

Modular Type of Learning Management System Services Formation based on Semantic Proximity

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Abstract: Despite the many ready-made LMS solutions, there is a problem of creating LMS systems with a flexible architecture and meeting all user requirements. When creating such systems, it is difficult to take into account all the requirements for the functionality of the system. This paper proposes an approach to the formation of a service-oriented LMS based on modules. At the same time, depending on the functionality, the user can form the necessary functionality based on services, processes and objects. A cluster approach is used to form a finite set of modules.

Keywords: learning management system; online education; service-oriented approach; clustering; information technology; semantic proximity

Introduction

The use of modern information technologies in the educational process has led to the emergence of a special category of information systems – learning management systems (LMS - learning management system). This category provides a certain set of services that are focused on ensuring the implementation of the educational process at various levels [1, 2].

Over the past few years, the most interesting approach to software development has been based on user preferences and experience, the so-called user-oriented design [3-5]. This method is gaining more and more popularity among software developers, including those intended for training [6].

Recently, a new type of e-learning system has appeared, based on automatic recognition and prediction of user preferences, and self-adaptation to user requirements. This type of system is called adaptive learning management. Some researchers base training on the use of social networks and communication between trainees (students) and trainers (teachers) [7-9].

Some of current LMS systems are cloud-based and do not require a system administrator with experience in installing and maintaining software; however, there are also systems in which deep knowledge of programming languages such as PHP, JavaScript, knowledge of database management and administration, such as MySQL, Microsoft SQL Server is absolutely necessary [11].

Currently, the development and implementation of modern information and communication technologies in the educational process entails the transformation and search for new approaches to the implementation of LMS. One of these approaches is a service-oriented approach based on building a system from heterogeneous, loosely coupled parts, based on services as components with stationary interfaces and performing certain functions.

The study proposes a service-oriented architecture (SOA) approach that loosely connects various system components to reduce development time and costs [10]. In addition, a prototype of a training application with an API ecosystem is proposed, which takes into account the attractiveness and checks the functional and non-functional requirements for the system.

In this study, the authors determined which main categories of services are available in the LMS and proposed a reference model of LMS services. During the study, LMS services are divided into modules that implement similar functionality. On the basis of dedicated services, LMS modules of a specific educational institution are formed based on the requirements that are determined by this educational institution.

1 Materials and Methods

The methodology of this study consists in defining a set of services, forming a reference model, combining LMS services into modules based on the principles of semantic proximity and visualization of the results obtained.

1.1 Types of LMS Services

The functionality of LMS systems for a particular educational institution can solve various tasks depending on the features of the educational process in the educational institution. To solve problems, the LMS must provide a specific set of services that provide various aspects of the system.

The main LMS services can be classified into one of the following categories of services [12]:

1) Services for monitoring and controlling users. The services of this category are focused on fixing and evaluating the activity of various categories of users in various sections: user activity on a separate course and in the system as a whole, conducting various forms of control, evaluating various tasks performed by students on the course and forming the final grade for the course, etc.

2) Content monitoring and control services. Services of this category are focused on the support and control of methodological support of training courses based on a given set of requirements that are determined by the requirements of the educational process in a particular educational institution. These services can evaluate content formally (for example, the presence of certain educational components in a training course), and on the basis of expert evaluation.

3) Operational management and administration services. Services of this category are designed for operational management of work processes in the system. Services of this category can be divided into 2 subgroups:

- Services of operational management of the educational process. This subgroup of services is focused on the prompt response of problems that may arise during the educational process based on the control of certain parameters: information about the availability of courses for training, registration of students for courses, the occupancy of courses with various educational materials, etc.
- Hardware and software control services. This subgroup of services allows you to monitor and respond to problems that may arise in the operation of LMS software or hardware based on the collection and analysis of technical information about the activities of these components.

4) Analytics services. This category of services is aimed at carrying out analytical processing of various information contained in the LMS, as well as building various analytical reports and recommendations.

Based on the presented categories of LMS services and to implement the requirements for LMS systems, the authors propose a reference model of services for LMS systems.

1.2 Reference Model of LMS System Services

The reference model of LMS services is shown in Figure 1 [12].

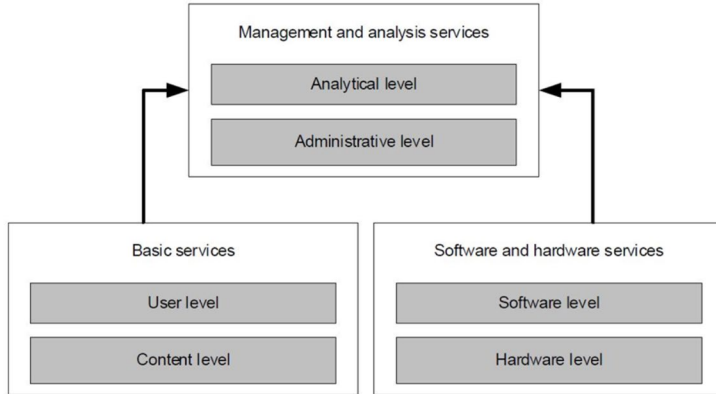


Figure 1
Reference model of LMS services

As can be seen from the diagram shown in Figure 1, LMS services are divided into 3 groups:

1) Hardware and software services. These services are represented by hardware and software components on the basis of which the LMS operates. These services are divided into the following levels:

- Hardware level. This level includes various types of hardware necessary for LMS operation (network equipment, telecommunication data transmission lines, servers, etc.)
- Software level. This level includes a variety of software that is involved in the operation of the LMS (operating systems, application servers, web services, Database Management Systems, etc.)

