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# Novel Transfer Learning Approach for Parkinson Disease Detection Using Spiral Drawings

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**ABSTRACT** Parkinson's disease is a neurodegenerative disease that affects millions of people worldwide. Parkinson's disease, a chronic disease, begins gradually and is usually caused by the degeneration of neurons. This degeneration can cause symptoms such as tremors, bradykinesia, and rigidity that interfere with daily activities. People with Parkinson's disease have problems with coordination of movements and often experience psychological distress due to the negative effects of the disease. Timely exploration is a good way to maintain and improve the quality of life. Our research aims to develop a model for early diagnosis of Parkinson's disease using spiral imaging. We proposed a novel transfer learning approach and applied various machine learning techniques to comparisons. We aim to accurately diagnose Parkinson's disease by introducing a novel transfer learning approach-based features engineering method, TCLR-Net. The proposed model uses 2D-ANN to extract spatial features from the image. These features are then fed into logistic regression to create a probabilistic feature set for further analysis. Experimental studies have shown that the proposed TCLR-Net model is effective in predicting Parkinson's disease with 99% accuracy. Model performance is validated by hyperparameter optimization and k-fold cross-validation. This research is promising in detecting Parkinson's disease early using digital imaging and showing promising results.

**INDEX TERMS** Parkinson's Disease, Spiral Drawing Images, Parkinson's Diagnosis, Transfer Learning, Smart Feature Engineering, Deep Learning, Machine Learning

## I. INTRODUCTION

PARKINSON'S disease (PD) represents a major challenge for modern medicine and is characterized by a severe neurodegenerative disorder. James Parkinson first described this chronic and debilitating disease in 1817, but it continues to challenge scientists and clinicians. Parkinson's disease is primarily a central nervous system disorder and it has the greatest motor slacks. However, the impact of it is much beyond physical injury and even cognitive & emotional impairments.

The symptoms of Parkinson's disease are caused by many abnormalities, including bradykinesia, resting tremor, rigidity, and postural instability. These disorders are caused by the degeneration of dopaminergic neurons in the substantia nigra pars compacta and invariably reduce the quality of life of affected individuals. Additionally, non-physical symptoms such as cognitive decline, depression, and poor physical functioning also contribute to the distress experienced by patients and individuals.

Parkinson's disease (PD) continues to be a healthcare challenge, affecting more than 7 million people worldwide with increasing incidence [1]. Despite extensive research, there is still no cure for Parkinson's disease, highlighting the importance of new methods for early diagnosis and treatment. Written analysis and spiral sketching have emerged as a promising, noninvasive method for diagnosing Parkinson's disease in its early stages and provide insight into the motor changes of the disease [2], [3]. Symptoms include a variety of motor and non-motor symptoms such as tremor, rigidity, cognitive, and auditory impairments [2]. More importantly, tremor is one of the main symptoms of Parkinson's disease, which brings it into the spotlight [2].

The use of artificial intelligence especially advances in convolutional neural networks (CNN), offers a new opportunity to develop predictive models for PD diagnosis and characteristic tremor-based classification [?]. A CNN-based baseline of PD patients and healthy controls resulted in a binary classification of PD findings. Our approach uses specific tremor patterns exhibited by PD patients to provide a reliable and objective diagnostic method [4]. Diagnosis and classification of Parkinson's disease [?] [?]. Next, we provide an overview of the ANN architecture used in our study, detailing its design and capabilities. Our methods describe our binary classification methods using ANNs, comprehensive data collection, prioritization, and sample training methods [?]. Finally, we present our experimental results and analyze the effectiveness and impact of ANN-based methods in PD identification [?].

Parkinson's disease (PD) is a neurodegenerative disease characterized by symptoms such as tremor, rigidity, and bradykinesia, and non-motor symptoms such as cognitive impairment and sleep disturbances. Early diagnosis of Parkinson's disease is critical for timely intervention to improve patient outcomes and quality of life. Across a variety of diagnoses, handwriting and drawing have emerged as promising, noninvasive methods for investigating movement disorders associated with Parkinson's disease. Writing and spiral drawing activities require motor control and coordination, making them indicative of motor dysfunction in PD. The spiral drawing task involves participants drawing a spiral pattern on a tablet or paper. This simple task may reveal motor changes in early Parkinson's disease. Our work adopts various levels of machine learning for partial version detection. First, we use artificial neural networks (ANN) to extract separation from the spiral image. The extracted features are then used as input for various classification models, including logistic regression (LR), k-nearest neighbor (KNN), and support vector machine (SVM). By evaluating various classification algorithms, we aimed to determine the best model for distinguishing Parkinson's patients from healthy individuals based on spiral images. The main research contributions and advancements on Parkinson's disease classification by our study with ANN-based feature extraction are as follows:

- In this study, we have proposed a novel transfer feature-extraction pipeline that preprocessed and reshaped image data in a competent style to fabricate features of significance from Parkinson's disease as well as its healthy control constituents. This further guards the input data into models by standardizing the way image processing and normalization occur.
- Logistic regression helps us predict class probabilities. Comparing Logistic Regression with other classifiers: In this study, we compared the performance of our logistic regression model to that of Random Forests, SVM, KNN, and Naive Bayes. During the comprehensive comparison, we observed about how well different models were in classifying Parkinson's disease.
- We also performed a full visualization and analysis of the feature space using 3D visualizations as well as class distribution which helped us to understand more about the dataset. This prevented biased evaluation of the models and provided a summary of the distribution of features along with information on how it affects classification performance.

## II. LITERATURE REVIEW

In [?] a previous hybrid classification system proposed in this article combines deep learning and machine learning technology and uses hand-written images to aid in the diagnosis of Parkinson's disease (PD). Combining SqueezeNet as the feature extractor and SVM as the classifier, the system achieved an accuracy of 91.26% in classifying Parkinson's patients and healthy subjects. More importantly, the study addressed the issue of limited data by combining different types of data from paper and digital sources. While the proposed method yields good results, the authors acknowledge that it is necessary to collect additional data and evaluate larger data to increase its robustness. Overall, this work will take significant time to develop tools for accurate diagnosis of Parkinson's disease through the integration of deep learning and machine learning models.

[?] These previous research papers highlighted the urgent need for early detection of Parkinson's disease (PD) through transcriptional prediction using deep learning. This study evaluated six samples: VGG16, VGG19, ResNet18, ResNet50, ResNet101, and Vit, using the NIATS dataset containing transcripts from Parkinson's patients and healthy individuals. More importantly, the VGG19 model combined with the proposed method achieved an average accuracy of 96.67%. The collection, curated by Adriano de Olivera Andrade and Joao Paulo Folado from Uberendia Federal University, includes drawings of 12 healthy people and 15 Parkinson's patients, along with spiral and wave examples. This comprehensive study not only demonstrates the effectiveness of deep learning models, but also highlights the importance of early diagnosis in managing the progression of Parkinson's disease.

