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Research Trends in Cyber-Physical Systems within Information Systems: A Bibliometric Approach

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ABSTRACT

This study presents a comprehensive bibliometric analysis of research trends in Cyber-Physical Systems (CPS) within the Information Systems (IS) domain, utilizing data from the Scopus database (2010–2025) and analyzed using VOSviewer. By examining keyword co-occurrence, overlay mapping, density visualization, and collaboration networks, the study identifies the thematic structure, intellectual linkages, and global research collaborations shaping the CPS–IS landscape. Results reveal that CPS research is highly interdisciplinary, with central themes including internet of things, network security, machine learning, and information management, while emerging areas such as digital twin, intrusion detection, and false data injection attacks are gaining momentum. The overlay visualization indicates a recent shift toward AI-driven security and optimization in CPS applications. Authorship and country collaboration analyses highlight China, the United States, Germany, and India as leading contributors with extensive international linkages. This study contributes to the theoretical understanding of CPS as an integrated socio-technical construct in IS and provides practical insights for aligning research, policy, and industrial strategies with evolving technological priorities in the era of Industry 4.0.

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1. INTRODUCTION

The convergence of digital technologies with physical systems has fundamentally reshaped the architecture of modern information systems [1]. At the center of this transformation lies the concept of Cyber-Physical Systems (CPS)—integrated systems that combine computation, networking, and physical processes. Initially developed in engineering and control domains, CPS has since permeated various aspects of business, manufacturing, health, transportation, and service systems. Within the Information Systems (IS) domain, CPS is no longer a peripheral trend; it is becoming a pivotal framework to understand how data, devices, and decision-making processes interact in real-time environments [2], [3]. The integration of CPS into IS enables enterprises to build smarter, adaptive, and resilient systems capable of autonomous decision-making.

The rise of Industry 4.0 has further accelerated the application of CPS in organizational contexts. Enterprises are increasingly adopting CPS to support real-time analytics, intelligent automation, and

digital twins, which collectively drive digital transformation initiatives [4]. These systems enable seamless data exchange between operational technology (OT) and information technology (IT), facilitating improved process control and strategic agility. As organizations pursue digital maturity, the need to align CPS capabilities with information systems theories and architectures becomes even more pronounced [5]. This shift marks a significant evolution in how information systems are designed, implemented, and evaluated in real-world applications.

In academic research, CPS has traditionally been explored from a technical or engineering perspective. However, there is a growing acknowledgment that CPS must also be examined through an information systems lens, especially as the technology becomes embedded in business models and digital platforms. Researchers in IS are increasingly investigating topics such as CPS-enabled business processes, cybersecurity challenges in hybrid environments, and governance frameworks for CPS implementation [6], [7]. These developments have broadened the disciplinary boundaries of CPS research, bringing to light the need for a more holistic understanding of its positioning within IS literature.

Despite the growing relevance of CPS in IS, systematic assessments of research trends, knowledge structures, and thematic evolution remain limited. While a number of bibliometric analyses have been conducted on CPS in engineering or computer science [8], very few studies have mapped the intellectual landscape of CPS within the context of information systems. Such an analysis is crucial to reveal dominant research themes, influential authors and publications, and emerging areas that could define future scholarly work. The dynamic and interdisciplinary nature of CPS calls for a comprehensive bibliometric investigation that bridges the technical and organizational dimensions of IS.

Furthermore, understanding how CPS research aligns with core IS concerns—such as system integration, digital infrastructure, user interaction, and strategic alignment—offers valuable insights for both academics and practitioners. As CPS continues to evolve, its influence on enterprise architectures, innovation management, and service design will likely expand. A bibliometric approach allows us to trace these developments over time, identify gaps in current research, and suggest directions for a more integrated body of knowledge. By synthesizing existing literature through objective and visual methods, scholars can gain a deeper appreciation of how CPS is shaping the IS domain and vice versa.

Although the significance of Cyber-Physical Systems within Information Systems is increasingly recognized, there is a lack of systematic and visualized analysis regarding how CPS has been researched, conceptualized, and applied in IS literature. Most prior studies focus on CPS from technical standpoints without adequately capturing how IS scholars contribute to or engage with the topic. The absence of a consolidated bibliometric mapping limits the academic community's ability to discern the core themes, collaborative networks, publication trends, and theoretical intersections between CPS and IS. Without such insights, future research risks fragmentation, theoretical redundancy, and missed opportunities for interdisciplinary innovation. This study aims to fill the aforementioned gap by conducting a comprehensive bibliometric analysis of research trends on Cyber-Physical Systems within the Information Systems domain.

