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An Investigation into the Utilization of Ontology in Various Fields

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Abstract - A survey was conducted on the use of ontology in diverse fields such as manufacturing, life sciences, finance, disaster management & firefighting, material characterization & cosmetics products, cybersecurity, medical, among others. The survey provides an outline of existing ontologies across different domains, without any evaluation being carried out. The focus is on describing the general application of ontology in present-day domains. According to the survey, notable endeavor has been invested in the creation of ontology within the data analytics, informatics & knowledge engineering, artificial intelligence, medical, and manufacturing system domains. However, there appears to have been only a restricted amount of effort put into developing ontology in tourism, virtualization domain, transportation services domains.

Keywords – Ontology, Ontology Application, Ontologies.

1. Introduction

Ontology is a discipline in philosophy that deals with the nature of existence, the relationships between things, and the categories that can be used to organize knowledge. An ontology encompasses the identification of core concepts, term connections, data management, and knowledge classification, which eventually integrate to gather crucial information. Comparing different ontologies can be a complex task, as ontologies can vary widely in terms of their scope, structure, granularity, and expressiveness, etc. The scope of an ontology refers to the range of concepts and entities it covers. Some ontologies may be very broad and cover a wide range of topics, while others may be more narrow and focus on a specific domain or topic. The structure of an ontology refers to the way in which concepts and entities are organized and related to each other. Some ontologies may use a hierarchical structure, while others may use a more networked or graph-based structure. Ontologies can also vary in granularity, from coarse-grained ontologies that define high-level concepts and relationships, to fine-grained ontologies that define very specific concepts and relationships. Ontologies can differ in their expressiveness, or the degree to which they are able to represent complex relationships and constraints. Some ontologies are based on simple taxonomies or hierarchies, while others use more advanced representation languages that enable more sophisticated reasoning.

In recent years, there has been an explosive growth of interest in the applications of Ontology in various fields. Ontologies have been developed for use in artificial intelligence, knowledge management, biomedical research, e-commerce, and information science, among others. Here are some examples of how ontologies are used in different domains:

Artificial Intelligence: Ontologies are extensively used in AI applications, such as expert systems, intelligent agents, and robotics to represent knowledge, learn and to make inferences. They provide a formal representation of the concepts, relationships, and rules in a particular domain. This makes it easier for AI systems to reason and make decisions based on the available knowledge.

Knowledge Management: Ontologies are used in knowledge management systems in various fields, such as medicine, biology, and engineering to organize, categorize, and manage large amounts of data and information in a structured and systematic manner. They provide a common vocabulary for different stakeholders to communicate and share knowledge, which can improve collaboration and decision-making.

E-commerce: Ontologies are used in e-commerce to facilitate product search and recommendation systems by providing a standardized representation of products and services. They help to model and represent product information, user preferences, and buying behavior, which can be used to make personalized product recommendations and improve customer satisfaction. This can help in making it easier for users to find and purchase the products they need.

Data Science: Ontologies are used in data science to facilitate data integration, interoperability, and knowledge discovery. They help to standardize and harmonize data across different sources and make it easier to extract meaningful insights from large datasets.

Healthcare: Ontologies are used in healthcare to represent medical knowledge and to improve clinical decision-making. They help to standardize medical terminology, categorize diseases, and represent clinical guidelines, which can be used to develop decision support systems and improve patient outcomes. By defining the relationships among medical concepts, ontologies can help to improve diagnosis and treatment, as well as enable better research and analysis of medical data.

Natural Language Processing: Ontologies can be used in NLP to help computers understand the meaning of words and phrases in natural language. Ontologies can be used to improve natural language processing tasks such as text classification, information retrieval, and question answering. By providing a structured representation of concepts and their relationships, ontologies can help machines to identify synonyms, antonyms, and other semantic relationships and also help to improve the accuracy and effectiveness of these tasks.

Semantic Web: Ontologies are a key component of the Semantic Web, which aims to make web content more machine-readable and interoperable. Ontologies enable web content to be described in a standardized way, allowing machines to understand and process the content more effectively.

Decision Support Systems: Ontologies can be used to develop decision support systems that can help users make more informed decisions. By providing a structured representation of knowledge, ontologies can help identify and analyze relevant information, and provide recommendations based on that information.

Robotics: Ontologies can be used in robotics to help machines understand the world around them. By defining the relationships among objects and concepts, ontologies can help robots to navigate their environment and perform tasks more effectively.

