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# Ontology Based Semantic Enrichment for Improved Information Retrieval Model

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***Abstract:*** In the era of vast and heterogeneous information sources, efficient and accurate information retrieval is paramount for users seeking relevant content. This research focuses on enhancing information retrieval systems through the integration of ontology-based semantic enrichment. Traditional keyword-based search methods often fall short of capturing the intricacies of semantic relationships within a given domain, leading to suboptimal retrieval results. To address this limitation, the proposed work leverages ontologies, which represent structured, hierarchical knowledge frameworks defining the relationships among concepts. The proposed approach involves the development and integration of domain-specific ontologies to augment the semantic understanding of textual content. Through the utilization of these ontologies, the information retrieval process is enriched, allowing for a more nuanced and context-aware search experience. Semantic annotations, extracted from the ontologies, enhance the representation of documents, enabling more precise matching of user queries with relevant content. Furthermore, the research explores the integration of machine learning techniques to dynamically adapt and refine the ontological structures over time, ensuring the system's adaptability to evolving domains. The effectiveness of the proposed ontology-based semantic enrichment is evaluated through comprehensive experiments, comparing retrieval performance metrics against traditional methods. The anticipated outcome of this research is an information retrieval system that not only outperforms conventional keyword-based approaches but also provides users with more meaningful and contextually relevant results. The integration of ontology-based semantic enrichment holds promise for advancing the state-of-the-art in information retrieval, contributing to more sophisticated and intelligent search mechanisms in diverse application domains.

***Keywords:*** *Ontology, Semantic Enrichment, Information Retrieval, Knowledge Integration, Context-aware Search*

## 1. Introduction

The internet has emerged as the primary reservoir of information, attracting countless users seeking to fulfill their informational requirements. Information Retrieval (IR) systems are intricately crafted to provide outcomes intricately aligned with users' specific information inquiries, ensuring more targeted and efficient access to the vast wealth of online resources [1]. In an age characterized by an unprecedented proliferation of vast and heterogeneous information sources, the imperative for efficient and accurate information retrieval has become paramount. Users navigating this vast digital landscape increasingly demand not only a breadth of information but also relevance that aligns with their specific needs. Traditional keyword-based search methods, while foundational, have revealed inherent limitations in capturing the nuanced semantic relationships embedded within diverse domains [2]. This deficiency often results in suboptimal retrieval outcomes, prompting a critical need for innovative solutions.

This research squarely addresses the challenges posed by the limitations of traditional information retrieval systems. The focal point of our investigation lies in the augmentation of information retrieval processes through the strategic integration of ontology-based semantic enrichment [3]. Ontologies, sophisticated structured frameworks embodying hierarchical knowledge, emerge as a pivotal tool in our approach. These frameworks systematically define relationships among concepts, offering a more profound understanding of the semantic landscape within a given domain [4].

Our proposed methodology hinges on the development and seamless integration of domain-specific ontologies. These ontologies are meticulously crafted to deepen the semantic understanding of textual content, providing a more holistic and nuanced representation of information [5]. By harnessing the power of these ontologies, our approach enriches the information retrieval process, elevating it to a

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realm of context-aware and finely-tuned search experiences.

One of the fundamental issues with traditional keyword-based search methods is their inherent inability to comprehend the intricacies of semantic relationships [6]. Our research confronts this challenge by extracting semantic annotations from the integrated ontologies. These annotations serve as a bridge between user queries and the relevant content within documents. Through this mechanism, the retrieval system achieves a higher degree of precision, ensuring that user queries are matched with contextually pertinent information. Combining diverse ontologies within a specific domain into a unified and cohesive ontology is essential to represent a shared consensus within that domain.

Taking innovation a step further, our study delves into the integration of machine learning techniques. This dynamic integration aims to facilitate the adaptive evolution and refinement of ontological structures over time. By doing so, the system becomes inherently adaptable to the ever-changing dynamics of evolving domains. This forward-thinking approach ensures that the information retrieval system remains at the cutting edge, capable of delivering optimal results in the face of shifting landscapes.

