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A systematic review of ontology development methodologies for knowledge representation system for different domains

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Abstract

Ontology development methodologies offer systematic approaches for the design, construction, and maintenance of ontologies, which are fundamental to effective knowledge representation across various domains. With the increasing demand for semantic integration, data interoperability, and advanced reasoning, these methodologies have become central to how domain-specific knowledge is structured and utilized. While multiple tools and techniques exist to support ontology creation, there remains no universally accepted standard for ontology design.This study provides a critical review of key ontology development methodologies used in knowledge representation across multiple domains, focusing on their effectiveness in producing consistent, reusable, and scalable ontological systems. The review covers literature published between 2018 and 2024, sourced from major academic databases. The evaluation process involved selecting a broad range of relevant studies, examining the methodologies presented, and comparing the various strategies employed to build ontologies whether developed from the sratch or reused from existing models. Consideration was also given to the use of ontology languages and editing tools. Findings from the review reveal that many methodologies effectively integrate core ontology engineering principles with aspects of software engineering. However, the analysis also highlights several limitations, such as methodological gaps and inconsistencies that can hinder the development of robust knowledge representation systems.

Keywords: Ontology, semantic-web, development methodology, domain, knowledge representation

Introduction

The Semantic Web (SW), also known as the Web of Knowledge, has been a central topic of research for several years. Often described as Web 3.0, or the "web of meaning" (Hitler & Janowicz 2013), it is not a separate entity from the current web (Web 2.0) but is expected to evolve gradually from it (Grigoris & frank-van 2008). Different from the current web, unable on the one side to offer machine interpretability and on the other side to offer accurate information reaching, the Semantic Web primes to allow harmonious interaction between humans and machines (Noh 2015; Pan 2016). For the vision to be realized, a crucial technology, called ontology, is argued to be essential (Wang et al, 2013). Both the Semantic Web and ontologies are valuable means for knowledge modelling and inference, which are key to building intelligent systems (Pattuelli et al, 2015; Ramos 2015). In Computer Science, ontology represents a logical system, which may be expressed in knowledge representation languages such as First-Order Logic (FOL) or the popular Web Ontology Language (OWL) (Sanfilippo & Borgo, 2016). In the same sense, ontology can be seen as a data modeling technique for organizations with structured data repositories, based on a set of concepts, the semantic relationships between them and their restrictions in a particular knowledge domain.

The power of ontologies is best measured by their ability not only to define relations between classes and instances, but also to attribute causal properties to these relations, and to make inferences. (Meriyem et al, 2015; Thomas 2009; Wei et al 2012). A common definition of ontology (Barao et al, 2017), courtesy of (Gruber 1993), defines ontology as an explicit and formal representation of conceptualization. In the present, "explicit" means a semantic clarity of terms and boundaries in a real-world setting, "formal" highlights the orderly and machinable character of the model, and "conceptualization" describes the modeling of real-world scenarios in an abstracted manner with the aim of identifying the relevant terms.

Actual-world situations e.g., (agriculture, manufacturing, automation, construction, cybercrime, supply chain medicine, sports, religion, arts, and entertainment, and others), are often stated as domains (Dou et al 2015; Kang et al 2014). Ontology is defined as an agreed-upon knowledge of a particular field of study, which is able to provide a unifying framework to solve problems (kang et al 2014). Shared" emphasizes the role that ontology has in collaborative solutions to practical problems. In particular, as a semantic model, ontology offers a platform for accurate (i.e., granular) data integration and sharing. This ability allows ontologies to efficiently handle data inconsistency issues in distributed systems (Dnyanesh & Rahul, 2011). Researchers have utilized ontology to define a shared vocabulary within a domain, facilitating information sharing and reuse (Pratibha et al, 2011). In addition, the design of inference driven applications for real-world applications requires a rich data model, i.e., ontology, to standardize the vocabulary (Agyaponga-Kodua et al, 2013). It is also crucial to know why ontology development is done, namely sharing a common understanding of information structures among people or software agents, enabling the reuse of domain knowledge, making domain assumptions explicit, separating domain knowledge from operational knowledge, and analyzing domain knowledge (Noh 2015, Noy & McGuiness, 2001).
The creation of an ontology is an iterative engineering activity that is also difficult, tedious and time-consuming (Alexander 2006), and therefore it needs a well-designed methodology, which resembles software development. Nevertheless, there is no consensus for ontology creation (Anusha et al, 2015 & Bhaskar2010). As described by (Noh 2015), there is no "one size fits all" methodology for ontology design; whether an ontology design uses a particular methodology depends on the preferences of the designer.
As activities that should be appropriately dealt with, the activities of pre-development, development, and pos-development activities must not be neglected in order to build ontologies that follow the principles of reusability and semantic stability (Dnyanesh & Rahaul,2011). According to the broad literature presented in this paper, the most popular techniques are the approach proposed by (Saad & Shaharin 2016; Suarez-Figueroa et al, 2015) and others Ast M et al 2014). Languages ontology representation and editors (ontology management tools) play a fundamental role in the ontology creation process, supplementing ontology methodologies (Munir & Anjum, 2018). Nevertheless, in this review, attention is focussed on ontology development techniques, since they are the basis of the development process. The choice of ontology management tools for a selected method of ontology construction is ultimately driven by the expressive power of the ontology that is intended to be built. Those following the World Wide Web Consortium (W3C) standards, and others, for example, XML Topic Map (XTM) (Jarvenpaa et al, 2019), adhere to the International Organization for Standardization (ISO) standards. Of W3C standard languages. OWL is the language being used more and more owing to its expressive capacity (Caroll et al, 2015; Hacherouf et al 2015; Sengupta & Hiltzler 2014). Ontology editing applications include the software Protégé (Chujai et al, 2014; Enesi & Adewale 2015), and Protégé is well known for its role in shaping and maintaining ontologies. Despite the growth in the use of ontologies as a reliable way to structure and represent knowledge at the same time, development of ontologies in different domains is an ongoing issue. These issues arise as each domain brings with it a different context, which the ontology has to fit into, as well as the present limitations of what is achievable in terms of ontology development. Standardization remains an area of great concern. There are very different frameworks and guidelines in the development of ontologies, which in turn produces large differences in how they are designed, presented, and integrated within various domains. This issue also causes a lack of standardized approaches that hampers interoperability and complicates the reuse

of ontological models in multi-domain applications. In health, education, finance, and agriculture, each field has its own language, frameworks of thought, and set of practices. General purpose methods may not be able to address this issue without great adaptation, which in turn reduces their performance and scale in very specific settings.

