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Methods of Modelling Electronic Academic Libraries: Technological Concept of Electronic Libraries

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Abstract: The relevance of examining modelling methods in academic electronic libraries is justified by the need to understand the library's structure and ensure its operation in technological terms. The purpose of this study is to analyse the applied modelling methods for electronic libraries serving Kazakhstani and international higher education institutions. The study employed basic (structural, comparative-comparative) and additional (analytical-synthetic, graphical) methods. During this study, it was found that the main modelling methods for modern electronic libraries include the following: conceptual with the establishment of a clear hierarchy between objects of the electronic library and attributes of search queries, logical using search categorisation, informational employing the semantic principle of material construction and systemic-functional ensuring a balance between functions, structure, technologies and the management system. In particular, after modelling the structure of Kazakhstani, British and American digital libraries at universities, it was determined that the Yale University Electronic Library Collection is built on the method of logical modelling, the Electronic Library at L.N. Gumilyov Eurasian National University uses the systemic-functional method, the Cambridge University Electronic Library employs the informational method and the Al-Farabi Library uses the conceptual method.

Keywords: structure; university; digital space; search query; attributes

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1 Introduction

The analysis of the methods of modelling digital libraries is necessary from the perspective of understanding the technological concept of building library space, specifically parameters such as user-generated search queries, obtaining desired results, categorising information flows through search attributes and ensuring interconnections between resources. The process of modelling the structure of digital libraries is primarily related to establishing relationships and hierarchies between different objects and attributes of library space. Defining modelling methods is relevant as it improves search performance and provides accurate representation of data needed by the user.

Graphical representation of the modelled structure of digital libraries from different universities illustrates the multi-level nature and interconnections within library space, with clear understanding of the main information and search blocks of digital libraries established through drawings and tables (Barabash, Hlyebova and Kolomiyets 2023). Comparisons between Kazakhstani, British and American electronic libraries are necessary to comprehend similarities and differences in the technological concept of academic digital libraries within Kazakhstan and abroad, with such information useful for further studying Kazakhstani and international experiences in managing online catalogues.

According to Tiurkedzhy et al. (2022), modern practices in creating electronic libraries show insufficient content accessibility. The authors emphasise the need for processes related to optimising and promoting resources available in the library, however, this study did not focus on analysing search queries as one of the methods to ensure access to content. Elsewhere, in the study by Berdykulova et al. (2020), modifications to conventional university education into the digital realm are discussed, with the study conducted at the International University of Information Technologies in Almaty. Principles of transformation and advanced practices from international universities were explored, with the authors concentrating on the analysis of digital

transformation, not on the stage of establishment and development of electronic libraries within universities.

A study by Kamilova and Yap (2022) focuses on examining the implementation of subject-specific library practices, where it was established that librarianship in Kazakhstan has its specificity and similarities with international librarianship practices, however, this study does not analyse methods of modelling electronic libraries. In another study conducted by Tuenbayaeva and Kolbayev (2022), the advantages and disadvantages of electronic libraries are explored, leading to their classification, with the main types examined and a comparison made between Kazakhstani and international projects. The study also highlights the fundamental aspects of traditional libraries, delving into the functionality of digital libraries, however, graphical modelling of the structure of digital libraries is absent. Elsewhere, Habibi, Mohd Faiz Mohd and Sofwan (2022) aim to examine the functioning of digital libraries in the context of coronavirus, with the authors proposing solutions to the problem associated with school closures and the inability to conduct offline learning. This study aims for a narrower understanding of the functioning of electronic libraries, omitting the broader context of the phenomenon known as a digital library.

The purpose of this study is to examine methods related to modelling library space in electronic format, forming an understanding of the technological concept of the digital library through key technological parameters. The main objectives of this research are as follows: to examine electronic library spaces from the perspective of modelling methods and to structure digital electronic catalogues using examples from Kazakhstani and international university libraries. The subject of this study encompasses electronic libraries from Kazakhstani, British and American universities, viewed through the lens of modelling methods of digital libraries and the technological concept of digital library.