2) Basic services. These services are designed to provide the main function of LMS systems - training. These services are divided into the following levels:

- The level of content. This level includes services related to the support of working with various educational materials, conducting control activities, etc.
- User level. This level includes services related to the work of various categories of users in the LMS (user registration in the system, sharing access to various types of educational resources, logging user actions, etc.)

3) Management and analysis services. These services are designed to monitor the operation of the LMS system and conduct analysis based on data that accumulates during the operation of software and hardware services and basic services. These services are divided into the following levels:

- Administrative level. At this level, services aimed at operational management of the educational process are presented.
- Analytical level. At this level, services are provided for conducting analytical analysis based on data that was collected during the operation of the LMS.

The division of LMS services into the groups and levels listed above allows you to split services based on their functionality and combine them into functional modules that can be presented in LMS systems.

1.3 Combining LMS Services into Modules

Combining LMS services into modules will solve the following tasks [19]:

- 1) Determine the list of services that should be provided in the LMS, depending on the requirements of a particular educational institution.
- 2) Manage changes to LMS requirements. Changing the LMS requirements in this case can be solved in one of the following ways:
 - by including and/or excluding modules from the LMS;
 - inclusion of a new service in an existing module;
 - creating a new module and including it in the LMS.

The following principles will be used to split the services:

- 1) The module is a specific set of services similar in their characteristics
- 2) The module has the possibility of expansion, which allows you to include new services in the existing module that are similar in their characteristics to the services available in the module
- 3) Extensibility of the module system. In case of new LMS services, the list can be revised by including new models and redistributing services between modules.
- 4) The presence of dependencies between modules. This principle assumes that any service of one module may depend on one or more services of other modules and, accordingly, the inclusion of some module in the LMS requires the inclusion of dependent modules.

1.4 Methodology of Combining LMS Services into Modules

As was mentioned in section 1.3, modules should be combined into services with similar characteristics. That is, the integration of services into modules should be carried out on the basis of their semantic proximity. In this study, the semantic proximity of services is determined by the following formula 1 [13, 14]:

$$SI(f_x, f_y) = \sum_{i=1}^n w_i SI_i \quad (1)$$

where, SI_i – is a measure of the i -connection between two services, w_i – is the weighting factor for the i -link.

To determine the semantic proximity of services, the following measures of connections and weight coefficients for them were used (Table 1) [13, 14]:

Table 1
Link measures and weighting factors

| Designation | Link measure description | Weight coefficient |
|-------------|--|--------------------|
| SI_{BP} | The ratio of the cardinal set of processes using both services to the cardinal number of the set of processes using at least one service | 0,5 |
| SI_{ER} | The ratio of the cardinal set of entities that are read in both services to the cardinal number of the set of services that are read by at least one of the services | 0,27 |
| SI_{EW} | The ratio of the cardinal set of entities that change in both services to the cardinal number of the set of services that change the essence of at least one of the services | 0,23 |

To conduct a study based on the proposed model of combining LMS services into modules, it is necessary:

- define a list of LMS services;
- determine the list of processes that are carried out in the LMS;
- determine the list of objects that operate in the LMS;
- determine which services are involved in the implementation of a certain LMS process;
- determine which objects are used in the service to read their data;
- determine which objects are being created or modified in the service;
- based on the similarity of services, combine them into modules.

Combining services based on their semantic proximity can be done using the clustering method. To implement clustering, the FOREL algorithm is used since the number of clusters can be calculated during the operation and is a priori unknown [15, 16]. The scheme of operation of the clustering algorithm is shown in Figure 2.

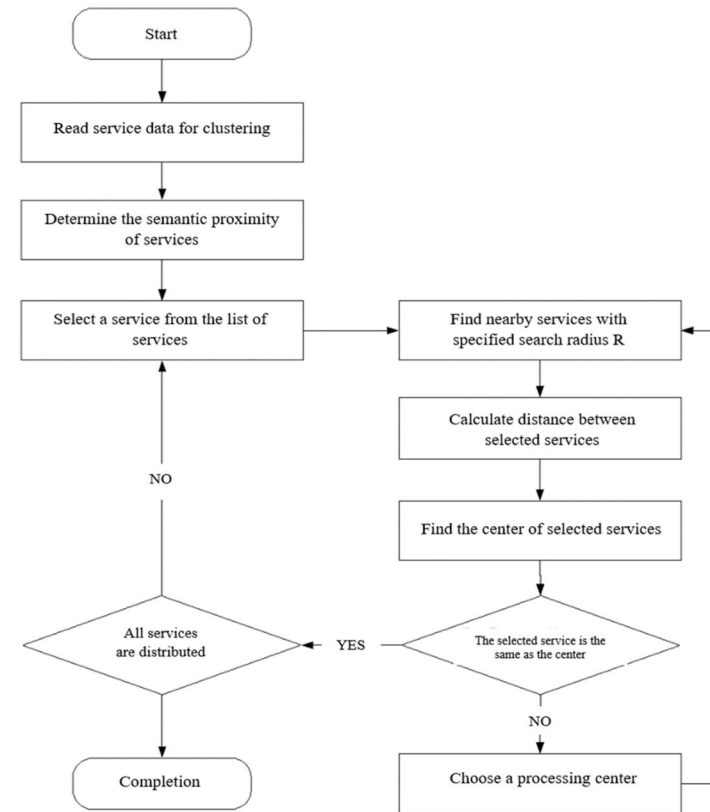


Figure 2

The scheme of the clustering algorithm Forel

2 Results

2.1 Approbation of the LMS Service Pooling Model

The study was conducted on the basis of the educational portal of D. Serikbayev East Kazakhstan Technical University [21], which has an LMS of its own design [17, 18].