Related Works

An ontology development paradigm acts as a roadmap for ontology developers (Wei et al, 2012). Many proposals for ontology creation have been made (Brusa et al, 2008; K Jacksi 2019; M Ashburner et al 2000, Ahmed et al 2018). Nevertheless, there is no agreement between researchers regarding a standard methodological approach for the creation of ontologies in different domains. As a result, ontology projects tend to either use or design their own method appropriate to the particular area of discourse. A method of choice or design is generally selected or designed with regards to the requirements of the application and to the likely future of the ontology (Noy et al, 2001). Previous work done on ontology design methodologies has contributed significantly to the development and standardization of effective practices in building ontologies. A comparative analysis was carried out on the most cited ontology design methodologies is described later in this section. The review analysis in building ontology methodologies was based on ontology characteristics which are user-centered design, modular design, and domain-oriented design. The iterative development process for design science research incorporates design principles and competency-based evaluation.

Gawich et al, (2012) presented a methodology for building ontologies the project called kactus. The main objective of this author for this methodology was to evaluate the feasibility of a complex system knowledge reusability. This methodology stated the following processes: it produces a list of tasks and terms; augments the domains concepts and relations identified during the previous step; provides a specification of the application to know the application views of components and context. The methodology makes a preliminary design based on the relevant top-level ontological categories taking as input the list of terms and tasks developed during the previous phase, redesigning the structure of the ontology in order to make a definitive design, augment the domain with the concepts and relations identified during the previous steps. Thus, the challenges in this kactus methodology is the lack of a a clear evaluation process.

Guha et al, (1992) described the methodology they followed to build the Cyc ontology at the Microelectronics and Computer Technology Corporation. Cyc ontology processes large amounts of common-sense knowledge with the important attempt of codification. The authors described a method composed of three processes to build the ontology, which were computer aided codification of knowledge, codification and manual extraction of knowledge, and computer-human aided extraction and codification of knowledge. This method of this Cyc project is not oriented to answer a determined collection of competency questions but it rather covers a wide spectrum of common-sense knowledge.

As reported by (Schreiber 2013), Common KADS is a vital methodology for knowledge base representation systems not specifically tailored for design and construction of ontologies. However, this is a methodology which includes components for reuse and this methodology recognizes the essence of knowledge-model elements or a combination of them, with the fact that many parts of a given model are not recurring and reused in different domain field. Common KADS methodology is known for knowledge identification, consisting of getting familiarized with information sources, glossary and scenarios, knowledge specification and identification of component for reusability. It helps to choose the task template in the domain conceptualization, and knowledge refinement phases, which validates the knowledge model with complete knowledge bases.

Suarez-Figueroa et al, (2015) focuses on the use of ontology design patterns (ODP). This methodology establishes the reutilization of ontologies from a public ontology repository and a set of known ontology designs patterns to integrate them by means of a re-engineering process. In general, the methodology defined here are the use of available design patterns, where requirements are identified followed by dividing and transforming the problem into partial problems, matching the problem with ontology design patterns, selecting the patterns, making a composition of selected patterns, evaluating the patterns design solution and integrating partial designs solutions. The NEON methodology depends on the existence of a repository of ontology common problems and a collection of ontology design patterns associated with general use cases (M.c Suarez-Figueroa. 2012). in this scenario the competency question will be specified in line with the methodology and the use case study. This work proposes the the utilization of additional tools to support the end users in the validation and correlation of competency questions.

Pinto et al, (2004), who reported diligent as another ontology methodology which combines ontology engineering with other related disciplines such as data integration, metadata management, and semantic annotation. It emphasizes the alignment of ontologies with existing standards and good practices in various domains. Diligent methodology follows a modular and layered approach, focusing on ontology reuse, ontology mapping and the integration of ontologies into existing information systems.

Noh (2015), reported a methodology to build ontologies consisting of the following steps:(1) determine the scope of the study and the domain of the ontology, (2) highlight the important terms, (3) reuse existing ontologies, (4) define classes, and class hierarchy, (5) define properties of classes, define facets of properties, and create instances. The methodology does not include an evaluation step but is well explained.

The methodology presented by Uschold & King (1995) focuses on the development of high-qualities ontology based on a sound theoretical framework. It emphasizes conceptual clarity, consistency, and formalism. The methodology involves stages such as identification of the domain and scope, definition of key terms and concepts, evaluation of the ontology against specific criteria and identification of relationships.

Saad & Shaharin (2016) focuses on ontology development using the protégé ontology editor. It provides a user-friendly interface for creating, editing, and managing ontologies. The methodology emphasizes the integration of reasoners to support logical inference and classification. The Protégé- framework enables collaborative development, ontology reuse, and integration with other tools and systems.

Methodology for literature exploration

This systematic literature review makes use of a literature search with a systematic process as the method adopted for the review. A comprehensive literature review was conducted using Google Scholar, ScienceDirect, and Scopus as search engines, spanning the period from 2018 to 2024. The search was done on the search engine using the following phrase or set of keywords "Ontology development methodologies for knowledge representation system for different domains". This review was initially motivated by the fact that ontology is demonstrating its effectiveness as a model for representing complicated information, which is accomplished through established procedures. Ontology hacking is an unethical technique that results from ontology design without methodology, which does not comply with software engineering principles. Even though there is not a system of ontology design methodology that is perfect, ontology design must be based on a certain approach (Noy & McGuinness (2001). Therefore, the aim of this paper is to review existing ontology development methods for knowledge representation for different domains and identify the strengths and weaknesses in building the ontology. This study examines a broad range of works pertaining to modeling complicated knowledge, ontology design methodology, and ontology design for different domains (Dnyanesh & Raul 2001). Ontology representation, ontology-based information retrieval techniques, ontology management tools, and related resources obtained from reliable online sources. The relevant theoretical insights and the shortcomings of formal procedures in ontology design methodology serve as the driving forces behind the systematic literature analysis. Among the factors taken into consideration for study were the ontological domains, subject granularity, ontology developed from scratch or reused, and methodologies employed across various platforms (Rizwan et al 2013; M.Gawich et al, 2012). The search database generated a total number of 131 articles on the topics at hand and the articles were filtered and some articles were removed based on the analysis of the title, methodology and abstract. In addition, 85 articles were excluded. Furthermore, 25 out of the remaining articles also dropped due to the unsatisfactory results of the findings. Hence, after careful consideration 15 articles are found suitable for this review study with different characteristics such as title, abstract, methodological approach and the results. Details of the completed search and their results are displayed in figure 2 below as follows:

Figure 1: Steps for Review

Figure 1 illustrates the steps involved for the systematic literature review. Step 1 relates to conducting a search for literature that is aligned to the pre-defined knowledge area. and the removal of duplicates Step 2 reviewed the titles, keywords, abstracts and excluded those that did not match the selection criteria. Step 3 reviewed full texts, and the introduction, and developed additional criteria for further inclusion and exclusion. Step 4 extracted relevant information from papers to answer questions RQ in Figure 1. Step 5 synthesized the literature according to classification of predefined topic, contribution of ontologies, scope of the ontology development, methodology and granularity of the ontology. Step 6, discussed the results, outlined the gaps and provided future research recommendations and finally step 7 is completed review paper.

