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Research Article

A Bibliometric Exploration of Automation and its Impact on Mechanical Engineering Research

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ABSTRACT

This bibliometric exploration delves into the dynamic landscape of automation's influence on mechanical engineering research.Leveraging the Scopus database and employing keyword search strategies targeting article titles, abstracts, and keywords from 1972 to 2022, this study examines the interdisciplinary nexus between automation and mechanical engineering. The top outcomes revealed a persistent focus on "mechanical engineering" as a foundational subject, fluctuating trends in thematic interests such as "control systems" and "robotics," and the pivotal roles of central authors within collaborative networks. Notably, collaboration networks identified influential figures like Wang X, Li D, and Zhang X, indicating their significant connections and influence within their respective networks. Future directions point toward deeper investigations into emerging themes like the convergence of information technology with automation, fostering global collaborations, and exploring correlations between academic output and real-world technological advancements. These findings underscore the dynamic and multifaceted nature of research within this field, paving the way for continued interdisciplinary exploration and innovation at the intersection of automation and mechanical engineering.

1. INTRODUCTION

Automation has profoundly revolutionized the landscape of mechanical engineering, fostering advancements that redefine manufacturing, innovation, and operational efficiency. This intersection marries the precision and principles of mechanical engineering with automated systems, amplifying productivity, reliability, and adaptability across various industries. The seamless integration of automation into mechanical engineering processes, ranging from robotic systems in manufacturing to automated control in complex machinery, has ushered in an era of transformative capabilities and possibilities. This study embarks on a comprehensive bibliometric exploration to dissect the evolving dynamics and impacts of automation within the realm of mechanical engineering. Hypothesis: Within the vast spectrum of automation's application in mechanical engineering, we hypothesize a dynamic correlation between thematic trends, collaborative networks among researchers, and the evolving scholarly impact across various thematic areas.

This correlation is expected to reveal insights into influential research topics, key contributors within collaborative networks, and global authorship patterns, shaping the scholarly landscape within this interdisciplinary field.This paper is structured as follows: The methodology section details the approach taken in conducting the bibliometric analysis, outlining the database used, search strategies, and limitations encountered. The results section provides a comprehensive presentation of findings, encompassing annual scientific production, average citations per year, trend topics, collaboration networks, and corresponding authorship patterns. Following the results, the discussion section interprets and correlates the outcomes across different sections, drawing connections between trends, network structures, thematic interests, and global authorship patterns. Finally, the conclusion encapsulates the key insights, highlights the top results, identifies future directions, and addresses gaps for further exploration within the domain of automation and its impact on mechanical engineering research[1-5].

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2.METHODOLOGY

2.1 Data Collection

The primary database chosen for this bibliometric analysis is Scopus due to its comprehensive coverage of scholarly literature across various disciplines. Scopus was selected for its extensive repository of engineering-related research articles, ensuring a robust dataset for the study.

2.2 Search Strategy

The search strategy employed the following keywords: ("Automation") AND ("Mechanical Engineering"). These keywords were applied to target article titles, abstracts, and keywords, aiming to capture pertinent publications directly related to the intersection of automation and mechanical engineering.

2.3 Inclusion Criteria and Filters

The search results were filtered to encompass documents published within the timespan from 1972 to 2022. Additionally, the subject area was confined to engineering, ensuring the relevance and specificity of the retrieved documents.

2.4 Data Retrieval

Upon executing the search query, a total of 1,038 documents were obtained. However, when employing the biblioshiny application for data analysis, a total of 1,000 documents were successfully captured and utilized for further analysis.

2.5 Data Processing and Analysis

RStudio, along with the R programming language, was employed for data extraction and analysis. The biblioshiny package within R facilitated the extraction of figures and tables crucial for the bibliometric exploration.

2.6 Assessment of Metadata Completeness

The completeness of bibliographic metadata across the 1,000 documents was evaluated. Notably, various metadata elements were assessed for completeness, including author information, publication year, document type, abstract, journal details, keywords, affiliations, DOIs, and more.The assessment revealed varying degrees of completeness across metadata categories, as shown in Table 1. While certain elements such as author information, publication year, and document type demonstrated excellent completeness (0% missing), critical metadata elements like cited references and science categories were completely missing for the dataset.

