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Mapping the Evolution of Cybernetics: A Bibliometric Perspective

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Abstract: In this study, we undertake a comprehensive bibliometric analysis of the cybernetics research field. We compile a dataset of 4856 papers from the ISI Web of Science database spanning 1975–2022, employing keywords related to cybernetics. Our findings reveal an annual growth rate of 7.56% in cybernetics research over this period, indicating sustained scholarly interest. By examining the annual progression of scientific production, we have identified three distinct periods characterized by significant disruptions in yearly publication trends. These disruptions have been thoroughly investigated within the paper, utilizing a longitudinal analysis of thematic evolution. We also identify emerging research trends through keyword analysis. Furthermore, we investigate collaborative networks among authors, their institutional affiliations, and global representation to elucidate the dissemination of cybernetics research. Employing n-gram analysis, we uncover diverse applications of cybernetics in fields such as computer science, information science, social sciences, sustainable development, supply chain, knowledge management, system dynamics, and medicine. The study contributes to enhancing the understanding of the evolving cybernetics landscape. Moreover, the conducted analysis underscores the versatile applicability across various academic and practical domains associated with the cybernetics field.

Keywords: cybernetic; cybernetics; bibliometric analysis; n-gram analysis; thematic evolution

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1. Introduction

Cybernetics, a pivotal field that emerged and evolved significantly throughout the 20th century, serves as a scientific domain with the primary objective of elucidating the optimal means of controlling complex systems [1]. This pursuit is grounded in the recognition of various factors that possess the potential to disrupt both the system itself and its broader environment. The genesis of Cybernetics stemmed from a fundamental gap in scientific understanding: the absence of a coherent framework for comprehending system dynamics [2], the intricate interplay of external influences [3], and the system's capacity for adaptation in response to unforeseen events. Notably, the impetus for exploring Cybernetics gained prominence during World War II [4], as scholars undertook a concerted effort to scrutinize its principles [5]. This initiative was driven by profound concerns regarding post-war reconstruction, the revitalization of cities, and the imperative of fostering international trade relations [6].

To analyze and identify the characteristics of a system using cybernetics, one should employ specific techniques. These techniques include presenting data in a simplified manner to maximize information utilization, which can be accomplished through tools like the Support Vector Machine [7] or various visualization tools [8]. Additionally, modeling the real problem can be achieved using methodologies such as Bayesian Networks [9], Neural Networks [10], or Fuzzy Logic [11], and the results can be controlled through the application of principles from fields like Supply Chain Management [12] or Enterprise

Management [13]. Nevertheless, there is a strong relationship between the evolution of technology, environmental laws, and the cybernetics domain. With all these, there exists some characteristics that have different effects and which could be analyzed using the methods presented above [14]. Initially, the domain of cybernetics presented formidable challenges in comprehension due to its interdisciplinary nature, drawing from diverse disciplines such as economics, physics, chemistry, mathematics, statistics, medicine, and others. What sets cybernetics apart from other domains is its unparalleled versatility, as it finds application across a multitude of domains [15].

In recent years, the field of Cybernetics has evolved along diverse trajectories, yielding fresh insights into addressing the evolving needs of society. Notably, it has yielded the Cybernetic Transportation System (CTS) [16], offering a comprehensive framework [17] for optimizing public transportation [18]. As international regulations increasingly prioritize the transition from individual vehicular transportation to more environmentally sustainable public transportation modes [16], this system has experienced heightened demand and encountered challenges in adapting to emerging technologies [19], leading to an environment characterized by heightened activity and reduced adaptability [20]. Furthermore, in the context of contemporary Cybernetics, Umpleby [21] discusses how the recent developments in Cybernetics have challenged the key issues in the philosophy of science. For those seeking to delve into the origins of Cybernetics and its evolution over time, Novikov's book [22] emerges as a pivotal reference. Moreover, the work of Von Glasersfeld [23] brings to light both Cybernetics as a discipline and adopting a Cybernetic attitude when discussing a certain subject.

Given that Cybernetics stands as one of the most adaptable sciences [24], its applicability spans diverse domains, encompassing critical areas such as addressing scholar dropout concerns [25] and forecasting the primary factors contributing to social and economic challenges. In the contemporary landscape, the accessibility of knowledge acquisition and information processing has significantly improved, primarily due to the ubiquity of the internet and the advent of electronic education (E-education) [26,27].

Cybernetics has played a pivotal role in this transformation, offering comprehensive insights into various scenarios and delineating the advantages and drawbacks associated with E-learning and E-education [28,29]. It is imperative to note that the successful implementation of this educational paradigm hinges on specific prerequisites: universal access to the internet [30], possession of smart devices, reliable access to electricity [31], and proficiency in navigating the digital realm through personal computers or smartphones [32]. Regrettably, the realization of this revolutionary system remains limited to a select few countries, as not all the requisite conditions are currently met.

While E-learning has exhibited certain disadvantages [33], it emerged as an imperative measure during the pandemic, exemplifying the applicability of Cybernetics in situations where external factors [34] disrupt a system. This underscores the capacity of Cybernetics to adapt [35] and evolve under dynamic circumstances, thereby advancing our understanding of complex systems.

Recently, the profound impact of the COVID-19 pandemic has reverberated across all domains, including education and Cybernetics [36–39]. Discussing Cybernetics, Grinin et al. [36] showed that the COVID-19 pandemic has triggered the acceleration of the Cybernetic revolution. On the other hand, other authors have focused on using the means offered by Cybernetics to better understand the emerging pandemic [37,38].

As posited by Cybernetics, every facet of existence constitutes a complex adaptive system [40], necessitating continuous input from the environment [41] and other elements capable of influencing the relationships between agents [42]. In response to the pandemic, education and transportation, being vital for society, adapted persistently. Numerous simulations were conducted, leading to the implementation of enhanced controls over goods and services [43] to ensure compliance with evolving regulations [44].

The choice to research the field of Cybernetics was driven by its significance in the context of the technology-driven world we live in. Cybernetics is a science that aims to ensure that both people and the environment benefit from the continuous evolution of technology. It provides a framework for understanding and improving the systems that surround us, including ourselves as adaptive systems constantly seeking to evolve and adapt to our environment. Furthermore, Cybernetics sheds light on the role of technology within society and the broader systems of our world [45].

For our analysis, we utilized the Biblioshiny library within RStudio developed by Aria and Cuccurullo [46], which provided us with powerful tools to examine the selected papers comprehensively [47]. Through this library, we were able to analyze various aspects of Cybernetics research. The aspects include: the evolution of annual scientific production, the average number of citations per year, significant author collaborations, notable publication outlets, collaborative networks between countries, prolific authors in the field, and the most frequently occurring word groups in titles and abstracts. We employed a range of visual tools such as collaboration maps, three-fields plots, collaboration networks, and WordClouds to effectively identify and present the most relevant data and information. These tools and methods played a crucial role in our analysis, enabling us to extract valuable insights and information from the wealth of data available in the field of Cybernetics [48,49].

The structure of the remainder of this paper is as follows: Section 2 presents the paper's selection process using the Web of Science (WoS) platform. As a result, a number of 4856 papers are extracted and examined in Section 3 of the paper. Relevant information such as: the number of authors; average citations per year; contribution of each country; collaboration map; analysis of the top 10 most cited papers; word clouds; and the existing connections between authors, countries, and affiliations, is presented within the body of Section 3. The limitations of the paper are discussed in Section 4, while the concluding remarks close the paper.

2. Materials and Methods

Given the paper's primary aim of investigating the cybernetics domain, the dataset was meticulously extracted from the Web of Science (WoS) website, encompassing publications from the inception of the field up to the conclusion of the year 2022.

The initial query involved filtering titles containing either "cybernetic" or "cybernetics" as keywords, yielding a total of 3021 relevant papers for analysis (Table 1).

Table 1. Data selection steps.

Exploration Steps	Questions on Web of Science	Description	Query	Query Number	Count
1	Title	Contains one of the cybernetics keywords	(TI = (cybernetic)) OR TI = (cybernetics)	#1	3021
2	Abstract	Contains one of the cybernetics keywords	(AB = (cybernetic)) OR AB = (cybernetics)	#2	4504
3	Keywords	Contains one of the cybernetics keywords	(AK = (cybernetic)) OR AK = (cybernetics)	#3	3592
4	Title/Abstract/Keywords	Contains one of the cybernetics keywords	#1 OR #2 OR #3	#4	8336
5	Language	Limit to English	(#4) AND LA = (English)	#5	7563
6	Document Type	Limit to Article	(#5) AND DT = (Article)	#6	5036
7	Year published	Exclude 2023	(#6) NOT PY = (2023)	#7	4856
		Exclude 2024	(#7) NOT PY = (2024)	#8	4856

To offer a comprehensive exposition of our analytical process and methodologies, we have presented a graphical representation in Figure 1. We began with a description of our purpose in doing this work, which was to find out which works were the most significant in terms of the development of the field of cybernetics and the interest of researchers in it. We proceeded by building the database, selecting certain works, and applying filters to the titles, abstracts, or content level. Upon the curation of the database, we loaded the Bibliometrix package into the RStudio console window by using the *biblioshiny( )* command [50]. In the document produced, we made different graphs that we interpreted with the help of specific indicators. A very important role was played by the creators of the research papers, their collaborators, as well as their preferences for various publications or what they wanted to document within the research area. We looked at what the production of the papers had been over time and identified the countries of origin with the help of thematic maps or the links between authors with the help of a collaborative network. The most cited papers found were rigorously analyzed, calculating indicators such as total citations (TC), total citations per year (TCY), or normalized TC, and then reviewed. We looked for the most relevant groups of words identified at title or abstract level, by illustrating a word cloud as well as an evolution over time of their usage. Furthermore, we illustrated three-field plots to show the different links existing between the most frequently used words, authors, countries of origin, or journals. Once the analysis was performed, in the last step of the paper we drew some conclusions, realizing once again how important the research field was to make certain discoveries.

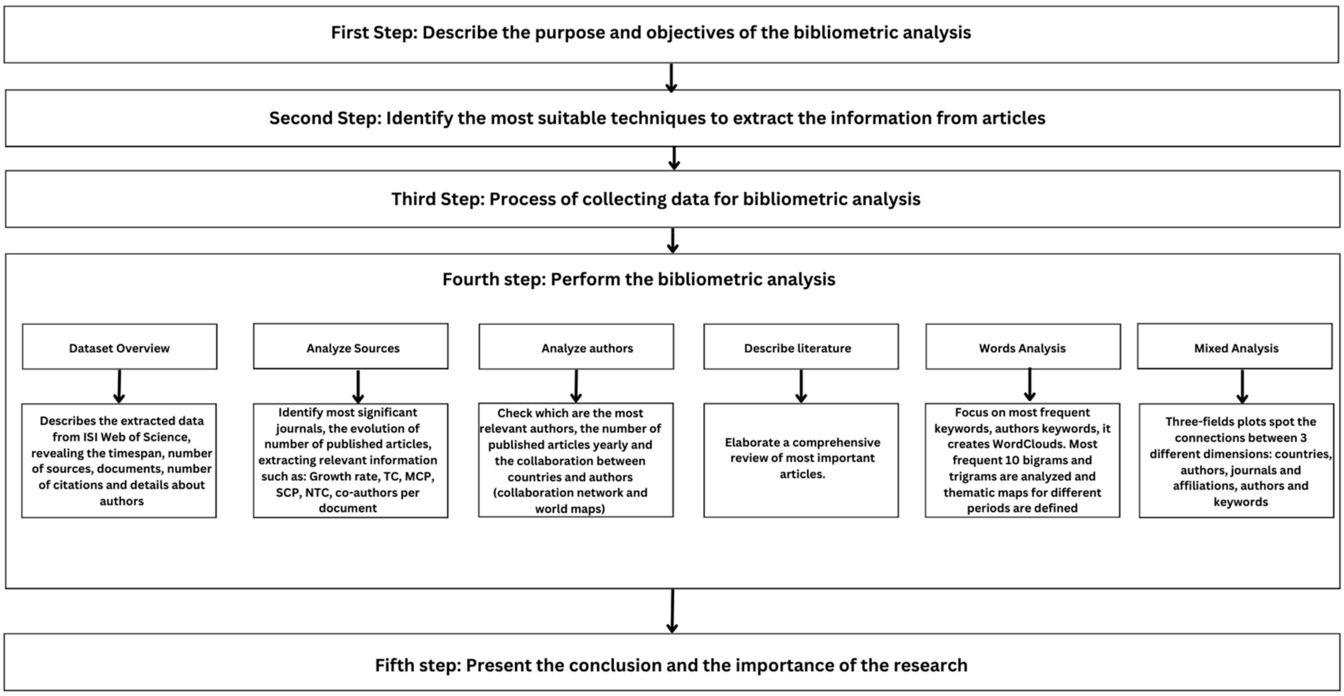

Figure 1. Methodological approach to bibliometric analysis.

The second query mirrored the first, with the exception that it sought the keywords "cybernetic" and "cybernetics" within the abstracts of the papers. This approach yielded a broader dataset, returning a total of 4504 articles (Table 1).

For the third query, a more comprehensive approach was undertaken, wherein the keywords within the papers were systematically examined, and a loop was employed to identify those containing "cybernetic" or "cybernetics". This method yielded a dataset comprising 3592 papers as is presented in Table 1.

