Innovative Emerging Ontology-driven Frameworks: A Systematic Literature Review

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ABSTRACT

Previous research has shown that ontologies and related semantic web technologies have positioned themselves as good solutions for data integration and resource reusability. Pitfalls and traps in modelling domains can be avoided if researchers and scholars adopt and use ontology-driven frameworks for their research. This research work aims to review currently developed or proposed ontology-driven frameworks, and clearly illustrate their development, application, and practicality. The review then ultimately addresses three main research questions driving the literature review through a synthesis of information that exists about ontology-driven frameworks. Search strings were used to obtain articles from online electronic databases. The PRISMA chart was used for the final selection of the 60 articles for review. A method of scoring called the Assessment of Multiple System Reviews (AMSTAR) was used on the included studies for quality assessment. The AMSTAR mean overall result was 9, the median 10, and the standard deviation 0.99. The results reveal a downward trend of ontologies in 2010, with Web Ontology Language (OWL) being the most used language for ontology-driven frameworks and systems, with over 70% usage.

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1. INTRODUCTION

The rapid growth rate of everyday work procedures in fields like health, traceability, cyber security, and online education has been accompanied by challenges that hinder the success of the systems they use. [1] stress that the current global competitiveness among organizations has led to a need for the reduction of information technology operations expenditures. Furthermore, the lack of sharing techniques and reusing existing data has caused the generation of inconsistent data. Reusability will save time and effort for users in their research, as well as support and maintain organization activities [1]. [2] concur that smooth business operations are hindered by mismatches of data and inconsistent data challenges that bring limitations to data interoperability. According to [1], these challenges can be solved by the application of semantic web technologies in the affected research fields, for example, cyber security, healthcare, and smart technologies. Moreover, the sharing and reusing of data across community boundaries, organizations, and applications can be provided by a common semantic web framework.

[3] identified ontologies as the main effective research in semantic web.[2] agrees that perfect data exchange and integration can be provided by ontologies as semantic model representations that provide a description to multiple entities and their properties of a domain of discourse. [3] defines an ontology as a conceptual non-static model used to describe information systems at the knowledge and semantic level, with the ability to capture changes in relations and meaning. Pitfalls and traps can be avoided if researchers and

scholars adopt or create frameworks for research. [4] acknowledges the importance of frameworks as research tools in the science fields. He adds their importance in the theoretical development and structuring of empirical inquiry for sustainable sciences, environmental sciences, social-ecological systems, and governance research. As important as frameworks have been described, [4] says the development and application of frameworks are not clear all the time despite the numerous frameworks available.

This systematic literature review aims to review articles that have developed or proposed ontology-driven frameworks and clearly illustrate their development, application, and practicality. An ontology-driven framework was designed by [3] for a network education resources library for accessing and reusing resources in education. Thus, achieving interoperability among education resources distributed repositories. [5] states that frameworks are important in providing step-by-step guidance to developers, researchers, and scholars in their field of research. However, as much as frameworks are effective in synthesizing and main concepts communication they are limited if they are static and theoretical. In 1753 James Lind conducted the first systematic review [6]. Their published paper aimed to impart a summary of scurvy evidence that was unbiased and concise.

Systematic reviews took off from there and have over the years grown tremendously. According to [7], systematic literature reviews yield comprehensive summaries of studies that are in relation to the research question. Additionally, they allow synthesizing past studies to strengthen the foundation of knowledge for a specific topic. In the same light, this paper has conducted a systematic literature review of previous studies that have employed ontology-driven frameworks by selecting relevant articles through a selection criterion that included Assessment of Multiple System Reviews (AMSTAR) quality assessment. The selection of the articles was driven by some research questions. The final selected articles were analyzed, synthesized, and the outcome of the evaluated articles was presented and discussed.

This review provides an updated perspective on ontology-driven frameworks applied across various fields, offering a synthesis of recent evidence for evidence-based practices in the research field. The review identifies research gaps in ontology-driven frameworks, highlighting areas of concern in studies and potential future improvements for future research improvement in these frameworks. The rest of the paper is organized as follows: Section 2 presents the methodology – a systematic literature review step-by-step process. Section 3 is the analysis and results of the selected articles. Section 4 presents an extensive discussion of the findings that answer the research questions. The last, Section 5, concludes the systematic literature review.

2. METHODOLOGY – SYSTEMATIC LITERATURE REVIEW

This paper presents a systematic literature review based on research questions exploring and summarizing information that already exists about ontology-driven frameworks. The existing studies are synthesized in an unbiased and thorough manner. Systematic review is defined as a way to identify, interpret, and evaluate relevant research that is available to specific research questions [8]. According to [9], the review should be fair and supported by a search strategy that is predefined for complete assessment to draw conclusions that are possible from the research studies selected and the positioning of future activities in research [9]. With the review, gaps will be identified in the current research to assist in determining the focus for further research investigations and improvements. Three main stages in the systematic literature review (SLR) adopted from [10]: Planning, Conducting, and Reporting. The review proceeds iteratively, starting with protocol development and refinement as the review proceeds. The stages are adapted to suit this review, ensuring a comprehensive understanding of the literature.

2.1. Review Protocol

According to [10], the methods used to undertake the systematic review are specified by the review protocol. The review protocol is pre-defined early in the review process to reduce research bias. There are three main phases used to undertake the systematic literature review. The first method is Planning the review which is conducted at the beginning of the review. It includes the sub-methods: Defining review scope, specifying research questions, Specifying search string, and Specifying search engines and filters. The second phase of the system literature review is the main phase, Conduction the review. It has the following sub-methods; Access search engine, Apply search string and filters, Read title and abstract, Paper out of scope, Rejected Paper, Reading and classification of article, and Met Inclusion criteria. In the third and last phase the articles are analyzed, synthesized, and results presented.

