Original Research Paper

Enhancing Semantic Web Retrieval Through Ontology-Driven Feature Extraction: A Novel Proposition

[1]Meer Hazar Khan, [2]Muhammad Imran Sharif, [3]Mehwish Mehmood, [4]Fernaz Narin Nur, [5]Md Palash Uddin, [6]Zahid Akhtar, [7]Kamran Siddique and [8]Sadia Waheed Awan

[1]*Department of Computer Science, Institute of Southern Punjab, Multan, Pakistan*
[2]*Department of Computer Science, Kansas State University, Manhattan, USA*
[3]*School of Electronics, Electrical Engineering and Computer Science, Queen's University Belfast, Belfast, United Kingdom*
[4]*Department of Computer Science and Engineering, Notre Dame University Bangladesh, Dhaka, Bangladesh*
[5]*School of Information Technology, Deakin University, Geelong, Australia*
[6]*Department of Network and Computer Security, State University of New York Polytechnic Institute, Utica, USA*
[7]*Department of Computer Science and Engineering, University of Alaska Anchorage, Anchorage, USA*
[8]*Department of Computer Science, University of Wah, Wah Cantt, Pakistan*

Article history
Received: 10-09-2023
Revised: 16-11-2023
Accepted: 29-12-2023

Corresponding Author:
Muhammad Imran Sharif
Department of Computer Science, Kansas State University, Manhattan, USA
Email: imransharif@ksu.edu

Abstract: Web images represent unstructured data sets which often lead to challenges when users try to locate distinct images via text-based searches on the web. Such difficulties stem from different factors, e.g., redundant image storage, irrelevant metadata tags, and incorrect associations. To overcome this issue, we propose a semantic model based on the ontology language that enables users to find images that exactly match their queries. The proposed technique employs a simple procedure where users generate image captions by constructing an ontology for each image in the repository. In order to fit the existing ontology domains, the ontology generation relies on information gathered from the image's visual and textual elements, including low-level features like color, name, and shape. Next, constructing the ontology establishes accurate relationships with existing ontology concepts using the "an" and "is a part of" relationships. The resulting text with immersed ontology information yields accurate results, leading to easy retrieval using semantics keyword searches. Our framework relies on two main ontology concepts, i.e., animals and vehicles. In this study, we used a dataset of MAT files comprising images, content, and information to study the ontology of animals (e.g., wolves, foxes, and dogs) as well as the ontology of vehicles. The overall comparative evaluation of the proposed framework was performed under various conditions to obtain valuable insights.

Keywords: Semantic, Metadata, Redundancy, Local and Global Features, Ontology, Owl, RDF Schema

Introduction

The use of web-based technologies and the internet is growing exponentially, thus web services and pages are getting heightened attention from both vendors and researchers. It is easy to see that research efforts are widely being focused on studying portals and e-commerce platforms. Nevertheless, the demand for better Quality of Service (QOS) and personalized user-centric services is also on the rise. One potential direction to address this issue is an amalgamation of semantics (i.e., creating meaningful structures) and capabilities of artificial intelligence. Therefore, our target is merging two prominent areas in the contemporary web landscape, i.e., web semantics and web mining (Casteleiro *et al*., 2017). Ontology plays an important role in improving our understanding of web data. Nowadays, Ontology is hugely being utilized in various research and applications domains such as including artificial intelligence, web semantics, and natural language processing (Casteleiro *et al*., 2017). Two implementations based on ontological representations of SNOMED CT are proposed, one based on the OWL API and the other on the W3C SPARQL 1.1 query language. The analysis of the functional capabilities required for SCTQL.

