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Bibliometric Study of the global application of collaborative robotics in industry

Estudio Bibliométrico de la aplicación global de la robótica colaborativa en la industria

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Collaborative robotics in industry, interactive robots, industry 4.0, bibliometric study.

Robótica colaborativa en la industria, robots interactivos, industria 4.0, estudio bibliométrico.

ABSTRACT: The collaborative robot is an industrial robot that operates collaboratively with humans, safely assisting them in their tasks and improving productivity. This study focuses on analyzing the bibliographic production of the application of collaborative robotics in industry, using a bibliometric study with Scopus metadata. These data were analyzed with the VOSviewer tool for generating visualization networks, by bibliographic mapping the worldwide scientific production. A total of 6309 publications were analyzed, with Chinese authors Wang L. and Wang Y. standing out as the main producers, with 24 publications, demonstrating the academic interest of that country in this subject. There was a positive trend in publications in the last ten years, with an increase of 288%, and the preferred publications are articles (91.3%). It was possible to identify that the most significant bibliographic production on collaborative robotics in industrial processes is more representative in developed countries such as China, Italy, Germany, and the United States. The work revealed the challenges faced by industries in Latin America in implementing Industry 4.0. Due to the absence of business policies and cooperative alliances, it is concluded that these industries in developing countries increase the gap in the integration of emerging technologies and that, due to a lack of knowledge and interest, sometimes they are free tools that can be linked in the company.

RESUMEN: El robot colaborativo es un robot industrial que trabaja en colaboración con los humanos, asistiéndoles de forma segura en sus tareas y mejorando la productividad. El estudio se centra en el análisis de la producción bibliográfica sobre la aplicación de la robótica colaborativa en la industria, mediante un estudio bibliométrico con metadatos de Scopus. Estos datos se analizaron con la herramienta VOSviewer para generar redes de visualización, mediante el mapeo bibliográfico de la producción científica mundial. Se analizaron 6309 publicaciones, destacando a los autores chinos Wang L y Wang Y. como principales productores, con 24 publicaciones, demostrando el interés académico de ese país en esta temática. Se evidenció una tendencia positiva

de las publicaciones en los últimos 10 años con un a aumento del 288% y la preferencia de la publicación es por medio de artículos (91.3%). Se permitió identificar que la producción bibliográfica más significativa sobre la robótica colaborativa en los procesos industriales es más representativa en países desarrollados como China, Italia, Alemania y Estados Unidos. El trabajo reveló los desafíos que enfrentan las industrias en América Latina para implementar la Industria 4.0. Se concluye que estas industrias de países en desarrollo, por la ausencia de políticas empresariales y alianzas cooperativas, aumentan la brecha en la integración de tecnologías emergentes y que, por desconocimiento e interés, en ocasiones son herramientas gratuitas que pueden ser vinculadas en la empresa.

1. Introduction

Since the 20th century, technological advances have shown an accelerated rise, being inserted in every context in which the human being intervenes, generating a series of significant transformations and giving rise to innovation in social, economic, political, and industrial processes [1]. In the specific case of production systems, these advances have had significant repercussions since they have been progressively inserted into industrial processes, giving rise to a new industrial revolution based on automation, technology, and innovation [2]. In particular, automation plays a fundamental role in advancing industrial processes through the implementation of collaborative robotics (COBOTs), a technology based on robots programmed to work alongside humans under principles of care and safety. In turn, it helps to optimize the efficiency, effectiveness, productivity and competitiveness of the industry in the global market. COBOTs have been progressively evolving and with the help of technology-based programs, they have been inserted in industrial environments, offering possibilities for improving the initiation, development, and completion of supply chains, providing growth, profit generation, and products transformation, and incorporating greater flexibility and individualization of manufacturing processes [3].

Some studies have determined the benefits of applying COBOTs in industrial processes, such as the acceleration of repetitive industrial processes, contributing to the human-robot symbiosis, and considering human safety as a first measure of delimiting security spaces. In addition, the application of collaborative robotics in industry has contributed significantly to the productivity and competitiveness demanded by the globalized economy [4]. It is worth mentioning that the use of robots, in particular, high-tech robots, is justified by the use of Flexible Manufacturing Systems, (FMS), in particular when integrated by a Computer Integrated Manufacturing approach (CIM approach); for mass production, it is quite cost-effective to use traditional automatic machines without sophisticated interfaces and flexible features. These technological resources are easily integrated into changing markets, reducing production costs [5]. However, the drawbacks of using COBOTS are the high costs, specifically when implemented in mass production industries, since in some countries they require permits and special procedures that demand high upfront investments, being on many occasions impossible to implement for small and medium-sized companies (SMEC) in Latin American countries [6].