In pursuit of the specific objective of identifying articles pertaining to the domain of cybernetics, a filtering mechanism was instituted during the fourth iteration of our analysis. This filtering process scrutinized both the titles and abstracts for the presence of keywords such as "cybernetic" or "cybernetics". Subsequent to this filtering, a total of 8336 relevant papers were identified.

As part of the refinement process, we retained only those papers published in the English language, invoking an additional filter. Consequently, this step yielded a reduced corpus of 7563 papers following the fifth iteration.

In the sixth stage of our analysis, we imposed further restrictions by excluding conference publications, resulting in a subset of 5036 articles that were subjected to subsequent examination.

In the final step, we instituted two chronological constraints by excluding articles published in the years 2023 and 2024, culminating in a final corpus of 4856 articles for our comprehensive analysis.

3. Dataset Analysis

The overarching goal of the analysis was to discern the most pertinent articles within the cybernetics domain, ascertain the primary authors associated with these articles, identify the predominant sources or journals in which they were published, and gauge the impact of these papers. This impact assessment was conducted with a focus on individual countries and their respective contributions, as well as the influence of these articles on various journals.

3.1. Dataset Overview

At the outset, our analysis was primarily oriented toward conducting an exploratory examination of the dataset. This initial phase aimed to provide a comprehensive overview, emphasizing critical aspects such as the number of sources, authors, and the temporal scope. Table 2 encapsulates the essential dataset statistics, encompassing a time frame commencing in 1975 and extending to 2022, inclusive of 1542 unique sources and a corpus of 4856 documents. The average publication year across these documents stands at 14.8 years. Furthermore, the dataset exhibits an average of 12.05 citations per document and an average of 1.194 citations per document per year, a small value compared with other domains. In total, there were 130,036 references, which shows how complex cybernetics is, which requires a lot of information from different areas.

Table 2. Main information about data.

Indicator	Value
Timespan	1975:2022
Sources	1542
Documents	4856
Average years from publication	14.8
Average citations per document	12.05
Average citations per year per document	1.194
References	130,036

The initial year in which the first 11 papers were published was 1975. Subsequently, there was a consistent positive trend in the number of publications until the turn of the 21st century. However, from the beginning of the 21st century, there was a notable oscillation characterized by periods of growth and decline. Beginning in 2017, there was an exponential surge in publications, apart from 2021. The pinnacle of publications within the cybernetics domain was reached in 2023, with a record of 338 papers, as illustrated in Figure 2. The annual growth rate was approximately 7.56% during this period.

The metric of average citations per year is of paramount significance as it serves as an indicator of the papers' utility in furthering scientific research. Figure 3 provides a comprehensive overview, commencing from the inaugural year of paper publication in 1975, where an initial average of 0.1 citations per year was observed. Subsequently, there was a notable uptick in these averages at the outset of the 1990s, culminating in 1992 with an average of 1.3 citations per year. Throughout the remaining analyzed period, the values exhibited considerable volatility, with a remarkable zenith recorded in 2020, representing the highest value of 4.1 citations per year.

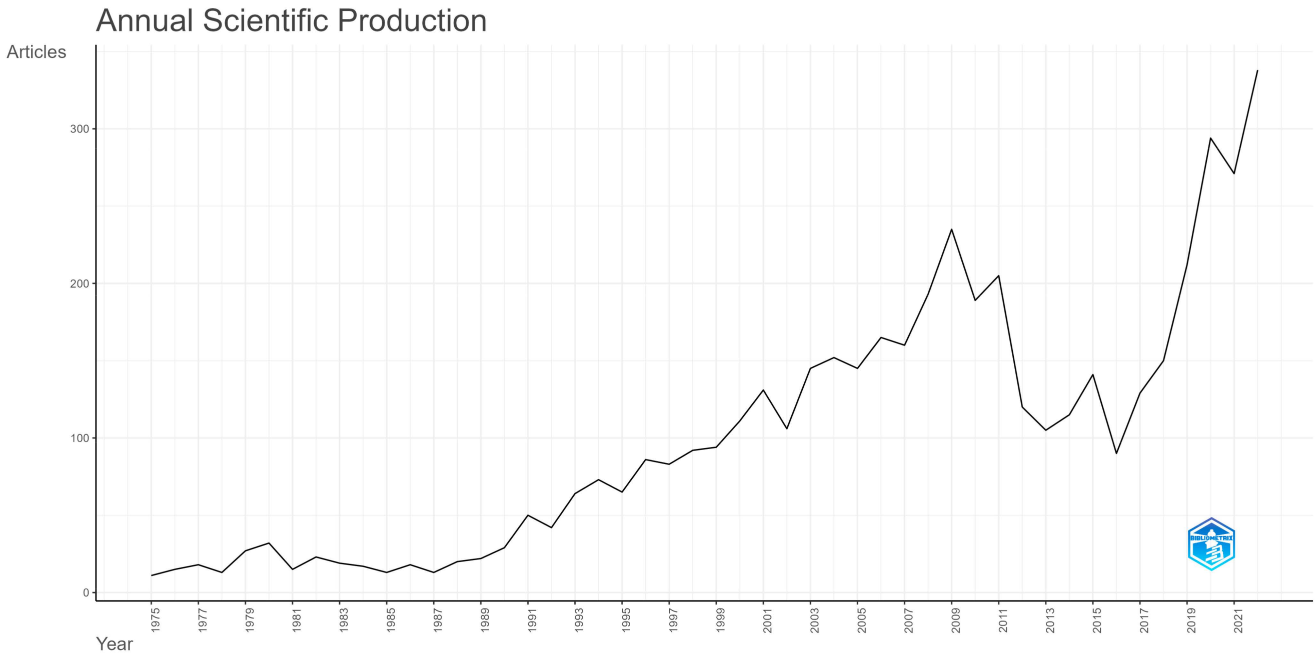

Figure 2. Annual scientific production evolution.

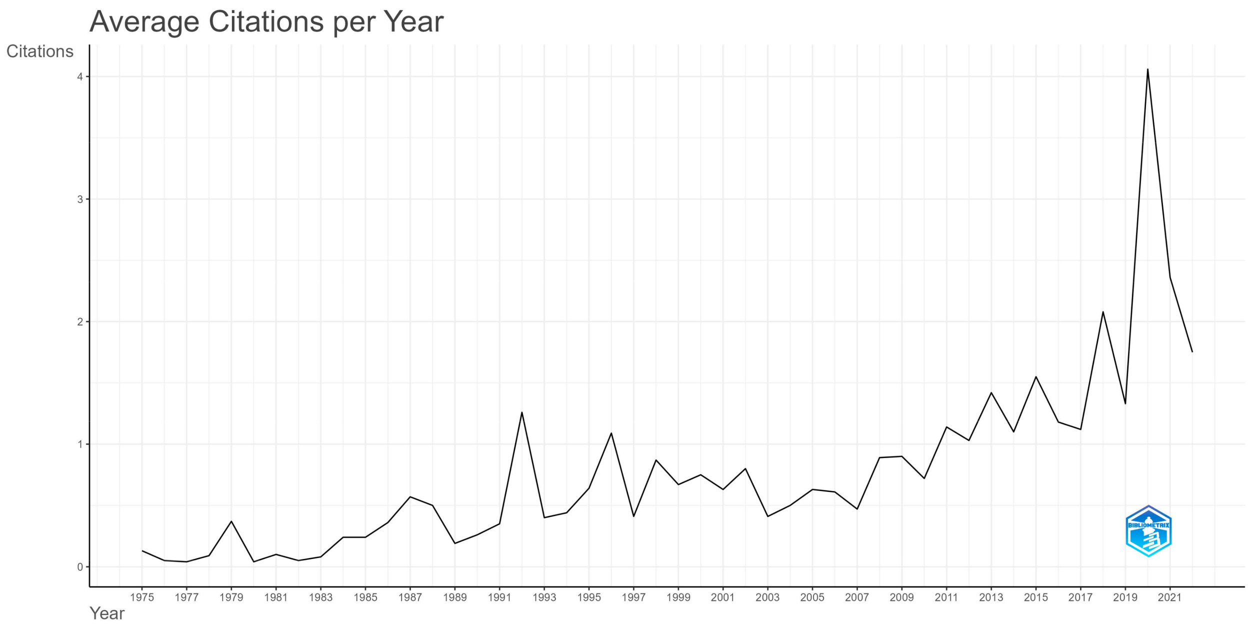

Figure 3. Annual average article citations per year evolution.

Table 3 presents the number of keywords plus and the number of author's keywords for the selected papers. The analysis reveals that a total of 4183 keywords were extracted from the titles of the papers, with an average of 0.86 keywords per document. In addition, there were 9848 author-generated keywords, averaging 2.02 keywords per document.

Table 3. Document contents.

Indicator	Value
Keywords plus	4183
Author's keywords	9848

Table 4 offers an exhaustive compilation of data concerning the authors of cybernetics papers. It presents a total of 7368 distinct authors, among whom 1656 authors have authored a solitary document. Specifically, there are 2451 single-authored papers, and on average, these authors have contributed 1.48 articles each. The remaining 5712 documents are products of collaborative efforts, featuring contributions from multiple authors. In such cases, individual authors are credited with a cumulative appearance of 10,229 instances, indicating that some authors have made multiple contributions, averaging 1.388 appearances per author. Furthermore, on average, authors appear 1.517 times per document. Notably, the substantial number of single-authored publications is reflected in the collaboration index and authors per document indices, both of which are elaborated in Table 5.

Table 4. Authors.

Indicator	Value
Authors	7368
Author appearances	10,229
Authors of single-authored documents	1656
Authors of multi-authored documents	5712

Table 5. Authors collaboration.

Indicator	Value
Single-authored documents	2451
Documents per author	0.659
Authors per document	1.52
Co-authors per documents	2.11
Collaboration index	2.38

Collaboration among authors is indeed a critical aspect of research, as indicated in Table 5. The dataset includes a total of 2451 single-authored documents, and on average, each document involves 2.11 co-authors, highlighting the collaborative nature of research in the cybernetics domain. The collaboration index, standing at 2.38, offers valuable insights into the landscape of authors contributing to the field of cybernetics within scientific articles. Notably, this index underscores a distinctive pattern, revealing a comparatively lower degree of authorship collaboration when juxtaposed with other academic disciplines. This observation finds support in the figures for authors per document, which average at a modest 1.52, and documents per author, which stand at merely 0.659. It is plausible to posit that the intricate nature of the domain, coupled with a potential dearth of comprehensive information in certain areas, may contribute to these observed trends.

3.2. Sources

When it comes to sources, which represent the journals that have published papers in the selected field of cybernetics, it has been observed that "Kybernetes" stands out as the most prominent source with a substantial 1683 available papers, firmly securing the top position. In contrast, "IEEE Transactions on Cybernetics" holds the second position with a considerably lower count of 182 sources, and "Cybernetics and Systems" follows with 69 sources. "IEEE Transactions on Systems Man Cybernetics-System" maintains the fourth position with 57 sources. The remaining sources within the top 20 exhibit notably fewer papers, as depicted in Figure 4.

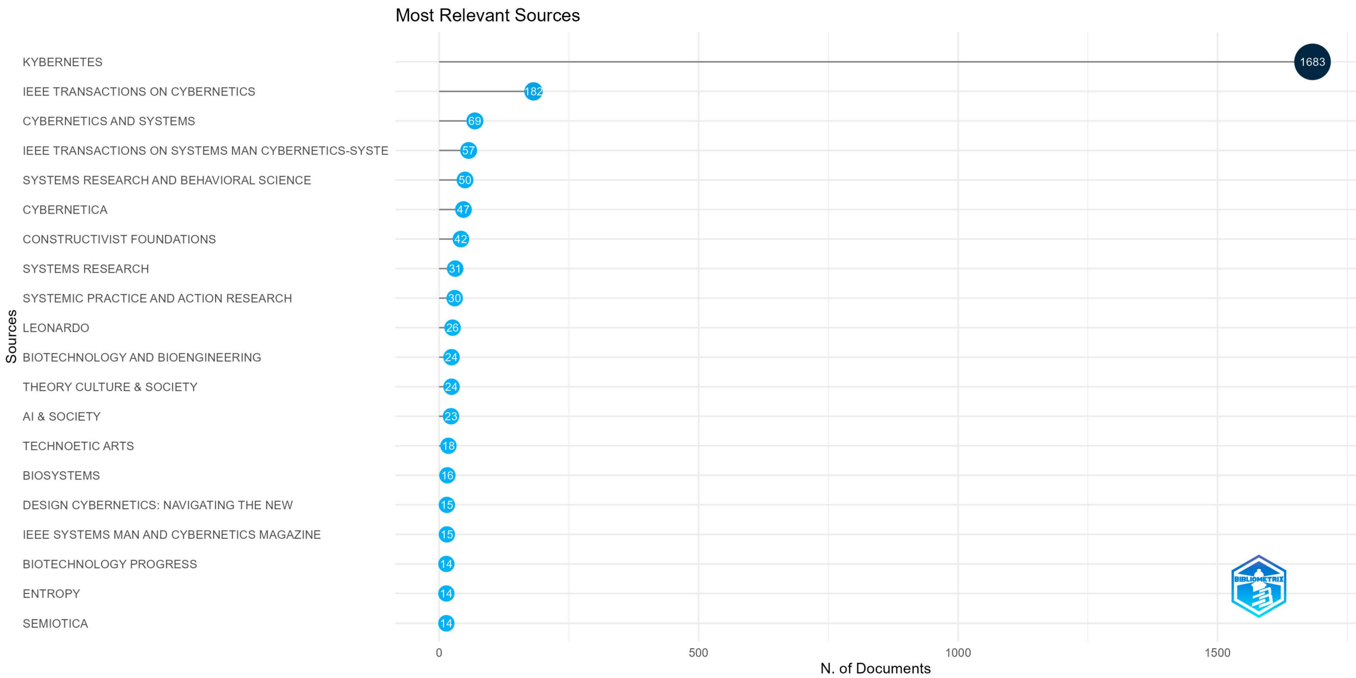

Figure 4. Top 20 most relevant journals.