Ontology can be utilized for improving decision-making within the field of online media, especially images on the world wide web (Borth *et al*., 2013). Borth *et al*. (2013) provide a methodical, data-driven approach to create a large-scale sentiment ontology based on web crawling folksonomies and psychology. We often face the challenge of getting irrelevant and less precise results to user queries on search engines such as Google, Netscape, and Yahoo, which usually leads to frustrated users. Towards this problem, we turn to web images as our dataset and apply text queries in the search engine to find the exact image on the web. However, we unfortunately fall short of getting precise results. Various factors are instrumental in this problem, including redundancy in stored images; irrelevant meta tags mean false caption generation on images and incorrect associations relationships between different concepts. As we stated above, ontology plays a vital role, but constructing a viable ontology remains a big challenge as it is a very perplexing task. It is a resource-consuming and time-intensive task. Several studies and models have been proposed to ensure the efficient reuse of existing ontologies. But the complexities persist owing to the multifaceted issues such as:

1. Locating domain-specific ontologies: Identifying domain ontologies for further reuse
2. Integrating concepts: Combining concepts from different ontologies into the desired domain by making it more coherent and comprehensive using an object-oriented approach
3. Continuous knowledge acquisition: Updating the knowledge from newly discovered ontologies
4. Effective knowledge sharing: Using the same medium to share their domain information easily

This research presents our pilot attempt to build a large-scale multi-modality ontology for web image classification. The main objective is to enable the use of text-based ontology construction. Our approach attempts to harness both structural and content-related features of web data to establish real-world objects and their conceptual relationships (Chen, 2005; Liu, 2022). For future better understanding, we also train our classifiers using image features with the development of a middle-level training set. However, our research will also show empirical results that utilize ontologies with various learning methods to enhance decision-making accuracy (Bannour and Hudelot, 2011). Image retrieval could become easy by having correct domain-specific knowledge and relationships on the web. Thus, we propose to use an agent that builds a precise before uploading an image. Next, our ontology construction procedure establishes precise relationships with existing ontology concepts based on the "an" and "is a part of" relationships. A novel procedure is introduced for easy-to-use and flexible retrieval of color pictures, integrating knowledge group tools and cutting-edge image analysis methods. This technique attempts to overcome the limitations of prior frameworks, such as the limited terminology or the need to access key images and avoid physical alteration of weight. Namely, the obtained results contain a large set of static images. Utilizing ontology-constructed text can lead us to an accurate result when the users enter a query into the search box, i.e., easy retrieval using semantics with the keyword search (Malki, 2016). Feature extraction is one of the main processes that are usually involved in creating a classification framework. The classification framework given in Fig. 1, includes image collection, image segmentation, feature extraction, image annotation, image classification on SVM, concept semantics, and image content database.

The main contribution of this study is to provide search engine users with results which closely associated with their queries. Often, the users looking for accurate results from a search engine face unrelated results due to various factors such as the most common redundancy in stored images, irrelevant meta tags, and incorrect relationships. To overcome the problem, we propose a semantic model that uses the ontology language, empowering the user to find the exact image relevant to their queries. The framework in this study ensures that a notable part of the data undergoes automated and efficient processing with a combination of the two aforementioned methodologies. Consequently, the user can get semantically enriched results aligning their query.

Ontology-Based Information Retrieval

If we take the animal class as an illustrative example, human beings can easily differentiate them using visual traits. But a machine cannot define them so straightforwardly. Machines rely on more conceptual understandings, e.g., names of animals, their diet, and their natural habitats. To attain a better level of understanding, the machine needs the use of ontology. Nonetheless, we have pertinent questions:

1. Hierarchical relationships: Is there any hierarchical relationship present on the web data that is the same as the ontology created
2. Automatic ontology construction: Can oncology creation be automated knowing that manual construction can be so time-consuming
3. Content limitation: Can we put a limit on the web content or not

An ontology fundamentally shows an intricate relationship between key concepts forming a domain area. The relationship is given in Fig. 2. Upon the introduction of the ontology, we can unfold several application opportunities by merging techniques like information retrieval with web agents and semantics schemas of content. Sirea tackles the problems of content-based image retrieval and keyword-based image retrieval (Majeed *et al*., 2013). Ontology is very important in applications of the semantic web.

