A Model of a Distributed Information System Based on the Z39.50 Protocol

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Abstract: Based on the analysis of typical scenarios of information servers, the tasks that should be solved when organizing an access control system for distributed information resources are formulated. The possibilities of the Z39.50 technologies as the most suitable for building such a system are considered. Within the framework of this technology, three access control models are discussed, which differ in the degree of integration of information server functions with the Z39.50 technologies.

In this regard, the task of integrating information resources based on the use of metadata to ensure the relationship between heterogeneous sources of information and their effective use is the most urgent and is being brought to the fore today.

The creation and support of distributed information systems and digital libraries that integrate heterogeneous information resources and operate in various software and hardware environments requires special approaches to managing these systems. If the resources or data themselves can be managed locally, even for distributed information systems, then the task of managing access to distributed resources cannot be solved within the framework of local administration. The justification of the last thesis can be seen when considering typical scenarios of the information server, which we will describe later in this paper.

Keywords: access, distributed information systems, storage, search, technology, model, Solr, Z39.50, metadata.

1. Introduction

The problem of access to information (including computing) resources is one of the main problems that arise in the activities of the scientific and educational community. Currently, there is a transition to a distributed scheme for creating and maintaining scientific and information resources, on the one hand, and the desire for virtual unity by providing free access to any resources in the network through a limited number of "access points", on the other [1].

It is obvious that with the growth of the number of resources, various problems associated with their support and management invariably arise. First of all, these problems are caused by the need to duplicate data used by different resources. If the stored data is updated frequently enough, logical contradictions between the data on different resources periodically arise, which can become a source of errors and failures in the functioning of resources. In addition, the very fact of duplication greatly increases the work of system administrators associated with maintaining resources. Constantly acting factors in the formation of a single (virtual) information space of the organization are [2]:

- hierarchy of information systems and resources;
- heterogeneity of resources and software and hardware environments combined in a single network operating space;
- distribution of information infrastructure elements.

The realization of the need to integrate heterogeneous information resources led to the creation of integrated (unified) scientific information systems (SIS), which would allow establishing links between heterogeneous documents, organizing unified catalogs of documents, as well as creating specialized search systems. The main problem associated with the functioning of integrated distributed information systems is widely known – it is practically a non-functioning information updating system [3; 4]. It is almost impossible to solve this problem by administrative methods. Note that the effective operation of information resources is possible only if they are constantly supported by the authors.

Apparently, the only way to solve this problem is to integrate the data of local information and reference systems existing in the organization within an integrated distributed information system and give these systems the functions of global (corporate) authentication and authorization of users to access information resources.

Distributed information systems that support scientific and educational activities can work with various information systems. The main goal of creating a distributed information system supporting scientific and educational activities is to accelerate the pace and improve the quality of information exchange in the scientific environment. One of the most pressing issues is the division of the unified compatibility of the information system and the work on the systematization of information resources into professional areas. These can be scientific articles, scientific documents, electronic collections, ontological descriptions, data sets, logical descriptions, and so on. Semantic connections between information resources increase their value and provide additional opportunities for searching and identifying information [5].

2. Distributed information system architecture

Distributed information resources the development of information resources of an organization leads to the need to create an infrastructure for their integration into a single information system that provides transparent access to distributed information.

The development of global information and computing networks today leads to a change in the fundamental paradigms of working with information resources. Today, the transition to distributed resources is relevant, the creation of an infrastructure for their integration into a single information system that provides transparent access to distributed information.

Therefore, the most important task related to the technology of working with information is to study ways to integrate distributed data sources and create a scientific reserve in the field of distributed information systems and databases to develop a technology that supports the creation and operation of large-scale information infrastructures based on virtual integration. This technology will allow creating global infrastructures from dozens and hundreds of heterogeneous databases and solving strategic tasks in the field of automation of various forms of distributed activities. A narrower goal is to develop principles and software tools for virtual integration of distributed data sources based on international standards and recommendations for creating large-scale information infrastructures designed to virtualize data access to various DBMS using common rules and policies [6].

