Beyond Boundaries: Collaboration Networks and Research Output in Brazilian Computer Science

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Abstract. *This study examines collaborative dynamics within Brazilian computer science research through network analysis and bibliometric methods. Using OpenAlex data spanning 2015–2024, we analyze publication trends, citation metrics, and co-authorship networks to understand international engagement patterns and subfield collaboration differences. Our findings reveal that while Brazil ranks 12th globally in computer science output, approximately 75% of its publications involve exclusively domestic partnerships, with significant variation across subfields. Network analyses identify distinct clustering patterns organized by subfield, with influential bridging researchers facilitating knowledge transfer across disciplinary boundaries. The United States emerges as Brazil's primary international collaborator across all subfields, while the second major collaborator vary for each subdield. Our methodological framework provides a foundation for developing evidence-based strategies to optimize research investment and strengthen Brazil's position in the global scientific community.*

1. Introduction

Computer science research has experienced remarkable growth and transformation in the past decades [Bird et al. 2009, Biryukov and Dong 2010, Madaan and Jolad 2014, Wainer et al. 2009]. This expansion reflects the increasingly central role of the field in driving technological innovation, economic development, and societal advancement worldwide. Despite this global growth, significant regional disparities persist in research output, citation impact, and international visibility, particularly for emerging research communities such as those in Brazil, which ranks 12th globally in computer science publications but achieves substantially lower citation impact than leading nations.

Understanding the collaborative structures that underpin successful research ecosystems has thus become essential for countries seeking to enhance their global scientific position. Collaboration networks, the complex net of relationships between researchers, institutions, and countries, provide valuable insights into knowledge production dynamics and can help identify strategic pathways for strengthening research communities. This is particularly relevant for Brazil, where computer science research has shown consistent growth but faces challenges in achieving international recognition proportionate to its output volume.

In this study, we examine the collaborative dynamics within Brazilian computer science research through network analysis and bibliometric methods. Our investigation is guided by two primary research questions:

- **RQ1:** To what extent are Brazilian subfields collaborating with researchers and institutions in other countries?
- **RQ2:** What are the key differences in collaboration networks across Brazilian subfields of Computer Science?

To address these questions, we conduct a comprehensive bibliometric and network analysis using data from OpenAlex, focusing on publication trends, citation metrics, and co-authorship relations from 2015 to 2024. Our findings reveal notable variations in collaboration intensity among different subfields. Theoretical domains frequently engage in extensive international partnerships, whereas applied fields, such as Information Systems, exhibit a stronger inclination toward domestic collaborations. The structural properties of these collaboration networks, including the emergence of cohesive research clusters and influential bridging authors, play a decisive role in shaping the broader academic landscape and the influence of Brazilian research. Our contributions are threefold:

- We provide a mapping of Brazilian computer science collaboration networks across multiple subfields, revealing significant variations in international engagement patterns.
- We identify structural properties of high-impact collaboration networks, including the crucial role of bridging researchers who connect disparate communities.
- We demonstrate the relationship between strategic international partnerships, offering evidence-based insights for research policy development.

This paper is structured as follows: Section 2 reviews prior work on collaboration networks in computer science research. Section 3 outlines our methodology, including data collection and analytical techniques. Section 4 presents an overview of the global research landscape in computer science. Sections 5 and 6 address our research questions by analyzing international collaboration patterns and subfield network differences, respectively. Finally, Section 7 concludes the paper and proposes directions for future research.

2. Related Work

Scientific collaboration networks provide valuable insights into academic community structures and knowledge production dynamics. This section examines the fundamental properties of these networks, their international dimensions, and disciplinary variations in collaborative patterns.

2.1. Fundamental Network Properties

Pioneering studies settled essential structural characteristics of scientific collaboration by analyzing co-authorship relations through the network science and graph theory perspective. For instance, [Newman 2001a, Newman 2001b], documented distinctive power-law distributions in productivity across physics, biomedical research, and computer science, then introduced weighted networks that revealed connection strength depends on co-authorship frequency rather than mere collaborator quantity. This work uncovered significant disciplinary differences, with theoretical fields exhibiting lower average collaborator counts than experimental disciplines. Research by [Barabási et al. 2002], focused on journals in mathematics and neuro-science collaborations, concluded that these networks are scale-free and evolve through preferential attachment mechanisms.

The comprehensive comparison of [Newman 2004] within biology, physics, and mathematics revealed consistent "small world" properties despite variations in collaboration intensity, collectively establishing scientific collaboration networks' essential features scale-free organization, small-world connectivity, preferential attachment growth, temporal evolution, and disciplinary variation within consistent topological frameworks. Furthermore, [Elmacioglu and Lee 2005] confirmed the "six degrees of separation" phenomenon and the power-law distribution across different statistics in database research collected from DBLP, documenting increasing clustering coefficients over three decades. [Madaan and Jolad 2014] also used publications data of DBLP, covering more than two million publications and one million authors from the period of 1936 to 2013. Their results show that computer science collaboration is growing along with the average number of authors per publication.