These are just a few examples of how ontologies are used in different domains. Overall, ontologies are a powerful tool for representing and organizing knowledge, and their applications are constantly expanding as new domains and technologies emerge.

The examination of how ontology is applied in diverse domains was established on a compilation of research papers, relevant journals, and scholarly articles highlighting the advantages of ontology application and utilization. Such an investigation was conducted across various domains, including manufacturing, life sciences, finance, disaster management & firefighting, material characterization & cosmetics products, cybersecurity, medical, where the benefits of ontology have been demonstrated to be exceedingly contributory. It is important to note that the survey merely presents a general overview of the numerous ontology applications in present-day domains, and no attempt has been taken to assess them. Given the extensive impact of ontology in various fields, our survey does not aim to be comprehensive.

2. Ontology application in Medical Domain

According to [1], the study of protein structural domains has received less attention in terms of ontology annotations compared to full-length proteins. To fill this void and open new possibilities for research, the dcGO database has emerged providing systematic mappings from protein domains to ontologies by extending annotations for protein domains with multiple definitions such as SCOP, Pfam, and InterPro. Through better ontology hierarchy browsing, users may seamlessly traverse both ontology concepts and annotated domains.

[2] - This study presents an ontological model, which utilizes the decision tree algorithm, to predict the occurrence of breast cancer with a high level of reliability. The methodology involves extracting rules from the decision tree algorithm that differentiate between malignant and benign breast cancer patients. These rules are then incorporated into the Semantic Web Rule Language (SWRL) for use in the ontological reasoner. The findings of the study indicate that the ontological model achieved an impressive prediction accuracy rate of 97.10%. The practicality of this method is highlighted as it can be implemented in the medical realm to forecast the emergence of breast cancer, among other ailments. Our goal is to optimize the efficiency of the process by leveraging Java APIs for the entirety of the hardware utilized in this study.

3. Ontology application in Manufacturing Systems

[3] proposed a new trade space framework incorporating Ontology-based Engineering (OBE) elements. Along with existing Model-Based System Engineering (MBSE) and interoperability capabilities, these new additional elements allow for the reuse of formalized knowledge using knowledge graph technologies and generative algorithms. This shifts the cognitive process from the designer to an automatic process that generates design alternatives for DES and 3D simulations that support the decision making process. To demonstrate the framework, it was applied to design the aircraft fuselage orbital joint process, resulting in the ability for designers to make strategic decisions during the conceptual phase of design. Ultimately, the framework proves to be an advantageous paradigm for the design process.

[4] delves into the construction of a conceptual model OntoCosmetic – an ontology to support emulsion-based cosmetics design, and a framework built on OntoCAPE, a domain ontology catering to Process System Engineering. This article explains the complex design of formulated cosmetic products due to its composition of the cosmetic formulations from heterogeneous ingredients data, heuristics, etc. but it is still very experimental. The interpretation of the solution space induced by OntoCosmetc can be done by both designers and machines, facilitating comprehensive exploration and comprehension of the outcomes deriving from such exploration. The article further explores the practical application of OntoCosmetic via two use cases - the replacement of an ingredient in an existing formulation, and the investigation and narrowing down of the solution space when faced with a fresh formulation design problem.

The manuscript in [5] presents the MSLE, a novel ontology for laboratory equipment in the field of Materials Science. A primary challenge that scientists encounter in their research is the utilization of diverse lab equipment possessing several specifications and hence, the creation of a comprehensive ontology for equipment is required. To ensure a cohesive and unified ontology, the MSLE incorporates the main existing ontologies, the Semantic Sensor Network (SSN) and the Material Vocabulary (MatVoc), into its core framework. In order to address the issue of multiple acronyms and technical terms used for equipment, a proposal has been put forward to utilize the Simple Knowledge Organization System (SKOS) to establish a hierarchical structure for these terms. Gathering equipment language and abbreviations from numerous sources, they were then processed through the MSLE system by implementing the SKOS model. The development of the ontology was executed in a collaborative effort with esteemed professionals in the relevant field, with a keen concentration on the sizeable machinery utilized for material characterization. Constraints have been designed utilizing the Shapes Query Language (SHACL); a prototype has been showcased and authenticated, successfully demonstrating the significance of modeling constraints.