Regarding bibliometric analyses of COBOTs application, there are works such as the one developed by [7], focused on the use of COBOTs in logistic 4.0 environments, with optimistic results about their opportunities in an industrial context. Another more recent study by [8] focuses

on the multidisciplinary social robot literature and highlights the need for more reviews to develop a broader analysis, which impedes a better conceptualization of social robots and their social and organizational utility. Finally, there is a study focused on the importance of human-robot collaboration (HRC) towards advanced and sustainable production systems, performing a bibliometric analysis and literature review to provide a comprehensive overview of the Occupational Health and Safety issues in HRC [9]. In summary, these bibliometric studies establish interesting results in different areas and contribute to understanding the development of collaborative robots in diverse industrial environments and how they improve processes and worker safety.

Therefore, the purpose of this research is to perform a bibliometric analysis of the technological advances in the implementation of collaborative robotics in the global industry. It also provides a literary window and research trend of the study topic, using Scopus metadata and processing with VOSviewer. This review will give researchers a comprehensive overview of the literature on COBOT implementation in developed and developing countries.

This article is divided into six sections. The first introductory section establishes the concept of collaborative robots and the context of their application in industry. The second section presents a literature review that outlines the background of the application of collaborative robotics in industries in developed and developing countries. The third section describes the process of bibliometric review and data analysis. The fourth section presents the results of the bibliometric review, literature production, and trends in collaborative robotics. The fifth and sixth sections, represented by the discussion and conclusion, respectively, show the contrast between publications and implementation of the subject matter, as well as the advantages and difficulties in the developed and underdeveloped industries.

2. Literature review

Industrialization processes have presented significant technological advances since the 20th century; globalization and the expansion of economic frontiers worldwide have caused a significant effect on industry, as is the case with automation, which is a fundamental component in COBOTs for industrial optimization processes. On the other hand, the development of robots and technologies applicable to the industry has had an impact on the reduction of accidents in people performing risky activities [10, 11, 12]. In this context, it is also posited that collaborative robotics is directly related to automation. This technology facilitates flexible and safe interactions with operators, thereby enhancing operational safety and increasing both the competitiveness and revenue of the company [13].

In addition, the COBOTs market is very broad and has undergone processes of adaptation to the different needs of the industry. Also, they have security features, adaptability, flexibility, cooperation, and friendly user interfaces, allowing them to be manipulated by personnel with basic knowledge of robotics [14]. Due to the importance that COBOTs have taken concerning globalization, competitiveness, and the development of markets without borders, it is worth mentioning that surveys have been conducted on how the implementation of COBOTs is

interpreted, its advantages, disadvantages, and the interference in factors such as its operation, management, control, and optimization [15].

For a better understanding of this topic from a theoretical point of view, the analysis of the results of this bibliometric study allows addressing issues such as the Theory of Competitiveness, based on international trade, where developing countries can position themselves within the globalized economy; in addition, this theory seeks to design inclusive strategies for a positive impact on the social and economic processes of developing countries. Based on Porter's theory, competitiveness is conceived in terms of increasing participation in international markets and substantially raising living standards through productivity growth. In this framework, man is seen as the central figure, while environmental factors such as technology, infrastructure, and government investment are the main contributors [16].

Now, productivity and competitiveness will be defined from what is stated by [17], where productivity is observed from the efficiency in the use of their resources, determined by the factors of production, and where humans are a fundamental factor. Competitiveness is related to the participation of companies in highly competitive markets, for which they must prepare, update, and invest in technologies that lead them to acquire competitive advantages, and raise their standards by being sustainable in the global economy. It is also worth mentioning that technological advances occur within the framework of Industry 4.0, which, according to MinTIC, 2019 [18], is related to the fourth industrial revolution, merging digital, physical, and biological aspects for the improvement in the production of the product, from the beginning to the end of the supply chains through its development. However, Industry 4.0 goes further, and refers to this aspect as an industrial process that uses aspects of automation, advanced techniques, and intelligent technologies in production, facilitating the manufacturing phases of the product [3].

One of the technological advances of Industry 4.0 is collaborative robots, which complement human labor. This joint work allows the machine-human to optimize industrial productivity [19]. Likewise, COBOTs allow access to automation for small and medium-sized companies, although the implementation of these technologies is limited to large companies; however, the scenario may change if they become more accessible and the return on investment is more viable [20].

In the collaborative environment, human-robot interaction has had important results in the industrial sector, as in the case of augmented reality, where the user does not lose contact with the real world and uses the virtual environment for design and optimization [21, 22]. The abovementioned suggests that it is essential to recognize that industrial automation is the goal to be achieved due to the high competitiveness of modern industry, especially nowadays, where the economic environment is in permanent transformation; this process comprises a set of technological elements capable of reacting to foreseeable situations, related to the human-robot relationship and finding the most favorable condition [23]. However, in industry, these COBOTs open space, interconnecting process automation, the industrial internet of things, and collaborative work, working through robots, which are programmed to perform continuous tasks in a precise way [24].