2.2. International Collaboration

[Luukkonen et al. 1993] proposed fundamental metrics for analyzing international scientific collaboration, emphasizing the importance of both absolute measures to identify central collaborative countries and relative measures to reveal collaboration intensity regardless of country size. Building on these methodological foundations, [Guan and Ma 2004] conducted a comparative analysis across six major countries (USA, UK, Germany, Japan, India, and China) from 1993 to 2002, highlighting the dominant position of the USA in computer science publications and revealing how the rapid increase of China in publications resulted in lower international visibility despite growing output.

Regional analysis by [Wainer et al. 2009] examined Brazilian computer science output from 2001 to 2005, comparing it against other Latin American countries, BRIC nations, and developed economies. They conclude that while Brazil led regionally, it still lagged significantly behind global leaders. Complementing this, [Delgado-Garcia et al. 2014] documented significant growth in Latin American co-authorship networks between 1994-2013, identifying particularly strong collaborative ties between Brazil-Chile and Argentina-Brazil. [Niu and Qiu 2014] investigated Chinese international research collaboration, revealing a significant increase in international collaborations, with partnerships primarily concentrated among scientifically advanced countries accounting for over 80% of China's international co-authored publications.

Examining intra-national patterns, [Pessoa Junior et al. 2022] analyzed interdisciplinary collaborations within Brazil, finding that geographic proximity plays a pivotal role in shaping collaboration networks, with patterns reflecting economic disparities across Brazil's regions. More recently, [Okamura 2023] conducted a half-century analysis of global scientific collaboration using OpenAlex data, documenting China's dramatic rise across multiple disciplines and identifying a global "Shrinking World" phenomenon where research collaboration has increased worldwide, though noting a post-2019 divergence between the United States and China. [Haunschild and Bornmann 2024] also explored OpenAlex's capabilities for creating bibliometric global overlay maps to visualize research output, demonstrating techniques for normalizing data for meaningful comparisons between authors and institutions.

2.3. Computer Science Disciplinary Patterns

Research on collaboration within computer science has revealed distinct patterns across different specializations. [Bird et al. 2009] conducted pioneering quantitative analyses of collaboration differences across research subfields using network analysis methods. Their examination of DBLP data revealed significant variations, with Data Mining and Software Engineering showing high interdisciplinarity, while theory and cryptography exhibited more isolated patterns. [Biryukov and Dong 2010] extended this work by investigating the evolution of computer science communities from 1970 onwards. Their analysis of co-authorship graphs across 14 subfields revealed that Algorithms & Theory, Cryptography, and Programming Languages preferred small, weakly connected collaboration groups, while Computational Biology and Web areas demonstrated higher collaboration intensity. They also found researchers typically show higher publication activity in the middle stages of their careers.

Using DBLP data from 1936 to 2008, [Franceschet 2011] confirmed that scientific productivity among computer scientists follows Lotka's law's asymmetric distribution. The study characterized computer science collaboration as moderate compared to other fields, with conference papers showing higher collaboration intensity than journal publications, highlighting computer science's conference-centered culture. More recently, [Chakraborty 2018] introduced the Reference Diversity Index and Keyword Diversity Index to quantify interdisciplinarity in research fields. Their analysis provided evidence that interdisciplinary research in computer science has been steadily increasing, with Web and Data Mining fields demonstrating significantly higher interdisciplinarity than traditional areas like Algorithms and Databases. When it comes to impact analysis, citation patterns also reveal significant disparities across subfields. [Druszcz and Vignatti 2024] examined citation distributions within Brazilian computer science, finding that areas like Computer Vision typically accumulate substantially higher citation counts than Algorithms or Formal Methods. Their research highlighted limitations in applying uniform citation-based metrics across diverse specializations and demonstrated how normalization techniques can facilitate fairer impact comparisons across computer science's heterogeneous landscape.

3. Methodology

Our analytical framework utilizes OpenAlex by [Priem et al. 2022], a index of scholarly works that offers distinct advantages for bibliometric research through its open-access model and comprehensive metadata capabilities. Research by [Culbert et al. 2024] demonstrates that OpenAlex's reference coverage and citation rates are comparable to proprietary databases like Web of Science and Scopus when analyzing shared core corpora. According to [Velez-Estevez et al. 2023], it also provides superior metadata features, including higher ORCID identifier rates, detailed institutional affiliations with persistent identifiers, and comprehensive funding information.

We began our exploratory data analysis using the OpenAlex web-based[1] graphical user interface (GUI), which allowed us to perform primary searches by applying the main filters that established the scope of this work: articles or book-chapters (publication type), Computer Science (field), and 2015-2024 (year range). After applying these filters, we obtained a list of works and the corresponding statistical metrics, including the number

[1] https://openalex.org/

of publications found, citation count, open-access percentage, and rankings of countries, universities, and subfields publication total, and many others.