[6] focuses on the creation of Zero Defect Manufacturing (ZDM) ontology to digitalize the manufacturing systems ready for Industry 4.0 technologies globally. Manufacturers in the Industry 4.0 era are highly dependent on data-

driven technologies. The prevailing paradigm to assure higher quality and manufacturing sustainability is known as Zero Defect Manufacturing (ZDM). Significant increase in interest in ZDM has highlighted the need for an alternative approach to quality assurance, moving away from traditional methods such as Six Sigma and Lean manufacturing. In response to this need, the aim of this paper is to develop a ZDM ontology that can effectively align numerous software systems operating within a ZDM ecosystem using semantic methods. The ontology was created using principles outlined by the Industrial Ontology Foundry (IOF), and Basic Formal Ontology (BFO) was implemented as the upper level ontology. The developed ontology was then utilized in the Prediction Optimization Designer tool, which supports developers in creating new projects while reusing existing resources or responding to a specific challenge. The outcomes of the use case validation indicate that deploying Natural Language Processing (NLP) combined with Sentence-BERT and ontology-based search techniques centered on the ZDM ontology is a highly viable and promising approach to establish efficient search engines catering to the demands of the ZDM domain.

4. Ontology application in Artificial Intelligent

[7] studies the applications of Ontologies in the area of Life Sciences (LS) that include elements from molecular biology, medical, bioinformatics and other allied areas, derived from diverse fields, by investigating various existing biomedical ontologies and frameworks. This article compares the available ontology development environments (ODE), such as Topbraid Composer, Protégé, Ontostudio, etc., for creating ontologies from scientific resources in text format. The purpose of this work is to offer evidence that serves as both a foundational resource for individuals just entering into the realm of ontology, as well as a convenient point of reference for those with an established background in academic research.

In [8], the writers put forward an ontology for virtual human-building interaction experimentation, known as the Virtual Human-Building Interaction Experimentation Ontology (VHBIEO). This domain-level ontology expands upon the existing Ontology of Scientific Experiments (EXPO), with the aim to standardize the virtual human-building interaction experiments. It was created using cutting-edge ontology development techniques. To extract requirements and manage development, competency questions (CQs) were employed. The implementation of an application view (APV) by VHBIEO is designed to cater to specific application-related information. Extensive taxonomy evaluations were conducted to ensure consistency, completeness, and minimal redundancy, validating its structural integrity. Application evaluations followed to attest to its ability in facilitating the standardization and generation of easily readable, accessible, and processable machine data.

5. Ontology application in Data Analytics, Informatics and Knowledge Engineering

[9] compared and evaluated four popular Building Ontologies (Brick Schema, RealEstateCore, Project Haystack and Google's Digital Buildings) with respect to the Terminological Box (TBox) and the Assertion Box (ABox). From the systematic analysis of these ontologies, it is implicitly concluded that integration of Linked Building Data has no common Building Ontology, but also emphasized on Pattern Discovery Automation as one of the key elements for ongoing research in creating tools and systems in the field of buildings.

[10] proposed the Firefighters' Data Requirements (FFDR) ontology that models relevant architectural and environment data that are essential during a building fire emergency. The efficacy of the developed ontology is validated by interviewing firefighters with the help of a prototype web application who performed their emergency duties successfully in the hazardous building fire events. The proposed ontology can be used to identify potential digital data sources for fire emergency response and to devise a data integration framework.

[11] presented a consolidated view about various finance related ontologies pertaining to Unified Foundational Ontology (UFO) such as notably COFRIS, OntoREA, REA2, and ATE, especially for the purpose of financial reporting and standard setting. Initially, this piece elucidates the fundamental suppositions pertaining to the conceptualization of

exchange in COFRIS. Furthermore, it amalgamates the most recent advancements. The evaluation of the ontology is conducted through the assessment of its capability to answer competency questions. Additionally, it is compared to other UFO based exchange ontologies and addressed with existing conceptual frameworks and standards for accounting and financial reporting. The outcomes reveal the current level of development and applicability of exchange ontologies for standard setting purposes.

[12] introduces a domain ontology to identify knowledge-based risks in construction of onshore wind farm projects by means of mapping and automating the representation of project context and risk information which are otherwise very labor intensive and time-consuming even for the experts. The current research presents a method that aims to improve the management of knowledge for risk identification, making it easier to store, share, and reuse. The research study features an innovative risk ontology for a wind farm construction project, which has been verified by a panel of professionals in the field. The risk identification method based on the ontology considers project context and has successfully identified risk factors that have an impact on the onshore wind farm construction process. The proposed methodology underwent validation through an automated assessment of coherence, as well as a systematic evaluation based on specific criteria and application-based investigation with a tangible project. By employing this proposed approach, the identification process is enhanced and thus improves the construction of onshore wind farms.