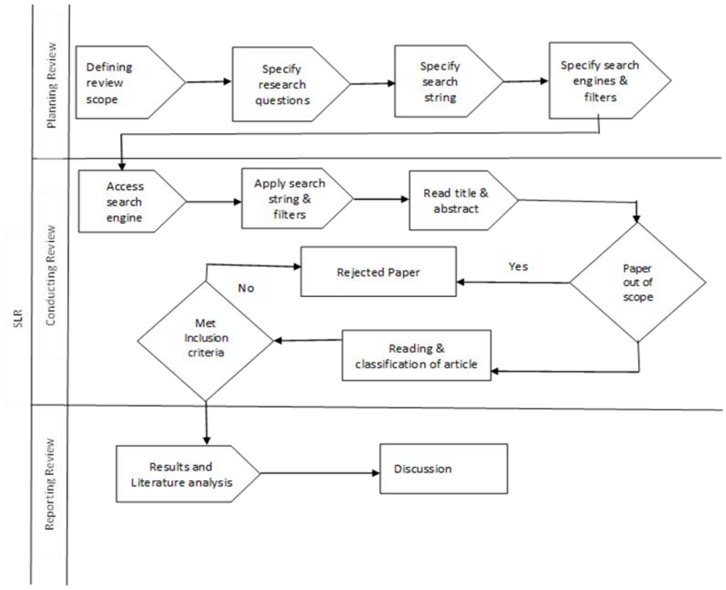

Figure 1. Systematic literature review process.

2.2. Planning the Review

(1) Review scope

More researchers and developers are adopting ontologies to address knowledge management system challenges. According to [11], the employment of ontologies is necessary for knowledge representation improvement. Over the years we have seen more ontology-driven frameworks appearing, but many questions arise. This is because with as many frameworks surfacing, there are very few reviews that are carried out that can inform researchers and developers about ontology-driven frameworks available. A framework is important in guiding future research. [12] believes a framework should be broadly applicable to the field it is intended for. An important aspect of employing both ontologies and frameworks is reusability. This literature review will enhance reusability and make ontology-driven framework adoption easier for researchers and developers. The researchers will get an insight into what type of ontology-driven or ontology-based framework is best suited for their challenge and which ontology they can adopt. Thus, avoiding redundancy, waste of time, and resource wastage. [13] insists that the rationale for research is given structure and support by a framework.

(2) Research questions

The following research questions will guide the review of ontology-driven frameworks. The review seeks to answer the questions by reviewing previous studies from researchers who studied ontology-driven frameworks.

RQ1. What challenges have inspired the development of ontology-driven frameworks?
RQ2. What are the impacts of the proposed/developed ontology-driven frameworks?
RQ3. What is the future outlook on ontology-driven frameworks?

(3) Inclusion and exclusion criteria

The study includes articles that are related to the research topic "Innovative emerging ontology-driven frameworks". The criterion is defined to identify the main papers that provide evidence and answers to the research questions, and to avoid the likelihood or reduce biases [14]. Studies from various fields that reported, evaluated, and discussed frameworks that are ontology-driven were included in this review. The inclusion criteria for the studies were primary studies, peer-reviewed journal articles, and peer-reviewed conference proceedings only. Secondary studies, non-peer-reviewed articles, non-English papers, duplicate papers, studies that do not use ontologies, and studies that do not use frameworks were excluded, as depicted in Figure 2. The date range for included studies was for literature published between 2010 and 2023. The decision for the chosen period was made to avoid repetition of work that has already been covered but gives a good spread in terms of coverage of evolving technology [14].

The process starts with the search engines first accessed then the composed search string and filters are applied. The articles that appear are selected and downloaded based on the title and abstract from the search engine. After saving the articles that seemed relevant from the title and abstract, the articles were further individually opened and checked if they aligned with the review scope. If the article does not meet the scope they are rejected, and the rest move to the next stage. After this, the articles are read and classified to make it easy to select the articles that meet the inclusion criteria. The articles that meet the inclusion criteria are the final relevant articles that are selected to be used in this review paper.

(4) Search and Selection Strategy

Electronic databases were used to search for articles included in this review. A search string was used to search for articles that fulfill the research questions based on the review topic "Innovative emerging ontology-driven frameworks". The search string selection was influenced by the basic rules defined by [15]. The rules state that keywords should be separated. Each separation of words gets synonyms and concatenated them firstly with the connector "OR" and then secondly with the connector "AND". The search string was used on the following electronic databases: Science Direct, IEEE Xplore, Taylor and Francis, Springer, Emerald, and JSTOR. Figure 2 depicts a PRISMA chart that shows the paper selection process at each stage as adopted from [16]. Before we explain the PRISMA chart, it is worth showing the search string process that was used to obtain the articles included in the study. The search strings are:

1. "Ontologies"
2. "Frameworks"
3. "Ontology Frameworks"
4. "Ontology-driven Frameworks"
5. "Ontologies" OR "Frameworks"
6. "Ontologies" AND "Frameworks"

The PRISMA chart adopted has four main phases: identification, screening, eligibility, and included. Each stage has a set of activities involved in which articles are reviewed and irrelevant articles are excluded from the study. The remaining articles move on to the next phase until the last stage where the final articles are selected. Six main databases were used to retrieve the articles as seen in Figure 2. Duplicate articles were excluded first, the first article found is the one that was saved, and the second duplicate was excluded. Then after reviewing abstracts, irrelevant articles were excluded, full articles were reviewed and the irrelevant excluded. The final selection included 60 articles for review.

