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THE CONCEPT OF AI-BASED INFORMATION SYSTEMS FOR THE ANALYSIS OF LEARNING FOREIGN WORDS

In the modern world, information systems based on artificial intelligence (AI) are increasingly used to automate learning and improve the educational process. One of the perspective areas of AI application is foreign language learning, particularly vocabulary acquisition. By integrating AI components, specifically those utilizing machine learning algorithms to analyze large volumes of data and provide automated recommendations to enhance the learning process, users gain constant access to self-assessment tools and automatic adjustment of cognitive workload.This paper examines the key role and significance of information systems for analyzing foreign language vocabulary acquisition with the help of AI. It investigates the working principles of such systems, their advantages, and various strategies used to enhance the efficiency of language learning, aiming for optimal results in acquiring new linguistic knowledge and improving learning outcomes. Learning new foreign terms is often a challenging task for many students, leading to a loss of motivation or slow progress, highlighting the urgent need for solutions that enhance material retention. Adapting to individual users, AI-based information systems have developed a range of services and platforms with global potential for language learning worldwide. These systems function by analyzing user behavior and success, based on specific indicators and metrics, whose numerical values are interpreted to identify patterns and correlations between user behavior and its impact on the system. The advantages of AI-based information systems for language learning are significant, offering an objective, reliable method for assessing learning achievements, eliminating the need for human intervention in many cases. Data collected by these systems serve as a valuable resource for analyzing user productivity, detecting common mistakes, creating effective study plans, and more. However, it's important to note that AI has not yet reached the level of understanding semantics or the cultural and historical nuances of certain words, complicating the implementation of more comprehensive functionality for evaluating and adjusting the learning process. This requires developers to prepare additional data through proprietary sources or gain useful input from user interactions with the system.

Keywords: information systems, artificial intelligence, machine learning, data analysis, foreign term acquisition, learning efficiency, adaptive learning.

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КОНЦЕПЦІЯ ІНФОРМАЦІЙНОЇ СИСТЕМИ НА ОСНОВІ ШТУЧНОГО ІНТЕЛЕКТУ ДЛЯ АНАЛІЗУ ВИВЧЕННЯ ІНОЗЕМНИХ СЛІВ

У сучасному світі інформаційні системи на основі штучного інтелекту (ШІ) все частіше використовуються для автоматизації навчання та покращення освітнього процесу. Однією з перспективних галузей застосування ШІ є вивчення іноземних мов, зокрема, поповнення лексичного запасу. Завдяки впровадженню штучного інтелекту, а саме компонентів, що використовують алгоритми машинного навчання для аналізу великих обсягів даних та автоматизованої системи рекомендацій задля покращення навчального процесу користувачі мають постійний доступ до оцінки власного рівня знань та автоматичного корегування рівня навантаженості на розумові ресурси. У статті детально досліджується ключова роль і значення інформаційних систем для аналізу вивчення іноземних слів з використанням штучного інтелекту. В ній розглядаються принципи роботи таких систем, їхні переваги та різні стратегії, що використовуються для покращення ефективності процесу навчання мов з кінцевою метою досягнення оптимальних результатів у засвоєнні нових мовних знань та підвищенні навчальних досягнень. Вивчення нових іноземних термінів є складним завданням для багатьох учнів, що часто призводить до втрати мотивації або повільного прогресу. Це підкреслює нагальну потребу в рішеннях, які сприяють підвищенню рівня засвоєння матеріалу. Адаптуючись під кожного окремого користувача, інформаційні системи з підсистемами на основі штучного інтелекту розвинули низку сервісів та платформ з перспективами для глобального використання їх з метою вивчення мов у всьому світі. Такі системи працюють шляхом аналізу поведінки та успішності користувачів, базуючись на певних визначених показниках та критеріях, числові значення яких інтерпретуються в закономірності і дають змогу встановити зв'язки між поведінкою користувача та її впливом на систему. Переваги інформаційних систем для вивчення іноземних мов на основі штучного інтелекту досить вагомі і пропонують об'єктивний, надійний метод оцінки навчальних досягнень, усуваючи потребу в людських ресурсах в загальному випадку. Дані, зібрані цими системами, слугують цінним ресурсом для аналізу продуктивності користувача та якості навчання, виявлення типових помилок, створення ефективних навчальних планів тощо. Проте варто відзначити, що рівень розвитку штучного інтелекту ще не досягнув того рівня, на якому він зможе розуміти семантику, культурні та історичні особливості тих чи інших слів. Це ускладнює впровадження більш комплексного функціоналу для оцінки та корегування навчального процесу і вимагає від розробника підготовки додаткових даних шляхом одержання власних джерел інформації або отримавши корисне навантаження з роботи користувачів системи.

