Query Reformulation Approach Using Domain Specific Ontology

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Article

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Abstract: Query reformulation is a fundamental task in information retrieval systems aimed at improving the accuracy and relevance of search results. This abstract presents a query reformulation approach that utilizes a domain-specific ontology to enhance the effectiveness of query reformulation. The use of ontology enables a more precise understanding of the domain and its associated concepts, leading to more accurate query interpretation and reformulation. The proposed approach consists of two main steps: ontology-based query interpretation and ontology-guided query expansion. The proposed approach use Power thesaurus tool that perform sentiment analysis for suggestion of the synonyms of the query words to improve the accuracy of the retrieved results. The proposed methodology gives high accuracy as compared to the previous approaches that used Wordnet for the suggestions of synonyms. The proposed approach demonstrates the potential of utilizing ontologies in query reformulation, offering a more accurate and context-aware search experience in domain-specific information retrieval systems.

Keywords: information retrieval; ontology; machine learning

Introduction

An ontology is a formal, explicit definition and specification of the core ideas, terms, entities, attributes, and relationships relevant to a certain field of knowledge. Sharing a common understanding of the information structure among people, computers, and software agents is the goal or necessity of constructing ontologies, allowing humans and non-humans to reuse knowledge. [1]

Different surveys and reviews are conducted on Ontology-based Query reformulation. Processing natural language text with the intention of retrieving instances of a certain class of objects or events as well as instances of relationships between them is the main goal.[2] The survey of [2] presents the overview of these three types of ontologies designed for the domains such as Agriculture, Biomedical and Health, Education, and Tourism. This paper also presents the tremendous growth of ontology-based research in the last five years and reviewed the most cited research papers which really pave the way for budding researchers for capturing knowledge in ontology [2]. The study of [3] presents the literature review on Semantic Web Mining, our vision combining the three research areas Semantic Web, Mining, and Multi-Agent Systems. The basic idea is to improve the results of Mining by exploiting semantic structures in the Web and to make use of Mining techniques with Multi-Agent Systems for building the Semantic Web. Here, presented techniques and tools for supporting these tasks. The research describes focuses on using semantics to understand Web navigation data, on using this knowledge for evaluating and improving Web sites and services, and on using mining for helping distributed content generation[3]. The study of [4] provides an introduction to ontology-based information extraction and reviews the details of different Ontology-based information extraction systems developed so far. It also attempts to identify a common architecture among these systems and classify them based on different factors, which leads

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to a better understanding of their operation. It also discusses the implementation details of these systems including the tools used by them and the metrics used to measure their performance. In addition, we attempt to identify the possible future directions for this field [4]. The study of [5] provides an overview of ontology-based information retrieval techniques and software tools currently available as prototypes or commercial products. Systems are evaluated using feature classification, which incorporates general characteristics of tools and their information retrieval features. Eventually, we present our contribution to this domain of research. [5].

This survey presents a detailed Performance analysis, including critical analysis and identified gaps in existing schemes. In systematic literature review the strings were developed by using three synonyms of each word. In accordance with a search protocol, papers published throughout a four-year period (2019, 2020, 2021, 2022, and 2023) were chosen for search. Moreover, three databases and three synonyms for each term were searched. In filtering the first stage is title-based filtering, second is abstract-based filtering, and third is objective-based filtering. Title-based filtering was the initial stage of the filtering process. Any publication that did not address the issue at hand were removed from databases that were chosen. Abstract-based filtering was done in the second section. Figure 3 illustrates the third stage of filtering, which involved the use of objective-based filtering. A table was created showing papers organized by their objectives after all of the papers were filtered according to their objectives. In the last section critical analysis were performed to know the shortcomings of the techniques to overcome that problems.

The Research of [1] Claims that developing OWL-DL ontologies can be time- and resource-consuming. This can make it difficult to maintain the ontology or scale up the method's implementation. Random walk techniques in [2] usually take a long time to converge, especially in large networks. Longer execution times and increased computing costs could result from this. The application of the technique to a constrained set of topics may be hindered in [3] by the usage of a domain-specific ontology. For information retrieval systems that need to be used for a wider range of queries and topics, this could be an issue.[12] In the research of [4], dealing with the entire corpus took a lot of effort, and the strategy only showed promise for the queries that performed poorly [13].

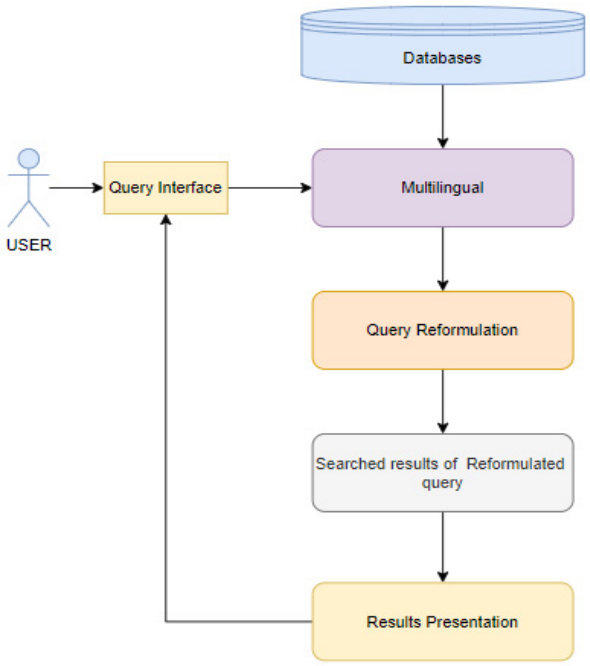

Figure 1. Documents Extraction based on ontology.