Following this initial exploratory analysis, we needed to collect more granular data for deeper analysis. OpenAlex offers the option to download a complete snapshot of its database, which uses the relational model of Postgres. However, we opted to retrieve data through their Application Programming Interface (API), and store our extractions locally by using comma-separated values (CSV) files. Yet, to effectively work with the API, we first familiarized ourselves with the underlying database model. Figure 1 presents a simplified entity-relationship diagram highlighting the main entities and properties relevant to our work.

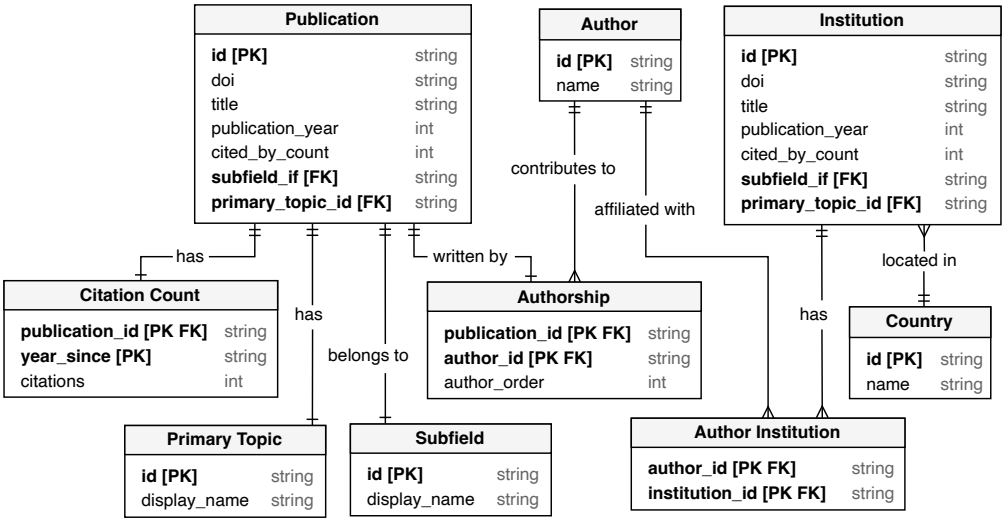

Figure 1. Simplified entity–relationship diagram from OpenAlex's database. Adapted from OpenAlex's API Documentation.

Figure 2 illustrates our complete data pipeline, which we structured into three primary phases: *Extraction*, *Processing*, and *Visualization*.

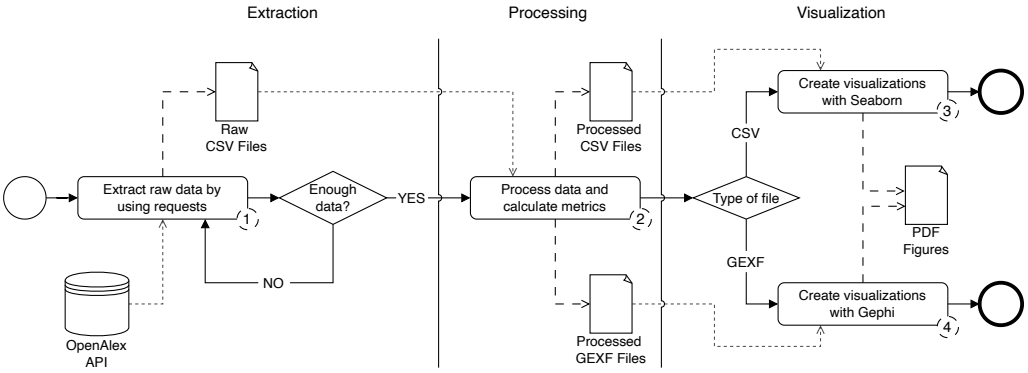

Figure 2. Data collection process.

The *Extraction* phase involved retrieving data from the OpenAlex API using Python scripts (version 3.13.0). The API provides two levels of metadata: *API Response Metadata*, which includes overall statistics such as total record count, citation counts, and database

response time; and *Publication Metadata*, which contains detailed information for each publication (e.g., title, authors, publication year, and country affiliations). This dual-level structure allowed us to efficiently gather both aggregate metrics and granular publication details.

Step 1 of our process entailed extracting both metadata levels. For simpler metrics such as publication counts for each country, we utilized only the API Response Metadata. For more detailed analyses, specifically for Brazilian publications, we retrieved the comprehensive Publication Metadata. Due to API request limitations, we implemented an efficient batching strategy, handling both pagination constraints (maximum 25 records per request) and organizing extraction by logical groups (e.g., one subfield at a time, one country at a time). The output of this step consisted of raw data stored in CSV files.

