

ADAPTIVE LEARNING SERVICE BASED ON SPACING EFFECT

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Abstract: In the article, the adaptive educational service is based on the mechanism of interval repetitions. This system allows the user to study material products without much effort. The technology "Training with reinforcement" has been used as a mechanism of interval repetitions. The technology and an adaptive service of development environment have been reasonably chosen. The structural scheme, the scheme of the algorithm of work, and the scheme of the database structure have been developed. The program has been implemented using the C# programming language and using ASP.NET technologies and its library.

The purpose of the study: to develop an adaptive learning service based on the technology of interval repetition.

Index Terms: training service, interval repetition, adaptive service.

I. INTRODUCTION

The mechanism of interval repetitions [1] is an approach to learning based on increasing the intervals between repetitions of previously studied material to benefit from the distribution effect. The idea behind interval repetitions is to make it easier to review the material so that you don't try to learn everything at once but can learn information in small portions with greater efficiency.

Although the principle can be helpful in many cases, it is most often used when the learner must study many facts and keep them in mind indefinitely. It is well suited for learning vocabulary in a foreign language due to its amount of words. This technology can also be used to train IT as well as to learn and memorize all kinds of information.

Interval repetitions are necessary for new information to be firmly stored in memory. Experiments have shown that even animals remember information much better if they use this approach to learning.

One of the most modern developments in interval repetition technology is the Duolingo service - a top-rated service aimed at learning foreign languages. This service allows to learn foreign languages online. Training is conducted in games with a rich set of tasks of different types. The main advantage is interesting information that helps in the study.

Also, a popular service that uses interval repetition technology is vocabulary.com. In this service, we can learn English words with the help of playing cards, the selection

of which is performed using the technology of interval repetitions.

As we can see, the technology of interval repetition is mainly used in studying foreign languages, but it can also be used to study other subjects. An example of such a service is SoloLearn, where we can learn the basics of several programming languages in the mode of interval repetitions. From this, we can conclude that this technology can study any material.

The relevance of this area is that the advantage of the technology of interval repetitions over other methods is better memorization of information through periodic duplication of the material passed. This allows to learn new material and periodically repeat the material that has already passed, leading to better memorization.

Prospects for development are significant, and the reason for this is that, at present, interval repetition is used for services in studying foreign languages. In other areas, this mechanism is not so popular.

Now, services that use the technology of interval repetition are top-rated among students who want to learn foreign languages, mathematics, physics, and programming languages. Services on this technology give preference to interactive learning in the form of game cards. Due to this approach, information remains in a person's memory for a long time. If you periodically repeat the same material, the probability of studying the material increases significantly.

Therefore, the issue of developing an adaptive learning service based on the mechanism of interval repetitions is particularly relevant. The paper develops solutions in the field of distance learning systems, which have been developing intensively recently, including the direction of using the mechanism of interval repetitions. Currently, services on this technology are popular and suitable for studying any material for children and adults.

Episodic memory [2] has played and continues to play an essential role in memory research. Over time, research has expanded from an emphasis on the content of personal experiences to include tasks that assess the context and awareness associated with memory retrieval. Episodic memory continues to be used in a heuristic sense to refer to certain kinds of functions. Still, the more critical use of the term is theoretical, where episodic memory refers to a type of memory system. Although a good deal of cognitive

research continues to explore the nature of episodic memory, the newest research areas have added the study of the brain to cognitive tasks.

Repeating an item in a list benefits recall [3] performance, and this benefit increases when the repetitions are spaced apart (Madigan, 1969; Melton, 1970). Retrieved context theory incorporates two mechanisms for these effects: contextual variability and study-phase retrieval.

ASP.NET [4] is a web application framework developed and marketed by Microsoft to allow programmers to build dynamic websites, web applications, and web services. It was first released in January 2002 with version 1.0 of the .NET Framework and is the successor to Microsoft's Active Server Pages (ASP) technology. ASP.NET is built on the Common Language Runtime (CLR), allowing programmers to write ASP.NET code using any supported .NET language. The ASP.NET SOAP extension framework allows ASP.NET components to process SOAP messages.

Synaptic inhibition [5] is essential in sculpting signals within cortical microcircuits. Synaptic inhibition prevents hyperexcitability at the most basic level by providing activity-dependent inhibition. During the application of pharmacological blockers of synaptic inhibition (see chapter: Synaptic Transmission), activity levels increase, often exhibiting hyper pathological synchronization that resembles electric seizure activity (see chapter: Epilepsy). Also, perhaps even more importantly, synaptic inhibition dynamically regulates activity levels and enables advanced processing and routing of information in circuits. In the simplest case, feedforward inhibition, afferent excitatory fibers provide input to two populations—excitatory and inhibitory neurons. Neurons in both populations fire action potentials. However, the amount of activity in the excitatory population is limited by the synaptic inhibition it receives from the inhibitory population.

