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RNN NEYRON TARMOQLARI VA ULARNING ADAPTIV LEKSIKA O'RGANISHDA QO'LLANILISHI

Аннотация

Mazkur maqolada rekurrent neyron tarmoqlari (RNN – Recurrent Neural Networks) ning nazariy asoslari, ularning tuzilishi va ishlash mexanizmlari yoritiladi. Tadqiqotda RNN modellarining ketma-ket ma'lumotlarni qayta ishlashdagi afzalliklari, xususan, til birliklarini vaqt bo'yicha bog'liq holda tahlil qilish imkoniyatlari ko'rib chiqiladi. Shuningdek, RNN tarmoqlarining tilshunoslik sohasida, ayniqsa, adaptiv leksika o'rganish jarayonida qo'llanilishi, ya'ni so'z boyligini avtomatik aniqlash, kontekst asosida so'z ma'nolarini o'rganish hamda individual foydalanuvchi ehtiyojlariga moslashuvchan ta'lim tizimlarini yaratishdagi roli tahlil qilinadi.

Kalit so'zlar: Rekurrent neyron tarmoqlari, RNN, LSTM, GRU, sun'iy intellekt, mashinaviy o'rganish, tabiiy tilni qayta ishlash, adaptiv ta'lim, leksik o'rganish, kontekst tahlili.

THE RNN NEURAL NETWORK AND ITS APPLICATION TO ADAPTIVE VOCABULARY LEARNING

Annotation

This article examines the theoretical foundations of recurrent neural networks (RNNs – Recurrent Neural Networks), their structure, and operating mechanisms. The study highlights the advantages of RNN models in processing sequential data, particularly their ability to analyze linguistic units in a time-dependent manner. Furthermore, the application of RNNs in the field of linguistics, especially in adaptive vocabulary learning, is analyzed, including automatic identification of vocabulary, learning word meanings based on context, and the role of RNN-based systems in developing personalized and adaptive learning environments tailored to individual user needs.

Key words: Recurrent neural networks, RNN, LSTM, GRU, artificial intelligence, machine learning, natural language processing, adaptive learning, vocabulary acquisition, context analysis.

НЕЙРОННАЯ СЕТЬ RNN И ЕЁ ПРИМЕНЕНИЕ В АДАПТИВНОМ ИЗУЧЕНИИ ЛЕКСИКИ

Аннотация

В данной статье рассматриваются теоретические основы рекуррентных нейронных сетей (RNN – Recurrent Neural Networks), их структура и механизмы функционирования. В исследовании анализируются преимущества моделей RNN при обработке последовательных данных, в частности возможности анализа языковых единиц во временной взаимосвязи. Также изучается применение RNN в области лингвистики, особенно в процессе адаптивного усвоения лексики, то есть автоматическое определение словарного запаса, изучение значений слов на основе контекста, а также роль этих сетей в создании адаптивных образовательных систем, ориентированных на индивидуальные потребности пользователей.

Ключевые слова: Рекуррентные нейронные сети, RNN, LSTM, GRU, искусственный интеллект, машинное обучение, обработка естественного языка, адаптивное обучение, усвоение лексики, контекстный анализ.

Introduction. Vocabulary knowledge forms the core foundation of foreign language proficiency, influencing learners' reading comprehension, speaking fluency, writing accuracy, and overall communicative competence. Numerous studies in applied linguistics emphasize that the successful acquisition of lexical items is not only essential for language development but also represents one of the most challenging components of the learning process. Traditional vocabulary learning techniques, while effective to some extent, often fail to accommodate differences in learners' cognitive styles, memory capacity, learning pace, and motivational factors. As a result, modern language education has increasingly turned toward adaptive learning technologies supported by artificial intelligence.