Figure 5 provides an insightful perspective on the impact of sources based on their local H-Index, with a specific focus on sources that possess an H-Index greater than 7. The H-Index serves as a valuable metric, shedding light on how frequently papers published in a particular journal have been cited a specific number of times.

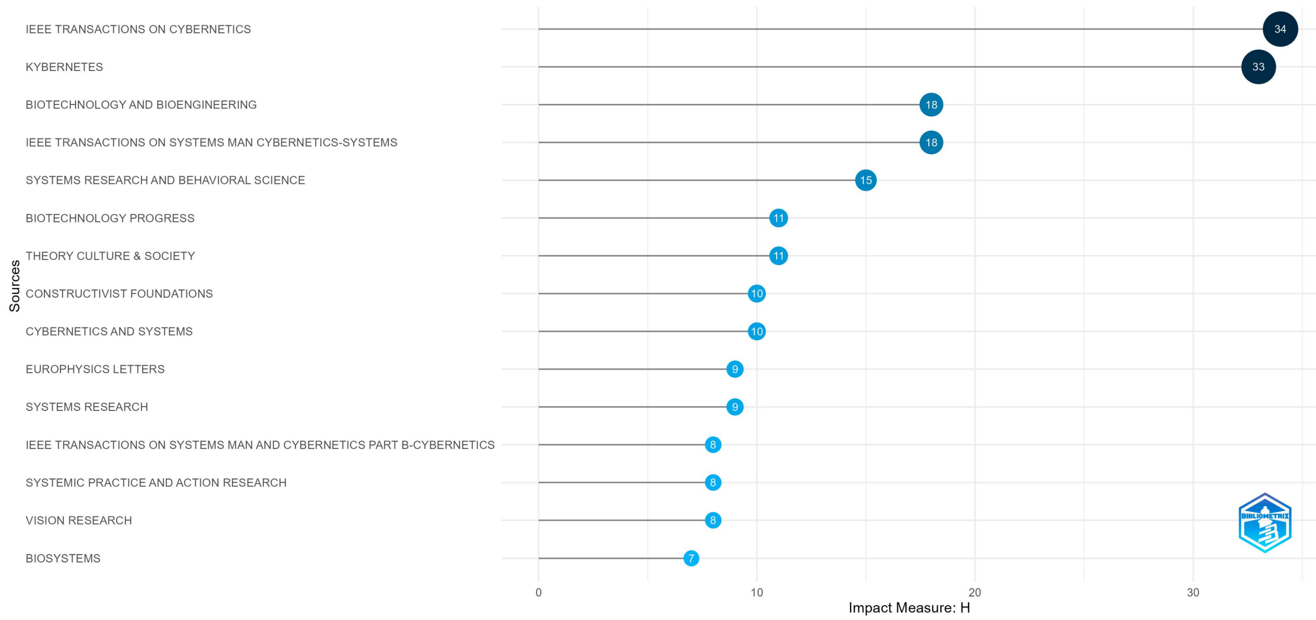

Figure 5. Journals' impact based on H-index.

At the forefront of this ranking is "IEEE Transactions on Cybernetics" with an impressive H-Index of 34, followed closely by "Kybernetes" with an H-Index of 33. "Biotechnology and Bioengineering" and "IEEE Transactions on Systems Man Cybernetics-Systems" both share an H-Index of 18. "Systems Research and Behavioral Science" commands an H-Index of 15, while "Biotechnology Progress" and "Theory Culture & Society" each possess an H-Index of 11. "Constructivist Foundations" and "Cybernetics and Systems" both exhibit an H-Index of 10. Beyond the top 10, the remaining sources in the top 20 have H-Index values lower than 10.

The analysis of the most prominent sources' production trends from 1975 to 2022, as depicted in Figure 6, underscores "Kybernetes" as a pioneering journal in the field of Cybernetics, having published its first scientific article in 1977. Kybernetes has consistently stood out as the most influential journal in the Cybernetics domain, amassing a total of 1683 papers by the year 2022.

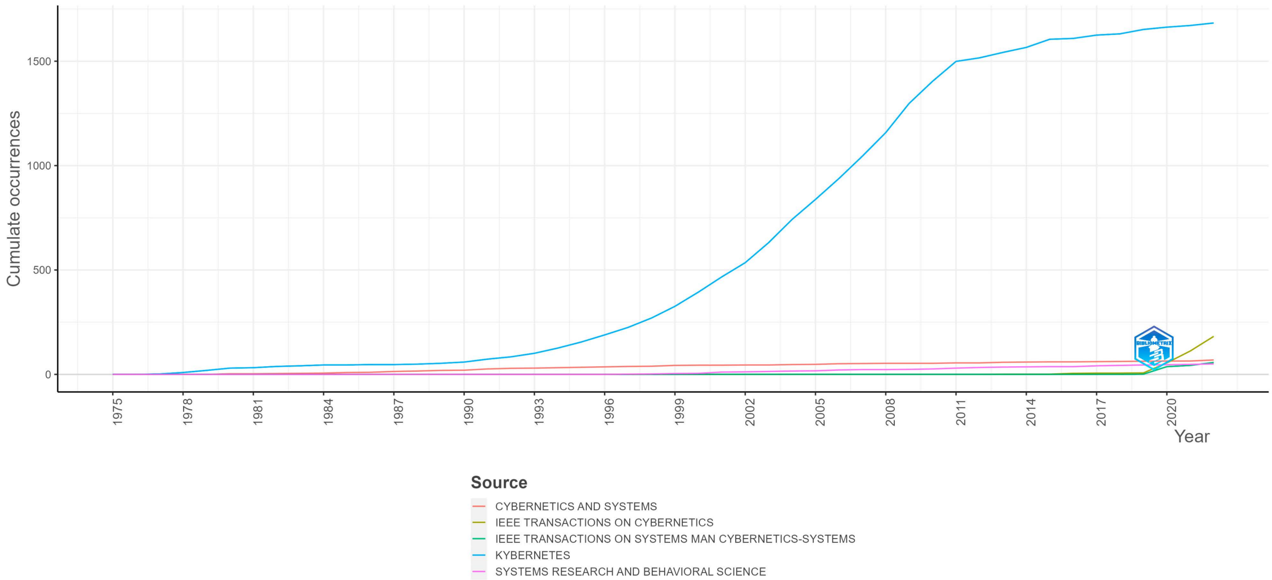

Figure 6. Journals' growth (cumulative) based on the number of papers.

In stark contrast, Cybernetics and Systems has published only 69 papers, and IEEE Transactions on Cybernetics is the second-most prominent source with 182 papers. The significant disparity between the number of published articles in Kybernetes and the second-ranked source, IEEE Transactions on Cybernetics, is striking, amounting to a staggering 1501 articles. Furthermore, IEEE Transactions on Systems Man Cybernetics-Systems has contributed 57 papers, while Systems Research and Behavioral Science has published 50 papers.

3.3. Authors

Authors play a pivotal role in the analysis, and a more comprehensive examination of their contributions is warranted. As depicted in Figure 7, the top 20 most influential authors in the Cybernetics domain are highlighted. Rudall BH stands out as the most prolific author with an impressive 98 papers to their name, followed closely by Cherruault Y with 70 articles and Lin Y, who has authored 64 articles. Andrew AM has contributed 55 papers, Ramkrishna D follows with 50 articles, and Yolles M has 34 papers to their credit. The remaining authors within the top 14 have authored between 19 and 21 papers, although their contributions are comparatively less substantial in comparison to the top 6.

The publication history of authors within the Cybernetics domain serves as a testament to the evolving importance of this field. Notably, Cybernetics gained prominence in 1978 when Rudall BH published the first article, establishing himself as the most influential author in this domain. Rudall BH's contributions span from 1990 to 2011, with at least one paper published each year during this period. Cherrault Y, another significant figure, made his debut in 1991, with a notable uptick in publications occurring in 2005 when he authored 21 papers, resulting in a total annual citation rate of 2.89. Lin Y initiated his Cybernetics publications in 1995 with a single article, and his contributions escalated in 2008 when he published an impressive 22 articles, resulting in a remarkable total annual citation rate of 11.81. Figure 8 presents the comprehensive list of the top 14 authors.

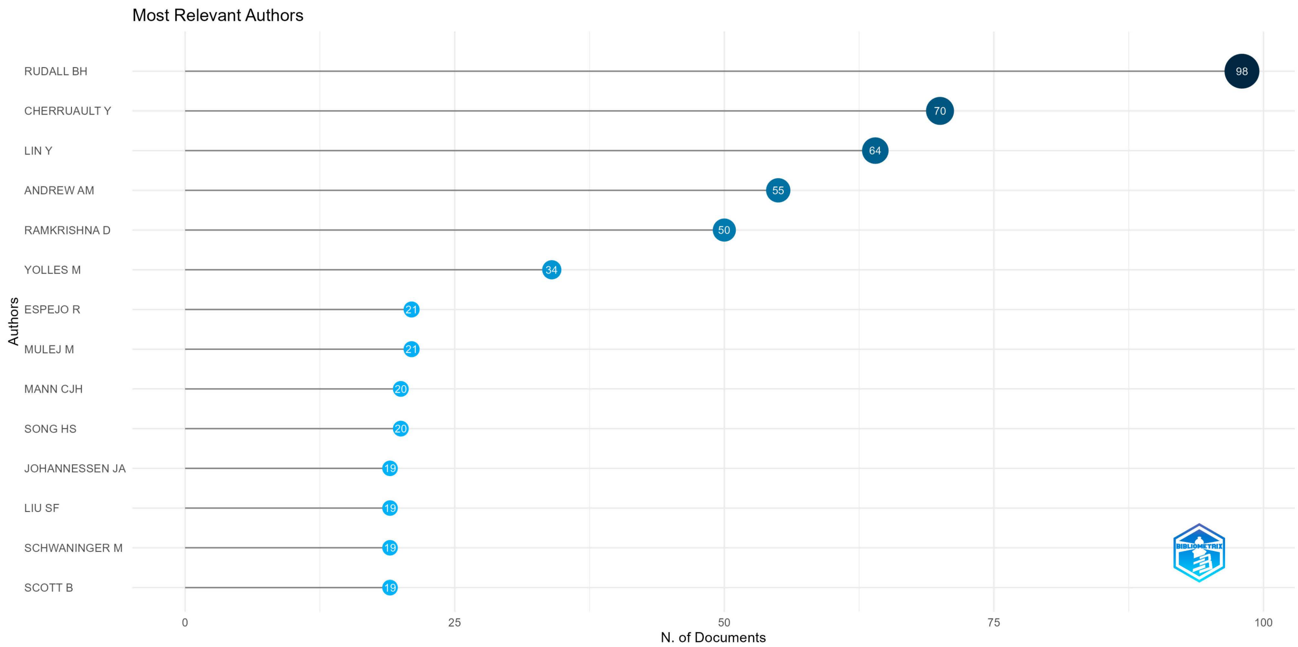

Figure 7. Top 14 authors based on number of documents.

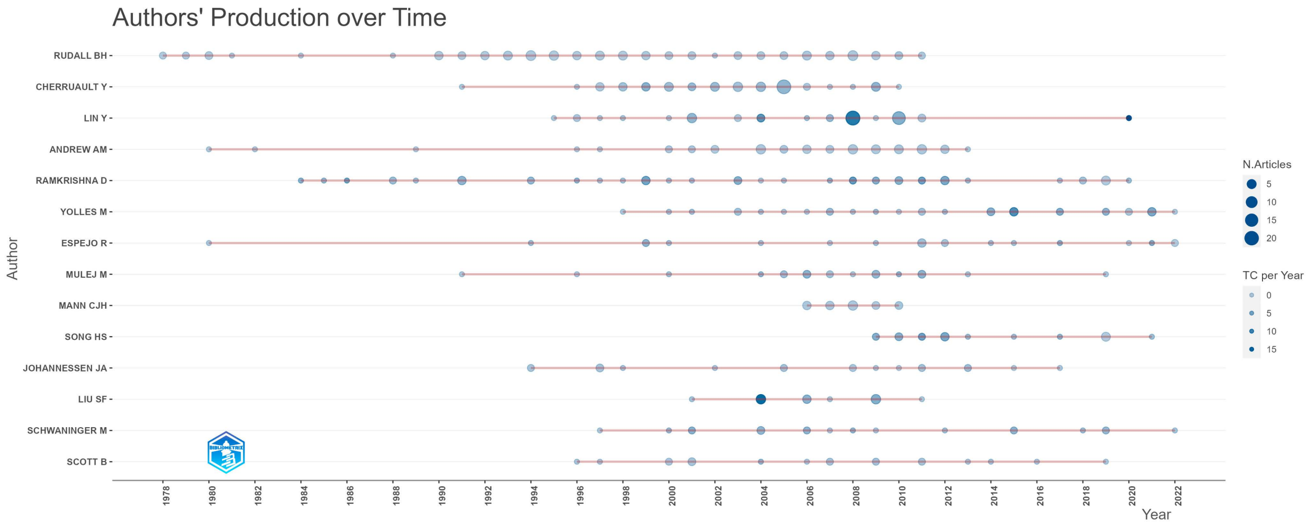

Figure 8. Top-14 authors' production over time.

