Full-Fledged Access and Usability of Content in a Digital Cultural Heritage Library: Approaches, Paradigms, and Implementation

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The current research presents an approach to the improvement of the librarian infrastructure via the integration of advanced technology and solutions aiming at an immediate, smooth, and continuous adaptation of the libraries in line with 21st-century needs. In particular, this article discusses the design and development of an innovative library environment ensuring descriptive cataloging, subject indexing, intelligent data searching, curation, and collection development aiming to meet the functional needs related to the increasingly growing users' expectations. The effectiveness of the approach has been validated in the Regional Library "Peyo Yavorov"–Burgas, Bulgaria, an associated content provider in the Bulgarian National Interdisciplinary Research E-Infrastructure for Bulgarian Language and Cultural Heritage Resources and Technologies (CLaDA-BG). Testing of the system was made to assure its stability and reliability.

CCS Concepts: • **Information systems → Digital libraries and archives**; **Specialized information retrieval; • Applied computing → Document management and text processing**;

Additional Key Words and Phrases: Digital libraries, digital content challenges, intelligent content management, complex types and grouping for cultural objects

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1 INTRODUCTION

The development of solutions for the intelligent digital management and presentation of knowledge and cultural heritage objects is oriented toward creating new research opportunities in the social sciences and humanities, and in learning. One of the main goals of the National Interdisciplinary Research E-Infrastructure for Bulgarian Language and Cultural Heritage Resources and Technologies integrated within European CLARIN and DARIAH infrastructures (CLaDA-BG) and the Institute of Mathematics and Informatics at the Bulgarian Academy of Sciences (IMI-BAS), as their technology partner, is to follow the guidelines of the European initiatives, and to foster innovative use of cultural resources and sustainable development of European cultural phenomena in a digital environment [1].

The research work of the IMI-BAS team is concentrated on the creation of an innovative library environment ensuring descriptive cataloging, subject indexing, intelligent data searching, curation, and collection development satisfying different users' needs and their research or learning interests. This article presents the creation of a Humanities and Social Sciences Data Storage, Retrieval, and Curation Environment and the implementation of the features in an optimal and detailed version.

1.1 Related Work

The object of the current research is digital content management systems and more specifically **Digital Libraries (DLs)** as a software solution for advanced storing, managing, preserving, and presenting diverse heritage resources [2]. The focus is providing full-fledged access and usability of the content in a digital cultural heritage library so that the main needs of learners and researchers are met [3, 4].

The main areas to work on include the following: the processing of cultural heritage content for import into a digital system, visual digitalization, and the other respective activities [5]; the creation of the metadata, detailed semantic structures that are used to present the knowledge about the objects, and standards [6–8]; the functionalities and architecture of the libraries; technological tools for the implementation and personalization; and content and services customization, among others. Mehta and Wang [9] and Li et al. [10] discuss DL services that are designed to meet the users' needs, such as a review of challenges of pandemic conditions and big data. Some advantages and disadvantages of using artificial intelligence for DL service as a perspective direction for the current developments are presented in the work of Hussain [11] and Omame and Alex-Nmecha [12]. Liu [13] analyzes the characteristics of digital protection of cultural heritage and discusses how to better establish the platform protection and management mechanism. The importance and sustainability of the specifics of the digital warehouses, the need for enhanced content discoverability and effective search, and its functionality and structure, linking data, and the role of the metadata are presented in the work of Woolcott and Shiri [14]. An evaluation of the information content, interface, and tasks as user interaction components for a DL is presented in the work of Li and Liu [15].

Most researchers face problems such as with the static metadata descriptive structures; badly presented heterogeneous and complex cultural content, missing interconnectivity of the content; lack of feedback from the users (end users, editors, creators of content, etc.) about their interests and content needs; lack of improvements for editors and reusability of a common metadata for different objects; missing customization of the search services and personalized content; and a non-intuitive interface.

The existing content management systems (e.g., WordPress and Joomla), repository management systems (DSpace and similar), and DL management systems (like KOHA) partially solve the mentioned issues. For example, it is difficult for content management to manage and present complex objects with heterogeneous and complex metadata. The repository management systems do not have a flexible presentation layer and are not intuitive, because they concentrate on the storage of the objects and content. The goal of DL management systems is to implement the support of processes in physical libraries which are usually used as external systems. They do not provide advanced presentation features.

The current implementation offers new solutions for dynamically extensible metadata descriptive structures, functionalities to help editors' activities, reusability of common metadata for different objects, and customized search services.

