Journal of Internet Services and Applications, 2023, 13:1, doi: 10.5753/jisa.2023.XXXXXX

Literature Review on Container-Based Virtualization Technologies

José A. Arias-Pinzón **[*Universidad del Quindío | josea.ariasp@uqvirtual.edu.co*]**
Anobis H. Correa-Urbano **[*Universidad del Quindío | anobish.correau@uqvirtual.edu.co*]**
Luis E. Sepúlveda-Rodríguez **[*Universidad del Quindío | lesepulveda@uniquindio.edu.co*]**
Christian A. Candela-Uribe **[*Universidad del Quindío| christiancandela@uniquindio.edu.co*]**

Facultad de ingeniería, Universidad del Quindío, Carrera 15 #12N, Armenia, Quindío, 630001, Colombia.

Received: DD Month YYYY • **Accepted:** DD Month YYYY • **Published:** DD Month YYYY

Abstract Container-based virtualization (CBV) has become a cornerstone of modern IT infrastructure, with technologies such as Docker and Kubernetes dominating application packaging and orchestration, respectively. Despite the proliferation of research in this domain, no existing secondary study systematically maps CBV technologies across both IT domains and academic dimensions (education, research, and outreach). This paper presents a Systematic Mapping Study (SMS) of 226 primary studies published between 2022 and 2024, identified through a hybrid strategy combining database searches across five digital libraries and forward/backward snowballing. Studies were classified using 11 IT domains and three academic dimensions, assessed through three quality indices (CVI, SCI, IRRQ), and organized into a novel dual-axis taxonomic structure. The results reveal a marked concentration around Docker (41.6%) and Kubernetes (29.6%), a dominance of IT Infrastructure as a research domain (75.66%), and a significant underrepresentation of education (11.06%) and outreach (5.88%) in the CBV literature. Six concrete research gaps are identified, including the need for alternative runtime evaluation, orchestration beyond Kubernetes, and empirical studies on CBV in educational contexts. The proposed taxonomy and identified gaps provide a structured foundation for researchers, educators, and practitioners navigating the rapidly expanding CBV landscape.

Keywords: Container-based virtualization, Systematic mapping study, Docker, Kubernetes, Cloud computing, Software engineering

1 Introduction

Cloud computing has established itself as a transformative paradigm in contemporary information technology, enabling scalable and resilient solutions through on-demand resource provisioning [Segun-Falade et al., 2024]. Among the foundational technologies supporting this paradigm, container-based virtualization (CBV) has gained significant traction due to its lightweight footprint, portability, and rapid deployment capabilities [Almoudane, 2025]. Unlike full virtualization, which emulates complete hardware environments, containers share the host operating system kernel while maintaining application isolation, resulting in substantially lower overhead [Kozhirbayev and Sinnott, 2017]. These properties have made CBV a preferred approach for deploying, managing, and scaling applications across distributed environments, facilitating continuous integration, agile development, and microservices architectures [Clement, 2025].

Within the CBV ecosystem, Docker has emerged as the *de facto* standard for container creation and management, while Kubernetes dominates container orchestration. However, the rapid evolution of this field has produced a diverse landscape of alternative technologies—including Podman, Singularity, LXC, gVisor, and Kata Containers—each optimized for specific use cases such as rootless operation, high-performance computing, or enhanced security [Baresi et al., 2024b]. This technological diversification necessitates a systematic analysis to identify which technologies are adopted in which contexts and to what extent.

Beyond industrial applications, CBV technologies have increasingly permeated academic settings, supporting education through reproducible laboratory environments, enabling research through portable computational pipelines, and facilitating outreach through accessible cloud-based platforms. However, the extent and nature of this academic adoption remain poorly characterized in the literature.

This paper presents a Systematic Mapping Study (SMS) that addresses this gap by mapping 226 primary studies (2022–2024) across 11 IT domains and three academic dimensions (education, research, outreach). The study contributes: *(1)* a comprehensive, reproducible mapping of the CBV research landscape; *(2)* a novel dual-axis taxonomic structure linking technologies to both IT domains and academic impact; and *(3)* the identification of six concrete research gaps with actionable future directions.

The remainder of this paper is organized as follows: Section 2 outlines the study motivation. Section 3 critically analyzes related works. Section 4 describes the SMS methodology. Section 5 addresses threats to validity. Section 6 presents the analysis, discussion, and future research directions. Section 7 concludes the paper.

2 Motivation

The adoption of cloud computing has produced a wide range of solutions based on container-based virtualization Hassan et al. [2022]. However, as noted by multiple authors Waseem et al. [2024]; Vhatkar and Bhole [2022]; Kithulwatta et al. [2022a], the literature remains fragmented: the high volume of publications makes it difficult to identify clear usage patterns, benefits, and limitations across application domains.

This study is motivated by three specific needs. First, there is no existing secondary study that simultaneously maps CBV technologies across multiple IT domains *and* academic dimensions (education, research, outreach). Second, the rapid proliferation of container technologies beyond Docker—including Podman, Singularity, gVisor, and others—requires a systematic assessment of their adoption and research coverage. Third, the potential of CBV as a transversal tool for academic activities (reproducible research, portable teaching environments, accessible outreach platforms) has not been systematically evaluated.

The expected outcomes include: *(i)* a comprehensive map of CBV research trends across 11 IT domains; *(ii)* a classification of studies by their contribution to education, research, and outreach; and *(iii)* a taxonomic structure that can guide technological decision-making for researchers, educators, and practitioners.

3 Related Works

Several secondary studies have addressed container-based virtualization (CBV) from different perspectives. To position the contribution of the present SMS, this section critically analyzes the existing literature organized by three dimensions: *(i)* scope and coverage, *(ii)* methodology, and *(iii)* domain focus. Table 1 synthesizes this comparative analysis.

Prior reviews differ substantially in the breadth of technologies and application contexts examined. Bentaleb et al. [2022b] and Sepúlveda-Rodríguez et al. [2022] both propose taxonomic classifications of virtualization technologies; however, neither extends its analysis to the academic dimension (education, research, and outreach). Similarly, Malhotra et al. [2024b] provide a systematic literature review focused exclusively on container lifecycle management—image detection, scheduling, security, and performance—without mapping these concerns to specific IT domains or educational contexts. In contrast, Kaiser et al. [2022b, 2023b] narrow their scope to ARM-compatible container technologies, prioritizing energy efficiency and edge computing performance. While valuable, this architectural focus limits the generalizability of their findings across the full spectrum of CBV use cases.

Among the related works, only Naydenov and Ruseva [2023a] adopt a systematic mapping methodology, focusing on container orchestration architectures in cloud computing. Their categorization scheme, however, is restricted to orchestration and does not encompass runtime technologies, academic applications, or cross-domain analysis. The remaining studies employ narrative or traditional review methods, which—while informative—lack the structured, reproducible search protocols and quality assessment mechanisms that characterize an SMS Kitchenham et al. [2010].

A common limitation across all reviewed studies is the absence of a cross-cutting analysis that maps CBV technologies to both IT domains (e.g., software development, HPC, security, AI) and academic dimensions simultaneously. None of the existing works: *(a)* provides a comprehensive mapping of CBV across multiple IT domains; *(b)* examines the role of containerization in education and outreach; or *(c)* offers a taxonomic structure linking technologies, domains, and academic impact.

Study	Type	Multi-domain	Acad.	Taxon.	Reprod.
Bentaleb et al. [2022b]	Review	✗	✗	✓	✗
Kaiser et al. [2022b]	Review	✗	✗	✗	✗
Sepúlveda-Rodríguez et al. [2022]	Review	✗	✗	✓	✗
Kaiser et al. [2023b]	Review	✗	✗	✗	✗
Naydenov and Ruseva [2023a]	SMS	✗	✗	✓	Partial
Malhotra et al. [2024b]	SLR	✗	✗	✗	Partial
This study	**SMS**	✓	✓	✓	✓

Table 1. Comparative analysis of related secondary studies. Multi-domain: covers multiple IT domains; Acad.: includes academic dimensions; Taxon.: proposes a taxonomy; Reprod.: provides reproducibility artifacts.

This SMS addresses these gaps by providing: *(1)* a systematic, reproducible mapping of 226 primary studies across 11 IT domains; *(2)* a novel classification linking CBV technologies to education, research, and outreach; and *(3)* a taxonomic structure that integrates technological and academic perspectives, enabling researchers and practitioners to identify both consolidated areas and under-explored research opportunities.

4 Review Method

This study follows a Systematic Mapping Study (SMS) methodology, guided by the established frameworks of Petersen et al. Runeson and Höst [2009] and Kitchenham and Charters Kitchenham et al. [2010]. Unlike a Systematic Literature Review (SLR), which aims to synthesize evidence on a specific question, an SMS provides a broad overview of a research area by classifying and categorizing existing literature Runeson and Höst [2009]. Following Mourao et al. [2017] and Nguyen et al. [2015], a hybrid search approach was adopted, combining automated database queries with manual snowballing to maximize coverage.

To ensure transparency and reproducibility, the SMS-Builder tool Candela-Uribe et al. [2022] was employed throughout the process for study identification, classification, data extraction, and quality assessment. The SMS process comprises six stages: (1) planning, (2) study search, (3) quality assessment, (4) data extraction, (5) study classification, and (6) results. Figure 1 illustrates these stages.

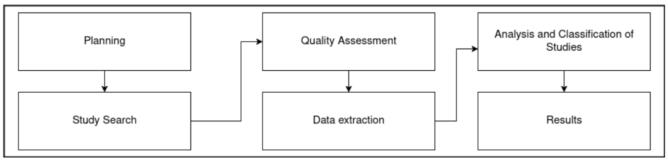

Figure 1. Stages of the SMS process

4.1 Planning

The planning stage established the research goals, questions, metrics, classification criteria, and quality assessment indices. Figure 2 summarizes the components of this stage.

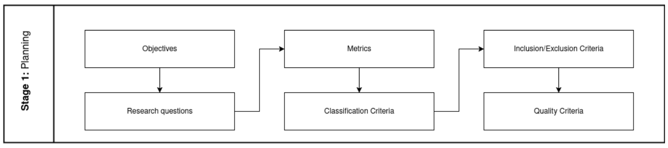

Figure 2. Composition of the planning stage

4.1.1 Study Goals

Two overarching goals were defined to guide this SMS, as presented in Table 2.

Goal	Description
G1	Identify studies related to CBV in education, research, and outreach.
G2	Classify studies related to CBV across IT domains, including software development, computational thinking, parallel computing, data analysis, artificial intelligence, computer networks, IT infrastructure, HPC, security, cloud computing, and blockchain.

Table 2. Goals of the study

4.1.2 Research Questions

The research questions were formulated using the GQM (*Goal Question Metric*) framework Needleman [2002] and the PICOC model Petticrew and Roberts [2008], which structures the population, intervention, comparison, outcome, and context of the study (Table 4). Two research questions were derived, as detailed in Table 3.

4.1.3 Metrics

Quantitative metrics were defined to measure the distribution of studies across the classification structure (Table 6). The search period was restricted to 2022–2024 to ensure currency.

Aspect	Description
Population	Studies related to CBV applied across IT domains, with emphasis on education, research, and outreach.
Intervention	Identification and classification of CBV studies within established IT domains.
Comparison	1. Comparison of CBV projects by reported success rates across IT domains. 2. Analysis of CBV impact on academic activities relative to alternative solutions.
Outcome	Classification structure mapping CBV studies to IT domains and academic dimensions.
Context	Education, research, and outreach contexts adopting CBV technologies.

Table 4. PICOC model specification

4.1.4 Research Topics

Based on the research questions and PICOC model, four research topics were defined: *Container-based virtualization*, *Education*, *Research*, and *Industry*. These topics were further refined through the IT domains identified as relevant to the study scope.

4.1.5 Inclusion and Exclusion Criteria

Table 5 presents the inclusion and exclusion criteria. The three-year window (2022–2024) balances currency with sufficient volume. Both journal articles and conference proceedings were included to capture the full publication landscape in this rapidly evolving field.

Metric	Description
M1	Number of studies identified per IT domain.
M2	Number of studies classified under education.
M3	Number of studies classified under research.
M4	Number of studies classified under outreach.

Table 6. Metrics defined for the analysis

4.1.6 Quality Assessment Criteria

Three quality indices were defined to evaluate the relevance and rigor of the selected studies.

Content Validity Index (CVI). The CVI assesses the degree to which each study aligns with the SMS objectives, adapted from established content validity methodology Almanasreh et al. [2019]; YAGHMAEI [2003]. Each study was independently rated by K evaluators (where K is odd, to prevent ties) on a scale from 0 (no relevance) to 5 (high relevance). Following the proportion-based CVI approach Almanasreh et al. [2019], we define the item-level CVI (I-CVI) as the proportion of evaluators who rate a study above a relevance threshold t:

$$\text{I-CVI} = \frac{n_t}{K} \tag{1}$$

Goal	Question	Description	Motivation
G1	Q1	Which studies related to container-based virtualization (CBV) technologies contribute to education, research, and outreach?	CBV enables environment reproducibility, facilitating the transfer of IT solutions across contexts. Understanding its academic penetration can stimulate cross-domain innovation.
G2	Q2	Which primary studies related to CBV technologies contribute to IT domains such as software development, HPC, AI, security, cloud computing, and others?	The goal is to provide a structured overview of CBV adoption across IT domains, enabling researchers and practitioners to identify trends without requiring exhaustive primary analysis.

Table 3. Research questions and their motivation

Category	Inclusion	Exclusion
Screening field	Abstract	—
Publication type	Journal articles and conference proceedings	Theses, book chapters, grey literature
Discipline	Computer Science, Information Technology, Engineering, IT Management	Disciplines unrelated to virtualization or computing
Time period	2022–2024	Before 2022
Language	English	Non-English publications

Table 5. Inclusion and exclusion criteria

where n_t is the number of evaluators assigning a score $\geq t$ (with $t = 3$ adopted in this study), and K is the total number of evaluators. An I-CVI ≥ 0.78 indicates acceptable content validity Almanasreh et al. [2019]. For aggregation across the study corpus, the Scale-level CVI based on the average method (S-CVI/Ave) is computed as the mean of all I-CVI values.

Scientific Citation Index (SCI). The SCI captures citation-normalized impact relative to publication recency. For a study with C citations accumulated between 2022 and 2024, published A years before the extraction date:

$$\text{SCI} = \frac{C}{A} \tag{2}$$

This normalization ensures that recently published studies with emerging citation counts are not penalized relative to older, more-cited works.

Index of Relationship to Research Questions (IRRQ). The IRRQ quantifies the coverage of a study with respect to the defined research questions. Given $Q = 2$ research questions in this SMS, the IRRQ for a study addressing n questions is:

$$\text{IRRQ} = \frac{n}{Q} \tag{3}$$

where $n \in \{0, 1, 2\}$ and $Q = 2$. Thus, IRRQ $\in \{0, 0.5, 1\}$, where 1 indicates full coverage of both research questions. This index enables identification of studies with broad versus narrow thematic relevance.

4.2 Stage 2: Study Search

A hybrid search strategy combining database queries and snowballing was employed. Figure 3 summarizes the components of this stage.

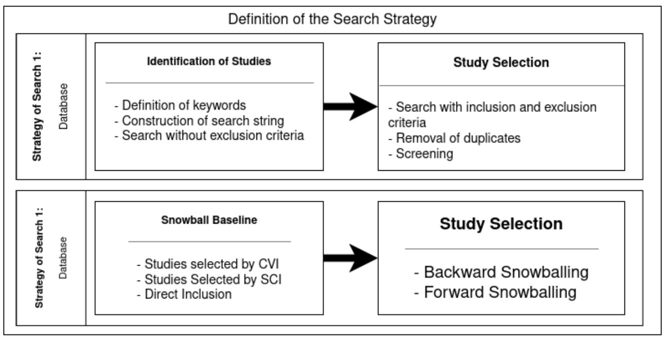

Figure 3. Composition of the study search stage

4.2.1 Defining the Search Strategy

Two complementary strategies were combined. The first involves automated search string execution in academic databases Jalali and Wohlin [2012]. The second, snowballing, identifies additional studies through backward (reference tracking) and forward (citation tracking) analysis of a seed set Jalali and Wohlin [2012]; Goodman [1961].

4.2.2 Search Strategy 1: Databases

This strategy comprises two phases: *Study Identification* (search string construction and execution) and *Study Selec-*

tion (criteria-based refinement).

- **Study Identification:** Five databases were queried: *ACM*, *IEEE Xplore*, *Springer*, *Science Direct*, and *Taylor & Francis*. Keywords were derived from the PICOC model (Table 7) and expanded with synonyms (Table 8). Boolean operators (*AND*, *OR*) and exact-phrase matching were used to construct database-specific search strings through iterative pilot searches. The complete search strings are available via the reproducibility artifacts (Section 4.6.3).
Execution across all databases yielded **6,530** preliminary results, with Springer contributing the largest share (**4,562**; 69.8%). Table 9 details the distribution.

Aspect	Description
Population	CBV, IT Domains, Education, Research, Outreach
Intervention	Identification, Classification
Comparison	Success rate, Evidence of use
Output	Classification of CBV studies per IT domain
Context	Education, Research, Outreach

Table 7. Keywords identified using the PICOC model

Keyword	Synonyms
Container-based virtualization	Application virtualization, Docker, Lightweight Virtualization
Education	Education System, Education Development, Higher Education
Research	Research Group, Research Proposal
Industry	IT Services, Technology Infrastructure, Cloud Computing

Table 8. Keywords for database search

- **Study Selection:** Application of inclusion and exclusion criteria reduced the set to **976** studies (Table 10), with Springer maintaining the largest contribution (**592**; 60.65%). After removing **274** duplicates, a screening process (title, abstract, and keyword review) excluded **593** irrelevant studies, yielding **110** selected studies from the database strategy. Figure 4 summarizes this process.