Initially, the list of services that are available in the LMS on the educational portal and the dependence of the service on other services was determined (Table 2) [20].

Table 2
List of LMS services

| Code | Service name | Depends on services | Service description |
|------|---|-------------------------|--|
| S01 | Academic progress | S30, S32 | student progress data is available. The report is equipped with filters by semester, a search system by discipline, by group, by the student's full name |
| S02 | Unverified works and appeals | S23, S30 | formation of a report on unverified works and submitted appeals on tests |
| S03 | Task completion schedule | S07, S13, S23 | uploading evaluated tasks and distance course tests |
| S04 | Control of students and teaching staff in accordance with the schedule of classes | S33, S34 | storing information about the educational process for a long time |
| S05 | Active tests | S13, S30 | contains data on students with active incomplete tests |
| S06 | Export of academic progress | S23, S30, S31, S32 | export of students' progress by control points of controls to the database of the educational portal |
| S07 | Flexibility of setting up a system for evaluating students' work | S01, S03, S30, S31, S32 | allows you to set up the evaluation of test tasks in accordance with the training system |
| S08 | Proctoring | S18, S30 | allows you to verify (confirm) the identity of the test taker, as well as observe his behaviour and what is happening on his computer screen to make sure that students are not cheating, does not resort to the help of other people, does not search for answers on the Internet |
| S09 | Managing groups | S30, S32, S33 | combining several discipline groups into one course |
| S10 | Testing | S01, S30, S32 | uploading tests for automatic control of students; control of the educational process: traditional, remote |
| S11 | Teachers | S31, S33, S34 | generating a report that allows you to view the activity of teachers in the distance learning system. Equipped with filters by semester, and inactivity of teaching staff by day, by full name of the teacher |
| S12 | Student activity | S24, S30, S31, S32 | the history of student visits allows you to see the log of user activity |

| | | | |
|-----|--|-----------------------------------|--|
| S13 | Test tasks | S23, S30, S31, S32 | generating a report on uploaded tests for courses, equipped with filters by semester, only distant learning –generating a report by groups of students with the use of distance learning technologies by teachers |
| S14 | Courses by type | S30, S31, S32, S33, S34 | generating a report with quantitative indicators on loaded resources in the course section of the semester, form of study, school, department |
| S15 | All courses | S10, S23, S30, S31, S32, S33 | generating a report with data on all courses on filling courses with content in accordance with the parameters of technical expertise, equipped with filters by semester, schools, departments and a search system by Discipline, teacher, group |
| S16 | Technical and methodological expertise service | S10, S23, S31, S33 | conducting methodological expertise on course content and technical expertise on quantitative indicators of course resources |
| S17 | Course academic progress | S01, S10, S23, S30, S31, S32, S33 | viewing the progress of students, by group of a certain course |
| S18 | File Storage | | a file sharing service that provides the user of a distance learning system with a place for his files and round-the-clock access to them |
| S19 | Video greeting | S18 | allows you to upload a video greeting of the teacher with brief information about the course, requirements, wishes in any video format |
| S20 | Course Forum | S24, S30, S32, S33 | allows you to discuss course topics offline |
| S21 | Chat | S30, S32, S33 | allows you to discuss course topics online |
| S22 | Private messages | S18, S30, S34 | allows you to receive user messages |
| S23 | Tasks | S18, S30, S31, S32, S33 | allows you to upload a task for two-way communication |
| S24 | User activity | S13, S21, S23, S30, S32, S33 | based on the data of the log of user actions in the LMS, a diagram of activity in the E Monitoring system is built, analytical diagrams are formed on the activity of various categories of users in the LMS |
| S25 | Examination session - Qualitative analysis | S01, S30, S31, S32 | Formation of an analytical diagram based on the results of the examination session of students in the E Monitoring system |

| | | | |
|-----|---|--------------------|---|
| S26 | Examination session - Academic progress | S01, S30, S31, S32 | Formation of an analytical chart on the progress of students in the context of courses in the E Monitoring system |
| S27 | Examination session - missed assignment | S01, S30, S31, S32 | Formation of an analytical diagram on the missed assignments of students in the E monitoring system |
| S28 | Video stream | S18 | allows video conferencing |
| S29 | Virtual boards | S18 | a tool that allows you to visualize the training material |
| S30 | Contingent accounting | | Accounting of the contingent of students |
| S31 | Training programs | | taking into account the list of training modules to study in any educational program |
| S32 | Individual training plan | | Accounting of training modules for students to study according to a certain educational program |
| S33 | Teacher's work plan | | Accounting of training modules conducted by the teacher |
| S34 | Personnel accounting | S33 | Personnel accounting service |

Next, a list of processes that go to the LMS and the services involved in each process is defined (Table 3).