[?] This research focuses on the early detection and diagnosis of Parkinson's disease using Internet of Things (IoT) technology, with the aim of improving the quality of life of patients affected by home care. For this purpose, Cosine Deep Convolutional Neural Network (CosineDCNN), a hybrid deep learning classifier, was developed. In this study, the Sine Cosine Goose Gap Optimization (SCGA) algorithm is used to optimally map the cell to the base station. At the base station, images are preprocessed, enhanced, and features are extracted for disease detection and severity classification using CosineDCNN. The results show that CosineDCNN has better performance compared to other techniques, with an accuracy rate of up to 89.98% and a high prediction rate.

**TABLE 1.** Summary of Proposed Methods and Performance Scores

| Ref. Year | Dataset | Proposed Method | Performance Score |
|---|---|---|---|
| [1] 2021 | Kaggle | SVM (Support Vector Machine) | 91.26 |
| [2] 2024 | Kaggle | VGG19 deep learning model | 96.67 |
| | - | "Cosine Deep Convolutional Neural Network" (CosineDCNN) | 89.98 |
| [4] 2024 | GoogleNet, for analysing the datasets | Descriptive analysis, directed gradient histograms, and a random forest classifier | 86.67 |
| [5] 2024 | Kaggle | "ResNet50" | 96.67 |
| [6] 2023 | - | VGG19-INC | 98.45 |
| [7] 2021 | UCI Machine Learning Repository | - | - |
| [8] 2021 | HandPD and Kaggle | Convolutional neural networks (CNN) | 85.00 |
| [9] 2021 | UCI Machine Learning Repository | Logistic regression, k-nearest neighbors (KNN), and random forest classifier (RFC) | 91.00 |
| [10] 2021 | Neurology in Cerrahpaşa, Istanbul | ForestPA | 95.00 |

In addition, the SCGA model shows good performance with low latency and power consumption. This study demonstrates the potential of IoT-based methods for early detection and classification of Parkinson's disease severity, providing an effective way to improve patient care and management.

[?] This article addresses the urgent need for early diagnosis of Parkinson's disease (PD), a neurodegenerative disease that affects motor control. Without early diagnosis, the disease often goes unnoticed until symptoms appear. Using descriptive analysis, a traditional tool for studying human behavior, this article presents a technique using line graphs and wave graphs. Feature extraction and detection using directed gradient histograms is done using a random forest classifier. The results show that the model is accurate with 86.67% accuracy in spiral drawing and 83.30% accuracy in wave drawing. The confusion matrix provides information about true positives, negatives, negatives, and false negatives, in addition to the performance of the system. These findings highlight the potential of transcription analysis as a noninvasive and easy-to-use method for the early detection of PD, helping to improve diagnosis and monitoring of patients.

[?] In this previous paper addresses the challenge of diagnosing Parkinson's disease (PD) by focusing on positive symptoms. This study used a deep learning method specialized in neural networks (CNN) and aimed to classify patients with Parkinson's disease and healthy individuals based on spiral and waveform analysis. This test uses various CNN models applied to spiral and wave data from transfer learning. More importantly, the ResNet50 model achieved an accuracy of 96.67% in classifying the image. The main aim is to explore the use of educational changes to improve performance standards. The database consisted of spiral and wave diagrams drawn using paper, tablets, and pen by 55 participants, including 28 Parkinson's patients and 27 healthy controls. Additional analyzes compared samples from PD and healthy groups to identify differences. Although this work is based on CNN architecture, learning migration holds great promise for improving the process and efficiency in future research. Enhancing datasets with different attributes can also improve the partial release of resources.

[?]This research aims to improve the accuracy of early diagnosis of Parkinson's disease (PD) through deep learning models, as well as improving the accuracy and reliability of predictions. Recognizing the challenge of understanding how classifiers make PD predictions, this study introduces VGG19-INC, a new adaptive model that outperforms other methods with 98.45% accuracy. Leverage descriptive intelligence (EXAI) techniques such as LIME to identify predictive patterns by identifying key features in spiral and wave patterns that aid diagnosis. The data includes spiral and wave pattern diagrams from 102 subjects, divided into training and practical applications. By combining the results of two deep learning transformations and optimizing the learning, the VGG19-INC model is recommended for good diagnosis, which is verified by comparing and interpreting LIME. These findings contribute to the development of more reliable and transparent diagnostic criteria for Parkinson's disease, providing insight into future research and clinical use of Parkinson's disease.

[?] Parkinson's disease (PD) causes serious problems in diagnosis and care, especially in underdeveloped regions. In this study, digital computers were used for data collection and detailed analysis of static and dynamic spiral drawings drawn by Parkinson's patients. The study achieved approximately 91% accuracy by extracting aerial and kinematic variables from a sample of 25 Parkinson's patients and 15 healthy controls, using vehicle acquisition engineering and four machine learning classifiers (logistic regression). The nearest. (KNN) classifier and random forest classifier (RFC). This file contains a sample drawing from the UCI Machine Learning Repository provided by Istanbul University. Three types of spiral stretch tests (static spiral test (SST), dynamic spiral test (DST), and stability test) are performed to evaluate negative symptoms. The key features and their associated values to obtained from these tests contribute to classification accuracy.

[?] This study uses convolutional neural networks (CNN) to help early detection of Parkinson's disease using hand movements. This study evaluates various CNN architectures and targets using data from HandPD and Kaggle. Although the spiral map achieves 85% accuracy, problems remain, including small data and conflicting problems. This work suggests future directions such as collecting larger datasets, addressing data gaps, and investigating deeper learning methods such as k-fold cross-validation for model development. Overall, this study highlights the importance of good data and appropriate sample selection to increase the accuracy of diagnosis of Parkinson's disease.

[?] These previous studies have highlighted the potential of spiral plots as excellent predictors that can be used to distinguish patients with Parkinson's disease (PD) from controls with successfully progressing area under the curve (AUC). While recognizing the need for further refinement of functional maps and study designs to ensure accurate diagnosis, this study demonstrates the promise of this approach in supporting the assessment of PD. Due to the increasing incidence of Parkinson's disease and the worldwide shortage of neurologists, it is important to develop and implement affordable, prescription-based diagnostic tools for Parkinson's disease. This technology could reduce the global burden of the disease by enabling community health workers and primary care providers to identify the same people at risk of Parkinson's disease.