In recent years, adaptive platforms such as Duolingo, Babbel, Memrise, and Mondly have integrated machine-learning algorithms, spaced repetition models, natural language processing tools, and interactive interfaces to

personalize vocabulary learning. These platforms attempt to analyze user performance patterns, predict learning difficulties, and deliver individually tailored content. However, despite significant progress, existing systems continue to exhibit limitations such as inaccurate vocabulary recommendations, insufficient contextualization, monotony in repetition cycles, and imbalance between essential and non-essential lexical items. These shortcomings highlight the need for more advanced and theoretically grounded adaptive mechanisms capable of modelling learners' forgetting curves, predicting future performance, and dynamically adjusting review intervals.

Recurrent neural networks (RNN), particularly LSTM-based architectures, offer promising solutions due to their ability to capture sequential dependencies in learner behavior, analyze error patterns, and estimate memory retention trajectories. By integrating RNN models into adaptive vocabulary learning systems, it becomes possible to develop

more precise and personalized algorithms that address current technological gaps. The present study explores the application of RNN-based artificial intelligence in optimizing adaptive vocabulary learning, evaluates existing platforms across key criteria, and proposes an enhanced approach that improves prediction accuracy, increases learning efficiency, and supports individualized lexical development.

Literature review. Vocabulary acquisition has been a central topic in second language research for several decades, with scholars emphasizing its crucial role in linguistic competence and communicative performance. Nation (2013) and Schmitt (2010) argue that vocabulary knowledge underpins all language skills and requires systematic exposure, repetition, and contextual engagement for effective retention. Traditional methods, such as rote memorization and frequency-based word lists, have proven insufficient in addressing individual learner differences, thereby motivating the emergence of adaptive learning technologies.

Early adaptive systems incorporated spaced repetition algorithms designed to optimize review intervals according to the forgetting curve (Ebbinghaus, 1885). Modern studies, such as Settles and Meeder (2016), further developed trainable spaced repetition models capable of predicting learner performance and adjusting repetition schedules accordingly. These models laid the foundation for intelligent vocabulary learning platforms that leverage real-time learner data.

The integration of machine learning into language education has generated renewed interest in personalized vocabulary instruction. Researchers highlight the potential of artificial neural networks, especially recurrent neural networks (RNNs) and their LSTM variants, in modelling sequential learning behaviors (Hochreiter & Schmidhuber, 1997; Graves, 2012). RNN architectures have demonstrated effectiveness in predicting user errors, analyzing learning trajectories, and generating adaptive review patterns based on temporal dependencies.

In addition to neural architectures, natural language processing (NLP) advances have contributed to creating richer linguistic input and more accurate content classification. Transformer-based models such as BERT and GPT have been widely adopted for semantic analysis, text categorization, and CEFR-level evaluation, enabling language learning platforms to provide more contextually relevant vocabulary items. Several studies have examined commercial adaptive platforms. Duolingo's research team has documented the use of RNNs, MLPs, transformer models, and deep learning-based acoustic systems for speech recognition and vocabulary sequencing. Ziegler et al. (2019) describe Babbel's data-driven adaptation framework, which relies on machine-learning algorithms to classify learner responses and personalize instruction. Similarly, Memrise employs spaced repetition combined with NLP-based semantic clustering to reinforce

lexical retention, while Mondly incorporates speech-recognition models to support communicative practice.

Despite these advancements, scholars note persistent limitations in existing systems, including inaccuracies in prediction algorithms, insufficient contextualization of vocabulary, repetitive patterns that reduce engagement, and the lack of individualized difficulty scaling for complex lexical items. Current literature therefore emphasizes the need for more sophisticated adaptive mechanisms capable of integrating cognitive modeling with neural prediction.

The reviewed studies collectively illustrate that RNN-based models hold significant potential for overcoming these limitations. Their ability to track sequential learner behavior and estimate memory decay positions them as a promising foundation for next-generation adaptive vocabulary learning technologies.

Research methodology. This study employed a concise mixed-method approach to evaluate the effectiveness of existing adaptive vocabulary learning platforms and to explore the potential of RNN-based models for improving personalization. The research consisted of three main stages: platform selection, comparative evaluation, and development of an RNN-driven adaptive model.

