Quantum and Artificial Intelligence: Exploring Their Convergence Through Scientometrics

Cuántica e inteligencia artificial: explorando su convergencia desde la cienciometría

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Recibido: marzo 2 de 2023 - Evaluado: abril 16 de 2023 - Aceptado: Agosto 15 de 2023

Para citar este artículo / To cite this Article
C. A. Oviedo-Machado, L.D. Brito-Palmezano, W. A. Trillos-Sarmiento. T. I. Causil-Contreras "Quantum and Artificial Intelligence: Exploring Their Convergence Through Scientometrics", Revista de Ingenierías Interfaces, vol. 8, no.1, pp.1-18, 2025.

Abstract

Technological and scientific advancements in recent years have enabled us to manipulate technologies that were once considered unimaginable. Among these, Artificial Intelligence (AI) and quantum physics have emerged as pivotal forces, significantly enhancing our capacity to achieve goals and solve complex problems. Given their growing relevance, a comprehensive review of the scientific output underpinning this new era is both timely and necessary. Such a review allows us to trace the increasing scholarly interest in these domains and to identify emerging trends in the synergy between them. Accordingly, the objective of this article is to present a scientometric analysis of the academic literature related to both AI and quantum science. To achieve this, we examined peer-reviewed articles indexed in the Web of Science (WoS) and Scopus databases, focusing on key indicators such as publication volume, citation patterns, and collaboration networks among countries, journals, and authors. The findings reveal a notable increase in interest toward the integration of AI and quantum technologies in recent years, driven by their combined potential to deliver enhanced performance across a wide range of disciplines.

Keywords: Quantum Computing, Artificial Intelligence, Scientometrics, AI-Quantum Convergence, Bibliometric Analysis, Interdisciplinary Research.

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*Artículo inédito: "Quantum and Artificial Intelligence: Exploring Their Convergence Through Scientometrics".
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Resumen

El avance tecnológico y científico moderno nos ha permitido manipular tecnologías que hace algunos años no podríamos imaginar posibles. El uso de la inteligencia artificial y la física cuántica han marcado un avance que potencia la capacidad para cumplir objetivos y resolver problemas complejos. Debido a su relevancia en crecimiento, es menester una revisión de la producción científica que ha permitido este nuevo paso en la humanidad, conocer cómo se ha aumentado el interés a través de los años y las tendencias emergentes de la sinergia de ambos campos. Teniendo en cuenta lo anterior, el objetivo de este artículo es presentar un análisis cienciométrico sobre la producción científica sobre ambas disciplinas. Para cumplir eficazmente nuestro propósito, se analizaron los artículos científicos encontrados en las bases de datos Web of Science (WoS) y Scopus, considerando los datos de número de publicaciones, citas de referencia, y red de colaboraciones de países, revistas y autores. Finalmente, los resultados evidenciaron que la IA y cuántica juntas dan un mejor rendimiento en muchas disciplinas, razón por la cual se ha incrementado el interés por esta combinación en los últimos años.

Palabras clave: Computación Cuántica, Inteligencia Artificial, Cienciometría, Convergencia IA-Cuántica, Análisis Bibliométrico, Investigación Interdisciplinaria.

1. Introduction

In recent years, quantum physics and artificial intelligence (AI) have gained increasing prominence in the development of new technologies with applications across various sectors. In particular, quantum computing has generated considerable expectations due to its ability to solve complex problems by leveraging principles such as superposition and entanglement [1]. This convergence between AI and quantum computing has driven significant advances in fields such as healthcare, where the integration of quantum algorithms and explainable artificial intelligence (XAI) techniques enables more transparent and scalable analysis of complex data [2]. Likewise, marketing and education have been transformed through the use of intelligent systems that automate processes, enhance user experience, and open up new pedagogical possibilities [3], [4].

While existing reviews address AI applications in various domains, many focus on specific case studies or theoretical perspectives, without delving into the scientometric evolution of the field. For instance, recent research has demonstrated AI's potential in solving quantum mechanics problems [5] and optimizing material science processes through algorithmic explainability [6]. However, there remains a lack of studies analyzing the joint development of AI and quantum computing from a scientometric perspective, which limits a consolidated understanding of their trajectories, collaboration networks, and emerging themes. This article aims to address this gap through a comprehensive analysis that sheds light on the relationship between these two disruptive technologies across diverse domains, from agriculture [7] to out-of-distribution (OOD) data detection in continual learning [8].

To this end, a scientometric analysis was conducted using the Scopus and Web of Science (WoS) databases, including documents containing the keywords "Quantum" and "Artificial Intelligence" in their titles, without temporal restriction. The dataset comprised articles, books, book chapters, and conference proceedings. The analysis included visualizations showing the distribution of publications by country, journal, and time period, in order to highlight the scientific output and major collaboration networks. This approach enables a better understanding of how the convergence between AI and quantum computing is evolving, while also identifying key contributors and topics with significant future potential.

