysed the IHC from the perspective of those who helped to consolidate this important national scientific event, as well as in the expansion of the Human-Computer Interaction area in the Brazilian scenario, that is, its researchers-authors. In total, 1,443 authors were identified and analysed in the study presented in this work, which considered 873 publications of three IHC tracks: Full Papers, Short Papers, and Innovative Ideas and Emerging Results. Issues related to the publications and to the co-authorship relationships of these authors over the years and in the different article tracks of the IHC were considered. In order to describe their research trajectories within the IHC itself, the study presents, in different scales of time, how these authors evolved in relation to their contributions over time. In addition, this paper analyses how the authors contributed with each other and originated the complex collaboration network of the IHC. For this, co-authorship networks and groups of authors who published together were explored, aiming to clarify the collaborations between these authors, as well as how they evolved until the edition of 2022. In this sense, this work seeks, with each research question, to simplify the presentation of results through different visualizations, which were planned and created to describe information that are not clearly evident when observing the IHC publications in a “disconnected” manner. The results of this study are revealed, described and analysed under different perspectives, as well as discussed in details in this paper.

**Keywords:** IHC, scientific community, HCI, bibliometric study, authors, data visualization.

## 1 Introduction

Bibliometric studies seek to understand the situation of scientific research in different contexts, for example, by analysing a specific scientific venue (e.g., Cheong and Corbitt [2009]), a specific subject of interest of a group of authors (e.g., Mora *et al.* [2017]), or even a particular area of knowledge (e.g., Koumaditis and Hussain [2017]). In this type of study, data associated with the literature are subjected to different quantitative and statistical techniques, and, as a result, it is possible to obtain characteristics that describe the situation of the investigated “entity” in different aspects and dimensions [Mukherjee *et al.*, 2022; Kraus *et al.*, 2022]. According to Donthu *et al.* [2021], the techniques applied in a bibliometric analysis may be classified into two types, i.e., performance analysis and scientific mapping.

In the case of performance analyses, metrics related to publications that seek, for example, to identify the number of authors who contributed to scientific productions, or metrics related to citations (such as those that seek to reveal the total number of citations of contributions), or even metrics related to the impact of scientific production (e.g., h-index and g-index) may be highlighted [Mukherjee *et al.*, 2022; Kraus

*et al.*, 2022]. In scientific mapping, there are analyses of co-authorship networks, which are often used to understand the cooperation between authors of publications in the scientific community, in addition to co-citation and co-word analyses [Mukherjee *et al.*, 2022; Kraus *et al.*, 2022].

In network analysis, we can highlight social networks, which are networks of people represented by vertices, connected by links that represent the relationship between them, where these relationships can have different meanings [Newman, 2018]. Social networks have been explored in different ways since the second half of the last century [Newman, 2001], and different types of social networks emerged with the evolution of research in the area, such as co-authorship networks [Newman, 2003]. The co-authorship networks are applied in scientific contexts such that, in its structure, the vertices are researchers and the links between them represent scientific collaborations, i.e., publications in which they are co-authors.

When conducting an analysis of co-authorship networks in any scientific context, it is possible to understand, for example, how knowledge is disseminated among authors [Feng and Kirkley, 2020], as well as issues related to the diversity of knowledge [Rodan and Galunic, 2004]. In these analyses, different questions can be explored, such as the size of

the largest connected component of the network [Newman, 2004b], which can clarify, for instance, whether the scientific community is strongly connected. In addition, clustering is also frequently explored in these networks [Newman, 2003], revealing groups of people that present strong connection between them, that is, groups of researchers that published together above the observed mean [Newman, 2001].

Historically, the IHC<sup>1</sup> has two main tracks in which the researchers of the field seek to publish the results of their works, i.e., Full Papers and Short Papers<sup>2</sup>. The calls for the Full Papers track (usually, limited to ten pages of content) occur since the first edition of the Symposium, in 1998. Over the years this track received different names, such as Full Technical Papers and, more recently, Research Papers. The calls for Short Papers (usually, limited to four pages of contents) started in the fifth edition, in 2002, but were closed in the 18th edition of the Symposium, in 2019. In the following year, 2020, a new track emerged. The calls for the Innovative Ideas and Emerging Results track (usually, limited to six pages of content<sup>3</sup>) began to occur in the 19th edition, in 2020.

It should be emphasized that the difference between the old Short Papers track and this new Innovative Ideas and Emerging Results track does not reside, in essence, only in the maximum number of pages allowed for the articles, but rather in their key purpose. As described in its first call<sup>4</sup>, although this new track comes to “replace” the old Short Papers, its goal is quite different, being intended for articles with new but concrete ideas with the potential to evolve, as well as works in progress that are relevant to the community. For this reason, in the study presented in this work, we considered these three tracks to be the main tracks of the Symposium and, therefore, they were included separately for analysis purposes.

In this context, the goal of the present study is to analyse the IHC from the perspective of the authors of the publications from the three aforementioned tracks, which is a different focus in relation to works that have previously analysed the Symposium (e.g., the works of Lima *et al.* [2018], Lima *et al.* [2019], and Lima *et al.* [2021]<sup>5</sup>). Thus, questions will be investigated according to the main tracks of IHC papers, i.e., Full Papers, Short Papers, and Innovative Ideas and Emerging Results. The **Research Questions** (RQs) defined for this study are:

- **RQ1:** Who are the main authors of the IHC?
- **RQ2:** How have the authorship of IHC articles evolved over the years?
- **RQ3:** What are the co-authorship networks of IHC articles?
- **RQ4:** How has the collaboration between authors of the IHC evolved over the years?
- **RQ5:** How has the co-authorship networks of IHC articles evolved over the years?

<sup>1</sup>Throughout this article, the acronym “IHC” will refer to the Brazilian Symposium on Human Factors in Computing Systems.

<sup>2</sup>In the edition of 2023, the IHC also included a new Experience Reports track.

<sup>3</sup>In 2023, this limit was modified to 10 pages of content.

<sup>4</sup>[ihc2020.ufvjm.edu.br/ideias\\_inovadoras.php?lang=en-US](http://ihc2020.ufvjm.edu.br/ideias_inovadoras.php?lang=en-US).

<sup>5</sup>The work of Lima and Miranda [2023] summarizes a series of studies that were performed over the IHC to contribute to its scientific community.

All of these questions are relevant for the Brazilian Human-Computer Interaction community. Answering them in detail can help researchers who “orbit around” the Symposium to better understand the path of their peers in the event, and even their own trajectory within the IHC; who knows, even in a broader sense, within the area of Human-Computer Interaction itself, since the event certainly impacts, in different ways, the different careers of the distinct researcher-authors of the IHC. The data, information, and novel visualizations presented in this article can also generate important considerations for groups of authors, as they were also put into perspective, for example, by shedding light on the complex co-authorship network formed around the IHC articles in this work.

This paper is organized as follows: Section 2 presents the related works; in Section 3, the method employed in the study is described in detail; results are presented in Section 4 and discussed in Section 5; and, finally, Section 6 concludes the article.

## 2 Related work

The co-authorship networks are analysis artefacts that help to understand the situation of research in a given field, specifically, with relation to the contributions between the authors. These networks are employed in bibliometric studies as a way to perform a scientific mapping from the articles’ authors. Analyses of co-authorship networks may reveal characteristics that, in principle, were unknown, especially when the study involved a rather large quantity of data. In these analyses, different approaches may be utilized, either in a more statistical manner, involving metrics associated to the networks, or in a more exploratory manner, by observing, for example, the structure and organization of the networks.

In the literature, it is even possible to find well-defined methods that help researchers when developing an analysis of co-authorship networks (e.g., Cowhitt *et al.* [2020]). In the study of Newman [2004a], for example, statistical properties of three co-authorship networks are evaluated, such as the number of authors, the network diameter, and the assortativity coefficient of the network, which refers to the correlation between the number of co-authors of the researchers present in the network. In the study developed by Nunes da Silva *et al.* [2022], the analysis also involves metrics related to the networks, but in this case, the study is interested in the co-authorship networks of undergraduate programs on Computer Science in Brazil. The study of Sood *et al.* [2021] reveals how contributions between authors of different nationalities occur through a more exploratory approach, using the visualization of the co-authorship network in addition to the use of metrics. In this study, issues that go beyond co-authorship networks were also analysed, such as the most cited works and the themes that were explored.

In the Brazilian scenario, scientific communities from different sub-areas of Computing have already sought to perform this kind of analysis. For example, in the research developed by Racca *et al.* [2021], the authors investigated the co-authorship network of the Brazilian Symposium on Collaborative Systems (SBSC) in relation to the publications

from 2013 to 2019, and in the study of Procópio *et al.* [2011], the co-authorship network of the Brazilian Symposium on Data Bases (SBBDB) was analysed. In the literature, the analysis of these networks also demonstrates relevance when the study seeks to understand the research performed in a certain research field, conference or journal (e.g., the works of Molontay and Nagy [2021], Köseoglu *et al.* [2018] and Cipresso *et al.* [2018]). Similar analyses were also performed in fields of research outside of Computing (e.g., in the works of de Souza Oliveira Filho [2020], do Nascimento *et al.* [2019], Zanghelini *et al.* [2016] and Moraes *et al.* [2020]). Different fields of knowledge were also analysed in a more global context. In the study of Li *et al.* [2009], for example, the authors evaluated the worldwide research in the area of stem cells.

Considering the Brazilian research scenario specifically in Human-Computer Interaction, we can highlight three works that sought to perform analyses involving co-authorship networks, that is, the researches of Gasparini *et al.* [2014], Barbosa *et al.* [2017] and de Mendonça *et al.* [2018]). In the work developed by Gasparini *et al.* [2014], the authors analysed the full papers published in the IHC during the period ranging from 1998 to 2013, under different perspectives related to the authors, such as the diversity of nationalities and fields of activity. In addition, the subjects and themes explored in the publications of the event were also analysed. In this study, the authors presented the co-authorship networks for the full papers of the IHC, both from the last edition at that time (i.e., in 2013) and their evolution in different slices of time. Regarding the analysis of the themes and subjects explored in the publications, the authors considered the keywords of the full papers, which included a mapping of the evolution of the subjects over the years.

In the work of Barbosa *et al.* [2017], the IHC is analysed under different perspectives, since its first edition (i.e., in 1998) to 2015. In this work, the co-authorship networks of the full papers of the Symposium are analysed, as well as their evolution over the years. In addition to co-authorship networks, the authors of this study also analysed issues related to the origin of scientific productions published in the IHC, as well as topics and citations. In the analysis of citations, for example, the authors verified citations within the scope of the HCI itself, in addition to authors citing their own articles.

Moving on to the work conducted by de Mendonça *et al.* [2018], the focus was not on analysing the IHC co-authorship network, but the Brazilian research in the area. To do so, the researchers selected the 29 most prolific authors of the IHC (this was the terminology adopted in the study) and, from their Lattes Curriculum, their co-authors were identified and their names extracted to build the co-authorship network. In this work, the authors sought to bring different information in the visualizations of the co-authorship networks. In relation to the vertices of the networks, different entities were represented through colouring, such as prolific authors, their co-authors and their master's and doctoral students, as well as the authors' institutions and scientific venues in which they published. In this sense, a general network was presented, with all the information described and with different segments being explored later on, such as supervision networks. After the visual analysis of the networks, the researchers explored different centrality metrics, such as degree and closeness.

Considering the related works presented above, the importance of studies that analyse conferences or journals in different areas of knowledge using bibliometric approaches is evident. In the specific case of Brazilian research in Human-Computer Interaction, we can highlight the researches conducted by Gasparini *et al.* [2014], Barbosa *et al.* [2017] and de Mendonça *et al.* [2018]. Based on these works, the current study intends to bring new knowledge related to the authorship and co-authorship of the IHC. In addition to bringing updated data, the present study also considers the three tracks of the Symposium, that is, Full Papers, Short Papers and Innovative Ideas and Emerging Results. In doing so, the tracks can be analysed and compared in relation to their authors, and the co-authorship networks can be analysed under the perspective of each one of them, according to the method described in the following section.

### 3 Method

To answer the research questions of this work, as presented in Section 1, the method was divided into three general stages: (i) data collection; (ii) pre-processing; and (iii) processing. The following subsections describe the activities performed in each of these steps.

#### 3.1 Data collection

The first stage (i) consists in collecting the data that would be employed in the analyses, which would “basically” be the name of the authors who published in the three main tracks of the IHC. The database that was employed was the digital portal of the Special Commission on Human-Computer Interaction (CEIHC<sup>6</sup>) from the Brazilian Computer Society (SBC), which maintains, in different pages, the Proceedings of all editions of the IHC. To extract the desired data, that is, the names of the authors of the publications, a web scraping technique was used. For this, scripts in the Python programming language were developed.

These scripts access the pages from CEIHC to automatically extract the names of the authors of each publication, separating the authors by publication, and the publications by edition. Then, the collected data were organized, locally, in a database constructed specifically for the performing of this study. It is important to highlight that, to reach this level of automation, it was necessary to understand the source-code structure from the pages of CEIHC, to only then be able to correctly collect the data.

#### 3.2 Preprocessing

The pre-processing stage (ii) had two main goals: (ii.a) to select the publications of the three main tracks of the IHC; and (ii.b) to index the authors according to the variations of their names. All tasks of this stage were performed manually. Considering (ii.a), the track of each publication was verified in the page of CEIHC itself. Based on this information, only the publications from the tracks of Full Papers, Short Papers and Innovative Ideas and Emerging Results were kept. The

<sup>6</sup>[comissoes.sbc.org.br/ce-ihc/](https://comissoes.sbc.org.br/ce-ihc/).

name of the corresponding track was associated for each of these publications.

For (ii.b), it was observed that the authors presented variations in their names, thus needing to be indexed. Initially, all identified distinct names were organized in alphabetical order, to facilitate the indexing process. Therefore, a unique identifier was associated to different variations of names for the same authors. In addition to indexing, the variations of names were also normalized, that is, they were replaced by a single variation. This indexing and normalization processes were performed manually to avoid errors. In a few situations, in order to guarantee the integrity of the manipulated data, it was necessary to consult the author's curriculum in the Lattes Platform to confirm their identity.

### 3.3 Processing

The third stage, data processing (iii), aimed at generating the necessary artefacts that would collaborate to the analysis and answer the research questions. For this, it was necessary the creation of different graphs and visualizations, in addition to the calculation of several quantitative information related to this data. Therefore, the following subsections describe in details each visualization that was created and the calculated indexes that compose the current work.

#### 3.3.1 Publication history

At first, the authors were investigated in relation to the quantity of publications ( $N$ ) that they have in each track. The value for  $N$  was defined empirically, after the initial data analysis, aiming at selecting the highest number of authors without negatively impacting the visualization of information. Thus, for each track, authors who had  $N$  or more publications were selected as being the main authors of the corresponding track of the Symposium. A heat map was created for each track, with the objective of representing the contribution history of the main authors. The visualization presents the authors' number of publications in each edition of the corresponding track, and the authors were listed according to the total number of publications, visible at the right of each author's name.

In case of a tie in the total number of publications, the criterion used to order the authors was the number of most recent publications, and if the tie persists, the last adopted criterion was to order the authors by name, in alphabetical order; this last criterion only needed to be applied in the publication history of the track Innovative Ideas and Emerging Results, since the first two criteria were not completely sufficient, given that this track has only three editions and a relatively similar data distribution. In addition, the authors with the highest number of publications amongst the main authors were separated by a dashed line in the publication history (these authors are above this dashed line). The placement of the line was defined in such way that half of the main authors are selected; however, in the case that the division coincided with a sequence of equal amounts of publications, the line would go up or down in order to find the approximate point that divided the list of authors into two sets, as close as possible to half.

#### 3.3.2 Szymkiewicz-Simpson Coefficient

To verify the similarities between IHC tracks in relation to their authors, the Szymkiewicz-Simpson Coefficient ( $K_{SZ}$ ) was employed. It is a coefficient related to the Jaccard Index [Vijaymeena and Kavitha, 2016], which summarizes the similarity between two sets of elements based on the smallest of them<sup>7</sup>. Korepanova *et al.* [2020], upon the analysis of six different binary coefficients that verify the similarity between social circles, concluded that the Szymkiewicz-Simpson Coefficient produces better results. This coefficient is given by Equation (1).

$$K_{SZ(X,Y)} = \frac{|X \cap Y|}{\min(|X|, |Y|)} \quad (1)$$

Thus, in the context of this work, the Szymkiewicz-Simpson Coefficient was employed to verify the similarities between IHC tracks considering the two following sample of authors: (i) from all authors, and (ii) from main authors only. Therefore, for each track, the sets of authors related to samples (i) e (ii) were considered for analysis. These sets were named based on the set of samples and track, that is, for the analysis of sample (i), the sets of all authors of Full Papers, Short Papers, and Innovative Ideas and Emerging Results were named, respectively, as *ALL\_FULL*, *ALL\_SHORT*, and *ALL\_IDEAS*. For the analysis of sample (ii), the respective identifiers were: *MAIN\_FULL*, *MAIN\_SHORT*, and *MAIN\_IDEAS*.

#### 3.3.3 Map of publication variation

To complement the publication history of the main authors, an analysis that considers different periods of time from the tracks throughout the editions of the event was performed. In order to do so, it was necessary to define these periods of time, which in this work are named as moments ( $M_x$ ), and that consider the editions of the IHC. All IHC editions, comprised between 1998 and 2022<sup>8</sup>, were then divided into three-editions blocks corresponding to a single moment.

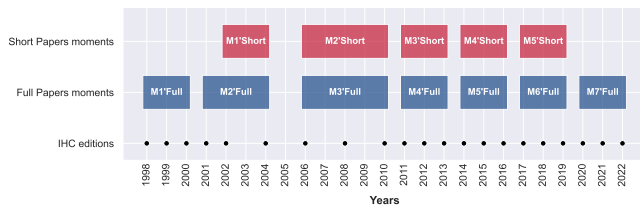
For this study, as many blocks as possible were selected so that the created visualizations were not compromised. Blocks with few editions (e.g., two editions) could result in small volumes of data, making visual and comparative analyses between time periods difficult. Blocks with many editions (e.g., four or more editions) could result in larger volumes of data, hiding events that happened throughout the IHC editions. Therefore, seven moments were defined for Full Papers and five moments for Short Papers, as presented in Figure 1<sup>9</sup>.

For Full Papers, the moments were named considering a chronological order, as follows: M1'Full (IHC'98, '99 and '00), M2'Full (IHC'01, '02 and '04), M3'Full (IHC'06, '08 and '10), M4'Full (IHC'11, '12 and '13), M5'Full (IHC'14, '15 and '16), M6'Full (IHC'17, '18 and '19), and M7'Full (IHC'20, '21 and '22).

<sup>7</sup>In the case of the Jaccard Index, similarity is calculated differently based on the number of all unique elements present in both sets, i.e. the union between them [Fletcher *et al.*, 2018].

<sup>8</sup>At the time of this study, the most recent edition of the IHC occurred in 2022 and, for this reason, it was the last edition considered in this analysis.

<sup>9</sup>All images presented in this work were generated and inserted in a vectorial "format". This allows for the reader to enlarge the figures without loss of resolution, considering that the manuscript is in a PDF format.



**Figure 1.** Overview of the moments defined for the Full Papers and Short Papers tracks of the IHC.

In the case of Short Papers, the identifiers for moments were: M1'Short (IHC'02 and '04), M2'Short (IHC'06, '08 and '10), M3'Short (IHC'11, '12 and '13), M4'Short (IHC'14, '15 and '16), and M5'Short (IHC'17, '18 and '19). The Innovative Ideas and Emerging Results track was not analysed in the perspective of moments given its low number of editions, that is, only three editions that, together, could only be grouped into a single moment, which would not make possible for a comparative analysis with other moments.

A heat map visualization was elaborated in the analysis of the map of publication variation for the main authors' moments. In the columns from this heat map are presented moments related to each track, while the rows present the main authors. Thus, four values are presented in each cell of the heat map, each related to the respective author and in a given moment, that is, the number of positions that the author gained or lost in comparison to the previous moment (the moment in which the author first appears in the ranking has infinite value), his/her current position in the ranking in a given moment, the number of new publications, and the total number of publications to the respective moment, being these last two values presented between parentheses. Unlike the publication history, this new visualization would have a greater focus on the position of the authors in the ranking of each moment of the track, so the third criterion (i.e., alphabetical order) was not used in this new analysis. Thus, authors who tie in the two previously mentioned criteria in relation to publication history would assume the same position in the ranking. It is important to highlight that, in this analysis, the moments are not isolated, but incremental, that is, the second moment corresponds to its respective editions plus the first moment, and so on.

In order to present an overview of the authors who occupy the same position in the ranking, the total number of authors and the number of positions in the ranking at the respective moment are presented in the "caption" of the columns of this visualization. It is also important to highlight the issue of the colouring of the cells in this visualization, which considered the number of positions that each author gained or lost from one moment to another. The visualization has a color palette on its right side, which shows the color for each value. To avoid discrepancies in cell colors, the upper and lower outliers were calculated using the interquartile range, which received specific colors being identified, respectively, at the top and at the bottom of the color palette of this visualization.

### 3.3.4 Co-authorship network

In the co-authorship networks, which are essentially graphs, each vertex corresponds to an author, and each edge represents a co-authorship relationship. In these co-authorship networks, it is usually possible to observe the existence of several groups

of isolated authors, thus, for each track, the largest group of authors was selected and defined as the "main group", and the other isolated groups were treated and defined as the "minor groups". In the visualization of networks, the size of the vertex and the thickness of the edges are directly proportional, respectively, to the number of publications by the author and the number of contributions between two authors. Thus, in the context of each track, the co-authorship networks, divided into a main group and minor groups, had the names of the main authors presented in the respective groups.

In addition to the main group and the minor groups, the formation of clusters in the co-authorship networks of each IHC track was also explored. These clusters represent groups of strongly connected authors based on their co-authorship relationships, which may reveal sets of authors who share the same co-authorship circle. In the visualization, the different clusters are identified by different colors, which are expressed through the vertices and edges.

### 3.3.5 Co-authorship matrix

In the analysis of co-authorship relationships, in addition to co-authorship networks, another visualization was also constructed, that is, the co-authorship matrix, which is a heat map that quantifies the contributions between the main authors of the tracks, with one of these matrices being generated for each track. In co-authorship networks, it is possible to visually observe the proportion of the co-authorship relationships between authors through the thickness of the edges. Aiming at complementing the co-authorship networks, the co-authorship matrix was developed to quantify these relationships, more specifically, between the main authors of each track. To do so, the main authors were arranged vertically and horizontally in each matrix, so that the number of times that the pair of authors published together was indicated in the cell of the matrix corresponding to the "crossing" of these authors in the rows and columns of the matrix. In the vertical listing of the authors' names, between parenthesis, it is reported the number of different researchers that the respective author has co-authorship relationships. In this case, these co-authorship relationships regard only those with other authors present in the matrix. In practice, for a given author  $A$ , this number represents the number of authors that  $A$  has co-authorship relationships amongst those that are also listed in the matrix. All co-authorship relationships were defined based on the authors' unique identifiers, and were posteriorly filtered considering the main authors for each of the tracks.

### 3.3.6 Timeline of groups of authors

In this work, groups with two, three, four, etc. authors were also explored. We sought to identify the main groups of IHC authors and present how their publications evolved over the editions of the event. Due to the small number of editions (i.e., three) of the Innovative Ideas and Emerging Results track, only the Full Papers and Short Papers tracks were considered for the purposes of this specific analysis. Initially, it was necessary to select these groups, thus three criteria were defined to identify: (i) the groups of authors that had at least one author amongst the main authors of the track; (ii.a) groups

that presented at least two publications; and (ii.b) the groups that had a set of authors in common.