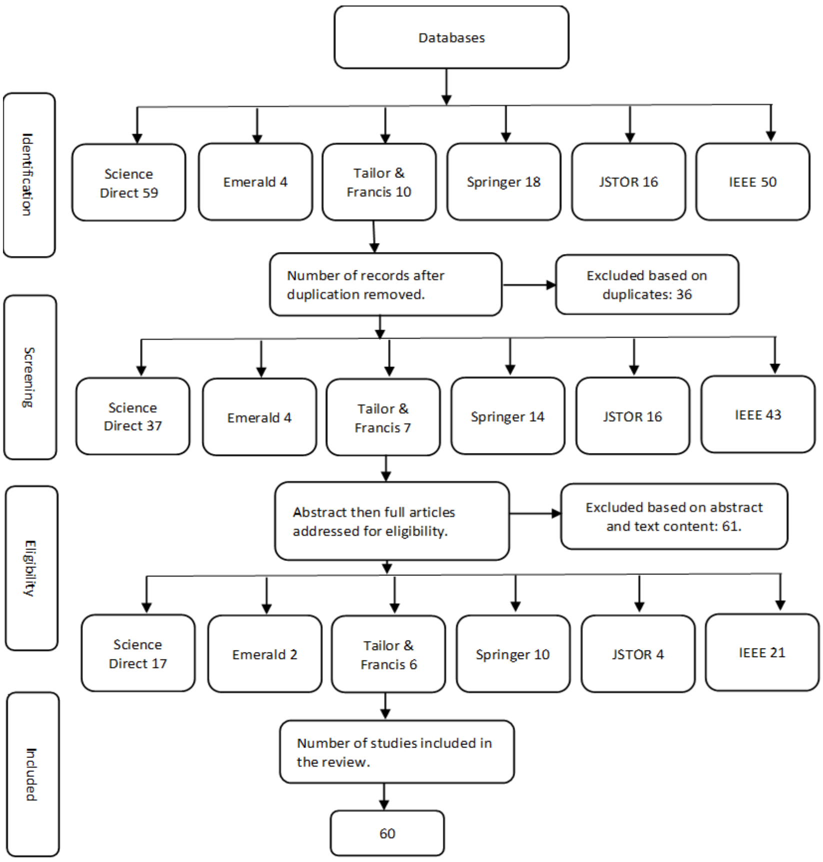

Figure 2. PRISMA chart for journal searching from databases. Adopted from [16]

(5) Quality Assessment

A method of scoring called AMSTAR was used in the included studies for quality assessment. They were scored based on an evaluation criterion to check if they were relevant, credible, and complete. An evaluation of the articles that were selected was carried out against the 11 quality criteria. The quality assessment instrument is presented in Table 1 with answers based on the studies reviewed. The set of quality criteria questions was adapted from two sources [14, 17], with edits made to each question to correspond with the research questions and scope of this review. The included articles for this review were independently assessed and the quality score was computed by calculating the sum of the answer scores, which will result in scores from 0 to 11. Three classifications were used in the rating of the selected reviews as recommended by [18]. First, it is the score from 0 - 4 being low quality, 5-8 moderate quality, and 9-11 as high quality. The AMSTAR rating is a methodological quality system review, rating Yes=1, No=0, and Not applicable=0. [19] states that the AMSTAR assessment was created in 2007 with feasibility, time, and reliability in mind.

Table 1. Quality assessment criteria. Y=Yes, N=No, NA=No Answer. Adopted from [14, 17]

Number	Criteria Question	Possible answer
1.	Is there a rationale for why the study was undertaken? [14]	Y=1 N=0 NA=0
2.	Is the paper based on research (or is it merely a ‘‘lessons learned’’ report based on expert opinion)? [14]	Y=1 N=0 NA=0
3.	Is there a clear statement of the goals of the research? [14]	Y=1 N=0 NA=0
4.	Is the proposed technique clearly described? [14]	Y=1 N=0 NA=0
5.	Is there an adequate description of the context in which the research was carried out? [14, 17]	Y=1 N=0 NA=0
6.	Is the study/ framework evaluated? [14]	Y=1 N=0 NA=0
7.	Is there a discussion about the results of the study? [14]	Y=1 N=0 NA=0
8.	Are the limitations of this study explicitly discussed? [14]	Y=1 N=0 NA=0
9.	Does the research add value to the body of knowledge? [14, 17]	Y=1 N=0 NA=0
10.	Was a comprehensive literature search performed? [17]	Y=1 N=0 NA=0
11.	Were the methods used to develop/adapt an ontology-driven or ontology-based framework in the studies appropriate? [17]	Y=1 N=0 NA=0

(6) Data extraction and Synthesis

The data extraction and synthesis of papers that were selected was conducted to identify information from the selected papers. The information from selected papers answered the research questions of this review paper. The first step is the extraction of data from the 60 selected papers through the selection process seen in the previous Section 2.2.4. The paper abstract, introduction, main contents, and conclusion were read and analyzed looking for answers to the research questions. Microsoft Excel was used as a tool for the extraction of data. Categories were created on the Excel spreadsheet based on the scope of this review and research questions. The categories included: identifier, author, year, paper type, research method, quality assessment, ontology language, and the research questions. Each paper selected was analyzed and the answers were extracted and pasted on the spreadsheet. The second step after the data extraction was the data synthesis. The synthesis of the extracted data was presented in multiple forms (presented in the results Section 3), tables and graphs for better visualization of the information.

3. ANALYSIS AND RESULTS

Data was extracted from a total of 60 research studies that were able to meet the inclusion criteria. Before the results are analyzed and presented for each of the research questions, the results of the assessment of the quality are depicted, and an informative overview of the studies characteristics are presented.

3.1. Quality assessment results

The assessment of the quality of the studies selected was done to increase the accuracy of results found from the extracted data. The quality assessment helps determine the validity deduction presented and for establishing the coherence and credibility synthesis of data results [17]. Table 2 presents the results of the methodological quality assessment using AMSTAR of the papers reviews. The results show that out of the 60 systematically reviewed articles, none were low quality (0-4), 5 articles were moderate quality (5-8), and 55 were of high quality (9-11). The AMSTAR mean overall results were 9, the median 10, and the standard deviation 0.99.