Ключові слова: інформаційні системи, штучний інтелект, машинне навчання, аналіз даних, вивчення іноземних термінів, ефективність навчання, адаптивне навчання.

Introduction

The problem of learning foreign languages becomes increasingly essential for professional and personal growth. This especially affected a large number of Ukrainians who were forced to move to other countries and start to intensely study these countries' language. However, for many people, learning a new language is complicated by

a lack of time or financial resources for regular tutoring sessions [1]. This challenge drives the search for alternative solutions that allow for effective vocabulary development and don't require the constant teacher involvement.

One of the solution in the context is use of information systems with automated processes that use AI technologies to analyse user activity by criterias and offer him personalized recommendations to improve quality of vocabulary acquisition. Such systems can adapt the process of learning to individual user needs, making language learning more efficient, even with limited time using special techniques of learning processes, considering personal capabilities, helping organize material, tracking progress and correcting mental loading to avoid motivation burnout [2-3].

Domain analysis

In the case of study a lot of literature sources were analyzed. Thus, this study [4] informs the integration of AI into facilitating language teaching and learning guided by the mobile learning principle. The paper [5] pursues an analysis of the challenges and prospects of full integration of artificial intelligence at the university levels, in teaching foreign languages. The study community includes 180 university administrators at various administrative positions, and 120 university lecturers from Jordanian and Saudi institutions. The study [6] used bibliometrics to uncover historical trends in AI in EFL. The study utilized Biblioshiny, a web-based tool in the bibliometrix package that analyses bibliographic database data, to examine downloaded Web of Science (WoS) data. The Bibliometrix R Package and Biblioshiny software created tables and graphs. The study searched the WoS website for studies with "Artificial Intelligence (AI)" in the title, abstract, and keywords to find bibliographic data. From 2013 to 2023, WoS focused on Language and Linguistics in Language Education. The work [7] involved 13 preparatory class students studying at the School of Foreign Languages at a university in Turkey. The students were introduced to ChatGPT through learning experiences over a span of four weeks by the researcher as a language teacher. The qualitative data collected from the interviews were analysed using thematic analysis. The findings suggest that ChatGPT positively affects students' learning experiences, especially in writing, grammar, and vocabulary acquisition, and enhances motivation and engagement through its versatile and accessible nature in various learning activities.

Due to number of computers growth there are certain requirements related to developing computer literacy in general or creating solutions for specific tasks. Knowledge of foreign languages, particularly English language has become crucial for accessing up-to-date information and communication with tech community at work or global professional communities participation online. English serves as the primary language of technology and science worldwide, but there are also needs for tourism, migration, international cooperation etc.

According to statistics from the Kyiv International Institute of Sociology shown in Figures 1 and 2 the majority have none of four comprehension skills in most common languages [8-9]. Half of the population can't read and understand simple English text.