Decentralization [6] is the foundation that gives companies more independence over their collaboration, data ownership, better privacy and security, a more robust and resilient communications infrastructure, and massive scalability.

Memory [7] is vital to how we perceive the world. Human beings have both short-term and long-term memory capacities, and we can create better designs by understanding how memory works and how we can work with that capacity rather than against it. This is important for all designers, but particularly for information visualization designers who need to ensure that their work is ready and understood by the viewer for it to be immediately helpful.

Cyber-physical systems [8] (CPSs) are where the greening of computing and greening by computing meet. In these systems, computing is utilized to fortify and increase the efficacy of traditionally physical systems—intelligent grids for power generation and distribution are commonly cited examples. CPSs, especially in critical infrastructure systems, require three fundamental attributes: safety, security, and sustainability—collectively denoted as S3. The three are conflicting design objectives; e.g., reducing

the environmental footprint of a CPS may make it less safe. CPSs are significantly less deterministic than even cloud computing, as a CPS, by definition, is closely coupled to its physical environment. The unpredictability of this physical environment creates challenges such as intermittent power supply and unknown load characteristics.

The Unified Modeling Language (UML) [9] is a general-purpose, developmental modeling language in software engineering that is intended to provide a standard way to visualize the design of a system.

Reinforcement learning (RL) [10] is an area of machine learning concerned with how intelligent agents should take action in an environment to maximize cumulative reward. Reinforcement learning is one of three basic machine learning paradigms, alongside supervised and unsupervised learning.

II. PURPOSE OF THE WORK

The purpose of creating an adaptive learning service is to make it exciting and easy to learn new material for students. There are few such training services in the product market, so there will be little competition.

To implement the mechanism of interval repetitions in the service developed in work, machine learning methods, namely reinforcement training. Reinforced learning is a field of machine learning inspired by behavioral psychology that examines what actions software agents should perform in a given environment to maximize some notion of aggregate reward. Due to its versatility, this task is studied in many other disciplines, such as game theory, control theory, operations research, information theory, optimization based on modeling, collective intelligence, statistics, and genetic algorithms. In the literature on operations research and management, the field of reinforcement learning is called approximate dynamic programming. The theory of optimal control has studied the problem of reinforced learning. Still, most studies have been concerned with the very existence of optimal solutions and their characteristics rather than aspects of learning or approximation. In economics and game theory, reinforced learning can be used to explain how equilibrium can arise with limited rationality.

The paper considers modern methods and techniques of learning based on the technology of interval repetitions. The software system's structure and its work algorithms are developed. The choice of means for the realization of adaptive educational service is made. Data structures have also been designed to help software components interact correctly and efficiently with each other.

The work initiates support for up to 20 simultaneous clients connected to the server. A server response time of less than 100 ms is also implemented.

III. ANALYSIS OF THE PROBLEM OF ADAPTIVE TRAINING SERVICE DEVELOPMENT

Repetition with intervals is a powerful technique that will help you memorize information in much less time than would otherwise be required. The idea of repeating

repetitions is to make your repetitions easier or to review the sessions so that you don't try to squeeze all the knowledge into your brain.

No need to practically try to remember everything in one session. Although our brains are not technically muscles, they should still be treated as such.

Studying a textbook is like training your brain. But the only difference is that when we learn, we try to complete all our studies in one day instead of arranging them over time. So, going through a whole night the day before an exam is the same as trying to run thousands of miles a day before a marathon. It just doesn't work.

Stuffing, all you do is tire your brain and lose all the memories you've managed to create. Memories in your brain become more robust due to repeated, spaced classes, which is what spaced repetition is.

Let's look at how to use spaced repetition to learn and how to make the most of this powerful memory technique. There is a binding of contexts to memory, which is required

in this theory. Similar data will also be needed to assess whether memories of later trials are linked to data from previous tests, which is needed for the study phase search theory. It will be necessary to re-evaluate all these competing theories of distance learning as more information about the dynamics of memory networks becomes available. Indeed, different ideas may be applied to other memory systems.

Interval repetition is a memory technique that involves viewing and remembering information with optimal intervals between intervals until the data is absorbed sufficiently. This technique helps your brain retain more information because it keeps the material fresh and makes you actively remember. The repetition interval can be applied to any form of learning, from elementary math problems to graduating computer algorithms.

The block diagram (Fig. 1) consists of four main components. The components responsible for data storage are the user database and the task database.

