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Efficient Integration of Deep Reinforcement Learning in Robotic Systems through Simplified Real-Time Command Processing

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A B S T R A C T

Efficient integration of Deep Reinforcement Learning (DRL) into robotic systems faces challenges due to the computational complexity and vast parameter requirements of traditional models. This paper introduces a novel framework combining DRL with heuristic algorithms to simplify command generation for Unmanned Aerial Vehicles (UAVs) and Unmanned Ground Vehicles (UGVs) in manufacturing tasks. By decomposing system states and actions into distinct categories—time scheduling, task assignment, and trajectory planning—the proposed approach employs lightweight Deep Q-Networks and the Dijkstra algorithm for optimization. This design minimizes computational overhead, accelerates convergence, and reduces memory usage while ensuring effective task execution. Numerical evaluations highlight the efficiency gains of the simplified DRL model over conventional approaches, showcasing a significant reduction in parameters, training time, and inference latency. The findings demonstrate the potential for this modular optimization strategy to enhance the performance of autonomous systems across diverse domains.

Keywords :*Deep Reinforcement Learning, heuristic algorithms, low complexity, UAV, UGV.*

INTRODUCTION

Deep Reinforcement Learning (DRL) has emerged as a transformative approach for enhancing the decision-making and operational efficiency of robotic systems. By learning the optimal strategies from complex and dynamic environments, DRL has demonstrated significant advantages in areas such as task automation, trajectory planning, and multi-agent coordination. However, the practical implementation and training of DRL models remain challenging due to their huge computational overheads, large parameter space, and the dynamic nature of the environments they operate in. These challenges often result in longer training times, high memory requirements, and difficulty in real-time deployment, particularly in resource-constrained settings.

To overcome the abovementioned weakness in DRL training and deployment, researchers have developed low-complexity, energy-efficient heuristic solutions to integrate with the traditional DRL models. The solutions include space segmentation [1], task state simplification [2], node-pair routing optimization [3], and heuristic path planning with lightweight Q-learning [4]. Besides, to generate a fast convergence rate, Clustering and Genetic Algorithms are applied to reduce multi-robot task complexity [5], while hierarchical structures in Multi-Armed Bandit problems [6] and K-means-based problem classification [7] are utilized to achieve rapid convergence and significant computational savings. These methods establish a foundation for scalable, efficient algorithm development in this project.

This paper addresses these challenges by proposing a novel integration of DRL with heuristic optimization techniques to simplify the decision-making process for autonomous robotic systems. The focus is on Unmanned Aerial Vehicles (UAVs) and Unmanned Ground Vehicles (UGVs) assigned to execute manufacturing tasks. The optimization objective is to minimize task completion time while ensuring efficient coordination between multiple agents. Traditional DRL frameworks cannot address such complex scenarios due to the large number of the variables regarding time scheduling, task allocation, and trajectory planning.

The proposed framework decomposes the system state and action spaces into three distinct categories: time scheduling, task assignment, and trajectory planning. Lightweight Deep Q-Networks (DQNs) are employed to address task scheduling and assignment, while the trajectory planning problem is solved using the Dijkstra algorithm. This approach significantly reduces the computational complexity and communication overheads, which enables the real-time task execution with lower resource requirements.

SYSTEM MODEL

The proposed system focuses on the efficient execution of manufacturing commands by Unmanned Aerial Vehicles (UAVs) and Unmanned Ground Vehicles (UGVs). These vehicles collaborate to complete a set of tasks while minimizing the total time required. The complexity of the problem is caused by the synchronization of various operational components, including time scheduling, task assignment, and trajectory planning. Each vehicle is assigned a subset of tasks, and the completion time for all tasks is dependent on the coordination between UAVs and UGVs. Fig. 1 shows that the unmanned vehicles are assigned to complete the individual tasks in a timely manner.

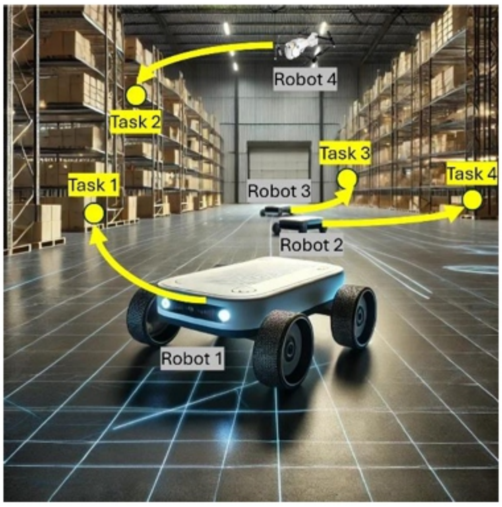

Fig. 1. A concept diagram of the UAV and UGV systems. Each Umanned Vehicle is assigned to complete the assigned task at the specific time.

The optimization objective is defined as minimizing the total task completion time, expressed as:

$$\underset{\{a_i^{\mathrm{UAV}}(t)\},\{a_j^{\mathrm{UGV}}(t)\}}{\mathrm{minimize}} \left\{T_i^{\mathrm{UAV}}\right\}, \left\{T_j^{\mathrm{UGV}}\right\}$$

where T_j^{UGV} is the total time consumption for an UGV to complete all the assigned tasks.
T_i^{UAV} is the total time consumption for an UAV to complete all the assigned tasks.
$a_j^{\mathrm{UGV}}(t)$ is the action taken by an UGV at time t.
$a_i^{\mathrm{UAV}}(t)$ is the action taken by an UAV at time t.

Time-series decision-making, which considers both the short-term coordination among multiple vehicles and the long-term planning across the task sequence, forms the core of this framework. To address the computational challenges of using a large-scale DRL model, the system state is decomposed into three simplified categories:

1. Time Scheduling: Prioritizing and sequencing tasks based on time requirement and dependencies.
2. Task Assignment: Allocating tasks to unmanned vehicles based on their current state and proximity.
3. Trajectory Planning: Determining the optimal path for each unmanned vehicle to complete its assigned tasks efficiently.

The action space is defined based on the categorization for decision-making. Two lightweight Deep Q-Networks (DQNs) are utilized to manage time scheduling and task assignment, while the Dijkstra algorithm is employed for trajectory optimization. This hybrid methodology enables the DRL to learn the complex decision patterns and enables the heuristic algorithms to determine the real-time path trajectory.

The principles of DQN and Dijkstra algorithm are introduced below.

Deep Q-Networks (DQNs) are a pivotal component of the proposed framework, enabling efficient decision-making by approximating the optimal action-value function . The action-value function represents the expected cumulative reward when taking action in state and following the optimal policy thereafter. Mathematically, the action-value function is defined as:

$$Q(s,a) = \mathbb{E}[r + \gamma \max_{a'} Q(s',a') \mid s,a]$$

where γ is the discount factor, and r is the reward received at time. In practice, DQNs utilize a neural network to approximate , where represents the network parameters. During training, the network minimizes the temporal difference (TD) error between the predicted and the target value, calculated as:

$$\delta = \left(r + \gamma \max_{a'} Q(s',a';\theta^{-})\right) - Q(s,a;\theta)$$

where $r + \gamma \max_{a'} Q(s',a';\theta^{-})$ are the parameters of a target network, periodically updated to stabilize training. $Q(s,a;\theta)$ is the predicted Q-value. The loss function used to train the DQN is typically the mean squared error (MSE) between the target Q-value and the predicted Q-value:

$$\mathcal{L}(\theta) = \mathbb{E}_{(s,a,r,s')}[(y - Q(s,a;\theta))^2]$$

By iteratively updating the parameters using experience replay and the Bellman equation, DQNs learn to approximate the optimal action-value function effectively. In the proposed system, DQNs are employed to manage time scheduling and task assignment. These networks facilitate the decomposition of complex decisions into manageable sub-problems, allowing UAVs and UGVs to operate efficiently in dynamic environments. The lightweight nature of the networks ensures reduced computational requirements, making them suitable for real-time applications in resource-constrained scenarios.

Dijkstra's algorithm is a classic graph traversal method used to find the shortest path from a source node to all other nodes in a weighted graph with non-negative edge weights. The algorithm operates by iteratively selecting the unvisited node with the smallest tentative distance, updating the distances to its neighbors, and marking it as visited. It guarantees an optimal solution by maintaining a priority queue of nodes based on their distances. The core update equation for a neighboring node

$$d(v) = \min(d(v), d(u) + w(u, v))$$

Where $d(v)$ is the shortest distance to node v, and $d(u)$ is the shortest distance to node is the weight of the edge between two nodes. This process continues until all nodes have been visited, resulting in the shortest paths from the source node to all others.

By applying three levels model, including two small-scale DQN models and a Dijkstra algorithm, the DQN model scale can be greatly reduced and the convergence speed can be significantly increased compared to the single DQN model. The structure of the proposed model is shown in Fig. 2.

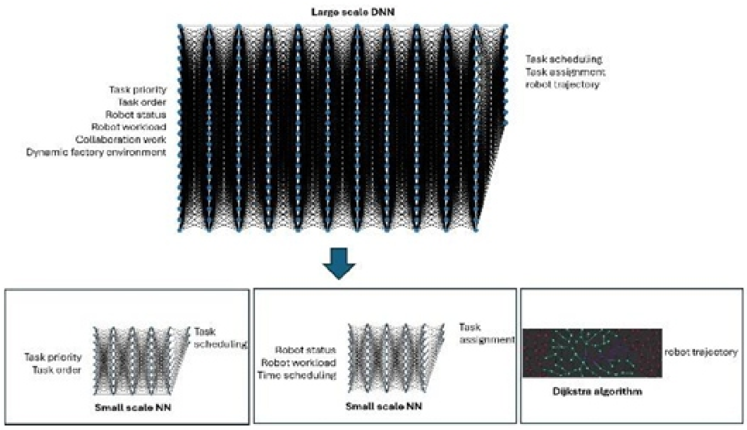

Fig. 2. The large scale Deep Neural Network(DNN) in single DQN model is very difficult to train. The proposed three levels model are shown on the bottom, where two lightweight DQN models, including two small scale DNN models and a Dijkstra algorithm are used for task scheduling, task assignment and robot trajectory planning.

SIMULATION RESULTS

In Fig. 3, the comparison of the energy consumption between the Original DRL and the proposed three-level method is shown as the number of robots increases. The three-level method performs great in energy saving, which indicates better energy efficiency when scaling up the system, whereas the Original DRL exhibits a steeper increase, which shows its limitations in energy management.

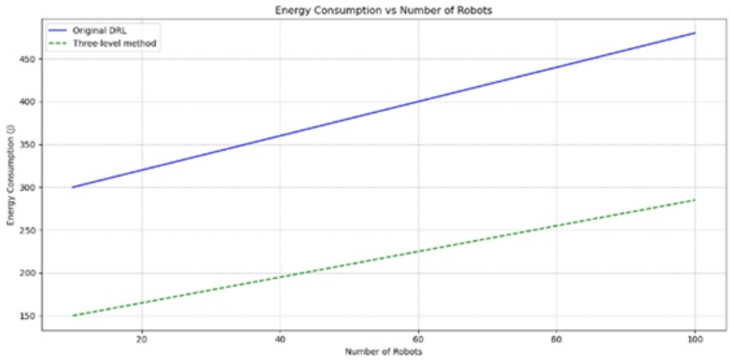

Fig. 3. Energy Consumption vs. Number of Robots for Original DRL and Three-level method.

In Fig. 4, the relationship between task success rate and the number of robots for the Original DRL and the Three-Level Model is shown. As the number of robots increases, the task success rate decreases for both models, but the Three-Level Model maintains a higher success rate overall, showcasing its robustness in handling larger-scale deployments.

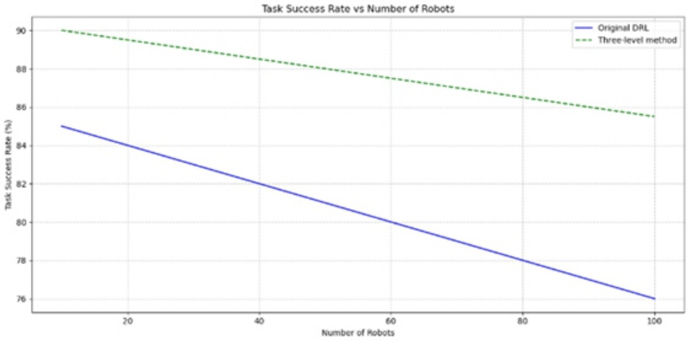

Fig. 4. Task Success Rate vs. Number of Robots for Original DRL and Three-level method.