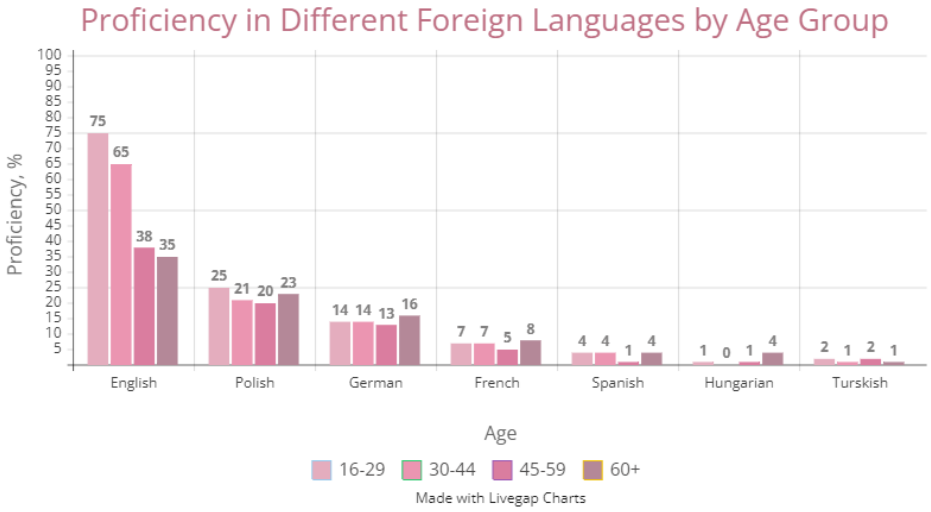

Fig. 1. Proficiency in different foreign languages by age group in Ukraine

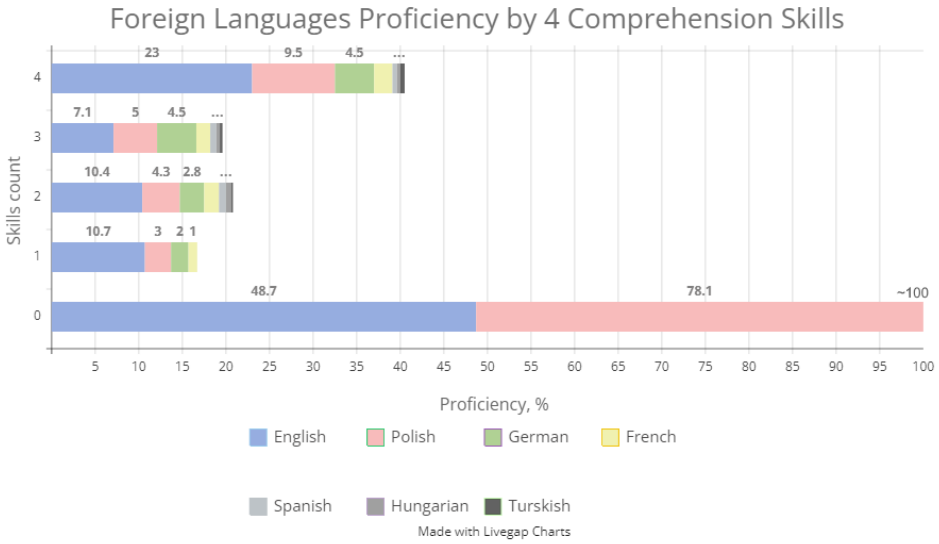

Fig. 2. Foreign languages proficiency by 4 comprehension skills in Ukraine

The simpliest solution such as vocabulary development in context could improve the situation.

With educational purposes on remote usually is used Learning Management System, providing with access to online learning materials, allowing users to complete assignments, receive feedback from teachers in real time from anywhere in the world, forcing at the time to improve time management skill [10].

But such systems should provide human resources to manage learning process, create and organize materials and assess knowledge quality.

To simplify and automate the studying process platforms and services for consistent and gamified study specific subject were created.

Analysis of existing solutions and technologies

The platforms and services provide flexible access to education, allowing users to study anytime and anywhere using computers or mobile devices. These platforms offer a wide range of courses, interactive lessons, and assessments using preprocessed materials and automated data analysis systems. Specifically platforms for learning foreign languages offer specialized tools for mastering grammar, vocabulary, speaking, and listening skills. Many incorporate gamification elements, like points, local currency and achievements, to motivate users. These platforms may include live sessions with native speakers and multimedia content.