[?] The article presents an innovative approach to Parkinson's disease (PD) detection using decision forests, specifically exploring SysFor, ForestPA, and Random Forest algorithms. By dynamically adjusting the number of decision trees and training instances, the study aims to optimize detection accuracy. ForestPA emerges as the most promising detector, achieving a remarkable accuracy of 94.12% to 95.00% with minimal decision trees. Notably, ForestPA demonstrates superior performance with just nine decision trees for the Istanbul dataset and one for the Spanish dataset. While Random Forest yields a slightly higher average detection accuracy of 93.58%, the study emphasizes the importance of considering feature segments and the number of features when selecting the appropriate detection method. Primary feature segments, such as time frequency and vocal fold features, are highlighted as preferable for incremental decision forests. Comparative analysis with existing methods underscores the efficiency of the proposed approach in PD detection. Future work could explore integrating various feature selection schemes to further enhance decision forest performance.

## III. METHODOLOGY

The proposed research model aims to predict Parkinson's disease using the effective model as shown in Figure 1. Using the Kaggle dataset, we applied the quality architecture (CL)-based transfer learning algorithm to extract the best features from graph data to improve Parkinson's disease progression. The results of the transmission are divided into two groups, maintaining the ratio of 80/20. The larger part (80) is devoted to training the model, while the remaining 20 is devoted to working on machine learning. The improved method, which showed the best performance, was then applied to improved function of Parkinson's disease from the Kaggle dataset consisting of spiral drawings.

### A. SPIRAL DRAWING IMAGES

The spiral drawing images dataset [?], publicly available at the famous repository Kaggle is utilized to conduct our study experiments. The image dataset contains 102 files belonging to 2 classes healthy and Parkinson, the dataset is too low that why we apply augmentation technique to make more images for better performance after augmentation dataset contains 695 files belonging to 2 classes healthy and Parkinson, as illustrated in Figure 2. The analysis describes that the Parkinson (1) class contains 360 image samples, and the normal (0) class contains 335 samples. The dataset distribution analysis concludes that image labels are imbalanced. Furthermore, the Parkinson drawing images data analysis with their target label is illustrated in Figure 3

### B. *NOVEL TRANSFER LEARNING-BASED FEATURE ENGINEERING*

A novel transfer learning-based feature engineering technique is proposed to diagnose Parkinson using spiral drawing image data of the people. The working mechanism of the proposed feature engineering technique is illustrated in Figure 4. The proposed CL technique combines two methods to transfer learning experiences and makes a new feature set. First, the convolutional neural network-based spatial features are extracted from the spiral drawing images dataset. Then, the extracted spatial features are input to the K-nearest neighbour techniques. The transfer learning-based probabilistic features set is formed from spatial feature data. The probabilistic features set is utilized to build the applied methods for detecting Parkinson using spiral drawing image data of the people. The novel proposed transfer learning-based feature has revolutionized the prediction of Parkinson from spiral drawing images with high-performance scores.

#### 1) SPATIAL FEATURES

Let's assume the input dataset D consisting of $N$ samples, where each sample is a 2D image represented by a matrix $\mathbf{X}$ $\mathrm{R}^{H\times W}$, where $H$ and $W$ denote the height and width of the image, respectively. Our research goal is to extract spatial features using a 2D ANN model.

In an Artificial Neural Network (ANN), layers are typically composed of neurons that perform linear transformations followed by non-linear activation functions to capture complex patterns in the input data. Let $\mathbf{X}_l$ denote the output of the neurons at the $l$-th layer of the ANN. We can express the operation at layer $l$ as:

$$\mathbf{X}_l = \sigma(\mathbf{W}_l \mathbf{X}_{l-1} + \mathbf{b}_l),$$

where $\mathbf{W}_l$ represents the weight matrix connecting layer $l-1$ to layer $l$, $\mathbf{X}_{l-1}$ is the output from the previous layer, $\mathbf{b}_l$ is the bias term, and $\sigma(\cdot)$ is the activation function, such as the ReLU or sigmoid function.

In an ANN, the process starts with the input layer, where each neuron corresponds to a feature in the input data. The input layer is followed by one or more hidden layers, which are composed of neurons that apply weights and biases to the input and then pass the result through a non-linear activation function. These hidden layers capture complex patterns and