Fig. 5 illustrates the comparative performance of the Original DRL and the Three-Level Model across key metrics: Task Success Rate, Energy Consumption, Latency, Scalability, and Communication Overhead. The Three-Level Model demonstrates significant improvements in most metrics, especially in terms of reduced energy consumption and better scalability, while maintaining comparable task success rates and communication overhead.

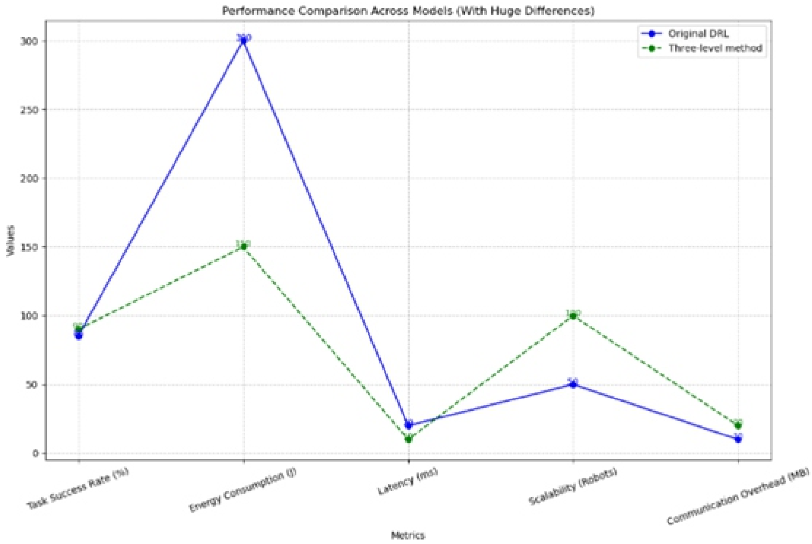

Fig. 5. Performance Comparison Across Original DRL and Three-Level Model.

CONCLUSIONS

The study demonstrates the superiority of the Three-Level Model over traditional DRL in handling large-scale robotic systems. By reducing energy consumption, maintaining higher task success rates, and improving scalability, these approaches address the limitations of conventional methods. The Three-Level Model, in particular, balances performance and resource efficiency, which shows its robustness in dynamic environments with increasing unmanned vehicles. These results highlight the importance of integrating heuristic algorithms with the deep reinforcement learning techniques to enhance the efficiency and scalability of autonomous systems and generating the simplified real-time commands in real-world applications.

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Precise Driver's Drowsiness Detection Using a Combination of Proven Methods with a Neuro-Dynamic Structure

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A B S T R A C T

Drowsiness can impair reaction time, increasing the risk of severe accidents. Many current studies concentrate on a single symptom of drowsiness, which can lead to false alerts. This paper presents a new method for detecting drowsiness in real time. The proposed approach utilizes four deep learning architectures based on convolutional neural networks: AlexNet for extracting environmental features, ResNet50V2 for recognizing hand gestures, VGG-FaceNet for facial feature extraction, and FlowImageNet for analyzing behavioral features. To maximize the benefits of the aforementioned methods, we suggest using a single-layer neural network. Since drowsiness is a dynamic phenomenon, capturing its evolving features requires a dynamic neural network with adaptive delays, specifically an Adaptive Time Delay Neural Network (ATDNN) with adjustable weights. Our implementation of this neuro-dynamic approach on the NTHUDDD and our custom datasets demonstrates that it achieves greater accuracy (99.1% and 98.6%, respectively) compared to existing methods in the literature.

***Keywords** :Adaptive Time Delay Neural Networks (ATDNN), Convolutional Neural Network (CNN), Drowsiness Detection, Neuro-Dynamic structure.*

INTRODUCTION

Drowsiness represents a transitional state between full wakefulness and consciousness, causing slower reaction times and impaired memory [1]. The US National Highway Traffic Safety Administration reports that drowsiness contributes to about 100,000 traffic accidents each year worldwide, leading to over 1,500 deaths and more than 70,000 injuries [2]. This problem is widespread globally. Since drowsiness greatly affects driving safety, detection systems are essential as they offer early warnings before drowsiness becomes critical and hazardous.

Machine Learning (ML) has been applied across numerous fields, offering substantial benefits like high accuracy, adaptability to various datasets, effectiveness with both small and large datasets, and scalability regarding data volume and computational resources [3]. In drowsiness detection systems, as in other areas, machine learning techniques are utilized. Different models, such as Convolutional Neural Networks (CNNs), Long Short-Term Memory (LSTM) networks, and Recurrent Neural Networks (RNNs), are used to train on datasets and identify key features related to drowsiness.

Datasets for developing driver drowsiness detection systems fall into three primary categories: 1) vehicle-based like steering wheel angle, lateral and longitudinal acceleration 2) facial-based like rapid blinking and yawning 3) biological signals such as electroencephalography (EEG) and electrocardiography (ECG) [4]. While biological signals offer high accuracy, they are also intrusive, as they necessitate the attachment of sensors to the driver, which can be uncomfortable and distracting during driving. In many works they used a combination of these methods for example a combination of vehicular and facial, vehicular and biological, and vehicular and biological methods. This way can help to get a more accurate result. Also, considering different symptoms in one group simultaneously can give a better result compared with experimenting with just one symptom.

Despite various methods developed by researchers for detecting drowsiness, existing approaches continue to encounter significant challenges. Relying on a single symptom of drowsiness often results in unreliable and inaccurate outcomes. Additionally, static machine learning models lack memory and are unable to track drowsiness over time. To overcome these limitations, this paper presents a new approach for drowsiness detection and its contributions are as follows:

1-This paper utilizes four deep learning architectures based on convolutional neural networks: AlexNet for extracting environmental features, ResNet50V2 for recognizing hand gestures, VGG-FaceNet for extracting facial features, and FlowImageNet for analyzing behavioral features. Each model is pretrained through transfer learning, with extra layers incorporated to improve performance, thereby harnessing the combined strengths of an integrated framework.

2-To fully leverage the advantages of the previously mentioned methods, we propose employing a single-layer neural network. Given that drowsiness is a dynamic process, capturing its changing characteristics necessitates a dynamic neural network with adaptive delays, specifically an Adaptive Time Delay Neural Network (ATDNN) with adjustable weights.

The rest of the paper is structured as follows: Section 2 provides a literature review of previous studies related to this work. Section 3 outlines the proposed method within the overall detection framework. Section 4 details the experimental results from the training and testing phases of the proposed method. At last, the paper will be concluded.

LITERATURE REVIEW

Researchers have explored various methods for detecting drowsiness, including facial, biological, and vehicular techniques [5]. Facial detection methods identify drowsiness by analysing features such as eye blinking rate, yawning, nodding, head movements, and eyebrow raising [6]. A summary of the factors considered in these three types of drowsiness detection techniques is illustrated in Figure 1. Facial detection approaches rely on video recordings of the driver to assess signs of drowsiness. However, using cameras for this purpose presents challenges, especially in conditions with variable lighting or when drivers wear glasses, sunglasses, masks, or have their heads turned away from the camera. Facial-based methods primarily use two approaches: facial landmarks and machine learning techniques. Landmark-based methods typically calculate the Eye Aspect Ratio (EAR) in the eye region and the Mouth Aspect Ratio (MAR) in the mouth region to detect yawning and predict drowsiness.

Biological-based drowsiness detection methods often require direct physical contact, making them intrusive. These techniques monitor physiological indicators such as heart rate, heart rate variability, pulse rate, respiration patterns, breathing frequency, body temperature, and electrical activity of the brain and eyes. Devices like Electroencephalograms (EEG), Electrooculograms (EOG), Electromyograms (EMG), and Electrocardiograms (ECG) are commonly used for these measurements. However, a major limitation of this approach is the need for drivers to be physically connected to monitoring equipment, which can be uncomfortable and impractical for continuous use. These measurement tools fall into two main categories: signal-based and image-based. The former relies on signal processing, while the latter depends on image analysis.

In contrast, vehicle-based methods offer a non-intrusive alternative, as they do not require direct interaction between the driver and monitoring sensors. These techniques assess driving behavior by analyzing parameters such as steering angle fluctuations, steering angular velocity, lateral and longitudinal acceleration, deviation angle, displacement from the road's centerline, and vehicle speed [5]. This approach allows for drowsiness detection without interfering with the driver's comfort or mobility.

In [7], a real-time drowsiness detection system was developed using facial features like Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR). Videos were recorded in a real driving environment and converted into frames. Facial landmarks were extracted using a Haar Cascade classifier and the Dlib library, combined with a logistic regression classifier. This approach achieved 92% accuracy with Dlib but dropped to 86% using Haar Cascade, due to its poor eye detection. A limitation of this method is that relying on MAR and EAR metrics may lead to inconsistent accuracy, as threshold values can vary between individuals.

In [8], the study focused on detecting drowsiness through the eyes using the MediaPipe library [9] to extract the eye region. Researchers trained three deep learning models—ResNet50v2, InceptionV3, and VGG-16—on this region, achieving real-time detection. MediaPipe's face mesh method was employed to identify 468 facial landmarks, from which four were selected to define the eye region. ResNet50v2 achieved the highest accuracy of 99.71%. However, the study mainly focused on the eyes, neglecting other potential drowsiness indicators.

In [10], a drowsiness detection system was developed using four deep learning models, combined through a simple averaging method. FlowImageNet analysed facial expressions and behaviours like nodding, while AlexNet focused on environmental factors such as lighting and glasses. VGG-FaceNet extracted facial features like lips and eyebrows, and Res-Net captured hand gestures related to yawning. A threshold of 0.24 was used to indicate drowsiness, yielding an accuracy of 85%. This relatively low accuracy suggests limited precision, possibly due to the model's focus on specific features while neglecting others like head movements and drooping cheeks.

Most studies primarily focus on the eyes and mouth, overlooking other drowsiness indicators such as raised eyebrows, head movements, and drooping cheeks, which can affect the accuracy of predictions. While bio-signal methods like EEG and ECG provide high accuracy, these devices are expensive, not typically available in vehicles, and are often intrusive, causing discomfort for the driver.

To assess driver drowsiness, we use the levels described in [11], which are based on [12] but with some modifications to the scales. The authors categorized drowsiness into five levels, as detailed in Table 1. Fig.1 illustrates the levels of drowsiness for both the international dataset and the dataset prepared by the authors of this paper.

Table 1. Drowsiness levels [11].

Drowsiness Levels	Features
1-Not Drowsy	Line of sight moves fast and frequently. Facial movements are active, accompanied by body movements.
2-Slightly Drowsy	Line of sight moves slowly. Lips are open.
3-Moderately Drowsy	Blinks are slow and frequent. There are mouth movements.
4-Significantly Drowsy	There are blinks that seem conscious. Frequent yawning.
5-Extremely Drowsy	Eyelids close. Head tilts forward or falls backward.

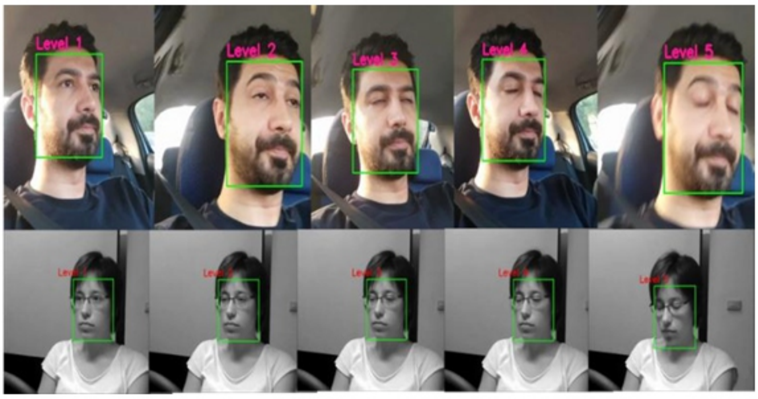

Figure 1. Five levels of drowsiness in two datasets

In this study, we introduce a framework that incorporates four distinct models. Rather than relying on a straightforward and conventional approach of averaging and merging multiple models, we implement an intelligent weighting mechanism. This approach adjusts the weight of each branch within a single-layer neural network, which is positioned at the output of the four selected models. Given the dynamic nature of the drowsiness process, we develop an Adaptive Time-Delay Neural Network to extract adaptive rules and establish a neuro-dynamic structure. The specifics of the proposed framework are detailed in the following section.

FRAMEWORK

Instead of using a basic voting method, this study employs a smart weighting approach by adding a layer at the output of the four models. Recognizing that drowsiness develops gradually over time, a neuro-dynamic structure is adopted with adaptive weight adjustment rules. In the structure of ATDNN, each neuron is described by a delay associated with all the weights. The framework is depicted in Fig.2.