2.7 Handling of Missing Metadata

The study acknowledged the presence of missing metadata, especially regarding keywords, affiliations, DOIs, and cited references. To mitigate the impact of missing data on the analysis, alternative methodologies were employed. The study did not solely rely on missing metadata to derive results, ensuring the robustness and reliability of the findings

TABLE I.COMPLETENESS OF BIBLIOGRAPHIC METADATA

Metadata	Description	Missing Counts	Missing %	Status
AU	Author	0	0	Excellent
DT	Document Type	0	0	Excellent
LA	Language	0	0	Excellent
PY	Publication Year	0	0	Excellent
TI	Title	0	0	Excellent
TC	Total Citation	0	0	Excellent
AB	Abstract	13	1.3	Good
SO	Journal	18	1.8	Good
ID	Keywords Plus	137	13.7	Acceptable
C1	Affiliation	219	21.9	Poor
DI	DOI	445	44.5	Poor
DE	Keywords	561	56.1	Critical
RP	Corresponding Author	659	65.9	Critical
CR	Cited References	1000	100	Completely missing
WC	Science Categories	1000	100	Completely missing

3.RESULTS

3.1 Main Information

The dataset gathered for this bibliometric analysis spans a significant period from 1972 to 2022, encompassing a total of 1,000 documents sourced from 385 distinct journals, books, and conference proceedings. Figure 1 provides a visual representation of various key insights derived from this dataset. Examining the timespan of publications, it is evident that the average document age within this corpus stands at 15 years, showcasing the longevity and historical depth of the research material. Furthermore, an annual growth rate of 7.18% reflects a consistent influx of literature on the intersection of "Automation" and "Mechanical Engineering" over the years.

Regarding the nature of the documents, the majority consist of conference papers (468), followed by articles (323), books (14), book chapters (46), and various other types, as delineated in Figure 1. Notably, there were no references directly available within this dataset, suggesting a potential limitation in accessing the cited sources directly from the documents. Authors played a crucial role in contributing to this body of work, with a total of 2,090 unique authors identified across the dataset. Among these, 232 documents were authored by a single individual, indicating a significant presence of sole-authored contributions. Collaboration among authors was also prominent, as seen by an average of 2.52 co-authors per document and a relatively low percentage (6.2%) of international co-authorships.

When we looked through the documents, specific words gave us crucial clues about the research field. We found a total of 8,603 keywords, which included 6,803 Keywords plus (ID) and 1,790 Author's Keywords (DE). This discovery provided us with a thorough understanding of the various subjects and main ideas discussed in the mechanical engineering literature on automation. In essence, the dataset we examined in this study is quite extensive, covering different types of documents, involving many authors, and encompassing a wide range of keywords. It forms a solid foundation for conducting in-depth exploration and analysis in this area

Fig. 1. Visualization of Key Insights from the Bibliometric Analysis

3.2 Annual Scientific Production

The study of how much scientific work has been done in the field of automation within mechanical engineering, as shown in Figure 2, reveals an interesting trend in scholarly output over the past five decades, from 1972 to 2022. Initially, from 1972 to the late 1970s, there was a small amount of work, with only occasional articles published. But starting from the mid-1980s, there was a big increase in publications, especially after 1984. This increase led to a significant rise in the following years, showing a growing interest and emphasis on automation in mechanical engineering. The 1990s had a varied output, with the number of publications going up and down between single-digit and double-digit figures. However,as we moved into the 2000s, there was a more consistent trend of growth, with occasional high points and low points. The early 2000s experienced a notable increase in publications, peaking notably in 2013 with 104 articles published, a clear milestone in scientific output in this field. Afterward, there were fluctuations in the number of articles published each year, sometimes rising and sometimes falling.From 2012 to 2022, the last decade analyzed, there was a relatively consistent but varying amount of scientific work, with annual publication counts ranging from the mid-20s to the mid-60s. In the most recent years, like 2019 and 2020, there was a resurgence in scientific production, with 56 and 39 articles published, respectively. However, this was followed by a slight decrease in 2021 and 2022, settling around 30 to 35 articles per year. The changes in annual scientific production illustrated in Figure 2 highlight how research in automation within mechanical engineering is always changing. It shows times of significant growth, intermittent peaks, and fluctuations, indicating how the focus of scholarly contributions in this interdisciplinary field has evolved over time.

