

TEXT MINING AND TOPIC MODELLING FOR KNOWLEDGE DISCOVERY IN DIGITAL COLLECTIONS

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ABSTRACT

Kenyan research and academic libraries have been experiencing challenges managing the growing collections of digital scholarly publications making it hectic for librarians to systematically organize resources and users to access relevant content efficiently. Text mining has evolved as a strong method for obtaining insights from large textual sets of data, allowing for thematic analysis, automated knowledge discovery, and enhanced organization of content. Nevertheless, its usage in the Kenyan academic and research library context remains limited. This study explored text mining and topic modeling application on scholarly publications using open access digital libraries. The study sought to identify research patterns, establish latent themes, and express how these techniques could enhance accuracy in knowledge access, management of time, and thematic organization in the context of Kenyan academic and research libraries. The study involved collecting and preprocessing a corpus of library science and digital library articles. This included tokenization, stop word removal, and standardization. Using word cloud visualization, prominent terms were identified, while TF-IDF analysis displayed distinctive keywords. Dominant topics along with related document groupings were done using Latent Dirichlet Allocation (LDA), permitting insight into thematic constructs across the corpus. Analysis showed existence of three major topics that include digital library systems, open access and repository management, and scholarly publishing practices. We identified frequent terms like "library," "digital," "metadata," and "repositories", stressing on the use of text mining technology-driven library systems. The techniques expressed that text mining could systematically support automated classification, display latent trends, and facilitate resource discovery in libraries. This study showcases the capacity of text mining to improve content organization and knowledge discovery globally, hence should be practiced in Kenyan academic libraries. Future studies need to explore integration of AI driven text mining with library systems to further improve thematic analysis and user accessibility.

Keywords: text mining, topic modelling, Latent Dirichlet Allocation (LDA), TF-IDF, knowledge discovery, digital libraries, Kenyan academic libraries

INTRODUCTION

Libraries have traditionally worked as fundamental institutions for preserving, organizing, and distributing recorded knowledge through controlled vocabularies, structured cataloguing systems, and human-facilitated indexing. However, the rapid growth in digital technologies, has altered library collections into institutional repositories that contain large volumes of scholarly and multimedia content and large-scale digital libraries [1]. Although this revolution has expanded access; it has also presented problems regarding efficient resource management, information overload, and effective knowledge discovery.

The exponential rise in digital content has made traditional metadata-driven techniques increasingly ineffective. While manual cataloguing and subject indexing are precise, they require huge resources, and are also difficult to scale in settings where large document volumes are continuously added [2]. Besides, there is complication consistently classifying documents considering the interdisciplinary nature of contemporary scholarship, as documents usually span diverse subject domains. Thus, digital library users often struggle to detect emerging research trends, establish relevant materials, and make a comprehensive understanding of extensive collections [3]. As a result, computational techniques on text analysis have attracted prominence in the context of library and information science. Text analysis entails automated extraction of themes, patterns, and connections from unstructured textual information through machine learning methods, specifically natural language processing [1]. As opposed to traditional indexing, text mining gives room for scalable analysis of large corpora and reveals latent semantic constructs without sole dependence on predefined metadata. This capacity is critically important in digital libraries where full-text documents are instantly available [4].

Among text mining methods is the topic modelling, specifically Latent Dirichlet Allocation (LDA) which is an effective technique for establishing hidden thematic patterns and structures within document collections [5]. In topic modelling, the multidimensional nature of texts is

acknowledged through allowing documents to be correlated with multiple subjects, supporting more complex representations of scholarly communication. From empirical studies, topic modelling aids in trend detection, collection analysis, and research evaluation, thus informing strategic decision-making and evidence-based collection development [6]. Besides, the rise of open-access repositories like CORE further highlight the significance of text mining for libraries. While the open platforms expand knowledge access, their scale comes with navigational problems. Notably, topic modelling and text mining provide scalable solutions for summarizing and organizing such collections [7].

The techniques, though limited to parameter selection and interpretability, are best viewed as complementary tools that improve, rather than substitute, professional librarianship. This study presents text mining concept and its application to library science, applying the LDA concept to extract topics and patterns from open-source libraries online highlighting the importance of Kenyan libraries embracing text mining techniques for quick and precise information access.