Next, we analyse the layers added to each model through transfer learning and outline the weight adjustment rules for each branch in the dynamic mode. We selected the Exponential Linear Unit (ELU) as the activation function because it yielded better results. Notably, all models use the sparse categorical entropy loss function, which is optimal for multi-class classification and offers better performance than other loss functions. The formula for this loss function is given in (1). The formula of this loss function is shown in (1) in which y_i is the true label and $\hat{y}_i$ is the predicted value.

$$H(\hat{y}, y) = -\frac{1}{N(num\_class)} \sum_{i=1}^{N} \log(\hat{y}_i, y_i) \quad (1)$$

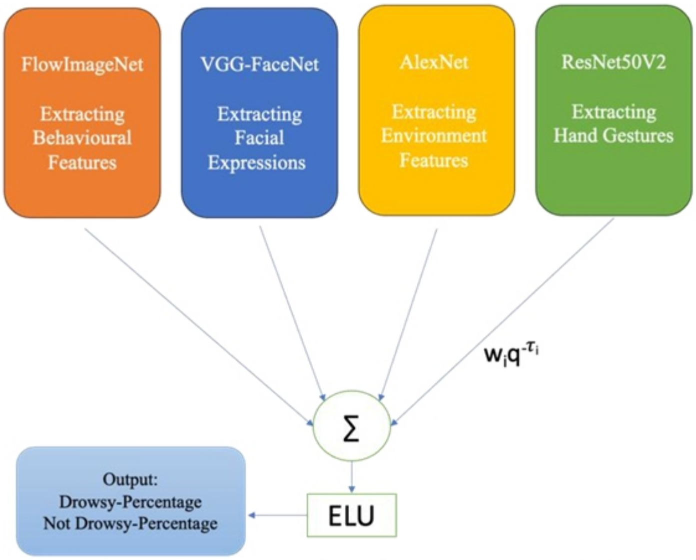

Figure 2. Framework of the proposed method

Adaptive Time-Delay Neural Networks (ATDNNs) have been introduced and applied in various fields, such as system identification for wind turbines [13] and turbo generators [14]. These networks closely resemble the structure of multi-layer feedforward neural networks, with only minor differences. In a typical neural network, each neuron computes the sum of its weighted inputs and processes this sum through a nonlinear activation function. In contrast, ATDNNs incorporate a time-delay for each weight associated with a neuron. The specific delays are chosen based on the application at hand, enabling the network to capture relationships between events occurring over time. This dynamic representation of input and output in a neuron is achieved by introducing a delay in each neuron's connection [13]. As illustrated in Fig.2, the time-delay is integrated, and the input-output relationship of the neuron is described by (2).

$$y(t) = \sigma(\sum_{i=1}^{N} w_i x_i (t - \tau_i)) \tag{2}$$

In (2), we represent the weights of neurons, τ_i is the delay, σ is the nonlinear activation function, $x_i(t-\tau)$ is the ith input with a delay, W_i is ith weight, and the summation is for i from 1 to Nth layer. It is important to note that in this formula, the output of the neuron at time *t* depends on previous input values, resulting in dynamic behaviour. This dynamic method is subsequently adjusted adaptively to appropriately represent various classes of nonlinear systems. This phenomenon is significant in drowsiness detection, as it does not occur suddenly but rather imposes itself on the driver dynamically, reducing alertness.

The layers shown are added to the pre-trained ResNet50V2, VGG-FaceNet, AlexNet, and FlowImageNet models using transfer learning to enhance performance (see Fig.3, Fig.4, Fig.5, and Fig.6). We compute the dynamic weighting rules to develop the smart weighting model. The dynamic weighting rules for each structure are detailed in (3), (4), (5), (6), (7), (8), (9) and (10). These weighting rules show the output of the jth neuron in the Lth layer at time t is denoted by $O_j^l(t)$. The weight and associated delay connecting the jth neuron in the lth layer to the ith neuron in the (L-1)th layer are denoted by W_{ji}^l and τ_{ji}^l, respectively. It is noticeable that j varies from 1 to N^L, i varies from 1 to N^{L-1}, and τ_{ji}^l varies from 0 to $\tau_{\max}$. Also, $net_j^l(t)$ is the weighted input of the jth neuron in the lth layer at time t. The weights Δw_{kj}^l and delays $\Delta \tau_{kj}^l$ adaptation laws in the following equations in this structure and others are based on these parameters.

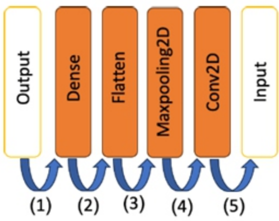

Figure 3. The layers added to a pre-trained ResNet50V2 structure

$$\frac{\partial O_k}{\partial w_{kj}} = \sigma'(net_k^5(t))[O_j^4(t-\tau_{kj}^5) + \sum_{p=1}^{N^4} w_{kp}^L \sigma'(net_p^4(t-\tau_{kp}^5)).....$$

$$\sum_{q=1}^{N^1} w_{lq}^2 \sigma'(net_q^1(t-....-\tau_{lq}^2))\, w_{q2}^1 \frac{\partial O_k^5(t-\tau_{kp}^5-...-1)}{\partial w_{kj}^5}].\operatorname{Re}LU'(X_{Conv,ijk}).X_{input,l} \tag{3}$$

$$\frac{\partial O_k}{\partial \tau_{kj}} = \sigma'(net_k^5(t))\sum_{p=1}^{N^4} w_{kp}^5 \sigma'(net_p^4(t-\tau_{kp}^5)).....$$

$$\sum_{q=1}^{N^1} w_{lq}^2 \sigma'(net_q^1(t-....-\tau_{lq}^2))\, w_{q2}^1 \frac{\partial O_k^5(t-\tau_{kp}^5-...-1)}{\partial \tau_{kj}^5} + w_{q1}^1 \frac{\partial u(t-\tau_{kp}^5-...-1)}{\partial \tau_{kj}^5}] \tag{4}$$

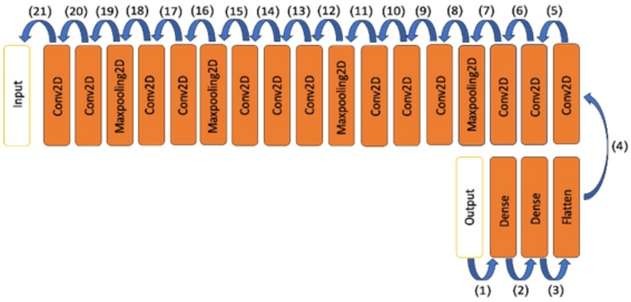

Figure 4. The layers added to a pre-trained VGG-FaceNet structure

$$\frac{\partial O_k}{\partial w_{kj}} = \sigma'(net_k^{21}(t))[O_j^{20}(t-\tau_{kj}^{21}) + \sum_{p=1}^{N^{20}} w_{kp}^L \sigma'(net_p^{20}(t-\tau_{kp}^{21}))....$$

$$\sum_{w=1}^{N^1} w_{wv}^2 \sigma'(net_w^1(t-\tau_{kp}^{21}...-\tau_{wv}^2))\, w_{w2}^1 \frac{\partial O_k^{21}(t-\tau_{kp}^{21}....-\tau_{w2}^1-1)}{\partial w_{kj}^{21}}.$$

$$\operatorname{Re}LU'(X_{Conv13,ijk}).X_{input,l} \tag{5}$$

$$\frac{\partial O_k}{\partial \tau_{kj}} = \sigma'(net_k^{21}(t))\sum_{p=1}^{N^{20}} w_{kp}^L \sigma'(net_p^{20}(t-\tau_{kp}^{21}))....$$

$$\sum_{w=1}^{N^1} w_{wv}^2 \sigma'(net_w^1(t-\tau_{kp}^{21}...-\tau_{wv}^2))\, w_{w2}^1 \frac{\partial O_k^{21}(t-\tau_{kp}^{21}....-\tau_{w2}^1-1)}{\partial \tau_{kj}^{21}}$$

$$+w_{w1}^1 \frac{\partial u(t-\tau_{kp}^{21}....-\tau_{w2}^1-1)}{\partial \tau_{kj}^{21}} \tag{6}$$

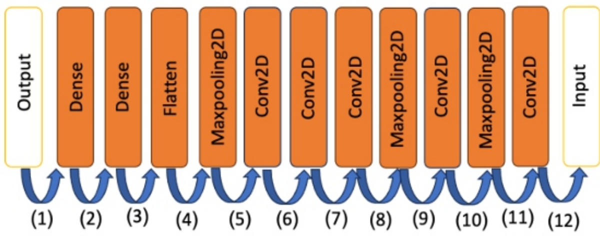

Figure 5. The layers added to a pre-trained AlexNet structure

$$\frac{\partial O_k}{\partial w_{kj}} = \sigma'(net_k^{13}(t))[O_j^{12}(t-\tau_{kj}^{13}) + \sum_{p=1}^{N^{12}} w_{kp}^L \sigma'(net_p^{12}(t-\tau_{kp}^{13}))....$$

$$\sum_{f=1}^{N^1} w_{sf}^2 \sigma'(net_f^1(t-\tau_{kp}^{13}...-\tau_{sf}^2))\, w_{f2}^1 \frac{\partial O_k^{13}(t-\tau_{kp}^{13}....-\tau_{f2}^1-1)}{\partial w_{kj}^{13}}].$$

$$\operatorname{Re}LU'(X_{Conv5,ijk}).X_{Input,l} \tag{7}$$

$$\frac{\partial O_k}{\partial \tau_{kj}} = \sigma'(net_k^{13}(t))\sum_{p=1}^{N^{12}} w_{kp}^L \sigma'(net_p^{12}(t-\tau_{kp}^{13}))....$$

$$\sum_{f=1}^{N^1} w_{sf}^2 \sigma'(net_f^1(t-\tau_{kp}^{13}...-\tau_{sf}^2))\, w_{f2}^1 \frac{\partial O_k^{13}(t-\tau_{kp}^{13}....-\tau_{f2}^1-1)}{\partial \tau_{kj}^{13}}]$$

$$+w_{f1}^1 \frac{\partial u(t-\tau_{kp}^{13}....-\tau_{f2}^1-1)}{\partial \tau_{kj}^{13}} \tag{8}$$

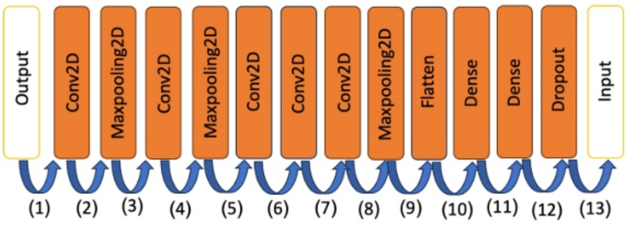

Figure 6. The layers added to a pre-trained FlowImageNet structure

$$\frac{\partial O_k}{\partial w_{kj}} = \sigma'(net_k^{14}(t))[O_j^{13}(t-\tau_{kj}^{14}) + \sum_{p=1}^{N^{13}} w_{kp}^{L}\sigma'(net_p^{13}(t-\tau_{kp}^{14}))....$$
$$\sum_{h=1}^{N^1} w_{fh}^{2}\sigma'(net_h^{1}(t-\tau_{kp}^{114}...-\tau_{fh}^{2}))\, w_{h2}^{1}\frac{\partial O_k^{14}(t-\tau_{kp}^{14}....-\tau_{h2}^{1}-1)}{\partial w_{kj}^{14}}].$$
$$\mathrm{Re}\,LU'(X_{Conv5,ijk}).X_{Input,1} \tag{9}$$

$$\frac{\partial O_k}{\partial \tau_{kj}} = \sigma'(net_k^{14}(t))\sum_{p=1}^{N^{13}} w_{kp}^{L}\sigma'(net_p^{13}(t-\tau_{kp}^{14}))....$$
$$\sum_{h=1}^{N^1} w_{fh}^{2}\sigma'(net_h^{1}(t-\tau_{kp}^{114}...-\tau_{fh}^{2}))\, w_{h2}^{1}\frac{\partial O_k^{14}(t-\tau_{kp}^{14}....-\tau_{h2}^{1}-1)}{\partial \tau_{kj}^{14}}]$$
$$+w_{h1}^{1}\frac{\partial u(t-\tau_{kp}^{14}....-\tau_{h2}^{1}-1)}{\partial \tau_{kj}^{13}} \tag{10}$$

RESULTS

We evaluated our proposed method using multiple datasets, including the widely recognized NTHUDDD dataset on drowsiness and a custom dataset we created as in Fig. 7. The NTHUDDD dataset is an academic dataset developed by the Computer Vision Lab at National Tsing Hua University in China [15]. Initially introduced at the Asian Conference on Computer Vision in 2016, it was designed for detecting driver drowsiness using video recordings. This dataset comprises high-speed infrared video footage in AVI format, with a resolution of 480 × 640 pixels.