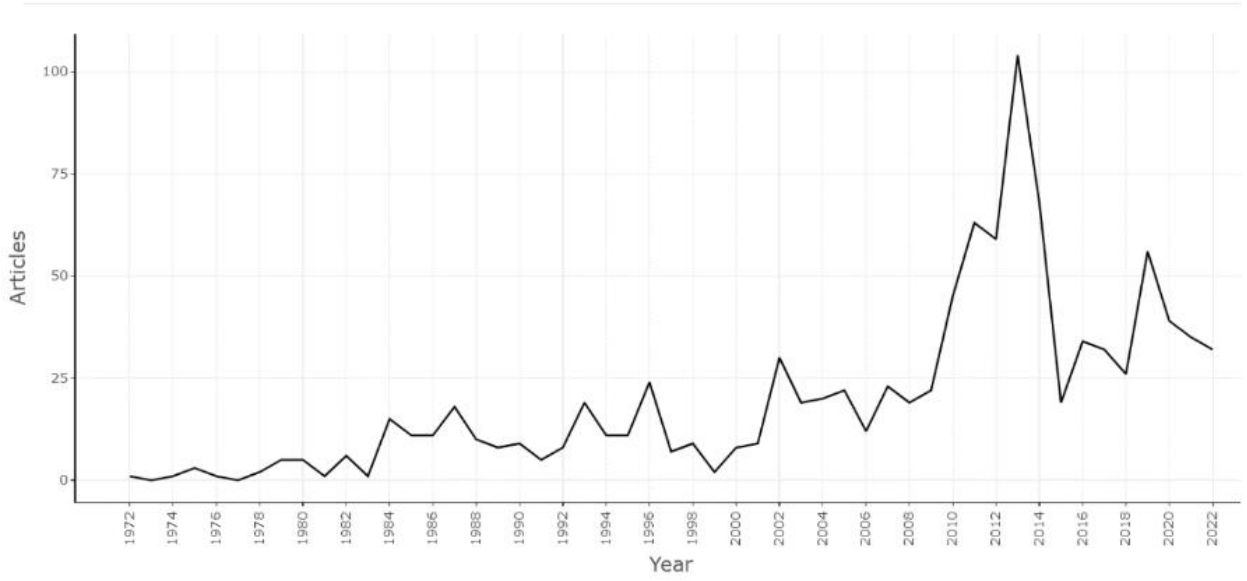

Fig. 2. Visualization of Annual Scientific Production

3.3Average Citations per Year

The analysis of the average citations per year, depicted in Figure 3, unveils a comprehensive insight into the scholarly impact and reception of publications in the domain of automation within mechanical engineering over the years from 1972 to 2022. The earlier years from 1972 to the late 1970s witnessed relatively minimal citations, indicating a negligible academic impact during those periods. However, as the research landscape evolved, a noticeable shift emerged in the mid-1980s, particularly from 1986 onwards. This phase marked a significant increase in the mean citations per article, signifying a growing recognition and influence of publications related to automation in mechanical engineering.

Throughout the subsequent decades, there were notable fluctuations in mean citations per year, indicative of varying reception and impact of scholarly output within different periods. Notably, the late 1980s and early 1990s saw peaks in citation impact, reflecting the heightened influence and recognition of the research conducted during these periods. A notable surge in citations per article was observed in certain landmark years, such as 1990, where the mean citations peaked at 12.67, signifying the exceptional impact and recognition of publications during that year. Similarly, peaks in mean citations per article were also observed in 2001, 2008, 2011, and 2015, each representing periods of heightened academic attention and influence within the field.

The last decade, from 2012 to 2022, displayed a varying but generally consistent range of mean citations per article. Notably, 2015 stood out with an exceptionally high mean citation count of 48.63, indicating a year with remarkably impactful publications within the domain. It's important to note that while there are fluctuations in the mean citations per article across the years, the trend overall demonstrates an increasing academic impact and recognition of research within the intersection of automation and mechanical engineering, depicting the evolving influence and reception of scholarly output over time