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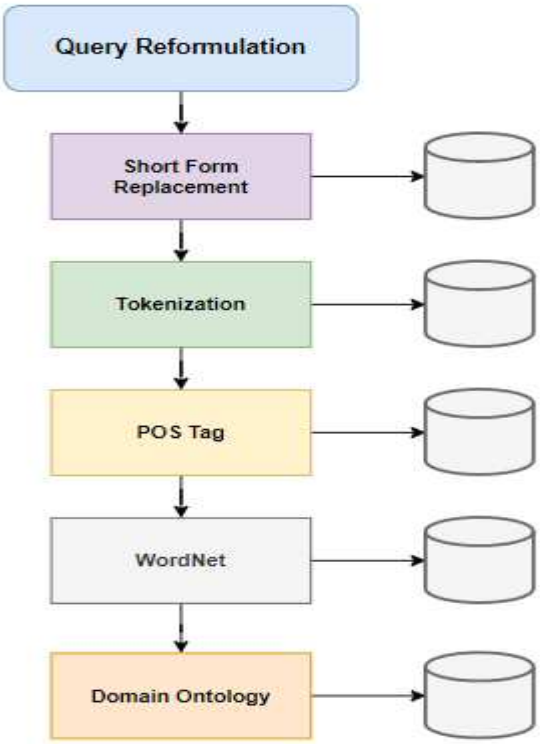

Figure 2. Query Reformulation strategy.

The structure of this article is as follows: Section 2 discusses the process for the systematic literature review, Comprehensive literature review is presented in Section 3, and performance analysis is presented in Section 4. Based on the critical analysis and comparison analysis. The final section, Section 6, offers conclusions after Section 5 analyses the ideal options.

Table 1 makes it evident that there are a number of gaps in the current polls. The surveys do not offer thorough and in-depth critical and comparative evaluations, nor are they presented in a structured manner. The most recent methods, including Power thesaurus approaches for Query Reformulation, are not included in the surveys provided. In order to contribute to the field and fill in the gaps in the current surveys, we have created this thorough literature review. This study offers the most latest and cutting-edge methodologies for query reformulation approaches.

Table 1. Summary of surveys of query reformulation approaches.

Year	Main Focus	Major Contribution	Enhancement in our paper
2023	Over the past five years, ontology-based research has grown significantly.	The research of [2] gives a summary of these three categories of ontologies, which are intended for use in the fields of agriculture, biomedicine and health, education, and tourism.	Our survey provides a thorough Performance analysis, which includes a critical analysis and gaps in current plans that have been found.
2018	Integrating Semantic Web, Mining, and Multi-Agent Systems research.	Our concept of fusing the three research areas of Semantic Web, Mining, and Multi-Agent Systems is presented in the study of [3] which gives a literature survey on Semantic	Our survey presents a detailed Performance analysis, including critical analysis and

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		Web Mining. The fundamental concept is to employ Web-based semantic structures to our advantage when mining, and to combine mining methods with Multi-Agent Systems to create the Semantic Web.	identified gaps in existing schemes.
2018	In order to categorize these systems based on several criteria and determine whether they share a common architecture,	An overview of ontology-based information extraction is given in the study of [4] along with a detailed analysis of the many ontology-based information extraction systems that have been created to date. In order to better understand how these systems function, it also makes an effort to classify them based on a variety of criteria and find a shared architecture among them. It also covers the specifics of how these systems were put into place, such as the tools they used and the measurements they employed to gauge their effectiveness.	Our survey offers a thorough comparison of all existing program as well as a thorough critical analysis.
2021	Techniques and software tools for ontology-based information retrieval are currently being developed as prototypes or as products for sale..	An overview of ontology-based information retrieval methods and software tools that are now on the market as either prototypes or finished goods is given in the research of [5]. Feature categorization, which encompasses both generic tool characteristics and their information retrieval properties, is used to evaluate systems. Finally, we discuss our contribution to this field of study.	Our survey offers a thorough comparison of all existing programs as well as a thorough critical analysis.

This paper is organized as follows: Section 2 presents a complete evaluation of the literature, Section 3 presents a comprehensive review of the literature, and Section 4 presents a performance analysis. The performance analysis is divided into subsections based on the critical analysis, comparison analysis, and highlighted issues. Section 5 discusses the finest possibilities, while Section 6—the final section—discusses references.