It is important to mention that in relation to the sequence of application of the criteria, initially, the groups that satisfy (i) are selected and, subsequently, (ii.a) and (ii.b) were applied “at the same time”. This way, the groups selected by (ii.a) and (ii.b) have passed, necessarily, by criterion (i). In relation to criterion (ii.a), it is possible to list, for example, the groups of authors who published together in more than one edition. For criterion (ii.b), it is possible to identify groups of authors which, despite having a single publication, had groups of authors that published together more than once. In general, in relation to (ii.b), the groups that had joined other authors to compose bigger groups, and groups that had “dissolved” and composed smaller groups were selected.

In this analysis, groups were defined from the sets of authors of each paper. Groups of two authors (i.e., pairs), for example, were defined based on publications that only contained two authors, while trios were defined based on publications that only contained three authors. Thus, even if the authors of a duo  $D$ , who collaborated on an article published in a given edition of the IHC, have previously collaborated with other authors in a quartet  $Q$ , the publications of  $D$  do not intersect with the publications of  $Q$ , that is, the publications of  $D$  are those published solely by the pair of authors.

Each group of authors identified in IHC publications, regardless of track, received a unique identifier. These identifiers made possible to verify not only how each group of authors evolved in the different tracks, but also if they are present in other tracks. These unique identifiers were assigned considering all of the identified groups, not just the selected ones, since they were important, from the beginning, for the manipulation of the data referring to the groups. Each identifier presents a tag “G[x]\_”, being “x” the size of the group, followed by a value (e.g., “G2\_11” for representing a pair of authors with identifier “11”, “G4\_23” to represent a quartet of authors with identifier “23”, and “G6\_58” to identify a sextet of authors with identifier “58”). This value is assigned incrementally, as each group is identified in the database that was built for this study, which necessarily follows the order of the IHC Proceedings, from the first to the last edition.

In addition, the unique identifiers of the groups from Full Papers were defined first, followed by the groups from the Short Papers track. Therefore, the groups from Short Papers that do not appear in Full Papers have higher values than those groups from Full Papers. Another point worth mentioning is the arrangement of the names of the authors from each group, which were ordered alphabetically both to simplify data manipulation and to be presented in this article.

For this analysis, one visualization was created for each track, aiming at presenting the evolution of the authorship of the selected groups. The visualization works as a timeline that presents two dimensions: time, which considers the editions of the respective track; and the size of the groups of authors. This way, the position in which the groups appear will depend on the edition in which they were published and how many authors comprise them. That is, the timeline may be seen as a kind of matrix, in which the columns represent the time (i.e., editions or moments of the IHC) and the rows represent the size of the group, in such way that the groups are placed in

the cells of this matrix representation.

In the labels of rows, at the right side of the description of sizes of groups of authors, it is presented the number of groups that present the respective number of authors. In this visualization, the groups selected by (ii.a) and (ii.b) have different formats, respectively, square and diamond, and their size also corresponds to the number of publications in the respective edition. With the groups organized in their proper positions, the links between them were added, which could be of two types: continuity, intended for groups with two or more publications; and intersection, assigned to groups that presented subgroups.

Regarding continuity links, it is important to highlight that they do not exist if the publications of the respective group are all in the same edition. In this case, the number of publications of the group in the respective edition is represented by the size of the square. Given that the groups represented by diamonds necessarily have only one publication, they all have the same minimum size. In the visualization, continuity links are continuous lines, while intersecting links are dashed.

### 3.3.7 Evolution of the co-authorship networks

With the goal of complementing the IHC co-authorship networks, we also performed a temporal analysis which explored how these networks evolved over the editions of the event. Given the low number of editions (i.e., three), the evolution of the networks for the Innovative Ideas and Emerging Results track was not considered for analysis. The editions of the Full Papers and Short Papers tracks were grouped considering the moments previously defined in Section 3.3.3 (an overview of these moments is presented in Figure 1). In this analysis, the moments were not considered in a isolated manner, but incrementally. That is, the evolution considered the different moments of the networks in such way that, for every new moment, new editions were included, with all editions considered by the last moment. For example, in the case of Full Papers, the co-authorship network of the first moment (i.e., M1'Full) would refer to the editions from 1998 to 2004. For each moment, the main group and the smaller ones were separated and presented in different visualizations. In addition, for the context of each moment, a value of  $N$  was defined to indicate which authors would have their names displayed in the network. This value was defined empirically in such way as to select the highest number of authors so that it would not impair the visualization.

### 3.3.8 Technical notes on the creation of the visualizations

For creating the visualization histories (described in Section 3.3.1), the publication variation maps (described in Section 3.3.3), the co-authorship matrices (described in Section 3.3.5), and the timelines of groups of authors (described in Section 3.3.6), it was necessary to perform several tasks, with some of them partially or completely automatized using scripts, developed by the authors of this work using the Python programming language. All of the data organization process was performed using the Pandas library<sup>10</sup> [pandas development team, 2020; Wes McKinney, 2010], and the visualizations

<sup>10</sup>[pandas.pydata.org](https://pandas.pydata.org).

were generated with two other libraries, that is, Matplotlib<sup>11</sup> [Hunter, 2007] and Seaborn<sup>12</sup> [Waskom, 2021].

To identify and create the co-authorship networks (described in Section 3.3.4), it was first necessary to create the graphs formed by the authors. To do so, scripts in the Python programming language were also developed with the library NetworkX<sup>13</sup> [Hagberg et al., 2008], commonly employed in analyses of co-authoring networks (e.g., [Higaki et al., 2020]). The visualizations of the co-authorship networks were generated using the Gephi tool<sup>14</sup> [Bastian et al., 2009], widely used in analyses of networks (e.g., Aggrawal and Arora [2016], Donthu et al. [2020] and Hosseini et al. [2018]). The process of cluster identification was aided by the same tool, which uses a heuristic algorithm based on modularity to identify graph communities [Blondel et al., 2008].

The resources used to support this study, that is, the Python libraries and the Gephi tool, possess a certain learning curve to be used effectively. The Gephi tool, for example, is relatively complex and has several functionalities, which must be correctly understood for its correct use. For this, on the digital portal of the tool, it is possible to find different tutorials that assist in learning the functionalities of Gephi, ranging from the simpler ones (e.g., importing a data file related to a graph) to the more complex ones (e.g., adjusting the visual distribution of a graph's nodes). As for the Python libraries, their use can be understood with the help of technical documentation, as well as through tutorials available on their respective digital portals.

## 4 Results

This section presents the results of this work in the same sequence as the research questions are defined in Section 1.

### 4.1 RQ1: Who are the main authors of the IHC?

Before describing the main authors of IHC articles, it is necessary to present a few answers related to this central question. The **total number of IHC authors** is 1,443 researchers, which compose the universe of all authors in the history of the Symposium. Considering the three IHC tracks as described in Section 1, these authors are divided as follows: 1,053 authors in the Full Papers track, 445 authors in the Short Papers track, and 177 authors in the Innovative Ideas and Emerging Results track. The **distribution of IHC authors in these tracks** is as follows (Figure 2): the vast majority (i.e., 86.07%) published, exclusively, in a single track of the Symposium (1,242), while 11.78% published in two tracks (170), and only 2.15% had articles published in all three tracks (31).

The main authors of the IHC tracks were selected according to the number of their contributions. For this selection, the information regarding the 873 articles that were published in the IHC from 1998 to 2022 were collected, being 621 from Full Papers, 191 from Short Papers, and 61 from Innovative

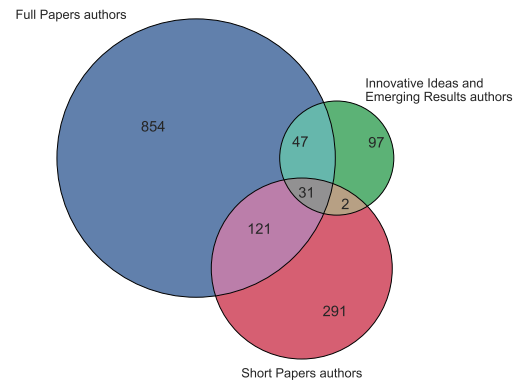


Figure 2. Number of authors in the IHC tracks.

Ideas and Emerging Results. Thus, for each track, a distinct value for  $N$  was defined in such way as to identify its main authors. As described in Section 3, these values were established empirically while considering the data sample from this study, aiming at obtaining a good information visualization in the figures that compose this work. Therefore, Figure 3 presents the portion of authors with different quantities of published articles in the three tracks, with the values of  $N$  for each track defined as: Full Papers,  $N = 5$ ; Short Papers,  $N = 3$ ; and Innovative Ideas and Emerging Results,  $N = 2$ .

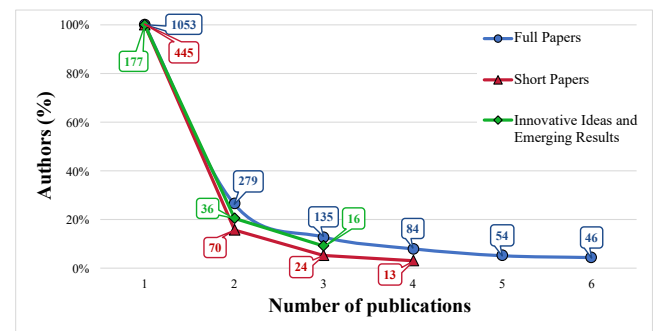


Figure 3. Number of authors by IHC track, according to their number of publications.

The main authors of each track were selected based on the values previously described and may be observed in Figure 4, where the publication history of these authors are presented, and therefore shows **how the main authors published throughout the editions of the IHC** for each track: Full Papers, 54 authors (Figure 4a); Short Papers, 24 authors (Figure 4b); and Innovative Ideas and Emerging Results, 36 authors (Figure 4c). It is important to highlight that organizing the publication history into a ranking solely assists in the analyses presented in this study. The authors of this work have no intention of instigating any form of competition among researchers, with the ranking merely serving for ordering.

From the publication history of the Full Papers, it is interesting to observe, for example, that M. Cecilia C. Baranauskas, in addition to being the author with most published articles in this track (i.e., 63;  $M = 300$ ), is also the only one who published in all 21 editions of the Symposium. Also noteworthy is the constant frequency of publication on this track, since its first edition in 1998, by the following four authors: Raquel O. Prates (43;  $M = 2.04$ ), Clarisse S. de Souza (41;  $M = 1.95$ ), Simone D. J. Barbosa (36;  $M = 1.71$ ), and Milene S. Silveira (28;  $M = 1.33$ ).

<sup>11</sup>matplotlib.org.

<sup>12</sup>seaborn.pydata.org.

<sup>13</sup>networkx.org.

<sup>14</sup>gephi.org.

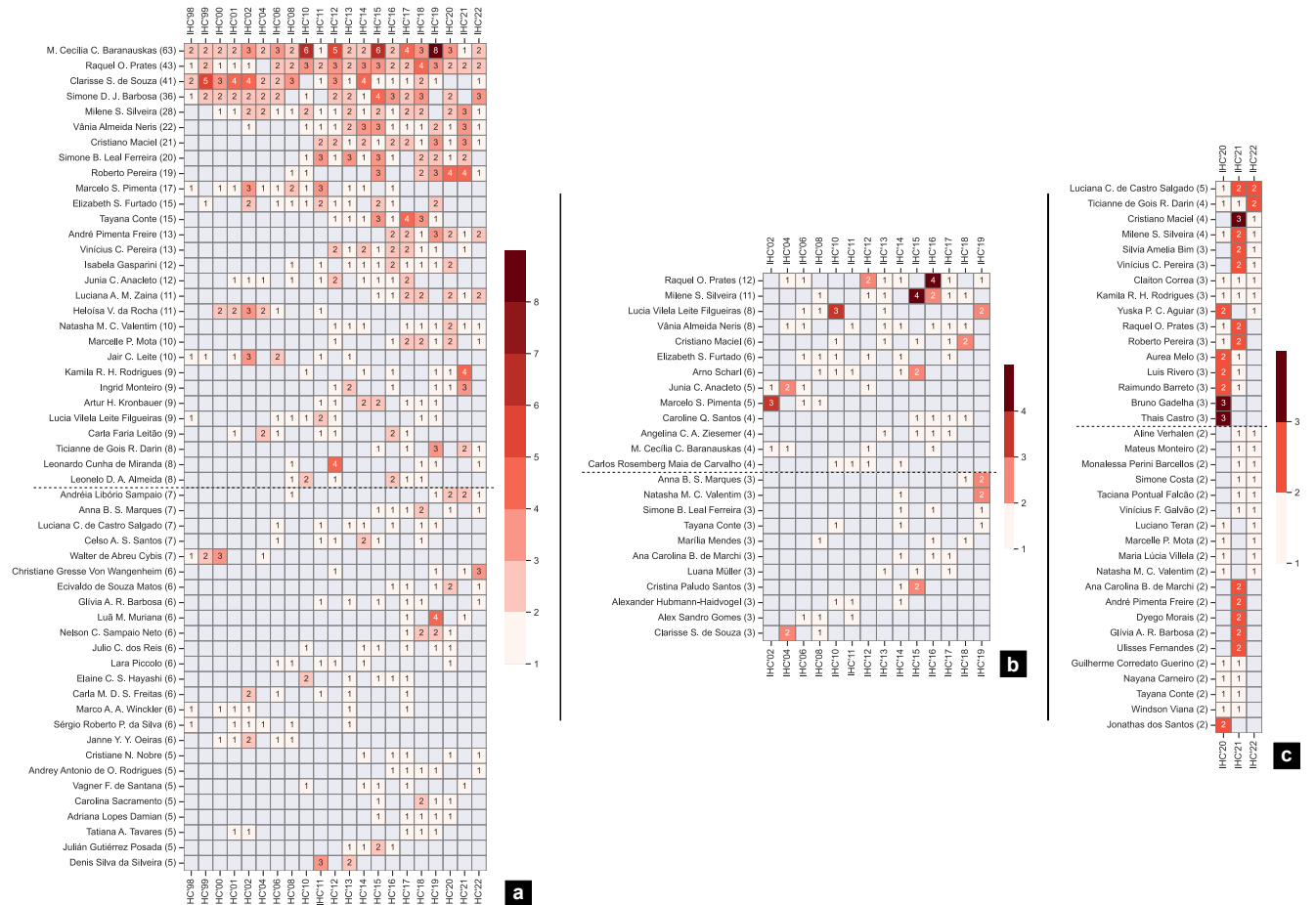
It may also be noted that, since 2011, the publications of Vânia Almeida Neris (22;  $M = 1.04$ ) and Cristiano Maciel (21;  $M = 1.00$ ) are also recurring in this track. For the publication history of Short Papers, it is possible to notice that none of the 24 main authors of this track have articles published in all of the 14 editions, and the four authors with most of the published works in this track are: Raquel O. Prates (12;  $M = 0.85$ ), Milene S. Silveira (11;  $M = 0.78$ ), Lucia Vilela Leite Filgueiras (8;  $M = 0.57$ ), and Vânia Almeida Neris (8;  $M = 0.57$ ).

In the publication history of Innovative Ideas and Emerging Results, it is possible to identify the four authors who most published in this track: Luciana C. de Castro Salgado (5;  $M = 1.66$ ), Ticianne de Gois R. Darin (4;  $M = 1.33$ ), Cristiano Maciel (4;  $M = 1.33$ ), and Milene S. Silveira (4;  $M = 1.33$ ). We also find it worth to mention that, in these publication histories, we could also observe the names of some authors who are no longer amongst us, such as Junia C. Anacleto and Sérgio Roberto P. da Silva, or even those authors who have been retired for many years, such as Heloísa V. da Rocha; the contributions of these authors remain marked in the Brazilian community of Human-Computer Interaction to this day.

In relation to the **similarities of IHC authors between the event tracks**, the results from the calculation of the coefficients were:  $K_{Sz}(ALL\_FULL, ALL\_SHORT) = 0.342$ ;  $K_{Sz}(ALL\_FULL, ALL\_IDEAS) = 0.441$ ; and  $K_{Sz}(ALL\_SHORT, ALL\_IDEAS) = 0.186$ .

It is important to highlight that, in terms of absolute values, *ALL\_FULL* and *ALL\_SHORT* presented more authors in common (i.e., 152). However, the highest similarity coefficient was calculated between *ALL\_FULL* and *ALL\_IDEAS*, although they present less authors in common (i.e., 78). This means that almost half (i.e., 44.1%) of the 177 authors of *ALL\_IDEAS* are in *ALL\_FULL*, while 34.2% of the 445 authors from *ALL\_SHORT* are in *ALL\_FULL*. For *ALL\_SHORT* and *ALL\_IDEAS*, it is possible to notice that the ratio of authors in common between these two tracks is much smaller, that is, only 18.6% of the 177 authors from *ALL\_IDEAS* are also in *ALL\_SHORT*. These results indicate that the authors of Full Papers, in general, have been contributing more in this new track in comparison to how much they have contributed to the Short Papers track in the past.

Regarding the **similarity between the main authors of the IHC tracks**, the values resulting from the coefficient calculations are:  $K_{Sz}(MAIN\_FULL, MAIN\_SHORT) = 0.583$ ,  $K_{Sz}(MAIN\_FULL, MAIN\_IDEAS) = 0.361$ , and  $K_{Sz}(MAIN\_SHORT, MAIN\_IDEAS) = 0.25$ . It can be noticed a greater similarity between Full Papers and Short Papers tracks in regard of their authors, considering that 58.3% (i.e., 14) of the *MAIN\_SHORT* 24 authors are also in *MAIN\_FULL*. Similarly to the previous similarity analysis between all authors, the smallest identified similarity was between the tracks Short Papers and Innovative Ideas and Emerging Results, where only 25.0% (i.e., 6) of the 24 *MAIN\_SHORT* authors are in *MAIN\_IDEAS*.



**Figure 4.** Publication history of IHC main authors by track: (a) Full Papers: 54 authors ( $N \geq 5$ ); (b) Short Papers: 24 authors ( $N \geq 3$ ); and (c) Innovative Ideas and Emerging Results: 36 authors ( $N \geq 2$ ) (above the dashed lines are authors with most publications).



These results suggest that fewer authors among the main ones from the Full Papers track have been contributing to this new track, although these same authors have contributed extensively in the past with the Short Papers track; naturally, this index also represents the fact that some of the main authors from Full Papers are no longer active due, for example, to the aforementioned situations.

In general, in relation to each track of the Symposium, we can highlight the authors with most publications (these authors are above the dashed line in the publication history), that is, the first 29 from Full Papers, the first 13 from Short Papers, and the first 16 from Innovative Ideas and Emerging Results. In the case of Full Papers, this group of authors contributed to 64.73% of all publications of this track. It becomes clear the importance of these authors, even while representing only 2.75% of the 1,053 authors of Full Papers.

For Short Papers, the 13 authors correspond to just 1.23% of the authors from the track, but contributed to 36.13% of all publications. For Innovative Ideas and Emerging Results, the 16 authors correspond to only 1.52% of authors from the track, and even so, this group contributed to more than half of the publications of the track (i.e., 50.82%).

Finally, we can still highlight that the authors who most published in the three tracks represent 86 different researchers when united in a single group. It is important to emphasize the importance of these researcher-authors for the Symposium, as despite representing a small portion (i.e., 5.96%) of the total number of authors (i.e., 1,443), these 86 authors alone contributed to almost three-quarters (i.e., 74.34%) of the IHC publications, that is, 649 out of the 873 Symposium articles.

## 4.2 RQ2: How have the authorship of IHC articles evolved over the years?

From the results of research question #1, described in the previous subsection, it was possible to verify how the publications of the main authors of the IHC are distributed throughout the editions of the event. In this research question, we will expand the previous analysis and observe the situation of these main authors at different moments, bearing in mind that, in general, each of the moments is composed of three consecutive editions of a track, following the same sequence of editions of the Symposium. In Section 3.3.3, the moments of each track (i.e., Full Papers and Short Papers) were defined, in addition to the other procedures related to this particular analysis. Thus, for the analysis of the **publication variation by IHC moments for Full Paper authors**, the 54 main authors of this track were considered, with seven different moments of the editions of this IHC track from 1998 to 2022. The publication variation map of this track is shown in Figure 5. It is also important to keep in mind that the analysis of publication variation by IHC moments considers moments incrementally (i.e., the union of moments), in order to portray the “picture” of the authors, in relation to a track of the Symposium, from the first moment (i.e., from M1) to the moment of interest (i.e., any M<sub>x</sub>).

Initially, by observing the publication variation map of the main authors of Full Papers, we can identify the moments in which authors sharply gained or lost positions in the ranking, either up or down. In this visualization, these situations are

highlighted in the cells of the heat map according to the colors, respectively, of the top (dark blue) or bottom (brown) of the color palette (which is on the right side of the figure). We can also highlight those authors who remained in the same position, or who rose positions, in the ranking for more than one consecutive moment. This way, it is possible to identify the authors who presented works at the event for a certain period of time which comprises several editions of the Symposium, so that they managed to maintain or progress in the ranking for consecutive moments.

In this line of reasoning, we can highlight the authors who remained or rose in the ranking in all seven moments (followed by their position in the final ranking and the interval of moments in which they remained or progressed in the ranking): M. Cecília C. Baranauskas (1°; M1-M7'Full), and Milene S. Silveira (5°; M1-M7'Full). There were also situations in which authors presented two distinct intervals with more than one consecutive moment in rise or stability in the ranking: Simone D. J. Barbosa (4°; M1-M3 & M5-M7'Full), and Clarisse S. de Souza (3°; M1-M3 & M5-M6'Full).

Next, we highlight the author who remained or rose in the ranking in almost all moments (i.e., six consecutive moments, in the total of seven): Vânia Almeida Neris (6°; M2-M7'Full). In sequence we present authors which rose or maintained their position in the ranking for five consecutive moments: Raquel O. Prates (2°; M3-M7'Full), and Isabela Gasparini (15°; M3-M7'Full).

Also, it is important to mention those authors who maintained or rose positions in the ranking for more than half of the moments (i.e., four consecutive moments): Cristiano Maciel (7°; M4-M7'Full), Simone B. Leal Ferreira (8°; M3-M6'Full), Marcelo S. Pimenta (10°; M1-M4'Full), Marcelle P. Mota (20°; M4-M7'Full), and Luciana C. de Castro Salgado (32°; M3-M6'Full).

We can also identify those authors who maintained or increased their position in the ranking for three consecutive moments, which comprises a period of nine editions of the track. These authors are: Roberto Pereira (9°; M5-M7'Full), Tayana Conte (12°; M4-M6'Full), André Pimenta Freire (13°; M5-M7'Full), Vinícius C. Pereira (14°; M4-M6'Full), Junia C. Anacleto (16°; M2-M4'Full), Luciana A. M. Zaina (17°; M5-M7'Full), Jair C. Leite (21°; M1-M3'Full), Ticianne de Gois R. Darin (27°; M5-M7'Full), Anna B. S. Marques (31°; M5-M7'Full), Celso A. S. Santos (33°; M3-M5'Full), Ecivaldo de Souza Matos (36°; M5-M7'Full), Carla M. D. S. Freitas (43°; M2-M4'Full), Janne Y. Y. Oeiras (46°; M1-M3'Full), Andrey Antonio de O. Rodrigues (48°; M5-M7'Full), and Adriana Lopes Damian (51°; M5-M7'Full).

Finally, we can highlight the authors who maintained or rose positions in the ranking for two consecutive moments (which comprises the interval of six editions): Elizabeth S. Furtado (11°; M3-M4'Full), Heloísa V. da Rocha (18°; M1-M2'Full), Natasha M. C. Valentim (19°; M6-M7'Full), Lucia Vilela Leite Filgueiras (25°; M3-M4'Full), Carla Faria Leitão (26°; M2-M3'Full), Leonardo Cunha de Miranda (28°; M3-M4'Full), Andréia Libório Sampaio (30°; M6-M7'Full), Christiane Gresse Von Wangenheim (35°; M6-M7'Full), Glívia A. R. Barbosa (37°; M6-M7'Full), Julio C. dos Reis (40°; M5-M6'Full), Lara Piccolo (41°; M3-M4'Full), Sérgio Roberto P. da Silva (45°; M1-M2'Full), and Carolina

Sacramento (50°; M5-M6'Full).