Table 2. Research Quality Assessment Criteria

Publication	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	AMSTAR Score
[62]	1	1	1	1	1	1	1	0	1	0	1	9
[68]	1	1	1	1	1	0	1	0	1	1	1	9
[69]	1	1	1	1	1	1	1	0	1	0	1	9
[63]	1	1	1	1	1	0	1	0	1	1	1	9
[64]	1	1	1	1	1	1	1	0	1	0	1	9
[33]	1	1	1	1	0	0	1	0	1	0	1	7
[65]	1	1	1	1	1	1	1	0	1	1	1	10
[71]	1	1	1	1	1	0	1	0	1	1	1	9
[72]	1	1	1	0	0	0	1	0	1	1	1	8
[1]	1	1	1	1	1	1	1	0	1	0	1	9
[61]	1	0	1	1	1	1	1	0	1	0	1	8
[67]	1	1	1	1	1	0	1	0	1	0	1	8
[70]	1	1	1	0	0	1	1	0	1	0	1	7
[74]	1	1	1	1	1	0	1	0	1	1	1	9
[75]	1	1	1	1	1	1	1	0	1	1	1	10
[73]	1	1	1	1	1	0	1	1	1	1	1	10
[3]	1	1	1	1	0	0	1	1	1	0	1	9
[66]	1	1	1	1	1	0	1	0	1	1	1	9
[42]	1	1	1	1	1	0	1	0	1	1	1	9
[75]	1	1	1	1	1	1	1	0	1	1	1	10
[74]	1	1	1	1	1	0	1	0	1	1	1	9
[38]	1	1	1	1	1	1	1	0	1	1	1	10
[53]	1	1	1	1	1	1	1	0	1	1	1	10
[47]	1	1	1	1	1	1	1	0	1	1	1	10
[45]	1	1	1	1	1	1	1	1	1	1	1	11
[44]	1	1	1	1	1	1	1	0	1	1	1	10
[36]	1	1	1	1	1	1	1	1	1	1	1	11
[20]	1	1	1	1	1	1	1	1	1	1	1	11
[29]	1	1	1	1	1	0	1	0	1	1	1	9
[34]	1	1	1	1	1	1	1	0	1	1	1	10
[40]	1	1	1	1	1	0	1	0	1	1	1	9
[58]	1	1	1	1	1	1	1	0	1	1	1	10
[46]	1	1	1	1	1	1	1	0	1	1	1	10
[59]	1	1	1	1	1	1	1	1	1	1	1	11
[43]	1	1	1	1	1	0	1	0	1	1	1	9
[57]	1	1	1	1	1	0	1	0	1	1	1	9
[50]	1	1	1	1	1	0	1	0	1	1	1	9
[41]	1	1	1	1	1	1	1	0	1	1	1	10
[25]	1	1	1	1	1	0	1	0	1	1	1	9
[54]	1	1	1	1	1	1	1	1	1	1	1	11
[18]	1	1	1	1	1	1	1	0	1	1	1	10
[52]	1	1	1	1	1	1	1	0	1	1	1	10
[54]	1	1	1	1	1	1	1	1	1	1	1	11
[56]	1	1	1	1	1	1	1	1	1	1	1	11
[28]	1	1	1	1	1	1	1	0	1	1	1	10
[49]	1	1	1	1	1	1	1	1	1	1	1	11
[60]	1	1	1	1	1	1	1	1	1	1	1	11
[19]	1	1	1	1	1	1	1	0	1	1	1	10
[32]	1	1	1	1	1	1	1	0	1	0	1	9
[35]	1	1	1	1	1	0	1	1	1	1	1	10
[37]	1	1	1	1	1	1	1	1	1	1	1	11
[39]	1	1	1	1	1	1	1	0	1	1	1	10
[51]	1	1	1	1	1	0	1	0	1	1	1	9
[48]	1	1	1	1	1	1	1	0	1	1	1	10
[24]	1	1	1	1	1	1	1	1	1	1	1	11
[22]	1	1	1	1	1	1	1	1	1	1	1	11
[26]	1	1	1	1	1	1	1	1	1	1	1	11
[31]	1	1	1	1	1	1	1	0	1	1	1	10
[30]	1	1	1	1	1	0	1	0	1	1	1	9
[27]	1	1	1	1	1	0	1	1	1	1	1	10

3.2. Overview of the studies

The following sub-section presents a visualization of the results that were deduced from the 60 studies in the form of graphs for better understanding and interpretation.

(1) Publication trends throughout the years

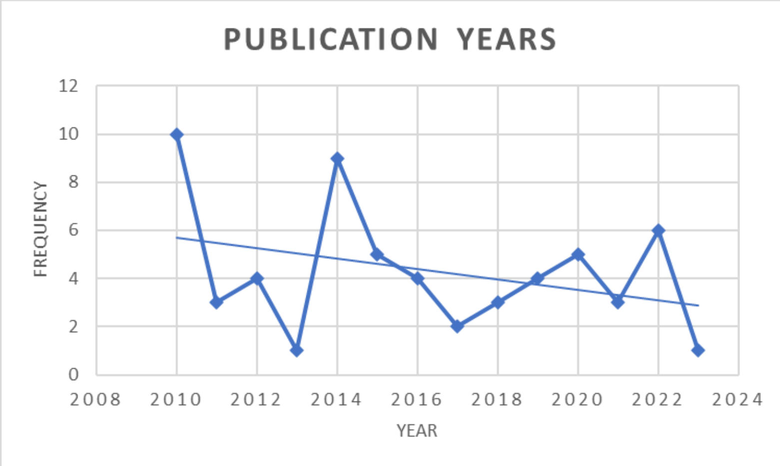

Figure 3. Trend of the years the articles were published.

The studies selected for review were chosen based on a date range from 2010 to 2023. This was to appreciate the peek points and trends of research conducted in ontology-driven frameworks. As illustrated in Figure 3, in 2010 the frequency was high, and ontologies were popular but the next couple of years show an up-and-down trend. In 2010 Ontology Alignment Evaluation Initiative1 (OAEI) was holding ontology matching workshops for automating most of the ontology processes [20]. The downward trend thereafter was caused by researchers and developers focused on understanding and implementing the newly introduced concepts. 2010 to 2014 was also a time when new technologies like Machine Learning and the Internet of Things were introduced. Researchers had to find ways to integrate them with their existing work, thus causing a temporary slowdown.

2014 showed a comeback in ontology studies with researchers publishing the discoveries and innovations they had been working on. From 2015, the trend was up and down. The trend from 2018 to 2022 shows that ontologies have been on the rise with a high peek in 2022. Recent 2023 research work has yet to be published, the actual trend will be visible in 2024. Despite these trends, the future of ontologies is still promising, and the usage of ontologies is still relevant. Ontologies have been mainly used in Healthcare, but the growing trends show recent usage in Cyber Security, Agriculture, and Smart technology. With more fields adopting ontologies, this review will be useful and relevant to guide and inform researchers and developers on past and current ontologies to assist in ontology development for their domain. Research by Ashraf [21] states that 34.3% more people are using the internet than in the past years. With more people using the internet semantic web particularly ontologies show promising growth.

(2) Languages used in Ontologies

The ontology-driven frameworks proposed/developed were created using different programming languages to reach their goal. Figure 4 below shows the different programming languages in the studies reviewed and the bar charts illustrate the percentage of the most used language. As illustrated, the Web Ontology Language (OWL) is the highest used language for ontology-driven frameworks and systems at over 70%. The lowest is First-order logic and Python programming languages with less than 10%.

