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SYSTEM DYNAMICS AND DIGITAL TWINS: A BIBLIOMETRIC INSIGHT INTO REAL-TIME DATA INTEGRATION

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Abstract

With the increasing complexity of business systems, there is a growing need for models that support real-time decision-making based on up-to-date data and dynamic system behaviour. One direction is the integration of system dynamics, a methodology for modeling complex systems based on feedback loops, with digital twins that enable real-time data integration. Although interest in combining system dynamics with other methods is increasing, the methodological connection between these two approaches is still insufficiently explored. This paper presents a bibliometric analysis of existing research in area of digital twins and system dynamics, using the Scopus, Web of Science and IEEE scientific literature databases. The analysis identifies leading researchers, journals, conferences, research groups, and scientific-professional associations active in this field. The database query resulted in 236 publications after 79 duplicates were removed. Based on the analysis and defined criteria, three researchers, three journals, three conferences, and scientific-professional sources were selected. The presented results reveal publication trends and collaboration networks, as well as existing research gaps that hinder practical integration. The research findings will contribute to concrete practical application in future phases, aiming to connect system dynamics with real-time data.

Keywords: system dynamics; digital twins; real-time data; bibliometric analysis; simulation modeling

1. Introduction

Understanding and modeling complex systems is important for decision-making under conditions of uncertainty [1], [2]. In this context, there is an increasing need for the integration of models with up-to-date data to ensure adaptability and accuracy of predictions in dynamic environments [3]. The application of computer models enables the simulation of different scenarios and the prediction of possible consequences of decisions before they are implemented in the real system. Such models are used in a wide range of domains – from business management and production to ecological systems [4], [1]. There are numerous methodologies for modeling complex systems, but for the purpose of this research, system dynamics was chosen. System dynamics was chosen due to the ability to view the system as a whole and to observe feedback loops, flows in the system, as well as stock accumulation, which is especially relevant nowadays when the need for circularity is growing, and in that context, it is increasingly important to monitor where resources go in enterprises.

Originally developed for understanding long-term changes in complex systems, system dynamics today increasingly require extensions in order to respond to the challenges of an ever-changing environment [5], [6], [2]. Its application is widely spread in the field of business decision-making, sustainable development, resource management, and process optimization [7], [5], [2]. Classical system dynamics models primarily rely on historical data, which can limit their ability to predict in dynamic systems [8]. One of the potential solutions to this problem is the connection of system dynamics with the digital twin methodology, which enables the integration of real-time data into simulation models. Digital twins enable dynamic modeling and process optimization based on real-time data [9], [10], [11]. The use of real-time data, as a concept of digital twins, allows for the adjustment of models and decision-making based on current conditions, thereby increasing the accuracy and efficiency of the process [12], [2]. However, there still exists a research gap in how digital twins can relate to system dynamics to improve the precision of predictions and adaptability of the models. The motivation for studying the topic of this paper arose from participation in the project focused on modeling and circular economy, and from the motivation due to the identified gap in current research.

The aim of this paper is to conduct a bibliometric analysis of relevant literature to explore the current state of research in the field of connecting system dynamics and digital twins. The following are the research questions that will be answered in this paper, and it is noted that the questions are related to the field of system dynamics and digital twins: Who are the leading researchers in the research field and their research groups?; What are the two to three strongest scientific journals in the field?; What are the three strongest international conference in this field?; What international scientific-professional associations operate in this field?

In the paper, after the introduction, materials and methods are presented for the purpose of literature search. This is followed by the results chapter where the results obtained by searching databases are presented. Then, a discussion describes the review of the results obtained, with a conclusion at the end.

2. Methods

The paper uses a bibliometric analysis closely related to system dynamics as a methodology in combination with the methodology of digital twins in the form of real-time data. In order to reach relevant publications on the mentioned topic, the Scopus, WoS and IEEE databases were used. It was necessary to create a query that would cover a satisfactory spectrum of publications in order to conduct research and analysis. The search strategy was focused on the areas of system modeling and digital twins. Considering that system modeling is a broad term, it was decided to immediately concentrate on the area of system dynamics. Likewise, when speaking of digital twins in this context, they are often also referred to as real-time data, the concept of which is indeed part of the scope of this research. The keywords were selected for the purpose of accurately searching for relevant information on the possibility of connecting the methodology of system dynamics and digital twins, as real-time data.
It was decided that in all databases the query would be used:

TITLE-ABS-KEY (("system dynamics" OR "system modeling" OR "dynamics system*" OR "simulation modeling") AND ("decision-making" OR "sustainability" OR "business process*" OR "resource management") AND ("real-time data" OR "digital twin" OR "data-driven simulation" OR "predictive analytics" OR "Internet of Things" OR "IoT")) AND PUBYEAR > 2001 AND PUBYEAR < 2026

The stated query was originally created in the Scopus database, but the same query was also used in other databases, Web of Science and IEEE, with only the names of the search fields being different. The search field in Scopus was "title, abstract, keywords", in Web of Science it was "Topic" (which also covers titles of papers, abstracts, and keywords), while in IEEE there is no similar way to select the search field, therefore the "Abstract" field was selected. The year set as a limit in the query, 2002. is the year when the concept of digital twins was first mentioned.
In the paper, as the research questions state, the most significant researchers, their research groups, scientific journals, scientific conferences, and international scientific-professional associations are determined according to precisely defined criteria.