1.2 Purpose and Objective of the Article

This article's objective is to present an approach to improve the librarian infrastructure via an innovative environment, named the *Humanities and Social Sciences Data Storage, Retrieval and Curation Environment* (CHCS-DSRCE, https://cultis.math.bas.bg/en) by providing advanced descriptive cataloging, subject indexing, intelligent data searching, curation, and development of collections that answer user needs. The solution is created for the Regional Library "Peyo Yavorov"–Burgas, Bulgaria, an associated content provider in CLaDA-BG.

The main goals of the publication are to identify and provide technological solutions for the challenges of the process of creation, management, and curation of digitalized cultural heritage resources. Section 2 focuses on challenges faced by a library that needs to digitize a huge amount of cultural objects with versatile structures and forms. The section also presents the creation of descriptive metadata schemas for capturing fully the cultural heritage knowledge. Section 3 discusses the achieved result and more details on how the developed system solves the challenges mentioned in Section 2. It also discusses details of how the selected technologies (database type, open source frameworks, etc.) complement the implemented functionalities to help in solving the problems of managing cultural content in digital form. Results of the system testing are made and presented to assure its stability and reliability. Our conclusions and future work are presented in Section 4.

2 MATERIALS AND METHODS

2.1 DL Challenges: The Experience in the Regional Library "Peyo Yavorov"–Burgas

The Regional Library "Peyo Yavorov"–Burgas (also called *Burgas Library*) proved itself as an example of a system that is a cultural institute that not only collects and stores digital items but also provides services for people to use, research, and search for DL documents in different languages and formats. The Burgas Library has integrated different new technological tools and approaches to provide better services for full-fledged access to resources to people with different expertise, needs, or social status. By using software such as zSpace and mozaBook, the library also offers innovative training for areas like science, technology, engineering, and math. Different educational modules are being developed to make laboratory simulations for physics, chemistry, and biology, among others. Those demonstrations are meant to be available for people of different ages and needs, even with special needs.

The process of offering full-fledged access includes a wide spectrum of services and tools and requires the development of a modern digital infrastructure using content descriptive structures, which are going to make sure that not only the data is stored securely but also offers intelligent access and editing.

The amount of library assets offered by Burgas Library is enormous—60,000 unique items including 353 bibliographic objects like periodic journals, published in the region since the beginning of the last century, books, photographs, postcards, and posters, among others. Currently, the employees of Burgas Library are prioritizing the digitalization of the most valuable and rare collections and are preparing their descriptive metadata. The current research demonstrates and tests the collection "Posters for events in the town of Burgas and the region".

Because of the large number of items and their versatile types, there are several problems that we are going to address in the next section, starting with the structure of the data:

- Versatile data means a complex structure of the data.
- Proper types to save the digital content—items can be both material and non-material objects of different types.
- Metadata and additional details to help with the search of the items and automatic grouping.

- Adequate access to the items—the more objects with versatile structures the library needs to store, the more difficult to provide adequate access to them. A database with a lot of unusable objects and digital content that is not accessible and searchable is something that should be avoided.
- Copyright problems with digital content.

2.2 Formal Structures for Detailed Content Description

DLs today are transformed from simple document stores of digital content to very sophisticated content management systems that are offering numerous services to their users, depending on the needs of said users. The main purpose of each DL is to ensure all digital items are easily created, updated, and stored. Because new collections can be created from existing digital resources and intelligent search is available, library documents are easily digitized to form collections, based on the data models that are used to standardize content descriptive structures, according to the recommendations of Dublin Core Metadata Initiative and CIDOC reference model as well as the Europeana Data Model (EDM) [16]. Standardization of the content descriptive structures will ensure successful integration with external systems. However, the descriptive structures should comply with the specific requirements and needs of the library and the services it offers, and the heterogeneity in the area of content indexing [17]. Respectively, the model should be flexible and open sourced, and it should allow improvements and extensions because of the rapid improvements and novelties in DLs.

As part of the DigiCult project (https://digicultproject.eu/), a base ontology and a model for the digital presentation of objects of material and non-material cultural heritage were created as well as hierarchies of collections. RDF technology is used for modeling a complex semantic network. Relationships are described using ordered triples of the type: resources, properties, and assertions. A resource is an object identified by a uniform identifier (URI). This way, resources can be located on the network and retrieved as needed. Properties are a special type of resource that describe the resource's relationships with other resources, such as "made by" and "created on."

