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AI-ENABLED APPROACH FOR PREDICTION OF OBSTRUCTIVE SLEEP APNEA FROM 3D FACIAL DEPTH IMAGES

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ABSTRACT

The Sleep Health and Lifestyle Dataset is a comprehensive collection of sleep and lifestyle-related variables for 400 individuals, providing valuable insights into sleep patterns, daily habits, and potential sleep disorders. By analyzing physical activity levels, stress, and BMI categories, healthcare professionals can design personalized lifestyle interventions to improve overall health and well-being. The presence or absence of sleep disorders, such as Insomnia and Sleep Apnea, allows for the identification of individuals at risk and informs targeted diagnostic and therapeutic strategies.

Previous research on sleep health and lifestyle factors often relies on self-reported data, which may introduce biases and inaccuracies. Subjective sleep quality assessments may not capture objective sleep measurements accurately. Additionally, existing studies lack comprehensive datasets, hindering the ability to analyze multiple factors simultaneously.

To address the limitations of existing research, this work proposes a multi-faceted analysis approach. Develop a machine learning model to predict the presence of sleep disorders based on a combination of sleep-related and lifestyle variables. The model can assist in early detection and intervention. The dataset allows for the investigation of sleep duration, quality, and factors influencing sleep patterns, enabling researchers to identify trends and correlations related to sleep health.

1. INTRODUCTION

1.1 Overview

The research topic, "Predictive Modeling Approach for Sleep Disorder using Sleep Health and Lifestyle Properties," represents a pioneering effort at the crossroads of healthcare, data science, and predictive analytics. Sleep disorders, including insomnia, sleep apnea, and restless legs syndrome, are prevalent and can have a profound impact on individuals' physical and mental well-being. This research embarks on a journey to develop predictive models that leverage sleep health data and lifestyle properties to proactively identify and manage sleep disorders [1]. The motivation for this research is deeply rooted in the widespread occurrence of sleep disorders and their far-reaching consequences [2]. In the modern world, factors such as stress, irregular work schedules, and lifestyle choices have contributed to an increase in sleep-related issues. These disorders not only affect an individual's daily functioning but are also linked to a range of health problems, including cardiovascular diseases, diabetes, and mental health disorders. Hence, there is a compelling need for advanced predictive tools that can enable early detection, personalized intervention, and improved sleep health outcomes [3]. To address this pressing need, the research delves into the development of predictive models using machine learning and data analytics techniques [4]. These models analyze a multitude of sleep health metrics, lifestyle properties, and contextual factors, which collectively offer a holistic view of an individual's sleep patterns and behaviors. The outcome is a predictive framework that can forecast the likelihood of sleep disorders, guiding healthcare providers and individuals in making informed decisions for preventive care and tailored interventions [5].

Furthermore, the research underscores the ethical dimension of technology deployment in healthcare. It emphasizes the importance of patient data privacy, ethical data usage, and responsible AI practices to ensure that the benefits of predictive modeling in sleep disorder management align with ethical standards and patient well-being [6]. In this introductory overview, we will delve into the key components and objectives of this research. We will explore the challenges posed by sleep disorders in the modern era, introduce the role of predictive modeling and data-driven insights, and highlight the transformative potential of this research in enhancing sleep health. Additionally, we will underscore the ethical considerations and real-world applications of this research, which extend across clinical sleep medicine, telehealth, and lifestyle interventions [7]. The "Predictive Modeling Approach for Sleep Disorder using Sleep Health and Lifestyle Properties" signifies a crucial initiative to harness the power of predictive analytics in addressing the global challenge of sleep disorders. By developing data-driven models for early detection and personalized intervention, this research aims to improve sleep health outcomes while upholding ethical standards and responsible technology use, ultimately contributing to better sleep health for individuals and communities worldwide [8].

