

A Neural Network-Based Study of the Performance of a Developed Foreign Language Teaching System

Oleh Krupii and Kostiantyn Kasian

Zaporizhzhia Polytechnic National University, 64 Zhukovsky str., Zaporizhzhia, 69063, Ukraine

Abstract

The purpose of the work is to provide high-quality study of foreign languages in the conditions of distance education.

To achieve this goal it is necessary to perform the following tasks:

- to analyze and select technologies for the development of server and client part of the service;
- determine the requirements for the service;
- design the service according to certain requirements;
- implement the service, using selected technologies;
- analyze the results..

Keywords 1

Database, web-service development, web system, foreign language courses, node.js, vue.js, firebase, neural network, CEUR-WS

1. Introduction

In the time of computerization and automation of almost all spheres of human life, an important criterion is the minimum of time and resources spent with maximum efficiency. The online service is an alternative to the usual classes with the teacher, because the student can without leaving home with a minimum of time to find material for self-study, with the most effective methods.

The events of the beginning of 2020 related to the pandemic have finally convinced all educational institutions and everyone sitting at home in the need to have and use reliable distance learning systems. Uncertainty about the future and protection against the virus, the introduction of quarantine and the need to work / study from home have convinced the world that e-learning is the solution to many problems.

Studying the experience of distance learning of millions of students and employees of companies, including negative, there is a clear understanding of what characteristics should have an ideal e-learning system.

When learning a language, the main problem is learning words: ordinary memorization will not give any results in terms of learning a language and one of the effective ways to learn words is to read books in the "original", ie in English and search for new words there. Therefore, the chosen topic is especially relevant right now [1].

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EMAIL: krupiiolog@gmail.com (O. Krupii); konst_k@yahoo.com (K. Kasian)

ORCID: 0000-0002-3349-8883 (O. Krupii); 0000-0002-1257-156X (K. Kasian)



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- implement the service, using selected technologies;
- analyze the results obtained.

2. Analysis of modern services construction technologies

To achieve the goal of this scientific work it is necessary to develop a service for learning foreign languages, which will provide the user:

- intuitive and user-friendly interface;
- stable connection of the student with the service;
- courses for self-study of the material;
- convenient methods of payment;
- stability of the service as a whole.

To create a quality service, it is necessary to analyze the technologies of creating web pages PHP and JavaScript, as well as server technologies Node.js and PHP and software solutions in the form of Vue, React frameworks. Angular. And also to analyze the relational and non-relational database management systems: Mysql and Firebase, respectively. Consider them further.

3. System design

The service, developed as part of this research, provides the opportunity to read books in the original and watch the exact translation of several sentences, listen to professional reading to understand pronunciation and learn new words that follow the text and added by the translator based on basic knowledge needed to read and memorizing them by repeated.

Creating a service allows you to avoid being tied to a place and time where classes can be held and a more effective way to learn new words and understand the language in general.

3.1. Description of the subject area

3.1.1. Product context

This software package is independent of other software products and completely autonomous in performing its functions.

In the context of this document, the software package is understood interconnected structure consisting of the following components:

- web-application;
- DB;
- DBMS.

3.1.2. Service functions

The functions of this service are:

- the function of viewing the exact translation together with the original text;
- the function of learning words by the method of multiple repetition;
- function of listening to books;
- function of listening to words for correct pronunciation;
- function of viewing and editing the database.

3.1.3. User characteristics

For a holistic understanding of the developed system, the characteristics of all users of the system are described (Table 1).

Table 1

Service users

User	Characteristic
Visitor	A person who went to the site to view information about training with subsequent registration.
Student	A person who registered on the site for training purposes
Administrator	A person who can edit a variety of information on the site.
Translator	The person responsible for the text content of the site and the creation of new translations.

3.1.4. Limitation

The service must meet the following restrictions:

- The site should move quickly between pages;
- full and error-free implementation of the declared functions;

3.1.5. Assumptions and dependencies

The service works normally only if a browser is installed on the PC (Google Chrome, Opera, Mozilla Firefox, etc.).

Internet dependence: the service works normally only if the Internet works without restrictions on the computer.

3.2. Software architecture design

Software architecture design is a development process that is performed after the stage of analysis and formation of requirements. The task of such design is to transform system requirements into software requirements and build a system architecture based on them.

The construction of the system architecture is carried out by defining the objectives of the system, its input and output data, the decomposition of the system into subsystems, components or modules and the development of its overall structure.

Defining a software architecture is a process of defining a structured solution that will meet all technical and operational requirements, but should include the following parameters:

- system reliability. To minimize failures and errors of work, and accordingly maintenance costs;
- productivity and speed of work;
- flexibility and scalability of the system;
- software security. Protect data from unauthorized access by attackers.