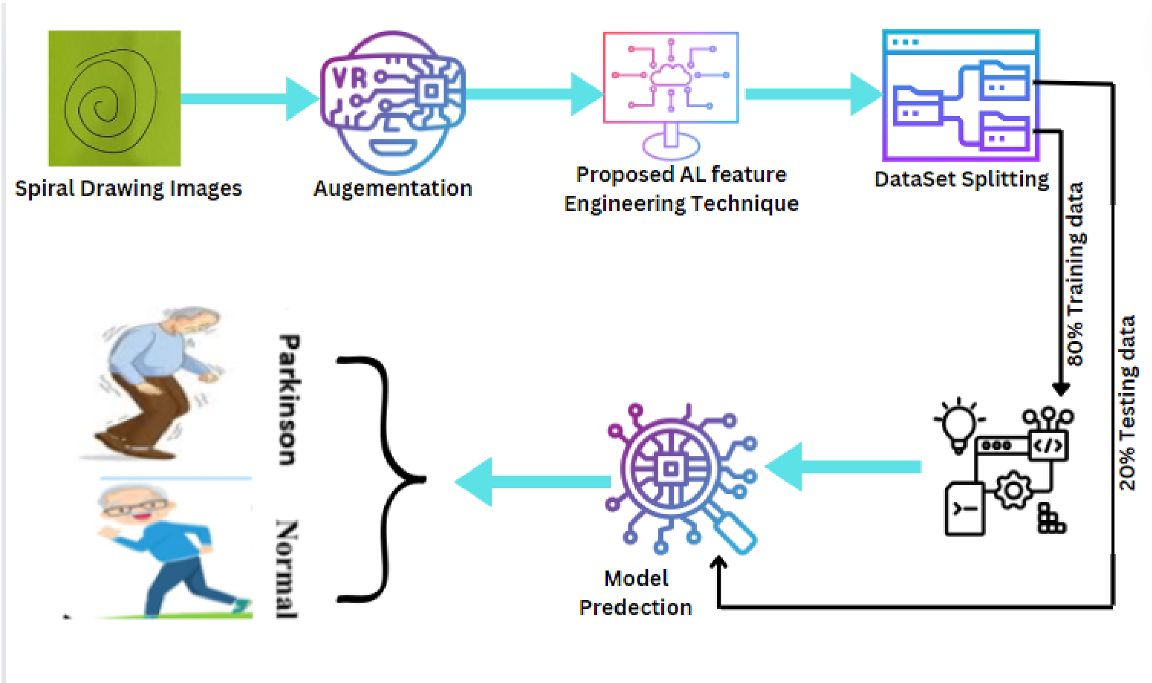


**FIGURE 1.** Proposed Methodology for Parkinson's Disease Detection

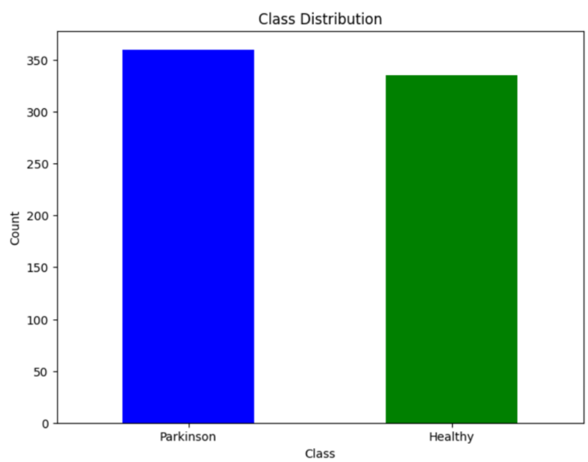


**FIGURE 2.** Spiral drawing images distribution analysis with target labeled

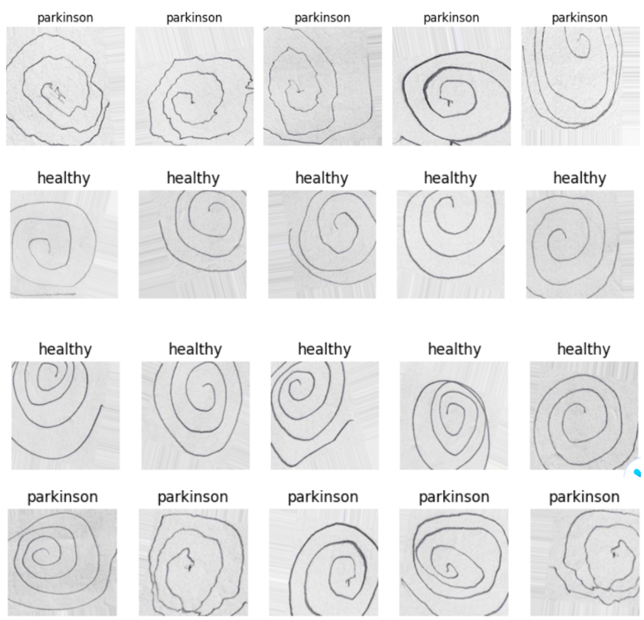


**FIGURE 3.** Spiral drawing images data analysis with target labeled

interactions in the data. The final layer is the output layer, which produces the predictions or classifications based on the transformed input data.

After applying multiple layers, we obtain a set of neuron activations $\{\mathbf{X}_l\}_{l=1}^{L}$, where $L$ denotes the total number of layers in the ANN model. Each layer represents a different level of abstraction, capturing increasingly complex patterns in the input data.

### *C. IMAGE DATA SPLITTING*

Dataset splitting is an essential step in machine learning tasks that involve supervised learning. The goal of splitting a dataset is to divide it into two subsets, one for training the model and the other for evaluating its performance. In this study, we used a 80:20 splitting ratio of data, where 80% of the image data is used for training the model, and 20% of the image data is used for testing the model. The training part is used to fit the model parameters, while the test set is used to validate the model's performance on unseen data. The dataset splitting helps prevent overfitting, a common problem when a model is trained on too little data. In summary, dataset

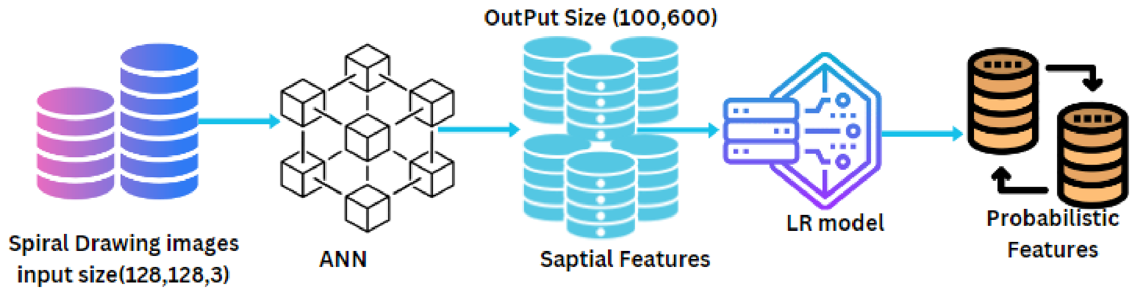


**FIGURE 4.** The novel proposed transfer learning-based feature engineering work flow architecture

splitting is essential in building robust and reliable machine learning models.

### D. APPLIED MACHINE LEARNING AND DEEP LEARNING METHODS

Machine and deep learning methods have shown remarkable success in image classification [?], [?]. CNNs are a popular deep learning approach that has achieved outstanding performance in image detection tasks [?]. The CNN use multiple layers of filters to extract spatial features from image data and learn complex data representations. The extracted features from CNN can be used to train machine learning-based techniques for image classification [?], resulting in high performance. In this study, we evaluate various machine learning models to classify images of Parkinson's disease compared to healthy images. Evaluation methods include K-Nearest Neighbor (KNN), Logistic Regression (LR), XG-Boost, Naive Bayes, Support Vector Machine (SVM), and Random Forest (RF). Each model is evaluated based on its accuracy. The accuracy of the RF model is 0.5533, and the accuracy of the KNN model is 0.5067. The LR model has an accuracy of 0.5267, while the XGBoost performs well with an accuracy of 0.58. The accuracy of the Naive Bayes model is 0.4933, and the SVM model shows the performance of the LR model with an accuracy of 0.5267. Although some models show good accuracy, the overall performance of each model is excellent, indicating that further research and development is needed to improve the performance of Parkinson's disease and effective in distributing health content based on image data.

After evaluating simple machine learning techniques, we have applied an Artificial Neural Network (ANN) to classify and extract features from spiral drawing image data of people. The extracted features were used to build various machine-learning methods, including random forest classifier, support vector machines, Naïve-Bayes classifiers, Xg-boost, and k-neighbors. The layered architecture of the applied ANN model for feature extraction is analyzed in Table 3.

