Bibliometric Research in the Field of Robotics

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Abstract. This article analyzes the research trends and hot topics in global robotics research in the past decade from the perspective of bibliometrics. From the perspective of publication trends, the data of research papers published in the global robotics field from 2015 to 2024 shows significant volatility in this field. 2015 was a milestone in the development of robotics research, followed by periodic fluctuations. The total number of papers in mainland China ranks first, but the proportion of highly cited papers is low, reflecting the characteristics of "large scale and weak quality". In terms of research direction, there are six core research themes, including the intelligence and interaction of robot systems, reinforcement learning and deep learning technologies, which reveal the characteristics of interdisciplinary and technological integration in the field.

Keywords: Bibliometric; robotics; research topic

1 Introduction

In 2015, General Secretary Xi Jinping sent a letter congratulating the opening of the first World Robot Conference, pointing out that with the continuous integration of informatization and industrialization, the intelligent industry represented by robot technology has flourished and become an important symbol of technological innovation in the current era [1]. In the past decade, significant progress has been made in both technology and applications in the global robotics field. On the technical level, with the rapid development of technologies such as artificial intelligence, big data, and cloud computing, the level of robot intelligence has greatly improved, enabling it to complete various complex tasks more efficiently and accurately. Especially with the breakthroughs in technologies such as deep learning and machine vision, robots have become more capable of autonomous learning and adaptation, further expanding their application scope. In terms of applications, robots are gradually increasing in the home and service industries, such as household cleaning robots, educational robots, and medical care robots [2-4]. Using ChatGPT Generative artificial intelligence, represented by large-scale language buildings (LIMs) such as DeepseeK, has achieved new breakthroughs, accelerating the transition from weak artificial intelligence to strong artificial intelligence and general intelligence, and will also bring innovation and transformation upgrades to robot research and application [5].

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In depth analysis of the research status in the field of robotics not only helps to grasp industry development trends, clarify technological innovation directions, but also has certain reference significance for promoting the development of Chinese universities and enterprises, enhancing national scientific and technological strength, and international competitiveness.

2 Data sources and research methods

2.1 Data sources

The Web of Science Core Collection is a globally recognized academic information retrieval platform in academia. Based on Bradford's Law in bibliometrics, it collects information on important academic journals and international academic conference papers in various disciplines, divided by journal, covering 252 disciplines. A journal can belong to multiple WOS discipline classifications at the same time. The InCites database collects data from the seven indexed databases of the Web of Science core collection over the past 30 years, with diverse indicators for detailed scientific research data analysis, comprehensive research evaluation indicators, flexible data mining tools, and intuitive data visualization display.

This article searched for relevant research papers in the discipline category of Robotics on the Web of Science Core Collection data platform [6]. The publication time was limited to 2015-2024, and the literature types were limited to journal articles, conference papers, and reviews. A total of 132823 papers were retrieved on February 28, 2025, and the dataset was imported into InCites Benchmarking & Analytics ™ Analyze the platform.

2.2 Research methods

By using quantitative statistical methods to analyze the distribution, structure, and evolution of academic literature, the focus is mainly on indicators such as the number of literature, authors, institutions, and citation relationships, to identify development trends in the field, evaluate academic influence, and explore knowledge networks. For example, by analyzing high-frequency keywords or highly cited papers, research hotspots and core theories can be revealed; By analyzing the co-occurrence frequency of keywords in literature within the same paper, a correlation network is constructed to reveal the intrinsic connections between topics.

This article uses the paper output indicators (publication volume, number of highly cited papers) and paper influence indicators (citation frequency, standardized citation influence) in Insites for evaluation. At the same time, in order to conduct cluster analysis on research topics in the field of robotics, visually present the domain knowledge structure, identify research sub domains and their cross directions, and use cluster analysis or visualization tools (such as VOSviewer) keyword co-occurrence analysis functions to analyze the pure text data downloaded from wos. There are two types of keyword clustering algorithms in VOSviewer: Full Counting and Fractional Counting. The former refers to the complete counting of the occurrence of keywords in keyword co-occurrence network analysis. The Fractional Counting method adjusts the counting weight based on the appearance of keywords in multiple literature. This article adopts the Full Counting calculation method to more comprehensively reflect the distribution of keywords in literature.

