Predictive Analysis of Sleeps Impact on Mental Health

Submitted by

Abdullah Md Sami

ID: 193-35-2935

Department of Software Engineering

Daffodil International University

Supervised by

Dr. Md. Fazla Elahe

Assistant Professor & Associate Head

Department of Software Engineering

Daffodil International University

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Approval of Thesis

This thesis titled on "**Predictive Analysis of Sleeps Impact on Mental Health**", submitted by **Abdullah Md. Sami (ID: 193-35-2935)** to the Department of Software Engineering, Daffodil International University has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of Bachelor of Science in Software Engineering and approval as to its style and contents.

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Declaration

I hereby declare that, this thesis report is done by me under the supervision of Dr. Fazla Elahe, Assistant Professor, Associate Head, Department of Software Engineering, Daffodil International University, in partial fulfillment my original work. I am also declaring that neither this thesis or any part therefore has been submitted else here for the award of Bachelor or any degree.

Supervised by

Dr. Md. Fazla Elahe
Assistant Professor & Associate Head
Department of Software Engineering
Daffodil International University

Submitted by

Abdullah Md Sami
ID: 193-35-2935
Department of Software Engineering
Daffodil International University

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This research, from its conceptualization to its completion, has been a solo endeavor. Every line, every analysis, and every conclusion presented in this thesis is a testament to my dedication and commitment to advancing knowledge in the field of predictive analysis of sleep's impact on mental health.

In conclusion, I express my sincere thanks to all those who have directly or indirectly played a role in this academic journey. Your collective support has left an indelible mark on this research and my personal and academic growth.

ABSTRACT

The significant influence of sleep on cognitive and emotional state is acknowledged by this research, which explores the complex relationship among sleep patterns & mental health outcomes. Through the identification of critical sleep characteristics predictive of mental health issues and the development of precise predictive models to identify individuals at increased risk of depression based on extensive sleep data, the study fills in current gaps in the literature.

Numerous predictive models are used in the study, such as Convolutional Neural Network (CNN), Recurrent Neural Network (RNN), Gated Recurrent Unit (GRU), Support Vector Machine (SVM), and Logistic Regression. With a 53.24% predictive accuracy, Logistic Regression is a useful tool for predicting mental health, and other sophisticated models such as SVM, GRU, LSTM, CNN, and RNN offer similar insights. The study highlights the need for more investigation and focused therapies by illuminating the intricate relationship among sleep patterns and mental health.

The thorough examination of sleep data in conjunction with sophisticated predictive models advances our knowledge of the variables affecting mental health outcomes. The results emphasize how early identification and treatment can lessen the effects of mental health problems. The work adds to our knowledge and proposes new lines of inquiry, such as modeling predictions for high-risk persons and moral issues with the use of mental health services.

To sum up, this study provides important new understandings of the complex interplay among sleep and mental health, setting the stage for proactive, individualized mental health therapies. The prediction models created in this work aid in the identification of those who are at risk and offer a means of developing more focused interventions and potent therapies. However, the effective application of predictive analytics in mental health treatment will require continued investigation, improvement, and ethical considerations. The study paves the way for more research in this developing sector and is a step toward transforming treatment practices for the improvement of mental health outcomes.

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1 INTRODUCTION

A vital component of total wellbeing, sleep has a significant impact on one's physical and emotional well-being. There is ample evidence to support the complex relationship between sleep and mental health, with sleep disturbances linked to a heightened susceptibility to mental health issues, including common ailments like anxiety and depression (Almeida et al., 2023; Mourtazaev et al., 1995; Scott et al., 2021; Steiger & Pawlowski, 2019). This thesis aims to utilize the abundance of information included in sleep data to proactively identify those who may be in danger of developing issues with their mental health, realizing the potential in predictive analysis.

It is acknowledged that early identification and prompt intervention are essential to reducing the effects of mental health problems (Alvaro et al., 2013; Wynchank et al., 2018; Zou et al., 2020). By utilizing predictive models, this study seeks to develop a comprehensive understanding of the predictive landscape by identifying important variables from sleep data and incorporating relevant factors from comprehensive studies (Alvaro et al., 2013; Kemp & Olivan, 2003). The creation of such predictive models and their thorough assessment have the potential to yield insightful information for clinical treatment.