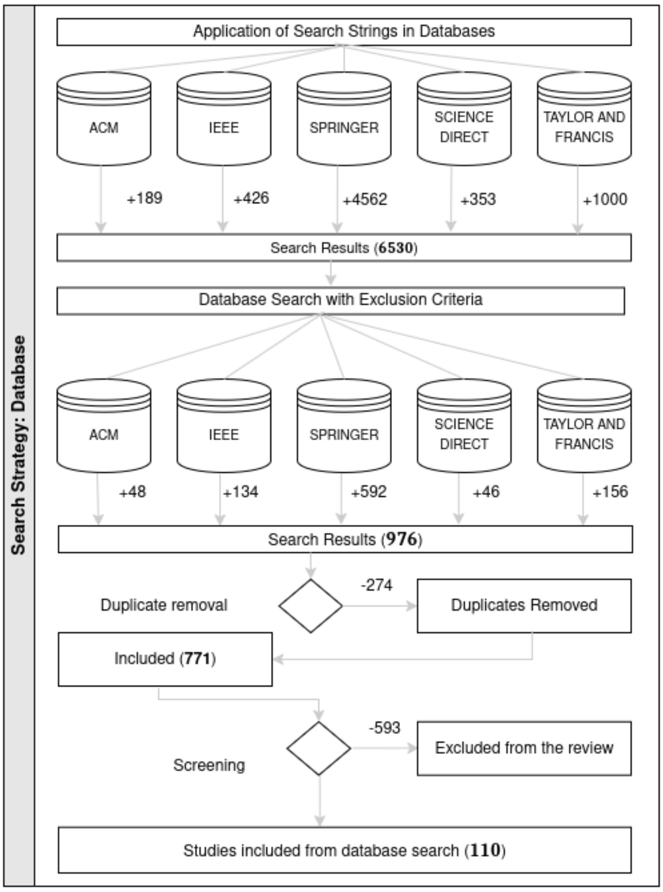

Figure 4. Summary of activities and results obtained in the database search strategy

4.2.3 Search Strategy 2: Snowballing

The snowballing search strategy began with the identification of the base set of articles. This base set is obtained from Search Strategy 1. The procedure consisted of two phases:

The first phase, called *Base Line Construction*, aims to establish the articles on which a citation and reference analysis will be performed. To form this initial set of studies, several criteria were applied, including the CVI *(Content Value Index)*, the SCI *(Study Citation Index)*, and the direct inclusion criterion. The second phase, called *Study Selection*, focuses on the analysis of references *(Backward Snowballing)* and citations *(Forward Snowballing)* corresponding to each article Wohlin [2014].

The base line construction started from the **110** articles obtained in the database search strategy. From this set, **25** articles were selected using the SCI quality criterion. The choice of this criterion is based on the fact that it does not depend on the authors' assessment, but rather on the number of citations received by each article, which constitutes an objective indicator of academic relevance. The result of this process was a total of **25** articles selected for the base line. The selection was made through a citation frequency analysis, from which the first quartile **(Q1)** corresponding to the most cited articles was extracted. As part of the SMS process, studies can also be incorporated through direct inclusion. This procedure consists of adding an article

Criterion	ACM	IEEE	Science Direct	Springer	Taylor and Francis
Search results using keywords only	189	426	4562	353	1000
Contribution percentage	2.89%	6.52%	69.86%	5.4%	15.31%

Table 9. Search results per database using keywords

Criterion	ACM	IEEE	Science Direct	Springer	Taylor and Francis
Search results after applying keywords only	48	134	46	592	156
Contribution percentage	4.91%	13.72%	4.71%	60.65%	15.98%

Table 10. Search results per database using keywords after applying inclusion/exclusion criteria

previously known by the authors, without it coming directly from a database. This approach provides flexibility to the search process as it allows integrating works considered relevant by the authors for the research objective. In this case, one article was incorporated through direct inclusion, bringing the total to **26** articles in the base line.

After the base line construction, the reference analysis was performed, which allowed identifying a total of **495** new articles. The forward search process was conducted using Google Scholar, which provides information on the number of citations for each article, following the practices described in Ali et al. [2019]. Regarding the backward search, **87** additional articles were obtained.

14 duplicate articles were removed from the backward and forward search results. Subsequently, the *Screening* process was applied again, which, as in the previous phase, consisted of reviewing the title, abstract, and keywords of each work. This procedure reduced the set to **116** articles selected through the snowballing search strategy. Figure 5 presents a summary of the process followed in this search strategy.

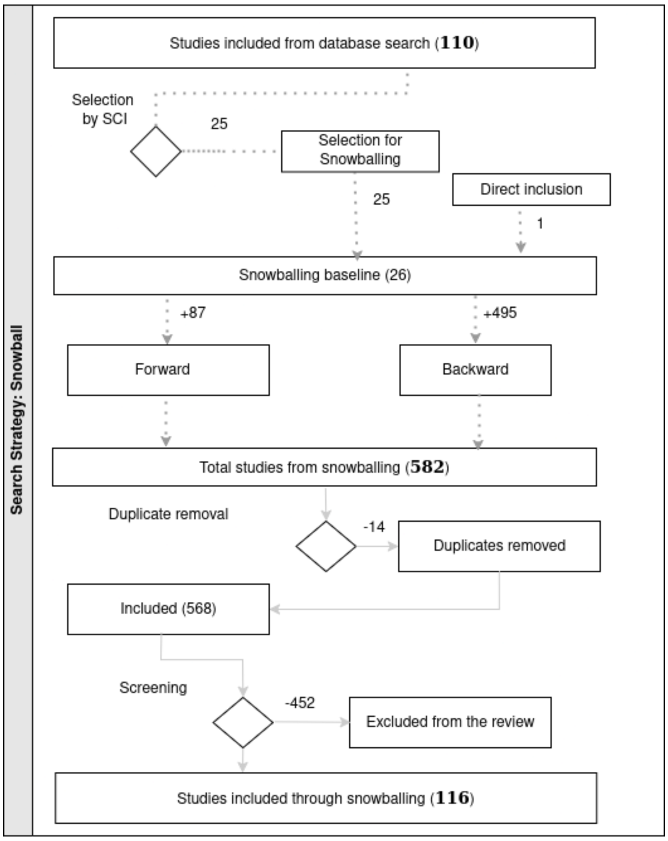

Figure 5. Summary of the snowballing search strategy

4.2.4 Results of the Study Search

The combined search yielded **226** primary studies: **110** from databases, **115** from snowballing, and **1** through direct inclusion. The near-equal split between strategies (Table 11) confirms the complementarity of the hybrid approach.

Strategy	Studies	%
Databases	110	48.67%
Snowballing	115	50.88%
Direct Inclusion	1	0.44%
Total	**226**	**100%**

Table 11. Results of the study search

4.3 Stage 3: Quality Assessment

Although quality assessment is not mandatory in an SMS Ali et al. [2019], incorporating it strengthens the rigor of the mapping and brings it closer to a systematic review Wohlin [2014]. Three complementary indices—CVI, SCI, and IRRQ—were applied to evaluate study relevance.

4.3.1 Content Validity Assessment (CVI)

Each study was independently rated by an odd number of evaluators ($K \geq 3$) on a 0–5 relevance scale. The proportion-based I-CVI (Equation 1) was computed for each study, and studies with I-CVI ≥ 0.78 were considered to have acceptable content validity. Two assessment rounds were conducted: the first during baseline construction for snowballing (Section 4.2.4), and the second after all 226 studies were identified, with results reported in Section Study Classification.

4.3.2 Citation-Based Quality Assessment (SCI)

The SCI (Equation 2) was computed using citation data from Google Scholar and the SMS-Builder tool Candela-Uribe et al. [2020]. A frequency analysis identified the top quartile (Q1) of studies by SCI, representing those with the highest citation-normalized impact.

4.3.3 Research Question Coverage Assessment (IRRQ)

The IRRQ (Equation 3) was computed for each study based on its thematic alignment with Q1 and Q2, as determined through the classification process. Studies with IRRQ $= 1$ (addressing both research questions) were identified through frequency analysis as the most thematically comprehensive.

4.4 Stage 4: Data Extraction

After completing study search and quality assessment, **226** primary studies were identified and labeled SPS001 through SPS226. The complete list is provided in Table 12.

4.5 Stage 5: Study Classification

The SPS were classified using the topics defined during planning (Table 13). A single SPS may be associated with multiple topics; for example, SPS069 is classified under IT Infrastructure, Security, Cloud Computing, and Research. This multi-label approach reflects the interdisciplinary nature of CBV research and enables cross-domain analysis.
Following classification, each SPS was evaluated using the CVI, SCI, and IRRQ quality indices. Tables 14, 15, and 16 present the top-quartile studies for each index, disaggregated by topic and year.

4.6 Stage 6: Results

This section presents and interprets the findings from the SMS, organized in three parts: (1) an overview of the SPS corpus with source and temporal analysis, (2) a technology and domain distribution analysis with interpretation of observed trends, and (3) a keyword co-occurrence analysis.

4.6.1 Overview of the SPS Corpus

The SMS identified **226** selected primary studies (SPS), listed in Table 12. The following subsections analyze the distribution of these studies across sources, technologies, academic dimensions, and quality indices.

Source and strategy distribution. Table 17 presents the classification of CBV technologies by academic dimension. Docker dominates across education, research, and outreach, accounting for **100** SPS (44.24%). This predominance reflects Docker's mature ecosystem, extensive documentation, and low barrier to entry, which collectively facilitate adoption in academic contexts where ease of deployment is prioritized over specialized performance characteristics.
Table 18 maps IT domains to academic dimensions. IT Infrastructure is the most represented domain, with **171** SPS (75.66%), indicating that containerization research remains strongly anchored to infrastructure-level concerns such as deployment, scaling, and resource management.

ID	Ref	ID	Ref
SPS001	Pastor-Galindo et al.	SPS002	Moysiadis et al.
SPS003	Malviya and Dwivedi	SPS004	Šimon et al.
SPS005	Yaory and Manuaba	SPS006	Kamieniarz and Mazurczyk
SPS007	Voulgaris et al.	SPS008	Nakarmi et al.
SPS009	Chen et al.	SPS010	Betz et al.
SPS011	Xi et al.	SPS012	Li et al.
SPS013	Madi and Esteves-Verissimo	SPS014	Wang and Li
SPS015	Raj	SPS016	Modey et al.
SPS017	Yang and Dai	SPS018	Wu et al.
SPS019	Bracke et al.	SPS020	Abas et al.
SPS021	Fischer et al.	SPS022	Li et al.
SPS023	Deng et al.	SPS024	Yin et al.
SPS025	Malhotra et al.	SPS026	Yuan and Liao
SPS027	González-Abad et al.	SPS028	Ruiz Ródenas et al.
SPS029	Ebrahimpour et al.	SPS030	Ye et al.
SPS031	Liagkou et al.	SPS032	Baresi et al.
SPS033	Ghorbian and Ghobaei-Arani	SPS034	Aktolga et al.
SPS035	Joraviya et al.	SPS036	Nakakaze et al.
SPS037	Soderi et al.	SPS038	Qian
SPS039	Galantino et al.	SPS040	Aldiabat et al.
SPS041	Kumar and Kaur	SPS042	Aung et al.
SPS043	Dimova et al.	SPS044	Azuma et al.
SPS045	Ndigande et al.	SPS046	Husain et al.
SPS047	Yarmilko et al.	SPS048	de Oliveira Filho et al.
SPS049	Ajith et al.	SPS050	Timonen et al.
SPS051	Kotenko et al.	SPS052	Silva et al.
SPS053	Hettiarachchi et al.	SPS054	Fava et al.
SPS055	Savitha et al.	SPS056	Dogani et al.
SPS057	Purahong et al.	SPS058	Benzi et al.
SPS059	Chaurasia et al.	SPS060	Kaiser et al.
SPS061	Stojanović et al.	SPS062	Kanagachalam et al.
SPS063	Vaidya et al.	SPS064	Jolak et al.
SPS065	Hao et al.	SPS066	Blanco et al.
SPS067	Wang et al.	SPS068	Naydenov and Ruseva
SPS069	Ganne	SPS070	Raj et al.
SPS071	Rashid and Qasha	SPS072	Pavao et al.
SPS073	Zhang et al.	SPS074	Candemir and İncereis
SPS075	Choi et al.	SPS076	Pankowski and Powroźnik
SPS077	Moussa et al.	SPS078	Geng et al.
SPS079	Chen et al.	SPS080	Gao et al.
SPS081	Spahn et al.	SPS082	Zhang et al.
SPS083	Kaiser et al.	SPS084	Patra et al.
SPS085	Wu et al.	SPS086	VS et al.

Continues on the next page

Table 12 – continued

ID	Ref	ID	Ref
SPS087	Waseem et al.	SPS088	Bentaleb et al.
SPS089	Malan	SPS090	Keller Tesser and Borin
SPS091	Kaur	SPS092	El Khairi et al.
SPS093	Choi et al.	SPS094	Alelyani et al.
SPS095	Joraviya et al.	SPS096	Nelson and Shoshitaishvili
SPS097	Zhou et al.	SPS098	Bentaleb et al.
SPS099	Kim et al.	SPS100	Saxena et al.
SPS101	Yu et al.	SPS102	Horchulhack et al.
SPS103	Chamoli and Mittal	SPS104	Sobieraj and Kotyński
SPS105	Patra et al.	SPS106	Gharaibeh et al.
SPS107	Dipta et al.	SPS108	Gu et al.
SPS109	Jeon et al.	SPS110	Roy et al.
SPS111	Karumudi et al.	SPS112	Barbie et al.
SPS113	Ramanathan et al.	SPS114	Lee et al.
SPS115	Sedov and Lazarev	SPS116	Kostolny et al.
SPS117	Jang and Luo	SPS118	Flora and Antunes
SPS119	Ukene et al.	SPS120	Molnár et al.
SPS121	Dakić et al.	SPS122	Kaiser et al.
SPS123	Barletta et al.	SPS124	Rosa et al.
SPS125	Barros et al.	SPS126	Zeng et al.
SPS127	Gupta et al.	SPS128	Frasão et al.
SPS129	Gamess and Parajuli	SPS130	Alif and Munggaran
SPS131	Moric et al.	SPS132	Eroshkin et al.
SPS133	Singh et al.	SPS134	Kuity and Peddoju
SPS135	Narasimhulu et al.	SPS136	Entrialgo et al.
SPS137	Dogani et al.	SPS138	Lee et al.
SPS139	Ma et al.	SPS140	Kosińska et al.
SPS141	Zheng et al.	SPS142	Bellavista et al.
SPS143	Johansson et al.	SPS144	Carrión
SPS145	Carrión	SPS146	Botez et al.
SPS147	Haq et al.	SPS148	Dubey et al.
SPS149	Bannon	SPS150	Abbadini et al.
SPS151	Geetha et al.	SPS152	Fernalld et al.
SPS153	Mills et al.	SPS154	Han et al.
SPS155	Yang et al.	SPS156	Karmakar and Arri
SPS157	Mailewa et al.	SPS158	Barnawi et al.
SPS159	Pérez et al.	SPS160	Barletta et al.
SPS161	Zuppelli et al.	SPS162	Bhuiyan et al.
SPS163	Mondal et al.	SPS164	Mondal et al.
SPS165	Wong et al.	SPS166	Song et al.
SPS167	Bracke et al.	SPS168	Alamoush and Eichelberger
SPS169	Joshi et al.	SPS170	Kumar et al.
SPS171	Mthembu et al.	SPS172	Eng et al.

Continues on the next page

Table 12 – continued

ID	Ref	ID	Ref
SPS173	Kurniawan et al.	SPS174	Melo et al.
SPS175	Widodo et al.	SPS176	Kithulwatta et al.
SPS177	Fu et al.	SPS178	Abdulah et al.
SPS179	Jeong et al.	SPS180	Gackstatter et al.
SPS181	Ersted Rasmussen et al.	SPS182	Xie et al.
SPS183	Lee et al.	SPS184	Karamzadeh and Shameli-Sendi
SPS185	Alyas et al.	SPS186	Mehran and Ulus
SPS187	Du et al.	SPS188	Xu et al.
SPS189	Al-Obaidi et al.	SPS190	Zehra et al.
SPS191	Haq et al.	SPS192	Saxena et al.
SPS193	Rajasekar et al.	SPS194	Thurimella et al.
SPS195	Al Qausar et al.	SPS196	Shrestha and Ray
SPS197	Agrawal and Singh	SPS198	Antonova et al.
SPS199	Burchart and Haake	SPS200	Mujkanovic et al.
SPS201	Hristev et al.	SPS202	Zhou et al.
SPS203	Yang et al.	SPS204	Jackson and Wurst
SPS205	Li et al.	SPS206	Ashari et al.
SPS207	Dobslaw et al.	SPS208	Rosmaninho et al.
SPS209	Álvarez et al.	SPS210	Wang et al.
SPS211	Amoiridis et al.	SPS212	Schmidt et al.
SPS213	Augustyn et al.	SPS214	Choi et al.
SPS215	Rodriguez et al.	SPS216	Kunekar et al.
SPS217	Shakya and Tripathi	SPS218	Arifiansyah et al.
SPS219	Kwon et al.	SPS220	Haresh et al.
SPS221	Malhotra et al.	SPS222	Kjorveziroski and Filiposka
SPS223	Kjorveziroski and Filiposka	SPS224	Li et al.
SPS225	Rosa et al.	SPS226	Kim et al.

Technology landscape analysis. Figure 6 shows the distribution of studies by source and strategy. Of the database-sourced studies (110 SPS), IEEE Xplore and ACM Digital Library jointly contribute 68.18%, reflecting the strong alignment of CBV research with computing-focused venues. The snowballing strategy (115 SPS) was dominated by forward snowballing (92.17%), suggesting that CBV is an expanding field where newer publications actively cite foundational works.

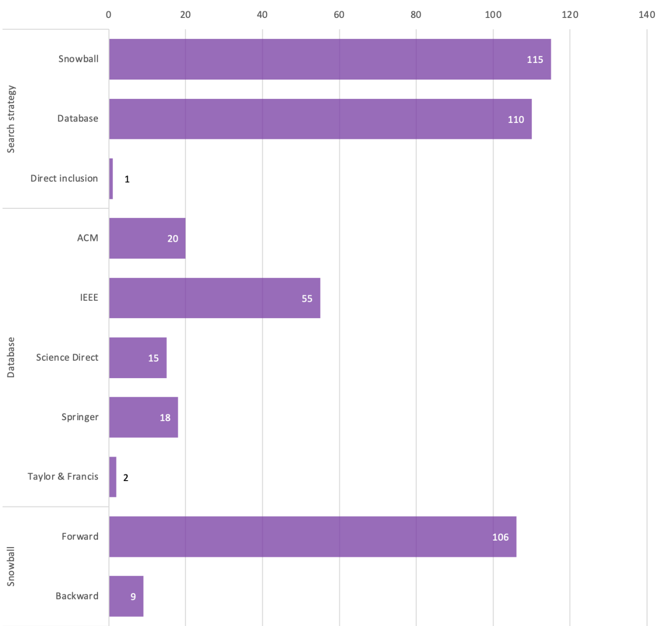

Figure 6. SPS by source and search strategy

Figure 7 reveals the distribution of container runtime technologies. Docker leads with **94** SPS, followed distantly by Podman (7), LXC and Containerd (4 each), and Singularity, runC, and gVisor (3 each). This concentration raises an important finding: *despite the growing ecosystem of alternative container runtimes designed for security (gVisor, Kata Containers), HPC (Singularity), and rootless operation (Podman), the research community remains heavily Docker-centric*. This gap between technological diversity and research coverage represents an opportunity for future studies to evaluate emerging runtimes in domains where Docker's limitations are well documented.