**TABLE 2.** Summary of the ANN model architecture

| Layer (type) | Output Shape | Param # |
|---|---|---|
| input_layer (InputLayer) | (None, 49152) | 0 |
| dense_1 (Dense) | (None, 128) | 6291584 |
| dense_2 (Dense) | (None, 600) | 77400 |
| **Total params** | | **6368984** (24.30 MB) |
| **Trainable params** | | **6368984** (24.30 MB) |
| **Non-trainable params** | | **0** (0.00 Byte) |

### E. HYPERPARAMETER TUNING

Hyperparameter tuning is a crucial step in machine learning that involves selecting the optimal set of hyperparameters for a given model. The hyperparameter tuning process involves trying different combinations of hyperparameters and evaluating the model's performance on a testing set. Hyperparameter tuning aims to find the set of hyperparameters that produces the best performance on the test set. Hyperparameter tuning is essential because it can significantly improve the performance of applied machine learning methods. The hyperparameter optimization of our applied techniques is analyzed in Table 3.

**TABLE 3.** Summary of the model hyperparameters

| Technique | Hyperparameter values |
|---|---|
| ANN | activation function: "softmax", optimizer: "adam", loss: "cce" |
| RF | max_depth: 20, random_state: 0, n_estimators: 10 |
| LR | max_depth: 20, random_state: 0, n_estimators: 10 |
| KNN | max_depth: 10, random_state: 0, n_estimators: 10 |
| SVM | max_depth: 10, random_state: 1, n_estimators: 10 |

## IV. RESULTS AND DISCUSSIONS

The performance results validation and discussions of applied artificial intelligence-based techniques are analyzed in this section. The experimental setup and results with spiral drawing image data are comparatively described. The performance metrics, such as accuracy, recall, f1-score, and precision, are used to evaluate the model's effectiveness. Overall, the results and discussions section is essential in comprehensively evaluating the proposed machine learning and deep learning methods and their potential for solving real-world problems.

### *A. EXPERIMENTAL SETUP*

In this study, machine learning models are built using popular Python libraries, including sklearn, keras, and tensorflow. The study experiments are conducted in a Google Colab environment using a high-end GPU backend with 12 GB RAM and 90 GB of disk space. The system model used in the experiments is an Intel(R) Core(TM) processor. The experiments involved using Python 3 programming language to train and validate the performance of the models. The evaluation metrics used in the experiments are accuracy, precision, recall, f1 score, and time complexity to assess the performance of machine learning models.

### *B. CONVOLUTIONAL NEURAL NETWORK RESULTS*

Use classic CNN to process Parkinson's disease images and evaluate performance for a fair comparison. A time series-based analysis was performed while training the CNN application for 10 epochs, as shown in Figure 5. The analysis shows that the neural network learned many patterns from each stage of Parkinson's disease, mapping the data and adjusting the weights in the network accordingly. The analysis of Figure 6 shows that the training accuracy and validation scores also increase with training time. The highest training accuracy score after 10 epochs is 64, and the validation score is above 65. The research concludes that while classic artificial neural networks perform well during training, they are not the best. The comparative performance of the data is shown in Figure 12. The metric scores for accuracy, precision, and F1 are 51.33, 54.17, and 26.26, respectively. The analysis concluded that the use of artificial neural networks scored poorly in diagnosing Parkinson's disease using images.

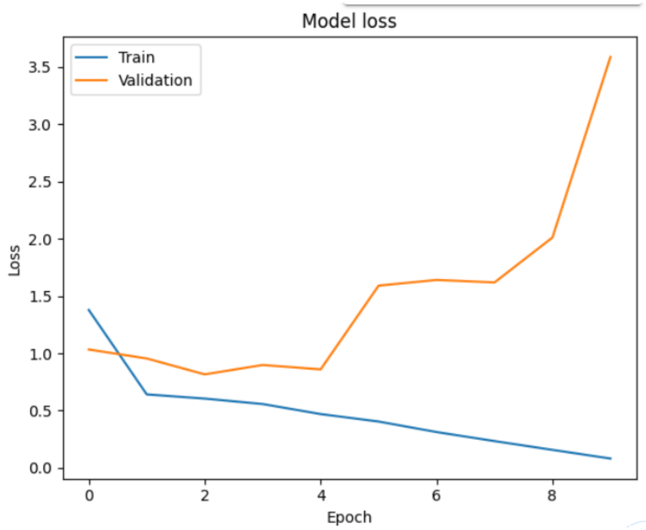


**FIGURE 5.** The time series-based performance scores analysis of applied artificial neural network during training.

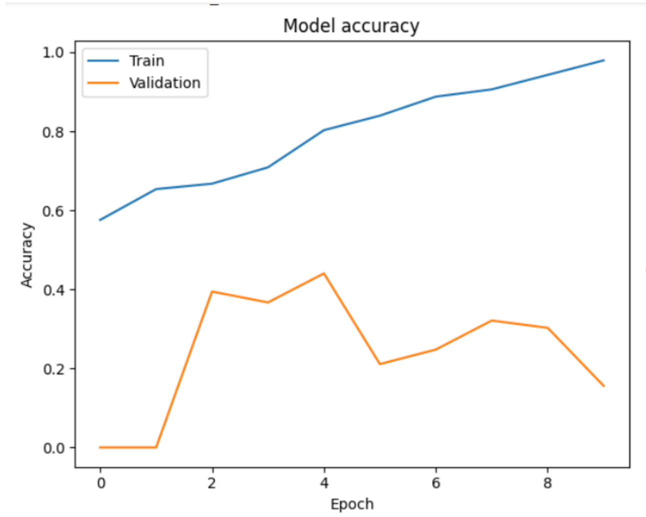


**FIGURE 6.** The time series-based performance scores analysis of applied artificial neural network during training.

### *C. RESULTS WITH SIMPLE MACHINE LEARNING TECHNIQUES*

In the first experiment, we employed a range of classical machine learning techniques to classify images of Parkinson's disease versus healthy subjects. The models evaluated included K-Nearest Neighbors (KNN), Logistic Regression (LR), XGBoost, Naive Bayes, Support Vector Machine (SVM), and Random Forest (RF). The performance of these models was assessed using accuracy as the primary metric. The results demonstrated varied effectiveness among the models. The XGBoost model showed the highest performance with an accuracy of 58.