Table 3
List of processes in the LMS and the services involved in them

| Code | Process name | Services | Description of the process |
|------|----------------------------------|---|---|
| P1 | Formation of the course content | S03, S07, S10, S13, S14, S15, S18, S19, S23, S28, S31, S32 | courses formation process: creating a course, uploading training materials, uploading training tasks, distributing points for each task, etc. |
| P2 | Assessment of the course content | S03, S14, S15, S16, S23, S31 | conducting an examination of the course content based on formal parameters and expert evaluation |
| P3 | The learning process | S01, S02, S03, S05, S08, S09, S11, S12, S17, S20, S21, S22, S28, S29, S30, S31, S32, S33, S34 | Conducting training courses |
| P4 | Assessment of knowledge | S01, S02, S05, S06, S10, S17, S20, S21, S24, S25, S26, S27, S31, S32 | Carrying out various forms of control measures within the framework of training courses |
| P5 | System operation analysis | S01, S04, S05, S11, S12, S16, S24 | Conducting an analysis of the system in order to identify problem areas in the work |

At the next stage, the list of objects that are involved in the project is determined and for each object it is determined in which services the object data is read, and in which services the object is changed (Table 4).

Table 4
List of objects

| Code | Object name | Reading Services | Change Services | Description of the object |
|------|----------------------|--|--|--|
| O1 | Student | S01, S02, S04, S05, S06, S08, S09, S10, S12, S13, S17, S18, S19, S20, S21, S22, S24, S25, S26, S27, S28, S29, S30, S32 | S22, S30 | The objects represent the student who is being trained in the courses |
| O2 | Teacher | S02, S03, S04, S09, S10, S11, S13, S14, S15, S18, S20, S21, S22, S24, S28, S29, S33, S34 | S22, S33, S34 | the object represents a teacher who creates courses in the system and conducts classes |
| O3 | Content | S03, S04, S07, S09, S10, S13, S14, S15, S16, S20, S21, S23, S24, S31 | S07, S09, S18, S19, S20, S21, S23, S31 | the object represents various types of materials that can be presented at courses (files, assignments, etc.) |
| O4 | Academic performance | S30, S31, S32 | S32 | the object is a set of information about progress on various types of tasks in courses |
| O5 | User activity | S02, S04, S05, S10, S11, S12, S20, S21, S23, S24, S33 | S08, S10, S20, S21, S23, S28, S29, S33 | the object is a log of the user's activity in the system and the artifacts generated by it |
| O6 | Curriculum | S01, S04, S14, S15, S16, S17, S25, S26, S27, S31, S32, S33 | S31, S32 | the object represents a list of disciplines to study |
| O7 | File storage | S18, S30, S33 | S18 | File storage |

At the final stage, a list of software modules has been determined into which the services presented in Table 2 will be combined. To do this, a list of predefined modules was first defined (Table 5):

Table 5
Predefined modules

| Code | Module name | Services |
|------|------------------------------|----------|
| M01 | Personnel accounting module | S34 |
| M02 | Contingent accounting module | S30 |
| M03 | Module of training programs | S31 |
| M04 | Curriculum Module | S32, S33 |

The remaining unallocated modules are formed based on formula 1. Semantic similarity of services is determined for the distribution. Figure 3 shows a matrix of semantic proximity of services.

