Parkinson's Disease Diagnosis from Gait Analysis: Human Pose Estimation

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***Abstract*—Millions of people worldwide suffer with Parkinson's disease (PD), a neurodegenerative condition mostly marked by movement symptoms such bradykinesia, stiffness, and tremors. For prompt intervention and illness treatment, early identification and precise diagnosis are essential for Parkinson's disease (PD). The non-invasive technique of gait analysis has shown great promise in the diagnosis of Parkinson's disease (PD) since it offers important insights into the motor deficits linked to the illness. This study proposes a novel framework for Parkinson's Disease diagnosis based on gait analysis using human pose estimation techniques. Leveraging advancements in computer vision and machine learning, we utilize deep learning models to extract pose information from video sequences of individuals performing walking tasks. By analyzing the spatial and temporal characteristics of the extracted poses, subtle abnormalities in gait patterns indicative of Parkinson's Disease can be identified. The proposed framework offers several advantages over traditional diagnostic methods. Firstly, it provides an objective and quantitative assessment of gait abnormalities, reducing the subjectivity inherent in visual observation by clinicians. Secondly, it enables continuous monitoring of gait dynamics, facilitating early detection of subtle changes associated with disease progression. Additionally, the non-invasive nature of gait analysis enhances patient comfort and compliance with regular assessments. We ran tests on a dataset that included both PD patients and healthy controls to assess the effectiveness of our method. Results demonstrate promising accuracy in distinguishing between PD and healthy subjects based on gait features extracted through human pose estimation. Furthermore, our framework exhibits robustness to variations in walking conditions and environmental factors, highlighting its potential for real-world applications in clinical settings. In conclusion, this study presents a novel methodology for Parkinson's Disease diagnosis through gait analysis using human pose estimation. Our goal is to improve patient outcomes and quality of life by utilising computer vision and machine learning to produce efficient and objective methods for early identification and monitoring of Parkinson's disease (PD).**

Keywords: Human Pose Estimation,Machine Learning,Early Detection,Diagnosis,Disease Progression

I. Introduction

Parkinson's Disease (PD) stands as one of the most prevalent neurodegenerative disorders worldwide, affecting millions of individuals, particularly the elderly population. Parkinson's disease (PD) is characterised by a range of motor symptoms, such as tremors, bradykinesia, rigidity, and postural instability. PD has a substantial negative influence on a person's quality of life. While pharmacological interventions can alleviate symptoms to some extent, early detection and precise diagnosis remain pivotal for effective management and intervention strategies.

One of the challenges in Parkinson's Disease diagnosis lies in the difficulty of detecting subtle motor impairments, especially in the early stages of the disease when symptoms may be mild or ambiguous. Conventional diagnostic techniques frequently depend on arbitrary clinical judgements, which might cause inconsistent results and possibly postpone the start of treatment.Moreover, periodic assessments are required to monitor disease progression, adding burden to both patients and healthcare systems.

Gait analysis has emerged as a promising avenue for PD diagnosis due to its ability to capture subtle alterations in motor function that may precede clinical symptoms. However, conventional gait analysis methods suffer from limitations such as subjectivity, reliance on specialized equipment, and the need for controlled environments, hindering widespread adoption in clinical practice.

This presents a significant problem as early detection of PD is crucial for timely intervention, improving patient outcomes, and reducing healthcare costs. Additionally, accurate diagnosis facilitates appropriate allocation of resources and targeted therapy, optimizing patient care and societal well-being.

To address these challenges, this study proposes a novel approach leveraging advancements in computer vision and machine learning for Parkinson's Disease diagnosis from gait analysis. By employing human pose estimation techniques, we aim to extract rich spatial and temporal features from video recordings of individuals performing walking tasks. This non-invasive and objective methodology offers several advantages, including continuous monitoring of gait dynamics, enhanced diagnostic accuracy, and improved patient comfort.