Thus, in different countries around the world, the use of COBOTs has been implemented in various areas of the industry with high investment costs, such as automotive, pharmaceutical, manufacturing, and food, among others, obtaining a higher performance in terms of productivity [25, 26, 27]. In this sense, the Inter-American Development Bank considers it is important to delve deeper into this field so that companies and industries worldwide can count on financial aid for the growth of industry, and minimize the obstacles that have so far prevented them from reaching significant standards in production, quality, and competitiveness, in addition to developing strategies that will allow developing country industries to make substantial investments in this field in the future, making companies sustainable over time [28]. On the other hand, it must be said that the incursion of robots in the industrial sector and their impact on the labor and social fields have the purpose of implementing artificial intelligence technologies in Europe, to open a space for safe COBOTs, aiming to increase the productivity of the processes and improve the ergonomics and safety of the workplaces [29, 30].

Other studies have characterized the automation process of the industry in Spain, highlighting digital transformation as the axis of the current economy, emphasizing the need to focus education towards digitalization and the positive use of technology in industry [31]. In France, for example, the integration of COBOTs in the mechanical industry had a positive impact on the performance of operations, even with limited development time, as the combination of tasks has optimized processes, giving rise to new ideas for automation in studies conducted under the Lean Manufacturing environment [32, 33].

The use of COBOTs has also been included in the orthopedic device industry, especially for assisting older adults with limited movement in bed and developing robotic systems in collaboration with the nurse to improve the care process. Likewise, this technology is used in the medical field, in routine interventions where COBOTs can be integrated into common life activities [34, 35]. On the other hand, some studies go beyond the vertiginous advance of industrial automation, analyzing the impact of applying robotics in the company and its meaning for the future of the human being, especially in the subject of employment, since there are many fears generated from the possible replacement of man by machine [36]. On the contrary, COBOTs aim to combine the resistance of robots with the flexibility and problem-solving skills that humans have, promoting the use of COBOTs and strengthening HRC through simultaneous work in shared spaces. In view of what has been said, it is necessary to facilitate human-robot operations so that the benefits can be seen, especially in repetitive operations, loading of heavy objects, assembly, inspection, and repair of machinery; in this sense, the assistance of robots in human work is important when the process goes beyond human capabilities [37].

Competitiveness is a fundamental component of 21st century industrial markets, so comparative studies in South American countries provide essential information to identify the factors that have hindered the industry growth in these countries [38]. In addition, it is a priority to strengthen research processes towards the acquisition and application of collaborative robotics in South American industry, in order to achieve optimal, competitive processes with high production capacity and with workers trained in the interaction with COBOTs. Since it is an emerging industry in most South American countries, only Chile, Argentina, and Brazil have deeply applied

collaborative robotics in their industry. Still, in the case of small and medium enterprises, the implementation of these technologies is limited [39].

It is also important to bear in mind that the economy of South American countries and their industrial production systems have shown a lag, in addition to low investment, compared to the industry of developed countries. In this sense, countries such as the United States, China, and Europe have extensively implemented production systems based on Industry 4.0 and collaborative robotics [2]. This problem of developing countries has been analyzed in depth by different authors, who have approached industrial automation in small and medium-sized companies in Mexico and explained the importance of investing in automation and Industry 4.0, and thus streamlining the production processes of goods and services [40]. Other authors have investigated the development that using these technologies has had in manufacturing companies associated with the digitization of industrial processes [39]. Likewise, authors have analyzed the implementation of Industry 4.0 in Latin America, starting from the policies and strategies in countries such as Mexico, Brazil, and Argentina without neglecting the importance of the challenges that must arise from the development of this kind of productive activity [41].

On the other hand, studies have referred firstly to the origins and development that the fields of robotics and automation have experienced from a global perspective and an exploration at the Latin American level, in addition to the support, capacity, and services that can be implemented in different sectors of industry and combined with other disciplinary fields [10]. Finally, he explains the fast changes that are taking place in the inhabitants of Latin America in order to understand the social impact of this industry within the framework of the IV industrial revolution.

In Colombia, some studies present an evolutionary panorama of industrial automation, where technological processes are not properly encouraged, and emphasize the lack of a national policy to support these transformations to favor the competitiveness required by globalization [42]. Other authors focus on the cooperative action between two agents, one robotic and the other from the software, to create a robotic multi-agent system based on cooperation and thus reach the construction of computational models to improve work environments [43]. Other research in Colombia describes the importance of using COBOTs in the recycling industry, presenting the design of a safety protocol that allows optimizing the task of waste separation, proposing a system that integrates artificial vision with an industrial robot, and thus ensuring human-robot interaction considering International Organization for Standardization (ISO) standards [44].