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | S01 | S02 | S03 | S04 | S05 | S06 | S07 | S08 | S09 | S10 | S11 | S12 | S13 | S14 | S15 | S16 | S17 | S18 | S19 | S20 | S21 | S22 | S23 | S24 | S25 | S26 | S27 | S28 | S29 |
| S01 | 1.00 | 0.63 | 0.39 | 0.50 | 0.82 | 0.53 | 0.00 | 0.30 | 0.23 | 0.18 | 0.56 | 0.65 | 0.30 | 0.30 | 0.30 | 0.45 | 0.83 | 0.07 | 0.14 | 0.39 | 0.39 | 0.26 | 0.00 | 0.62 | 0.67 | 0.67 | 0.67 | 0.22 | 0.26 |
| S02 | 0.63 | 1.00 | 0.42 | 0.39 | 0.74 | 0.57 | 0.00 | 0.34 | 0.39 | 0.37 | 0.58 | 0.58 | 0.37 | 0.28 | 0.28 | 0.23 | 0.80 | 0.14 | 0.09 | 0.70 | 0.70 | 0.43 | 0.07 | 0.60 | 0.55 | 0.55 | 0.35 | 0.43 | |
| S03 | 0.39 | 0.42 | 1.00 | 0.34 | 0.33 | 0.23 | 0.30 | 0.17 | 0.35 | 0.26 | 0.45 | 0.36 | 0.58 | 0.74 | 0.74 | 0.45 | 0.36 | 0.23 | 0.17 | 0.26 | 0.26 | 0.26 | 0.42 | 0.37 | 0.23 | 0.23 | 0.23 | 0.42 | 0.26 |
| S04 | 0.50 | 0.39 | 0.34 | 1.00 | 0.50 | 0.28 | 0.05 | 0.05 | 0.16 | 0.22 | 0.59 | 0.59 | 0.39 | 0.39 | 0.39 | 0.59 | 0.34 | 0.09 | 0.05 | 0.22 | 0.22 | 0.11 | 0.11 | 0.70 | 0.34 | 0.34 | 0.34 | 0.11 | 0.11 |
| S05 | 0.82 | 0.74 | 0.33 | 0.50 | 1.00 | 0.53 | 0.00 | 0.30 | 0.23 | 0.26 | 0.65 | 0.83 | 0.30 | 0.23 | 0.23 | 0.36 | 0.65 | 0.07 | 0.14 | 0.47 | 0.47 | 0.26 | 0.09 | 0.70 | 0.49 | 0.49 | 0.49 | 0.22 | 0.26 |
| S06 | 0.53 | 0.57 | 0.23 | 0.28 | 0.53 | 1.00 | 0.00 | 0.27 | 0.09 | 0.32 | 0.23 | 0.37 | 0.32 | 0.23 | 0.23 | 0.23 | 0.62 | 0.09 | 0.27 | 0.32 | 0.32 | 0.14 | 0.00 | 0.55 | 0.87 | 0.87 | 0.87 | 0.14 | 0.14 |
| S07 | 0.00 | 0.00 | 0.30 | 0.05 | 0.00 | 0.00 | 1.00 | 0.00 | 0.32 | 0.32 | 0.00 | 0.00 | 0.59 | 0.34 | 0.34 | 0.14 | 0.00 | 0.62 | 0.73 | 0.18 | 0.18 | 0.00 | 0.50 | 0.07 | 0.00 | 0.00 | 0.00 | 0.25 | 0.00 |
| S08 | 0.30 | 0.34 | 0.17 | 0.05 | 0.30 | 0.27 | 0.00 | 1.00 | 0.59 | 0.30 | 0.25 | 0.39 | 0.09 | 0.00 | 0.00 | 0.00 | 0.39 | 0.09 | 0.27 | 0.43 | 0.43 | 0.64 | 0.12 | 0.07 | 0.14 | 0.14 | 0.14 | 0.62 | 0.87 |
| S09 | 0.23 | 0.39 | 0.35 | 0.16 | 0.23 | 0.09 | 0.32 | 0.59 | 1.00 | 0.20 | 0.32 | 0.32 | 0.27 | 0.14 | 0.14 | 0.07 | 0.32 | 0.25 | 0.32 | 0.57 | 0.57 | 0.68 | 0.18 | 0.20 | 0.07 | 0.07 | 0.07 | 0.43 | 0.68 |
| S10 | 0.18 | 0.37 | 0.26 | 0.22 | 0.26 | 0.32 | 0.32 | 0.30 | 0.20 | 1.00 | 0.14 | 0.14 | 0.45 | 0.27 | 0.27 | 0.05 | 0.22 | 0.36 | 0.32 | 0.55 | 0.55 | 0.14 | 0.42 | 0.44 | 0.30 | 0.30 | 0.30 | 0.53 | 0.37 |
| S11 | 0.56 | 0.58 | 0.45 | 0.59 | 0.65 | 0.23 | 0.00 | 0.25 | 0.32 | 0.14 | 1.00 | 0.82 | 0.30 | 0.30 | 0.30 | 0.40 | 0.40 | 0.07 | 0.00 | 0.30 | 0.30 | 0.34 | 0.09 | 0.53 | 0.23 | 0.23 | 0.23 | 0.26 | 0.34 |
| S12 | 0.65 | 0.58 | 0.36 | 0.59 | 0.83 | 0.37 | 0.00 | 0.39 | 0.32 | 0.14 | 0.82 | 1.00 | 0.30 | 0.23 | 0.23 | 0.40 | 0.49 | 0.07 | 0.14 | 0.30 | 0.30 | 0.34 | 0.09 | 0.53 | 0.32 | 0.32 | 0.32 | 0.26 | 0.34 |
| S13 | 0.30 | 0.37 | 0.58 | 0.39 | 0.30 | 0.32 | 0.59 | 0.09 | 0.27 | 0.45 | 0.30 | 0.30 | 1.00 | 0.62 | 0.62 | 0.30 | 0.30 | 0.64 | 0.59 | 0.20 | 0.20 | 0.18 | 0.32 | 0.43 | 0.30 | 0.30 | 0.30 | 0.43 | 0.18 |
| S14 | 0.30 | 0.28 | 0.74 | 0.39 | 0.23 | 0.23 | 0.34 | 0.00 | 0.14 | 0.27 | 0.30 | 0.23 | 0.62 | 1.00 | 1.00 | 0.58 | 0.30 | 0.30 | 0.25 | 0.11 | 0.11 | 0.07 | 0.57 | 0.34 | 0.30 | 0.30 | 0.30 | 0.23 | 0.07 |