The article proceeds with a detailed explanation of the applied methodology, including the search strategy and notable features of the selected documents. This is followed by an analysis of scientific output by countries, journals, and authors, highlighting the top contributors in each category and their respective collaboration networks. The article concludes by emphasizing the multidisciplinary importance and growing interest in the integration of AI and quantum technologies.

2. Methodology

This study was conducted using a scientometric approach to analyze the scientific production related to the convergence between AI and quantum physics [9], [10], [11]. A systematic search was carried out in the Scopus and WoS databases, both internationally recognized for their comprehensive coverage of high-quality scientific literature. The search strategy employed the keywords “Quantum” and “Artificial Intelligence” in the titles of the documents. Various types of publications were included—scientific articles, books, book chapters, and conference proceedings—providing a broad and representative overview of the state of the art in this thematic intersection. Publications were retrieved from both Scopus and WoS, with the search focused specifically on the terms “Quantum” and “Artificial Intelligence,” which allowed for the collection of a significant number of documents connecting quantum physics with AI. The results are summarized in Table I.

Table I. Search parameter used in both databases.

Parameter	Web of Science	Scopus
Range	2004 - 2025	
Date	April 4, 2025	
Document Type	Paper, book, chapter, conference proceedings	
Words	(TITLE-ABS-KEY (quantum) AND TITLE ("artificial intelligence")) TI=(quantum) AND AB=(artificial intelligence)	
Results	525	548
Total (Wos+Scopus)		1012

Using the selected documents, relevant data such as title, abstract, keywords, authors, institutional affiliations, and DOI were collected. This information was organized into a structured database to facilitate subsequent analysis [12], [13], [14]. The main objective was to examine how the relationship between artificial intelligence and quantum technology has evolved in the academic literature. To identify patterns of collaboration, recurring topics, emerging trends, and co-authorship or country-level connections, the software Gephi was employed. This tool enabled the visualization of relationships within the publication set through network graphs. These visualizations made it possible to detect research communities, central authors in the field, and regions with the highest scientific output, providing a clearer view of the current landscape and research dynamics surrounding this topic.

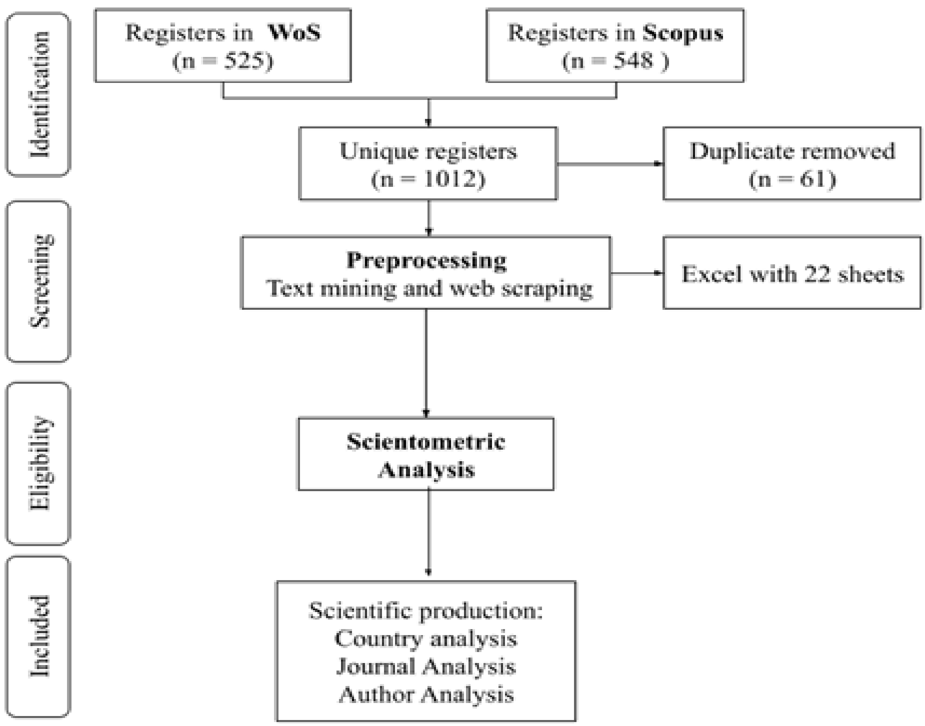

Figura 1. Database search criteria and results.

3. Results

Scientific Annual Production

The annual analysis of scientific production is of great importance as it allows for the identification and examination of patterns on a specific topic over time. Figure 2 illustrates the changes in scientific output from 2004 to 2024. In the early years, between 2004 and 2017, there was limited scientific production, with output fluctuating throughout that period. However, starting in 2018, there was a significant increase, culminating in 2024 with the highest peak recorded 296 publications in that year (red line).