The effectiveness of our proposed ontology-based semantic enrichment is rigorously evaluated through comprehensive experiments. These experiments involve a meticulous comparison of retrieval performance metrics against traditional keyword-based methods. Through empirical analysis, we seek to substantiate the superiority of our approach, showcasing its capacity to outperform conventional methods and deliver results that are not only more accurate but also more contextually relevant.

Anticipating the outcomes of this research, we envision the emergence of an information retrieval system that transcends the limitations of conventional keyword-based approaches. Our approach holds the promise of not only meeting but exceeding user expectations, delivering results that are not just exhaustive but also meaningful. The integration of ontology-based semantic enrichment stands poised to redefine the state-of-the-art in information retrieval, ushering in a new era of sophistication and intelligence in search mechanisms across diverse application domains. As we navigate the ever-expanding digital landscape, the impact of this research reverberates in its potential to revolutionize how users access and interact with information in the digital age. The basic process of information retrieval process consists of two steps represented in Figure 1.

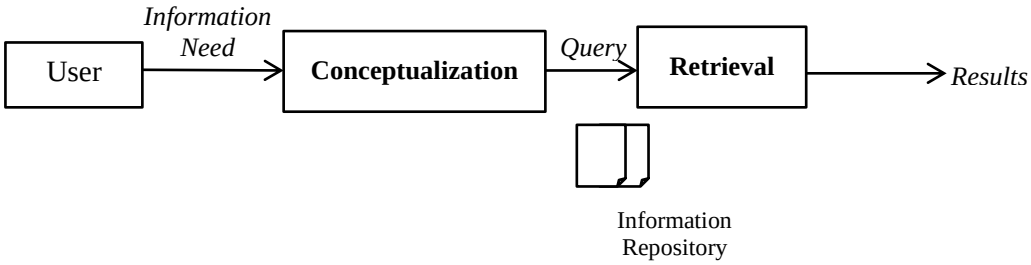


**Fig. 1.** Basic Process of IR

Conceptualization refers to the process of forming and expressing abstract ideas or concepts. In the context of information retrieval, it involves translating a user's information needs into a well-defined query or set of queries that can be used to search for relevant information. Clear conceptualization is crucial as it bridges the gap between a user's vague information needs and the structured representation of those needs in the form of a query. It helps define the scope and nature of the desired information.

Retrieval is the process of obtaining relevant information from a database or collection based on a user's query. It involves searching for and presenting documents or data that match the user's conceptualized information needs.

Retrieval is the operational phase where the system uses the conceptualized query to search through indexed documents and retrieve those that are deemed most relevant. This phase relies on algorithms and techniques for efficient and accurate document retrieval.

## 2. Literature Review

To address the limitations of existing web systems and leverage their strengths through query expansion, a novel framework is introduced by [7] for information retrieval, grounded in fuzzy ontology. This innovative framework employs domain-specific knowledge for ontology construction, utilizing both predefined domain ontologies and a global ontology, ConceptNet. Through the amalgamation of these resources, a fuzzy ontology is generated. The constructed fuzzy ontology is then employed to identify the most semantically relevant words for a given query, facilitating query expansion. The

application of the proposed fuzzy membership concept enables the identification of highly related concepts within the specific domain, further enhancing query expansion. The integration of this query expansion process with current search engines contributes to the development of a semantic web capable of addressing the contextual nuances of queries.

[8] Introduced an advanced Arabic topic-discovery architecture (EATA) designed to employ ontology for an efficient Arabic topic classification mechanism. Within this architecture, we present a semantic enhancement model aimed at refining Arabic text classification and topic discovery techniques by leveraging the abundant semantic information present in Arabic ontology. In this study, we utilize the vector space model, specifically the term frequency-inverse document frequency (TF-IDF), along with the cosine similarity approach to categorize newly introduced Arabic textual documents.