Step 2 focused on data processing and transformation. We consolidated the batched data by concatenating groups, and also made some cleaning to produce comprehensive processed files. For publication metrics comparisons, we maintained the CSV format. For collaboration network analysis, we constructed co-authorship networks where nodes represent researchers and edges denote collaborative relationships, with edge weights corresponding to collaboration frequency. These networks were exported as GEXF files generated using the Python NetworkX library (version 3.4.2).

The final phase of our process involved *Visualization* of the analyzed data through two parallel approaches. In *Step 3*, we employed Jupyter Notebooks (version 7.3.2) to generate plots and charts from the processed CSV data. For *Step 4*, we utilized Gephi (version 0.10.0) to visualize and analyze the GEXF network files, enabling sophisticated network visualization. Both visualization pathways produced figures in PDF format for integration into our research publication.

All code developed for data extraction, processing, and visualization, along with comprehensive documentation, is available in our public GitHub repository[2].

4. Global Research Landscape

Research performance metrics serve as indicators for understanding scientific knowledge advancement worldwide, quantifying both research production volume and impact within the broader scientific community. As this study examines collaboration patterns between Brazil and other countries, we first establish a glimpse of the global computer science research landscape over the 2015-2024 period. According to Table 1, Brazil ranks 12th among the top 15 countries in computer science research output, with 76,184 publications and 447,919 citations. This positions Brazil in the middle tier of global research productivity, significantly behind leaders like China (694,103 publications) and the United States (474,474 publications), but ahead of neighboring Latin American countries. Brazil's citation ratio of 5.88 falls below many countries in the analysis, particularly compared to high-impact nations like Australia (22.8), Great Britain (21.62), and the United States (20.21). While Brazil maintains substantial publication output, its research achieves less global citation impact than many international counterparts.

Figure 3 reveals distinctive patterns in Brazil's computer science research profile compared to other major research nations. The visualization illustrates the research

[2]https://anonymous.4open.science/r/beyond_boundaries-B636/README.md

	Code	Country	Total Publications	Citations	Ratio
1	CN	China	694,103	8,280,834	11.93
2	US	United States of America	474,474	9,590,230	20.21
3	IN	India	311,644	2,224,750	7.14
4	ID	Indonesia	266,047	755,078	2.84
5	DE	Germany	141,044	1,960,782	13.9
6	GB	Great Britain and Northern Ireland	140,019	3,026,576	21.62
7	JP	Japan	103,265	799,048	7.74
8	FR	France	92,131	1,011,787	10.98
9	CA	Canada	84,076	1,562,176	18.58
10	RU	Russian Federation	83,214	363,210	4.36
11	IT	Italy	80,647	1,021,944	12.67
12	BR	Brazil	76,184	447,919	5.88
13	ES	Spain	75,433	944,337	12.52
14	KR	South Korea	74,421	994,882	13.37
15	AU	Australia	68,502	1,561,906	22.8

Table 1. Summary of research output and citation count (articles and book chapters only) metrics across 15 countries, showing publication volume, cumulative citations, and citation ratios. Data from 2015 to 2024, inclusive. Source: OpenAlex.

priorities of Brazil, China, the United States, and Indin. We note that Brazil demonstrates a pronounced specialization in Information Systems, consistently representing 35-40% of its total publications throughout the analyzed timeframe, significantly higher than the United States (15%), and China, that got 20% at its highest point and then it decrease to 10%.