Finally, in the case of experimentation and application of collaborative robotics in Colombia, the application of a recycling factory where COBOTs have been implemented in the selection of the recycling process is known so far [44]. This determines that it is an underdeveloped technology and that it is necessary to implement it for the optimization of different industrial areas of training through collaborative robotics for Industries 4.0 [31].

3. Bibliometric methodology

Nowadays, different techniques are used to analyze bibliographic data, being bibliometric analysis a rigorous method to process and study metadata extracted from scientific databases; its importance

lies in the relationship it establishes between journal citations, articles, publications, and collaborations between authors and countries. But, in this process of bibliometric analysis, not only does it quantitatively evaluate the attributes of the publications, but it is also possible to interpret the connections of the data with emerging trends and themes, providing valuable information for the academic community as to the current state of the subject of study [45]. The literature was selected from the Scopus database. For the search formulas, keywords such as "collaborative robotics", "Cobots", "co-robot", "collaborative robot", and "industrial robot" were included.

3.1 Data selection criteria

The articles were selected based on relevance and the temporality of the study, and they were published in the period from 2013 to 2022 (10 years). Likewise, the thematic area of the publications was another filter performed in the Scopus database, prioritizing the topics of engineering, materials science, and environmental sciences. Only research articles, reviews, and book chapters were selected for review. It should be noted that this topic has been widely studied in recent years due to the interest in technological advances and the insertion of these advanced technologies in the industry, which has led to a growing innovation and transformation of industrial processes supported by collaborative robotics.

3.2 Data analysis

Bibliometric analysis is instrumental in representing bibliographic production in the scientific field. Currently, it is possible to use different programs that allow the visualization of science, starting from the extraction of metadata. The analysis of this research consisted of making visualization maps using the keyword “Collaborative Robotics” by means of bibliometric analysis with VOSviewer, using metadata extracted from Scopus. These metadata were downloaded in CSV and RIS formats for further processing. This free software is a useful tool to visualize any bibliometric network by taking nodes for analysis. This software is one of the most widely used in bibliometric studies; it was chosen because it facilitates the processing of metadata and offers excellent network visualizations [45]. To obtain a visualization, VOSviewer applies the association strength normalization technique, then the VOS mapping technique, where VOS stands for similarity visualization, and finally, the clustering technique. A cluster is a set of closely related nodes according to the type of link being analyzed; each node is assigned to exactly one cluster [45]. For this purpose, a bibliographic mapping was carried out, grouping authors, keywords, and geographical area of publication. As the results of the collaborative networks are interpreted, it is intended to identify gaps in the publications and implementation of COBOTs in developing and developed countries.

4. Results

The scientific production on COBOTs experienced remarkable growth during the period under analysis. Descriptive results on annual production, types of papers used, and network visualizations of author, country, and keyword collaborations are presented below.

4.1 Descriptive data

The production of literature related to COBOTs has increased gradually from 2013 to 2022, finding 33705 documents indexed in the Scopus database, represented in different publications developed

by academics and professional authors focusing their interest on collaborative robotics for the industry. From this sample, 6309 publications were selected to perform the analysis. Figure 1 shows the number of documents produced on the horizontal axis, while the vertical axis shows the years covered in the study. The upward curve obtained shows a significant increase in publications annually. The data obtained show an increasing trend of publications concerning the topic of collaborative robotics in the ten years of study (2013 to 2022). There were 319 publications in 2013 and 1,238 in 2022, indicating an increase of 288%. Regarding the type of manuscript to publish research results, authors prefer to publish research articles (91.3%) followed by book chapters (5.4%) and reviews (3.3%).