4. Realization of service

This section describes the process of creating software in the form of a server part, using the following technologies: Node.js as a server part, NoSQL database Firebase and JavaScript programming language with Vue.js framework.

The process of creating software is time consuming and includes a large amount of tasks and requirements that need to be defined and performed.

4.1. Service functions

Since the software platform for development is the Node.js server from Firebase for a list of books and their parts, it is necessary to describe the data model that will be to be used. Since the Firebase NoSQL database, the information in it is stored in the form of collections and has a data type such as map - is an object embedded in the collection. If indexed, it is possible to query subfields, which can also contain data types: map, array and others. The database consists of 3 collections:

- books - is used to store general data about the book, and links to the components (Table 2);
- bookParts - serves to store the text of parts of books and words for study → (Table 3);
- userData - is used to store user data (Table 4).

Table 2

The structure of the data model of the books collection

Field name	Data type	Data
description	string	The title of the book is in Russian
imageUrl	string	Link to the picture of the book
level	array	Level of language proficiency for reading
parts	array: map(id, title, youtube_id)	Links to the components of the book
title	string	The title of the book is in English
youtube_playlist_id	string	Link to a playlist listening to this part
cost	number	The price of the book

Table 3

The structure of the data model of the bookParts collection

Field name	Data type	Data
BookTitle	string	The title of the book is in English
bookId	string	Unique book identifier
bookPartId	string	Unique identifier of a part of the book
content	string(map(sentences(array) origText, transText)	Contains the original text and its translation
partTitle	string	The designation of the part that the user will see
words	map(map("word"(origPrefix, origText, transText, type	The words are recommended for study. Their original, translation, prefix if available and word type (word, stable expression)

Table 4

The structure of the data model of the userData collection

Field name	Data type	Data
books	map(map(map(map)	Contains information about the user's books (when the book was last added, and which parts have been read)
words	map(map)	Contains information about words that have been added for study and how many times they have been repeated

There is a separate page in Firebase for authorization and registration, which allows you to easily use the necessary functions for this, and automatic encryption, including registration via e-mail, phone number or other popular services. To prevent chaotic registrations, it is possible to set a limit of registrations per day and check via e-mail and limit 1 account to 1 e-mail. Also, one of the main features of Firebase is the ability to host without complex settings and usage fees, there is the ability to roll back to a previous version of the site if there is an unexpected error or vulnerability.

To configure access to the database, you need to create a file with access keys and specify the path to it.

4.2. Implementation of the client part of the web application

When you run a program that passes through the console, Node.js "reads" a file with a list of used, then also reads all imported modules-files, the list of which is in the file package.json, checks for errors, and if not - will start writing code.

Since the site has a duplicate part of the site - a header and a basement, to use the general settings for this would be predictable, so there are 3 files that were once created. The App.vue file imports the header and basement, and the template determines their location on the page.

Given that JS is used as a single programming language for service development, and the same variables are used throughout the project, to access the database, routing between pages, for example, you need to create a file in which to initialize the main variables and specify additional installed packages. To do this, use the file main.js

To start using the basic functions of the service, mandatory registration or authorization, e-mail and password are read from the appropriate fields, and be sure to specify a username. If you enter incorrectly, you will receive an error message and ask you to enter the correct data. Also, to improve the user experience of interaction with the service, there is login data caching and automatic login with unchanged data.

After logging in to the profile, the functions of changing the login data are available for quick transition. The second tab of the personal account has a list of books that the user reads and the opening of the last part that the user read. The third tab is the process of learning new words by reviewing the translation and listening to the correct pronunciation. The added word is written to the database in the personal profile collection. After each click of the button "I remembered this word" there is a record in the database about the increase in the number of studies and when you set the value to "5" the word will no longer be displayed before the study.

5. Research of developed web service

The purpose of the study is a program that will predict the average response time of the server under given conditions based on the neural network.

The object of research - is a web service created using Node.js technology

The study is conducted to show the use of a neural network that is useful in the work and software development, by predicting the details of the development software.

5.1. The course of the experiment

The task is to predict the time of response by the web server to a request from the user, with certain factors that in one way or another affect the system, and the time of response to the request. The main factors were: the stack of software with which the system was developed;

- the type of HTTP request that affects the amount of data processed, the progress of operations performed;
- the number of simultaneously connected users, or users whose requests are processed in the same period of time.
- to solve this problem, the following steps were taken to conduct the experiment:
- carrying out load testing of the server part of the development system;

- construction of a mathematical model - a system of equations - using a neural network;
- forecasting the response time to the request, using a programmed mathematical model with parameters that are not included in the primary sample of input data, and conducting stress testing with the same data;
- calculation of the root mean square error based on the obtained experimental and actual data.

In order to conduct research, it is necessary to collect primary data for further use in calculations for the neural network. The main parameter that must be obtained when forecasting is the response time of the server part of the web system to the user's request.