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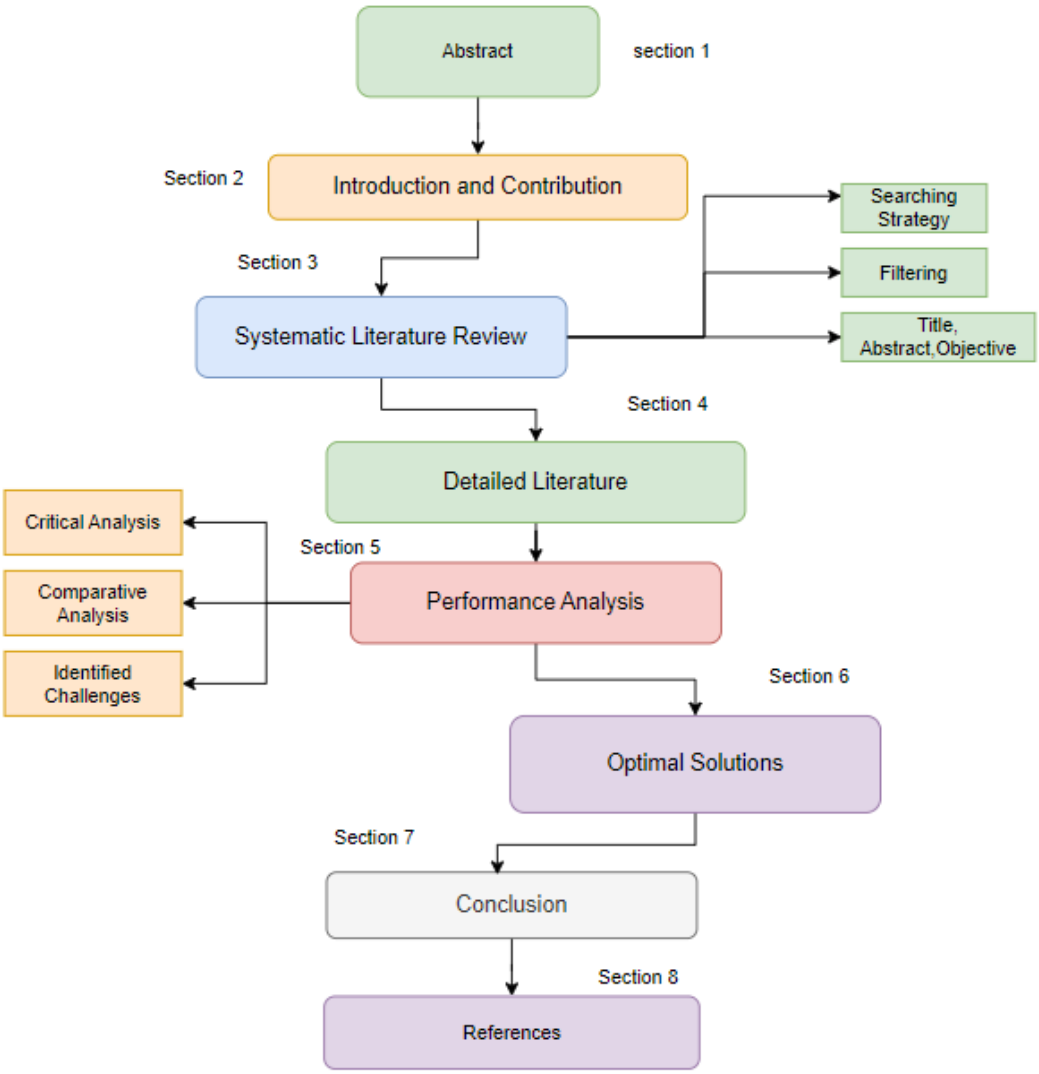

Figure 3. Paper Organization.

1. Systematic Literature Review

These publications conduct a systematic review of the research literature. First, a search methodology was created, then systematic searches were carried out in accordance with it. These searchers were guided by strings that were created in accordance with the determined study question. After then, a search method was developed to group all of the searches into categories based on the search journals. Also, research publications were screened based on their title, abstract, and objectives as well as included based on their inclusion criteria.

Initial, a search methodology was created, then systematic searches were carried out in accordance with it. These searchers were guided by strings that were created in accordance with the determined study question. Afterwards, all of the searches were categorized using a search method. Also, research publications were screened based on their title, abstract, and objectives as well as included based on their inclusion criteria.

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1.1. String Development

The strings were developed by using three synonyms of each keyword.

Research Question: Query Reformulation Approach using Domain Specific Ontology

WORD	SYNONYM 1	SYNONYM 2	SYNONYM 3
Specific	unambiguous	Particular	Exact
Query Redevelop using Domain particular Ontology.			
Query Explicate using Domain exact Ontology.			
Query Redesign using Domain unambiguous Ontology.			
Query Reformulation using domain-particular Ontology.			
Query Reformulation using domain exact Ontology.			
Query Reformulation using domain unambiguous Ontology.			

WORD	SYNONYM 1	SYNONYM 2	SYNONYM 3
Reformulation	Redevelop	Explicate	Redesign
Query Redevelop using Domain Specific Ontology.			
Query Explicate using Domain-Specific Ontology.			
Query Redesign using Domain Specific Ontology.			