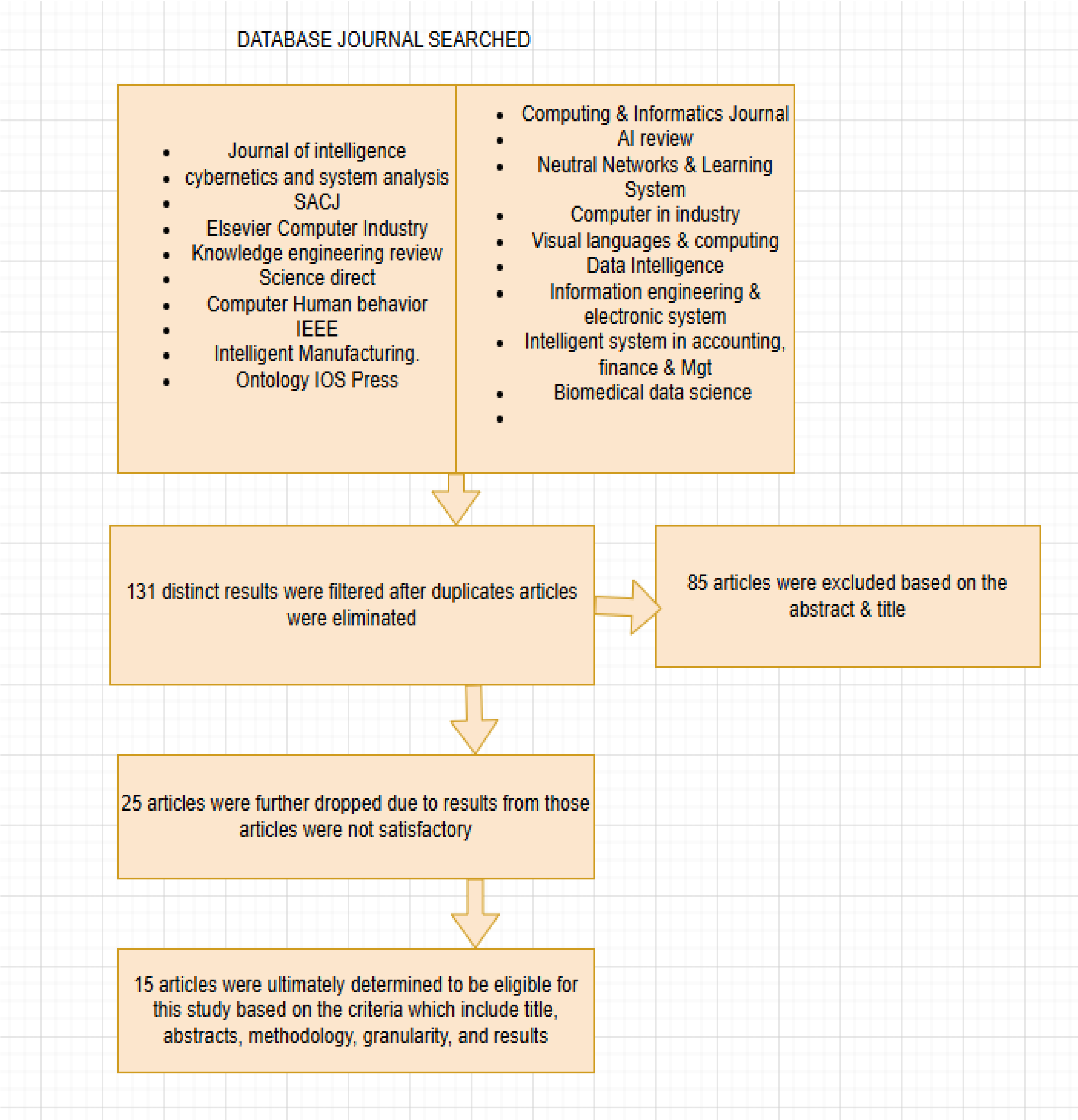

Figure 2: A systematic database search

Discussion

In this review, research questions formed the focus of this paper. The research questions are related to the ontology methodology and the evaluation metrics as specified in guidelines for the principles of software (ontology) engineering. The following evaluation criteria are listed as follows:

i. First resercah question criteria was on the methodology design for different domain ontology reuse/developed from scratch with language editor- This phase involvd a consideration of the literature title, domain, methodology, language editor, scratch/reuse, ontology language.
ii. Second research question criteria pertained to a comparison of the methodologies for creation of domain ontologies from 2018-2024.

1. ONTOLOGY METHODOLOGY ACROSS DIFFERENT DOMAINS

Table 2 shows the analysis of methodological design for different domain ontologies, which were built either from stractch or reusedas well as the ontology language editor used The approaches were used for the different starting domains' modeled ontologies. However, they are utilized for ontology modeling in any field. For instance, the manufacturing domain (Anusha et al 2015; Godpower 20216) and the Biomedical domain (Abdelghany et al, 2019) both used (Noy & McGuiness 2016) to model ontology. (Uschold & king, 1995) were involved in the development of cybercrime and automated vehicles Ontology (Ceccaroni et al, 2000). Moreover, based on the review of over 100 high-impact articles, this study found that the middle-out approach appears to be the more prevalent method for identifying ontology concepts, as noted in both G. Brusa et al. (2008) and Kim et al. (1995)."The top-down approach was well-liked in the study conducted by the (Saad & Shaharin, 2016). In a similar vein, developers use OWL and Protégé more often than the dozens of ontology management tools (both private and open source) available, even if webODE and ontoEdit were created specifically for the methodology. Additionally, Table 1 showed some ontologies modeled for different domains that took into account the first resercah question set of requirements based on the literature examined on domains, language editor, methodologies, build from scratch or reuse and ontology language

Table 1: Methodology and ontology language editor usage across different domain

Literature	Domain	Methodologies	Ontology Language Editor	Build from Scratch or Reuse	Type of Ontology Language
(Jarvenpaa et al, 2019)	Manufacturing	Gruniger & Fox	OWL and Protégé	New	Web Based Ontology Language
(Sanfilippo et al, 2019)	Manufacturing	Gruninger & Menzel	OWL and Protégé	New	Web Based Ontology Language
Haendel et al (2018)	Biomedical Disease	Noy-McGuiness and Arp	OWL2-DL and protégé	New	Web Based Ontology Language
Kim et al, (2018)	Supply Chain Ontology	Noy and McGuiness	OWL and RDF	New	Web Based Ontology Language
Guizzardi (2020)	Review Ontology Development	Methontology, Gruninger and Fox, Noy and McGuiness	OWL	New	Web Based Ontology Language
Palagin et al, 2024)	Automation Construction	Fox, Noy and McGuiness	SWRL, N3Logic, RIF, OWL	New	Semantic Web Rule Language