To evaluate the effectiveness of the proposed method on a custom dataset, we compiled data in a real driving environment involving 15 individuals—12 males and 3 females. This dataset includes subjects under diverse conditions such as daylight, nighttime, and both with and without glasses. During data collection, we made a concerted effort to capture behaviours like yawning, raised eyebrows, slow blinking, head movements, and nodding.

EVALUATION

To evaluate our classification task, we used a confusion matrix and examined four metrics: accuracy, precision, recall, and F1-score. The results are summarized in Table 2. The confusion matrix, which includes true positives (TP), true negatives (TN), false positives (FP), and false negatives (FN), is illustrated for two different scenarios (see Fig.8). Fig.9 and Fig.10 show the accuracy and loss metrics throughout the training process for these scenarios. The goal during training is to minimize the output loss when processing training data. The training results for both scenarios show a steady increase in accuracy and a consistent decrease in loss for both training and validation, indicating that the proposed method is effective. Specifically, in scenario 1, the TP and TN values for predicting drowsy and not drowsy states are both 99% as in Fig. 8.

Figure 7. Frames of our dataset

Table 2. The results of evaluation parameters on the proposed method with two datasets.

Num	Scenario	Label	Precision	Recall	F1-Score	Support	Accuracy
1	Neuro-Dynamic Structure on NTHUDDD	Drowsy Not-Drowsy	0.987 0.995	0.987 0.985	0.986 0.986	1010 1153	**0.991**
2	Neuro-Dynamic Structure on our dataset	Drowsy Not-Drowsy	0.979 0.993	0.979 0.978	0.979 0.985	1010 1153	0.986

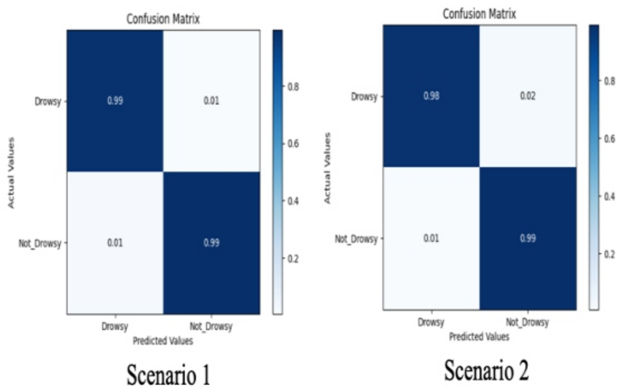

Figure 8. Confusion matrix for two scenarios

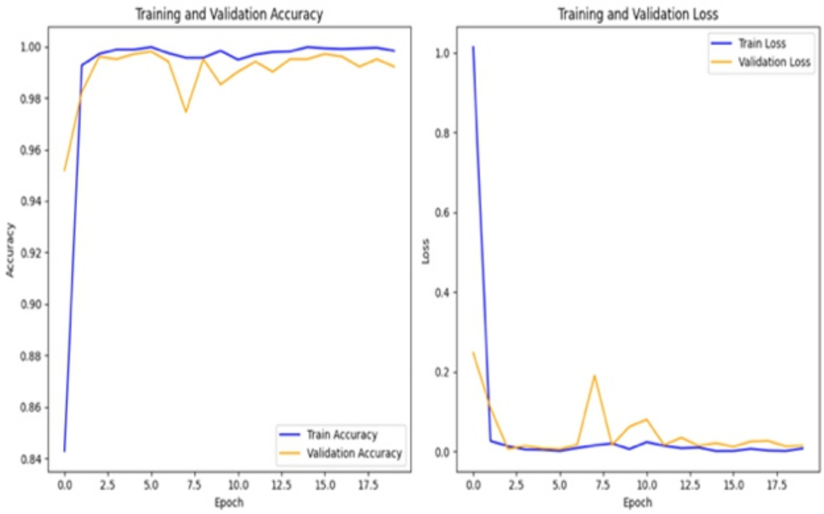

Figure 9. Metrics for scenario1: Accuracy and Loss

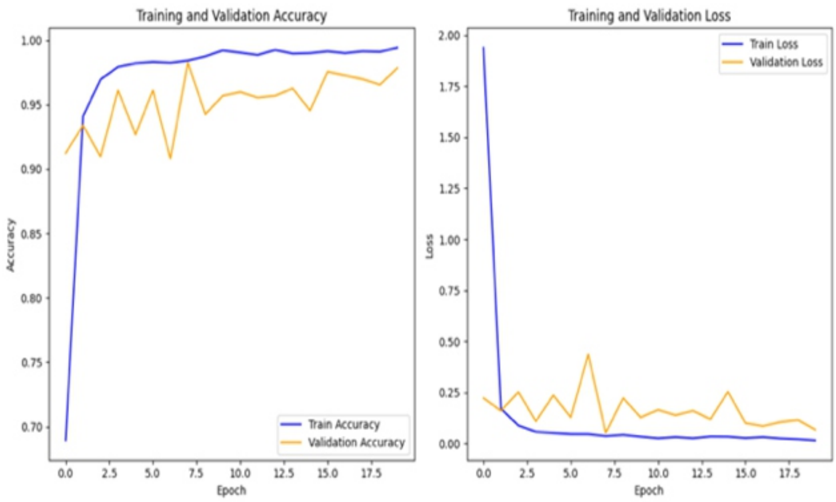

Figure 10. Metrics for scenario 2: Accuracy and Loss

Tables 3 and 4 compare the accuracy of two approaches: simple voting and the static model. The results clearly demonstrate that the static model significantly outperforms the simple voting method across both datasets. The implementation results of the proposed structure on these datasets are shown in Fig.11. A key advantage of this structure is its ability to accurately detect drowsiness even when yawning with hands covering the face, as evidenced by the high accuracy shown in Fig.12.

Table 3. Comparison of accuracy between two states on NTHUDDD dataset.

Structure	Accuracy	Voting	Neuro-dynamic Structure
AlexNet	92.73	87.47	**99.1**
VGG-FaceNet	83.03		
ResNet50v2	84.12		
FlowImageNet	90		

Table 4. Comparison of accuracy between two states on our dataset.

Structure	Accuracy	Voting	Neuro-dynamic Structure
AlexNet	92	86.49	**98.6**
VGG-FaceNet	81.93		
ResNet50v2	82.68		
FlowImageNet	89.35		

Figure 11. Evaluation of proposed structure on two datasets

Figure 12. Detecting drowsiness even yawning with hand

CONCLUSION

This study employed four convolutional neural network architectures—AlexNet, Res-Net50V2, FlowImageNet, and VGG-FaceNet—and combined their results using a neuro-dynamic structure. Initially tested on the NTHUDDD dataset, a leading resource for sleepiness detection, the proposed approach proved to be more effective than the individual methods. The method was also validated on a custom dataset created for this study, demonstrating its robustness across various datasets. The dynamic technique showed substantial improvements over previous methods like averaging. Ultimately, the neuro-dynamic architecture achieved accuracies of 99.1% and 98.6% on the two datasets, respectively. Given its high accuracy, the system is well-suited for real-world applications and could be integrated into hardware for use in vehicles. In future work, this system is expected to be implemented for signal data, which is distinct from image data. Additionally, by incorporating all three categories of data—vehicle-based, biological-based, and facial-based—we can achieve a more comprehensive assessment of drowsiness. Furthermore, this system could be applied to lateral and longitudinal vehicle speed data, as well as vehicle trajectory tracking, since driving behaviour can serve as an indicator of driver drowsiness.

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Machine Learning based Robotic End Effector System for Monitoring and Control of External Bleeding of Vehicle Accident Victims, Review Paper

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ABSTRACT

Vehicle accidents are on the rise in the roads due to over speeding, poor roads, and misjudgment during driving, not forgetting overloading and lack of proper vehicle maintenance. Private transport has increased rapidly, thereby resulting in many accidents on the roads. Whenever there is an accident, it has been realized that some accident victims who would have survived the accident end up dead due to continuous bleeding. As a result, many lives are lost because of a lack of emergency measures to avoid that constant loss of blood through external bleeding. In this regard, there is a need to design a robotic system based on machine learning (ML) to monitor and control the external bleeding from vehicle accident victims in the shortest possible time through the utilization of software such as SolidWorks, Matlab, and proteus. The nanotechnology-based system interfaced with the robotic end-effector shall be used to apply to stop gel through the utilization of Comsol software. The robotic system shall be integrated with a monitoring system for precise and useful quantification of the bleeding wound, thus the importance of machine learning to achieve accurate information.

Keywords :*Machine Learning, monitoring of external bleeding, nanotechnology, Robotic end effector.*

INTRODUCTION

The issue of sense is fundamental in robotics applications such as in the medical field, for instance, the sense of touch is critical for detection in the medical field to monitor desired objects of interest. This is needed for detecting smoothness and roughness as the response to the sense of touch ([26], 2013). MEMS-based bio-medical sensors are analyzed in detail since MEMS devices are becoming popular in detecting biomedical-related issues such as glucose bio-inspired robotic fingers have utilized the advantage of tissue softness characteristic in sensing surgical pressure variations ([18], 2012).

Some sensors have been analyzed for force sensing application in robotic hands, especially tactile sensors. MEMS and silicon have been used to improve the efficiency of these tactile sensors in robotic hand operations. For instance, piezoresistive and polymers have been used to enhance grasping concepts. In this regard, it is justified to pursue the design of an optimized robotic hand that can mimic the real human hand ([1], 2015). One of the features of cooperating like human beings is the grippers and manipulators which have been designed as autonomous making them operate or maneuver in difficult environments ([12], 2017).

According to Oddo et al piezoresistive sensor system has been explored at the microscale to improve the whole system of sensing effectively ([12], 2017). Information taken using tactile sensors can be processed using machine learning in order to guide the robotic system to perform even in an unknown environment ([21], 2008).The skin provides a large variable degree of sensitivity since it is the largest organ in human beings.

Blood leakage and blood loss are a serious and real threat to human lives and up to date, more than 40% of adult blood volume can be lost thus high mortality ([31], 2018). Road traffic accidents (RTA) is among the top causes of high road fatality rate worldwide. Statistics from WHO, has confirmed that 5.6 million people die in unintentional injuries of whom 65% are victims of RTA yet, despite implementing many ways and efforts in trying to curb road traffic accidents, through use of machine vision systems and use of stiff penalties and fines, the annual number of deaths is still on the rise. Therefore there is a need for serious investigations in the epidemiology of RTA ([13], 2014).

In the whole world, road traffic accidents have claimed many lives at an alarming rate and an estimated 3 million injuries every year. Although advancement in technology had resulted in minimum reduction due to autonomous driving, human driving is still increasing, posing more serious accidents thus, a lot has to be done in the automotive industry to minimize loss of life. In this regard, robotics can play a role where medical attention is of need for the injured person in the vehicles ([20], 2019). Since vehicle safety is one of the major priorities for any human when he/she is in a vehicle or any mode of transport. In this regard, many types of research have resulted in developments of safety features for the vehicles such as airbags for the rear front and side-ways, not forgetting seat belts. With all these efforts, vehicle accidents are resulting in many victims who instantly die on the spot whilst some injured end up losing their life due to lack of instant medical attention within the vehicle as some preventable deaths are still left being unattended which is a cause of concern ([20], 2019).

The The fact that most accidents happen at night or in an isolated place along the road had caused more injured victims to eventually die because of a lack of immediate help in terms of the red cross, ambulance team, and police to the site. Due to this scenario relatives cry because of some injured who end up dying because of a lack of support. With all this in mind, a robotic system for real-time monitoring of the victims with first aid assistance has therefore been identified as the way to go. This had to be installed inside the vehicle in a strategic position which makes it robust even after the accident as it remains undamaged due to collision ([20], 2019).

Surgery systems based on robotics technology have been on the rise where MEMS and nanotechnology have been on demand to make designs within a microchip which are multifunctional, intelligent and robust. These microchips can be placed even inside the body, on tissue and even in the blood for different medical applications that need automatic real-time monitoring and control ([11]). These devices are being used to monitor and control different diseases within human beings ([8], 2015). A A prototype for a skin surface coupled with personal wearable health monitoring which can cater to various body surfaces and positions within the body has been developed for instance scenarios where sensors are placed on the arm wrist to sense blood pressure based on waveforms ([15], 2018). Approximately 1.3 million people die annually as a result of road traffic accidents and more than 91% of road traffic accidents are from low and middle-income countries such as Nepal ([7], 2020).