2. METHOD

This study employs a bibliometric analysis using VOSviewer to explore the development and thematic structure of research on Cyber-Physical Systems (CPS) within the Information Systems (IS) domain. Bibliometric analysis offers a systematic, quantitative method to evaluate scholarly outputs, enabling researchers to identify key themes, influential publications, and collaborative networks within a specific research area [9]. In this study, VOSviewer was chosen because of its proven capability in constructing and visualizing bibliometric

maps, making it particularly suitable for uncovering relationships among keywords, authors, and citations in a large body of literature.

The dataset was retrieved exclusively from the Scopus database due to its extensive coverage of peer-reviewed literature in both technical and managerial disciplines. A carefully designed search query was applied to capture publications containing the terms "Cyber-Physical Systems" and "Information Systems" in the title, abstract, or keywords. To maintain focus and relevance, the study included only journal articles and conference papers published between 2010 and 2025 in English. This period was selected to encompass the rapid rise of Industry 4.0 and the subsequent integration of CPS concepts into organizational and information systems research. All bibliographic records were downloaded in CSV format compatible with VOSviewer's data processing requirements.

Once the data were prepared, VOSviewer was used to conduct co-occurrence analysis of keywords, co-authorship network mapping, and citation analysis. The co-occurrence analysis helped identify dominant research themes and emerging topics by visualizing how frequently keywords appear together across the dataset. Co-authorship mapping revealed collaboration patterns among researchers and institutions, while citation mapping highlighted influential studies and their interconnections.

3. RESULT AND DISCUSSION

3.1 Keyword Co-Occurrence Analysis

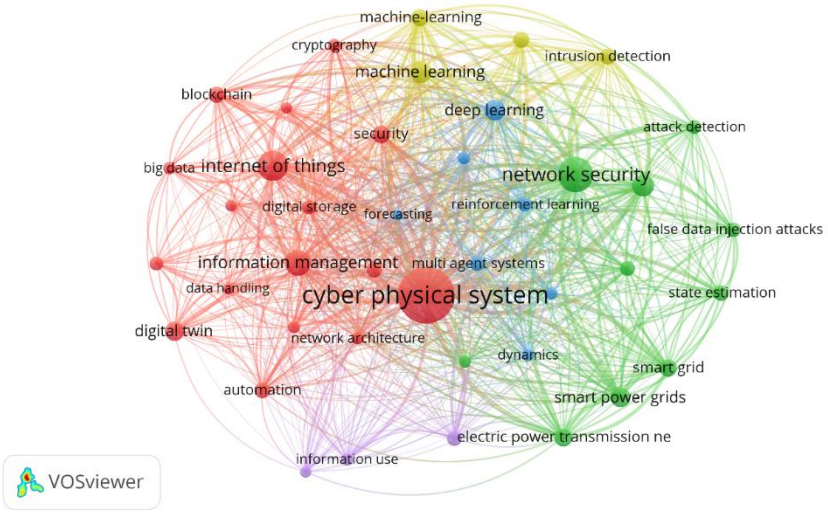

Figure 1. Network Visualization
Source: Data Analysis

Figure 1 illustrates the **keyword co-occurrence map** for Cyber-Physical Systems (CPS) research within the Information Systems domain. At the core of the map lies the dominant keyword "cyber physical system," represented with the largest node, signifying its centrality and highest frequency of occurrence in the dataset. This central positioning reflects CPS as the primary thematic anchor linking multiple research directions, from technical infrastructures to applied domains. Surrounding this core are distinct but interconnected thematic clusters, each represented by a different color, indicating subfields or related research topics that frequently appear together in publications.

The **red cluster**, which includes terms like *internet of things*, *information management*, *digital twin*, and *blockchain*, highlights research that integrates CPS with data-driven and networked technologies. The Internet of Things (IoT) is particularly prominent here, underscoring its close relationship with CPS in enabling real-time monitoring and control in interconnected environments.

Concepts such as digital twins and blockchain indicate a growing interest in using virtual modeling and distributed ledger technologies to enhance CPS performance, security, and reliability within information systems. This cluster represents the data-centric and integration-focused dimension of CPS research.