[13] introduces RoboDesign ontology that offers a comprehensive depiction of the significant elements within the scope of building and inspection domain objects that influence the assessment of hardware design requirements for robots. Additionally, it delves into the correlation between specific hardware requirements for robots and the characteristics of complex buildings, along with their associated defects. The RoboDesign ontology comprises of two primary domain ontology models, namely the Robot System Model and the Building and Defect Model. An internal evaluation of the ontology is conducted through content assessment and automated consistency checking. Moreover, the implementation of the proposed ontology in two wall-climbing inspection robot design cases is carried out to comprehensively investigate the robot's application environment. The validation outcomes demonstrate that the proposed ontological model allows for the efficient retrieval of the necessary information required to determine a particular hardware requirement.

6. Ontology mapping and evaluation in the Tourism domain

[14] showcased a Tourism-focussed ontology framework which allows for effective classification, naming, and organization of knowledge. The tourism types coined by experts and professionals reflect the multifaceted connotations of different tourism categories and contain a vast amount of valuable tourism-related information. A comprehensive tourism-type ontology comprised of 232 tourism classes, 155 naming elements, 22 subcategories, and six categories has been developed. Serving as the inaugural classification framework of its kind, this compilation represents a significant milestone in the tourism industry for effectively organizing and categorizing tourism-related concepts. Moreover, the development of a tourism-focused ontology enhances the current body of research on comprehensive tourism understanding. This type of ontology can serve as an initial structure for arranging all-encompassing tourism knowledge, as well as serving as the groundwork for creating a standardized nomenclature system specific to tourism.

7. Ontology application in Textile & Clothing Industry

[15] proposed 4Step-Rule-Set (4SRS) method for Ontological Design and its application in Real Industrial Projects. Current methods for constructing an ontology, particularly those utilizing agile techniques, have produced notable outcomes. However, there is a deficiency in integration and alignment with a comprehensive development framework. Accordingly, the initial rendition of a semantic model has been established to facilitate the synchronization with the previously established instructional framework. The

Ontological Design process can be effectively implemented using the 4SRS Method, which is based on the VModel 4SRS. This approach ensures that the ontological design process is aligned with a reliable and proven development methodology. The proposed method is exemplified in a tangible scenario where an ontology is created for a specific constrained aspect of a domain problem. The first stage of building a comprehensive information system involves developing an ontology tailored to a particular domain. A newly devised method tackles this crucial step and boasts a detailed specification. Furthermore, its applicability has been demonstrated in a real-life case study within the Textile industry.

8. Ontology application in Question Answering

[16] presented in-depth survey on the Components, Benchmark Criteria and Techniques used in ontology-based question answering systems (OBQAS). In this paper, it is explained that how the technology era shifted towards the answer-driven search instead of big pack of words to return an answer to user posted natural language query. Selecting between 2007 to 2016, authors carefully chosen the top 15 most popular OBQAS to tabulate various functional components. The surveyed OBQAS were also compared based on domain, approach used or technology involved.

[17] have conducted a comprehensive review of literature on ontology-based question answering (QA) systems that address various types of questions. The review includes a thorough analysis of the evaluation procedures employed by these systems, as well as an in-depth discussion on the distinctive challenges encountered by each approach and the corresponding strategies employed to overcome them. Lastly, a summary of major research topics is presented that are currently unexplored in ontology-based question answering.

[18] presents a new methodology for designing and implementing an ontology-based answer extraction module aimed at enhancing the accuracy of extracted answers of the transportation service on the twitter platform. The methodology involves utilizing a question base, question preprocessing and employing similarity matching prior to answer extraction. The ontology was developed using Protégé, while the answers are obtained through the use of SPARQL query language.