3 Quantitative analysis

3.1 Publication trend

According to the data of research papers published in the global robotics field from 2015 to 2024 (Fig. 1), there is a certain degree of volatility in the research in this field. 2015 was a milestone in the development of artificial intelligence, with the highest number of published papers in nearly a decade, reaching a peak of 15569 papers. However, in 2016, the number dropped sharply by 22.6%, possibly due to short-term adjustments after technological breakthroughs. There will be periodic fluctuations between 2017 and 2022, of which there will be local highs in 2020 (14717) and 2022 (15087). The former may be related to emergency research such as medical robots promoted by COVID-19 epidemic, while the latter may benefit from the continuous investment in industrial intelligence policies. The number of papers will continue to decline to 12310 and 11791 in 2023-2024, reflecting the stage saturation or resource allocation adjustment of research hotspots.

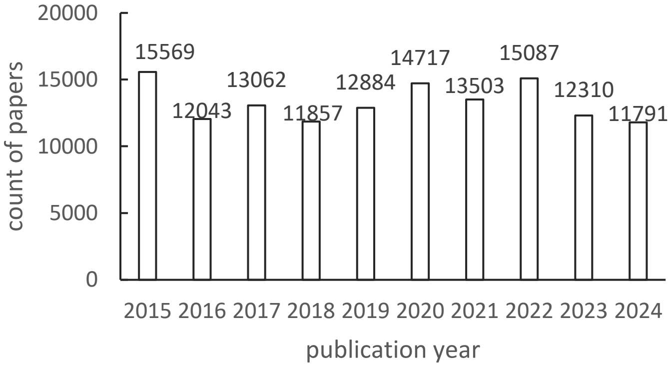

Fig. 1. Global Posting Trend

3.2 Regional distribution of the paper

There are significant differences in research output and international cooperation in the field of robotics among major countries around the world. Mainland China ranks first with a total of 30296 papers, but the proportion of highly cited papers is the lowest (0.23%), reflecting the characteristics of "large scale and weak quality"; The United States has the second highest total number of papers (24759), with a high citation rate of 0.43%, indicating a significant lead in research quality. The total number of papers and high citation rates in Japan (9749) and South Korea (5138) are both relatively low, indicating limited research influence. In terms of international cooperation, the UK (57.36%), France (48.26%), and Canada (47.44%) have the highest proportion of international cooperation papers, relying on cross-border collaborative innovation; However, the proportion of international cooperation in mainland China is only 20.1%, and the localization characteristics of research are prominent (Table 1).

Table 1. Global Major Countries' Paper Output and High-Level Paper Situation

country name	papers	highly cited papers	percentage of highly cited papers	international collaborative papers	percentage of international collaborative papers
China Mainland	30296	71	0.23	6091	20.1
USA	24759	106	0.43	7226	29.19
Japan	9749	4	0.04	2481	25.45
Germany (Fed Rep Ger)	9700	21	0.22	3749	38.65
United Kingdom	7314	30	0.41	4195	57.36
England	6418	26	0.41	3669	57.17
Italy	6090	21	0.34	2742	45.02
South Korea	5138	16	0.31	1050	20.44
France	5062	8	0.16	2443	48.26
Canada	4142	7	0.17	1965	47.44

Analysis citation performance of papers from global major countries (Table 2), there is a significant difference in research influence and journal quality, with the United States showing the most outstanding overall performance, ranking first in total citation count (343334) and CNCI (1.91). Q1 region papers account for 41.59%, and cited papers account for 77.61%, reflecting its dual advantages in research quantity and quality, thanks to the collaborative innovation of top universities and enterprise laboratories. The scale of papers published in mainland China ranks second in the world (with a total of 182739 citations), but the CNCI (0.79) and Q1 region share (23.02%) are significantly lower than those in Europe and America, with only 66.12% of cited papers(Table 2), reflecting the current situation of "large scale, weak quality" or being influenced by the "quantity for quality" strategy and technology application orientation.

Table 3. Citation Performance of Papers from Global Major Countries

country name	citations	percentage of cited papers	CNCI	papers in Q1	percentage of papers in Q1	papers in Q2	percentage of papers in Q2
USA	343334	77.61	1.91	2667	41.59	2668	41.6
China Mainland	182739	66.12	0.79	2100	23.02	3019	33.1
Germany (Fed Rep Ger)	105685	77.9	1.52	710	35.52	977	48.87

United Kingdom	87587	78.88	1.48	794	37.21	940	44.05
England	78296	79	1.52	695	37.47	812	43.77
Italy	70603	78.75	1.25	627	34.3	799	43.71
Switzerland	64755	84.54	2.62	412	46.4	397	44.71
Japan	50444	64.77	0.66	366	17.62	750	36.11
France	47826	76.21	1.13	379	29.96	590	46.64
South Korea	44304	73.39	0.98	475	32.69	568	39.09

3.3 Institutional analysis

Analysis the institution competitiveness distribution (Table 4), European research institutions have demonstrated a competitive advantage centered on research quality, with the typical representative being the Swiss Federal Institutes of Technology Domain. The institution ranks first in the world with an outstanding performance of 26 citations per article (a total of 53307 citations), and its proportion of international collaborative papers is as high as 52.86%. It has successfully constructed a collaborative development model of "high-quality output deep international cooperation".