According to the DigiCult model, the cultural objects are described through metadata defined in three main parts [18]. The first and second are used for describing non-complex cultural objects, whereas the third is used for describing complex cultural objects or collections.

The first part ensures the provisioning of basic information about the cultural heritage object. The "object" can be intangible or any kind of tangible cultural object, such as music/recordings, text material/book, graphic material/map, song, photographic image, and costume. This part includes attributes such as Name, Inventory number (an identifier of the original object), Description, Genre, Date of creation, Time period, Language; Type; Duration/Size; Synonym (any alternative title); and Material (the medium/physical carrier), Location (spatial characteristics), Keywords. The attributes Description and Keywords allow any other important data about the cultural heritage object to be provided by the creator of the record for this object.

The second part of metadata is used for representing data about the particular digitization process, such as digital object characteristics, copyrights, and access rights. The attributes included in this part are as follows: Digitized by, which specifies who (person/organization) the creator of the digital resource is; Format, which is the format of the concrete digital representation; Copyright owner, which is the name of the owner of the copyrights; Date of digitization; Digital size, which is the size or duration of the digital resource (minutes/bytes); Copyright description/Data Management, which indicates the copyright, usage, and access rights; and Description files, which are links to other files with annotation and/or description of the object (MPEG annotation, Dublin Core annotation, etc.).

The third part includes attributes such as follows: Name, which is the name of the collection; Synonym, which is the alternative name of the collection; Identifier, which is the unique key for the collection; Creator/observer, which is the entity that gathers objects together following implicit or explicit criteria or accrual policy; Copyright, which is information about rights held in and over the collection; Description, which is a summary of the content and topics of the collection; Key object, which is a 'key object' from the collection, be it a masterpiece or a good exemplar; *IsPart*, which is any other collection(s) that contain the current collection; *HasPart*, which is any other

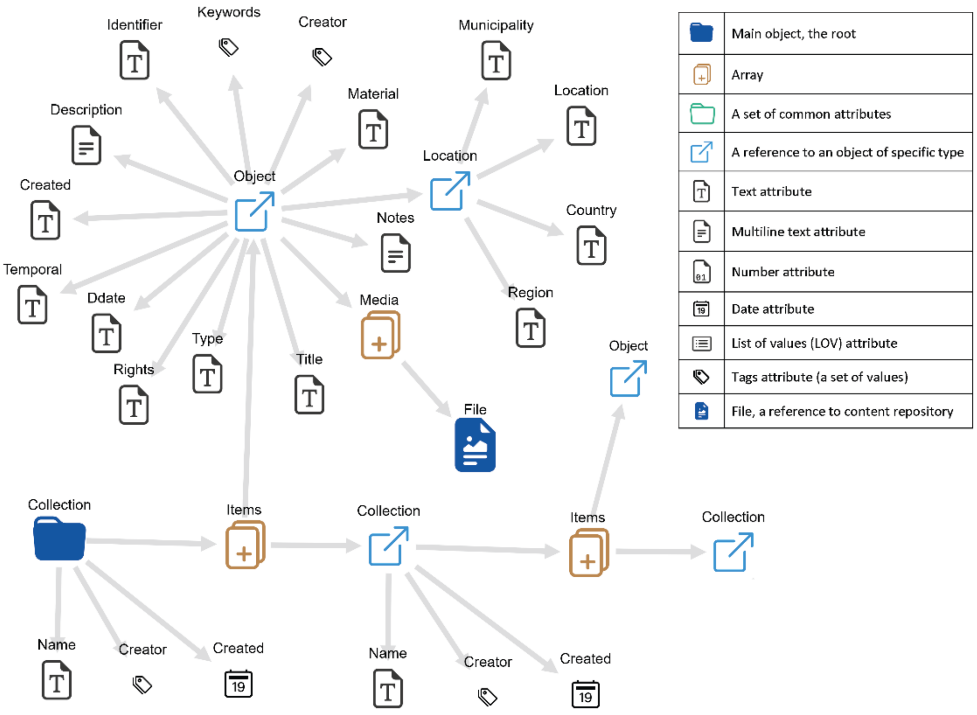

Fig. 1. Burgas Library metadata model.

collection(s) contained within the current collection; Type, which is the type or nature of objects or resources in the collection (e.g., audio recordings); Genre, which is the genre of objects or resources in the collection (e.g., classical music); Format, which is the format (media type) of the objects in the original collection; Language, which is the language(s) in the collection (If text); Keywords, which are terms that describe the overall topical content of the objects in the collection; Location, which is the place(s) or area(s) associated with most or all of the objects in the collection; and Time period, which is the time period(s) associated with most or all of the objects in the collection. Any collection could include other objects and collections. One object could be associated with many collections. Support of circular references ensures the possibility of a repeatable model to be used and creates conditions for easy grouping and extraction of knowledge.