In the recent past, Kenyan academic and research libraries have increasingly adopted open-access and digital repositories podiums to support research, teaching, and innovation. However, the speedy expansion of full-text digital collections has outdone the capability of traditional indexing, cataloguing, and metadata-based retrieval systems regularly employed in these libraries. Consequently, users usually experience limited identification of relevant resources, information overload, and difficulty establishing developing study themes within open-access and institutional repositories such as CORE. Thus, while there exist advanced topic modelling and text mining methods, their practical usage in the context of Kenyan digital library remains low, with inadequate empirical research proving their efficacy for large-scale knowledge discovery. This gap limits the ability of researchers and librarians to methodically support evidence-based collection development, analyze content trends, and enhance access to knowledge by users. Accordingly, there is a need to assess how topic modelling and text mining can be used in digital collections to enhance knowledge discovery in Kenyan digital libraries.

Study Objectives

This study sought to examine use of [text mining and topic modelling methods on digital library](#) collections to improve content organization, automated knowledge discovery, and thematic analysis in the context of Kenyan academic and research libraries. Specific objectives were to;

1. collect and preprocess scholarly publications from open access digital libraries using text mining techniques.
2. employ topic modelling to establish research patterns and latent themes within the corpus.
3. create visualization and interpret the identified topics, establishing insights that can improve knowledge access accuracy and time management in the context of academic libraries in Kenya.

LITERATURE REVIEW

Topic Modelling Techniques for Knowledge Discovery

Topic modelling is a text mining technique that obtains latent thematic compositions from large collections of documents. It is specifically important for digital libraries as it allows documents to be presented as combinations of subjects, reflecting the multidimensional nature of academic information. The most widely used mining technique is Latent Dirichlet Allocation (LDA). It assumes that every document is acquired from a range of topics where each topic is distinguished by a distribution of words [8]. LDA is widely employed in the digital library studies to establish research trends, reveal hidden themes, and support automated content categorization [9]. The second technique is Non-Negative Matrix Factorization (NMF) and Latent Semantic Analysis (LSA); these have been applied to extract latent semantic structures in text corpora. These methods vary in their mathematical tactic but share the common goal of reducing dimensionality and unearthing existing themes [10].

Latest improvements in topic modelling have combined contextual embedding and deep learning to enhance topic consistency and interpretability. Techniques like neural topic and BER Topic models apply transformer-based embedding to obtain contextual meaning prior to

clustering words into topics ^[11]. Such methods are particularly important in handling vast, varied digital collections with significant variation in vocabulary and writing styles. Besides, topic modelling has been employed to detect topics dynamically, tracking topic evolution over time, providing intuitions into emergent research routes and alterations in scholarly focus ^[12]. Although topic modelling provides formidable means for knowledge discovery, its success relies on careful parameter tuning and accurate topic quality evaluation. Notably, while the advances are evident worldwide, Kenya has limited empirical evidence regarding adoption and performance of topic modelling in digital academic libraries. Thus, Existing studies mainly focus on well-resourced settings with robust computing infrastructure and high-quality metadata, which is not a reflection of the realities in many Kenyan institutions. Besides, there is insufficient research assessing application of topic modelling in the context of open-access repositories like CORE to support Kenyan research and academic libraries in refining knowledge discovery, collection management, and research trend analysis. This gap stresses the need for context-particular research that evaluates topic modelling effectiveness, interpretability, and practical utility in the context of Kenyan library digital collections.

Preprocessing and Feature Engineering in Text Mining

Text mining and topic modelling success mainly relies on actual preprocessing and feature engineering. Usually, raw text data from digital collections have noise including special characters, HTML tags, and irrelevant segments like footnotes or references. It is therefore important to preprocess data, involving cleaning to reduce noise and enhance quality of extracted characteristics ^[13]. In text mining and topic modelling, preprocessing steps involve tokenization, stemming, stop-word removal, and lemmatization. While tokenization involves breaking texts into meaningful units, stop-word removal removes common words carrying little semantic value such as “the”, and “and”. On the other hand, stemming and lemmatization reduce words to their base forms, enhancing alignment in the vocabulary used for analysis ^[14]. Notably, through feature engineering, cleaned data is transformed into numerical representations appropriate for modelling. Traditional techniques, specifically Term Frequency–Inverse Document Frequency (TF-IDF) and Bag-of-Words (BoW) have been applied to represent document-term connections ^[15]. TF-IDF is especially efficient for

displaying important terms through balancing term frequency with general document occurrence. Nonetheless, these approaches may not capture semantic meaning and context. Therefore, current techniques employ word embedding like GloVe, Word2Vec, and contextual embedding from transformer models like BERT [16]. These embedding capture contextual usage and semantic similarity, improving retrieval accuracy and topic coherence.