This publication variation map can also help in identifying authors who only rose in position, or that maintained the same position in the ranking since the moment in which they first published a paper to the seventh and last moment. These authors are (followed by their position in the final rank and the moment in which they first made a contribution to the track): M. Cecília C. Baranauskas (1°; M1), Milene S. Silveira (5°; M1), Vânia Almeida Neris (6°; M2), Cristiano Maciel (7°; M4), André Pimenta Freire (13°; M5), Isabela Gasparini (15°; M3), Luciana A. M. Zaina (17°; M5), Marcelle P. Mota (20°; M4), Ticianne de Gois R. Darin (27°; M5), Anna B. S. Marques (31°; M5), Ecivaldo de Souza Matos (36°; M5), Andrey Antonio de O. Rodrigues (48°; M5), and Adriana Lopes Damian (51°; M5). These authors maintained or increased their position throughout the moments since they started publishing in the Full Papers track.

In the publication variation map of the main authors of Full Papers, it was possible to see how the main authors have been contributing with articles in this track over the years. In Figure 6, aiming to complement the previous results, another overview is presented considering all of these main authors. In this sense, it is possible to identify the number of authors who published exactly a certain number of publications, in each of the seven different moments in the graph of Figure 6a. For example, in the first moment (i.e., M1'Full) there were 63 authors with a single published article, nine authors with exactly two published articles, and no author with exactly three published articles.

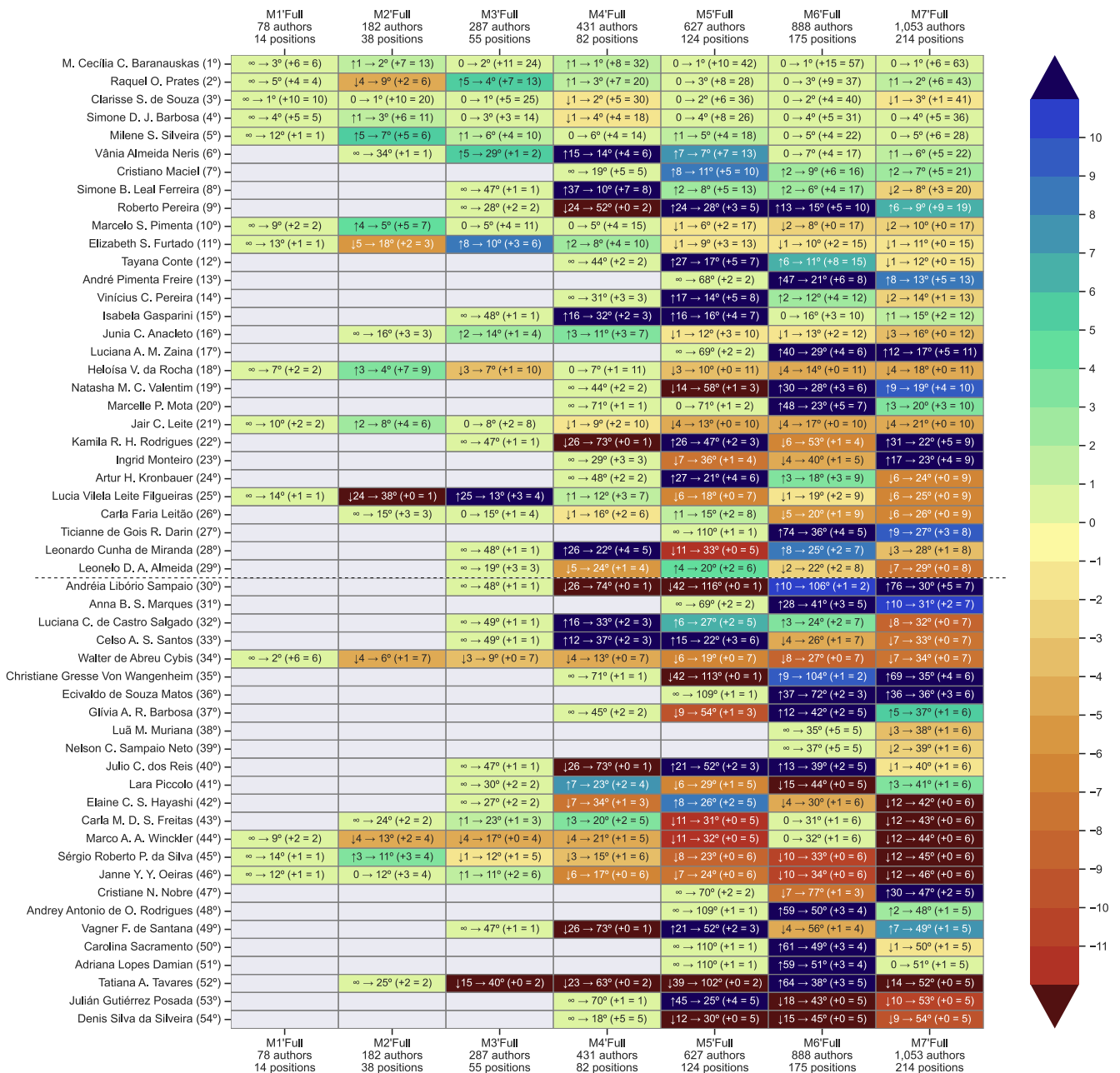


Figure 5. Publication variation map of the 54 main authors of Full Papers throughout the seven moments defined for this IHC track.

In contrast, in the last moment (i.e., M7'Full), it is possible to notice the existence of 774 authors with a single article, 144 authors with two articles, 51 authors with three articles, and even 30 authors with four articles. It is noticed, therefore, that there are 999 authors with less than five articles published of the total of 1,053 authors on this track. In Figure 6b we can observe the number of authors that have published at least a given number of articles in each of the seven moments. For example, in the case of moment M1'Full it is clear the existence of an author with at least 10 publications, and it is also clear that, in this same moment (i.e., M1'Full), there is no author with 11 or more publications. It is also possible to note that there are seven authors with at least 21 publications in moment M7'Full.

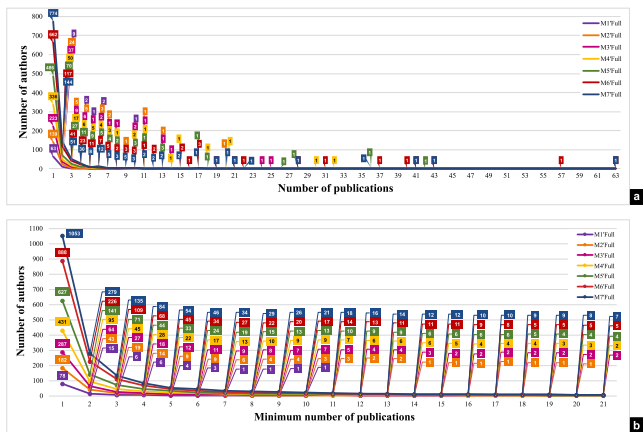


Figure 6. Number of authors, in the seven different moments defined for the Full Papers track of the IHC, according to: (a) the exact number of publications; and (b) the minimum number of publications.

When crossing the presented data, for example, in Figure 6b with Figure 5, we can identify who exactly are the seven authors with at least 21 publications, that is, the first seven “of the last column (i.e., M7'Full)” of the publication variation map of the Full Paper main authors. As seen, both graphs of Figure 6 complement the visualization presented in Figure 5 with additional information.

Moving on to the analysis of the **publication variation by IHC moment of Short Paper authors**, the 24 main authors of this track were selected to compose the publication variation map (Figure 7). In this map, as defined in Section 3.3.3, five different moments were considered for Short Papers, composed of the Symposium editions from 2002 to 2019. In a first look at the publication variation map of the main authors of Summarized Articles, we can identify, through the colors of the heat map, the moments in which the authors presented a sharp variation in the ranking, either up or down; these situations are represented by the colors located at the extremes of the color palette. We can also identify those authors who, over a sequence of moments, showed stability in the ranking or gained positions.

Unlike what happened in Full Papers, none of the main authors of Short Papers (i.e., 24 authors) went through all of the moments of the track (i.e., five) without losing positions in the ranking. However, one author kept this condition for four moments: Milene S. Silveira (2°; M2-M5'Short). It is also possible to identify the authors of this track who, for three consecutive moments, rose or remained in the same position in the ranking: Raquel O. Prates (1°; M3-M5'Short), Angelina C. A. Ziesemer (11°; M3-M5'Short), and Luana Müller (20°; M3-M5'Short).

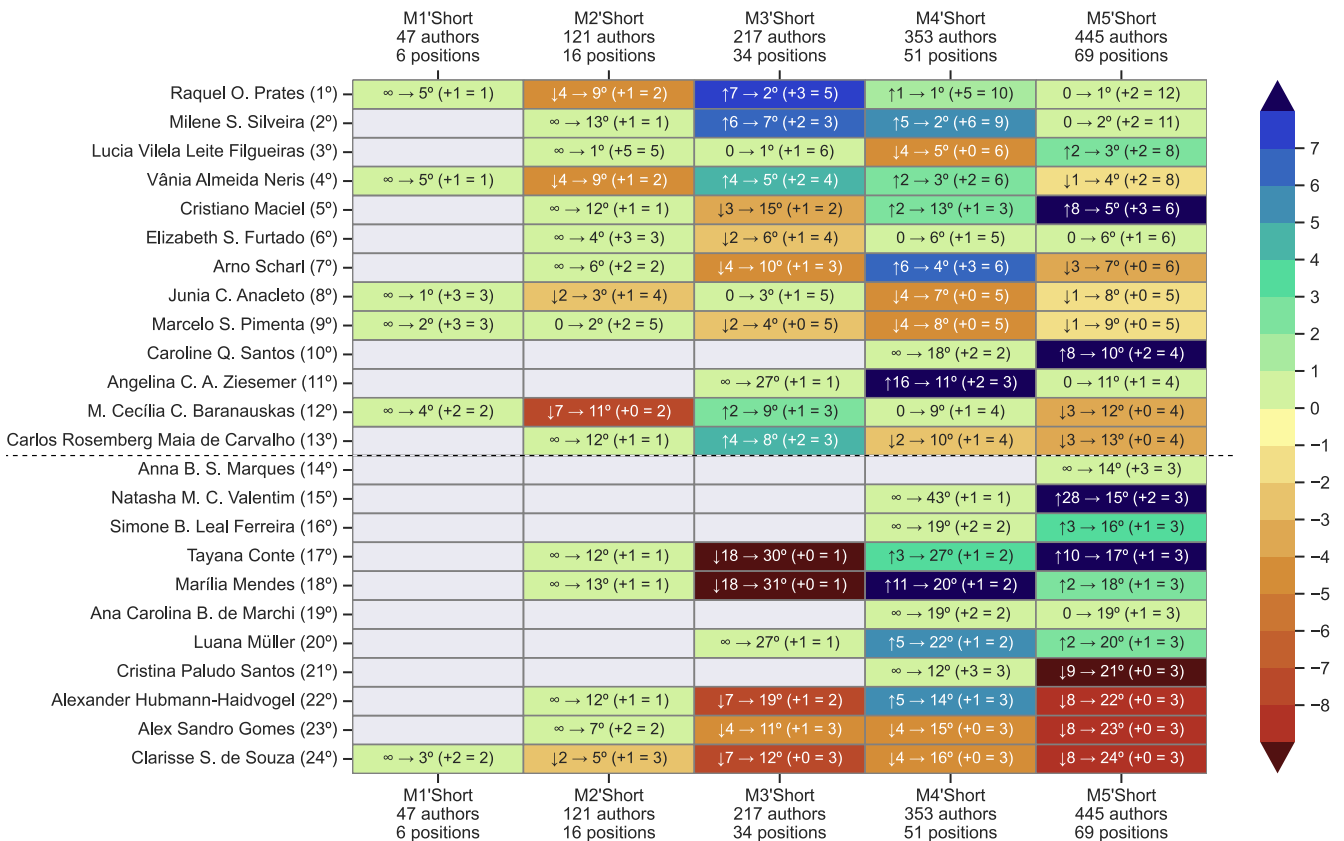


Figure 7. Publication variation map of the 24 main authors of Short Papers throughout the five moments defined for this IHC track.

Additionally, we can identify authors who maintained or increased their position in the ranking for two consecutive moments (which comprise intervals of five or six editions). These authors are a majority, totalling a group of 14 researchers, who are: Lucia Vilela Leite Filgueiras (3°; M2-M3'Short), Vânia Almeida Neris (4°; M3-M4'Short), Cristiano Maciel (5°; M4-M5'Short), Elizabeth S. Furtado (6°; M4-M5'Short), Marcelo S. Pimenta (9°; M1-M2'Short), Caroline Q. Santos (10°; M4-M5'Short), M. Cecília C. Baranauskas (12°; M3-M4'Short), Carlos Rosemberg Maia de Carvalho (13°; M2-M3'Short), Natasha M. C. Valentim (15°; M4-M5'Short), Simone B. Leal Ferreira (16°; M4-M5'Short), Tayana Conte (17°; M4-M5'Short), Marília Mendes (18°; M4-M5'Short), and Ana Carolina B. de Marchi (19°; M4-M5'Short).

It is also possible to notice authors who, from the first moment in the track that they published until the moment M5'Short, did not lose any positions in the ranking, that is, they only rose or maintained their position. These authors were: Milene S. Silveira (2°; M2'Short), Caroline Q. Santos (10°; M4'Short), Angelina C. A. Ziesemer (11°; M3'Short), Natasha M. C. Valentim (15°; M4'Short), Simone B. Leal Ferreira (16°; M4'Short), Ana Carolina B. da Marchi (19°; M4'Short), and Luana Müller (20°; M3'Short).

To complement the previous results, an overview of all authors of this track is presented in Figure 8. The graph in Figure 8a shows the total number of authors who have exactly a certain number of publications at each moment in this track. Upon observing this graph from the perspective of authors with a single publication, it can be seen that, for each moment, this number increases. For example, in moment M1'Short there were 41 authors with a single publication in this track, while in moment M5'Short there were 375 authors.

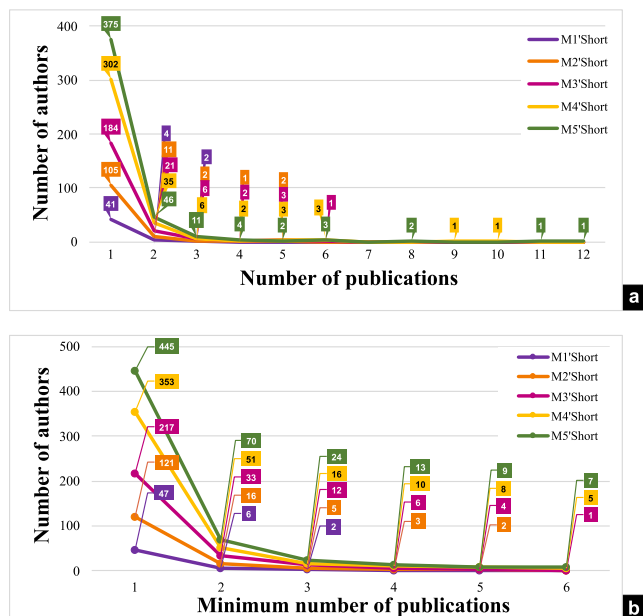


Figure 8. Number of authors in the five different moments defined for the Short Paper IHC track, according to: (a) the exact number of publications; and (b) the minimum number of publications.

Moving on to authors with more than a single publication, it can be seen that at the moment M1'Short only four authors had two articles published in this track, while at the moment M5'Short this number had increased to 46 authors. It is found,

therefore, that of the 445 authors in this track, there are 421 authors with less than three published articles. In the graph of Figure 8b, the total of authors with at least a given number of publications is presented for the different moments of Short Papers. When observing this graph, one can notice that, for example, only two authors present at least three publications in moment M1'Short.

When comparing, for example, the graph of Figure 8 to the visualization of Figure 7, one can observe that the seven authors with at least seven publications in moment M5'Short are, exactly, the seven first authors of the “last column” (i.e., M5'Short) of the publication variation map of Short Papers.

After presenting the results of the publication variation analysis by moments of the IHC for Full Papers and Short Papers, it is important to mention that the approach adopted for this research question, i.e., by using rankings, did not seek to compare the researcher-authors in relation to their contributions, generating any kind of competitiveness. The real goal was to seek to portray the history of the main authors of the IHC, presenting the evolution of their publications throughout the editions of the event. The results presented here also serve as a basis and complement for the following analyses, which will seek to answer other research questions.

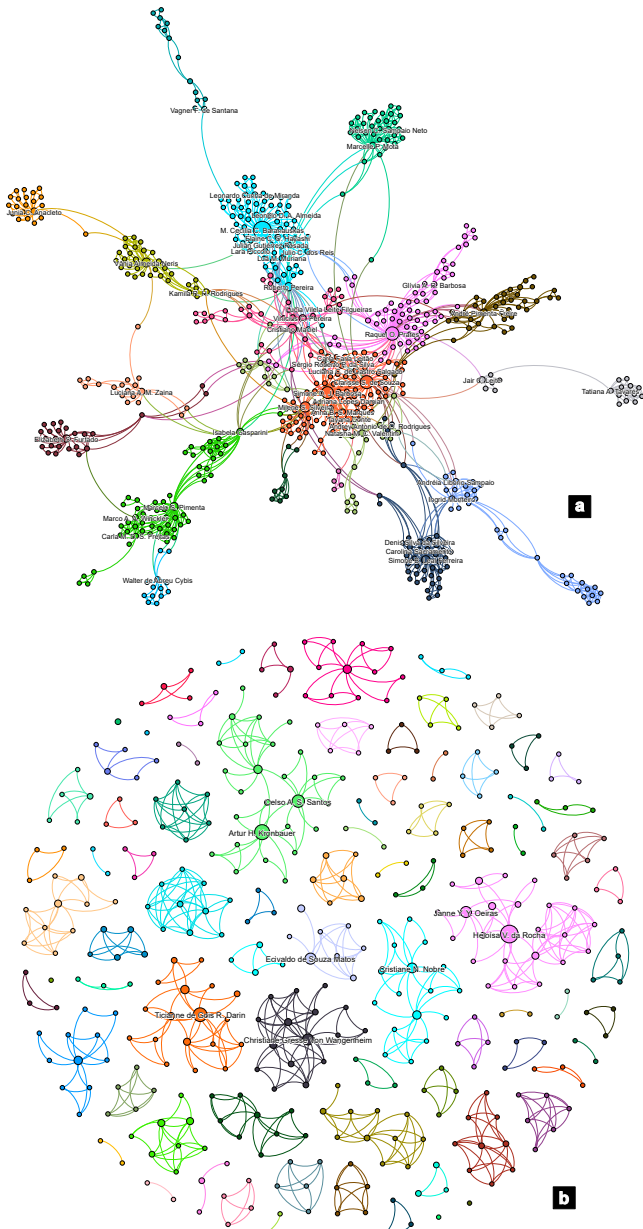
### 4.3 RQ3: What are the co-authorship networks of IHC articles?

The previous research question allowed to observe the contributions of the main authors of the tracks throughout the editions of the Symposium. However, visualizing the existing relationships between these authors, that is, mapping the “links” of these authors with each other in their own publications, could help to understand how they have been collaborating. Thus, this research question seeks to identify existing co-authorship networks from the articles of the Symposium tracks.

Figure 9 presents<sup>15</sup> the **co-authorship networks of the Full Papers track**. In this visualization, authors with five or more articles ( $N \geq 5$ ) had their names displayed. Most of the 1,053 authors on this track compose a large network of 652 researchers, with the main group of connected authors (Figure 9a). The remaining authors are distributed in a set of 81 smaller groups of authors, with 401 researchers (Figure 9b). The importance of the 54 main authors of this track is highlighted, 46 with their names displayed in (a) and eight with their names displayed in (b), since they represent only 5.13% of the Full Papers authors, but that have almost three-quarters of the articles published in this track (74.56%).

When observing the main group from the Full Papers track, it is possible to identify distinct clusters of authors (which are differentiated by colors in the visualization). Amongst these clusters, two present the highest number of main authors in the network (i.e., nine, in both). Considering the 18 authors from these two clusters, we may highlight M. Cecília C. Baranauskas and Clarisse S. de Souza as authors with the most publications in their respective clusters.

<sup>15</sup>In figures (a) and (b) of all co-authorship networks of this Section 4.3, the size of the vertices and the thickness of the edges are possibly in different scales.



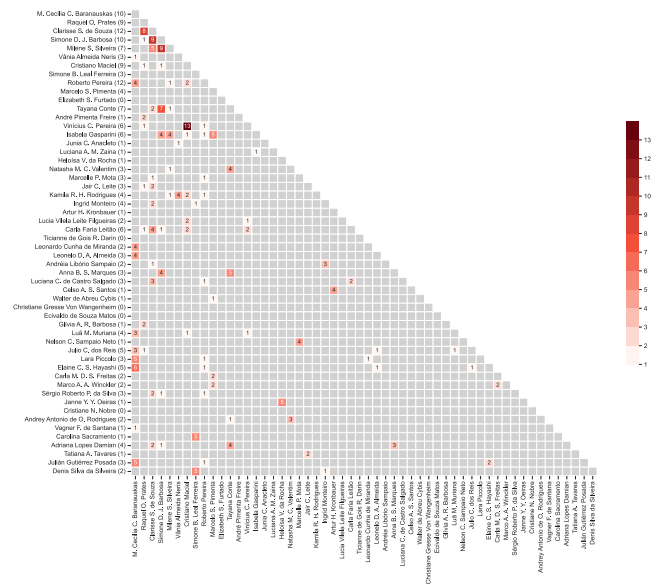
**Figure 9.** The general co-authorship networks of the Full Paper track of the IHC, from 1998 to 2022: (a) the main group; and (b) the 81 smaller groups.

Furthermore, it is interesting to observe the co-authorship relationship between authors from different clusters. In this sense, the relationships that stand out are those formed by: Raquel O. Prates and Clarisse S. de Souza, Isabela Gasparini and Simone D. J. Barbosa, and Isabela Gasparini and Milene S. Silveira. In the smaller groups of authors, we can observe that each of these groups represents a cluster in the network, given that they are isolated.

From the co-authorship networks of the Full Papers track, it is inferred that many connections (edges) between authors (vertices) were established, originally, due to a supervision relationship, that is, supervisor-supervised, in addition to other established relationships that may be traced to the time of formation of the authors, mainly at a postgraduate level. However, in this work we were able to visualize relationships between authors whose origin does not seem to be directly related to orientation or contemporaneity, but the result of other research interests that emerged over time and during the Symposium editions themselves.