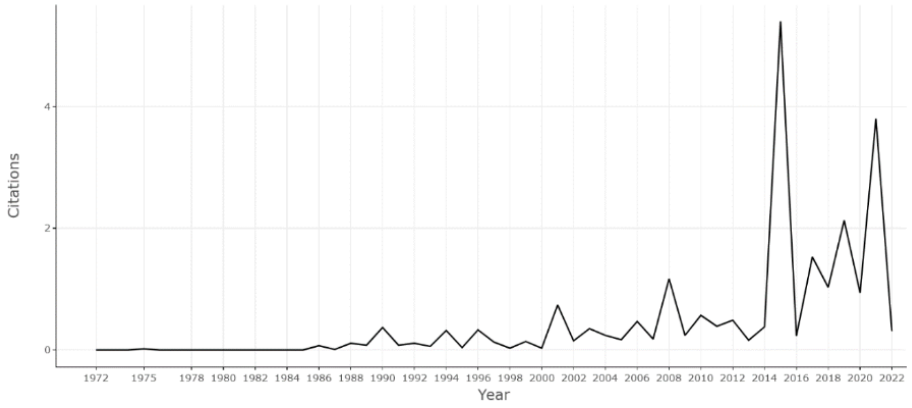

Fig. 3. Visualization of Average Citations per Year

3.4 Corresponding Author's Countries

Understanding the geographical distribution of corresponding authors in the realm of automation within mechanical engineering is crucial in delineating the global landscape of scholarly contributions. Figure 4 provides an overview of the countries where corresponding authors are situated concerning the articles published in this domain. The analysis of corresponding authorship by country reveals a diverse representation, with varying frequencies of participation. China emerges as the predominant contributor, accounting for 135 articles, representing approximately 13.5% of the total articles studied. This underscores China's substantial involvement and leadership in scholarly output within the field of automation and mechanical engineering.

Following China, Germany and the United States stand out as significant contributors, with 33 and 30 articles, respectively. Germany, with its 3.3% contribution, and the United States, accounting for 3% of the total articles, affirm their prominent roles as active participants in shaping the scholarly discourse within this interdisciplinary domain. Slovenia, India, Slovakia, Czech Republic, Italy, and Serbia also make notable contributions, albeit with relatively smaller article counts. Each of these countries presents varying levels of engagement, reflecting a diverse global participation in research endeavors related to automation within mechanical engineering.

Interestingly, while Slovenia and Slovakia had a lower total article count, their proportion of multiple corresponding papers(MCP) indicates a more substantial ratio concerning the total number of articles authored. This suggests a higher tendency for multiple corresponding authorships within these countries, signifying collaborative efforts and a potential emphasis on joint research initiatives within these regions. The data underscores a globalized effort in research collaboration, with varying degrees of participation from different countries. The diverse representation of corresponding authorship highlights the multinational nature of scholarly contributions in this field, indicating a collaborative and interconnected approach to advancing knowledge and innovation in automation within mechanical engineering