Optical non-intrusive based methods have been used in detecting blood through the utilization of infrared ray or visible ray from a semiconductor laser ([30], 1994). A human being has got many senses however the sense of touch has dominated so much especially when it comes to environment perception for instance through the utilization of surface texture for detecting objects ([26], 2013). The issue of blood loss is a serious issue because a certain amount of blood is not replaced, this results in death as this had been witnessed at accident victims and on the battlefield. Many methods have been used in trying to minimize or reduce this blood loss through the use of pressure dressings and absorbent materials. A quick Clot can instantly and successfully stop bleeding by absorbing large quantities of fluid and concentrating on platelets to augment clotting however, this is has been implanted only to compressible and exposed wounds ([4], 2009).

In this era for innovation and industrialization for the betterment of our society and economy, transport, and safety cannot be separated. Therefore, fatal injuries on the road need a research approach to stop. Robotic manipulators rely on image systems for proper guidance to surpass human limitations by introducing automated targeting and treatment delivery methods for surgeons ([14], 2015).

Robotics in medical field

End effector position calculations only based on kinematic proved to be less effective especially in the joints and links of the robot as a result, designs based on machine vision can be implemented in the surgical tools so that operations can be improved. Tool operations algorithms were developed for guided tracking ([9], 2018). Robotics end effectors application in the medical field has become very popular, needles are being used in surgery with the help of machine vision techniques ([29], 2008).

A Although robotic systems are now being applied in the medical field, it is still entering at a slow rate especially in complex medical situations, however, outside the operating room robots can still assist human beings like in blood sampling, force sensing and even guiding robots position and its orientation like guiding the needle tip ([32], 2018). Diagnostic blood testing which is very vital in the medical field is being enhanced through an image-guided venipuncture robotic system thus precision, time, and efficiency are guaranteed ([2], 2017). Micro-actuator technologies based on nanotechnology concepts such as the Shape Memory Alloy (SMA) have led to innovations such as the miniature ultrasound motors which can be implemented in dexterous artificial hands and these latest technologies boosted the number of degrees of freedom for robotic joints thus much better flexibility and efficiency ([22], 2002).

Many technologies have been introduced to reduce or eliminate accidents on the road such as automatic speed control based on ultrasonic sensors, automated collision avoidance systems, tire pressure monitoring systems for preventing accidents but all this had been of benefit to a lesser extent because accidents occur due to many reasons. One of the significant reasons is human error which has caused many casualties. Systems have been designed again through research to come up with airbags so that the harm to the accident victims can be reduced however this is not 100% because accidents differ in their intensity and type of collision thus in vehicle collisions some scenarios are helpless however in some cases quick assistance like red cross can be of great help if it happens to be available in time. In this regard, it has been realized that some victims die due to lack of instant support, for instance, external bleeding can lead to death, and if quick assistance is rendered many lives can be spared from death. Since accidents occur at any place and any time, immediate help cannot be found to provide service which can stop external bleeding as the victims wait for an ambulance or Red Cross. In this case, there is a need to design a robotic end effector which can instantly monitor external bleeding and automatically stops the bleeding thus saving lives.

Using the bio-inspired system, healing of the wound goes through different stages using chemicals that are released to initiate the healing process at the site of the wound, and the process involves inflammation, wound closure, and matrix remodeling ([27], 2008). The The advancement in robotic application in the medical field has resulted in soft robots in the medical field, and it has resulted in the efficiency and precision in complex tasks ([5])([3], 2018).

Robotics technology has got many applications in areas or situations where there is narrow space and where visibility and point of need are not clear for instance, in the medical field where the sensors need to mimic the soft skin and real hand dexterity to achieve this, the need to design and develop robotic manipulators and end effectors which can give maximum performance in a limited space with high sensitivity such as the human tissue ([10], 2019). Robots needs to have a closed-loop system so tasks which are thought being only accomplished by humans can also be done through the Implementation of the complex sensory system though thus this is an area where there is more research needed to have robots which similar human character ([6], 2018).

Robots have gained much favour in medical applications, and recently soft robotics that mimics human characteristics are now at the centre stage of research ([23], 2013). A non-contact handheld sensor based on near-infrared had been used for wound imaging, and this system had managed to differentiate between a wound and a healed one ([16], 2016). Optical imaging can be limited to wound depth of microns to mm but NIRS go deeper to around mm to cm([16], 2016).

Machine vision systems

Machine learning is of significant contribution in imaging to have perfect results therefore, artificial intelligence has to be explored in detail. MEMS field contributed to the development of challenging cantilever designs which have gained favor in the detection of disease([17], 2015). MATLAB has been implemented in the analysis of wound images and classification through consideration of healing status including color changes in the process. A collection of wound image databases from the open-source wound images can be collected before segmentation techniques are implemented to extract the region of interest ready for filtering to remove noise from wound images, reduction in the area of the wound indicates healing. Segmentation of the wound from the wound image involves projecting the needed information by identifying the region of interest ([19], 2014).

The release of proinflammatory mediators leads to the rapid expression of adhesion proteins on the surface of endothelial cells of the vessel wall and other chemoattractants that begin to recruit and guide leukocytes to the region of the injury. Neutrophils arrive at the wound site soon after the injury to deal with invading pathogens ([28], 2019).

MATLAB has great power and merit when it comes to matrix operating however, when implemented in real-time functions such as camera in real-time processing , digital image stitching and feature detecting it is too slow([25], 2017). There is a need for another efficient tool designed for computational efficiency and with great focus on real-time applications as a result, a new C ++ skin image processing program based on OpenCV has been developed which when compared with MATLAB, OpenCV is a free open source image processing library and very efficient for processing real-time video images. Above all, the OpenCV library is a very useful tool in image processing due to the distinct interface to another compiled language. The ongoing video program is successful for recognizing edges, removing skin surfaces, ROI computations, just as face location ([25], 2017).

MATERIALS AND METHODS

Table 1: Summary of related works

Title	Author	Methods and brief description	weaknesses	strengths	uniqueness
Robotic Arm and Image Processing	Koparde et al., 2020	The detection and recognition are done using OpenCV library of Image Processing in python. While all the processing is done on raspberry pi which works on Raspbian OS based on Debian-Linux OS.	The system cannot be in position to deal with complex images such as bleeding wounds.	Raspberry Pi offer flexible control for the robotic arm. The total programming model is developed in Python which is very compatible with controller being used for the robotic arm control.	The robotic arm is based on 4 Degree of Freedom (4 DOF) . is quite good for achieving the task without complications.
ROBOTIC ARM WITH REAL-TIME IMAGE PROCESSING USING RASPBERRY PI , BOTH AUTOMATED AND MANUALLY	Therese, 2018	Raspbian OS based on Linux is used in raspberry pi for processing the hardware. Code is written in python for identification and detection of the object and its color. Simple CV libraries have allowed enhancing image processing for color of object and for controlling robotic arm for pick and place.	The system relies on color for identification which is a challenge when background is not considered and also light needs to be taken into consideration for precision and accuracy results.	A robot is capable of detecting and placing the pre-specified object. The code for detection of color has been written in Python which is very compatible easy to link with robotic arm control.	A Robotic Arm with Real-Time Image Processing using Raspberry Pi has been designed for fast identification and detection.
A review of semantic segmentation using deep neural networks	(Guo et al., 2018	Use of semantic segmentation which has the ability to segment an unknown image into different parts and objects.	It often occurs that the best methods for a dataset are fine-tuned for only the imagery of a specific situation, place, or context, so the generality is unclear which a challenge is. 2. Determine the amount of data necessary to train the algorithm is a challenge as some require enormous amounts of labeled datasets	1. It can improve computational efficiency. 2. It can improve accuracy by eliminating background noise. 3. It can give both theoretical and deep insights into both how visual systems work and what the limitations are. 4. Having extremely accurate image segmentation would be very beneficial.	Some of the top methods require rather heavy usage of near-supercomputers for the training phase which may not be available in all contexts. The system is now intelligent and better trained to handle new images.

Deep Learning Techniques for Medical Image Segmentation	Hesamian et al., 2019	medical image segmentation and batch normalization	They require a large number of annotated samples to perform the training task. Collecting such huge dataset of annotated cases in medical image processing is often a very tough task and performing the annotation on new images will also be very tedious and expensive.	Deep learning techniques have greatly improved segmentation accuracy thanks to their capability to handle complex conditions.	This survey is focusing more on deep learning techniques applied in the medical segmentation, has a more in- depth look into their structures and methods.
Deep Reinforcement Learning for the Control of Robotic Manipulation : A Focussed Mini-Review	Liu et al., 2021	Deep Reinforcement Learning in Robotic Manipulation Control	The challenges of learning robust and versatile manipulation skills for robots with DRL are still far from being resolved satisfactorily for real-world applications. DRL-based methods are not widely used in real-world robotic manipulation applications due to sampling efficiency and generation, Where more progress is still required.	learning algorithms are safe, reliable and predictable in real scenarios, especially if a move to other applications that require safe and correct behaviors with high confidence, such as surgery or household robots taking care of the elder or the disabled.	Deep Reinforcement Learning algorithms for the Control of Robotic Manipulation for guiding the movements of robotic joints.
Computer Vision Based Robotic Arm Controlled Using Interactive GUI	Intisar et al., 2021	This paper presents a design and implementation of a robotic vision system operated using an interactive Graphical User Interface (GUI) application.	The device also has a few limitations: (i) the robotic arm goes through the required motions even if the object picked up is dropped, and (ii) there is no feedback mechanism for the system apart from being watched over and reported by the user.	The main advantage of the design compared to previous attempts is user-friendly operation and flexibility.	The microcontroller used to control the system can be changed to a Raspberry Pi, allowing all joints of the robotic arm to be manipulated simultaneously. A line of motion camera can be added to the system instead of a webcam, which would allow the workspace to be three-dimensional to two-dimensional.
Research on Face Recognition Based on CNN	Wang & Li, 2018	CNN and python library. Convolutional and down sampled layers of CNN are constructed using the OpenCV convolution function and the down sampling function.	CNN issue of large datasets is the challenge unless if pre-trained is utilized	This article simplifies the CNN model by layering the convolutional and sampling layers together.	The basic principle of multi-layer perceptron MLP is studied to grasp the full connection layer and classification layer in face recognition.

Brain Tumour Segmentation Using Convolutional Neural Network with Tensor Flow	(Malathi & Sinthia, 2019	convolutional neural network for MRI brain tumor segmentation using tensor. segmentation is performed using various tools like MATLAB, LABVIEW, and many others. Python programming has been used .	The proposed work utilizes python programming instead of MAT LAB. Because the features are listed below in order to choose 1. Python code is more compact and readable than MATLAB 2. The python data structure is superior to MATLAB 3. It is an open source and also provides more graphic packages and data sets.	The accurate segmentation helps in clinical diagnostic, it also helps to increase the lifetime of the patient. It helps to perform the segmentation accurately.	Segmentation of brain tumour implemented using CNN architecture based on Python code.
Wound image segmentation using clustering based algorithms	Farmaha & Banaś, 2019)	Usage of neural networks or DNN usage of GPU-parallelized computations to increase speed performance,	High dependence on training data. The heterogeneity of training images affects the allocation of features and segmentation. For better results, more homogeneous images are needed, fixed size and shape segments are needed for autoencoder.	Provides improvement of the results during data accumulation. Autoencoder, as one of the simplest, plays an important role in solving clustering problem and is present as an important part of many methods.	Based on the results it can be stated that neural networks can be used while solving image segmentation problem.
Classification of Ulcer Images Using Convolutional Neural Networks	(Nilsson & Velic, 2018)	The need of rewriting the functions for augmentation, provided in Keras is a challenge.	One issue regarding the implementation of the network includes the drawbacks of Keras. The library has many useful tools and is simple to use, but the structure for building networks does not allow editing of individual building blocks in many cases. The limited data set was the major concern during the study as it affected the results as larger data sets are typically applied for training CNNs.	Increasing the data set could yield better performance for classifying venous leg ulcers. A larger data set also introduces the possibility of including more classes, enabling the classification of other wounds as well.	For future data collection, variations in the images should be taken into consideration such as different lighting, angles, and taking the images from different distances. This would enable the network to recognize the ulcers in a larger variety of settings which could potentially make the network's predictions on images taken from a closer distance are more certain.

