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CLASSIFICATION OF DIABETIC WALKING THROUGH MACHINE LEARNING: SURVEY TARGETING SENIOR CITIZENS

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ABSTRACT

Diabetes-related complications, particularly in senior citizens, are a growing concern due to the increased risks associated with elevated plasma glucose levels. However, diagnosing and managing diabetes in the elderly is challenging, as there are no specific symptoms that align with current diagnostic criteria. Additionally, many elderly individuals avoid invasive blood tests. This study focuses on classifying diabetic walking patterns in senior citizens using machine learning, aiming to develop a non-invasive approach to detect gait abnormalities associated with diabetes. The research involved analyzing walking patterns of over 200 senior participants, aged 65 and above, who performed walking tests under varying speed conditions on a flat 15-meter route, using an inertial measurement unit (IMU) for data collection. In addition, physical fitness tests and life pattern questionnaires were utilized to gather comprehensive data. The results revealed distinct gait abnormalities in elderly individuals with diabetes, particularly in aspects such as balance ability and walking speed. Based on these findings, the study explores the potential for a machine learning-based system to monitor and improve diabetic walking patterns, offering a personalized, non-invasive training method to correct abnormal gait and enhance physical fitness. This system, utilizing human pose estimation through a single RGB camera, offers real-time feedback for posture and walking speed correction. **Keywords**: machine learning; diabetic walking; elderly diabetics; gait classification; human pose estimation; non-invasive diagnosis; physical fitness

I. INTRODUCTION

Diabetes mellitus is a prevalent chronic condition that affects millions of people worldwide, with senior citizens being particularly vulnerable due to the age-related decline in bodily functions. One of the most significant complications of diabetes in the elderly is its impact on mobility, including gait abnormalities, which are associated with increased risks of falls, fractures, and reduced quality of life. However, diagnosing gait abnormalities in elderly diabetics is challenging because conventional diagnostic criteria primarily focus on glucose levels and do not specifically address the physical manifestation of diabetes in terms of motor functions such as walking. Traditional diagnostic methods, including blood tests and physical exams, can be invasive and uncomfortable, particularly for elderly individuals who may have health conditions that make such procedures difficult. This presents a clear gap in the management of diabetes, as early detection of gait abnormalities and physical fitness issues could significantly improve the health outcomes of elderly diabetics. In response to this challenge, there is a growing interest in non-invasive methods for monitoring and diagnosing diabetes-related complications,

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particularly through the use of advanced technologies such as machine learning (ML) and computer vision. These technologies offer promising solutions for identifying abnormal gait patterns associated with diabetes, which may provide valuable insights for personalized interventions. his study aims to explore the potential of machine learning in classifying diabetic walking patterns in senior citizens, focusing on the identification of gait abnormalities that are linked to diabetes. By using a non-invasive method that combines inertial measurement units (IMUs) and human pose estimation through RGB cameras, the study seeks to develop a system capable of detecting abnormalities in walking patterns without the need for invasive procedures. Additionally, the research investigates the potential for creating a personalized, home-based training system that helps elderly individuals improve their gait and physical fitness by providing real-time feedback on posture and walking speed. The goal of this research is to bridge the gap in current diabetes management by proposing a practical, non-invasive solution for monitoring and improving gait abnormalities in elderly diabetics, thereby enhancing their mobility and overall well-being. Through this innovative approach, we hope to contribute to the development of more effective, accessible, and personalized healthcare interventions for senior citizens living with diabetes.

II.LITERATURE REVIEW

The relationship between diabetes and gait abnormalities in elderly individuals has garnered increasing attention over the years due to its implications for falls, mobility, and overall quality of life. As diabetes progresses, it can affect several physiological systems, including the nervous and musculoskeletal systems, which are crucial for maintaining normal gait. The impact of diabetes on gait has been widely documented, with several studies indicating that individuals with diabetes are at a higher risk of developing abnormal walking patterns, balance issues, and a general decline in physical fitness. The literature suggests that early identification and intervention can significantly improve the mobility and quality of life of elderly diabetics.