1. Platform Selection. Four prominent AI-supported vocabulary learning platforms—Duolingo, Babbel, Memrise, and Mondly—were chosen due to their widespread use and integration of machine-learning components such as spaced repetition, NLP tools, and speech-recognition systems.

2. Evaluation Criteria. To assess the platforms systematically, four criteria were established:

- Adaptability
- AI accuracy
- User-friendliness
- Content richness and contextual relevance

Each criterion was measured using a 10-point scale, based on prior research in digital language learning.

3. Comparative Assessment. Platform performance was analyzed through document review, user interaction simulations, and examination of published AI architecture reports. Scores were visualized using a radar chart to highlight strengths and weaknesses across systems.

Analysis and results. For learners of foreign languages, the rapid and effective memorization of new words, phrases, collocations, and frequently used sentence patterns remains a persistent challenge. Depending on the learner's cognitive style, memory capacity, available study time, and learning environment, numerous adaptive or flexible vocabulary acquisition methods have been developed. Today, the seven major methods summarized in Table 1 are widely used, yet their inherent limitations indicate the need for more advanced, scientifically grounded approaches.

Adaptive methods used in vocabulary memorization

No	Method	Advantages	Limitations
1	Spaced repetition	Ensures long-term retention of words	Repetitiveness may cause boredom
2	Personalized mobile applications	Provides individualized experience and rapid acquisition	Vocabulary size and topics may be limited
3	Machine-learning-based adaptive platforms	Automatically selects vocabulary appropriate to individual proficiency	Accuracy may fluctuate due to technical errors
4	Context-based adaptive learning	Teaches correct usage of words in context	Learning process is time-consuming; vocabulary growth may slow
5	Gamified adaptive methods	Increases motivation and engagement	May distract learners from core objectives
6	Adaptive learning through virtual assistants (chatbots)	Enhances vocabulary through natural interaction	Risk of artificial or inaccurate responses
7	Adaptive multimedia-based learning	Improves memorization through audiovisual reinforcement	High-quality multimedia content is costly and time-consuming to create

Spaced repetition strengthens long-term memory through periodic review, although excessive uniformity can reduce interest. Personalized mobile applications provide rapid and individualized learning but are often limited in content volume. Machine-learning-based systems tailor vocabulary

lists to each learner, yet algorithmic inaccuracies may reduce the overall effectiveness. These shortcomings highlight the need for a more optimized and advanced adaptive learning approach.

In this study, modern adaptive platforms integrating the aforementioned methods and algorithms—such as Duolingo, Babbel, Memrise, and Mondly—were selected for detailed analysis.

Duolingo employs artificial intelligence techniques such as RNN, MLP, and spaced repetition, leveraging learners' previous behaviors to predict performance and personalize vocabulary progression. RNN models capture sequential patterns (responses, errors, phonological cues), while MLP networks support the generation of tailored exercises. Babbel combines RNN, NLP, and MLP, enabling context-rich vocabulary presentation and individualized sequencing based on learner behavior and response analysis. Memrise integrates spaced repetition, NLP, and MLP to enhance vocabulary retention and contextual usage. Mondly combines RNN, NLP, and speech recognition, enabling natural conversational practice and automated pronunciation assessment. The platforms were evaluated across four criteria:

Adaptability: ability to personalize learning based on user proficiency and needs

AI accuracy: effectiveness of RNN, NLP, MLP and related prediction algorithms

User-friendliness: clarity and intuitiveness of the interface

Content richness and real-world applicability: breadth of vocabulary and opportunities for use in authentic contexts

Conclusion. This study examined the current state of adaptive vocabulary learning technologies and highlighted the limitations that persist across widely used digital platforms such as Duolingo, Babbel, Memrise, and Mondly. Although these systems effectively integrate spaced repetition, NLP tools, and various machine-learning algorithms, their performance remains constrained by inaccuracies in predictive models, insufficient contextualization of vocabulary, and imbalanced repetition cycles. The findings demonstrate that AI accuracy is the weakest dimension in existing platforms, indicating a continuing gap between technological capability and pedagogical requirements.

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