The tasks of distributed, as well as conventional, information systems are to store information and provide it to users in a convenient form. As a rule, such systems can be organized based on various technological solutions aimed at implementing a particular distribution paradigm. Based on the main functions of information systems, various aspects of distribution can be considered:

1. Distributed information storage (distributed storage, network data storage systems, network file systems).
2. Distributed DBMS (adding, upgrading, changing data).
3. Access control to distributed information and distributed information management.
4. Search for information in distributed sources.
5. Extracting information from distributed sources.
6. Visualization of information from distributed (heterogeneous) sources in unified user interfaces [13].

Distributed information systems represent an increasingly important trend for computer users. Distributed processing is a method for implementing a single logical set of processing functions on several physical devices so that each of them performs some part of the total required processing. Distributed processing is often accompanied by the formation of a distributed database. A distributed database exists when data elements stored in several places are interconnected, or if a process (program execution) in one place requires access to data stored in another place.

Distributed information systems to support scientific and educational activities is intended for the collection, classification, analysis of text publications of the Kazakh segment of electronic mass media for the management of information resources.

The purpose of creating the system: To develop a system for distributed information systems to support scientific and educational activities, to create a program to study the capabilities of the Apache Solr platform for processing distributed data, which uses big data technologies [7].

A set of the most general functional requirements for the IP support of scientific and educational activities was identified.

1) Collection of information resources.
2) The relevance of the documents.
3) The relevance, completeness, reliability of the origin of the documents.
4) The use of intelligent services for processing user requests.
5) Knowledge extraction.
6) Support for non-centralized information system architectures.
7) Structuring of the information space.
8) The use of information classification in information search
9) Adaptive presentation of information.
10) The historicity of the information.
11) Archive.
12) Support for distribution.

In the conditions of working in a distributed environment, the following requirements are imposed on the IR support for scientific and educational activities:

- support of accepted metadata standards for data export and import;
- support of information exchange protocols with other information systems;
- support for the ability to link to internal resources both in user interfaces and at the system level.

The task of information systems is to store information and provide it to users in a convenient form. As a rule, such systems can be organized based on various technological solutions aimed at implementing a particular distribution paradigm. The distribution paradigm can be considered from the point of view of the architecture of information systems. Note that most information systems today are built on the principle of a three-tier architecture with the conditional division of links on clients, application servers, and database servers. Based on this, we can distinguish three main groups of distributed systems that implement the principle of distribution at the appropriate level.

The creation and support of distributed information systems and electronic libraries that integrate heterogeneous information resources and operate in various software and hardware environments require special approaches to managing these systems [8]. All information is stored in a DBMS based on the freely distributed PostgreSQL software, user and administrative interfaces are implemented based on Apache Solr. In the search area, Apache Solr has become the de-facto platform for creating production applications. Although Solr is designed to scale using a distributed, partitioned architecture, the platform is mainly designed around providing low-latency search for users.

To implement a system for processing large amounts of data, the task is to create a mock-up application. The application demonstrates the processing of big data distributed on several machines using the example of counting identical words in text datasets. Usually, the data set has to be distributed across several different machines. Since these machines work on the network, the system administrator has to take into account all the complexities of network programming. One of the problems of working with large amounts of data is the difficulty of transferring them between servers for subsequent processing. Also, due to a large number of nodes, frequent failures of individual nodes are possible, so the issue of reliability is also very important. This problem can be solved using the Apache Solr technology [9].