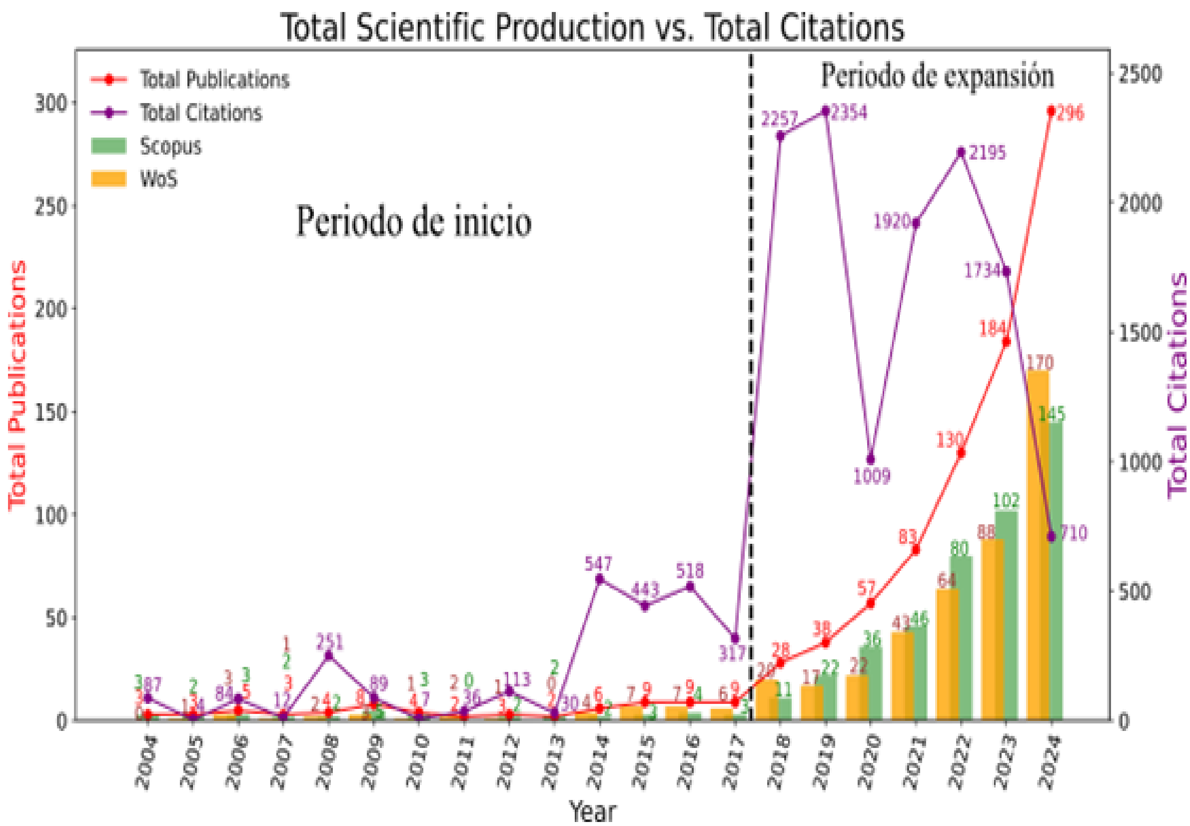

Figure 2. Total Scientific Production vs Total Citations

The analysis of annual scientific production between 2004 and 2024 is highly relevant, as it allows the identification and examination of patterns over time. Figure 2 shows the changes in scientific output from 2004 to 2024.

In general terms, this evolution in scientific production over the years can be divided into two periods: an initial period (2004–2017) characterized by low scientific output, and an expansion period (2018–2024) in which there was a significant increase in scientific production—this being the period with the majority of the total output.

Initial Period (2004–2017):

The total number of publications during this period was 70, with an average of 5 publications per year. The number of publications increased from 3 in 2004 to 9 in 2017, representing an average annual growth rate of 8.85%. The total number of citations was 2,538, with an average of 181.28 citations per year, which is relatively low compared to the following expansion period.

During this initial period, the most cited article in the Scopus database—and also the most cited across both databases—was the one by Dilsizian & Siegel (2014), with a total of 371 citations according to Scopus. This study analyzed how artificial intelligence and big data can transform cardiac imaging and personalized diagnostics. Thanks to its high citation count, the paper helped lay the groundwork for AI applications in cardiology (Dilsizian and Siegel 2014).