Dou et al, (2018)	Cultural Heritage Ontology	DSRM	NLP Technology	New	Natural Language Processing (NLP) Technology
Tarus et al, (2018)	E-Learning Ontology	Methontology & Fox	OWL and RDF	New	Web Based Ontology Language
Abdellatif et al, (2018)	Business Process Reengineering Ontology	Analytical Hierarchy Processing Techniques (AHP)	OWL, SWRL, RDF, SPARQL	New	Web Based Ontology Language
Chhim et al, (2019)	Manufacturing Process Ontology	Ushold & King, Noy & McGuiness and Pinto & Martins	OWL, SWRL, RDF, SPARQL	Reuse	Web Based Ontology Language
Bagschick et al, (2018)	Automated Vehicles	Aree et al	Owl-DL and Protege	New	Web Based Ontology Language
Donalds et al, (2019); Gayathri & Uma, (2018)	Cybercrime Ontology & Robotic Path Ontology	DSRM	OWL and Protege	New	Web Based Ontology Language
Palagin et al, (2024)	Knowledge Design Ontology	Methontology	OWL	New	Web Based Ontology Language

2. COMPARISON OF METHODOLOGIES FOR DESIGNING DOMAIN ONTOLOGIES

The process and techniques for ontology development are covered in the methodology for ontology development, a handbook for ontology developers (Sure-Vetter, 2009). There are different established development approaches (Alsanad et al, 2019; DeNicola & Missikoff, 2016; E. Blomqvist et al, 2010). There is no single technique to create domain ontologies in this setting; instead, various researchers have done it in different ways. Furthermore, several approaches encompass different facets of ontology development and concentrate on ontology development in different ways. For instance, few methodologies concentrated on scope of domain analysis and ontology, and there was no design phase or information on the tasks they carried out when developing the ontology.

In addition to comparing various approaches, this study established ctriteria that served as the foundation for the analysis and comparison. the techniques. Selected evaluation criteria (EC), which encompass fourteen distinct facets of technique for creating domain ontologies, were established by looking at trends and demands that have changed over the past ten years. This will facilitate a better understanding of various ontology development approaches and be able to choose an appropriate methodology for creating a domain ontology of the discourse domain with the aid of these evaluation criteria.

