Research Output of Nanorobot with Special Reference to Scopus Database: Scientometric Analysis

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Abstract

The analysis reveals interesting patterns in research productivity and citation activity over time. The year 2020 stands out as the period with the highest research output, while the early years had limited publication and citation activity. The findings also highlight influential authors in the field, such as Sitti M and Li Y, who have made significant contributions and achieved high H-indices and citation counts. The study further examines the publication types and sources that contribute to nanorobot research, emphasizing the predominance of articles and the impact of journals such as IEEE Robotics and Automation Letters. The analysis also sheds light on global collaboration, with China and the United States leading in terms of research output, followed by countries like India, Japan, and Iran. Moreover, the study identifies highly cited papers that have played a pivotal role in shaping the field of nanorobotics. These findings provide valuable insights into the research landscape of nanorobotics, including trends in research output, influential authors and sources, and global collaborations. The analysis contributes to the understanding of the field's development, impact, and knowledge diffusion, offering a comprehensive overview of the research output in nanorobotics. Researchers, scholars, and practitioners interested in nanorobotics will benefit from the identified influential papers and the understanding of key contributors and research trends. This scientometric analysis serves as a valuable resource for further exploration, advancement, and interdisciplinary collaborations in the field of nanorobotics.

Keywords: *Nanorobot, Research Output, Scopus Database, Robotics, Scientometrics*

Introduction

Nanorobots, a groundbreaking field at the intersection of nanotechnology and robotics, have garnered significant attention due to their potential applications in various domains, particularly in medicine. The ability of these miniature robots to perform precise and targeted tasks at the nanoscale holds immense promise for revolutionizing medical techniques and treatments. In recent years, a growing body of research has focused on the development and application of nanorobots, leading to numerous advancements in the field. This scientometric analysis aims to explore the landscape of nano robot research, with a specific emphasis on publications indexed in the Scopus database. By examining the scientific literature, this study seeks to provide insights into the current trends, key contributors, and major research themes driving the field of nanorobotics. The present study explores the Indian contribution to Nano Robot Research with special reference to Scopus database for the period of 1991- 2023.

Onososen, Adetayo Olugbenga, and Innocent Musonda (2022) studied the research focus for construction robotics and human-robot teams towards resilience in construction through a scientometric review published in the Journal of Engineering, Design, and Technology. The authors' meticulous approach and thorough analysis contribute to the understanding of the research landscape in this field, making this paper a valuable resource for researchers and practitioners interested in construction robotics and human-robot teams.

Coccia (2018) conducted a scientometric study published in Scientometrics, focusing on the general properties of the evolution of research fields, namely the human microbiome, evolutionary robotics,

and astrobiology. Coccia's study contributes to the understanding of the evolving landscape of these fields and offers a foundation for further exploration and advancement in human microbiome, evolutionary robotics, and astrobiology research.

Feng et al. (2021) conducted a scientometric study published in the Asian Journal of Surgery, aiming to analyze the top 100 most-cited publications based on Web of Science in the field of robotic versus laparoscopic surgery. Feng et al.'s study provides a valuable overview of the most influential publications in this domain, offering researchers and clinicians valuable insights into the current state and future directions of robotic and laparoscopic surgical techniques.

Objectives

The present study aims to analyze the growth pattern of Global nano robot Research in terms of publication output as reflected in Scopus database during the period 1991-2023.

The following objectives were formulated

- To analyze the growth pattern of global Nanorobot Research.
- To explore the most prolific author of Nanorobot Research
- To measure the Country wise publications
- To explore the source and institutional metrics of research output
- To measure the most global cited documents
- To find out the emerging areas in the field of Nanorobot Research

Materials and Methods

Scopus citation database is used as a source of data and retrieved 1046 records for the period of 1991-2023 on Nano robot research. A search query performed for "nano robots" with the restriction to All Open Access Publication in global level. The present study attempts to find out the publication pattern of Global research in the field of Nano ronto. The extracted data were analyzed using the Biblioshiny and VoS viewer and SPSS.

Results and Discussion

Growth Pattern of Nano robot Research

Data indicates the growth of Nano robot research output during 1991-2023. The highest research output during the 20-year period was in the year 2020 (285) and the lowest (1) in 2001, 2003, 2004. Further the year wise distribution during the years 2013(50), 2014 (71), 2015 (81) indicates that these years were relatively more productive in relation to total number of publications in Nano robot research.

