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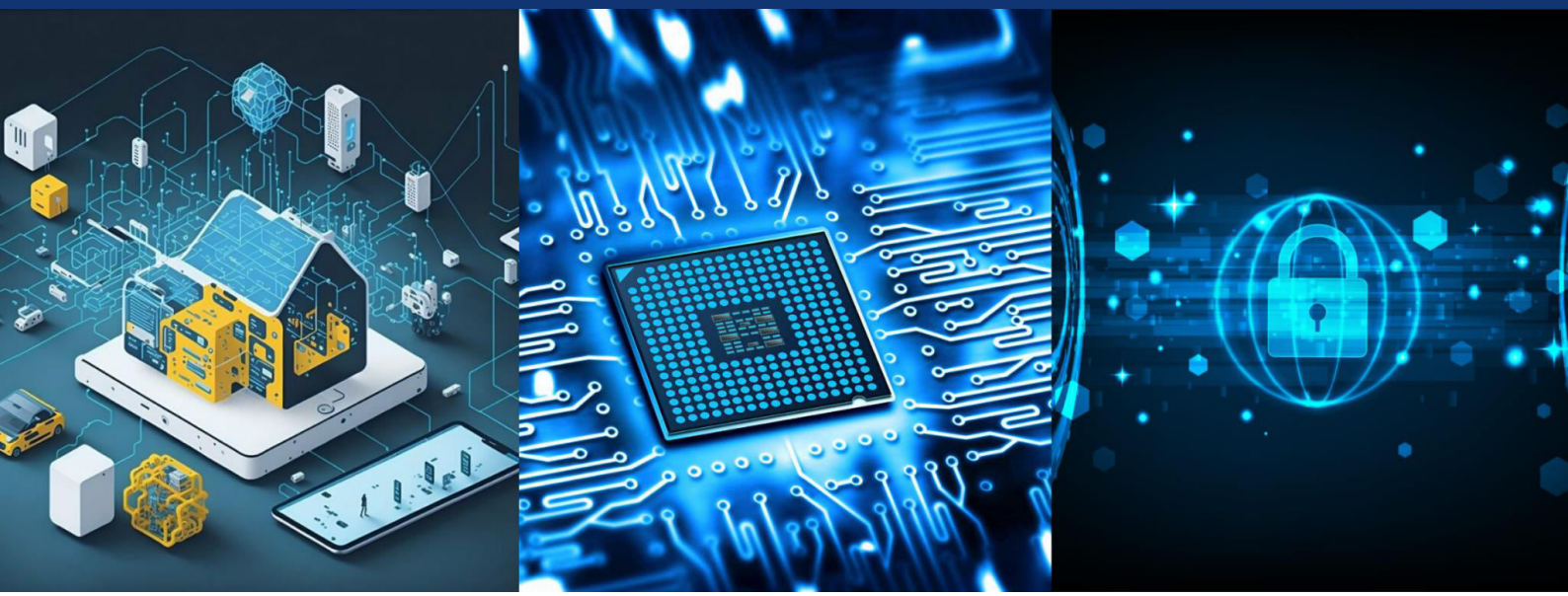