Such platforms as usual focus on in-depth studying skills like speaking or reading or help to learn language in general, it would be more superficial. The following is a brief review of four popular platforms with different methods of education.

1.Duolingo

Duolingo starts with a survey to assess the user's motivation and skill level, then unlocks lessons based on the first completed one. It highlights new words in pink, adding them to the user's vocabulary. Depending on progress, users can finish lessons early or unlock multiple lessons at once. The platform also adapts content based on the user's age to apply additional censorship when necessary, making it safe for younger learners [11].

2.LingoDeer

LingoDeer starts by assessing the user's language proficiency and offers a structured learning path with grammar-focused lessons. It emphasizes grammar rules and sentence structures more than vocabulary alone, integrating practice exercises with real-life scenarios. Users can unlock new levels of learning by completing quizzes, and progress is tracked through detailed reports. LingoDeer also allows offline learning, making it accessible even without an internet connection. The platform customizes content based on the user's native language, ensuring a more tailored learning experience [12].

3.Anki

Anki uses a spaced repetition system (SRS) to help users memorize information more effectively, focusing on long-term retention. Users create or download customizable flashcard decks for language learning or other subjects. Anki adjusts the frequency of card reviews based on how well the user remembers each item, promoting efficient study sessions. It's highly flexible, allowing learners to control the pace and depth of their learning by adding multimedia like images, sounds, or videos to flashcards. This makes Anki particularly useful for vocabulary building or mastering complex topics [13].

4.Quizlet

Quizlet provides a broad set of study tools, from flashcards to games and quizzes, tailored for various subjects, including language learning. Users can create their own study sets or access thousands of other people sets.

Quizlet's "Learn" mode adapts to how well the user knows each term, offering more frequent reviews for tougher words and phrases. It also includes interactive activities like matching games and tests to keep learning engaging. The platform offers voice-enabled cards for pronunciation practice and allows users to collaborate in study groups [14].

More complete comparison is in Table 1. In context of the topic such systems as analysis of data and based on that corrections exist as part of bigger systems, more complex systems with its own data collection and processing components, where developers can include their own metrics and produce user progress evaluation methods more efficiently. As an independent system it will require data collection from users. It may be a framework or SaaS platform solutions in this case but in the context end user is a student.

Table 1

Comparison of language learning system with automated analysis of user progress

Characteristic	Duolingo	LingoDeer	Anki	Quizlet
Learning Method	General gamified study of all four comprehension skills, grammar and cultural aspects explanations	Structured in-deep grammar learning with real life scenarios, vocabulary learning	Spaced repetition system based vocabulary development	Flashcards with sentence examples, images, games and quizzes for self-paced learning
Languages	Official support of over 40 languages, but require much human resources to manage it	Focus on Asian languages, but also offers some European ones	Relies on user-created sets	Relies on user-created sets
Disciplines	Primarily language learning with focus on grammatic basics and vocabulary	Strong emphasis on grammar and sentence structure	Vocabulary	Vocabulary; also it's possible to add images, use complex terms, descriptions and context sentence example
Gamification	Strong: points, streaks, leaderboards, achievements	Soft: progress tracking and rewards for lesson completion	Minimal: focus on pure learning efficiency without rewards inside the system	Moderate: study games, progress tracking
Interactivity	High interactivity with exercises like matching, translating, and speaking challenges, notifications and different stories of characters.	Interactive lessons with quizzes, multiple-choice, and sentence construction exercises.	Limited to interactive flashcards; no in-depth exercises or quizzes.	Moderate interactivity: matching games, quizzes, and tests for interactive learning.
Adaptation	Adapts difficulty based on user performance, unlocking levels based on progress.	Content adapts based on the user's native language and performance in lessons.	Spaced repetition adapts based on how well the user remembers each card.	Adapts based on progress of the user inside of each set independently, offering frequent reviews for hard terms.
Media Support	Supports text, images, and limited audio for pronunciation practice.	Supports text, audio, and offline learning for convenience.	Supports text, images, sounds, and videos in flashcards.	Text, images, and audio, with voice-enabled flashcards for pronunciation practice.
Price	Free with ads. Duolingo Plus for $6.99/month	Free with limited basic only lessons. Premium $14.99/month or $39.99/year	Free desktop and mobile version. One-time fee (~$25), completely free via web.	Free with basic features. Quizlet Plus for $35.99/year.