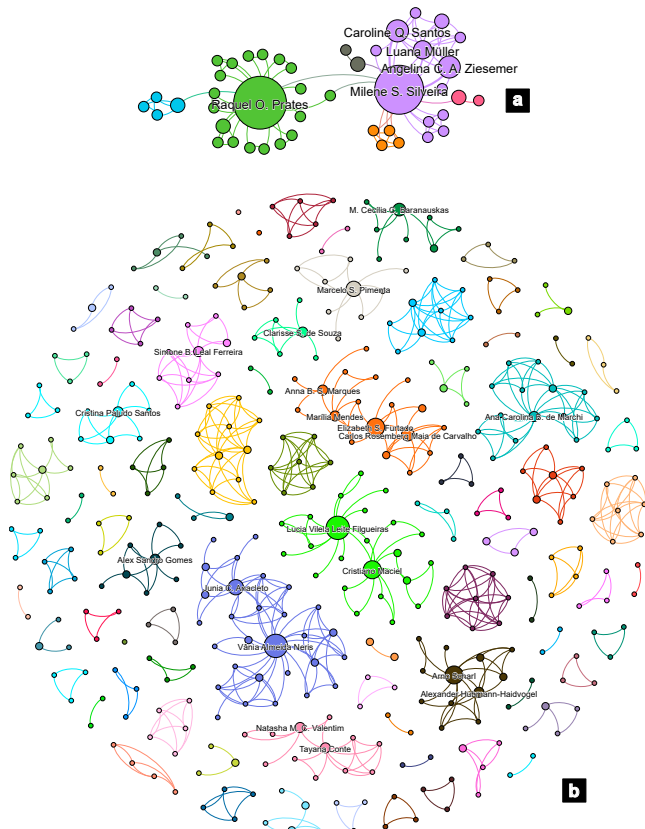
The networks presented above clarify these connections through, for example, links between authors from different clusters. In this sense, two scenarios seem possible: that the authors published together for whatever reasons at some point, even though they are from different clusters; and that the connections were initially established in the past and, over time, the author began to “separate” themselves from their original cluster, creating their own (and new) connections, for example, with their students.

Aiming to complement the visualization of the co-authorship networks of Full Papers, Figure 10 presents the co-authorship matrix of the track, which clarifies, in a quantitative manner, the collaborations between the main authors of the track; these values could help to better understand the size of the vertices and thickness of the edges of the networks. From this matrix, we can conclude that the main authors of the Full Papers track, Vinícius C. Pereira and Cristiano Maciel, were the pair of authors which most published together, with a total of 13 articles. Next, we can highlight two other pairs of authors who published, each pair, nine articles: Clarisse S. de Souza and Simone D. J. Barbosa, and Milene S. Silveira and Simone D. J. Barbosa.



**Figure 10.** Co-authorship matrix ( $N \geq 5$ ) of the Full Paper track of the IHC.

We can also highlight Clarisse S. de Souza and Roberto Pereira, the authors who published the most together with the other main authors of this track. Altogether, there were 12 different co-authorship relationships for each of them; in the visualization, this data appears, in parentheses, next to the name of each author. The visualization also shows the authors who published with ten authors amongst those in the matrix: M. Cecília C. Baranauskas and Simone D. J. Barbosa, and the authors who published with nine other authors: Raquel O. Prates and Cristiano Maciel. For the **co-authorship networks of the Short Papers track**, 445 authors were considered to generate the visualizations of Figure 11. Differently from the Full Papers track, where most of the authors formed a large, connected group, the authors of the Short Papers track are more spread out into smaller groups, being the largest of them composed of 45 authors (Figure 11a).



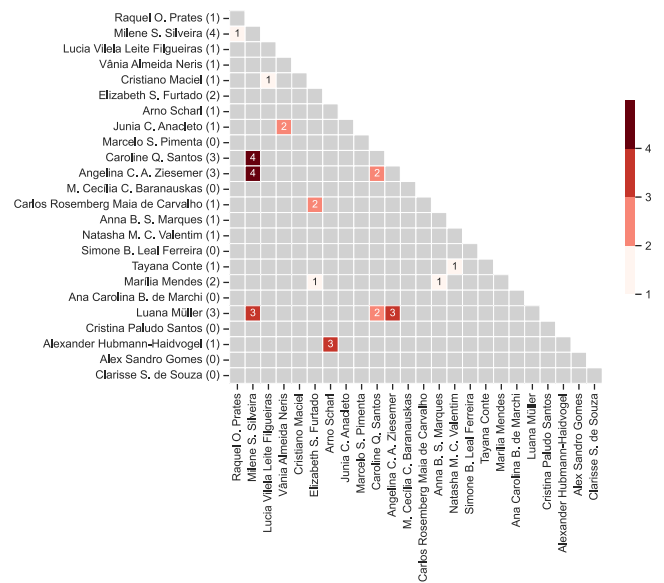
**Figure 11.** The general co-authorship network for the Short Papers track of the IHC, from 2002 to 2019: (a) main group; and (b) the 84 smaller groups.

The remaining authors are distributed into 84 smaller groups, totalling 400 authors (Figure 11b). In this visualization the names of authors with three or more articles ( $N \geq 3$ ) are displayed, with a total of 24 authors, being five of the main group and the remaining 19 in the smaller groups. It is worth mentioning the importance of this authors for the Short Papers track, as despite representing only 5.39% of the 445 track authors, they contributed to almost half of the published articles (i.e., 48.69%).

In the co-authorship networks of the Short Papers track, the number of isolated groups, although similar, is slightly higher than Full Papers. However, by observing the size of the networks, it can be noticed that, for Short Papers, the authors are much less distributed between the smaller groups than the authors in the main group. In a general sense, the portion of authors that are in the main group and those in the smaller groups are, respectively, 10.11% and 89.89%, while those values for Full Papers are 61.92% and 38.08%. This indicates that authors are more spread out in this track, and they also appear not to seek new co-authorship relationships, in contrast to what can be observed in Full Papers.

Considering the main group, two clusters stand out, being one from Raquel O. Prates and the other one from Milene S. Silveira. Regarding the 84 smaller groups, it is possible to observe that the majority of the main authors of the track are in those groups, such as Vânia Almeida Neris and Junia C. Anacleto, who are in the biggest group amongst those 84, and Lucia Vilela Leite Filgueiras and Cristiano Maciel, who are in the second biggest group. It is also worth to highlight the third biggest group, which presents four of the main authors of the track: Elizabeth S. Furtado, Carlos Rosemberg Maia de Carvalho, Anna B. S. Marques, and Marília Mendes.

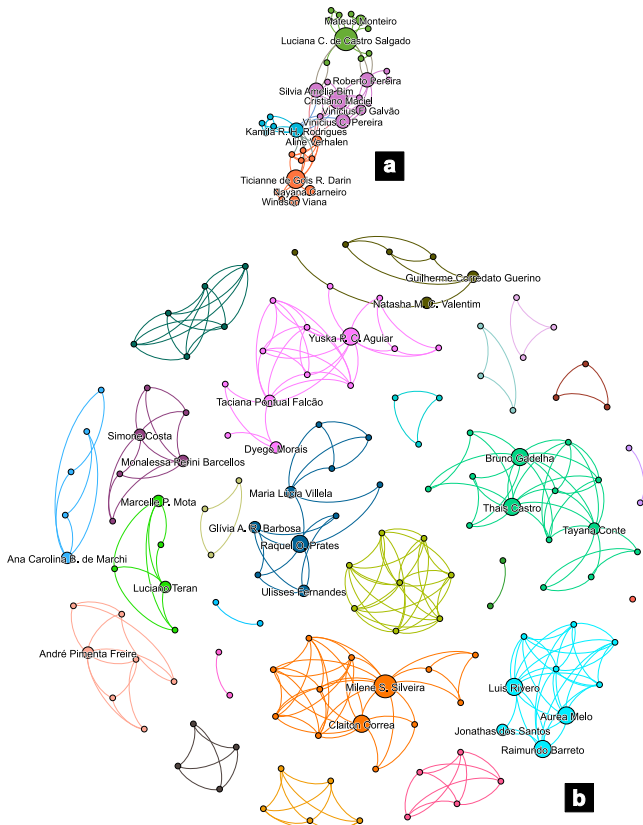
In the co-authorship matrix of the Short Papers track (Figure 12), one can see in a quantitative manner the collaboration between the main authors of this track. From this matrix, it is noticed that Milene S. Silveira presents the highest number of co-authorship relations with the main authors of the track (i.e., four). The author Milene S. Silveira published four articles in partnership with Caroline Q. Santos and four with Angelina C. A. Ziesemer; these two are the highest co-authorship relationships indicated in this matrix.



**Figure 12.** Co-authorship matrix ( $N \geq 3$ ) for Short Papers of the IHC.

Regarding the co-authorship networks of the Innovative Ideas and Emerging Results track (Figure 13), the 177 authors of this track are divided into 26 isolated groups, with the main group (Figure 13a) containing 36 authors, while the 25 smaller groups (Figure 13b) contain 141 authors. In this visualization all authors with two or more publications ( $N \geq 2$ ) had their names displayed. In total, these were 36 authors, being 12 in the main group and the remaining 24 in the smaller groups. As with the other tracks, it is worth mentioning the importance of these 36 authors, since they represent 20.34% of the 177 authors of the Innovative Ideas and Emerging Results track, but contributed to a little more than three-quarters of all articles in this track (75.41%).

It can also be noted that three editions of this track were enough for the formation of a co-authorship network composed by a main group of 36 authors. On the other hand, most of the authors of the track remain isolated in the 25 smaller groups. Figure 14 presents the co-authorship matrix of the 36 main authors of this track. Even with only three editions, it is possible to observe pairs of authors that already published three times in the track: Vinicius C. Pereira and Cristiano Maciel, Claiton Correa and Milene S. Silveira, Luis Rivero and Aurea Melo, Luis Rivero and Raimundo Barreto, Raimundo Barreto and Aurea Melo, and Bruno Gadelha and Thais Castro. From the 36 main authors of this track, Cristiano Maciel and Vinicius C. Pereira are the authors who most published (i.e., six) with other authors who are present in this matrix of the main authors of the track.

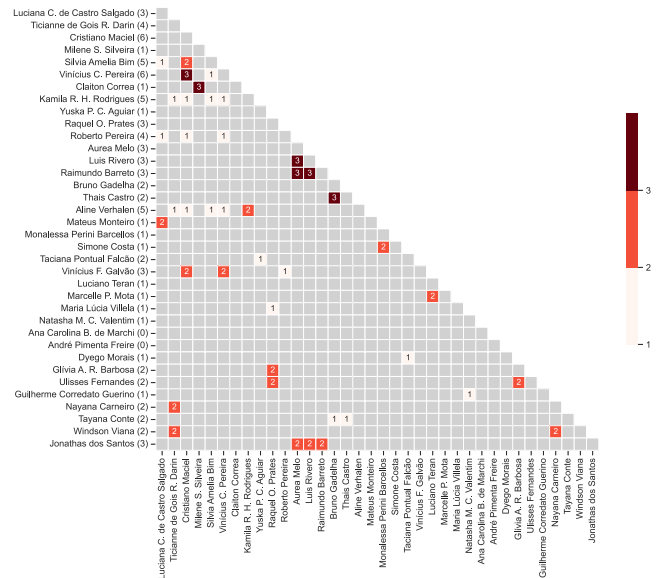


**Figure 13.** The general co-authorship networks of articles from the Innovative Ideas and Emerging Results track of the IHC, from 2020 to 2022: (a) the main group; and (b) the 25 smaller.

Given the presentation of the results of this research question, it is important to mention that the co-authorship matrix is a visualization that aims at complementing the co-authorship network, providing data that quantifies the relationships between authors, which is visible in the co-authorship network only through the thickness of the edges. The co-authorship matrix, despite being a useful visualization, has certain limitations as it cannot accurately map relationships between a larger set of authors, such as, for example, trios, quartets and quintets; these groups with more than two authors can be “hidden” in this visualization. Thus, these other relationships will be better explored in the next research question.

#### 4.4 RQ4: How has the collaboration between authors of the IHC evolved over the years?

Section 4.2 presented a temporal analysis of the main authors of Full Papers and Short Papers of the IHC, thus expanding the analysis performed in Section 4.1. This research question resumes this temporal analysis in an analogous way, that is, after presenting and analysing the co-authorship networks in Section 4.3, this section verifies how collaborations between authors of Full Papers and Short Papers tracks have evolved over the years. With this research question, the seek to expand the results presented in the previous section, where it was possible to perceive the evolution of the pairs of authors from the networks and the co-authorship matrix considering, for example, the thickness of the edges and the values presented in cells, respectively. However, we can go further and analyse groups with three or more co-authors, which may reveal



**Figure 14.** Co-authorship matrix ( $N \geq 2$ ) of the Innovative Ideas and Emerging Results track of the IHC.

trios, quartets, quintets, etc. who collaborated in different publications. This way, we can identify these larger groups of authors that, until then, were “hidden” in the structure of the networks and in the co-authorship matrix, and verify how they published or migrated between groups over the editions of the IHC.

Therefore, the **main groups of authors of the Full Papers track** were selected. It is worth to keep in mind, as described in Section 3.3.6, that the selection process considered as a first criterion (i) the groups that presented, at least, one author of the 54 main authors of Full Papers. From these groups, and based on criterion (ii.a), the groups of authors who published together more than once were selected. At the same time, criterion (ii.b) was applied from the resulting set after the application of (i) and, therefore, the groups that presented subgroups of authors in common were also selected, as defined by (ii.b). It is interesting to observe that it may exist groups selected, simultaneously, by both (ii.a) and (ii.b), that is, those with two or more publications that present a subgroup of authors in common with other groups.

In total, it was identified 564 groups of authors and, from those, 172 groups (i.e., 30.50%) were selected, being 33 through criterion (ii.a) and 139 through criterion (ii.b), both after the application of criterion (i). From these 172 groups, 63 are composed by two authors, 58 by three, 29 by four, 14 by five, seven by six, and one by eight.

Tables 1 to 4 present, in total, the 172 main groups of authors of the Full Papers track. In these tables, for each exact group of authors, it is presented the number of publications that they have together ( $N$ ) and which groups are contained in them (subgroups), either from Full Papers or from Short Papers. From these groups, we can highlight those compose, exclusively, by authors classified as main authors from the track, which are (26): G2\_6, G2\_7, G2\_8, G2\_12, G2\_16, G2\_17, G2\_34, G2\_36, G2\_47, G2\_51, G2\_62, G2\_63, G2\_65, G2\_105, G2\_158, G2\_165, G3\_6, G3\_7, G3\_8, G3\_48, G3\_91, G3\_96, G3\_117, G3\_131, G4\_42, G4\_52.

**Table 1.** The 62 main pairs of authors of the Full Papers track of the IHC. Names in bold indicate the main authors of the track, and groups tagged with (\*) are composed, exclusively, by main authors of the track.

ID	Authors name	N	Subgroups
G2_1	<b>M. Cecília C. Baranauskas</b> , Osvaldo Luiz de Oliveira	3	n.a.
G2_2	Alysson B. Prado, <b>M. Cecília C. Baranauskas</b>	3	n.a.
G2_6 (*)	<b>Clarisse S. de Souza</b> , <b>Jair C. Leite</b>	1	n.a.
G2_7 (*)	<b>Clarisse S. de Souza</b> , <b>Raquel O. Prates</b>	1	n.a.
G2_8 (*)	<b>Clarisse S. de Souza</b> , <b>Simone D. J. Barbosa</b>	1	n.a.
G2_12 (*)	<b>Heloisa V. da Rocha</b> , <b>Janne Y. Y. Oeiras</b>	2	n.a.
G2_16 (*)	<b>Clarisse S. de Souza</b> , <b>Sérgio Roberto P. da Silva</b>	2	n.a.
G2_17 (*)	<b>Jair C. Leite</b> , <b>Tatiana A. Tavares</b>	2	n.a.
G2_18	<b>M. Cecília C. Baranauskas</b> , Marcos Augusto F. Borges	2	n.a.
G2_20	Amanda Meincke Melo, <b>M. Cecília C. Baranauskas</b>	2	n.a.
G2_24	Celmar Guimarães da Silva, <b>Heloisa V. da Rocha</b>	1	n.a.
G2_29	<b>Heloisa V. da Rocha</b> , Luciana A. S. Romani	1	n.a.
G2_33	Maira Greco de Paula, <b>Simone D. J. Barbosa</b>	1	n.a.
G2_34 (*)	<b>Milene S. Silveira</b> , <b>Simone D. J. Barbosa</b>	1	n.a.
G2_36 (*)	<b>Leonelo D. A. Almeida</b> , <b>M. Cecília C. Baranauskas</b>	3	n.a.
G2_37	<b>Raquel O. Prates</b> , Rodrigo Ferreira da Silva	2	n.a.
G2_39	Albert Schilling Gomes, <b>Elizabeth S. Furtado</b>	1	n.a.
G2_47 (*)	<b>Elaine C. S. Hayashi</b> , <b>M. Cecília C. Baranauskas</b>	3	n.a.
G2_49	<b>Jair C. Leite</b> , Lirisei Gomes de Sousa	1	n.a.
G2_50	<b>Jair C. Leite</b> , Macilón Araújo Costa Neto	2	n.a.
G2_51 (*)	<b>Lara Piccolo</b> , <b>M. Cecília C. Baranauskas</b>	3	n.a.
G2_53	<b>Lucia Vilela Leite Filgueiras</b> , Plínio Thomaz Aquino Jr.	1	n.a.
G2_58	<b>Milene S. Silveira</b> , Tiago da Silva	1	n.a.
G2_62 (*)	<b>Cristiano Maciel</b> , <b>Vinicius C. Pereira</b>	2	n.a.
G2_63 (*)	<b>Artur H. Kronbauer</b> , <b>Celso A. S. Santos</b>	2	n.a.
G2_64	Bruno Santana da Silva, <b>Simone D. J. Barbosa</b>	1	n.a.
G2_65 (*)	<b>Clarisse S. de Souza</b> , <b>Ingrid Monteiro</b>	1	n.a.
G2_66	Débora Maurmo Modesto, <b>Simone B. Leal Ferreira</b>	1	n.a.
G2_67	Eduardo H. Tanaka, <b>Heloisa V. da Rocha</b>	1	n.a.
G2_71	Franco Eusebio Garcia, <b>Vânia Almeida Neris</b>	1	n.a.
G2_74	Heiko Hormung, <b>M. Cecília C. Baranauskas</b>	1	n.a.
G2_80	Luana Müller, <b>Milene S. Silveira</b>	1	n.a.
G2_81	<b>M. Cecília C. Baranauskas</b> , Roberto Romani	1	n.a.
G2_82	<b>M. Cecília C. Baranauskas</b> , Samuel B. Buchdid	1	n.a.
G2_88	Tatiana Alencar, <b>Vânia Almeida Neris</b>	2	n.a.
G2_90	Bernardo Alves Villarinho Lima, <b>Leonelo D. A. Almeida</b>	2	n.a.
G2_98	<b>Eivaldo de Souza Matos</b> , Jean C. S. Rosa	1	n.a.
G2_99	Emanuelly F. M. Barros, <b>Raquel O. Prates</b>	1	n.a.
G2_100	Guilherme C. Pereira, <b>M. Cecília C. Baranauskas</b>	2	n.a.
G2_105 (*)	<b>Julián Gutiérrez Posada</b> , <b>M. Cecília C. Baranauskas</b>	1	n.a.
G2_107	Manoel Pereira Junior, <b>Raquel O. Prates</b>	1	n.a.
G2_109	Maria Lúcia Vilela, <b>Raquel O. Prates</b>	1	n.a.
G2_110	<b>Raquel O. Prates</b> , Simone I. R. Xavier	1	n.a.
G2_111	Renata Bianchi, <b>Vânia Almeida Neris</b>	1	n.a.
G2_112	Rogério Aparecido Campanari Xavier, <b>Vânia Almeida Neris</b>	1	n.a.
G2_113	Daniel Domingos Alves, <b>Eivaldo de Souza Matos</b>	3	n.a.
G2_114	André de Oliveira Bueno, <b>Junia C. Anacleto</b>	1	n.a.
G2_115	<b>André Pimenta Freire</b> , Lucas Pedrosso Carvalho	1	n.a.
G2_117	<b>Artur H. Kronbauer</b> , João Batista da Silva Júnior	1	n.a.
G2_118	Bianca Melo, <b>Tecianne de Gois R. Darin</b>	1	n.a.
G2_122	Eliana A. Moreira, <b>M. Cecília C. Baranauskas</b>	1	n.a.
G2_124	Emanuel Felipe Duarte, <b>M. Cecília C. Baranauskas</b>	1	n.a.
G2_127	Fabrice H. Sales Pereira, <b>Raquel O. Prates</b>	1	n.a.
G2_134	<b>Junia C. Anacleto</b> , Vinicius Ferreira	1	n.a.
G2_139	<b>M. Cecília C. Baranauskas</b> , Marley Luque Carbaljal	2	n.a.
G2_141	<b>M. Cecília C. Baranauskas</b> , Yusseli L. M. Mendoza	1	n.a.
G2_152	Deógenes P. da Silva Junior, <b>Roberto Pereira</b>	1	n.a.
G2_158 (*)	<b>Glívia A. R. Barbosa</b> , <b>Raquel O. Prates</b>	1	n.a.
G2_160	José V. da Silva, <b>M. Cecília C. Baranauskas</b>	1	n.a.
G2_163	<b>Luciana A. M. Zaina</b> , Süellen Martinelli	1	n.a.
G2_165 (*)	<b>Luã M. Muriana</b> , <b>M. Cecília C. Baranauskas</b>	1	n.a.
G2_166	Maira Codo Canal, <b>Roberto Pereira</b>	1	n.a.
G2_168	<b>Raquel O. Prates</b> , Tatiane G. Guimarães	1	n.a.

In relation to the evolution of the collaboration between the authors of the Full Papers track, the timeline of the main groups of authors of this track (Figure 15) illustrated the evolution and the relations of these 172 main groups. Upon observing this visualization, we can identify for example, the groups selected through criterion (ii.a), which published in more than one edition or presented two or more publications in a single edition of Full Papers, after the application of criterion (i).

In total, there were 33 groups of authors with at least two publications and that presented, at least, one of the 54 main authors of the track: G2\_1, G2\_2, G2\_12, G2\_16, G2\_17, G2\_18, G2\_20, G2\_36, G2\_37, G2\_47, G2\_50, G2\_51, G2\_62, G2\_63, G2\_88, G2\_90, G2\_100, G2\_113, G2\_139, G3\_7, G3\_16, G3\_17, G3\_82, G3\_83, G3\_91, G3\_96, G3\_100, G3\_104, G3\_131, G3\_132, G3\_160, G4\_79, G5\_23. From these 33 groups, only one presented all publications in a single edition of Full Papers (i.e., G3\_83), while the other groups had their publications distributed in more than one edition.

In addition, we can highlight groups of authors that present the longest sequence of publications in distinct editions.

**Table 2.** The 58 main trios of authors of the Full Papers track of the IHC. Names in bold indicate the main authors of the track, and groups tagged with (\*) are composed, exclusively, by main authors of the track.