DOI: 10.3844/jcssp.2024.487.494

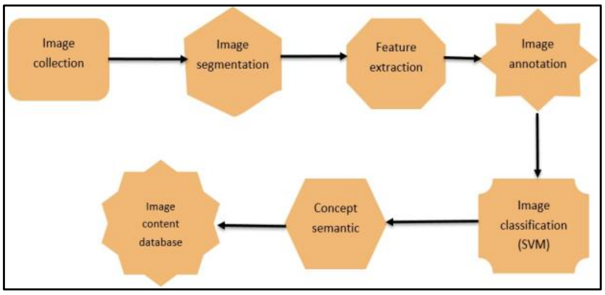

Fig. 1: General steps for image classification (Adla *et al*., 2012)

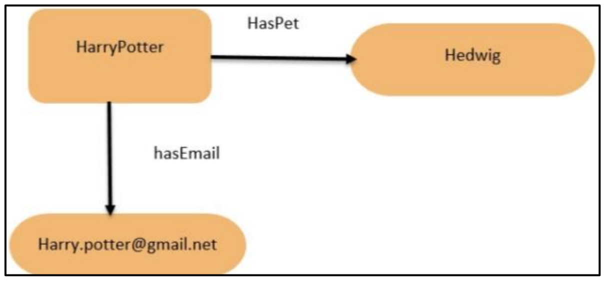

Fig. 2: Relationship (Buraga *et al*., 2014)

Table 1: Comparison table

Model	Year	Techniques	Dataset	Ontology used	Sematic concepts	Classifications	Feature extraction	Flaws/ critical analysis	Classifiers
Wikipedia2Onto	2010	Auto MMooto, association rule	Web online images	Wolf (animal)	Present (743)	Present	Local + global	Image retrieval system module	Not present
Multimodality image retrieval system	2011	Garden resources in the DBpedia	BBC sports	Sports news	Present ball category	Present	Textual + visual	Semantic matchmaking module	Not present
CBIR systems	2014	SPARQL protégé software	Security, military, agriculture and food information	Icon ontology	Hypernymy/ hyponymy (ISA) and metonymy (OARTOF) relationships web 3.0	Present	Content - based	Multi-object image retrieval, symbolic language	Not present
ONTO-CIF, SAW (Situation Awareness)	2007	Military intelligence	NATO	Situation as being composed of entitles	Not present (general)		Spatio-temporal context	Manual work Bublin Core (DC), Metadata Object Description Schema (MODS)	Not present
JC3IEM model (joint command present and communication information exchange data model),	2005	Intelligence analysis	Military	CONON (CON text Ontology)	Present (7900)	Present	CON text	Metadata formats, using automatic metadata generation for research papers	Not the
OntoEnhanced	2009	Spreading The activation Techniques (SAT)	Animal	Canine category of the animal kingdom	Present	Present	Textual	Construction the semantic network with multi-modality ontology	Not present
PREFA	2017	Text2Onto, rank techniques	Forum for information retrieval-based) evaluation 2010 and clueweb09 (Category B) test data	Web portals	Present (ranking	Present	Product features	Time and search optimization algorithms	
FBVO	2015	Folksoomy-based visual ontology, DAG construction algorithm	Flickr and Instagram		139 825 concept nodes, 2.4 million flicker images		Visual content and textual semantics	Search results using hyperlinks, logs and user's profiles	Cognition

Nonetheless, building image-based databases generates significant problems in finding the desired image. The semantic web is playing a very imperative role in information access by using sources like OWL, RDFs, and SPARQL (Benítez-Hidalgo *et al*., 2023). To address the intricacies of semantics, advanced semantic technologies using ontology is front running candidate. Like Content-Based Image Retrieval (CBIR), the integration of semantics and ontology is playing a vibrant role in image retrieval (Wang *et al*., 2008). This search mechanism leads to an optimized solution achieving more refined results (Negm *et al*., 2017; Khalid and Noah, 2011). An agent is referred to as any robot, software agent, or human being in knowledge discovery that involves the exploration of a large collection of data to identify meaningful patterns for generalized and useful conclusions. Using the OTTO text mining approach, we can extract valuable data from web applications (Bloehdorn *et al*., 2005). The next step is to use that data for decision-making practice using agent systems. To effectively apply decision-making processes, a multi-agent distributed Decision Support System (DSSMAS) logical architecture is employed, using the extracted text in the final decision-making process. This holistic strategy attempts to address problems in the domain, including the domain, including:

- Finding domain ontologies for further reuse
- Combining concepts into a desired domain by making it possible using an object-oriented approach
- Acquisitive knowledge from newly discovered ontologies
- Using the same medium to share their domain information

The construction of ontologies by means of protégé software provides semantic understandings of image substances. In the traditional CBIR systems, the images are retrieved by using the given keyword by users. Ontology delivers a holistic approach bridging granular details of image contents, including low-level visual features, with human cognition. An ontology web language is further accustomed to form an ontology. Ontology can be constructed in two ways: Basic and domain-oriented. These ontologies have potential applications in military, geospatial imaging, and image retrieval in medical (Negm *et al*., 2017). A comparative analysis of different models is presented in Table 1.