2 Materials and Methods

The theoretical foundation of this study consists of works by contemporary librarians, technologists in the library field, addressing key questions and challenges related to academic electronic libraries, for example, improvement of electronic library management systems, improvement of the search query system and ensuring communication between users and library staff. In analysing the models, websites of four electronic libraries were utilised: Al-Farabi Library (digital catalogue), Electronic library – L.N. Gumilyov Eurasian National University, Cambridge University Electronic Library and Yale University Electronic Library Collection. Based on them, the logical, informational, conceptual (meaningful) and system-functional method of modelling digital library was considered.

Structural analysis in this study was employed to model the structure of electronic libraries through vertical and horizontal alignments of relationships within the system. Based on the data obtained, key methods used for modelling the aforementioned electronic libraries were determined: conceptual (substantive), system-functional, logical and informational. Regarding the technological concept of electronic libraries, essential parameters necessary for the efficient operation of digital libraries were presented, with attention also given to the thematic, genre-based content and the search query system in each digital library. The results of the online library modelling were visually represented through diagrams and tables.

In this study, a comparative analysis was employed to examine the technological parameters of four digital libraries: Electronic library – L.N. Gumilyov Eurasian National University, Al-Farabi Library (digital catalogue), Yale University Electronic Library Collection and Cambridge University Electronic Library. The comparison was based on the following set of parameters: information categorisation using search attributes, the presence of dictionaries-classifiers, thematic segmentation of materials, distribution of materials based on genre principles, user-friendly information search, presentation of information in a readable format and support for interconnections between resources.

The analytic-synthetic method in this study was applied to explore key issues directly related to the technological concept of electronic libraries and methods of their modelling, as well as effective ways to establish connections between users and library management systems, while some methods for enhancing modelling and designing new digital libraries were also considered. The analysis encompassed the works of contemporary researchers involving surveys and questionnaires, based on experimental methods of cognition.

Graphical analysis was utilised in this study to represent the structure of online libraries that employ different modelling methods, using four diagrams. Moreover, for clarity in presenting the research results, a table was created representing the key technological parameters of academic electronic libraries. Thus, the study incorporated fundamental methods, structural and comparative-comparative analyses, along with supplementary methods, analytic-synthetic and graphical analyses. Each of these methods was employed to investigate various elements contributing to the functioning and management of electronic libraries.

3 Results

An electronic (digital) library is one type of information system where documents are stored in machine-readable form, with access to these documents provided from a single point. An academic electronic library is affiliated with a specific educational institution and serves the purpose of providing teachers and students with electronic materials for learning and research. The main requirements for the technological aspects of an electronic library include storage and protection of materials, geographical mapping, data accuracy, the use of an adequate number of dictionaries-classifiers, establishing connections between information resources and providing information in the preferred format chosen by the user. Technologically, the electronic library can be represented as a multi-level structure consisting of the following components: data repository, metadata server, application server and reference dictionaries (Abdymanapov et al. 2021; Ronzhes 2023; Tammaro et al. 2022).

Modelling is the process of examining specific objects through the understanding of their construction and the analysis of their models, the relationships between their elements and expressing predictions regarding them. In the context of modern electronic libraries, various modelling methods can be identified, such as conceptual, system-functional, structural-activity, logical and informational, while earlier methods such as system-structural, process-oriented, content-logical and informational-activity methods have also been utilised.

The conceptual method of modelling an electronic library involves designing a structure for the subject area where a connection between concepts, their characteristics and classification is ensured. In such a model, the required elements are a root physical object that relates to all structural parts of the library and is represented by the following attributes: identifier, title, topic, keywords, version or annotation and man-made objects indicating the source of information: organisations, publishers, authors, projects, scientific journals and conferences. There are well-known conceptual models such as Functional Requirements for Bibliographic Records (FRBR), Functional Requirements for Subject Authority Data (FRSAD) and Conceptual Reference Model (CIDOC-CRM).

The system-functional method of modelling an electronic library is based on the interaction between key elements: function, structure, technologies and management. In this approach, the relationship between functions and structure is particularly important; for instance, enriching the structure stimulates its functions and vice versa (Akanova et al. 2022; Kozhasheva et al. 2022). The stability of the system is maintained from the technological perspective through the interconnection between management and technologies. Technological advancements in the library contribute to enhancing its functionality, and management must ensure the implementation of all specified functions.