The first step for this is to conduct load testing - queries with different parameters at each step, but with the same parameters. To perform load testing, it is necessary to perform a certain number of requests at a time. This means that you must be able to send up to 500 simultaneous requests or more to be able to track the server's response and determine the average request time.

Thus, it was decided to perform load testing using a special software tool Apache JMeter, which allows you to generate simultaneously connected users with specified query parameters (query type, header parameters, query body, etc.), and generate reports required for forms (tables, graphs, etc.).

In the Apache JMeter software package, queries were configured for each of the methods allowed by the web server, with the necessary parameters of query headers and bodies, where necessary, and with a different number of competing users. The number of simultaneous queries varied and was configured as follows: 5, 10, 20, 40, 50, 60, 80, 100 and further up to 1000, in increments of 10. A total of 530 scenarios were generated (Fig. 1).

HTTP Request

Name: HTTP Request

Comments:

Basic | Advanced

Web Server

Protocol [http]: Server Name or IP: localhost Port Number: 8080

HTTP Request

Method: PUT Path: /api/v1/todos/86d9ec2c-e99a-4eb4-b41b-037b7e7ec1f9 Content:

☐ Redirect Automatically ☒ Follow Redirects ☒ Use KeepAlive ☐ Use multipart/form-data for POST ☒ Browser-compatible headers

Parameters | Body Data | Files Upload

```

1 {
2   "name": "Chai",
3   "text": "Make White Tea",
4   "done": true
5 }

```

HTTP Header Manager

Name: HTTP Header Manager

Comments:

Headers Stored in the Header Manager

Name:	
Content-type	application/json

Aggregate Report

Name: Aggregate Report

Comments:

Write results to file / Read from file

Filename:

Label	# Samples	Average	Median	90% Line	95% Line
HTTP Request	380	27	10	81	
TOTAL	380	27	10	81	

Figure 1: Fragment of settings and results of load testing

The formation of the mathematical model was carried out using a neural network of direct propagation, which indicates that the results on layer n depend only on the results obtained on layer $n-1$, where n is the current layer of the neural network.

The type of neural network was chosen with a teacher who presents the input images of the network, compares the resulting outputs with those provided to him as the primary, and then adjusts the weights of the network so as to reduce differences. It is difficult to imagine such a learning mechanism in biological systems, although this approach has led to great success in solving applied

problems, it is rejected by those researchers who believe that artificial neural networks must use the same mechanisms as the human brain.

The input parameters for the network, or training data, were the results of load testing, as well as non-numerical parameters (query types, technology stack), which were reduced to the form of numerical values (Table 5).

Table 5

Input parameters to the neural network.

x1	x2	x3	y
0	0	5	5
0	0	10	3
0	0	20	3
0	0	40	4
0	0	50	3
0	0	60	3
0	0	80	3
0	0	100	2
0	0	120	2
0	0	140	2
...
1	4	960	2155
1	4	980	2224
1	4	1000	2262

Yes, a particular request to the web system was numbered from 0 to 4, because the web service was able to process 5 different requests. The stack of used technologies was denoted as follows: 0 - Node.js technology in conjunction with the Firebase database. The number of queries is a numeric parameter and was used in its original form.

An example of input parameters is presented in Table 6.

Table 6

Normalized input parameters to the neural network

x1	x2	x3	y
0.0	0.00	0.0000	0.0018
0.0	0.00	0.0050	0.0009
0.0	0.00	0.0151	0.0009
0.0	0.00	0.0352	0.0013
0.0	0.00	0.0452	0.0009
0.0	0.00	0.0553	0.0009
0.0	0.00	0.0754	0.0009
0.0	0.00	0.0955	0.0004
0.0	0.00	0.1156	0.0004
0.0	0.00	0.1357	0.0004
...
1.0	1.00	0.9598	0.9527
1.0	1.00	0.9799	0.9832
1.0	1.00	1.0000	1.0000

In addition, the neural network must also present a sample with the resulting parameters, with a combination of input parameters. This is done so that the neural network has the opportunity to "learn" and, based on primary data, to form a result that is close to the reference values, with the lowest error rate.

Next, the neural network is trained. Training is carried out using a three-layer neural network, in duplicate. The first layer uses four neurons. In the second layer, in the first case, three neurons are used, in the second - four. But the last layer uses one neuron, because the result that is predicted is the time the web server responds to the request, and it is only one.

The learning process is carried out using the MatLab software package, which, thanks to its built-in capabilities and applications, allows you to work with neural networks.

In order to carry out the process of "learning" the neural network, you need:

- input parameters, because the neural network with the teacher is used;
- programmed neural network construction function, based on inputs data.

All input parameters, ie the set x_1 , x_2 , x_3 , and y , were represented as two matrices $[530 \times 3]$ and $[530 \times 1]$, respectively, and were declared in a separate `a1.m` file, a special format used by the MatLab software environment.

