



Article

Comprehensive Review and Future Research Directions on Dynamic Faceted Search

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Abstract: In modern society, the increasing number of web search operations on various search engines has become ubiquitous due to the significant number of results presented to the users and the incompetent result-ranking mechanism in some domains, such as medical, law, and academia. As a result, the user is overwhelmed with a large number of misranked or uncategorized search results. One of the most promising technologies to reduce the number of results and provide desirable information to the users is dynamic faceted filters. Therefore, this paper extensively reviews related research articles published in IEEE Xplore, Web of Science, and the ACM digital library. As a result, a total of 170 related research papers were considered and organized into five categories. The main contribution of this paper is to provide a detailed analysis of the faceted search's fundamental attributes, as well as to demonstrate the motivation from the usage, concerns, challenges, and recommendations to enhance the use of the faceted approach among web search service providers.

Keywords: academic search engines; exploratory search; faceted navigation; faceted search; faceted taxonomy; information filtering; web technologies



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1. Introduction

Search Engines (SEs) have become some of the most necessary tools for Internet users. Generally, an SE is an information retrieval (IR) application that locates the most relevant information and then accurately conveys the results to the users based on the specified queries [1–5]. Meanwhile, exploratory search (ES) has a similar mechanism as SEs except that it further narrows down the search results using faceted classification. It, therefore, has the potential to give a complete overview of a topic based on fewer queries [6,7]. However, both SEs and ES have specific issues, such as the user's poor vocabulary and search-result overload challenges [8].

Faceted search (FS) is considered as one of the ES techniques that aids users in exploring items of interest within such a vast data repository. The FS technique provides relevant results with less user effort and reduces information overload [9,10]. Several conventional search filters could narrow down the search results; however, FS is more effective and highly flexible compared to conventional filters, especially with increased search complexity. Moreover, the interface of FS contributes to preventing users from losing track of their searches. Therefore, FS has received significant attention from researchers in the last decade [11,12].

The main research objective of this work is to determine the requirements and motivations that enhance the understanding of the FS implementation. The work reviews related works based on several perspectives, including (1) the scope of research, (2) the purpose of the study, and (3) the performance evaluation measures. Moreover, the work considered some other points of interest, including the architecture, applications, issues, research questions, motivation, recommendation criteria, and open challenges in using FS. This paper applies the Systematic Literature Review (SLR) method provided by [13–15] to analyze the existing literature. The SLR method is suitable for pinpointing the main idea of FS and is used to refine and provide a landscape for future research to identify relevant issues, challenges, and the line of research in FS. The remainder of this paper is organized as illustrated in Figure 1.

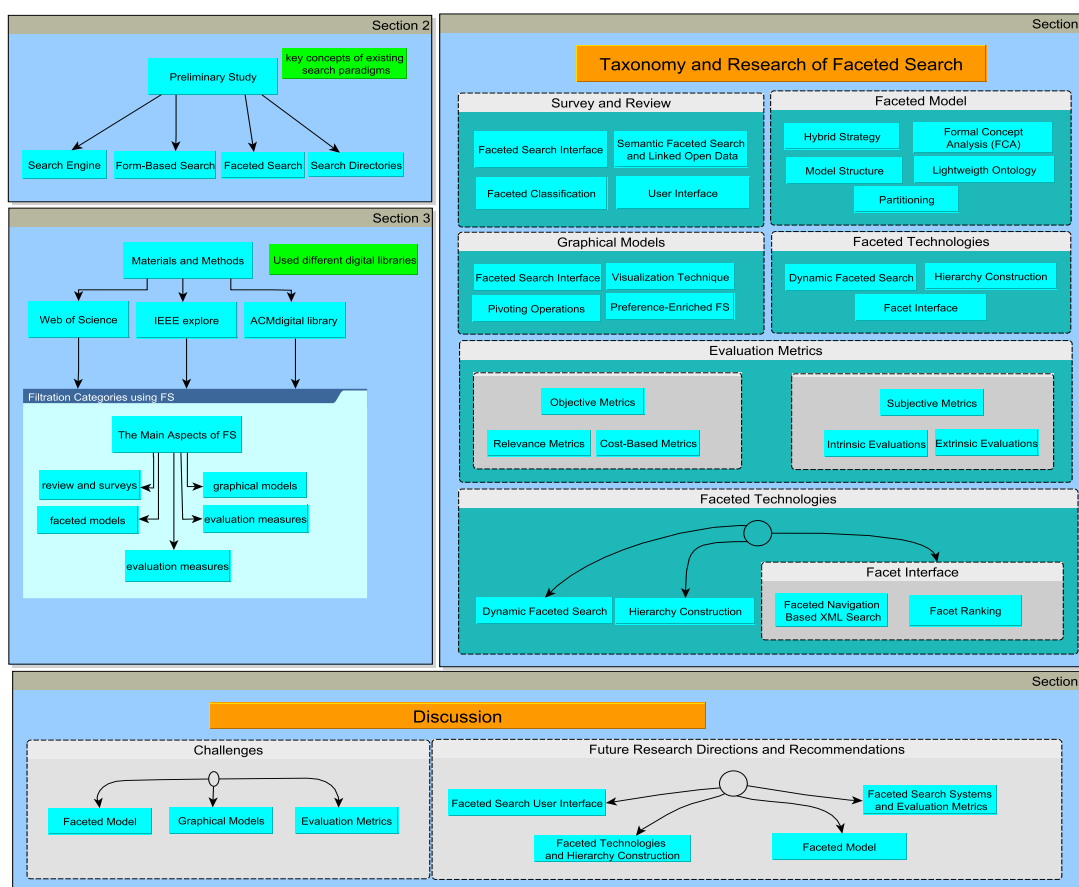


Figure 1. Diagrammatic view of the organization of this survey paper.

2. Preliminary Study

This section presents the fundamental concepts of some existing search paradigms, including SEs, search directories, form-based search, and FS. Then, a comparative study of these search paradigms is presented.

2.1. Search Engines

The main workflow of any conventional search engine is collecting keywords from the websites' index pages, whereas a web crawler finds information to put into the index file. Although most conventional search engines follow standard methods, they may still use different features, algorithms, pages, or files to optimize the results. Moreover, they usually utilize different ranking algorithms to determine the order of the results based on predefined criteria.

2.2. Search Directories

Search directories perform the same function as SEs, but they do not use computers to rank pages; instead, they utilize crowdsourcing for page ranking. People visit the submitted site and approve the site for a relevant directory. Yahoo! Directory was one of the best-known examples of search directories, although many people confuse it with an SE.

2.3. Form-Based Search

This approach supports an advanced query interface to perform complicated searches. The full-text search dialogue box runs in a form-based tab. Using multiple queries can narrow the search by selecting categories in the full-text search tab in the search pane. Once the user understands how to use the search operators, the user can also type different search queries in the full-text search tab.

2.4. Faceted Search

The term facet means “little face” and is often used to describe one side of a many-sided object, especially a cut gemstone. In the context of information science, where the item being described is an information object, facets could refer to the object’s author, date, topic, etc. The term was introduced by Ranganathan, an Indian mathematician, when he presented a facet analysis theory in the 1930s [16]. Ranganathan applied the principles of faceted classification to organize all of the human knowledge in libraries using five main facets, including (1) personality, (2) matter or property, (3) energy, (4) space, and (5) time.

Faceted search is a technique that involves enhancing conventional search engines by integrating an improved navigation system. This allows users to narrow down search results by applying multiple filters based on suggested categories. A faceted classification system semantically categorizes the search results into various explicit dimensions, called facets, enabling the categories to be accessed and ordered in multiple ways rather than in a single, predetermined taxonomic order [17,18]. Several faceted search systems have been designed and deployed during the last two decades. It is worth mentioning that the system’s success in supporting end-users depends on the details of the domain of interest (e.g., searcher’s tasks, familiarity with the facets, etc.). A summary of the essential components of faceted search is outlined in Figure 2 below. Most faceted search-enabled engines show the query, the facet structure, the previously specified subset of results, and sometimes, a detailed view of an individual item. Furthermore, Table 1 lists the comparison between FS with other search paradigms, which clearly shows the main characteristics of these search mechanisms.

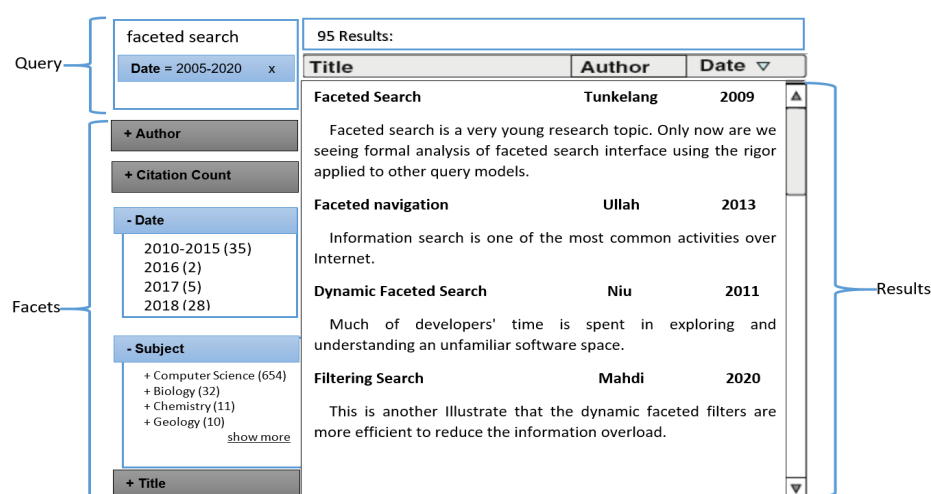


Figure 2. Faceted search, interface example, illustrating facet browsing, searching, and the tight coupling of the two.

Table 1. Comparison of faceted search with other search paradigms.

Criteria	Faceted Search	Search Engine	Search Directories	Form-Based Search
Search Interface	It uses dynamic and multidimensional taxonomies to satisfy various search needs [19].	Crawlers visit a website, read the information on that site and the meta tags and download documents. Then, the crawler returns all the information to a central repository of the SE, which indexes the data, for example Google.	A directory offers a hierarchical representation of hyperlinks to web pages and presentations, broken down into topics and subtopics.	It provides multiple query options.
Support Previous Knowledge	Handles uncertainty in the search and the possible lack of knowledge [7].	It searches documents for specific keywords and returns a list of documents.	Human editors commonly review and classify the web pages and presentations, which are added to the directory.	Similar to FS.
Discovery Function	(1) It refines search results using different facets; (2) the number of data items in each category can be used in the next navigation.	The SE allows the user to ask for content that meets specific criteria and retrieve a list of references that match these criteria.	Web directories collect different resources.	Similar to SE.
Diversification of Search Results	It uses only a small number of facet terms.	The user enters search words into the SE interface, which is typically a web page with an input box.	Although many web directories offer a search functionality of some kind, search directories are fundamentally different from SEs in two ways.	Similar to SE.
Ranking	It supports facet and searches result in rankings.	It applies and parses the search request into a form that the SE can understand. The SE then executes the search operation on index files. The SE interface returns the search results to the user after ranking.	Most directories are edited by humans, and their corresponding URLs are manually gathered by crawlers, but submitted by site owners.	Similar to SE
Main Advantage of FS amongst Other Types	(1) It guides potentially interesting subsets of the document collection; (2) it explores items of interest within a vast data repository; (3) it provides access to unstructured data whilst maintaining the refining capability of faceted navigation.	It forces the user to browse through long lists. Such a method is ineffective when searchers are unable to define their search precisely.	(1) Lists in web directories are sometimes outdated if humans were unable to edit and verify them for a certain amount of time; (2) the unavailability of crawlers indicates that the URL must be manually submitted to the search directory for users to discover the site, for example Google Directory.	It is slow because users have to write their search queries and know how to use search operators.