| S15 | 0.30 | 0.28 | 0.74 | 0.39 | 0.23 | 0.23 | 0.34 | 0.00 | 0.14 | 0.27 | 0.30 | 0.23 | 0.62 | 1.00 | 1.00 | 0.58 | 0.30 | 0.30 | 0.25 | 0.11 | 0.11 | 0.07 | 0.57 | 0.34 | 0.30 | 0.30 | 0.30 | 0.23 | 0.07 |
| S16 | 0.45 | 0.23 | 0.45 | 0.59 | 0.36 | 0.23 | 0.14 | 0.00 | 0.07 | 0.05 | 0.40 | 0.40 | 0.30 | 0.58 | 0.58 | 1.00 | 0.32 | 0.00 | 0.00 | 0.05 | 0.05 | 0.00 | 0.26 | 0.45 | 0.32 | 0.32 | 0.32 | 0.00 | 0.00 |
| S17 | 0.83 | 0.80 | 0.36 | 0.34 | 0.65 | 0.62 | 0.00 | 0.39 | 0.32 | 0.22 | 0.40 | 0.49 | 0.30 | 0.30 | 0.30 | 0.32 | 1.00 | 0.07 | 0.14 | 0.55 | 0.55 | 0.34 | 0.00 | 0.45 | 0.75 | 0.75 | 0.75 | 0.26 | 0.34 |
| S18 | 0.07 | 0.14 | 0.23 | 0.09 | 0.07 | 0.09 | 0.62 | 0.09 | 0.25 | 0.36 | 0.07 | 0.07 | 0.64 | 0.30 | 0.30 | 0.00 | 0.07 | 1.00 | 0.71 | 0.18 | 0.18 | 0.18 | 0.33 | 0.11 | 0.07 | 0.07 | 0.07 | 0.43 | 0.18 |
| S19 | 0.14 | 0.09 | 0.17 | 0.05 | 0.14 | 0.27 | 0.73 | 0.27 | 0.32 | 0.32 | 0.00 | 0.14 | 0.59 | 0.25 | 0.25 | 0.00 | 0.14 | 0.71 | 1.00 | 0.18 | 0.18 | 0.14 | 0.37 | 0.07 | 0.14 | 0.14 | 0.14 | 0.39 | 0.14 |
| S20 | 0.39 | 0.70 | 0.26 | 0.22 | 0.47 | 0.32 | 0.18 | 0.43 | 0.57 | 0.55 | 0.30 | 0.30 | 0.20 | 0.11 | 0.11 | 0.05 | 0.55 | 0.18 | 0.18 | 1.00 | 1.00 | 0.39 | 0.37 | 0.44 | 0.30 | 0.30 | 0.30 | 0.42 | 0.50 |
| S21 | 0.39 | 0.70 | 0.26 | 0.22 | 0.47 | 0.32 | 0.18 | 0.43 | 0.57 | 0.55 | 0.30 | 0.30 | 0.20 | 0.11 | 0.11 | 0.05 | 0.55 | 0.18 | 0.18 | 1.00 | 1.00 | 0.39 | 0.37 | 0.44 | 0.30 | 0.30 | 0.30 | 0.42 | 0.50 |
| S22 | 0.26 | 0.43 | 0.26 | 0.11 | 0.26 | 0.14 | 0.00 | 0.64 | 0.68 | 0.14 | 0.34 | 0.34 | 0.18 | 0.07 | 0.07 | 0.00 | 0.34 | 0.18 | 0.14 | 0.39 | 0.39 | 1.00 | 0.00 | 0.14 | 0.09 | 0.09 | 0.09 | 0.52 | 0.77 |
| S23 | 0.00 | 0.07 | 0.42 | 0.11 | 0.09 | 0.00 | 0.50 | 0.12 | 0.18 | 0.42 | 0.09 | 0.09 | 0.32 | 0.57 | 0.57 | 0.26 | 0.00 | 0.33 | 0.37 | 0.37 | 0.37 | 1.00 | 0.00 | 0.14 | 0.00 | 0.00 | 0.00 | 0.28 | 0.12 |
| S24 | 0.62 | 0.60 | 0.37 | 0.70 | 0.70 | 0.55 | 0.07 | 0.07 | 0.20 | 0.44 | 0.53 | 0.53 | 0.43 | 0.34 | 0.34 | 0.45 | 0.45 | 0.11 | 0.07 | 0.44 | 0.44 | 0.14 | 0.14 | 1.00 | 0.53 | 0.53 | 0.53 | 0.14 | 0.14 |
| S25 | 0.67 | 0.55 | 0.23 | 0.34 | 0.49 | 0.87 | 0.00 | 0.14 | 0.07 | 0.30 | 0.23 | 0.32 | 0.30 | 0.30 | 0.30 | 0.32 | 0.75 | 0.07 | 0.14 | 0.30 | 0.30 | 0.09 | 0.00 | 0.53 | 1.00 | 1.00 | 1.00 | 0.09 | 0.09 |
| S26 | 0.67 | 0.55 | 0.23 | 0.34 | 0.49 | 0.87 | 0.00 | 0.14 | 0.07 | 0.30 | 0.23 | 0.32 | 0.30 | 0.30 | 0.30 | 0.32 | 0.75 | 0.07 | 0.14 | 0.30 | 0.30 | 0.09 | 0.00 | 0.53 | 1.00 | 1.00 | 1.00 | 0.09 | 0.09 |
| S27 | 0.67 | 0.55 | 0.23 | 0.34 | 0.49 | 0.87 | 0.00 | 0.14 | 0.07 | 0.30 | 0.23 | 0.32 | 0.30 | 0.30 | 0.30 | 0.32 | 0.75 | 0.07 | 0.14 | 0.30 | 0.30 | 0.09 | 0.00 | 0.53 | 1.00 | 1.00 | 1.00 | 0.09 | 0.09 |
| S28 | 0.22 | 0.35 | 0.42 | 0.11 | 0.22 | 0.14 | 0.25 | 0.62 | 0.43 | 0.53 | 0.26 | 0.26 | 0.43 | 0.23 | 0.23 | 0.00 | 0.26 | 0.43 | 0.39 | 0.42 | 0.42 | 0.52 | 0.28 | 0.14 | 0.09 | 0.09 | 0.09 | 1.00 | 0.75 |
| S29 | 0.26 | 0.43 | 0.26 | 0.11 | 0.26 | 0.14 | 0.00 | 0.87 | 0.68 | 0.37 | 0.34 | 0.34 | 0.18 | 0.07 | 0.07 | 0.00 | 0.34 | 0.18 | 0.14 | 0.50 | 0.50 | 0.77 | 0.12 | 0.14 | 0.09 | 0.09 | 0.09 | 0.75 | 1.00 |