The structural–activity method of modelling an electronic library involves the participation of the university library, teachers, copyright holders and students. Teachers provide the content of the electronic library, and copyright holders regulate this process, while system management enables communication with all these entities, coordination, technological support, extraction of necessary information, information enrichment and evaluation of search effectiveness (Abylgazova et al. 2023). The logical method of modelling an electronic library is based on graphical representation of processes with forecasting expected results in the system of contextual relationships. With the help of this model, the conceptual representation of entities is expanded through additional information (description of characteristics, restrictions) of attributes. Logical connections are established between all elements of the library regardless of their location and content.

The informational method of modelling electronic libraries is based on representing information through a system of signals describing variable quantities, interconnections between them and an object's state under changing external conditions (Revak and Gren 2022). It is usually constructed based on the identification of information flows (internal, external) and their impact on the management system. This method is often used for building semantic libraries, where semantic technologies, taxonomies, ontologies and thesauri are applied to describe object properties; semantic search, recommendation generation and categorisation functions are available for libraries of this type (Kummervold et al. 2021).

The electronic catalogue of Al-Farabi Library includes books, theses, dissertations, article card catalogue, periodicals, rare materials, electronic resources, media library, as well as collections from Wiley online library, Ebsco, Springer and ScienceDirect, with access to it provided in three search modes: simple, advanced and professional. In the simple search format, users can sort the results by document type, shelf number, systematic indexes, headings, keywords, access points, annotation and table of contents. The "display format" function allows selecting options such as full, brief, with explanations, museum, person, learner, image catalogue, electronic document delivery, archive of completed references and requests for collection. The interface of the electronic library also includes sorting options by author, title, year of publication, date of acquisition,

personalities, printing and sending the search results via email (Pluzhnyk and Drok 2023). Modelling using advanced search involves filling in information about the author, title, keywords, year of publication and document type. The professional search includes categories such as author, editor, compiler, co-author, personalities, collective publishers, title, journal or newspaper, keywords, book provision, specialty, subject heading, year of publication, publisher, document type, nature, language, storage location, as well as ISBN and DOI indexes. The structure modelling of Al-Farabi Library's electronic catalogue is presented in Figure 1.

Thus, when creating the electronic catalogue of Al-Farabi Library, the key method is conceptual modelling, as the root object is based on a physical object called "search mode", having attributes such as keywords, title, document type, publisher, journal and personalities. Genre-based modelling of the database is conducted, encompassing books, dissertations, periodicals and article records (Doszhan 2022; Nadirova 2018).

The electronic library of the L.N. Gumilyov Eurasian National University provides a choice of two main categories: database and search type. The database consists of components such as the book catalogue, works of the professional teaching staff of L.N. Gumilyov Eurasian National University, periodicals and bulletins. Various search types are provided: simple, advanced, dictionary-based and cross-searching. New books, dissertations and abstracts are separated into distinct groups and reports. The simple search includes material selection based on all specified words or any of them, the year of publication and genre (books, journals, articles, dissertations, abstracts, textbooks), while the advanced search involves fields, topics and