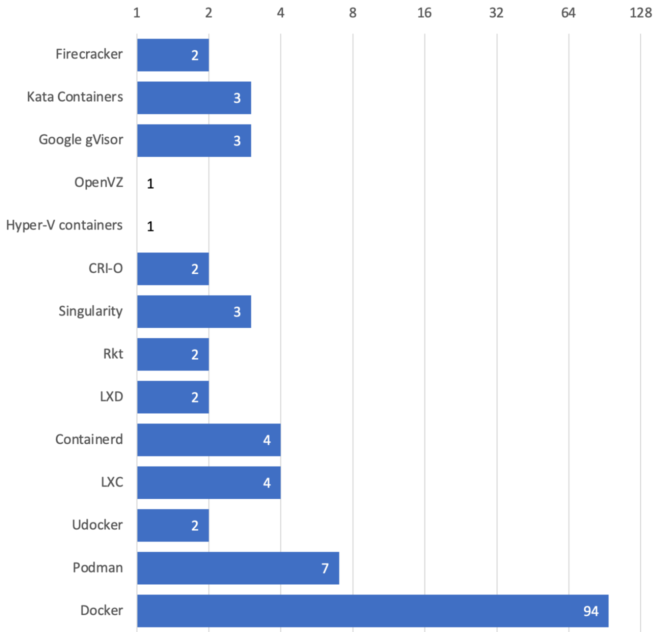

Figure 7. Distribution of container runtime technologies across SPS

Figure 8 shows orchestrator distribution. Kubernetes dominates with **67** SPS, confirming its status as the *de facto* standard for container orchestration. Docker Swarm (9 SPS) and Apache Mesos (5 SPS) trail significantly. The marginal representation of alternatives such as OpenShift (2), Docker Compose (3), and cloud-native services (Amazon ECS/EKS, 1 each) suggests that *academic research has not yet systematically evaluated the trade-offs between Kubernetes and its alternatives*, particularly in edge computing, serverless, and resource-constrained environments where lighter orchestration solutions may be more appropriate.

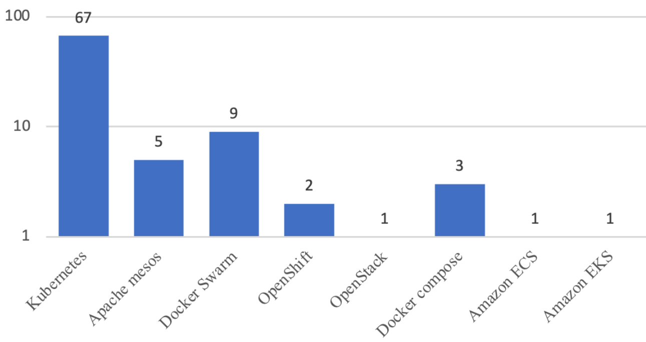

Figure 8. Distribution of orchestrator technologies across SPS

Academic dimension analysis. Figure 9 illustrates the intersection of studies across academic dimensions. Research dominates with **187** exclusive SPS, while Education (19 exclusive) and Outreach (8 exclusive) remain underrepresented. Notably, *no study simultaneously addresses all three dimensions*, revealing a significant fragmentation in academic production. Only 6 SPS bridge Research and Education, and 6 bridge Research and Outreach, with zero overlap between Education and Outreach. This finding suggests that the potential of CBV as a transversal tool linking teaching, research output, and societal impact remains largely unexplored.

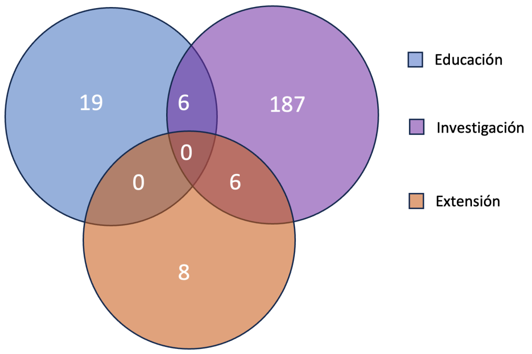

Figure 9. Venn diagram of SPS across academic dimensions

Topic and temporal distribution. Figure 10 shows topic distribution per research question. For Q1, Research accounts for 83.61% of studies, while Outreach represents only 5.88%—a disparity that underscores the limited penetration of containerization into community engagement and societal applications. For Q2, IT Infrastructure leads (41.28%), followed by Cloud Computing (14.37%), while Blockchain (0.76%) and Parallel Computing represent emerging but underexplored intersections with CBV.

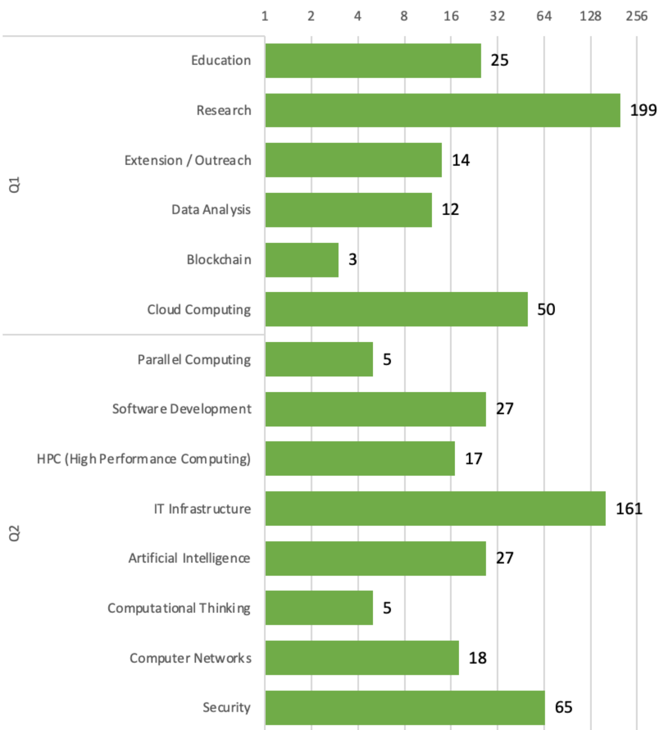

Figure 10. SPS distribution by research questions and topics

The temporal analysis (Figure 11) reveals sustained growth, from **49** SPS in 2022 to **107** in 2024 (a 118% cumulative increase). The sharpest growth occurred between 2023 and 2024 (+52.85%), coinciding with the maturation of Kubernetes-based cloud-native architectures and the proliferation of edge computing applications. The CVI index shows an upward trend (from 7 to 9, +28.57%), suggesting that more recent studies exhibit stronger alignment with the SMS objectives. The SCI index remains stable around 18, with a slight recovery in 2024 (+11.76% over 2023), while the IRRQ index exhibits sustained growth from 30 to 39 (+30% cumulative), indicating increasing thematic breadth in newer publications.

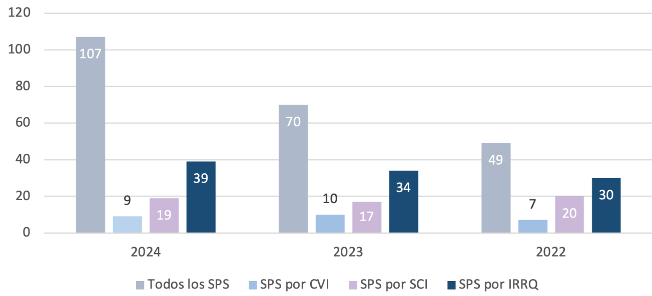

Figure 11. SPS by year and quality indices

Figure 12 presents the quality indices disaggregated by topic. IT Infrastructure not only has the highest volume (73 SPS, 43.71% of Q2) but also concentrates the highest-quality studies across all three indices, reinforcing its centrality to the CBV research landscape. The Outreach topic, with only 8 SPS (7.33% of Q1), represents the most significant gap identified in this mapping.

Figure 13 presents a cross-analysis of keywords. The term "*Container*" enables the identification of 57 SPS, while education-related keywords (*Learning*, *Cybersecurity education*) appear in only 2 SPS each—further evidence that the academic community has not yet developed a robust vocabulary linking CBV to educational and outreach applications.

Table 13. Classification of SPS studies by topic and year

RQ	Topics	2022	2023	2024
Q1	Research	SPS002, SPS003, SPS007, SPS013, SPS017, SPS023, SPS039, SPS041, SPS044, SPS053, SPS059, SPS062, SPS064, SPS069, SPS070, SPS071, SPS073, SPS077, SPS079, SPS080, SPS083, SPS085, SPS088, SPS092, SPS098, SPS099, SPS105, SPS137, SPS143, SPS144, SPS145, SPS146, SPS149, SPS154, SPS155, SPS157, SPS176, SPS177, SPS180, SPS182, SPS187, SPS191, SPS192	SPS004, SPS012, SPS015, SPS027, SPS029, SPS034, SPS046, SPS047, SPS055, SPS056, SPS057, SPS060, SPS066, SPS067, SPS068, SPS075, SPS076, SPS081, SPS084, SPS086, SPS090, SPS093, SPS094, SPS097, SPS103, SPS117, SPS119, SPS126, SPS127, SPS134, SPS135, SPS138, SPS150, SPS153, SPS159, SPS165, SPS166, SPS167, SPS171, SPS173, SPS174, SPS175, SPS179, SPS183, SPS185, SPS189, SPS195, SPS200, SPS201, SPS203, SPS205, SPS208, SPS209, SPS212, SPS220, SPS221, SPS222, SPS223, SPS225, SPS226	SPS001, SPS005, SPS006, SPS008, SPS009, SPS010, SPS011, SPS014, SPS016, SPS018, SPS019, SPS021, SPS022, SPS024, SPS025, SPS026, SPS028, SPS030, SPS032, SPS033, SPS035, SPS036, SPS040, SPS043, SPS045, SPS048, SPS049, SPS050, SPS051, SPS052, SPS054, SPS061, SPS065, SPS074, SPS082, SPS087, SPS091, SPS095, SPS100, SPS102, SPS104, SPS106, SPS107, SPS108, SPS109, SPS110, SPS111, SPS113, SPS118, SPS121, SPS122, SPS123, SPS124, SPS125, SPS128, SPS129, SPS130, SPS131, SPS132, SPS133, SPS136, SPS140, SPS141, SPS142, SPS147, SPS148, SPS151, SPS156, SPS158, SPS160, SPS161, SPS162, SPS164, SPS168, SPS169, SPS170, SPS172, SPS178, SPS184, SPS186, SPS188, SPS190, SPS193, SPS194, SPS196, SPS197, SPS198, SPS202, SPS210, SPS213, SPS214, SPS215, SPS216, SPS217, SPS219, SPS224
	Education	SPS038, SPS058, SPS101, SPS146, SPS187, SPS204	SPS020, SPS072, SPS075, SPS116, SPS120, SPS152, SPS206, SPS207, SPS218	SPS042, SPS089, SPS096, SPS115, SPS124, SPS139, SPS151, SPS163, SPS198, SPS199
	Outreach	SPS002, SPS031, SPS037, SPS099	SPS078, SPS112, SPS208, SPS220	SPS010, SPS063, SPS114, SPS181, SPS211, SPS213
Q2	Software development	SPS002, SPS037, SPS038, SPS044, SPS053, SPS058, SPS098, SPS101	SPS015, SPS078, SPS086, SPS120, SPS183, SPS195	SPS008, SPS010, SPS022, SPS028, SPS042, SPS043, SPS096, SPS100, SPS118, SPS133, SPS172, SPS215, SPS224
	Computational thinking	SPS187	SPS116	SPS042, SPS115, SPS198

RQ	Topics	2022	2023	2024
	Parallel computing	SPS017	SPS020, SPS134, SPS223	
	Data analysis	SPS037, SPS071, SPS157	SPS183, SPS209	SPS001, SPS005, SPS028, SPS045, SPS061, SPS082, SPS129
	Artificial intelligence	SPS023, SPS037, SPS053, SPS059, SPS073, SPS077, SPS080, SPS149, SPS154, SPS177	SPS027, SPS072, SPS078, SPS183, SPS209	SPS011, SPS030, SPS040, SPS051, SPS082, SPS095, SPS142, SPS148, SPS161, SPS169, SPS170, SPS181
	Computer networks	SPS105, SPS187	SPS046, SPS094, SPS103, SPS159	SPS010, SPS019, SPS048, SPS106, SPS110, SPS113, SPS132, SPS139, SPS164, SPS198, SPS216, SPS219
	IT infrastructure	SPS003, SPS007, SPS017, SPS023, SPS031, SPS037, SPS038, SPS039, SPS062, SPS069, SPS070, SPS073, SPS077, SPS079, SPS083, SPS085, SPS088, SPS092, SPS099, SPS105, SPS137, SPS143, SPS144, SPS145, SPS146, SPS149, SPS154, SPS155, SPS176, SPS177, SPS180, SPS182, SPS187, SPS204	SPS004, SPS012, SPS020, SPS027, SPS029, SPS034, SPS046, SPS047, SPS055, SPS056, SPS057, SPS060, SPS066, SPS067, SPS068, SPS075, SPS076, SPS078, SPS081, SPS084, SPS090, SPS094, SPS103, SPS112, SPS117, SPS119, SPS126, SPS134, SPS135, SPS150, SPS152, SPS159, SPS167, SPS171, SPS173, SPS174, SPS175, SPS179, SPS183, SPS185, SPS189, SPS200, SPS201, SPS205, SPS206, SPS207, SPS208, SPS212, SPS218, SPS220, SPS222, SPS223, SPS225	SPS009, SPS011, SPS014, SPS018, SPS019, SPS021, SPS024, SPS025, SPS026, SPS030, SPS032, SPS033, SPS036, SPS048, SPS049, SPS051, SPS052, SPS054, SPS074, SPS082, SPS087, SPS089, SPS091, SPS095, SPS096, SPS100, SPS102, SPS104, SPS106, SPS107, SPS109, SPS110, SPS111, SPS115, SPS121, SPS122, SPS123, SPS124, SPS125, SPS129, SPS130, SPS131, SPS132, SPS136, SPS140, SPS148, SPS151, SPS156, SPS160, SPS163, SPS164, SPS168, SPS169, SPS170, SPS172, SPS178, SPS181, SPS184, SPS186, SPS188, SPS190, SPS196, SPS197, SPS198, SPS199, SPS210, SPS211, SPS213, SPS214, SPS215, SPS216, SPS217, SPS219, SPS224
	HPC	SPS017, SPS041, SPS062, SPS083, SPS098	SPS027, SPS090, SPS134, SPS200	SPS008, SPS014, SPS018, SPS114, SPS121, SPS129, SPS178, SPS194
	Blockchain			SPS063

RQ	Topics	2022	2023	2024
	Security	SPS013, SPS064, SPS069, SPS070, SPS079, SPS083, SPS092, SPS155, SPS157, SPS191, SPS192	SPS034, SPS047, SPS081, SPS086, SPS093, SPS094, SPS097, SPS119, SPS126, SPS127, SPS138, SPS150, SPS153, SPS165, SPS166, SPS175, SPS183, SPS189, SPS203, SPS221, SPS226	SPS001, SPS006, SPS009, SPS016, SPS022, SPS025, SPS035, SPS040, SPS043, SPS049, SPS050, SPS051, SPS065, SPS082, SPS108, SPS118, SPS125, SPS128, SPS129, SPS131, SPS141, SPS147, SPS156, SPS158, SPS160, SPS161, SPS162, SPS170, SPS188, SPS190, SPS193, SPS214, SPS219
	Cloud computing	SPS002, SPS003, SPS031, SPS069, SPS070, SPS071, SPS079, SPS080, SPS085, SPS099, SPS137, SPS143, SPS146, SPS149, SPS177	SPS012, SPS015, SPS029, SPS055, SPS056, SPS084, SPS126, SPS173, SPS179, SPS185, SPS222	SPS018, SPS019, SPS025, SPS026, SPS030, SPS032, SPS033, SPS043, SPS045, SPS087, SPS091, SPS109, SPS111, SPS136, SPS163, SPS193, SPS194, SPS197, SPS202, SPS210, SPS213, SPS214, SPS216, SPS217

Table 14. Studies with the highest CVI index, classified by topics

RQ	Topics	2022	2023	2024
Q1	Research	SPS003, SPS007, SPS083, SPS145, SPS146	SPS068, SPS174	SPS032, SPS136, SPS151, SPS168
	Education	SPS038, SPS146	SPS152, SPS206	SPS089, SPS115, SPS151
Q2	Software Development	SPS038		
	Computational Thinking			SPS115
	Data Analysis	SPS037, SPS071, SPS157	SPS183, SPS209	SPS001, SPS005, SPS028, SPS045, SPS061, SPS082, SPS129
	IT Infrastructure	SPS003, SPS007, SPS038, SPS083, SPS145, SPS146	SPS068, SPS152, SPS174, SPS206	SPS032, SPS089, SPS115, SPS136, SPS151, SPS168
	HPC	SPS083		
	Security	SPS083		
	Cloud Computing	SPS003, SPS146		SPS032, SPS136

Table 15. Studies with the Highest SCI Index, Categorized by Topic

RQ	Topics	2022	2023	2024
Q1	Research	SPS003, SPS044, SPS064, SPS083, SPS092, SPS137, SPS143, SPS145, SPS157, SPS176, SPS187, SPS192	SPS027, SPS029, SPS126, SPS165, SPS173, SPS223	SPS028, SPS032, SPS033, SPS054, SPS140, SPS197, SPS215
	Education	SPS187	SPS020, SPS072	
Q2	Software development	SPS044		SPS028, SPS215
	Computational thinking	SPS187		
	Parallel computing		SPS020, SPS223	
	Data analysis	SPS157		SPS028
	Artificial intelligence		SPS027, SPS072	
	Computer networks	SPS187		
	IT infrastructure	SPS003, SPS083, SPS092, SPS137, SPS143, SPS145, SPS176, SPS187	SPS020, SPS027, SPS029, SPS126, SPS173, SPS223	SPS032, SPS033, SPS054, SPS140, SPS197, SPS215
	HPC	SPS083	SPS027	
	Security	SPS064, SPS083, SPS092, SPS157, SPS192	SPS126, SPS165	
	Cloud computing	SPS003, SPS137, SPS143	SPS029, SPS126, SPS173	SPS032, SPS033, SPS197