Skin Cancer Detection : A Review Using Deep Learning Techniques	Dildar et al., 2021)	This review is focused on ANNs, CNNs, KNNs, and RBFNs for classification of lesion images.	One of the major challenges in neural network-based skin cancer detection techniques is the extensive training that is required, which is a time-consuming process and demands extremely powerful hardware.	CNN gives better results than other types of neural networks when classifying image data because it is more closely related to computer vision than others.	Autonomous full-body photography will automate and speed up the image acquisition phase. For accurate skin cancer detection in dark-skinned people, a neural network must learn to account for skin color and size variations using enough images.
Applied sciences A Systematic Overview of Recent Methods for Non-Contact Chronic Wound Analysis	(Marijanovi, 2020	Create precise 3D models of the segmented wound surface. The system would be able to autonomously detect wounds, record them from multiple views and create precise 3D models of the segmented wound surface.	There is need of high pixel smartphone and RGB-D cameras with high computation power. Contact methods have drawbacks that are easily overcome by non-contact methods like image analysis,	Wound assessment being fast and accurate in order to reduce the possible complications, and therefore shorten the wound healing process.	Due to the improvements in automated wound analysis, the advent of artificial intelligence and the robotic systems can be foreseen. The future development will see the realization of an AI-driven automatic system for wound analysis comprised of robot manipulator with an attached high precision industrial 3D camera and high resolution RGB camera.
Convolutional neural networks for wound detection: the role of artificial intelligence in wound care	Ohura et al., 2019	This study explored whether or not wound segmentation of a diabetic foot ulcer (DFU) and a venous leg ulcer (VLU) by a convolutional neural network (CNN) Methods: CNNs with different algorithms and architectures were prepared. The four architectures were SegNet, LinkNet, U-Net and U-Net with the VGG16 Encoder Pre-Trained on ImageNet (Unet_ VGG16).	CNNs for wound detection showed good segmentation accuracy when using the U-Net_VGG16 architecture. However, in terms of the calculation processing, U-Net was considered to be the most practical.	Best results were obtained with U-Net as it demonstrated the second-highest accuracy in terms of the area under the curve (0.997) and a high specificity (0.943) and sensitivity (0.993), with the highest values obtained with Unet_VGG16.	The U-Net CNN constructed using appropriately supervised data was capable of segmentation with high accuracy. U-Net was also considered to be the most practical architecture and superior to the others in that the segmentation speed was faster than that of Unet_VGG16.

Deep Learning on Wound Segmentation and Classification : A Short Review and Evaluation of Methods Used	Kaswan et al., 2020	Methods used include Convolutional neural networks (CNN), Fully convolutional networks (FCN) and Recurrent neural networks (RNN) and several other architectures have been proposed with AlexNet being the most well-known architecture for classification purposes	Many of the approaches from the literature, requires a huge chunk of labeled wound datasets and some find it difficult or impossible to create such sets. Deep learning also requires a high amount of computational resources to achieve the best accuracy.	The method can be implemented on a mobile platform to assist the patient in their own wound care and surgical recovery from the comfort of their home. Deep learning can be produce results with great accuracy and repeatability.	Recent work suggests that most of the wound segmentation was done on deep learning techniques which have been a good sign. The CNN-Based Segmentation was found to produce compelling evidence that the strategy proposed is more reliable when compared to other research reported, with regards to their method approaches on wound segmentation.

DISCUSSIONS

The study in different reviews had indicated the issue of image identification and classification using different platforms. Image processing has been done using ordinary image processing which proved to work with general images however when it comes to medical images such as ulcer wounds studies have shown that better systems need to be used.in this case, machine learning was introduced to enhance the issue of image analysis and classification. Shortfalls insensitivity, process time, accuracy, and efficiency were still major issues as result this paved way for deep learning where using convolutional neural network (CNN) has been implemented but this did not produce perfect results. This pushed for different architectures such as U-Net, AlexNet, and VGG16 among others have been analyzed to verify the one with better efficiency.

However, medical images are 3 dimensional (3D) and this means architectures for images analysis are still to be verified which can cater for 3D images. Issue of large data sets have been a challenge in spite of that, CNN's ability for pre-training has put it upfront to analysis further for implementation in image processing. For the code for image processing and analysis, from the review, it has shown that python OpenCV is much better than MATLAB. Moreover, a robotic arm with few joints reduces the complexity of the design hence boost power-saving and speed of operation. From many authors' points of view, it is clear that complicated medical images such as bleeding wounds have not been looked at. The issue of implementing deep learning in python needs to be verified since authors have indicated that python in OpenCV is better than MATLAB. The reviewed papers were silent on the issue of control of the monitored conditions of wounds, therefore, there is more study needed to develop a system that shall rely on feedback from monitored bleeding wounds based on deep learning.

CONCLUSION

To conclude the image analysis studies in different reviews have shown great improvements especially in the medical field however, it has shown that there is still a lot to be done to verify amongst the architecture for deep learning, to analyze the issue of datasets and pre-training whilst utilizing python OpenCV. Also to analyze the 3D aspect of the image so that bleeding wounds can be interpreted well in order to get the area and the centroid values so that signals can be generated to guide the robotic arm.

RECOMMENDATIONS

There is still further study needed to develop a control system based on a robotic arm and image analysis system. There is still further study needed to control dispensing of fluid for stopping bleeding through the design of a system based on image analysis feedback whilst guided by the robotic arm. Future study on the robotic arm design which has minimum degrees of freedom (DOF) is much better as this reduces the complexity and response time of the system.

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Transforming Language Education: Opportunities and Challenges of AI

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A B S T R A C T

This study explores the diverse applications of artificial intelligence (AI) in language education and its potential to create more engaging, accessible, and efficient learning environments. A descriptive research methodology is employed in this study to explore the applications and impacts of AI in language education. A comprehensive review of existing literature forms the backbone of the research, allowing for an assessment of various AI-driven technologies and their effectiveness in enhancing learner engagement and language proficiency. Data is collected from a range of sources, including academic journals, case studies, and reports on the implementation of AI in educational settings. With rapid technological advancements, AI has become an integral part of daily life, including the education sector, which has embraced these developments. As AI technologies evolve, their role in education has expanded, introducing innovative approaches to language learning. The integration of AI into language education is transforming traditional teaching and learning methods by offering advanced tools that support and enhance the educational process. This study examines various AI-driven technologies, such as intelligent tutoring systems, language learning applications, and conversational agents, and evaluates their effectiveness in improving learner engagement and language proficiency. In addition to its benefits, the study addresses the challenges and limitations of AI in language instruction. Key issues include accessibility, data privacy concerns, and the irreplaceable value of human interaction in the learning process. While AI provides significant advantages, the findings emphasize that it should be used to complement, rather than replace, traditional teaching methods. Ultimately, AI has the potential to reshape education by enhancing learning experiences, improving accessibility, and increasing efficiency. Neglecting its integration would mean missing significant opportunities for growth and innovation. Therefore, educators and institutions are encouraged to adopt AI responsibly and effectively to maximize its benefits in language education.

Keywords :*AI in Education, AI Tools, AI-driven Technologies, Digital Learning, EdTech, Educational Innovation.*

INTRODUCTION

Envision a classroom environment where educational experiences are uniquely tailored to each learner's individual pace, preferences, and challenges. Thanks to advances in Artificial Intelligence (AI), this is no longer just a vision. AI's systems based on the adaptive approach have significantly reshaped the field of language education by moving from conceptual possibility to practical application. AI refers to the capacity of computer systems to execute tasks traditionally requiring human intelligence [1] [2]. AI in education represents a transformation that combines technology with pedagogy to create more effective learning environments. The integration of AI into language education is revolutionizing how languages are learned and taught. Recent literature reveals several trends and insights regarding AI technologies and their applications in second and foreign language education. AI applications in education support learners' individual learning processes, enhance their motivation, and promote long-term retention [3].

The importance of AI in language education today lies in its transformative power to enrich teaching and learning through personalized, scalable and efficient tools. AI-supported platforms and applications such as Duolingo and Babbel offer content tailored to the individual needs of learners, while tools such as ELSA Speak provide real-time feedback on pronunciation. AI- powered applications can provide both more financially affordable solutions and make language learning accessible to different populations, such as communities in remote locations where there are limited or lack of educators. These innovations make language education more adaptive, interactive and accessible, preparing learners for a globalized world. However, the effective utilization of such tools requires substantial planning and preparation [4]. Beyond its impact, it is crucial to understand how it is implemented and to what purposes it serves, especially in the context of learners' use.

The inclusion of AI in education indeed presents two significant challenges. Firstly, AI is already generating new teaching methods, which are being implemented across various educational levels. Secondly, as noted, we are facing a more radical challenge: the creation of a completely new educational system as a consequence of AI implementation [5]. This transformation requires careful consideration of both the opportunities and the potential disruptions that AI brings to the educational landscape.

Consequently, educators have a lot of responsibility for the integration of AI into education. It is up to educators to develop innovative strategies and integrate technological tools into education, including artificial intelligence, to increase learners' motivation, to support effective learning of the target language. These are not challenges that educators can overcome all by themselves, as they require a great deal of innovation on their part. This study presents a comprehensive literature review to identify key trends and recurring findings in studies examining applications of AI in language education. It aims to contribute to the literature by addressing developments in understanding and using AI-supported language learning and teaching. By analysing a number of recent studies, the paper highlights the transformative potential of AI in enhancing personalized learning, accessibility and efficiency in language education. It also addresses the challenges and ethical considerations associated with AI implementation, providing a comprehensive overview of the current state and future directions of AI in language education.

AI IN LANGUAGE EDUCATION: BRIDGING TECHNOLOGY AND PEDAGOGY

The Birth and Evaluation of Educational AI

The use of artificial intelligence in language education dates to the 1960s when researchers and educators explored the potential impact of computers on education. The first computer-based instruction systems (CBI) paved the way for interactive learning experiences with programmed instructions [6]. In the 1970s and 1980s, the focus shifted to intelligent tutoring systems (ITS) and improvements were recorded in this field [7]. The focus here was to imitate human instructors by giving personalized feedback and guidance to learners. The real advances were made in the 1990s with the introduction of natural language processing (NLP) and machine learning. Early applications of NLP in education led to the development of educational systems that could understand and respond to learner queries in natural language [8]. In the 2000s, adaptive learning and e-learning have made great progress. The widespread availability and accessibility of the internet has led to the rise of online learning platforms that use artificial intelligence to personalize learning experiences. With Adaptive Learning Technologies, some systems have used AI to personalize the content and pace of instruction to the needs of individual learners. Thus, the 2000s was a time of great growth of E-Learning Platforms and Adaptive Learning [8]. In the 2010s, AI-supported tools such as learning analytics, virtual assistants and gamification came into play in the field of education [9]. These new innovations have given a basis for more sophisticated language learning applications, such as automatic essay scoring and speech recognition systems [10]. As a result of these developments and knowledge accumulation over the years, artificial intelligence has become quite popular in language education in recent years. The integration of AI into language education has evolved from simple computational components to sophisticated, adaptive systems that offer learners personalized and interactive experiences.

Finally, the point that AI reached in the field of education in the 2020s has gained a completely different dimension with the introduction of Chat-GPT in 2022. Towards the mid-2020s, there has indeed been a significant shift in AI. As advanced AI applications become more integrated into various aspects of our lives, the ethical issues that currently occupy our minds have also moved to the forefront. However, the successful integration of AI into language education demands a nuanced consideration of ethical issues such as data privacy, equity and fairness, and ensuring that these advanced tools are complementary to, rather than substituting for, the human components of education. As for the disadvantages of productive AI, we can say that concerns have been raised on many issues, as we will try to explain in more detail in the challenges and limitations section.

Shaping the Future of Language Education through AI

Consider a scenario in which learning a new language is as effortless and personalized as having a random conversation with a friend. The integration of AI into education is turning this into a reality. AI-powered tools such as adaptive learning platforms, intelligent tutoring systems and conversational AI are transforming language education by providing dynamic, interactive and personalized learning experiences. They provide real-time feedback, adjust to individual learning speeds and make education accessible to learners in remote areas. As AI continues to progress, it is not only enriching traditional teaching methods but also offering innovative approaches that deeply engage learners and significantly reduce the workload of educators.

In essence, AI builds a transformative bridge between pedagogy and technology in language education. As noted by OpenAI, “Open AI builds its text-generating models by using machine-learning algorithms to process vast amounts of text data, including books, news articles” [11]. Such technological tools provide real-time feedback and create an enriching learning environment by analysing a learner’s individual characteristics such as learning speed and knowledge level. Moreover, AI increases the effectiveness of language learning instruction and makes it more accessible to different population groups in remote areas that would otherwise be difficult to address.