The affiliations associated with the most significant contributions in the Cybernetics domain are indeed noteworthy. Leading the list is Nanjing University Aeronaut and Astronaut with an impressive 81 articles, closely followed by Purdue University with 72 papers. Slippery Rock University has contributed 63 papers, while the University of Alicante has 53 articles to its credit. The University of Reading and University of Maribor have produced 49 and 45 articles, respectively, while Huazhong University of Science and Technology has 42 papers. Liverpool John Moores University follows closely with 41 scientific articles. The University of Paris has 35 articles, and the University of Wales Coll Cardiff and the University of Illinois have 34 papers each. The remaining affiliations within the top 18 have produced fewer than 30 articles each. For the full list of the affiliations and the number of articles, please refer to Figure 9.

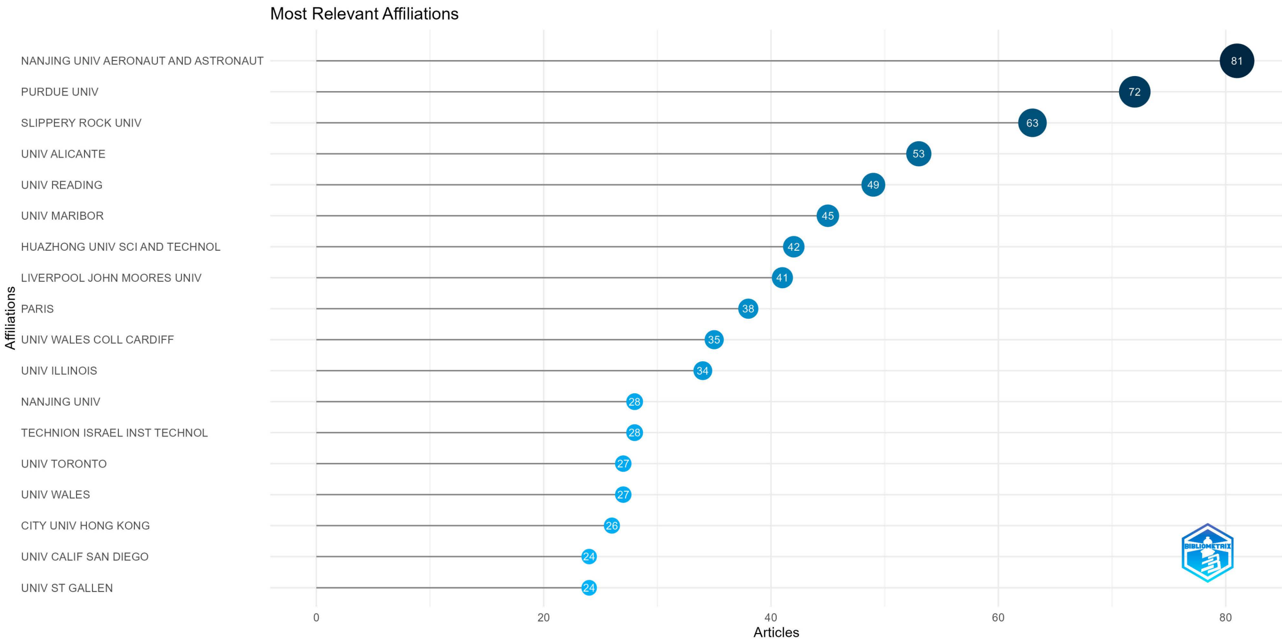

Figure 9. Top 18 most relevant affiliations.

Figure 10 provides a comprehensive overview of the most influential countries in terms of authors who have published articles related to the Cybernetics domain. The United States of America stands at the forefront, with a total of 925 articles. Among these, 840 articles are Single Country Publications (SCPs), and 85 are Multiple Countries Publications (MCPs), accounting for a frequency of 19%. China follows closely with 672 papers, consisting of 495 SCPs and 177 MCPs, representing a frequency of 13.8%. The United Kingdom holds the third position with 569 articles, of which 505 are SCPs and 64 are MCPs, with a frequency of 11.7%. Canada has contributed 164 articles, 134 SCPs and 30 MCPs, resulting in a frequency of 3.4%. Germany follows with 147 published articles, comprising 127 SCPs and 20 MCPs, equating to a frequency of 3%. France is next with 126 articles, 109 SCPs and 17 MCPs, featuring a frequency of 2.6%. Italy has 113 articles, with 88 SCPs and 25 MCPs, and a frequency of 2.3%. Spain has 110 papers, including 86 SCPs and 24 MCPs, with a frequency of 2.3%. Russia has 105 articles, 102 SCPs and 3 MCPs, with a frequency of 2.2%. Australia rounds out the top 10 with 102 papers, 73 SCPs and 29 MCPs, and a frequency of 2.1%. Additional countries can be found in Figure 10.

Figure 11 offers a clear visualization of countries with a significant number of published articles in the field of Cybernetics, employing a color scale where intensity corresponds to the article count. In the realm of Cybernetics, the United States and China emerge as the leading contributors, with 1469 and 1456 articles, respectively, closely matched in frequency. Following closely, the United Kingdom claims the third position with 823 articles, while Canada follows with 288. In contrast, some countries, such as Malta and Panama, have published only one article, while others are shaded in gray, indicating an absence of published articles in the field.

Figure 12 illustrates the countries where the highest number of citations were recorded for articles by their own researchers. As anticipated, the United States stands out with the highest number of citations at 16,127, reflecting an average of 17.40 citations per article. China follows with 8450 citations and an average of 12.60 citations per article, while the United Kingdom has 8015 citations, yielding an average of 14.10 citations per article. These figures underscore the strong impact and recognition of research contributions in the field of Cybernetics originating from these nations.

In Figure 12, the last country that appears in the upper ranks of the table is Singapore. Singapore has accumulated a total of 483 citations, with an impressive average of

18.60 citations per article. This suggests a notably high impact for the Cybernetics research originating from Singapore.

Figure 13 provides a valuable map for visualizing international collaborations in the field of Cybernetics. The United Kingdom (UK) and the United States (USA) are shown to have engaged in research collaborations with 41 other countries.

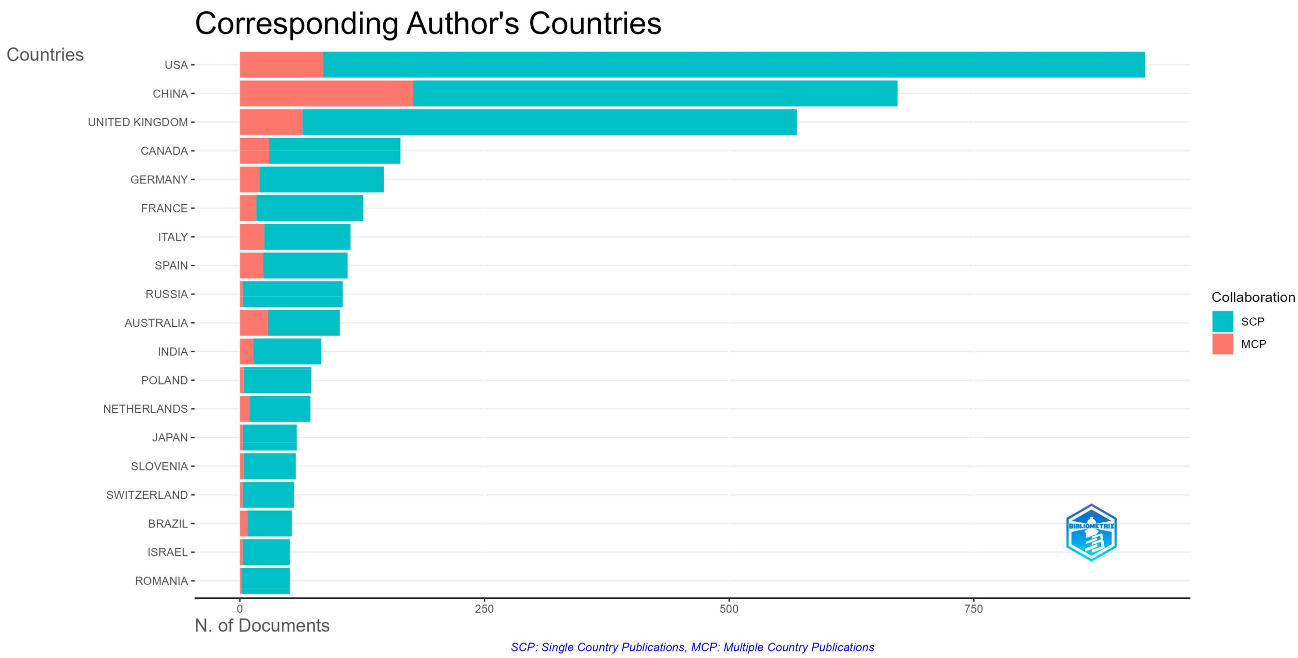

Figure 10. Top 19 most relevant corresponding author's country.

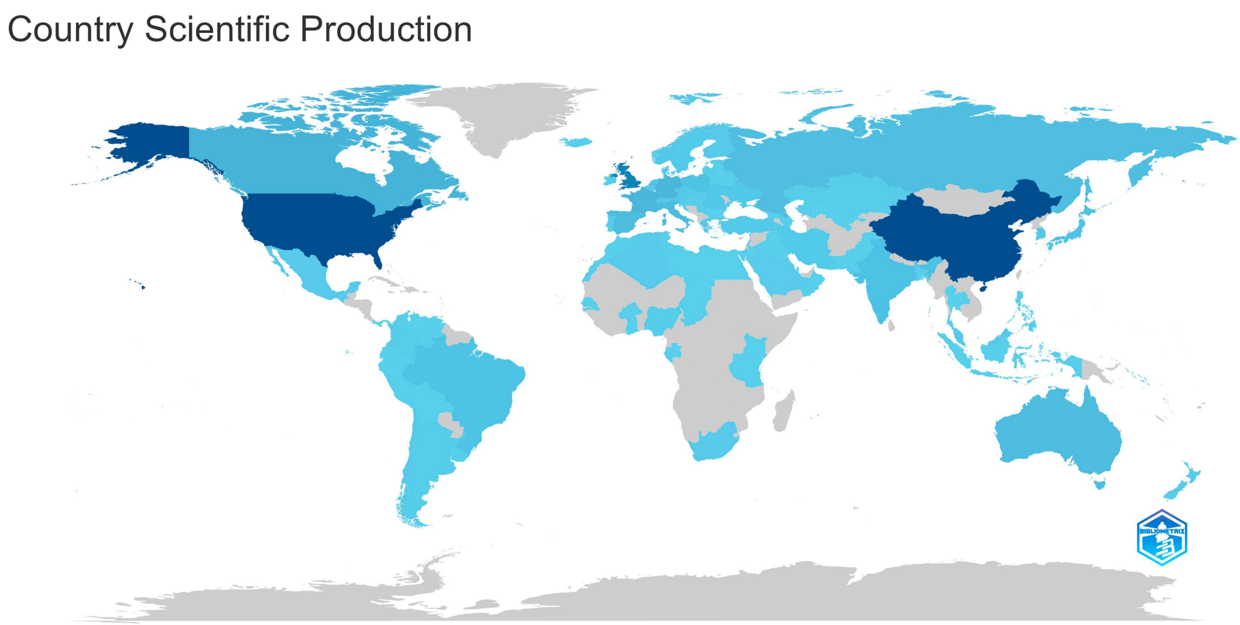

Figure 11. Scientific production based on country.