Declaring a function in the `mynetwork.m` file is necessary in order to access it from the MatLab command line. To run this file, you must run the following command at the command prompt of the software environment:

`mynetwork ()`,

that is, call the declared function. Which is done twice, with different numbers of neurons on the second layer of the network, namely: with three and four neurons. After that, a neural network is created and the learning process takes place. In the learning process, for each of the neurons on each of the layers of the network, the coefficients are selected so that the error of the resulting value was less than mine. And in addition, the function of neuron activation plays an important role.

Some of the most common features are:

- single jump - as long as the weighted average amount is less than a certain value, the activation function returns zero, and when it becomes larger - one;
- sigmoid function or sigmoid - often used in multilayer neural and other networks with continuous signals. Smoothness and continuity of function are important positive qualities;
- hyperbolic tangent - also often used in networks with continuous signals. Its peculiarity is that it can return negative values of the result [22].

It should be noted that the sigmoid function is differentiated along the entire abscissa, which is widely used in many learning algorithms [23].

The single jump function is not suitable, because the resulting sample must have the original data, which must differ by thousands, and the hyperbolic tangent use does not make sense, because the output parameters must be greater than zero (Fig. 2).

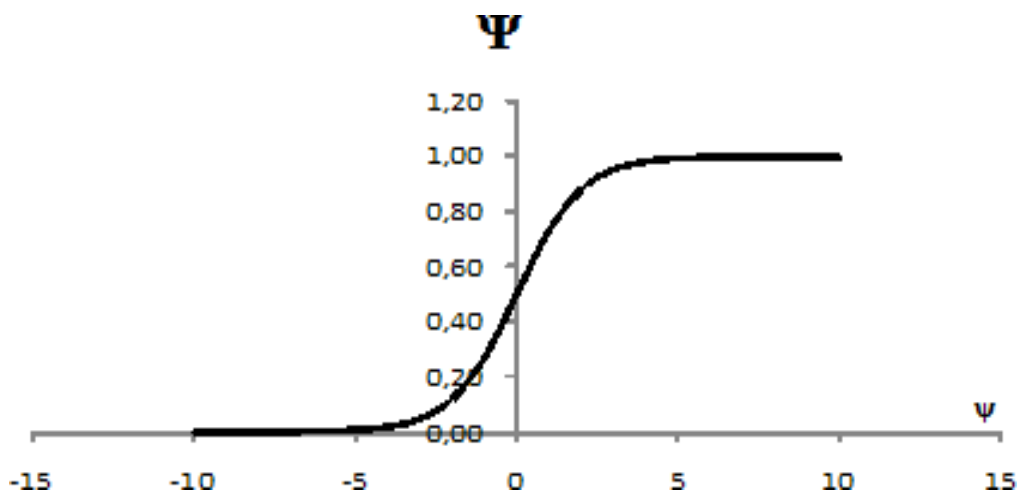


Figure 2: Graph of sigmoid function [22]

Thus, at the end of the program code, the necessary data is displayed to the command line, namely: free coefficients and weights for each of the input parameters on each of the layers of the neural network. The fragment of the matrix of the obtained weights are presented in Table 7.

Table 7
Fragment of weights

Ball number	Neuron number in the layer, p	Offset value, w_0	Connections	
			Synapse	Weighting factor
1	1		x_1	-12.5209
			x_2	6.8718
			x_3	-4.3979
	2		x_1	-2.3574
			x_2	-10.1994
			x_3	0.8109
	3		x_1	2.3552
			x_2	-2.2162
			x_3	-6.2792
			x_1	-1.9711
			x_2	4.5408
			x_3	-8.5333
...	
3	1	$\rho(2,1)$	3.9744	
		$\rho(2,2)$	-8.5445	
		$\rho(2,3)$	-12.2602	
		$\rho(2,4)$	17.6687	

Also, after executing the programmed code, the results of the neural network are obtained in the form of a graph (Fig. 3).