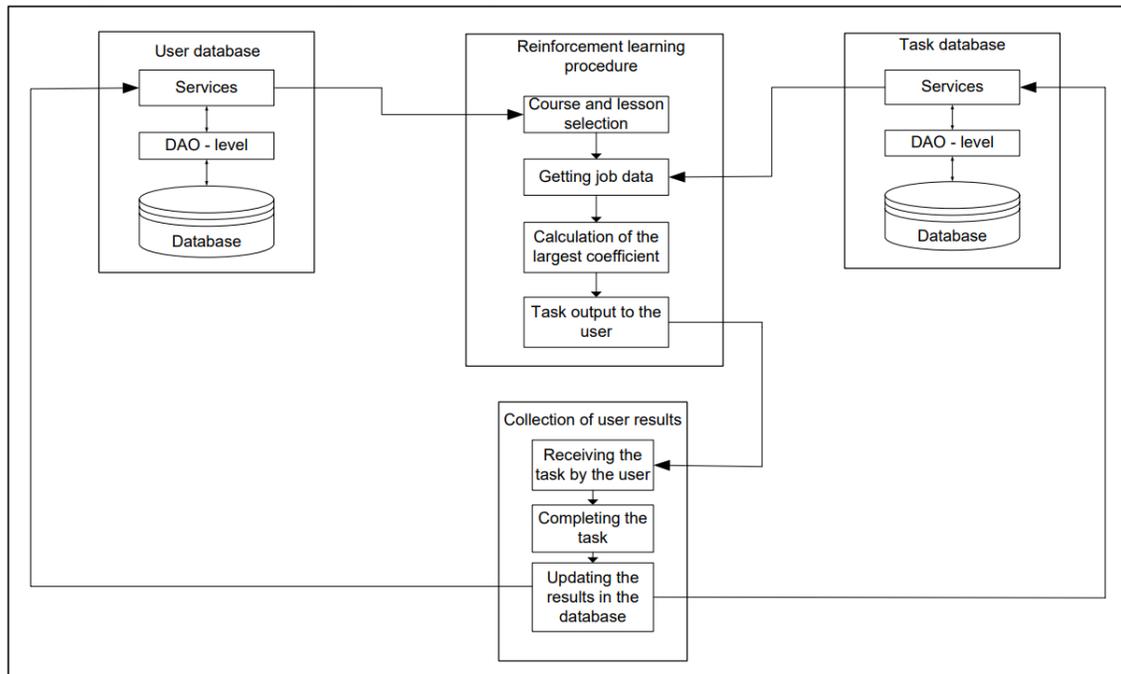


Fig. 1. Block diagram

The "Reinforced Learning Procedure" component involves processing input from the user and calculating the highest factor using the "greedy method".

The next component, "Collecting user results," is responsible for receiving a response from the user and checking it for correctness.

As we can see in (Fig. 1), the adaptive learning service constantly interacts with the database, allowing to continually use relevant information and the method of interval repetitions as accurately and efficiently as possible.

The work of the service begins with the user logging into the site. It reflects the component "Start" (Fig. 2). After logging in, we receive up-to-date information about the user from the database. Next, the user chooses the course and lesson that he will study. After studying the lesson information, the user moves on to the task. The task is calculated according to the method of training with reinforcement.