Preprocessing decisions substantially impact topic modelling results. For instance, exceedingly aggressive stop-word removal may remove domain-specific terms; on the other hand, inadequate cleaning may result in poor topic quality. Thus, preprocessing needs to target the research objectives and characteristics of the digital collection. Yet in Kenya, there are limited studies on preprocessing techniques for digital collections, particularly considering the linguistic variety and contrasting metadata quality in local repositories. Digital libraries in Kenya usually contain documents having inconsistent formatting, mixed language content, and incomplete metadata, which may demand for a customized preprocessing method. Subsequently, there is a demand for empirical research that assesses the influence of different preprocessing and feature engineering techniques on topic modelling precision and interpretability in Kenyan digital library context.

Research Gap in Kenyan Digital Libraries

While there exist extensive studies on text mining and topic modelling in the context of digital libraries internationally, empirical research specific to Kenyan academic and research libraries are limited. Thus, published studies usually focus on developed nations where data availability and digital infrastructure are advanced, leaving a gap for understanding the influence of these methods in the context of Africa with unique infrastructural, linguistic, and resource constraints. Thus, whereas digital repositories are growing in Kenya, their metadata quality and search capacities remain weak, resulting in challenges on knowledge discovery. Besides, limited evidence exists regarding the practical usage of topic modelling for supporting library services like research trend analysis, collection development, and user centered discovery in Kenyan academic and research institutions. This study addresses the gap by evaluating application of text mining and topic modelling methods on open-access

digital collections, dwelling on how these techniques can enhance knowledge access in the Kenyan academic setting.

This study applied text mining and topic modelling methods to extract scholarly articles from open-access digital repositories, specifically CORE, analyzed the extracted articles in library and information science to discover knowledge structures, latent themes, and patterns. Notably, whereas CORE corpus is worldwide, results relate to improving collection management, knowledge discovery, and research support in the context of Kenyan academic libraries. The study excluded local repositories and proprietary databases because of access limitations. It however stresses the larger pertinence of computational text analysis in guiding decision-making, enhancing digital library services, and supporting evidence-based techniques in Kenya's library sector.

METHODOLOGY

Research Design

Research design was quantitative, where machine-learning text mining technique was applied to extract latent themes from digital information within the realm of digital libraries. The study employed a corpus-based computational workflow, integrating retrieval of documents, preprocessing, feature engineering, topic modelling, and model evaluation. Primarily, the study employed Latent Dirichlet Allocation (LDA) as the topic modelling algorithm considering its capacity to represent documents of diverse topics and themes as distributions over words [17]. The study dwelt on establishing main topics in digital library research, such as information retrieval, metadata standards, open access, digital preservation, and scholarly communication. The methodology supports automated knowledge discovery through transforming unstructured text into structured topic interpretations that can be computed and interpreted using statistical measures.

Data Collection and Sampling

Data was acquired from the CORE open-access repository through CORE API and the search query "library science OR digital libraries" using the link, <https://api.core.ac.uk/>. A total of 500 documents, published between 2015 and 2024, were sampled to capture modern research

trends. The articles were downloaded in PDF format and stored in a structured directory. In support of subsequent analysis and interpretation, metadata such as title, publication year, author, and DOI were recorded. Files were then converted to plain text using PyMuPDF, allowing computational processing. The sampling technique was targeted on ensuring adequately large corpus for robust topic modelling while keeping alignment to the research domain and evading exceedingly broad document retrieval.