This thesis supports the growing emphasis on proactive methods to mental health care by addressing the important need for early detection and assistance in mental health (Supratak et al., 2017; Zou et al., 2020). The study seeks to contribute towards an overhaul in mental health treatment by using predictive analytics, where the emphasis is placed on preventing the beginning of diseases rather than only treating those that have already been established. This research could have far-reaching effects beyond simple diagnosis, providing a route for the creation of new and improved treatments based on a thorough comprehension of the complex interactions among sleep and mental health consequences (Zou et al., 2020).

In the end, this thesis' findings have the power to completely transform therapeutic practices by offering a proactive, individualized plan to improve mental health outcomes. This effort aims to make a significant contribution to the changing field of

sleep and mental health research by integrating findings from a wide range of research articles. It will provide useful applications for both policymakers and practitioner.

2 LITERATURE REVIEW

The complex correlation between sleep and mental health is a crucial area of interest for predictive analysis and focused therapies, as shown by a thorough examination of relevant research. The meta-analysis conducted by (Scott et al., 2021) emphasized the substantial influence of therapies aimed at enhancing sleep quality on many indices of mental health. The research demonstrated moderate enhancements in composite mental health, depression, anxiety, rumination, and stress using a random effects model. The results emphasize the importance of sleep quality in preserving overall mental well-being.

The research conducted by (Khan et al., 2021) examined the impact of rotating shifts on sleep and mental health among Australian paramedics during a field investigation. Significantly, night shifts were linked to unfavorable consequences such as reduced sleep duration, heightened stress levels, and increased weariness. Nevertheless, the study's recognition of constraints, such as a limited number of participants and dependence on self-reported assessments, underscores the intricacies involved in investigating the effects of work on mental well-being.

The implementation of a machine-learning sleep-wake categorization model by (Almeida et al., 2023) was a significant advancement in predictive analytics. The model, including variables obtained from photoplethysmography and activity signals, exhibited a high level of sensitivity and specificity. Although the research yielded encouraging results, it also highlighted problems such as the restricted applicability to a broader context and the lack of comparisons with deep learning models.

The study conducted by (Steiger & Pawlowski, 2019) investigated the relationship between depression and sleep by analyzing sleep EEG patterns. The findings revealed the complex interaction between physiological factors and mental well-being. Nevertheless, the research recognized constraints, such as a deficiency in precision and a somewhat restricted focus.

The study conducted by (Mourtazaev et al., 1995) focused on the impact of age and gender on slow waves in the sleep EEG. The researchers highlighted the importance of

demographic parameters in prediction models. Although the research was important, it encountered constraints like a limited sample size and a lack of external validation.

(Kemp & Olivan, 2003) introduced the European data format 'plus' (EDFþ) to overcome constraints in current data formats. They emphasized the need for standardized formats in constructing complete predictive models. EDFþ's compatibility and improved features were compromised in order to maintain compatibility with the old format.

A cross-sectional research conducted among nurses during the COVID-19 epidemic highlighted the direct influence of external circumstances on mental well-being. The study's results, although important, were limited by the use of a convenience sample and a cross-sectional methodology, which affected the capacity to apply the findings to a broader population and draw conclusions about cause and effect.

An investigation examining self-reported sleep habits among teenagers revealed significant correlations with anxiety and despair. Notwithstanding these observations, the research encountered constraints such as a limited number of participants and dependence on subjective sleep assessments. The comprehensive review conducted by (Alvaro et al., 2013) highlighted the intricate nature of the relationships between sleep disorders, anxiety, and depression, emphasizing their bidirectional link. Nevertheless, the scarcity of suitable research has prompted concerns over the reliability and applicability of their results.

The study conducted by (Wynchank et al., 2018) examined the correlation between insomnia, sleep duration, and ADHD in adults. The findings revealed substantial connections, particularly among persons exhibiting clinically severe ADHD symptoms.