In order to improve the user experience, it is proposed to develop a system that integrates various functionalities for collecting, processing, and analyzing data, assisting the user in enhancing their learning outcomes. This system would combine several core features designed to optimize vocabulary acquisition through the use of machine learning algorithms.

The operation of language learning analysis

The proposed information system utilizes automated analysis of user progress to personalize word recommendations by calculating the necessary number of repetitions using spaced repetition methods. The analytical component integrates with data collection and processing processes, enhancing the accuracy of recommendations [15].

The system's adaptation to user progress is ensured through weekly fine-tuning of the model, which updates recommendations based on lessons, allowing the system to evolve according to the user's learning dynamics without the burden of retraining after each lesson. After each session, recommendations are updated, influencing the selection of new vocabulary, the number of words introduced in a lesson, and sentence suggestions.

Evaluation criteria assist in assessing the effectiveness of the learning process through data analysis conducted by machine learning algorithms. This process includes forecasting the number of repetitions needed for words, monitoring user attention, and adapting the learning pace accordingly [16].

1. Progress coefficient

Means the percentage of learned terms relative to the total and is expressed as (1):

$$progressCoefficient = \frac{c}{N} \quad (1)$$

, where *c* represents count of learned terms; *N* – count of all user's terms.

Higher value of progress coefficient means high performance user results.

It affects recommendation system, which is based on user achievements, motivation and directly terms stats that characterize how difficult to learn and remember these terms, groupped by lexical field and soundex compatibility.

2. Learnability coefficient

The learnability coefficient assesses how easily new vocabulary or concepts can be acquired by learners. It considers the complexity of the words or concepts being taught and the learners' backgrounds.

The formula is as follows (2):

$$learnabilityCoefficient = r1 * r2 * (\frac{Tavg}{T+Tavg}) \quad (2)$$

, where *r1* retention, *r2* recall, *Tavg* user's mean answer time, *T* mean answer time lesson.

Higher parameter value indicates that user has better ability to remembering new terms. Respectively if value is low system should provide some changes in recommendation system to choose simplier terms and reduce their count to optimal. Can be modified to use logistic equation with additional dynamically changing weight coefficients to gain more complex control over the parameter.

3. Retention rate

The retention rate characterize user's ability to keep terms over time. It helps to optimize learning process relying on long-term and short-term memory models and is crucial for evaluating the long-term strategy effectiveness (3):

$$retentionRate = \frac{1}{e^{\frac{1}{lt}}} * \frac{(1-mwl)+sr}{2} \quad (3)$$

, where *mlt* is average value of time of the last meeting of all terms from the lesson; *mwl* is average value of terms property which measures their learnability, the value is based on performance of all users; *sr* – ratio of correct answers number to number of words in the lesson.

A high retention rate indicates that the user prefer to learn terms using long-term memory model. Also it can be used to analize user memory abilities.

4. Recall rate

The recall rate assesses ability of the user to retrieve learned vocabulary from memory when prompted. It is an essential measure of active learning in short time period (4):

$$recallRate = (mr * 0.1 + sr * 0.3) + (\frac{1}{\exp^{\frac{1}{mlt}*cr}}) * 0.6 \quad (4)$$

, where *mr* – motivation rate; *sr* – ratio of correct answers number to number of words in lesson; *mlt* – average last meeting time for each word of the lesson; *cr* – average count of repeating for each word of the lesson.

It is possible to reduce result to average value which is equal to 0.5 with increasing number of words in the lesson to a certain amount using weight coefficients due to simplicity of the analysis system.