9. Ontology application in Trajectory inference from Vehicular Data

[19] paper delves into an exploration of semantic ontology-based techniques for modeling, retrieval and inference with respect to incomplete mobile trajectory data. In the realm of mobile trajectory data, the effectiveness of widely-utilized methodologies is heavily dependent on the completeness and accuracy of the dataset at hand. Unfortunately, sparsity and incompleteness are all too common, severely impeding pattern inference outcomes. To tackle this troublesome predicament and to improve the comprehensibility of mobile trajectory data, a methodology has been devised to convert latitude and longitude coordinates arranged in spatio-temporal sequence into semantic locations. This is followed by the design of an ontology model that incorporates movement of vehicles by defining semantic rules that govern the location relationships between road intersections and vehicle movements. Using this ontology model as the knowledge base and semantic query results as the training set, an ontology-based Markov logic network has been developed to solve the problem of mobile trajectory inference with incomplete data. This approach offers a powerful means of enhancing the interpretability of mobile trajectory data and providing valuable insights into vehicular movements.

10. Ontology developed in the domain of Virtualization

[20] proposed a solution based on utilizing ontologies to efficiently manage interdependency between safety and cybersecurity with a comprehensive understanding of developing safety-critical systems involving Network Function Virtualization (NFV) technology. In the event of an anomaly, whether intentional or unintentional, these systems could potentially have consequences on both humans and the environment. The proposition of this work is a novel safety ontology for NFV framework that encompasses breakdown types pertaining to reliability, availability, maintainability, and integrity. Using this illustration,

it is plausible to devise an operational procedure that mitigates the likelihood of discordance between safety and cybersecurity, consequently optimizing their interdependence. The execution results demonstrate that the ontology seamlessly manages the association between safety and cybersecurity, with negligible impact on the time taken to make decisions. This, in turn, underscores the effectiveness of our NFV framework methodology.

11. Miscellaneous applications of Ontologies in different domains

[21] presents a numerical approach for constructing scenarios that assess emergency situations. The method utilizes ontological methods and the Element-Object-Consequence (EOC) model, and concisely characterizes the knowledge, concepts, attributes, and associations of the disaster scenario. By reducing the details of data from the document to the data level, the ontological structure of disasters simplifies the granularity of the information. The EOC model utilizes disaster ontology as its foundation and employs a multiclass framework to create a comprehensive process scenario. It achieves adaptation of a disaster scenario by merging key components such as objects, elements, environments, and consequences to formulate a holistic approach. Although not comprehensive, this paper outlines a theoretical methodology for constructing quantitative scenarios. The approach consists of several steps, including structuring and quantifying information related to disasters, quantifying critical data using attribute variables, building relationships among ontologies and components of the EOC model, constructing quantitative scenarios, and finally, scenario deduction. To achieve this, the methodology employs a technical approach that combines ontologies, semantic analysis, the EOC model, and data/knowledge bases.

[22] has developed a Swine Gut Microbiota Federated Query Platform (SGMFQP) that is built upon an ontology-based framework. This platform is designed to provide an efficient and automated query service for swine feeding and gut microbiota related information. The SGMFQP is constructed using a domain-specific Swine Gut Microbiota Ontology (SGMO), which enables the creation of independent queries irrespective of the individual data source's organization. Furthermore, a template-based query interface provides support for this process. The utilization of a Datalog+-oriented federated query engine enables the transformation of queries into tailored sub-queries that align with the specific requirements of each data source. Moreover, an automated workflow orchestration mechanism governs the execution of queries in each database source and facilitates the consolidation of resultant outcomes. The system is notably efficient, a fact that has been validated through multiple successful implementations across various swine feeding scenarios.

[23] - This article presents OntoZoning, an ontology designed to capture the relationships between zoning types, land uses, and more specific land use programs in Singapore. By linking this ontology to geospatial data stored in a knowledge graph, the article illustrates how users can execute multi-domain queries on urban data. Adopting a semantic web approach significantly improves access to and the usability of land use regulation data, particularly for site selection and exploration purposes. While acknowledging the difficulty of defining some concepts in the land use regulation field, the article suggests that OntoZoning can be linked to a broader urban planning regulatory framework, based on the principles of the semantic web.

[24] - Examining the impact of a suitable subsumer, termed the Consensus Common Subsumer (CCS), on the excellence of term similarity assessment is the central focus of this study. This issue is approached as an optimization problem utilizing the Particle Swarm Optimization algorithm, recognized as one of the most capable optimization methodologies. Empirical evaluation, based on acknowledged biomedical benchmarks and ontologies, highlights the precision of the proposed technique when compared to state-of-the-art methods. A series of experiments were conducted to verify the effectiveness of the proposed approach using domain-specific knowledge resources including MeSH and SNOMED-CT, as well as a generic knowledge resource like WordNet. The experimental results unequivocally demonstrate

that the proposed approach outperforms state-of-the-art approaches.