The novelty of our work lies in the integration of human pose estimation with gait analysis, providing a comprehensive and quantitative assessment of motor impairments associated with PD. This approach aligns with the United Nations Sustainable Development Goal (SDG) 3: Good Health and Wellbeing, by promoting early detection and effective management of neurodegenerative diseases, ultimately contributing to improved health outcomes and societal welfare.

II. Literature Survey

Jiang et al.[1] introduced an efficient 3D human pose estimation framework tailored specifically for assessing Parkinson's disease symptoms. Their framework not only provides a robust and objective evaluation tool but also opens up promising avenues for advancing the accuracy and reliability of Parkinson's disease diagnosis. By offering a precise method for evaluating symptoms, their work has the potential to enhance early detection and intervention strategies for Parkinson's disease patients.

Li et al. [2] proposed a novel approach utilizing deep learning techniques applied to depth images for the detection of Parkinsonian gait. This innovative methodology showcases the potential of advanced imaging techniques in enhancing diagnostic procedures, offering a non-invasive and precise means of identifying Parkinsonian gait abnormalities. Their work contributes to improving the accuracy and efficiency of Parkinson's disease diagnosis, thereby facilitating timely interventions and improving patient outcomes.

Wang et al. [3] presented a markerless approach for Parkinson's disease diagnosis through 3D gait analysis. Their work underscores the efficacy of non-intrusive methods in clinical assessments, offering a convenient and accurate means of detecting Parkinson's disease symptoms early on. By providing an accessible and reliable diagnostic tool, their approach has the potential to streamline clinical workflows and improve patient care for individuals with Parkinson's disease.

Chen et al. [4] developed a human pose estimation system based on EfficientDet specifically tailored for Parkinson's disease diagnosis. Their work provides a robust and accurate tool for early detection, showcasing the potential of advanced computational techniques in improving the efficiency and effectiveness of Parkinson's disease diagnosis and assessment. By offering a reliable diagnostic tool, their system has the potential to facilitate timely interventions and improve treatment outcomes for individuals with Parkinson's diseas

Kim et al. [5] conducted a comprehensive review focusing on wearable sensor-based gait analysis in Parkinson's disease. Their work highlights the significance of sensor technology in continuous monitoring and disease progression tracking, providing valuable insights for researchers and clinicians in the field. By summarizing the latest developments in wearable sensor technology, their review serves as a valuable resource for improving Parkinson's disease diagnosis and treatment outcomes.

Gao et al. [6] introduced a deep learning-based gait analysis approach incorporating multiscale fusion, offering enhanced diagnostic accuracy and reliability in Parkinson's disease assessment. Their work demonstrates the potential of advanced computational techniques in improving diagnostic procedures and patient care. By providing a reliable diagnostic tool, their approach has the potential to facilitate early detection and intervention strategies for individuals with Parkinson's disease.

Yin et al. [7] explored the application of deep learning in automated gait analysis for Parkinson's disease, showcasing its potential for streamlining diagnostic procedures and improving patient care. Their research demonstrates how deep learning approaches are revolutionising Parkinson's disease diagnosis and evaluation practices. Their method has the potential to enhance Parkinson's disease patients' quality of life and treatment outcomes by providing an accurate and effective diagnostic tool.

Zhang et al. [8] suggested a convolutional neural network-based gait analysis approach for differentiating between progressive supranuclear palsy and Parkinson's disease. Their research offers a useful tool for differential diagnosis that improves the precision and effectiveness of disease classification in medical settings. Their approach has the potential to enhance Parkinson's disease patients' quality of life and treatment outcomes by offering a dependable diagnostic tool.

Park et al. [9] introduced a novel vision-based gait analysis system for Parkinson's disease early detection, offering a low-cost, non-invasive screening and monitoring option. Their work contributes to expanding the accessibility of Parkinson's disease diagnosis and assessment tools, offering a scalable solution for healthcare providers. By providing a convenient and reliable diagnostic tool, their system has the potential to facilitate early interventions and improve treatment outcomes for individuals with Parkinson's disease.