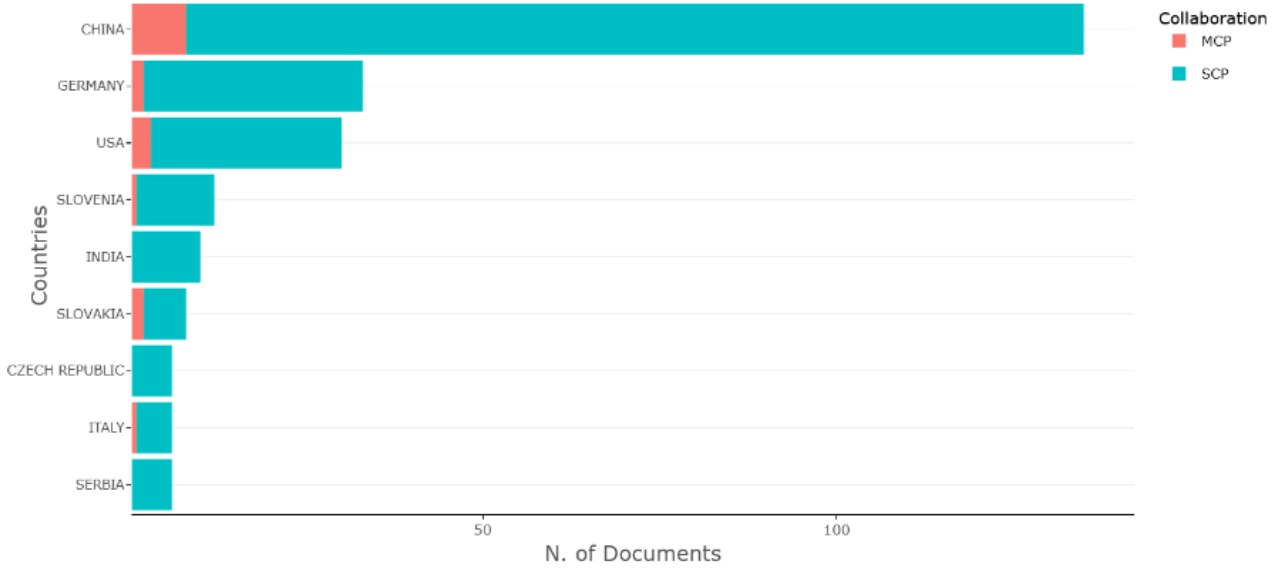

Fig. 4. Visualization of Corresponding Author's Countries

3.5. Trend Topics

Analyzing the trend topics within automation and mechanical engineering provides a nuanced understanding of the evolving focal points and interests in scholarly research over time. Figure 5 presents an insightful portrayal of key thematic areas and their temporal trends, shedding light on the progression and significance of various topics within this domain. "Mechanical engineering" emerges as the most prevalent and consistent topic, with a substantial frequency count of 469. This foundational subject maintains a continuous presence throughout the years, showcasing its enduring relevance and centrality in research discussions within the field.

The analysis reveals certain thematic areas experienced distinct periods of prominence. "Computer-aided design" exhibited an initial surge in the 1990s, peaked around 2002, and maintained a steady but relatively declining trend thereafter, indicating a sustained but decreasing focus on this topic in recent years. "Engineering education" saw a consistent rise in frequency over the years, reflecting a growing emphasis on pedagogical aspects within the discipline, reaching its zenith around 2017. This trend signifies a heightened interest in nurturing and advancing educational practices in automation and mechanical engineering.

Similarly, "control systems," "process control," and "control" displayed consistent trajectories, depicting an enduring relevance and sustained attention across different periods, indicating the continuous importance and evolution of control-related themes within the field. Themes like "robots," "robotics," "mechatronics," and "manufacture" witnessed fluctuating patterns, indicating phases of increased attention followed by periods of relative decline in scholarly focus. These trends suggest alternating cycles of intensive research and potential shifts in thematic emphasis within automation and mechanical engineering.

Interestingly, "information technology" displayed a sudden rise and plateaued trend, indicating a concentrated burst of interest around 2011 that maintained a steady presence in subsequent years, highlighting a focused exploration of the intersection between information technology and the field of study. "Students" surfaced as a topic with a moderate but consistent frequency, indicating a sustained interest in issues concerning students within the context of automation and mechanical engineering, potentially reflecting research related to student engagement, development, or experiences within this domain. The trends depicted in Figure 5 underscore the dynamic nature of thematic interests within automation and mechanical engineering, showcasing the ebb and flow of scholarly attention and the evolution of key topics over time.