ID	Authors name	N	Subgroups
G3_4	Celmar Guimarães da Silva, <b>Heloisa V. da Rocha</b> , Luciana A. S. Romani	1	G2_24 & G2_29
G3_5	<b>Clarisse S. de Souza</b> , Claudia de Castro O. Monteiro, <b>Simone D. J. Barbosa</b>	1	G2_8
G3_6 (*)	<b>Clarisse S. de Souza</b> , <b>Jair C. Leite</b> , <b>Raquel O. Prates</b>	1	G2_6 & G2_7
G3_7 (*)	<b>Clarisse S. de Souza</b> , <b>Milene S. Silveira</b> , <b>Simone D. J. Barbosa</b>	2	G2_8 & G2_34
G3_8 (*)	<b>Clarisse S. de Souza</b> , <b>Raquel O. Prates</b> , <b>Simone D. J. Barbosa</b>	1	G2_7 & G2_8
G3_9	<b>Clarisse S. de Souza</b> , <b>Raquel O. Prates</b> , Tom Carey	1	G2_7
G3_11	Flávia Rossler, <b>M. Cecília C. Baranauskas</b> , Osvaldo Luiz de Oliveira	1	G2_1
G3_16	Ana Maria Nicolaci-da-Costa, <b>Carla Faria Leitão</b> , Daniela Romão-Dias	2	n.a.
G3_17	Claudia Bauzer Medeiros, Juliano Schimiguel, <b>M. Cecília C. Baranauskas</b>	3	n.a.
G3_22	<b>Carla M. D. S. Freitas</b> , Paulo R. G. Luzzardi, Ricardo A. Cava	1	n.a.
G3_24	Clarissa M. de A. Barbosa, <b>Clarisse S. de Souza</b> , <b>Raquel O. Prates</b>	1	G2_7
G3_25	<b>Clarisse S. de Souza</b> , Gilda Dahis, <b>Simone D. J. Barbosa</b>	1	G2_8
G3_29	Elton Santana, <b>Jair C. Leite</b> , Lirisei Gomes de Sousa	1	G2_49
G3_30	<b>Heloisa V. da Rocha</b> , <b>Janne Y. Y. Oeiras</b> , José Claudio Vahl Júnior	1	G2_12
G3_35	Albert Schilling Gomes, David Falcao Barbosa, <b>Elizabeth S. Furtado</b>	1	G2_39
G3_38	Bruno Santana da Silva, <b>Simone D. J. Barbosa</b> , Viviane Cristina Oliveira Aureliano	1	G2_64
G3_48 (*)	<b>Lara Piccolo</b> , <b>Leonardo Cunha de Miranda</b> , <b>M. Cecília C. Baranauskas</b>	1	G2_51
G3_49	<b>Lucia Vilela Leite Filgueiras</b> , Mauricio Cirelli, Plínio Thomaz Aquino Jr.	1	G2_53
G3_54	<b>Milene S. Silveira</b> , Otávio A. Martins Netto, <b>Simone D. J. Barbosa</b>	1	G2_34
G3_56	Alessandro José de Souza, <b>Jair C. Leite</b> , Macilón Araújo Costa Neto	1	G2_50
G3_59	<b>Artur H. Kronbauer</b> , <b>Celso A. S. Santos</b> , Vânia Maria Vieira	1	G2_63
G3_63	<b>Clarisse S. de Souza</b> , Eduardo Tommo Tolmasquim, <b>Ingrid Monteiro</b>	1	G2_65
G3_66	<b>Cristiano Maciel</b> , <b>Lucia Vilela Leite Filgueiras</b> , Luciana Borges	1	n.a.
G3_71	Franco Eusebio Garcia, Rogério Aparecido Campanari Xavier, <b>Vânia Almeida Neris</b>	1	G2_71 & G2_112
G3_73	<b>Glívia A. R. Barbosa</b> , Luiz Paulo Damilton Corrêa, <b>Raquel O. Prates</b>	1	G2_158
G3_75	<b>Isabela Gasparini</b> , Marcelo S. Pimenta, Marcos H. Kimura	1	n.a.
G3_76	<b>Julián Gutiérrez Posada</b> , <b>M. Cecília C. Baranauskas</b> , Roberto Romani	1	G2_105 & G2_81
G3_80	Manoel Pereira Junior, <b>Raquel O. Prates</b> , Simone I. R. Xavier	1	G2_107 & G2_110
G3_81	Maria Lúcia Vilela, <b>Raquel O. Prates</b> , Simone I. R. Xavier	1	G2_109 & G2_110
G3_82	Aron Daniel Lopes, <b>Cristiano Maciel</b> , <b>Vinicius C. Pereira</b>	2	G2_62
G3_83	Luiz Gustavo de Souza, <b>Simone D. J. Barbosa</b> , <b>Tayana Conte</b>	2	n.a.
G3_91 (*)	<b>Anna B. S. Marques</b> , <b>Simone D. J. Barbosa</b> , <b>Tayana Conte</b>	2	n.a.
G3_95	Bruno Brochado Ribeiro, Débora Maurmo Modesto, <b>Simone B. Leal Ferreira</b>	1	G2_66
G3_96 (*)	<b>Carla Faria Leitão</b> , <b>Cristiano Maciel</b> , <b>Vinicius C. Pereira</b>	2	G2_62
G3_100	<b>Clarisse S. de Souza</b> , Luana Müller, <b>Milene S. Silveira</b>	2	G2_80
G3_101	<b>Clarisse S. de Souza</b> , Mary Beth Rossom, <b>Raquel O. Prates</b>	1	G2_7
G3_104	Claudio S. Pinhanez, Rogério Abreu de Paula, <b>Vagner F. de Santana</b>	2	n.a.
G3_112	Evertton M. de Menezes, Heiko Hormung, <b>M. Cecília C. Baranauskas</b>	1	G2_74
G3_114	Franco Eusebio Garcia, <b>Kamila R. H. Rodrigues</b> , <b>Vânia Almeida Neris</b>	1	G2_71
G3_117 (*)	<b>Isabela Gasparini</b> , <b>Milene S. Silveira</b> , <b>Simone D. J. Barbosa</b>	1	G2_34
G3_125	<b>Julián Gutiérrez Posada</b> , <b>M. Cecília C. Baranauskas</b> , Vanessa R. M. L. Maíke	1	G2_105
G3_128	<b>M. Cecília C. Baranauskas</b> , Samuel B. Buchdid, Vanessa R. M. L. Maíke	1	G2_82
G3_129	Marcelo Barbosa, Tatiana Alencar, <b>Vânia Almeida Neris</b>	1	G2_88
G3_131 (*)	<b>Adriana Lopes Damian</b> , <b>Clarisse S. de Souza</b> , <b>Tayana Conte</b>	2	n.a.
G3_132	Luciano Silva, <b>Roberto Pereira</b> , Rúbia E. O. Schultz Ascari	3	n.a.
G3_139	<b>Andrey Antonio de O. Rodrigues</b> , Eduardo Feitosa, <b>Natasha M. C. Valentim</b>	1	n.a.
G3_143	<b>André Pimenta Freire</b> , Lucas Pedrosso Carvalho, <b>Raquel O. Prates</b>	1	G2_115
G3_145	<b>Artur H. Kronbauer</b> , Jorge Campos, João Batista da Silva Júnior	1	G2_117
G3_146	Bernardo Alves Villarinho Lima, <b>Leonelo D. A. Almeida</b> , Patricia Leite	1	G2_90
G3_151	Cassio T. Batista, Erick M. Campos, <b>Nelson C. Sampaio Neto</b>	1	n.a.
G3_158	Eliana A. Moreira, <b>Julio C. dos Reis</b> , <b>M. Cecília C. Baranauskas</b>	1	G2_122
G3_159	Fabrice H. Sales Pereira, Fernanda Tempesta, <b>Raquel O. Prates</b>	1	G2_127
G3_160	Franklin M. da C. Lima, <b>Leonardo Cunha de Miranda</b> , <b>M. Cecília C. Baranauskas</b>	2	n.a.
G3_177	Adriano Ferretti Borgatto, Adriano Lima, <b>Christiane Gresse Von Wengenheim</b>	1	n.a.
G3_181	<b>Andrey Antonio de O. Rodrigues</b> , Eduardo Feitosa, Maria Lúcia Vilela	1	n.a.
G3_187	Bianca Melo, Rossana M. de C. Andrade, <b>Tecianne de Gois R. Darin</b>	1	G2_118
G3_199	<b>Kamila R. H. Rodrigues</b> , Renata Bianchi, <b>Vânia Almeida Neris</b>	1	G2_111
G3_200	Larissa Albano Lopes, <b>Luciana A. M. Zaina</b> , Süellen Martinelli	1	G2_163

For two distinct editions, there are 24 groups: G2\_12 (IHC'00 and '02), G3\_7 (IHC'00 and '02), G2\_16 (IHC'01 and '02), G2\_17 (IHC'01 and '02), G3\_16 (IHC'01 and '04), G2\_18 (IHC'02 and '04), G2\_20 (IHC'02 and '06), G2\_50 (IHC'06 and '13), G2\_37 (IHC'08 and '10), G2\_63 (IHC'11 and '14), G2\_62 (IHC'12 and '13), G2\_88 (IHC'13 and '14), G3\_82 (IHC'14 and '15), G3\_104 (IHC'14 and '17), G2\_100 (IHC'15 and '17), G3\_100 (IHC'15 and '18), G2\_90 (IHC'16 and '18), G3\_91 (IHC'16 and '17), G3\_96 (IHC'16 and '17), G3\_131 (IHC'17 and '19), G4\_79 (IHC'17 and '20), G5\_23 (IHC'17 and '18), G3\_160 (IHC'18 and '22), and G2\_139 (IHC'19 and '20).

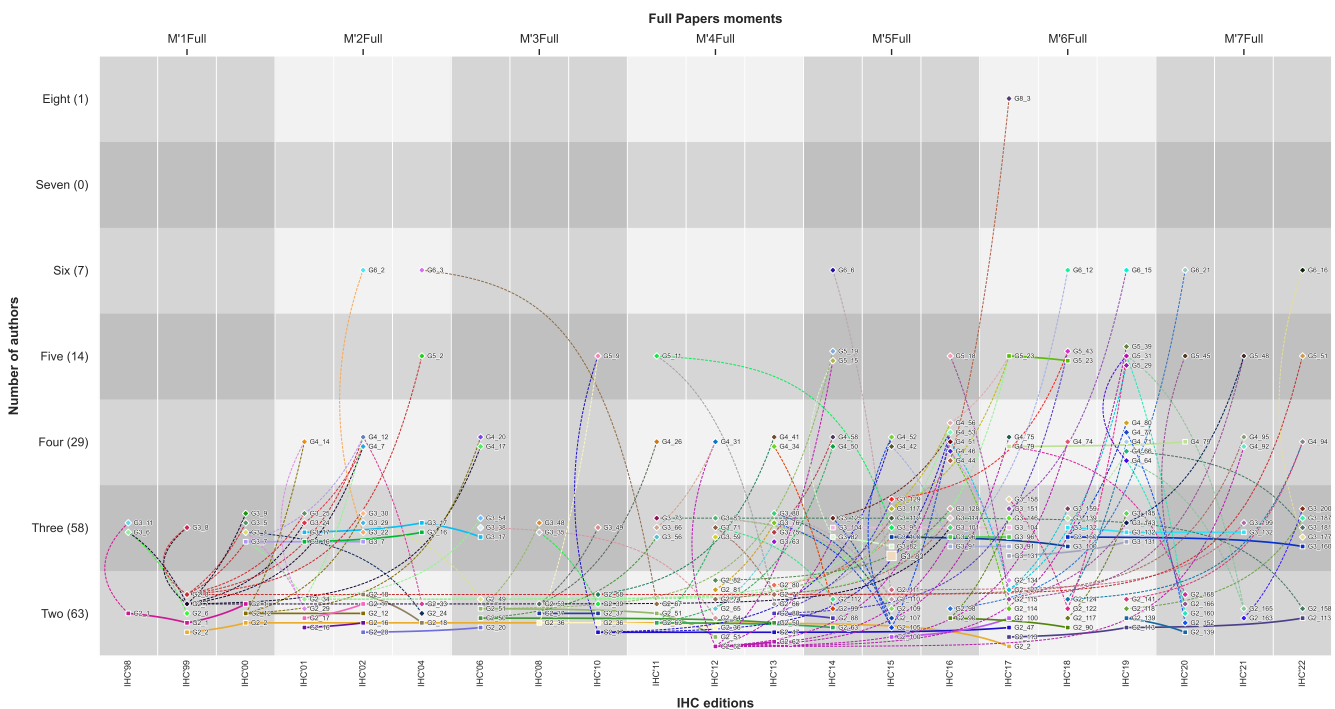


**Table 3.** The 29 main quartets of authors of the Full Papers track of the IHC. Names in bold indicate main authors of the track, and groups tagged with (\*) are composed, exclusively, by main authors.

ID	Authors name	N	Subgroups
G4_7	Ana Maria Nicolaci-da-Costa, Clarissa M. de A. Barbosa, <b>Clarisse S. de Souza, Raquel O. Prates</b>	1	G2_7 & G3_24
G4_12	<b>Clarisse S. de Souza</b> , Maira Greco de Paula, <b>Milene S. Silveira, Simone D. J. Barbosa</b>	1	G2_8, G2_33, G2_34 & G3_7
G4_14	Fernanda M. P. Freire, <b>Heloisa V. da Rocha, Janne Y. Y. Oeiras</b> , Luciana A. S. Romani	1	G2_12 & G2_29
G4_17	<b>Carla Faria Leitão, Clarisse S. de Souza</b> , Elton José da Silva, <b>Raquel O. Prates</b>	1	G2_7
G4_20	Fernanda M. P. Freire, <b>Heloisa V. da Rocha, Janne Y. Y. Oeiras</b> , Ricardo Luis Lachi	1	G2_12
G4_26	Andrey Masiero, <b>Lucia Vilela Leite Filgueiras</b> , Mayara Gonçalves Leite, Plínio Thomaz Aquino Jr.	1	G2_53
G4_31	<b>Cristiano Maciel, Lucia Vilela Leite Filgueiras</b> , Luciana Borges, <b>Vinicius C. Pereira</b>	1	G2_62 & G3_66
G4_34	Emanuelly F. M. Barros, Lidia Silva Ferreira, Natália S. Santos, <b>Raquel O. Prates</b>	1	G2_99
G4_41	<b>Milene S. Silveira, Natasha M. C. Valentim, Tayana Conte</b> , Tiago da Silva	1	G2_58
G4_42 (*)	<b>Adriana Lopes Damian, Anna B. S. Marques, Simone D. J. Barbosa, Tayana Conte</b>	1	G3_91
G4_44	Alexandre A. Freitas, Bianchi S. Meiguins, Carlos G. R. Santos, <b>Marcelle P. Mota</b>	1	n.a.
G4_46	Andre de Oliveira Bueno, <b>Junia C. Anacleto</b> , Lucas Cesar Ferreira, Vinicius Ferreira	1	G2_114 & G2_134
G4_50	<b>Artur H. Kronbauer, Celso A. S. Santos</b> , Diferson Machado, Omar G. Junior	1	G2_63
G4_51	<b>Cristiano Maciel</b> , Fabricio H. Sales Pereira, <b>Raquel O. Prates, Vinicius C. Pereira</b>	1	G2_62 & G2_127
G4_52 (*)	<b>Elaine C. S. Hayashi, Julián Gutiérrez Posada, M. Cecilia C. Baranauskas, Roberto Pereira</b>	1	G2_47 & G2_105
G4_53	<b>Elaine C. S. Hayashi, Julián Gutiérrez Posada, M. Cecilia C. Baranauskas</b> , Vanessa R. M. L. Maiké	1	G2_47, G2_105 & G3_125
G4_56	Felipe Ciacia de Mendonça, <b>Isabela Gasparini, Milene S. Silveira, Simone D. J. Barbosa</b>	1	G2_34 & G3_117
G4_58	<b>Isabela Gasparini</b> , Lucas Felipe da Cunha, <b>Marcelo S. Pimenta</b> , Marcos H. Kimura	1	G3_75
G4_64	Andressa C. dos Santos, José V. da Silva, <b>Luã M. Muriana, M. Cecilia C. Baranauskas</b>	1	G2_160 & G2_165
G4_66	<b>Andrey Antonio de O. Rodrigues</b> , Eduardo Feitosa, Maria Lúcia Villela, <b>Natasha M. C. Valentim</b>	1	G3_181 & G3_139
G4_71	Camilla V. L. T. Brennan, Celso A. R. L. Brennan, Emanuel Felipe Duarte, <b>M. Cecilia C. Baranauskas</b>	1	G2_124
G4_74	<b>Cristiano Maciel</b> , Danilo Barros dos Santos, Eunice P. S. Nunes, <b>Vinicius C. Pereira</b>	1	G2_62
G4_75	<b>Cristiano Maciel</b> , Ketelem Campos, Thais Justi de Toledo, <b>Vinicius C. Pereira</b>	1	G2_62
G4_77	Deógenes P. da Silva Junior, Emerson André Fedechen, <b>M. Cecilia C. Baranauskas, Roberto Pereira</b>	1	G2_152
G4_79	Francisco A. M. Valério, Heloisa Candello, <b>Raquel O. Prates</b> , Tatiane G. Guimarães	2	G2_168
G4_80	Franklin M. da C. Lima, Gabriel Vasiljevic, <b>Leonardo Cunha de Miranda, M. Cecilia C. Baranauskas</b>	1	G3_160
G4_92	<b>Cristiano Maciel</b> , Daniele Trevisan, <b>Roberto Pereira, Vinicius C. Pereira</b>	1	G2_62
G4_94	Emanuel Felipe Duarte, Jéscia Nobre, <b>M. Cecilia C. Baranauskas</b> , Yussell L. M. Mendoza	1	G2_124 & G2_141
G4_95	Fernando Proença, Franco Eusébio Garcia, Paula Souza, <b>Vânia Almeida Neris</b>	1	G2_71

**Table 4.** Main groups of authors of the Full Papers track (14 quintets, seven sextets and one octet) of the IHC. Names in bold indicate main authors of the track.

Group	ID	Authors name	N	Subgroups
Quintets	G5_2	Adéle Malta Pontes, <b>Carla Faria Leitão, Clarisse S. de Souza, Simone D. J. Barbosa</b> , Violeta S. T. D. B. Quental	1	G2_8
	G5_9	<b>Elaine C. S. Hayashi, Julio C. dos Reis, Leonelo D. A. Almeida, M. Cecilia C. Baranauskas</b> , M. Cecilia Martins	1	G2_47 & G2_36
	G5_11	Bruno Brochado Ribeiro, Débora Maurmo Modesto, <b>Denis Silva da Silveira</b> , Eliane Pinheiro Capra, <b>Simone B. Leal Ferreira</b>	1	G2_66 & G3_95
	G5_15	Alexandre N. Araujo, Aron Daniel Lopes, <b>Cristiano Maciel</b> , Philippe Marcel M. Ramalho, <b>Vinicius C. Pereira</b>	1	G2_62 & G3_82
	G5_18	<b>André Pimenta Freire</b> , Bruno Piovesan Melchiori Peruzza, Flávia Santos, Lucas Pedrosa Carvalho, Lucas Pereira Ferreira	1	G2_115
	G5_19	Anna de Liddo, Harith Alani, <b>Lara Piccolo, M. Cecilia C. Baranauskas</b> , Miriam Fernandez	1	G2_51
	G5_23	Felipe Ciacia de Mendonça, <b>Isabela Gasparini, Milene S. Silveira</b> , Rebeca Schroeder, <b>Simone D. J. Barbosa</b>	2	G2_34, G3_117 & G4_56
	G5_29	Amanda Fernandes Pereira, Ana Paula de Carvalho, Fabrício H. Sales Pereira, Oto Braz Assunção, <b>Raquel O. Prates</b>	1	G2_127
	G5_31	Andressa C. dos Santos, Eliana A. Moreira, José V. da Silva, <b>Luã M. Muriana, M. Cecilia C. Baranauskas</b>	1	G2_122, G2_160, G2_165 & G4_64
	G5_39	<b>Cristiano Maciel, Luã M. Muriana</b> , Patricia C. de Souza, Thais Justi de Toledo, <b>Vinicius C. Pereira</b>	1	G2_62
	G5_43	Luciano Machado, Luciano Neris, Marcelo Barbosa, Tatiana Alencar, <b>Vânia Almeida Neris</b>	1	G2_88 & G3_129
	G5_45	Alisson Puska, <b>Lara Piccolo</b> , Luiz Adolpho Baroni, Maira Codo Canal, <b>Roberto Pereira</b>	1	G2_166
	G5_48	<b>André Pimenta Freire</b> , Joana Gabriela Souza, Lucas Pedrosa Carvalho, Mariana Aparecida dos Santos, <b>Raquel O. Prates</b>	1	G2_115 & G3_143
	G5_51	<b>Clarisse S. de Souza</b> , Gabriel Barbosa, Helio Lopes, José Luiz Nunes, <b>Simone D. J. Barbosa</b>	1	G2_8
Sextets	G6_2	<b>Carla M. D. S. Freitas</b> , Luciana P. Nedel, <b>Marcelo S. Pimenta, Marco A. A. Winckler</b> , Paulo R. G. Luzzardi, Ricardo A. Cava	1	G3_22
	G6_3	Christian Baudet, Eduardo H. Tanaka, <b>Heloisa V. da Rocha</b> , Miguel Galves, Márcio Juliano, Thiago T. Coelho	1	G2_67
	G6_6	Alexandre A. Cardoso, Antônio A. P. Prates, Marcos O. Prates, Maria L. B. Villela, <b>Raquel O. Prates</b> , Simone I. R. Xavier	1	G2_110
	G6_12	<b>Anna B. S. Marques</b> , Jacilane de H. Rabelo, Rodrigo Figueiredo, <b>Simone D. J. Barbosa, Tayana Conte</b> , Warlem Amorim	1	G3_91
	G6_15	Cassio T. Batista, Denis D. Diniz Martins, Erick M. Campos, <b>Nelson C. Sampaio Neto</b> , Renan F. Cunha, Suzane S. dos Santos	1	G3_151
	G6_16	Adriano Ferretti Borgatto, Adriano Lima, Aldo Von Wangenheim, <b>Christiane Gresse Von Wangenheim</b> , Jean Hauck, Osvaldo Martins	1	G3_177
	G6_21	Beatriz B. do Rêgo, <b>Ecivaldo de Souza Matos</b> , Felipe A. Garrido, Jean C. S. Rosa, Nuno J. Nunes, Pedro D. Valente	1	G2_98
Octets	G8_3	Alexandre A. Freitas, Bianchi S. Meiguins, Brunelli P. Miranda, Bruno A. F. Murakami, Carlos G. R. Santos, <b>Marcelle P. Mota</b> , Paulo R. S. C. Junior, Tiago D. O. Araújo	1	G4_44



**Figure 15.** Timeline of the 172 main groups of authors of the Full Papers track of the IHC.

Considering the sequence of three distinct editions, there are eight groups: G2\_1 (IHC'98, '99 and '00), G2\_2 (IHC'99, '00 and '17), G3\_17 (IHC'00, '04 and '06), G2\_51 (IHC'06, '11 and '12), G2\_36 (IHC'08, '10 and '12), G2\_47 (IHC'10, '13 and '17), G2\_113 (IHC'17, '19 and '22), and G3\_132 (IHC'18, '19 and '21).

In relation to criterion (ii.b), after the application of criterion (i), a total of 139 groups were selected, being 46 duos, 44 trios, 28 quartets, 13 quintets, seven sextets, and an octet. In this timeline of main groups of authors from the Full Papers track, it is possible to observe how smaller groups joined with other authors to form larger groups, and how larger groups "separated" to form smaller groups. This information may be observed through the links between groups represented as dashed lines. In practice, one example would be the trio G3\_6, which published a paper in the first edition of the IHC (i.e., in 1998) and, in IHC'99, was separated and composed the pair G2\_7, which published in this composition (i.e., in pair) for the first time in 1999<sup>16</sup> and, posteriorly, returned to form larger groups with other authors and publish in future editions, as the trio G3\_9, which published in IHC'00.

At this point, we can compare the co-authorship matrix of Full Papers (Figure 10) with the groups defined for the track (Tables 1 to 4). In this co-authorship matrix, the cell values indicate the number of times that two authors have published together, either in a duo formation or in collaboration with other authors, forming larger sets (e.g., trios or quartets). Thus, the groups presented in Tables 1 to 4 serve to expand the view shown in the co-authorship matrix, detailing how the respective authors published together, that is, whether they had the contribution of other authors in their publications.

According to the Full Papers co-authorship matrix, for example, Cristiano Maciel and Vinícius C. Pereira published 13 times together in the track. By looking at Tables 1 to 4, one can see that, in two of these publications, Cristiano Maciel and Vinícius C. Pereira published alone, four times with a third author (i.e., in a trio), five times in different quartets, and twice in quintet formations with other authors.

Considering the small groups that published in an edition and later returned to contribute with other authors, thus forming larger groups, we can highlight, for example, G2\_7, G2\_8 and G2\_62. These are the groups with the most number of connections with other larger groups, representing the subgroups of authors which most appear in the selected groups.