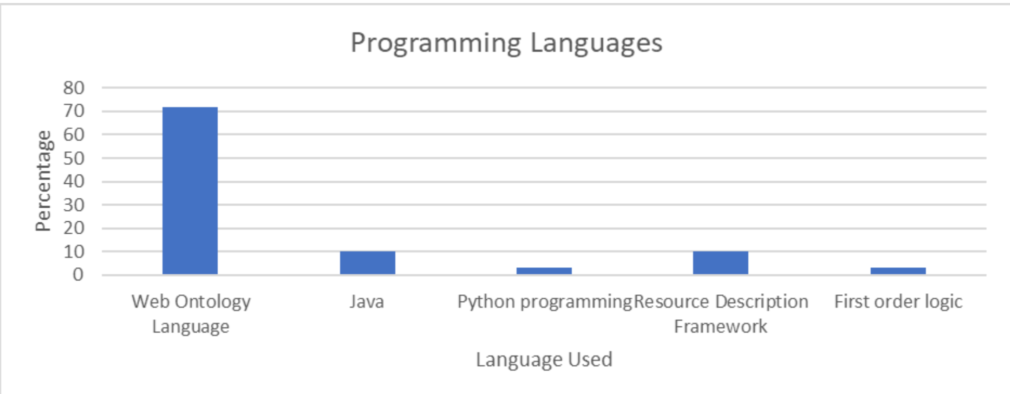

Figure 4. Programming languages used for ontologies.

(3) Type of source

Figure 5. Ontology-drive frameworks article sources.

The total number of studies that were chosen for the review of ontology-driven frameworks was 60. The sources selected for review were journal articles and conference proceedings only. Figure 5 shows that the majority of the studies were journal articles at 65% and the rest were conference proceedings at 35%.

4. DISCUSSION

The discussion section will be addressing the three main research questions regarding the results found in the systematic literature review, focusing on challenges faced by current and emerging fields. Researchers employ ontology-driven frameworks to counter these challenges, and the future direction of integrating these frameworks is discussed to provide innovative solutions.

4.1. RQ1 Discussion

RQ1. What challenges have inspired the development of ontology-driven frameworks?

The research question aimed to identify challenges in various fields that inspired the development of ontology-driven frameworks. Data extraction and synthesis of 60 selected studies were conducted to identify these challenges and develop ontology frameworks. Figure 6 shows various fields implementing ontology-driven frameworks to address challenges faced. Health and biomedical have the highest percentage of ontology-driven frameworks, with 22% implemented, while project management has the lowest implementation. The proposed framework addresses each field's challenges and outlines the proposed solutions.

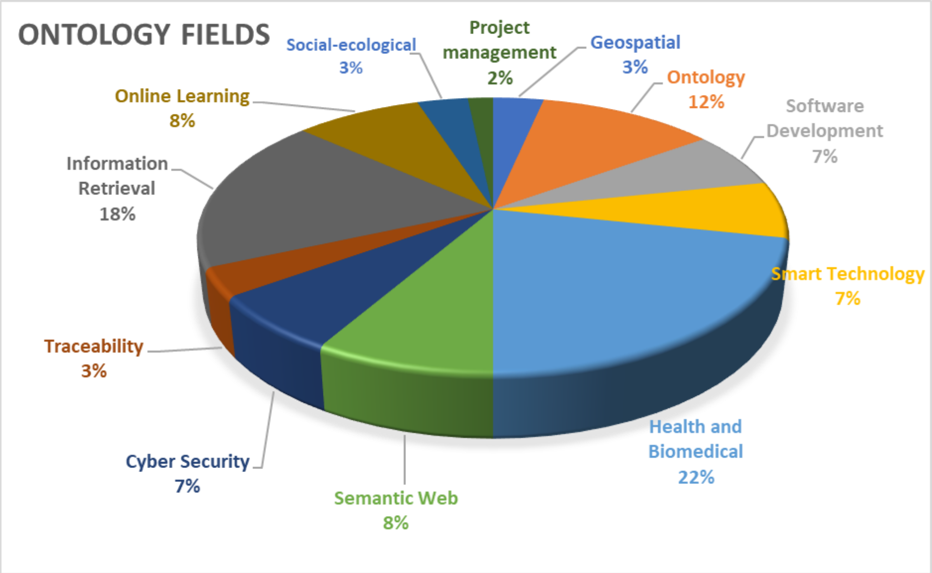

Figure 6. Various fields employing ontology-driven frameworks.

(1) Cyber security

[22, 23, 24] explored cybersecurity threats in various business spheres, proposing an ontology-driven framework for addressing challenges. These studies focused on various aspects of cybersecurity, aiming to provide a comprehensive solution. Martins et al. emphasize the importance of an interdisciplinary approach in cyber security for large enterprises, emphasizing asset protection and management as top priorities. They propose knowledge graphs for security modeling and an ontology classification framework for cybersecurity terminology validation, addressing threats and attacks on large organizations. [24] argue that ontologies, designed to address domain knowledge questions, can help automate threat modelling by simplifying data creation. They believe that ontologies are the solution to cyber security challenges, as they address the lack of context in the data collected. In the same vein, [24] developed Rantology, a dedicated ontology for digital blackmail, focusing on ransomware assaults. Ransomware has become a significant threat, with [25] predicting exponential growth in ransomware attacks, with losses expected to double in the next decade.

(2) Project Management

The history of humans has marked megaprojects as being symbolic unique endeavors such that the principles of project management used prior are not suitable nor applicable. As indicated by [26], embarking on the megaprojects holistic study is extremely difficult. He says that the difficulty comes from the lack of frameworks created to systematically guide and assess megaprojects research and megaprojects. Additionally, there are possible risks of bias when it comes to the project planning and researched topics. [26] presents megaprojects ontological framework to assist in analyzing megaprojects individually and synthesizing megaproject research corpus. He developed an ontology framework by deconstructing the purpose and symbolism of megaprojects into categories and dimensions. The framework will be used for mapping extent literature for megaprojects. It is also used for the identification of dominant gaps in research and themes.