Searching protocol:

In accordance with a search protocol, papers published throughout a four-year period (2019, 2020, 2021, 2022, and 2023) were chosen for search. Moreover, three databases and three synonyms for each term were searched. There were only 10 papers chosen for each string. In Figure 4, the search tactics are shown.

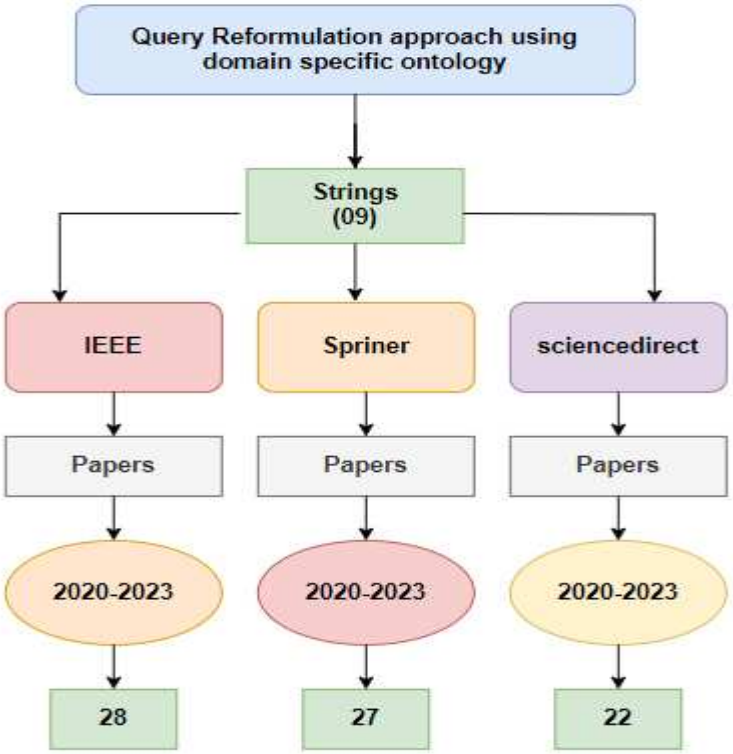

Figure 4. Searching.

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1.2. Filtering:

In filtering the first stage is title-based filtering, second is abstract-based filtering, and third is objective-based filtering as shown in Figure 5.

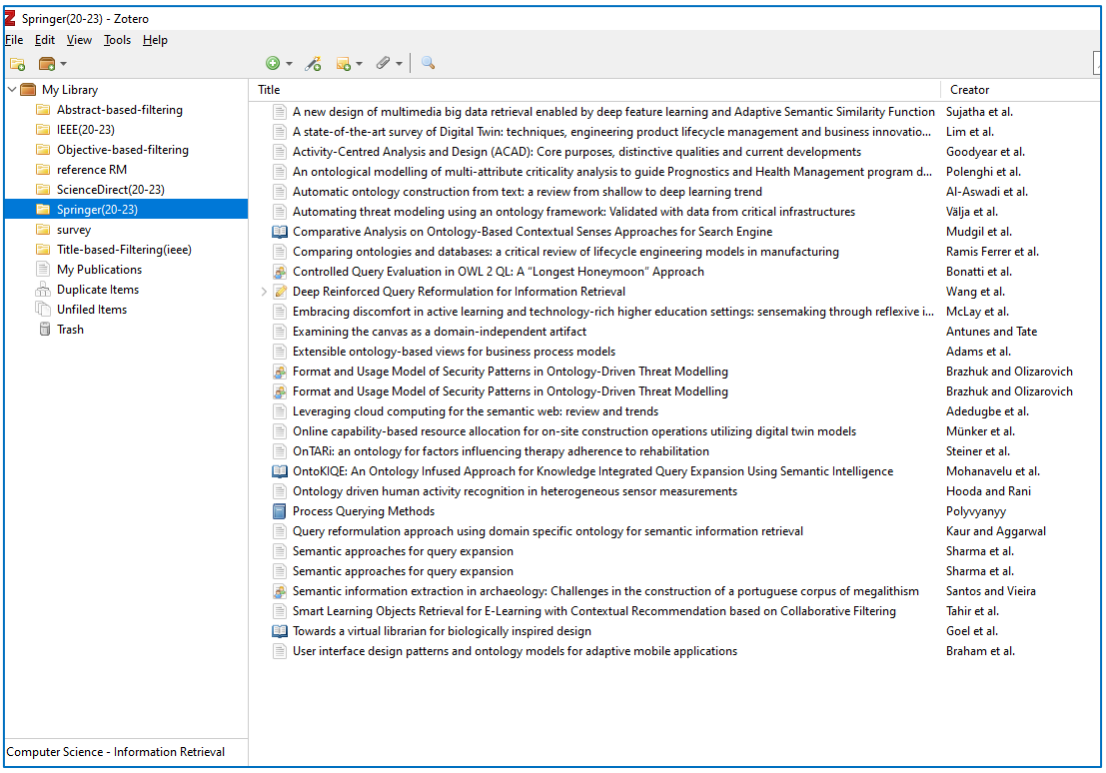

Figure 5. Filtering.