The authors in the group G2\_7 first published in this track in IHC'99 and, posteriorly, returned to publish with other authors in IHC'00 (G3\_9), '01 (G3\_24), '02 (G4\_7), '06 (G4\_17) and '16 (G3\_101). The pair G2\_7 also composed a larger group in IHC'99 (G3\_8), and had already published previously (i.e., IHC'98) in trio G3\_6. The pair G2\_8, which also published for the first time in IHC'99, returned to contribute in Full Papers in editions IHC'00 (G3\_5 and G3\_7), '01 (G3\_25), '02 (G4\_12), '04 (G5\_2) and '22 (G5\_51). In addition, in relation to G2\_8, it is worth mentioning that this pair also published, in IHC'99, as part of a trio (i.e., G3\_8). Finally, in relation to the pair G2\_62, which published for the

first time more recently, that is, in IHC'12, it formed larger groups and returned to contribute in IHC'14 (G3\_82 and G5\_15), '16 (G3\_96 and G4\_51), '17 (G4\_75), '18 (G4\_74), '19 (G5\_39) and '21 (G4\_92). In the edition that they published for the first time (i.e., IHC'12), the pair G2\_62 also participated in the quartet G4\_31.

Moving on to the groups that emerged after the separation of larger groups, we highlight the pair G2\_105, which published in IHC'15, but the authors of this group had already contributed before, in a larger group, specifically in IHC'13 (G3\_76) and '14 (G3\_125); the pair G2\_110, which also published in IHC'15, but had already contributed in larger groups in the editions of 2012 (G3\_81) and 2013 (G3\_80) of this track; and G2\_160, a pair that, alone, published for the first time in Full Papers in the IHC'20 edition, but had already published with other authors two times in IHC'19 (G4\_64 and G5\_31). These groups (i.e., G2\_105, G2\_110 and G2\_160) stand out by their connections with larger groups that had already published in the IHC, that is, their authors had already published several times, with larger groups, in past editions.

The **main groups of authors of the Short Papers track** were selected according to criteria (i), (ii.a) and (ii.b), previously defined in Section 3.3.6. Thus, from a total of 183 identified groups of authors, 20 groups (i.e., 10.93%) were selected and classified as main groups of the Short Papers track. It was noticed that none of these groups had published less than two articles, i.e., no group was selected by criterion (ii.a). Therefore, the 20 groups were selected by criterion (ii.b), based on the groups that had already been selected by (i). In general, were selected: eight pairs, six trios, one quintet, two sextets, and one septet.

Table 5 presents these 20 main groups of authors. In this table, for each exact number of authors is presented the number of articles that they published together (*N*) and which groups are contained in them (subgroups), either from Full Papers or Short Papers. Upon observing this table, it is also possible to note that four groups are composed, exclusively, by main authors: G2\_175, G2\_191, G2\_216 and G3\_227.

After the selection of groups, the timeline of the main groups of authors for the Short Paper track was created (Figure 16) and presents the **evolution of the collaboration between authors of the Short Papers track**, specifically, considering the main groups of this track. Given that no group that satisfied criterion (ii.a) was selected, there are no groups in this timeline that published more than once, either in the same edition or in different editions, and thus all connections are dashed links in this visualization.

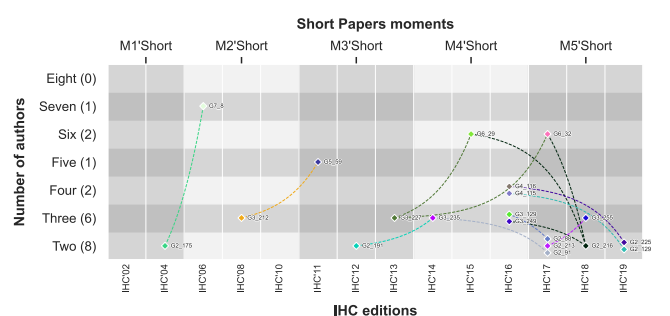


Figure 16. Timeline of the 20 main groups of authors of the Short Papers track of the IHC.

<sup>16</sup>As mentioned in Section 3.3.6, the groups were defined according to the groups of authors in each publication of the IHC. That is, the pairs were defined from publications with two authors, the trios from publications with three authors, and so forth.

**Table 5.** The 20 main groups of authors of the Short Papers track of the IHC. Names in bold indicate the main authors of the track, and groups tagged with (\*) are composed, exclusively, by main authors.

Group	ID	Authors name	N	Subgroups
Pairs	G2_88	Tatiana Alencar, <b>Vânia Almeida Neris</b>	1	n.a.
	G2_91	Camila Loliola Brito Maia, <b>Elizabeth S. Furtado</b>	1	n.a.
	G2_129	Geanderson E. dos Santos, <b>Raquel O. Prates</b>	1	n.a.
	G2_175 (*)	<b>Junia C. Anacleto, Vânia Almeida Neris</b>	1	n.a.
	G2_191 (*)	<b>Carlos Rosenberg Maia de Carvalho, Elizabeth S. Furtado</b>	1	n.a.
	G2_213	<b>Cristiano Maciel</b> , Vinicius F. Galvão	1	n.a.
Trios	G2_216 (*)	<b>Caroline Q. Santos, Milene S. Silveira</b>	1	n.a.
	G2_225	Patricia F. Amorim, <b>Simone B. Leal Ferreira</b>	1	n.a.
Trios	G3_129	Marcelo Barbosa, Tatiana Alencar, <b>Vânia Almeida Neris</b>	1	G2_88
	G3_212	Albert Weichselbraun, <b>Arno Scharl</b> , Gerhard Wohlgenannt	1	n.a.
	G3_227 (*)	<b>Angelina C. A. Ziesemer, Luana Müller, Milene S. Silveira</b>	1	G2_80
	G3_235	Camila Loliola Brito Maia, <b>Carlos Rosenberg Maia de Carvalho, Elizabeth S. Furtado</b>	1	G2_91 & G2_191
	G3_249	<b>Caroline Q. Santos, Isabel Manssour, Milene S. Silveira</b>	1	G2_216
Quartets	G3_255	<b>Cristiano Maciel, José Viterbo, Vinicius F. Galvão</b>	1	G2_213
	G4_115	Bárbara Gabrielle C. O. Lopes, Geanderson E. dos Santos, Maria Lúcia Villela, <b>Raquel O. Prates</b>	1	G2_129 & G2_109
Quartets	G4_116	Humberto S. Pacheco, Patricia F. Amorim, Priscyla Barbosa, <b>Simone B. Leal Ferreira</b>	1	G2_225
	G5_59	Albert Weichselbraun, <b>Alexander Hubmann-Haidvogel, Arno Scharl</b> , Astrid Dickinger, Gerhard Wohlgenannt	1	G3_212
Sextets	G6_29	<b>Angelina C. A. Ziesemer, Caroline Q. Santos, Luana Müller, Luciana S. Espindola, Milene S. Silveira, Pedro A. Pires</b>	1	G2_216, G2_80 & G3_227
	G6_32	<b>Angelina C. A. Ziesemer, Caroline Q. Santos, Luana Müller, Luciana S. Espindola, Luisa Oliveira, Milene S. Silveira</b>	1	G2_216, G2_80 & G3_227
Heptets	G7_8	Americo Talarico Neto, Aparecido Fabiano P. de Carvalho, Henry Lieberman, <b>Junia C. Anacleto, Muriel de Souza Godoi, Sílvia Zem-Mascarenhas, Vânia Almeida Neris</b>	1	G2_175

Regarding the groups selected by (ii.b), the visualization shows how small groups formed larger ones, and how larger groups “broken apart” to form smaller ones. When observing this timeline from the perspective of smaller groups that form larger ones, we can notice, for example, that the authors of the trio G3\_227, which published in IHC’13, returned and published with other authors in IHC’15 (G6\_29) and ’17 (G6\_32), thus forming two larger groups, both composed by six researchers. Amongst the selected groups, G3\_227 is the one that presents the most connections with larger groups that published in following editions. In this case, it can be observed that despite the trio G3\_227 had published only once in IHC’13, these authors joined with others and returned to publish in two posterior editions, indicating that the specific set of authors in this trio published three times together.

Considering the groups of authors who emerged from larger groups, the pair G2\_216 is the group with most connections with larger groups that published in previous editions. This group published an article in IHC’18 and was formed after the “dismemberment” of three groups: G6\_29 (IHC’15), G3\_249 (IHC’16) and G6\_32 (IHC’17). From this, we can observe that the pair of G2\_216, in addition to having published once in IHC’18, had been co-authors three times with larger groups in previous editions, indicating that this pair of authors published four times together.

Finally, considering the main groups of authors selected for the Full and Short Papers tracks, it can be noticed that, especially for Short Papers, the groups, in a general sense, do not return to publish after a while, either in the same group of authors or originating another group, either larger or smaller. When observing the timeline of the main groups of authors of Short Papers, for example, the lack of connection between groups in the first and last editions of the track is clear. Furthermore, the groups from Short Papers, in addition to being more concentrated, are also more connected by dashed

lines in the last editions, indicating, for example, that given sets of authors started to publish more with different groups.

For Full Papers, it is possible to notice groups of authors that, after publishing for the first time in past editions, have returned to contribute more recently, whether in the same group of authors, or in larger or smaller groups. For example, the pairs G2\_7 and G2\_8, which published for the first time in IHC’99, but returned to publish in the track years later with larger groups, respectively, in IHC’16 (G3\_101) and ’22 (G5\_51). Still analysing the groups of these two tracks, it is possible to perceive that there are groups that are present in both, that is, G2\_88 and G3\_129. It is important to highlight that, in relation to these two groups of authors, the pair G2\_88 is also in the trio G3\_129.

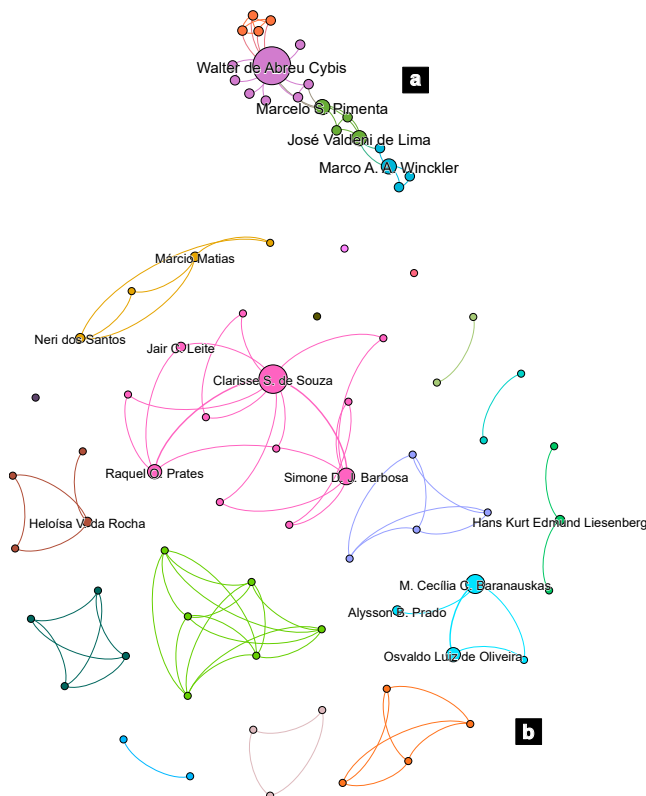
#### 4.5 RQ5: How has the co-authorship networks of IHC articles evolved over the years?

The analysis of the research question presented in Section 4.3 allowed us to have a current “photograph” of the networks of co-authors of the main tracks of the Symposium. This research question analyses, after exploring the various existing groups within these networks (Section 4.4), their evolution over different periods of time, presenting the “photographs” at different moments that preceded the networks that were previously presented (Section 4.3). This analysis is performed only for the Full Papers and Short Papers tracks, as the evolution of the co-authorship networks for the Innovative Ideas and Emerging Results track was not explored due to the short period of existence of the track, that is, of only three editions. Full Papers are in all 21 editions of the IHC, while Short Papers appears in the editions between 2002 and 2019. The different moments were employed for each track, as defined in Section 3.3.3 (an overview is presented in Figure 1). For each moment, a distinct value for  $N$  was selected, and all authors with number of publications higher or equal to  $N$  had their names displayed in the networks.

Moving on to the **evolution of the co-authorship networks of the Full Papers track**, the moments were defined as follows: IHC’98, ’99 and ’00, with  $N = 2$  (M1’Full); IHC’01, ’02 and ’04, with  $N = 3$  (M2’Full); IHC’06, ’08 and ’10, with  $N = 3$  (M3’Full); IHC’11, ’12 and ’13, with  $N = 4$  (M4’Full); IHC’14, ’15 and ’16, with  $N = 4$  (M5’Full); IHC’17, ’18 and ’19, with  $N = 5$  (M6’Full); and IHC’20, ’21 and ’22, with  $N = 5$  (M7’Full). As described in Section 3.3.7, the co-authorship networks were not created isolated for the editions of each moment, but incrementally considering all editions of the previous moments. Thus, for example, M2’Full corresponds to the editions of M1’Full plus the editions IHC’01, ’02 and ’04.

With the definition of the moments, the co-authorship network of M1’Full was created (Figure 17)<sup>17</sup>. In this network, 18 groups of isolated authors were identified, with the largest one presenting 20 authors (Figure 17a), and the remaining 17 smaller groups (Figure 17b) are composed by 58 authors. Up to the year 2000, therefore, 44 articles had been published in this track by 78 authors.

<sup>17</sup>The sizes of vertices and thickness of edges are possibly in different scales in figures (a) and (b) of all co-authorship networks of Section 4.5.

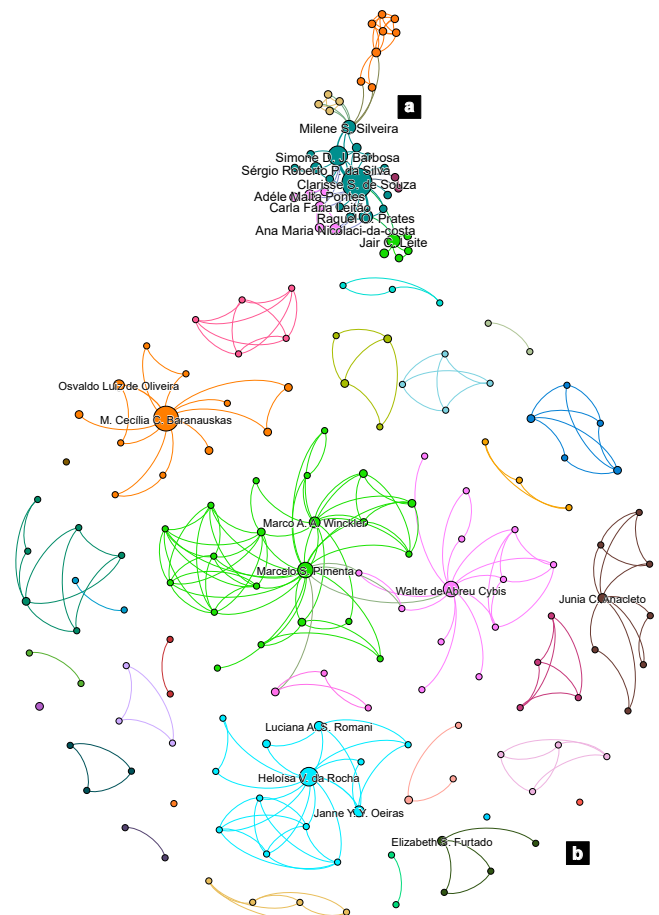


**Figure 17.** Evolution of the co-authorship networks of the Full Papers track with editions IHC'98'99'00 (M1'Full): (a) the main group, and (b) the 17 smaller groups.

Considering the co-authorship network of M2'Full (Figure 18) which, keeping in mind, corresponds to M1'Full with three more editions (i.e., IHC'01, '02 and '04), 30 groups of isolated authors were identified. From those, the largest group presented 40 authors (Figure 18a), and the remaining 29 smaller groups, composed by 142 authors, are presented in Figure 18b. Up to 2004, therefore, 110 articles had been published in the Full Papers track by 182 authors, that is, a difference of 66 publications when compared to M1'Full, which represents an increase of 150%. Another issue that should be mentioned is the new authors that appear in M2'Full, that is, in total, 104 authors published for the first time in the Full Papers track of the IHC in the editions from 2001 to 2004, an increase of 133.34% in relation to the number of authors of the previous moment.

In the co-authorship network of M3'Full (Figure 19), which corresponds to M2'Full with three more editions (i.e., IHC'06, '08 and '10), 41 groups of isolated authors were identified. From these 41 groups, the largest of them had 105 authors (Figure 19a), while the remaining (i.e., 40 smaller groups) presented 182 authors (Figure 19b). Up to the year 2010, therefore, 174 articles had been published in the Full Papers track by 287 authors, which represents a difference of 64 publications to M2'Full, that is, an increase of 58,18%. In addition, it is also worth mentioning the difference in the number of authors, that is, there were 105 new authors in M3'Full, representing an increase of 57.69%.

For the co-authorship network of M4'Full (Figure 20), it was identified a total of 54 groups of isolated authors, being the largest of them composed by 174 authors (Figure 20a). In relation to the 53 smaller groups, 257 authors were identified (Figure 20b). Until the year 2013, therefore, the number of

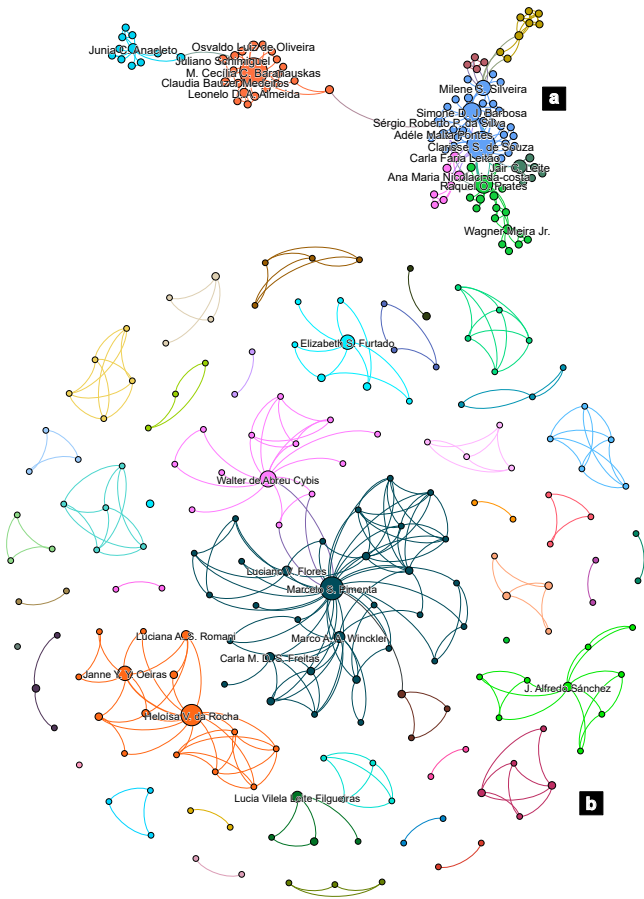


**Figure 18.** Evolution of the co-authorship networks of the Full Papers track plus the editions IHC'01'02'04 (M2'Full): (a) the main group; and (b) the 29 smaller groups.

published articles by the 431 authors in the Full Papers track was 261, which represents a difference of 87 publications to M3'Full, an increase of 50%. In M4'Full, the number of new authors increase from 287 to 431, that is, there were new 144 authors that published in the Full Papers track between 2011 and 2013, which represents an increase of 50.17% in relation to the number of authors from M3'Full to M4'Full.

In the co-authorship network of the fifth moment of the Full Papers track (Figure 21), which corresponds to M4'Full with three more editions (i.e., IHC'14, '15 and '16), 68 groups of isolates authors were identified. Of these groups, the main one was composed of 328 authors (Figure 21a), while the 67 smaller groups presented 299 authors (Figure 21b). Up to the edition of 2016, 373 publications had been made in the Full Papers track, which represents an increase of 112 publications, that is, 42.91%, to the previous moment (i.e., M4'Full). In addition, it is also worth to note about the number of new authors in M5'Full, which went from 431 in M4'Full to 627, an increase of 196 authors (i.e., 45.47%).

In the co-authorship network corresponding to M6'Full (Figure 22), 83 groups of isolated authors were identified, being the main one composed by 499 authors (Figure 22a). In comparison, 389 authors were identified in the 82 smaller groups (Figure 22b). At the end of this moment (i.e., in 2019), 522 publications had been made in the Full Papers track, representing an increase of 149 publications in relation to the previous moment (i.e., M5'Full), a percentage increase of 39.95%.



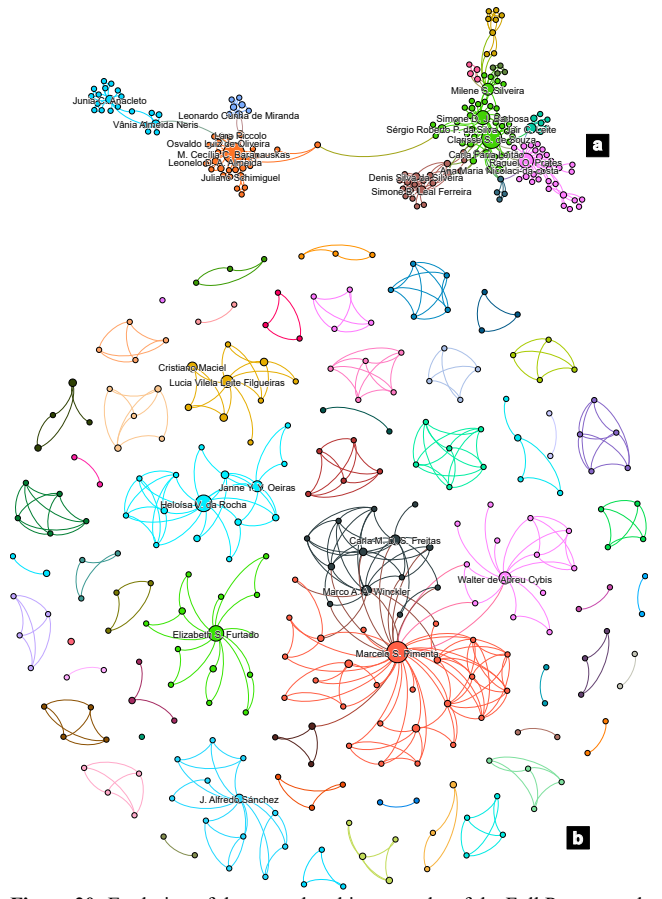
**Figure 19.** Evolution of the co-authorship networks of the Full Papers track plus the editions IHC'06'08'10 (M3'Full): (a) the main group; and (b) the 40 smaller groups.

It is worth to mention the number of new authors that published in the Full Papers track between 2017 and 2019. In total, there were 261 new authors, making M6'Full the period in which more authors appeared in the track, according to the absolute value. In M6'Full, there was an increase of 41.63% in the number of authors in relation to the previous period.

The evolution of M7'Full, with three more editions (i.e., IHC'20, '21 and '22), is the last resulting network presented previously in Figure 9, which represents the general network of the Full Papers track of the IHC, considering the data of all 21 editions of the Symposium. From 1998 to 2022, after this last stage (i.e., M7'Full), 621 articles had been published by 1,053 authors, representing a difference of 99 publications to M6'Full, a percentage increase of 18.96%.

It is also worth commenting on the increase in the number of new authors that emerged in M7'Full. In total, there were 165 authors that published for the first time in the Full Papers track between the editions of 2020 and 2022. In this moment, the percentage increase in relation to the number of authors was 18.58%.