Materials and Methods

In the current context, we introduce a model based on the ontological approach system architecture that defines the work of the various components of the IR system and the synergy between them. The proposed model is presented in Fig. 3. This diagram provides a comprehensive depiction of architectural complexities involved in image retrieval via semantics techniques. The semantic image retrieval system comprises the following components:

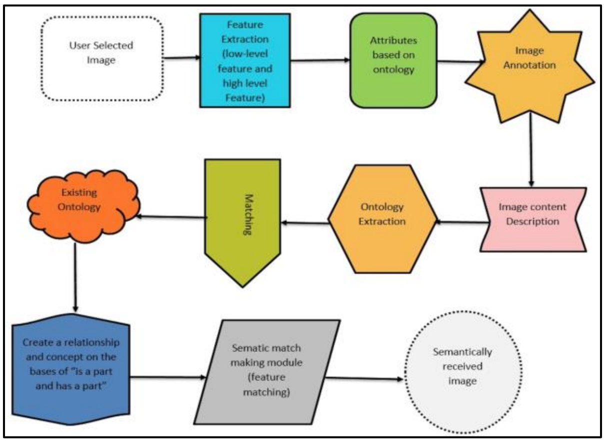

Fig. 3: Proposed model

- Ontology and image analysis
- System architecture query processing device
- Module of matching
- Image processing
- Ontology manager module
- The module of ranking for the image
- Ontology and high-level features

Various applications use ontology which is usually hierarchy-based illustrations describing many concepts and their association or relationships. Such associations/relationships mainly manifest via word connections that are primarily categorized into three types: "Instance of", "part-of" and "is-".

In this model, an image collection methodology suited to search in large selections of heterogeneous images is presented. The proposed strategy employs a completely unsupervised segmentation algorithm to partition images into distinct areas. From these areas, low-level features encompassing color, position, shape, and size are extracted. These features are then automatically organized into suitable intermediate-level descriptors forming an easy and coherent vocabulary called object ontology. Object ontology serves as a pivotal component enabling the qualitative definition of high-level ideas that users seek in a human-centered style. During the querying procedure, irrelevant image areas are filtered out using intermediate-level descriptors. In the due course, a relevance assessment technique, using low-level features, is invoked to produce the final query results. This approach bridges the gap between keyword-based approaches, which usually assume the presence of rich image captions or manual annotation, and query-by-example approaches (Zhang *et al*., 2012). The model improves efficiency by proposing automated means of image retrieval (Zangeneh and McCabe, 2020). A novel hybrid semantic indexing technique is proposed with the combination of machine learning and ontology for unstructured text content (Sharma and Kumar, 2023). For the purpose to achieve higher performance and processing quantum machine learning is used effectively to compute different tasks (Umer and Sharif, 2022). Pre-trained model is used for detecting diabetic foot ulcers into suitable groups like normal/abnormal and ischaemia/non-ischaemia (Amin *et al*., 2022). Ontology-based framework for standardization in multi-objective optimization. The framework's primary ontology, Moody, addresses anything from the formalization of evolutionary algorithms (Aldana-Martín *et al*., 2024). An ontology-driven reference framework (OntReF) and a Blockchain-based Reference Model (BbRM) for the SRM of both traditional and blockchain-based applications has been proposed for security purpose (Iqbal *et al*., 2024):

```
<owl:Class rdf:ID="Vehicle">
<rdfs:Label>Vehicle</rdfs:Label>
</owl: Class>
<owl:Class rdf:ID="Vehicle Concepts">
<rdfs:Label>Vehicle Concepts</rdfs:Label>
<rdfs:subClassOf rdf:Resource="#Vehicle"/>
</owl: Class>
<owl:Class rdf:ID="Car">
<rdfs:subClassOf rdf:Resource="#Vehicle Concepts"/>
</owl: Class>
<owl:Class rdf:ID="Toyota">
<rdfs:SubClassOf rdf:Resource="#Car"/></owl:Class>
```