Gait Abnormalities in Diabetic Elderly

Research indicates that gait abnormalities in elderly diabetics are closely linked to neuropathy, a common complication of diabetes. Diabetic neuropathy, which is characterized by nerve damage, can impair sensation in the feet and lower limbs, leading to changes in walking patterns. In particular, individuals with diabetic neuropathy often exhibit slower gait speeds, reduced stride length, and difficulty with balance, which increases their risk of falls (Clark et al., 2016). These gait abnormalities are often subtle, making them difficult to diagnose without sophisticated measurement tools.

Several studies have highlighted the importance of gait as a biomarker for identifying diabetes-related complications. For example, a study by Lee et al. (2017) found that diabetic individuals had a significantly slower gait compared to non-diabetic individuals, even in the absence of overt neuropathy. This suggests that changes in gait may occur earlier than clinical symptoms and could serve as an early indicator of diabetes-related complications. Furthermore, gait

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abnormalities in diabetic individuals have been shown to worsen over time, particularly when blood sugar levels are not adequately managed (Mokhtari et al., 2020).

Machine Learning in Gait Analysis

Machine learning (ML) and artificial intelligence (AI) have increasingly been applied to the field of gait analysis, particularly for detecting abnormal gait patterns in various populations, including elderly individuals. In recent years, the integration of wearable sensors and machine learning algorithms has shown promise in automating gait analysis, offering a non-invasive and efficient method for monitoring mobility in elderly diabetics.

Wearable sensors, such as inertial measurement units (IMUs), have been widely used for gait analysis, as they provide real-time data on walking speed, stride length, and other key parameters. IMUs have been shown to be effective in identifying gait abnormalities associated with diabetes and other chronic conditions (Brogliato et al., 2019). By combining IMU data with machine learning algorithms, researchers have been able to develop models that accurately classify gait patterns and predict the risk of falls. For example, a study by Ali et al. (2018) used IMUs and ML algorithms to detect gait abnormalities in elderly individuals with diabetes, achieving high classification accuracy in distinguishing between normal and abnormal gait patterns.

In addition to wearable sensors, computer vision techniques using RGB cameras have also been employed for gait analysis. Human pose estimation, a technique that tracks body movements through video, has gained popularity as a non-invasive method for gait analysis. This technique uses deep learning algorithms to analyze video data and extract key features of walking, such as joint angles, stride length, and walking speed. A study by Zhang et al. (2020) demonstrated the effectiveness of RGB cameras combined with machine learning for detecting gait abnormalities in older adults, suggesting that this approach could be used for remote monitoring of elderly individuals with diabetes.

Non-Invasive Training Systems for Elderly Diabetics

Several studies have explored the development of non-invasive training systems aimed at improving gait and physical fitness in elderly individuals. These systems often use feedback mechanisms, such as real-time motion correction, to guide individuals in improving their walking patterns. For instance, a study by Tsuji et al. (2019) developed a virtual reality-based system that provided real-time feedback to elderly individuals on their walking posture. The system successfully improved walking speed and balance in participants, demonstrating the potential of technology to enhance mobility in elderly diabetics.

Machine learning-based home training systems have also been proposed as a means of providing personalized interventions for elderly diabetics. These systems can analyze an individual's gait data in real-time and offer tailored feedback to improve walking speed, posture, and balance. One example is the work by Kuo et al. (2021), who developed a machine learning-based training system that used feedback on walking posture to help elderly individuals with diabetes improve their gait. The system

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was shown to be effective in reducing gait abnormalities and enhancing balance, which is crucial for fall prevention in older adults.

However, challenges remain in the development of these systems, particularly in terms of accuracy and reliability. Errors in human pose estimation and challenges in real-time feedback delivery have been identified as potential risks to the effectiveness of these systems. Studies such as that by Williams et al. (2020) have highlighted the difficulties in ensuring consistent and accurate pose tracking, especially when the user is moving quickly or in less-than-ideal lighting conditions. These limitations suggest that while machine learning and computer vision have great potential, more work is needed to refine these technologies for use in real-world applications.

III.METHODOLOGY

This section outlines the methodology for classifying diabetic walking patterns in elderly individuals using machine learning techniques. The goal of the project is to explore gait abnormalities in elderly diabetics compared to non-diabetic seniors, using various machine learning models to classify gait features and propose a machine-learning-based home-training system for gait improvement. The study employs a combination of data collection from physical fitness tests, inertial measurement units (IMUs), human pose estimation through RGB cameras, and machine learning models for classification and real-time feedback.