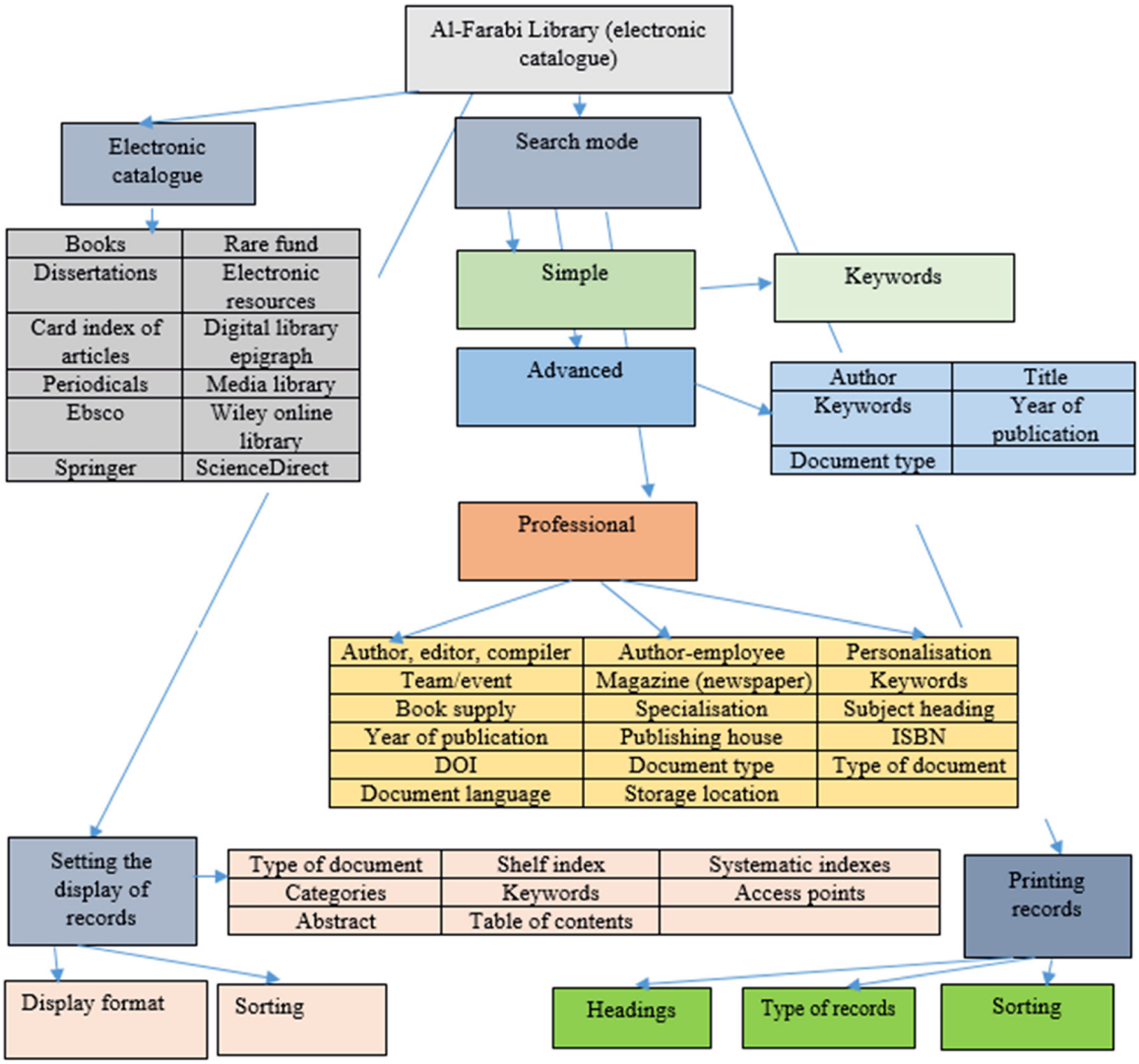

Figure 1: Modelling of the structure of the Al-Farabi Library (digital catalogue). Source: compiled by the authors.

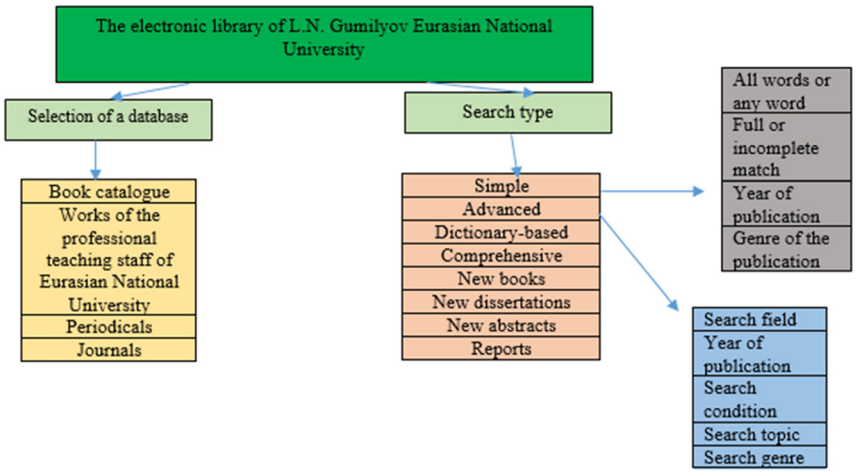

Figure 2: Modelling the structure of L.N. Gumilyov Eurasian National University Library. Source: compiled by the authors.