2.5. Research Questions

In view of conducting a systematic literature review, the research questions play a prominent role in deciding the search strategy and analysis. We identified the following Research Questions (RQs) for this research:

- RQ1. What does the existing research literature reveal about the faceted search approach of web search service providers?
- RQ2. What are the primary aims, vision, and trends for faceted search, and what research can be highlighted in this area?
- RQ3. What are the existing gaps for research prospects in the faceted search approach for web search services?
- RQ4. What are the existing motivations for usage, concerns, challenges, and recommendations to enhance the faceted approach of web search service providers?

RQ5. What are the points of interest, such as the architecture, applications, issues, re-search questions, motivations, recommendation criteria, and open challenges, in using faceted search?

3. Theoretical Foundations

For the purposes of this review, we broke down the underlying components of faceted search into five primary categories, collecting the articles in these five aspects based on the papers of Gary Marchionini and Ryen W. White as follows:

1. Review and survey: The current state-of-the-art of faceted search and its applications are well described and summarized in the recently published survey and review articles and the technological challenges and concerns of faceted search;
2. Faceted models: We review the currently available literature concerning faceted search to provide a research overview of the practices and guidelines for developing effective faceted search interfaces used in research to support users' needs to understand and explore information [8,18];
3. Faceted technologies: We focus on the fundamental idea of FS, which is to solicit and capture keywords supplied by a user from which to prune out branches of the hierarchy irrelevant to the user's informational need. A taxonomy can serve as more than a means to representing knowledge: its organization of information can also enable us to make information accessible and findable [8];
4. Graphical models: We discuss visualized category overviews of the information space and focus on the dynamic filtering and exploration of the result set by tightly coupling the browsing and searching functions [20,21];
5. Evaluation measures: To evaluate exploratory search systems, we must target the longer-term effect on the user of using this cognitive prosthetic and the current task performance. Evaluation metrics facilitate the incremental improvement of search technologies by assessing system performance and reducing comparisons between experimental systems. Process-specific measures of learning, mental transformation, confidence, engagement, and affect are essential and result in relevance and utility across multiple query iterations and search sessions [6,22].

4. Materials and Methods

As mentioned in the Introduction, in this research, we followed the SLR method to collect the related research articles based on two concepts: "faceted search" and "refining information". The research article collection was carried out via three reputed digital libraries; (1) Web of Science, as it provides multidisciplinary research articles in the fields of science; (2) IEEE explore, which provides articles specialized in the field of electrical and electronics engineering; (3) the ACM digital library, which has a comprehensive database for computing and information technology.

Many searches on the three mentioned databases were performed in July 2021 using several keywords (or phrases) such as "faceted search", "faceted-search", "faceted model", "faceted taxonomy", "faceted", "faceted applications", "faceted browsing", and "faceted classification". The keywords were only slightly different. Subsequently, these keywords were joined using the conjunctions "OR" and "AND" followed by "Refining Information". Figure 3 shows the search queries that were used in this work. We excluded some results corresponding to letters, magazine articles, and book chapters. The main goal of this exclusion was to obtain the most recent scientific articles and enhance the FS application's capability to refine information. Then, the results were divided into two classes: (1) general and (2) coarse-gained. The latter is discussed in five subsequent sections obtained from the study results in which the Google Scholar SE was utilized to define the study's direction.

The significance of the collected articles was evaluated to retain the most related articles among a large number of collected literature articles. Moreover, the included articles were categorized based on two criteria: (1) performing the initial screening to

identify the relevant results; (2) applying three iterations in the filtering process to remove the redundant and duplicated articles.

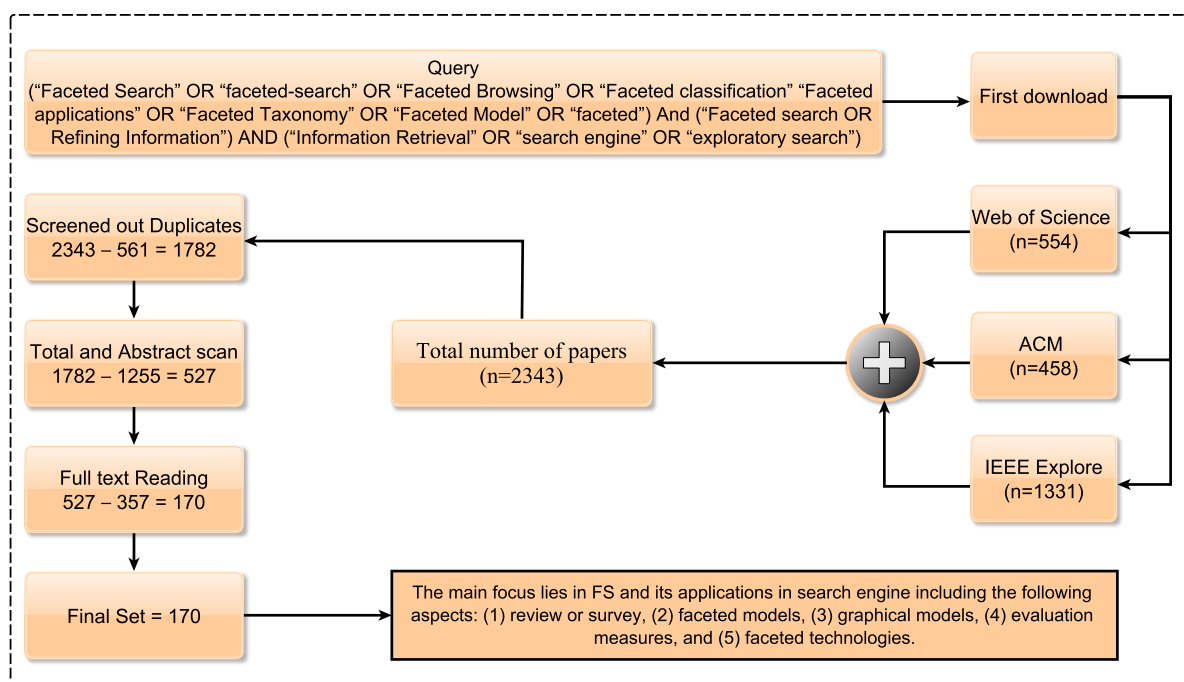


Figure 3. Research methodology guideline.

As highlighted earlier, an article was excluded if it did not satisfy the selection criteria listed as follows: (1) the English language is not the language used to write the paper; (2) faceted search and/or information refining were the main focus of the paper; (3) the research interest in the paper was only concentrated on FS without information refinement. Moreover, after the second exclusion cycle, the articles could be eliminated if ES was not included or: (1) the contribution of the paper did not consider any aspects of refining information based on FS; (2) the discussion in the paper was only focused on refining information based on FS and did not consider any other topic.

In this work, articles underwent extensive filtration, whereby the remaining articles were later categorized into five categories based on the proposed methods to enhance FS in refining information. The categories were: (1) review and surveys, (2) faceted models, (3) graphical models, (4) evaluation measures, and (5) faceted technologies. Subsequently, further subcategorization was performed according to the authors' writing and presentation of the articles to readers.

Figure 3 illustrates our results where there were 2343 research articles gathered based on the user queries, of which 554 were obtained from WOS, 1331 from IEEE, and 458 from ACM digital libraries. All selected articles were published between 2005 and 2021. These articles were later divided into three groups: (1) 561 redundant articles, (2) 1255 irrelevant based on the titles and abstracts, and (3) the 170 articles that fell within the FS search criteria.

Figure 4 presents the statistics of the different categories above for the articles related to FS. In the figure, it can be seen that the 170 articles from the three databases were divided into review and surveys (25), faceted models (35), graphical models (30), evaluation measures (36), and faceted technologies—those that describe enhancement to FS (44).

Figure 5 shows the statistics of the articles based on the publication year between 2005 and 2021. For each year, the figure shows the number of research articles for each of the five categories. It can be seen that in the early years, such as 2005, only four articles were published. Between 2006 and 2008, the number increased gradually from six in 2006 to

fifteen in 2009. From 2010 onwards, it can be seen that the number of publications was consistent until 2020, where the number of publications reached up to 37 research articles. This indicates the increased research trend towards the faceted search concept.

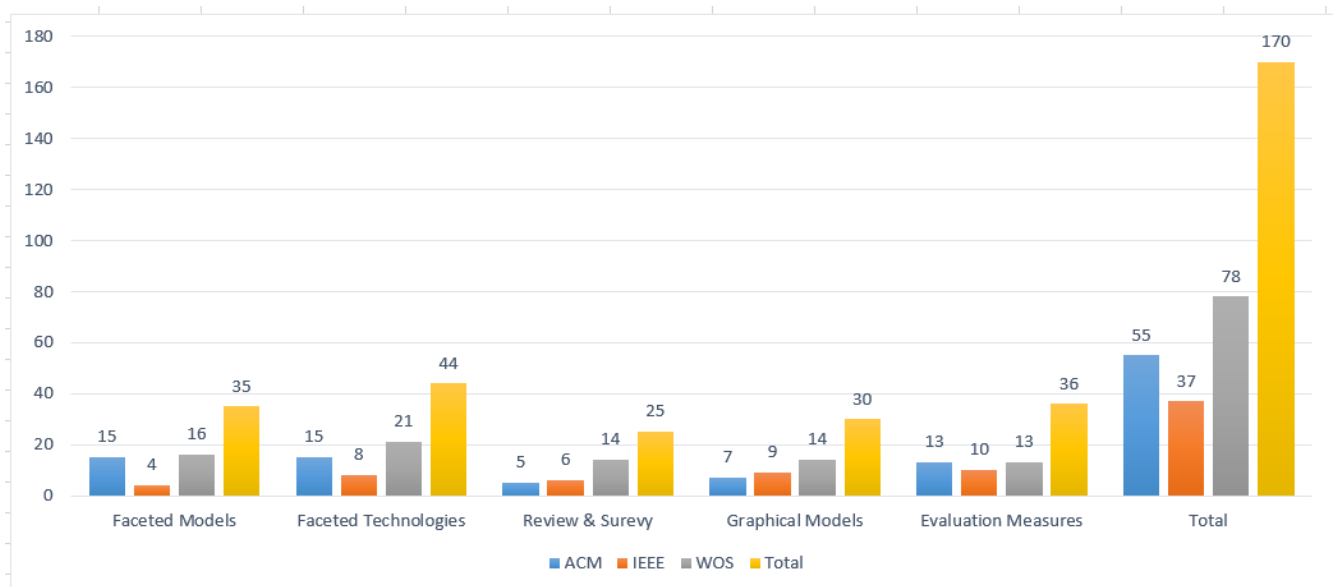


Figure 4. Articles categorized based on their contribution.