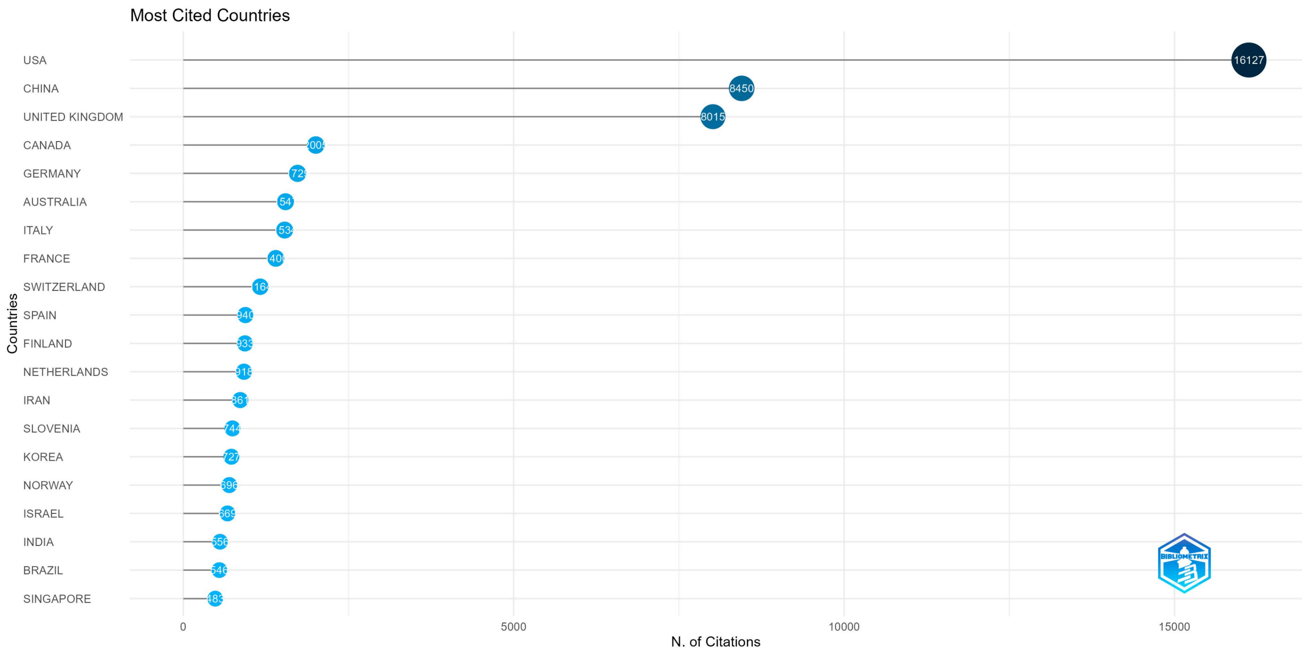

Figure 12. Top 20 countries with the most citations.

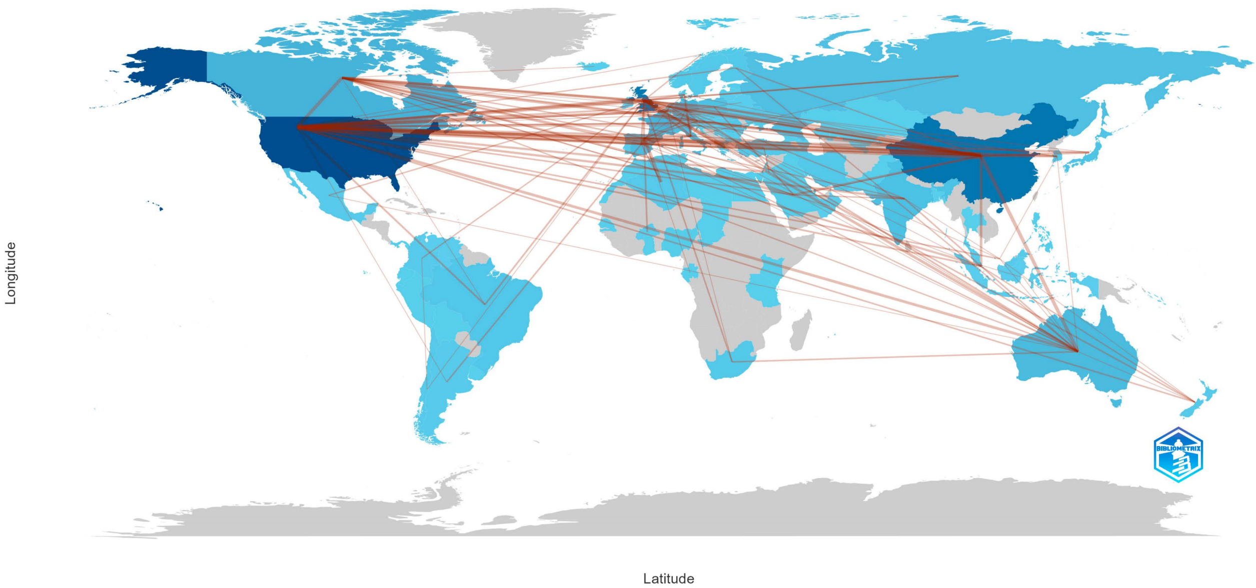

Figure 13. Country collaboration map.

According to Figure 13, several prominent collaborations stand out, including the partnership between the USA and China, resulting in a substantial 125 scientific papers. Additionally, the USA and the UK collaborated on 31 papers, while China and Australia, as well as France and Algeria, each yielded 25 scientific papers through their collaborations. These collaborations reflect the global nature of Cybernetics research and the importance of international partnerships in advancing this field.

Figure 14 presents a visual representation of collaborative networks at the author level in the field of Cybernetics. The visualization reveals the presence of 6 distinct clusters involving 18 authors. To achieve this visualization, settings were configured to include a minimum of two edges and the removal of isolated nodes. This network analysis helps illustrate the collaborative relationships among authors within the Cybernetics domain, showcasing the interconnectedness and collaborations that contribute to the advancement of this field.

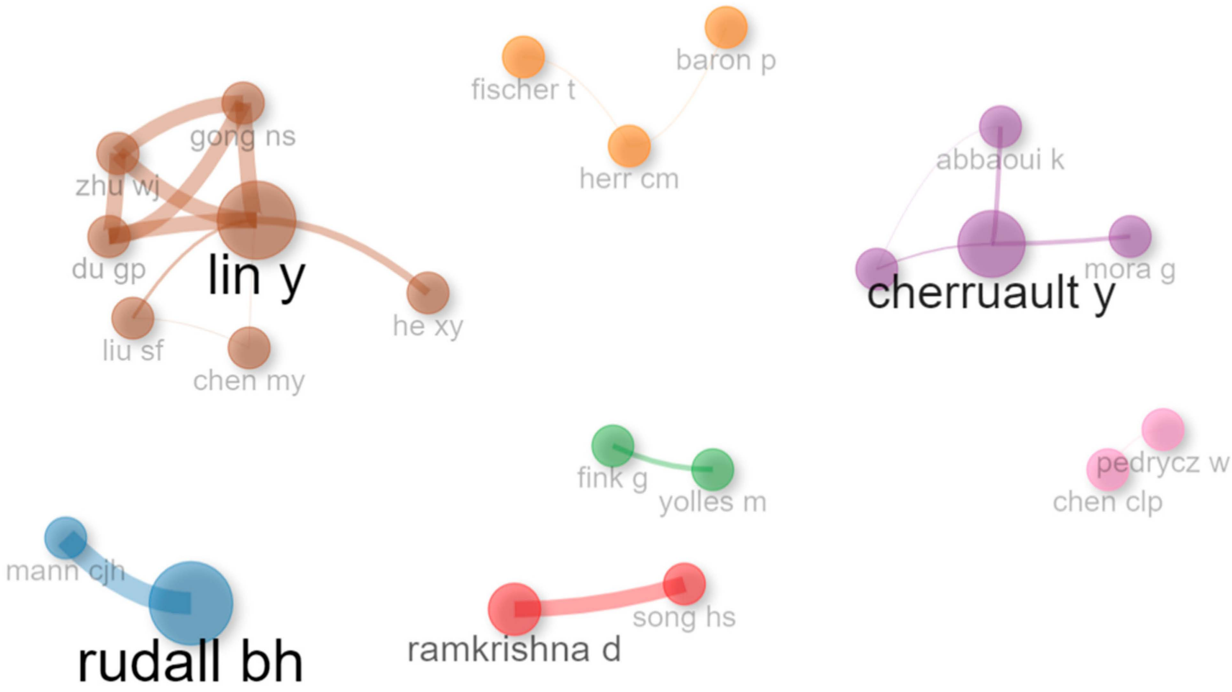

Figure 14. Top 50 authors collaboration network.

Figure 14 illustrates the clustering of authors within the dataset. Notably, the first three clusters consist of two authors each.

Cluster 1, marked in red, comprises the authors Ramkrishna D and Song HS. Their research is primarily centered on the application of cybernetic modeling to predict metabolic function. Moreover, they have introduced a hybridized cybernetic model, denoted as L-HCM, within their body of work [51–54].

In Cluster 2, represented by the color blue, we find Rudall BH and Mann CJH. Their scholarly focus encompasses an exploration of the interplay between the evolution of cybernetics and the development of scientific rationality. Additionally, they investigate the role of cybernetics in the advancement of robotics [55,56].

Cluster 3, distinguished by its green hue, showcases the collaborative efforts of Yolles M and Fink G. Their research endeavors center around the development of a comprehensive psychosocial model tailored for enterprise analysis. Their work aims to elucidate and address underlying problems within organizations and their origins [57,58].

Cluster 4, in the shade of purple, features a more extensive membership, including Cherruault Y, Mora G, Abbaoui K, and Inc M. These authors have contributed significantly to the mathematical domain, where they have made notable strides in the application of the Adomian Decomposition Method (ADM). Their applications span from solving nonlinear Korteweg-de Vries equations to addressing partial difference equations with boundary conditions. ADM, within their studies, emerges as a pivotal tool for resolving a wide spectrum of nonlinear partial and ordinary differential equations [59–61].

Cluster 5, depicted in a shade of orange, showcases the collective work of Fischer T, Herr CM, and Baron P. These authors have delved into the realm of cybernetics design, offering insights into second-order cybernetics and emphasizing the critical role of feedback mechanisms in various domains [62,63].

Cluster 6, in the hue of brown, is home to Lin Y, Liu SF, Du GP, Gong NS, Zhu WJ, He XY, and Chen MY. Their research contributions encompass a novel technique for assessing risky investments, known as the utility index method [55], an innovative approach to exponential prediction [56], and the development of models for measuring technological progress [64].

In Cluster 7, marked in pink, Pedrycz W and Chen CLP have pioneered concepts related to statistical learning theory (SLT). Their work has introduced a dynamic conflict model that exhibits adaptability across different subgroups [65,66].

3.4. Analysis of Literature

In this section of the article, we conduct a comprehensive literature review, that features the 10 most cited papers globally within the field of Cybernetics. This section provides valuable information, including the number of authors involved in each paper, the publication source, the year of publication, the total number of citations (TC), and the total number of citations per year (TCY) for each paper. Additionally, an indicator referred to as the normalized number of citations (NTC) is included, calculated by dividing the total number of citations for an article by the average number of citations received by all papers published in the same year. This analysis offers insights into the impact and relevance of these influential papers within the Cybernetics domain.

3.4.1. Top 10 Most Cited Papers—Overview

In Table 6, the paper authored by Rhodes [67], takes the top spot in terms of the number of citations, amassing an impressive total of 1873 citations. This paper also boasts a high TCY coefficient of 66.89 and an NTC of 61.41, indicating its significant impact and relevance over the years.

The paper by Wright et al. [68] follows closely with a total citation count of 1128 citations, even 31 years after publication. Unlike the most cited paper mentioned earlier, this paper has a TCY of 35.25 and an NTC of 28.00.

It is noteworthy that among the top 10 most cited papers, the total number of citations ranges from 465 and upward, with TCY values consistently above 16 and an average NTC of 37.8. Additionally, most of these papers have 1 or 2 authors, with the exceptions being Brechbühler et al. [69], which has 3 authors, and Manno et al. [70], which involves 9 authors. This information highlights the influence and impact of these highly cited papers within the field of Cybernetics.

Table 6. Top 10 most global cited documents.

No.	Paper (First Author, Year, Journal, Reference)	Number of Authors	Region	Total Citations (TC)	Total Citations per Year (TCY)	Normalized TC (NTC)
1	Rhodes, RAW., 1996, Political Studies, [67]	1	UK	1873	66.89	61.41
2	Wright, PM., 1992, Journal of Management, [68]	2	USA	1128	35.25	28.00
3	Rose, N., 2000, The British Journal of Criminology, [71]	1	UK	733	30.54	40.89
4	Malmi, T., 2008, Management Accounting Research, [72]	2	USA	730	45.63	51.03
5	Walker, J., 2011, Security Dialogue, [73]	2	UK	659	50.69	44.47
6	Mannoor, MS., 2013, Nano Lett, [70]	9	USA	586	23.27	37.47
7	Craig, RT., 1999, Communication Theory, [74]	1	USA	579	23.16	34.58
8	Ghobakhloo, M., 2018, Journal of Manufacturing Technology Management, [75]	1	UK	556	92.67	44.43
9	Brechbühler, C., 1995, Computer Vision and Image Understanding, [69]	3	USA	478	16.48	25.74
10	DeYoung, CG., 2015, Journal of Research in Personality, [76]	1	USA	465	51.67	33.26

3.4.2. Top 10 Most Cited Papers—Review

The most cited papers had a crucial role in the evolution of Cybernetics and in this section, papers will be analyzed separately, to observe the contribution of each one.

Among the scholarly works in the field of cybernetics, Rhodes [60] stands out as the most cited article, offering profound insights into the concept of "governance", which was previously shrouded in ambiguity. Rhodes' discourse meticulously dissects the multifaceted applications of governance from diverse perspectives, including its integration within socio-cybernetic systems. Moreover, Rhodes expounds upon essential characteristics inherent to the cybernetic paradigm, such as self-organizing networks and coordination. Notably, Rhodes underscores the importance of mutual adjustment and trust, elucidated through a real-world case study within the British government.