Results and Discussion

In the current context, we propose a model based on the ontological approach, whose system architecture defines the work of the various components of the IR system and the synergy between them. The model's simulator is depicted in Fig. 4. The diagram provides the detailed architectural framework designed for image retrieval using semantics techniques and involves the following components used in the SIR system:

- Query processing device
- Matching segment
- Ontology manager module

Query Processing Device

The processing device plays a vital role in receiving user input queries from the web domain. These queries indicate the particular content that has the user's interest and that they want to examine/search. The user can provide input via two methods.

Inputs Based on Text and Image

The initial technique for input in the model is purely text-based. In this procedure, the user must enter any text that contains information about the object the user wants to find. This practice is often used by existing search engines like AltaVista and Google. The motivation for integrating this scheme with SIR systems (reference model) is to offer services to users who prefer a straightforward approach without the need for intricate interactions with the model's architecture. Users are plainly required to provide textual annotations or requests, e.g., lion, fox, and elephant. A similar process is performed in the text-based query processing module (Manzoor *et al*., 2012). The second procedure we use for inputs is image-based (Sarwar *et al*., 2013). In this method, the users are encouraged to submit images containing information about the object that they seek. The input images can contain single or multiple objects and the user has the flexibility to provide descriptive choices (options) for input images. This practice is valuable when the user wants to examine the associated items/images in the same way as a conventional image search (Zhang *et al*., 2012). Still, this technique delivers litheness in input procedures and it offers a completely new domain to our searching algorithms. When inputs are received from the user, dedicated processing devices are utilized to tackle queries by these inputs. As a knowledge base and ontology base are used, the queries are further formulated in SPARQL language. This process contains the following two mechanisms. The example data set is presented in Fig. 5.

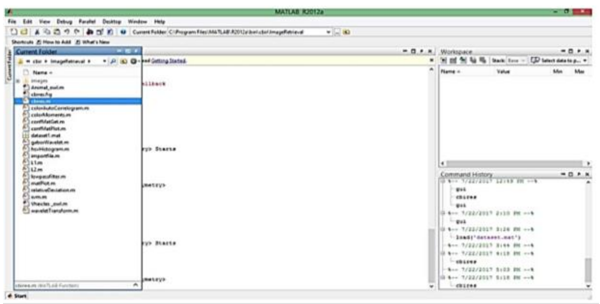

Fig. 4: Simulator

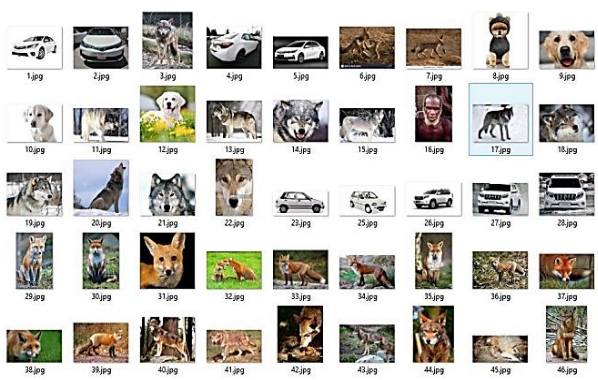

Fig. 5: Data set

DOI: 10.3844/jcssp.2024.487.494

Textual Query

This segment is liable for constructing the queries based on textual inputs. The process starts by detaching all regular stemmer words (-the ‖, -is‖ -and‖, -on‖…) from this input text. Next, SPARQL queries are generated with all probable-OR‖ and -AND‖. These generated queries have to pass through to matching segments.