[25] - The fundamental objective of this research is to meticulously develop the ontologies for the stratigraphic field. The accomplishment of this task is attributed to a collective, crowd-sourced effort led by domain experts representing significant stratigraphic sub-disciplines. The initial phase of this endeavor involves the identification of essential terminologies from established scholarly resources. Subsequently, these terms are efficiently merged into the Geoscience Professional Knowledge Graphs (GPKGs) of the state-of-the-art Deep-time Digital Earth Project. Through a meticulous process, professional judgement with aid from an automatic Homonym detection tool on the GPKGs platform was utilized to address semantic heterogeneities. Subsequently, these terms were differentiated as either classes or properties and organized within a top-down hierarchical framework. This process resulted in the construction of seven ontologies for major stratigraphic branches, namely Lithostratigraphy, Biostratigraphy, Chronostratigraphy, Chemostratigraphy, Magnetostratigraphy, Cyclostratigraphy, and Sequence Stratigraphy. Notably, the Biostratigraphy ontology is elaborated here. In addition, a preliminary prototype of a semantic search engine was developed to explore the potential implementation of our research for improved querying of stratigraphic references.

Due to limited space, only a few key domains in ontology engineering and applications were addressed. Other domains may include agriculture, chemistry, engineering, computer science, education, geoscience, library and many more which are briefly explained in survey done by [26]. Our intention is for this paper to serve as both an introduction for those new to the ontology field and a convenient reference for established scholars.

Conclusion

This paper presents a survey on the utilization of ontology in various fields, relying on existing literature and not intended to be comprehensive. The survey does not include an evaluation of the sources. Results indicate that ontology has been implemented in diverse domains such as medical, manufacturing systems, artificial intelligence, data analytics, informatics and knowledge engineering, and many others. Ontologies can differ in a number of ways, including their scope, structure, granularity, and expressiveness, among others. Overall, the choice of ontology will depend on the specific needs of the application or domain, as well as the available resources and expertise for working with different ontologies. Some ontologies may use strict logical formalisms such as OWL or RDF, while others may use more informal or natural language-based approaches. These are just a few examples of the many applications of ontologies. With their ability to represent and manage knowledge in a structured and systematic way, ontologies have the potential to support a wide range of applications in various fields. In conclusion, ontology provides a powerful framework for organizing information and knowledge within various fields of study. Its ability to categorize and create relationships between different aspects of knowledge has led to its increasing use in fields such as biomedicine, e-commerce, and information science. The applications of ontology are wide-ranging and promise to have a significant impact on how we organize and access information in the future.

Conflicts of interest

The authors declare no conflicts of interest.

References

[1] R. Arista, X. Zheng, J. Lu, and F. Mas, ‘An Ontology-based Engineering system to support aircraft manufacturing system design’, Journal of Manufacturing Systems, vol. 68, pp. 270–288, 2023.

[2] S. Babalou, A. Algergawy, and B. König-Ries, ‘SimBio: Adopting Particle Swarm Optimization for ontology-based biomedical term similarity assessment’, Data & Knowledge Engineering, vol. 145, p. 102137, 2023.

[3] V. Bali and A. Verma, “A Study on Components, Benchmark Criteria and Techniques used in Ontology-based Question Answering Systems”, Int J Intell Syst Appl Eng, vol. 10, no. 1s, pp. 09–17, Oct. 2022.

[4] C. Bao, C. Lu, J. Lin, J. Gough, and H. Fang, ‘The dcGO Domain-Centric Ontology Database in 2023: New Website and Extended Annotations for Protein Structural Domains’, Journal of Molecular Biology, p. 168093, 2023.

[5] I. Blums and H. Weigand, ‘Consolidating economic exchange ontologies for financial reporting standard setting’, Data & Knowledge Engineering, vol. 145, p. 102148, 2023.

[6] C. Chokwitthaya, Y. Zhu, and W. Lu, ‘Ontology for experimentation of human-building interactions using virtual reality’, Advanced Engineering Informatics, vol. 55, p. 101903, 2023.

[7] W. Franco. et al., ‘Ontology-based Question Answering Systems over Knowledge Bases: A Survey’, in Proceedings of the 22nd International Conference on Enterprise Information Systems - Volume 1: ICEIS, 2020, pp. 532–539.