System tasks:

1) Collection, storage, and selection of unique publications from the Internet space to the system database
2) Distribution of publications by topic: clustering, classification, the definition of thematic combinations, ranking, and filtering (by social spheres, regions, industries, etc.)
3) Determination of information occasions
4) Calculation of the degrees of informative features of publication, such as collective use of purchased electronic literature catalogs, databases, and bibliographic publications

5) identification of information trends

To meet these requirements, it is necessary to create an infrastructure (an information service or a center) for the presentation and exchange of metadata – structured information about information resources and access rules to them. Currently, many information centers engaged in the collection and dissemination of metadata are actively interested in organizing interaction to exchange their existing funds. As a rule, such integration of funds is based on the development of a standard for the format for the presentation of metadata, simultaneously with the unification of arrays of normative reference information.

As part of the tasks set, the architecture of the information system was developed (Figure 1) to systematize the resources of the electronic library, a multi-level DL architecture is used, consisting of a data warehouse, a repository, a metadata server, an application server, a dictionary, reference books, as well as a software implementation of the developed architecture deployed on existing hardware and put into operation.

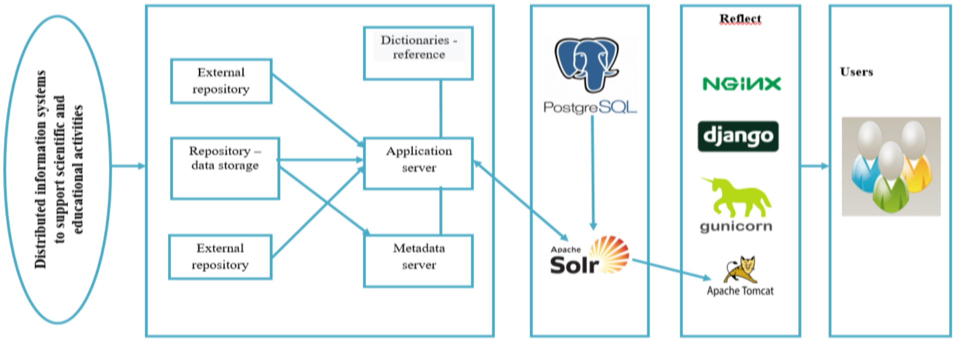

Figure 1. The architecture of a distributed information system for supporting scientific and educational activities

Based on the described information system and a database of publications on information, technologies have been created.

- A detailed dictionary (thesaurus) of concepts and key terms in computer science and tools for its modification.
- Thesaurus on information security as part of the thesaurus on computer science.

The system continues to develop both in terms of expanding functionality and adding new information resources.

The repository is an autonomous search engine and includes:

- Electronic catalog data;
- Indexing profile of electronic catalog entries;
- Indexes for searching and viewing the electronic catalog.
- The repository can contain many electronic catalogs.

This model allows us to create various configurations of the electronic library catalog based on one or more repositories. Once created, the configuration can change dynamically during operation. It should be noted here that only one of the available data indexing profiles is used for the repository. This profile cannot be changed as long as there is at least one electronic catalog in the repository.

3. Model and metadata of distributed information systems

Creating efficient and adaptive distributed systems allows you to significantly speed up the speed of data processing. To consider this issue, we will analyze the problems that arise during the design and operation of distributed systems.

For distributed information systems that include many different databases with different structures and content, the issue of searching for information in databases using ontologies, thesauri, and classification schemes presented in the form of separate databases is very relevant.

There are many different ways to build databases, organize access to their contents, and implement explicit and implicit links between the database and other information resources.

-geographical materials (maps, satellite images, field observation data, etc.), as well as relevant metadata databases;

Many of these methods are based on strict ontological models and, for practical implementation, impose very strict requirements on the organization of information systems and databases, up to the complete overload of information into intermediate storages, the functional properties of which make it possible to identify all semantic relationships between information objects based on specified ontological models. Such an approach has a right to exist, but the question remains how to enable the search for semantically related information in existing distributed information resources, and in the case when they cannot be overloaded into specialized repositories [10].

As a result of using this protocol, it is possible to create distributed information systems that include databases of various organizations.