In the current development, the DigiCult model described earlier was adapted so a solution for formally describing and linking objects together while ensuring the ability to output them into a metadata format usable for future-proofing to be developed. The created metadata model for describing the object content is presented in Figure 1 and is defined by the following tree structure:

- The *Object* data type defines basic information about the digitized object, such as main descriptors like Title, Type, Creator, and Identifier. The Object can be an intangible or tangible cultural heritage object, such as music/records, textual material/book, graphic material/map, song text, photographic image, and costume.
- The *Media* item presents an array of digital assets, such as all files (images, audio, video, etc.) related to the object.
- The *Location* element is a separate data structure (a custom complex data type, different *Objects* can refer to one *Location*).

- The *Collection* item contains an array of heterogeneous elements—both Objects and Collections, thus implementing the nested structure of collections (i.e., hierarchy of collections). There is no limit to the level (depth) of the hierarchy.

In conclusion, it should be noted that the model could be continuously modified by adding new categories and fields as well as by changing the condition of the fields as access levels and reviewing the changes made to the system by the users. This editing functionality is provided by a module for the management of the metadata model of CHCS-DSRCE.

3 RESULTS AND DISCUSSION

In this section, we discuss what was implemented to store digital content and provide proper access to the items. Structure, different modules, functionalities, and types the systems provide for the creation and grouping of the object all provide pieces of the solution to transform versatile content into digital content. The complex yet easy-to-manage structure of the data would lead to full-fledged access to the data, and automatic grouping, which will enhance searching. The solution is based on the authors' experience gained in various cultural heritage projects and implementations [19, 20].

The *Humanities and Social Sciences Data Storage, Retrieval and Curation Environment* is a complex web-based infrastructure containing a rich set of technologies aiming to support a great variety of digital cultural units. Its powerful features and components providing flexible storing, presenting, and managing data and metadata make it suitable for lots of applications. The basic prototype of CHCS-DSRCE is able to store and manage different types of digitized copies of cultural heritage objects, including text, graphics, video, audio, 3D formats, or other media objects as well as the relevant metadata. Resources digitization is performed by CLaDA-BG partners.

3.1 Core Environment: Metadata and User Data Management

Every object in a DL consists of two components: the actual object and its metadata. Whereas the digital objects are the primary documents [21], the metadata is more important, because it transforms the DL from a simple document storage to a management system that could facilitate intelligent grouping, searching, and so forth of digital objects.

The core environment consists of the main features and custom features. The custom features are those made available for specific platform implementations such as the presented solution for Regional Library "Peyo Yavorov." The main features are part of the core environment. They include the following:

- A module for basic management and presentation of metadata and data.
- A module for creating and managing the structure of the metadata.
- Modules for administrating the system, which are mainly responsible for managing the users and media repositories [20].

The media repository takes care of storing data and metadata for every cultural asset. The metadata information is stored in a well-indexed complex record with references to its corresponding data unit(s).

The metadata models (schemas) are created and managed by the model management module. Figure 2 depicts the form for building metadata structures (descriptors). The service manages the "object metadata descriptive structure," supporting flexible functionalities to build, edit, and extend its meta descriptors (also called *items* in Figure 2).

The metadata of each individual object is created manually by the users-editors or automatically by importing in the description form (also called the *metadata creation form*) of the cultural objects presented in Figure 3.