The motivation rate calculations pass different parameters which are decreasing or increasing the result depending on their influence potential and meaning.

High recall rate indicates strong memory retrieval and understanding of terms.

In context of the system the value is used for forecasting user's forgetting curve and predict the moment when it needs to push an old term to the user right before it should be forgotten.

5. Motivation rate

The motivation rate gauges learners' engagement and willingness to participate in the learning process. It reflects how invested learners feel in acquiring new vocabulary and improving their language skills.

Based on session and progress relations the motivation rate is used to gauge engagement and involvement into the learning process. It reflects how user investments of time and efforts converts into vocabulary expansion

over time. This is also necessary to tailor behavior of the system relatively to behavior of the user, calculate mental load, predict time deviations to activate notifications etc. (5):

$$motivationRate = pr * 0.2 + \left(\frac{1}{\frac{1}{exp^{sf}}^{*0.4}} + \frac{1}{ds} * 0.3 + \frac{1}{sc} * 0.1\right) * 0.8 \quad (5)$$

where *pr* is progress rate; *sf* - user session frequency per time interval (as default is interval between model fine-tuning procedure); *ds* - average user session duration; *sc* – all user sessions count.

High motivation rate value indicates that user has high productivity capabilities and involvement into learning process. Its value is used to adjust coefficient for machine learning algorithms, analysis of user statistics and other formula calculations.

The analitical component, as mentioned above is a part of more complex system inside of which it is used with its own criteria and their values interpretation. So the data is collected from outside and is stored in database. The schematic illustration of how the process of evaluating user knowledge rate performs (Figure 3) shows the sequence of data flow and there is some difference between user statistics, analysis criteria and defining criteria values meaning inside of model data preprocessing block. While stats are used in different calculations, statistics dashboards and criteria evaluating, model data preprocessing should prepare and transform all data from the previous sources into suitable for training ML models. After fine-tuning the results of analysis will be used in the component of learning process correction, interpreting values and making appropriate changes to behavior of the system.

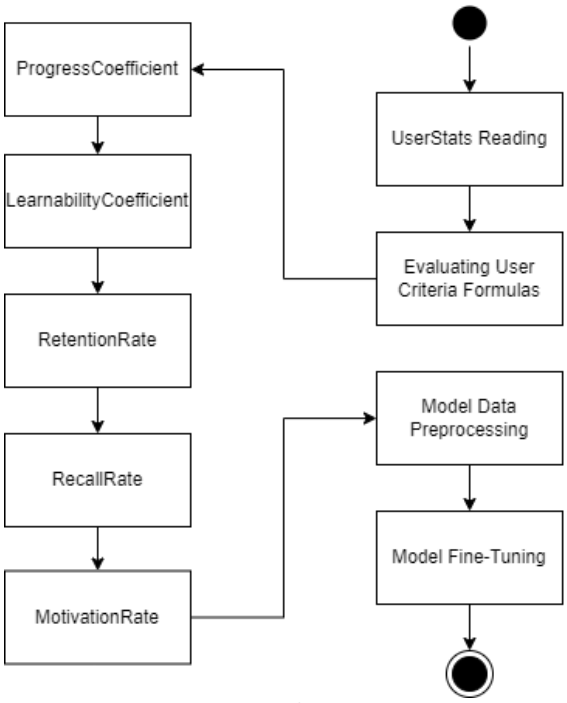

Fig. 3. Graphic representation of user knowledge rate analysis

Now it's possible to calculate the knowledge rate, which is a numeric assessment of all user parameters. This value allows for an objective evaluation of knowledge levels, even if a user has a smaller number of learned terms recorded in the system compared to others. Such an assessment is a complex process involving the search for patterns in the influence of each parameter on the outcome, so a neural network will be used.

Dynamic changes in weight coefficients for the neural network will be based on the analysis of large data volumes for each user individually. The weight coefficients affect various values to adjust the result to optimal average values at the start of the system with small amount of data to train the model. On the schematic basic values of weights are determined by impact on the real knowledge base and studying potential (Figure 4).