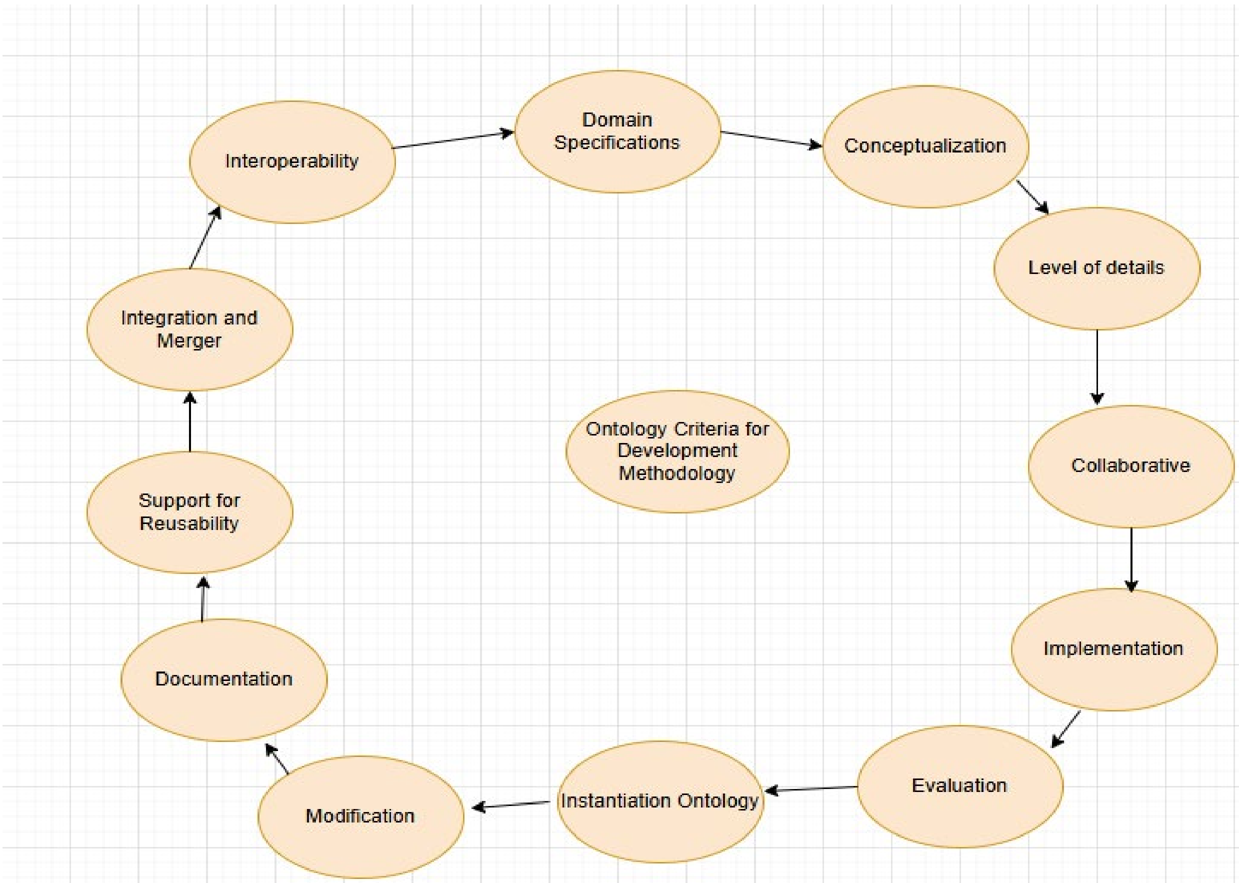

Figure 3: Criteria for ontologies development

Figure 3 above shows the evaluation criteria used to compare ontology development methodology from various domains. The first phase comprises domain analysis, conceptualization, level of detail, collaborative creation, execution, assessment, instantiation, modification and maintenance. Therefore, the first nine documentation explains a methodology's technical fine-grained level and aids the developers in comprehending a specific ontology development technique. While the last five of the evaluation criteria talk about the coarse-grained level of a methodology, and they include reusability support, support for integration, interoperability support, methodology based on accepted practices and human estimation. This review compares the methodology for ontology development based on the evaluation criteria (C1-C12), which is the focus when it comes to ontology development as taken from (Sattar et al, 2020). In addition, they denote evaluation criteria entries as either T for True and F for false in comparing the methodologies as shown in the table below: C1: Domain Specification- This is also known as knowledge acquisition. There are no domain-specific recommendations in domain analysis, and it takes a lot of resources. Things get complex when ontology is involved, which combines information from several disciplines. For team members who are unfamiliar with or have a contentious understanding of the terminology used in the ontologies, training seminars are crucial. C2: Conceptualization- Is the conceptualization activity supported or included in the suggested methodology. C3: Level of details- Does the methodology include specifics regarding procedures and techniques for different activities? The level of detail criterion in this instance is assessed on a scale of 1 to 5, with 1 indicating relatively little detail. C4: Collaborative building- entails having many ontology development group stakeholders working on the same ontology from the same location or from various locations concurrently, and without compromising the ontology development tasks overall effectiveness. C5: Implementation – does the methodology apply a conceptual ontology model to a representation language. In this situation, manual construction is needed but it is time-consuming and not preferred by ontology developers to use a formal conceptual model. Ontology building from a formal model, however, necessitates consideration of the semantic distinctions between the representation language and the formal model. C6: Evaluation- Does the evaluator possess a solid understanding of ontology to perform the evaluation component, and an adequate comprehension of ontology is an important component of the ontology evaluation process's success. C7: Instantiation Ontology - Does the methodology use any instantiation techniques or methods? It is easier to process an ontology's population than it is to process sources with inadequate organization, including XML data, relational tables, and documents. C8: Maintenance/Modifications - The issue of evolution is a persistent challenge for ontologies. Given the intricacy of the modifications that must be made, to make this duty easier and guarantee its dependability, maintenance procedures whether manual, semi-automatic, or automated are becoming more and more important. C9: Documentation- Does the methodology offer thorough documentation of the steps and procedures involved in creating an ontology? Documentation aids in the comprehension of the ontology, its application, repurposing, and potential revisions. C10: Support for Reusability - The process of developing an ontology is tedious and time-consuming. Application-dependent ontologies are typically expensive to reuse. In this situation, by giving domain ontologies created with the same upper ontology a shared conceptual framework, the usage of upper-level or foundational ontologies lowers the costs associated with reusability. C11: Support for integration and merging- The degree of overlap between two integrating ontologies determines how well they integrate. Same language used for representation. Accuracy (accurate mapping rate) and recall (found mapping rate) are used to quantify the quality of integration. C12: Support for interoperability- Systems must have the same underlying framework (same high-level notions) in order to be interoperable. The ontologies that resulted will therefore be able to share their notions more easily and have a shared global conceptual structure.

Table 2: Comparison of the methodologies for creation of domains ontologies extracted from 2018-2024

S/N	Methodology	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
1	The development of an ontology for describing the capabilities of manufacturing resources (Chujai et al, 2014)	T	T	5	F	T	T	T	T	T	F	T	T

2	Formal Ontologies in Manufacturing (De Nicola & Missikoff, 2016)	T	T	2	F	F	F	T	F	F	F	F	T
3	A Census of Disease Ontologies (Caroll et al, 2015)	T	T	4	F	T	T	T	T	T	F	T	T
4	Towards an ontology-driven blockchain design for supply chain provenance (De Nicola & Missikoff, 2016)	T	T	4	F	T	T	T	T	F	F	T	T
5	A scientometric analysis and critical review of construction related ontology (Gruber, 1993)	T	T	4	T	T	T	T	T	F	F	T	T
6	Knowledge graph based on domain ontology and natural language processing technology for Chinese intangible cultural heritage (Dou et al, 2018)	T	T	4	F	T	T	T	T	F	F	T	T
7	Ontology-based system engineering: A state-of-the-art review (Grigoris & Frank, 2008)	T	T	5	T	T	T	T	T	F	F	F	T
8	Knowledge-based recommendation: a review of ontology-based recommender systems for e-learning (Gomez-Perez, 2001)	T	T	4	T	T	T	T	T	F	F	T	T
9	Overcoming business process reengineering obstacles using ontology-based knowledge map methodology (Abdellatif et al, 2018)	T	T	4	T	T	T	T	T	T	F	T	T

Table 2: (Continued)

10	Product design and manufacturing process-based ontology for manufacturing knowledge reuse (Aminu et al, 2020)	T	T	4	T	T	T	T	T	F	T	T	T
11	Ontology based scene creation for the development of automated vehicles (Alexander 2006)	T	T	4	T	T	T	T	T	F	F	T	T
12	Toward a cybercrime classification ontology (Anusha et al, 2015)	T	T	4	T	T	T	T	T	F	F	T	T
13	Ontology based knowledge representation technique, domain modeling languages and planners for robotic path planning (Gayathri & Uma, 2018)	T	T	3	F	T	T	F	T	T	F	T	T
14	Method of developing an ontological system with automatic formation of knowledge base user queries (Dou et al, 2015)	T	T	4	F	T	T	T	T	F	F	T	T
15	Ontology-based knowledge representation for addictive manufacturing (G.Brusa et al, 2008)	T	T	4	F	T	T	T	T	F	F	T	T

From table 2, which shows that most of the approaches examined offer domain analysis, conceptualization, implementation, assessment, instantiation, and a domain ontology example even though most of them have not covered every aspect of the methods and tasks required. It is challenging to adhere to a technique for creating ontologies for a particular topic with less detail (Fawei et al, 2018; J.Li & Alian, 2018; S.John, et al, 2018). Furthermore, most of the approaches examined (in contrast to Table 2) do not help with the upkeep, documentation, and development of collaborative ontologies, ontology localization, integration, and interoperability. Ontology should make modification and maintenance possible and practical since the ontology requirements do change with time. Thus, modification should be maintained and supported are supported in a few of the approaches. Several aspects have been explored, including maintenance, collaborative ontology development, documentation, localization, and support for reuse, integration, and interoperability. For instance, maintenance is discussed by Abdelghany et al. (2018), Dou (2015), and Jarvenpaa et al. (2019). Additionally, only a limited number of scholars address documentation for example, Dou et al. (2015), Gayathri and Uma, and Jarvenpaa et al. (2019) which serves as an important aid in understanding an ontology.

Ontology construction is an evolutionary process, and the involvement of subject-matter experts, ontology engineers, technical writers, and other human resources might not be possible. Accordingly, the joint creation of ontologies will allow sharing of major human capital on a global scale. Therefore, the further supportive development of ontologies will contribute to the correct application of the ontology construction strategy. Collaborative ontology creation is offered by (Tarus et al, 2018; Yang et al, 2019; Zhong et al, 2019). In addition, it is also infeasible to define one overall large ontology to cover such a large and complex subject. There would be a number of subdomains, and an ontology is needed for each subdomain. Here, subdomain information systems are required to communicate with each other. Systems should share the same support structure (same abstractions) to be interoperable. Therefor the final ontologies will have a global conceptual structure that will promote concept reuse (Aminu et al, 2020). Interoperability is ensured by the methods proposed in (Sanfilippo et al, 2019; Zheng et al,2012). Subdomain information systems also require ontology integration. Such fusion is made available by integration of the ontology presented by (Chhim et al, 2019; Donalds & Osei, 2019; Dou et al, 2018; Jarvenpaa et al 2019; Kim et al, 1995).