(3) Traceability

Traceability is defined [27] as the capability of accessing information about a product or anything throughout the product's life cycle using a system with identifications recorded. [28, 29] discuss traceability challenges in food supply chains that employ ontologies. [28] emphasizes the importance of food traceability, while [28] emphasizes requirements traceability. Traceability is crucial for product recall and safety management, as it ensures product quality and safety for consumers. [28] identified challenges in bridging the gap between engineering and traceability requirements in the food supply chain. Existing systems struggle with scalability and interoperability due to data overload, supply chain complexity, and re-engineering. They propose an ontological framework for traceability, providing a structured view of solutions for basic, scalable, and interoperable traceability assurance. [29] proposed MURPET, a multi-perspective requirements traceability framework, to address challenges faced by software developers in handling large-scale requirements from stakeholders. The framework utilizes ontologies for knowledge management and automatically generates traceability relations through the ontology matching mechanism.

(4) Education

[30, 31] emphasize the importance of Electronic Learning (E-learning) in transforming information societies into knowledge societies. They argue that improving content and addressing challenges hinder its effectiveness. There is consensus among [32, 33], that the E-Learning area is rapidly growing but there still exists challenges that hinder its effectiveness that need to be addressed. However, [34] argues that automating processes based on E-learning specifications is unfeasible due to a lack of standards and specifications. Educational resources are increasingly being sought by students, researchers, teachers, and industry employees. [31] highlight the challenges faced by learners in accessing these resources. Researcher [30], employs an ontology-driven approach to handling challenges. The study by [30] likewise has the objective of meeting the educational needs of learners. [30] addresses this issue by focusing on mathematical thinking and problem-solving, addressing the distress experienced by students in learning mathematics. Educational ontologies should incorporate popular mathematical thinking features to enhance learners' learning experience.

(5) Social Ecology

Several challenges that affect the social-ecological systems have been identified by [34] and present ontologies as a solution to the challenges. The first challenge identified is the complexity of systems, there is a need for adequate analysis of the system. Furthermore, the lack of integration discovered in various research results to form cohesive theoretical statements is a scattering problem. [34] present the panacea challenge where there is no account for the overreliance on the policy prescriptions. The research presented by [35] identifies preexisting framework challenges in the social ecology field for agriculture. Like the researcher [34], He introduces ontologies as a solution to social ecology. According to [35] sustainable agriculture is a way to make sure there is agriculture to be practiced and developed in the future. He states that a transition is imminent and substantial change is imminent. Moreover, the transition can be done by agroecology with deep analysis of frameworks and investigating theories existing for sustainability transitions.

(6) Knowledge Management

[36] defines ontology measurement as collecting and then calculating precise ontological entities related using ontology metrics. As stated by [36], to measure the ontologies correctly and effectively will condition an evaluation of ontologies that is significant and beneficial. [36] found that the rapid increase of ontology-based systems has derived challenges in ontology measurements. Furthermore, managing the development of ontology systems will greatly reduce project failures. An analysis carried out recently on the current state, challenges, and future direction in ontology engineering by [37] exposed some issues. The issues are also highlighted in research by [38], stating the main issue being the unanswered important questions in ontology development. Her text addresses eight questions on project management, transitions, and task recommendations using a linked open-terms methodology, incorporating 18 projects and 20 years of ontological engineering lessons.

(7) Geospatial

[39] highlight the importance of geospatial clustering in geospatial systems and knowledge discovery. It involves allocating objects based on density, geographical space, connectivity, and reachability, while also allocating dissimilar objects. However, challenges like lack of focus on user goals and domain knowledge hinder its success. Wang et al. propose a GEO_CLUST framework, incorporating GeoCO ontology for clustering and geospatial domain knowledge. Geospatial research by [40] agrees that ontologies can be an effective way to solve the challenges in geospatials. [40] proposes an ontology-enabled framework for an environment suitable for geospatial problem-solving. Additionally, the framework uses ontologies for domain knowledge base for experts. The experts formalize the semantics in geospatial and model conceptual workflows of problems used for semantic inference and reference. [40] explain that the framework will allow teamwork between domain experts, solution seekers, and web service providers to semantically explore and find geographic information services solving specific class of problems in geospatial.

(8) Software Development

The first stage in software development as identified by [41] is requirement engineering which represents and examines the domain of the problem for adequate solutions. The requirement process enhances the software development quality and reduces the risk of project failure, flooded budget, and project delays [41]. Even so, the author [41] discovered that methods traditionally used are not adequate for the problems related to requirements engineering. He states that the main challenges are the ineptitude for requirement specification reuse in various domains, no interoperability among the heterogeneous requirements models, and the requirements validation lack of focus. [41] suggest that a semantic approach specifically ontologies is needed to solve the problems by representing variability and commonalities in the requirements covering multiple domains and applications. [42] stresses the importance of domain knowledge in selecting engineering materials, highlighting the need for a scalable, open, and shared knowledge framework. The ontology-based knowledge framework by [42] offers powerful knowledge services for material selection challenges in the engineering and software industries.

(9) Biomedical and Healthcare

[43] highlight challenges in healthcare and the biomedical field, such as data quality issues and lack of systematic validation mechanisms. [44, 45] emphasize the importance of teamwork in the healthcare industry, emphasizing the need for effective systems and frameworks to ensure the survival of humans, plants, and machines. [45] emphasize the importance of an ontology-based framework in interdisciplinary healthcare, addressing challenges like individual diagnosis and medical specialist knowledge. They propose implementing a cardiac management program to improve the quality of cardiac rehabilitation programs, leveraging ontologies to standardize worldwide practice. [46] highlight the challenges faced by healthcare professionals in the IOT era, including manual tasks and patient outcomes.[47] emphasize the need for smart health services, while [48] address similar challenges, such as remote patient monitoring, variant disease diagnosis, telemedicine, and remote treatments for specific diseases. [49, 50, 51] highlight the benefits of ontologies in healthcare management, emphasizing the need for powerful technology for unstructured data and clinical decision-making.

(10) Smart Technology

[52] suggests that service robots can utilize common knowledge to perform tasks in home appliances, as they possess unique motion primitives for each operating part. However, these robots are still not yet capable of executing these tasks. [52] propose a framework for ontology edition, focusing on motion primitives, knowledge representation by ontologies, and a graphical user interface. They suggest that robots can perform tasks by implementing motion skills and providing home appliance operation knowledge. [53] highlight the importance of mobile applications in smart environments, as people own multiple devices. [53] advocates the importance of fast, reliable retrieval of services in smart mobiles, addressing challenges in managing distributed applications and identifying situations. This is crucial for users to access content from their physical environment. [53] proposed a PCSiF framework for parallel composite situation identification, enhancing performance in detecting incoming events. An abnormalities detection framework is presented by [54] for smart homes, addressing functionality disruptions caused by abnormalities in smart home systems. This framework utilizes semantic web ontologies for anomaly management.