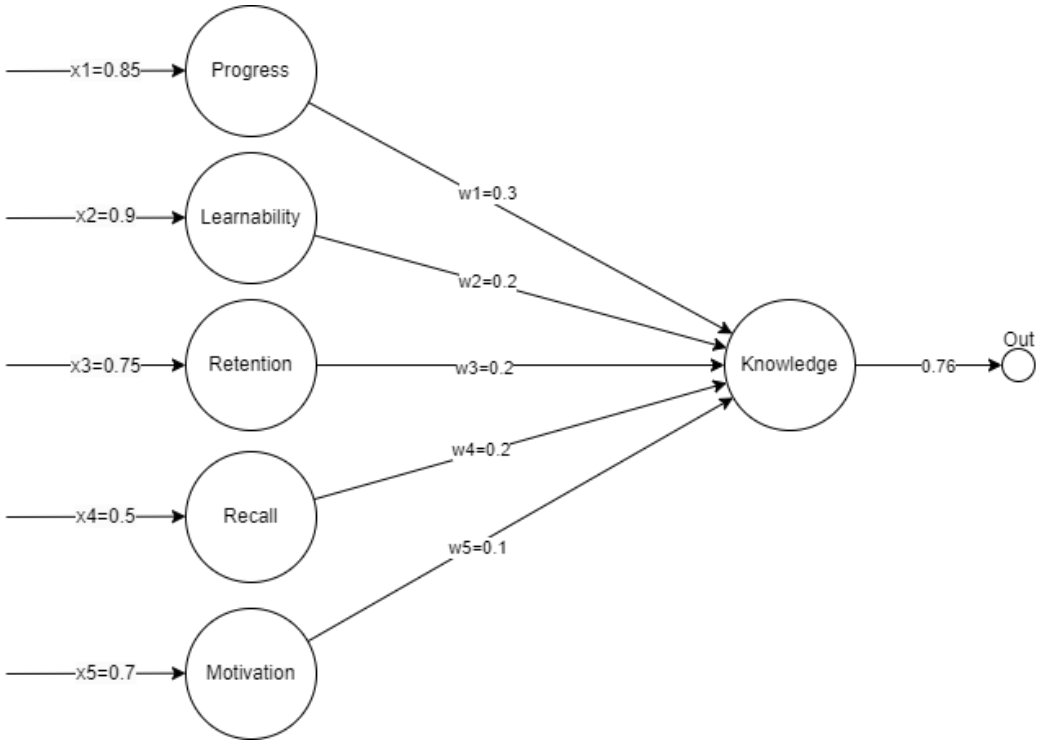

Fig. 4. Schematic representation of assessing user knowledge rate neural network operating principle

The graph of the model's learning curve is shown in Figure 5. From this we conclude that the best validation performance was achieved at epoch 3 with a value of 0.019485. This indicates that the neural network reached its optimal generalization ability early in the training process. After this point, further training likely did not improve performance, and may have led to overfitting, as the error on the validation set either remained stable or began to increase. The early stopping criterion would be effective here to prevent the model from overfitting.