conditions, where the year of publication and genre can be selected, with the cross-search encompassing the entire database. Figure 2 models the structure of the Electronic Library of L.N. Gumilyov Eurasian National University.

Therefore, the library of L.N. Gumilyov Eurasian National University utilises modelling close to the system-functional approach, as there is a clear connection between structure, functions, technologies and resource management. In particular, a comprehensive approach to the document structure is demonstrated, encompassing all key elements: thematic (main heading), genre-based (type of literature) and management aspects (storage sigla). The branching search functionality allows expanding the library's capabilities over time and enriching it with new resources in response to user demands.

Cambridge University Electronic Library is modelled based on thematic principles through collection names: "Selected Collections", "Discovery" and "Partner Collections." Choosing the "View all collections" function reveals several links, which can be classified into categories: named after scientists, cultural figures ("Darwin Manuscripts", "Joseph Needham" and "Stern and Sterniana"), based on national or geographical affiliation ("Japanese Works", "Islamic Manuscripts" and "Spanish Little Books") and named after universities, libraries and communities ("Westminster College" and "Royal Asiatic Society"). The library offers standard (word and phrase search) and advanced search (search by keywords, full text, individual words, collection, classification, titles, authors, research subjects, language, location and the year of publication). Figure 3 models the structure of the Cambridge University Electronic Library.

Thus, the academic Cambridge University Electronic Library is based on the use of informational modelling, as it is built on a semantic principle; articles and books are categorised into distinct groups based on the interrelation between them and can be moved to other thematic groups when the external environment conditions change, specifically user information search parameters. This library system involves conceptual modelling, providing advanced search options based on attributes such as keywords, title, author, collection, subject and language.

Yale University Electronic Library Collection is filled with thematic-based collections: "Database of the Music Library's Letters", "Historical Archive of Yale Daily News", "Church of Northern India" and "Treatises on Music Theory – Digital Collection." Two search types are provided: (1) by words and phrases; and (2) by search query and date. The feature of the advanced search is that only one parameter can be selected for the search query, not multiple ones simultaneously, as in the libraries presented above. Figure 4 models the structure of the Yale University Electronic Library Collection.

Thus, it can be concluded that the space of Yale University Electronic Library Collection is modelled using a logical method since it presents detailed categorisation not only based on standard attributes like title, subject, date and type but also clear detailing. For instance, searches are conducted based on categories such as "relation is referenced by", "relation is format of", "coverage-spatial", "date-issued" and "date-modifies." The library's collections are modelled on a thematic principle (Nadirova 2018).

The technological concept of modern electronic libraries is based on a set of processes, techniques, operations and methods that ensure the effective functioning of the library, including the creation, storage and utilisation of library products in electronic mode. To provide all the necessary functions of an academic library in an online format, attention should be paid to parameters such as categorising information using search attributes, the presence