The second most influential article, penned by Wright [61], delves into the realm of Human Resource Management (HRM), a domain traditionally lacking in comprehensive theoretical underpinnings. Wright embarks on the development of a novel framework known as Strategic Human Resource Management (SHRM), providing a rigorous foundation for HR practices. SHRM is scrutinized from various angles, including a cybernetic perspective, which aids in identifying optimal strategic and non-strategic HR practices. Wright further introduces robust models for power and resource dependence, albeit with recognized limitations, underpinning the overarching success of SHRM and its potential for refinement.

In the year 2000, Rose [64] directed attention toward the control of different dimensions of illegal activities, advocating for the creation of accessible political programs and emphasizing the contemporary necessity of rehabilitation. Integral to this process is the restoration of moral order and the reintegration of affected individuals. Employing the framework of cybernetics, Rose offers a multi-dimensional exploration of illegalities and proffers strategies for aiding individuals in their journey back into society. This sensitive domain necessitates rigorous regulatory frameworks and adherence to established laws to ensure the seamless reintegration of individuals into society, free from complications. A pivotal advantage of utilizing cybernetics in this context is its inherent capacity for continuous feedback and adaptive responsiveness.

Rhodes [67] is the most cited article on Cybernetics and the paper explains what "governance" is, a term which was unclear at that point. It presents the uses of governance from different perspectives, one of them being socio-cybernetic systems. Rhodes describes other characteristics of cybernetics, such as self-organizing networks or coordination. In the end, based on a real example from the British government, the author presents the most important characteristics for optimum governability: mutual adjustment and trust.

In the second most relevant article, Wright [68] describes Human Resource Management (HRM), which does not have enough theoretical foundations, and tries to develop a new one called Strategic Human Resource Management (SHRM). SHRM is then presented from different perspectives, including the cybernetics point of view, which helps in finding the best strategic and non-strategic practices of HR. At the same time, Wright presented the optimum power and resource dependence models, which have some limitations but are working well and can be improved.

In 2000, Rose [71] focused on how to control different regimes of illegalities, by creating political programs and providing access to every patient, rehabilitation is necessary in present times. They must recover their moral order and readapt their ration. Using cybernetics, the author tried to provide different dimensions of illegalities and show how to help people become reintegrated into society. It is a sensible domain, which requires a lot of regulations and laws to be implemented and respected, in order to make people rejoin society, without any issues. The big advantage of using cybernetics is the feedback that comes continuously, and it can adapt based on that.

A structured concept of Management Control Systems (MCS) has been described by authors [72], providing solutions for actual problems from different perspectives, one of them being cybernetics. This approach helps to discover a distinction between manager behavior toward the employees and how this can affect decisions. In the end, a solution has been provided.

Walker and Cooper [73] developed an article based on resilience, which appeared initially in the USA in the 1970s. They tried to adopt the existing theory, which was developed during the Cold War, the second-order cybernetics and complex systems theory, describing what resilience is, and how complex systems theory can be applied combined with contemporary neoliberal doctrines. Complex systems interfere with external factors and convert them into endogenous features, which help the system to adapt and remove perturbations. They also presented the evolution of cybernetics, complex system theory and how important it is, the impact of resilience, and how to use resilience instead of natural resource management.

The possibility of creating bionic organs [70] is one of the most revolutionary events in medicine. Using cybernetics, the design and implementation of bionic devices have been simplified a lot, creating different scenarios and predictions on the resistance of materials, the compatibility of the human body, and functional electronic component durability. Since cybernetics is a complex system, which is changing based on the input. Using cybernetics, 3D printing Computer-Aided Design (CAD) was tested and implemented, helping millions of patients, by simulating different scenarios, materials, techniques, and technologies. The results confirmed what cybernetics showed previously: a huge success in creating cyborg ears that receive electromagnetic signals. This is only a small step compared with what cybernetics and medicine can achieve together.

Craig [74] in his paper, tried to explain the theory of Communication using many areas, such as Cybernetics, which is highly sensitive to noise. The author concluded that if there is a mismatch between the function and structure of the problem, information processing will become difficult and the message will not be correctly and fully understood. Cybernetics distinguishes between mind and matter only from one perspective. The author predicts the future, trying to explain how robots will communicate with people at some point, having a crucial role in creating an "interpersonal" discussion. This makes Cybernetics one of the most powerful domains, with huge applicability, not only for humans but also for Artificial Intelligence. The act of communicating is difficult even for humans, with unpredictable and hard-to-understand behaviors, that is why Cybernetics has been used because it has the power to create many scenarios, to cover all the possibilities, but it can also step ahead, focusing on robots.

Another study presented the importance of Industry 4.0, a complex system that is computed by many technologies and design principles [75]. From a Cybernetic point of view, Industry 4.0 is an evolution, adapting to the latest requirements in design and technology, making people more interested in it. The focus group consisted of students, helping them to create strategic roadmaps much more easily and offering the possibility to create priorities, budgets, capabilities, or goals. Cybernetics helped in developing the system, trying to gain feedback from the clients at every moment and adapting to their requirements. It is also useful to large companies because it can transform the activity of the employees, making them much more productive and efficient; however, this depends on the industry. Operational and strategic management is also available in Industry 4.0, Cybernetics created the optimum solution using one of its main characteristics, automatic adaptation.

Brechbühler et al. [69] showed a parametric representation for a worldwide technique, creating 3D objects. The purpose of the paper is to explain and show object surfaces at a scale as close as possible to reality, based on shape descriptors. Authors skipped traditional limitations using cybernetics, by creating systems, comparing their behavior, and keeping the most suitable one. It is crucial to have a big resistance, a specific geometry. Everything can be tested with parametrization techniques. In the end, a model that describes the ideal 3D object based on different parameters was created.

The focus of the authors was on the Cybernetic Big Five Theory (CB5T) [76], which provides a clear idea about the personality hierarchy based on three levels. Many hypotheses were tested (biological and psychological), trying to define some traits. CB5T offers continuous evolution and adaptation, which are specific to Cybernetics. It took some time to predict the adaptation characteristics because they are more complex and the personality is different from person to person, but in the end, there was a scenario that also included personalities and the evolution of each one. The trend of CB5T is positive and the mechanism has a self-adaptive architecture, receiving continuous data. However, there are some limitations as it is very difficult to predict personalities and how they can modify.

Table 7 provides a brief summary of the top 10 most globally cited documents, highlighting information related to the data used in the studies and their main purpose.

Table 7. Brief summary of the content of top 10 most globally cited documents.

No.	Paper (First Author, Year, Journal, Reference)	Title	Data	Purpose
1	Rhodes, RAW., 1996, Political Studies, [67]	The new governance: governing without government	Governance data	To highlight the importance of networks and how governments evolved in the 20th century
2	Wright, PM., 1992, Journal of Management, [68]	Theoretical perspectives for strategic human resource management	Human resource management historical data	To present the theoretical development of Strategic Human Resource Management (SHRM) and how different models can be applied
3	Rose, N., 2000, The British Journal of Criminology, [71]	Government and control	Synthetic data	To discuss the political programs against crimes. The implication of the criminal justice system
4	Malmi, T., 2008, Management Accounting Research, [72]	Management control systems as a package—opportunities, challenges, and research directions	Synthetic data	To describe the Management Control Systems (MCS) and how cybernetics can provide different perspectives
5	Walker, J., 2011, Security Dialogue, [73]	Genealogies of resilience: from systems ecology to the political economy of crisis adaptation	Synthetic data	To highlight the importance of resilience and how cybernetics helped
6	Mannoor, MS., 2013, Nano Lett, [70]	3D-printed bionic ears	Synthetic data	To create in 3D ears, using latest technology and cybernetics
7	Craig, RT., 1999, Communication Theory, [74]	Communication theory as a field	Synthetic data	To explain the importance of communication, the particularities, and how cybernetics can be applied
8	Ghobakhloo, M., 2018, Journal of Manufacturing Technology Management, [75]	The future of manufacturing industry: a strategic roadmap toward industry 4.0	Unlabeled data about technologies	To show what is the technology trends in Industry 4.0, analyzing 178 documents, using IBM technology
9	Brechbühler, C., 1995, Computer Vision and Image Understanding, [69]	Parametrization of closed surfaces for 3D shape description	Medical data	To connect between 3D objects, a parametric and global description
10	DeYoung, CG., 2015, Journal of Research in Personality, [76]	Cybernetic Big Five Theory	Questionnaire data	To understand from a comprehensive and mechanistic point of view the Big Five Theory, what are the benefits, and how to adapt to reality

3.4.3. Words Analysis

In the subsequent analysis, we delve into identifying the most commonly used words in the selected papers, with the aim of gaining insights into the research methods and the scope of the studies. To commence, we conducted a search for the most frequently occurring words in the keywords plus section. Notably, the word "model" emerged as the most frequently used term, appearing 147 times. This was followed by "systems", which occurred 135 times; "design" with 81 occurrences; "performance" with 64 occurrences; "dynamics" appeared 60 times; "growth" with 57 occurrences; and "framework" with 52 occurrences.

This analysis reveals that the majority of the words listed in Table 8 are closely associated with the field of Cybernetics, describing its core concepts and characteristics and providing valuable insights into the nature of research within this discipline.

Table 8. Top 10 most frequent words in keywords plus.

Words	Occurrences
Model	147
Systems	135
Design	81
Information	76
performance	64
management	62
Dynamics	60
Science	58
Growth	57
Framework	52

In Table 9, we can see the top 10 words most frequently used by authors in their papers. As anticipated, the term "cybernetics" is the most prevalent, with an impressive 2218 occurrences. Alongside this fundamental term, other keywords closely associated with the field of Cybernetics include "systems theory" (185 occurrences), "modeling" (123 occurrences), and "artificial intelligence" (98 occurrences). Additionally, within the context of Cybernetics, it is noteworthy to mention "optimization" (70 occurrences), "systems" (68 occurrences), "design" (67 occurrences), "complexity" (65 occurrences), and "information" (63 occurrences). The recurrent use of these words by authors underscores their significance in Cybernetics research, reflecting their essential roles in shaping the discourse and methodology within the field. An illustrative instance of the convergence between cybernetics and "artificial intelligence" lies in their mutual pursuit of comprehending and emulating specific behavioral phenomena.

Table 9. Top 10 most frequent words in authors' keywords.

Words	Occurrences
Cybernetics	2218
systems theory	185
Modelling	123
artificial intelligence	98
Optimization	70
Systems	68
Design	67
second-order cybernetics	66
complexity	65
Information	63

Figure 15 provides two word clouds, each representing the top 50 most commonly used words in the selected papers. These word clouds are generated based on two different sources: on the left side, we have the cloud of words derived from keywords plus, and on the right side, we have the cloud of words extracted from authors' keywords.

(**A**) Top 50 words based on keywords plus

(**B**) Top 50 words based on authors' keywords

Figure 15. Top 50 words based on keywords plus (**A**) and authors' keywords (**B**).

In the left word cloud, we can identify various concepts frequently associated with the field of Cybernetics, such as "modelling", "systems", "design", "information", "performance", "management", "behavior", "algorithm", "networks", "optimization", "convergence", "classification", "organizations", "algorithms", "impact", "selection", and "communication".

Conversely, the right word cloud prominently features the word "cybernetics", reflecting authors' frequent use of this term in titles, abstracts, and content. Additionally, other terms preferred by authors in the field of Cybernetics are visible, including "systems theory", "modeling", "artificial intelligence", "optimization", "automation", "learning", "computers", "neural networks", "cognition", "research", "control", "simulation", "decision making", and "control systems". These word clouds offer a visual representation of the key concepts and focal points within the domain of Cybernetics research.

Table 10 provides insights into the 10 most frequently encountered groups of two words or bigrams within the abstracts and titles of the analyzed articles.

Table 10. Top 10 most frequent bigrams in abstracts and titles.

Bigrams in Abstracts	Occurrences	Bigrams in Titles	Occurrences
systems theory	232	contemporary systems	63
second-order cybernetics	216	cybernetic model	57
artificial intelligence	195	cybernetic approach	51
cybernetic model	158	second-order cybernetics	34
social systems	136	viable system	33
neural network	114	system model	30
system model	112	artificial intelligence	28
viable system	111	cybernetic modeling	27
experimental results	106	neural networks	25
information theory	106	systems theory	25

In the left portion of the table, we observe the word groups extracted from the abstracts. The most common group, "systems theory", appears 232 times, underscoring its significance in the domain of Cybernetics. Other frequently occurring groups include "second-order cybernetics" (216 occurrences), "artificial intelligence" (195 occurrences), and "social systems" (136 occurrences), all of which reflect key themes and topics within Cybernetics research.

