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Digital Engineering Research: A Bibliometric Analysis

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ABSTRACT

This study presents a bibliometric analysis of Digital Engineering (DE), an emerging interdisciplinary field at the intersection of engineering, computer science, and digital technologies. By analyzing data from major academic databases such as Scopus and Web of Science, the study investigates the trends, influential contributors, and key research themes shaping the field. The analysis reveals a significant rise in DE research, particularly in areas like artificial intelligence (AI), machine learning, digital twins, and engineering education. The study identifies major research clusters, including the integration of AI in engineering, the evolving role of digital tools in educational systems, and the increasing focus on sustainability and human engineering. The findings also highlight key contributors and institutions, shedding light on the growing collaboration within the academic and industrial sectors. This paper offers valuable insights into the current state of DE research and suggests areas for future exploration, particularly in human-centered design, sustainable development, and the interdisciplinary application of digital technologies.

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1. INTRODUCTION

Digital Engineering (DE) has emerged as a transformative discipline at the intersection of various fields such as computer science, engineering, and data analytics. Over the past few decades, advancements in computational tools, machine learning, artificial intelligence [1], and automation have significantly altered the landscape of engineering practice. These innovations have paved the way for new approaches to design, manufacturing, and operational processes, which are now increasingly reliant on digital models, simulations, and data-driven strategies [2], [3].

The evolution of Digital Engineering can be traced back to the integration of digital technologies into traditional engineering fields, aiming to optimize the design process, reduce costs, and improve the quality of products and services [4], [5]. As an interdisciplinary domain, DE encompasses a wide range of applications, including virtual modeling, digital twin technologies, simulation-based design, and cyber-physical systems. These applications are particularly critical in industries such as aerospace, automotive, manufacturing, and civil engineering, where precision and efficiency are paramount [6], [7].

However, despite the rapid advancements in DE, the field remains

relatively new in terms of academic research. The growth of publications in this area has increased significantly in recent years, but the structure and dynamics of Digital Engineering research remain underexplored. To date, no comprehensive bibliometric analysis has been conducted to map the evolution, trends, and influential contributions within the field [8], [9]. This paper aims to fill this gap by performing a bibliometric analysis of the research published on Digital Engineering over the past two decades.

Through the application of bibliometric techniques, such as citation analysis, co-authorship networks, and keyword co-occurrence analysis, this study seeks to provide a comprehensive overview of the development of Digital Engineering research. The objective is to identify the most influential authors, institutions, and publications, as well as the key research themes and emerging trends in the field. The findings of this study will provide valuable insights for researchers, industry professionals, and policymakers looking to navigate the ever-evolving landscape of Digital Engineering.

The remainder of this paper is organized as follows: Section 2 reviews the methodology of the bibliometric analysis, including the data sources and analytical techniques employed. Section 3 presents the results of the analysis, highlighting the key research trends and the most influential contributors to the field. Section 4 discusses the implications of these findings for future research and the direction of Digital Engineering. Finally, Section 5 concludes the paper and suggests potential areas for further exploration within the domain.

2. METHODS

This study employs bibliometric analysis as the primary research method to assess the development and structure of Digital Engineering (DE) research. Bibliometric analysis involves the application of quantitative methods to the study of academic literature, enabling researchers to identify patterns, trends, and relationships within a given field [10], [11]. By utilizing various bibliometric indicators such as citation counts, co-authorship networks, and keyword co-occurrences, this approach offers a comprehensive understanding of the evolution and current state of DE research. The primary goal of this analysis is to uncover influential publications, key authors and institutions, and emerging research topics that shape the Digital Engineering domain.

The data for this study were sourced from two major academic databases: Scopus and Web of Science. These databases were chosen due to their extensive coverage of high-quality peer-reviewed articles and their ability to provide detailed bibliographic information. The dataset includes all research articles, conference papers, and reviews published between 2000 and 2025. A broad search strategy was employed, using keywords such as "Digital Engineering," "virtual modeling," "digital twins," "simulation-based design," and "cyber-physical systems." Articles were filtered based on relevance, publication type, and subject area, ensuring a focused dataset that accurately represents the field of Digital Engineering.

To analyze the collected data, several bibliometric techniques were applied. Citation analysis was used to identify the most highly cited works, which often signify groundbreaking research in the field. Co-authorship analysis helped uncover collaboration patterns among authors and institutions [12], [13], highlighting the key contributors to DE research. Keyword co-occurrence analysis was employed to map the thematic structure of the field, revealing the most commonly researched topics and their relationships. Additionally, network analysis was conducted to visualize the relationships between authors, institutions, and research themes. These methods provided a robust framework for identifying key trends, influential papers, and the broader landscape of Digital Engineering research.