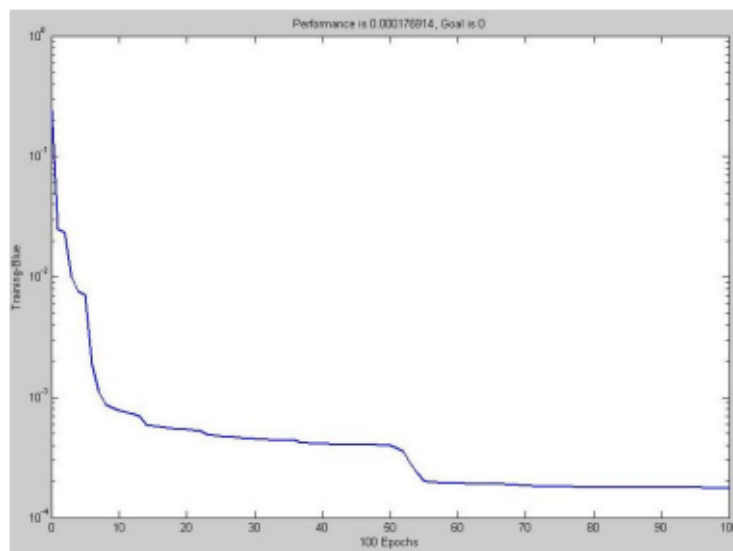


Figure 3: The result of the neural network structure 3-3-1

Thus, the constructed neural network model is a hierarchical structure that contains neurons, and allows you to predict the time required by a computer web system to form a response to a user's request to it. The value of the standard error of the model is acceptable for this kind of problems solved using the synthesized model.

The resulting error when learning a network with a 4-4-1 structure achieves a result of 1.49×10^{-5} , while the error when learning a network with a structure of 4-3-1 is 1.76×10^{-5} . As you can

see, the difference between the two results is not significant, however, the smaller the error the better. Therefore, it is decided to use a mathematical model based on the results of learning a network with a structure with four neurons on the second layer. The structure of the network is presented in Fig. 4.

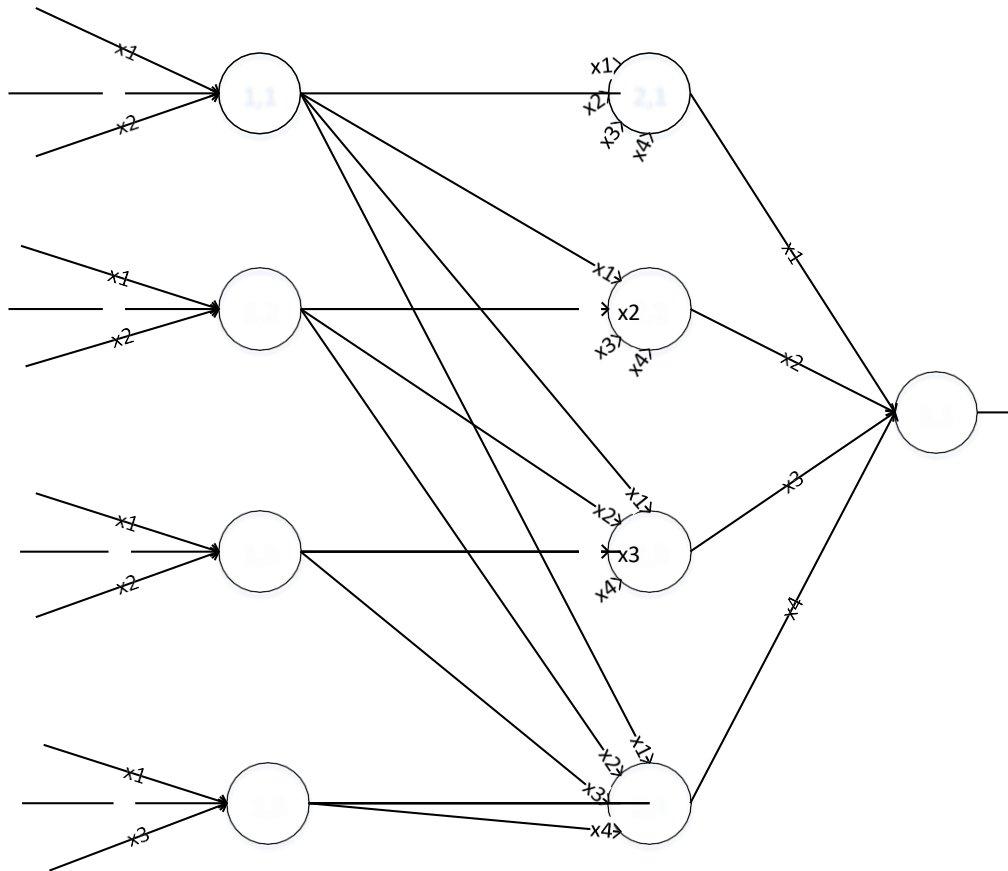


Figure 4: The structure of the neural network on which the training was conducted

Thus, the constructed neural network model is a hierarchical structure that contains neurons, and allows you to predict the time required by a computer web system to form a response to a user's request to it. The value of the standard error of the model is acceptable for this kind of problems solved using the synthesized model.

It was decided to build a system for predicting the response time of the server to the user's request using the programming language Node.js. The program has the form of an application for working from the command line. This is very minimalist, but at this stage of development the system does not require a rich user interface, and does not have a large amount of executable commands. Therefore, it will not be difficult to remember the main options. In addition, applications written using the Node.js programming language have very good performance characteristics, so this program is a good foundation for future research and improvements. An example of the program is shown in Fig. 5.

```
GET --t node
Input conditions:
  technology: node
  method: GET
  concurrent users: 193

Predicted response time is 1.0018792025914591 ms
```

Figure 5: Example of the application for predicting the response time of the server to the user's request

The built system has three main options:

- query type (--m, method);
- number of simultaneously connected users (--cu, c-users);
- technology on which the web system is built (--t, technology).