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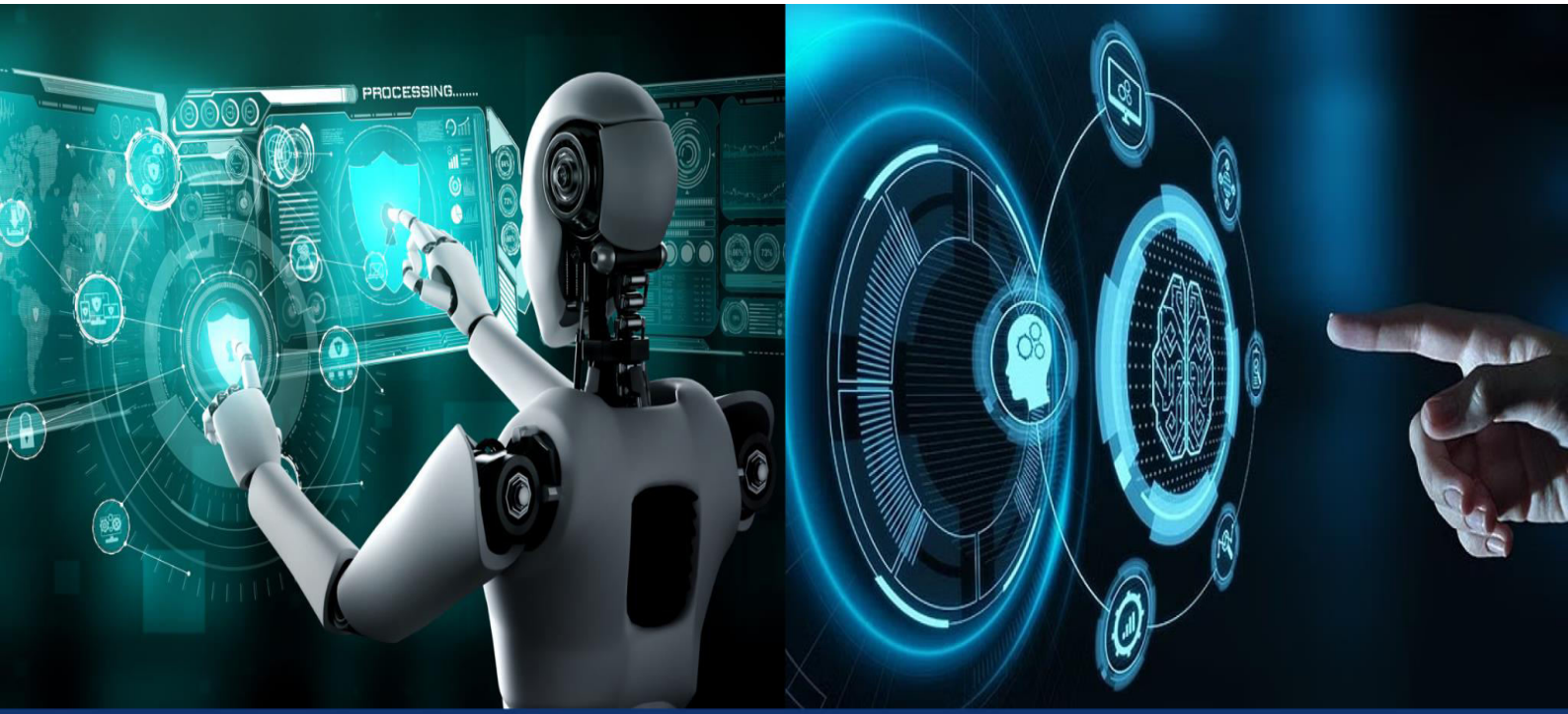

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Artificial Intelligence for Speech Classification and Enhancement of Speech and Language Disorders

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ABSTRACT: To identify the characteristics and outcomes of peer-reviewed literature on the application of Artificial Intelligence (AI) in assessing speech, language, and voice disorders (SLVDs) published in English from 2000 to 2024, we conducted a scoping review following the Arksey and O'Malley framework. Several databases were searched for peer-reviewed journal articles using the terms "artificial intelligence," "language," "speech," and "voice disorders" in their abstract or title. The speech module provides individualized exercises and uses machine learning algorithms and voice-to-text APIs to identify conditions like dysarthria and stuttering with 88–92% accuracy. The system, which was developed using Django and features like DeepSpeech and Whisper API, guarantees both therapeutic help and educational value. It is appropriate for both academic and clinical application because to its high user engagement and diagnostic efficacy.

KEYWORDS: Assessment, Artificial Intelligence, Language Disorders, Speech Disorders, Voice Disorders.