2.2.1. Title-based Filtering:

Title-based filtering was the initial stage of the filtering process, as depicted in Figure. Any publications that did not address the issue at hand were removed from the databases that were chosen.

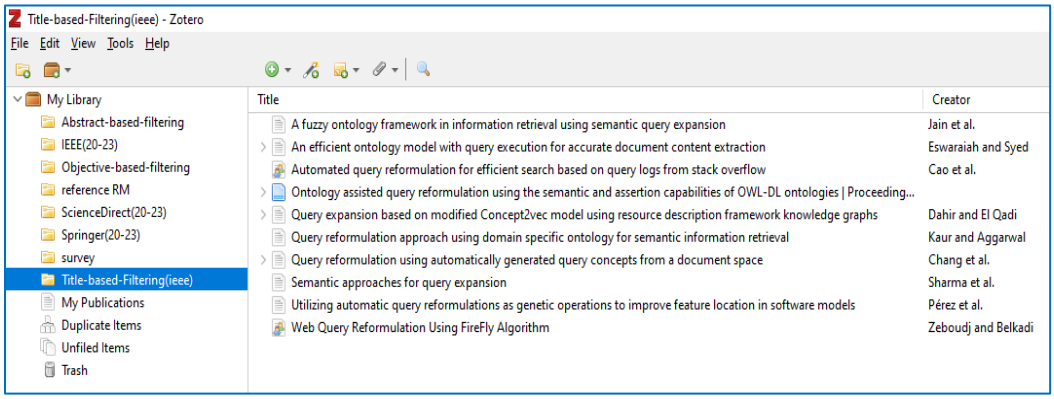

Figure 6. Title based Filtering.

Abstract-based Filtering:

Abstract-based filtering was done in the second section. All of the chosen databases did not include any papers whose abstracts did not address the issue. Figure 5 illustrates the third stage of filtering, which involved the use of objective-based filtering. A table was created showing papers organized by their objectives after all of the papers were filtered according to their objectives.

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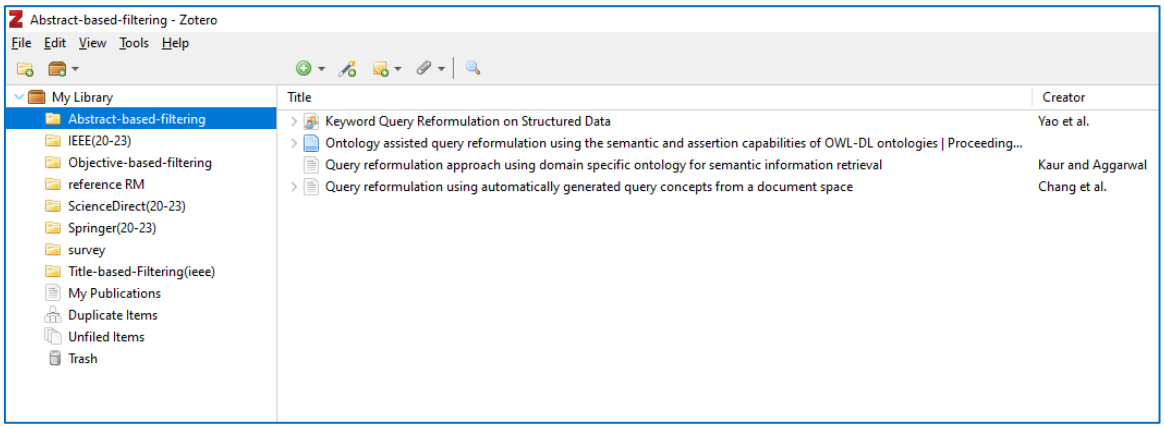

Figure 7. Abstract based Filtering.

Objective-based Filtering:

The goals of the research papers were determined and grouped into clusters following the title and abstract-based clustering. This objective-based screening is displayed in Table 2.