Researchers were included in the selection if they met at least three of the following four criteria: if there is at least one publication relevant to the field of system dynamics and digital twins, if there is citation of relevant publications in the field of system dynamics and digital twins, editorial membership in at least one scientific journal, and the total citation count of relevant works related to the topic of system dynamics and digital twins must be greater than 40. Authors whose works are not cited, authors whose research is not connected with the research area related to system dynamics and digital twins, and those who have not published in scientific journals were excluded from the analysis. For each author, it is also a condition that they must be active in at least one research group.

The initial set of journals is identified by searching in relevant databases using the predefined query, with all journals that publish works related to digital twins and system dynamics initially included. In order to keep the analysis focused on the most relevant sources, journals that primarily cover medical topics were excluded from the set, except if they directly deal with system modeling. By reviewing the Scimago Journal Country Rank, journals with a small number of citations and those not belonging to ranked categories were also eliminated. For the ranking of the remaining journals, criteria of impact in the academic community were used according to inclusion in the Q1 or Q2 quartile according to SJR, as well as the citation of relevant works published in a particular journal by reviewing Research Gate. Priority was given

to journals in the Q1 quartile with a higher H-index and greater citation count. For the analysis of relevant scientific conferences, clear selection criteria were defined, which include inclusion and exclusion criteria. Selected conferences must be thematically related to system dynamics and digital twins and have international recognition. Priority is given to conferences whose papers are indexed in the Scopus, WoS, or IEEE databases and those with a long-standing tradition. Scientific conferences excluded from the initial set are those conferences held at irregular intervals or one-time conferences.

The selection criterion for scientific-professional associations was the sponsorship of scientific conferences identified as the most prominent. For additional review of the content of identified scientific-professional associations, the Google search engine was used.

3. Results

The aforementioned search resulted in a total of 236 publications; the total number was obtained after eliminating duplicates, of which there were 79 duplicates in total.

Table 1 shows the most relevant authors of the published publications related to the research area, as well as their research groups. Additionally, the table shows whether the author is an editor of a scientific journal and which ones, as well as the number of papers related to the research area and the citation count of the papers. Table 1 was created after the application of the criteria described in the chapter "Materials and Methods", and after applying the criteria, only three authors were obtained.

Author	Research groups[1]	Journal editorial[1]	Number of papers related to system dynamics and digital twins	Citation count of selected papers[2]
Hu, Xiaolin	SIMS Lab (Georgia State University) - USA	International Journal of Modeling, Simulation, and Scientific Computing (IJMSSC), and International Journal of Agent Technologies and Systems (IJATS)	6	49
Ding, Zhikun	TRIZ and patent laboratory (TP Lab - Shenzhen University), Guangdong Laboratory of Artificial Intelligence and Digital Economy(SZ) - China	/	3	509
Onggo, Bhakti Stephan	Centre for Operational Research, Management Science and Information Systems (CORMSIS) - UK	Journal of Simulation	4	177

[1] Source: Websites of institutions and researcher profiles (Scopus, ORCID profile, ResearchGate profile)
[2] Source: Scopus

Table 1. Overview of the leading researchers

Table 2 shows the most relevant journals of published publications related to the research area through a presentation of the total citation count of selected papers, Q and H-index of the scientific journal, and additionally the publications where the potential for further research on the research topic was recognized (references).

Journal	Total citation counts of papers on ResearchGate	Q1[1]	H-index[1]	References

System Dynamics Review	SIMS Lab (Georgia State University) - USA	International Journal of Modeling, Simulation, and Scientific Computing (IJMSSC), and International Journal of Agent Technologies and Systems (IJATS)	65	[13], [14]
IEEE Access	TRIZ and patent laboratory (TP Lab - Shenzhen University), Guangdong Laboratory of Artificial Intelligence and Digital Economy(SZ) - China	/	243	[15], [16]
Sustainability	Centre for Operational Research, Management Science and Information Systems (CORMSIS) - UK	Journal of Simulation	169	[17], [18], [19], [4]
[1] Source: Scimago Journal & Country Rank				