In the right portion of the table, we find bigrams extracted from the article titles. Compared to the occurrences in abstracts, title-based bigrams typically have lower frequencies due to the limited number of characters in titles. The most frequent title-based bigrams include "contemporary systems" (63 occurrences), "cybernetic model" (57 occurrences), "cybernetic approach" (51 occurrences), "second-order cybernetics" (34 occurrences), "viable system" (33 occurrences), and "system model" (30 occurrences). These title-based bigrams provide insights into the specific areas of focus and emphasis within Cybernetics research articles. The occurrence of the "viable system" bigram within the top bigrams was expected, as the Viable System Model (VSM) is a cybernetic core component that was conceptualized to elucidate the adaptability of enterprises in the face of dynamic environmental changes. VSM serves as a framework for depicting the organizational structure of viable or self-regulating systems, comprising five interdependent subsystems. Its utility extends across diverse domains, ranging from operations management to educational contexts [77]. On the other hand, even the occurrence of the "neural network" bigram was expected due to its connection with cybernetics. A neural network represents a machine learning approach that empowers computers to acquire knowledge from observational data. Network structures consist of interconnected nodes that exchange information via weighted connections, the weighting being contingent upon their capacity to yield specific outcomes [78].

Table 11 provides insights into the top 10 trigrams or groups of three words with the highest frequencies of usage, both in the abstracts and titles of the analyzed articles.

Table 11. Top 10 most frequent trigrams in abstracts and titles.

Trigrams in Abstracts	Occurrences	Trigrams in Titles	Occurrences
viable system model	103	viable system model	28
heinz von foerster	49	heinz von foerster	13
system model vsm	47	abstract neural automata	7
selected current research	36	systems unitary science	6
systemic yoyo model	36	air-force logistics command	4
valuable periodic review	33	contemporary cybernetics systems	4
adomian decomposition method	32	cybernetic coping scale	4
beers viable system	30	cybernetic transportation system	4
applied practical implications	24	cybernetics deviation-amplifying mutual	4
artificial intelligence ai	24	cybernetics past achievements	4

In the left portion of the table, we observe the trigrams extracted from the abstracts. The most common trigram, "viable system model", appears 103 times, indicating its significance in Cybernetics research. Other frequently occurring trigrams include "heinz von foerster" (49 occurrences), "system model vsm" (47 occurrences), "selected current research" (36 occurrences), "systemic yoyo model" (36 occurrences), "valuable periodic review" (33 occurrences), "adomian decomposition method" (32 occurrences), "beers viable system" (30 occurrences), "applied practical implications" (24 occurrences), and "artificial intelligence ai" (24 occurrences). These trigrams provide insights into specific topics and areas of focus within the field of Cybernetics.

On the right portion of the table, we find trigrams extracted from the article titles. The most frequent title-based trigram is "viable system model" (28 occurrences), followed by "heinz von foerster" (13 occurrences), "abstract neural automata" (7 occurrences), and "systems unitary science" (6 occurrences). Several trigrams registered 4 appearances each, including "air-force logistics command", "contemporary cybernetics systems", "cybernetic coping scale", "cybernetic transportation system", "cybernetics deviation-amplifying mutual", and "cybernetics past achievements". These title-based trigrams shed light on specific themes and topics emphasized in the titles of Cybernetics research articles. The occurrence of the trigram represented by the name of Heinz von Foerster was also expected due to his connection with the cybernetic field. More specifically, in 1974, Heinz von Foerster distinguished between first-order cybernetics and second-order cybernetics, emphasizing the absence of the observer's role in first-order cybernetics. This variant underscores the significance of negative feedback and conceives the system as an independent entity. Conversely, second-order cybernetics introduces the quandary of impoverished closed-system dynamics. Furthermore, it adopts a reflective and philosophical stance, with a diminished emphasis on control mechanisms [79].

In the following, we present some figures, made for the unigrams found in the titles, illustrating the thematic evolution (Figure 16) and a thematic map (Figures 17–19) for the three periods of significant disturbances in the annual publication trends. Since some words represent specialized terms specific to cybernetics, we decided to eliminate some of them: “cybernetic”, “model”, “models”, “system”, “systems”, “theory”, and “approach”.

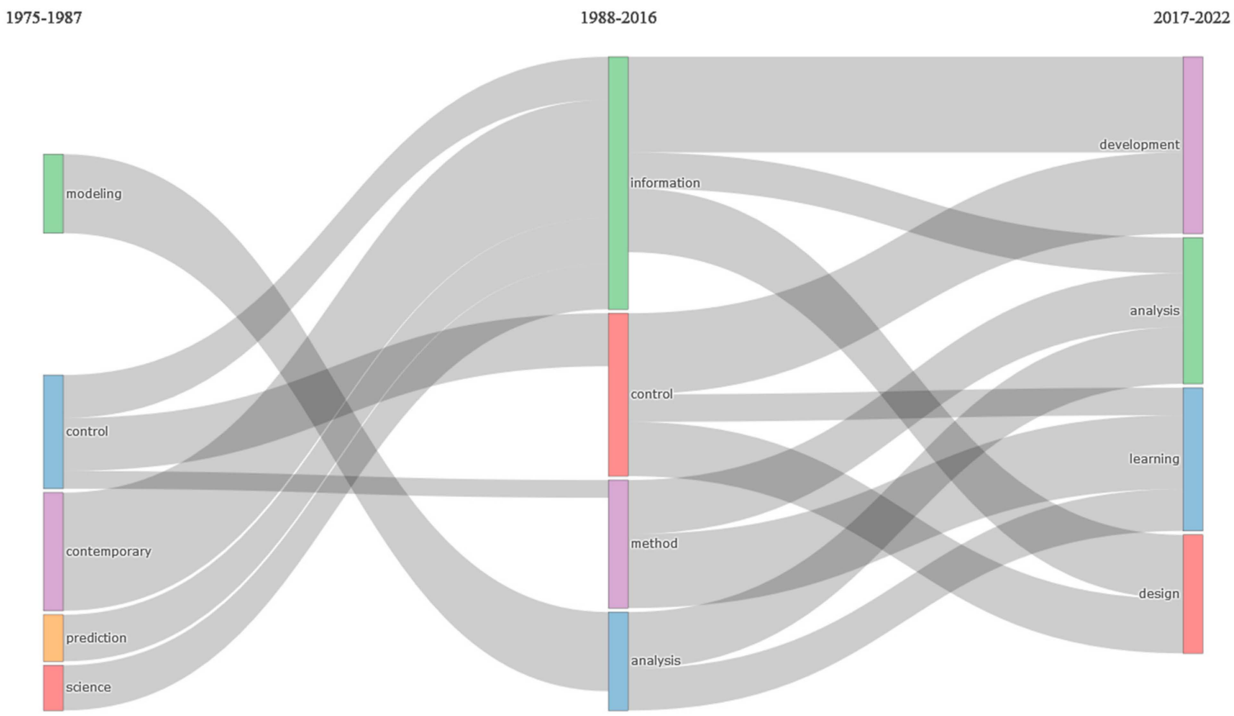

Figure 16. Thematic evolution.

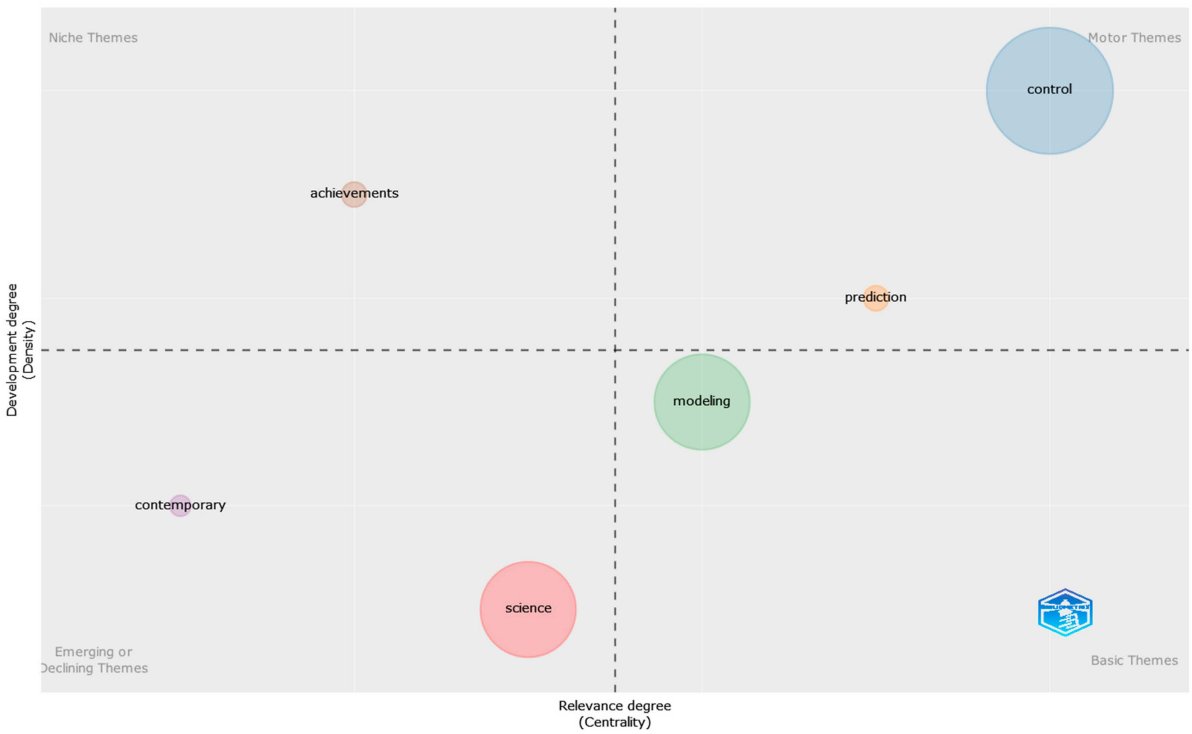

Figure 17. Thematic map for the 1975–1987 period.

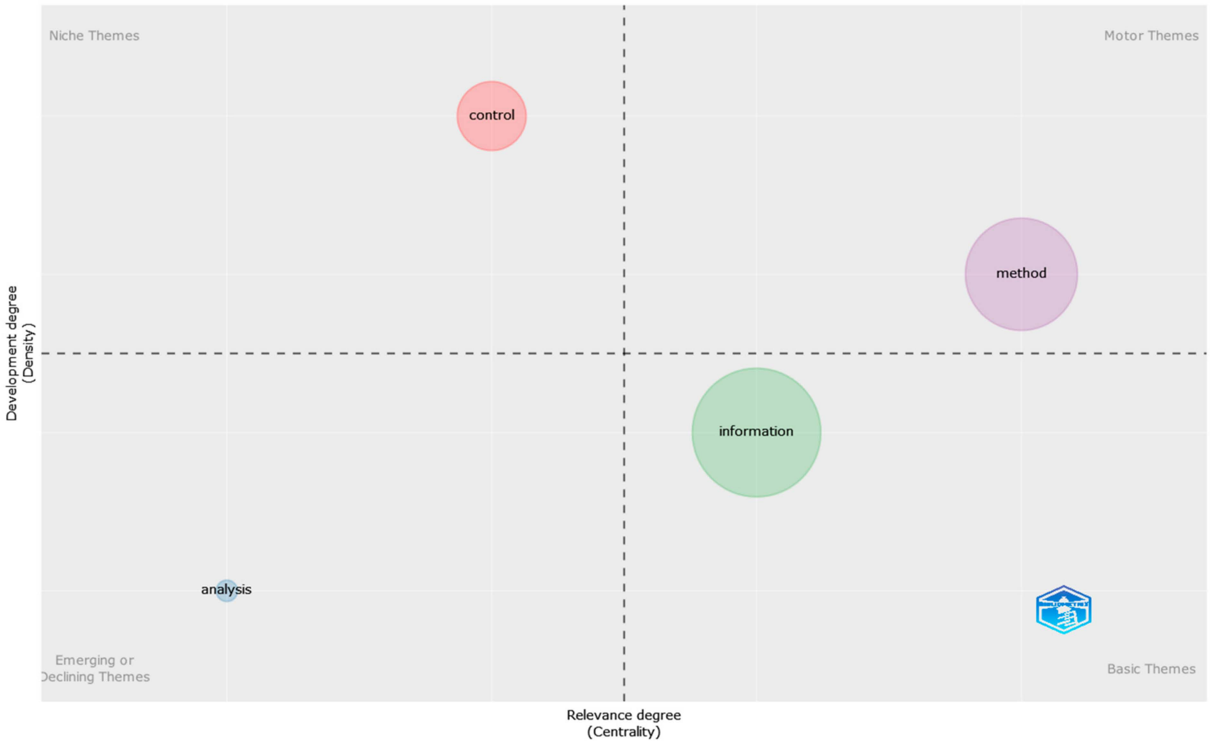

Figure 18. Thematic map for the 1988–2016 period.