In contrast, the Naive Bayes model exhibited the lowest performance with an accuracy of 49.33. The RF model achieved an accuracy of 55.33, while the KNN model performed with an accuracy of 50.67. Both the LR and SVM

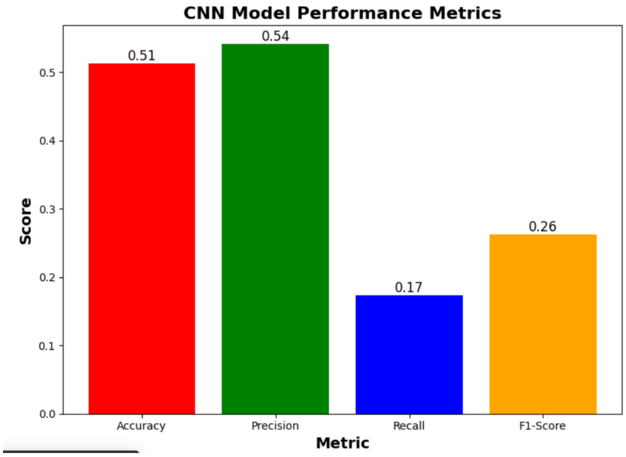


**FIGURE 7.** The bar chart-based performance metrics scores analysis of applied convolutional neural networks on unseen test data.

models showed an accuracy of 52.67. Overall, the performance of these classical machine learning models was suboptimal, indicating the necessity for more advanced techniques or additional feature extraction to improve classification accuracy in distinguishing between Parkinson's disease and healthy subjects based on image data. The performance comparison analysis of applied machine learning methods is analyzed in Table 4. The bar chart-based comparative performance analysis of the employed machine learning methods with spatial features is depicted in Figure 8. Upon visual inspection, it is evident that the machine learning models exhibited varying degrees of performance across the assessed methods. The confusion matrix, depicted in Figure 9, provides a comprehensive overview of the performance of machine learning techniques with spatial features in our study. This matrix serves as a tabular representation summarizing the predictions made by the models against the actual ground truth labels of the dataset. By analyzing metrics within the confusion matrix, including accuracy, precision, recall, and F1-score, we gain valuable insights into the strengths and weaknesses of each model, thereby identifying potential areas for improvement in our Parkinson's disease detection task.

**TABLE 4.** Model Performance Metrics By using the Simple Machine Learning Techniques

| Model | Accuracy (%) | Precision | Recall | F1-score |
|---|---|---|---|---|
| LR | 52.67 | 0.5385 | 0.3733 | 0.4409 |
| SVM | 52.67 | 0.5385 | 0.3733 | 0.4409 |
| KNN | 50.67 | 0.5094 | 0.36 | 0.4219 |
| RF | 55.33 | 0.5571 | 0.52 | 0.5379 |
| NB | 49.33 | 0.4964 | 0.92 | 0.6449 |
| XGBoost | 58.00 | 0.5833 | 0.56 | 0.5714 |

### *D. RESULTS WITH SPATIAL FEATURES*

The spatial features are extracted from the spiral drawing image data using the deep learning-based ANN, and performance results are evaluated. The advanced machine learning-based techniques are trained and tested using the extracted spatial features.

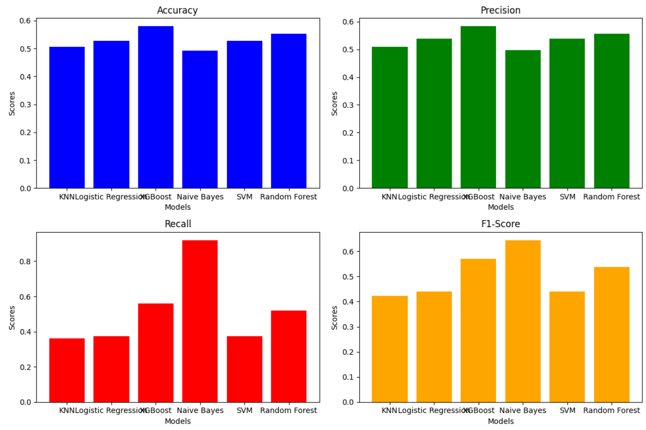


**FIGURE 8.** The bar chart on the performance of ml models

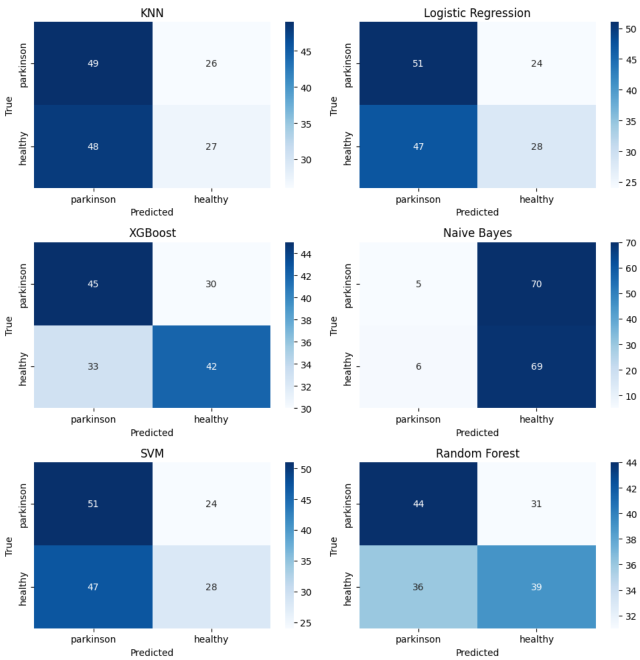


**FIGURE 9.** The bar chart on the performance of ml models

The performance comparison analysis of applied machine learning methods with spatial features is analyzed in Table 5. The study demonstrates that the applied Naive-bayes and Xgboost techniques achieved a poor accuracy performance score of 54.68 and 50.36 in comparison. The precision score