Table 2. Overview of the leading journals

Table 3 provides an overview of the most relevant conferences based on the number of publications retrieved through database queries, the publisher, and the H-index of each conference. A review of relevant scientific conferences is also important due to their thematic focus, which provides insight into current research and technological trends. As stated, the focus of this paper is on the topic of digital twins and system dynamics, as interconnected methodologies for the simulation, analysis, and optimization of complex systems. A clear example of thematic alignment can be seen in the DAAAM conference: For instance, [20] demonstrate how the digital twin methodology is implemented in the context of intelligent automation, with particular emphasis on the integration of physical and virtual systems, creating opportunities for dynamic modeling of system behavior over time [20]. [21] further highlight the challenges in developing digital twins for technologically complex environments, in which key elements—such as feedback loops, accumulations, and time delays—are precisely those addressed by system dynamics. [22] explore the visualization and dynamic analysis of spatial manipulators with closed structure, providing a concrete example of the use of mathematical modeling and simulation within virtual environments, which is highly relevant to digital twin development [22].

Conference	**Number of publications[1]**	**Publisher[2]**	**H-index[3]**	**Sponsor (Scientific-Professional Associations)[4]**
Winter Simulation Conference	5	ACM, IEEE	64	ASA
DAAAM (Danube Adria Association For Automation & Manufacturing)	3		22	DAAAM International Vienna
International Academic Mindtrek Conference	2	ACM	12	ACM
[1] Number of publications obtained by querying the Scopus, WoS and IEEE databases [2] Source: Official websites of scientific conferences [3] Source: Scimago Journal & Country Rank [4] Source: Official websites of the conference and proceedings				

Table 3. Overview of the leading conferences

Recognized scientific-professional associations include the Association for Computing Machinery (ACM), DAAAM International Vienna and the American Statistical Association (ASA).

4. Discussion

The use of bibliometric analysis enabled the identification of the most prominent researchers, scientific journals, and conferences in the field of system dynamics and digital twins. This approach is based on objective data from relevant scientific databases (Scopus, IEEE, WoS), ensuring an unbiased mapping of the research field. The identification of researchers Hu X., Zhikun D., and Onggo B. S. confirms that the analyzed publications are focused on advanced research in systems modeling and digital twins and provides an overview of researchers based on predefined criteria. The inclusion of research groups contributes to understanding the organizational context of the research and the influence of specific institutions on the development of the field.

The established inclusion and exclusion criteria enabled the formation of the final results. The focus on indexed papers contributed to ensuring scientific quality, but at the same time, there is a possibility of excluding smaller, yet innovative studies that are not part of major academic databases. Additionally, the elimination of journals and conferences with a low impact factor meant that sources such as Sustainability, IEEE Access, and System Dynamics Review were recognized as leading in the field, but niche publications with specialized audiences may have been omitted.

The selection of keywords was fundamental to the relevance of the search. By using terms such as system dynamics, digital twin, and real-time data, precise filtering of publications was enabled, but publications using alternative terminology may have been overlooked.

The results of the journal and conference analysis confirm that the identified sources are key to the scientific community in this field. The high H-index of journals such as IEEE Access (243) and System Dynamics Review (65) indicates their scientific importance and impact. The journals presented in Table 2 cover a wide range of research topics.

With the selected journals, coverage of the research themes is ensured, whereby Sustainability and System Dynamics Review cover sustainability and system dynamics, while IEEE Access addresses the technical aspects of digital twins and simulation models. Conferences such as the Winter Simulation Conference, DAAAM, and International Academic Mindtrek Conference have also proven to be relevant for the exchange of the latest research.

In terms of research limitations, it is possible that the inclusion of additional databases would allow a broader understanding of the interconnections within the field.

5. Conclusion

The research provided a bibliometric analysis of literature in the field of integrating system dynamics and digital twins. Using bibliometric analysis, the most prominent researchers, leading scientific journals, conferences, as well as relevant research institutions and associations were identified. The results show that in recent years there has been a significant increase in the number of publications in this field, especially in 2024. The advantages of this research include quantitative analysis of trends, as well as a foundation for future research. The study also has certain limitations. These include the exclusive focus on publications in selected databases (WoS, Scopus, and IEEE), which may result in missing relevant papers from other sources.

The literature review identified a research gap, namely that there is still no established methodology for linking digital twins and system dynamics. The lack of such a methodology, as identified through this quantitative research, lays the groundwork for new practical research and further investigation toward the development of a methodology. Importantly, to date, no bibliometric study has specifically addressed the integration of system dynamics and digital twins. This makes the presented analysis valuable foundation for future research. By mapping the current scientific state, this paper lays the groundwork for a more structured approach to methodological development in this emerging field. The results show that, despite increasing interest, there is still no standardized or widely accepted framework for the integration of real-time data from digital twins into system dynamics models. This research gap reveals a need for interdisciplinary efforts. Future studies can expand on this work by exploring concrete case studies, developing domain-specific integration frameworks.

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