Image-Based Query

A fundamental module is responsible for creating queries from our image-oriented inputs initiated with the perception of image objects via the shape-based feature extraction mechanism (Alani *et al*., 2003). After object identification, various sub-steps are executed:

- Color-based extraction: Initially, the detected items are delivered to an extraction method that is based on color and practices the MTH algorithm suggested by Guang-Hai in his recent research. This step involves careful consideration of pixel color values to ensure accuracy
- Structural classification: Next, the identified particles are transferred to the structural classification process so that the structure (if possible) can be identified in the detected particles
- Ontological concept formation: In the third phase, the low-level profile extracted from the previous two steps is converted into a higher ontological concept. If the image contains the description users are looking for, it becomes a concept. After successful completion of these procedures, the SPARQL query is created using the parameters

Matching Segment

This section takes the SPARQL query as input for the query engine and works according to an ontology-based protocol to decompose the combined image. If this query returns the relevant results during the first search, the current output image will be passed to the current module for ranking the results. An Ontology example is given in Fig. 6. But if the searches are unfruitful (i.e., the relevant image is not found in our knowledge base repository), the matching module proceeds to the succeeding steps:

- Image search: The preceding module searches the internet for a related image by processing the query in existing search engines like Bing or Google
- Content verification: The outcomes returned by the search engines are then passed through the section of image processing for content authentication verification (Minu and Thyagharajan, 2014).

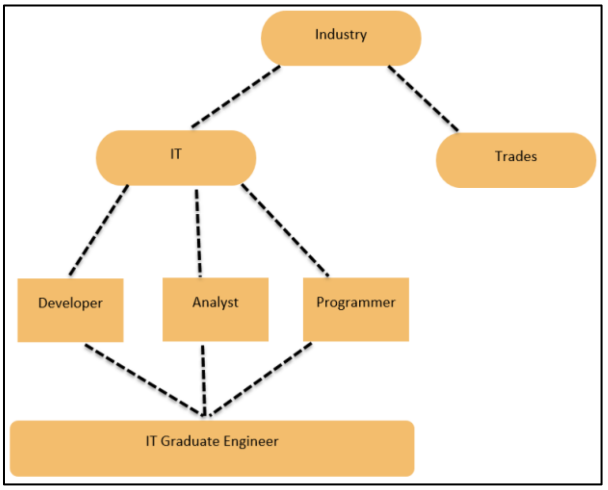

Fig. 6: An ontology example

Fig. 7: Results

Module for Image Processing

The image changes retrieved from the search engine may enhance or diminish the user's query. Therefore, the content of any image must be validated and supported. This section deals with the submission of image-based queries aimed at image content inspection via a shape-based feature extraction process (Ryszard, 2007). If these extracted features relate to a user's query, this image will be included in the general summary, otherwise, it will be rejected. As a result, these processes ignore the irrelevant images (Banu *et al*., 2022).

Ontology Manager Module

This component incorporates new applicable image types, features, and notions collected from search results and then clarified and subsequently refined to improve ontological-based facts.

Module of Ranking the Images

This module can customize the image as per the user's needs. It matches images with the approved module that corrects the images to their corresponding values. The resulting database is systematically organized, which provides the same benefits. After this processing, the user sees the top ten images (i.e., multiple images are presented) and the rest of the user's queries are displayed in descending order (Manzoor *et al*., 2012) Fig. 7 shows the result.

Conclusion

From our perspective, the user generates a caption (text) by constructing an ontology for each image in our repository and building relationships with different concepts. This text ontology is constructed based on the information given by the text and the resultant image from the initial search. It consists of high-level content as well as low-level features like color, names, shape, etc. Then, our constructing ontology is mapped to existing domain-specific ontologies like vehicles, sports, and animals, which have already been established, based on the "an" and "is a part of" relationship. This novel approach paves the way for the flexible and easy-to-use retrieval of color images, integrating cutting-edge image analysis techniques with knowledge management tools. These methods attempt to overcome the shortcomings of conventional approaches that often suffer from limited terms or the need for the accessibility of key images and manual input. The consequential framework is a result of extensive exploration of a large dataset of static images. After that, the given text ontology constructed can give an accurate result when users input queries in the search box. This accuracy is further improved by using semantics keyword search techniques. For more precise results, we use metadata formats, and automatic metadata generation for research papers and apply the construction of the semantic network to the multimodality ontology. Moreover, we utilize time and search optimization algorithms and search outcomes using hyperlinks, logs, and user profiles. If we include Metadata Object Description Schema (MODS), multi-object-based image retrieval, and symbolic language then it will lead to optimal results. To further improve the outcomes, modules like the Image retrieval system and semantic matchmaking module have been integrated.