(11) Semantic Web

The study presented by the researcher [55] carried out a project called The Semantic Reef Project, aimed at developing knowledge discovery, problem-solving, and data processing systems. The project is designed to test the ecological hypotheses for the derivation of environmental systems information. As explained by [55], the system will help in expanding understanding of the coral reef ecosystem and its management. However, more data is being collected in real-time by sensor networks, and increases the envisioned development of bottlenecks during data analysis because of the manual processing. Thus, managing the data is becoming unfeasible.[55] proposed ontology-based framework as a methodology for data overflow modulation, additionally improving knowledge extraction from collected data.

(12) Web Services

A semantic-based big data integration framework is introduced [56], focusing on probability logic and ontology matching, to address the complex and challenging big data environment. [57] emphasizes the need for consistent and reliable knowledge extraction from unstructured data on the internet. [58] propose the FAIBOUD Framework, a framework integrating ontologies for knowledge representation, to address challenges from technological developments and internet-based ontologies. The framework enables users to select appropriate adaptation methods based on user profiles, individual preferences, and context access. [58] emphasize the importance of considering individual preferences and multiple pathologies in understanding and addressing these challenges. [59] explored the challenges of managing multimedia content, while [60] identified the main challenge of retrieving, analyzing, organizing, and indexing information. Producers often produce large amounts of multimedia content without considering management. Ontologies can help with annotation and indexing multimedia files, providing knowledge representation features for efficient content management. [61] propose an ontology-based framework for digitized museum artifacts, addressing the growing number of unstructured digital contents. The framework automates image annotations and semantic retrieval, addressing challenges in analyzing, managing, and indexing visual content in the form of semantics.

(13) Information Extraction

[62]'s research reveals an enormous amount of literature in various fields, making manual reviews labor-intensive and time-consuming. They propose an automatic literature knowledge graph and reasoning network modeling framework based on ontology and Natural Language Processing for effective exploration of knowledge from literature. [63] state that the internet generation produces huge volumes of content on the web and that search engines have an important role in the retrieval of information from web pages. Most of the contents are semi-structured and unstructured (online portals inclusive e.g., ebay, craglist etc.) [63]. Additionally, the user-generated posts on the portals make it impossible to use standard query languages to retrieve useful information. In the case of online portals' information retrieval challenges, ontologies can be employed to allow storage of relevant information with formal descriptions [63]. Author [64] proposes an ontology methodology for information retrieval challenges in all web pages like understanding abstract details of multiple pages on the web without having to open them individually. [63, 64] propose ontological solutions for effective information retrieval on the internet.

4.2. RQ2 Discussion

RQ2. What are the impacts of the proposed/developed ontology-driven frameworks?

Table 3. Main Ontology impacts by Authors

Main Area of Impact	Publications
Scalability	[66]
Knowledge/ Data sharing	[66, 67]
	[65]
Integration	[1, 70, 72, 73, 74]
Reusability	[72]
Cross-platform sharing	[71, 72]
Knowledge management	[67, 68, 69]
Interoperability	[75, 76]
Information retrieval	[74, 77, 78]

Table 3 presents the main advantages of ontology-driven frameworks that have been observed by the reviewed authors in various fields. The Capture the Flag (CTF) ontology was proposed for concepts within competition representation to model the relationships, profiles, and skills of contestants, competing participants, and the environment. [65] says the importance of hacking competitions as a platform for cybercrime defense practice. Live experiences, investigations, and possible attack management are necessary to combat cybercrime. The CTF ontology framework can provide effective feedback on learning portfolios and content performance. [66] proposed an ontology-driven framework for collaborative knowledge sharing, focusing on domain knowledge. Their three-layer ontology improved the scalability and maintenance of decoupled ontology layers, enhancing the overall effectiveness of the framework.

Knowledge sharing and representation of ontologies can be effectively implemented by the framework proposed [67]. [67] agrees with [65] in that the framework he proposed can support different types of knowledge representation while addressing the data inconsistency and redundancy issues. [67, 68, 69] emphasize the advantages of knowledge management through ontologies in designing knowledge bases. [68, 70] applied this to a personalized management framework, providing users with tailored domain ontologies based on their preferences and requirements. [71] highlighted the benefits of knowledge management, focusing on cross-platform knowledge sharing through a semantic views cooperative framework. This approach helps collaborators exchange experiences and improves communication, enabling a better understanding of data and enhancing collaboration.

The medical information integration framework developed by [72] using ontologies has been able to overcome old ineffective cross-platform data sharing ways and integration of information. Operational reusability using technology by web services has been achieved by the framework. [70] advocate for the integration of ontologies in software engineering to improve functionality and reuse knowledge. [1] highlight the importance of ontologies in overcoming challenges and eliminating inconsistent information generation, ultimately leading to desired software development. Researchers [73, 74] agree with the vital role integration plays in various fields. To make it more effective he presented a framework that combines integration algorithms and similarity measures of ontologies.

Seamless sharing of information provided by semantic interoperability is one feature that inspired the proposed development of dental ICT system. [75] argues that the dental and medical field can increase patient care and their unfavorable outcomes by developing a system reusing the ontology SNOMEDCT. The system will allow for interoperability and cross-domain ontology between the dental and medical ICT systems. [76] agrees that ontologies aid interoperability through the conceptualization of concepts in a way that allows sharing and communication. Ontologies can also aid in overcoming traditional methods of information retrieval. A conceptual framework is presented by [77] that allows users to get relevant information for their searched queries only. [77] focused on information retrieval for the Marathi language for semantic matching and translation. Another semantic retrieval framework for efficient information retrieval was proposed by [78] providing specific and significant practical guidance to users in information retrieval.

4.3. RQ3 Discussion

RQ3. What is the future outlook on ontology-driven frameworks?