In [9], Bidirectional Long Short-Term Memory networks (LSTMs), trained on a substantial DBpedia dataset and a 2.8 GB Wikipedia corpus, are coupled with the Universal Sentence Encoder to enhance the ISO 27001-based information security ontology. The model undergoes training and testing in a high-performance computing (HPC) environment to manage Wiki text dimensionality. Notably, the approach achieves a test accuracy exceeding 80% when subjected to tests involving removed concepts from the ontology and web page instances, affirming its robustness and effectiveness. Existing ontology enrichment algorithms, relying on natural language processing and machine learning models, encounter challenges in contextually extracting concepts from words, phrases, and sentences. This underscores the demand for sequential deep learning architectures capable of navigating through dependency paths in text to uncover embedded vulnerabilities, threats, controls, products, and other security-related concepts.

[10] Introduced a framework for constructing an intelligent article knowledge graph, employing the BM25 probabilistic retrieval model. This framework aims to represent the conditional dependency structure between articles. The process involves generating conditional probability features using the Okapi BM25 Score and ranking documents based on the search query. Consequently, a high-dimensional BM25 score feature matrix is formed for all named entities in the collection. To address the challenge of high dimensionality, a solution is implemented by applying the singular value decomposition dimension reduction technique. Subsequently, pairwise cosine similarity is computed on the reduced dimensions to refine the knowledge graph.

[11] Provided a succinct overview of the historical development of speech recognition technology. In the realm of text retrieval, the paper introduces three principal models: the Boolean model, the vector model, and the probability model. The experimentation phase involved the creation of a text searcher designed to emulate document retrieval within a stack of text documents. Successful retrieval of keywords and document content based on the author was achieved across 300 text documents. However, certain limitations are acknowledged within this paper. Notably, the employed keyword retrieval method exhibits high time complexity. As the volume of data in the database increases, there is a substantial reduction in retrieval speed. Consequently, the paper suggests the exploration and implementation of more efficient retrieval methods in subsequent iterations to address this drawback.

[12] Introduced an innovative method for document indexing termed the Advanced Document-Indexing Method (ADIM), which incorporates an integrated evolutionary algorithm. The proposed Information Retrieval System (IRS) is structured into three main stages. In the initial stage, serving as preprocessing, the Advanced Document-Indexing Method (ADIM) is employed for dataset document reading, resulting in a set of two tables. The subsequent stage involves a query searching algorithm aimed at generating a set of words or keywords and retrieving related documents. The final stage, constituting the searching algorithm, encompasses two steps. The Modified Genetic Algorithm (MGA) within this framework proposes novel fitness functions, utilizing a cross-point operator with dynamic-length chromosomes and incorporating the adaptive function of the Culture Algorithm (CA).

## 3. Methodology

Information retrieval is a systematic process designed to cater to users' information needs within a vast dataset. It commences with users entering queries, and articulating their information requirements. Subsequently, the system processes these queries, employing techniques such as removing stopwords and stemming to distill key terms. To expedite the retrieval process, the system then generates an index, a data structure mapping terms to the documents containing them. The actual search phase utilizes the processed query and index to identify and rank relevant documents, employing algorithms that consider factors like keyword matching and document popularity. Once retrieved, documents undergo ranking and scoring based on their perceived relevance to the user's query. The final step involves presenting users with a ranked list of documents on a search results page, allowing them to review and select the most pertinent information. This iterative process can be refined through user feedback, enabling the system to learn and enhance its performance over time.

In the Conceptualization phase, the user endeavors to articulate their information requirements using the query syntax integral to the information retrieval process. However, the intricacies of an information need are only

partially captured in the query. Typically, users seek to approximate their needs in a query, highlighting only certain prominent aspects of their requirements. Consequently, the query is often expressed as a collection of terms associated with coordinating terms or symbols. Given that this stage frequently introduces ambiguities that manifest during the retrieval process, it becomes the primary origin for the refinement process.

In the Retrieval phase, the query undergoes execution against the underlying information repository, following a specified retrieval model, which could be Boolean, vector space, or probabilistic [13]. Essentially, each retrieval model revolves around the calculation of the relevance or "aboutness" of an information resource, denoted as about(r,q), where r represents the information resource and q denotes the query.