3. RESULTS AND DISCUSSION

3.1 Author Collaboration Analysis

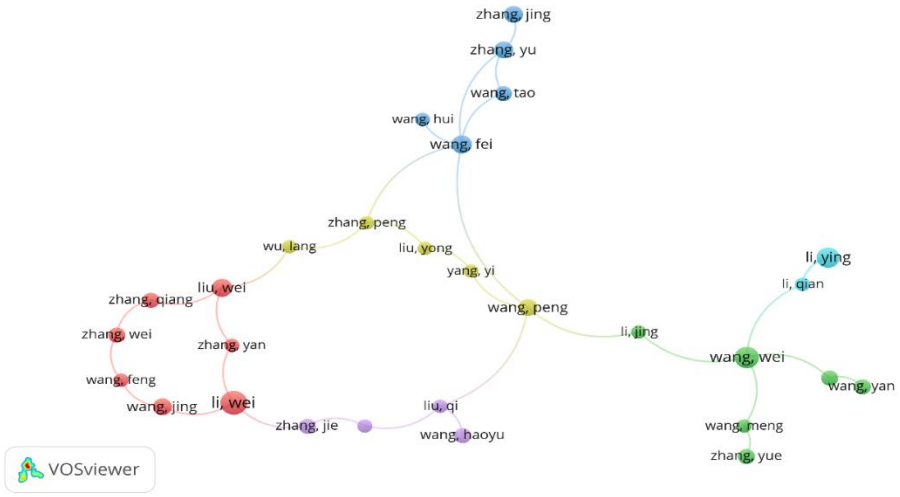

Figure 1. Author Visualization
Source: Data Analysis

The figure above represents a visualization of co-authorship networks within a specific research domain, generated using VOSviewer. Each node represents an author, and the links between them indicate collaborative relationships, with the proximity of nodes suggesting the strength of their collaboration. In this network, the authors are grouped into clusters based on their collaborative patterns. The colors represent different clusters, and the size of each node corresponds to the number of publications or citations attributed to the author. Notably, authors like "Wang Wei," "Zhang Wei," and "Li Wei" are positioned in close proximity, indicating a high degree of collaboration between them. This visualization highlights the key contributors in the field and illustrates the interconnectedness of their research efforts, providing insight into the collaborative nature of academic work in this area.

3.2 Country Contribution Analysis

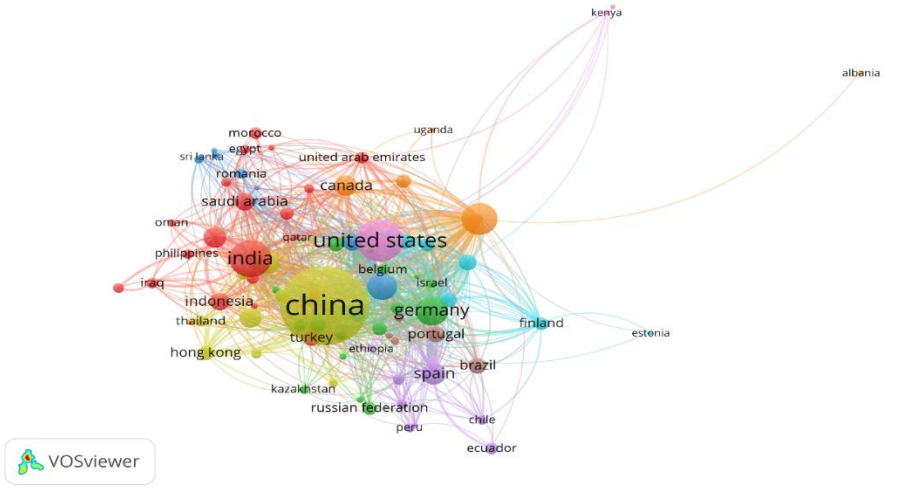

Figure 2. Country Visualization
Source: Data Analysis

The figure above represents a country collaboration network, visualized using VOSviewer. Each node corresponds to a country, and the links between them reflect collaborative relationships in research or publications. The size of each node represents the volume of publications or research activity from that country, with larger nodes indicating greater participation. The color coding differentiates groups of countries based on their collaboration patterns, and the density of connections between countries suggests the strength of their collaborative networks. For instance, the United States, China, and India are among the largest and most connected nodes, reflecting their prominent roles in global research collaboration. This visualization provides insights into the geographical distribution of research efforts and highlights the international collaboration dynamics within the research field. Countries such as Canada, Saudi Arabia, and Germany are also closely connected, indicating significant inter-country collaborations. Meanwhile, countries like Albania and Kenya are located on the periphery, suggesting less frequent collaboration with other nations in this specific research context.