Documenting scientific research plays an important role in modern science. Scientific articles allow us to systematize the results of the experiment. Published articles allow you to effectively share the results of the work done with colleagues working in this or related scientific fields. Metadata on which articles are written is also of great value. With large volumes of analyzed information, it is necessary to organize an effective way to store the metadata of articles. Metadata can be used to develop the scientific direction in which the article was written or to refute the results of the work done [11].

The integration of distributed information systems is based on metadata presented following unified data (information system profile). From the user's point of view, data integration should be understood as the ability to freely group any available heterogeneous data on any basis into arbitrary real and/or virtual collections and organize transparent end-to-end information search across all data arrays for the end-user.

The implementation of data integration mechanisms is unthinkable without their standardization — data of the same type should be described uniformly under regulatory documents. Thus, the following types of information resources should be provided in a standardized form:

-factual databases and metadata;
-bibliographic databases and electronic catalogs;
-full-text databases and digital repositories;

-authoritative databases (dictionaries, reference books, etc.)
-other resources (audio and video recordings, electronic presentations, etc.), provided with standardized metadata.

To ensure its functionality, an integrated information system must contain the following subsystems:

-identification of information resources;
-identification, authentication, and authorization of users;
-metadata management;
-management of information resources;
-collecting statistics;
-monitoring the availability of services and resources.

The implementation of IP subsystems should be based on open specifications related to international standards and recommendations. In a distributed environment, data synchronization mechanisms should be involved, for example, based on replications (Fig. 2). At the same time, standard protocols such as OAI-RMN, OAI-ORE, SRW/SRU, Z39.50, LDAP [12], etc. should act as network communication protocols.

Metadata is necessary to solve the following tasks:

1) providing information about documents, their content, structure, methods of use, etc.;
2) systematization and classification of documents;
3) organization of in-system processing procedures;
4) support of exchange with external IS.

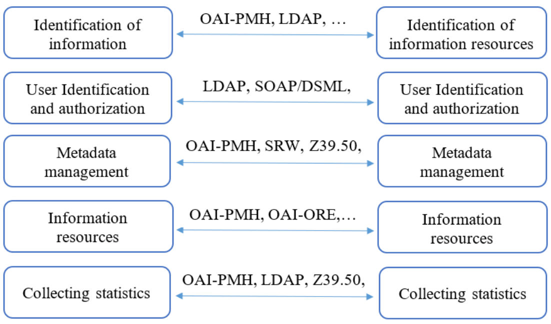

Figure 2. Network interaction of subsystems DIS

The practical implementation of SRW/SRU services will give a significantly new quality of the information system – the ability to include its resources in global search engines at a higher level than the level of external indexing of static web pages by other systems. Other possible types of search are related to the search for the specified templates and the search involving the ontology. The latter is a more intelligent type of search. Its implementation requires additional information about the subject area, including definitions of terms, entities, and relationships. It should be noted that the representation Currently, there are quite powerful information systems that meet the needs of researchers in information to one degree or another. However, the main drawback of most systems is the limited possibilities of ensuring the integration of resources both inside each of the systems and outside. It should be noted that the basis for the development of IP is, first of all, standards and international recommendations that form the IP profile. It is understood as a set of one or more basic normative and technical documents (standards and specifications) focused on solving a specific task (implementation of a given function or group of functions of an application or environment), indicating, if necessary, selected classes, subsets, options of basic standards required to perform a specific function. The most important is the metadata profiles of the in formation circulating in the system. The choice of a profile should be based on the following requirements:

- include the main types of information required to support scientific work;
- be open, i.e. provide access to relevant information on these descriptions;
- be extensible, i.e. provide the possibility of detailing descriptions;
- provide information integration capabilities;
- provide opportunities for unique identification of information;
- provide the ability to host and search for information in a distributed environment;
- be focused on modern and promising technologies for describing and using information;
- provide opportunities for interoperability with the external environment.

Metadata is divided into the following classes (Fig. 3).