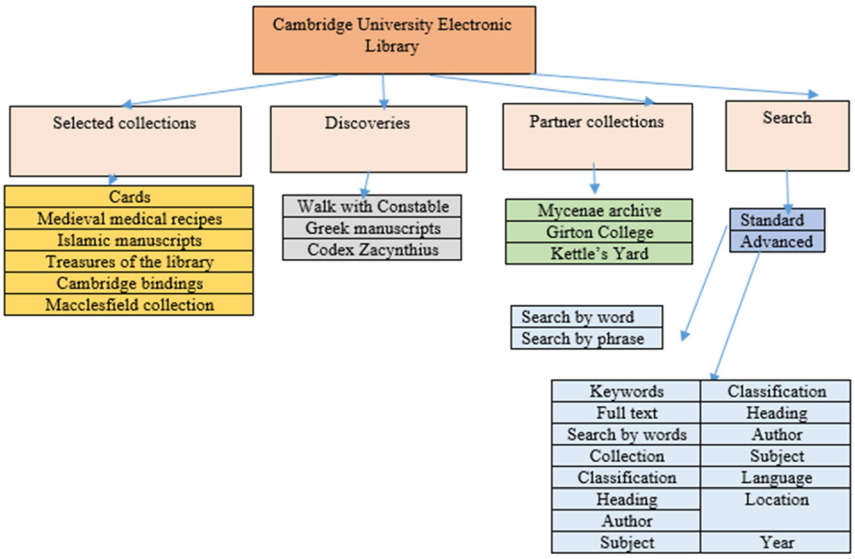

Figure 3: Modelling the structure of the Cambridge University Electronic Library. Source: compiled by the authors.

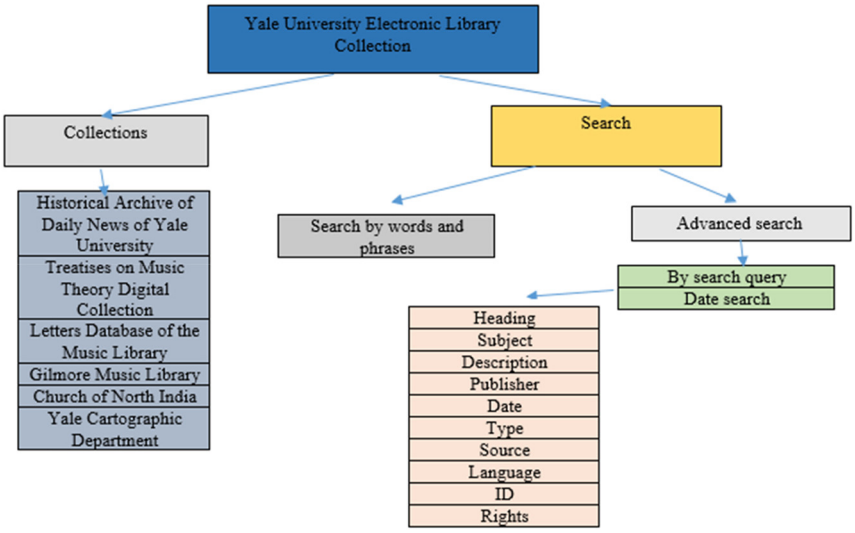

Figure 4: Modelling the structure of Yale University Electronic Library Collection. Source: compiled by the authors.

of dictionaries-classifiers for material identification, thematic and genre-based classification of materials, convenient information retrieval, providing data in a readable format and supporting relationships between information resources within the library. Table 1 shows the correlation between the technological parameters of the discussed academic libraries.

After analysing the technological parameters of Kazakhstani, British and American electronic libraries, the following points can be noted. Firstly, Kazakhstani online resources are focused on the genre-based principle of material distribution, while British and American libraries often use the thematic principle. Secondly, the remaining technological parameters are common: support for relationships between resources, convenient information retrieval and categorisation through the introduction of search attributes. Thirdly, to thus implement the technological concept of an electronic library, different modelling methods can be used, such as conceptual, system-functional, structural-activity, logical and informational. However, modern libraries tend to lean towards using conceptual modelling, which is based on establishing relationships at different levels of the electronic library hierarchy.

4 Discussion

The purpose of a paper by Wang and Ding (2022) is the development of strategies for creating intelligent digital libraries. The authors emphasise that in this context, the task is to ensure an accurate level of clustering, enabling the provision of intelligent recommendations for digital library

Table 1: Comparison of technological parameters of electronic libraries.