The second most cited article during this period—and the most cited from the WoS database—was by Dunjko, Taylor, and Briegel (2016). They proposed a systematic approach to improving machine learning algorithms through quantum information techniques. Their article, *"Quantum-Enhanced Machine Learning,"* demonstrated quadratic and exponential improvements in efficiency and performance, establishing it as a major contribution to the field (Dunjko et al. 2016)**.**

Expansion Period (2018–2024):

The total number of publications during this period was 816, with an average of 116.57 publications per year. The number of publications increased from 28 in 2018 to 296 in 2024, indicating an average annual growth rate of 47.7%. This period accounts for 92% of the total analyzed publications, reflecting a much higher scientific output than the initial period (2004–2017). In addition to the sharp rise in the number of publications, there was also a significant increase in annual citations, with a total of 12,179 citations and an average of 1,739.85 citations per year. This not only suggests a greater output but also a higher academic impact, especially since the scientific production in each year of this period exceeded that of the previous year. Another detail visible in the data is that, according to the Scopus (green bars) and WoS (yellow bars) databases, Scopus has led in article production from 2019 to 2023.

The most cited article during this expansion period—and overall—was by Dunjko and Briegel (2018), with 692 citations in Scopus and 586 in WoS. This article reviewed the key advances connecting classical AI techniques with quantum algorithms, making it a foundational work in the field of quantum artificial intelligence [15]. Another highly relevant article during this period—and the second most cited in the WoS database—was by Yang Liu et al. They developed a novel technique to create anti-counterfeiting security labels using quantum dots through inkjet printing, and employed AI for authentication. These labels generate random fluorescent patterns that can only be verified by specific AI algorithms [16]. This surge in scientific output demonstrates the growing recognition and integration of artificial intelligence in the field of quantum science and other scientific domains.
Country Analysis

Table II presents the scientific output of the top 10 countries with the highest contributions and influence in the field of artificial intelligence and quantum technologies. It enables the analysis of variables such as productivity, measured by the number of published articles; impact, assessed through citation counts; and quality, based on Scimago journal quartile rankings. China leads in terms of productivity, with 208 publications, representing 17.42%

of the total, establishing itself as the primary content generator in this domain. On the other hand, the United States surpasses all other countries in terms of impact, with 3,834 citations (18.52%), indicating greater influence and visibility per published article.

In terms of quality, China also stands out with 107 publications in top-tier journals, followed by the United States with 82. These results position China as the leader in overall scientific production, the United States as the benchmark in impact, and both countries as key players in high-quality scientific research. India and Italy exhibit moderate contributions; notably, India shows significant output with relatively lower impact, whereas Italy demonstrates a remarkable share of Q1 publications in proportion to its overall productivity. Collectively, the data highlight a concentration of scientific leadership in China and the United States, accompanied by a growing participation from European and Asian countries.

Table II. Countries with the greatest contribution to artificial and quantum intelligence research, scientific production, citations and quartile distribution

Country	Production		Citation		Quality			
	Count	%	Count	%	Q1	Q2	Q3	Q4
China	208	17.42	3509	16.99	107	34	4	6
Usa	190	15.91	3884	18.8	82	29	3	5
India	128	10.72	834	4.04	29	21	7	3
Italy	56	4.69	816	3.95	22	8	5	2
Germany	51	4.27	1505	7.29	25	4	5	1
United Kingdom	43	3.6	955	4.62	18	8	5	1
Spain	39	3.27	952	4.61	16	10	1	3
Canada	38	3.18	861	4.17	25	3	2	0
Korea	32	2.68	338	1.64	17	6	0	1
Saudi Arabia	32	2.68	638	3.09	15	10	3	1

Source: Self-prepared.

A group of researchers in China published a study on a technology that helps control how light moves within optical chips, which is highly useful in both electronics and quantum computing. By using special materials known as piezoelectrics, the scientists can adjust and modify optical signals quickly and with low energy consumption. This enables the correction of manufacturing defects and the development of new devices such as tunable lasers or components that direct light in a single direction. This advancement, described in the article "Piezoelectric tuning and modulation in integrated photonics" [17], illustrates how photonics—the use of light instead of electricity—is opening new possibilities for future technologies.

Meanwhile, a recent publication by Springer Nature proposes a novel method of reviewing scientific information using artificial intelligence. Instead of having a person read all the articles, a machine organized and summarized content on complex topics such as climate change or planetary evolution. The goal was to make information more accessible to students, researchers, or professionals who need to quickly learn about a subject. This initiative, presented in the book "Machine-Generated Literature Overviews for Interdisciplinary Topics" [18], demonstrates how AI tools can help locate, structure, and better understand large volumes of scientific information.

Figure 3 presents the global network of scientific collaboration among countries in research on artificial intelligence and quantum technology. The United States stands out as the main connection hub, followed by China, India, and the United Kingdom, reflecting their central roles in international cooperation. The colors represent communities of countries that tend to collaborate more frequently with each other. The size of the nodes indicates each country's level of participation, and the thickness of the lines represents the strength of their connections. Seven major communities were identified, revealing a structure that is diverse yet interconnected. Additional graphs show a significant increase in the number of countries involved and the strength of their connections since 2022, indicating accelerated global interest in the convergence of AI and quantum technologies. Overall, the figure underscores the importance of international cooperation in driving progress in these key areas.