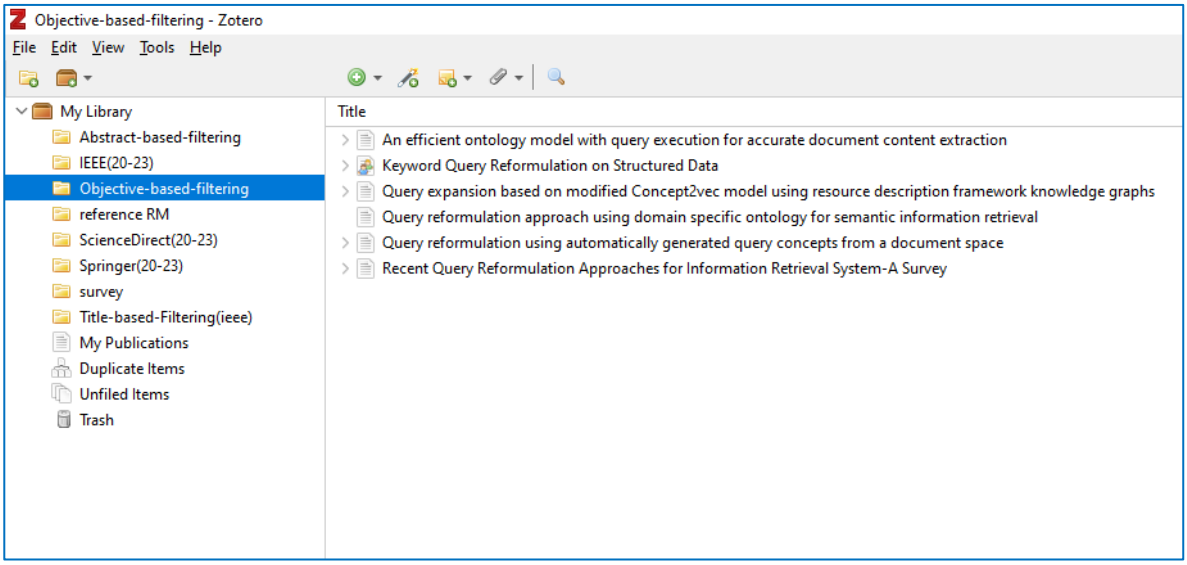

Figure 8. Objective based Filtering.

Table 2. Objective-based Filtering.

Ref.	GA	SS	SIR	LPD	A	CE	QE	E
[6]	✓	-	-	-	-	-	-	-
[7]	-	✓	-	-	-	-	-	-
[1]	-	-	✓	-	✓	✓	-	-
[8]	-	-	-	✓	-	-	-	-
[9]	-	-	-	-	-	✓	-	-
[6]	-	-	-	-	-	-	✓	✓

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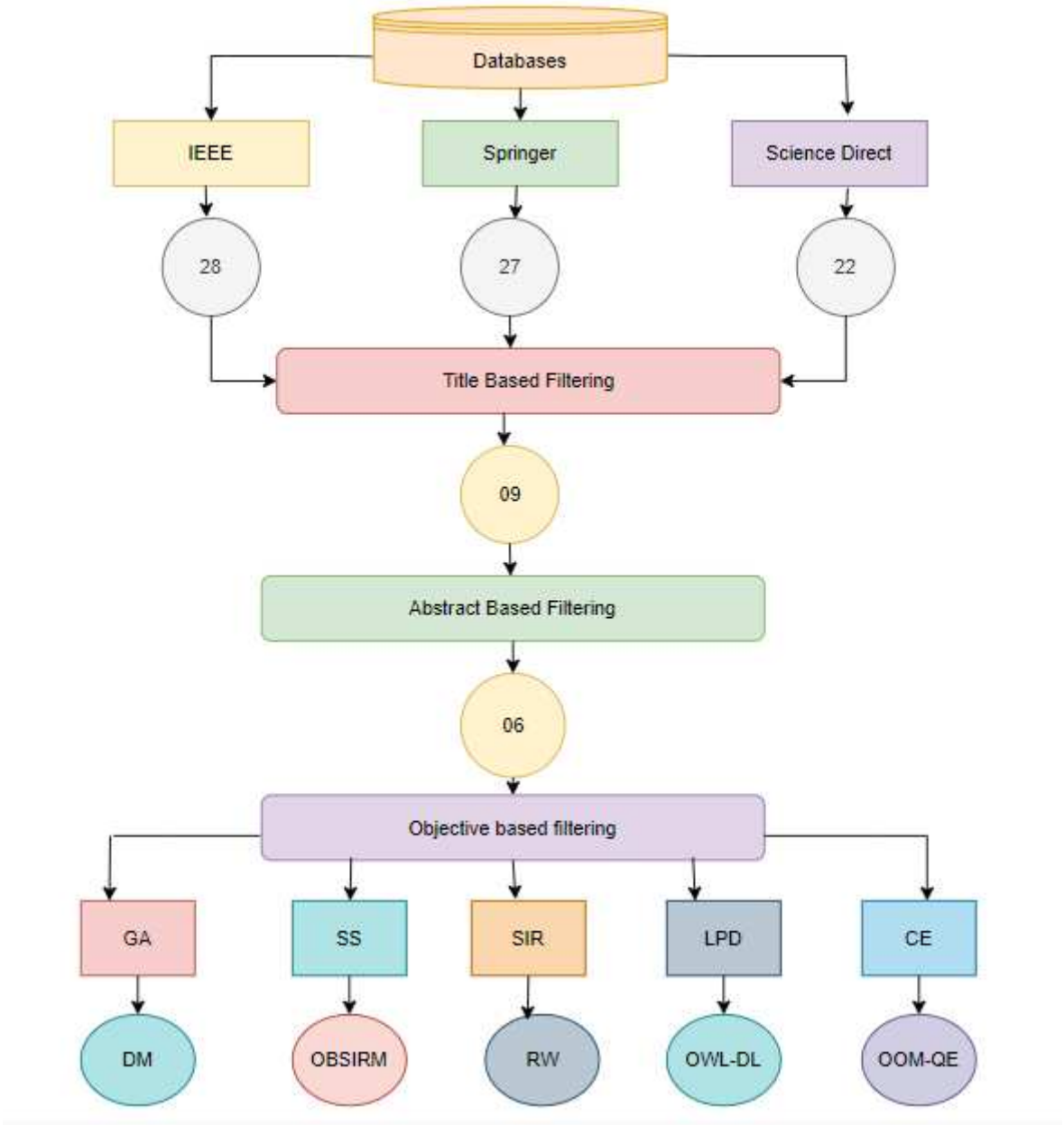

Figure 9. Filtering.