Acknowledgment

Thank you to the publisher for their support in the publication of this research article. We are grateful for the resources and platform provided by the publisher, which have enabled us to share our findings with a wider audience. We appreciate the effort.

Funding Information

The authors have not received any financial support or funding to report.

Author's Contributions

Meer Hazar Khan: Conceptualization, methodology, software designed.

Muhammad Imran Sharif: Conceptualization, methodology, software designed, Data curation, written-original drafted preparation, interim reviewed and edited.

Mehwish Mehmood and Fernaz Narin Nur: Visualization, investigation.

Md Palash Uddin: Validation

Zahid Akhtar, Sadia Waheed and Kamran Siddique: Supervision and written-reviewed and finalization.

Ethics

The material is the author's own original work, which has not been previously published.

References

Adla, A., Nachet, B., & Ould-Mahraz, A. (2012). Multi-agents model for web-based collaborative decision support systems. In *ICWIT* (294-299).

Amin, J., Anjum, M. A., Sharif, A., & Sharif, M. I. (2022). A modified classical-quantum model for diabetic foot ulcer classification. *Intelligent Decision Technologies*, *16*(1): 23-28. https://doi.org/ 10.3233/IDT-210017

Alani, H., Kim, S., Millard, D. E., Weal, M. J., Hall, W., Lewis, P. H., & Shadbolt, N. R. (2003). Automatic ontology-based knowledge extraction from web documents. *IEEE Intelligent Systems*, *18*(1), 14-21. https://doi.org/10.1109/MIS.2003.1179189

Aldana-Martín, J. F., del Mar Roldán-García, M., Nebro, A. J., & Aldana-Montes, J. F. (2024). MOODY: An ontology-driven framework for standardizing multi-objective evolutionary algorithms. *Information Sciences*, 120184. https://doi.org/10.1016/j.ins.2024.120184

Bannour, H., & Hudelot, C. (2011, June). Towards ontologies for image interpretation and annotation. In *2011 9th International Workshop on Content-Based Multimedia Indexing (CBMI)* (211-216). IEEE. https://doi.org/10.1109/CBMI.2011.5972547

Banu, J. F., Muneeshwari, P., Raja, K., Suresh, S., Latchoumi, T. P., & Deepan, S. (2022, January). Ontology-based image retrieval by utilizing model annotations and content. In *2022 12th International Conference on Cloud Computing, Data Science and Engineering (Confluence)* (300-305). IEEE. https://doi.org/10.1109/Confluence52989.2022.9734194

Benítez-Hidalgo, A., Navas-Delgado, I., & Roldán-García, M. D. M. (2023). NORA: Scalable OWL reasoner based on NoSQL databases and Apache Spark. *Software: Practice and Experience*, *53*(12), 2377-2392. https://doi.org/10.1002/spe.3258

Bloehdorn, S., Cimiano, P., Hotho, A., & Staab, S. (2005). An ontology-based framework for text mining. *Journal for Language Technology and Computational Linguistics*, *20*(1), 87-112. https://doi.org/10.21248/jlcl.20.2005.70

Borth, D., Ji, R., Chen, T., Breuel, T., & Chang, S. F. (2013, October). Large-scale visual sentiment ontology and detectors using adjective noun pairs. In *Proceedings of the 21st ACM International Conference on Multimedia* (223-232). https://dl.acm.org/doi/abs/10.1145/2502081.2502282

Buraga, S., Alboaie, S., & Alboaie, L. (2014). The Use of XML technologies for exchanging information within a multi-agent system. *International Journal of Computing*, *2*(3), 26-33. https://doi.org/10.1007/978-3-540-39872-1_13

Casteleiro, M. A., Tsarkov, D., Parsia, B., & Sattler, U. (2017). Using semantic web technologies to underpin the SNOMED CT query language. In *Artificial Intelligence XXXIV: 37th SGAI International Conference on Artificial Intelligence, AI 2017, Cambridge, UK, December 12-14, 2017, Proceedings 37* (217-231). https://doi.org/10.1007/978-3-319-71078-5_20