Data Preprocessing and Feature Engineering

Data preprocessing was performed using two Python libraries, NLTK and spaCy. Normalization of texts entailed transforming all text to lowercase and removing numerical digits, punctuation, and special characters. The text was further split using tokenization, resulting in individual words. Thereafter, stopwords removal was conducted to remove common English domain-specific stopwords like “doi”, “et al.”, and “https”. Tokens were reduced to their base forms through lemmatization, ensuring coherent representation of word variations. Through noise filtering, tokens having less than three characters and terms featuring in less than two articles or in more than half of documents were removed. Feature engineering was then conducted, involving developing a TF-IDF matrix and a Bag-of-Words (BoW) corpus. A dictionary was then generated using Gensim to map every peculiar token to an identifier; BoW representation also captured term frequencies in each document. Using Scikit-learn, TF-IDF was computed to stress on significant terms and mitigate common term weights. Feature matrices were then stored for input into the LDA model.

Topic Modelling and Parameter Tuning

Topic modelling was executed through Gensim library. Thus, using grid search over the number of topics, eta (topic-word density), alpha (document-topic density), and number of passes, the LDA model parameters were tuned. The candidate topic numbers ranged between 5 and 15, and the final number was chosen based on interpretability and coherence. Every model run resulted in document-topic distributions and topic-word distributions. The topics were categorized based on the highest likelihood terms, targeting subjects like open access, information retrieval, metadata standards, digital preservation, and research analytics. The

ultimate model was chosen based on attaining the highest consistency score while holding diverse topic separation.

Model Evaluation and Output Reporting

Model assessment entailed both quantitative and qualitative measures. Quantitatively, topic coherence (C_V), was used to assess model fitness and interpretability. Coherence values were calculated using Gensim's coherence model. Qualitative validation entailed manual review of top keywords and sampling documents related with every topic to validate thematic relevance. Reporting involved generation of non-interactive outputs, including a table of topics alongside their top keywords with odds, a table containing topic distributions in the selected documents, graphs displaying topic prevalence, and coherence scores across dissimilar topic numbers.

RESULTS AND DISCUSSION

Data Mining and topic identification

The mined set showed five research works focused on diverse library science aspects. The first document discussed open-source repositories alongside their implications for libraries; stressing the role of open access and resource sharing. The next 3 documents dwelt on digital libraries and technology in librarianship. They included topics such as distributed digital library management, digital librarian education, and conceptual structures of digital libraries. The documents expressed strong emphasis on organizational and technological dimensions of library systems. The fifth document examined publishing practices in the context of Digital Humanities, showcasing research on scholarly communication and knowledge dissemination as shown on table 1. This distribution show that the collection covers both theoretical and practical aspects of library science, with specific focus on digital library systems in the context of research and publishing. When applied in the Kenyan library context, the text mining concept can help library users locate documents based on relevant topics, reducing time waste on manual search of documents.

Table 5. Theme identification and classification

	text
0	Open source repositories: Implications for lib...
1	Computational sense: the role of technology in...
2	Managing complexity in a distributed digital l...
3	What is a digital library?: Possibilities from...
4	Publishing as Sharing: observations from Oral ...

Text Preprocessing and Tokenization

Through tokenization using document titles and abstracts, every text entry was broken down to a list of meaningful words also referred to as tokens; stopwords and punctuations were removed at this level. The resulting values are presented on table 2 below.

Table 6. Tokenization results

	text	tokens
0	Open source repositories: Implications for lib...	[open, source, repositories, implications, lib...
1	Computational sense: the role of technology in...	[computational, sense, role, technology, educa...
2	Managing complexity in a distributed digital l...	[managing, complexity, distributed, digital, l...
3	What is a digital library?: Possibilities from...	[digital, library, possibilities, idea, digita...
4	Publishing as Sharing: observations from Oral ...	[publishing, sharing, observations, oral, hist...

The table shows that in the first document, “Open source repositories: Implications for libraries”, was tokenized into ['open', 'source', 'repositories', 'implications', 'libraries'], seizing the main terms that exhibit its main aim. This was the same case with subsequent documents like the digital library systems and technology in librarianship where words like ['computational', 'technology', 'education'] or ['digital', 'library', 'distributed'] were retained, showing their organizational and technical themes. Words such as “the”, “is”, “for” were filtered out through tokenization and text reduced to core content words, which were then used for further analyses such as topic modeling, keyword extraction, and similarity comparisons. The tokenization activity practically demonstrates how text mining can automate content

organization and theme discovery, an aspect that can be adopted in Kenyan academic libraries to enhance knowledge access, search accuracy, and service efficiency.