The research system in the United States exhibits a balanced development of quality and collaboration. Institutions represented by the Massachusetts Institute of Technology (MIT) and the University of California system maintain a high academic influence while maintaining an international collaborative paper ratio of 28% -33%, with each paper being cited 20-25 times. This scientific research ecosystem not only retains independent innovation capabilities, but also optimizes knowledge flow efficiency through moderate international cooperation, reflecting the sustained technological leadership and institutional flexibility of the United States in the field of robotics.

Chinese scientific research institutions have a significant advantage in the quantity dimension. The Chinese Academy of Sciences leads the world with an absolute number of 2715 papers. Harbin Institute of Technology (1787) and Tsinghua University (1421) have also entered the top ten camp in the number of papers. However, the average citation frequency (7-9 times) is significantly lower than that of top international institutions, and there is also a significant gap in the proportion of international collaborative papers (15.33% -25.69%). This "high output low impact" scissors gap phenomenon reveals that the systematic synergistic mechanism between scale expansion and quality improvement has not yet been effectively established.

Table 5. Number of papers and International Collaboration of Global Major Research Institutions

Institution	Papers	Citations	Average citations per paper	International collaborative papers	Percentage of international collaborative papers
Chinese Academy of Sciences	2715	20150	7	521	19.19
Centre National de la Recherche Scientifique (CNRS)	2674	25732	10	1189	44.47
University of Cali-	2202	43476	20	630	28.61

fornia System					
Swiss Federal Institutes of Technology Domain	2062	53307	26	1090	52.86
Harbin Institute of Technology	1787	11522	6	274	15.33
Carnegie Mellon University	1738	33053	19	506	29.11
Massachusetts Institute of Technology (MIT)	1732	43981	25	564	32.56
Technical University of Munich	1421	16710	12	365	44.48
Tsinghua University	1421	13190	9	632	25.69
Shanghai Jiao Tong University	1413	15324	11	298	21.09

Analysis paper impact of global major research institutions (Table 4), the institutions in the United States and Europe demonstrate more outstanding academic influence. The Massachusetts Institute of Technology (MIT) has become a quality benchmark with outstanding performance in CNCI 3.39 and Q1 journal papers accounting for 57.39%, and its high citation paper proportion (0.98%) is also significantly ahead; The University of California System (CNCI 2.93) and the Swiss Federal Institute of Technology (CNCI 2.85, with a high citation rate of 1.21%) rank second and third respectively, forming a high-quality research cluster of the "US European bipolar". These institutions have achieved a systematic strengthening of academic discourse power through the publication of high impact journals and the increase in academic innovation density.

In contrast, although the Chinese Academy of Sciences ranks first in the number of 2715 papers, its CNCI (0.93), the proportion of highly cited papers (0.41%) and the proportion of Q1 journal papers (24.57%) are significantly lower than those of international leading institutions, revealing the structural contradiction of "scale expansion quality lag". Although Harbin Institute of Technology (CNCI 0.81) and Tsinghua University (CNCI 1.41) have entered the top ten in terms of paper volume, the proportion of highly cited papers (0.28% -0.42%) and Q1 journals (25.75% -30.71%) is still insufficient, and there is a need to shift from "quantity driven" to "quality driven".

It is worth noting that the French National Center for Scientific Research (CNRS) and the Technical University of Munich performed moderately in terms of journal proportion (29.99%, 28.5%) and CNCI (1.14, 1.67) in Q1, but there was a significant gap in the proportion of highly cited papers (0.11%, 0%), indicating a non-linear correlation between journal partitioning and academic influence. This also indicates that simply pursuing publication in high tier journals may not necessarily translate into substantial academic breakthroughs, and it is necessary to strengthen the integration of research originality and international collaboration networks. In the future, competition in the field of robotics will focus more on the coordinated evolution of the "quality innovation" dual dimensions. China needs to transform its research paradigm and optimize its international cooperation mechanisms to break through the current bottleneck of "large but not strong" development.