I. INTRODUCTION

This project presents an AI-powered application that combines automated speech disorder detection and treatment with gamified language learning. Targeting young students and those with speech impairments, it tackles the shortcomings of conventional language teaching methods and the dearth of easily available speech therapy [8]. The system improves vocabulary, grammar, and pronunciation through gamification

features like challenges, prizes, and interactive simulations. With real-time feedback and customized exercises, it simultaneously uses machine learning (SVM, DeepSpeech) and speech APIs (Whisper, DeepSeek) to identify illnesses including stuttering and articulation problems.

Communication is significantly impacted by speech, language, and voice disorders (SLVDs), as illustrated through various conditions. Aphasia, for instance, poses challenges in understanding, expressing oneself in both written and verbal forms, and reading. This highlights the intricate interconnections within the brain's language networks (Kohlschein et al., 2017). Apraxia of speech similarly affects the precise and consistent production of speech sounds. Another disruptive communication disorder is fluency disorders, exemplified by stuttering, which interferes with the natural flow of words, causing disruptions in rhythm and pace (American Speech-Language-Hearing Association [ASHA], n.d). Furthermore, language disorders, such as expressive and receptive issues that hinder effective communication and understanding of language rules (Albudoor & Peña, 2022). Conversely, dysarthria arises from neurological damage, manifesting as unclear speech, characterized by slurring or slowing down of speech (Song et al., 2022).

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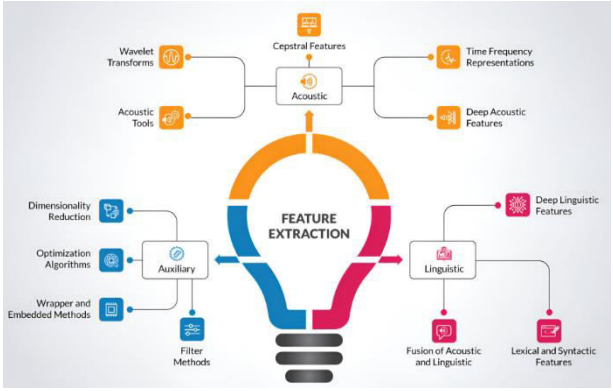

Fig 1: Artificial Intelligence for Speech Classification and Enhancement of Speech

Additionally, vocal cord issues contribute to voice disorders, marked by pitch variations, heightened volume, or hoarseness, complicating effective communication (Compton et al., 2022). Collectively, these disorders curtail personal expression and hinder participation in social and professional activities, underscoring the crucial need for precision in assessing SLVDs [10]. The traditional assessment of SLVDs usually relies on subjective evaluation methods grounded in clinical expertise. SpeechLanguage Pathologists (SLPs) commonly employ observational techniques, standardized tests, and patient interviews for diagnosis and treatment planning. Despite their widespread use, these methods have limitations, including variability in subjective evaluations among clinicians, resulting in potential diagnostic inconsistencies (Pravin & Palanivelan, 2022). Additionally, traditional assessments can be labor-intensive due to time-consuming processes and may not entirely capture an individual's condition in dynamic or real-world scenarios (Al-Banna et al., 2022).

The platform, which is based on Django, guarantees user engagement and successful rehabilitation while providing a scalable, inclusive solution that combines healthcare and education for better communication skills and wider accessibility [1]. The output is supplied through the mobile application, which offers users progress tracking, individualized therapy activities, and real-time feedback, after the disorders have been identified. With the help of machine learning algorithms like SVM and DeepSpeech and voice-to-text APIs like Whisper and DeepSeek, this AIpowered smartphone app can identify speech abnormalities like stuttering, dysarthria, phonological [5].

II. RELATED WORKS

The study by Muqdad Al-Karawi et al.[8] investigates the use of internet gaming as a technique for informal English language learning among children in China, India, Chile, and Hungary who are between the ages of 8 and 14. It demonstrates how gaming fosters social, cognitive, and linguistic development by providing an immersive setting in which kids organically pick up conversational skills, contextual language use, and vocabulary. The study fills up the gaps in previous studies, especially the dearth of perspectives that are culturally varied and child-focused. Results show how gaming can promote intercultural dialogue and cooperative problem-solving in a relaxed environment. The authors advise creating kid-focused, culturally sensitive games and incorporating gaming into English curriculum. Future studies ought to look at long-term impacts, study particular game genres, and take into account larger cultural contexts.