Visualization of Frequent Terms with WordCloud

The next analytics, WordCloud, was developed using the above tokens, showing words based on their frequency. Words such as “implications”, “education”, “source libraries”, “digital,” “library,” and “repositories” generally appear larger, showing their prominence as shown on figure 1 below. Further, this demonstrates how text mining can be applied to support Kenyan academic libraries through showcasing visually the dominant topics in collections, allowing fast content summarization, enhanced collection understanding, and more effective user guidance without manual review.

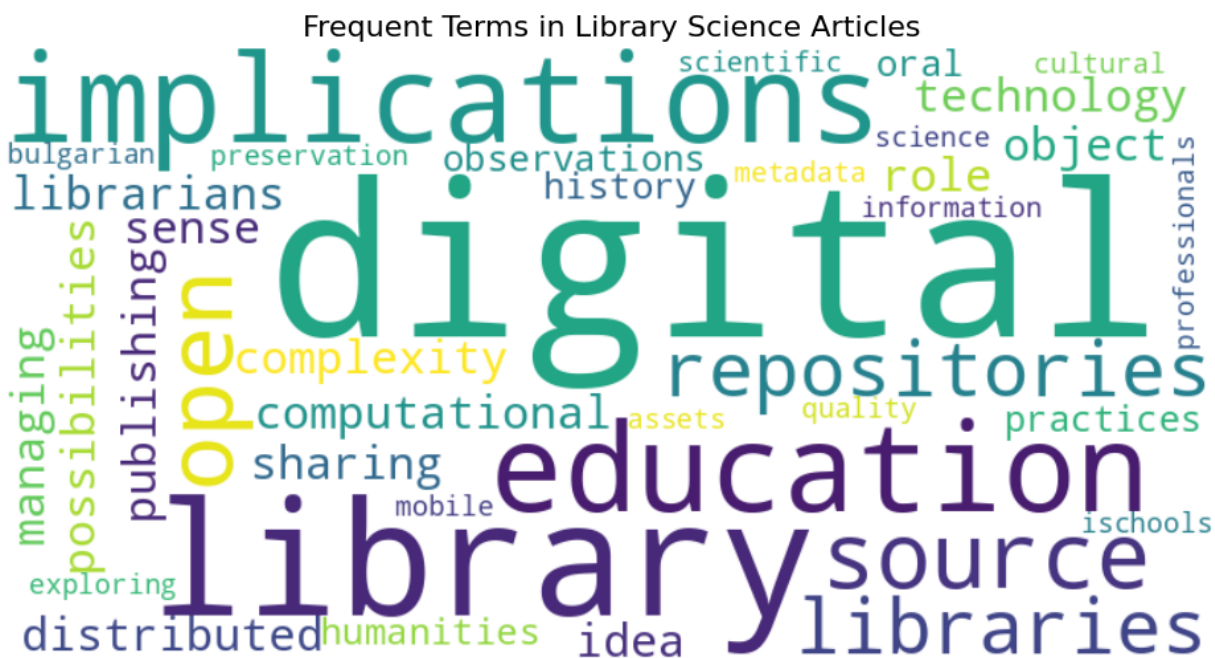


Figure 1. Work frequency

The words were further extracted using TF-IDF (Term Frequency-Inverse Document Frequency). Here, as shown on table 3, top 20 keywords like “library,” “digital,” “libraries,” “education,” “metadata,” “computational,” and “humanities” emerged to represent the core concepts across the library science articles. Here, words that are particularly distinctive in each document were highlighted, showing how text mining helps researchers and librarians

quickly understand the research focus areas, dominant themes, and specialized terminology within the collection.

Table 7. Text extraction

Top 20 TF-IDF Keywords:

