Systematic Literature Review on Digital Twin Architectures for TwinArch Design

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ABSTRACT

The Systematic Literature Review process documented in this documentation is the SLR conducted in the "TwinArch: A Digital Twin Reference Architecture" work. The conducted systematic literature reviews aims at investigating the state-of-the-art on Digital Twin architectures with respect to the Software Engineering Institute *Views & Beyond* methodology. A good abstract shortly summarizes the paper by covering: (i) a presentation of the topic covered, (ii) the research followed, (iii) the main findings of the study, and (iv) the outcome of the investigation. Please if using this work remeber to cite our work.

KEYWORDS

Systematic Literature Review, Digital Twin, Software Architecture

1 MOTIVATION

Present the topic of the literature review, including background of research field, goal, methodology, and contribution of the paper (e.g., map of the state of the art, reusable classification approach, evaluation of results, discussion of results, and target audience)

2 RELATED WORK

Section dedicated to the related work, i.e., similar / relevant studies, and how your study fits in the overall research picture. Usually, this section includes secondary studies which address the same / similar topic to the one addressed in your study.

3 STUDY DESIGN

3.1 Research Goal

This study aims to characterize the state-of-the-art of Digital Twin architectures with respect to the ISO 42010 standard and the SEI View & Beyond method. The research investigates how current architectural models are designed and documented, adopting the Goal-Question-Metric (GQM) approach [5] to define its core research objective.

Purpose	Characterize
Issue	Digital Twin architectures for
Object	understanding their design and documentation
Viewpoint	from researchers and developers perspective.

3.2 Research Questions

To achieve these goals, we formulated four Research Questions (RQs).

RQ1: *How are the primary studies categorized according to the SEI architectural views?*
Rationale: This research question aims to identify which SEI architectural views are most commonly used to guide the documentation of Digital Twin architectures. Understanding the alignment between the architectural views presented in the primary studies and the ones advocated by SEI (e.g., Module, Component & Connector, and Allocation views) is critical to assessing the adherence of DT architectures to standardized documentation practices.

RQ2: *How are the primary studies classified based on the SEI architectural styles?*
Rationale: The goal of this research question is to determine which architectural styles are most frequently employed and to identify the core elements and relationships commonly found in DT architectures. Architectural styles play a key role in defining system organization, communication, and constraints, and different views may require distinct styles tailored to specific purposes. By examining how these styles are applied, we can uncover patterns in element selection, common relationships, and constraints, offering insights into the design decisions made in the development of DT architectures.

RQ3: *What type of notation (informal, semi-formal, or formal) is mostly used to document DT architectures?*
Rationale: this question focuses on assessing the types of notations and modeling languages employed for documenting DT architectures. Notations can be classified into three categories: informal (e.g., textual descriptions or sketches), semi-formal (e.g., UML diagrams), and formal (e.g., Architecture Description Languages). Understanding the preferred documentation approaches within the field is essential for evaluating how well these notations convey key architectural aspects. By identifying trends in notation usage, we aim to assess how they influence the clarity, precision, and consistency of DT architecture documentation.

3.3 Initial search

The research questions were broken down into facets, and a list of synonyms, abbreviations, and alternative spellings was created for

each term following the guidelines of Kitchenham and Charters [4]. Additional terms were derived from subject headings used in journals and scientific databases. The search string was constructed by combining terms using conjunctions (AND) and disjunctions (OR) for each main concept. To validate its effectiveness, the search string was tested using a set of five control studies [1–3, 6–8] previously identified by one of the authors. The accuracy of the search string was evaluated by verifying if these control studies were successfully retrieved when applied to the Scopus search engine. The finalized search string is the following:

("Digital Twin" **OR** "Virtual Twin" **OR** "Digital Replica" **OR** "Virtual Replica") **AND** (Architect* **OR** Framework **OR** Platform **OR** Document* **OR** View **OR** Style)

The selection process began by executing the search string in the Scopus database on June 2024 that resulted in 5508 studies.

3.4 Application of selection criteria

To support the selection of retrieved studies by the automated search strategy, we defined inclusion and exclusion criteria to include or discard a manuscript.

ic. To be included in our analysis, a study must accomplish all the following ic:

- IC1: The study is related to the topic under investigation, i.e., defining and documenting dts architectures.
- IC2: The study is written in English.
- IC3: The study is peer-reviewed.
- IC4: The study is a primary study.
- IC5: The study has been published after 2019.
  Rationale: Despite dt has over 20-year history, publications on dt architectures have significantly increased since 2019 [**?**].
- IC6: The study was published in journals or conference proceedings.
- IC7: The study was published in high-ranking venues.

ec. We excluded a publication if it satisfies at least one of the five ec listed below:

- EC1: The study is an earlier version of a more recent or complete version that has been identified.
- EC2: The study contains similar content to other studies by the same authors and was published later in different venues.
- EC3: The study treats dts as software characterized solely by simulated models.
- EC4: The study conflates the concept of dts with the Metaverse.
  Rationale: The Metaverse is a virtual world designed for social interactions and immersive experiences, while dts replicate physical assets for operational use.
- EC5: The study confuses the modeling aspects of dts with ai models.
  Rationale: ai models are tailored algorithms for specific analyses, whereas dt offers holistic system representation integrating ai for analytics and prediction.

3.5 Snowballing

If a snowballing approach was used for the literature review, its details should be documented in this subsection

3.6 Data Extraction

Report in this section the data extraction followed to gather the data for the study (e.g., what process did you followed to gather the data in the companion data extraction spreadsheet?)

3.7 Data Synthesis

What approach did you followed to carry out the data synthesis process and summarize the data extracted from the primary studies?

3.8 Study Replicability

To ensure the replicability of the study, you should document in this section the data you make available (e.g. via Google Drive) to replicate the findings, this include: * the research protocol * the complete list of primary studies * the parameters composing the potential classification framework you built * the raw extracted data of each selection phase

3.9 Threats to Validity

In this section, the most prominent threats to validity of your study should be discussed (the following categories are just an example suggestion). They have been moved with study design, as one should consider them before study execution.

3.9.1 External validity.

3.9.2 Internal validity.

3.9.3 Construct validity.

3.9.4 Conclusion validity.

4 RESULTS

In this section, the results of the literature review should be reported. This section can be split up according to the specific focus of the literature review, e.g. Publication Trends, Research Focus, and Potential for Industrial Adoption (see Running example)

5 DISCUSSION

In this section, the results of the literature review should be reported. This section can be split up according to the specific focus of the literature review, e.g. Publication Trends, Research Focus, and Potential for Industrial Adoption (see Running example)

6 CONCLUSION

Conclusion of your investigation, including (i) few sentence to introduce the topic considered, (ii) short summary of the research method followed, (iii) main findings, and (iv) potential implications and future work

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