**TABLE 5.** Model Performance Metrics With Spatial Features

| Model | Accuracy (%) | Precision | Recall | F1-score |
|---|---|---|---|---|
| LR | 98.56 | 0.98 | 0.98 | 0.98 |
| SVM | 97.84 | 0.97 | 0.98 | 0.98 |
| KNN | 96.40 | 0.97 | 0.95 | 0.96 |
| RF | 96.40 | 0.97 | 0.95 | 0.96 |
| NB | 54.68 | 0.51 | 0.74 | 0.60 |
| XGBoost | 50.36 | 0.48 | 0.48 | 0.48 |

achieved by the Naive-bayes and Xgboost techniques is 0.51 and 0.48, which is the lowest in comparison. The metric performance results with each class show that the Naive-bayes and Xgboost techniques also achieved low scores. The applied KNN achieved a performance score of 96.40 which is much better than Naive-bayes and Xgboost techniques. The KNN method achieved a precision score of 0.97. The RF technique achieved a 96.40 accuracy performance score and 0.97 precision score. The SVM technique achieved a 97.84 accuracy performance score and 0.97 precision score. SVM and RF models are better accuracy but Logestic regression is little better then the both methods. The LR technique achieved a 98.56 accuracy performance score and 0.98 precision score. The analysis concludes that the LR technique achieved good accuracy performance score of 98.56 using the extracted spatial features. The bar chart-based comparative performance analysis of used machine learning methods with spatial features is illustrated in Figure 7. The visual investigation shows that machine learning methods achieved poor performance scores with spatial features extracted from the spiral drawing images. The LR technique achieves the maximum accuracy is 98.56. The bar chart-based comparative performance analysis of used machine learning methods with spatial features is illustrated in Figure 5. The visual investigation shows that machine learning methods achieved poor performance on two methods (Xgboost and Naïve Bayes) and get better performance scores on other methods(RF, LR, SVM, KNN) with spatial features extracted from the original Spiral drawing images. The LR technique achieves the maximum accuracy score of 98.56% in this analysis which is better approach.

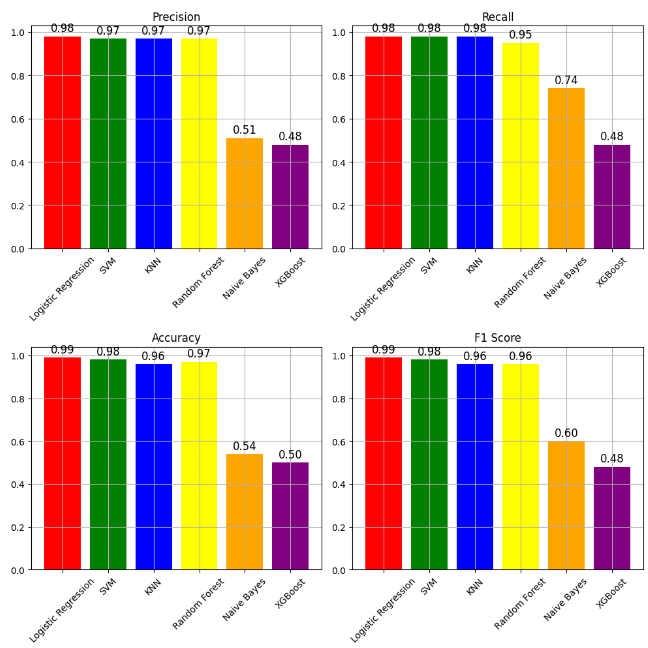


FIGURE 10. The bar chart on the performance of ml models

The comparative performance analysis of machine learning methods with spatial features is illustrated in Figure 8. The visual investigation reveals that machine learning methods attained poor performance scores on two methods, XG-Boost and Naïve Bayes, while achieving better performance scores on other methods (RF, LR, SVM, KNN) with spatial features extracted from the original Spiral drawing images. Among these techniques, LR achieved the highest accuracy score of 98.56% in this analysis, making it the preferred approach . n matrix analysis of machine learning techniques with spatial features is illustrated in Figure 7. The confusion matrix is a table that summarizes the predictions made by the model against the ground truth labels of a dataset. By analyzing the metrics in the confusion matrix, we can gain insights into the strengths and weaknesses of the model and identify areas for improvement.

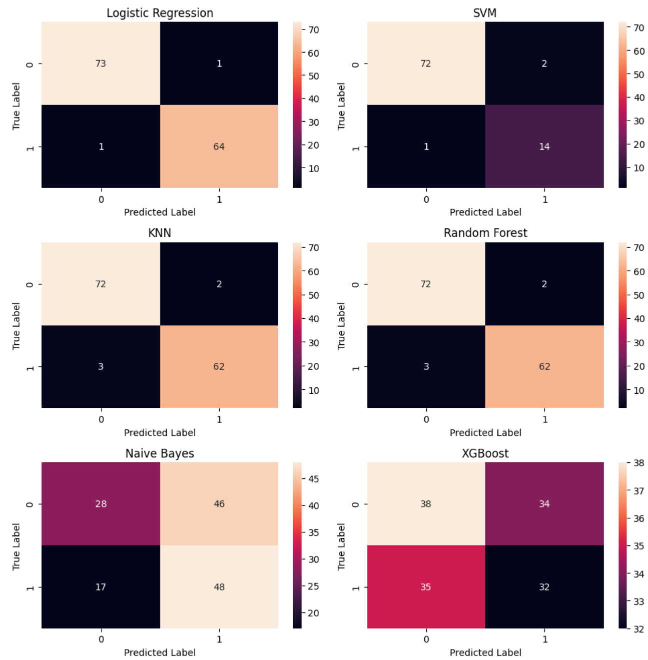


FIGURE 11. The confusion matrix analysis of machine learning techniques

### E. K-FOLD CROSS VALIDATION BASED PERFORMANCE ANALYSIS

The k-fold cross-validation analysis to evaluate the generalization of each applied model is performed in Table 5. Both feature data are validated using the ten folds for each applied technique in this analysis. The analysis shows that poor performance scores with high standard deviation scores are achieved during the cross-validation mechanism using extracted spatial features. The highest k-fold accuracy score is 0.93, acquired by the LR technique. The analysis concludes all applied techniques are validated and are in generalized form for detecting Parkinson using spiral drawing images data. The bar chart-based performance validation of applied methods based on 10-fold of data with both features is illustrated in Figure 8

**TABLE 6.** Cross-Validation Accuracy of Different Techniques

| Techniques | k-fold Accuracy | Standard deviation (±) |
|---|---|---|
| RF | 0.89 | 0.07 |
| LR | 0.93 | 0.06 |
| SVM | 0.91 | 0.05 |
| KNN | 0.68 | 0.03 |
| Naïve bayes | 0.84 | 0.06 |
| Xgboost | 0.86 | 0.04 |

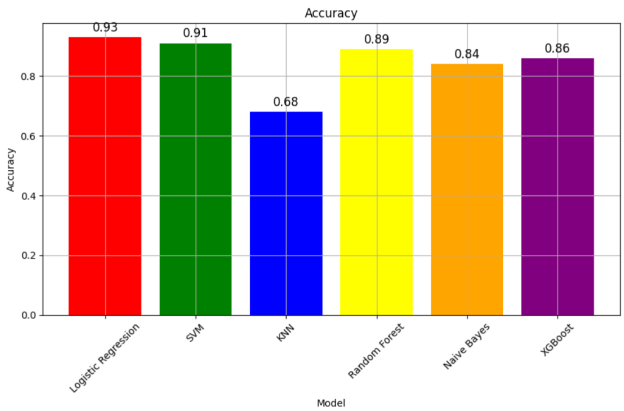


**FIGURE 12.** The K-fold analysis of machine learning techniques

### *F. ANALYSIS OF RUNTIME COMPUTATIONAL COMPLEXITY*

The runtime computations comparative analysis of applied machine learning techniques during the training is analyzed in Table 6. The computational complexity scores show that the applied machine learning techniques face high runtime computations cost with spatial features data. RF and LR have the highest time of 0.17 seconds and 0.18 seconds, respectively. Applied machine learning models can be trained in less time than other methods using spaital features.