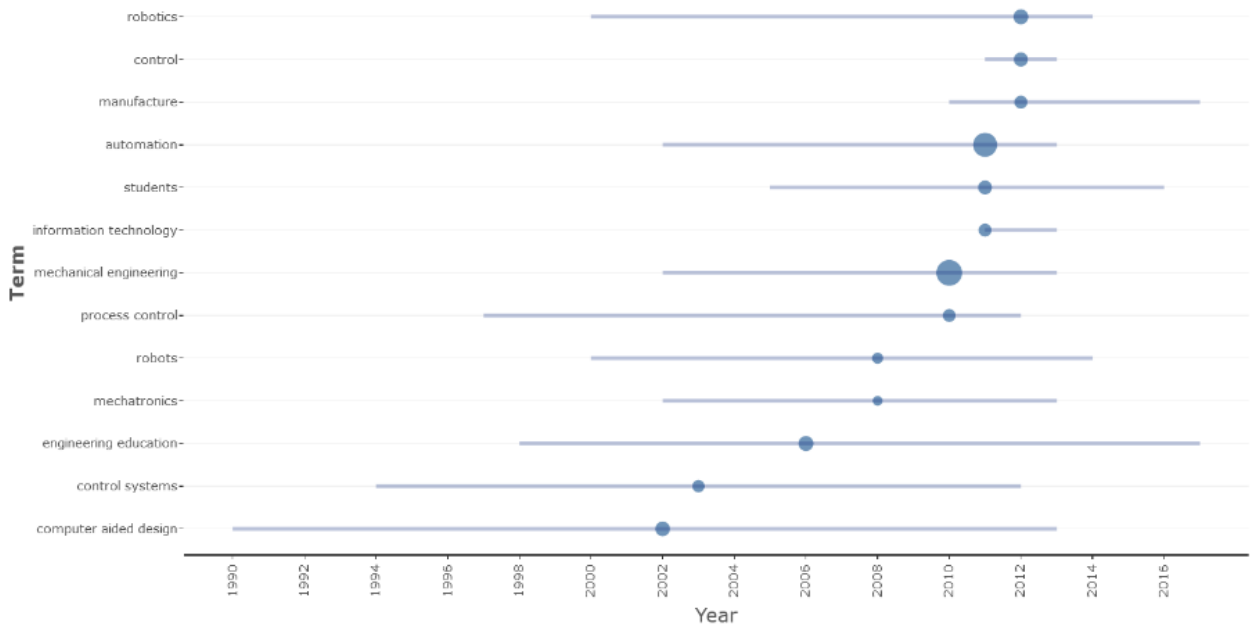

Fig. 5. Visualization of Trend Topics

3.6 Collaboration Network

The Collaboration Network analysis, represented in Figure 6, sheds light on the interconnectedness and roles of various researchers (nodes) within the field of automation and mechanical engineering. Authors like Wang [6], Li D [7], Li J [8], Li Y [9], Wang P [10], and Yang J [11] are among those with notable betweenness centrality values. This metric indicates their pivotal roles in connecting different researchers within the network. Additionally, their higher PageRank values and closeness centrality signify their significant influence and proximity to other researchers in this collaborative network.

Other key contributors, such as Zhang X [12] and Li S [13], exhibit considerable betweenness centrality, showcasing their importance in facilitating connections among researchers. Their contributions play a crucial role in bridging connections within their respective collaborative circles. Kuric I [14], Císar M [15], Shah JJ [16], Summers [16], Lin CY [17], Crossman GR [18], and others demonstrate equal betweenness and closeness centrality values, suggesting an equally influential role within their respective collaborative networks. Their interconnectedness within these networks is crucial for knowledge exchange and collaboration.

Authors in Clusters 6 to 10 exhibit lower betweenness and closeness centrality values, indicating a potential focus on more localized interactions or collaborations within their specific groups. However, they still contribute to the overall collaborative network, albeit with fewer connections to researchers outside their immediate circles. This analysis of authors within the Collaboration Network unveils the significance of certain individuals as central connectors, facilitating collaboration and knowledge dissemination within the field of automation and mechanical engineering.

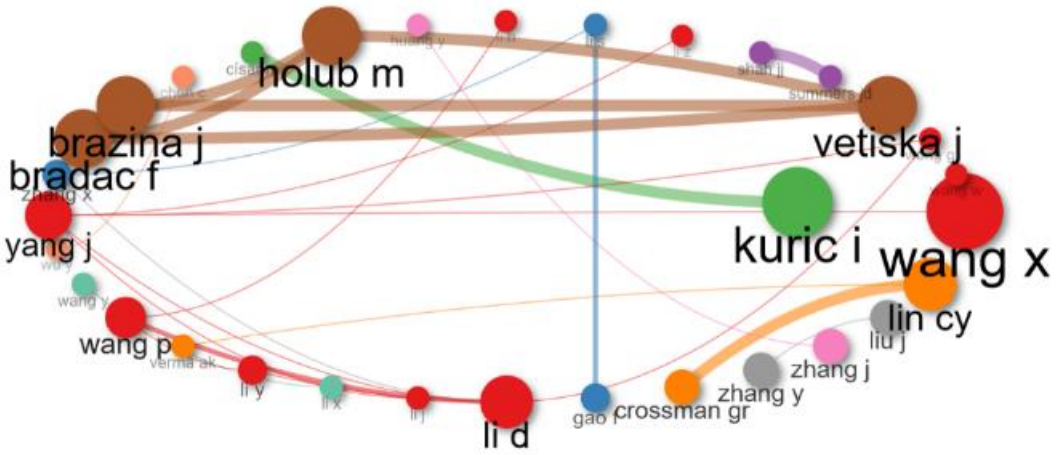

Fig. 6. Visualization of Collaboration Network

4. DISCUSSION

The bibliometric analysis conducted on automation and its impact on mechanical engineering research unveiled multifaceted insights into various dimensions of scholarly contributions in this interdisciplinary field. The exploration encompassed diverse aspects, including the annual scientific production, average citations per year, trend topics, collaboration networks, and corresponding authorship patterns. The examination of annual scientific production revealed a nuanced trajectory of scholarly output over five decades, from 1972 to 2022. The trend exhibited intermittent fluctuations and peaks, signifying shifts in research focus and productivity within the domain. Notably, the peak in publications around 2013 aligns with the culmination of several key thematic areas, as observed in the analysis of trend topics. This suggests a potential correlation between the surge in publications and the culmination of thematic interests that year.