The effectiveness of the retrieval phase is assessed by examining both recall and precision. To evaluate this performance, specific metrics are employed based on the given query and the response of the information retrieval system. The key parameters involved in this assessment include: K is the count of relevant resources present in the entire repository, N is the total number of resources retrieved by the information retrieval system and Nr is the number of retrieved resources that are deemed relevant to the query.

Considering N, K > 0 then,

$$Recall = \frac{N_r}{K} \quad (1)$$

That is, it represents the proportion of relevant resources that are successfully retrieved during the retrieval process.

$$Precision = \frac{N_r}{N} \quad (2)$$

This refers to the proportion of retrieved resources that are deemed relevant.

The basic ontology based information retrieval system is depicted in Figure 2.

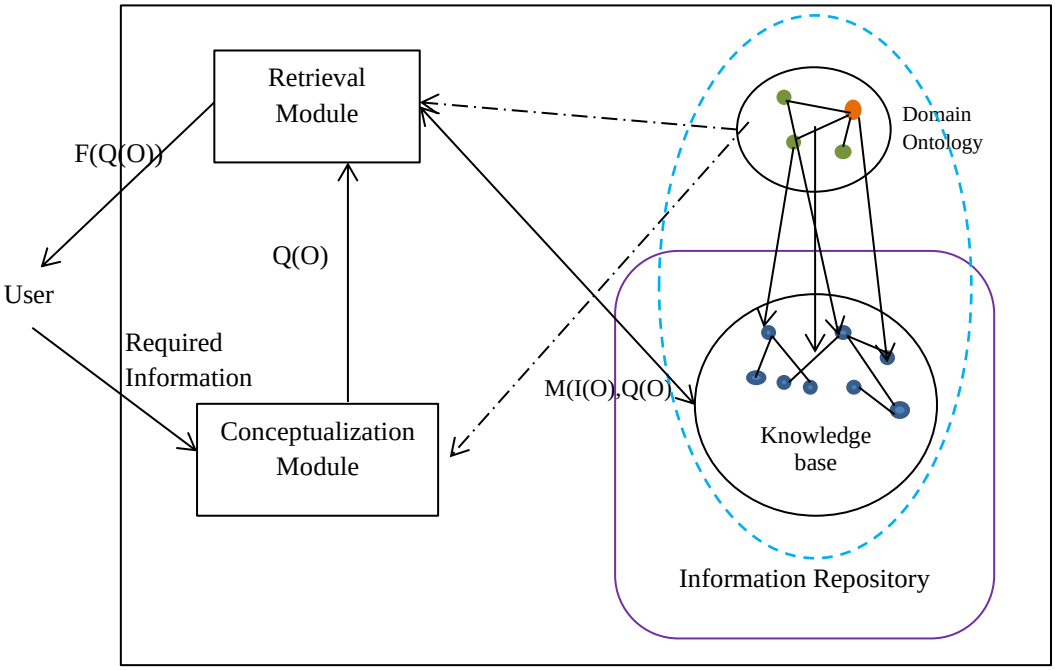


**Fig. 2.** Improved Ontology based Information Retrieval Model

In the context of ontology-based information retrieval (IR), this paper adopts a specific interpretation of the fundamental retrieval model. The representation is expressed as $L_{Res}$ = KB(O), where a resource is conceptualized as a collection of relation instances (facts) extracted from the corresponding knowledge base (KB). This collection can be viewed as a set of instance assertions. In this perspective, the relations (concepts) for which a fact is asserted to be an instance collectively form the comprehensive description of the resource. In the formulation $L_{Query}$ = Ω(O), a query is conceptualized as an ontology-based query denoted as Q(O). The rationale behind this choice is that all resources represented by facts retrieved for query Q(O), specifically the set of facts F(Q(O)), should be included in the retrieval.