Table 16. Studies with the Highest IRRQ Index, Classified by Topic

RQ	Topics	2022	2023	2024
Q1	Research	SPS002, SPS003, SPS007, SPS039, SPS044, SPS053, SPS059, SPS064, SPS070, SPS071, SPS073, SPS080, SPS083, SPS092, SPS137, SPS143, SPS145, SPS146, SPS155, SPS157, SPS176, SPS177, SPS187, SPS192	SPS027, SPS029, SPS055, SPS066, SPS067, SPS068, SPS081, SPS093, SPS094, SPS117, SPS126, SPS134, SPS153, SPS165, SPS167, SPS173, SPS174, SPS183, SPS195, SPS205, SPS209, SPS221, SPS223, SPS226	SPS005, SPS008, SPS010, SPS019, SPS021, SPS028, SPS030, SPS032, SPS033, SPS036, SPS045, SPS048, SPS054, SPS061, SPS082, SPS106, SPS107, SPS113, SPS129, SPS136, SPS140, SPS151, SPS168, SPS172, SPS178, SPS184, SPS197, SPS198, SPS214, SPS215, SPS216, SPS219
	Education	SPS038, SPS058, SPS101, SPS146, SPS187, SPS204	SPS020, SPS072, SPS116, SPS120, SPS152, SPS206, SPS207, SPS218	SPS089, SPS096, SPS115, SPS151, SPS163, SPS198, SPS199
	Outreach	SPS002, SPS031, SPS037	SPS078, SPS112	SPS010, SPS063, SPS114
Q2	Software development	SPS002, SPS037, SPS038, SPS044, SPS053, SPS058, SPS101	SPS078, SPS120, SPS183, SPS195	SPS008, SPS010, SPS028, SPS096, SPS172, SPS215
	Computational thinking	SPS187	SPS116	SPS115, SPS198
	Parallel computing		SPS020, SPS134, SPS223	
	Data analysis	SPS037, SPS071, SPS157	SPS183, SPS209	SPS005, SPS028, SPS045, SPS061, SPS082, SPS129
	Artificial Intelligence	SPS073	SPS209	SPS082
	Computer networks	SPS187	SPS094	SPS010, SPS019, SPS048, SPS106, SPS113, SPS198, SPS216, SPS219
	IT infrastructure	SPS003, SPS007, SPS031, SPS037, SPS038, SPS039, SPS070, SPS073, SPS083, SPS092, SPS137, SPS143, SPS145, SPS146, SPS155, SPS176, SPS177, SPS187, SPS204	SPS020, SPS027, SPS029, SPS055, SPS066, SPS067, SPS068, SPS078, SPS081, SPS094, SPS112, SPS117, SPS126, SPS134, SPS152, SPS167, SPS173, SPS174, SPS183, SPS205, SPS206, SPS207, SPS218, SPS223	SPS019, SPS021, SPS030, SPS032, SPS033, SPS036, SPS048, SPS054, SPS082, SPS089, SPS096, SPS106, SPS107, SPS115, SPS129, SPS136, SPS140, SPS151, SPS163, SPS168, SPS172, SPS178, SPS184, SPS197, SPS198, SPS199, SPS214, SPS215, SPS216, SPS219
	HPC	SPS083	SPS027, SPS134	SPS008, SPS114, SPS129, SPS178
	Security	SPS064, SPS070, SPS083, SPS092, SPS155, SPS157, SPS192	SPS081, SPS093, SPS094, SPS126, SPS153, SPS165, SPS183, SPS221, SPS226	SPS082, SPS129, SPS214, SPS219
	Cloud computing	SPS002, SPS003, SPS031, SPS070, SPS071, SPS080, SPS137, SPS143, SPS146, SPS177	SPS029, SPS055, SPS126, SPS173	SPS019, SPS030, SPS032, SPS033, SPS045, SPS136, SPS163, SPS197, SPS214, SPS216

Table 17. Classification of SPS studies by technology of **VBC** and academic dimension

Topics	Education	Research	Outreach
CRI-O		SPS068, SPS083	
Containerd		SPS066, SPS068, SPS083, SPS223	
Docker	SPS020, SPS038, SPS042, SPS058, SPS072, SPS089, SPS096, SPS101, SPS115, SPS116, SPS120, SPS124, SPS152, SPS187, SPS198, SPS199, SPS204, SPS206, SPS207, SPS218	SPS002, SPS004, SPS005, SPS007, SPS008, SPS011, SPS017, SPS021, SPS030, SPS039, SPS040, SPS041, SPS043, SPS044, SPS045, SPS046, SPS048, SPS049, SPS051, SPS053, SPS054, SPS055, SPS059, SPS060, SPS061, SPS065, SPS066, SPS071, SPS074, SPS079, SPS080, SPS081, SPS083, SPS093, SPS097, SPS099, SPS100, SPS102, SPS103, SPS104, SPS105, SPS106, SPS107, SPS119, SPS122, SPS124, SPS126, SPS129, SPS133, SPS153, SPS155, SPS172, SPS173, SPS174, SPS176, SPS177, SPS180, SPS182, SPS187, SPS188, SPS191, SPS192, SPS197, SPS198, SPS205, SPS209, SPS216, SPS219, SPS220, SPS221, SPS225, SPS226	SPS002, SPS037, SPS063, SPS078, SPS099, SPS112, SPS114, SPS220
Firecracker		SPS107, SPS205	
Google gVisor		SPS107, SPS184, SPS205	
Hyper-V containers		SPS068	
Kata Containers		SPS184, SPS205, SPS224	
LXC		SPS066, SPS068, SPS083, SPS157	
LXD		SPS068, SPS083	
OpenVZ		SPS083	
Podman		SPS007, SPS046, SPS060, SPS068, SPS083, SPS129, SPS174	
Rkt		SPS068, SPS083	

Topics	Education	Research	Outreach
Singularity		SPS041, SPS060, SPS068	
Udocker		SPS027, SPS068	

Table 18. Classification of SPS studies by IT domain and academic dimension

Topics	Education	Research	Outreach
Data analysis		SPS001, SPS005, SPS028, SPS045, SPS061, SPS071, SPS082, SPS129, SPS157, SPS183, SPS209	SPS037
Blockchain			SPS063
Cloud computing	SPS146, SPS163	SPS002, SPS003, SPS012, SPS015, SPS018, SPS019, SPS025, SPS026, SPS029, SPS030, SPS032, SPS033, SPS043, SPS045, SPS055, SPS056, SPS069, SPS070, SPS071, SPS079, SPS080, SPS084, SPS085, SPS087, SPS091, SPS099, SPS109, SPS111, SPS126, SPS136, SPS137, SPS143, SPS146, SPS149, SPS173, SPS177, SPS179, SPS185, SPS193, SPS194, SPS197, SPS202, SPS210, SPS213, SPS214, SPS216, SPS217, SPS222	SPS002, SPS031, SPS099, SPS213
Parallel computing	SPS020	SPS017, SPS134, SPS223	
Software development	SPS038, SPS042, SPS058, SPS096, SPS101, SPS120	SPS002, SPS008, SPS010, SPS015, SPS022, SPS028, SPS043, SPS044, SPS053, SPS086, SPS098, SPS100, SPS118, SPS133, SPS172, SPS183, SPS195, SPS215, SPS224	SPS002, SPS010, SPS037, SPS078
HPC		SPS008, SPS014, SPS017, SPS018, SPS027, SPS041, SPS062, SPS083, SPS090, SPS098, SPS121, SPS129, SPS134, SPS178, SPS194, SPS200	SPS114

Topics	Education	Research	Outreach
Artificial intelligence	SPS072	SPS011, SPS023, SPS027, SPS030, SPS040, SPS051, SPS053, SPS059, SPS073, SPS077, SPS080, SPS082, SPS095, SPS142, SPS148, SPS149, SPS154, SPS161, SPS169, SPS170, SPS177, SPS183, SPS209	SPS037, SPS078, SPS181
Computational thinking	SPS042, SPS115, SPS116, SPS187, SPS198	SPS187, SPS198	
Computer networks	SPS139, SPS187, SPS198	SPS010, SPS019, SPS046, SPS048, SPS094, SPS103, SPS105, SPS106, SPS110, SPS113, SPS132, SPS159, SPS164, SPS187, SPS198, SPS216, SPS219	SPS010
Security		SPS010, SPS019, SPS046, SPS048, SPS094, SPS103, SPS105, SPS106, SPS110, SPS113, SPS132, SPS159, SPS164, SPS187, SPS198, SPS216, SPS219	
IT infrastructure	SPS020, SPS038, SPS075, SPS089, SPS096, SPS115, SPS124, SPS146, SPS151, SPS152, SPS163, SPS187, SPS198, SPS199, SPS204, SPS206, SPS207, SPS218	SPS003, SPS004, SPS007, SPS009, SPS011, SPS012, SPS014, SPS017, SPS018, SPS019, SPS021, SPS023, SPS024, SPS025, SPS026, SPS027, SPS029, SPS030, SPS032, SPS033, SPS034, SPS036, SPS039, SPS046, SPS047, SPS048, SPS049, SPS051, SPS052, SPS054, SPS055, SPS056, SPS057, SPS060, SPS062, SPS066, SPS067, SPS068, SPS069, SPS070, SPS073, SPS074, SPS075, SPS076, SPS077, SPS079, SPS081, SPS082, SPS083, SPS084, SPS085, SPS087, SPS088, SPS090, SPS091, SPS092, SPS094, SPS095, SPS099, SPS100, SPS102, SPS103, SPS104, SPS105, SPS106, SPS107, SPS109, SPS110, SPS111, SPS117, SPS119, SPS121, SPS122, SPS123, SPS124, SPS125, SPS126, SPS129, SPS130, SPS131, SPS132, SPS134, SPS135, SPS136, SPS137, SPS140, SPS143, SPS144, SPS145, SPS146, SPS148, SPS149, SPS150	SPS031, SPS037, SPS078, SPS099, SPS112, SPS181, SPS208, SPS211, SPS213, SPS220

Topics	Education	Research	Outreach
		SPS151, SPS154, SPS155, SPS156, SPS159, SPS160, SPS164, SPS167, SPS168, SPS169, SPS170, SPS171, SPS172, SPS173, SPS174, SPS175, SPS176, SPS177, SPS178, SPS179, SPS180, SPS182, SPS183, SPS184, SPS185, SPS186, SPS187, SPS188, SPS189, SPS190, SPS196, SPS197, SPS198, SPS200, SPS201, SPS205, SPS208, SPS210, SPS212, SPS213, SPS214, SPS215, SPS216, SPS217, SPS219, SPS220, SPS222, SPS223, SPS224, SPS225	

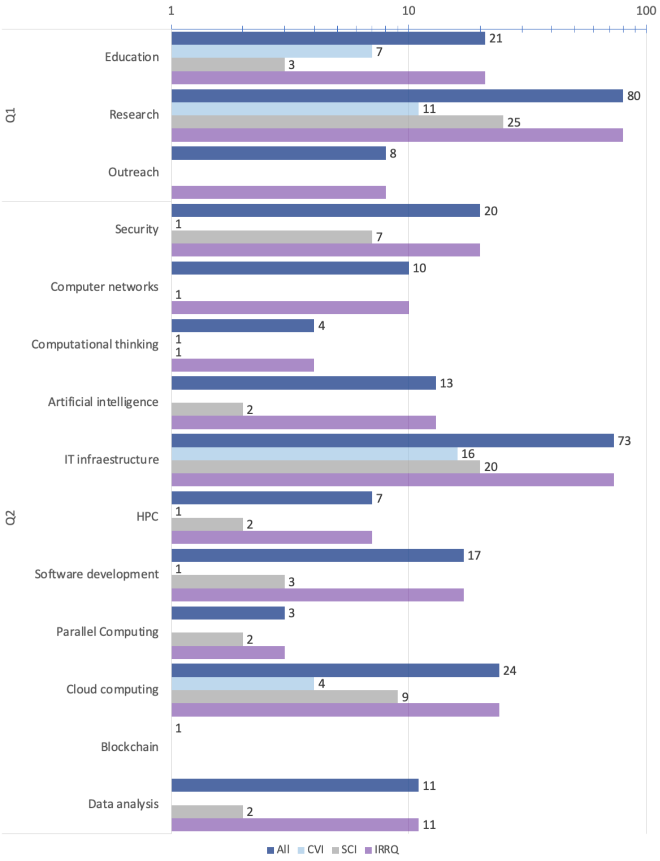

Figure 12. SPS by quality indices, topics, and research questions

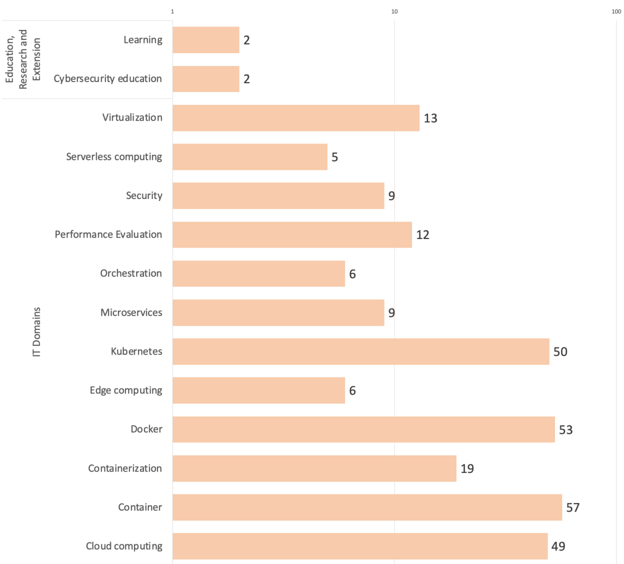

Figure 13. SPS keyword co-occurrence analysis

4.6.2 Word Cloud Visualization

Figure 14 presents the keyword cloud generated from the 226 SPS (terms with frequency > 1). The three dominant clusters—*Docker*, *Container*, *Kubernetes*, *Cloud Computing* (61.6%); *Containerization*, *Container Orchestration*, *Virtualization*, *Microservices* (13.08%); and *Performance evaluation*, *Edge computing*, *Machine learning*, *Security* (9.09%)—reflect the current thematic structure of CBV research. Notably, terms related to education, teaching, and outreach are absent from the high-frequency clusters, confirming the finding that academic applications of CBV remain an under-investigated research area.

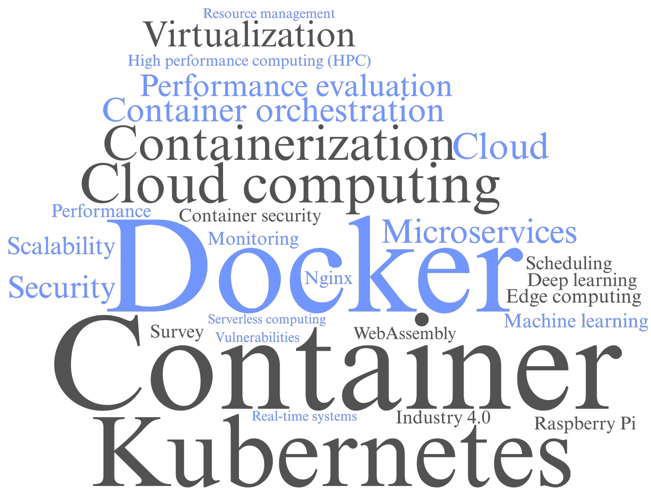

Figure 14. Keyword cloud of the 226 SPS

4.6.3 *Reproducibility*

To ensure full reproducibility, two verification mechanisms are provided:

1) A public SMS-Builder instance containing all process data: https://sms-vbc.iti.grid.uniquindio.edu.co/sms.xhtml. Credentials: *"invitado"* for both username and password.
2) A Docker image integrating all required documentation: https://hub.docker.com/r/anubis1001/tg-vbc-sms-builder.

5 Threats to Validity

Four categories of threats to validity are identified, along with the mitigation strategies employed.

5.1 Selection Bias

Seven measures were implemented to mitigate selection bias. First, the SMS followed established guidelines Runeson and Höst [2009]; Kitchenham et al. [2010], including GQM and PICOC frameworks. Second, five major databases were queried. Third, synonyms were included for all key terms to ensure broad coverage. Fourth, search strings were iteratively refined through pilot searches. Fifth, a hybrid strategy combining database search with snowballing increased coverage. Sixth, alert systems (Endnote, Mendeley, Google Scholar) monitored for newly published studies. Seventh, three quality indices (CVI, SCI, IRRQ) provided complementary assessment perspectives. The CVI and IRRQ indices carry inherent subjectivity; this was mitigated through collaborative evaluation by an odd number of independent evaluators ($K \geq 3$).

5.2 Classification Errors

Studies were classified according to the topics defined during planning, corresponding to CBV technologies, IT domains, education, research, and outreach. Multi-topic classification was permitted when a study's scope spanned multiple areas. All classifications underwent peer review by an odd number of evaluators to reduce individual bias.

5.3 Data Extraction Inaccuracy

The SMS-Builder software Candela-Uribe et al. [2020] was used for structured data extraction, minimizing manual processing errors. Peer review was conducted on extracted data following the recommendations of Kitchenham and Charters Kitchenham et al. [2010].

5.4 Search Protocol Errors

The search protocol was executed under peer review: one evaluator implemented the protocol while a second independently verified the process. SMS-Builder was used throughout to reduce manual data handling and ensure process consistency.

6 Analysis, Discussion, and Future Research Directions

The SMS results reveal several cross-cutting patterns that merit interpretation beyond descriptive statistics. This section synthesizes the key findings, proposes a taxonomic structure, identifies research gaps, and outlines concrete future research directions.

6.1 Proposed Taxonomic Structure

The classification of 226 SPS across IT domains and academic dimensions motivates a taxonomic structure (Figure 15) that organizes the CBV research landscape along two axes: *(i)* the IT domain (software development, IT infrastructure, cloud computing, HPC, security, AI, etc.) and *(ii)* the academic dimension (education, research, outreach). This dual-axis taxonomy constitutes a novel contribution, as no prior secondary study has simultaneously mapped both dimensions. The taxonomy can serve as a decision-support tool for researchers identifying relevant literature, for educators designing container-based curricula, and for practitioners selecting technologies aligned with domain-specific requirements.