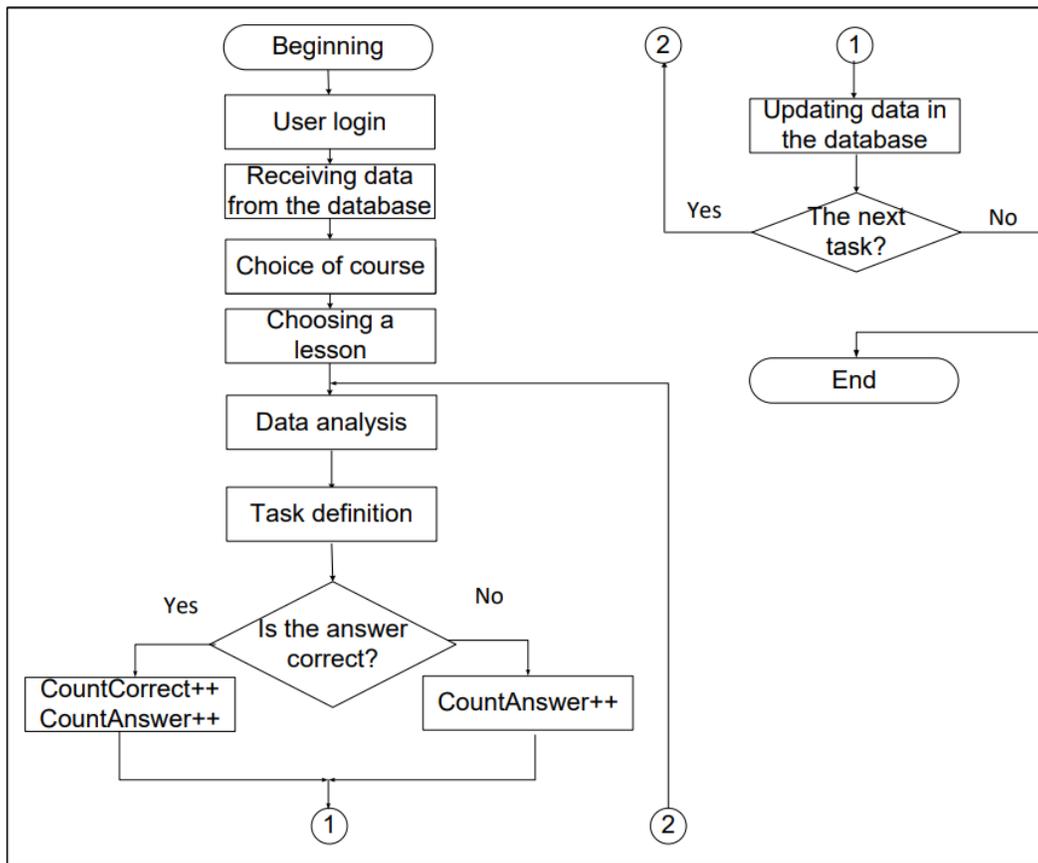


Fig. 2. Algorithm of adaptive learning service

When the user answers the question, the answer is checked. If the user answered correctly, then for this task, the number of attempts and the number of correct answers is increased by one; if the answer was wrong, then only the number of attempts is increased by one. After that, the user is asked if he wants to continue to pass tasks on this topic. If the user answers what he wants, a new job is calculated, and the script is repeated. And if the user does not wish to continue, he returns to the choice of course, after which the whole algorithm is repeated.

IV. CHOICE OF MEANS FOR IMPLEMENTATION OF ADAPTIVE TRAINING SERVICE

There are many programming languages for service development. In my work, I decided to use the C# programming language and the ASP.NET Core MVC platform. ASP.NET Core is free software that is more productive and optimized than its predecessor, ASP.NET. ASP.NET is highly compatible with ASP.NET MVC, which combines the functionality of technologies such as MVC, Web API, and Web Page.

The advantage of this technology is the MVC (Model-view-controller) pattern - an architectural template used in software development.

.NET is a platform from Microsoft that allows to create software applications. It is believed that the .NET Framework was created as an alternative to the popular Java programming language. The main difference between the two programming languages is that the .NET Framework is officially designed to work with Microsoft products. Since then, the .NET Framework has undergone long development and improvement, and there is now a new generation of this platform called .NET Core.

The main difference between the .NET Core platform and the .NET Framework is that it is cross-platform. Many believe that C# and the .NET platform are the same. But they are different. .NET Framework is compatible not only with C# but also with other programming languages, such as F#, VB.NET, and C++.

Each component of the template (Fig. 3) is responsible for its functions.

- 1) Model is the central component of the MVC template and reflects the behavior of the service, independent of the user interface.
- 2) The view is a representation of the information that the user receives at the exit.
- 3) Controller - this component receives input data and converts it into commands for the model or view.

The C# programming language was used to create the adaptive learning service. C# is an object-oriented, text-safe programming language for the .NET platform.

Features of ASP.NET Core:

- 1) The modular structure is distributed as NuGet packages.
- 2) Optimized for the Internet.
- 3) HTTP requests are straightforward and modular.
- 4) Applications are cross-platform, allowing to run them on Windows, Mac, and Linux.
- 5) The source is open and community-oriented.
- 6) Cloud-based environment configuration system.

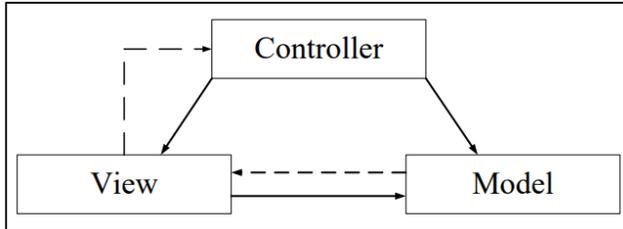


Fig. 3. Diagram of the interaction between the components of the template

To accomplish this task, I chose the action-value methods. Reinforced learning is learning machine learning of models to make a sequence of decisions. The agent knows to achieve a goal in an uncertain, potentially complex environment. During reinforcement training, artificial intelligence encounters a game situation. The computer uses trial and error to find a solution to the problem. For a machine to do what a programmer wants, artificial intelligence receives either a reward or a punishment for its actions. Its goal is to maximize the overall prize. Enhanced learning differs from controlled learning in that the indicated labeled I / O pairs are not required, and there is no need to explicitly correct suboptimal actions. Instead, the focus is on finding a balance between exploration (unexplored territory) and exploitation (for today's knowledge).