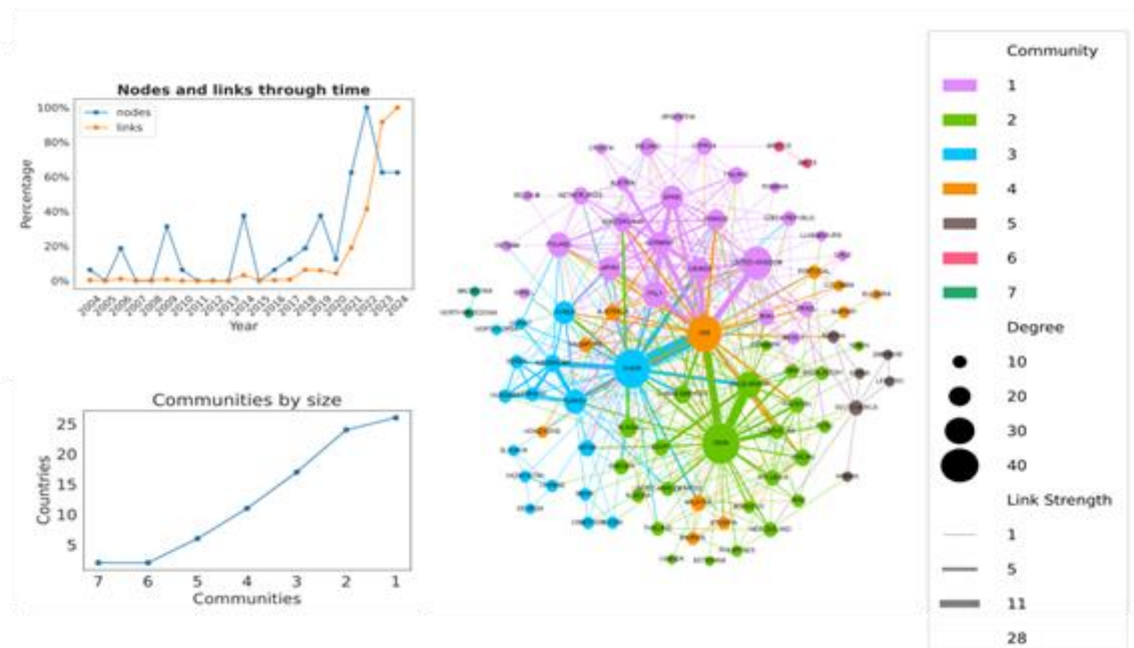

Figure 3. Collaboration network by countries for artificial intelligence and quantum mechanics research

Journal Analysis

Table III presents the top ten journals with the highest scientific output on artificial intelligence and quantum technologies, including the number of articles indexed in WoS, Scopus, and the total count (excluding duplicates), along with their SJR, h-index, and

Scimago quartile ranking. The top journals range from 9 to 31 total publications, and eight out of the ten journals show a greater number of articles indexed in WoS, highlighting that WoS offers broader indexing of articles on artificial intelligence and quantum technologies for the leading journals in the field.
Additionally, the top journals exhibit an average h-index of 207.7, influenced by six journals surpassing 150 points—an indicator that confirms their high bibliometric impact in the domain.

Table III. Top diez revistas por producción científica sobre inteligencia artificial y cuántica

Journal	SN	WoS	Scopus	Total	SJR	H-Index	Quartile
Lecture notes in computer science (including subseries lecture notes in Artificial Intelligence and lecture notes in Bioinformatics)	03029743	0	31	31	0.352	499	Q2
Scientific Reports	20452322	17	4	20	0.874	347	Q1
Optical and Quantum Electronics	03068919	14	9	19	-	80	-
Optics Letters	01469592	16	0	16	0.971	305	Q1
Ieee Access	21693536	14	3	16	0.849	290	Q1
Journal of the Optical Society Of America B:Optical Physics	07403224	15	0	15	0.475	161	Q2
Quantum Machine Intelligence	25244906	12	3	14	1.059	23	Q1
Ceur Workshop Proceedings	16130073	0	10	10	0.166	69	-
Quantum Information Processing	15700755	9	0	9	0.477	79	Q2
Applied Optics	21553165	9	0	9	0.451	224	Q2

Source: Self-prepared.