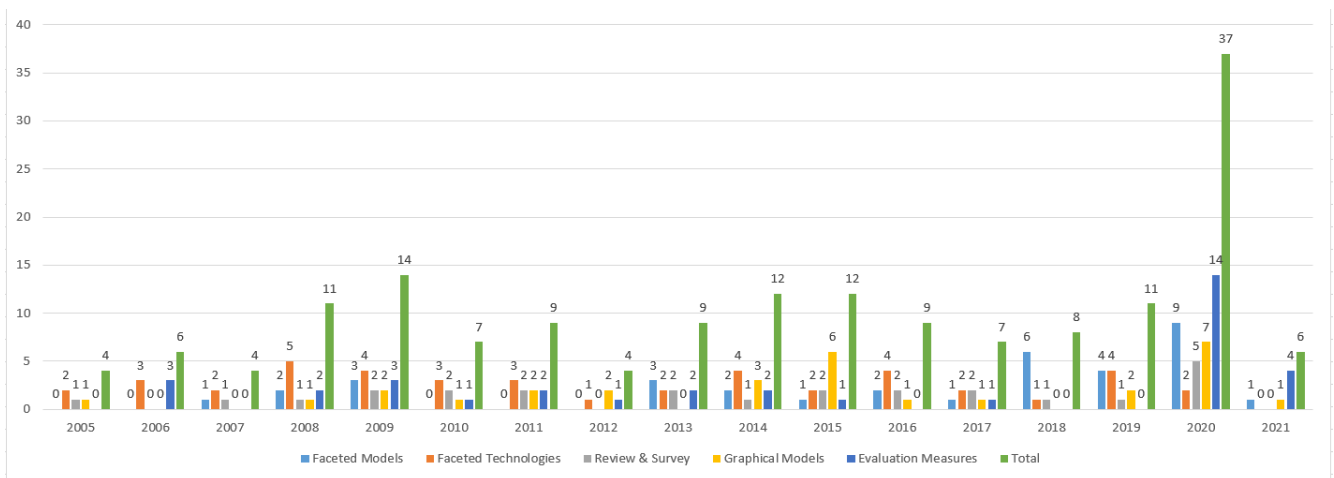


Figure 5. Articles published between 2005 and 2021.

5. Taxonomy and Research of Faceted Search

In view of comprehensive FS, which has been developed in recent years, we developed an FS taxonomy representation of the existing literature, as illustrated in Figure 6. The presented approach consisted of several facets, including essential techniques, evaluation measures, graphical models, and faceted models. Considering the facet model's characteristics, suitable terminologies that can be of good use are structure, interactivity, theoretical foundation, etc. Additionally, the facet was composed of precisely three keywords/terms: dynamic faceted, interface, and hierarchy. These coincided with the other stages. Subsequently, the matrices of the evaluation consisted of two subterms as follows: "subjective" and "objective", explaining the proposed system in detail with the help of a block diagram: RQ1. What does the existing research literature reveal about the faceted search approach of web search service providers?

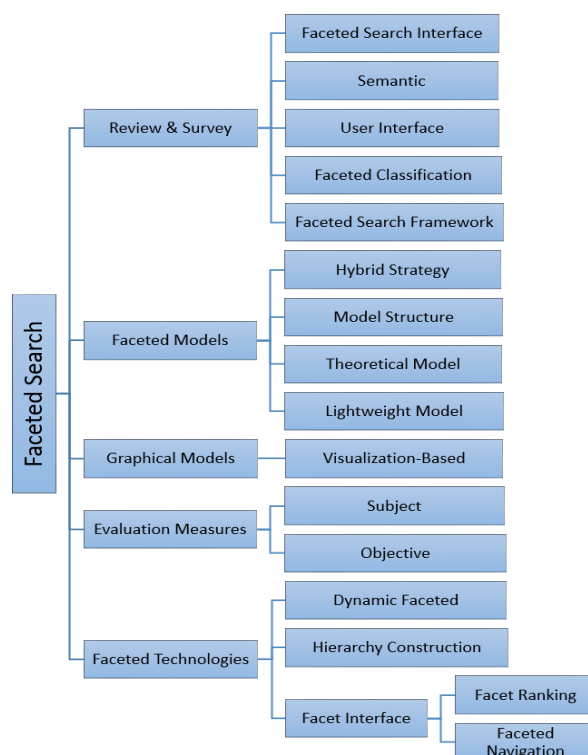


Figure 6. Taxonomy of faceted search.

5.1. Survey and Review

The current state-of-the-art FS and its applications are well described and summarized in the recently published survey and review articles. Three studies reviewed the technological challenges and concerns about FS [8,23,24]. The other 25 articles in this category were divided into four subcategories. The representative surveys of these studies on FS are summarized and discussed as follows:

1. **FS interface:** The papers in this subcategory investigated the framework or the platform model based on the prototype that will be developed. One paper [25] dissected the behavioral characteristics of ES and identified six tasks, namely: knowledge acquisition, comparison, planning, finding, answering, and navigating questions. These comparisons helped in evaluating the compatibility of this report and discovery on various sorting experiments;
2. **Semantic FS and linked open data:** The papers in this subcategory surveyed the most recent studies concerning RDF/S datasets and elaborated on the interaction of session-based approaches for ES. Three papers [26–28] focused on several aspects of these datasets, including the assumed target user, the configuration of the underlying information structure, and the generality and features of the browsing structure. The article [29] developed several evaluation models that adopted a user-centered ES method. The complexities and obstacles in ES were also discussed, as seen by the lack of strategies for evaluating ES models. One paper [30] proposed a comprehensive tutorial. This new information visualization mechanism can help users create informed design considerations about integrating information visualization into their interactive information search;
3. **User interface:** The papers under this category presented an improved user interface design for FS. Among the collected research articles, two papers [31,32] reviewed the concept of ES and its primary theoretical grounds and explained such a complex concept by demonstrating the context of its problem and its search procedure. They also predicted the direction of advancements in the ES area depending on the social state of information search. The authors of [9,33–36] studied the development of new decision support tools and explored the visual knowledge system. The main

contribution of these studies was to find out how a system can achieve the intended enhancement based on the survey that was performed on the projects by using meta requirements. The authors argued that enterprise users in petroleum manufacturing, for instance, can help explore the SE results related to word repetition filters. Other collected studies presented an overview of FS. The research in the library of “future-generation” catalogs that combine FS outcomes was later evaluated based on the questions of what is known by now regarding FS and the way to design improved research for FS in library catalogs [37–41];

4. Faceted classification: These analyzed the interface that enables faster and easier access to the required information. The articles [42,43] discussed six main facets of searches: query sessions, space, user attitude, technical requirements, space of contents, and user racial background. They also presented an interface that enables smoother access to the required information, which illustrates the motivations and needs for FS. The lack of all organizations can further summarize the result of faster and easier access to all sorts of information;
5. Faceted search framework: The papers in this subcategory investigated visualizing browsing and refining search results to allow users to build complex search queries visually. This proposed FS can also solve the problem of lexical uncertainty in current search engines and result in greater user interest [44,45].

RQ2. What are the primary aims, vision, and trends for faceted search, and what research can be highlighted in this area?

5.2. Faceted Model

The second category included 35 related research articles. This category was divided into five subcategories as follows: hybrid strategy [46]; model structure [47,48]; formal concept analysis (FCA) [49]; lightweight ontology [50]; and partitioning [51]. These works were presented to improve the reachability of relevant information objects and user behavior. Moreover, this also improves the user searching process by implementing the activity of the data exchange category-theoretic model [52] and the Random Forest (RF) model [53]. The main facets that were presented here were (1) trees and (2) graphs. Both were obtained from the taxonomy of the faceted data structure. It is meaningful to mention that the former facet shows the data-structure-specific faceted taxonomy [54]. In Table 2, we briefly compare the facet models mentioned above by model structure, the main concepts, and other key aspects.

Table 2. Comparison of existing facet models.

Ref	Time	Model	Data	Main Concepts	Structure	Ranking	Improvement, A: Advantages, D: Drawbacks
[46]	2017	ES strategy	Web pages	Automatically selecting	Facet extraction Form-based search	None	Presented an ES approach that enables users to differentiate all data efficiently. A: minimizes the large and overwhelming datasets into small and precise information that is in line with the user’s interest. D: more tests are needed.
[47]	2009	Driven and domain-neutral approach	Real datasets comprising blog posts	Manually selecting attributes from the database	Keyword search	Relevance to a search query	Modern searching approaches that are similar to FS, which allows progressive improvements for query keywords. A: enables enhanced data analysis and searching models. D: manual browsing is the only option to obtain results without assistive query features.
[51]	2018	Distinguishes the facet combinations on spatial bases through combining, partitioning	Text mining	Automatically select based on information extraction results	Based on users’ selection	None	The combinations of facets to consequently enhance ordinary FS through understanding the analysis, which has important footprints in spatial capacity. A: it has been upgraded to a geo-visual analytics system by using an easier and simpler user interface. D: not possible to locate an advanced type for exploring the FS literature.

Table 2. Cont.