Administrative or service metadata. They contain only official information, such as the date of modification of the document, the name of the owner of the document (not to be confused with the author), access rights to the document, etc [16].

System metadata. Provide technological tasks of the resource management system, for example, contain rules for providing documents to the user, rules for converting data schemas of structural metadata, rules for determining associative relationships between documents, etc [13].

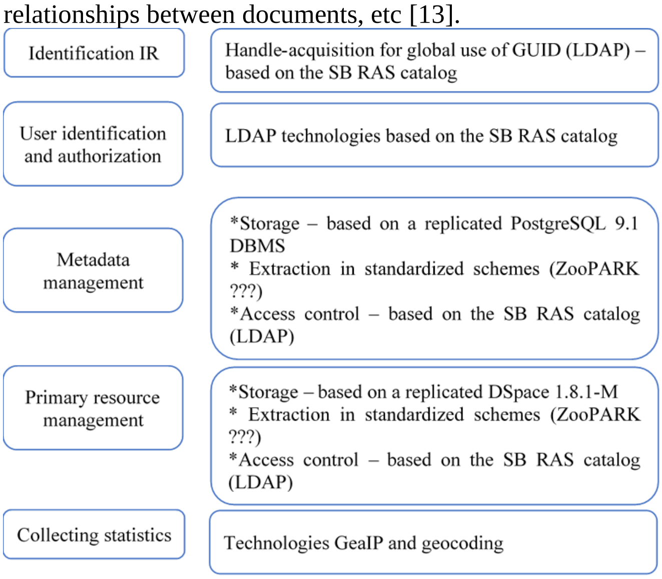

Figure 3. Basic technologies of the DIS component

The realities of building such management systems turn out to be such that, as a rule, these systems are already being implemented on a very highly developed infrastructure of heterogeneous resources, and the choice of a universal approach turns out to be necessary. However, if the management system is being built simultaneously with the infrastructure and it becomes possible to build a common system based on an integrated set of products, the advantages of the first method may be decisive [14].

Users and applications are provided with a full set of services (user and administrative) for access to the information resources of the system (Fig. 4).

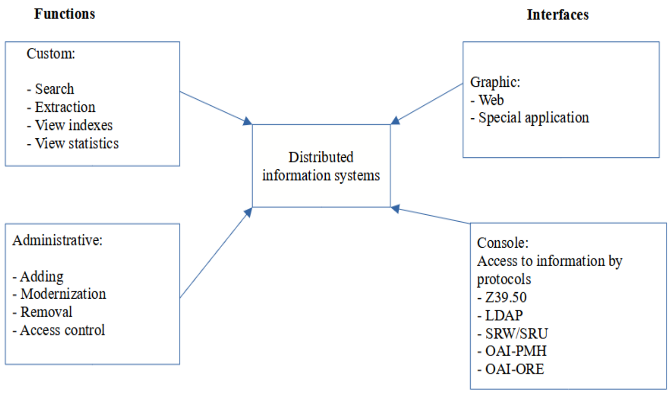

Figure 4. Interface structure DIS

The developed model can be used as a standard model of the system for working with documents related to scientific and educational activities since it solves the main tasks imposed on such systems: ensuring reliable long-term storage of digital (electronic) documents while preserving all semantic and functional characteristics of the source documents; ensuring "transparent" search and user access to documents both for familiarization and for analyzing the facts contained in them; organizing the collection of information on remote digital repositories that support the OAI-PMH, SRW/SRU and Z39.50 protocols.

4. Z39. 50 technology

To search for records, you need to specify a list of database servers and a list of database names to search for, as well as formulate a search query containing search criteria. In traditional systems using Z39. 50, it is also necessary to know additional information to build a query: the syntax of the query language for each DBMS, as well as the structure, field names, and data types of each database.

If the listed characteristics are different in a group of selected servers and databases, even a very simple query cannot be executed for the entire group. In Z39. 50, this problem is solved by building a specific search model and standardizing its components.

