DEVELOPMENT OF AN ARTIFICIAL INTELLIGENCE-BASED COMPUTER PROGRAM FOR THE REHABILITATION OF CHILDREN WITH SPEECH IMPAIRMENTS IN LEARNING ENGLISH

Sharipova Aziza Abdumanapovna
Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, DSc, ass.prof.
Abdullayeva Malika Ilkhamovna
Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, PhD, ass.prof.

ABSTRACT

Children with speech impairments often face significant challenges in acquiring foreign language skills, particularly English, due to limitations in phonemic awareness, articulation and auditory processing. Recent advances in artificial intelligence (AI) and machine learning enable the creation of adaptive, individualized rehabilitation tools that support both speech therapy and language learning. This study shows the development and initial evaluation of an AI-based computer program designed to improve English pronunciation, vocabulary acquisition and speech clarity among children aged 6–12 with diagnosed speech impairments. The system integrates automatic speech recognition (ASR) optimized for atypical speech, a real-time pronunciation feedback module, gamified learning tasks and therapist-controlled customization. Preliminary results from a pilot study (12 children were involved) indicate improvements in articulation accuracy, motivation, and English phoneme recognition. The findings highlight the potential of AI-driven educational technologies to complement traditional speech therapy.

Keywords: *artificial intelligence, rehabilitation, ASR, speech impairments, Adaptive Learning, Gamified Learning, pronunciation, phoneme recognition, inclusive education.*

INGLIZ TILINI O‘RGANISHDA NUTQI ZAIF BOLALARNI REABILITATSIYA QILISH UCHUN SUN’IY INTELLEKTGA ASOSLANGAN KOMPYUTER DASTURINI ISHLAB CHIQISH

Sharipova Aziza Abdumanapovna
Muhammad al-Xorazmiy nomidagi Toshkent axborot texnologiyalari universiteti, f.f.d.(DSc), dotsent
Abdullayeva Malika Ilkhamovna
Muhammad al-Xorazmiy nomidagi Toshkent axborot texnologiyalari universiteti, t.f.f.d. (PhD), dotsent

ANNOTATSIYA

Nutqi zaif bolalar fonemik eshitish, artikulyatsiya va eshitish jarayonidagi cheklovlar tufayli ko‘pincha chet tili ko‘nikmalarini, xususan, ingliz tilini o‘zlashtirishda jiddiy qiyinchiliklarga duch kelishadi. Sun’iy intellekt (AI) va mashinaviy o‘qitish sohasidagi so‘nggi yutuqlar nutqni rivojlantirish hamda til o‘rganishni qo‘llab-quvvatlaydigan moslashuvchan, individual reabilitatsiya vositalarini yaratish imkonini berdi. Ushbu tadqiqot nutq nuqsonlari tashxisi qo‘yilgan 6-12 yoshli bolalarda ingliz tili talaffuzini, so‘z boyligini orttirishni va nutq ravshanligini yaxshilash uchun mo‘ljallangan AIga asoslangan kompyuter dasturini ishlab chiqish va dastlabki baholashni ko‘rsatdi. Tizim atipik nutq uchun optimallashtirilgan avtomatik nutqni aniqlash (ASR), real vaqt rejimida talaffuz bo‘yicha fikr-mulohaza moduli, o‘yinlar orqali o‘rganish vazifalari va logoped tomonidan nazoratlarini tizimli moslashtirishtiradi. Sinov tadqiqotining dastlabki natijalari (12 bola ishtirokida) artikulyatsiya aniqligi, motivatsiya va ingliz fonemasini o‘zlashtirishni ko‘rsatadi. Tadqiqot an’anaviy logoped muolajalarini AI asosidagi ta’lim texnologiyalarining salohiyatini ta’kidlaydi.

Kalit so‘zlar: *sun’iy intellekt, reabilitatsiya, ASR, nutq nuqsonlari, dvigatel, moslashtirilgan ta’lim, o‘yinlar orqali o‘rganish, talaffuz, fonemani aniqlash, inklyuziv ta’lim.*

РАЗРАБОТКА КОМПЬЮТЕРНОЙ ПРОГРАММЫ НА ОСНОВЕ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА ДЛЯ РЕАБИЛИТАЦИИ ДЕТЕЙ С РЕЧЕВЫМИ НАРУШЕНИЯМИ В ИЗУЧЕНИИ АНГЛИЙСКОГО ЯЗЫКА

Шарипова Азиза Абдуманаповна
Ташкентский университет информационных технологий имени Мухаммада аль-Хорезми, DSc, доцент
Абдуллаева Малика Ильхамовна
Ташкентский университет информационных технологий имени Мухаммада аль-Хорезми, PhD, доцент