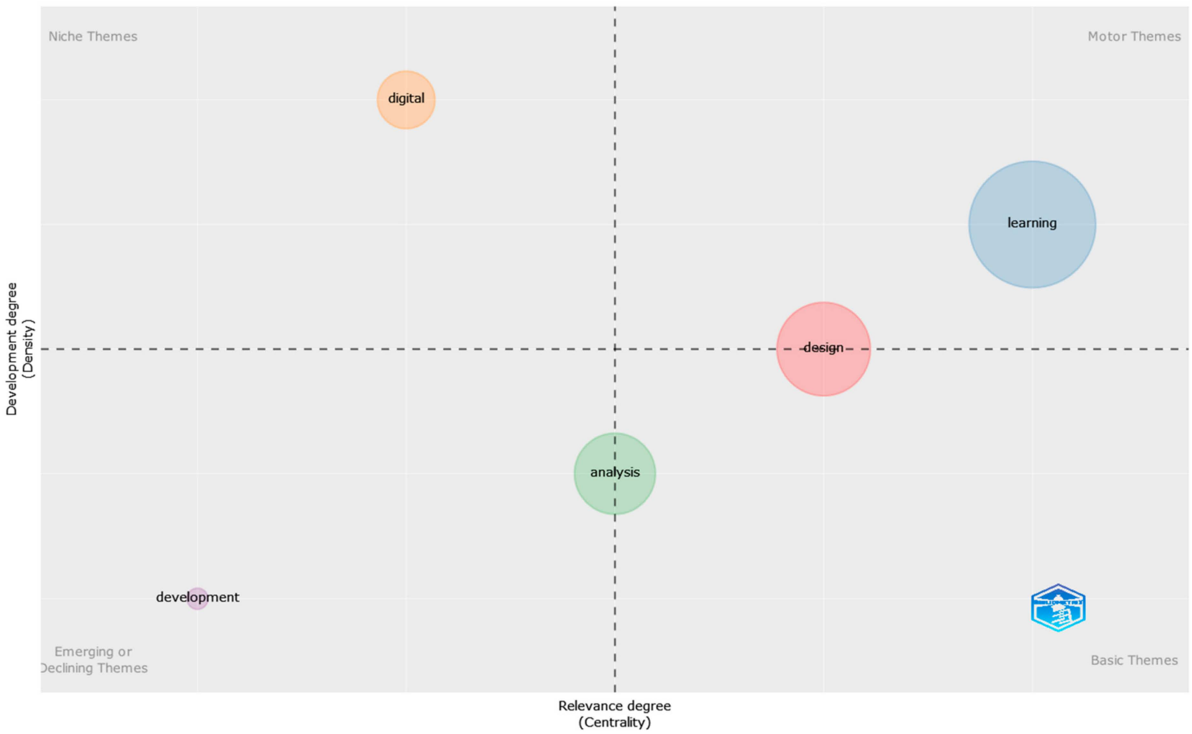

Figure 19. Thematic map for the 2017–2022 period.

Figure 16 helps us to observe which words were the most frequent in the three identified time periods and how they were combined to form new terms. In the initial period, 1975–1987, the word "control" showed a merger with "contemporary", "prediction", and "science" into "information". In turn, the word identified in the second period became the basis for the formation of other terms such as "development", "analysis", and "design".

Most of the high-frequency words from the 1988–2016 period are combined and, in turn, form new terms describing cybernetics.

Figure 17 shows the highest frequency of certain unigrams at title level for the period 1975–1987. We can see that during this period, the emphasis was on "control" in the "Motor Therm" box and on "prediction", but the orange bulb of this term is much smaller compared to the blue one. The term "control" is very important in cybernetics because it occurs when a closed system adjusts itself using a feedback loop. A high number of articles can also be seen in the "Basic Themes" quadrant, where most of them contain the word "modeling".

Compared to the previous period (Figure 17), in Figure 18 (years 1988–2016) we can observe a higher number of articles in the "Basic Themes" quadrant, where the word "information" predominates in the titles, as opposed to the "Motor Themes" quadrant, where the bubble indicates the unigram "method". During this period, most authors started to develop and use cybernetic methods for modeling. "Control" has now moved into the "Niche Themes" category, representing a sector that has already been explored.

In the most current period 2017–2022 (Figure 19), the focus has shifted toward learning-related work. Cybernetics is a science that is constantly changing, and able to adapt and co-evolve. That is why learning in this field cannot end, making research extremely important. Compared to Figure 18, the articles with the theme "analysis" have reached the border between the "Emerging of Declining Themes" and "Basic Themes" quadrant, previously being fully in the "Emerging of Declining Themes" and also having a smaller number of articles in its composition.

3.5. Mixed Analysis

In Figures 20 and 21, we have two diagrams that provide a visual representation of the connections between countries, authors, keywords, and affiliations within the field of Cybernetics research.

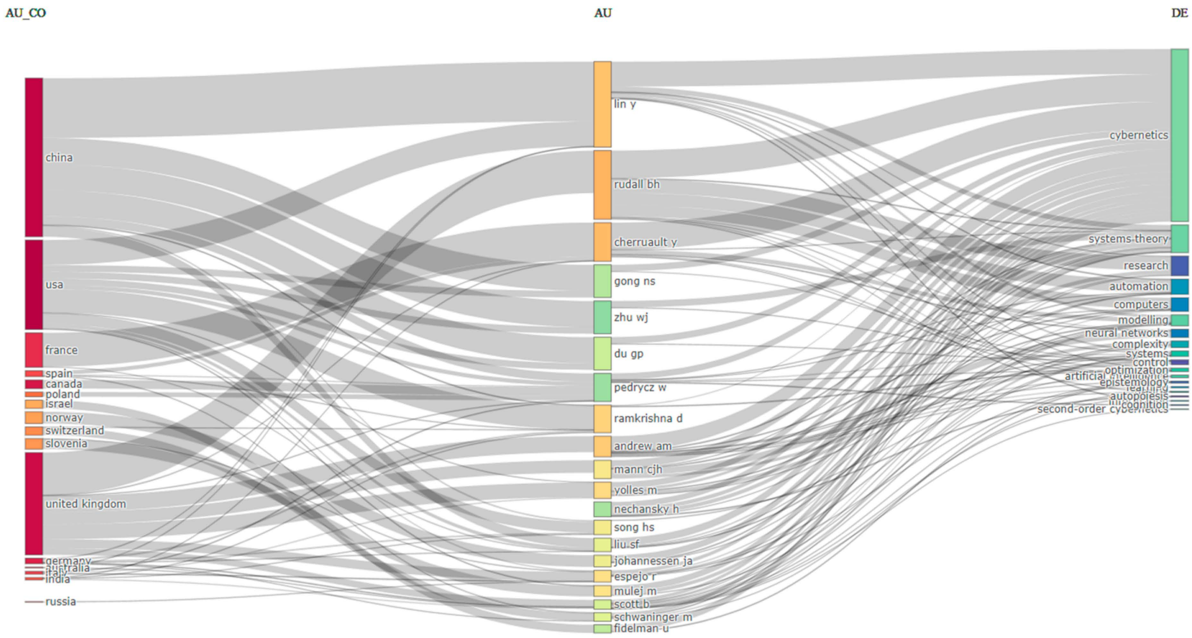

Figure 20. Three-fields plot: countries (left), authors (middle), keywords (right).

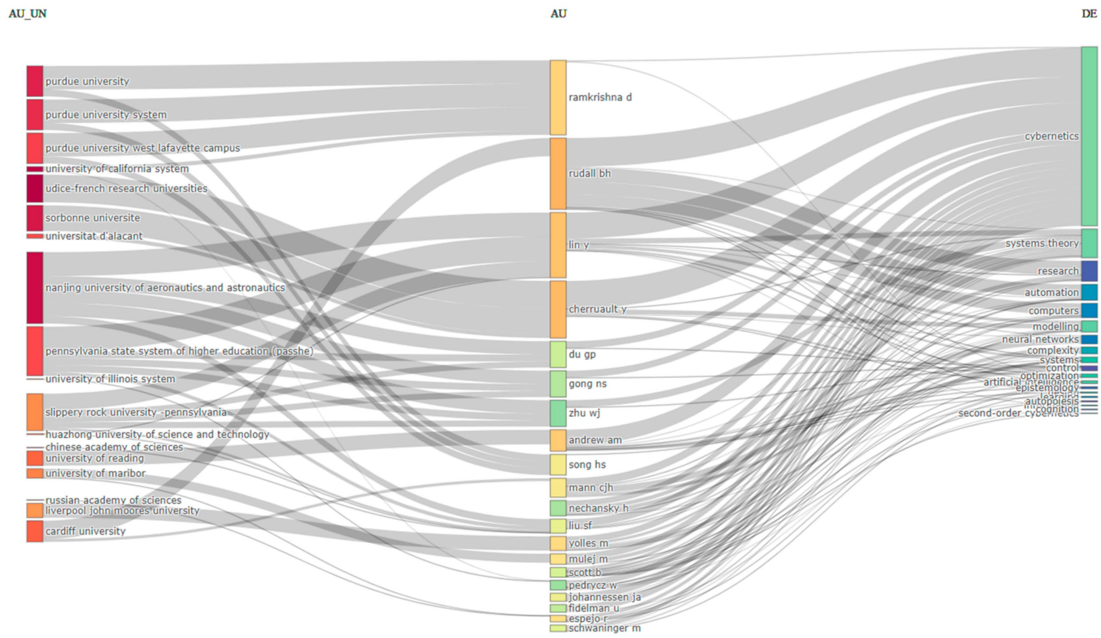

Figure 21. Three-fields plot: affiliations (left), authors (middle), keywords (right).

Figure 20 illustrates the connections between the top 20 most active countries, authors, and frequently used keywords. China emerges as the most actively participating country in publishing Cybernetics articles, with eight prominent authors including Lin Y., Gong NS., Zhu WJ., Du GP., Pedrycz W., Ramkrishna D., Song HS., and Liu SF. The keywords frequently encountered in the papers published by these authors include “cybernetics”, “systems theory”, “research”, and “modeling”. Following China, other countries with significant collaborations include the United Kingdom, the United States of America, and France.

Figure 21 provides a visual representation of the collaborative links that exist between affiliations, authors, and keywords within the analyzed Cybernetics research articles.

Figure 21 offers a visual representation of the connections between the top 20 most active affiliations, authors, and frequently used keywords. It provides insights into how affiliations, authors, and keywords are interrelated within Cybernetics research.

These diagrams facilitate the identification of key connections and collaborations among countries, authors, affiliations, and keywords in the field of Cybernetics, offering a comprehensive overview of the research landscape in this domain.

In terms of universities actively involved in Cybernetics research, Nanjing University of Aeronautics and Astronautics in China emerges as the most prominent, followed by the Pennsylvania State System of Higher Education in the USA. Prominent authors in the field include Ramkrishna D. from the USA, Rudall BH. from the UK, Lin Y. from China, Cherruault Y. from France, and Du GP. from China. Notably, the top keywords used in these research articles are consistent with those identified in Figure 20, including terms like “cybernetics”, “systems theory”, “research”, and “modeling”.

These diagrams offer a visual perspective on the collaborative relationships between affiliations, authors, and keywords in the field of Cybernetics, helping to elucidate the research landscape and the key players within it.

4. Limitations

While our analysis aimed to identify the most relevant papers in the field of Cybernetics, we acknowledge that there were certain limitations in conducting this study.

First, in terms of temporal limitations, our paper includes articles published over a 47-year period from 1975 to 2022.

When we set out to produce this article, we chose to extract only publications from ISI Web of Science indexed journals. If we had chosen to add other publications available in other databases, then our results might have been influenced by them, due to the interest of cybernetics researchers.

There were limitations in terms of filtering the titles of the papers that were selected or their abstracts, as can be seen at the beginning of our analysis in the Section 2 in Table 1. By searching for more keywords in the field, we could have identified papers that included other subfields. In terms of language, the selected papers were only in English, without introducing papers in other languages.

To carry out the present analysis, we used the Biblioshiny library, which is located within R. We must acknowledge that the use of this library involves the use of the R package, even though at a reduced level of knowledge.

5. Conclusions

When selecting the research area for our paper, our aim was to ascertain the most pertinent scholarly works spanning an extensive historical continuum within the realm of cybernetics. Our initial approach entailed the meticulous curation of 4856 papers from the ISI Web of Science database, primarily guided by specific keyword criteria. These selected papers subsequently underwent comprehensive bibliometric analysis. Since 1975, the field of Cybernetics has undergone a remarkable evolution, solidifying its status as one of the most dynamic and captivating domains of study.

Leveraging the Biblioshiny library in R, we executed an extensive analysis of our carefully curated dataset. Upon refining our database through specific filters, we embarked on an in-depth exploration of the evolutionary trajectory of scholarly production within this discipline. Our investigation encompassed various facets of the data, encompassing averages of publication years, citation counts, references, temporal trends in publication output, authorship details, collaborative patterns, national origins, and the principal journals of publication. Additionally, we identified and meticulously scrutinized the top 10 most cited papers, applying diverse bibliometric indicators such as Total Citations (TC), Total Citations per Year (TCY), and Normalized Total Citations (NTC). Furthermore, we employed textual analysis techniques to unveil the most prevalent terms, bigrams, and trigrams within titles and abstracts, thereby gaining deeper insights into the specific terminologies and areas of application within the realm of Cybernetics.

To convey this wealth of data, we harnessed an assortment of tables and graphical representations, including collaboration maps, three-field plots, collaboration networks, and word clouds. These visualization techniques provided us with a nuanced understanding of the Cybernetics landscape, illuminating its significance and its contributions to pivotal discoveries.

As for prospective research avenues, we recommend the exploration of additional Cybernetics databases, such as Scopus, to further enrich the breadth and depth of scholarly investigations within this field.

In summary, Cybernetics holds a significant place in contemporary science, particularly in the realm of modeling. It has evolved and expanded its influence across various fields over time. We believe that our study offers valuable insights into the ongoing development of this discipline, and it may be of interest to those curious about its evolution.

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