The journal with the highest number of publications on artificial intelligence and quantum technologies is Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) (LNCS). It also holds the highest h-index among the top journals, with an impressive score of 499, and a Q2 ranking. However, its SJR (SCImago Journal Rank) is relatively low, indicating that while it has accumulated a high number of citations over time, it does not stand out in terms of prestige. In contrast, Quantum Machine Intelligence leads in SJR with a value of 1.059 but has a more modest h-index of 23. Between these two extremes, a group of journals—Optics Letters, Scientific Reports, and IEEE Access—stand out for combining high h-indices (above 290) with strong SJR values (above 0.8), reflecting both high citation volume and notable scientific prestige. One of the most recent contributions from LNCS, published in the proceedings of the 19th International Conference on Hybrid Artificial Intelligence Systems (HAIS 2024), proposes the integration of quantum computing principles into decision trees used in supervised machine learning, aiming to enhance inferential efficiency [19]. LNCS is particularly known for publishing peer-reviewed papers derived from academic conferences, such as the recent

HAIS 2024 volume, which includes 52 current research articles across areas such as Deep Learning and Evolutionary Computation and Optimization [20], [21].

Scientific Reports ranks as the second most prolific journal in both Scopus and WoS. Its most cited article is by Goto Hayato, titled "Bifurcation-based adiabatic quantum computation with a nonlinear oscillator network", in which he describes a quantum nonlinear oscillator network that functions analogously to neural computing systems. This network generates quantum superpositions instead of conventional qubits and achieves higher success probabilities in solving the Ising problem compared to classical simulations [22]. The journal also includes other recent publications on quantum AI [23], [24]. In conclusion, Table III demonstrates that journals publishing most frequently on AI and quantum topics tend to exhibit strong bibliometric indicators. Most feature high h-index values, and in several cases, elevated SJR scores, reflecting both a significant volume of publications and strong scientific influence in the field.

Figure 4 illustrates the journal citation network, the community distribution diagram, and the node-link graph over time. The citation network highlights three main clusters of journals: The first group emphasizes studies on how quantum processing capabilities can enhance machine learning, and conversely, how AI techniques can be applied to the control, design, and improvement of quantum systems [25], [26]. The second group focuses on interdisciplinary research involving AI and quantum computing in biomedical and pharmaceutical applications [27], [28]. The third group comprises journals centered on the application of AI to optimize traditional methods in quantum mechanics, including research in materials science, computational chemistry, and clean energy technologies [29], [30].

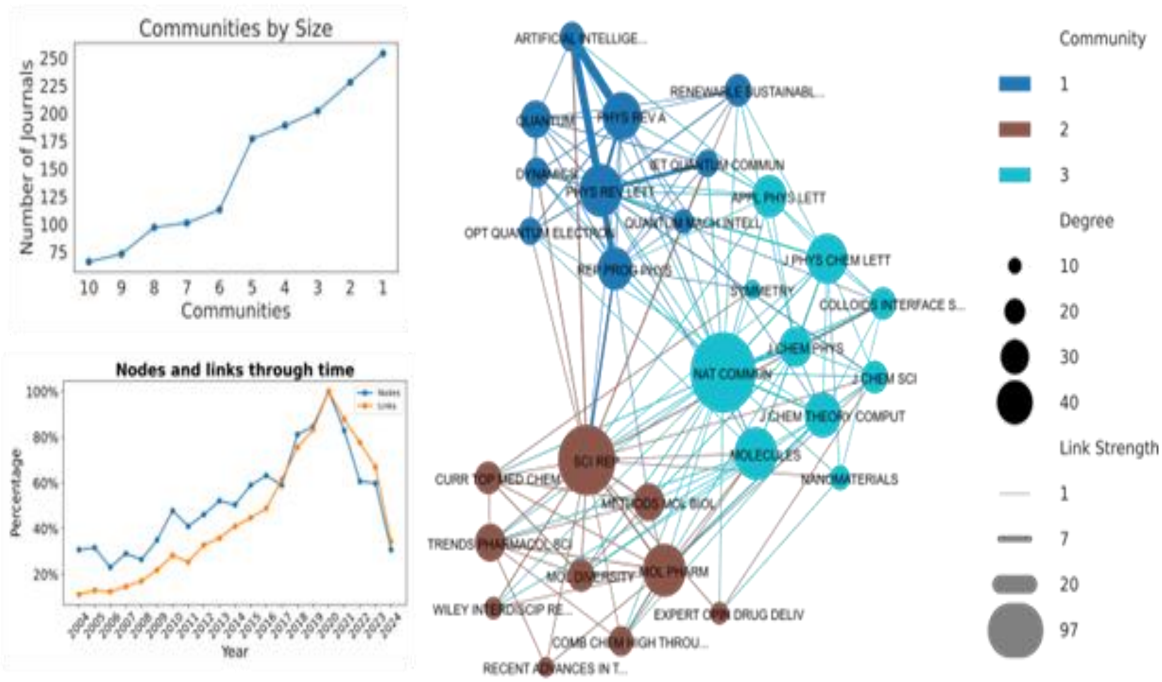

Figure 4. Network of major collaboration between journals, divided into focus communities.