Furthermore, in the equation IR = I(O) ⊆ $L_{Res}$, it is asserted that an information repository, or collection, encapsulates a set of all concept instantiations. This implies that the repository encompasses all instances corresponding to the represented concepts. The matching function, denoted as M(I(O), Q(O)), which assesses the compatibility between the repository and the provided query, is executed via logical inference defined by the logical language employed in representing the ontology denoted as O.

The semantic annotation is represented as I(O), query interpretation is represented as Q(O), matching function is

represented as M(I(O),Q(O)), ranking as R, and retrieval as (R,k).

$$A_i = \{(term, concept) | term \in I_i \; concept \; \epsilon \; O\} \quad (3)$$

Here, Ai represents the set of annotations for document Ii. The annotations link terms in the document to relevant concepts in the ontology.

$$Q(O) = QueryInterpretation\,(Q, O) \quad (4)$$

This formula signifies that the user's query Q is interpreted within the context of the ontology O, resulting in a representation Q(O) that aligns with the ontology's conceptual structure.

$$M\big(I(O), Q(O)\big) = MatchingFunction\big(I(O), Q(O)\big) \quad (5)$$

This equation signifies that the matching function M is applied to the annotated information repository I(O) and the interpreted query Q(O) to determine the relevance of each document in the repository to the user's query.

$$R = Ranking\left\{M\big(I(O), Q(O)\big)\right\} \quad (6)$$

In the above equation, the relevance scores obtained from the matching function are used to rank the documents.

Utilizing a logic-based matching function, the ontology-based retrieval model derives advantages from the impeccable precision and recall attained in logic-based retrieval. The Ontology-based Information Retrieval Model is a comprehensive approach that integrates various components to enhance the precision and relevance of information retrieval. Let's delve into the key elements of this model:

The user represents individual seeking information. Users express their information needs through queries, initiating the retrieval process. The conceptualization module is the initial phase where users formulate their information needs. Here, users translate their queries into a structured representation, often using keywords or phrases. This module plays a crucial role in shaping the direction of the subsequent retrieval process.

The retrieval module is responsible for executing the actual search based on the conceptualized query. It interfaces with the information repository and leverages the domain ontology to retrieve relevant documents. The retrieval module incorporates algorithms and models to match user queries with the knowledge stored in the repository.

The information repository is a database or collection of documents containing valuable information. This repository serves as the source from which the retrieval module extracts documents based on user queries. The efficiency of retrieval relies on how well the repository is indexed and organized.

The domain ontology is a structured representation of concepts, entities, and their interrelationships within a specific domain. It provides a formalized framework that enhances semantic understanding. The ontology assists in categorizing and relating information, enabling more accurate retrieval. Relationships within the ontology guide the retrieval module in determining the relevance of documents to user queries.

The knowledge base is the collective information derived from the domain ontology and the information repository. It includes structured data and relationships that contribute to the overall understanding of the domain. The knowledge base evolves as the system learns from user interactions and feedback.

### 3.1 Ontology-based Information Retrieval Model Workflow

User Conceptualization:

Users articulate their information needs through queries in the conceptualization module.

Query Translation:

The conceptualized query is translated into a format compatible with the ontology-based retrieval model.

Retrieval Process:

The retrieval module uses the translated query to search the information repository, applying logic-based matching against the domain ontology.

Semantic Understanding:

The domain ontology enhances semantic understanding, allowing the retrieval module to consider context, relationships, and hierarchies.

Precision and Recall:

The model aims for high precision and recall, ensuring retrieved documents are both accurate and comprehensive in addressing user needs.

Knowledge Base Enrichment:

User interactions and feedback contribute to the refinement of the knowledge base, continuously improving the system's performance.

## 4. Results and Discussion

The research presented in this study demonstrates a significant improvement in information retrieval systems through the integration of ontology-based semantic enrichment. The proposed approach involves the development and incorporation of domain-specific ontologies to enhance the semantic understanding of textual content. These ontologies serve as structured and hierarchical knowledge frameworks that define relationships among concepts within a given domain.