Reusability allows you to integrate new components into the target ontology and utilize the old ontology, which makes the ontology creation process exhausting and uninteresting. There are few authors that make mechanisms available for reusing ontology in (Chhim et al, 2019). Finally, most of the methods the study reviewed were not based on any established method. In conclusion, this review on ontology development methodologies shows that developmentis a tedious and complex task. According to the review literature, it could be concluded that ontology development based on the experience of a few projects would not be sufficient for building domain ontologies. Therefore, a gap is identified in the current approaches to ontology development, as pointed out in the systematic literature review. From the analysis presented in the table, only one published work addresses reusability in ontology development, and there is a limited body of literature on interoperability. The review further revealed that the few techniques, actions, and approaches employed in building ontologies are either poorly documented or not documented at all.The collaborative construction aspect of domain ontology is rarely studied by researchers, and the collaborative construction of ontology is one of the most important parts in ontology construction.

Conclusion

In this review paper, ontologies approchesfor the knowledge representation of various domains are reviewed from the perspective from a resercaher. In recent years, a large number of approaches have been suggested by researchers. This article surveys the development of ontology approaches in the period between 2018 and 2024.The reviews were categorized into 2 categories of criteria for the evaluation of relevant manuscripts which are methodologhies design for different domain ontology, criteria pertained to a comparison of the methodologies domain ontologies from 2018-2024 . The evaluation criteria were (1) identification of various literature domains on the development on ontology development. The review identified 15 articles from 2018-2024 on different domains ranging from manufacturing ontology, biomedical disease ontology, supply chain ontology, general ontology, automation construction ontology, cultural heritage ontology, e-learning ontology, automated vehicles construction, cybercrime ontology, knowledge design ontology, and scientific digital libraries ontology. The second criteria was to screen the articles for alignment to the objectives of this systematic literature review. This paper also identified the database set where the articles were published.

The first criterion was whether the ontology development was new/developed from scratch and identify the language editor used. In doing this, this review can concluded that (Noy & McGuiness, 2001; Palagin et al, 2024; Bonanci et al, 2016) is the highest method used in all this literature review analysis followed by methontology. On the other hand, on ontologies language, it was deduced that OWL Protege is frequently used by the review papers, follows by OWL-DL and protege, OWL & RDF, SPARQL, SWRL. On the aspect of building from scratch or new, all the generated articles on development of ontology were built from scratch, while only one talks about re-use. On the aspect of ontology language, all articles made use of the web-based ontology language as the generally accepted ontology language, followed by semantic web rule language, and natural language processing.

The main result is that collaborative approaches based on well validated paradigms, like Design Science Research, are very powerful. These approaches should focus on interoperability, reusability, merging, detailed documentation, reliable human resource prediction and the presence of at least one example of ontology derived using the approach. In addition, the use of tools for collaborative development, maintenance, and improvement of modular ontologies is advantageous in domain ontology construction.

Designing a methodology for developing and evaluting a domain ontology is a complex task that requires the inclusion of specific criteria, identified as C1–C12. Although some of these criteria emerge from standard practices, aspects, such as collaborative ontology construction, interoperability, and grounding in an established practice, are frequently lacking and are thus recommended for inclusion. These missing components are critical for the development of successful domain ontologies development. This paper highlights key criteria deemed important for the domain ontology research community, offering a foundation for establishing a comprehensive methodology for ontology development. However, not all existing ontology development methodologies were reviewed, as the sheer volume of approaches, some outdated or lacking detailed explanations, made such inclusion impractical. This systematic review makes several key contributions to the understanding and advancement of ontology development methodologies (ODMs) and their role in knowledge representation systems (KRS) across multiple domains. It also identifies prevailing methodological approaches such as top-down, bottom-up, and middle-out and evaluates their relative popularity, strengths, and limitations in ontology construction and reuse.This systematic review adds to what is already contributed to a large body of research in ontology engineering through its comparative analysis of present ontology development approaches in many fields. The key contribution report on the collection, classification, and evaluation of a range of ontology development approaches (for example Methontology, NeOn, DILIGENT, OntoClean) which was reviewed in terms of their basic elements,qualify, pros and cons. Also, the contribution shows how these approaches have been used in health care, education, e government, agriculture, and information systems, which are used to point out trends and context-based variables that play a role in approach choice. Additionally, the review presents a decision-making tool for ontology engineers, system designers and researchers, which is used in the choice or adaptation of appropriate approaches for knowledge representation in specific domains. In addition, the review considered how these approaches have played out in very different fields, which in turn gave an insight into what works best in what setting. The NeOn methodologies, for example, show the re-use and alignment of present ontologies, which is very important for the integration of knowledge from many sources. In business intelligence and e-government this interoperability plays out in the form of data sharing and service integration. Additionally, well thought out ontologies, which are put together via methods like Methontology are modular and thus reusable. This, in turn, allows for growth and change as domain knowledge changes. Furthermore, educational ontologies, for example, were being used across the board in different curricula, which in turn improves learning analytics and curriculum development. In engineering ,ontologies were used n the representation of parts, functions and workflows throughout the life of a product. ODM's also here play a role in the cross-system integration of design, manufacture and maintenance systems which in turn fosters collaborative engineering and digital twin technologies. While the ontology development methodology does bring a lot to the table, they also present some issues. Effective ontology development requires an indepth knowledge of the domain and technology know how, which limits the participation of non-experts. In addition, there is a lack of universal tools and standards, which hampers interoperability and re use across different platforms and domains.

Recommendation and Future Work

Despite the considerable progress achieved in ontology engineering, the present analysis highlights several limitations inherent in existing ontology development methodologies. To address these shortcomings, we recommend the following:

1. The design of hybrid methodological frameworks that integrate the strengths of established approaches such as Methontology and NeOn while providing modular support for both domain-specific customization and cross-domain interoperability to promote consistency in ontology structure and semantics.

2. Ontology lifecycles must mandate ongoing engagement with domain experts, employing participatory design techniques and collaborative platforms to ensure ontological models accurately reflect stakeholder knowledge and requirements.

3. Rigorous evaluation metrics encompassing accuracy, completeness, maintainability, and usability should be embedded within each development phase, creating an iterative feedback loop that continually refines the ontology according to empirical performance data.

Looking ahead, future research must empirically validate these proposed enhancements as recommended in diverse, real-world contexts to assess their practical viability. In particular, there is significant potential in leveraging machine-learning techniques to automate aspects of concept extraction, relationship identification, and ontology population from large unstructured datasets. Finally, advancing multilingual and cross-cultural ontology representations will be critical for minimizing semantic bias and fostering global interoperability within the Semantic Web and linked-data ecosystems. Collectively, these directions promise to enhance the adaptability, robustness, and societal impact of ontology-based knowledge representation across disciplines.

References

Abdelghany, N. Ramadan, and H. Hefni, "An Agile Methodology for Ontology Development," International Journal of Intelligent Engineering and Systems, vol. 12, pp. 170-181, 04/30 2019.

AbdEllatif, M., Farhan, M. S., & Shehata, N. S. (2018). Overcoming business process reengineering obstacles using ontology-based knowledge map methodology. *Future Computing and Informatics Journal*, *3*(1), 7-28.

Agyapong-Kodua, K., Niels, L., Robert, D., & Svetan, R. (2013) 'Review of semantic modeling technologies in support of virtual factory design' International Journal of Production Research, Vol. 51, No. 14, 4388–4404.