By definition, a DL is a collection of digital items; however, they can be of different types, and one item can be a combination of text and an image or video and audio [22]. In the platform, every item's attribute (descriptor) may

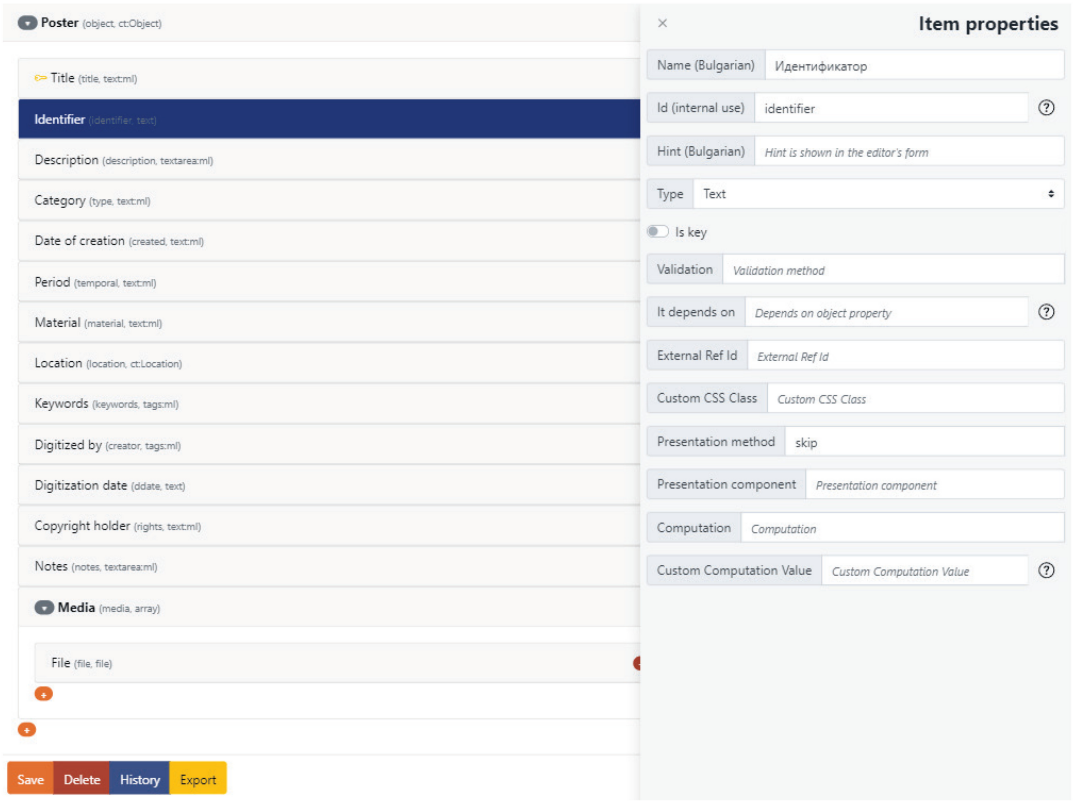

Fig. 2. Form for building metadata structures (descriptors).

have a pre-defined type specification, determined by the object's metadata. The platform not only supports the standard user interface types (scalar and non-scalar, e.g., text, textarea, text (multilingual), textarea (multilingual), rich textarea, form tags, number, date, time, array, dropdown, single and multiple-choice controls, files) but also allows customized (complex) types, such as domain-specific pre-defined non-scalar object types. The complex type provides the flexibility to describe all material and non-material cultural objects and eliminates the need for the redefinition of common descriptive items for each specific object type.

Items with similar attributes (descriptors) could be grouped in a separate general scheme, which combines the common elements of the objects. The specifics of the different types of objects are added as additional properties of their corresponding descriptive schemes. For example, the creation of a separate descriptive model of an object of type "Location" (see the Object->Location relation in Figure 1) would save space in the database, reduce redundancies, and create a traceable relation between the main objects sharing this common descriptive item.

This approach is also underlying for the efficient use of the platform's search engine, enabling, simplifying, and boosting the performance of a unified search mechanism that allows the users to perform complex search queries within the whole content, using simple search operations.

The structure creation module could also manage relationships between objects showing their complex or heterogeneous descriptive structure (in Figure 1, the following relations: one Collection may contain many Collections, one Collection may contain many Objects) and support preliminary defined descriptive schemas and standards in the cultural heritage field, including Dublin core and CIDOC-CRM, among others.