Author Analysis

Analyzing scientific collaboration networks enables the identification of networking strategies employed by researchers. It also allows for the assessment of researchers' significance based on their scholarly output and the impact of their publications. Table IV presents the ten most prolific authors in the field of AI and quantum technologies, based on both their academic productivity and social network metrics.The results position Dr. Zhang as the most productive researcher, with a total of 16 publications, despite not having the highest citation count or h-index. His recent work on a source-independent quantum random number generator demonstrates significant applicability in quantum mechanics [31]. A noteworthy observation within the top-ranked authors is the case of Dr. Briegel, who, although he has published ten articles and holds the highest total citation count (2,181) and the highest h-index, ranks lower due to relatively weaker social network metrics compared to other authors.

Table IV. Top 10 Most Outstanding Authors in IA and Quantum

Author	Papers Total	Total Citations	H-Index	Effective_Size	Constraint	CDI
Zhang Y	16	131	6	818.93	0.0	0.01
Liu Y	13	629	6	493.88	0.01	0.04
Yüksel S	13	30	4	78.69	0.08	0.16
Zhang J	13	222	5	514.06	0.01	0.04
Dinçer H	12	30	4	69.83	0.1	0.16
Zhang X	12	166	5	455.95	0.01	0.04
Li Z	11	227	4	400.71	0.01	0.04
Briegel H	10	2181	9	45.38	0.07	0.13
Li X	10	315	4	435.82	0.01	0.04
Wang Y	10	274	6	650.63	0.01	0.04

Regarding social network metrics, effective size measures the extent of an author's collaborative reach. For instance, Dr. Briegel—whose research includes the development of a machine learning agent capable of decision-making through single-photon quantum walks [32] —has the lowest effective size, suggesting that his collaborators are also closely connected among themselves. However, his constraint score is low (0.07), indicating that his network is non-redundant and allows for the introduction of novel information. On the other hand, in terms of the Collaboration Diversity Index (CDI), Drs. Yüksel and Dinçer exhibit the highest values (0.16), suggesting they maintain the most diverse academic collaborations among the top-ranked researchers. Overall, the leading group comprises authors with high total citation counts, such as Dr. Briegel (2,181), followed by Dr. Liu (629), whose study on anti-counterfeiting labels made with quantum dots—which produce unique optical patterns verifiable through artificial intelligence—has garnered 450 citations to date [16]. Furthermore, all authors in the top 10 display a constraint score equal to or below 0.1, reflecting open networking structures that facilitate the exchange of new information and promote innovation.

Figure 5 illustrates the scientific collaboration network of the most prolific authors working at the intersection of AI and quantum technologies, based on their personal research networks. The network reveals three distinct clusters formed through social network analysis. The largest and most interconnected cluster includes prominent scholars such as Yingyu Zhang and Yuanzhen Li from Liaocheng University in Liaocheng, China. These researchers collaborated on the development of the Quantum Artificial Bee Colony Spanning Tree (QABCST) algorithm—an innovative hybrid of Artificial Bee Colony (ABC) optimization and quantum computing aimed at enhancing spanning tree construction in industrial wireless sensor networks [33]. This cluster also includes Dr. Ye Wang, a recognized expert in the study of open quantum systems and quantum dissipation processes [34]. The second cluster is composed of two prominent academics, Joongheon Kim and Sooyun Park, affiliated with Korea University in Seoul, South Korea. Their recent work introduced the Quantum Multi-Agent Reinforcement Learning (QMARL) framework, designed to optimize meta-space decision-making processes [35]. Finally, the third cluster is led by the distinguished Professor

Alán Aspuru-Guzik, whose research has focused on the application of AI and quantum computing tools in the fields of chemistry and materials science [36].