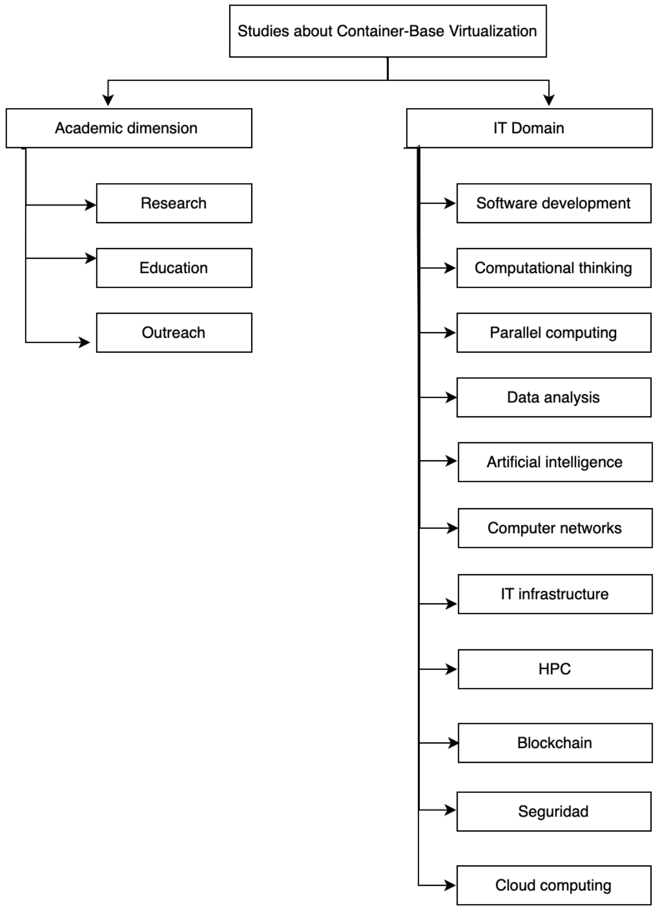

Figure 15. Proposed taxonomic structure for CBV research

6.2 Key Findings and Interpretation

Technology concentration and its implications. The dominance of Docker (94 SPS, 41.6%) and Kubernetes (67 SPS) reveals a significant concentration risk in the research literature. While Docker's ubiquity reflects its first-mover advantage and ecosystem maturity, it also implies that findings from the CBV research corpus may not generalize to alternative runtimes with different security models (gVisor, Kata Containers), permission models (Podman), or HPC optimization (Singularity/Apptainer). Researchers should critically evaluate whether conclusions drawn from Docker-centric studies apply to their specific deployment contexts.

The IT Infrastructure bias. IT Infrastructure accounts for 75.66% of the mapped studies, creating a pronounced bias toward deployment and management concerns. Domains such as Blockchain (0.76%), Parallel Computing (1.77%), and Computational Thinking (2.21%) remain severely underexplored despite clear potential for containerization. For instance, container-based approaches to reproducible blockchain testing environments, portable parallel computing frameworks, and interactive computational thinking platforms represent viable but unaddressed research directions.

The academic dimension gap. The fragmentation across academic dimensions—with Research dominating (83.61%) and Outreach representing only 5.88%—reveals a missed opportunity. Containerization's core strengths (portability, reproducibility, environment isolation) are precisely the attributes needed for effective outreach and knowledge transfer. The absence of studies simultaneously addressing education, research, and outreach suggests that the academic community has not yet leveraged CBV's transversal potential.

Temporal trends and maturation signals. The 118% growth in publications from 2022 to 2024, combined with the increasing CVI and IRRQ indices, indicates both growing interest and improving methodological alignment with the field's core questions. However, the stable SCI around 18 suggests that while more studies are published, citation impact has not proportionally increased—a pattern consistent with a rapidly expanding but potentially fragmenting research area.

6.3 Identified Research Gaps

Based on the SMS findings, the following research gaps are identified:

RG1: **Alternative runtime evaluation.** Systematic comparative studies of container runtimes beyond Docker (e.g., Podman, Singularity, gVisor, Kata Containers) across performance, security, and usability dimensions are critically needed.

RG2: **Orchestration beyond Kubernetes.** Research evaluating lightweight orchestration alternatives (K3s, Nomad, Docker Compose) for edge computing, IoT, and resource-constrained environments is underrepresented.

RG3: **CBV in education and outreach.** Empirical studies measuring the impact of containerization on learning outcomes, curriculum design, and outreach program effectiveness are nearly absent from the literature.

RG4: **Cross-domain integration.** No identified study bridges all three academic dimensions simultaneously, presenting an opportunity for holistic CBV adoption frameworks.

RG5: **Emerging IT domains.** The intersection of CBV with blockchain, quantum computing simulation, and computational thinking requires dedicated investigation.

RG6: **Security of container ecosystems.** While security appears in 65 SPS, most address container isolation rather than supply-chain security, image provenance, or runtime attestation—areas of growing practical concern.

6.4 Future Research Directions

Building on the identified gaps, the following concrete research directions are proposed:

- **Benchmarking frameworks:** Development of standardized benchmarking methodologies for comparing container runtimes and orchestrators across heterogeneous hardware (x86, ARM, RISC-V) and workload profiles (HPC, microservices, AI training).
- **Educational impact studies:** Controlled experiments measuring the effect of container-based laboratory environments on student learning outcomes, engagement, and skill transferability in computer science education.
- **Outreach and knowledge transfer:** Design and evaluation of container-packaged educational platforms that facilitate technology transfer from universities to industry and communities, particularly in resource-limited settings.
- **Security posture analysis:** Comprehensive studies on container supply-chain security, including image scanning effectiveness, Software Bill of Materials (SBOM) adoption, and runtime security monitoring in production environments.
- **Lightweight orchestration for edge/IoT:** Empirical evaluation of Kubernetes alternatives in edge and IoT deployments where resource constraints and latency requirements differ from cloud-native assumptions.

6.5 Implications for Research and Practice

For *researchers*, this SMS provides a structured entry point into the CBV literature, enabling targeted investigation of underexplored domains and informed positioning of new contributions. The identified gaps (RG1–RG6) offer concrete starting points for future studies. For *practitioners*, the technology distribution analysis highlights both the safety of Docker/Kubernetes adoption (given extensive research backing) and the risk of overlooking better-suited alternatives for specific use cases. For *educators*, the near-absence of containerization in formal educational frameworks represents an opportunity to develop innovative pedagogical approaches leveraging CBV's reproducibility and portability.

7 Conclusions

This paper presented a Systematic Mapping Study (SMS) on container-based virtualization (CBV) technologies, covering 226 primary studies published between 2022 and 2024. The study employed a hybrid search strategy (database queries and snowballing), three quality assessment indices (CVI, SCI, IRRQ), and a dual-axis classification spanning 11 IT domains and three academic dimensions (education, research, outreach).

The main contributions and findings are as follows:

1. **Comprehensive mapping:** The SMS provides the first systematic mapping that simultaneously covers CBV technologies across IT domains and academic dimensions, addressing a gap identified in all prior secondary studies.
2. **Technology concentration:** Docker (41.6%) and Kubernetes (29.6%) dominate the research landscape, while alternative runtimes (Podman, Singularity, gVisor) and orchestrators (K3s, Nomad) remain significantly underrepresented despite their growing industrial relevance.
3. **Domain imbalance:** IT Infrastructure accounts for 75.66% of the corpus, while domains such as

Blockchain (0.76%), Parallel Computing (1.77%), and Computational Thinking (2.21%) represent critical blind spots in current research.

4. **Academic fragmentation:** Research dominates (83.61%) while Education (11.06%) and Outreach (5.88%) remain underexplored. No study simultaneously addresses all three academic dimensions, indicating that CBV's transversal potential for academic activities remains unrealized.
5. **Taxonomic structure:** A novel dual-axis taxonomy organizes the CBV literature by IT domain and academic dimension, providing a structured reference for researchers, educators, and practitioners.
6. **Research gaps:** Six concrete gaps (RG1–RG6) were identified, with corresponding future research directions including alternative runtime benchmarking, educational impact studies, outreach frameworks, supply-chain security analysis, and lightweight orchestration for edge/IoT.

The growing publication rate (118% increase from 2022 to 2024) confirms the vitality of this research area but also underscores the risk of literature saturation without adequate systematization. The taxonomic structure and reproducibility artifacts provided with this study aim to mitigate this challenge.

As future work, we plan to conduct controlled comparative evaluations of container runtimes and orchestrators across heterogeneous hardware platforms, and to design and evaluate container-based pedagogical frameworks for computer science education.

References

Sherhan Upahm Abas, Fecir Duran, and Adem Tekerek. A raspberry pi based blockchain application on iot security. *Expert Systems with Applications*, 229:120486, 2023.

Marco Abbadini, Michele Beretta, Dario Facchinetti, Gianluca Oldani, Matthew Rossi, and Stefano Paraboschi. Lightweight cloud application sandboxing. In *2023 IEEE International Conference on Cloud Computing Technology and Science (CloudCom)*, pages 139–146. IEEE, 2023.

Sameh Abdulah, Jorge Ejarque, Omar Marzouk, Hatem Ltaief, Ying Sun, Marc G Genton, Rosa M Badia, and David E Keyes. Portability and scalability evaluation of large-scale statistical modeling and prediction software through hpc-ready containers. *Future Generation Computer Systems*, 161:248–258, 2024.

Shreyas Agrawal and Dhawan Singh. Study containerization technologies like docker and kubernetes and their role in modern cloud deployments. In *2024 IEEE 9th International Conference for Convergence in Technology (I2CT)*, pages 1–5. IEEE, 2024.

Vishnu Ajith, Tom Cyriac, Chetan Chavda, Anum Tanveer Kiyani, Vijay Chennareddy, and Kamran Ali. Analyzing docker vulnerabilities through static and dynamic methods and enhancing iot security with aws iot core, cloudwatch, and guardduty. *IoT*, 5(3):592–607, 2024.

Ilter Taha Aktolga, Elif Sena Kuru, Yigit Sever, and Pelin Angin. Ai-driven container security approaches for 5g and beyond: A survey. *arXiv preprint arXiv:2302.13865*, 2023.

Yousuf Al-Obaidi, Ioannis Sorokos, and Andreas Schmidt. Safetykube: Towards orchestration at the edge for critical production systems. 2023.

Muhammad Juan Al Qausar, Haryono Soeparno, Ford Lumban Gaol, and Yulyani Arifin. Software metrics for container-based applications: Systematic literature review. In *2023 International Conference on Information Management and Technology (ICIMTech)*, pages 125–130. IEEE, 2023.

Ahmad Alamoush and Holger Eichelberger. Open source container orchestration for industry 4.0–requirements and systematic feature analysis. *International Journal on Software Tools for Technology Transfer*, 26(5):527–550, 2024.

Maram Aldiabat, Qussai M Yaseen, and Qusai Abu Ein. An efficient random forest classifier for detecting malicious docker images in docker hub repository. *IEEE Access*, 2024.

Abdullah Alelyani, Amitava Datta, and Ghulam Mubashar Hassan. Dascheduler: Dependency-aware scheduling algorithm for containerized dependent jobs. *Journal of Grid Computing*, 21(3):46, 2023.

Abdulrazzaq Qasem Ali, Abu Bakar Md. Sultan, Abdul Azim Abd Ghani, and Hazura Zulzalil. A systematic mapping study on the customization solutions of software as a service applications. *IEEE Access*, 7:88196–88217, 2019. .

Rayhan Gusty Alif and Lulu Chaerani Munggaran. Implementation of gitops in containerized infrastructure. *Rabit: Jurnal Teknologi dan Sistem Informasi Univrab*, 9(1):154–161, 2024.

Enas Almanasreh, Rebekah Moles, and Timothy F Chen. Evaluation of methods used for estimating content validity. *Research in social and administrative pharmacy*, 15 (2):214–221, 2019.

Mohamed Almoudane. A comprehensive study on virtualization techniques and their role in cloud computing, 05 2025.

Guillermo Chinarro Álvarez, César Alejandro Achig Ramírez, Javier Andión, Juan C Dueñas, et al. Toward an integrated and supported machine learning process. In *2023 7th International Young Engineers Forum (YEF-ECE)*, pages 37–42. IEEE, 2023.

Tahir Alyas, Nadia Tabassum, Muhammad Waseem Iqbal, Abdullah S Alshahrani, Ahmed Alghamdi, and Syed Khuram Shahzad. Resource based automatic calibration system (rbacs) using kubernetes framework. *Intelligent Automation & Soft Computing*, 35(1), 2023.

Vassileios Amoiridis, Ulf Behrens, Andrea Bocci, James Branson, Philipp Brummer, Eric Cano, Sergio Cittolin, Joao Da Silva Almeida Da Quintanilha, Georgiana-Lavinia Darlea, Christian Deldicque, et al. Towards a container-based architecture for cms data acquisition. In *EPJ Web of Conferences*, volume 295, page 02031. EDP Sciences, 2024.

VM Antonova, MA Egorov, VP Blinov, EE Malikova, and AY Malikov. Studying the principles of infocommunication network virtualisation using the docker platform. In *2024 Systems of Signals Generating and Processing in the Field of on Board Communications*, pages 1–5. IEEE, 2024.

Fitra Arifiansyah et al. Utilization of virtual reality for docker learning. In *2023 IEEE International Conference on Data and Software Engineering (ICoDSE)*, pages 244–249. IEEE, 2023.

Muhammad Fikri Ashari, Adhitya Bhawiyuga, and Achmad Basuki. The development of hands-on lab platform using container-based virtualization technology. In *Proceedings of the 8th International Conference on Sustainable Information Engineering and Technology*, pages 304–310, 2023.

Dariusz R Augustyn, Łukasz Wyciślik, and Mateusz Sojka. Tuning a kubernetes horizontal pod autoscaler for meeting performance and load demands in cloud deployments. *Applied Sciences*, 14(2):646, 2024.

Lynn Htet Aung, Soe Thandar Aung, Nobuo Funabiki, Htoo Htoo Sandi Kyaw, and Wen-Chung Kao. An implementation of web-based answer platform in the flutter programming learning assistant system using docker compose. *Electronics*, 13(24):4878, 2024.

Hideaki Azuma, Shinsuke Matsumoto, Yasutaka Kamei, and Shinji Kusumoto. An empirical study on self-admitted technical debt in dockerfiles. *Empirical Software Engineering*, 27(2):49, 2022.

Ryan Bannon. *Leveraging machine learning to reduce cold start latency of containers in serverless computing*. PhD thesis, Dublin, National College of Ireland, 2022.

Alexander Barbie, Wilhelm Hasselbring, and Malte Hansen. Enabling automated integration testing of smart farming applications via digital twin prototypes. In *2023 IEEE Smart World Congress (SWC)*, pages 1–8. IEEE, 2023.

Luciano Baresi, Giovanni Quattrocchi, and Nicholas Rasi. A qualitative and quantitative analysis of container engines. *Journal of Systems and Software*, 210:111965, 2024a.

Luciano Baresi, Giovanni Quattrocchi, and Nicholas Rasi. A qualitative and quantitative analysis of container engines. *Journal of Systems and Software*, 210:111965, 2024b. ISSN 0164-1212. . URL `https://www.sciencedirect.com/science/article/pii/S0164121224000086`.

Marco Barletta, Marcello Cinque, Catello Di Martino, Zbigniew T Kalbarczyk, and Ravishankar K Iyer. Mutiny! how does kubernetes fail, and what can we do about it? In *2024 54th Annual IEEE/IFIP International Conference on Dependable Systems and Networks (DSN)*, pages 1–14. IEEE, 2024a.

Marco Barletta, Luigi De Simone, Raffaele Della Corte, and Catello Di Martino. Failover timing analysis in orchestrating container-based critical applications. In *2024 19th European Dependable Computing Conference (EDCC)*, pages 81–84. IEEE, 2024b.

Nada Barnawi, Razan AITooq, and Mohammed Almukaynizi. Mitigating container escape threats through effective countermeasures: A survey. In *Proceedings of the 10th World Congress on Electrical Engineering and Computer Systems and Sciences (EECSS'24)*, 2024.

Pedro HSS Barros, Marcelo QA Oliveira, Omid Orang, Felipe AR da Silva, Fabricio J Erazo-Costa, Allana Tavares Bastos, Petrônio CL Silva, Glauber Soares dos Santos, Antonio AF Loureiro, Martín Gómez Ravetti, et al. Flautim: A federated learning platform using k8s and flower. In *Simpósio Brasileiro de Sistemas Multimídia e Web (WebMedia)*, pages 87–90. SBC, 2024.

Paolo Bellavista, Simon Dahdal, Luca Foschini, Davide Tazzioli, Mauro Tortonesi, and Riccardo Venanzi. Kubernetes enhanced stateful service migration for ml-driven applications in industry 4.0 scenarios. In *2024 IEEE Annual Congress on Artificial Intelligence of Things (AIoT)*, pages 25–31. IEEE, 2024.

Ouafa Bentaleb, Adam SZ Belloum, Abderrazak Sebaa, and Aouaouche El-Maouhab. Containerization technologies: Taxonomies, applications and challenges. *The Journal of Supercomputing*, 78(1):1144–1181, 2022a.

Ouafa Bentaleb, Adam S.Z. Belloum, Abderrazak Sebaa, and Aouaouche El-Maouhab. Containerization technologies: taxonomies, applications and challenges. *Journal of Supercomputing*, 78(1):1144–1181, 2022b. ISSN 15730484. . URL `https://doi.org/10.1007/s11227-021-03914-1`.

Ouafa Bentaleb, Abderrazak Sebaa, S Kalli, and Adam SZ Belloum. Deployment of a programming framework based on microservices and containers with application to the astrophysical domain. *Astronomy and Computing*, 41: 100655, 2022c.

Matteo Benzi, Giovanni Lagorio, and Marina Ribaudo. Automatic challenge generation for hands-on cybersecurity training. In *2022 IEEE European Symposium on Security and Privacy Workshops (EuroS&PW)*, pages 496–503. IEEE, 2022.

Tobias Betz, Long Wen, Fengjunjie Pan, Gemb Kaljavesi, Alexander Zuepke, Andrea Bastoni, Marco Caccamo, Alois Knoll, and Johannes Betz. A containerized microservice architecture for a ros 2 autonomous driving software: An end-to-end latency evaluation. In *2024 IEEE 30th International Conference on Embedded and Real-Time Computing Systems and Applications (RTCSA)*, pages 57–66. IEEE, 2024.