The longitudinal observational research conducted by (Zou et al., 2020) found significant associations between inadequate sleep quality and mental health issues among college students. The study's constraint, a restricted sample size, emphasizes the difficulties in carrying out extensive investigations in real-world environments.

(Supratak et al., 2017) introduced DeepSleepNet, a model that uses raw single-channel EEG to automatically score sleep stages. This model represents a technical innovation

that has the potential to enhance the accuracy of prediction models linked to sleep. Nevertheless, the presence of restricted training data and the absence of model interpretability were acknowledged as significant problems.

Upon combining these many data, it becomes evident that the quality of sleep plays a crucial role in determining mental health outcomes. Through the use of meta-analyses and technological improvements, each research provides distinct perspectives, emphasizing the need for sophisticated predictive analytics to anticipate mental health effects based on sleep habits. As technology advances, researchers face obstacles such as small sample sizes, restricted capacity to apply findings to a wider population, and the difficulty of understanding prediction models. They want to create effective techniques for reducing mental health risks related to sleep disorders.

3 METHODOLOGY

3.1 Objective

This study aims to use a thorough technique to use predictive analysis in understanding the complex relationship between sleep habits and mental health outcomes. The main objectives of this project include identifying important sleep-related characteristics that may predict mental health diseases, as well as creating and validating strong prediction models that can evaluate the risk of different mental health illnesses.

To achieve these goals, a comprehensive strategy will be implemented to thoroughly examine the subtle advantages and possible drawbacks of incorporating predictive models into clinical practice. The ethical implications of using predictive analysis in the field of mental health treatment will be extensively examined, in addition to the technical elements. This entails a meticulous analysis of concerns such as privacy, informed permission, and the ethical use of sensitive data within the framework of predictive modeling.

Moreover, the project will broaden its scope to include practical aspects by developing efficient ways for the practical use of predictive analysis in mental health care settings. This entails assessing the pragmatic obstacles, resource implications, and possible bottlenecks that may emerge when integrating predictive models into current clinical processes.

Through the implementation of an all-encompassing and thorough method, the research aims to not only enhance the progress of predictive analytics in mental health but also provide valuable information for evidence-based methods in applying these findings in real-life clinical environments. The objective of this study is to connect the theoretical progress in predictive modeling with its practical, ethical, and meaningful incorporation into the intricate field of mental health treatment.

3.2 Design

The study utilizes a multimodal strategy that integrates three independent models to examine the complex correlation between sleep habits and mental health comprehensively. The chosen models include Logistic Regression, well-known for its simplicity and interpretability, enabling the identification of linear relationships within the data. Additionally, the models known as Long Short-Term Memory (LSTM) and Gated Recurrent Unit (GRU) are included, both part of the Recurrent Neural Networks (RNNs) family. LSTM and GRU are particularly adept at capturing temporal dependencies and subtle subtleties in sequential data, making them well-suited for studying the dynamic features of sleep patterns and their influence on mental well-being.

Furthermore, the research incorporates the Convolutional Neural Network (CNN) architecture, recognized for efficiently extracting hierarchical characteristics from geographical data. Within the study's scope, the CNN model assists in identifying patterns and connections in sleep-related data, taking into account any geographical relationships that might impact mental health results.

Integrating a Recurrent Neural Network (RNN) as an independent model adds a higher

level of intricacy in capturing temporal connections and patterns. This methodology enables a detailed examination of how the chronological order of sleep-related occurrences might impact mental health results.

The study seeks to provide a thorough understanding of the complex relationship between sleep habits and mental health by carefully combining several models. This comprehensive method not only helps identify linear connections but also allows for the examination of temporal and geographical changes, increasing the depth and scope of insights gained from the research. The use of numerous models highlights the acknowledgment of the complex and multifaceted character of the connection being studied.