[8] E. D. Guyo, T. Hartmann, and S. Snyders, ‘An ontology to represent firefighters data requirements during building fire emergencies’, Advanced Engineering Informatics, vol. 56, p. 101992, 2023.

[9] M. Jalali, M. Mail, R. Aversa, and C. Kübel, ‘MSLE: An ontology for materials science laboratory equipment – Large-scale devices for materials characterization’, Materials Today Communications, vol. 35, p. 105532, 2023.

[10] A. Karunarathne, C.M.W. Arachchi, G. C. Perera, W.A.M.N. Bandara and G. U. Ganegoda, 'Ontology Based Answer Extraction for Customer Support in Transportation Service', in Proceedings of 15th Annual Sessions of Sri Lanka Association for Artificial Intelligence (SLAAI), pp. 67–72, 2019.

[11] L. Ma and T. Hartmann, ‘A proposed ontology to support the hardware design of building inspection robot systems’, Advanced Engineering Informatics, vol. 55, p. 101851, 2023.

[12] S. Magapu, ‘A Survey on Usage of Ontology in Different Domain’, International Journal of Applied Information Systems, vol. 4, 09 2012.

[13] H. E. Massari, N. Gherabi, S. Mhammedi, Z. Sabouri, H. Ghandi, and F. Qanouni, ‘Effectiveness of applying Machine Learning techniques and Ontologies in Breast Cancer detection’, Procedia Computer Science, vol. 218, pp. 2392–2400, 2023.

[14] E. Mohamed, N. Gerami Seresht, and S. AbouRizk, ‘Context-driven ontology-based risk identification for onshore wind farm projects: A domain-specific approach’, Advanced Engineering Informatics, vol. 56, p. 101962, 2023.

[15] G. Panzarella, P. Veltri, and S. Alcaro, ‘Using ontologies for life science text-based resource organization’, Artificial Intelligence in the Life Sciences, vol. 3, p. 100059, 2023.

[16] T. F. Pereira et al., ‘The Adoption of 4Step-Rule-Set Method for Ontological Design: Application in a Real Industrial Project’, Procedia Computer Science, vol. 219, pp. 405–415, 2023.

[17] F. Psarommatis, F. Fraile, and F. Ameri, ‘Zero Defect Manufacturing ontology: A preliminary version based on standardized terms’, Computers in Industry, vol. 145, p. 103832, 2023.

[18] J. Qian and Y. Liu, ‘Quantitative scenario construction of typical disasters driven by ontology data’, Journal of Safety Science and Resilience, vol. 4, no. 2, pp. 159–166, 2023.

[19] Z. Qiang et al., ‘A Systematic Comparison and Evaluation of Building Ontologies for Deploying Data-Driven Analytics in Smart Buildings’, Energy and Buildings, p. 113054, 2023.

[20] J. Serna, A. Gabriel, V. Boly, V. Falk, and P. C. Narváez-Rincón, ‘An ontology for the design of emulsion-based cosmetic products: Development and applications’, Computers & Chemical Engineering, vol. 173, p. 108213, 2023.

[21] H. Silvennoinen et al., ‘A semantic web approach to land use regulations in urban planning: The OntoZoning ontology of zones, land uses and programmes for Singapore’, Journal of Urban Management, vol. 12, no. 2, pp. 151–167, 2023.

[22] M. Tao, ‘Semantic ontology enabled modeling, retrieval and inference for incomplete mobile trajectory data’, Future Generation Computer Systems, vol. 145, pp. 1–11, 2023.

[23] D. Varvarigou, D. Espes, and G. Bersano, ‘Ontology-based Solution for Handling Safety and Cybersecurity Interdependency in NFV Safety Architecture’, Procedia Computer Science, vol. 220, pp. 527–534, 2023.

[24] Y. Wang et al., ‘SGMFQP: An ontology-based Swine Gut Microbiota Federated Query Platform’, Methods, vol. 212, pp. 12–20, 2023.

[25] H. Xu et al., ‘A comprehensive construction of the domain ontology for stratigraphy’, Geoscience Frontiers, p. 101461, 2022.

[26] P. Zhang, J. Wang, and R. Li, ‘Tourism-type ontology framework for tourism-type classification, naming, and knowledge organization’, Heliyon, vol. 9, no. 4, p. e15192, 2023.