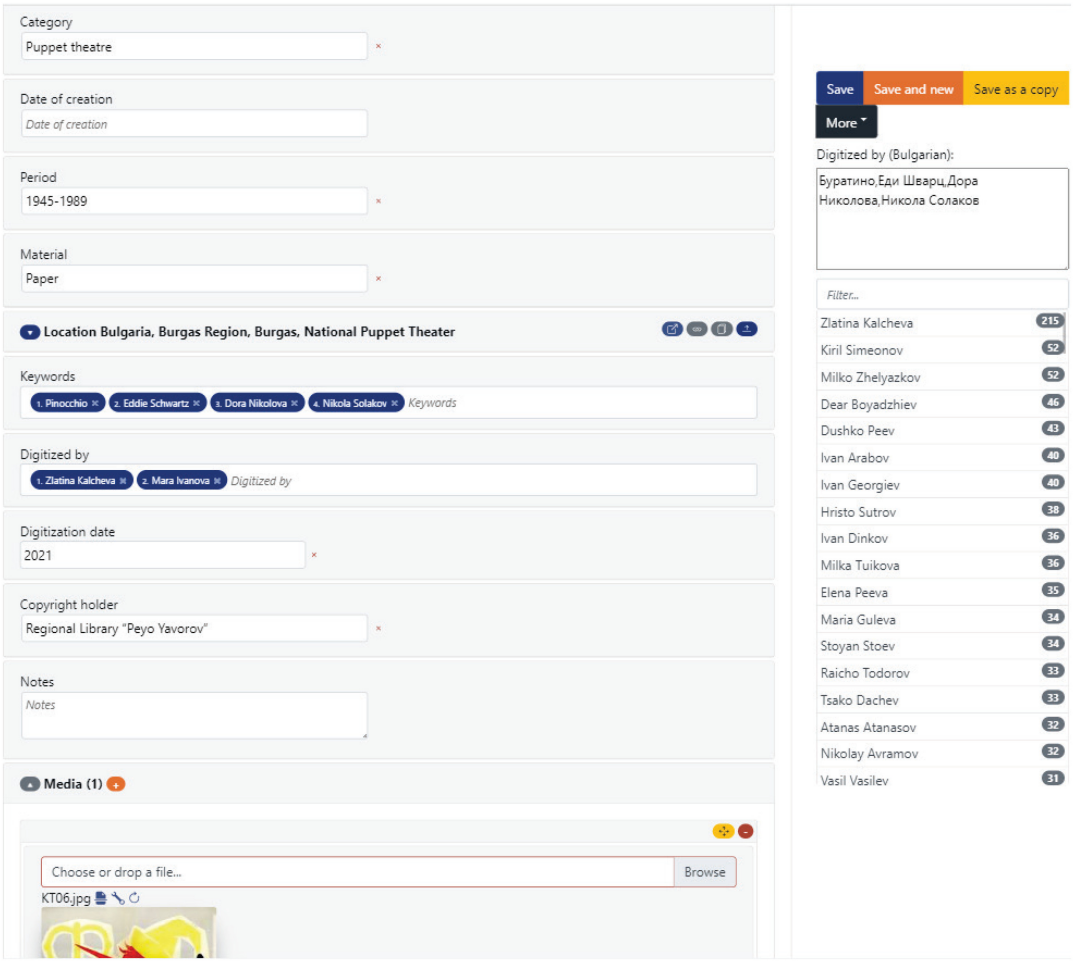

Fig. 3. Metadata creation form.

The full metadata managing stack for creating, storing, editing, deleting metadata, backing up, and version control is covered by the functional module for managing and presenting metadata. The module is also responsible for user searches, data filtering, access management, and metadata presentation over a variety of user devices.

The fundamental purpose of the creation and editing features is to make user input as fast and efficient as possible. It is crucial to minimize user input errors and reduce the time for editing a single unit when there is a need for managing large volumes of data. For these specific goals, different features are implemented: structuring of the annotation template using trees and tree-based sections, features for metadata re-usage, suggestions, autocomplete options based on previously entered metadata, partial/full import of data, and metadata, bulk data transform. Services are implemented to meet specifically the content provider's needs, such as advanced collection creation, management and curation (thematic collections, time-dependent collections in a calendar structure, etc.), search in the text media objects, advanced objects preview and ordering, and different device support. Users with appropriate roles are able to define categories of metadata and the characteristic(s) of the objects which will be used for aggregation and grouping. Object characteristics can be different based on the specific application domain. The module creates groups of objects based on the given criteria and presents them