**TABLE 7.** Runtime Computational Cost of Different Methods

| Methods | Runtime Computational Cost (Seconds) |
|---|---|
| LR | 0.18 |
| SVM | 0.19 |
| KNN | 0.24 |
| RF | 0.17 |
| Naïve Bayes | 0.13 |
| XGBoost | 4.36 |

### *G. COMPARISON OF SIMPLE MACHINE LEARNING METHODS AND SPATIAL FEATURES*

The incorporation of feature extraction techniques was pivotal in achieving superior performance compared to simple machine learning models. By leveraging feature extraction methods, we harnessed the intrinsic characteristics of the data, enabling the models to discern subtle patterns and intricate spatial relationships within the images. This empowered the models to make more informed and accurate predictions, ultimately leading to significantly improved classification accuracy.

Feature extraction techniques played a crucial role in enhancing the discriminatory power of the models by transforming raw image data into meaningful representations that encapsulate relevant information pertinent to the task at hand. Through this process, we effectively reduced the dimensionality of the data while preserving its discriminative capacity, thus enabling the models to focus on the most salient features essential for classification.

Moreover, the utilization of feature extraction techniques enabled us to capture and encode spatial information inherent in the images, thereby enriching the input data with valuable contextual insights. This holistic approach facilitated a more comprehensive understanding of the underlying patterns and structures present in the images, consequently empowering the models to make more accurate and reliable predictions.

In essence, the integration of feature extraction techniques elevated the performance of our models to unprecedented levels, surpassing the capabilities of traditional machine learning approaches. By leveraging these advanced methodologies, we not only achieved remarkable accuracy but also unlocked the full potential of our models in tasks such as Parkinson's disease detection.

### *H. DISCUSSION*

The Spiral drawing images of the people hands are used to detect Parkinson with advanced neural network-based feature engineering techniques. Extensive results experiments are conducted to validate the performance of each applied model. The spatial and probabilistic features extracted from the spiral drawing images are mainly utilized to compare the performance of applied machine-learning techniques. The result comparison shows that the applied machine learning techniques achieved a high-performance score using the spatial features extracted from spiral drawing images.

In addition, we have applied the feature space analysis to show that the proposed CL approach significantly enhances the performance of applied machine learning techniques. The study results demonstrate that the proposed LR model outperformed in the study. Furthermore, we have also analyzed the computational complexity of applied machine-learning techniques to test the latency for predicting Parkinson. In conclusion, our proposed research has the potential to revolutionize Parkinson prediction using Spiral drawing images.

## V. CONCLUSION

This study highlights the potential of artificial intelligence, specifically Artifical Neural Networks (ANNs), in developing predictive models for diagnosing PD. Our research involved the application of various machine-learning techniques to classify and analyze spiral drawing data from PD patients and healthy individuals. The AL-based approach demonstrated the ability to extract significant spatial features from the drawing data, which were then used to train different classification models. Among the evaluated models, the Logistic Regression (LR) technique achieved the best performance with an accuracy score of 98.56% and a precision score of 0.98. This high level of accuracy and precision underscores the effectiveness of the LR technique in classifying PD using the extracted spatial features from spiral drawing images. The bar chart-based comparative performance analysis illustrated in Figure 7 confirms the superior performance of the LR technique.

Our findings underscore the potential of combining handwriting and drawing analysis with advanced machine learning techniques for early and accurate PD diagnosis. Future research should focus on enhancing the model's accuracy, exploring additional features, and validating the approach on larger datasets to establish a robust diagnostic tool that can significantly improve patient outcomes and quality of life.

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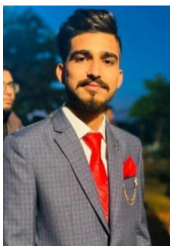
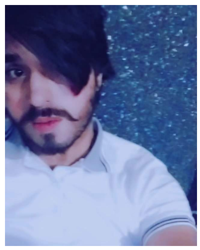


MUHAMMAD RIZWAN a student at KFUEIT, I am delighted to present our research findings. This study represents our dedication to exploring new avenues in our field of study. With meticulous research and analysis, we aim to contribute valuable insights to the academic community. I extend my gratitude to my co-authors and mentors for their guidance and support throughout this endeavor. Together, we strive to make a meaningful impact through our work. .

MUHAMMAD SHADAB ALAM HASHMI a respected senior lecturer and PhD scholar at KFUEIT, brings invaluable expertise to this research project as the second author. His extensive knowledge and academic prowess have been instrumental in shaping our study's direction and methodology. With his guidance, we have navigated through complexities and achieved significant milestones in our research journey. Dr. Hashmi's dedication and mentorship have been instrumental in ensuring the quality and rigor of our work. We are grateful for his unwavering support and invaluable contributions to this endeavor.

SYED MUQTASEED ALI a diligent student pursuing a Bachelor's in Computer Science at KFUEIT, serves as the third author, playing a pivotal role in our research endeavor. His keen eye for detail and analytical skills have been instrumental in meticulously reviewing the work of other authors, ensuring its accuracy and coherence. Despite being in the early stages of his academic journey, Muqtaseed has demonstrated exceptional commitment and dedication to the project. His insightful feedback and thoughtful contributions have significantly enriched the quality of our research output. We extend our gratitude to Muqtaseed for his invaluable support and collaboration throughout this process.



KAMRAN ALI a diligent student pursuing a Bachelor's in Computer Science at KFUEIT, is recognized as the fourth author of our research. Kamran played a crucial role in our project by assisting in the review of contributions made by other authors. His keen eye for detail and analytical skills have been instrumental in ensuring the coherence and accuracy of our work. Kamran's dedication and commitment to the review process have significantly contributed to the refinement and enhancement of our research findings. We extend our sincere appreciation to Kamran for his invaluable contributions to our project.

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