The annual trends in total citations per year for a specific set of years. The data provides valuable insights into the citation impact and longevity of the publications within this timeframe. Several notable observations can be made. Firstly, in the early years, such as 1991, 1992, and 1993, there were either no publications or minimal citation activity. This suggests that the research output during that period may have had limited visibility or impact. However, starting from 1994, there is an increase in the number of publications, with some years showing higher citation counts. For instance, the year 2003 stands out with a significant number of publications (20) and the highest mean total citation per year

(3.59), indicating a strong impact and recognition of the research in that particular year. Moreover, the data reveals that the mean total citation per article and mean total citation per year vary across the years, indicating fluctuations in the citation impact of the publications. Additionally, the "CitableYears" column highlights the number of years for which articles remain citable, ranging from 12 to 31 years. This suggests that some publications have a longer-lasting impact and continue to be relevant for an extended period. Table 1 provides a comprehensive overview of the citation patterns and longevity of publications within the given timeframe, shedding light on the trends and impact of research in different years.

Most prolific authors

The top 10 prolific authors based on their H-index, G-index, total citations (TC), number of publications (NP), and the year of their first publication (PY_start). The data provides valuable insights into the research impact and productivity of these authors. Several notable observations can be made. Firstly, the authors Sitti M and Li Y stand out with the highest H-indices of 15 and 14, respectively, indicating their significant impact in the field. Moreover, Li Y has the highest G-index of 20, suggesting a high number of highly cited publications. The m-index, which measures the ratio of the H-index to the number of years since the first publication, ranges from 0.318 to 1.25, indicating varying levels of impact relative to the authors' career duration. Additionally, the total citation counts (TC) vary widely, with the highest being 1567 for Sitti M and the lowest being 115 for Lutz P. The number of publications (NP) ranges from 9 to 25, reflecting the authors' research output. Furthermore, the year of the first publication (PY_start) spans from 2001

to 2015, showcasing the longevity and experience of these authors in the field.

Predominant source of publication

The predominant source of publications by the researchers of nanorobot engineering research in India. 442 articles were published in 20 most refereed journals out of 1987 articles in total publications. Out of which 100 (22.62%) papers were published in "IEEE Robotics and Automation Letters" followed by "IEEE International Conference on intelligent on Robot 58, (13.12%) and so on. The most impactful sources based on their H-index, G-index, m-index, total citations (TC), number of publications (NP), and the year of the first publication (PY_START). The data provides insights into the influential sources in the field. Notably, the IEEE Robotics and Automation Letters stand out as the most impactful source with an H-index of 17, indicating its significant influence and high citation count. The Proceedings - IEEE International Conference on Robotics and Automation also demonstrates strong impact with a high G-index of 28, suggesting a high number of highly cited publications. Furthermore, the International Journal of Robotics Research and the IEEE Transactions on Robotics exhibit notable impact with an H-index of 12 and 14, respectively. The m-index, which measures the ratio of the H-index to the number of years since the first publication, ranges from 0.22 to 2.43, indicating varying levels of impact relative to the source's age. Additionally, the total citation counts (TC) range from 69 to 1112, reflecting the sources' overall influence and recognition within the research community. The number of publications (NP) varies from 5 to 84, representing the breadth and depth of research output by these sources. The year of the first publication (PY_START)

spans from 1996 to 2020, showcasing the longevity and contribution of these sources to the field. Table 3 provides valuable insights into the most impactful sources in the field, shedding light on their influence, visibility, and scholarly contributions.

Institutionwise distribution

The predominant institutions in Nanorobot research. The highest output was observed from the Chinese Academy of Sciences (62), Nagoya University (45), Femto-St - Sciences et Technologies (43), and ETH Zürich (42). Additionally, both the Ministry of Education China and City University of Hong Kong have 37 publications each. CNRS Centre National de la Recherche Scientifique follows closely with 35 publications, among others. This data indicates that the University of Chinese Academy of Sciences has the highest number of publications in Nano Robot research.

Collaboration with countries

The country-wise collaboration in Nano Robot research. The data indicates that China has the highest number of publications with 483, accounting for 24.31% of the total. The United States follows closely behind with 400 publications, representing 20.13% of the total. India and Japan also have significant contributions with 195 (9.81%) and 182 (9.16%) publications, respectively. Other countries such as Germany, France, South Korea, Iran, and the United Kingdom also demonstrate notable involvement in the field. This table highlights the global nature of Nano Robot research, with contributions from various countries across different continents.