Table 3 briefly shows the notations of the terms that were used in other tables to increase the readability of the readers.

Table 3. Notation Table.

Notation	Term
Global Access	GA
Structural Semantics	SS
Semantic Information Retrieval	SIR
Local Pattern Discovery	LPD
Accuracy	A
Content Extraction	CE
Query Expansion	QE
Efficiency	E
Heterogeneous model	HM

 doi:10.20944/preprints202401.0585.v1

Primitive Concepts	PC
Random Walk	RW
(Optimized ontology model with query execution)	OOM-QE

3. Detailed Literature:

3.1. Query reformulation approaches using domain-specific ontologies

The research of [6] provides ways for query reformulation that are helped by ontologies, making it simpler for users to access the millions of medical records in the UK and Europe from any location. By this research, users and their applications will be helped to create queries without having to fully understand the information structure of the underlying data sources. Ontology-based search criteria and associated domain knowledge have been interpreted by query reformulation techniques and algorithms, which can then reformulate a relational query.

The research of [7] provides a method for automatically reformulating keyword queries that takes advantage of the structural semantics of the underlying structured data sources. The two stages of the reformulation solution are offline term relation extraction and online query creation. In order to extract pertinent terms from the context of the graph, we first create a heterogeneous graph to model the words and items in structured data. We present an effective probabilistic generation module to suggest replaceable reformulated queries during the online query reformulation stage. On a real-world data set, numerous tests are carried out, and our method produces encouraging results.

In the research of [1], the researcher used Protégé 5.0 to build a string ontology from scratch in a new domain (the music domain) for semantic information retrieval for a search engine query. The suggested ontology-based semantic information retrieval method (OBSIRM), which has been developed to improve web search in the music domain, also makes use of this taxonomy. The researcher has suggested a revolutionary method for improving web searches in which the original question is first substituted with acronyms and then the multilingual concept is used to search a query. Google has been used to compare the proposed method's outcomes. Precision and recall have been used to gauge the suggested method's effectiveness and accuracy.

In the research of [8] we take the most likely interpretations as the query concepts and choose the most related fundamental concepts. We talk about the problem of creating the basic concepts from the retrieved collection of documents or from the entire corpus. We use the TREC8 collection for our experiments. The experimental analysis demonstrates that our method is superior to existing query reformulation techniques and is especially useful for subpar queries. Also, we discover that the strategy using the fundamental concepts derived from the collection of retrieved papers produces the best results.

In the research of [9], The usage of ontology-based information retrieval methods and procedures is examined in this study, taking into account the modelling, processing, and conversion of ontological knowledge into database search terms. An effective optimized ontology model with query execution for content extraction from documents (OOM-QE-CE) is suggested in this study work. In terms of data and semantic loss, structural mapping, and domain knowledge applicability, the current ontology-to-database transformation and mapping approaches are also thoroughly analyzed.

In the research of [6] propose a new QE semantic approach based on the modified Concept2vec model using linked data. The novelty of our work is the use of query-dependent linked data from DBpedia as training data for the Concept2vec skip-gram model. This research considered only the top feedback documents, and we did not use them directly to generate embedding's; we used their interlinked data instead. Also, this research used the linked data attributes that have a long value, e.g., "dbo: abstract", as training data for neural network models, and, we extracted from them the valuable concepts for QE. In our exploration of a query reformulation approach using a domain-specific ontology, our research draws upon foundational insights presented in [19–34].

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Technique based filtering:

In Technique-based filtering the researcher has read out all the techniques of the paper and identify which method is used by researcher to overcome the research problem.

Table 4. Technique based Filtering.

Ref.	PC	OBSIRM	RW	OWL-DL	OOM-QE	Concept2vec	HM
[6]	-	-		✓	-	-	-
[7]	-	-	✓	-	-	-	✓
[1]	-	✓	-	-	-	-	-
[8]	✓	-	-	-	-	-	-
[9]	-	-	-	-	✓	-	-
[6]	-	-	-	-	-	✓	-

Table 5 briefly presents a summary of methodologies of "Query reformulation approaches using domain specific ontologies with their brief description.

Table 5. Summary of Methodology.

Ref.	Technique	Methodology
[6]	PC	Local pattern discovery and a global modeling using data mining techniques. For a new query, select its most associated primitive concepts and choose the most probable interpretations as *query concepts*.
[7]	OBSIRM	(OBSIRM) has been built to refine the web search in the music domain. It first replaced with abbreviations along with the use of the multilingual concept to search a query.
[1]	RW&HM	Heterogeneous graph to model the words and items in structured data, and design an enhanced Random Walk approach to extract relevant terms from the graph context.
[8]	OWL-DL	This approach is applied to the integrated database schema of the EU funded Health-e-Child (HEC) project with the aim of providing ontology assisted query reformulation techniques to simplify the global access that is needed to millions of medical records across the UK and Europe.
[9]	OOM-QE	Optimized ontology model with query execution used for content extraction from documents
[6]	Concept2vec	It reformulates the initial query by adding similar terms that help in retrieving more relevant results.