The integration of ontology-based semantic enrichment is shown to address the limitations of traditional keyword-based search methods. Keyword-based approaches often struggle to capture the intricacies of semantic relationships within a domain, leading to suboptimal retrieval results. In

contrast, the proposed method leverages ontologies to enrich the information retrieval process, providing a more nuanced and context-aware search experience.

Semantic annotations extracted from the ontologies play a crucial role in enhancing the representation of documents. This enrichment facilitates more precise matching of user queries with relevant content, thereby improving the overall effectiveness of the information retrieval system. The research emphasizes the importance of incorporating domain-specific ontologies to capture the unique semantics of different application domains.

Additionally, the study explores the integration of machine learning techniques to dynamically adapt and refine ontological structures over time. This adaptive approach ensures the system's capability to evolve with changing domains, maintaining a high level of accuracy and relevance in information retrieval.

The primary challenge in achieving effective retrieval lies in the inverse relationship between precision and recall. In other words, an increase in recall often leads to a decrease in precision, and vice versa, as depicted in Figure 3.

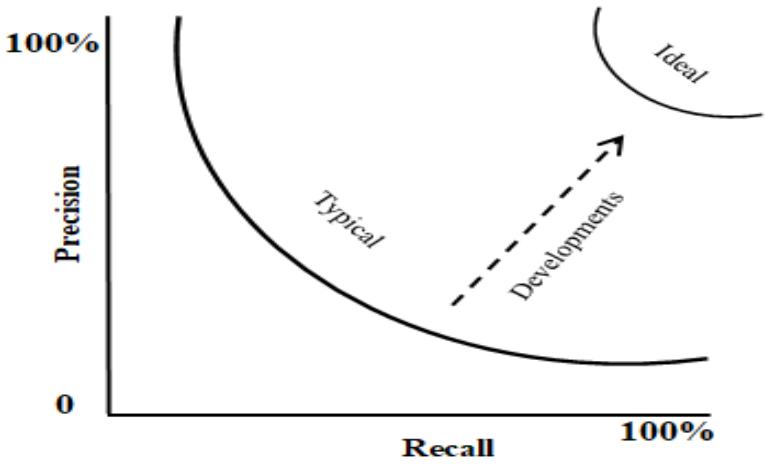


**Fig. 3.** Trade-off of Precision-Recall

The trade-off between precision and recall is a fundamental concept in information retrieval and machine learning. Precision and recall are two metrics used to evaluate the performance of classification or retrieval systems, and they often have an inverse relationship. Understanding this trade-off is crucial in designing systems that balance the need for accuracy and completeness. The trade-off between precision and recall is often visualized using a precision-recall curve. As one metric improves, the other tends to degrade, creating a trade-off scenario. Increasing precision typically involves being more conservative in predicting positive instances, which reduces the number of false positives but may miss some true positives. Increasing recall involves being more inclusive in predicting positive instances, capturing more true positives but potentially increasing the number of false positives.