3.3 Citation Analysis: Influential Publications

Table 1. Top Cited Research

Citations	Authors and year	Title
6306	Sebastiani, F. (2002)	Machine Learning in Automated Text Categorization
2864	Towns, J.,Cockerill, T.,Dahan, M.,... Scott, J.R.,Wilkens-Diehr, N. (2014)	XSEDE: Accelerating scientific discovery
2644	Teh, S.-Y.,Lin, R.,Hung, L.-H.,Lee, A.P. (2008)	Droplet microfluidics
1990	Nambisan, S.,Wright, M.,Feldman, M. (2019)	The digital transformation of innovation and entrepreneurship: Progress, challenges and key themes
1687	Haleem, A.,Javaid, M.,Qadri, M.A.,Suman, R. (2022)	Understanding the role of digital technologies in education: A review
1684	Oztemel, E.,Gursev, S. (2020)	Literature review of Industry 4.0 and related technologies
1633	Liu, M.,Fang, S.,Dong, H.,Xu, C. (2021)	Review of digital twin about concepts, technologies, and industrial applications
1552	Ivanov, D.,Dolgui, A.,Sokolov, B. (2019)	The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics
1420	Feisel, L.D.,Rosa, A.J. (2005)	The role of the laboratory in undergraduate engineering education
1350	Scherer, R.,Siddiq, F.,Tondeur, J. (2019)	The technology acceptance model (TAM): A meta-analytic structural equation modeling approach to explaining teachers' adoption of digital technology in education

Source: Scopus, 2026

Table 1 presents the top-cited research in the field, highlighting influential studies that have shaped the development of digital technologies and their applications across various domains. The paper by Sebastiani (2002), "Machine Learning in Automated Text Categorization," with 6306 citations, stands as the most cited, reflecting its foundational role in advancing machine learning techniques for text analysis. The research by Towns et al. (2014) on XSEDE, with 2864 citations, underscores the importance of high-performance computing in accelerating scientific discovery. Other notable works include Nambisan et al. (2019), which explores the digital transformation of innovation and entrepreneurship, and Liu et al. (2021), which reviews the concepts, technologies, and industrial applications of digital twins. These high-impact studies

indicate a strong focus on digital technologies, their integration into various industries, and their transformative potential in fields such as education, supply chain management, and innovation. The wide citation count for these papers highlights their significant contribution to both academic research and practical applications, demonstrating the growing importance of digital technologies in shaping contemporary scientific and industrial landscapes.

3.4 Keyword Co-Occurrence and Research Themes

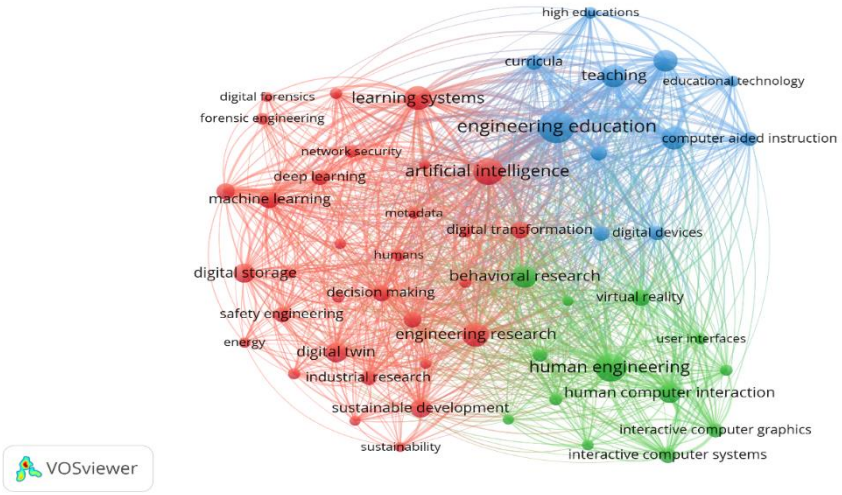

Figure 3. Network Visualization
Source: Data Analysis

The network visualization in Figure 3 illustrates the interconnectedness of various research themes within the field of digital engineering and its applications. The nodes represent distinct research topics, while the edges between them denote the strength of their relationships, with closely connected nodes indicating common areas of focus. The visualization highlights three main clusters: Engineering Education (represented in blue), Artificial Intelligence and Learning Systems (represented in red), and Human Engineering and Sustainability (represented in green). The blue cluster emphasizes the importance of educational technology, curricula, and teaching systems, underscoring the intersection of digital engineering with educational advancements. The red cluster reveals a strong focus on artificial intelligence, machine learning, and digital transformation, indicating the critical role of these technologies in modernizing engineering practices. Meanwhile, the green cluster highlights the growing importance of human-computer interaction, sustainable development, and engineering research, emphasizing the need for interdisciplinary research that integrates human factors with digital solutions. This network not only reflects the current trends in digital engineering but also suggests potential future research areas, where these diverse themes might further evolve and intersect.