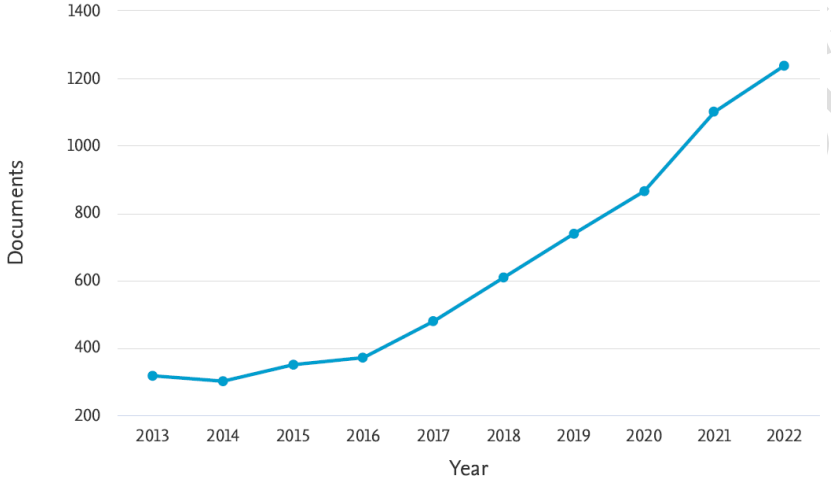

Figure 1 Number of manuscripts registered in Scopus by year of publication

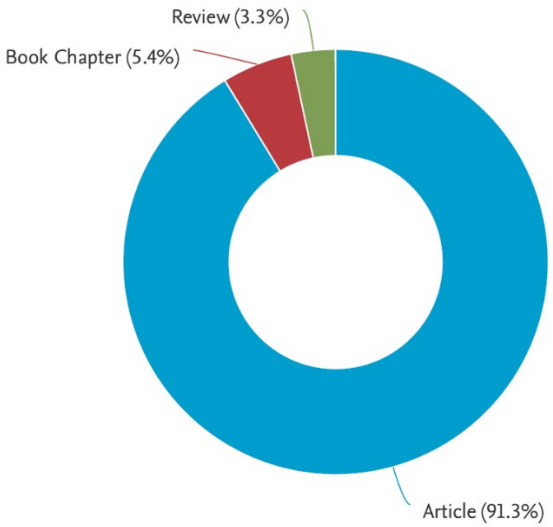

Figure 2 Distribution of selected manuscripts between 2012 – 2023

In Figure 2, it can be observed that 91.3% of the selected documents are journal articles, indicating that 5,873 manuscripts are published in scientific journals. Additionally, 5.4% of the manuscripts consist of book chapters addressing the topic of COBOTs, while only 3.3% are review articles.

These review articles provide detailed, selective, and critical analyses that integrate essential information regarding the analysis and application of collaborative robotics in industry.

4.2. Co-authorship bibliometric mapping

Regarding the authors with the highest number of citations and published papers related to the topic of collaborative robotics, Wang L and Wang Y were found, with an output of 24 publications each. The topics of these two authors focus on robotic assembly, control, and design in industry. It was found that the most cited author was Wang L, with 581 citations, although Wang Y presents greater collaboration with other authors. The research interests of these authors focus on the thematic areas of engineering and computer science, with relevant works on industrial robots and intelligent robotic manufacturing. The overall number of citations is led by Bonev I.A., with 773 citations, but with a relatively low total link strength with other authors of 11. Bonev's contributions to high precision and experimental evaluation of errors in industrial robots are highlighted. Other authors with relevant co-authorship links are Tian W, with 74; Liao W, with 50; Chen Y, with 40; Liu H, with 38; and Vidoni, with 37. These results can be used to understand the real impact of collaborative robotics in industry.

Figure 3 shows a visualization of the network of authors by co-authorship, analyzing the authors with the highest number of publications. The circles represent each author, revealing the larger the circle, the greater the production. Collaborative networks identified by color groups are also evident; although there is more cohesion between authors of the same color, they can also be associated with authors of other groups.