Chen, T. (2005, December). From low-level features to high-level semantics: Are we bridging the gap? In *Seventh IEEE International Symposium on Multimedia (ISM'05)* (179-179). IEEE computer society. https://doi.org/10.1109/ISM.2005.62

Khalid, Y. I. A. M., & Noah, S. A. (2011, October). Ontology modelling of multimodality image retrieval system for sport news domain. In *KEOD* (400-406). https://doi.org/10.5220/0003652804000406

Iqbal, M., Kormiltsyn, A. Dwivedi, V., & Matulevicius, R. (2024). Blockchain-based ontology driven reference framework for security risk management. *Data and Knowledge Engineering*, *149*, pp: 102257. https://doi.org/10.1016/j.datak.2023.102257

Liu, B. (2022). *Sentiment Analysis and Opinion Mining*. Springer Nature. ISBN-10: 9783031021459.

Malki, Z. (2016). Ontology-based framework for semantic text and image retrieval using chord-length shape feature. *Int. J. Multimedia Ubiquitous Eng.*, *11*, 179-188. http://dx.doi.org/10.14257/ijmue.2016.11.11.15

Manzoor, U., Ejaz, N., Akhtar, N., Umar, M., Khan, M. S., & Umar, H. (2012, December). Ontology based image retrieval. In *2012 International Conference for Internet Technology and Secured Transactions* (288-293). IEEE.

Majeed, Saqib, Zia ul Qayyum and Sohail Sarwar (2013). SIREA: Image retrieval using ontology of qualitative semantic image descriptions. *2013 International Conference on Information Science and Applications (ICISA)*, (pp.1-6). https://doi.org/10.1109/ICISA.2013.6579466

Minu, R. I., & Thyagharajan, K. K. (2014). Semantic image description for ontology based image retrieval system. *International Journal of Applied Engineering Research*, *9*(26), 9332-9335. http://www.ripublication.com/ijaer.htm

Negm, E., AbdelRahman, S., & Bahgat, R. (2017). PREFCA: A portal retrieval engine based on formal concept analysis. *Information Processing and Management*, *53*(1), 203-222. https://doi.org/10.1016/j.ipm.2016.08.002

Ryszard, S. C. (2007). Image feature extraction techniques and their applications for CBIR and biometrics systems. *International Journal of Biology and Biomedical Engineering*, *1*(1), 6-16. https://doi.org/10.48084/etasr.4450

Sarwar, S., Qayyum, Z. U., & Majeed, S. (2013). Ontology based image retrieval framework using qualitative semantic image descriptions. *Procedia Computer Science*, *22*, 285-294. https://doi.org/10.1016/j.procs.2013.09.105

Sharma, A., & Kumar, S. (2023). Machine learning and ontology-based novel semantic document indexing for information retrieval. *Computers & Industrial Engineering*, *176*, 108940. https://doi.org/10.1016/j.cie.2022.108940

Umer, M. J., & Sharif, M. I. (2022). A Comprehensive Survey on Quantum Machine Learning and Possible Applications. *International Journal of E-Health and Medical Communications (IJEHMC)*, *13*(5), 1-17. https://doi.org/10.4018/IJEHMC.315730

Wang, H., Jiang, X., Chia, L. T., & Tan, A. H. (2008, October). Ontology enhanced web image retrieval: Aided by wikipedia & spreading activation theory. In *Proceedings of the 1st ACM International Conference on Multimedia Information Retrieval* (195-201). https://doi.org/10.1145/1460096.1460128

Zangeneh, P., & McCabe, B. (2020). Ontology-based knowledge representation for industrial megaprojects analytics using linked data and the semantic web. *Advanced Engineering Informatics*, *46*, 101164. https://doi.org/10.1016/j.aei.2020.101164

Zhang, D., Islam, M. M., & Lu, G. (2012). A review on automatic image annotation techniques. *Pattern Recognition*, *45*(1), 346-362. https://doi.org/10.1016/j.patcog.2011.05.013