The environment is usually presented as a Markov decision-making process (MDP), as many learning algorithms use dynamic programming techniques to reinforce this context. The main difference between classical active programming methods and supported learning algorithms is that the latter does not require knowledge of the exact mathematical model of MDP, and they target large MDPs where accurate methods become impossible [6].

Current research topics include adaptive methods that work with fewer parameters under a large number of conditions, focus on research tasks in large IPRs, large-scale empirical assessments, learning and action on partial information (e.g., predictive representation), modular and hierarchical reinforced learning, improvement of existing

methods of the value function and strategy search, algorithms that work well with large spaces, transfer learning, lifelong learning, effective planning based on samples (for example, based on the Monte Carlo tree search). Distributed Reinforcement Learning is also a topic of interest in modern research. There is also a growing interest in real-life reinforcement applications. The benefits of reinforced learning are gathered here.

Reinforced learning algorithms, such as CR, have also been studied as a dopamine-based model of brain learning. In this model, dopaminergic projections of black matter on the basal ganglia act as a prediction error. Reinforced learning has also been used as part of the human skills model, especially concerning the interaction between implicit and explicit skills learning (the first publication on this application was in 1995-1996, and there have been many subsequent studies).

Although the designer sets a reward policy - that is, the rules of the game - he does not give the model any clues or suggestions for solving the game. It depends on how the model completes the task to maximize the reward, from completely random trials to sophisticated tactics and superhuman skills. Using search power and much testing, reinforcement training is currently the most effective way to hint at machine creativity. Unlike human beings, artificial intelligence can gain experience from thousands of parallel games if the learning enhancement algorithm runs on a robust computing infrastructure.

The disadvantage of the method of weighted evaluation is the limitation, as increasing the number of steps of interaction with the environment increases the amount of memory required to calculate and the number of calculations themselves.

V. IMPLEMENTATION OF ADAPTIVE TRAINING SERVICE

The popular UML modeling language (Unified Modeling Language) was used to develop the precedent chart). Also, due to the UML diagram, it is easier to understand the program code and structure in more detail.

As we can see (Fig. 4), in our model, we see three critical links of interaction, the system, the administrator, and the user.

The administrator can access system configuration, bit management, and user learning outcomes.

The user can customize the system, choose courses and see their learning outcomes.

The system manages the database based on the administrator and the user's actions and changes the training configuration based on interval repetitions.

The created diagram will help further develop the functionality that should be implemented and available for each participant.

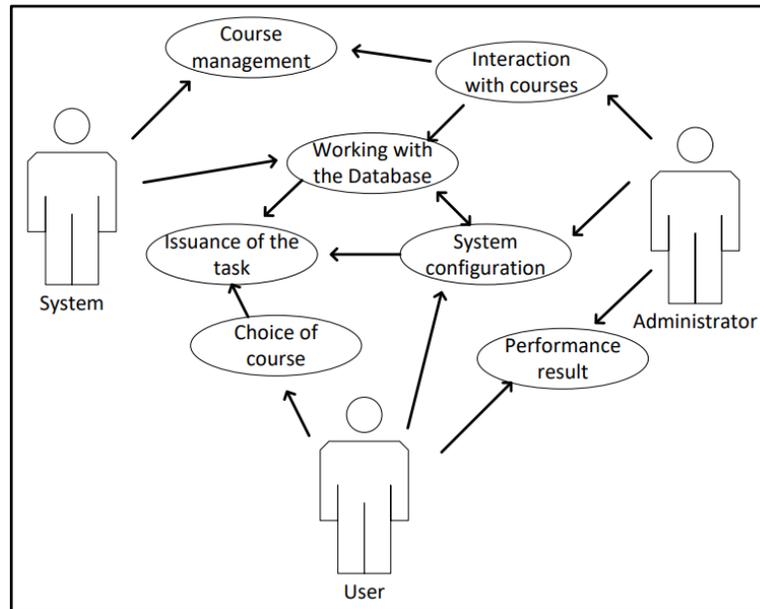


Fig. 4. Software system precedent diagram

At this stage, I developed the structure of the database. Working with data is very important; you must plan and create a functional design to work effectively. The data model determines the logical structure of the database. In developing this database, I used a relational model, which means that relationships of varying degrees are normalized and user-friendly. All tables contain columns and rows that are visually understandable, and at the same time, each table includes information on a particular object and its relationship.