Md Olid Hasan Bhuiyan, Souvik Das, Shafayat H Majumder, Suryadipta Majumdar, and Md Shohrab Hossain. On detecting malicious code injection by monitoring multi-level container activities. In *CLOSER*, pages 15–26, 2024.

David Fernández Blanco, Frédéric Le Mouël, Trista Lin, and Amir Rekik. Can software containerisation fit the car on-board systems? In *2023 IEEE International Conference on Cloud Computing Technology and Science (CloudCom)*, pages 123–130. IEEE, 2023.

Robert Botez, Cărălin-Marian Petruti, Iustin-Alexandru Ivanciu, and Virgil Dobrota. Kubernetes-based load balancer as a service for private cloud infrastructures. In *2022 14th International Conference on Communications (COMM)*, pages 1–6. IEEE, 2022.

Vincent Bracke, Gillis Werrebrouck, José Santos, Tim Wauters, Filip De Turck, and Bruno Volckaert. Online dynamic container rescheduling for improved application service time. *Journal of Network and Systems Management*, 31(4):80, 2023.

Vincent Bracke, José Santos, Tim Wauters, Filip De Turck, and Bruno Volckaert. A multiobjective metaheuristic-based container consolidation model for cloud application performance improvement. *Journal of Network and Systems Management*, 32(3):61, 2024.

Marc Burchart and Joerg M Haake. Supporting collaborative writing tasks in large-scale distance education. *IEEE Transactions on Learning Technologies*, 17:1051–1068, 2024.

C.A. Candela-Uribe, L.E. Sepúlveda-Rodríguez, J.C. Chavarro-Porras, J.A. Sanabria-Ordoñez, J.L. Garrido, C. Rodríguez-Domínguez, and G. Guerrero-Contreras. SMS-Builder Project. `https://github.com/grid-uq/sms-builder`, 2020. Accessed: 2025-08-11.

Christian A. Candela-Uribe, Luis E. Sepúlveda-Rodríguez, Julio C. Chavarro-Porras, John A. Sanabria-Ordoñez, José Luis Garrido, Carlos Rodríguez-Domínguez, and Gabriel Guerrero-Contreras. SMS-Builder: An adaptive software tool for building systematic mapping studies. *SoftwareX*, 17:100935, 2022. ISSN 23527110. . URL `https://doi.org/10.1016/j.softx.2021.100935`.

Ali İhsan Candemir and Nilgün İncereis. Comparative analysis of transaction performance in different virtualization environments. *Acta Infologica*, 8(2):176–187, 2024.

Carmen Carrión. Kubernetes scheduling: Taxonomy, ongoing issues and challenges. *ACM Computing Surveys*, 55 (7):1–37, 2022a.

Carmen Carrión. Kubernetes as a standard container orchestrator-a bibliometric analysis. *Journal of Grid Computing*, 20(4):42, 2022b.

Sushant Chamoli and Varsha Mittal. Docker networking: A security review. In *2023 7th International Conference on Trends in Electronics and Informatics (ICOEI)*, pages 624–629. IEEE, 2023.

Pravar Chaurasia, Shubha Brata Nath, Sourav Kanti Addya, and Soumya K Ghosh. Automating the selection of container orchestrators for service deployment. In *2022 14th International Conference on COMmunication Systems & NETworkS (COMSNETS)*, pages 739–743. IEEE, 2022.

Chen Chen, Wei Shen, and Honghai Liu. Construction of cloud computing password application system based on docker technology. In *2022 International Conference on Artificial Intelligence of Things and Crowdsensing (AIoTCs)*, pages 175–179. IEEE, 2022.

Kai Chen, Yufei Zhao, Jing Guo, Zhimin Gu, Longxi Han, and Keyi Tang. A container escape detection method based on a dependency graph. *Electronics*, 13(23):4773, 2024.

Dongmin Choi, Hyunmin Seo, Kwanwoo Kim, Myoungsung You, Seungwon Shin, and Jinwoo Kim. Uncovering threats in container systems: A study on misconfigured container components in the wild. *IEEE Access*, 2024.

Kihan Choi, Hyungseok Seo, Hyuck Han, Minsoo Ryu, and Sooyong Kang. Credscache: Making overlayfs scalable for containerized services. *Future Generation Computer Systems*, 147:44–58, 2023a.

Young-Don Choi, Binata Roy, Jared Nguyen, Raza Ahmad, Iman Maghami, Ayman Nassar, Zhiyu Li, Anthony M Castronova, Tanu Malik, Shaowen Wang, et al. Comparing containerization-based approaches for reproducible computational modeling of environmental systems. *Environmental Modelling & Software*, 167:105760, 2023b.

Mateo Clement. Role of cloud-native technologies in agile software developmen. 01 2025.

Vedran Dakić, Mario Kovač, and Jurica Slovinac. Evolving high-performance computing data centers with kubernetes, performance analysis, and dynamic workload placement based on machine learning scheduling. *Electronics*, 13(13):2651, 2024.

Assis T de Oliveira Filho, Eduardo Freitas, Pedro RX do Carmo, Eduardo Souto, Judith Kelner, and Djamel FH Sadok. Analysis of sr-iov in docker containers using rtt measurements. *Computer Communications*, 228:107961, 2024.

Qiqing Deng, Xinrui Tan, Jing Yang, Chao Zheng, Liming Wang, and Zhen Xu. A secure container placement strategy using deep reinforcement learning in cloud. In *2022 IEEE 25th International Conference on Computer Supported Cooperative Work in Design (CSCWD)*, pages 1299–1304. IEEE, 2022.

Tanja Dimova, Igor Kalendar, Daniel Denkovski, Danijela Efnusheva, and Marija Kalendar. An innovative approach of api automation testing implemented on cloud environments using container management services. 2024.

Debopriya Roy Dipta, Thore Tiemann, Berk Gulmezoglu, Eduard Marin, and Thomas Eisenbarth. Dynamic frequency-based fingerprinting attacks against modern sandbox environments. In *2024 IEEE 9th European Symposium on Security and Privacy (EuroS&P)*, pages 327–344. IEEE, 2024.

Felix Dobslaw, Kristian Angelin, Lena-Maria Öberg, and Awais Ahmad. The gap between higher education and the software industry—a case study on technology differences. In *Proceedings of the 5th European Conference on Software Engineering Education*, pages 11–21, 2023.

Javad Dogani, Farshad Khunjush, and Mehdi Seydali. K-agrued: A container autoscaling technique for cloud-based web applications in kubernetes using attention-based gru encoder-decoder. *Journal of Grid Computing*, 20(4):40, 2022.

Javad Dogani, Reza Namvar, and Farshad Khunjush. Auto-scaling techniques in container-based cloud and edge/fog computing: Taxonomy and survey. *Computer Communications*, 209:120–150, 2023.

Wenliang Du, Honghao Zeng, and Kyungrok Won. Seed emulator: An internet emulator for research and education. In *Proceedings of the 21st ACM workshop on hot topics in networks*, pages 101–107, 2022.

Anuj Dubey, Charu Priya Singh, and Deepak Nadig. Leveraging large language models for intent-based generation of cloud-native configurations. In *2024 IEEE International Conference on Advanced Networks and Telecommunications Systems (ANTS)*, pages 1–6. IEEE, 2024.

Hossein Ebrahimpour, Mehrdad Ashtiani, Fatemeh Bakhshi, and Ghazaleh Bakhtiariazad. A heuristic-based package-aware function scheduling approach for creating a trade-off between cold start time and cost in faas computing environments. *The Journal of Supercomputing*, 79(11):12142–12190, 2023.

Asbat El Khairi, Marco Caselli, Christian Knierim, Andreas Peter, and Andrea Continella. Contextualizing system calls in containers for anomaly-based intrusion detection. In *Proceedings of the 2022 on Cloud Computing Security Workshop*, pages 9–21, 2022.

Kalvin Eng, Abram Hindle, and Eleni Stroulia. Patterns of multi-container composition for service orchestration with docker compose. *Empirical Software Engineering*, 29(3): 65, 2024.

Joaquín Entrialgo, Manuel García, Javier García, José María López, and José Luis Díaz. Joint autoscaling of containers and virtual machines for cost optimization in container clusters. *Journal of Grid Computing*, 22(1):17, 2024.

Ivan Eroshkin, Lukas Vojtech, and Marek Neruda. Improving quality of 5g/6g/xg network through reliability estimation in kubernetes. In *European Wireless 2024; 29th European Wireless Conference*, pages 77–84. VDE, 2024.

M Ersted Rasmussen, C Dueholm Vestergaard, J Folsted Kallehauge, J Ren, M Haislund Guldberg, O Nørrevang, et al. Raddeploy: A framework for integrating inhouse developed software and artificial intelligence models seamlessly into radiotherapy workflows. phys imaging radiat oncol 2024; 31, 2024.

Felipe Bedinotto Fava, Luiz Felipe Laviola Leite, Luís Fernando Alves Da Silva, Pedro Ramires Da Silva Amalfi Costa, Angelo Gaspar Diniz Nogueira, Amanda Fagundes Gobus Lopes, Claudio Schepke, Diego Luis Kreutz, and Rodrigo Brãndao Mansilha. Assessing the performance of docker in docker containers for microservice-based architectures. In *2024 32nd Euromicro International Conference on Parallel, Distributed and Network-Based Processing (PDP)*, pages 137–142. IEEE, 2024.

Kourtnee Fernalld, TJ OConnor, Sneha Sudhakaran, and Nasheen Nur. Lightweight symphony: Towards reducing computer science student anxiety with standardized docker environments. In *Proceedings of the 24th Annual Conference on Information Technology Education*, pages 15–21, 2023.

Tim Fischer, Denis Hirn, and Gökhan Kul. A reproducible tutorial on reproducibility in database systems research. *Proceedings of the VLDB Endowment*, 17(12):4221–4224, 2024.

Jose Flora and Nuno Antunes. Evaluating intrusion detection for microservice applications: Benchmark, dataset, and case studies. *Journal of Systems and Software*, 216: 112142, 2024.

Anderson Frasão, Tiago Heinrich, Vinicius Fulber-Garcia, Newton C Will, Rafael R Obelheiro, and Carlos A Maziero. I see syscalls by the seashore: An anomaly-based ids for containers leveraging sysdig data. In *2024 IEEE Symposium on Computers and Communications (ISCC)*, pages 1–6. IEEE, 2024.

Yuqi Fu, Naseem Machlovi, Ying Mao, Jiayin Wang, Long Cheng, and Qingzhi Liu. Performance evaluation of resource management schemes for cloud native platforms with computing containers. In *2022 IEEE International Performance, Computing, and Communications Conference (IPCCC)*, pages 414–415. IEEE, 2022.

Philipp Gackstatter, Pantelis A Frangoudis, and Schahram Dustdar. Pushing serverless to the edge with webassembly runtimes. In *2022 22nd IEEE International Symposium on Cluster, Cloud and Internet Computing (CCGrid)*, pages 140–149. IEEE, 2022.

Stefano Galantino, Fulvio Risso, Andrea Cazzaniga, Fabrizio Garrone, Roberta Terruggia, and Riccardo Lazzari. An edge-based architecture for phasor measurements in smart grids. In *2022 AEIT International Annual Conference (AEIT)*, pages 1–6. IEEE, 2022.

Eric Gamess and Mausam Parajuli. Image-processing workloads and ddos attack resilience: Evaluating docker and podman containers on raspberry pi and odroid. In *Proceedings of the 2024 ACM Southeast Conference*, pages 138–147, 2024.

Avinash Ganne. Cloud data security methods: Kubernetes vs docker swarm. *International Research Journal of Modernization in Engineering Technology*, 4(11):1–6, 2022.

Pengxiang Gao, Rui Wan, Chen Wang, and Yunchang Cheng. Container load prediction algorithm based on arima model and bp neural network. In *2022 IEEE 6th Advanced Information Technology, Electronic and Automation Control Conference (IAEAC)*, pages 334–337. IEEE, 2022.

J Geetha, DS Jayalakshmi, E Naresh, and N Sreenivasa. Lightweight cloud-based solution for digital education and assessment. *Science & Technology Libraries*, 43(3):274–286, 2024.

Jipu Geng, Xiaoyan Zheng, Xiaohan Lai, Lei Zhao, and Yibai Xu. Construction and implementation of electric power deep learning computing service platform. In *2023 4th International Conference on Computer Engineering and Intelligent Control (ICCEIC)*, pages 492–495. IEEE, 2023.

Taha Gharaibeh, Steven Seiden, Mohamed Abouelsaoud, Elias Bou-Harb, and Ibrahim Baggili. Don't, stop, drop, pause: Forensics of container checkpoints (conpoint). In *Proceedings of the 19th International Conference on Availability, Reliability and Security*, pages 1–11, 2024.

Mohsen Ghorbian and Mostafa Ghobaei-Arani. A survey on the cold start latency approaches in serverless computing: an optimization-based perspective. *Computing*, 106(11): 3755–3809, 2024.

Jose González-Abad, Alvaro Lopez Garcia, and Valentin Y Kozlov. A container-based workflow for distributed training of deep learning algorithms in hpc clusters. *Cluster Computing*, 26(5):2815–2834, 2023.

Leo A Goodman. Snowball sampling. *The annals of mathematical statistics*, pages 148–170, 1961.

Yue Gu, Xin Tan, Yuan Zhang, Siyan Gao, and Min Yang. Epscan: Automated detection of excessive rbac permissions in kubernetes applications. In *2025 IEEE Symposium on Security and Privacy (SP)*, pages 3199–3217. IEEE, 2025.

Chakshu Gupta, Thijs Van Ede, and Andrea Continella. Honeykube: Designing and deploying a microservices-based web honeypot. In *2023 IEEE Security and Privacy Workshops (SPW)*, pages 1–11. IEEE, 2023.

Siqi Han, Wanting Li, En Zhang, Jilin Shi, Wei Wang, and Xuesong Lu. Mladder: An online training system for machine learning and data science education. In *Proceedings of the 31st ACM International Conference on Information & Knowledge Management*, pages 4862–4866, 2022.

Yu Hao, Xu Zhang, and Dongbin Wang. Cpced: a container escape detection system based on cni plugin. In *2024 IEEE 23rd International Conference on Trust, Security and Privacy in Computing and Communications (TrustCom)*, pages 242–253. IEEE, 2024.

Md Sadun Haq, Ali Şaman Tosun, and Turgay Korkmaz. Security analysis of docker containers for arm architecture. In *2022 IEEE/ACM 7th Symposium on Edge Computing (SEC)*, pages 224–236. IEEE, 2022.

Md Sadun Haq, Ali Şaman Tosun, and Turgay Korkmaz. Lucid: A framework for reducing false positives and inconsistencies among container scanning tools. *IEEE Access*, 2025.

S Haresh et al. Virtualization using docker container for reproducible desktop environment. In *2023 Intelligent Computing and Control for Engineering and Business Systems (ICCEBS)*, pages 1–4. IEEE, 2023.

Arooj Hassan, Sabeen Hussain Bhatti, Sobia Shujaat, and Yujong Hwang. To adopt or not to adopt? the determinants of cloud computing adoption in information technology sector. *Decision Analytics Journal*, 5:100138, 2022. ISSN 2772-6622. . URL `https://www.sciencedirect.com/science/article/pii/S2772662222000698`.

Lasal Sandeepa Hettiarachchi, Senura Vihan Jayadeva, Rusiru Abhisheak Vikum Bandara, Dilmi Palliyaguruge, Udara Srimath S Samaratunge Arachchillage, and Dharshana Kasthurirathna. Artificial intelligence-based centralized resource management application for distributed systems. In *2022 13th International Conference on Computing Communication and Networking Technologies (ICCCNT)*, pages 1–6. IEEE, 2022.

Pedro Horchulhack, Eduardo K Viegas, Altair O Santin, Felipe V Ramos, and Pietro Tedeschi. Detection of quality of service degradation on multi-tenant containerized services. *Journal of Network and Computer Applications*, 224:103839, 2024.

Rosen Hristev, Magdalena Veselinova, and Kristiyan Kolev. System architecture for automated backup and recovery of disk volumes in containers.

Husain Husain, Khairan Marzuki, Lalu Zazuli Azhar Mardedi, et al. Analysis and implementation of comparison between podman and docker in container management. *International Journal of Electronics and Communications Systems*, 3(2):57–67, 2023.

Stoney Jackson and Karl R Wurst. Teaching with vs code devcontainers: Conference workshop. *Journal of Computing Sciences in Colleges*, 37(8):81–82, 2022.

Samireh Jalali and Claes Wohlin. Systematic literature studies: database searches vs. backward snowballing. In *Proceedings of the ACM-IEEE international symposium on Empirical software engineering and measurement*, pages 29–38, 2012.

Hung-Chin Jang and Shih-Yu Luo. Enhancing node fault tolerance through high-availability clusters in kubernetes. In *2023 IEEE 3rd International Conference on Electronic Communications, Internet of Things and Big Data (ICEIB)*, pages 30–35. IEEE, 2023.

Jueun Jeon, Sihyun Park, Byeonghui Jeong, and Young-Sik Jeong. Efficient container scheduling with hybrid deep learning model for improved service reliability in cloud computing. *IEEE Access*, 12:65166–65177, 2024.

Byeonghui Jeong, Jueun Jeon, and Young-Sik Jeong. Proactive resource autoscaling scheme based on scinet for high-performance cloud computing. *IEEE Transactions on Cloud Computing*, 11(4):3497–3509, 2023.

Bjarne Johansson, Mats Rågberger, Thomas Nolte, and Alessandro V Papadopoulos. Kubernetes orchestration of high availability distributed control systems. In *2022 IEEE International Conference on Industrial Technology (ICIT)*, pages 1–8. IEEE, 2022.

Rodi Jolak, Thomas Rosenstatter, Mazen Mohamad, Kim Strandberg, Behrooz Sangchoolie, Nasser Nowdehi, and Riccardo Scandariato. Conserve: A framework for the selection of techniques for monitoring containers security. *Journal of Systems and Software*, 186:111158, 2022.

Nidhi Joraviya, Bhavesh N Gohil, and Udai Pratap Rao. Abhids: An anomaly-based host intrusion detection system using frequency of n-gram system call features and ensemble learning for containerized environment. *Concurrency and Computation: Practice and Experience*, 36(23): e8249, 2024a.

Nidhi Joraviya, Bhavesh N Gohil, and Udai Pratap Rao. Dlhids: deep learning-based host intrusion detection system using system calls-to-image for containerized cloud environment: N. joraviya et al. *The Journal of Supercomputing*, 80(9):12218–12246, 2024b.