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[ 'assets' 'bulgarian' 'complexity' 'computational' 'cultural' 'digital'
  'distributed' 'education' 'exploring' 'history' 'humanities' 'idea'
  'implications' 'information' 'ischools' 'librarians' 'libraries'
  'library' 'managing' 'metadata' ]
```

Document similarity

The concept of document similarity was further analyzed, which according to information presented in figure 1, shows that while documents shared key words, they were all low in similarity, expressing divergence of topics. It is, however, worth noting that documents like 2 and 3 had lowly average similarity, highlighting some level of consistency in research topics.

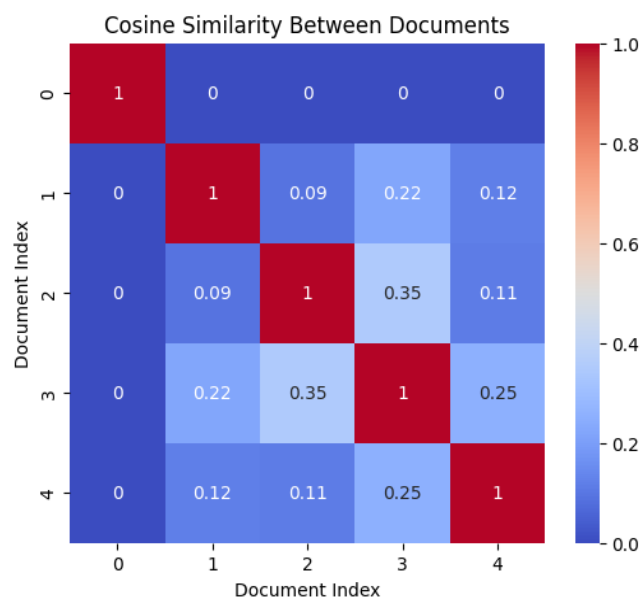


Figure 2. Document similarity

Coherence

The final aspect tested was coherence used to evaluate the model. Results show that the model attained a 0.4514 coherence score, which is an indication of moderate level of thematic alignment across the extracted topics. Further qualitative validation conducted manually on top keywords for every topic aligned with the quantitative coherence, showing sharing of words across documents, and key word dominance. These results provide explicit evidence regarding main knowledge and themes structures which exist in the digital library collection. This supports the conclusions on research trends, topic prevalence, and the potential for enhancing content organization and knowledge discovery in Kenyan academic libraries.

CONCLUSION AND FUTURE WORK

This study explored text mining and topic modeling method application in the context of digital libraries to enhance automated knowledge discovery, content organization, and thematic analysis regarding Kenyan research and academic libraries. Data preparation was done using curated corpus of digital library and library science articles to remove irrelevant terms and standardize data for analysis. Information was then tokenized to reveal key concepts like “metadata,” “library,” “digital,” “repositories,” and “education,”, showing the main themes in the collection. Visualization, done through WordCloud, highlighted the recurrent topics. Distinctive words, on the other hand, were identified using TF-IDF analysis on each document. Topics were then modelled, grouping the corpuses into meaningful groups, among them digital library systems, repository management and open access, and scholarly publishing practices. These findings demonstrate that text mining can methodically unearth latent trends and structures in large collections, providing librarians and researchers with actionable insights for enhancing resource organization and knowledge access. It thus shows that text mining, when correctly applied in the context of Kenyan research and academic libraries, can enhance accuracy and save time on document search.

Implications

Results demonstrate practical application of text mining in Kenyan academic and research libraries. It shows that librarians and researchers can effectively organize collections through automatic categorization of documents into topics; reducing duration spent on manual grouping. Use of visualizations like Word Clouds provides an immediate overview of dominant research themes making it easier for library users to navigate the materials and establish appropriate resources. Further, TF-IDF keyword analysis supports automated discovery of knowledge. This highlights specialized concepts and terms that may else be overlooked. For instance, themes associated with metadata management and digital library systems were clearly eminent, demonstrating the role of text mining in recommending readings, tailoring search results, and establishing gaps in library holdings. In general, these techniques improve content organization, discoverability, and thematic insight, addressing directly the needs of research and academic communities in Kenya.

Limitations

This study was subject to some limitations. To start with, text mining works on digital libraries. This becomes a challenge to academic and research libraries with purely manual operations like in the case of most Kenyan academic institutions. The study also extracted few documents from the open access library, limiting the number of topics extracted. Finally, the research dwelt on titles and abstracts, implying that full-text analysis could disclose additional insights that were not captured here. However, the findings are enough to express the practical utility of text mining techniques in academic libraries.

Future Research Directions

Future studies should focus on improving the practical usage of text mining in Kenyan libraries to mine many documents from diverse backgrounds to increase theme identification and improve the depth of topic discovery. There is also need to develop country specific search engines for Kenya to enable researchers and library users to search using key words instead

of manual document identification. Finally, there is need to explore interactive visualizations for topic distributions and keyword trends to aid researchers and librarians understand collection content and establish emerging areas of interest.

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