This review will help other researchers, developers, and evaluators to use the information to start or further their research being more informed about ontology-driven frameworks applied in different fields such as medicine, engineering, cyber security, smart technology, and web services. The lack of empirical research done on ontology-driven frameworks leaves a gap to further conduct and evaluate them in a specific field. Most of the frameworks proposed have not been developed into practical systems that can be used. Developers can use any of the frameworks that align with their system requirements and follow the framework guidelines to develop an actual system or improve their existing system. According to [79] the mobile publishing industry is still young and upcoming, so many questions are still unanswered. Furthermore, the mobile reading rate is increasing rapidly which will require more focus. [79] promise to continue his research by furthering and completing the mobile industry chain ontology. The question answering framework by [80], conducted experiments and the precision of the returned answers were improved but an integration of modular ontologies was proposed in the future. The modular ontologies are expected to give satisfactory results for users.

[77] proposed an ontology framework for the Marathi language, overcoming previous retrieval limitations. This framework can be applied to other languages, benefiting regions with native languages and English-speaking populations, as international systems often use English for communication. While ontologies have been presented at the core of solutions to various challenges presented, it is important for the developed ontologies to be evaluated for their effectiveness. [81] developed a criterion for quality evaluation of ontologies, and it has been applied to five ontologies. His study expects to create a website for different ontologies of various domains where the quality evaluation results can be viewed. Ontologies address scalability, integration, interoperability, knowledge management, and reusability which are properties that can overcome limitations of systems that have been developed over the years or add to newly developed systems.

5. ILLUSTRATION OF ONTOLOGY-DRIVEN FRAMEWORKS: CASE STUDIES

This section presents two case studies that will demonstrate the ontology frameworks that have been implemented and used to enhance and make effective developments in the education field. The first case study is based on gamification studies and the second case study presents project-based collaborative learning.

Researchers [82] state a branch of the education domain called gamification studies is based on student motivation. Gamification studies are used to increase student learning performance through motivation enhancement. [82] describe the process as first classifying the behavioural profiles, that is "user types" and "gamer", used to personalize the student's experiences. Furthermore, it is important in education research to inspect the behavioural profiles broadly for the development of a design that is instructional based on the learner's motivation and essential drivers. It was discovered [82] that there is subjectivity, demanding research, categorization that is difficult, and complexity among the concepts that had to be bridged. Author [82] presents an ontology-driven framework that they designed, evaluated, and implemented to represent the relationships for education adopting Jung's archetypes. It is an approach that models user profiles with game features taxonomy, and a revised taxonomy for the classification of the type of learning activities adapted from Bloom. The ontology can create designs that are instructional and personalized according to the student's type of learning activity. The research demonstrates how ontology has been effective in gamification designs for supporting learning [82]. Moreover, the ontology framework is being used to develop gamified education systems that are personalized and gamified strategies that are unplugged.

The second case study is based on an ontology-driven framework applied to animal traceability. The improvement of processes in the farm by using generated data to carry out in-depth analysis is called precision farming [83]. Moreover, most of the farming activities are being computerized with the creation of applications for effective and efficient farming. According to [83] they started a project that focuses on dairy production optimization in the farms of Eastern Canada. The project was done by designing a domain ontology called the dairy cattle performance ontology (DCPO). The DCPO is used to integrate structures that are complex to a heterogeneous way of data from dairy in a unified framework. The external data will be extensible through the framework. DCPO also produces a vocabulary that is common for both knowledge management tools that are automated and animal traceability stakeholders. [83] state that in the future they expect the ontology framework to provide predictive neural models through explainability.

6. CONTRIBUTION

This review study provides a literature review that is well-structured and comprehensive. Synthesizing knowledge that exists about ontology-driven frameworks from a wide spectrum of articles. The review offers a literature consolidation that presents a clear understanding of the ontology-driven framework's current landscape, thus contributing valuable insights and resources to developers and researchers. The use of the AMSTAR quality assessment framework for the evaluation of selected papers ensured a methodological rigor of quality assessment. This was done to initiate a criterion that is reliable for future ontology reviews. Practical applications are discussed in detail in the findings and case study section of the review to demonstrate practical implications to developers and researchers. Furthermore, it serves as a guiding principle for leveraging ontology frameworks when addressing challenges in the real world of diverse domains, adopting actionable knowledge for project implementation.

The major contribution is the answered research questions. Answering research question 1 showcases the challenges that are critical and have spurred ontology developments. Such challenges as security concerns and having a clear foundation for the driving factors for creating ontology frameworks. Addressing the research question 2 the review outlined and identified the ontology-driven frameworks impacts. Illustrating the contribution of the frameworks to reusability, interoperability, information retrieval, and sharing knowledge in various domains. Through research question 3 an insight into the future outlook of ontology-driven frameworks is contributed by highlighting modular ontologies potential and the proposition of a criteria for ontology quality evaluation. This information will give an effective direction to future development and research in the ontology field.

7. CONCLUSION

This research study presented a systematic literature review guided by the research questions to explore and summarize information that already exists about ontology-driven frameworks. The PRISMA chart was adopted for searching relevant journals from electronic databases and a total of 60 articles were selected. The articles went through rigorous selection criteria starting from search criteria to abstract exclusion. Quality assessment of the selected articles was conducted using the AMSTAR quality assessment tool. The results show that out of the 60 systematically reviewed articles, none were low quality (0-4), 5 articles were moderate quality (5-8), and 55 were of high quality (9-11). These results proved that the articles selected were of high quality and relevant to answering the research questions. The objective of this research was achieved with the research questions answered from the review as follows; RQ1. What challenges have inspired the development of ontology-driven frameworks? Some of the core challenges found are imprecise models automated from domain knowledge, lack of security modelling of organizational assets and potential attacks, digital blackmail with ransomware assaults, the poor operating performance of traceability technologies, and overwhelming navigation process of educational online resources.

RQ2. What are the impacts of the proposed/developed ontology-driven frameworks? The second findings of this research question were major impacts like interoperability, knowledge sharing, reusability, information retrieval, and cross-platform sharing. RQ3. What is the future outlook on ontology-driven frameworks? Modular ontologies are still in experimental phases, and they promise to give satisfactory results in the future. A criterion will be developed for the quality evaluation of ontologies. Overall, the finding in this review is that ontology-driven frameworks play an essential role in bridging challenges and providing solutions in multiple fields as described in each research question. This review will provide a researcher, or developer with insights into various solutions that ontology-driven frameworks have addressed.

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