Alexander, C. Y. (2006). Methods in biomedical ontology. Journal of biomedical informatics, 39(3), 252-266.

Alsanad, A. Chikh, and A. Mirza, "A Domain Ontology for Software Requirements Change Management in Global Software Development Environment," IEEE Access, vol. 7, pp. 49352-49361, 01/01 2019.

Aminu, E. F., Oyefolahan, I. O., Abdullahi, M. B., & Salaudeen, M. T. (2020). A review on ontology development methodologies for developing ontological knowledge representation systems for various domains.

Anusha, I. W., Athula G., & Gihan, N. W. (2015) User centered ontology for SriLanka farmers' Ecological Informatics, 140-150

Ashraf, J., Chang, E., Hussain, O. K., & Hussain, F. K. (2015). Ontology usage analysis in the ontology lifecycle: A state-of-the-art review. Knowledge-Based Systems, 80, 34-47.

Ast, M., Glas, M., Roehm, T., & Luftfahrt, V. B. (2014). Creating an ontology for aircraft design. Deutsche Gesellschaft für Luft-und Raumfahrt-Lilienthal-Oberth eV.

Bagschik, G., Menzel, T., & Maurer, M. (2018, June). Ontology based scene creation for the development of automated vehicles. In *2018 IEEE Intelligent Vehicles Symposium (IV)* (pp. 1813-1820). IEEE.

Barão, A., de Vasconcelos, J. B., Rocha, Á., & Pereira, R. (2017). A knowledge management approach to capture organizational learning networks. International Journal of Information Management, 37(6), 735-740.

Bhaskar, K. & Savita S. (2010) 'A Comparative Study Ontology Building Tools for Semantic Web Applications' International journal of Web & Semantic Technology (IJWesT) Vol.1, Num.3, July 2010 DOI: 10.5121/ijwest.2010.1301 1.

Bonanci, R., Nabuco, O. F. & Junior, I. P. (2016). Ontology models of the impacts of agriculture and climate changes on water resources: Scenarios on interoperability and information recovery' Future Generation Computer Systems. 54 (2016) 423–434

Carroll, J., Herman, I., & Patel-Schneider, P. F. (2015). OWL 2 web ontology language RDF-based semantics. W3C Recommendation (October 27, 2009).

Ceccaroni, L, Cortés, U & Sánchez-Marré, M, (2000) 'WaWO – an ontology embedded into an environmental decision-support system for wastewater treatment plant management' Workshop on Applications of Ontologies and Problem-solving Methods.14th European Conference on Artificial Intelligence (ECAI'00)2–1–2–9

Chhim, P., Chinnam, R. B., & Sadawi, N. (2019). Product design and manufacturing process-based ontology for manufacturing knowledge reuse. *Journal of Intelligent Manufacturing*, *30*(2), 905-916.

Chujai, P., Kerdprasop, N., & Kerdprasop, K. (2014). On transforming the ER model to ontology using protégé OWL tool. International Journal of Computer Theory and Engineering, 6(6), 484.

De Nicola and M. Missikoff, "A Lightweight Methodology for Rapid Ontology Engineering," Commun. ACM, vol. 59, pp. 79-86, 03/01 2016.

Dnyanesh, R. & Rahul, C. A (2011). Generic ontology development framework for data integration and decision support in a distributed environment. International Journal of Computer Integrated Manufacturing Vol. 24, No. 2, 154–170

Donalds, C., & Osei-Bryson, K. M. (2019). Toward cybercrime classification ontology: A knowledge-based approach. *Computers in Human Behavior*, *92*, 403-418.

Dou, D., Wang, H., & Liu, H. (2015, February). Semantic data mining: A survey of ontology-based approaches. In Semantic Computing (ICSC), 2015 IEEE International Conferenc on (pp. 244-251). IEEE.

Dou, J., Qin, J., Jin, Z., & Li, Z. (2018). Knowledge graph based on domain ontology and natural language processing technology for Chinese intangible cultural heritage. *Journal of Visual Languages & Computing*, *48*, 19-28.

E. Blomqvist, V. Presutti, E. Daga, and A. Gangemi, "Experimenting with eXtreme Design," in Knowledge Engineering and Management by the Masses, Berlin, Heidelberg, 2010, pp. 120-134.

Enesi, F. A. & Adewale, O. S. (2015) ‘A Mechanism for Detecting Dead URLs in XTM-Based Ontology Repository’ International Journal of Computer Applications (0975 – 8887) Volume 111 – No 12.

Fawei, J. Pan, M. Kollingbaum, and A. Wyner, "A Methodology for a Criminal Law and Procedure Ontology for Legal Question Answering: 8th Joint International Conference, JIST 2018, Awaji, Japan, November 26–28, 2018, Proceedings," ed, 2018, pp. 198-214.

G. Brusa, M. L. Caliusco, and O. Chiotti, "Towards ontological engineering: a process for building a domain ontology from scratch in public administration," Expert Systems, vol. 25, pp. 484-503, 2008.

G. Brusa, M. L. Caliusco, and O. Chiotti, "Towards ontological engineering: a process for building a domain ontology from scratch in public administration," Expert Systems, vol. 25, pp. 484-503, 2008.

Gayathri, R., & Uma, V. (2018). Ontology based knowledge representation technique, domain modeling languages and planners for robotic path planning: A survey. *ICT Express*, *4*(2), 69-74.

Gómez-Pérez, A. (2001). Evaluation of ontologies. *International Journal of intelligent systems*, *16*(3), 391-409.

Grigoris, A. & Frank-van, H. (2008). A Semantic Web Primer. The MIT Press Cambridge, Massachusetts London, England.

Gruber, T. R. (1993). A Translation Approach to Portable Ontology Specifications. Knowledge Acquisition, 5(2): 199-220.

Guha, R. V., & Lenat, D. B. (1992). Language, representation and contexts. *JOURNAL OF INFORMATION PROCESSING-TOKYO-*, *15*, 340-340.

Guizzardi, G. (2020). Ontology, ontologies and the “I” of FAIR. *Data Intelligence*, *2*(1-2), 181-191.

Hacherouf, M., Bahloul, S. N., & Cruz, C. (2015). Transforming XML documents to OWL ontologies: A survey. Journal of Information Science, 41(2), 242-259.

Haendel, M. A., McMurry, J. A., Relevo, R., Mungall, C. J., Robinson, P. N., & Chute, C. G. (2018). A census of disease ontologies. *Annual Review of Biomedical Data Science*, *1*(1), 305-331.

Hitzler, P., & Janowicz, K. (2013). Linked Data, Big Data, and the 4th Paradigm. Semantic Web, 4(3), 233-235

J. Li and S. Alian, Design and Development of a Biocultural Ontology for Personalized Diabetes Self-Management of American Indians, 2018.

Järvenpää, E., Siltala, N., Hylli, O., & Lanz, M. (2019). The development of an ontology for describing the capabilities of manufacturing resources. *Journal of Intelligent Manufacturing*, *30*(2), 959-978.