The **green cluster** focuses on *network security*, *smart grids*, *state estimation*, and *false data injection attacks*, revealing a strong emphasis on cybersecurity and resilience in CPS-enabled infrastructures. Much of this work deals with safeguarding critical systems—especially in the energy sector—against cyber threats that can disrupt physical processes. The prominence of terms like *attack detection* and *intrusion detection* reflects the ongoing challenge of protecting hybrid cyber-physical environments, where vulnerabilities in digital systems can have tangible impacts on physical assets and services. This cluster captures the risk management and protection aspect of CPS research.

The **yellow cluster**, featuring keywords such as *machine learning*, *deep learning*, and *reinforcement learning*, illustrates the role of artificial intelligence in enhancing CPS capabilities. These methods are applied for predictive analytics, anomaly detection, and adaptive control in dynamic environments. The close connections between AI terms and CPS suggest a trend toward embedding intelligence into physical systems to enable autonomy, optimization, and self-healing capabilities. This aligns with broader developments in Industry 4.0, where AI-driven CPS solutions are transforming industrial operations and decision-making processes.

The **purple and blue clusters** include terms like *network architecture*, *multi agent systems*, *dynamics*, and *electric power transmission*, which represent the infrastructural and operational backbone of CPS. The purple cluster leans toward system design and architectural concerns, while the blue cluster captures engineering and control elements, including how CPS interacts with power systems and other physical infrastructures. Together, these clusters highlight the foundational research that supports the implementation of CPS across various domains, ensuring scalability, interoperability, and efficient operation.

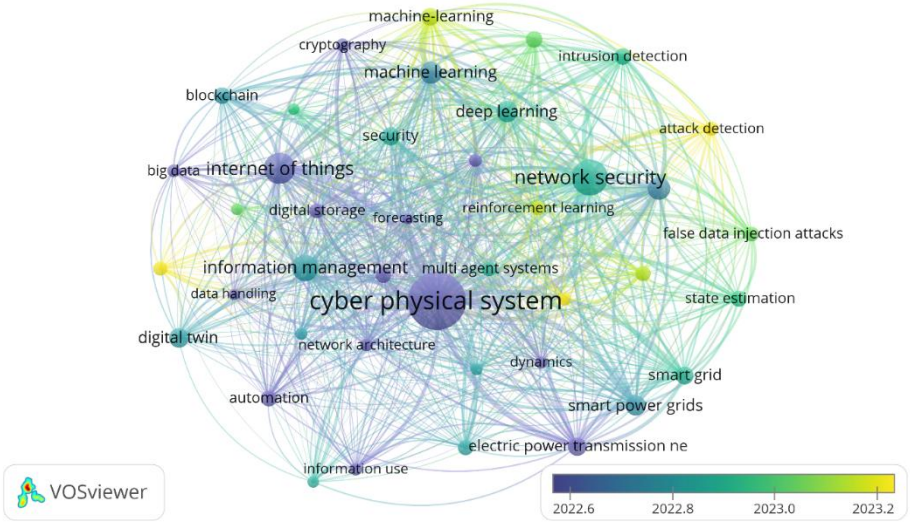

Figure 2. Overlay Visualization
Source: Data Analysis

Figure 2 presents the **temporal evolution** of research keywords related to Cyber-Physical Systems (CPS) within the Information Systems domain. The color gradient—from dark blue (earlier occurrences) to yellow (more recent occurrences)—highlights how specific themes have emerged or evolved over time. Core terms such as *cyber physical system*, *internet of things*, and *information management* appear in darker shades, suggesting that they have been central to the discourse for a longer period, serving as foundational concepts in the literature. In contrast, newer research directions, such as *intrusion detection*, *attack detection*, and *digital twin*, are shaded in lighter green to yellow, reflecting their recent surge in attention and their role in shaping the current research agenda.

A closer look at the temporal spread reveals that **security-oriented topics** (*network security*, *false data injection attacks*, *state estimation*) and **AI-driven approaches** (*reinforcement learning*, *deep learning*) have gained prominence in the last two to three years. This trend suggests a shift from purely infrastructural discussions toward addressing operational risks and enhancing system autonomy. The progression from blue to yellow around these nodes indicates that the research community is increasingly focused on applying machine learning techniques to secure and optimize CPS operations, especially in critical sectors like energy and manufacturing. The prominence of these recent topics underscores the growing recognition of CPS as complex, adaptive systems requiring robust, intelligent control mechanisms.