Ref	Time	Model	Data	Main Concepts	Structure	Ranking	Improvement, A: Advantages, D: Drawbacks
[52]	2018	Astera	Joining the attributes of several formats using the FS formulation	Graph model and semantic links to the collection, ImageCLEF from Wikipedia	It can solely be a representation of data if inherent features are not used	Hybrid ranking method	Focused on the reachability analysis of the collections of multimodal graphs. A: how different facets and the types of links affect the reachability of adequate information objects. D: requires increasing the semantic and similarity links' effects to enhance the graph reachability.
[53]	2019	Random Forest (RF) approach	Text mining	Query formulation extraction results	Use nodes to automatically generate queries to the users	Relevance to a search query keyword search	The interactions of users in real time was investigated from the perspective of both human factors and data science, respectively. A: the results in this work are relevant in understanding the searchers in order to present or improve a practical model of FS. D: a high-quality facet was selected while only one university library was considered.
[55]	2019	TogoGenome	Genome database	Semantic web-based	Keyword searches	None	Presented a semantic FS approach by gene functional annotation, taxonomy, phenotypes, and environment based on the related anthologies. A: Each module in the pages is separately served as TogoStanza, which is a generic framework for rendering an information block as IFRAME/web components. D: users cannot edit and test these queries for similar purposes with ease.
[56]	2019	FS system for Thai research articles	knowledge extraction from facets and two-level FS	The FS system was constructed based on the Apache Solr SE	Knowledge discovery tool	Real-time metadata	Provided the approach to the design and implementation of a knowledge discovery tool in terms of FS. A: system design for FS is explained together with data preparation. D: needs to work on manually extracting the metadata from all the datasets.
[57]	2019	Content-based recommendation	Records collected of Parliamentary Proceedings	Profile-based expert recommendation and document filtering	Representing profiles based on different information sources and expert finding	Recommendation	Provided text clustering to automatically build compound profiles of experts to properly reflect the topics in which they are usually interested. A: represented using multifaceted profiles. D: tackling the problem of how recommendations and filtering problems would be affected when experts are represented by temporary profiles.
[58]	2019	Combines full-text search with facets	Metadata-based clustering	Modeling user interests to identify the user interests and investigate the relation between them	Search behavior is related to specific parts within the collection	Reranking of the results by time	Improved system support or refine recommendations in interactive IR. A: a typical digital library with a richly annotated historical newspaper collection and an FS interface. D: requires further exploration of the users interested in specific parts of the collection to use different search techniques.
[59]	2019	Utilizes the bag-of-words model to transform visual feature into a vector representation	Multimedia databases from the LSC dataset	FS lifelog system to a VR-platform	Extracting visual features from the image was performed	Ranked list of images	Provided a LifeSeeker interactive lifelog SE. A: helps solve the lexical gap between novice users and the concept annotation tools employed for annotating the collection. D: enhances the free-text search system.
[60]	2016	Category-theoretic model	Database schemas	Automatically selecting	Natural hierarchical relationships, form-based search	How many occurrences	Illustrated and enforced the fact that facets browsing can be modeled by category theory to enhance the development of interfaces to integrate several facets of browsing approaches. A: describing the terminologies to expand the approach can be utilized to integrate the facets. D: recommended to further investigate the visualization impact in FS models such as DELVE because several parts can be affected by that interaction.

Table 2. Cont.

Ref	Time	Model	Data	Main Concepts	Structure	Ranking	Improvement, A: Advantages, D: Drawbacks
[61]	2018	QDMiner	Build two datasets from scratch	Dynamically mine the query text by categorizing and extracting repeatable texts and repeat at the top results	Presents two models, the context similarity model to arrange the query facets and the website model	None	Issues related to identifying the query facets. These facets are found in different categories and groups of texts and phrases describing and summarizing the query context. A: finding enhanced query facets is demonstrated by designing the fine-grained parity between the repeated lists. D: requires further exploration on the output to improve the facets and enhance the query extraction.
[62]	2008	FlExplorer	Web page	Automatically select based on the information extraction result	Subject hierarchy	Preferences for prestige, results' selection, and workload usage	Proposes an authoritative approach that obtains the faceted materialized taxonomies. A: enables better control over terms' taxonomies, objects, and facets' description, e.g., modification and deletion. D: expands the FlExplorer, which is able to act as a mediator to manage the information remotely.
[63]	2015	The theoretical bases category is used for FS	Text mining	Automatically select based on information extraction results	Uses nodes to automatically generate queries to the users	None	Directed towards the complexity of the structure among the morphism categories. A: utilizes the abstract directories to produce the algorithms, which are a model that can be applied repeatedly. D: it requires containing faceted ES phase models. Filters such as zoom, filter, and overview will be implemented.
[64]	2014	eTACTS	Data from the pool of participants	Few facets were used to index the resulting trials whereby each describes a unique feature of the query text; this enables a user to choose the facets to filter and minimize the number of results	Arranged and reordered them based on the initial search rank	Top ranked by conventional SEs	It digs out the consecutive tags of eligibility obtained from the free-text clinical trials to be utilized in indexing them. A: (1) frequently minimizes the SE results from more than a thousand trials to approximately ten; (2) describes trials that are randomly not top ranked by typical SEs; (3) obtained a higher number of perfect trials than conventional SEs. D: (1) assessment of the users mentioned by this work is focused on showing the effectiveness of an easy case study; (2) user assessment is focused on a singular medical condition, which describes the search of the user.
[65]	2009	FacetLens	The orientation that links both the dataset and the facets	Pivot operations to enable users to have easy navigation of the facet dataset by utilizing the relationships that link the items	Metadata structure	Rank criterion	Define the interactive visualization algorithm's efficiency in upholding the understanding of the datasets within the facets. A: facet relationships can be improved and made clearer to enhance the directivity by exploiting the coloring and animation, timing, etc. D: requires more accurate features that contribute to enhancing the FacetLens user experience.
[66]	2013	MultiFacet	An interface of faceted browsing to uphold several types of data	Developed an FS system, to expand the current system of faceted browsing	The approach builds facets for graphics using computer visual techniques	None	Features of MultiFacet provide glimpses at the multimedia without defining the type of media. A: (1) an approach that enables facets' integration from texts, graphics, etc.; (2) graphical facets are constructed using low-level visual attributes of these graphics. D: requires embedding users to study to indicate the efficiency of the MultiFacet interface.
[67]	2018	Facetize	Linked data, publishing method that facilitates data linking	Contributes to users with no specific technical background to purify the datasets and transform them into easily explorable data	Features of the approach in the context of the verbal communication system and also emerging	Ranked based on reference focused objects	Structure and the flow of facetizing an editor that enables users to change the datasets, either static or dynamic, to the extent of it being fully explored automatically or manually. A: various tasks are supported by features such as data deletion, editing, visibility, selection, etc., which provides users a friendly interface. D: approaches to anticipate the lost data are not available.

Table 2. Cont.

Ref	Time	Model	Data	Main Concepts	Structure	Ranking	Improvement, A: Advantages, D: Drawbacks
[68]	2008	FacetZoom	Continuous and discrete datasets	FacetZoom, a unique widget that joins the browsing of facets with the expandable user interface	Hierarchical facets are space-filling widgets to enable quick traversal in all stages and maintain the context	None	The space-structuring widgets and data are applied and sampled, respectively, using the two prototypes. A: multilateral and enables static search and browsing features in the diversity of application settings. D: needs to differentiate between the performance of all widgets to different techniques.
[69]	2017	Object property framework	Datasets of DBpedia, LOD, and YAGO2	Proposed techniques of purifying the subtaxonomy while upholding two experiments to enforce the outstanding performance in terms of effectiveness and efficiency	Inheritance Richness (IR) to intrude the subtaxonomy structure	None	Establishes a faceted taxonomy to arrange the heterogeneous facilities, allow the different categories of facilities using the subtaxonomies, and uphold the FS navigation for related information applications. A: framework in which the facets are described using an object feature to extract the relevant data; also contributes to creating the concept taxonomy-generation algorithm. D: (1) several legacies exist in subtaxonomies; (2) it is difficult to realize and understand the concept hierarchies; (3) the identification of entities and its mapping should be realized in generating the taxonomies.
[70]	2019	Multifaceted Trust Model	(1) Yelp, (2) LibraryThing	Yelp, Booking, Expedia, and LibraryThing provided by social networks	Finding general classes of data in order to create models applicable to different case studies	None	Multifaceted trust model to integrate local trust, represented by social links, with various types of global trust evidence provided by social networks. A: integrated into collaborative filtering; the resulting system was tested on two public datasets. D: need to evaluate the model on different datasets.
[71]	2020	COVIDSeer	CORD-19 Dataset	Uses CeKE-TA, which uses only the title and abstract	Uses a combination of title, abstract, and available full-texts	None	Built and integrated a filtering mechanism for further accessing the results of a query of interest. A: Allows users to select filters from one or multiple categories; the intersection of all is presented in the search results. D: implements author name disambiguation so as to correctly associate every author to his/her research paper.
[72]	2021	XNLP	Metadata structure	Interactive browser-based system embodying a living survey	Keyword search matches	None	Interactive browser-based system embodying a living survey of recent research in the field of Explainable AI (XAI) within the domain of Natural Language Processing (NLP). D: aware of other papers that should be included.
[73]	2020	SAUCE	Lexical Database	Allows artists to find different types of assets in different ways depending on personal preference	Indexing of text and language structures	None	Discusses some of the requirements of modern asset storage systems for VFX and animation. A: introduces two systems that were built to address these challenges as part of the collaborative EU funded “SAUCE” project; DNEG’s search and retrieval framework and Foundry’s back-end asset storage.
[74]	2020	DeepHate	Latent representations	Deep learning model that combines multifaceted text representations such as word embeddings	Real-world datasets	None	Deep learning framework known as DeepHate, which utilizes multifaceted text representations for automatic hate speech detection. A: evaluated DeepHate on three publicly available real-world datasets; extensive experiments showed that DeepHate outperformed the state-of-the-art baselines. D: incorporating nontextual features into the DeepHate model and improving the posts’ sentiment and topic representations with more advanced techniques.

Table 2. Cont.

Ref	Time	Model	Data	Main Concepts	Structure	Ranking	Improvement, A: Advantages, D: Drawbacks
[75]	2020	Newspaper Navigator	Examples of searching	Open faceted search, which empowers users to specify their own facets in an open domain fashion	Users need to knowhow to define and refine facets	None	Walks through examples of searching with Newspaper Navigator and highlights the facet learning and exploration affordances. D: Facet categories must be predefined and may not align with the facets that a user desires during the search process.
[1]	2020	Data lake organization	Proposes an approximate algorithm	For the data lake organization problem	Structures optimized for dataset discovery	Participants' rankings	Probabilistic model of how users interact with an organization; proposes an approximate algorithm for the data lake organization problem. D: plans to compare organizations with existing taxonomies and to provide techniques for metadata enrichment.
[76]	2020	Simulation-based evaluation	Size and the granularity of the sought object ranking	Extension of the model with two parameters that enable specifying the desired answer	Structured query	The Smartfsrank ranking	Extended model for FS that aims at improving the exploration experience of the users. Proposed two parameters that specify the desired properties of the returned answers. Investigated indexes and algorithms for scalability, i.e., for enabling faceted search with automated ranking over very big datasets.
[77]	2020	LINDASearch	Open Linked datasets	Semantic search, faceted navigation, data unification, discovering, and generation of search recommendations over the information contained	Semantic Web	Key ranking techniques	Linked data principles and practices to be adopted by an increasing number of data providers, which leads to the creation of a global data space on the web. LINDASearch is a system for semantic search, faceted navigation, data unification, discovering, and generation of search recommendation over the information contained in the Open Linked datasets available in the web of data. Limitations to search through datasets from multiple domains.
[78]	2020	SPARQL engines	RDF dataset	Presents a schema-agnostic faceted browsing benchmark generation framework for RDF data and SPARQL engines	Similarity-based	None	Framework comes with an intermediate domain-specific language. Thereby, the approach is SPARQL-driven, which means that every faceted search information need is intentionally expressed as a single SPARQL query. Presented a schema-agnostic faceted search benchmark generation framework for triple stores. Comparison of the generated benchmarks with existing SPARQL-driven benchmarks in order to provide a bigger picture such as by means of assessing the similarities and differences of benchmarks w.r.t. the SPARQL language features used.
[79]	2014	Hippalus	Small dataset	Described and evaluated Hippalus, a system that offers exploratory search enriched with preferences	Faceted and dynamic taxonomies	Preference-ranked list	Hippalus supports the very popular interaction model of Faceted and Dynamic Taxonomies (FDT), enriched with user actions, which allow the users to express their preferences. The Hippalus system demonstrates the feasibility of this extension.