Technological parameter	Al-Farabi Library (electronic catalogue)	The electronic library of L.N. Gumilyov Eurasian National University	Cambridge University Electronic Library	Yale University Electronic Library Collection
Categorisation of information using search attributes	+	+	+	+
Presence of dictionaries-classifiers for material identification	–	+	–	–
Availability of thematic segmentation of materials	–	+	+	+
Distribution of materials by genre	+	+	–	–
Convenient information search	+	–	+	+
Provision of information in a user-friendly format	+	–	+	+
Support for relationships between resources	+	–	+	+

Source: compiled by the authors.

users. The technological basis of modern academic electronic libraries can be considered as cluster analysis, involving the division of sample objects into specific clusters so that objects within one cluster are highly similar to each other, while objects from different clusters significantly differ. In the study of Kreutz et al. (2023), the necessity of considering the relationship between the capabilities of information systems and user behaviour when using digital libraries is discussed, with the dataset published in this work therefore representing possible solutions for modelling digital libraries that meet users' basic requirements. In examining the modelling methods of modern academic electronic libraries, it was revealed that establishing a connection between user queries and search results is based on attributes such as publisher, journal, description, title, keywords and date.

Research by Lamba and Madhusudhan (2022) focuses on how thematic modelling based on intelligent analysis can be used in digital libraries, while also discussing important issues such as the advantages and disadvantages, problems, tasks and options for using thematic modelling, which is particularly characteristic of British and American libraries. Geographical names (countries, territorial areas), book authors, or themes uniting books from the entire list can be used in the categories of scientific literature. As noted by Riady et al. (2023), the digital library system aims to satisfy users and create an environment where they can feel valuable, with such a strategy enabling the electronic library to maintain relevance and success in the digital world and stay competitive. Modelling methods for modern electronic libraries are associated with establishing vertical and horizontal relationships between objects in the library structure, categorising attributes and their branched structure in the search system, and comparing functions, structure and management of technological parameters.

One of the new methods of development is the hybrid recommendation method based on Semantics and Popularity in Academic Community-based Egos for Recommendation (SPACE-R), which ensures quality, semantic similarity indicators and maintaining the structure of citation nodes. The research by Yadav and Pervin (2022) showed significant improvements in information retrieval when using this method – from 45.53 % to 78.18 %. For maximum support of semantic indicators in information retrieval, it is better to use methods of conceptual (substantive) and informational modelling. In the study by Williams (2023), the discourse regarding North American academic libraries between 1990 and 2020 is explored, with the research showing that digital initiatives enable more flexible project management. The technological concept of modern electronic libraries is directly linked to the continuous improvement not only of material quality but also of communication between the user and the system when delivering search results.

Factors influencing information retrieval play a significant role in the study of electronic library modelling. Alzahrani et al. (2019) describe the results obtained from analysing data collected through surveys from 978 respondents from Malaysian universities. The authors note that the main success indicators are the quality of the system, information and services, which can be realised in the system-functional model of the electronic library where there is a balance between functionality, structure, technologies and system management, ensuring technological development and the enrichment of library resources. As

noted by Guimei (2019), considering the active development of network resources, electronic libraries will have to create data models that can accommodate all the necessary information, with one possible solution to this problem being data clustering, meaning the service technology will become more automatic and personalised. The author assigns a crucial role to further improving the service concept, with logical and conceptual modelling methods built based on data clustering since they aim to establish relationships between different objects in the electronic library.

Using intelligent analysis, the function of forecasting recommendations can be provided through clustering, meaning users can be pre-grouped based on their profiles and search criteria. The study by Kovacevic, Devedzic and Pocajt (2010) describes clustering and predictive classification methods, with the logical method of electronic library modelling based on predicting search results based on contextual relationships between objects. However, the problem of university libraries is that often the necessary resources are not provided immediately due to delays in delivery times (Koshoeva, Chynybaev and Bakalova 2023). Khan (2016) indicates that libraries, primarily, should be customer-oriented, with information about user requests obtainable from surveys and questionnaires. Establishing a connection between users (students) and the university library is best tracked using the structural-functional method of electronic library modelling.

Liu and Luo (2011) emphasise the user factor, highlighting the differences in the use of electronic libraries by students and graduate students in China; in particular, they arise due to different accents in terms of information search. Modern electronic library search systems are typically based on attributes such as content (title, keywords, topic), genre (journal, publication) and digital (code, identifier). Elsewhere, Isah et al. (2013) examine digital libraries in terms of their components and characteristics, focusing particularly on the DELOS models and the 5S theory, with the concept of their mutual application analysed to clarify the features of electronic libraries. Modelling academic electronic libraries has shown that they are structured through search systems (standard and advanced) as well as thematic and genre principles.