After that, an experiment was performed - predicting the response time of the web server to the user's request using the built program. The experiment was performed with input data that were not used as input data in neural network training. Also, stress testing was performed with the same input parameters, to use them as actual data, and to compare with the results obtained after the experiment (Table 8).

Table 8

Fragment of weights

x1	x2	x3	y - predicted	y - actual
1	2	3	4	5
0	0	15	1.009	7
0	0	193	1.0018	3
0	0	2432	1.0099	304
1	2	3	4	5
0	0	325	1.0156	4
0	1	654	4.8245	556
0	1	765	13.2793	275
...
0	4	2456	93.8975	1004
0	4	233	1.0059	4
1	0	15	7.0305	4
1	0	193	5.1405	3
1	0	2432	9.108	863
1	0	325	4.9065	7
1	1	654	11.9618	58
1	1	765	29.8991	81
...
1	4	2456	2250.4607	535
1	4	233	122.2504	1

Based on the results of the experiment, a graph is constructed (Fig. 6), which clearly shows the dependence of the response time of the web server to the request, the number of users, technology, and type of request.

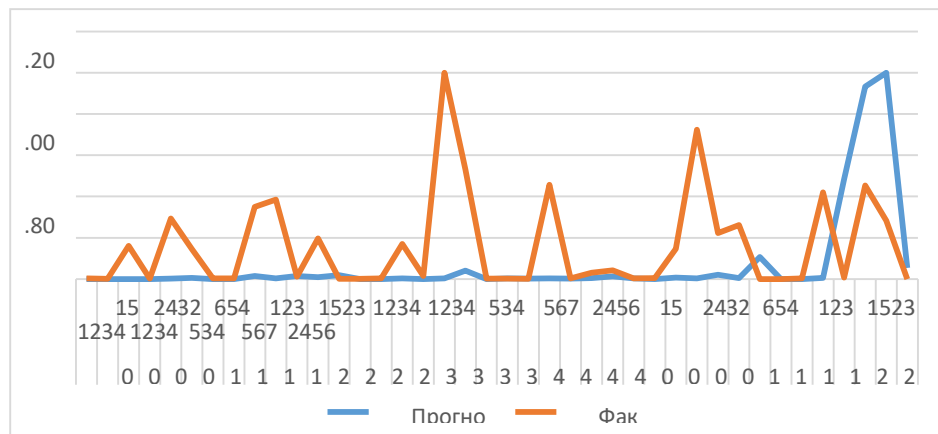


Figure 6: The result of the experiment. Projected and actual data

As can be seen from the graph, the results of the experiment are quite different, but there is also a sufficient number of ranges from matching or almost matching results of the experiment. This result may be due to the fact that the experimental sample was radically different from the training, and the set of actual values obtained during stress testing was not natural. The root mean square error of $2.3 \cdot 10^{-3}$ indicates even more the fact that the results of the experiment differ by two orders of magnitude from the training sample.

However, the error value remains within acceptable values and suggests that the experiment was quite successful. Therefore, we can recommend this model for predicting the response time of a web server to a user's request for application in practice, and in solving daily tasks.

In addition, the task of predicting the response time of the web system may also depend on additional parameters by which the application can work, such as database type, operating system type, application of scaling, network bandwidth, etc.

Thus, we can conclude that the proposed system can not only find application, but also be improved and developed for forecasting, using more complex parameters of operating conditions.

6. Results of work

As a result of the work and on the basis of the created layouts the following web pages were formed: the main page of the service (Fig. 7), the page with the list of books to read. (Fig. 8).