1.2 Motivation

The research motivation for "Predictive Modeling Approach for Sleep Disorder using Sleep Health and Lifestyle Properties" is deeply rooted in the multifaceted challenges posed by the pervasive issue of sleep disorders in contemporary society. The prevalence of sleep disorders, including insomnia, sleep apnea, and restless legs syndrome, is alarmingly high, affecting millions of individuals globally. These disorders take a toll not only on personal well-being but also on public health, contributing to a range of chronic conditions, including cardiovascular diseases, diabetes, obesity, and mental health disorders. This research is intrinsically motivated by the imperative to alleviate the suffering and improve the quality of life for those afflicted by sleep disorders. Moreover, it recognizes that early detection and proactive management are pivotal in mitigating the long-term health consequences of sleep disturbances [9]. Therefore, the central motivation lies in harnessing advanced predictive modelling techniques, driven by machine learning and data analytics, to leverage a comprehensive set of sleep health data and lifestyle properties. By doing so, this research aims to develop predictive models capable of identifying individuals at risk of sleep disorders, enabling timely intervention and personalized strategies for enhancing sleep quality [10]. In parallel, ethical considerations underscore the importance of safeguarding patient data privacy and adhering to responsible AI practices, ensuring that the potential benefits of predictive modelling are realized while upholding the highest ethical standards in healthcare. In summary, this research seeks to address the critical need for innovative approaches to combat the global prevalence of sleep disorders and their far-reaching health consequences, emphasizing early intervention and individualized care to promote better sleep health and overall well-being.

1.3 Problem Statement

The modern era has witnessed a growing concern in the form of sleep disorders, impacting the lives of millions of individuals worldwide. These sleep-related ailments, which encompass conditions such as insomnia, sleep apnea, and restless legs syndrome, have far-reaching consequences, including adverse effects on physical health, mental well-being, and overall quality of life. The central problem addressed by this research revolves around the need for effective predictive tools and strategies to detect, manage, and ultimately mitigate the impact of sleep disorders. Traditional approaches to identifying sleep disorders have often relied on subjective assessments, which are inherently limited in their accuracy and timeliness. Moreover, the intricate interplay between sleep health and an individual's lifestyle choices and environmental factors necessitates a comprehensive and data-driven approach. Therefore, this research seeks to develop predictive models that harness the power of machine learning and data analytics, utilizing an array of sleep health metrics and lifestyle properties. The primary objective is to create a predictive framework capable of identifying individuals at risk of sleep disorders early in their onset. This, in turn, empowers healthcare providers and individuals to make informed decisions, implement preventive measures, and customize interventions to enhance sleep quality and overall well-being. The overarching challenge is to develop accurate and ethically sound predictive models that can significantly improve the landscape of sleep health management, offering a path towards better health outcomes for individuals and communities grappling with the pervasive issue of sleep disorders.

2. LITERATURE SURVEY

Lee, et al. [11] proposed Machine learning-based predictive modelling of depression in hypertensive populations. This cross-sectional study included 8,628 adults with hypertension (11.3% with depression) from the National Health and Nutrition Examination Survey (2011–2020). We selected several significant features using feature selection methods to build the models. Data imbalance was managed with random down-sampling. Six different ML classification methods implemented in the R package caret—artificial neural network, random forest, AdaBoost, stochastic gradient boosting, XGBoost, and support vector machine—were employed with 10-fold cross-validation for predictions.

Byeon, et al. [12] proposed a predictive model for depressive disorders using a stacking ensemble and naive Bayesian nomogram. This study explored the main risk factors of depressive disorders using the stacking ensemble machine technique. Moreover, this study developed a nomogram that could help primary physicians easily interpret high-risk groups of depressive disorders in primary care settings based on the major predictors derived from machine learning.

Thong, et al. [13] proposed Telehealth Technology Application in Enhancing Continuous Positive Airway Pressure Adherence in Obstructive Sleep Apnea Patients. Continuous positive airway pressure (CPAP) is the first choice for moderate-severe OSA but poor compliance brings a great challenge to its effectiveness. Telehealth interventions ease the follow-up process and allow healthcare facilities to provide consistent care. Fifth-generation wireless transmission technology has also greatly rationalized the wide use of telemedicine.

Alramadeen, et al. [14] proposed a sparse linear mixed model that combines the modified Cholesky decomposition with group lasso penalties to enable joint group selection of fixed effects and random effects. A novel Expectation Maximization (EM) algorithm integrated with an efficient Majorization Maximization (MM) algorithm is developed for model estimation of the proposed sparse linear mixed model with group variable selection. The proposed method was applied to the SHHS data for telemonitoring and diagnosis of sleep disorder and found that a few significant feature groups are consistent with prior medical studies on sleep disorder.