5.3. Graphical Models

These platforms can provide the information in audio format and graphics, such that it is no longer isolated. Therefore, it is said that they are occasionally connected through the metadata and semantic links, which poses several challenges in the retrieval of graph-based information. Subsequently, the focus of this research shows the important challenges faced when interacting with multiple data types and modalities, whereby each comes with unique intrinsic features and retrieval approaches.

The thirty articles in this category were inquiries ranging from migrating graphics and text to the advanced fusion of several approaches receiving considerable attention in the past few years [80–82]. The original or the subsets of data sources collected using the

IR system can be visually illustrated to help users better use it. These techniques can either operate together or separately to improve system performance [83].

The visual illustration of data can contribute to decision making, information delivery, and data analysis. Nevertheless, this includes minimal interactivity-related data [84]. Therefore, it is advised that it should contain an adequate interactive interface to be more understandable, easy-to-use, approachable, and meaningful. Moreover, accessing the data is becoming relatively difficult when the amount of data grows rapidly. Hence, visualization techniques help users obtain better results from a large dataset [85]. It is noteworthy that facets do not convey much information when using visualization [86–90]. In Table 3, we briefly compare the visualization techniques based on their data collection approaches, the faceted methods used, and the ranking improvement, identifying the advantage and drawbacks of each.

Table 3. Comparison of existing facet graphical models.

Ref	Model	Framework	Data Collection	Faceted Used	Ranking	Improvement, A: Advantages, D: Drawbacks
[89]	Knowminer search	FS model, extended by interactive visualizations that allow users to analyze various elements of the consequence set	Presents a visually supported FS interface; Apache Lucene SE is the backend of the search solution	Allows functionality for organizing interesting portfolio search outcomes and promotes social characteristics for rating and boosting SE outcomes	None	Search interface allows both search kinds. An FS interface allows the search outcome set to be effectively narrowed down. A: the visualization of entities and records in distinct situations: (i) the geo-visualization shows the distribution of extracted geo-references; (ii) the display of trends and correlations between facets; (iii) the visualization of graphs allows the exploration of relations between entities and records; (iv) the data landscape provides an overview of the search result set's topical structure. D: need to extend portfolio features, for instance by automatically applying portfolio suggestions for SE results, offering sophisticated search using a portfolio as a query seed.
[90]	PivotPaths	Showcases PivotPaths, as an interactive visualization to search the resources of faceted data	Selected the Internet Movie Database's top-grossing films and retrieved film information from the Rotten Tomatoes film rating page	Interface was intended to allow big collections to be traversed casually in an aesthetically pleasing way, encouraging exploration	Showcases a visualization canvas that reorders facet values and spatial data resources	Supports pivoting operations as lightweight techniques of interaction that trigger gradual transitions between views A: shared the results of the iterative design-and-evaluation method, which included semistructured interviews and the implementation proposed for a big academic publication database. D: improves the experience of strolling and obtains clearer knowledge of how exploratory and casual navigation styles can be supported.
[91]	DEEPEYE	Based on visualization by examples, automatically recommends and generates visualizations	Visualization use cases and real-world datasets	Provides keyword searches and FS	Graph-based approach	Presented visualization recognition techniques to decide which visualizations are meaningful and visualization ranking techniques to rank the visualizations. A: gives the user the keyword search and allows click-based FS. D: difficult to steer; has keyword search and FS.
[92]	Versatile timeline tool	Allows the user to explore relations between laboratory values and a multitude of diagnoses	Clinical research database	Developed a user interface for FS based on the Solr SE	None	Presented an integrated decision support system FS and information visualization based on textual information extraction. A: the use case of mammography featured an adapted FS application on the results of an adapted information extraction pipeline. D: required more user control of the information extraction process.
[93]	FS information exploration model	Geographical knowledge of semantic representation for the exploration of IR from heterogeneous data	Noisy datasets; data exploration is sparse	Supports faceted exploration; model based on transparency sliders	Ranked list	FS supporting a flexible visualization of heterogeneous geographic data. A: graphical representation of the search context using alternative types of widget that support interactive data visualization. D: model only supports the specification of hard visualization constraints on facet values.

Table 3. Cont.

Ref	Model	Framework	Data Collection	Faceted Used	Ranking	Improvement, A: Advantages, D: Drawbacks
[94]	The Lifelog Search Challenge (LSC)	Interactive retrieval from multimodal lifelogs	LSC'20 datasets; the metadata provided can be split into four categories: location, time, activities, and visual concepts	Searching system ranging from faceted windows in virtual reality	Ranking documents based on visual features	Built to address three crucial challenges, which are accurate searching, fast processing, and straightforward. A: supports querying sequential moments and visualizing the movements between them on the map. This map can work as a filtering option also. D: need to utilize all given elements in the dataset, visual similarity retrieving is also intriguing.
[95]	Online communities	Online communities' GUI designers	Automated GUI exploration to collect data	The component height and width in a scatter plot	Ranking mechanism based on time	GUI designers share their design artwork and learn from each other. A: designers collect, analyze, search, summarize, and compare GUI designs on a massive scale. D: requires the crowdsourcing method to filter out apps with low-quality UI design.
[96]	Facet graphs	Achieves related semantic data's graph-based structure	Consists of a group of nodes that are marked by semantic nodes' relationships	FS and combines it with a visualization	None	Technique and instrument, which enables people to more effectively access and explore Semantic Web information, leveraging semantic data's particular features. A: the strategy uses the FS idea and combines it with a visualization that takes advantage of the graph-based structure of related semantic data. D: integration of suitable zooming functionality in conjunction with a focus and context method to encourage users to maintain an overview even when using huge facet sizes in a single graph.
[97]	PFSgeo	Geographical map input to imply that focus is restricted; preferences are defend	Geographical data	Preference-enriched FS for geographical data	Ranking of spatial data	ES process, in particular the Preference-enriched FS (PFS) process. A: enhanced to explore datasets that also contain geographical information. D: tiny dataset of 20 hotels only.
[98]	Based browsing paradigm and a web browser extension companion	Users traverse graph-based data	Data web	Typical FS interface such as Internet catalog browsing	None	It is necessary to update the web browsing paradigm of one web page at a time because the typical unit of web information to interact with will no longer be an entire web page. A: lower data bits and countless data bits. D: needs to formulate complex structured queries.
[99]	NeSim	Multifaceted graph, graph-clustering algorithms	Facet is a group of features that emulate the relationships among the nodes in a specific context	Google Publisher Dataset	None	Optimizations to improve the scalability, efficiency, and quality of the clusters. A: addresses the problem of finding communities from multifaceted graphs. D: finding subgraphs with specific link topologies; the problem of merging results from several community discovery algorithms on a single graph.
[100]	Hōpara	Information visualization	Wikipedia web site	Facets of visualization	The total strength ranks them	To make it simpler to explore Wikipedia. A: abstracting from the content of the document and enabling users to navigate the resource at a greater level. D: cannot provide conclusive, objective evidence of the usefulness of Hōpara; only the subjective emotions of customers about it.
[101]	VisGets	Visualization of data widgets that manipulate a web query	Web browser	Coordinated opinions can provide a deeper understanding of the dimensions of these facets	Ranking mechanism based on relevancy	Researched how coordinated visualizations could improve the search and exploration of WWW information by facilitating the formulation of these kinds of queries. A: provides visual overviews of web assets to the information seeker and provides a means of visually filtering the data and facilitating the development of dynamic SE queries combining filters from more than one data dimension. D: to know more about the potential role of interactive visualizations in searching for data, considers additional data spaces and formats beyond RSS as fresh VisGets kinds.

Table 3. Cont.

Ref	Model	Framework	Data Collection	Faceted Used	Ranking	Improvement, A: Advantages, D: Drawbacks
[102]	Visual search interfaces, information visualization	Fuzzy filtering idea proved convenient to solve comparative tasks, but also confused some searchers who tried to fix a search assignment	Financial products dataset	Feature used to reduce the result set was the facet filter, whereas less frequently, the fuzzy filter was used	None	Presented an interface notion that enables multiple product search, analysis, and comparison approaches beginning with a single product or summarizing the entire information set. A: the idea is based on two methods of visualization that enable multidimensional information to be represented across a set of parallel axes: parallel coordinates and parallel sets. D: needed for each axis to spread junctions; class internal rearrangement of these positions based on the zoom level, filters, attribute value, and adjacent axis could assist with decreasing visual clutter and increasing the precision of the filter.
[103]	Facet graphs	Enables individuals to access data contained in the Semantic Web in accordance with their semantics	Uses football field examples	Facets are represented as a node graph visualization and can be added and removed interactively by the users	None	Tools are described as something that, according to their semantic descriptions, enables people to access data stored in the web. A: challenges include massive data volumes, massive semantic relationships within the data, and highly complex search queries. D: appropriate zooming functionality must be integrated with conjunction with a focus and context method to encourage users to maintain an overview even when using huge facet sizes in a single graph.
[104]	Refinery	Interactive visualization system described by associative browsing attributes taken from ES	Visualizes query nodes that are within the results subgraph, gives explanatory context, and facilitates serendipitous discovery	Presents the outcomes of research conducted by 12 scholarly scientists using the conference publishing data browser system	Ranked by overall relevance	Examines associative browsing as a strategy for bottom-up exploration of large, heterogeneous networks. A: these guidelines motivate the refinery's query model, which allows users to simply and expressively construct queries using heterogeneous sets of nodes. D: nothing is collection-specific in strategy; in almost every collection, you need to use two categories: time and phrases.
[105]	Multiple view faceted interface micro visualizations	A novel version of the RD instrument was launched to explore and analyze recommended outcomes	Provided visual representation for FS using streamlined, data type-specific micro visualization representations	Micro visualization filters were used; for comparison, the equivalent text-based faceted descriptors were displayed	Provides transparency on the impact of specific topical interests on recommendations' ranking	Consists of one primary visualization for information exploration and several miniaturized visualizations displaying the filters. A: the goal is to decrease user load and to optimize screen area usage. D: in the long run, micro visualizations need to be interactive, as well as ways to realize an optimized version of the RD for tiny screen mobile devices.
[106]	Graphs selected	Manual chart construction with interactive navigation of a variety of automatically generated visualizations	IMDB and Rotten Tomatoes	Mixed-initiative scheme supporting the FS of suggested graphs selected on the basis of statistical and perceptual measures	Various rankings of relevance based on statistical measures	Visualization tools require manual view specification: analysts must choose data variables and then choose which transformations and visual encoding to use. A: explore models of probabilistic recommendations that can learn better ranking features over time D: supplement manual chart building with interactive navigation of a gallery of visualizations generated automatically.
[107]	Receptor	Graph search functionalities by automatically translating the text query into nodes	A system to assist sensitivity reviewers by searching large collections to find latent relations	Faceted search with various search filters such as document creation date, authors, and origins.	None	Is a new solution that aims to provide sensitivity reviewers with the ability to explore a collection of documents to discover latent relations between entities and events that can be a reliable indicator of sensitive information.
[108]	Map-based faceted exploration model	Map-based faceted exploration model	Shared data for user collaboration	Faceted exploration model	Ranked-list visualization	Model is based on interactive widgets, which support information exploration at two granularity levels, i.e., by projecting a map on specific data categories and/or according to specific attributes of items. D: Depending on their roles, users might need to access different, long-lasting custom views of shared information space in some scenarios.