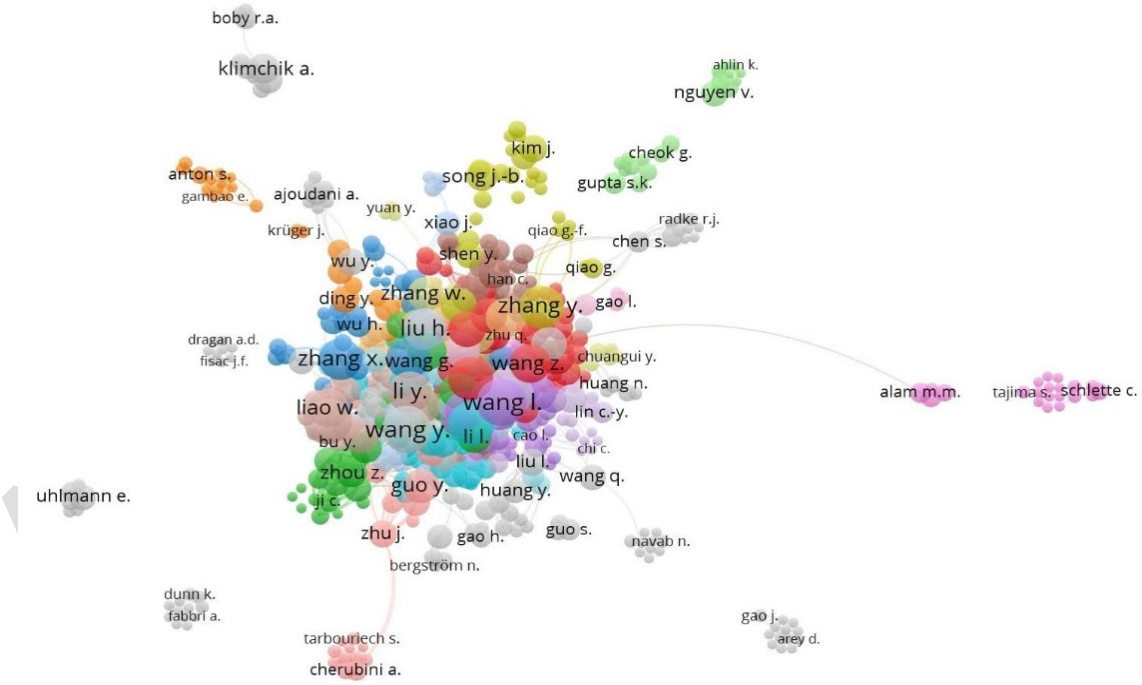

Figure 3 Display network of authors by co-authorship

4.3. Bibliometric keyword mapping

The keyword co-occurrence analysis was performed using VOSviewer, providing a visualization of the trend in the use of keywords in the articles analyzed, which serves to develop the study topics in each research study. Co-occurrences in this keyword network help to deepen the knowledge of the topic and identify its growth in the literature.

Figure 4 indicates the degree of relationship of the keywords, determined by the subject matter of the articles and reflecting the core content of the research literature [46]. The map shows that the keywords that appear most frequently are "industrial robots", "collaborative robots", and "robotics", i.e., they show a clear trend in recent publications. The analysis of each keyword used the program to calculate the occurrences that the keyword has with other words and the total link strength. Likewise, Table 1 shows the 20 most used keywords in collaborative robotics in the industry, which resulted from processing the 6309 publications that were part of the extracted metadata. The weight of co-occurrences and total link strength of each keyword can also be evidenced. The keyword with the highest occurrence (n=1079) and strength of association (9047) was industrial robots.

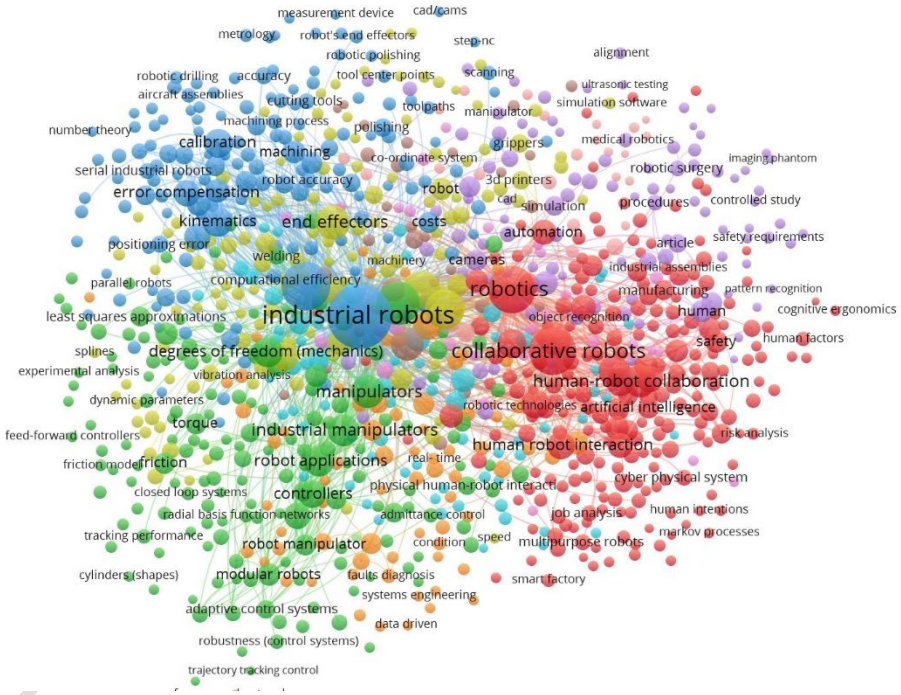

Figure 4 Keyword co-occurrence mapping

Table 1 Most frequent keywords of the authors

Keywords	Occurrences	Total link strength
Industrial Robots	1079	9047
Collaborative robots	419	3376
Robotics	406	3873
Robots	327	2836

Robot programming	232	2337
Machine design	198	1942
End effectors	159	1584
Manipulators	144	1570
Manufacturing	138	1356
Human-robot collaboration	131	1201
Agricultural robots	129	1329
Industrial manipulators	121	1442
Collaborative robotics	113	751
Degrees of freedom (mechanical)	109	1253
Kinematics	107	1092
Robotic applications	106	1240
Industrial research	95	929
Trajectories	94	1015
Calibration	92	900
Intelligent robots	91	916

4.4 Geographical bibliometric mapping of the publication

The 6309 articles selected as metadata for this research on the application of robotics in industry were obtained from 20 countries, as shown in Table 2. China was the country with the most publications (n = 600), followed by Italy with 189, and in third place Germany with 177. The United States is in fourth place with 161 publications on the subject, and the United Kingdom is in fifth place with 102 papers. In reference to citations and total link strength, China continues in first place with 6616 (144), followed by Italy with 4148 (99). Although Germany has 2023 citations, its collaboration strength (106) is greater than that of Italy. The same case was found in the United States with 2803 (84), and in the United Kingdom with 1736 (90).