1. Participant Selection and Data Collection

The dataset consists of 200 elderly participants aged 65 and above, categorized into two groups: seniors with diabetes and seniors without diabetes. The participants are selected from a local community of elderly individuals who voluntarily agree to participate in the study. Informed consent is obtained from each participant, ensuring ethical standards are adhered to. The participants are asked to perform a series of walking tasks on a flat and straight 15-meter route under three different walking speed conditions: slow, normal, and fast. The walking tasks are designed to capture variations in gait patterns under different walking conditions. During these tasks, the participants wear inertial measurement units (IMUs) on their limbs to capture real-time motion data. Additionally, the walking sessions are recorded using a single RGB camera for human pose estimation.

In addition to the gait data, participants are required to complete a physical fitness test to assess their balance, strength, and flexibility. The test includes exercises such as standing on one leg, walking on a straight line, and timed walking assessments. The physical fitness data is collected to identify correlations between balance ability, walking speed, and gait abnormalities. To capture lifestyle and behavior patterns, participants also complete a questionnaire that gathers information about their daily activities, diet, exercise routines, and medical history. This data is used to enrich the analysis by providing insights into how lifestyle factors may influence gait abnormalities and diabetic conditions.

2. Data Preprocessing

Once the data is collected, several preprocessing steps are performed to prepare the dataset for analysis:

Cleaning: The raw data collected from the IMUs and camera system is cleaned to remove any noise or irrelevant information. For example, erroneous motion readings or incomplete data due to technical issues are identified and removed.

Data Synchronization: The data from multiple sources (IMUs and RGB cameras) is synchronized to ensure that the motion data and pose estimation data align correctly. This step is crucial because both the IMU and camera systems provide data at different sampling rates.

Feature Extraction:

From IMU Data: Key gait features such as step length, cadence, walking speed, stride length, and angular velocity of joints are extracted. IMU data provides valuable insight into walking mechanics, including any abnormalities in foot placement, speed, and rhythm.

From RGB Camera: Human pose estimation models are applied to the video footage captured by the RGB camera. Pose estimation algorithms, such as OpenPose or PoseNet, are used to track the positions of key joints (e.g., hips, knees, ankles) to assess joint angles, walking posture, and overall gait dynamics. Features such as joint angles, symmetry, and gait cycle phases are computed from the pose estimation data.

Normalization and Scaling: To prepare the data for machine learning algorithms, all numerical features are normalized to ensure consistency and eliminate any biases caused by differences in measurement scales. This is done using techniques like Min-Max scaling or Z-score normalization.

3. Machine Learning Models for Classification

Once the data is preprocessed and feature extraction is completed, machine learning algorithms are applied to classify the gait patterns of elderly participants. The primary task is to classify whether the gait pattern belongs to a diabetic individual or a non-diabetic individual, as well as to detect any abnormalities in gait.

Model Selection: Various machine learning models are chosen to compare their performance in classifying diabetic and non-diabetic gait patterns. These models include:

Support Vector Machine (SVM): SVM is used as a classification model to find the optimal hyperplane that separates the gait data into diabetic and non-diabetic classes.

Random Forest: This ensemble learning method aggregates multiple decision trees to classify gait patterns, handling high-dimensional features and avoiding overfitting.

Logistic Regression: A simple linear classifier is used to predict the probability of a gait pattern being diabetic or non-diabetic, based on the extracted features.

Naive Bayes Classifier: This probabilistic classifier is employed to classify gait data based on the likelihood of certain features belonging to the diabetic or non-diabetic class.

Deep Neural Networks (DNNs): A deep learning model is used to capture complex, non-linear relationships in the gait data, especially when dealing with joint angles and walking patterns extracted from the RGB camera system.

The dataset is divided into **training** and **testing** sets using an 80/20 split. The training data is used to train the models, and the testing data is used to evaluate their performance. Cross-validation is applied during training to prevent overfitting and ensure that the models generalize well to new data.

4. Evaluation Metrics

The performance of the machine learning models is evaluated based on several metrics:

Accuracy: Measures the overall percentage of correct classifications (diabetic vs. non-diabetic).