In the **evolution of the co-authorship networks of the Full Papers track**, different situations may be observed, such as the emerging of new groups, the union of small groups, the insertion of small groups into the main group, and the emerging of authors that stand out by their number of publications. The main group of M1'Full (Figure 17a), for example, becomes a small group at the moment M2'Full (Figure 18b), as some of the smaller groups of M1'Full (Figure 17b) joined and composed a main group of M2'Full (Figure 18a).



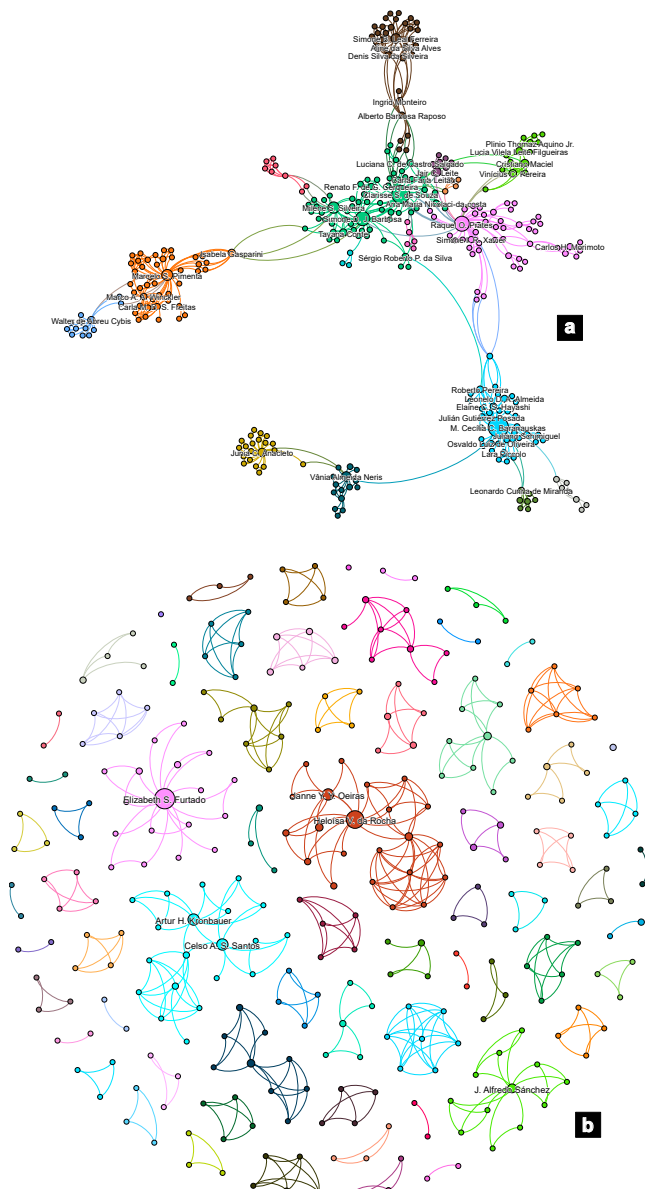
**Figure 20.** Evolution of the co-authorship networks of the Full Papers track plus the editions IHC'11'12'13 (M4'Full): (a) the main group; and (b) the 53 smaller groups.

The group that was considered as a main group in M1'Full continues with the same “status” (i.e., of small group) in M3'Full (Figure 19b) and also in M4'Full (Figure 20b) until moment M5'Full, in which it returns to be part of the main group (Figure 21a). Throughout the moments of Full Papers, different situations of migrations of authors occur, that is, smaller groups that become integrated into the main group. Figure 23 presents a general overview in relation to the number of authors who migrate between groups isolated from the networks, as well as new authors and those who remain in their respective groups.

From the evolution of the networks of the Full Papers track, it is possible to note that the main groups of M2'Full (Figure 18a), which originated from the union of smaller groups from M1'Full (Figure 17b) with new authors, continues to be the main group to the last moment (i.e., M7'Full). Over the years, this group receives new authors, that is, that had never published in the IHC, and integrates authors who had already published in the Symposium, but were isolated in smaller groups.

It is important to note that, although the main group of the IHC at the moment M7'Full presented most of the authors of the Full Papers track (i.e., 652), most of them did not come from small groups that already existed in the Symposium, but were new authors which, over the years, have been included in the main group. That is, most small groups do not seem to join the main group.

To understand how the main group of the Full Papers track evolved and became what was presented in Figure 9a, it is

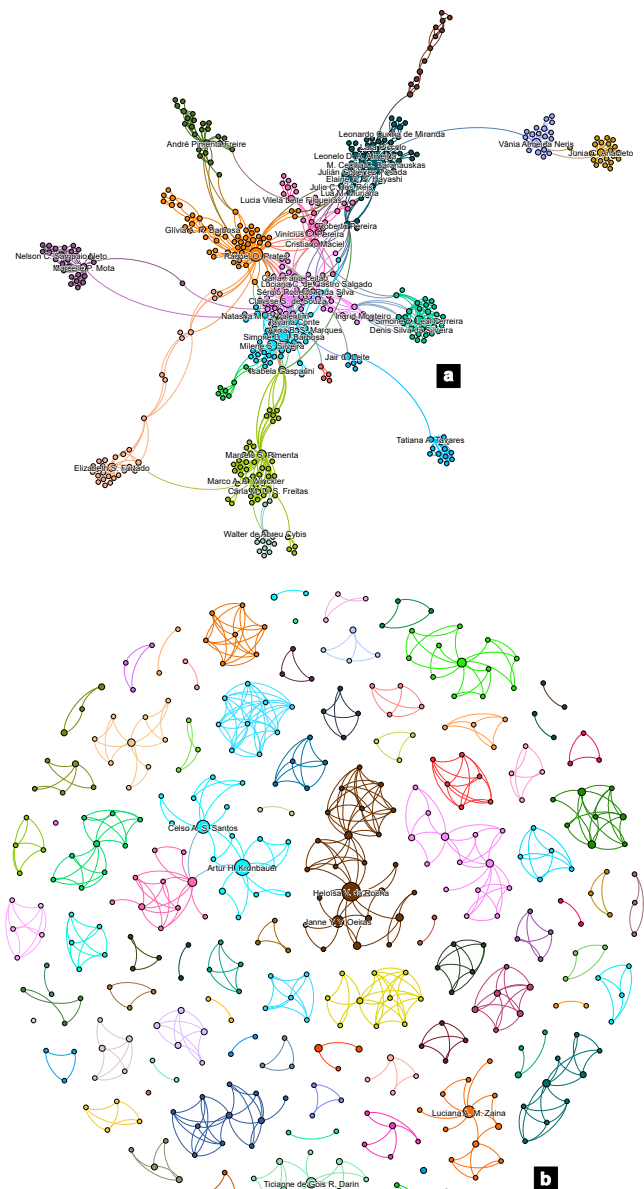


**Figure 21.** Evolution of the co-authorship networks of the Full Papers track plus the editions IHC'14'15'16 (M5'Full): (a) the main group; and (b) the 67 smaller groups.

worth understanding, for example, how smaller groups were aggregated over time, more specifically from the perspective of the main authors at each moment, that is, those who had their names displayed on the networks.

In the case of the main group of moment M3'Full (Figure 19a), 30 authors were integrated from smaller groups of M2'Full (Figure 18b), and three of them were already main authors in the second moment, being them: M. Cecília C. Baranauskas, Osvaldo Luiz de Oliveira, and Junia C. Anacleto. In the main group of M4'Full (Figure 20a), only three authors of the smaller groups of M3'Full were aggregated, and none of them were in the set of main authors.

In moment M5'Full (Figure 21), the main group received 73 authors which belonged to the smaller groups of moment M4'Full (Figure 20b). From these authors, six were part of the set of main authors from smaller groups of M4'Full (Figure 20b): Marcelo S. Pimenta, Lucia Vilela Leite Filgueiras, Walter de Abreu Cybis, Cristiano Maciel, Carla M. D. S. Freitas, and Marco A. A. Winckler.



**Figure 22.** Evolution of the co-authorship networks of the Full Papers track plus the editions IHC'17'18'19 (M6'Full): (a) the main group; and (b) the 82 smaller groups.

It is also worth mentioning that some of these authors (i.e., Walter de Abreu Cybis, Marcelo S. Pimenta, e Marco A. A. Winckler) were in the main group of moment M1'Full. In relation to the main groups of moment M6'Full (Figure 22a), 40 authors were integrated from the smaller groups of M5'Full (Figure 21b). From these 40 authors, only Elizabeth S. Furtado was part of the set of main authors of the smaller groups of M5'Full. For the last moment, i.e., M7'Full (Figure 9), from 46 authors of the smaller groups of M6'Full (Figure 22b) which were included in the main group of M7'Full (Figure 9a), only one was already a main author in moment M6'Full (Figure 22a): Luciana A. M. Zaina.

Moving on to the **evolution of the co-authorship networks of the Short Papers track**, the definition of the moments resulted in the following sets of editions: IHC'02 and '04, with  $N = 2$  (M1'Short); IHC'06, '08 and '10, with  $N = 2$  (M2'Short); IHC'11, '12 and '13, with  $N = 3$  (M3'Short); IHC'14, '15 and '16, with  $N = 3$  (M4'Short); and IHC'17, '18 and '19, with  $N = 3$  (M5'Short).

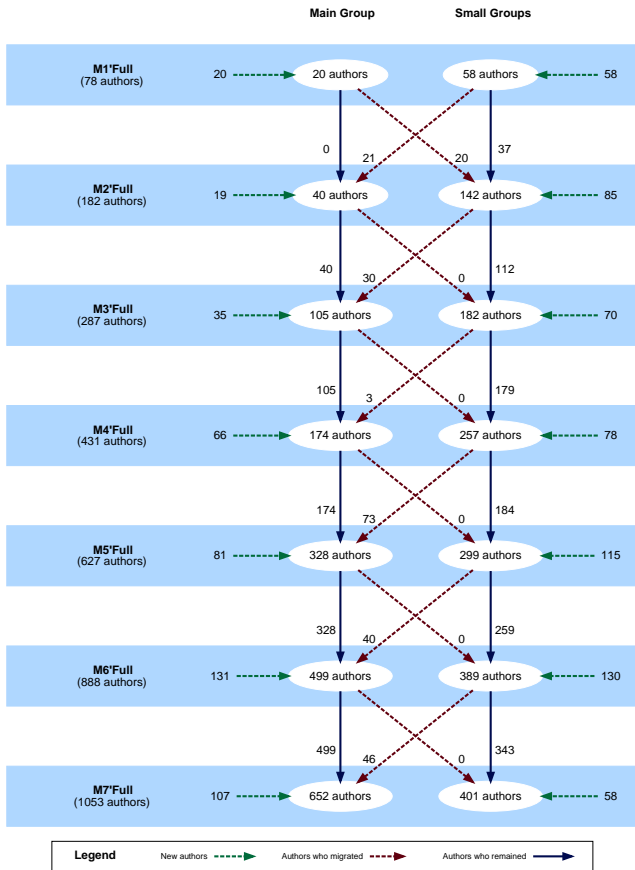


Figure 23. Map of movement of authors in the main and small groups along the seven moments of the Full Papers track of the IHC.

Then, the co-authorship network of the editions of M1'Short was created (Figure 24) and it was possible to identify 14 groups of isolated authors, with the main group (Figure 24a) being composed of six authors, while the remaining 13 groups (Figure 24) were composed, in total, of 41 authors. From 2002 to 2004, 21 articles had been published in the Short Papers track by 47 authors.

In relation to the co-authorship network of M2'Short (Figure 25), which corresponds to the moment M1'Short with three more editions (i.e., IHC'06, '08 and '10), a total of 33 groups of isolated authors were identified, with the largest group composed of 12 authors (Figure 25a). The other 32 smaller groups, composed by 109 authors, can be seen in Figure 25b.

From 2002 to 2012, 55 articles had been published in the Short Papers track by 121 authors, representing an increase of 34 publications when compared to M1'Short, i.e., a percentage increase of 161.90%. In addition, 74 new authors emerged in the Short Papers track during this period, that is, the number of authors more than doubled from M1'Short to M2'Short, with a percentage increase of 157.45%.

In the co-authorship network of M3'Short (Figure 26), 48 groups of isolated authors were identified, being the largest of them formed by 20 authors (Figure 26a). Considering the 47 smaller groups (Figure 26b), 197 authors were identified. In M3'Short, the number of articles in the Short Papers track, from 2002 to 2013, was equal to 93, being published by 217 authors, which represents a difference of 38 publications from M2'Short, an increase of 69.10%.

Considering the authors, 96 new authors who published in

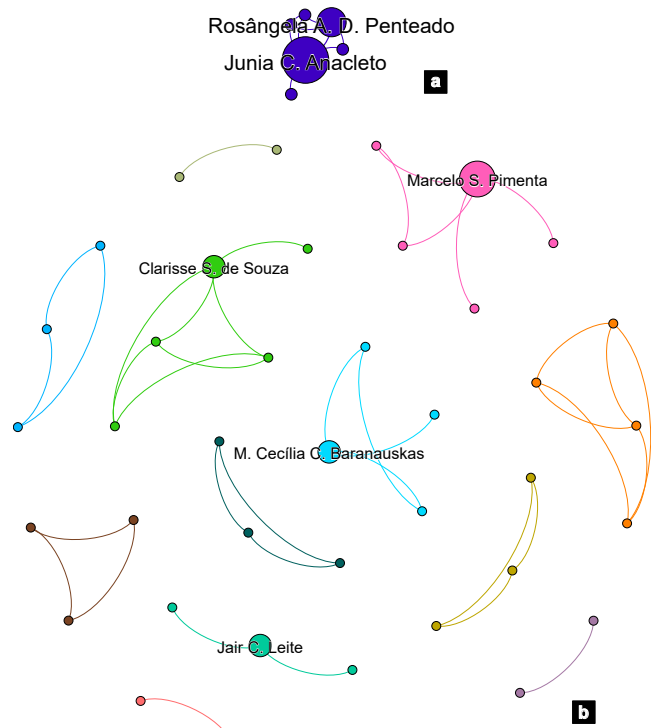


Figure 24. Evolution of the co-authorship networks of the Short Papers track with the editions IHC'02'04 (M1'Short): (a) the main group; and (b) the 13 smaller groups.

Short Papers were identified, which represents an increase of 79.34% in the number of authors from M2'Short to M3'Short, more specifically in the editions between 2011 and 2013.

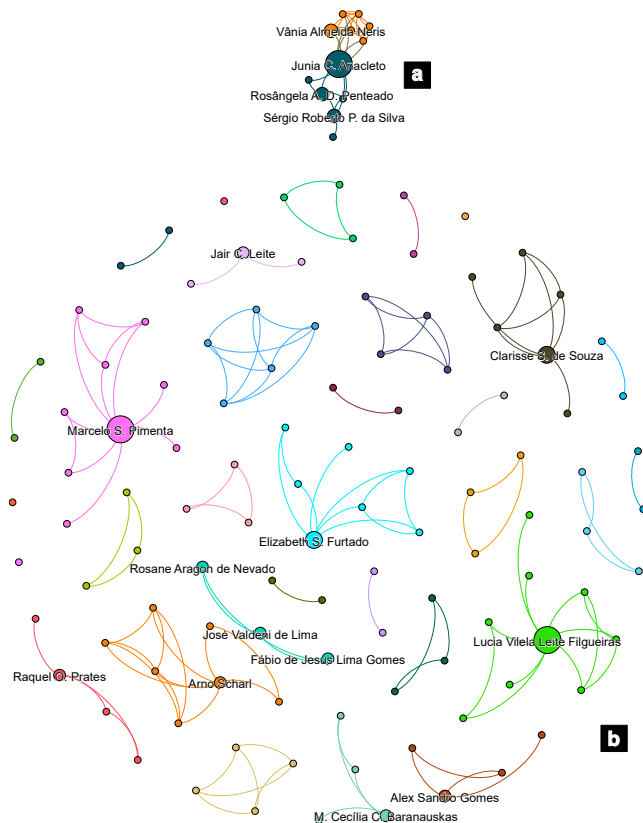
Considering the co-authorship network of M4'Short (Figure 27), which consists of M3'Short plus three editions (i.e., IHC'14, '15 and '16), a total of 70 groups of isolated authors was identified. In the main group of M4'Full (Figure 27a), i.e., in the largest group of isolated authors, 41 authors were identified, while it was noted the presence of 312 authors in the 69 smaller groups (Figure 27b).

Up to the 2016 edition, 148 articles had been published in the Short Papers track, that is, there were 55 new publications in relation to the third moment, which represents an increase of 59.14%. It is also worth commenting on the number of authors that, in M4'Full, reached a total of 353, showing that there were 136 new authors on the track between 2014 and 2016, an increase of 62.67%.

In total, 43 new articles were published from M4'Short to M5'Short, that is, between the editions from 2017 to 2019 of the Short Papers track. In addition, 92 new authors were identified in the last three editions of the track, which represents a percent increase of 26.06% in the number of authors.

The evolution of M5'Short, with three more editions (i.e., IHC'17, '18 and '19), corresponds to the network presented previously in Figure 11, which is the last network of the Short Papers track of the IHC, comprising all data. From 2002 to 2019, 191 articles were published in the Short Papers track by 445 authors.

In the evolution of the co-authorship network of Short Papers, the values referring to the migration and permanence of authors in the main and smaller groups, as well as the cases of new authors, can be observed in the mapping shown in Figure 28.



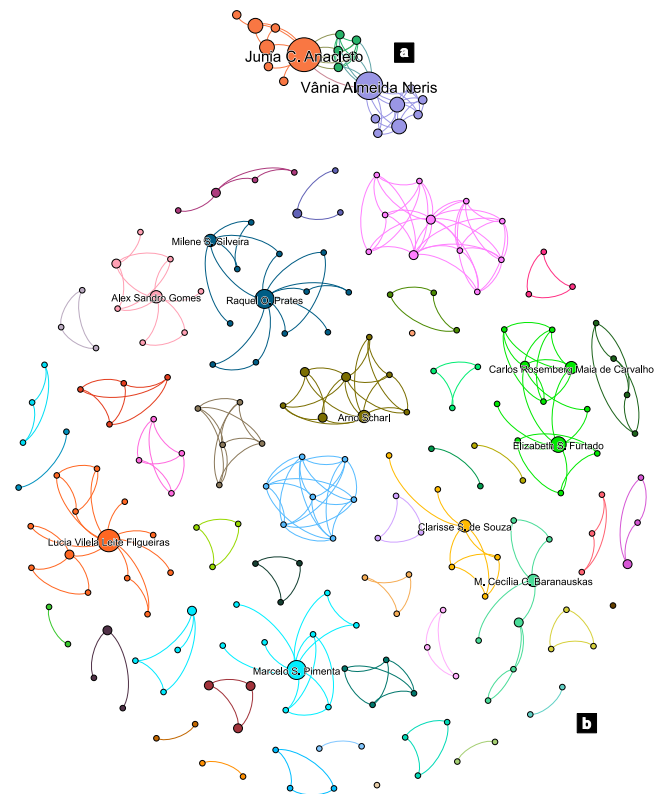
**Figure 25.** Evolution of the co-authorship networks of the Short Papers track plus the editions IHC'06'08'10 (M2'Short): (a) the main group; and (b) the 32 smaller groups.

It is interesting to observe, for example, how the main group in M4'Short (Figure 27a), which emerged from a small group in M3'Short (Figure 26b), integrates new authors, i.e., the group presented 15 authors, but in a period of three editions (i.e., IHC'14, '15 and '16), received 26 new authors. Of these 15 authors that started to compose the main group in M4'Short and were part of smaller groups of the previous moment, two were already considered main authors in M3'Short (Figure 26a): Raquel O. Prates and Milene S. Silveira.

Another detail that can be observed is regarding the main groups of M2'Short, M3'Short and M5'Short, which did not received any authors from the smaller groups of the previous moments, that is, they only integrated new authors who had not yet published in the track. Even when considering the sets of new authors included in the main groups and smaller groups of the five moments, it is possible to notice that the largest portion is always integrated into the smaller groups.

Finally, it is worth mentioning that the Short Papers co-authorship network, despite having fewer authors, has its authors more concentrated in smaller groups than the Full Papers network. In the case of Full Papers, the main group, starting from M2'Full, becomes the main destination for IHC authors until the last moment of the network's evolution, which justifies the number of authors in the network in Figure 9a (i.e., 652 authors) be the highest than the union of all smaller groups of Figure 9b (i.e., 401 authors).

In the Short Papers track, the main destination of the authors tends to be the smaller groups. That is, in the case of Full Papers, the authors, for most of the time, become part of the main group, while in Short Papers they join small groups that do not tend to increase over time.



**Figure 26.** Evolution of the co-authorship networks of the Short Papers track plus the editions IHC'11'12'13 (M3'Short): (a) the main group; and (b) the 74 smaller groups.

## 5 Discussion

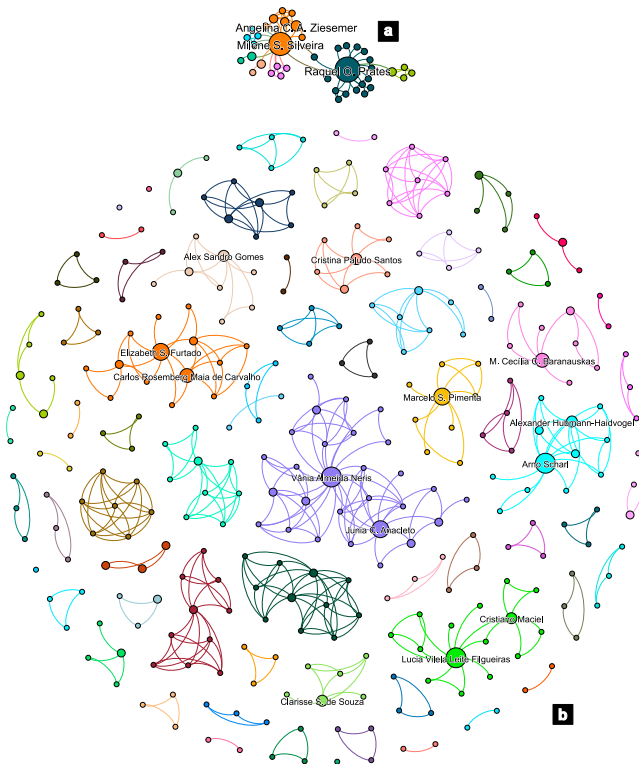
Guided by the research questions defined in Section 1, this work analysed the main authors of the IHC (RQ1), the evolution of the authorship of these authors in the Symposium (RQ2), the co-authorship networks of the event (RQ3), the evolution of the collaboration between IHC authors (RQ4), and how co-authorship networks of the event have changed/evolved over time (RQ5). In all research questions, the analyses were performed in the main tracks of the IHC, i.e., Full Papers, Short Papers, and Innovative Ideas and Emerging Results, in the period of time between 1998 and 2022.

In the case of the research questions focused on temporal analysis (i.e., RQ2 and RQ4), only the Full Papers and Short Papers tracks were considered, given that the calls for the Innovative Ideas and Emerging Results track only occurred, to the moment when this study was conducted, in three editions of the event. From the results of this work, new knowledge about the IHC emerged that had not yet been presented in the literature, nor in related works, as described in Section 2.

In relation to RQ1, the main authors of each track were selected according to their number of publications. With this, it was possible to verify the relevance of these authors in the corresponding tracks. For example, in Full Papers, 5.13% of the authors contributed with 74.56% of the publications, and in Short Papers, these values were, respectively, 5.39% and 48.69%. Still in relation to RQ1, as another differential of the present work, we present the publication history of the main authors in the context of each track of the IHC (Figure 4).

