PRISMA 2020 Checklist (Partial only)

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	n.a.
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	n.a.
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Generative artificial intelligence (genAI) plays a key role in improving AI-based digital twins (DTs), enabling more dynamic, adaptive, and accurate industrial simulations, essential as Industry 5.0/6.0 paradigms evolve and are implemented. In industry, genAI can simulate complex manufacturing processes or entire production lines, enabling companies to optimize operations, predict maintenance needs, reduce downtime, and develop more scenarios for correct operation (e.g., for faster transitions to new products or new materials) and address potential failures. GenAI also helps DTs continuously learn and evolve by generating new data and scenarios based on historical and current inputs. This capability ensures that DTs remain current and reflective of the real systems they represent, for both operational and training purposes (e.g., training operators for situations that rarely occur on a real production line). Furthermore, it facilitates the creation of synthetic data, which is important for training AI models when real-world data is scarce or expensive. This accelerates the development and improvement of DTs, increases the predictive accuracy, personalization, and operational efficiency of AI-based digital twins, making them more reliable and versatile tools in medicine and industry. However, in addition to strengths, it is also worth considering threats to prepare for risk mitigation. This article helps you capture and maintain a balance between opportunities and threats in this area..
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Within this work, the following research questions (RQs) were formulated: 1. leading topics and years of publication, 2. leading authors, their affiliations and countries, 3. leading sources of founding and ESGs.
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Criteria for inclusion of articles in the review: English-language original and review articles, also full-text conference articles and chapters in books, open source, indexed by major bibliometric databases: WoS and Scopus. (2016-2025) Criteria for exclusion from the review: languages other than English, other forms of publication (reports, abstracts, etc.),



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			no full text available Open Source, older than 2016.
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	WoS, Scopus
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Detailed sets of English keywords were also defined, reflecting the main thematic areas of the review. Exemplary, carefully constructed search strings included combinations of terms like "generative AI", "digital twin", "industry", "Industry 5.0" and "Industry 6.0". Appropriate logical operators (AND, OR) and phrases enclosed in quotation marks were used to precisely narrow down or broaden search results.
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	The final phase comprised the selection and data extraction process. Initially, a comprehensive pool of articles was gathered based on the defined keywords. A preliminary selection was then conducted, assessing thematic relevance based on titles and abstracts, thereby eliminating publications that clearly didn't meet the established criteria. For the remaining, initially qualified articles, a full content analysis was carried out to verify their scientific quality. At this stage, the bibliographies of highly rated articles were reviewed to identify additional, valuable sources that might have been missed in the initial search.
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	From each finally selected article, key information was meticulously extracted, such as the method applied, the specific area of application within the IIoT environment, and the main results achieved and practical applications. The data collected in this manner served to construct section 3, enabling systematic categorisation and an in-depth analysis of current research trends in the discussed field. As a result of this rigorous and systematic review, over 45 carefully selected publications were analysed, forming a solid basis for drawing conclusions regarding the potential, challenges, and directions for further research on the application of fuzzy set theory in the context of ensuring IIoT system security.
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	n.a.
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	n.a.
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	n.a.



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Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	n.a.
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Article subsection 2
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	n.a.
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	n.a.
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	n.a.
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	n.a.
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	n.a.
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	n.a.
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	n.a.
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	n.a.
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	n.a.
Study characteristics	17	Cite each included study and present its characteristics.	n.a.
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	n.a.
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	n.a.
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	n.a.
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Article Section 3 and section 4
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	n.a.
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	n.a.

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Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	n.a.
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	n.a.
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Article Discussion section
	23b	Discuss any limitations of the evidence included in the review.	n.a.
	23c	Discuss any limitations of the review processes used.	n.a.
	23d	Discuss implications of the results for practice, policy, and future research.	n.a.
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	n.a.
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	n.a.
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	n.a.
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	n.a.
Competing interests	26	Declare any competing interests of review authors.	n.a.
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	n.a.

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