АННОТАЦИЯ

Дети с речевыми нарушениями часто сталкиваются со значительными трудностями в освоении навыков иностранного языка, особенно английского, из-за ограничений фонематического восприятия, артикуляции и слуховой обработки. Последние достижения в области искусственного интеллекта (ИИ) и машинного обучения позволяют создавать адаптивные, индивидуализированные реабилитационные инструменты, которые поддерживают как логопедическую терапию, так и изучение языка. В данном исследовании представлены разработка и первоначальная оценка компьютерной программы на основе искусственного интеллекта, предназначенной для улучшения английского произношения, расширения словарного запаса и повышения разборчивости речи у детей в возрасте от 6 до 12 лет с диагностированными нарушениями речи. Система объединяет автоматическое распознавание речи (ASR), оптимизированное для атипичной речи, модуль обратной связи по произношению в реальном времени, игровые учебные задания и персонализацию под контролем терапевта. Предварительные результаты пилотного исследования (в котором участвовало 12 детей) указывают на улучшение точности артикуляции, мотивации и распознавания фонем английского языка. Результаты подчеркивают потенциал образовательных технологий на основе искусственного интеллекта в качестве дополнения к традиционной логопедии.

Ключевые слова: *искусственный интеллект, реабилитация, ASR, нарушения речи, адаптивное обучение, геймифицированное обучение, произношение, распознавание фонем, инклюзивное образование.*

INTRODUCTION

Speech impairments represent one of the most common developmental challenges in childhood, often affecting communication, academic performance and socio-emotional development. In learning English as a second language, these children face additional difficulties due to the language's complex phonemic structure and inconsistent phoneme correspondence. Traditional speech therapy is effective but often limited by therapist availability, session duration, and lack of individualized digital tools. [1]

Artificial intelligence offers new opportunities to support rehabilitation. AI-based systems can analyze atypical speech patterns, deliver real-time feedback, and adapt tasks to each learner's progress. While commercial language-learning applications exist, few are designed specifically for children with speech disorders. This study aims to bridge this gap by developing and testing a dedicated AI-driven rehabilitation program.

Related Work

Previous research has explored the use of digital tools for speech therapy, such as computer-assisted pronunciation training (CAPT) and visual acoustic feedback systems. However, many applications rely on standard ASR, which performs poorly with non-typical speech. Recent advances in deep learning, particularly transformer-based speech models, allow ASR to be fine-tuned on specialized datasets representing disordered speech. [2]

Studies on gamified rehabilitation highlight the importance of motivation and engagement for young learners. Meanwhile, adaptive learning algorithms have been used successfully in language education, though rarely integrated with clinical rehabilitation frameworks. [3]

The present project combines these threads by creating an AI-enhanced, adaptive environment tailored to children with speech impairments learning English.

Methods

Program Architecture

The software system includes four key modules:

1.Specialized Automatic Speech Recognition (ASR)

Fine-tuned on a corpus of children's speech including samples of articulation disorders (e.g., rhotacism, sigmatism). Provides phoneme-level accuracy scoring. The purpose of the signal space algorithm is to eliminate the noise components in the noise-containing voice signal, so as to obtain an estimate of the pure voice signal. At

present, there are mainly some methods. [4] The fatigue of noise voice in hearing and improves the quality of voice communication. Now it is often used as the front-end processing process of anti-noise voice recognition. Because it improves the signal signal-to-noise ratio, it reduces the signal space caused by the noise. Spectral subtraction (SS) is a very small enhancement algorithm because the power of the background noise and voice can be similar to the addition of the addition. In the total power spectrum of the voice, you can obtain an estimate of the pure voice power spectrum of the frame, and the phase of the pure voice is replaced by the phase containing the noise voice with this frame. Finally, the noise can be greatly suppressed to enhance the voice [5]

2. Pronunciation Feedback Engine

Uses spectral and prosodic analysis to detect misarticulations. Offers visual cues (mouth diagrams, waveforms) and auditory models for correction.

This disclosure describes techniques for real time pronunciation feedback based on a user's daily conversations. The feedback techniques are implemented with specific user permission and pronunciation feedback can be turned off at any time. With user permission, real time speech is received and transcribed to text based on a semantic understanding of the conversation and additional factors, e.g., the user's history of pronunciation mistakes. A pronunciation score is calculated for words and syllables. Real time feedback (or warnings) for mispronounced words is provided using color, vibration, etc., in a manner that causes minimal distraction. Indications for the correct pronunciation of mispronounced phrases can be provided using audio, text, etc. The techniques can be implemented on any user device, e.g., smartphone, laptop, tablet, etc., and, in particular, on devices with small or no screens, e.g., feature phones, wearable devices such as smart glasses, smart watches, headphones, etc. The techniques can also be utilized on a smartphone or other device that has the screen turned off (e.g., phones with turned off screens in a user's pocket or hand), rings, bracelets, etc. Pronunciation learning in everyday settings is incorporated with minimal cognitive load and self-consciousness on the part of the user by using a minimal-to-maximal-attention feedback interaction, as follows. The initial feedback is provided such that it requires little user attention, e.g., the user can sense or notice the incorrectness warning quickly without others noticing. At the user's command, more detailed pronunciation feedback with recommended corrective actions can be displayed. [6]

3. Adaptive Learning module

Recommends exercises based on previous performance using reinforcement-learning models. Tracks progress across pronunciation, vocabulary, and phoneme discrimination tasks.