While the generative AI module working in the text field prepares content based on the learner’s interests and learning speed, other modules active in the video and audio fields can personalize the teaching [12]. In today’s educational landscape, as traditional approaches to learning and teaching have lost their effectiveness, new approaches to language teaching have begun to take their place within the possibilities offered by artificial intelligence. Along with the potential to lead to new approaches in language teaching, AI applications also provide language simulation with human conversation in an interactive way that brings the learner more into the learning process [13]. For instance, interacting with an AI tool tailored for a specific purpose that provides instant feedback, can distinguish between correct and incorrect answers, allows foreign language learners to have the possibility of meaningful interactions. Furthermore, as Kohnke also emphasized, such tools can significantly reduce the teacher's workload, such as in answering routine teacher questions, enabling learners to complete tasks without delay and reduce feelings of isolation [14].

The integration of AI into language education has opened a new era of individualized and interactive learning. AI-powered tools have not only increased the efficiency of language education but also made it more accessible to diverse populations. By providing real-time feedback and adjusting content to individual learner needs, AI creates an enriching and engaging educational experience. As AI continues to progress, it offers innovative approaches that benefit both learners and educators, with the promise to further revolutionize education and fundamentally shape the future of learning and teaching. The number of technologies and applications that will reshape language education and link language teaching and AI with new approaches and methodologies is quite large. Even as this study continues, many AI-powered technologies and applications are being added to this list. For this reason, we have limited the AI technologies and applications related to language teaching to ten categories. These can be used interrelatedly or in combinations across categories. This categorization will provide insights into the specific functions and benefits of AI technologies and applications in language education. Before addressing these applications and platforms, however, it would be useful to discuss programs that use adaptive technologies and traditional methods to clarify some points: Adaptive Language Learning Technologies and Traditional Learning Technologies.

Adaptive learning makes use of a variety of advanced technologies to create personalized learning experiences. Algorithms in adaptive technologies are designed to implement individualized learning. Therefore, it would not be correct to claim that every application or computer system we encounter is adaptive. In other words, what we are underlining here is this: Adaptive systems are specifically designed to individualize learning experiences based on user performance, needs and preferences. Adaptive platforms such as Duolingo or Memrise, which are among the most widely used applications, use algorithms to dynamically adjust learning and provide individualized feedback. Whereas traditional AI-powered applications such as Google Translate or Grammarly focus on static functions such as grammar correction or language translation, without tailoring their responses to individual users. Traditional, non-adaptive educational technologies, such as the first Computer Assisted Language Learning (CALL) systems, present a single content, assuming that all users have the same characteristics without taking individual differences into account. The key point of difference lies in adaptability: modern AI platforms can increase engagement and learning outcomes through individualization, while traditional technologies primarily serve more overall, static goals, making the content interactive or effective in meeting individual learning needs.

AI-Powered Communities, Platforms and Applications

AI-powered Adaptive Language Learning Platforms

AI-powered adaptive language learning platforms and applications are designed to personalize the learning experience by analysing learners' progress, their strengths and weaknesses, and providing tailored content and feedback. Adaptive learning platforms harness the power of AI to create dynamic and personalized learning experiences, adjusting content delivery based on individual learner progress and performance, as noted by Russell and Norvig [15]. In recent years, adaptive language learning platforms such as Duolingo, Babbel, Rosetta Stone, Busuu, Memrise, ELSA Speak, Mondly, Talkpal, Loora AI and MakesYouFluent have completely changed the way individuals learn new foreign languages by offering personalized and engaging learning experiences tailored to each learner's individual needs and progress. Choosing between these platforms depends on the user's needs: those looking for a gamified learning experience usually choose Duolingo, while those who want to improve their pronunciation can choose ELSA Speak. For those who like to learn through social interaction, Busuu is an ideal option. The compatibility of adaptive learning with individualization and learner-centred modern education supports its integration into educational environments. The integration of these systems leverages AI to meet the unique needs of each learner in a scalable and efficient way.

Intelligent Tutoring Systems (ITS) in Language Education

All paragraphs must be indented. All paragraphs must be justified, i.e. both left-justified and right-justified. Intelligent Tutoring Systems (ITS) are systems that provide personalized instruction and feedback to learners without human involvement but by imitating humans. They use (AI) to individualize teaching methods and approaches, the content to be learned, and the pace of teaching/learning according to learners' individual needs and capabilities. “Intelligent tutoring systems (ITS) are able to provide a personalized approach to learning by assuming the role of a real teacher/expert who adapts and steers the learning process according to the specific needs of each learner” [16]. ITS consist of four key components, as outlined by Kang & Maciejewski (2000) [17]: (1) Expert Knowledge Module provides the information to be taught, (2) Student Model Module represents dynamically the learner’s competence, (3) Tutoring Module designs and regulates instructional interactions with the learner, (4) User Interface Module controls the interactions between the system and the learner. Concrete examples of ITS in-language education include AutoTutor, which uses Natural Language Processing (NLP) to navigate learners through conversational contexts, and Duolingo, which adjusts the levels of difficulty based on learner performance to ensure that the content corresponds to the learner's skill level. Such systems exemplify the potential of ITS to engage, individualized learning experiences that can greatly increase language learning.

Conversational AI and Chatbots

Conversational AI and chatbots, supported by technologies such as NLP and machine learning, a practical application of this technology, have opened new pathways for language learning by providing learners with interactive, personalized and scalable solutions. Tools such as Duolingo, ChatGPT, Busuu, Replika, Elsa Speak and Microsoft AI-based chatbots fulfil a variety of needs, from grammar and pronunciation to conversational fluency. The important thing is to choose a chatbot that is appropriate for the learner's proficiency level and goals. Language learners are eager to use chatbots, and this preference has been driven by ease of accessibility and a greater sense of comfort [18]. Compared to interactions with human tutors, chatbots allowed learners to practice without fear of being judged or making mistakes. “By leveraging natural language processing and machine learning technologies, conversational AI enables personalized and interactive learning, while also providing assistance to teachers and educators in evaluating students’ work and developing curricula and learning aids” [19]. Shawar highlighted some other benefits of different chatbots in language learning such as learner enjoyment, low language anxiety, endless repetition opportunity and multimodal skills [20]. Chatbots offer several advantages in language learning. A chatbot has unlimited patience and can instantly respond to any requests using natural language. Moreover, chatbots can focus on specific subjects and interests and provide specialized learning experiences without the need for a human tutor or interlocutor [21] [22] [23]. These features help to lower learners' anxiety, encourage willingness to communicate. In the context of language learning, chatbots provide a unique opportunity to practice speaking skills in a low-stress environment, making their content an important tool for learners of all levels.

Language Processing and Translation Tools

Language processing and translation tools offer numerous opportunities for both learners and educators. They have become an inseparable part of modern language education. Translation is itself a highly multifaceted and complex process, with a number of interdependent sub-processes and tasks, each of which involves cognitive, linguistic and technological skills. Alcina highlighted “the relation between translation and the computer began with the development of software for machine translation; the real boom in translation technologies was marked by the development of electronic dictionaries and terminological databases, the arrival of the Internet with numerous possibilities for research and communication, and the emergence of computer-assisted/aided translation (CAT) tools” [24]. AI-supported translation tools such as Google Translate, Replika, DeepL not only provide effective language learning and accessible facilities but also offer a dynamic learning process as in other AI-supported applications and tools. Google Translate is one of the most widely used translation tools for quick translation, which supports more than 100 languages and offers features such as text, speech and image translation [25]. Specialized platforms and applications are preferred in all areas as well as in education. One of these platforms, DeepL, has developed itself quite a lot in this field. “It’s no wonder, then, that enterprise customers are seeking out purpose-built translation platforms that are tailored to their specific needs, that integrate with their tech stacks, and that provide the accuracy, security, and compliance they require” [26]. DeepL's greatest advantage in machine translation is articulated as a direct result of its uniquely specialized Language Artificial Intelligence platform. Through the analyses of thousands of carefully selected and trained language experts, the results are processed for continuous improvement [26]. As technological developments progress, the increasing integration of NLP-supported adaptive translation tools into language education is likely to provide even more innovative solutions for both learners and educators. Language processing and translation tools are transforming language education, making it more available, engaging and relevant for both learners and educators. These tools offer numerous advantages; however, careful implementation and guidance is required to increase their potential while decreasing their limitations.

Speech Recognition and Pronunciation Tools

Speech recognition and pronunciation tools are essential components of language education. These tools utilize AI, machine learning and NLP to improve learners' speaking skills by providing instant feedback, which is one of the most important elements in speech skill development. They provide learners with instant feedback on their speaking skills, helping them improve their pronunciation, fluency and confidence in the target language. Examples such as Speechling, Google Assistant, Duolingo and Rosetta Stone are examples of the effectiveness of these technologies in providing engaging and approachable learning settings. All of the platforms in this area have at least one or more features that make them stand out uniquely. If we discuss a few of them, we analyse their characteristics in the references as follows: Speechling gives individual guidance and feedback on pronunciation, helping students to improve their skills through speaking practice and repetition [27]. Google Assistant is similarly considered as a useful tool for improving pronunciation and speaking skills by offering real-time speech recognition and feedback [28]. In the case of Duolingo, it was mentioned that it uses AI to tailor lessons to student progress and offers features to improve speaking skills while providing a gamified and engaging learning experience. [29]. Rosetta Stone provides learners to practice speaking in real-life situations by using speech recognition to create engaging language learning experiences [30]. These tools perform speech analysis, identify and correct learners' errors and provide feedback, enabling personalized and autonomous learning. Although some problems are encountered, continuous advances in AI and NLP promise even more powerful and inclusive tools in the future, and these tools are becoming an essential component in language teaching.

Content Creation and Curation Tools

Content creation tools are software or platforms that allow educators to create curated learning materials such as quizzes, videos, games and interactive lessons. There are many AI tools that can contribute to both content creation and language teaching. A few of these stand out: ChatGPT, Claude, DALL-E. ChatGPT, developed by OpenAI, which we are all familiar with since 2022, can simulate human-like interactions and perform a wide range of linguistic tasks. In addition to all this, it can create purposeful texts, answer questions in a logical framework, and even create code or visual content [31]. Claude, another chatbot developed by Anthropic, has the ability to interact with humans in the similar way with ChatGPT, in addition to fulfilling the need to produce a variety of different contents [31]. DALL-E is also a tool developed by OpenAI, which generates visual content based on textual information [31].

Content Curation Tools are designed to gather, organize and deliver relevant learning resources from large online data pools specialized to the needs of specific learners or topics. Following is some of the practices to implement to achieve effective language training content curation: Evernote, Feedly, Scoop.it, Wakelet, BBC Languages and Duolingo’s Educator Dashboard. Scoop.it and Wakelet are examples of resource aggregation that help educators to collect articles, videos and language practice materials in an organized way for easy access by learners [32] [33]. BBC Languages and Duolingo's Educator Dashboard are examples of Language Specific Libraries. These libraries bring together language-specific exercises, cultural resources and practice materials for targeted learning outcomes [34]. Leveraging AI tools like ChatGPT, Claude, and DALL-E, as well as content curation platforms like Evernote, Feedly, Scoop.it, and Wakelet, can significantly increase the effectiveness of language education by providing diverse, engaging, and well-organized learning materials tailored to specific educational needs.

Learning Analytics Tools

AI-powered learning analytics tools in language education are a variety of tools designed to improve education through insights based on data obtained from users. Learning analytics tools enable language education to be reshaped by providing insights into learners' performance, engagement in the learning process and progress. Engagement analytics tools analyse learner engagement and motivation, while diagnostic tools provide feedback on specific skills such as grammar or pronunciation. Social and collaborative tools provide analysis results of group interactions, whereas resource utilization tools help to optimize the use of learning material. Emotion analysis tools analyse the learner's emotional reactions. In addition, real-time visualization tools and multimodal analytics combine various data sources for comprehension of the learning process. With these tools, educators can make informed decisions, use data collection, analysis and visualization to help individualize the learning experience and adjust teaching strategies. Examples of AI-supported learning analytics tools in language education include OpenAI's ChatGPT, which generates personalized learning materials; Knewton, a learning platform that tailors its content to individual learner needs; and Duolingo's engagement analytics tools such as Quizlet, which analyses learner results and problem areas in learning [35]. Engagement analytics tools such as Quizlet assess learner engagement and motivation. Diagnostic tools such as Grammarly, which analyses grammar and writing skills and provides goal-oriented feedback [36]. Edmodo is one of the in-group social and collaborative analysis tools; whereas Scoop.it helps educators to organize and optimize learning materials [37]. Replika is also one of the emotion analysis tools and makes evaluations by analyzing students' emotional reactions. Furthermore, real-time visualization tools such as Tableau offer real-time, actionable data analyses. AI-powered learning analysis tools have completely changed language education by utilizing learner data to improve learning outcomes and instructional practices. AI-powered analysis tools provide a deeper understanding of learner needs and challenges.