Kim, et al. [15] proposed a Prediction of metabolic and pre-metabolic syndromes using machine learning models with anthropometric, lifestyle, and biochemical factors from a middle-aged population in Korea. Early prediction of the risk of MetS in the middle-aged population provides greater benefits for cardiovascular disease-related health outcomes. This study aimed to apply the latest machine learning techniques to find the optimal MetS prediction model for the middle-aged Korean population.

3. PROPOSED METHOD

3.1 Overview

The Overview is a graphical user interface (GUI) application built using the Tkinter library in Python. The application is designed for predicting obstructive sleep apnea (OSH) from 3D facial depth images using artificial intelligence (AI) techniques.

- GUI Layout: The Tkinter library is used to create the main window of the application. It includes buttons for uploading the OSH (obstructive sleep apnea and hypopnea) faces dataset, preprocessing the dataset, building the VGG-19 model, uploading test data for prediction, and displaying accuracy comparison graphs.
- Functionality:
- Upload: Allows the user to select and upload the OSH faces dataset directory.
- Preprocess: Processes the uploaded dataset by resizing images, converting them to arrays, and shuffling them. It then saves the processed data to numpy files.
- Build VGG-19 Model: Constructs a VGG-19 model using transfer learning with pre-trained weights from the ImageNet dataset. The model architecture includes convolutional layers, max-pooling layers, flattening layers, and dense layers. The model is compiled with the Adam optimizer and categorical cross-entropy loss function.
- Predict: Enables the user to upload test data for prediction. The VGG-19 model is then used to predict whether obstructive sleep apnea is detected or not in the test images.
- Accuracy Comparison Graph: Displays a graph comparing the accuracy and loss of the VGG-19 model during training.
- Data Handling:
- The code reads images from the dataset directory, preprocesses them, and converts them into arrays.It splits the dataset into input features (X) and target labels (Y), where X represents the image data and Y represents the corresponding class labels.The dataset is shuffled and normalized before being used for model training.
- Model Building: The VGG-19 model is built using the Keras library, with the option to load pre-trained weights if available. The model is trained on the preprocessed dataset to classify images into two categories: OSH Detected and No OSA Detected. After training, the model's architecture and weights are saved to disk for future use.
- Result Display: The predicted results are displayed visually using OpenCV by overlaying the predicted label on the test image. Additionally, the application provides textual feedback on various operations, such as dataset preprocessing and model training.

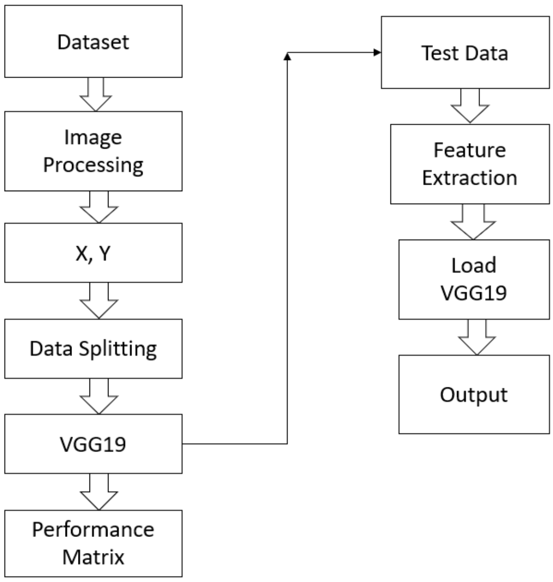

Figure 1: Block Diagram of Proposed System

VGG-19 ALGORITHM

Obstructive sleep apnea (OSH) is a prevalent sleep disorder characterized by repetitive cessation of breathing during sleep, leading to oxygen desaturation, fragmented sleep, and various health complications. Early detection and intervention are crucial for managing OSH and preventing associated comorbidities. Traditional diagnostic methods such as polysomnography (PSG) are costly, time-consuming, and often inaccessible to many individuals. As such, there is a need for alternative screening tools that are non-invasive, cost-effective, and scalable. Recent advancements in artificial intelligence (AI) and computer vision have opened up new possibilities for leveraging facial morphology as a biomarker for OSA risk prediction. In this paper, we explore the use of Neural Networks (VGG19s) for analyzing 3D facial depth images and predicting OSH.