It is possible to infer that the countries with the highest publications have a strong investment in research, which is reflected in the production of scientific literature, especially engineering, and innovation. This suggests that in some of these countries, such as China, the United States, Germany, and Japan, collaborative robotics has been successfully implemented in many industries. However, this premise may also be influenced by the intimate knowledge of each industry and the real contribution to the efficiency of production lines, which makes it competitive and different from other companies. It is worth mentioning that in China, the main funding source for this research is the National Natural Science Foundation, associated with the National Council of China. The geographical mapping presented in Figure 5 indicates that China collaborates with the United States, the United Kingdom, and Germany. In contrast, Germany primarily receives collaboration from other European countries. Similarly, France and the United States engage in collaborative efforts with China, India, and Romania.

Table 2 Countries with the highest production in publications

Country	Documents	Citations	Total link strength
China	600	6616	144

Italy	189	4148	99
Germany	177	2023	106
United States	161	2803	84
United Kingdom	102	1736	90
Japan	96	694	27
South Korea	78	1254	29
France	76	1567	61
Spain	68	1094	46
Canada	52	1658	31
Russian Federation	52	327	18
Sweden	52	1147	44
India	51	562	25
Poland	48	324	9
Portugal	39	742	25
Brazil	30	300	14
Denmark	29	558	43
Slovakia	29	188	9
Australia	27	337	22
Mexico	26	277	11

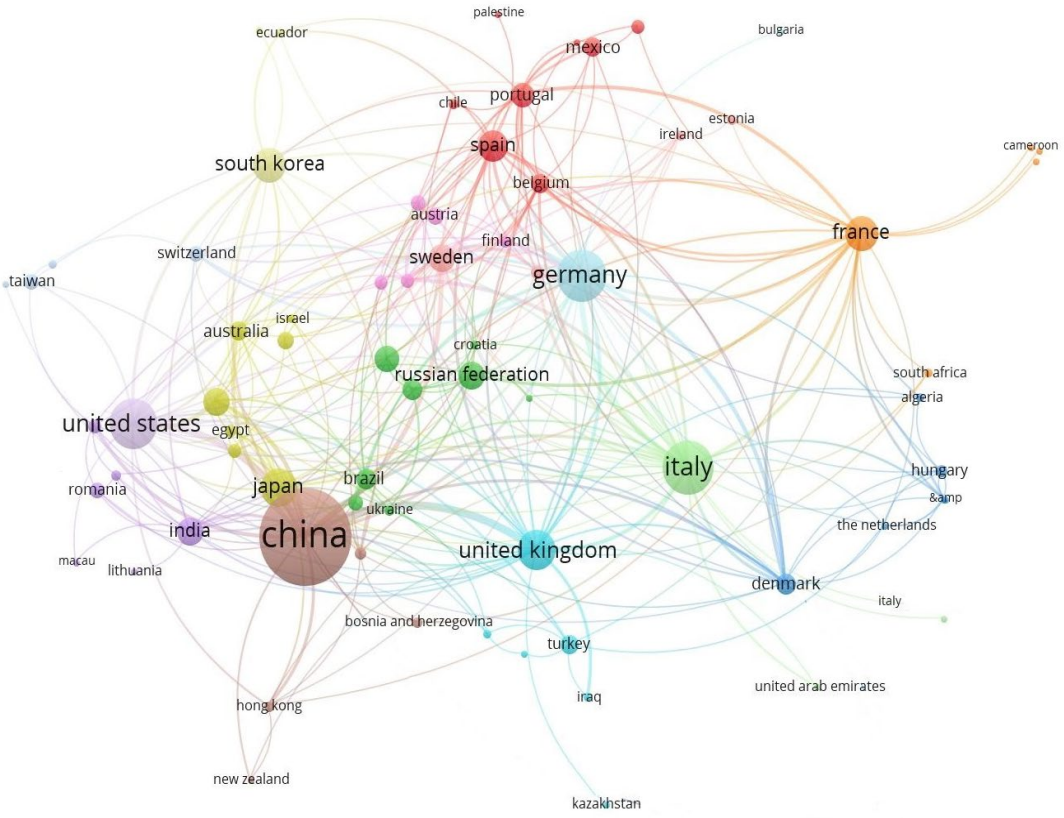

Figure 5 Geographic mapping of publications

5. Discussion

The economic interest is more important in supporting industrialization than the use of modern technology. Still, the global markets require automation, giving rise to the insertion of collaborative robots or COBOTs to optimize industrial processes, becoming an option that has generated a substantial impact on the sector, based mainly on information technology. However, in the present work, China has the highest production of publications on collaborative robotics, followed by Italy and Germany, leaving the United States in fourth place. This differs from the findings of [9] and [47], which show that the United States is the country that contributes the largest number of publications.