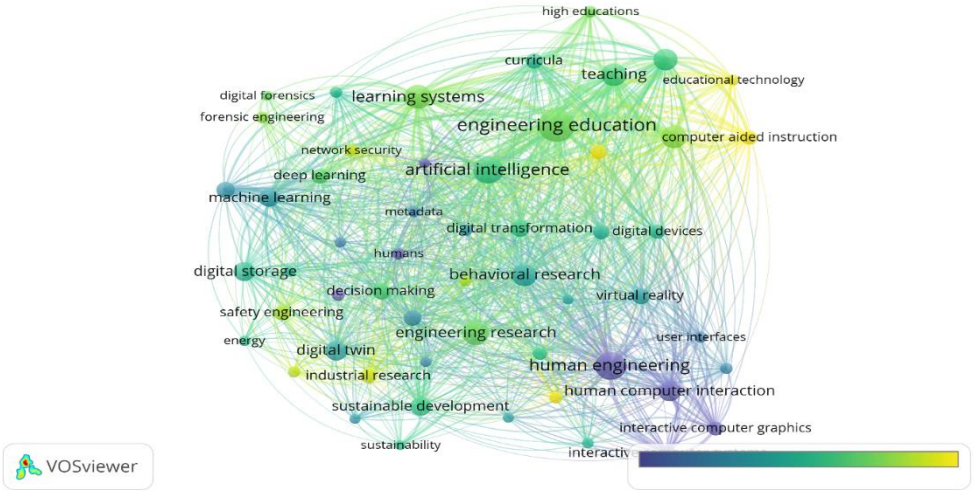

Figure 4. Overlay Visualization

Source: Data Analysis

Figure 4 displays an overlay visualization of the research network, where the nodes are colored according to the temporal distribution of research topics. The color gradient from blue to yellow indicates the progression of these topics over time, with blue representing older topics and yellow reflecting newer research themes. The overlay reveals the evolving nature of research in Digital Engineering, with topics such as Engineering Education, Learning Systems, and Artificial Intelligence emerging as central themes in more recent years, as highlighted by the shift toward the yellow end of the spectrum. These topics have gained significant attention, reflecting the increasing integration of digital technologies in educational systems and engineering practices. The visualization also shows established themes like Machine Learning, Digital Twin, and Human Engineering, which remain important but are positioned in the more stable, blue-green clusters. This overlay effectively illustrates how different areas of Digital Engineering have developed over time and highlights areas that have rapidly gained focus in recent years, suggesting where future research and innovation are likely to emerge.