Having created a logical structure of the database, you must carefully plan the values of tables, their contents, and

the interaction of tables with each other. Each table should be responsible for its category and part of the system of adaptive learning service based on interval repetitions. For the service, I have developed a database, properties, and tables which we will now consider.

Consider the general structure of the database and the relationships between tables. In this section, the design and plains of the database were developed (Fig. 5), which stores specific information about users of the service and the courses that these users take.

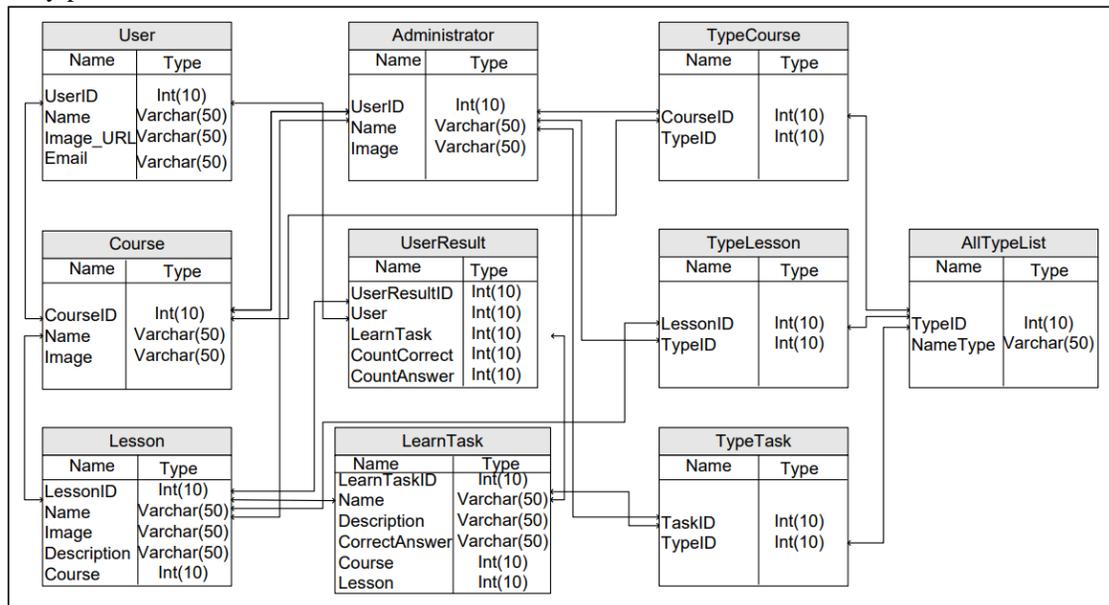


Fig. 5. The structure of the database has been developed

The database structure shows the relationships and interactions of the tables with each other. Intelligent and efficient planning of the database structure increases the speed of working with data and therefore increases the speed of the entire service.

It is necessary to structure the data to obtain accurate results and a further selection of tasks for the user. A data structure is a critical component because the work of the database and software parts must interact directly, and this interaction occurs through data. At this stage, I have developed a data structure in which each component can interact in a coordinated manner, which allows us to perform data operations efficiently and quickly.

The work of the user and the server takes place at the level of data that they transmit to each other. Collaborative work requires a transparent and efficient structure in data exchange. So, let's look at the design and data types used in the service based on interval repetitions.

The data structure for the adaptive learning service based on the technology of interval repetitions involves five central nodes, which are my tables that store all user data, courses, and learning outcomes.

- User {UserID, Name, Email, Image_URL}
- Course {Course ID, Name, Image}
- Lesson {LessonID, Name, Image, Description, Course}

- LearnTask {LearnTaskID, Name, Description, CorrectAnswer, Course, Lesson}
- UserResult {UserResultID, User, LearnTask, CountCorrect, CountAnswer}

In this data structure, virtually all components depend on the user. Each user has one or more courses he has chosen to study. Each class includes lessons with material to be explored. And in turn, each lesson contains a task through which we check how well the user has learned the topic.

The UserResult data structure stores information about each task passed by the user and the score for this task. This table will have the most significant impact on the selection of functions by reinforcement training. As we see above, each structure is based on a different system, so it is necessary to form data types to exchange data between tables correctly and efficiently.

After creating an adaptive training service, you need to test the service and the correctness of the algorithm.

To verify the correctness of the service, we will test and, in parallel, investigate the change in data in the database.

I have already created my user account for the test.

Let's pay attention to the results of the user (Fig. 6), which were before the beginning of the testing of the service. All courses, lessons, and tasks are filled with test data.