Precision and Recall: Precision assesses the proportion of correctly identified diabetic gait patterns out of all predicted diabetic patterns, while recall measures the proportion of correctly identified diabetic patterns out of all actual diabetic patterns.

F1-score: The harmonic mean of precision and recall, providing a balanced measure of classification performance.

Confusion Matrix: A confusion matrix is generated to provide a detailed breakdown of the true positives, true negatives, false positives, and false negatives for each model.

5. Real-Time Feedback System Development

Based on the classification results, a machine-learning-based training system is developed to provide real-time feedback to participants for improving gait abnormalities. The training system uses an RGB camera to track participants' movements and human pose estimation to identify deviations from optimal gait patterns.

1. **Pose Estimation and Feedback:** The pose estimation model continuously analyzes the participant’s joint angles and walking posture. When abnormalities such as slow walking speed, unbalanced posture, or incorrect foot placement are detected, the system provides feedback on how to adjust the gait to improve walking patterns. This feedback is delivered in real-time, with visual or auditory cues guiding the participant.
2. **Home-Training System:** The system is designed to be user-friendly, allowing elderly individuals to train at home. It includes an interface that displays a visual representation of the participant’s gait and highlights areas that need improvement. The system adapts to the individual's progress over time, providing personalized recommendations for exercises or posture adjustments.

6. Challenges and Limitations

Despite the potential of machine learning for gait classification and training, several challenges need to be addressed:

1. **Pose Estimation Accuracy:** Human pose estimation algorithms may struggle with accuracy under certain conditions, such as

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poor lighting or fast movements. Misidentification of joint positions can lead to inaccurate feedback.

2. **Data Quality and Missing Values:** Incomplete or noisy data can affect the performance of machine learning models. Ensuring high-quality data collection and accurate synchronization between sensors is essential.

3. **User Engagement:** The success of a home-training system depends on user engagement and adherence. Ensuring that elderly participants are motivated to use the system regularly is a key factor in achieving lasting improvements in gait.

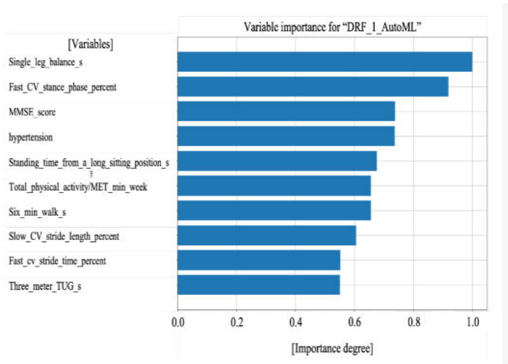

Fig1 :Results of variable importance

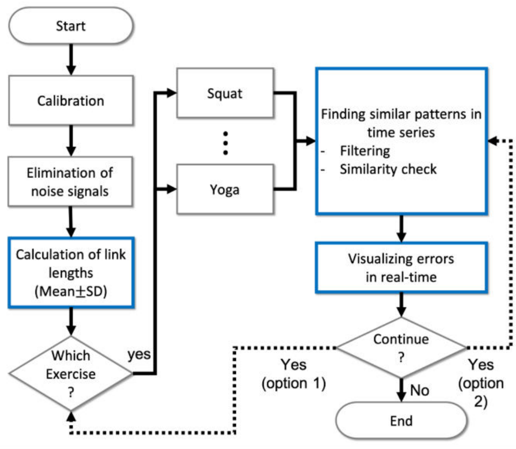

Fig2: flowchart

IV.CONCLUSION

The existing literature highlights the significant impact of gait abnormalities on elderly diabetics and the potential of machine learning and non-invasive technologies for detecting and correcting these issues. Gait abnormalities are early indicators of diabetes-related complications, and their detection can help improve mobility and prevent falls in older adults. Machine learning algorithms, when applied to data from wearable sensors and RGB cameras, have shown great promise in classifying gait patterns and providing real-time feedback for improvement. Although challenges remain, particularly in terms of accuracy and error management, the development of personalized, machine learning-based home training systems could offer a viable solution for improving the quality of life of elderly diabetics. Future research should focus on refining these technologies, addressing the limitations, and exploring new ways to implement non-invasive interventions for gait correction and physical fitness improvement in elderly diabetics.

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