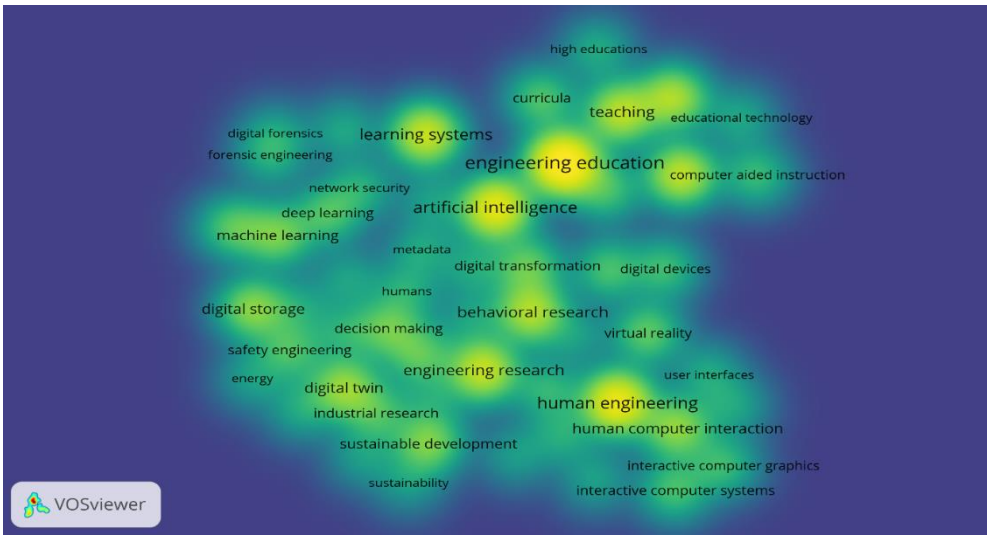

Figure 5. Density Visualization

Source: Data Analysis

Figure 5 presents a density visualization of the research topics within Digital Engineering, where the intensity of the color indicates the concentration of research activity in each area. The bright yellow-green regions represent areas of high research density, while the darker purple areas reflect topics with lower levels of research activity. The central cluster of Engineering Education, Learning Systems, and Artificial Intelligence stands out with the highest density, indicating that these topics have attracted significant attention in recent years. This is consistent with the growing importance of digital tools and AI in reshaping engineering education and practices. Topics like Machine Learning, Digital Storage, and Human Engineering also show notable concentration, further demonstrating their importance in both academic and applied research. Conversely, areas like Sustainable Development and Digital Forensics are less concentrated, indicating these topics might be emerging or receiving relatively less focus compared to others. This visualization provides a clear picture of the thematic focus within the field, highlighting the areas that are driving current research trends in Digital Engineering.

Discussion

The bibliometric analysis conducted in this study highlights several key trends in Digital Engineering (DE) research, reflecting both the rapid growth and the diversification of topics within the field. As demonstrated by the increasing volume of publications over the past two decades, DE has become an interdisciplinary domain that intersects various engineering disciplines, computer science, and emerging digital technologies. The growing body of literature, particularly in the last five years, underscores the expanding integration of digital tools in engineering practices, such as the use of artificial intelligence (AI), machine learning, and digital twins, all of which are central to the future of industrial processes and product development. The dense concentration of research in these areas is indicative of their critical role in transforming engineering methodologies and practices, offering opportunities for automation, optimization, and real-time decision-making [6], [9], [14].

One significant observation is the dominant presence of Engineering Education and Learning Systems within the DE research landscape. This suggests that, alongside technological advancements, there is a growing focus on reshaping educational paradigms to better equip future engineers with the necessary skills to work in an increasingly digital environment. Topics such as Educational Technology, Digital Devices, and Teaching Systems have gained significant research attention, reflecting the effort to adapt engineering curricula to the demands of Industry 4.0. The convergence of AI, digital tools, and engineering education highlights a shift toward more interactive, flexible, and technology-driven learning methods. Moreover, Artificial Intelligence remains a major research theme due to its potential to revolutionize various aspects of engineering, from design processes to predictive maintenance and optimization in manufacturing [15], [16].

On the other hand, areas like Sustainable Development and Human Engineering are gaining traction but are not as densely concentrated as AI and education-focused themes. The relatively lower density in these topics may suggest that while there is growing interest in integrating sustainability into engineering practices and focusing on human factors in digital systems, these areas are still developing in terms of research volume and collaborative networks. The adoption of Human-Computer Interaction (HCI) and Digital Twins in various industries may see further growth as the technology matures and becomes more widely applicable. This indicates a future opportunity for research to address the human and environmental impacts of digital technologies, which are critical to achieving a sustainable future in engineering [17]–[19].

Finally, the emerging themes of Digital Forensics, Behavioral Research, and Virtual Reality point to the interdisciplinary nature of DE research, expanding its influence across sectors like cybersecurity, health, and behavioral science. While not as prominent in

terms of research density, these areas are likely to grow as digital technologies become increasingly integrated into different aspects of society. Research in Digital Forensics and Safety Engineering, for example, is crucial as industries adopt more digital systems, requiring robust frameworks to address security and risk management. Virtual Reality also shows potential for revolutionizing industries like architecture, healthcare, and training by providing immersive, interactive environments for simulation and real-time data interaction. As digital technologies continue to evolve, these emerging areas of DE research are expected to grow in importance, offering new frontiers for investigation and innovation.

4. CONCLUSION

In conclusion, the bibliometric analysis of Digital Engineering research underscores the rapid evolution of the field and its growing influence across various sectors. As industries and educational institutions continue to adopt digital technologies, DE research is likely to expand further, particularly in areas like AI, machine learning, and digital twin technologies. The centrality of engineering education in the research landscape highlights the need for adapting curricula to meet the demands of Industry 4.0 and ensure that future engineers are equipped with the skills to leverage digital tools effectively. Although emerging topics such as sustainability and human engineering show promise, further research is needed to address the social, environmental, and human-centered aspects of digital technologies. The findings of this study serve as a foundation for future research in Digital Engineering, suggesting that collaboration between academia, industry, and policy makers will be essential in advancing the application and integration of digital technologies into engineering practices.

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