Recent studies highlight the growing role of Artificial Intelligence (AI) and gamification in language learning and speech-related applications. Gaming-based learning approaches have been shown to enhance vocabulary acquisition, communication skills, and learner engagement among children and young learners [8]. Similarly, gamification elements such as badges and reward systems improve motivation and user interaction in language-learning platforms.

In parallel, AI and machine learning techniques have been increasingly applied in healthcare and education domains to provide personalized and adaptive learning experiences [10]. Virtual reality-based systems, such as VR-supported language platforms, further enhance immersive learning but often lack integrated assessment and feedback mechanisms [2].

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Several studies have explored the application of machine learning and deep learning techniques for speech disorder detection. These approaches utilize feature extraction methods and classification algorithms to identify speech impairments with improved accuracy [3], [4], [9], [13]. However, most existing systems focus either on detection or learning separately, lacking a unified platform that integrates speech disorder diagnosis with interactive therapy and language enhancement.

Thus, there is a clear research gap in developing an integrated, AI-powered system that combines speech classification, real-time feedback, and gamified learning for both clinical and educational applications.

III. EXISTING SYSTEM

The existing systems for speech and language disorder assessment mainly depend on traditional clinical methods and separate language-learning applications. Speech-Language Pathologists (SLPs) perform manual evaluations using observation techniques, standardized tests, and patient interviews to identify disorders such as stuttering, dysarthria, aphasia, and articulation problems [3], [11]. These approaches are time-consuming, subjective, and highly dependent on clinical expertise. Variations in therapist experience may lead to inconsistent diagnostic results and reduced accuracy [10].

Several research works have introduced Machine Learning and Deep Learning methods for speech disorder classification. Techniques such as Support Vector Machine (SVM), Artificial Neural Network (ANN), Random Forest, and Convolutional Neural Network (CNN) are widely used for speech analysis and disorder detection [3], [9], [13]. Feature extraction techniques like Mel-Frequency Cepstral Coefficients (MFCC) are commonly applied to identify speech characteristics [4]. Although these systems improve classification accuracy, they mainly focus on speech disorder detection and lack integrated therapeutic support.

Existing language-learning systems use gamification and digital gaming techniques to improve vocabulary and communication skills among learners [8]. Some applications also use Virtual Reality (VR) for immersive learning experiences [2]. However, these platforms do not include real-time speech disorder diagnosis, automated speech analysis, or personalized therapy recommendations.

IV. PROPOSED SYSTEM

The proposed system introduces an AI-powered integrated platform for speech classification and enhancement of speech and language disorders using Machine Learning, Deep Learning, and Speech Recognition technologies. The system combines automated disorder detection, personalized therapy recommendation, and gamified language learning within a single framework.

Initially, speech samples are collected from users and preprocessed using noise removal, silence elimination, signal normalization, and segmentation techniques to improve speech quality and consistency [4]. The processed speech signals are then converted into feature representations using Mel-Frequency Cepstral Coefficients (MFCC), which effectively capture human auditory characteristics [4].

The extracted MFCC features are provided as input to a Convolutional Neural Network (CNN) model for speech disorder classification. The CNN model automatically learns hidden speech patterns and classifies speech into categories such as normal speech, stuttering, and dysarthria [9], [13]. This improves classification accuracy and reduces dependency on manual clinical analysis.

To further enhance speech analysis, the system integrates DeepSpeech and Whisper APIs for speech-to-text conversion and pronunciation analysis [7]. These APIs help identify fluency issues, pronunciation errors, and communication difficulties in real time.

Based on the classification results, the system generates personalized therapy exercises including pronunciation drills, fluency improvement tasks, reading activities, and vocabulary enhancement programs [11]. The therapy recommendations are customized according to the user's disorder type, severity level, and performance history.