In this sense, in the specific context of the Full Papers track, for example, where a small portion of authors (i.e.,



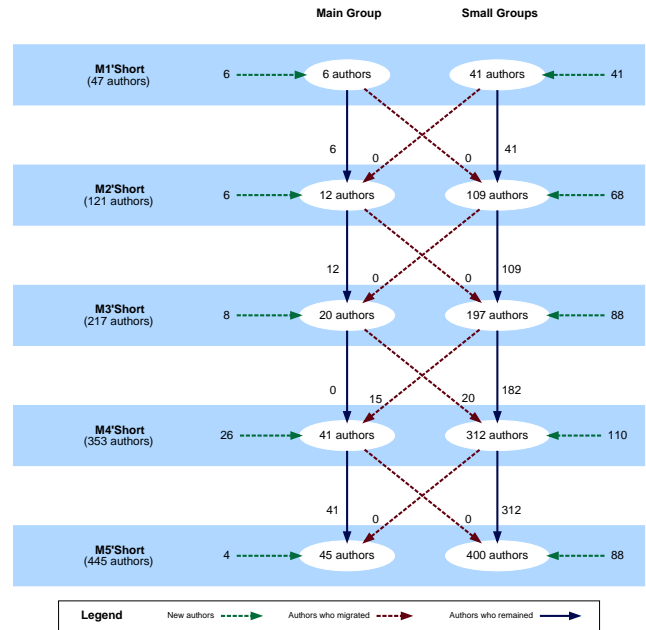


**Figure 27.** Evolution of the co-authorship networks of the Short Papers track plus the editions IHC'14'15'16 (M4'Short): (a) the main group; and (b) the 69 smaller groups.

5.13%) contributed to more than two-thirds of the track’s publications, one might initially assume that the community would not be so welcoming to new researchers. However, one can overcome this notion by observing the evolution of the co-authorship networks of the Full Papers track where, at each new moment of evolution, a considerable number of new authors become part of the IHC community, either in the main group or in smaller ones. Based on these observations, we understand that the community is indeed welcoming to new researchers, but that the majority of newcomers join through co-authorship relationships with researchers already known in the community, which justifies a portion of 5.13% of the total authors of the Full Papers track contributing to 74.56% of the publications.

In this case, when we generalize to both tracks (i.e., Full Papers and Short Papers), it is valid to consider that there is diversity in the community regarding the experience of its authors. Even though a small number of experienced authors contributed to the majority of the publications, new researchers are constantly connecting to the community, either forming a more isolated group of authors or creating co-authorship relationships with researchers already established in the community. Despite a small number of authors being involved in a large portion of the IHC publications, the community is always nurturing new researchers who, in a few years, may take over their own research at the Symposium.

Another analysis explored in this study, still in the context of RQ1, was the similarity between the tracks in relation to their authors, both in general and in relation to the main authors of each track. In this case, a coefficient was employed to verify the proportion of authors in common between the tracks. From the presented results, it was possible to verify a greater similarity between the general sets of authors of



**Figure 28.** Map of movement of authors in the main and small groups along the five moments of the Short Papers track of the IHC.

the Full Papers and Innovative Ideas and Emerging Results tracks, and when considering the main authors of the tracks, Full Papers and Short Papers are more similar.

For RQ2, which aims at complementing the results obtained from RQ1, the evolution of the authorship of the main authors of the Full Papers and Short Papers tracks was analysed at different moments of the IHC. This analysis, different from the one presented in RQ1, considered the position of the authors in each moment’s ranking, in order to show their path until they became the main authors in the last “photograph” of the moments of the Symposium. The objective of this research question, therefore, was to observe, through the position of the authors in the ranking, how their authorship evolved over the editions of the Symposium.

With the new notion of ranking adopted in this research question, it was possible to observe the situation of each author, in general, in the different moments of the tracks. That is, this analysis made possible to see beyond the sets of main authors of Full Papers and Short Papers, presenting information according to all existing authors in each of the different moments of the tracks. For this research question, the publication variation map was elaborated, bringing different information related to the authors. In this visualization, for example, it is possible to verify how authors gained or lost positions in the ranking over the moments of Full Papers (Figure 5) and Short Papers (Figure 7), with this information visually expressed through the colors of the cells in the heatmap.

The analysis of the co-authorship networks of the tracks was performed from the perspective of groups of isolated authors, being separated into a main group, which would be the largest isolated group, and smaller groups, which would be the other groups. In the co-authorship networks, the name of the main authors of each track was presented, thus allowing to see the co-authorship relationships of the authors in these networks. In the analysis of co-authorship networks referring to RQ3, the three main tracks of the IHC were considered.

In this research question, it was possible to expand the

understanding about a single dimension (i.e., number of publications) and start to observe the authors' co-authorship relationships. Thus, RQ3 explored co-authorship relationships and the formation of isolated groups and clusters of authors. In Figure 9a, for example, the largest isolated group of the Full Papers track is shown. In this group, it is possible to observe the clusters of authors that were formed from the co-authorship relationships. That is, even if these authors form a single group of considerable size, it is possible to separate it into clusters according to the concentration of their links, revealing sets of strongly connected authors.

In RQ4, the evolution of the collaboration between the authors of the IHC was analysed, more specifically, for the Full Papers and Short Papers tracks. The evolution, unlike what was explored in other research questions, was analysed according to the editions of the tracks, precisely to observe, with more granularity, when each group of authors published in each track. In total, there are 21 editions of Full Papers and 14 editions of Short Papers, comprised in a period of, respectively, 25 and 18 years, which can lead to changes in the sets of authors and acting groups, which is why this research question was proposed.

Another point that can be observed is the permanence of some groups that, even after several editions, return to publish in the IHC. In this case, it is important to highlight that the resumption of publications by a particular group may be motivated by only one of its authors, while others, although part of the respective group, may not have made new contributions. Therefore, to visualize this issue of the resurgence of publications by groups, it is important to observe the dynamics in the evolution of the groups (i.e., how groups gain or lose members) and which new relationships emerge.

In addition to time, this research question also made possible the analysis of the size of groups in which the authors published. Thus, the analyses previously presented were expanded, mainly in relation to RQ3, where the co-authorship networks were analysed. The evolution of collaboration presented groups of authors who published together more than once, either always with the same set of authors, or forming other groups (i.e., larger or smaller). For this, the main groups of authors of Full Papers (Tables 1 to 4) and Short Papers (Table 5) were selected, and their trajectories are presented in the timeline of the respective track (i.e., Figures 15 and 16, respectively). It is important to note that, in the analyses performed for this research question, each group of authors corresponds exactly to a set of authors who contributed to one of the analysed tracks.

From the evolution of the co-authorship networks, in relation to RQ5, it was possible to perceive that the migration of small groups to the main one varies according to the track. In the case of Full Papers, smaller groups tend to merge with the main group as time goes by. In this scenario, one can speculate that some authors, who were once newcomers and part of an isolated group at the Symposium, began to publish together with other authors who were already known by the community and part of the main group of the IHC.

In general, the movement of authors, transitioning from smaller groups to the main group, indicates that, in the IHC community, researchers have the opportunity to seek new co-authorship relationships and expand their collaboration

network. This migration behaviour can be motivated by various reasons, such as the exploration of a new research topic or the pursuit of new insights on a theme already explored by the researcher.

In addition, upon observing Figure 23, it is possible to notice that since moment M6'Full, the majority of new authors are already included in the main group. In this case, newcomers join the community by publishing in partnership with authors already recognized in the IHC. This partnership can occur, for example, through mentorship relationships. We can understand this as the main motivating factor for what was observed in Section 4.3, namely, that a small portion of authors (i.e., 5.13%) contributed to the majority of the Full Article publications (i.e., 74.56%). For the Short Papers track, the groups tend to remain isolated from each other. Thus, we can imagine that, in general, new authors, for example, did not publish again, or that they were unable to publish together with authors from other groups.

It is important to highlight that, as with the analyses performed to answer RQ4, the evolution of the co-authorship networks should also be observed concurrently with the history of publications (Figure 4), as it is possible to observe, amongst the main authors of the track, which ones published any paper in a given period and, consequently, contributed *de facto* to modifying the structure of the network.

## 5.1 Threats to validity

As threats to validity, we indicate any eventual inconsistencies in the data. Many activities had to be performed manually, such as the indexing of track publications and normalization of authors' names. This normalization was necessary due to, for example, discrepancies identified in the name of the authors, such as abbreviated middle name(s), diacritics (mainly, acute accent and circumflex, which sometimes were presented, sometimes were omitted), and even the omission of some intermediate names. In these activities, a rather large set of data had to be manipulated, thus eventual inconsistencies may have been included unintentionally into this set. Despite this possibility, in order to mitigate the occurrence of problems of this nature, several verifications were performed by the authors directly on the database of this study and also on the visualizations produced during the entire process of developing this work.

Finally, it is worth mentioning that in relation to the identification of publication tracks, more specifically in 2021, Full Papers and Innovative Ideas and Emerging Results were mixed, without identification, on the CEIHC page. Therefore, the track of each publication had to be checked manually in the digital portal of the IHC publisher (i.e., in the ACM Digital Library).

## 6 Conclusion

This work analysed 1,443 authors of 873 publications of the three main tracks of IHC, that is, Full Papers, Short Papers, and Innovative Ideas and Emerging Results. When considering the different tracks of IHC, it was possible to verify the similarity between them in relation to their authors.

In the case of the most consolidated tracks of the Symposium (i.e., Full and Short Papers) the results suggest, as presented in details in the article, that up to the moment when this study was conducted, the authors of Full Papers are contributing more to this new track than they contributed in the past with the Short Papers track. However, even if there is an intersection between the article tracks, it was possible to observe that most authors have been publishing in a single track, being it Full Papers, Short Papers or Innovative Ideas and Emerging Results.

In addition, the authors who published the most in each track were also analysed. The publication history of these authors was presented, which made it possible to identify, for example, the frequency of publication of the authors in the different tracks since their first edition, or even to highlight the authors who began to publish in recent years. Still in relation to these authors, the publication variation map was created, which made it possible to more clearly observe, for example, the moments in which the authors contributed the most, specifically, to the Full Papers and Short Papers tracks.

Then, this work expanded the view on the authors through co-authorship networks, which made it possible to verify the existing relationships of scientific contributions between IHC researchers in different tracks. From the analysis of these networks, it was possible to verify, for example, that in Full Papers, most of the authors form a large connected group. This large group, in turn, is divided into several clusters, according to the co-authorship relationships between the authors.

Regarding the evolution of co-authorship networks, one of the results revealed, for example, that for Short Papers most authors tend to remain isolated in small groups, that is, they do not appear to seek new co-authorship relationships with researchers who are outside their group. In contrast, for Full Papers, authors usually establish collaborations with researchers that are already known by the IHC community, that is, who were already part of the main group of Full Papers authors. The networks naturally have connections due, for example, to the relationship of supervision or co-supervision; however, due to the migrations of authors from smaller groups to the main group, the results suggest the emergence of spontaneous research networks.

In addition, the evolution of the networks made it possible to verify the participation of researchers who were active during the initial editions in which the Symposium was consolidating itself, but stopped publishing in the IHC track over the years, despite their valuable contributions and importance to the Brazilian community of Human-Computer Interaction, which can be complemented with the help of the publication history (Figure 4).

This work also analysed the main groups of authors from Full Papers and Short Papers. The selected groups represent sets of authors who published at least twice together, either in the same group or in a group composed of other authors. This analysis showed that groups of authors from the Short Papers track did not published again after a few editions; however, in the case of Full Papers, the groups returned, either with the same authors or originating a different group, whether larger or smaller. In addition, for Full Papers, it was possible to observe the existence of a higher number of set of authors that originated from other groups, which is aligned with what

was observed in the co-authorship networks. That is, the authors seek new co-authorship relationships, which resulted in the expansion of the largest connected component of the network of this track.

It is also interesting to notice the portion of groups of authors selected from the tracks, which was 30.50% in Full Papers and 10.93% in Short Papers. These values are in accordance with the observed in the co-authorship networks of these tracks where, in the case of Short Papers, the authors remained concentrated into isolated groups. That is, the fact that the portion of groups selected from Short Papers is smaller than Full Papers shows how the groups of authors tend to not publish again in future editions, either with or without the same group of co-authors. The fact that a group returns to publish with other authors, for example, originating a larger group, is another sign that the researchers are seeking new co-authorship relationships.

As a future work resulting from this present study, we aim at developing and publishing a public dataset with the IHC data, since there are several advantages in employing such dataset instead of performing a “scraping” from the source-code of the CEIHC pages. The data generated in this study has already gone through a few stages of “curatorships” (e.g., “normalization” of the names of authors and graphs of the co-authorship networks that have already been created) that may help to perform other future works. We envision that the publication of this dataset in the form of a public domain dataset and in an open scientific repository would have several advantages, such as data already tabulated for a better computational processing, and co-authorship networks already created and organized into structured files (e.g., GraphML).

We also propose, as another investigation that can be performed, to analyse the scientific production generated by IHC publications in the perspective of their impact in the literature, that is, through their citations. The articles from authors who most published in the three main IHC tracks could have been analysed, for example, in relation to the scientific venues (i.e., conference or journal) that they are commonly cited. In this way, it would be possible to evaluate the impact of research from IHC in a scenario that is out of its scope.

## Declarations

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## Authors' Contributions

The authors contributions, following the CRediT taxonomy, are as follows: Franklin M. da C. Lima (Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Software, Writing – original draft), Leonardo Cunha de Miranda (Conceptualization, Data curation, Formal Analysis, Investigation, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Writing – original draft), Gabriel Alves Mendes Vasiljevic (Formal Analysis, Writing – original draft), and M. Cecília C. Baranauskas (Conceptualization, Writing – review & editing).

## Competing interests

The authors have no conflicts of interest to disclosure.

## References

- Aggrawal, N. and Arora, A. (2016). Visualization, analysis and structural pattern infusion of dblp co-authorship network using gephi. In *2016 2nd International Conference on Next Generation Computing Technologies (NGCT)*, pages 494–500. IEEE.
- Barbosa, S. D. J., Silveira, M. S., and Gasparini, I. (2017). What publications metadata tell us about the evolution of a scientific community: the case of the brazilian human-computer interaction conference series. *Scientometrics*, 110(1):275–300.
- Bastian, M., Heymann, S., and Jacomy, M. (2009). Gephi: an open source software for exploring and manipulating networks. In *Proceedings of the international AAAI conference on web and social media*, volume 3, pages 361–362.
- Blondel, V. D., Guillaume, J.-L., Lambiotte, R., and Lefebvre, E. (2008). Fast unfolding of communities in large networks. *Journal of statistical mechanics: theory and experiment*, 2008(10):P10008.
- Cheong, C. and Corbitt, B. (2009). A social network analysis of the co-authorship network of the australasian conference of information systems from 1990 to 2006.
- Cipresso, P., Giglioli, I. A. C., Raya, M. A., and Riva, G. (2018). The past, present, and future of virtual and augmented reality research: a network and cluster analysis of the literature. *Frontiers in psychology*, page 2086.
- Cowhitt, T., Butler, T., and Wilson, E. (2020). Using social network analysis to complete literature reviews: a new systematic approach for independent researchers to detect and interpret prominent research programs within large collections of relevant literature. *International Journal of Social Research Methodology*, 23(5):483–496.
- de Mendonça, F. C., Gasparini, I., Schroeder, R., Silveira, M. S., and Barbosa, S. D. J. (2018). Scientific collaboration networks of the academic brazilian community of hci. In *Proceedings of the 17th Brazilian Symposium on Human Factors in Computing Systems*, pages 1–11.
- de Souza Oliveira Filho, J. (2020). A bibliometric analysis of soil research in brazil 1989–2018. *Geoderma Regional*, 23:e00345.
- do Nascimento, A. S., de Oliveira, F. S., and Bianconi, M. L. (2019). Bibliometric analysis of the brazilian periodical journal of biochemistry education. *Biochemistry and Molecular Biology Education*, 47(3):249–256.
- Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., and Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133:285–296.
- Donthu, N., Kumar, S., and Pattnaik, D. (2020). Forty-five years of journal of business research: a bibliometric analysis. *Journal of Business Research*, 109:1–14.
- Feng, S. and Kirkley, A. (2020). Mixing patterns in interdisciplinary co-authorship networks at multiple scales. *Scientific Reports*, 10(1):7731.
- Fletcher, S., Islam, M. Z., et al. (2018). Comparing sets of patterns with the jaccard index. *Australasian Journal of Information Systems*, 22.
- Gasparini, I., da Cunha, L. F., Kimura, M. H., and Pimenta, M. S. (2014). Análise das redes de coautoria do simpósio brasileiro sobre fatores humanos em sistemas computacionais. In *Proceedings of the 13th Brazilian Symposium on Human Factors in Computing Systems*, pages 323–332.
- Hagberg, A., Swart, P., and S Chult, D. (2008). Exploring network structure, dynamics, and function using networkx. Technical report, Los Alamos National Lab.(LANL), Los Alamos, NM (United States).
- Higaki, A., Uetani, T., Ikeda, S., and Yamaguchi, O. (2020). Co-authorship network analysis in cardiovascular research utilizing machine learning (2009–2019). *International Journal of Medical Informatics*, 143:104274.
- Hosseini, M. R., Martek, I., Zavadskas, E. K., Aibinu, A. A., Arashpour, M., and Chileshe, N. (2018). Critical evaluation of off-site construction research: A scientometric analysis. *Automation in Construction*, 87:235–247.
- Hunter, J. D. (2007). Matplotlib: A 2d graphics environment. *Computing in Science & Engineering*, 9(3):90–95. DOI: 10.1109/MCSE.2007.55.
- Korepanova, A. A., Oliseenko, V. D., and Abramov, M. V. (2020). Applicability of similarity coefficients in social circle matching. In *2020 XXIII International Conference on Soft Computing and Measurements (SCM)*, pages 41–43. IEEE.
- Köseoglu, M. A., Okumus, F., Putra, E. D., Yildiz, M., and Dogan, I. C. (2018). Authorship trends, collaboration patterns, and co-authorship networks in lodging studies (1990–2016). *Journal of Hospitality Marketing & Management*, 27(5):561–582.
- Koumaditis, K. and Hussain, T. (2017). Human computer interaction research through the lens of a bibliometric analysis. In *Human-Computer Interaction. User Interface Design, Development and Multimodality: 19th International Conference, HCI International 2017, Vancouver, BC, Canada, July 9-14, 2017, Proceedings, Part I 19*, pages 23–37. Springer.

- Kraus, S., Breier, M., Lim, W. M., Dabić, M., Kumar, S., Kanbach, D., Mukherjee, D., Corvello, V., Piñeiro-Chousa, J., Liguori, E., et al. (2022). Literature reviews as independent studies: guidelines for academic practice. *Review of Managerial Science*, 16(8):2577–2595.
- Li, L.-L., Ding, G., Feng, N., Wang, M.-H., and Ho, Y.-S. (2009). Global stem cell research trend: Bibliometric analysis as a tool for mapping of trends from 1991 to 2006. *Scientometrics*, 80(1):39–58.
- Lima, F. M. C. and Miranda, L. C. (2023). An analysis of authorship and co-authorship networks in the papers of two relevant events in the brazilian computing scenario. In *Proceedings of the XXII Brazilian Symposium on Human Factors in Computing Systems*, pages 1–11.
- Lima, F. M. C., Miranda, L. C., and Baranauskas, M. C. C. (2018). Two HCI communities in perspective: Revealing and contrasting trends. In *Proceedings of the 17th Brazilian Symposium on Human Factors in Computing Systems*, pages 1–10.
- Lima, F. M. C., Miranda, L. C., and Baranauskas, M. C. C. (2022). Visualizing and analyzing the evolution of authorship and co-authorship networks of articles from the brazilian symposium on human factors in computing systems. In *Proceedings of the 21st Brazilian Symposium on Human Factors in Computing Systems*, pages 1–11.
- Lima, F. M. C., Miranda, L. C., Vasiljevic, G. A. M., and Baranauskas, M. C. C. (2019). An intra and inter-conferences correlation analysis of the field of HCI: revealing new trends from the international and brazilian communities. In *Proceedings of the 18th Brazilian Symposium on Human Factors in Computing Systems*, pages 1–11.
- Lima, F. M. C., Vasiljevic, G. A. M., Miranda, L. C., and Baranauskas, M. C. C. (2021). An analysis of IHC and HCII publication titles: Revealing and comparing the topics of interest of their communities. *Journal on Interactive Systems*, 12(1):1–20.
- Molontay, R. and Nagy, M. (2021). Twenty years of network science: A bibliographic and co-authorship network analysis. In *Big data and social media analytics*, pages 1–24. Springer.
- Mora, L., Bolici, R., and Deakin, M. (2017). The first two decades of smart-city research: A bibliometric analysis. *Journal of Urban Technology*, 24(1):3–27.
- Moraes, R. R. d., Morel, L. L., Correa, M. B., and Lima, G. d. S. (2020). A bibliometric analysis of articles published in brazilian dental journal over 30 years. *Brazilian dental journal*, 31:10–18.
- Mukherjee, D., Lim, W. M., Kumar, S., and Donthu, N. (2022). Guidelines for advancing theory and practice through bibliometric research. *Journal of Business Research*, 148:101–115.
- Newman, M. (2018). *Networks*. Oxford university press.
- Newman, M. E. (2001). The structure of scientific collaboration networks. *Proceedings of the national academy of sciences*, 98(2):404–409.
- Newman, M. E. (2003). The structure and function of complex networks. *SIAM review*, 45(2):167–256.
- Newman, M. E. (2004a). Coauthorship networks and patterns of scientific collaboration. *Proceedings of the national academy of sciences*, 101(suppl\_1):5200–5205.
- Newman, M. E. (2004b). Who is the best connected scientist? a study of scientific coauthorship networks. In *Complex networks*, pages 337–370. Springer.
- Nunes da Silva, A., Breve, M. M., Mena-Chalco, J. P., and Lopes, F. M. (2022). Analysis of co-authorship networks among brazilian graduate programs in computer science. *Plos one*, 17(1):e0261200.
- pandas development team, T. (2020). pandas-dev/pandas: Pandas.
- Procópio, P., Laender, A. H., and Moro, M. M. (2011). Análise da rede de coautoria do simpósio brasileiro de bancos de dados. *SIMPÓSIO BRASILEIRO DE BANCO DE DADOS, Florianópolis, 2011. Proceedings... Florianópolis*.
- Racca, B. S., dos Santos França, J. B., Diir, B., and dos Santos, V. V. (2021). Análise das redes de colaboração científica no simpósio brasileiro de sistemas colaborativos. In *Anais Estendidos do XVII Simpósio Brasileiro de Sistemas Colaborativos*, pages 78–84. SBC.
- Rodan, S. and Galunic, C. (2004). More than network structure: How knowledge heterogeneity influences managerial performance and innovativeness. *Strategic management journal*, 25(6):541–562.
- Sood, S. K., Kumar, N., and Saini, M. (2021). Scientometric analysis of literature on distributed vehicular networks: Vosviewer visualization techniques. *Artificial Intelligence Review*, pages 1–33.
- Vijaymeena, M. and Kavitha, K. (2016). A survey on similarity measures in text mining. *Machine Learning and Applications: An International Journal*, 3(2):19–28.
- Waskom, M. L. (2021). seaborn: statistical data visualization. *Journal of Open Source Software*, 6(60):3021. DOI: 10.21105/joss.03021.
- Wes McKinney (2010). Data Structures for Statistical Computing in Python. In Stéfan van der Walt and Jarrod Millman, editors, *Proceedings of the 9th Python in Science Conference*, pages 56 – 61. DOI: 10.25080/Majora-92bf1922-00a.
- Zanghelini, G. M., de Souza Junior, H. R., Kulay, L., Cherubini, E., Ribeiro, P. T., and Soares, S. R. (2016). A bibliometric overview of brazilian lca research. *The International Journal of Life Cycle Assessment*, 21(12):1759–1775.