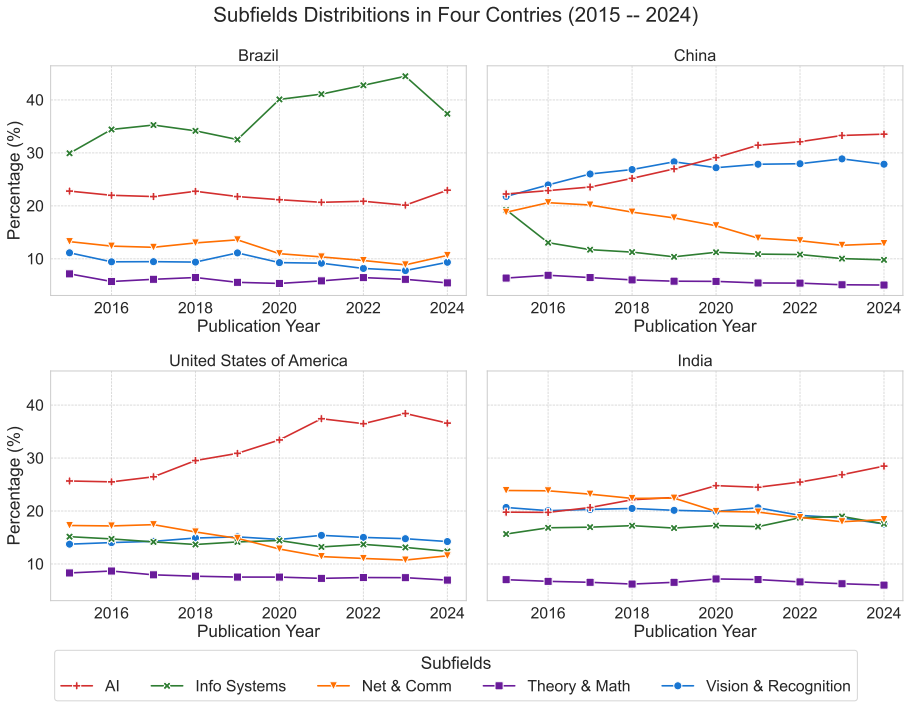

Figure 3. Percentage distribution of publications in the top five computer science subfields for Brazil, China, the U.S., and India (2015–2024), relative to each country's total publications per year.

Artificial Intelligence emerges as Brazil's second most productive area (20-25% of research output), aligning with global trends but showing more moderate focus compared to USA and China, that show dramatic increase from approximately 30% in 2015 to nearly 40% by 2024. AI is also the first subfield in research output in India, and shows growing trend, although it shows less disparity comparing to the other subfields in the country. Brazil exhibits lower activity in Computer Vision and Pattern Recognition, which is a domain that captures larger proportions in China. Computational Theory and Mathematics (less than 10% of publications) is particularly notable across the four countries.

The remarkable stability of Brazil's research distribution across subfields from 2015 to 2024 contrasts sharply with other countries' shifting priorities, particularly China's substantial pivot toward Artificial Intelligence. Despite the last range of the result (2023-2024) showing Information System decrease, and AI increase, the consistency likely reflects established institutional structures and funding mechanisms that favor continuity rather than rapid realignment toward emerging technologies. While this stability provides advantages for developing deep expertise in specific domains, particularly Information Systems, it may also indicate challenges in adapting to evolving global research priorities and technological trends.

5. International Collaborations (RQ1)

Our analysis of all computer science publications with Brazilian researcher participation reveals distinct patterns of international collaboration across different subfields, as shown in Table 2. Computational Theory and Mathematics demonstrates the highest rate of international collaboration (37.47%), followed by Computer Graphics and Computer-Aided Design (31.79%) and Computer Networks and Communications (32.64%). Notably, Information Systems, that despite having the largest volume of publications (26,609), shows the lowest international collaboration rate (16.76%).

Subfield	**International**		**Domestic**	
	Publications	%	Publications	%
Computational Theory and Mathematics	1,481	37.47	2,472	62.53
Computer Graphics and Computer-Aided Design	117	31.79	251	68.21
Computer Networks and Communications	2,576	32.64	5,315	67.36
Hardware and Architecture	358	30.62	811	69.38
Computer Vision and Pattern Recognition	1,744	28.05	4,473	71.95
Artificial Intelligence	4,157	29.33	10,015	70.67
Signal Processing	595	27.82	1,544	72.18
Software	224	27.76	583	72.24
Computer Science Applications	768	25.35	2,261	74.65
Human-Computer Interaction	397	21.58	1,443	78.42
Information Systems	4,459	16.76	22,150	83.24
Total	16,876	24.75	51,318	75.25

Table 2. Distribution of Brazilian computer science publications across different subfields (2015 to 2024), comparing international collaborations versus domestic-only research.

Further nuances in collaboration patterns emerge from Figure 4, which displays normalized percentages of non-Brazilian authorship across various computer science subfields.

The heatmap reveals that collaboration intensity varies significantly by partner country and subfield. The United States consistently appears as Brazil's primary international collaborator across all subfields, with particularly strong connections in Computational Theory and Mathematics (20.9%), Computer Graphics and Computer-Aided Design (20.7%), and Hardware and Architecture (20.3%). European countries, particularly France, Germany, and Spain, show specialized collaboration patterns, with France having notable engagement in Hardware and Architecture (11.7%) and Computational Theory and Mathematics (9.4%).

Figure 4. International collaboration heatmap for Brazilian computer science publications by subfield and partner country. Values represent the percentage of international collaborations normalized by total publications in each subfield, with darker blue indicating higher collaboration intensity.

Considering recurrent collaborations in highly cited publications, we can also see patterns by looking at the network structure, as illustrated in Figure 5. This network visualization presents recurrent co-authorship relationships in Brazilian computer science publications with at least 40 citations (1,687 total publications), which give give us a fraction of 10% of the whole dataset. Each node represents an author, with node sizes proportional to publication count, providing visual indication of research productivity. Additionally, they are colored according to authors' country affiliations. To clearly visualize strong, recurrent collaborations, we weighted the edges based on how frequently the nodes co-authored publications. We then filtered out weak connections, specifically those representing only single collaborations (edge weight less than two), and removed authors with no substantial collaborative relationships (isolated nodes). We applied the Fruchterman-Reingold layout algorithm to distribute nodes based on their connectivity patterns.