In Z39.50, search queries are always formulated not to a real database, but an abstract one. This abstract database has no structure and is characterized only by search attributes. Therefore, it is customary to call it a" Set of attributes " (AttributeSet).

Having received a request from the origin in the form of terms and search attributes, target, or rather, database provider, of course, will link it to a real database and convert it into a real syntax, but this procedure will remain invisible to the end-user. With this approach to the search procedure, all databases become the same for the user if they support the same set of search attributes.

The sets of search attributes make up the class of objects Z39. 50 {Z39.50 3} that are subject to standardization. The following attribute sets are currently standardized in the {Z39.50 3} class:

Table 1. Attribute sets Z39. 50

OID	Класс объектов
Z.1	application context definitions
Z.2	abstract syntax definition for APDUs
Z.3	attribute-set definitions
Z.4	diagnostic definitions
Z.5	record syntax definitions
Z.6	transfer syntax definitions
Z.7	resource report format definitions
Z.8	access control format definitions
Z.9	Extended services definitions
Z.10	user information format definitions
Z.11	element specification format definitions
Z.12	Variant set definitions
Z.13	database schema definitions
Z.14	tag set definitions
Z.15	negotiation definitions
Z.16	query definitions

Within each class, objects are assigned an identifier, the prefix of which contains the OID of the class. In particular, the RecordSyntaxDefinitions {Z39.50 5} class contains a SUTRS object whose OID is {Z39.50 5 101}. The full list of current OIDs can always be found in the global registry: http://lcweb.loc.gov/z3950/agency/defns/oids.html

All of the above are only concerned objects defined globally. Thanks to these definitions, any Z39.50 software from any manufacturer can unambiguously interpret and process a particular object. In addition, the Z39.50 standard allows the existence of locally defined objects, the scope of which is limited by the software of a particular manufacturer. Locally defined objects are also assigned an OID, but it is formed by adding after the prefix of the class code 1000 and the developer ID. To search for bibliographic information, a set of bib-1 attributes is used, as shown in Figure -5. Some attribute sets (gils, geo-1) include the bib-1 set, so this set is the main one.

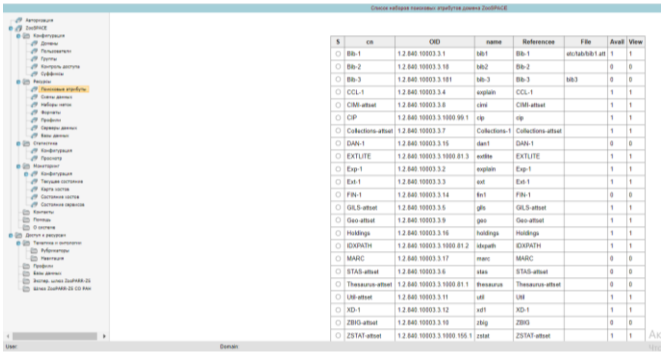

Figure 5. Search attributes

Search Attributes

The bib-1 set includes six types of attributes with numbers 1-6. When constructing a query in combination with a search term, specifying search attributes determines the criteria for selecting information. In each group, specific attributes are defined by a numeric value. Therefore, to specify the search attribute, you need to specify two numbers: type + value. It should be noted here that, strictly speaking, for an unambiguous attribute assignment, it is also necessary to specify a set of attributes, i.e. the triple OID + type + value. As will be seen below, this information is present in the request when referring to the attribute. However, in this section, the OID will be omitted, because everywhere we will talk about bib-1.

Attributes 1: Use

Attributes of this type indicate which semantic information the search term is associated with. There are 99 values defined in the bib-1 attribute set, which are given in the documentation. Among the Use values are corresponding to the fields author, title, keywords, year of publication, etc.:

4	Title
21	Subject
31	Date-publication
1003	Author

Among the Use attributes, some are associated with several fields at the same time:

1000	Author-name-and-title
1035	Anywhere

The last value is associated with all search fields.