Table 3. Cont.

Ref	Model	Framework	Data Collection	Faceted Used	Ranking	Improvement, A: Advantages, D: Drawbacks
[109]	FS	Retrieves data from a scholarly knowledge graph, which can be compared and filtered to satisfy user information needs better	Google Scholar	Dynamic facets, which means facets are not fixed and will change according to the content of a comparison	None	Implemented an FS system over a scholarly knowledge graph. The system provides the opportunity to save these configurations and the subset of retrieved data as a new comparison to the database, with a permanent URL that can be shared with other researchers and users. Federated knowledge graphs to improve dynamic FS further. For instance, it is intended to use GeoNames to enable spatial filtering on scholarly knowledge.

5.4. Evaluation Metrics

The fourth category included thirty-six articles focused on various techniques used to evaluate the different FS implementations. Generally, two metrics have been used to assess and evaluate FS, namely: objective metrics and subjective metrics.

RQ3. What are the existing gaps for research prospects in the faceted search approach of web search services?

5.4.1. Objective Metrics

These were evaluated through the objective metrics, which can be classified into two types: relevance metrics and cost-based metrics:

Relevance metrics: In FS, the matching between data items and facet terms in many cases is predetermined. Only a tiny number of FS systems support the automatic classification of search results based on facet terms [22,110]. Therefore, the relevant metrics of FS results are always high. However, the community of information retrieval has introduced several metrics to describe FS's binary and graded relevance. For binary relevance, the E-measure with their macro and micro forms, the F-measure, precision, and recall are considered primary metrics. For instance, the authors of [111,112] employed micro-F1, macro-precision, and macro-recall to evaluate the results of the deep classifier in FS. Moreover, Gomadam used precision and recall to measure the search process of FS. Meanwhile, the rank-biased precision [113], normalized discounted cumulative gain [114], mean reciprocal rank [115], binary preference [116], and mean average precision [117] are considered as the main graded relevance metrics [118–120]. Alternatively, [76,121–123] exploited normalized discounted cumulative gain to rank the output of their facet discovery algorithms.

Cost-based metrics: These are used to investigate the time consumption and memory usage of the FS system. In this regard, one paper [124] calculated the completion time of retrieval tasks to describe the efficiency of FS in mobile devices. Furthermore, [125] applied two cost-based metrics: the time spent on calculating the number of attribute–value pairs of facet terms and the memory usage in the index storing process [126–128].

5.4.2. Subjective Metrics

Contrary to objective metrics, the subjective metrics assess and evaluate the simplicity and flexibility of FS [129–135]. Two main methods are usually used here, namely intrinsic and extrinsic evaluations:

Intrinsic evaluations: Standard query facets are built by human annotators and used as the ground truth to compare with facets produced by separate schemes [136,137]. Usually, facet annotation is performed by first pooling facets produced by the separate schemes [138,139]. Annotators are then asked to group or regroup terms into preferred query facets in the pool and to offer scores for each of the query facets [140,141], as can be seen in Figure 7.

The general intrinsic evaluation steps of the FS system are summarized as follows: (1) human annotators build the facets of the query; (2) the ground truth is compared with

multisystem facets; (3) in order to group or regroup conditions into preferred query facets in the pool, annotators are asked to pool facets produced by different technologies.

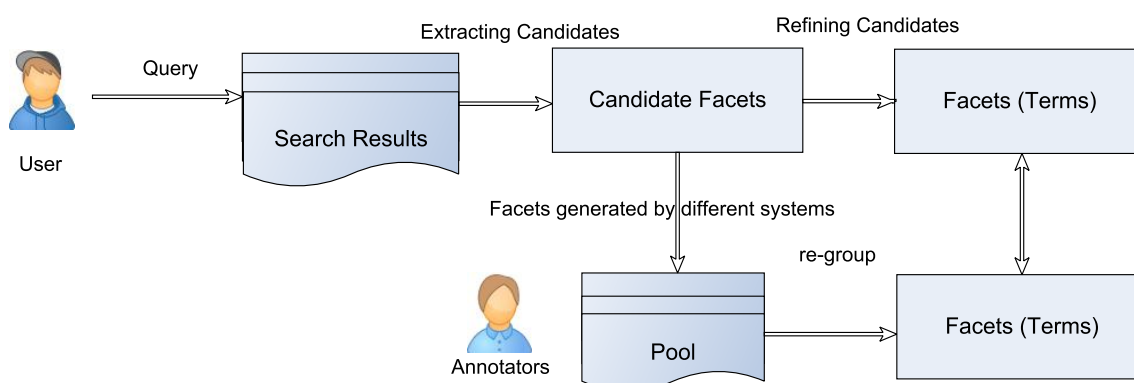


Figure 7. General intrinsic evaluation of a faceted search system.

It is worth mentioning that the intrinsic evaluation is not based on any particular search task. It thus may not reflect the actual utility of the generated facets in assisting the search. Therefore, the extrinsic evaluation has been proposed and applied by many related works:

Extrinsic evaluation: This is a system based on an interactive search task that incorporates FS [142,143]. The general extrinsic evaluation steps for a faceted search system are as follows: (1) evaluate a system based on an interactive search task that incorporates FS; (2) the gain can be measured by the improvement of the reranked results; (3) the cost can be measured by the time spent by the users giving facet feedback; (4) based on the user model, we can estimate the time cost for the user, as can be seen in Figure 8.

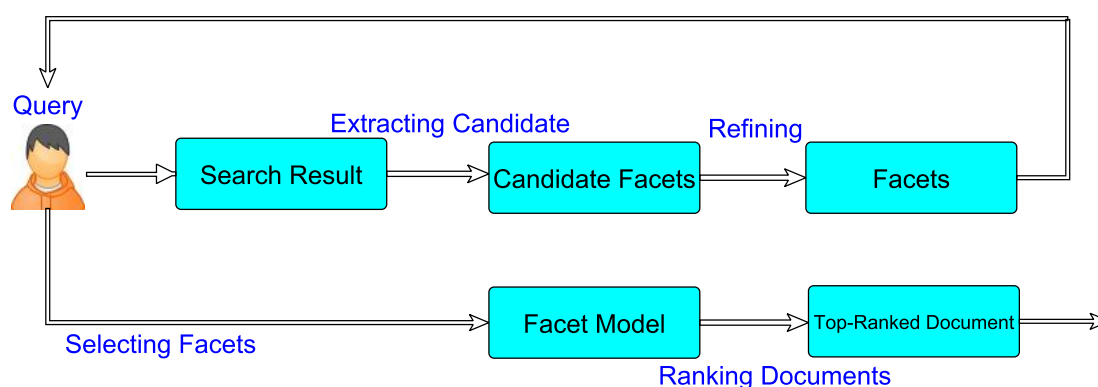


Figure 8. General extrinsic evaluation of a faceted search system.

5.5. Faceted Technologies

The five categories included forty-four articles focused on the fundamental idea in FS being to solicit and capture keywords supplied by a user from which to prune out branches of the hierarchy irrelevant to the user's information need. This style of search can be applied to both faceted (e.g., a unidimensional version of Epicurious) and unfaceted sites (e.g., ODP). FS over a faceted site typically involves matching the terms in the query to the available values for the facets remaining unfilled to simplify the hierarchy at any point. FS techniques integrate navigational (e.g., Yahoo!) and direct search (e.g., Google) to help users determine which portions of a classification contain the information desired. In other words, they combine browsing and search, leading to a mixed-initiative mode of interaction. FS is broad and refers to a family of related search techniques for information

hierarchies as variations on this idea. In this section, we discuss the idea and showcase a few specific examples. Search results' ranking in FS is similar to that in the traditional IR domain. It has been extensively studied for years [144,145].

5.5.1. Dynamic Faceted Search

This extends traditional FS to support more prosperous information discovery tasks over more complex data models. The ability to view flexible and dynamic aggregations over faceted data as typically found in business intelligence applications over structured data would allow users to make more informed drill-down and roll-up choices, which will support them in making better decisions [146]. Typical FS applications operate over a set of (predetermined) indexed facets, i.e., the facets and attributes associated with each document must be known at indexing time.

The articles [146,147] extended traditional FS to support more prosperous information discovery tasks over more complex data models. The ability to view flexible and dynamic aggregations over faceted data as typically found in business intelligence applications over structured data would allow users to make more informed drill-down and roll-up choices, which will support them in making better decisions.

The articles in [148,149] extended traditional FS over more advanced data systems to promote a vast amount of data discovery tasks. The proposed solution would work if the underlying data source can evaluate a ranked list of tuples. References [150,151] described a structure for an e-commerce dynamic ordering system. The structure discussed particular elements of e-commerce, such as the possibility of numerous hits, the classification of factors by their respective characteristics, and the wealth of numerical elements, unlike current alternatives. Others [152,153] described the choice of different categories within the Semantic Web setting with priority given to implementing the decision-making assistance scheme, the ontological visual facet navigation system.

5.5.2. Hierarchy Construction

In query interfaces, hierarchical categories were used early on. The search results, which represent hierarchical tags, can assist consumers in defining or further refining (or expanding) applications. SEs, such as the Yahoo search engine and OpenDirectory, are relevant, but each show a human hierarchical classification; consumers can browse through the hierarchical class folder taking a hyperlink of the topic. Additional schemes assist consumers in defining suitable subsets from massive outcomes by arranging outcomes into hierarchical categories [154].

In the field of FS hierarchy building, there have been several works. The conventional paradigm for keyword Google data pages (a catalog of documents ordered by relevance) makes the findings slightly connected with the general data area. Search settings, therefore, do not entirely misuse the value of the intrinsic attributes of the hierarchy. Adverse schemes also typically do not show the entire magnitude of the accessible hierarchical metadata, which also leaves identifying the models or connections between facets tough [155,156].

The authors in [157,158] used input to divide tasks and allow designers to discover a familiar technology through new relationships. In an attempt to allow designers to manage complicated computer environments flexibly, they introduced a strategy that characterizes code pieces and some other aspects.

5.5.3. Facet Interface

This combines data-oriented text assessment with a new GUI layout to enhance device assistance for browsing and choice in company data collection. A facet-based software intended to operate at an Internet printer offers a wealth of customer knowledge that combines search and navigation approaches for a location.

Some related studies have proposed analytical search tools that present a fresh collection of scheme assessment methods. However, there is still a lack of metrics reflecting the required outcomes. ES applications invariably require the effective involvement of

customers, which means that the variability of the customers in the experimental layout must be counterbalanced [159]. Many works, particularly the work guided by [160,161], have focused on these aspects.