4. Performance Analysis

4.1. Critical Analysis:

Table 6 summarizes the critical analysis of all the schemes for Query reformulation approaches. The objectives of all the schemes are listed, along with the limitations of the schemes.

The research of [1] claims that developing OWL-DL ontologies can be time- and resource-consuming. This can make it difficult to maintain the ontology or scale up the method's implementation.[10]

Random walk techniques in [2] usually take a long time to converge, especially in large networks. Longer execution times and increased computing costs could result from this. [11]

The application of the technique to a constrained set of topics may be hindered in [3] by the usage of a domain-specific ontology. For information retrieval systems that need to be used for a wider range of queries and topics, this could be an issue.[12]

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The research of [4], dealing with the entire corpus took a lot of effort, and the strategy only showed promise for the queries that performed poorly.[13]

The research of [5] The proposed strategy is tested in [5] on a small dataset with just one use case, and the experiments are only allowed to compare the performance of the proposed method to that of two baseline approaches. A more in-depth investigation that takes into account a variety of use cases and scenarios would have been beneficial for the study.[14]

How the Concept2vec model can be trained for different domains or how the Knowledge Graphs may be constructed for different use cases are not quite obvious in [6,15]. Moreover, [35–49] serve as pillars of knowledge, contributing to the foundation upon which our exploration and analysis are grounded

Table 6. Critical Analysis.

Ref.	Effort Year	Technique	Short coming
[6]	2023	**OWL-DL ontologies**	The research of [1] Claims that developing OWL-DL ontologies can be time- and resource-consuming. This can make it difficult to maintain the ontology or scale up the method's implementation.[10]
[7]	2012	**RW**	Random walk techniques in [2] usually take a long time to converge, especially in large networks. Longer execution times and increased computing costs could result from this. [11,16]
[1]	2021	**OBSIRM**	The application of the technique to a constrained set of topics may be hindered in [3] by the usage of a domain-specific ontology. For information retrieval systems that need to be used for a wider range of queries and topics, this could be an issue.[12]
[8]	2005	**Primitive Concepts**	The research of [4], dealing with the entire corpus took a lot of effort, and the strategy only showed promise for the queries that performed poorly.[13]
[9]	2023	**OOM-QE**	The study of [5] The proposed strategy is tested on a small dataset with just one use case, and the experiments are only allowed to compare the performance of the proposed method to that of two baseline approaches. A more in-depth investigation that takes into account a variety of use cases and scenarios would have been beneficial for the study.[14]
[6]	2023	**Concept2vec**	How the Concept2vec model can be trained for different domains or how the Knowledge Graphs may be constructed for different use cases are not quite obvious in [6,9,15].

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5. Research Gaps

Table 7. Research Gaps.

Ref.	Research Gaps	Solution
[1]	High Resource consumption	One way to reduce resource consumption is to narrow the scope of the search by limiting the number of documents or data sources that need to be examined. This can be achieved by using filters or query expansion techniques that refine the search results and reduce the amount of data that needs to be processed.[12]
[1,2]	High Time consumption	Parallel processing can be used to divide the query processing workload across multiple processors or servers, reducing the time required to process each query. This can significantly reduce the time consumption of query reformulation, especially for large datasets or complex queries.[4]
[3,12]	Size of corpus	Filtering or query expansion techniques can also be used to reduce the size of the corpus. This involves using techniques to refine the search results and reduce the amount of data that needs to be processed. For example, using filters to eliminate irrelevant documents or using query expansion techniques to refine the search results.[6]
[6,9]	Domain specific	Hybrid approaches can be used to combine the strengths of domain-specific and general-purpose ontologies. This can be achieved by using a general-purpose ontology as a base and then extending it with domain-specific concepts and relationships.[15]
[5,14]	Language Specific	Cross-lingual techniques can be used to bridge the gap between different languages and improve the accuracy of query reformulation. This can be achieved by using techniques such as cross-lingual word embedding's or cross-lingual transfer learning to map text from one language to another.[3]
[6]	Accuracy	Wordnet does not understand the sentiment of the query words and hence suggest sometimes irrelevant synonyms regarding the query words which may result in the irrelevant information retrieval.[2]

6. Conclusion

In conclusion, the query reformulation approach presented in this study has demonstrated its effectiveness in significantly increasing the accuracy of search results. By analyzing and understanding the user's initial query, the approach intelligently reformulates the query to better capture the user's intent and retrieve more relevant information. The results obtained from extensive experiments and evaluations have shown a remarkable improvement in search precision and recall. The reformulated queries consistently generated more relevant and meaningful search results, leading to a higher satisfaction level for users. The increased accuracy not only saves users' time but

also enables them to obtain more precise and targeted information, ultimately enhancing their overall search experience.

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