Attributes *2: Relation*

The Relation attributes indicate how the search term relates to the selected data from the fields defined by the Use attribute, for example

1	Less than
3	Equal
6	Not equal

Attributes 3: Position

The Position attributes indicate where the search term should be located in the field defined by the Use attribute, for example

1	First in field
3	Any position in field

Attributes *4: Structure*

The Structure attributes indicate which structure the search term has, for example

1	Phrase
2	Word
4	Year

Attributes *5: Truncation*

The Truncation attributes indicate what a search term is, for example

1	Right truncation
100	Do not truncate
102	RegExpr-1

Attributes 6: Completeness

The Completeness attributes indicate what is the required area of the match when searching, for example

2	Complete subfield
3	Complete field

Thus, to search for records in which the author Ivanov or Ivanova occurs, you need to set:

bib-1 1=1003 2=3 3=3 4=2 5=1 6=2 “Serikbayeva”

Types of requests in Z39. 50

There are several types of requests provided in Z39.50:

```
-- Query Definitions

BEGIN
EXPORTS Query;

Query:   = CHOICE {
        type-0   [0]   ANY,                 --
        Любойtype-1    [1]
                 IMPLICIT RPNQuery,         --
        RPN
        type-2   [2]   OCTET STRING,        -- CCL
        ISO 8777type-100  [100]  OCTET STRING,  -
        - CCL Z39.58 type-101  [101]  IMPLICIT
        RPNQuery,       -- RPN
        type-102  [102]  OCTET STRING,
        type-104  [104]  IMPLICIT EXTERNAL}-- SQL
  END
```

In this case, a type-0 request is any query in the syntax of the DBMS that the server is associated with. The target must pass requests of this type to the database provider without modification.

Type-2 and type-100 queries are queries in CCL syntax. They are rarely used in Z39. 50 and will not be discussed here.

Type-104 – SQL queries are of interest. This is a new type of request that has
been included in the Z39.50 standards since February 2000. Today, there are practically no servers that support SQL queries in Z39. 50. Nevertheless, its definition should be given:

```
--SQL Query Definition

     SQLQuery   ::=              SEQUENCE {
           abstractDatabaseFlag   [0] BOOLEAN OPTIONAL,
           queryExpression        [1] IMPLICIT
           InternationalString }

        -- as defined in the SQL Standard [ISO/IEC9075]

        -- with/without Z39.50 schema abstraction extension as

        -- specified by the flag

 -- end SQL Query Definition
```

As you can see, the SQL query is a simple text string. However, it can be built in two ways: in the usual way (abstractDatabaseFlag = FALSE) and through an abstract data schema (abstractDatabaseFlag = TRUE). In the following chapters, the discussion of this type of request will continue.

The most interesting queries are type-1 and type-101-RPN requests (RPN
- Reverse Polish Notation – reverse Polish notation). For version 3 of the Z39.50 protocol, both types are no different. Type-1 requests (RPN) are mandatory for all Z39. 50 servers. Support for other types of requests by the Z39.50 servers is optional [13].

5. Building RPN Requests

The RPN request can be represented as a tree, in the nodes of which there are binding operators (AND, OR, AND-NOT). The leaves of this tree are the "term attributes" (APT) blocks. Figure 6 schematically shows the RPN request.

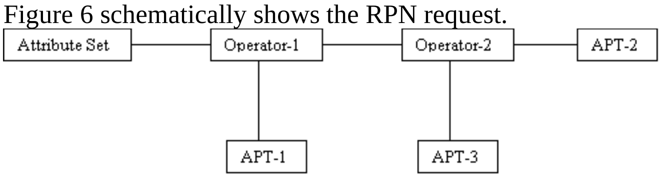

Figure 6. The structure of the RPN request

Each attribute is a pair that reflects the attribute type and its value. The following search attributes are present in the given example: type "Use" and value "CreatorName" (1=2035), type "Relation" and value "Equal" (2=3), type "Position" and value "Any position in field" (3=3), type "Structure" and value "Word" (4=2), type "Truncation" and value "Right truncation" (5=1) and type "Completeness" and value "Incomplete subfield" (6=2).