Suyash Joshi, Basit Hasan, and R Brindha. Optimal declarative orchestration of full lifecycle of machine learning models for cloud native. In *2024 3rd International Conference on Applied Artificial Intelligence and Computing (ICAAIC)*, pages 578–582. IEEE, 2024.

Shahidullah Kaiser, Md Sadun Haq, Ali Şaman Tosun, and Turgay Korkmaz. Container technologies for arm architecture: A comprehensive survey of the state-of-the-art. *IEEE Access*, 10:84853–84881, 2022a.

Shahidullah Kaiser, Md Sadun Haq, Ali Saman Tosun, and Turgay Korkmaz. Container Technologies for ARM Architecture: A Comprehensive Survey of the State-of-the-Art. *IEEE Access*, 10:84853–84881, 2022b. ISSN 21693536. .

Shahidullah Kaiser, Ali şaman Tosun, and Turgay Korkmaz. Benchmarking container technologies on arm-based edge devices. *IEEE access*, 11:107331–107347, 2023a.

Shahidullah Kaiser, Ali Saman Tosun, and Turgay Korkmaz. Benchmarking Container Technologies on ARM-Based Edge Devices. *IEEE Access*, 11:107331–107347, jan 2023b. ISSN 2169-3536. . URL `https://doaj.org/article/2033f2041344497d9369c7846d31d01e`.

Shahidullah Kaiser, Ali Saman Tosun, and Turgay Korkmaz. Exploring the viability of unikernels for arm-powered edge computing. *arXiv preprint arXiv:2412.03030*, 2024.

Kacper Kamieniarz and Wojciech Mazurczyk. A comparative study on the security of kubernetes deployments. In *2024 International Wireless Communications and Mobile Computing (IWCMC)*, pages 0718–0723. IEEE, 2024.

Srinidhi Kanagachalam, Khikmatullo Tulkinbekov, and

Deok-Hwan Kim. Blosm: Blockchain-based service migration for connected cars in embedded edge environment. *Electronics*, 11(3):341, 2022.

Amirmohammad Karamzadeh and Alireza Shameli-Sendi. Reducing cold start delay in serverless computing using lightweight virtual machines. *Journal of Network and Computer Applications*, 232:104030, 2024.

Gobinda Karmakar and Harwant Singh Arri. Mathematical approaches to securing kubernetes: Analyzing log data volume in a complex landscape.

Madhavi Karumudi et al. Efficient workload portability and optimized resource utilization using containerization in a multi-cloud environment. In *2024 5th International Conference on Data Intelligence and Cognitive Informatics (ICDICI)*, pages 823–828. IEEE, 2024.

Tanvir Kaur. Containers in multi-cloud environments: Benefits, challenges, and best practices. 2024.

Rafael Keller Tesser and Edson Borin. Containers in hpc: a survey. *The Journal of Supercomputing*, 79(5):5759–5827, 2023.

Byoung Soo Kim, Sang Hyeop Lee, Ye Rim Lee, Yong Hyun Park, and Jongpil Jeong. Design and implementation of cloud docker application architecture based on machine learning in container management for smart manufacturing. *Applied Sciences*, 12(13):6737, 2022.

Taeyoung Kim, Seonhye Park, and Hyoungshick Kim. Why johnny can't use secure docker images: Investigating the usability challenges in using docker image vulnerability scanners through heuristic evaluation. In *Proceedings of the 26th International Symposium on Research in Attacks, Intrusions and Defenses*, pages 669–685, 2023.

Barbara Kitchenham, Rialette Pretorius, David Budgen, O. Pearl Brereton, Mark Turner, Mahmood Niazi, and Stephen Linkman. Systematic literature reviews in software engineering-A tertiary study. *Information and Software Technology*, 52(8):792–805, 2010. ISSN 09505849. .

W. M. C. J. T. Kithulwatta, K. P. N. Jayasena, Banage T. G. S. Kumara, and R. M. K. Tharanga Rathnayaka. Integration with docker container technologies for distributed and microservices applications: A state-of-the-art review. *International Journal of Systems and Service-Oriented Engineering*, 12(1), 2022a. . URL `https://doi.org/10.4018/IJSSOE.297136`.

WMCJT Kithulwatta, KPN Jayasena, BTGS Kumara, and RMKT Rathnayaka. Performance evaluation of docker-based apache and nginx web server. In *2022 3rd International Conference for Emerging Technology (INCET)*, pages 1–6. IEEE, 2022b.

Vojdan Kjorveziroski and Sonja Filiposka. Webassembly orchestration in the context of serverless computing. *Journal of Network and Systems Management*, 31(3):62, 2023a.

Vojdan Kjorveziroski and Sonja Filiposka. Webassembly as an enabler for next generation serverless computing. *Journal of Grid Computing*, 21(3):34, 2023b.

Joanna Kosińska, Grzegorz Brotoń, and Maciej Tobiasz. Knowledge representation of the state of a cloud-native application. *International Journal on Software Tools for Technology Transfer*, 26(1):21–32, 2024.

Jozef Kostolny, Veronika Karcolova, Monika Vaclavkova, and Linda Blahova. Enhancing learning outcomes with interactive courses. In *2023 21st International Conference on Emerging eLearning Technologies and Applications (ICETA)*, pages 324–329. IEEE, 2023.

Igor V Kotenko, Maxim V Melnik, and Georgii T Abramenko. Anomaly detection in container systems: Using histograms of normal processes and an autoencoder. In *2024 IEEE 25th International Conference of Young Professionals in Electron Devices and Materials (EDM)*, pages 1930–1934. IEEE, 2024.

Zhanibek Kozhirbayev and Richard O. Sinnott. A performance comparison of container-based technologies for the cloud. *Future Generation Computer Systems*, 68:175–182, 2017. ISSN 0167-739X. . URL `https://www.sciencedirect.com/science/article/pii/S0167739X16303041`.

Animesh Kuity and Sateesh K Peddoju. Investigating performance metrics for container-based hpc environments using x86 and openpower systems. *Journal of Cloud Computing*, 12(1):178, 2023.

Bablu Kumar, Anshul Verma, and Pradeepika Verma. Optimizing resource allocation using proactive scaling with predictive models and custom resources. *Computers and Electrical Engineering*, 118:109419, 2024.

Mandeep Kumar and Gagandeep Kaur. An empirical study of containerized mpi and gui application on hpc in the cloud. In *2022 2nd International Conference on Innovative Sustainable Computational Technologies (CISCT)*, pages 1–6. IEEE, 2022.

Pankaj Kunekar, Nidhi Bhavsar, Kriti Das, and Sachi Bhavsar. Use of docker containerization and load balancer to scale a flask application. In *2024 4th International Conference on Soft Computing for Security Applications (ICSCSA)*, pages 534–541, 2024. .

Arya Putra Kurniawan, Muhammad Nasry Ashar, Fajrul Hidayat, Salsabila Salsabila, Pramudya Tiandana Wisnu Gautama, Ary Mazharuddin Shiddiqi, and Hudan Studiawan. Performance evaluation for deploying dockerized web application on aws, gcp, and azure. In *2023 IEEE International Conference on Control, Electronics and Computer Technology (ICCECT)*, pages 346–350. IEEE, 2023.

Soonhong Kwon, Wooyoung Son, and Jong-Hyouk Lee. Vdirs: Vulnerable docker image response system. In *Proceedings of the 2023 International Conference on Intelligent Computing and Its Emerging Applications*, pages 78–83, 2023.

Hoo-Ki Lee, Sung-Hwa Han, and Daesung Lee. Kernel-based container file access control architecture to protect important application information. *Electronics*, 12(1):52, 2022.

Si Woo Lee, Yeong Gwang Choi, and Jae Wook Jeon. Enhancing autonomous driving systems through ros2 and aws cloud: V2i interaction and hpc data processing. In *2024 IEEE 33rd International Symposium on Industrial Electronics (ISIE)*, pages 1–6. IEEE, 2024.

Wonjun Lee, Yung Ryn Choe, and Raiat Subhra Ghosh. Recurrent neural network and convolutional neural network for detection of denial of service attack in microservices. In *2023 International Conference on Machine Learning and Applications (ICMLA)*, pages 1451–1456. IEEE, 2023.

Bin Li, Yuzhuo Zhan, and Shenghan Ren. A fast cold-start solution: container space reuse based on resource isolation. *Electronics*, 12(11):2515, 2023a.

Guoqing Li, Keichi Takahashi, Kohei Ichikawa, Hajimu Iida, Chawanat Nakasan, Pattara Leelaprute, Pree Thiengburanathum, and Passakorn Phannachitta. The convergence of container and traditional virtualization: Strengths and limitations. *SN Computer Science*, 4(4):387, 2023b.

Mingyang Li, Hongchao Hu, and Wenyan Liu. A secure container placement algorithm based on microservice invocation criticality. In *2024 IEEE 2nd International Conference on Control, Electronics and Computer Technology (ICCECT)*, pages 234–240. IEEE, 2024a.

Zhexiong Li, Deze Zeng, and Ranzhao Chen. Webassembly or container? joint optimization of microservice consolidation and deployment towards cost efficient edge-end consortium. In *2024 IEEE/ACM 32nd International Symposium on Quality of Service (IWQoS)*, pages 1–10. IEEE, 2024b.

Vasiliki Liagkou, George Fragiadakis, Evangelia Filiopoulou, Christos Michalakelis, Thomas Kamalakis, and Mara Nikolaidou. A pricing model for container-as-a-service, based on hedonic indices. *Simulation Modelling Practice and Theory*, 115:102441, 2022.

Tie Ma, Long Luo, Hongfang Yu, Xi Chen, Jingzhao Xie, Chongxi Ma, Yunhan Xie, Gang Sun, Tianxi Wei, Li Chen, et al. Klonet: an {Easy-to-Use} and scalable platform for computer networks education. In *21st USENIX Symposium on Networked Systems Design and Implementation (NSDI 24)*, pages 2025–2046, 2024.

Taous Madi and Paulo Esteves-Verissimo. A fault and intrusion tolerance framework for containerized environments: A specification-based error detection approach. In *2022 International Workshop on Secure and Reliable Microservices and Containers (SRMC)*, pages 1–8. IEEE, 2022.

Akalanka Mailewa, Susan Mengel, Lisa Gittner, and Hafiz Khan. Mechanisms and techniques to enhance the security of big data analytic framework with mongodb and linux containers. *Array*, 15:100236, 2022.

David J Malan. Containerizing cs50: Standardizing students' programming environments. In *Proceedings of the 2024 on Innovation and Technology in Computer Science Education V. 1*, pages 534–540. 2024.

Ruchika Malhotra, Anjali Bansal, and Marouane Kessentini. Vulnerability analysis of docker hub official images and verified images. In *2023 IEEE International Conference on Service-Oriented System Engineering (SOSE)*, pages 150–155. IEEE, 2023.

Ruchika Malhotra, Anjali Bansal, and Marouane Kessentini. A systematic literature review on maintenance of software containers. *ACM Computing Surveys*, 56(8):1–38, 2024a.

Ruchika Malhotra, Anjali Bansal, and Marouane Kessentini. A Systematic Literature Review on Maintenance of Software Containers. *ACM Computing Surveys*, 56(8), 2024b. ISSN 15577341. .

Anshita Malviya and Rajendra Kumar Dwivedi. A comparative analysis of container orchestration tools in cloud computing. In *2022 9th International conference on computing for sustainable global development (INDIACom)*, pages 698–703. IEEE, 2022.

Ali Mehran and Dogan Ulus. Runtime verification containers for publish/subscribe networks. *arXiv preprint arXiv:2408.06380*, 2024.

Pedro Melo, Lucas Gama, Jamilson Dantas, David Beserra, and Jean Araujo. Performance evaluation of container management tasks in os-level virtualization platforms. In *2023 IEEE International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE)*, pages 1–6. IEEE, 2023.

Alan Mills, Jonathan White, and Phil Legg. Longitudinal risk-based security assessment of docker software container images. *Computers & Security*, 135:103478, 2023.

Prince Modey, Emmanuel Freeman, Stanley Opoku-Yeboah, and Ebenezer Avulekpor. A hybrid security algorithm in container-based virtualization environments using residue number systems. In *2024 Conference on Information Communications Technology and Society (ICTAS)*, pages 107–112. IEEE, 2024.

György Molnár, Cserkó József, and Karl Éva. Evaluation and technological solutions for a dynamic, unified cloud programming development environment: Ease of use and applicable system for uniformized practices and assessments. In *2023 IEEE 21st World Symposium on Applied Machine Intelligence and Informatics (SAMI)*, pages 000237–000240. IEEE, 2023.

Subrota Kumar Mondal, Xiaohai Wu, and Rui Pan. On rapid application deployment with kubernetes. In *Proceedings of the 2024 4th International Conference on Artificial Intelligence, Automation and Algorithms*, pages 76–80, 2024a.

Subrota Kumar Mondal, Zhen Zheng, and Yuning Cheng. On the optimization of kubernetes toward the enhancement of cloud computing. *Mathematics*, 12(16):2476, 2024b.

Zlatan Moric, Vedran Dakic, and Matej Kulic. Implementing a security framework for container orchestration. In *2024 IEEE 11th International Conference on Cyber Security and Cloud Computing (CSCloud)*, pages 200–206. IEEE, 2024.

Erica Mourao, Marcos Kalinowski, Leonardo Murta, Emilia Mendes, and Claes Wohlin. Investigating the Use of a Hybrid Search Strategy for Systematic Reviews. *International Symposium on Empirical Software Engineering and Measurement*, 2017-November:193–198, 2017. ISSN 19493789. .

Walid Moussa, Mona Nashaat, Walaa Saber, and Rawya Rizk. Comprehensive study on machine learning-based container scheduling in cloud. In *International Conference on Advanced Machine Learning Technologies and Applications*, pages 581–592. Springer, 2022.

Vasileios Moysiadis, Konstantinos Tsakos, Panagiotis Sarigiannidis, Euripides GM Petrakis, Achilles D Boursianis, and Sotirios K Goudos. A cloud computing web-based application for smart farming based on microservices architecture. In *2022 11th International Conference on Modern Circuits and Systems Technologies (MOCAST)*, pages 1–5. IEEE, 2022.

Sabelo Justice Mthembu, Ijeoma Noella Ezeji, and Matthew Adigun. Orchestration tools for efficient deployment of iot applications in fog computing: A systematic review. In *International Conference on Artificial Intelligence and its Applications*, pages 146–151, 2023.

Nina Mujkanovic, Juan J Durillo, Nicolay Hammer, and Tiziano Müller. Survey of adaptive containerization architectures for hpc. In *Proceedings of the SC'23 Workshops of the International Conference on High Performance Computing, Network, Storage, and Analysis*, pages 165–176, 2023.

Otoya Nakakaze, István Koren, Florian Brillowski, and Ralf Klamma. Adaptive retrofitting for industrial machines: utilizing webassembly and peer-to-peer connectivity on the edge. *World Wide Web*, 27(1):7, 2024.

Aakash Nakarmi, Harshit Kesharwani, Tamoshree Mallick, Sushant Jhingran, and Gaurav Raj. A comprehensive study on optimization techniques for microservices deployment. In *2024 Sixth International Conference on Computational Intelligence and Communication Technologies (CCICT)*, pages 133–140. IEEE, 2024.

Modugula Narasimhulu, Darapureddy Veera Mounika, Puttagunta Varshini, TK Rama Krishna Rao, et al. Investigating the impact of containerization on the deployment process in devops. In *2023 2nd International Conference on Edge Computing and Applications (ICECAA)*, pages 679–685. IEEE, 2023.

Nikolas Naydenov and Stela Ruseva. Cloud Container Orchestration Architectures, Models and Methods: a Systematic Mapping Study. In *2023 22nd International Symposium INFOTEH-JAHORINA, INFOTEH 2023*, pages 1–8, mar 2023a. ISBN 9781665475464. .

Nikolas Naydenov and Stela Ruseva. Cloud container orchestration architectures, models and methods: a systematic mapping study. In *2023 22nd International Symposium INFOTEH-JAHORINA (INFOTEH)*, pages 1–8. IEEE, 2023b.

Alain P Ndigande, Ismail Ari, and Sedat Ozer. Analysis and comparison of dockerized and standalone apache spark configurations for efficient distributed data processing. In *2024 Innovations in Intelligent Systems and Applications Conference (ASYU)*, pages 1–5. IEEE, 2024.

Ian G. Needleman. A guide to systematic reviews. *Journal of Clinical Periodontology*, 29(SUPPL. 3):6–9, 2002. ISSN 03036979. .

Connor Nelson and Yan Shoshitaishvili. Dojo: applied cybersecurity education in the browser. In *Proceedings of the 55th ACM Technical Symposium on Computer Science Education V. 1*, pages 930–936, 2024.

Phu H. Nguyen, Max Kramer, Jacques Klein, and Yves Le Traon. An extensive systematic review on the Model-Driven Development of secure systems. *Information and Software Technology*, 68:62–81, 2015. ISSN 09505849. .

Adam Pankowski and Paweł Powroźnik. Comparison of application container orchestration platforms. *Journal of Computer Sciences Institute*, 29:383–390, 2023.

Javier Pastor-Galindo, Hông-Ân Sandlin, Félix Gómez Mármol, Gérôme Bovet, and Gregorio Martínez Pérez. A big data architecture for early identification and categorization of dark web sites. *Future Generation Computer Systems*, 157:67–81, 2024.

Manoj Kumar Patra, Anisha Kumari, Bibhudatta Sahoo, and Ashok Kumar Turuk. Docker security: Threat model and best practices to secure a docker container. In *2022 IEEE 2nd International Symposium on Sustainable Energy, Signal Processing and Cyber Security (iSSSC)*, pages 1–6. IEEE, 2022.

Manoj Kumar Patra, Bibhudatta Sahoo, and Ashok Kumar Turuk. Container as a service in the cloud: An approach to secure hybrid virtualization. In *Recent Trends and Best Practices in Industry 4.0*, pages 59–76. River Publishers, 2023.

Adrien Pavao, Isabelle Guyon, Anne-Catherine Letournel, Dinh-Tuan Tran, Xavier Baro, Hugo Jair Escalante, Sergio Escalera, Tyler Thomas, and Zhen Xu. Codalab competitions: An open source platform to organize scientific challenges. *Journal of Machine Learning Research*, 24 (198):1–6, 2023.

Ricardo Pérez, Marco Rivera, Yamisleydi Salgueiro, Carlos R Baier, and Patrick Wheeler. Moving microgrid hierarchical control to an sdn-based kubernetes cluster: A framework for reliable and flexible energy distribution. *Sensors*, 23(7):3395, 2023.