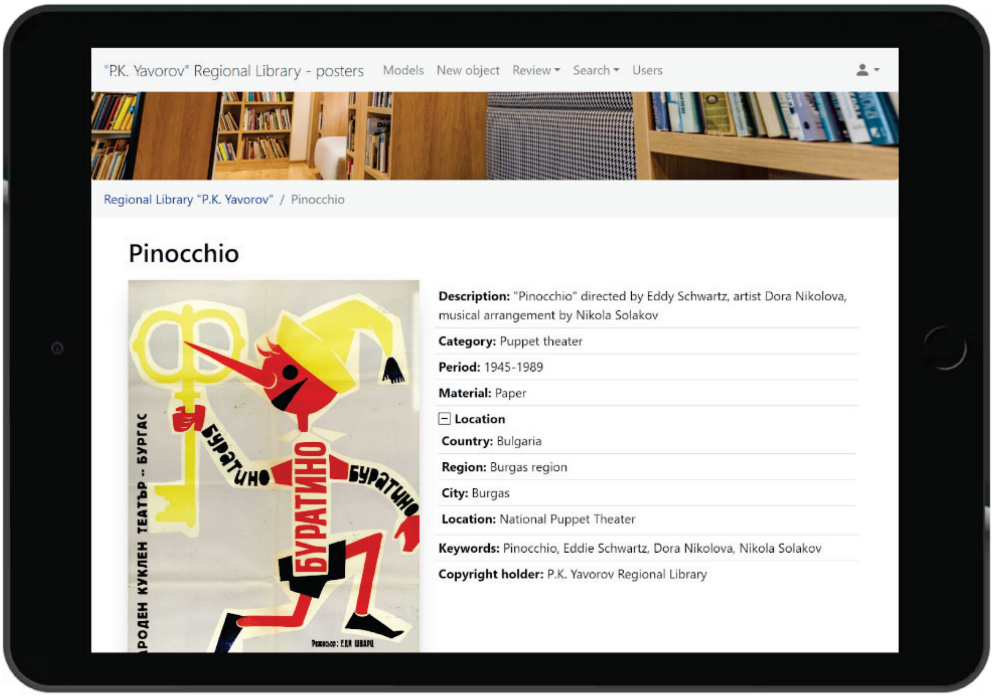

Fig. 4. Preview of the "Pinocchio" poster (digital object with metadata) on a tablet.

to users [23]. Users are able to use this information directly, or they can export it for further analysis in another system/tool.

The Regional Library "Peyo Yavorov"–Burgas specifies the metadata categories that will be used for grouping the objects into collections in the DL according to their needs to determine which kind of data and metadata will benefit from grouping it into collections to improve the context-based DL content usage for different purposes (namely, research and e-learning). Every user/editor will be able to define their own (public or private) collections of objects according to their needs and research specifics. Thus, a hierarchy of collections can be created and used for applying specific object grouping, filtering, and intersection for further analysis. The model that delivers this functionality is shown in Figure 1. Items represent arrays of polymorphic objects—that is, every array may contain objects of a different type, including collections. Thereby, a tree-based hierarchy is implemented. Figure 4 depicts the preview of the poster of the "Pinocchio" puppet theatrical performance, directed by Eddy Schwartz. The figure depicts the digital object and its metadata.

The module contains a feature for managing dictionaries of different domain-specific terms, which are part of the stored objects' descriptions (metadata). As a result, the DL also supports an automatically implemented search and tagging of a term (word form) throughout the database. This enables advanced search functionalities applied concurrently to both metadata and the content of digital objects. Additionally, it allows for full-text and regular searches in objects with diverse structures while sharing common characteristics.

The *user profile repository* stores user-specific data, including user profiles and user sessions. The administrative services contain features concerning user profiles and session management, metadata import, export, transform, definition of metadata and data backup policies, managing user activities logs, and metadata version control logs.

User management is mainly responsible for users' sign-in and sign-up (single sign-on is also available using OAuth, currently integrated with Google and Facebook), data changes, setting the access level, and so forth.

3.2 Technologies

The platform is based on open source software. The back-end is powered by a load-balanced Node JS Express 4 server behind Apache 2.4 (NGINX integration was also implemented) with an advanced firewall and security protection. We use the non-relational MongoDB Community Server 6.0 for the database management system. MongoDB is a document store database that is suitable for data with complex and diverse structures [24] and therefore is the preferred solution in this use case. The front-end is based on the MVVM design pattern and is built with the Vue JS framework, which allows good management for dynamic content, complex forms, and web pages in combination with reduced network load and good page performance. Bootstrap 4 is used to achieve responsiveness over different devices and to make the application more accessible (including for screen readers, etc.). Packaging and deployment are configured using WebPack 5. The application source code is managed by a Git version control system. Additional components for media management (converting, indexing, etc.) like FFmpeg, Sharp, PostScript utilities, and others are integrated.