The network reveals a fragmented structure with several small clusters and few larger, densely connected components. The largest component consists predominantly of Brazilian authors (gray nodes) forming a central hub, surrounded by international

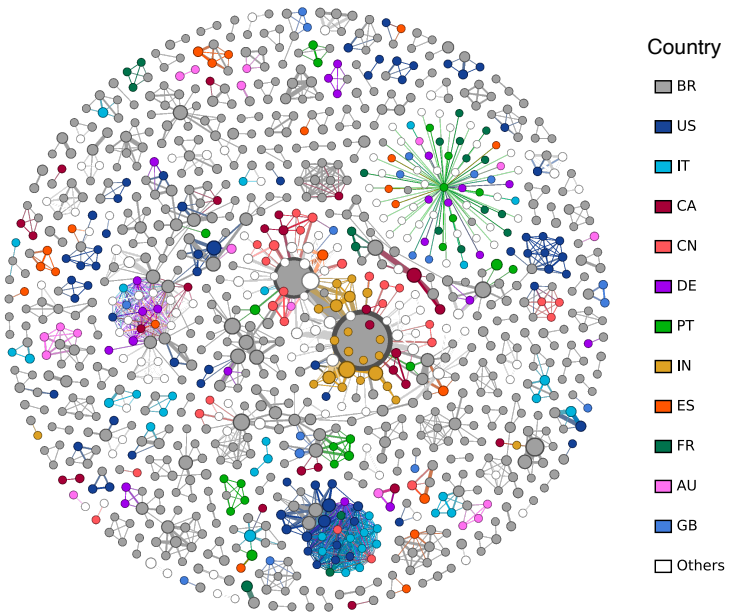

Figure 5. Network visualization of international co-authorship patterns in Brazilian computer science publications with at least 40 citations (1,687 total). Nodes represent authors colored by country affiliation, with node size proportional to the number of publications. Edges indicate recurring co-authorship relationships.

collaborators. This clustering pattern suggests that while many researchers collaborate within smaller, tightly knit groups, fewer engage in broader international networks. Notably, authors from the United States (dark blue) and European countries such as Italy (light blue), Germany (purple), and France (green) appear frequently in co-authorship relationships with Brazilian researchers. These international collaborations, however, appear concentrated around specific sub-networks rather than being evenly distributed throughout the network.

The collective analysis of these network structures, collaboration rates, and international partnerships reveals key insights about Brazilian computer science research. The overall tendency toward domestic collaboration is evident across all subfields, with approximately three-quarters (75.25%) of all publications involving exclusively domestic partnerships. This suggests strong internal research capacity but also identifies potential opportunities for increasing international engagement. The pronounced variation in international collaboration rates across subfields, ranging from 16.76% to 37.47%, indicates that certain domains in computer science are more conducive to cross-border research partnerships than others. Technical and theoretical fields generally exhibit higher internationalization, while applied areas like Information Systems and Human-Computer Interaction show stronger domestic orientation. These patterns likely reflect a combination of factors including research funding structures, infrastructure requirements, local industry partnerships, and the inherent nature of research questions being addressed in different subfields.

6. Subfield Collaborations (RQ2)

Our second research question examines collaboration patterns across different subfields of computer science in Brazil. We analyze cross-disciplinary co-authorship patterns, network

centralization metrics, and collaboration structures among highly cited publications. Figure 6 presents a heatmap of interdisciplinary collaborations within Brazilian computer science research. Hardware and Architecture specialists demonstrate strong collaboration with Networks and Communications (29.0%), while Computer Science Applications researchers frequently publish in Information Systems (25.7%). Information Systems researchers show substantial publication activity across multiple subfields including Networks and Communications (17.9%), Computer Science Applications (25.7%), and Software (27.9%).