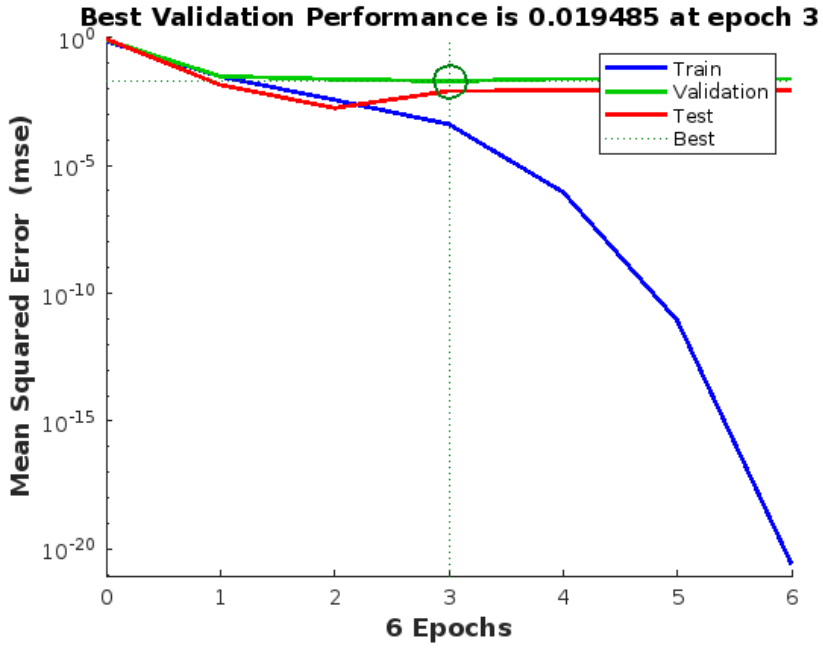

Fig. 5. The neural network model's learning curve

The proposed information system utilizes automated analysis of user progress to personalize word recommendations by calculating the necessary number of repetitions using spaced repetition methods. The analytical component integrates with data collection and processing processes, enhancing the accuracy of recommendations [16].

The system's adaptation to user progress is ensured through weekly fine-tuning of the model, which updates recommendations based on lessons, allowing the system to evolve according to the user's learning dynamics without

the burden of retraining after each lesson. After each session, recommendations are updated, influencing the selection of new vocabulary, the number of words introduced in a lesson, and sentence suggestions.

Evaluation criteria assist in assessing the effectiveness of the learning process through data analysis conducted by machine learning algorithms. This process includes forecasting the number of repetitions needed for words, monitoring user attention, and adapting the learning pace accordingly [17].

To ensure a high-quality assessment of the user's knowledge level it's recommended to follow specific rules regarding cognitive workload throughout the system, paying great attention to planning of learning processes that do not overwhelm users with information, implementing smooth integration of new information input using psycholinguistics methods [18], as excessive load can decrease learning effectiveness, motivation and as a consequence distort the quality of analysis and assessment.

To improve the information system for learning foreign words with automated progress analysis, several key enhancements can be implemented:

1) pass higher amount of more complex evaluation criteria. In addition to standard metrics it can incorporate metrics that use machine learning algorithms to be calculated;

2) integration of large language models to provide more sophisticated word recommendations. LLMs use big data to train to use words in context, which approximate their recommendations closer to real life cases and make sentence generation more natural considering semantic properties of training data;

3) anomaly detection based on time patterns to predict forgetting curve for each user individually and recommend terms before it will be forgotten; also, it can be used to detect user's sessions behavior deviations which triggers notification system;

4) depending on system throughput, workload, performance and hardware capabilities the frequency of model fine-tuning can be adjusted to maintain balance between optimal performance of the system and model's updating.

Conclusions

Nowadays the challenge of learning foreign languages remains a rather complex task requiring a systematic approach. An analysis of existing solutions has revealed that systems designed to analyze the acquisition of foreign vocabulary typically do not exist as standalone platforms, services, or applications. Instead, they are integrated within larger systems that directly provides the learning process tools while collecting essential data for analysis and effective adjustments.

A crucial factor influencing the development of such methods is automation, which aims to provide users with access to recommendation systems at any time, freeing up human resources for simpler assessments. It is vital to distribute the workload wisely to avoid overwhelming users and diminishing their motivation to learn. Addressing these challenges requires consideration of psycholinguistics aspects and the establishment of weights for decision-making coefficients.

Proposed method allows for passive vocabulary expansion, as it recommends new terms tailored to each user individually during the learning process and generate additional motivation. Its effectiveness is enhanced when used in conjunction with other learning methods, contributing to overall language development. For more complex assessments, it is necessary to involve professionals who can compile a comprehensive database of semantic meanings, as the current stage of artificial intelligence development cannot ensure alignment with cultural nuances and the semantic similarities of different words without additional human resources.

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