Facet ranking: If too many facets or facet terms exist, or the user interface has limited space to show most of them, only certain facets or terms are required. This needs a classification of the facets and conditions to select the most significant facets. The literature recognized two main types of facet ratings autonomous facets and the corresponding facets. The leading e-commerce sites (Amazon, eBay) use the FS of structured data, which typically shows all aspects of the present search result collection that are relevant. When too many attributes exist for one facet, the most common is displayed to the user, and the remainder is hidden with a “more” button. The first FS introductory version describes facets of an app with a user interface perspective. Standings in combination with a faced interface could be applied [162,163]. The autonomous fact-based evaluation techniques are primarily dependent on the identification ability of facet-based frequencies [164–167].

The first group introduced a faceted query strategy and classification of web APIs, which considers API characteristics or facets identified in their HTML illustrations. Furthermore, the query engine opportunities that permit a classification depending on weighted query conditions and facet conditions were explored [168–171].

The second group presented idea analysis and increased the classification by defining the primary subjects of articles, combining reinforcement learning with a new customer interaction layout to involve people in query management actively. This document, ranking SVM, was used to build a model ranking for the precise bug reports, learning to rank technology [172–175].

The third group suggested model description and FS application search algorithms move to a web of objects knowledge. It provided characteristics for rank facets depending on the usefulness of the test outcome records for partitioning. The scheme’s architecture also has its primary elements and its implementation as a portion of the query environment for the images [176–180].

Lastly, the final group described metaservices without prior indexing of the data stacks surrounding them. In addition, it suggested a set of fusion-based techniques for the sustainability of results to enhance efficiency, both that which is relevant and diverse. Experimental findings indicated that specific fusion methods that use the above techniques work better than cutting-edge fusion processes for diversifying outcomes [181–184];

Faceted navigation-based XML search: For many applications, XML is now the conventional data format, and accurate recovery techniques are desired. Generally, there are approximately two types of recall methods, notably path-based methods and search for keywords, and they do not work if users do not need any tangible data. This is to increase XML data recovery effectiveness [185].

FS articles focused on types of applications provided on XML data to enable consumers to discover the information needed from XML data by specifying variable content sets for the present query findings. The main application was also demonstrated, which is an integrated FS in nephrology based on information extraction results. The suitable conditions to summarize the present outcomes with the components of the verbal faces were obtained [186,187].

6. Discussion

Relevant studies on state-of-the-art faceted search-based filtering were presented in this review. The primary aims was to provide a new vision for faceted search and highlight research trends in this area. The survey revealed three aspects of the literature content: challenges in successfully utilizing these applications, recommendations to alleviate these difficulties, and the proposed general framework for the search and browse procedure. Topics related to faceted search based on information filtering are described in Figure 9.

RQ4. What are the existing motivations for usage, concerns, challenges, and recommendations to enhance the use of the faceted approach of web search service providers?

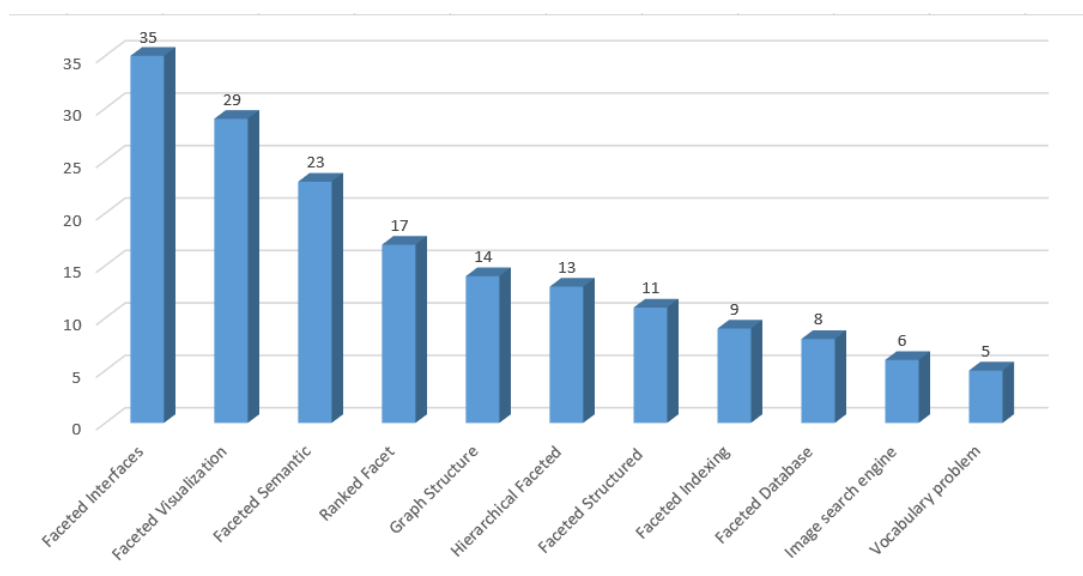


Figure 9. Topics related to faceted search based on information filtering.

6.1. Challenges

Although FS based on information filtering offers numerous benefits, these applications have limitations in SEs. The surveyed works indicated that researchers are concerned about challenges associated with FS and their use based on information filtering. The main challenges in adopting FS are classified according to their nature, presented in this section, and citations for further discussion are given. Although smart FS offers numerous benefits, the evaluation metrics demonstrate that these technologies are limited by information overload [9]. The surveyed works indicated that researchers are concerned about the challenges associated with information filtering and its use. The main challenges in adopting FS are listed below, along with citations for further discussion. The challenges are classified according to their nature (see Figure 10).

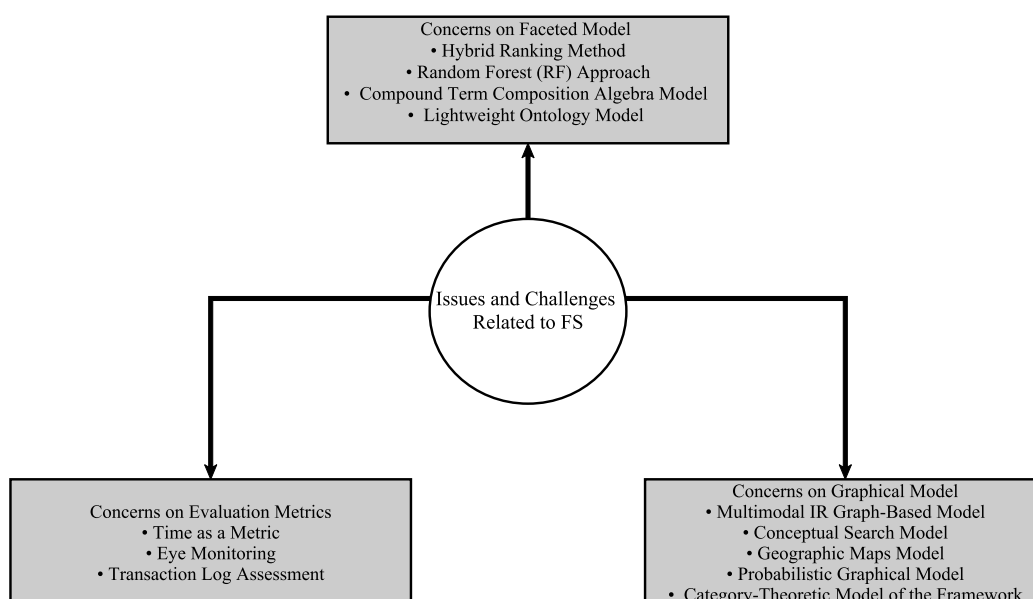


Figure 10. Categories of challenges for faceted search based on information filtering.

6.1.1. Faceted Model

Several researchers have focused on faceted models. Four typical set theory-based models are presented below.

Several researchers have focused on faceted models. Four typical set theory-based models are presented below: (1) the hybrid ranking graph-based approach, which describes facets as an imminent characteristic of object information, can also illustrate the information itself [52]; (2) Random Forest (RF) uncovers non-influential search-flexible variables; the RF model suggested that the minimal effect of cumulative action history on the facet addition verifies the findings of this work, which are similar to the fundamental context of long short-term memory [53]; (3) the theoretical model of compound term composition algebra (CTCA), which flexibly and effectively identifies important terms compared with the faceted taxonomy; being appropriate and effortlessly, it defines valid and invalid compound terms [188,189]; (4) the lightweight ontology model of a website and a context similarity approach to reorder facet queries; the lightweight ontology presumes that information may be duplicated in a multilist website; context similarity can enhance facets using fine-grained similarities, although unique facets of weighting can be obtained from different websites [61].

6.1.2. Graphical Models

Four typical graphics-based models are discussed in this section. The multimodal IR graph-based model combines distinct modes through face search formulation and models distinct information collection types with unique methods and connection types. (1) A conceptual search model is build that is suitable to describe various user actions in searching and exploring semantic data. The search model analyses facet graphs in terms of general data search demands, which are constructed in conjunction with semantically specific queries of graph visualization based on FS [96,190]. (2) Based on the Bayesian suggestion algorithm, a large amount of data that are widely used on the enterprise search platform Solr is visualized. The Bayesian suggestion algorithm and the probabilistic graphical model capture facet dependencies and determine valuable facets to be presented to users [191]. (3) Text in each visualization, such as clouds, are used to determine the frequency of words or phrases; word trees obtain the context surrounding a word or phrase, and phrase nets provide relationships between words or phrases that are unique [192–195]. (4) These can order facets by user's values and objects using best, worst, preferTo (relative preferences), aroundTo (over a specific value), and other actions that can order them lexicographically or based on their values or count values. The use of geographic maps to display focus items during the interaction and as inputs implies that the focus is restricted, and the preferences are defined [97].

6.1.3. Evaluation Metrics

Emotional reactions are typically gathered using post search questionnaires to evaluate the respondent's understanding of the scheme [63]. (1) Time as a metric is controversial because time is unsuitable for measuring exploratory assignments. The rapid completion of an exploratory task may suggest the absence of support in a search system for investigating and exploring [18]. (2) Eye monitoring stimulated recall and interviews to explore significant elements of gaze conducted in the face catalog interface. The top 10 gaze transitions derived from eye-tracking information indicate what searchers are looking in the faceted interface and suggest the relevant portion or element of the interface [32]. (3) Evaluating ES, assessment research aimed to assess hypotheses about customer needs and system specifications from prospective customers' perspectives and adopt either transaction log assessment or user testing, as well as to understand the search conduct of customers with the faceted interface [136].

6.2. Future Research Directions and Recommendations

Although FS has been extensively explored, several issues still need to be addressed. We gathered and described feasible and potential future investigations on faceted search (see Figure 11).