UserResultID	User	LearnTask	CountCorrect	CountAnswer
1	1	1	5	8
2	1	2	5	9
3	1	3	3	6
4	1	4	3	4
5	1	5	5	8
6	1	6	1	2
7	1	7	2	5
8	1	8	4	5
9	1	9	5	6
10	1	10	6	8

Fig. 6. User results before testing

Next, you need to choose a course (Fig. 7). For testing, I will select the first course, Speak Up.



Fig. 7. List of courses

In the picture, we see a list of available courses. Depending on your wishes, you can choose a method to

study and, accordingly, click on the name to switch to that course.

Choose Lesson 2 (Fig. 8).



Fig. 8. List of lessons for the Speak Up course

Above (Fig. 9), we see the lesson's name - "Lesson2", a class description containing test information, and a button to go to the tasks related to this lesson. By clicking the "Go

to Tasks" button, we will go to the page with the job, which will be displayed using the «Training with reinforcement» method.

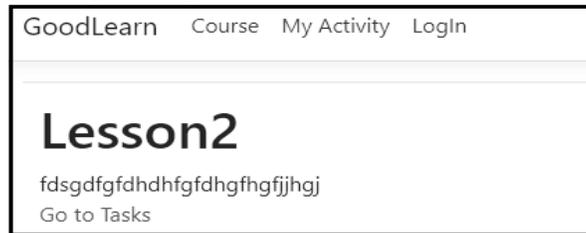


Fig. 9. Information about the second lesson

Since we chose the first course and the second lesson, the task for this lesson will be selected from the function table. The choice will be between the job with LearnTaskID = 4 and LearnTaskID = 5.

We see that Task22 has LearnTaskID = 5. Looking at the table of previous user results, we see that the user has worse results among these two tasks, with the fifth task, so the system offered this task (Fig. 10).

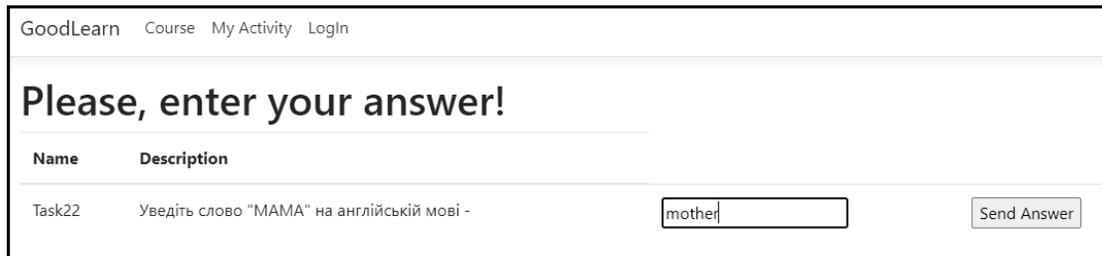


Fig. 10. Derived task

As you can see (Fig. 11), our answer was correct, and the user was informed.

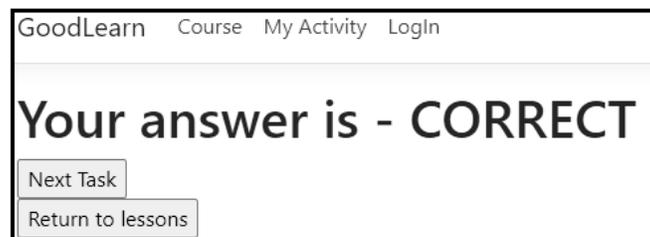


Fig. 11. The result of the task

In this figure, we can see the display of the user's result after passing the test. There are also two buttons available; by pressing the first one, we can go to the next

task, and by pressing the second one, we will return to the lesson selection.

Now let's look at the table of results (Fig. 12).

UserResultID	User	LearnTask	CountCorrect	CountAnswer
1	1	1	5	8
2	1	2	5	9
3	1	3	3	6
4	1	4	3	4
5	1	5	6	9
6	1	6	1	2
7	1	7	2	5
8	1	8	4	5
9	1	9	5	6
10	1	10	6	8
NULL	NULL	NULL	NULL	NULL

Fig. 12. Results after testing

Thus, testing the adaptive learning service based on the technology of interval repetitions was conducted. Since this is only test data, it isn't easy to be 100% sure of the correct operation of the service, but based on the data we received during testing, the service works well.

To study the load on the server, built-in utilities in Visual Studio can be used, called "profiling tools".

The speed of the service largely depends on the site load to the server. The load parameters on the server show below the opening time of the site's main page.

The first and critical parameter is CPU load. When opening the main page, our load is 9%, which we can see in (Fig. 13).