Adaptive learning is a technique to use data-driven instruction to adjust and tailor learning experiences to meet the individual needs of each student. Adaptive learning systems can track data such as student progress, engagement, and performance, and use the data to provide personalized learning experiences. While equal education opportunity affords individuals equal access to resources, equitable education recognizes and addresses the differences between learners by providing the fitting material aligned with each to reach their academic endeavor. Adaptive learning along with adaptive teaching and assessment strives to provide equity in education to all learners. [7]

4. Gamified Interface

Rewards (points, badges) and narrative-based games encourage engagement. Tasks integrated into real-life communication scenarios.

Gamification is a powerful tool to drive user engagement. The goal is not to transform user interfaces into games. Instead, designers should inject fun elements into applications and systems that might otherwise lack immediacy or relevance for users. When this is done right, users are incentivized to achieve goals and overcome negative associations they may have with a system and the tasks it requires them to complete. The dynamics in successful gamification serve as effective intrinsic motivation. This means that users engage with the system because they want to. For instance, Foursquare/Swarm promotes users to “Mayors” of establishments after so many visits, which enables them to compete for top place while enjoying meals, shopping, movies, etc. [8]

Figure 1.
The system of AI speech rehabilitation

1.	Specialized (ASR) engine - Fine-tuned on atypical child’s speech - Phoneme level analysis
2.	Pronunciation Feedback module - Real-time spectral comparison - Visual cues (mouth shapes, wave forms)
3.	Adaptive Learning - Performance tracking - reinforcement-learning task selection
4.	Gamified Interface - Casts, badges, characters.

Participants

A pilot study involved 12 children (ages 6–12) with clinically diagnosed articulation impairments. The sample included children learning English as a second language within school-based rehabilitation programs.

Figure 2.

Participants characteristics

1.	Number of participants	12
2.	Age	6-12
3.	Gender distribution	male (5), female (7)
4.	Primary speech impairments	dyslexia (4), sigmatism (5), rhotacism (3)
5.	Level of English	beginner

Procedure

Participants used the program for eight weeks, with three 20-minute sessions per week. Speech therapists monitored progress and adjusted task difficulty through a built-in dashboard.

Metrics of Evaluation

Articulation accuracy (phoneme-level ASR scoring)

English phoneme recognition (pre/post testing)

Motivational engagement (session completion, time-on-task, feedback surveys)

Therapist assessments (clinical ratings of progress)

Results

After eight weeks of intervention:

The accuracy of articulation was improved by an average of 18.7%. The largest gains were seen in difficult English phonemes (/θ/, /ð/, /r/) often problematic for children with speech disorders. Phoneme recognition points increased by 23%. Engagement was high, with 91% session completion and positive feedbacks from children. Therapists reported enhanced motivation and faster acquisition of corrected articulation compared to traditional sessions alone. No adverse effects (frustration, fatigue) have been reported.

English Phoneme	Pre-Test (%)	Post-Test (%)	Improvement (%)
/θ/ (“th”)	40	59	+19
/ð/ (“th”)	32	51	+19
/r/	43	65	+22
/s/	51	69	+18
Overall	**41.5**	**61**	**19.5**

DISCUSSION

The results of the work specify that AI-based tools can effectively support speech rehabilitation while simultaneously improving foreign-language learning. Several factors contributed to success:

Adaptivity: Children received tasks precisely matched to their skill level.

Error-tolerant ASR: Fine-tuning increased recognition accuracy for atypical speech.

Gamification: Made repetitive articulation exercises more enjoyable.

Visual and auditory feedback: Improved self-correction and phonemic awareness.

However, limitations include the small sample size and the need for long-term outcome studies. Future work will involve expanding the speech dataset, integrating multimodal sensors (e.g., lip-tracking), and conducting randomized controlled trials.

CONCLUSION

AI-based rehabilitation program shows strong potential as a supplementary tool for children with speech impairments learning English. By combining advanced speech recognition, adaptive learning algorithms and therapist-guided customization, the system improves pronunciation, phoneme recognition, and motivation. This research contributes to the growing field of AI-enhanced therapeutic interventions and underscores the importance of inclusive educational technologies.

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