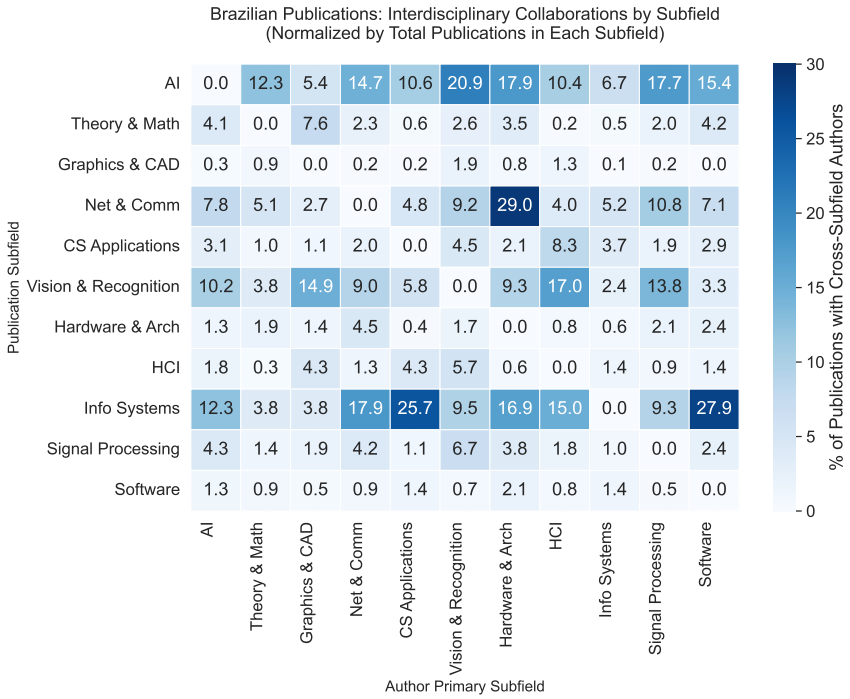

Figure 6. International Collaboration in Brazilian Computer Science Publications. The heatmap displays normalized percentages by the number of publications for each subfield. Darker blue indicates higher collaboration intensity, with values representing the percentage of international collaborations per publication.

Artificial Intelligence researchers display the most diverse collaboration pattern, with substantial contributions across nearly all subfields, particularly Computer Vision & Recognition (20.9%) and Hardware & Architecture (17.9%). Conversely, researchers specializing in Computational Theory & Mathematics, Software, and Graphics & Computer-Aided Design exhibit more limited cross-disciplinary engagement, suggesting these communities operate in more specialized research ecosystems.

Figure 7 illustrates the evolution of betweenness centralization metrics for the five most centralized computer science subfields in Brazil from 2015 to 2024. Artificial Intelligence consistently maintains the highest centralization values throughout most of the analyzed period, peaking between 2018-2020 before showing a slight decline. This pattern suggests the emergence of influential bridging researchers within AI who facilitate connections across previously disparate research groups.

Hardware & Architecture shows the most dramatic centralization increase, rising

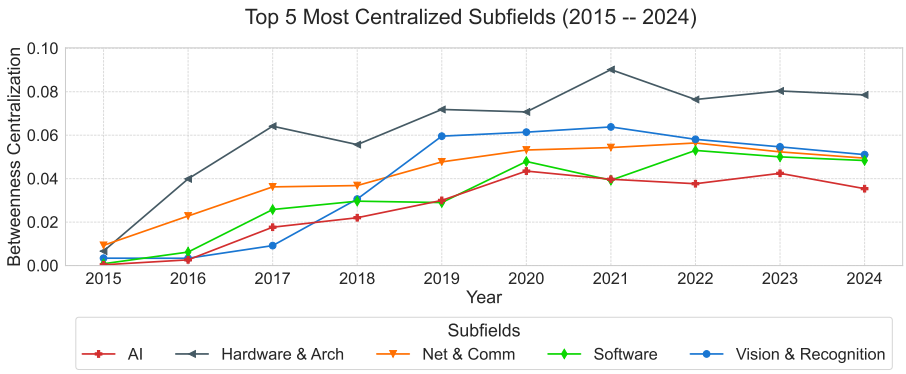

Figure 7. Betweenness Centralization of Most centralized computer science subfields in Brazil from 2015 to 2024.

steadily from 2015 to 2022 before experiencing a sharp decline. Networks & Communications demonstrates relatively stable centralization with moderate values throughout the period. Software exhibits significant volatility in centralization metrics, suggesting the community may experience more frequent reorganization. The overall trend shows generally increasing centralization until approximately 2022, followed by a broad decline, potentially indicating a maturation of the Brazilian computer science research ecosystem.

Figure 8 provides the same network presented on Section 5, displaying co-authorship recurrence in highly cited Brazilian computer science publications. Differently, this network's nodes are colored according to authors' primary research. It reveals distinctive clustering patterns organized largely by subfield. In this scenario, we can see a pronounced modular structure with clear clustering by subfield, particularly for Information Systems (dark green), Theory & Mathematics (purple), and Artificial Intelligence (red). This community structure indicates that despite cross-disciplinary collaborations, highly cited research still tends to emerge from within-field collaborations.

Notable exceptions include bridge nodes, that are researchers who connect otherwise disparate communities. These bridging authors, particularly visible between the AI and Computer Vision clusters and between Networks and Information Systems, appear to play crucial roles in facilitating knowledge transfer across disciplinary boundaries. When comparing this visualization with the country-based network in Figure 5, we observed that the two most productive authors (largest nodes), both affiliated to Brazilian institutions, yet they are from different primary subfields.

These analyses reveal that substantial variation exists in cross-disciplinary engagement, with fields like Artificial Intelligence demonstrating broad collaborative reach while others like Computational Theory maintain more specialized research ecosystems. Network centralization metrics suggest field-specific organizational structures that evolve over time. Despite some cross-disciplinary engagement, Brazilian computer science research communities remain primarily organized along traditional subfield boundaries, with knowledge transfer facilitated through a limited number of bridging researchers rather than through broad interdisciplinary integration.