Analyzing the average citations per year highlighted the evolving impact and recognition of various thematic areas within automation and mechanical engineering. The fluctuations in citation counts across different themes unveiled varying degrees of scholarly influence and interest over time. For instance, while "mechanical engineering" maintained a consistent presence and a high citation count throughout the years, other topics like "computer-aided design" and "engineering education" showcased differing trends, with periods of heightened impact followed by relative decline in citations. Moreover, the exploration of trend topics elucidated the evolving thematic interests within the field. Certain topics like "control systems," "process control," and "control" demonstrated consistent attention and research, emphasizing the enduring relevance of control-related subjects. Conversely, topics like "robots," "robotics," and "mechatronics" exhibited fluctuating patterns, suggesting alternating cycles of intensive research and potential shifts in thematic emphasis.

Examining the collaboration network among authors unveiled distinct roles and influences within the scholarly community. Authors such as Wang X, Li D, and Zhang X emerged as pivotal figures within their collaborative networks, demonstrating high betweenness centrality and significant influence in connecting various researchers. These central connectors play crucial roles in facilitating collaborations and knowledge exchange within their respective networks. Additionally, the patterns observed in corresponding authorship by country revealed a diverse global representation in scholarly contributions. China, Germany, and the United States emerged as significant contributors, signifying their substantial involvement and leadership in research output within automation and mechanical engineering. This globalized effort in research collaboration underscores the interconnectedness and diverse perspectives contributing to the advancement of knowledge in this field.

The connections among these discoveries reveal a vibrant landscape in the realm of automation and mechanical engineering research. The link between yearly scientific output, thematic trends, citation influence, collaborative networks, and worldwide authorship patterns indicates a complex and interconnected academic environment. These observations emphasize how research in this field encompasses various aspects, stressing the importance of collaboration across disciplines and ongoing exploration to tackle the evolving challenges and advancements in automation within mechanical engineering. The comprehensive analysis using bibliometrics offered a complete perspective on how automation influences research in mechanical engineering. It illuminated the ever-changing interests in themes, the impact of scholarly work, networks formed through collaboration, and the diverse global contributions, presenting a detailed picture of the multifaceted nature of research activities in this interdisciplinary field.

5.CONCLUSION

The extensive analysis using bibliometrics to assess how automation influences research in mechanical engineering unveiled several significant findings. The key findings showed the ongoing importance of "mechanical engineering" as a fundamental area of study, changes in the focus of interests over time, and differences in the scholarly impact among various subjects. Moreover, it emphasized the crucial roles played by prominent authors such as Wang X, Li D, and Zhang X within collaborative networks, highlighting their influential connections in this field. The global authorship patterns showcased the substantial contributions of countries like China, Germany, and the United States, illustrating their leadership in scholarly output. Future directions in this domain entail delving deeper into emerging themes like the convergence of information technology with automation, fostering more extensive global collaborations, and investigating the correlation between academic output and real-world technological advancements. Identified gaps urge further exploration into specific subdomains within automation, deeper analysis of technological influence on research trends, and a comprehensive understanding of the interdisciplinary impacts on practical applications within the field of mechanical engineering. These findings and future directions pave the way for continued research efforts aimed at enriching knowledge and fostering advancements in this multidimensional and evolving field.

Data source

The bibliometric data utilized for the analysis in this study was derived from a BibTeX file titled "A Bibliometric Exploration of Automation and its Impact on Mechanical Engineering Research." This file serves as the primary source of bibliographic information, containing metadata relevant to scholarly publications within the field of automation and its relationship to mechanical engineering. The BibTeX file is publicly available and was accessed from the GitHub repository here. It encompasses a comprehensive collection of bibliographic entries, including publication titles, authors, publication years, abstracts, keywords, and other pertinent metadata essential for conducting bibliometric analyses. The data source from the BibTeX file was utilized to extract valuable insights into trends, collaborations, thematic areas, authorship patterns, and the scholarly landscape within the intersection of automation and mechanical engineering in this research study.

Conflicts of Interest

None

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None

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