The advance of collaborative robotics requires broadening the scope of this type of study, going deeper into other databases such as the Web of Science, and having a broader view of the research carried out in different regions of the world. The results show that more and more research on collaborative robotics is being conducted in Asian, European, and North American countries, finding a significant number of studies and literature in China, Italy, Germany, the United States, Japan, the United Kingdom, South Korea, and France. Likewise, the bibliometric analysis made it possible to identify gaps and possibilities for future research. Some studies could be generated to identify strategies to make robotics more accessible in developing countries.

This study significantly enhances our understanding of the current literature on collaborative robotics worldwide. It analyzes studies based on frequently co-occurring keywords, which are crucial for the field. Key topics include industrial robots, human-robot collaboration (HRC), and configuration parameters such as controls, speed, force, and recognition components like cameras. These factors are essential for ensuring human safety while performing tasks alongside robots.

It is undeniable that the use of the VOSviewer was a key factor in determining which countries, authors, citations, and keywords had the most significant impact on the comparative analysis of the application of industrial COBOTs at a global level, being important for this, the visualization of geographical mapping networks, authors, and co-occurrence of keywords. These parameters are similarly used in the study of [7]. From the findings on issues related to collaborative robotics in the industry worldwide, a representative interest has been generated in researchers studying the benefits and economic gaps of its implementation. However, the interest in collaborative robotics goes beyond the economic and industrial developing countries, as it has also been used in the development of military equipment and strategy for war purposes [48].

The results obtained and the analysis suggested that there is abundant scientific production on the application of collaborative robotics in industry worldwide, especially in Asian and European countries and in the United States, where literary productions are increasing. The opposite is the case in Latin American countries, where progress in implementing industrial COBOTs is slow, as is the number of publications found [39]. In Colombia, publications on COBOTs are scarce, which shows the absence of bibliographic sources in this area of knowledge, and this may also be an index of the low implementation of COBOTs in industries. However, it is possible that implementations

in collaborative robotics that are carried out in the country may not be of interest to expose them as research in the academic literature.

6. Conclusion

This bibliometric analysis allowed us to conclude that studies and research in collaborative robotics show a large production in publications in developed countries [49], widening the gap with respect to Latin American countries, where there is little literature that addresses this subject, because, despite the efforts made by some industries in the application of COBOTs in their processes, few have managed to position themselves in the new globalized, competitive and technician markets [50]. However, some case studies on the implementation of collaborative robotics in different industries in Latin America are evident. This is the case of some manufacturing industries in Brazil, where the competencies of the company's personnel for the effective operation of Industry 4.0 are more representative than the constant acquisition of technology and technification [51]. On the other hand, the culture and administrative management in Latin America have interpreted robotics as something unattainable and out of reality, added to the absence of public and commercial policies that allow technological progress and societies to grow comprehensively and cooperatively, exacerbating the failures in bureaucracy and political favoritism. These barriers must be overcome in Latin America so that the fourth industrial revolution does not remain stagnant in these countries [52].

The application of COBOTs in industrial processes contributes, especially in the field of productivity and competitiveness, in addition to optimizing performance and tasks, with the use of new technologies developed as Industry 4.0. However, the collaboration networks analyzed show how technological progress is limited in developing countries [10, 11, 12, 20, 21]. Nonetheless, it also exposes the difficulties of the adoption processes of these technologies in different countries since it is not only the high costs that prevent their implementation, but also the procedures, authorizations, and licenses that are required to articulate the human-robot industrial processes, having important difficulties in Latin American countries, where the legal procedures are not fully regulated or have significant structural gaps. However, very few companies in Latin America have considered the implementation of technology in their manufacturing processes. Governments and business associations must join to develop public policies, financial incentives, training programs and inter-sectoral collaboration. Progress and development do not stop; Latin America has the challenge of not being left behind in the linkage of Industry 4.0 in its industries, being evident in the significant contribution on optimization processes and competitiveness in the industrial sector.

7. Declaration of competing interest

We declare that we have no significant competing interests, including financial or non-financial, professional, or personal interests interfering with the full and objective presentation of the work described in this manuscript.

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10. Author contributions

Contributed with the initial idea and drafted the article: J. A. Delgado-Camayo; reviewed and adjusted the article: F. J. Bedoya- Rodríguez; performed the data analysis and final adjustments to the article: J. A. Delgado-Camayo and F. J. Bedoya- Rodríguez.

11. Data availability statement

The data for the present study were extracted from the Scopus database and the information was limited to the last 10 years.

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