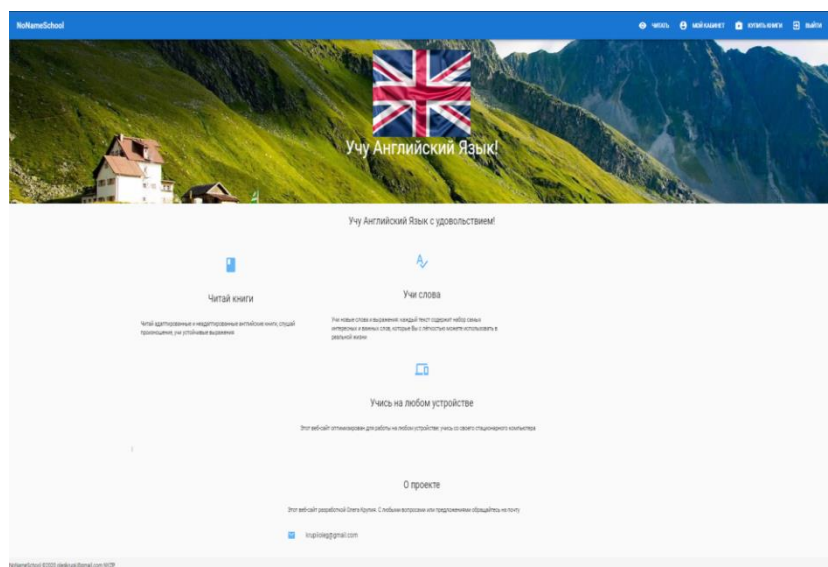


Figure 7: Main page of the service

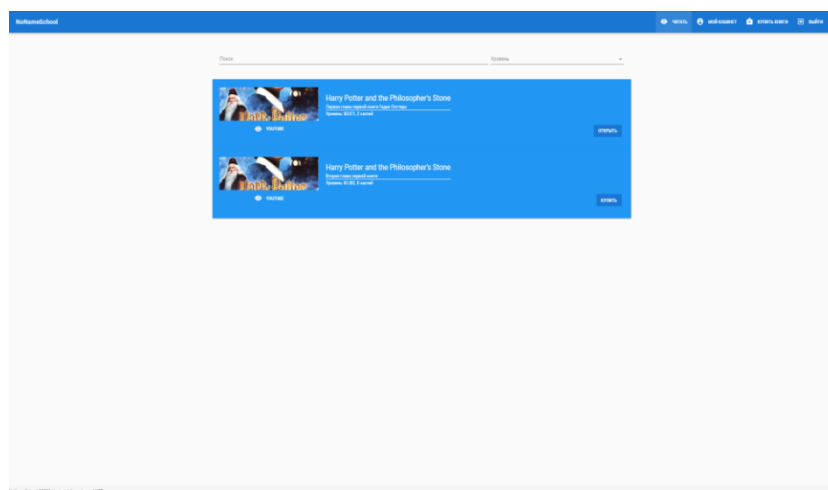


Figure 8: Page with a list of books

Also, when creating the system, the option of using mobile devices was taken into account, so the pages are optimized for this, all items of the personal account from the mobile device (Fig. 9).