Gamified Learning Tools

Gamified learning tools engage learners emotionally and cognitively by incorporating game elements such as challenges, competition and reward into the learning process. Such tools highlight the potential of gamification to make language learning more enjoyable, interactive and effective. Duolingo, Quizlet, Kahoot! Mondly, Classcraft, Memrise are some of the applications and platforms that offer gamified learning experiences. Almost all of them have similar features. Duolingo uses gamification techniques such as progress levels, experience points (XP), leaderboards and rewards to motivate learners. Its interactive exercises focus on vocabulary, grammar and pronunciation, making language learning feel like a game [38]. This popular language learning app offers interactive exercises and immediate feedback to develop language skills [39]. Kahoot! is another game-based learning platform that allows educators to create quizzes and interactive lessons by engaging learners through competition and rewards [40]. There is also a wide range of gamified learning platforms. Thanks to these platforms, learners are both motivated and a learning experience is realized in which cognitive and emotional engagement is active.

Virtual Reality (VR) and Augmented Reality (AR) Tools

These tools increase participation by providing learners with the opportunity to experience real-world language use and cultural contexts. VR: Provides an immersive, communicative environment where learners can interact and communicate using the target language. AR: Overlays virtual elements such as text, sounds or images on top of the real-world using devices such as smartphones or AR glasses. Some examples of VR and AR AI tools in language education: Mondly AR, Mondly VR, ImmerseMe (VR), Google Expeditions (AR). Mondly VR app offers language learning experiences by situating users in virtual settings where they have the opportunity to experience conversations with virtual characters. It helps learners improve their speaking and listening skills in a realistic setting [41]. The Mondly AR app brings language learning to life by overlaying digital content into the real world. Virtual items and characters are used for practicing vocabulary and expressions. Another app, ImmerseMe, uses virtual reality to create interactive language learning scenarios. Users can practice real-life conversations in various contexts, such as ordering food at a restaurant or checking into a hotel, enhancing their practical language skills [42]. Google Expeditions is primarily an educational tool, but it includes AR and VR experiences that can be used for language education. It allows students to explore virtual environments and learn vocabulary related to different topics [43].

By incorporating VR and AR AI tools into the education system, learners experience language learning processes in interactive, real-world situations and cultural contexts. These technologies increase engagement, improve communication skills and provide opportunities for effective learning.

Assessment and Feedback Tools

AI-driven assessment and feedback tools have a significant role in language education by providing interactive, individualized and real-time assessments of learners' skills. Conversational AI and chatbots are at the forefront of AI-driven assessment and feedback tools that provide immediate feedback on learners' evaluations. Grammarly, Write & Improve from Cambridge, and once again ChatGPT are some examples of AI Driven Assessment and Feedback Tools. An application can be included in more than one category according to its features and functions. The reason for including ChatGPT in this category is that it provides instant feedback to the learner and allows the learner to evaluate himself/herself by correcting mistakes. Grammarly is included in this category because it provides real-time feedback and assessment of grammar, punctuation and style. It helps learners improve their writing skills by offering suggestions and explanations for corrections [44]. Write & Improve by Cambridge is an AI-powered tool that assesses writing tasks and provides instant feedback. It works just like Grammarly. These tools use Learning Analytic Tools to analyse learner responses. Through the data obtained, they identify learner mistakes and provide corrective responses. The use of these tools not only contributes to the learner's skill development but also allows learners to evaluate themselves. In this way, learners are guided to continuously develop themselves.

CASE STUDIES ON AI-DRIVEN INNOVATIONS IN LANGUAGE EDUCATION

In an age of rapid technological developments, AI, which is at the forefront of these technological developments in the education sector, promises to transform education. The essence of AI's profound potential in education is indeed revolutionizing the education landscape in numerous ways. The series of case studies we examined consist of studies on the transformative potential of AI in academic frameworks worldwide. In the context of language learning, the main AI technologies are mostly machine learning, adaptive learning systems and NLP-based structures. While some of the previous studies we reviewed presented positive results regarding the effectiveness of AI in language education, others addressed its drawbacks such as its applicability and security risks. Chen's study on AI-based feedback tools in education emphasizes that these tools have a very important place in the field of education [45]. Another research explores the latest trend and innovations in educational technology, which highlights the impact and benefits of technologies such as AI, VR and blockchain in enhancing learning experiences and identifies the challenges such as digital literacy [46]. Qiao and Zhao investigated the effectiveness of AI-based language learning tools such as Duolingo in improving speaking skills and self-regulation. According to the results, learners using AI-based tools showed significant improvements in speaking skills and self-regulation compared to those using traditional methods [47]. The application of generative AI such as ChatGPT in educational settings has been proposed: Findings include a more personalized and efficient learning experience for students as well as easier and faster feedback for teachers [48]. A comparative analysis of AI-integrated teaching with traditional teaching methods showed that AI-integrated teaching methods have several advantages over traditional methods. The AI-integrated group showed significant improvements in proficiency and motivation thanks to personalized feedback and interactive learning experiences compared to the traditional group [49]. The advantages and disadvantages of developing four basic language skills (listening, reading, speaking, writing) in foreign language education with ChatGPT were analysed and the following conclusions were obtained [50]: ChatGPT improves listening skills through interactive exercises, although it lacks the naturalness of human intonation. AI's ability to produce a variety of materials and provide immediate feedback significantly helps comprehension in reading skill. ChatGPT facilitates speaking practice through simulated conversations, but the lack of real-time human interaction can limit natural skill development. Learners' writing skills improve significantly with ChatGPT's instant corrections and suggestions, helping them with grammar and style as well. Although ChatGPT is a useful tool for language learning, it is recommended to be used in combination with various other resources such as textbooks, language courses and real communication opportunities to improve foreign language proficiency [51]. Between 2016 and 2019, approximately 200 empirical studies on Data-Driven Learning (DDL) have been published, emphasizing the many advantages of DDL in language learning [51]. In the study carried out by Barrot, it is promoted that the use of AI-driven tools and applications such as Grammarly, which gives automated written corrective feedback, improve learner autonomy and learner accuracy [52]. Similar results were obtained in the experimental study conducted by Han and Sari [53]. They conducted a study with an experimental group and a control group including 75 university students studying English as a Foreign Language (ESL). They found that the experimental group that received both automatic and teacher feedback improved significantly more than the group that received only teacher feedback. Another area of AI is the inclusion of chatbots in the language learning process. In this way, the learning experience can be interactive, engaging, interactive and enjoyable, as well as personalized content. The results of another study suggested that students liked interacting with the system like chatbot [54]. Two other studies on this case emphasized that students enjoy interacting with chatbots and that by interacting with the system, students' feelings of anxiety in communication can be reduced and their desire to communicate can be increased. [55] [56]. It is emphasized that with the help of artificial intelligence, an effective teaching model can be created by combining detailed content, which usually includes the learner model, expert knowledge, rules that identify the errors and misconceptions that learners often make [57]. As a result of their study, Kim et al. obtained positive results regarding the use of chatbots. The artificial intelligence tools that learners used to complete speaking tasks contributed to the improvement of speaking performance in text-based and voice-based conversations. In addition, a comparison was made between these two types, and it was found that voice-based chatbot resulted in higher performance compared to text-based chatbot and face-to-face communication [58].

From enhancing personalized learning to improving administrative efficiency, AI's impact on language education practices opens the door to a future where technology and human expertise come together to create more inclusive, accessible, responsive, effective and individualized educational experiences.

CHALLENGES AND LIMITATIONS

In an era where we cannot keep up with the pace of technology, the integration of AI into education has emerged as an increasingly powerful transformative force that offers innovative and personalized learning experiences. From adaptive learning systems to chatbot-powered language practice, AI promises to reshape how learners acquire foreign languages. However, besides these benefits, there are also significant challenges and limitations that educators, learners and institutions need to consider. “Challenges include ethical concerns about data privacy and consent, ensuring pedagogical quality and validity, and managing learner perception and attitude” [59]. Learners and educators are concerned about the need for AI and AI-powered applications and platforms that raise ethical concerns such as data privacy and algorithmic components. The privacy and security of user data is at the forefront of ethical concerns. AI often requires large amounts of data to operate effectively, which raises concerns about how this data is collected, stored and used. It is crucial to take the necessary measures to ensure that users' data is protected and used ethically [60], [61]. AI-enabled systems can perpetuate and even reinforce existing biases from the data they obtain from users. This can lead to unfair treatment of learners based on their race, gender or socio-economic status. Addressing algorithmic biases so that they cannot be misused is essential to ensure equal learning opportunities for all learners [61]. There is a need for transparency about the algorithms of how AI-enabled technologies make decisions and what data they use and for what purposes. Educators and students need to understand how these systems work and be able to hold them accountable for their decisions about what kind of data they can access [60]. Concerns with the ethical use of AI in education include ensuring that AI tools are used to enhance learning without replacing the critical role of human educators. AI should support and complement human educators, not replace them [62].

Apart from algorithmic and ethical issues, it also raises pedagogical limitations, including the inability of AI to fully emulate the nuanced understanding and creativity of human educators, as well as issues of over-reliance on technology. “AI-based solutions run the risk of not fully grasping the complexity and nuances of language. Especially jokes, word games, and complex structures of the language may not be interpreted correctly by AI, which may lead to erroneous results” [63]. Sharadgah and Sa'di, in their review of studies between 2015-2021 on the use of AI in English language learning and teaching, pointed out gaps in the literature, including inherent issues such as body language, gestures, expressions, emotions, translation, lack of detailed descriptions of instructional materials used for AI-guided learning [64]. These can also include jokes, jokes and difficulties in interpreting complex language structures, which can lead to misunderstandings. Kolchenko emphasized that AI has pedagogical inadequacies, and, in this context, the templates formed as a result of learner-instructor interaction, in which emotional agents also come into play, cannot be adequately created by AI [65]. While most researchers recommend the use of AI tools widely, it is also recommended that they should be used with appropriate instructor guidance [66]. Kessler, on the other hand, also addressed concerns that educators are not yet ready to use AI effectively [67]. In this context, the integration of AI in the field of education requires a transformation in the role of traditional educators.

Furthermore, technical challenges of AI in educational context, such as system reliability and compatibility with existing educational infrastructures, also present limitations and issues, which are barriers to the integration of AI into education. For AI systems to be used effectively in educational environments, they need to be reliable, robust and sustainable. Technical failures or systemic inconsistencies risk disrupting learning and can undermine confidence in AI tools. Ensuring high reliability and minimizing downtime is crucial for the successful adoption of AI in education [68]. Technology breakdowns are common across various technologies, including connectivity issues and program or computer malfunctions [69]: AI technology can fail by providing incorrect answers or there can be challenges related to the limited capabilities of AI systems, where users desire more advanced functionalities from these systems. Among the technological limitations encountered in the use of AI is that many educational institutions do not yet have the necessary infrastructure to support advanced AI technologies such as hardware, software and networking. As a result, upgrading these systems can be costly and time-consuming, which is a significant barrier to AI integration [69] [70]. Another limitation associated with the integration of AI into education is that it requires significant investment in modern software, hardware and qualified staff. These costs can be prohibitive for many institutions, especially in underfunded or rural areas [70]. Another issue is the digital divide. Inequality in access to technology between different regions and socioeconomic groups can even worsen educational inequalities. To prevent the digital divide from widening, it is necessary to ensure equal access to AI tools [69]. It is essential that all of these issues and more are addressed to ensure that the potential of AI in language education is utilized effectively and equitably.

FUTURE DIRECTIONS

This study was compiled by examining recent research. The most used studies were those conducted on teaching English as a foreign language. Future studies can include more languages and research can be conducted. Case studies of concrete applications of AI in language education might be examined. How different educational institutions use AI and their findings can be emphasized. The issue of limitations and concerns regarding AI in foreign language education can be addressed more comprehensively as a separate study topic. Another issue that I realized during the research and literature review, which is only mentioned in a small way in many sources, can be included in comprehensive studies to inform educators about AI. On the other hand, when talking about the integration of AI into education, educational planning should be reshaped by providing a multi-faceted organization such as policy makers and educational programmers who prepare curriculum. Research can be conducted on the effects of AI applications in different geographical regions and cultures. In the context of this research, how AI interacts with local language policies and cultural differences in language teaching can be examined. There is conceptual confusion regarding AI, and there are important points that need to be clarified on this subject. In future studies, concepts related to this subject can be determined and used within this framework. In conclusion, while AI offers a wide range of opportunities in the field of language education through many applications and platforms, the integration of AI into educational environments needs to be carried out by carefully considering various factors.

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