Most relevant countries

The most relevant countries in Nano Robot research based on various metrics. China emerges as the leading country with 351 articles, accounting for 0.24 frequency and having a substantial share in terms of SCP (262) and MCP (89), with an MCP ratio of 0.25. The United States follows closely behind with 220 articles, a frequency of 0.15, and notable SCP (179) and MCP (41) values, resulting in an MCP ratio of 0.19. India, Japan, and Iran also demonstrate significant relevance in Nano Robot research, showcasing their contributions in terms of article count, frequency, SCP, and MCP metrics. Other countries such as France, Germany, South Korea, and Switzerland also exhibit noteworthy involvement in the field. This table highlights the diverse and global nature of Nano Robot research, with multiple countries actively contributing to the body of knowledge in this domain.

Most global cited documents

The most globally cited documents in Nano Robot research. These papers have made significant contributions and garnered high citation counts within the field. The paper titled "COLOMINA I, 2014, ISPRS J PHOTOGRAMM REMOTE SENS" stands out with a total citation count of 1752, averaging 194.6667 citations per year and a normalized TC value of 36.4145. Other notable papers include "LI J, 2017, SCI ROBOTICS" with 630 total citations, "WANG C, 2016, ADV MATER" with 610 total citations, and "GISSIBL T, 2016, NAT PHOTON" with 523 total citations. These highly cited papers have made significant impacts and have been influential in shaping the field of Nano Robot research. Researchers and scholars in this area can refer to these papers for valuable insights and knowledge.

Conclusion and Recommendations

- The highest research output in Nano Robot research was observed in the year 2020 (285 publications), while the lowest output was recorded in 2001, 2003, and 2004 (1 publication each).
- The data analysis reveals that early years had limited research output and citation activity, while from 1994 onwards, there was an increase in publications and varying citation counts. The year 2003 stood out with a significant number of publications and the highest mean total citation per year, indicating strong impact and recognition.
- Sitti M and Li Y demonstrate high H-indices, indicating their influential contributions. Li Y also stands out with a high G-index, denoting numerous highly cited publications. The m-index varies, suggesting different levels of impact relative to career duration.
- The findings indicate that the majority of contributions in nano robot research are articles (46.00%), followed by conference papers (42.43%). Review papers (7.80%) and book chapters (2.62%) also contribute to the research output. Notably, there are relatively fewer publications in categories such as books, editorials, letters, and short surveys.
- The findings reveal that among the total publications in nanorobot engineering research in India, the predominant source is the "IEEE Robotics and Automation Letters" with 100 articles (22.62%), followed by the "IEEE International Conference on

Intelligent Robot" with 58 papers (13.12%), and so on, in the top 20 most refereed journals.

- The findings reveal influential sources in the field of robotics and automation, with the IEEE Robotics and Automation Letters standing out as the most impactful source (H-index: 17).
- The findings reveal that the Chinese Academy of Sciences, Nagoya University, Femto-St - Sciences et Technologies, are among the top contributors in Nano Robot research, with the University of Chinese Academy of Sciences leading in terms of the highest number of publications.
- The findings highlight that English is the primary language used for publications in Nano Robot research, with Chinese, Japanese, and other languages also making notable contributions.
- The findings reveal a global collaboration in Nano Robot research, with China leading in terms of the highest number of publications, followed closely by the United States. India, Japan, and several other countries also contribute significantly to the field, emphasizing its global nature and widespread participation.
- The findings reveal that China leads in terms of the most relevant country in Nano Robot research, followed closely by the United States, India, Japan, and Iran. These countries demonstrate significant contributions in terms of article count, frequency, SCP, and MCP metrics, emphasizing the global and diverse nature of research in the field. Other countries such as France,

Germany, South Korea, and Switzerland also exhibit notable involvement in Nano Robot research.

- The findings highlight the most globally cited documents in Nano Robot research, with the paper titled "COLOMINA I, 2014, ISPRS J PHOTOGRAMM REMOTE SENS" leading the pack with a total citation count of 1752 These highly cited papers serve as valuable references for researchers and scholars seeking insights and knowledge in Nano Robot research.

Conclusion

The findings from the provided details indicate several key insights in the field of Nano Robot research. Firstly, there has been a significant increase in research output and citation activity from 1994 onwards, with notable productivity in 2013, 2014, and 2015. The top authors Sitti M and Li Y demonstrate influential contributions, with high H-indices and significant citation counts. Articles and conference papers are the predominant publication types, while influential sources such as IEEE Robotics and Automation Letters and IEEE International Conference on Robotics and Automation shape the field. China emerges as a leading country in terms of research output, collaboration, and relevance in Nano Robot research, followed by the United States, India, and Japan. Additionally, there are globally cited papers that have made significant impacts and serve as valuable references for researchers in the field. Overall, these findings highlight the dynamic and impactful nature of Nano Robot research across countries and sources.

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