Figure 3
Matrix of semantic proximity of services

After determining the semantic proximity matrix, a computational experiment was carried out with the following search radii:

- $R = 0.5$ – this radius corresponds to half of the maximum distance between services (Table 6)

Table 6
Modules obtained by clustering with a radius of 0.5

| Code | Module name | Services |
|------|---|------------------------------|
| M05 | The module of accounting of progress | S01, S06, S17, S25, S26, S27 |
| M06 | User Activity Module | S02, S05, S11, S12, S24 |
| M07 | Module of training tasks | S23 |
| M08 | Testing Module | S10 |
| M09 | Online communication module | S08, S09, S22, S28, S29 |
| M10 | Course content Control module | S03, S13, S14, S15 |
| M11 | Communication on the course module | S20, S21 |
| M12 | Course Examination Module | S16 |
| M13 | The module for monitoring the conduct of teaching staff classes | S04 |
| M14 | Course Setup Module | S07, S18, S19 |

- $R= 0.34$ – this radius corresponds to the average value of all elements of the semantic proximity matrix (Table 7)

Table 7
Modules obtained by clustering with a radius of 0.34

| Code | Module name | Services |
|------|--|------------------------------|
| M05 | User Activity Module | S04, S05, S24 |
| M06 | Task Module | S23 |
| M07 | Academic Progress Monitoring Module | S01, S06, S17, S25, S26, S27 |
| M08 | Module of Test Tasks | S13 |
| M09 | Proctoring Module | S08 |
| M10 | Testing Module | S10 |
| M11 | Examination Module | S16 |
| M12 | Visit Control Module | S11, S12 |
| M13 | Course Occupancy Control Module | S03, S14, S15 |
| M14 | Video Stream Module | S28 |
| M15 | Communication Module | S09, S22, S29 |
| M16 | Task Control Module | S02, S20, S21 |
| M17 | Module for Configuring Data Storage for the Course | S07, S18, S19 |

As a result, 14 modules were obtained for a search radius of 0.5 and 17 modules for a search radius of 0.34 for the initial list of services. The graphical distribution of services by modules for different search radii is shown in Fig. 4.

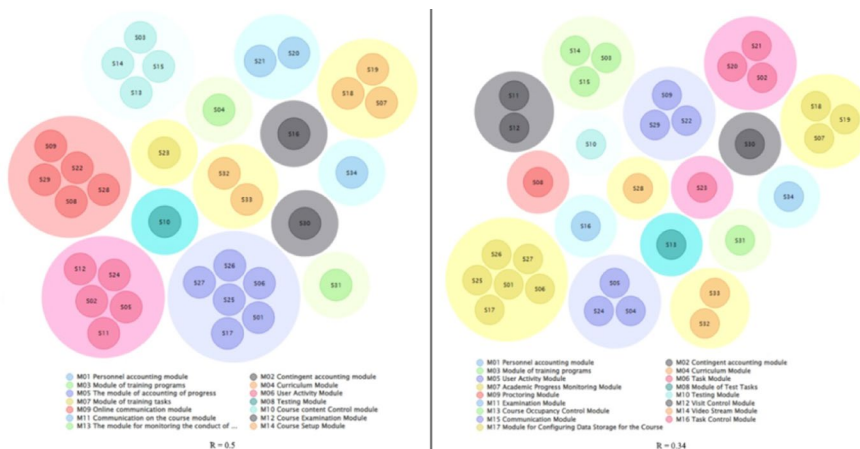


Figure 4
Distribution of LMS services by modules

After distributing the services by modules, you can determine the dependencies between the received modules based on the dependencies between the services.

For this study, the dependencies between the obtained modules are shown in Figure 5.



Figure 5
Distribution of LMS services by modules

The results of the experiment showed:

- 1) services similar in semantics were included in one cluster (module), for example, services S03, S13, S14, S15 were included in the module "Course content control module" at $\$R = 0.5$, at $\$R = 0.34$ services S03, S14, S15 were included in the module "Course content control module";
- 2) loosely coupled functions, regardless of the radius used to search for neighboring elements, are allocated to a separate cluster (service), for example, service S10;
- 3) the distribution of services with a high degree of connectivity depends on the clustering parameters, which makes it possible to identify these services in subsequent attempts, varying the radius of the search for neighbouring elements.

3 Software Implementation

To solve the above tasks, the authors have designed an information system database. The logical scheme of which is shown in Figure 6.

The developed database architecture of this study was implemented in the Microsoft SQL Server 2019 database management system in the form of a physical LmsModules database.