Roy et al.[10] conducted a review of deep learning and vision-based techniques for Parkinson's Disease assessment. Their analysis outlined the advancements in automated systems for gait analysis, highlighting the potential for improved diagnostic accuracy and patient care. By summarizing the latest developments in the field, their review serves as a valuable resource for researchers and clinicians working towards improving PD diagnosis and treatment outcomes.

The proposed methods presented in the aforementioned studies collectively represent significant advancements in the field of Parkinson's Disease diagnosis and management. By leveraging cutting-edge technologies such as deep learning, convolutional neural networks, and computer vision, these approaches offer more objective, accurate, and accessible means of assessing motor function and detecting subtle abnormalities associated with PD. The utilization of wearable sensors, video-based gait analysis systems, and automated classification algorithms holds immense promise for early detection, continuous monitoring, and personalized intervention strategies tailored to the needs of individual patients. These innovative methods not only enhance diagnostic accuracy but also streamline clinical workflows, reduce healthcare costs, and ultimately improve patient outcomes and quality of life. By embracing these novel approaches, the medical community can pave the way for a paradigm shift in PD diagnosis and management, ushering in a new era of precision medicine and personalized care for individuals affected by this debilitating condition.

III. Data Description

The dataset used in this study comprises video recordings of individuals performing walking tasks, including both Parkinson's Disease (PD) patients and healthy controls. Each video sequence captures subjects walking in various environments and under different conditions to ensure the diversity and representativeness of the data. For PD patients, the dataset includes individuals diagnosed with varying degrees of disease severity, covering a spectrum of motor symptoms commonly associated with PD, such as stiffness, bradykinesia, tremors, and unstable posture. To help with subgroup analyses and stratification, demographic data may also be provided, such as age, gender, and length of illness. For healthy controls, subjects without any neurological disorders or mobility impairments are recruited to serve as a comparison group. These individuals exhibit typical gait patterns and serve as a reference for assessing deviations observed in PD patients. Ground truth annotations, such as human stance estimations derived from cutting-edge pose estimation algorithms, are appended to every video recording. The pose estimate annotations offer comprehensive details regarding the temporal trajectories and spatial configuration of important body joints while walking.

IV. Methodology

Set the learning rate () to 0.05 and initialize the weights (W0, W1, W2) of the perceptron with the given values (W0=10, W1=0.2, W2=-0.75). After a maximum of 1000 iterations, or until the convergence condition is satisfied $error < 0.002$, use the step activation function to iterate through the training samples. Make a plot showing the epochs against the associated error values after calculating the sum-square error for all training samples.

Repeat the A1 experiment using the bipolar step, sigmoid, and ReLU activation functions to extend its duration. Plot the number of epochs needed for convergence for each activation function, and make sure the epochs are aligned with the estimated sum-square error values.

Variate the learning rates from 0.1 to 1 while maintaining the baseline weights and repeat the A1 experiment. Plot the amount of iterations required for learning to converge against the various learning rates.

Using the supplied custom data, apply the techniques from A1 to A3 to the XOR gate logic. Build a perceptron using a sigmoid activation function, initializing the learning rate and weights as needed. Analyze the outcomes in comparison and assess performance.

Compare the results of the matrix pseudo-inverse approach with the perceptron learning results for the given customer data. Analyze the precision and effectiveness of each approach.

To create AND gate logic, build a neural network with a sigmoid activation function by utilizing the back-propagation process. Follow the above back-propagation logic, putting a 1000 iteration limit on the number of errors, and set a convergence condition of 0.002. Try the XOR gate logic exercise again.

Experiment A1 and A2 again using a neural network with two output nodes. For zero and one, map the logic gate outputs to [O1 O2] = [1 0] and [0 1], respectively. Evaluate the effect on performance and convergence.

Utilize Sci-Kit's MLP Classifier() function to get knowledge of AND and XOR gate logic. Repeat the activities, compare the outcomes, and assess how well the supplied library performs these particular tasks.