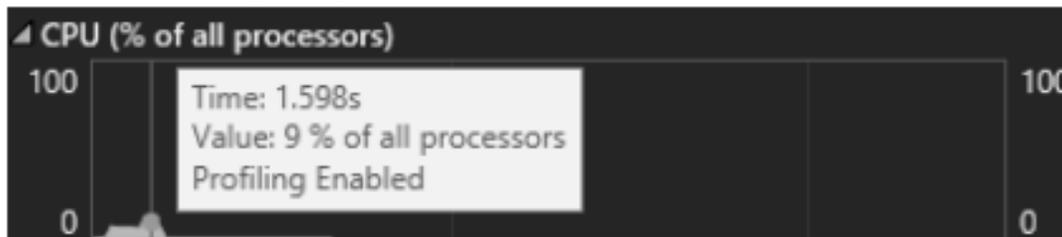


Fig. 13. CPU load

Later, this value drops to the 1st % and remains constant. So, the processor is loaded the most during startup, falls to low weight, and works stably.

The next step was to study the memory load. When opening the first page, the site's cache is immediately occupied by 84MB (Fig. 14).

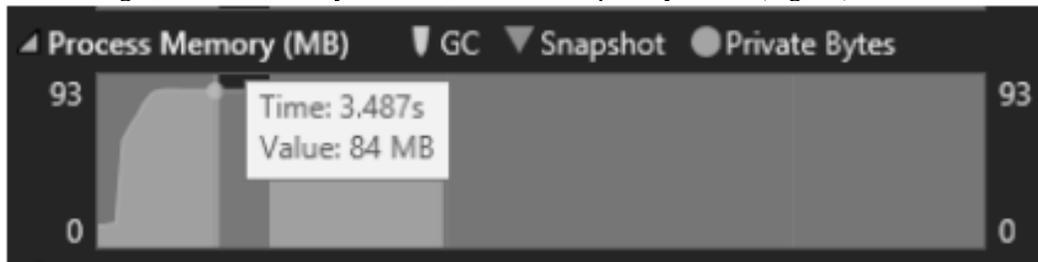


Fig. 14. Memory load

This is not very important since ASP.NET technology allows to load all style files on the first power-up, pictures,

and additional files, so that in the future, as quickly as possible, move between pages.

The value of the used memory is minimal (Fig. 15).

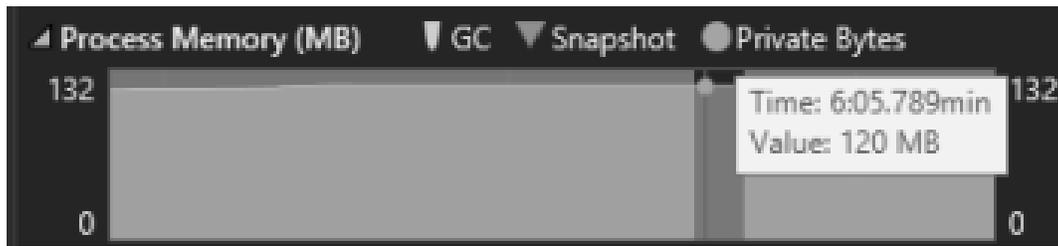


Fig. 15. Memory load during active use service

This is not strange since the service constantly interacts with the database and uses values written to the cache. So, the longer you use the page, the more memory will be used, but given the specifics ASP.NET technology works, then 132MB is not a very big value because all style files and pictures have been already uploaded to the site.

The next step is to pay attention to the speed of execution of database requests. The rate of implementation of recommendations in the site operation is critical. The faster the database responds to requests, the faster the service works more efficiently. As a result of the load testing server, the part is set to support up to 20 simultaneous client connections, and the response time of the server part is no more than 100 ms.

VI. CONCLUSION

This article thesis developed an adaptive learning service based on the mechanism of interval repetitions. The service allowed to learn new materials using convenient and modern teaching methods.

The first section considered modern methods and techniques of learning based on the technology of interval repetitions. The scheme of structural educational service was developed.

In the second section, the selection of means for implementing an adaptive educational service based on the technology of interval repetitions was conducted. Several programming languages and libraries for task implementation were reviewed and analyzed. The rationale for the chosen implementation method was provided. The best environment for service development was considered.

In the third section, data structures were developed to help interact with software components properly and effectively. The implementation of an adaptive training service based on interval learning technology was presented. The service was tested, and the service's load on memory, processor, and database performance analysis was studied.

When creating and implementing an adaptive learning service, support was provided for up to 20 simultaneous client connections to the server. As a result of load testing of the server part of the Internet service, it was found that the server response time is less than 100 ms.

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