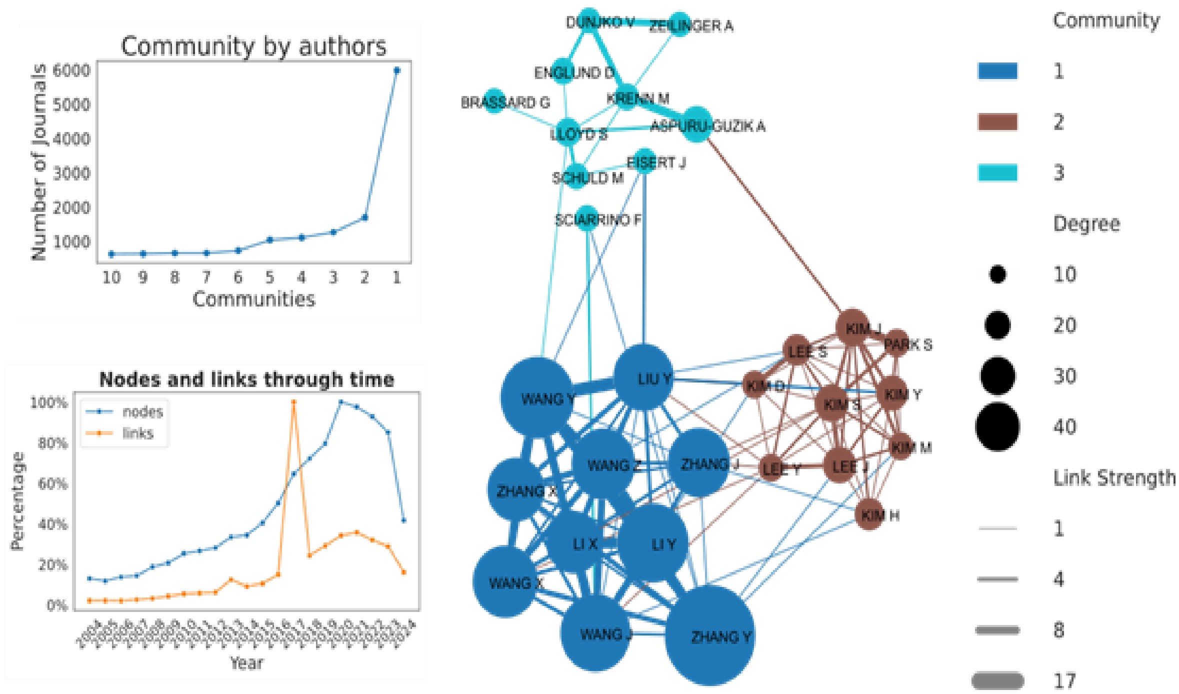

Figure 5. Collaborative Network of Prominent Authors and Their Interconnections

Conclusions

This article presents a scientometric analysis of the scholarly output on quantum technologies and AI, detailing their increasing popularity in recent years. The study is approached from multiple perspectives throughout the article, including annual publication trends, geographic distribution by country, journal, and author productivity. Data collection was conducted using two major databases (WoS and Scopus) which were integrated using data mining and web scraping algorithms to filter and consolidate the information, ultimately resulting in a corpus of 1,012 documents used for the analysis.

The findings reveal that the convergence of AI and quantum technologies has a wide array of applications and has sparked growing interest across several disciplines over the past decade. The scientometric analysis enabled the identification of descriptive statistics for total scientific output on this topic indexed in WoS and Scopus. Since 2018, the publication rate has shown a consistent upward trend, indicating a surge in interest in this emerging interdisciplinary field. Notably, this increase has been primarily driven by leading research nations such as China, the United States, and India, which together account for 44.0% of the total output, most of it published in Q1-ranked journals.

Several high-impact journals have begun to dedicate substantial focus to this area, especially through AI-related conference proceedings published in series such as Lecture Notes in Computer Science (LNCS). In terms of authorship, prominent researchers like Dr. Yingyu Zhang and Dr. Alán Aspuru-Guzik have made significant contributions, underscoring the interdisciplinary nature and optimization potential that AI and quantum technologies bring to fields such as chemistry, materials science, and pharmaceuticals.

A distinguishing characteristic of the AI–quantum synergy highlighted in this study is its wide-ranging applicability. Numerous articles propose hybrid methods combining quantum computing and AI, aiming to complement each domain while also enhancing performance in other knowledge areas. These hybrid approaches consistently outperform traditional methods, offering greater efficiency and success rates. Examples include quantum nonlinear oscillators applied to the Ising problem, quantum computing principles used to optimize decision trees in supervised learning, and new algorithms such as QABCST for quantum computing. Additional applications include quantum system simulation and control, experiments with silicon-based materials, and identification of chemical properties in simulated molecules, among others. These studies collectively exemplify the transformative potential of AI–quantum integration in driving technological advancement by enabling faster, more accurate processes.

The intersection of AI and quantum technologies constitutes an emerging interdisciplinary domain poised to optimize processes and yield improvements across numerous professional sectors. Beyond their evident impact on computer science and quantum physics, this convergence has also benefited disciplines such as chemistry, pharmaceuticals, materials science, and clean energy research. Nations, journals, and researchers are actively dedicating resources to explore and showcase the tangible benefits of this technological fusion, with the shared goal of reducing both time and error in scientific and technological development.

Despite its contributions, this study is subject to several limitations. The scientometric analysis was based solely on two databases (Scopus and WoS) which, while comprehensive, restrict the analysis to articles indexed in at least one of the two. Consequently, relevant publications outside these databases could not be included. Furthermore, the data collection was conducted on April 4, 2025, which excludes more recent publications from the dataset. Additionally, the author network analysis was conducted using an algorithm that prioritizes social network metrics, which may overlook researchers with innovative contributions but less visibility in network-based indicators.

Given these limitations, future research would benefit from expanding the scope of databases consulted to incorporate alternative perspectives and less conventional sources. It is also recommended to broaden the keyword strategy beyond title-based queries, as some impactful studies on AI and quantum technologies may not explicitly mention both terms in their titles.

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