Mark Petticrew and Helen Roberts. *Systematic reviews in the social sciences: A practical guide*. John Wiley & Sons, 2008.

B Purahong, J Sithiyopasakul, P Sithiyopasakul, A Lasakul, and C Benjangkaprasert. Automated resource management system based upon container orchestration tools comparison. *Journal of Advances in Information Technology*, 14(3), 2023.

Cheng Qian. An accurate financial aid system for university students built on a cloud platform. In *2022 International Conference on Knowledge Engineering and Communication Systems (ICKES)*, pages 1–6. IEEE, 2022.

Pallav Raj, Ravi Shankar Kumar, and Avneesh Kumar. Cloud security. In *2022 4th International Conference on Advances in Computing, Communication Control and Networking (ICAC3N)*, pages 1890–1894. IEEE, 2022.

Vinay Raj. A framework for migration of microservices based applications to serverless platform with efficient cold start latency. *Authorea Preprints*, 2023.

V Rajasekar, M Saračević, D Karabačević, D Stanujkić, A Hasić, M Azizović, and S Thirumalai. Security-enhanced qos-aware autoscaling of kubernetes pods using horizontal pod autoscaler (hpa). *Journal of intelligent management decision*, 3(3):175–186, 2024.

Shunmugapriya Ramanathan, Abhishek Bhattacharyya, Koteswararao Kondepu, and Andrea Fumagalli. Enabling containerized central unit live migration in 5g radio access network: An experimental study. *Journal of Network and Computer Applications*, 221:103767, 2024.

Shaimaa Fahad Rashid and Rawaa Putros Qasha. Cloud-based big data approach for managing multi-types data of cultural heritage. In *2022 International Conference on Communications, Information, Electronic and Energy Systems (CIEES)*, pages 1–6. IEEE, 2022.

Guillermo Rodriguez, Virginia Yannibelli, Fabio G Rocha, Dawitt Barbara, Igor M Azevedo, and Pablo M Menezes. Understanding and addressing the allocation of microservices into containers: A review. *IETE Journal of Research*, 70(4):3887–3900, 2024.

Giovanni Rosa, Simone Scalabrino, Gabriele Bavota, and Rocco Oliveto. What quality aspects influence the adoption of docker images? *ACM Transactions on Software Engineering and Methodology*, 32(6):1–30, 2023.

Giovanni Rosa, Federico Zappone, Simone Scalabrino, and Rocco Oliveto. Fixing dockerfile smells: an empirical study. *Empirical Software Engineering*, 29(5):108, 2024.

Rodrigo Rosmaninho, Duarte Raposo, Pedro Rito, and Susana Sargento. Time constraints on vehicular edge computing: A performance analysis. In *NOMS 2023-2023 IEEE/IFIP Network Operations and Management Symposium*, pages 1–7. IEEE, 2023.

Swarnabha Roy, Reece Dobson, Jack Campbell, and Stavros Kalafatis. Efficient resource allocation for multi-robot collaboration via traffic-aware pod autoscaling. In *2024 7th Conference on Cloud and Internet of Things (CIoT)*, pages 1–8. IEEE, 2024.

José Manuel Ruiz Ródenas, Javier Pastor-Galindo, and Félix Gómez Mármol. A general and modular framework for dark web analysis. *Cluster Computing*, 27(4):4687–4703, 2024.

Per Runeson and Martin Höst. Tutorial: Case studies in software engineering. *Lecture Notes in Business Information Processing*, 32 LNBIP:441–442, 2009. ISSN 18651348. .

S Savitha, C Sangana, K Devendran, L Pravin, M Rajkumar, and C Nirmal. Auto scaling infrastructure with monitoring tools using linux server on cloud. In *2023 7th International Conference on Computing Methodologies and Communication (ICCMC)*, pages 45–52. IEEE, 2023.

Adarsh Saxena, Sudhakar Singh, Shiv Prakash, Nand Lal Yadav, Tiansheng Yang, Raikumar Singh Rathore, and Shreya Singh. Design and implementation of flutter based multi-platform docker controller app. In *2024 International Conference on Decision Aid Sciences and Applications (DASA)*, pages 1–6. IEEE, 2024.

Vivek Saxena, Deepika Saxena, and Uday Pratap Singh. Security enhancement using image verification method to secure docker containers. In *Proceedings of the 4th International Conference on Information Management & Machine Intelligence*, pages 1–5, 2022.

Henri Schmidt, Zeineb Rejiba, Raphael Eidenbenz, and Klaus-Tycho Förster. Transparent fault tolerance for stateful applications in kubernetes with checkpoint/restore. In *2023 42nd International Symposium on Reliable Distributed Systems (SRDS)*, pages 129–139. IEEE, 2023.

Dmitrii Sedov and Andrei Lazarev. Enhancing it education through docker integration. In *2024 4th International Conference on Technology Enhanced Learning in Higher Education (TELE)*, pages 252–255. IEEE, 2024.

Segun-Falade, Osundare, Kedi, Okeleke, Tochukwu Ijomah, P. Abdul-Azeez, and Abdul-Azeez. Assessing the transformative impact of cloud computing on software deployment and management. pages 2062–2082, 08 2024. .

Luis E. Sepúlveda-Rodríguez, Julio C. Chavarro-Porras, John A. Sanabria-Ordoñez, Harold E. Castro, and Jeanna Matthews. A Survey of Virtualization Technologies: Towards a New Taxonomic Proposal. *Ingenieria e Investigacion*, 42(3), 2022. ISSN 22488723. . URL `https://openurl-ebsco-com.crai.referencistas.com/contentitem/edsdia:edsdia.ART0001545825?sid=ebsco:plink:crawler&id=ebsco:edsdia:edsdia.ART0001545825&crl=c`.

Santosh Shakya and Priyanka Tripathi. Using light weight container a mesh based dynamic allocation task scheduling algorithm for cloud with iot network. *International Journal of Information Technology*, 16(5):2847–2861, 2024.

Raju Shrestha and Akash Ray. Streamlining application deployment: A ci/cd pipeline for kubernetes. In *2024 IEEE International Conference on Cloud Engineering (IC2E)*, pages 253–255. IEEE, 2024.

Sérgio N Silva, Mateus AS de S Goldbarg, Lucileide MD da Silva, and Marcelo AC Fernandes. Application of fuzzy logic for horizontal scaling in kubernetes environments within the context of edge computing. *Future Internet*, 16 (9):316, 2024.

M Šimon, L Huraj, and N Búčik. A comparative analysis of high availability for linux container infrastructures. future internet, 15 (8), 2023.

Kamred Udham Singh, Ankit Kumar, Gaurav Kumar, Teekam Singh, Paras Kothari, and Anisha Sheikh. Increasing productivity in software development through the use of docker technology. In *International Conference on Universal Threats in Expert Applications and Solutions*, pages 157–165. Springer, 2024.

Maciej Sobieraj and Daniel Kotyński. Docker performance evaluation across operating systems. *Applied Sciences*, 14 (15):6672, 2024.

Mirco Soderi, Vignesh Kamath, Jeff Morgan, and John G Breslin. Advanced analytics as a service in smart factories. In *2022 IEEE 20th Jubilee World Symposium on Applied Machine Intelligence and Informatics (SAMI)*, pages 000425–000430. IEEE, 2022.

Somin Song, Sahil Suneja, Michael V Le, and Byungchul Tak. On the value of sequence-based system call filtering for container security. In *2023 IEEE 16th International Conference on Cloud Computing (CLOUD)*, pages 296–307. IEEE, 2023.

Noah Spahn, Nils Hanke, Thorsten Holz, Christopher Kruegel, and Giovanni Vigna. Container orchestration honeypot: Observing attacks in the wild. In *Proceedings of the 26th International Symposium on Research in Attacks, Intrusions and Defenses*, pages 381–396, 2023.

Dragan Stojanović, Dušan Jovanović, and Natalija Stojanović. Big medical data analytics using apache spark framework. In *2024 11th International Conference on Electrical, Electronic and Computing Engineering (IcETRAN)*, pages 1–5. IEEE, 2024.

Vijay Thurimella, Philipp Raith, Rolando P Hong Enriquez, Anderson Andrei Da Silva, Gourav Rattihalli, Ada Gavrilovska, and Dejan Milojicic. Serverless computing for dynamic hpc workflows. In *SC24-W: Workshops of the International Conference for High Performance Computing, Networking, Storage and Analysis*, pages 2096–2103.

IEEE, 2024.

Salla Timonen, Maha Sroor, Rahul Mohanani, and Tommi Mikkonen. Anomaly detection through container testing: A survey of company practices. In *International Conference on Product-Focused Software Process Improvement*, pages 363–378. Springer, 2023.

Daniel Ukene, Hayden Wimmer, and Jongyeop Kim. Evaluating the performance of containerized webservers against web servers on virtual machines using bombardment and siege. In *2023 IEEE/ACIS 21st International Conference on Software Engineering Research, Management and Applications (SERA)*, pages 144–152. IEEE, 2023.

Rohan Vaidya, Atharv Tembhurnikar, Chinmay Mohite, Sumit Puri, Swapneel Kulkarni, and Amar Buchade. Blockchain-powered certificate authentication: Enhancing trust and transparency. In *2024 IEEE International Conference on Blockchain and Distributed Systems Security (ICBDS)*, pages 1–5. IEEE, 2024.

Kapil Netaji Vhatkar and G.P. Bhole. A comprehensive survey on container resource allocation approaches in cloud computing: State-of-the-art and research challenges. *Web Intelligence*, 19(1):1–22, 2022. .

Konstantinos Voulgaris, Athanasios Kiourtis, Andreas Karabetian, Panagiotis Karamolegkos, Yannis Poulakis, Argyro Mavrogiorgou, and Dimosthenis Kyriazis. A comparison of container systems for machine learning scenarios: Docker and podman. In *2022 2nd international conference on computers and automation (compauto)*, pages 114–118. IEEE, 2022.

Devi Priya VS, Sibi Chakkaravarthy Sethuraman, and Muhammad Khurram Khan. Container security: precaution levels, mitigation strategies, and research perspectives. *Computers & Security*, 135:103490, 2023.

Chang Wang, Zhiqiong Liu, Jin Liu, Wang Li, and Junxin Chen. Towards a container scheduling policy for alleviating total startup latency in serverless computing platform. In *Third international conference on algorithms, microchips, and network applications (AMNA 2024)*, volume 13171, pages 466–474. SPIE, 2024.

Kun Wang, Song Wu, Kun Suo, Yijie Liu, Hang Huang, Zhuo Huang, and Hai Jin. Characterizing and optimizing kernel resource isolation for containers. *Future Generation Computer Systems*, 141:218–229, 2023.

Wenzhuo Wang and Jian Li. A feasibility study on containerization of traditional embedded systems. In *2024 4th International Conference on Electronic Information Engineering and Computer Communication (EIECC)*, pages 217–221. IEEE, 2024.

Muhammad Waseem, Aakash Ahmad, Peng Liang, Muhammad Azeem Akbar, Arif Ali Khan, Iftikhar Ahmad, Manu Setälä, and Tommi Mikkonen. Containerization in multi-cloud environment: Roles, strategies, challenges, and solutions for effective implementation. *arXiv preprint*, March 2024. . URL `https://arxiv.org/abs/2403.12980`. Preprint accepted for publication in Journal of Systems and Software (2025). Submitted 1 Mar 2024; last revised 8 Jul 2025 (version v3).

Muhammad Waseem, Aakash Ahmad, Peng Liang, Muhammad Azeem Akbar, Arif Ali Khan, Iftikhar Ahmad, Manu Setälä, and Tommi Mikkonen. Containerization in multi-cloud environment: roles, strategies, challenges, and solutions for effective implementation. *Journal of Systems and Software*, page 112558, 2025.

Dibyo Widodo, Prima Kristalina, Moch Zen Samsono Hadi, and Aprilia Dewi Kurniawati. Performance evaluation of docker containers for disaster management dashboard web application. In *2023 International Electronics Symposium (IES)*, pages 551–556. IEEE, 2023.

Claes Wohlin. Guidelines for snowballing in systematic literature studies and a replication in software engineering. In *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering*, EASE '14, New York, NY, USA, 2014. Association for Computing Machinery. ISBN 9781450324762. . URL `https://doi.org/10.1145/2601248.2601268`.

Ann Yi Wong, Eyasu Getahun Chekole, Martín Ochoa, and Jianying Zhou. On the security of containers: Threat modeling, attack analysis, and mitigation strategies. *Computers & Security*, 128:103140, 2023.

Gang Wu, Xiaozhen Li, and Chuan Li. A load balancing-based container migration mechanism in the smart grid cloud platform. In *2024 9th International Conference on Computer and Communication Systems (ICCCS)*, pages 1100–1104. IEEE, 2024.

Song Wu, Zhiheng Tao, Hao Fan, Zhuo Huang, Xinmin Zhang, Hai Jin, Chen Yu, and Chun Cao. Container lifecycle-aware scheduling for serverless computing. *Software: Practice and Experience*, 52(2):337–352, 2022.

Hajie Xi, Song Hu, He Zhang, Shuang Zhang, Jingnong Weng, and Jian Huang. A dynamic load balancing algorithm for stable pushing of docker images in nginx. In *2024 6th International Conference on Machine Learning, Big Data and Business Intelligence (MLBDBI)*, pages 239–243. IEEE, 2024.

Yulai Xie, Minpeng Jin, Zhuping Zou, Gongming Xu, Dan Feng, Wenmao Liu, and Darrell Long. Real-time prediction of docker container resource load based on a hybrid model of arima and triple exponential smoothing. *IEEE Transactions on Cloud Computing*, 10(2):1386–1401, 2020.

Yijiang Xu, Muxian Zhou, Qing Gao, Shikun Zhang, and Zhonghai Wu. Swat4j: Generating system call allowlist for java container attack surface reduction. In *2024 IEEE International Conference on Software Analysis, Evolution and Reengineering (SANER)*, pages 929–939. IEEE, 2024.

FARIDEH YAGHMAEI. Content validity and its estimation. *JOURNAL OF MEDICAL EDUCATION*, 2003.

Dali Yang and Wenbin Dai. A lightweight container design for microservice-based industrial edge applications. In *2022 IEEE 17th Conference on Industrial Electronics and Applications (ICIEA)*, pages 858–863. IEEE, 2022.

Nanzi Yang, Wenbo Shen, Jinku Li, Xunqi Liu, Xin Guo, and Jianfeng Ma. Take over the whole cluster: Attacking kubernetes via excessive permissions of third-party applications. In *Proceedings of the 2023 ACM SIGSAC Conference on Computer and Communications Security*, pages 3048–3062, 2023.

Yutian Yang, Wenbo Shen, Xun Xie, Kangjie Lu, Mingsen

Wang, Tianyu Zhou, Chenggang Qin, Wang Yu, and Kui Ren. Making memory account accountable: Analyzing and detecting memory missing-account bugs for container platforms. In *Proceedings of the 38th Annual Computer Security Applications Conference*, pages 869–880, 2022.

Ellyz Yaory and Ida Bagus Kerthyayana Manuaba. A comparative study of complex query performance on mysql and oracle databases for the oil and gas industry. In *2024 International Conference on Information Management and Technology (ICIMTech)*, pages 1–6. IEEE, 2024.

A Yarmilko, S Naumenko, et al. Analysis of information security issues in balancing multiple independent containers on a single server. In *Proceedings of the 3rd International Workshop on Information Technologies: Theoretical and Applied Problems*, pages 450–461, 2023.

Yuhan Ye, Dong Zhang, and Guo Feng. A patch-based network model for container workload forecasting. In *Proceedings of the 2024 International Conference on Cloud Computing and Big Data*, pages 272–277, 2024.

Jinyong Yin, Yuechang Zhao, and Honghui Wang. A static task allocation and scheduling algorithm for kubernetes cluster. In *2024 IEEE 7th International Conference on Information Systems and Computer Aided Education (ICISCAE)*, pages 175–179. IEEE, 2024.

Xiya Yu, Xuetao Zhang, Yuanyuan Shi, Changping Wu, and Xianhe Li. Design and implementation of vsto-based online compilation teaching system for c language. In *Proceedings of the 5th International Conference on Computer Science and Software Engineering*, pages 481–486, 2022.

Haibin Yuan and Shengchen Liao. A time series-based approach to elastic kubernetes scaling. *Electronics*, 13(2): 285, 2024.

Sehar Zehra, Hassan J Syed, Fahad Samad, Ummay Faseeha, Hamza Ahmed, and Muhammad K Khan. Securing the shared kernel: Exploring kernel isolation and emerging challenges in modern cloud computing. *IEEE Access*, 2024.

Qingyang Zeng, Mohammad Kavousi, Yinhong Luo, Ling Jin, and Yan Chen. Full-stack vulnerability analysis of the cloud-native platform. *Computers & Security*, 129: 103173, 2023.

Jiayin Zhang, Huiqun Yu, Guisheng Fan, and Zengpeng Li. Cold-start aware cloud-native service function chain caching in resource-constrained edge: A reinforcement learning approach. *Computer Communications*, 195:334–345, 2022.

Qingman Zhang, Ju Ma, Xiufeng Zhang, and Yongjia Liu. Container security assessment and reinforcement technology integrating big data and intelligent algorithms. In *2024 3rd International Conference on Data Analytics, Computing and Artificial Intelligence (ICDACAI)*, pages 622–626. IEEE, 2024.

Tao Zheng, Rui Tang, Xingshu Chen, and Changxiang Shen. Kubefuzzer: Automating restful api vulnerability detection in kubernetes. *Computers, Materials & Continua*, 81 (1), 2024.

Amelie Chi Zhou, Rongzheng Huang, Zhoubin Ke, Yusen Li, Yi Wang, and Rui Mao. Tackling cold start in serverless computing with multi-level container reuse. In *2024 IEEE international parallel and distributed processing symposium (IPDPS)*, pages 89–99. IEEE, 2024.

Yu Zhou, Weilin Zhan, Zi Li, Tingting Han, Taolue Chen, and Harald Gall. Drive: Dockerfile rule mining and violation detection. *ACM Transactions on Software Engineering and Methodology*, 33(2):1–23, 2023.

Marco Zuppelli, Massimo Guarascio, Luca Caviglione, and Angelica Liguori. No country for leaking containers: Detecting exfiltration of secrets through ai and syscalls. In *Proceedings of the 19th International Conference on Availability, Reliability and Security*, pages 1–8, 2024.