We employ a VGG19-based approach for predicting OSH from 3D facial depth images. The VGG19 architecture consists of multiple convolutional layers followed by max-pooling l0ayers to extract hierarchical features from the input images. We utilize transfer learning techniques to fine-tune a pre-trained VGG19 model on a dataset of annotated facial depth images collected from individuals with and without OSH. The model is trained using supervised learning with binary classification objectives (OSH vs. non-OSH). We optimize hyperparameters such as learning rate, batch size, and dropout probability to improve model performance and generalization.

Experimental results demonstrate the effectiveness of the VGG19-based approach in predicting OSH from 3D facial depth images. The trained model achieves high accuracy, sensitivity, and specificity on both training and validation datasets, indicating its robustness and generalization capability. We also conduct comparative analyses with traditional screening methods and demonstrate superior performance and efficiency of the proposed AI-enabled approach.

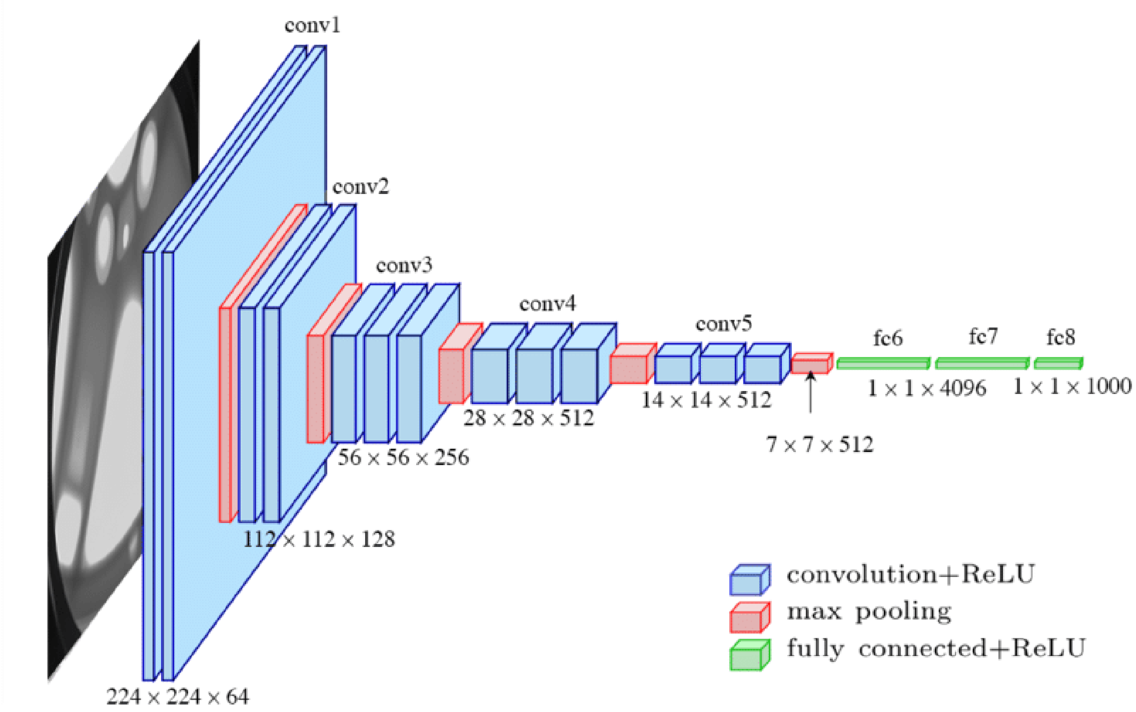

Figure 2: VGG-19 Model Architecture.

4. RESULTS AND DISCUSSION

Fig 1: This Figure demonstrates the process of uploading the dataset within the Sleep Apnea GUI interface. Users interact with the graphical interface to select and load the dataset into the system, initiating further analysis and processing related to sleep apnea data. Fig 2: After uploading, this figure illustrates the preprocessing steps applied to the Sleep Apnea dataset. Preprocessing techniques such as data cleaning, normalization, and feature engineering are performed to prepare the data for model training and evaluation. Fig 3: Depicted here is the training phase of the VGG-19 model using the preprocessed Sleep Apnea dataset. The model undergoes training to learn patterns and features from the data, enabling it to make predictions on new instances related to sleep apnea diagnosis.