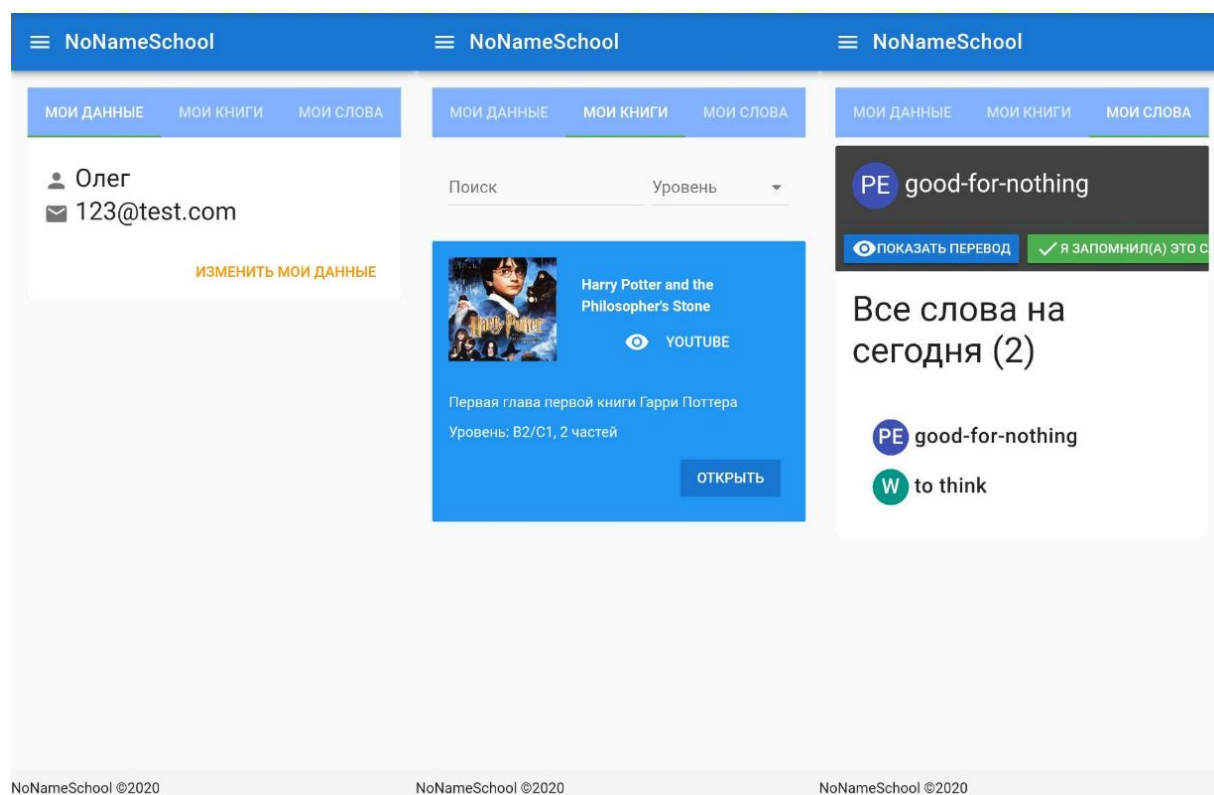


Figure 9: Mobile view of the personal account

The main page is an open part of the book, where you can see a YouTube video reading this part, a part with text, where you can see the translation by clicking on the question mark "?", And below the words to learn which to add by clicking on "+" (Fig. 10).

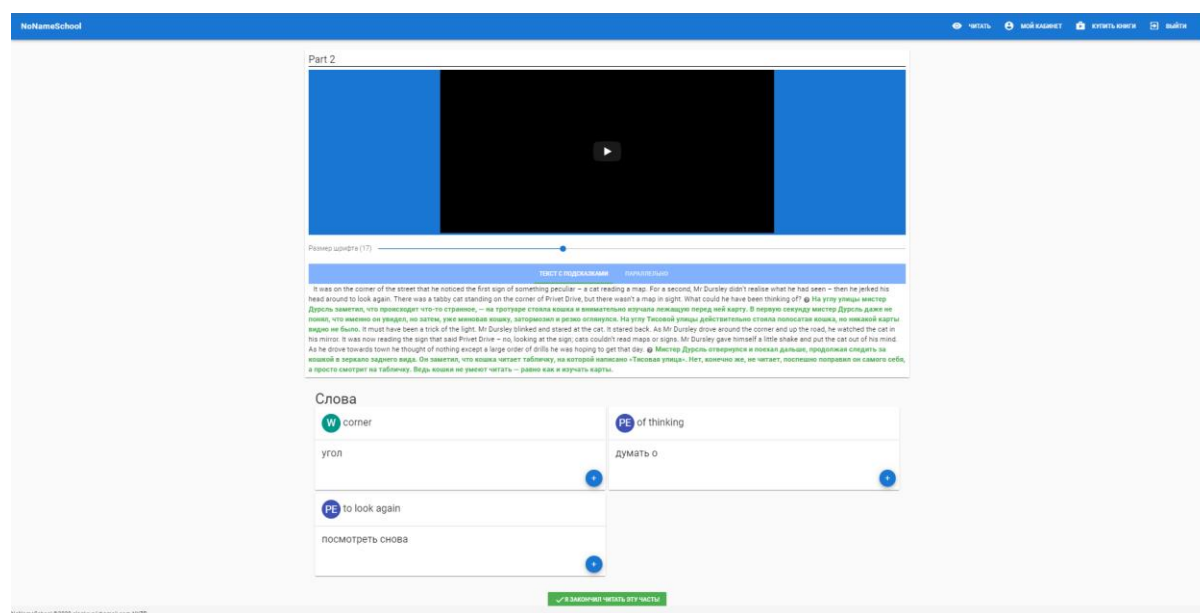


Figure 10: Page with an open book

The form on the payment page is used to pay for paid books (Fig. 11).

Figure 11: Payment page

7. Conclusions

Thus, in the scientific work a service for learning foreign languages was developed. The service allows users (students) to read adapted and unadapted foreign language books with translation, listen to their correct reading and memorize new words by repeating them repeatedly and listening. The response time of the web server to the user's request is also estimated.

The results of testing the system and comparing them with the actual values summed up, and decided that the experiment was successful, and the developed system can not only find application for everyday use, but also be improved by reducing server response time and more users .

As a result of scientific work:

- analysis of technologies for the server part: Node.js and PHP using databases such as MySQL and Firebase. Technologies such as JavaScript and PHP were analyzed for the client part of the service. An analysis was also performed among such frameworks as React, Angular, Vue.js;
- requirements for the service are defined, software modeling and layout are carried out,
- designed service, according to certain requirements;
- the server part of the service was implemented using Node.js technology with the Firebase database, and the client part using the JavaScript programming language with the Vue.js framework. As a result of development the service as a web system with a server and client component is received;
- load testing of the web service server was performed, and the actual response time to the user's request was detected, under different conditions (type of HTTP request, number of simultaneously connected clients), in order to compare the developed service, identify its actual performance, namely time spent to process a request from the user and to respond to the server of the website;
- a mathematical model based on a neural network is built to predict the response time of the web system server to the user's request.

The results of testing the system proved the efficiency of the system and decided that the work was done successfully and the developed system can be used for everyday life and is extremely relevant at a time when people are increasingly using time for self-development on the Internet.

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