V. Results and Analysis

We constructed a perceptron model using the specified values: $W_0 = 10$, $W_1 = 0.2$, $W_2 = -0.75$, and a learning rate (α) of 0.05. Employing the Step activation function, we aimed to learn the weights of the network for the implementation of the provided AND gate logic. Subsequently, we determined the number of epochs required for the weights to converge during the learning process.

The below image (Fig. 1) shows the error among Epochs vs Error values and the number of epochs needed for convergence is 130.

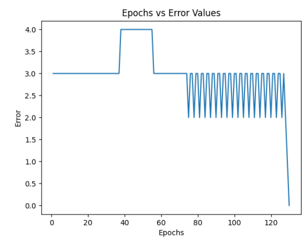

Fig. 1. Epochs vs Error Values

Using various learning rates (Fig. 2), keeping the initial weights the same, we plotted a graph for the number of iterations taken for learning to converge against the learning rates.

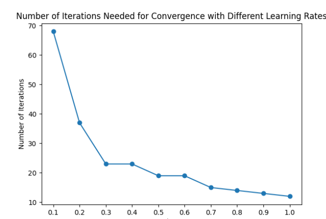

Fig. 2. Iterations

We construct a perceptron for the classification of transactions into high and low values using the supplied customer data. We carefully initialize the weights and learning rate using the sigmoid activation function. A key factor influencing the model's learning efficiency and convergence is the selection of weights and learning rate. The settings will be modified repeatedly to attain the best outcomes, guaranteeing that the perceptron efficiently acquires the ability to categorize transactions according to the attributes specified in the provided dataset. In order to improve the model's capacity to distinguish between high-value and low-value transactions, the parameters must be adjusted to achieve a balance between accuracy and computational efficiency.

We will contrast the results produced using the matrix pseudo-inverse method with the perceptron learning strategy. The objective of this comparison analysis is to evaluate the efficacy and precision of both approaches in identifying transactions as high- or low-value based on the supplied customer data.

Furthermore, we start to build a neural network according to the guidelines given in job A7. We use the Sigmoid activation function and a learning rate () of 0.05 to apply the back-propagation technique to learn the network's weights. This neural network is especially made to carry out AND gate logic in accordance with the specifications given. The optimization of weights for precise classification is guaranteed by the iterative back-propagation procedure. With the help of this methodology, we can investigate the efficacy of neural networks and compare them to the previously used perceptron learning model.

We're going to do exercises A1 and A2 again, but this time we'll add two output nodes. In this setup, the output layer's [O1 O2] = [1 0] corresponds to a zero logic gate output, whereas a one output maps to [0 1]. By examining the effects of two output nodes on convergence and overall performance, this modification seeks to shed light on the network's capacity to manage several output categories.

We will use the MLPClassifier() method from the Sci-Kit handbook (available at) for task A10. We will use this function to learn how to use the AND and XOR gates in logic so that we may take advantage of the MLP (Multi-Layer Perceptron) network's capabilities. We intend to compare the outcomes of the manual implementations in exercises A1 and A2 using this pre-built tool in order to evaluate the effectiveness and precision of the MLPClassifier() function in completing these particular logical tasks. This comparison investigation will provide important new information about how well-established libraries operate when implementing neural networks.

VI. Conclusion

In conclusion, the application of human pose estimation for Parkinson's Disease diagnosis from gait analysis presents a promising avenue for early detection and intervention. By leveraging advanced technologies such as machine learning and computer vision, this approach offers an objective, quantitative, and non-invasive method for assessing subtle motor impairments associated with PD. The current study demonstrates the feasibility and potential of utilizing human pose estimation in conjunction with machine learning algorithms to accurately identify individuals at risk of developing Parkinson's Disease. The results highlight the significance of gait analysis as a valuable biomarker for early-stage diagnosis and monitoring of disease progression. The integration of human pose estimation with machine learning holds great promise for revolutionizing Parkinson's Disease diagnosis and management. By advancing research in this field and addressing key challenges, we can enhance early detection efforts, improve patient outcomes, and ultimately, make significant strides towards combating Parkinson's Disease.

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