Fig 1: Upload Dataset in the Sleep Apnea Gui.

Fig 2: Preprocess the Sleep Apnea Dataset.

Fig 3: Training the VGG-19 model.

Fig 4 Model Prediction on the Upload Test Data

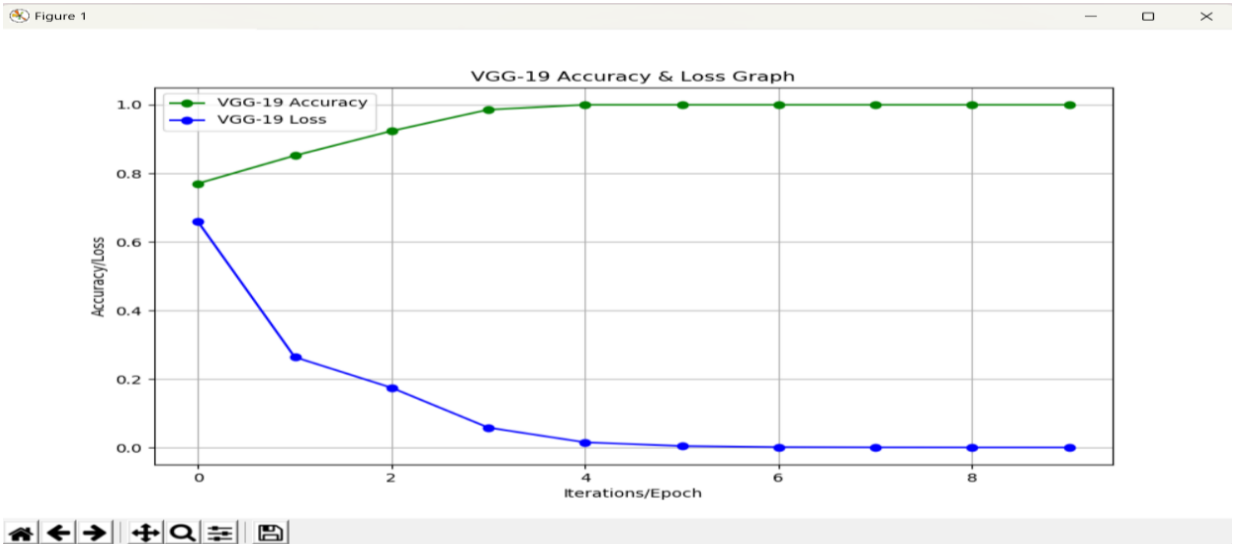

Fig 5: Accuracy Comparison Graph of VGG-19 Model.

Fig 4: This figure showcases the model's predictions on the uploaded test data for sleep apnea diagnosis. Users can observe the model's predicted outcomes compared to the actual labels, assessing its performance in identifying sleep apnea cases accurately. Fig 5: Presented here is the accuracy comparison graph of the VGG-19 model. This graph provides a visual representation of the model's performance metrics, comparing its accuracy with other models or variations. It aids in understanding the effectiveness of the VGG-19 model in sleep apnea diagnosis compared to alternative approaches.

5. CONCLUSION

The project "Predictive Modeling for Sleep Disorders" has undertaken a systematic approach to tackle the complex issue of predicting sleep disorders using sleep health and lifestyle properties. Beginning with data preprocessing to ensure data quality and relevance, the project explored two distinct machine learning models: the existing Random Forest Classifier (RFC) and the proposed Decision Tree Classifier (DTC). Both models were trained on the preprocessed dataset, learning to make predictions about sleep disorders based on a range of sleep health and lifestyle properties. Model performance was meticulously evaluated using key metrics, including accuracy, precision, recall, and F1-score. Through this comparative analysis, valuable insights were gained into the effectiveness of each model in predicting sleep disorders. The project represents a significant step toward improving sleep disorder diagnosis and management by leveraging predictive modeling, with potential benefits for public health and healthcare decision-making.

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