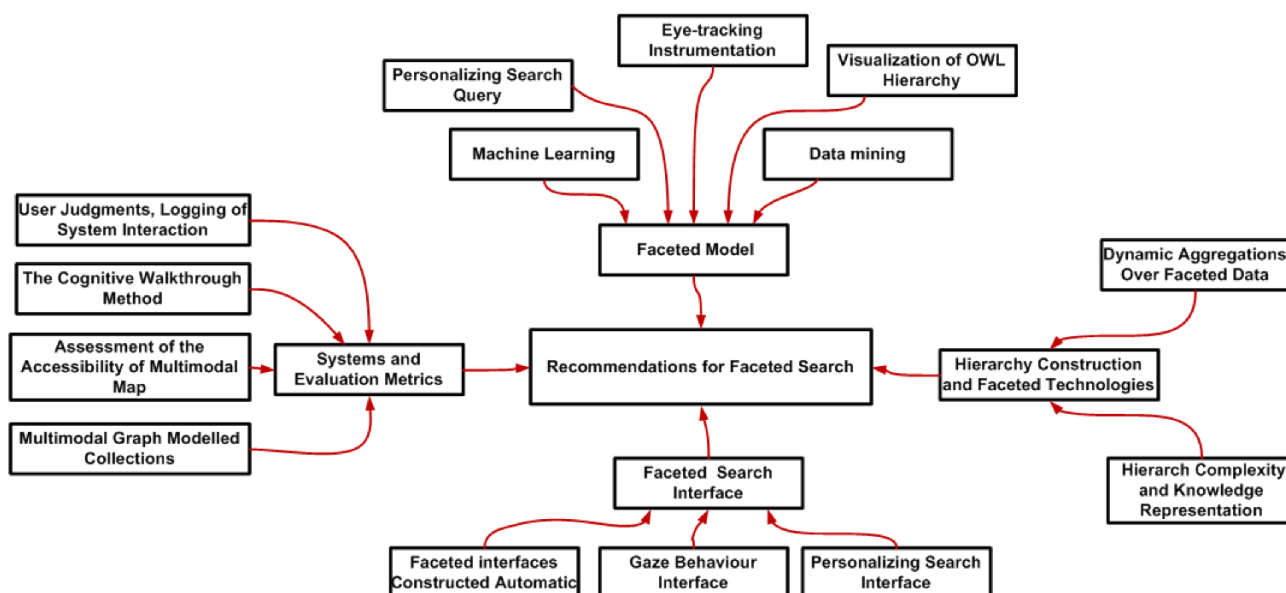


Figure 11. Categories of recommendations on faceted search.

6.2.1. Faceted Search User Interface

Users can confidently expand certain facets in the hierarchy of faceted interfaces, and web results can then be sectioned to enable switching to other hierarchies whilst browsing. These multifaceted interfaces allow the exposure of web content and help users rapidly find items of interest. The majority of faceted interfaces in current systems are manually constructed. Building strategies for the automated development of faceted interfaces is an important task that allows extensive faceted interfaces. Facets help improve the user experience for structured web searches. The following challenges must be addressed to utilize SE facets effectively: (1) given the restricted screen display property and wide range of possible facets, selecting the top-k vital facets is necessary, where k is generally a small quantity; (2) many structured data sources are available on engines, such as Amazon or Google. If the information is summarized as denormalized entity-type tables, thousands of such tables must be remembered [125].

Future investigations can focus on assessing additional interface factors and their impact on gaze behavior regarding the number of facets, matching the degree of facets with the topic/task, searcher domain knowledge, and search experience, the stage of the search, and high-level work task situations. Guidelines for possible work from a theoretical perspective have been proposed to examine the application of faceted issues with additional features suggested by practice, especially in negation sorting. Comprehensive face-related query features are also assessed in the ontology.

6.2.2. Faceted Model

The use of databases, data mining, machine learning, and other methods was suggested in the FS of [196]. These research areas are intended to focus on the contents and schemes of a database further by producing a reduced version that can describe the data at various granularity levels. Multiple methods, including random hikes, hierarchical clustering, and probabilistic synthesizing, are introduced to synthesize lists and opinions. Search databases are independent of queries; therefore, such methods are insufficient in

handling all the searches, although the findings of a particular question can be summarized during each phase.

In summary, this study investigated customer relationships with facets to comprehend real-time facet use during searching apart from current searches in creating algorithms for FS and empirical research in facet evaluation. Data mining and machine learning methods were used to connect facets, find vibrant variables, and improve search results [53].

Other future studies can also explore detection when queries have minimal ambiguity in intent, but seek content to cover various aspects and learn semantic query annotations suitable for the target purpose of each query. Such studies focus on personalized search based on models representing individual needs and intentions of users that can model the topical and even cognitive aspects of user intentions.

6.2.3. Faceted Search Systems and Evaluation Metrics

Several methods have been used to evaluate information retrieval systems from the point of view of their users. Each evaluation method concentrates on specific goals (e.g., evaluation of usability, usefulness, or retrieval performance of a system) and is subjected to different constraints. User involvement can take the form of relevance judgments, logging of system interaction, and observations of information-seeking behavior with the system.

The study aimed to evaluate the view of the assumptions of potential users. The method devised for this evaluation, denoted participative conceptual walkthrough, combines aspects of the cognitive walkthrough method from HCI with ideas from conceptual analysis and other established approaches. This method aims to evaluate the interactive information retrieval of the development process in the early stages and incorporate domain knowledge into the development of conceptual frameworks.

RQ5. What are the points of interest, such as the architecture, applications, issues, research questions, motivations, recommendation criteria, and open challenges, in using faceted search?

6.2.4. Faceted Technologies and Hierarchy Construction

Guided navigation tools can be significantly enhanced beyond essential search facets by understanding information further. The capacity to display versatile and vibrant aggregations over faceted information as typically seen in organized information in business intelligence applications can enable additional educated push-back and roll-up customer choices that can lead to solid decisions. Another problem is creating a fundamental data model in FS because of its minimal real-life information, which links records to pairs of principles across multiple facet hierarchies. For instance, papers describing products can demonstrate connected facet characteristics, which are dependent or unrelated (see Figure 12).

Hierarchical FS metadata, a highly understandable data model for SE interfaces, is intermediate in complexity between hierarchy and full knowledge representation. Although websites, especially e-commerce sites, have typically used category information for navigation, applications are commonly inconsistent, incomplete, or problematic in many cases. A device that uses metadata to access the digital library is an original efficiency survey, which allows the visual detection of implicit correlations between facets. Faceted systems typically hide the full extent of the available hierarchical metadata, making it difficult to identify patterns or linkages between facets. Thus, faceted environments are an exciting possibility for further investigations and refinement.

The first feature produces all the appropriate composite conditions consisting of one or more facet variables to ensure that the composite form chosen by the customer can be determined. The second function of facet ranking and facet representation is suitable for the inquiry, and the third user function is fed back from the designated SE facet terms. (a) Precalculation of paper facets and facet conditions (b) can take facets out of the study results. Two distinct and dynamic methods are available. The scheme changes the number of information pieces corresponding to facet conditions on the user interface and recounts

facet conditions around the exact moment for to follow navigation activities. Iterations proceed until the outcomes are achieved. Previous sections discussed how to build a unified template for heterogeneous XML data.

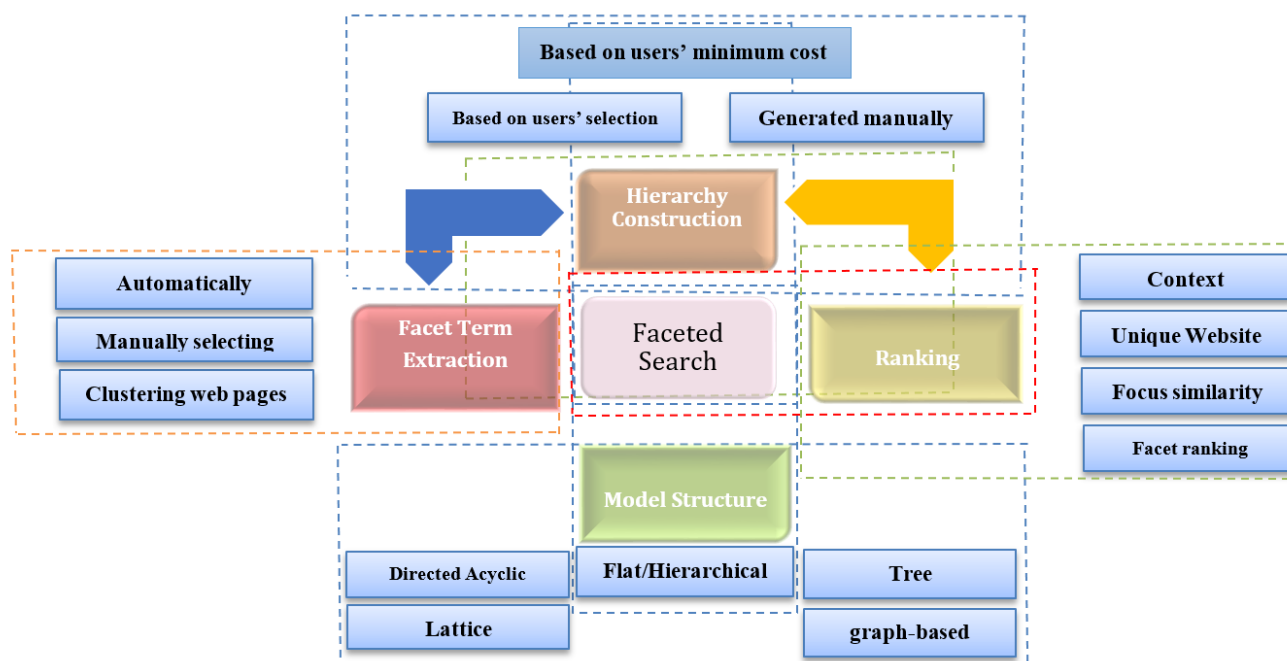


Figure 12. General framework. for a faceted search system.

Personalized search schemes and ES applications have attracted considerable research attention. The strength of synthetic intelligence methods was investigated separately to provide customized query outcomes following distinct customer concerns, environments, and duties. However, ES capitalizes on the strength of human intelligence and offers consumers strong web engines. They can reinforce each other because of the consistency of these methods. This study argued that customized survey schemes can improve this by enabling customers to communicate with the scheme and learn about the issue to achieve their end objective.

7. Conclusions

In this article, the descriptive faceted search model was reviewed and analyzed. Moreover, the progression of its techniques, including removing facet words, hierarchy, and facet classification, was described. Furthermore, we discussed the evaluation metrics of faceted search by highlighting the main characteristics of existing faceted search systems. Therefore, the fundamental features of this evolving area were identified, and the motivations and difficulties for using FS applications were demonstrated carefully. Furthermore, this paper highlighted many potential studies that can be undertaken, including automated faceted taxonomic design and visualization, significance assessment for FS outcomes, faceted interfaces, hierarchical structure, and graphic design. Our recommendations provided solutions to many challenges related to the use of faceted search. These challenges are linked to facet term extraction, hierarchy construction, compound term generation, and facet ranking. Finally, this review summarized the ideas of the related literature, thereby presenting a valuable reference for researchers.

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and A.R.A.; visualization, M.N.M. and H.N.; supervision, M.N.M. and Q.S.Q.; project administration, A.R.A.; funding acquisition, A.R.A. All authors have read and agreed to the published version of the manuscript.

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