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V. METHODS

1. Dataset Collection and Preprocessing

The first stage of the proposed system involves collecting speech samples from individuals with normal speech patterns and those affected by speech disorders such as stuttering and dysarthria. The dataset is obtained from publicly available speech databases and clinical recordings.

The collected speech signals undergo preprocessing to improve quality and remove unwanted noise.

Preprocessing Steps

- Noise removal using filtering techniques
- Silence removal
- Signal normalization
- Segmentation of speech signals into smaller frames

The normalization of signal amplitude is performed using:

$$x_{norm}(n) = \frac{x(n)}{\max(|x(n)|)}$$

Where:

- x(n) = original speech signal
- x_norm(n) = normalized signal

This preprocessing ensures consistency in feature extraction.

2. Feature Extraction using MFCC

Feature extraction is a crucial process for converting speech signals into numerical representations that can be analyzed by machine learning models.

The proposed system uses Mel-Frequency Cepstral Coefficients (MFCC) because they effectively capture speech characteristics similar to human auditory perception.

MFCC Extraction Process

1. Frame blocking
2. Windowing
3. Fast Fourier Transform (FFT)
4. Mel filter bank processing
5. Logarithmic transformation
6. Discrete Cosine Transform (DCT)

The Mel frequency conversion is defined as:

$$Mel(f) = 2595\log_{10}\left(1+\frac{f}{700}\right)$$

Where:

- f = frequency in Hz

MFCC coefficients extracted from each speech sample are used as input features for classification.

3. Speech Disorder Classification using CNN

The extracted MFCC features are fed into a Convolutional Neural Network (CNN) for classification.

CNN automatically learns hidden speech patterns associated with different speech disorders.

CNN Architecture

- Input Layer
- Convolution Layer
- ReLU Activation
- Max Pooling Layer
- Fully Connected Layer
- Output Layer

The convolution operation is expressed as:

$$y(i,j) = \sum_m \sum_n x(i-m, j-n)w(m,n)$$

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Where:

- x = input feature map
- w = kernel weights
- y = output feature map

The output layer classifies speech into:

- Normal Speech
- Stuttering
- Dysarthria

4. Speech Recognition using DeepSpeech / Whisper API

To improve speech analysis, the system integrates advanced speech recognition APIs such as DeepSpeech and Whisper API.

These APIs convert speech into text for linguistic analysis.

The probability of recognized text is calculated as:

$$P(W \mid X) = \frac{P(X \mid W)P(W)}{P(X)}$$

Where:

- W = word sequence
- X = speech signal

This helps identify pronunciation errors and fluency issues.

5. Personalized Therapy Recommendation

Based on classification results, the system generates customized therapy exercises.

The recommendation engine considers:

- Type of disorder
- Severity level
- User performance history

A scoring function is used:

$$\text{Score} = \frac{\text{Correct Responses}}{\text{Total Attempts}} \times 100$$

The system then recommends:

- Pronunciation drills
- Reading exercises
- Fluency training
- Vocabulary enhancement tasks

6. Gamification Module

To increase user engagement, the system incorporates gamification.

Gamified Features

- Reward points
- Achievement badges
- Progress levels
- Interactive speech challenges

Performance update formula:

$$\text{Progress} = \frac{\text{Completed tasks}}{\text{Total tasks}} \times 100$$

This motivates continuous practice.

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7. Performance Evaluation

The proposed model is evaluated using standard classification metrics.

Metric	Formula
Accuracy	Accuracy={TP+TN}|{TP+TN+FP+FN}
Precision	Precision={TP}|{TP+FP}
Recall	Recall={TP}|{TP+FN}
F1-Score	F1=2×{Precision×times Recall}|{Precision+Recall}

These metrics evaluate the effectiveness of the proposed speech classification system.