Simultaneously, some technical foundations—like *network architecture*, *multi agent systems*, and *electric power transmission*—remain in darker to mid-range hues, reflecting their consistent but less recently intensified research activity. This suggests that while these areas form the backbone of CPS studies, much of the novel academic momentum is concentrated in integrating advanced analytics, security frameworks, and cross-domain applications. The interplay of enduring foundational themes and emerging specialized topics points toward a maturing research field, where established knowledge is being extended through innovative, application-driven inquiries.

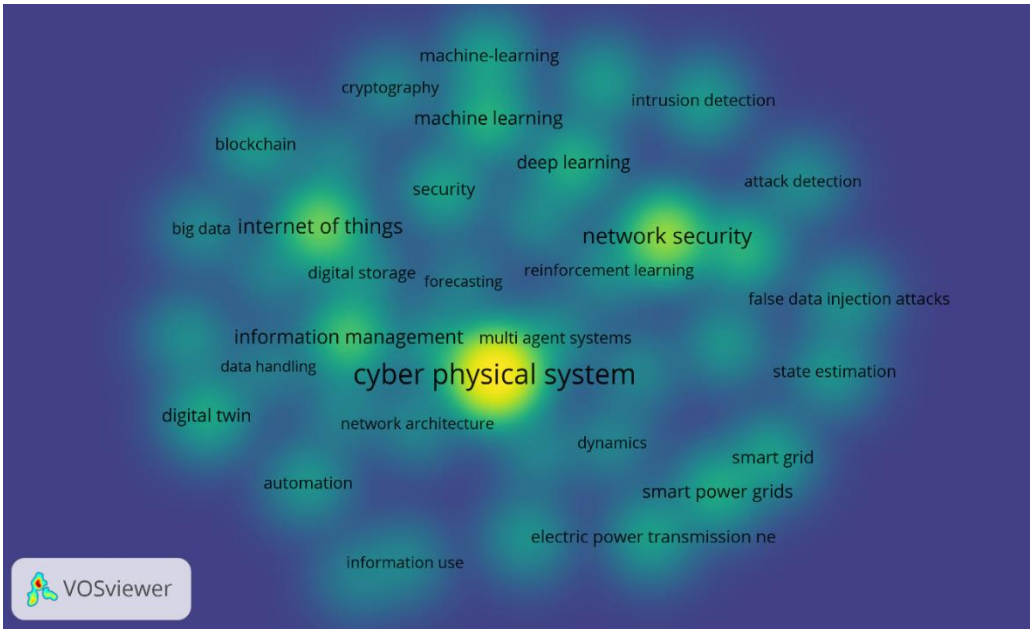

Figure 3. Density Visualization
Source: Data Analysis

Figure 3 illustrates the **frequency and prominence** of keyword usage in Cyber-Physical Systems (CPS) research within the Information Systems domain. Brighter yellow areas represent terms that appear most frequently in the dataset, while darker blue or green regions indicate less frequent but still relevant keywords. The term *cyber physical system* stands out as the most dominant and centrally positioned keyword, reflecting its role as the conceptual hub that connects various research themes. Surrounding high-density areas include *internet of things*, *network security*, *information management*, and *machine learning*, signifying their strong co-occurrence and central importance in the CPS–IS knowledge structure. Beyond these core terms, other high-density clusters reveal specialized research trajectories. For example, *digital twin* and *blockchain* appear in moderately dense zones, suggesting growing but not yet dominant research attention. Similarly, *smart grid*, *false data injection attacks*, and *intrusion detection* are positioned in areas of notable density, indicating their importance in security and infrastructure-focused studies.