As a result of performing a database search, the client can receive the following information from the server: an error message, the number of records found, or the records found themselves. The first answer option is associated with an error, the second and third options correspond to a successful search. Which of them will be received by the client depending on the parameters that are transmitted to the server along with the search query?

For this purpose, the concepts of the small, medium, and large sets are introduced. Here, a set is understood as a set of found records, numbered end-to-end. All records from the small set are always returned, all records from the large set are never returned, and some records are returned from the medium setting. Next, the following parameters are set.

* The upper limit of the small set, i.e. the maximum number of records in the small set, which begins with the first record.
* The lower bound of the large set, i.e. the number starting from which the records fall into the large set. All records whose numbers are greater than the upper limit of the small set, but less than the lower limit of the large set, are considered records from the middle set.
• The number of returned records from the average set.

By changing these three parameters, you can return any number of records, including none.

Finally, it should be noted that the server should save all the records found during the search in the session block for later use. If the server allows the option to assign a name to the search result, this saved population can be assigned a name, if not, the population is kept unnamed and rewritten during the subsequent search. Named result sets that are stored on the server can be used in subsequent RPN requests, where they act as the same operands as APT blocks.

To access the thesaurus database, the user should build an abstract query. For this purpose, a custom web application was developed (see the Appendix), which generates abstract queries to the thesaurus database. To get an abstract query, the user must fill in the form input fields with the following search parameters: the name of the search term, the name of a set of attributes, a search attribute of the Use type (Access Point). Optionally, the user can build queries to find more accurate information using additional search attributes and logical operators [15].

A recursive SQL query is built to the thesaurus database, which outputs all child terms of a given head term. The term tree extraction algorithm looks like this:

1. There is a selection of child elements of the first level of the specified head term;
2. Then the child elements of the first level are considered as the main elements. All child terms of a given head term are sampled again.

An abstract query for issuing a hierarchy of terms can be presented in the following form. First, the head term "Calculator" is extracted from the thesaurus database:

@or @attr bib-1 1=14 @attr 2=2 Компьютер

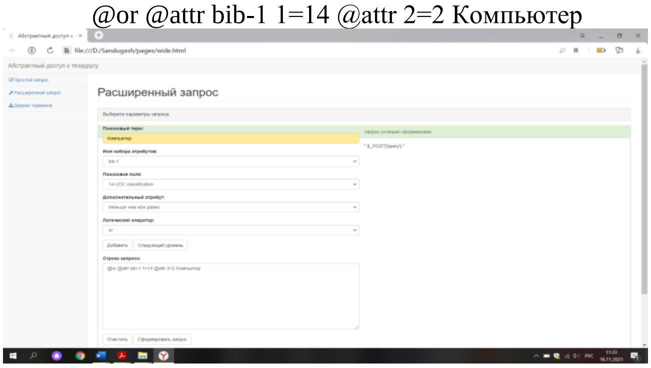

Figure7. Selection of abstract query parameters

6. Conclusions

The paper describes the development of an application for constructing abstract RPN (PDF) queries of the Z39.50 protocol to the thesaurus (from query generation to its execution), and also considers an alternative approach based on the CQL query language.

Using the developed application solves the problem of unified access to information. Since there are a large number of thesauri in the global network, each of which has its form of presentation and storage of information. Each database has a unique information storage structure, where each field has its name and purpose.

The developed WEB application interactively creates an RPN request, checks its correctness, and executes it. Moreover, the first two tasks are solved on the client's machine. Queries can be simple and complex. The whole range of queries from the Z39.50 archive has been implemented, including the search for "phrases" and "character sets" by some search terms.

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