3.3 Intelligent Content Management

The CHCS-DSRCE prototype that was created to manage digital collections of the Regional Library "Peyo Yavorov"–Burgas also includes all the basic modules presented in the previous section extended with several specific functionalities. The focus of those functionalities is on intelligent library units and metadata management. The Regional Library "Peyo Yavorov"–Burgas owns rich and diverse digital catalogs of library and cultural heritage units, which need to be managed and presented in their full brilliance, providing online readers with full-fledged access to the knowledge accumulated in its depositories. The big volume of library units requires well-defined functionality for search, ordering, flexible access, and preview, satisfying librarians' and viewers' needs, which were provided by the modules described in the previous sections—starting from proper types (including the complex type), the database that could accommodate diverse types and structures and services for managing that data. The CHCS-DSRCE Burgas Library prototype provides specific services for both managing objects and creating sets of objects according to users' needs, and manual (by user choice) and automatic object grouping (by pre-defined criteria).

3.4 Digital Content Accessibility, Protection, and Security

The content in the repository is protected in several ways, including watermarking and quality reduction of the content provided to end users (the original quality of the content is still available for power users). The quality reduction improves browsing performance and reduces network loads. Standard and custom security levels are available, defining the valid actions and content for specific users. Integration with translation services is implemented to help editors to make easier inline translations when necessary. An option for content approval is also available. A web-based server monitor is integrated (Netdata, only for Linux installations) to trace all performance indicators of the environment and to send alerts to administrators on critical events. The standard full-text search capability, provided by the MongoDB Community Edition database management system, is replaced by SPHINX Search. The achieved search performance (in terms of response time) is improved more than 10 times.

The environment provides technological support for different devices (i.e., PC, smart TV, tablet, smartphone) and customized preview options enabling accessibility and various usages.

3.5 System Tests

Every implementation of CHCS-DSRCE is subject to load and stress testing to assure system stability and reliability. The results from the load tests of the Regional Library "Peyo Yavorov" implementation are presented in Table 1.

The load test included simulation of 1,000 users working simultaneously with the system. A total of 41,000 user requests were processed for about 1 minute. A total of 90% of the requests were processed in less than 1.5 seconds each. The server CPU did not go above 10%, and system memory was held at around 25%. The tests were

Table 1. Results from the Load Tests of the Regional Library "Peyo Yavorov" Implementation

Unit	Value
	1,000
Number of Requests	41,000
Average response time (ms)	1,141
Median response time (ms)	1,177
90% Line (response time, ms)	1,469
95% Line (response time, ms)	2,023
99% Line (response time, ms)	4,238
Min response time (ms)	3
Max response time (ms)	32,077
Errors (%)	0.00
Throughput (requests per second)	607.92978
Received KB/sec	584.29
Sent KB/sec	304.24
Total processing time	1:07
Max CPU usage (%)	9
Max RAM usage (%)	25

performed on a server with the following parameters: Intel Xeon Gold 5118 CPU @ 2.30GHz (12 cores), 48GB RAM, 4TB RAID-10 SATA-3 storage, and Debian 10 OS. The tool used for the simulation was Apache jMeter 5.5.

4 CONCLUSION AND FUTURE WORK

One of the key priorities of IMI-BAS research activities is related to exploiting contemporary technological achievements, specifically the intelligent digital management solutions and representation of national cultural heritage objects and knowledge with a special focus on fostering and supporting the research activities of professionals and scientists in the humanitarian and social fields. A significant part of the institute's work in this direction was carried out within the CLaDA-BG project.

The presented model for complex collections hierarchy will be implemented and evaluated using all types of available objects of the Regional Library "Peyo Yavorov"–Burgas. A specific user interface for the search and result forms will also be evaluated to find the proper and most efficient presentation approach.

The main aspects and directions of the future work are related to expanding the functionality of the proposed solution and developing a front-end part for accessing and working with all the funds of the Burgas Library, including manuscripts, graphic publications, maps, and audio-visual content, among others.

The specification of backup policies and proper hardware scaling are key to operating a live version of the environment and ensuring its availability, flexibility, and appropriate levels of protection for both content objects and users. In this regard, the execution of security, load, stress, and performance tests and the analysis of the results of these tests are crucial.

The full-fledged DL cultural heritage content usability also requires the creation of proper functionality for personalization in the platform. This task is currently under implementation and will be based on the analysis of the user activity data, and a special model for content personalization will be developed.

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