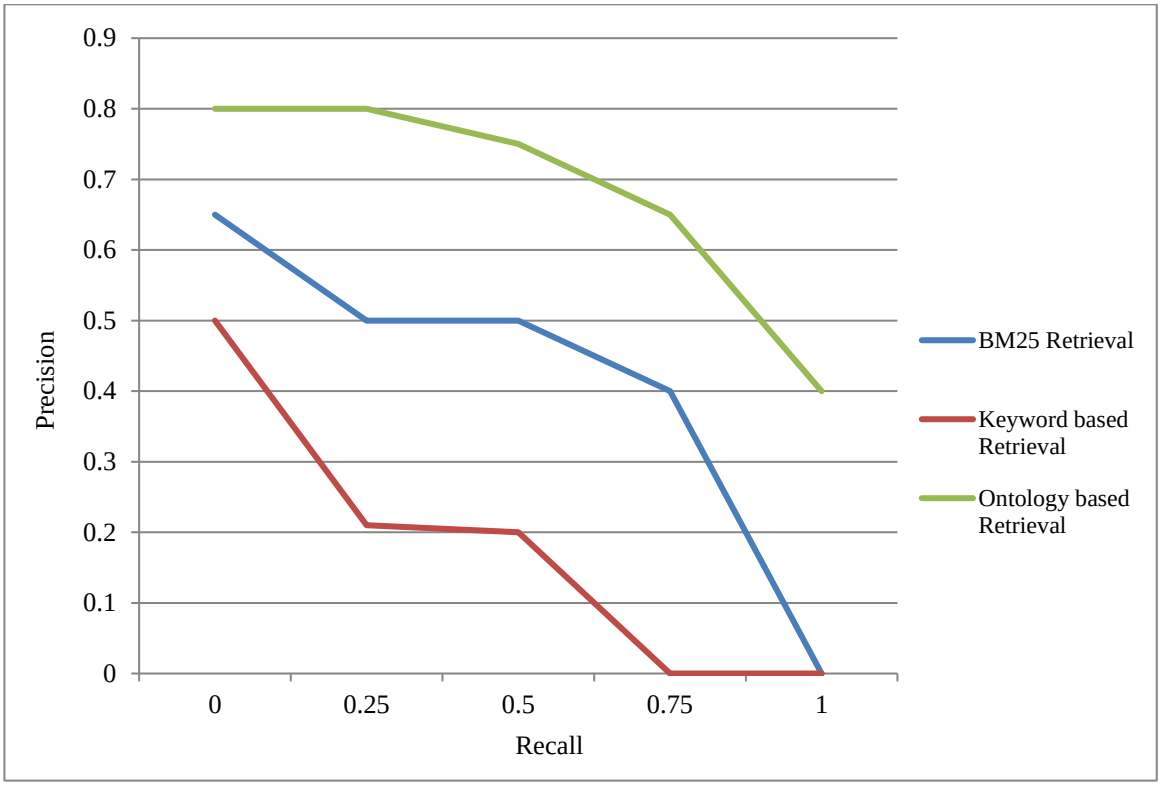


**Fig. 4.** Evaluation of Ontology based Retrieval with Existing Method

The findings of this research underscore the potential of ontology-based semantic enrichment in advancing information retrieval systems. By overcoming the limitations of traditional keyword-based methods, the proposed approach contributes to a more sophisticated and intelligent search mechanism. The structured nature of ontologies allows for a deeper understanding of the relationships among concepts, enabling a more nuanced interpretation of user queries and document content.

The metrics rely on a manual assessment, where all documents for each query are ranked on a scale from 0 to 5. In these experiments, a uniform weight of 1 was assigned to all query variables. Although the measurements are subjective and have limitations, they indicate the extent of improvement anticipated, particularly in comparison to a keyword-based engine. The outcomes are depicted in Figure 4. Based on this, the proposed ontology based information retrieval model outperforms the traditional retrieval models BM25 and keyword based retrieval.

The use of domain-specific ontologies proves crucial in capturing the domain-specific semantics, providing a tailored approach to information retrieval. This is particularly significant in diverse application domains where standard keyword-based methods may fall short of delivering relevant and contextually meaningful results.

The integration of machine learning techniques adds a layer of adaptability to the system. The ability to dynamically adapt and refine ontological structures over time ensures the longevity and relevance of the information retrieval system in the face of evolving domains. This adaptive feature contributes to the sustainability and effectiveness of the proposed approach in real-world applications.

The comprehensive experiments conducted to evaluate the effectiveness of ontology-based semantic enrichment demonstrate superior retrieval performance metrics compared to traditional methods. The results validate the hypothesis that a more semantic-aware approach leads to more meaningful and contextually relevant results for users.

In conclusion, the integration of ontology-based semantic enrichment in information retrieval systems holds significant promise for advancing the state-of-the-art. The proposed approach not only outperforms conventional keyword-based methods but also provides a foundation for more sophisticated and intelligent search mechanisms in diverse application domains. The research contributes to the ongoing efforts to enhance information retrieval systems, ultimately benefiting users seeking accurate and relevant content in the era of vast and heterogeneous information sources.