3.2 *Co-Authorship Analysis*

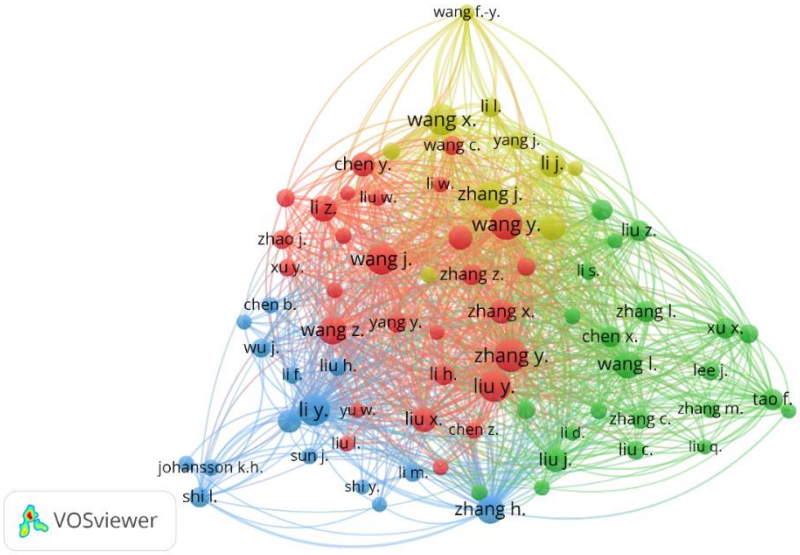

Figure 4. Author Visualization
Source: Data Analysis

Figure 4 shows a dense and highly collaborative research community in the field of Cyber-Physical Systems within Information Systems. Each node represents an author, with the node size proportional to the number of publications, and the colors indicating distinct collaboration clusters. The central cluster, dominated by authors such as *Wang J.*, *Zhang Y.*, and *Liu Y.*, reflects the most prolific and interconnected group, suggesting their significant influence on the field's development. Other notable clusters, such as those involving *Johansson K.H.* and *Shi Y.*, indicate smaller but still well-linked collaborative networks. The high density of links between clusters highlights a strong degree of interconnection, implying active cross-group cooperation and knowledge exchange. This structure suggests that the research landscape is driven by a mix of tightly knit core contributors and diverse collaborative efforts spanning geographical and institutional boundaries.

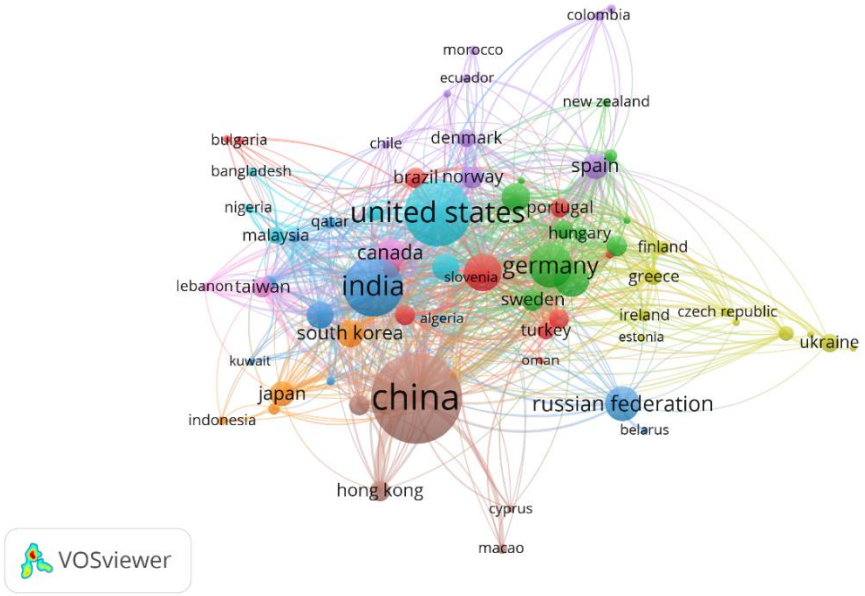

Figure 5. Country Visualization
Source: Data Analysis

Figure map illustrates the global research network on Cyber-Physical Systems within the Information Systems domain, highlighting the most active and interconnected nations. China emerges as the largest and most central node, indicating its dominant publication volume and extensive international collaborations, particularly with the United States, Germany, and India. The United States, positioned prominently in the network, also shows strong cross-continental partnerships, linking with both Asian and European research hubs. Germany serves as a major European connector, bridging collaborations across the EU, including with Spain, Sweden, and Finland. Notably, countries like Japan, South Korea, and the Russian Federation form significant regional clusters but also maintain global linkages. The dense web of connections suggests that CPS research is a highly international endeavor, with collaborative efforts spanning diverse geopolitical regions, enhancing knowledge exchange and fostering innovation through cross-border partnerships.