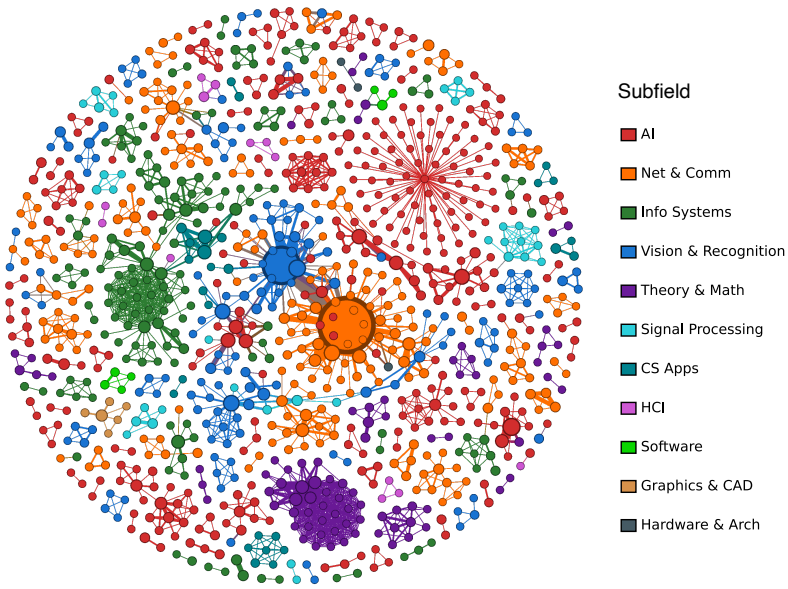

Figure 8. Network visualization of subfield co-authorship patterns in Brazilian computer science publications with at least 40 citations (1,687 total). Nodes represent authors colored by their primary subfield, with node size proportional to the number of publications. Edges indicate recurring co-authorship relationships.

7. Conclusion and Future Works

This study presents a comprehensive analysis of collaborative dynamics in Brazilian computer science research through bibliometric data and network analysis techniques. By leveraging OpenAlex data to examine publication trends, citation metrics, and co-authorship networks across multiple subfields, we have provided substantial insights into the structure and impact of research collaborations in the Brazilian context. Our findings directly address the research questions posed at the outset of this investigation:

Regarding RQ1 (international collaboration patterns), we found that approximately 75% of Brazilian computer science publications involve exclusively domestic partnerships, with significant variation across subfields. Theoretical domains such as Computational Theory and Mathematics (37.47%) and Computer Graphics and Computer-Aided Design (31.79%) demonstrate the highest rates of international collaboration, while Information Systems (16.76%) shows the lowest, despite being Brazil's most productive subfield. The United States consistently emerges as Brazil's primary international collaborator across all subfields, with European countries (particularly France, Germany, and Spain) showing more specialized collaboration patterns.

For RQ2 (subfield collaboration differences), our analysis reveals substantial variation in cross-disciplinary engagement. Artificial Intelligence researchers demonstrate the broadest collaborative reach, with significant contributions across multiple subfields, while areas such as Computational Theory and Mathematics maintain more specialized research ecosystems. Network centralization metrics indicate that influential bridging researchers play a crucial role in facilitating knowledge transfer across disciplinary boundaries, though Brazilian computer science research communities remain primarily organized along traditional subfield lines.

These findings have important implications for research policy and funding strategies. The correlation between international collaboration and citation impact suggests that targeted initiatives to enhance cross-border partnerships, particularly in applied fields like Information Systems, could significantly amplify the global visibility and influence of Brazilian research. Similarly, the identification of key bridging researchers between subfields highlights the importance of supporting interdisciplinary initiatives to foster innovation at the intersection of traditional domains.

Future work should extend this analysis in several directions. First, incorporating additional indexing databases such as Scopus, Google Scholar, and DBLP would provide validation of the observed patterns and enable more comprehensive bibliometric coverage, particularly for conference proceedings that may be underrepresented in OpenAlex. Second, a deeper investigation into the temporal evolution of collaboration networks could reveal how research communities form, evolve, and dissolve over time, potentially identifying catalysts for sustainable research ecosystems. Third, examining the relationship between institutional factors (e.g., funding mechanisms, geographic proximity, and organizational structures) and collaboration patterns could yield valuable insights into the systemic drivers of research productivity and impact.

By advancing our understanding of the structural and dynamic properties of research collaborations, this work contributes to the development of evidence-based strategies for enhancing the global competitiveness of Brazilian computer science research. The methodological approach and analytical framework presented here provide a foundation for future studies aimed at optimizing research investment, fostering strategic international partnerships, and ultimately strengthening Brazil's position in the global scientific community.

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