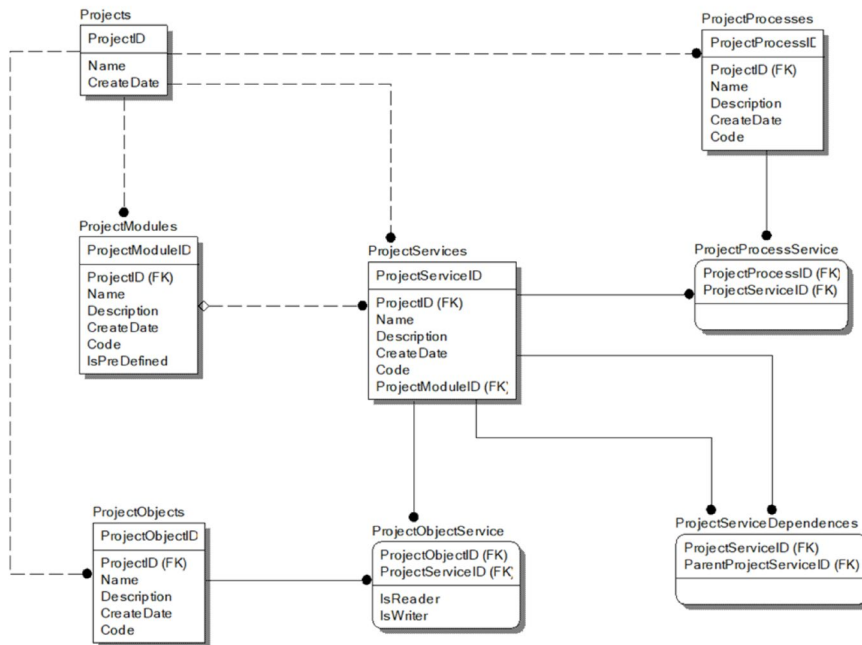


Figure 6

Logic diagram of the LMS modular construction database

At the final stage of this part of the study, a web application has been developed to work with the specified database. The architecture of the web application is shown in Figure 7. The web application is developed on the platform ASP.NET and it is divided into several levels:

- 1) The "DB Manager" component is located at the lower level. This component is responsible for interacting with the database described above in this section.
- 2) At the next level there is a "Module for working with database elements". This module contains components that allow you to extract data from our database and edit them.
- 3) The Forel Clusterer component implements mechanisms for distributing services across modules using the Forel clustering algorithm. To determine clusters, an assessment of the semantic proximity of services is used, according to the model described in Section 1.

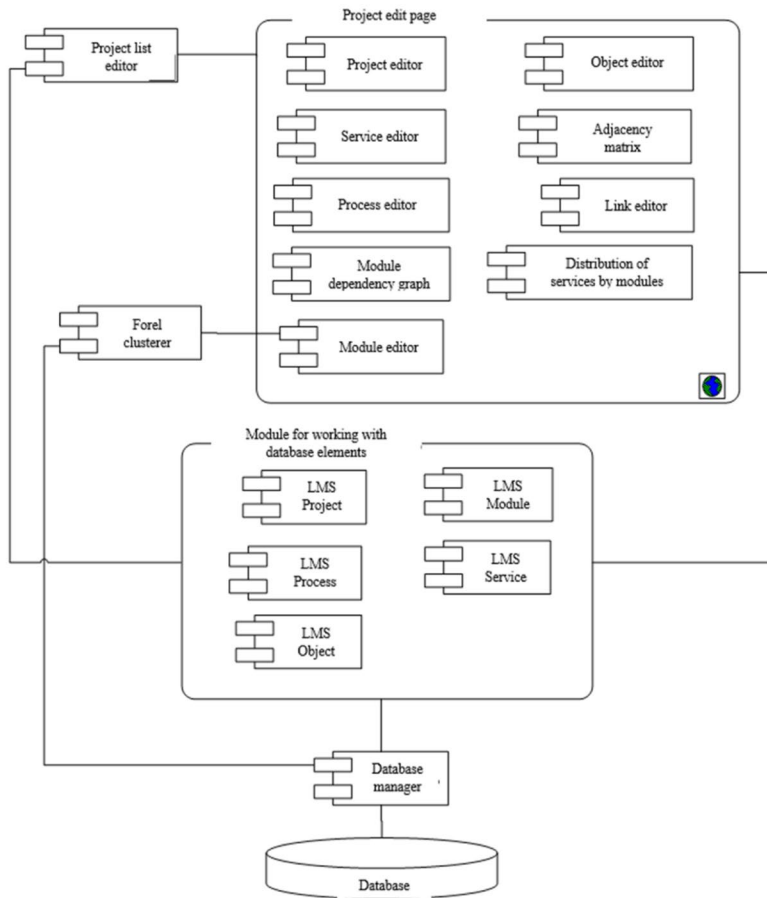


Figure 7
Web Application architecture

3) The "Project List Editor" page. On this page there is an option to create a new project, delete a project or copy an LMS project (Fig. 8).

previous modules are deleted, except the predefined ones. To generate modules, you can specify the cluster radius for Forel clustering.

- A graph of module dependencies. This component of the page displays a dependency graph between modules based on dependencies between services.
- Distribution of services by modules. This component of the page presents a graphical distribution of services according to the created models.

The developed web application allows you to form LMS modules based on the proposed clustering model.

The resulting software modules will increase the efficiency of their support and expansion, and also, based on the dependencies between the modules, it will allow you to predict how the expansion of functionality may affect other modules.

Conclusions

Within the framework of this study, a methodology for combining LMS services into modules based on semantic proximity is proposed. The integration of services is based on the processes in which the services are involved and on the objects with which the services work. As a clustering method, the Forel method was used, which allows clustering without a predefined number of clusters.

Based on the proposed methodology, a web application has been developed that allows the user to develop a unique LMS configuration based on its own preferences or requirements.

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