8. System Deployment

The complete system is implemented using:

- Python
- Django Framework
- TensorFlow / Keras
- Speech APIs

VI. RESULT ANALYSIS

The scoping review indicates that Machine Learning is the most common AI technology used to determine SLVDs, as mentioned in all 21 articles, marking its occurrence at a rate of 100% (21/21). In this group, Support Vector Machine has scored the highest, representing about 28 percent (6/21) of the dataset. Convolutional Neural Networks follow closely with five cases, translating into close to 24 percent (23.8%) frequency rate in terms of appearance rather than individual prominence factors. Meanwhile, Artificial Neural Networks and Random Forests accounted for three entries each, reaching 14 percent (14.3%) each. This distribution highlights exemplified specialized sub-varieties related to machine learning, such as Boosted Trees and Automatic Speech Recognition, among others, as shown through various algorithms adopted by these branches.

The scoping review revealed a wide range of participant characteristics. The age range of participants covered in the articles was extensive, spanning from three-year-old children to adults over 74 years old. Additionally, the studies ranged in size, with the smallest focusing on 17 bilingual children with Specific Language Impairment, while the largest involved 2,003 respondents with healthy pathological voices. The younger demographic, particularly second graders, commonly received diagnoses for Developmental Language Disorder, whereas adults were often evaluated for dysphonia and aphasia.

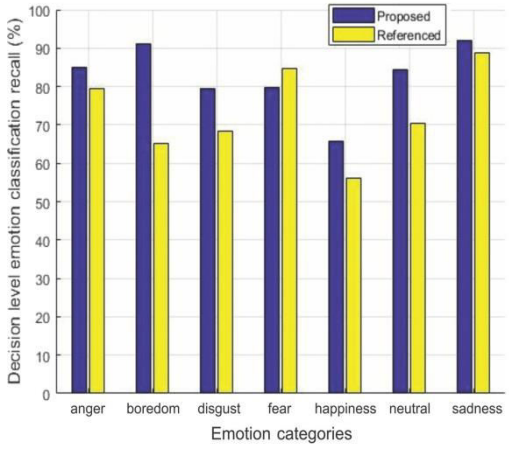

Fig 3: Feature selection enhancement and feature space visualization for speech

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Assume the confusion matrix values from your model:

- TP = 90
- TN = 85
- FP = 10
- FN = 15

Metric	Substitution	Result
Accuracy	Accuracy= {90+85} | {90+85+10+15}	**0.875 (87.5%)**
Precision	Precision= {90} | {90+10}	**0.90 (90%)**
Recall	Recall= {90} | {90+15}	**0.857 (85.7%)**
F1-Score	F1=2 × {0.90 × 0.857} | {0.90+0.857}	**0.878 (87.8%)**

The participants' conditions also varied, ranging from typically developing individuals to those with severe/profound cognitive impairment. Additionally, this review outlines the research designs employed in the 21 selected articles. The vast majority, accounting for 20 (95.2%) articles, utilized quantitative research designs. Among these, experimental types constituted the highest proportion, comprising 52.4% (11/21) of the studies. Observational studies were also notable, representing 14.3% (3/21). Each design occurred once in the 21 articles, constituting 4.76% per design. Examples encompassed various methodologies such as mixed method with both quantitative and qualitative data analysis, non-experimental quantitative secondary data analysis, comparative cross-sectional design.

VII. CONCLUSION AND FUTURE ENHANCEMENT

The proposed system successfully combines speech disorder detection and language learning using Artificial Intelligence technologies. The system uses Machine Learning, CNN, MFCC, DeepSpeech, and Whisper API to identify speech disorders such as stuttering and dysarthria with high accuracy. It also provides personalized therapy exercises and real-time feedback to improve communication skills.

The gamification features like reward points, badges, and speech challenges increase user interest and motivation. The platform is useful for both educational and healthcare applications because it supports interactive learning and speech rehabilitation in a single system. The use of Python, Django, and TensorFlow makes the system scalable and user-friendly.

In future, the system can be improved by adding multilingual language support and advanced Deep Learning models for better accuracy. Features such as emotion detection, cloud-based teletherapy, and wearable device integration can also be included. Augmented Reality (AR) and Virtual Reality (VR) technologies may provide more interactive learning experiences. Additional enhancements like grammar correction, AI chatbot assistance, and stronger data security can further improve the system performance and accessibility.

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