## 5. Conclusion

The research has extensively explored the complexities associated with improving information retrieval systems by integrating ontology-based semantic enrichment. Acknowledging the limitations inherent in traditional keyword-based approaches for capturing semantic relationships across diverse domains, this study introduced

an innovative method to overcome these challenges. The essence of this contribution lies in the development and integration of domain-specific ontologies—structured frameworks that delineate relationships among concepts. Through the incorporation of these ontologies, the goal was to enhance the semantic understanding of textual content, promising a search experience that is more nuanced and context-aware. Extracting semantic annotations from these frameworks aimed to further refine the representation of documents, allowing for a more precise alignment with user queries. Moving beyond the static integration of ontologies, the research has explored the dynamic adaptation and refinement of ontological structures. This forward-looking approach ensures the adaptability of the system to the evolving dynamics of different domains, thereby enhancing its longevity and relevance. The effectiveness of the proposed ontology-based semantic enrichment has undergone rigorous evaluation through comprehensive experiments. These experiments entailed a meticulous comparison of retrieval performance metrics against traditional methods, providing substantial evidence supporting the claim of superior performance.

**References**


[1] Guo, J., Fan, Y., Pang, L., Yang, L., Ai, Q., Zamani, H., Wu, C., Croft, W.B., & Cheng, X. (2020). A Deep Look into Neural Ranking Models for Information Retrieval. *Information Processing & Management*, *57*(6), 102067.

[2] Spyropoulos, A. Z., Bratsas, C., Makris, G. C., Garoufallou, E., & Tsiantos, V. (2023). Interoperability-Enhanced Knowledge Management in Law Enforcement: An Integrated Data-Driven Forensic Ontological Approach to Crime Scene Analysis. *Information*, *14*(11), 607.

[3] Lymperis, D., & Goumopoulos, C. (2023). SEDIA: A Platform for Semantically Enriched IoT Data Integration and Development of Smart City Applications. *Future Internet*, *15*(8), 276.

[4] Lee, J., & Song, J. (2023). Towards Semantic Smart Cities: A Study on the Conceptualization and Implementation of Semantic Context Inference Systems. *Sensors*, *23*(23), 9392.

[5] Bernasconi, E., Di Pierro, D., Redavid, D., & Ferilli, S. (2023). SKATEBOARD: Semantic Knowledge Advanced Tool for Extraction, Browsing, Organisation, Annotation, Retrieval, and Discovery. *Applied Sciences*, *13*(21), 11782.

[6] Liu, S., Chen, Y., Xie, X., Siow, J., & Liu, Y. (2020). Retrieval-augmented generation for code summarization via hybrid gnn. *arXiv preprint arXiv:2006.05405*.

[7] Jain, S., Seeja, K. R., & Jindal, R. (2021). A fuzzy ontology framework in information retrieval using semantic query expansion. *International Journal of Information Management Data Insights*, *1*(1), 100009.

[8] Hawalah, A. (2019). Semantic ontology-based approach to enhance Arabic text classification. *Big Data and Cognitive Computing*, *3*(4), 53.

[9] Sanagavarapu, L. M., Iyer, V., & Reddy, R. (2021). A deep learning approach for ontology enrichment from unstructured text. *arXiv preprint arXiv:2112.08554*.

[10] Zaeem, J. M., Garg, V., Aggarwal, K., & Arora, A. (2023, October). An Intelligent Article Knowledge Graph Formation Framework Using BM25 Probabilistic Retrieval Model. In *Iberoamerican Knowledge Graphs and Semantic Web Conference* (pp. 32-43). Cham: Springer Nature Switzerland.

[11] Chunhao Huang et al 2020 J. Phys.: Conf. Ser. 1607 012108

[12] Mhawi, DN., Oleiwi, HW., Saeed, NH., & Al-Taie, HL. (2022). An Efficient Information Retrieval System Using Evolutionary Algorithms. *Network*, *2*(4), 583-605.

[13] Ibrihich, S., Oussous, A., Ibrihich, O., & Esghir, M. (2022). A Review on recent research in information retrieval. *Procedia Computer Science*, *201*, 777-782.