3.3 Citation Analysis

Table 1. Most Cited Article

Citations	Author and Year	Title
791	[10]	Age of Information: An Introduction and Survey
624	[11]	Digital twin paradigm: A systematic literature review
563	[12]	From Artificial Intelligence to Explainable Artificial Intelligence in Industry 4.0: A Survey on What, How, and Where
484	[13]	Prognostics and Health Management (PHM): Where are we and where do we (need to) go in theory and practice
385	[14]	Cyber-physical systems architectures for industrial internet of things applications in Industry 4.0: A literature review

Citations	Author and Year	Title
371	[15]	Blockchain for the Internet of Vehicles towards Intelligent Transportation Systems: A Survey
337	[16]	Digital twin and its implementations in the civil engineering sector
327	[17]	Deep Learning Based Attack Detection for Cyber-Physical System Cybersecurity: A Survey
322	[18]	Navigating the confluence of artificial intelligence and education for sustainable development in the era of industry 4.0: Challenges, opportunities, and ethical dimensions
272	[19]	Differentiating digital twin from digital shadow: Elucidating a paradigm shift to expedite a smart, sustainable built environment

Source: Scopus, 2025

3.4 Practical Implication

The findings of this bibliometric study have several practical implications for policymakers, industry practitioners, and research institutions engaged in Cyber-Physical Systems (CPS) within the Information Systems (IS) domain. First, the prominence of keywords such as *internet of things*, *network security*, and *machine learning* highlights the need for organizations to invest in cross-disciplinary capabilities that bridge operational technology and IT security. This is particularly relevant for sectors such as energy, manufacturing, and transportation, where CPS adoption can deliver real-time operational intelligence but also exposes systems to heightened cybersecurity risks. Second, the global collaboration patterns indicate that fostering **international research partnerships** can accelerate innovation by combining complementary expertise, particularly between high-output countries like China, the United States, Germany, and India. Finally, industry players can use these insights to identify emerging focus areas—such as digital twins, smart grids, and intrusion detection systems—and align R&D investments with these evolving technological priorities to maintain competitiveness in Industry 4.0 and beyond.

3.5 Theoretical Contribution

From a theoretical perspective, this study contributes to the literature by mapping the intellectual structure and thematic evolution of CPS research within the IS discipline using bibliometric analysis. It extends the understanding of CPS beyond its engineering roots, framing it as an interdisciplinary construct embedded in the socio-technical fabric of information systems. The keyword co-occurrence, overlay, density, and authorship/country collaboration maps collectively demonstrate how CPS research integrates **technical, organizational, and strategic perspectives**, thereby offering a richer conceptualization of CPS as both a technological infrastructure and a driver of digital transformation. Moreover, by identifying the convergence of AI, IoT, and security research streams, this study provides an empirical basis for developing **integrative frameworks** that connect technological capabilities with organizational outcomes in CPS-enabled IS environments.

3.6 Limitations

Despite its comprehensive scope, the study has several limitations. First, the dataset was drawn exclusively from the Scopus database, which, while extensive, may not fully capture relevant publications indexed in other databases such as Web of Science, IEEE Xplore, or specialized repositories. This could result in a partial view of the research landscape, especially for region-specific or industry-focused studies. Second, the bibliometric analysis was based on title, abstract, and keyword fields, meaning that some relevant studies might have been omitted if they did not explicitly include CPS-related terms in these

metadata. Third, the methodology captures patterns of scholarly output and collaboration but does not assess the **qualitative depth** or practical impact of individual studies. Finally, as the field is rapidly evolving, the results represent a snapshot in time, and future analyses will be necessary to track emerging technologies, shifting thematic priorities, and evolving global collaborations.

3.7 Conclusion

This bibliometric study provides a comprehensive overview of research trends, thematic structures, and collaboration networks in the field of Cyber-Physical Systems (CPS) within the Information Systems (IS) domain. The findings reveal that CPS research is inherently interdisciplinary, integrating technological foundations such as IoT, machine learning, and network security with strategic and organizational perspectives relevant to IS. The analysis of keyword co-occurrence, temporal evolution, density mapping, and authorship/country collaborations demonstrates that while core topics like *cyber physical system* and *internet of things* remain central, emerging themes—such as *digital twin*, *intrusion detection*, and *false data injection attacks*—are driving new research directions. Strong international collaborations, particularly among China, the United States, Germany, and India, underline the global nature of CPS innovation and knowledge exchange. By mapping the intellectual landscape, this study not only highlights the current state of the field but also identifies opportunities for advancing CPS research toward more secure, intelligent, and integrated IS solutions in the era of Industry 4.0 and beyond.

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