Table 6. Paper Impact of Global Major Research Institutions

Institution	CNCI	Highly Cited Papers	Percent-age High-ly Cited Papers	Percent-age of papers in Q1	Percentage of papers in Q2
Chinese Academy of Sci-ences	0.93	11	0.41	24.57	38.14
Centre National de la Re-cherche Scientifique (CNRS)	1.14	3	0.11	29.99	47.52
University of California System	2.93	22	1	44.84	43.99
Swiss Federal Institutes of Technology Domain	2.85	25	1.21	48.55	44.2
Harbin Institute of Technol-ogy	0.81	5	0.28	25.75	36.29
Carnegie Mellon University	2.80	11	0.63	47.62	42.26
Massachusetts Institute of Technology (MIT)	3.39	17	0.98	57.39	36.62
Technical University of Munich	1.67	0	0	28.5	55.15
Tsinghua University	1.41	6	0.42	30.71	35.06
Shanghai Jiao Tong Univer-sity	1.21	9	0.64	31.32	37.94

3.4 Publication analysis

According to the performance of the journal (Table 5 and Table 6), the academic quality of core journals in the global robotics field exhibits significant hierarchical characteristics, with Q1 journals dominating in the impact dimension, but there is a differentiated competitive pattern within them. IEEE Transactions on Robotics has become a quality benchmark with a high citation rate of 1.95% (32 papers) and an absolute advantage of 59857 citations. Its Q1 partition attribute and high academic density form a positive cycle, highlighting its authority in the field of fundamental theory. Robotics and Computer Integrated Manufacturing (with a high citation rate of 1.91%) and Advanced Intelligent Systems (1.03%) both demonstrate breakthroughs in the quality of applied research, confirming the trend of the robotics discipline extending towards technological integration. Some high-yield journals exhibit an imbalance between scale and quality. IEEE Robotics and Automation Letters ranks first with 7462 papers, but the proportion of highly cited papers is only 0.23%. The Q2 partition attribute further limits its academic influence.

Table 7. Number of journal publications and citations

Journal	Papers	Citations	Highly Cited Papers	Percentage Highly Cited Papers
ieee robotics and automation letters	7462	100176	17	0.23
journal of intelligent & robotic systems	2050	23093	2	0.1
robotics and autonomous sys-tems	1795	34492	8	0.45

international journal of advanced robotic systems	1780	15674	1	0.06
ieee transactions on robotics	1641	59857	32	1.95
robotica	1474	11183	0	0
robotics and computer-integrated manufacturing	1309	38848	25	1.91
advanced intelligent systems	1258	16821	13	1.03
frontiers in neurorobotics	1255	11168	6	0.48
journal of mechanisms and robotics-transactions of the asme	1252	13331	3	0.24

Table 8. Journal partitioning and collaborative paper data

Journal	JIF Partition	International collaborative papers	Percentage of international collaborative papers
ieee robotics and automation letters	Q2	1740	23.32
journal of intelligent & robotic systems	Q2	419	20.44
robotics and autonomous systems	Q1	512	28.52
international journal of advanced robotic systems	Q3	265	14.89
ieee transactions on robotics	Q1	513	31.26
robotica	Q3	265	17.98
robotics and computer-integrated manufacturing	Q1	330	25.21
advanced intelligent systems	Q1	362	28.78
frontiers in neurorobotics	Q3	397	31.63
journal of mechanisms and robotics-transactions of the asme	Q2	303	24.2

4 Research topic analysis

Based on bibliometric analysis, a study was conducted on keyword clustering of over 130000 papers in the field of robotics, identifying six core research themes and revealing the characteristics of interdisciplinary and technological integration within the field (Fig. 2). Research topic clustering vocabulary can be see in table7.