The National Big Data Library Platform of Korea was analysed by Lee and Kwon (2023), examining 17 cases of its usage. The main functions included activity planning library, redesign, marketing library space and management of library collections. The development of the technological concept of electronic libraries at universities should focus on the precise formation of search queries, improving materials in terms of usability and quality and enhancing the relationship between users and library management. An analysis of libraries in Chinese universities by Shang et al. (2017) showed the need to integrate traditional, electronic and mobile libraries, with the authors believing that library development is linked to the use of advanced hardware equipment. This concept aligns with the system-functional method of modelling, ensuring the connection between library content and its management.

Researchers Iqbal and Rafiq (2023) argue that digital libraries should be studied based on specific models of success achieved by users. Evaluating the effectiveness of library modelling methods can also be associated with conducting surveys among students and staff supporting the electronic catalogue. According to McCray and Gallagher (2001), the technology for improving and speeding up work is related to the practice of assigning a unique identifier to a concept-object and linking it with other objects in the collection. Open access is associated with convenience of use; in addition to material accessibility, it is also essential to present them in a readable format, allowing printing and saving of materials.

Upadhayay (2020) emphasises the gradual expansion of electronic libraries, the improvement of library management mechanisms and information retrieval. The methods of modelling electronic libraries at universities are constantly evolving, driven by the update of the management system due to the transformation of user queries to the interface and the operation of the digital library. In the study by Budanović and Žumer (2021), it is indicated that to simplify data entry, it is necessary to create a prototype of a cataloguing interface based on the International Federation of Library Associations and Institutions – Library Reference Model (IFLA LRM). IFLA LRM is a conceptual model developed by the IFLA to provide a framework for describing bibliographic information and library catalogues. Cataloguing or categorising information is primarily associated with modelling all possible user queries through the development of a clear structure of search attributes.

Thus, comparing the results of this study with the results of other researchers has shown that electronic libraries at universities are based on establishing connections between objects within the library, creating a search system based on the analysis of user queries and providing all conditions for convenient use and storage of materials. The main focus is on material categorisation, methods to improve the search system and ensuring feedback between the user and the library.

5 Conclusions

This study established that the following modelling methods are used to implement the technological concept of electronic libraries: detailed categorisation of search in the Yale University Electronic Library Collection, systematic-functional approach with clear links between functionality, structure, management and technologies in the L.N. Gumilyov Eurasian National University, information modelling using semantic principles in the Cambridge University Electronic Library Collections and conceptual modelling involving hierarchical relationships between search attributes in the Al-Farabi Library. It is noteworthy that in the modern development stage of electronic libraries, conceptual (substantive) modelling of materials is used most frequently; through this method, an entire subject area is designed by establishing hierarchical relationships between library objects and various attributes such as titles, keywords, projects, scientific journals and authors.

Comparing the technological parameters of Kazakhstani, British and American electronic libraries, it was noted that categorising information using search attributes is characteristic of all the libraries under consideration. Parameters such as the presence of thematic segmentation of materials, convenient information retrieval, providing information in a readable format and supporting interconnections between search attributes are observed in three libraries, while material distribution based on genre is present in two libraries. Through the analysis of technological parameters, it was revealed that Kazakhstani online resources are structured based on the principle of genre distribution of materials, whereas British and American libraries focus on thematic principles of material distribution.

The development of novel technology solutions to improve search queries and user experience ought to be the primary emphasis of future research directions concerning electronic libraries. More research should be done on the relationships between the technological characteristics of digital libraries to find opportunities for optimisation, the interfaces and architectures of international electronic catalogues to compare and identify best practices and the thematic and genre content of the materials to enhance classification. Further research might look at the long-term effects of electronic libraries and model relationships with new technologies like blockchain, virtual reality and artificial intelligence, while ongoing research is essential to maximising the value of electronic libraries to academic communities, professors and students by enhancing accessibility, relevancy and knowledge sharing in the digital age. Improving digital library modelling techniques and technology conceptions is still essential for information science growth overall, not only for academic institutions.

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