K. Jacksi, "Design and Implementation of E-Campus Ontology with a Hybrid Software Engineering Methodology," Science Journal of University of Zakho, vol. 7, pp. 95-100, 09/30 2019.

Kang, Y. B., Haghighi, P. D., & Burstein, F. (2014). CFinder: An intelligent key concept finder from text for ontology development. Expert Systems with Applications, 41(9), 4494-4504.

Kim, H. M., & Laskowski, M. (2018). Toward an ontology-driven blockchain design for supply-chain provenance. *Intelligent Systems in Accounting, Finance and Management*, *25*(1), 18-27.

Kim, H. M., Fox, M. S., & Gruninger, M. (1995, April). An ontology of quality for enterprise modelling. In *Proceedings 4th IEEE Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises (WET ICE'95)* (pp. 105-116). IEEE.

M. Ashburner, C. A. Ball, J. A. Blake, D. Botstein, H. Butler, J. M. Cherry, et al., "Gene Ontology: tool for the unification of biology," Nature Genetics, vol. 25, pp. 25-29, 2000/05/01 2000.

M. C. Suárez-Figueroa, A. Gómez-Pérez, and M. Fernández-López, "The NeOn Methodology for Ontology Engineering," in Ontology Engineering in a Networked World, M. C. Suárez-Figueroa, A. Gómez-Pérez, E. Motta, and A. Gangemi, Eds., ed Berlin, Heidelberg: Springer Berlin Heidelberg, 2012, pp. 9-34.

M. Gawich, A. Badr, A. Hegazy, and H. Ismail, "A Methodology for Ontology Building," International Journal of Computer Applications, vol. 56, pp. 39-45, 10/01 2012.

M. N. Ahmad, K. B. A. Badr, E. Salwana, N. H. Zakaria, Z. Tahar, and A. Sattar, "An Ontology for the Waste Management Domain," in PACIS, Yokohama, Japan, 2018.

Meriyem, C., Adil, S., & Hicham, M. (2015). IT Governance ontology building process:example of developing audit ontology. International Journal of Computer Techniques, 2(1), 134-141.

Munir, K., & Anjum, M. S. (2018). The use of ontologies for effective knowledge Modeling and information retrieval. Applied Computing and Informatics, 14(2), 116- 126.

Noh, Y. (2015). Imagining library 4.0: creating a model for future libraries. The Journal of Academic Librarianship, 41(6), 786-797.

Noy, N. F. and McGuinness, D. L. (2001) 'Ontology Development 101: A guide to Creating Your First Ontology', Stanford University, Stanford, CA, USA, pp. 1-25.

Noy, N. F., & McGuinness, D. L. (2016). Ontology development 101: a guide to creating your first ontology Stanford University.

Palagin, O., Petrenko, M., & Malakhov, K. (2024). Challenges and role of ontology engineering in creating the knowledge industry: A research-related design perspective. *Cybernetics and Systems Analysis*, *60*(4), 633-645.

Palagin, O., Petrenko, M., Litvin, A., & Boyko, M. (2024). Method of Developing an Ontological System with Automatic Formation of a Knowledge Base and User Queries. *intelligence*, *1*(2), 3.

Pan, Y. (2016). Heading toward artificial intelligence 2.0. Engineering, 2(4), 409-413.

Pattuelli, M. C., Provo, A., & Thorsen, H. (2015). Ontology building for linked open data: A pragmatic perspective. Journal of Library Metadata, 15(3-4), 265- 294.

Pinto, H. S., Staab, S., & Tempich, C. (2004, August). DILIGENT: Towards a fine-grained methodology for DIstributed, Loosely controlled and evolvInG Engineering of oNTologies. In *ECAI* (Vol. 16, p. 393).

Pratibha, G., Sangeeta, D. & Bhanumurthy, K. (2011). Ontology Development Methods. DESIDOC Journal of Library & Information Technology, Vol. 31, No. 2, pp. 77-83.

Ramos, L. (2015). Semantic Web for manufacturing, trends and open issues: Toward a state of the art. Computers & Industrial Engineering, 90, 444-460.

Rizwan, I., Masrah A. A. M., Aida, M. & Nurfadhlina, M. S. (2013). An Analysis of Ontology Engineering Methodologies: A Literature Review. Research Journal of Applied Sciences, Engineering and Technology 6(16): 2993-3000

S. John, N. Shah, and C. Stewart, Towards a Software Centric Approach for Ontology Development: Novel Methodology and its Application, 2018.

Saad and S. Shaharin, "The Methodology for Ontology Development in Lesson Plan Domain," International Journal of Advanced Computer Science and Applications, vol. 7, 04/01 2016.

Sattar, A., Surin, E. S. M., Ahmad, M. N., Ahmad, M., & Mahmood, A. K. (2020). Comparative analysis of methodologies for domain ontology development: A systematic review. *International Journal of Advanced Computer Science and Applications*, *11*(5).

Suárez-Figueroa, M. C., Gómez-Pérez, A., & Fernandez-Lopez, M. (2015). The NeOn Methodology framework: A scenario-based methodology for ontology development. *Applied ontology*, *10*(2), 107-145.

Tarus, J. K., Niu, Z., & Mustafa, G. (2018). Knowledge-based recommendation: a review of ontology-based recommender systems for e-learning. *Artificial intelligence review*, *50*, 21-48.

Thomas C. J. (2009) 'Just what is an ontology, anyway?' IT Professional, 11, 22-27.

Uschold, M., & King, M. (1995). Towards Methodology for Building Ontologies. In IJCAI95 Workshop on Basic Ontological Issues in Knowledge Sharing. Montreal.

Uschold, M., & King, M. (1995). *Towards a methodology for building ontologies* (pp. 1-13). Edinburgh: Artificial Intelligence Applications Institute, University of Edinburgh.

Wang, W., De, S., Cassar, G., & Moessner, K. (2013). Knowledge representation in the internet of things: semantic modelling and its applications. automatika, 54(4), 388-400.

Wei Y., Wang, R. Hu, Y. & Wang, X. (2012). From Web Resources to Agricultural Ontology: a Method for SemiAutomatic Construction'Journalof Integrative Agriculture, 11(5): 775-783

Y. Sure-Vetter, S. Staab, and R. Studer, "Ontology Engineering Methodology," in Handbook on Ontologies, 2009.

Yang, L., Cormican, K., & Yu, M. (2019). Ontology-based systems engineering: A state-of-the-art review. *Computers in Industry*, *111*, 148-171.

Zheng, Y., He, Q., Qian, P. & Li, Z. (2012). Construction of the Ontology-Based Agricultural Knowledge Management System. Journal of Integrative Agriculture, 11(5): 700-709

Zhong, B., Wu, H., Li, H., Sepasgozar, S., Luo, H., & He, L. (2019). A scientometric analysis and critical review of construction related ontology research. *Automation in construction*, *101*, 17-31.

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