Cluster 1 core keywords include system (937), model (926), human robot interaction (694), and machine learning (677), demonstrating the focus on the intelligence and interaction capabilities of robot systems, covering system architecture design, behavior modeling, perception and cognitive technologies, as well as the application of machine learning in classification and decision-making. This theme emphasizes the efficiency optimization of collaboration between robots and humans (such as performance, 760), which is a typical field of cross fusion between robotics and artificial intelligence. The core keywords of Cluster 2 include robots (941), navigation (729), robot sensing systems (664), and reinforcement learning (650), indicating that the autonomy of mobile robots is the core, involving environment perception (SLAM, localization), path planning (collision avoidance), and dynamic task analysis. Reinforcement learning and deep learning techniques (641) play an important role in this topic, supporting real-time decision-making and adaptive learning in complex scenarios. Cluster 3 core keywords include optimization (880), algorithm (714), stability (638), and path planning (526), indicating algorithm innovation focused on robot motion control, including trajectory optimization, dynamic stability analysis, and multi-objective path planning. Combining simulation technology (685) with mobile robots (619) platform verification, the aim is to improve system execution efficiency and robustness. The core keywords of Cluster 4 include design (951), soft robots (526), actuators (505), and grassling (486), mainly focusing on soft robot design and physical interaction technology, researching flexible material drive (force, 685), grasping operation (grassling), and biomimetic structure (shape, 553). This theme focuses on the collaborative optimization of mechanical design and control systems, promoting the application of robots in precision operations and medical fields. Cluster 5 core keywords: motion (812), locomotion (619), rehabilitation (504), exoskeleton (476), Focusing on biomimetic movements (Legged Locomotion, Gait) and rehabilitation robots (Exoskeleton), combined with impedance control (431) technology, we aim to solve problems such as gait reconstruction and rehabilitation of movement disorders, demonstrating the deep penetration of robot technology in the medical and health field. Cluster 6 core keywords include dynamics (792), kinematics (716), manipulators (622), and industrial robots (324), with a focus on robot dynamics modeling and mechanical design, covering robotic arm kinematics analysis (kinematics), workspace optimization (workspace), and industrial robot system integration. This theme emphasizes engineering applications to serve the automation and high-precision operation needs of the manufacturing industry.

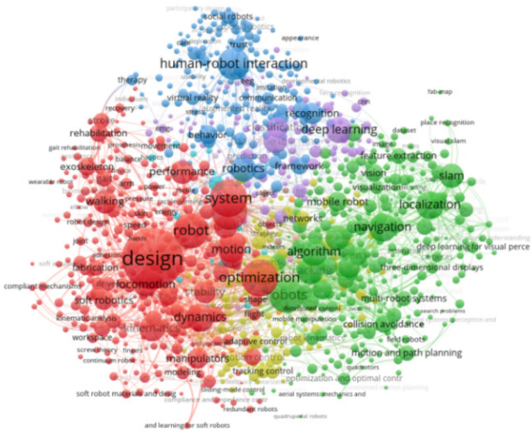

Fig. 2. Research topic clustering

Table 9. Research topic clustering vocabulary

label	cluster	Weight <Links>	label	cluster	Weight <Links>
system	1	937	design	4	951
model	1	926	force	4	685
human-robot interaction	1	694	manipulation	4	648
performance	1	760	soft robotics	4	526
robotics	1	812	actuators	4	505
recognition	1	653	control	4	572
machine learning	1	677	grasping	4	486
classification	1	600	shape	4	553
behavior	1	607	fabrication	4	376
perception	1	582	driven	4	464
robots	2	941	robot	5	924
task analysis	2	722	motion	5	812
navigation	2	729	locomotion	5	619
localization	2	603	walking	5	567
robot sensing systems	2	664	rehabilitation	5	504
slam	2	419	exoskeleton	5	476
reinforce-ment learning	2	650	legged lo-comotion	5	491
planning	2	525	gait	5	439
deep learning	2	641	stroke	5	403
collision avoidance	2	525	impedance control	5	431
optimization	3	880	dynamics	6	792
systems	3	822	kinematics	6	716
tracking	3	741	manipulators	6	622
algorithm	3	714	mechanism design	6	416
stability	3	638	manipulator	6	434
mobile robots	3	619	mechanisms	6	456
simulation	3	685	robot design	6	269
path planning	3	526	workspace	6	217
motion control	3	592	platform	6	372
mobile robot	3	504	industrial robots	6	324

5 Conclusion

In the field of global robot research, the number of papers published in Chinese Mainland has significantly exceeded that of other countries, but there are still deficiencies in influence, which is closely related to China's current research ecology and the paper quantity oriented assessment mechanism. In contrast, as a leader in global technological innovation, the United States not only has an advantage in the number of papers, but also has a particularly prominent global influence and cross regional cooperation in its papers. From a regional perspective, although countries in the Asia Pacific region have performed well in terms of total paper output, they still lag behind some European countries in terms of citation frequency, number of high-level papers, and international cooperation performance.

In the future, China urgently needs to transform its scientific research performance evaluation mechanism, abandon the traditional model of simply measuring the number of papers, and pay more attention to the originality and innovation of scientific research results. At the same time, regional and international cooperation should be strengthened to achieve a shift from leading in the number of papers to leading in research quality, enhance the core competitiveness of universities and research institutions, and thereby enhance China's international competitiveness in the field of robotics

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