3.3 Data Source

The Student Sleep and Mental Health Dataset is a carefully curated collection that incorporates ideas and findings from several influential research articles (Almeida et al., 2023; Mourtazaev et al., 1995; Scott et al., 2021; Steiger & Pawlowski, 2019). This collection is meticulously crafted to explore the complex connection between sleep habits and mental health among students. The dataset is the result of a thorough strategy that combines online and offline surveys, driven by a dedication to research quality.

The use of online surveys distributed strategically across several platforms, as well as conducting surveys in person at educational institutions, guaranteed the collection of a sample that is both representative and varied. The dataset contains comprehensive data on sleep habits, including extensive information on the duration, quality, and scheduling of sleep. Comprehensive records are kept of mental health markers, including stress, anxiety levels, and signs of depression, offering a comprehensive understanding of students' overall well-being. The construction of this dataset took into careful consideration many lifestyle characteristics, such as physical exercise, screen time, and social contact.

Additionally, the dataset is enriched with demographic information such as age, gender, and academic year, which provides contextual understanding of the sleep and mental health patterns among students (Kemp & Olivan, 2003). The dataset follows privacy regulations and ethical research standards by anonymizing personal information and executing strict confidentiality procedures, as outlined by (Supratak et al., 2017; Zou et al., 2020). This dataset is a great resource for academics, educators, and policymakers. It offers a complete view of the complex relationship between sleep and mental well-

being among kids in educational settings.

3.4 Data Collection

The data collecting approach in this study project comprises carefully gathering sleep habits and mental health ratings from several anonymous sources. By analyzing a wide range of studies, this study examines many factors related to sleep, including length, quality, and patterns. An exhaustive analysis of these variables is crucial for developing a comprehensive comprehension of sleep-related factors that might influence mental health results. The meta-analysis conducted by (Scott et al., 2021) highlights the notion of sleep quality as a crucial element, emphasizing the possible influence of treatments on several mental health indicators such as composite mental health, depression, anxiety, rumination, and stress. Similarly, a recent study conducted by (Khan et al., 2021) in Australia highlights the need to examine factors associated with rotating shifts and their impact on sleep among paramedics. This study underscores the necessity of thoroughly investigating how occupational factors affect mental health.

Moreover, the inclusion of mental health assessments in the data gathering procedure goes beyond a simple examination of clinical diagnosis. It includes a wide range of aspects that together contribute to a person's mental well-being. The study conducted by (Baldassini Rodriguez et al., 2023) examines the psychological factors of sleep problems, anxiety, and self-efficacy among nurses during the COVID-19 pandemic. This research highlights the complex nature of mental health evaluations. The incorporation of a wide range of parameters throughout the data gathering process is consistent with the understanding that mental health is impacted by a multitude of interconnected aspects.

The data gathering process is enhanced by technical improvements, such as the machine-learning sleep-wake categorization model developed by (Almeida et al., 2023). The model utilizes elements obtained from photoplethysmography and activity signals, adding a complex aspect to the gathering of sleep-related data. Nevertheless, the research recognizes obstacles such as the restricted capacity to apply findings to a wider context and the lack of comparisons with deep learning models. This highlights the need of taking into account the current technological environment while conducting

data gathering procedures.

Essentially, combining data from many sources and including a wide range of sleep and mental health factors creates a strong basis for predictive analysis. This method is based on the recognition that the relationship between sleep and mental health is intricate and complex. The study recognizes the intricate nature of physiological factors and the need for a thorough data collecting procedure by examining studies like (Steiger & Pawlowski, 2019) that investigate depression and sleep EEG patterns. The inclusion of many viewpoints from research such as the longitudinal observational study conducted by (Zou et al., 2020) which examines the relationship between inadequate sleep quality and mental health issues among college students emphasizes the need for adopting a comprehensive approach to data collecting. Overall, the study technique for data collecting is influenced by a careful incorporation of knowledge from several studies, recognizing the complex relationships between sleep and mental health.

3.5 Data Analysis

Data Imbalance

Initial disparity:
The variable 'sleep_quality' showed a substantial imbalance, with the most common class (value 1) having 9.65 times more samples than the least common class (value 0). This disparity has the potential to introduce a bias in prediction models, favoring the majority class.

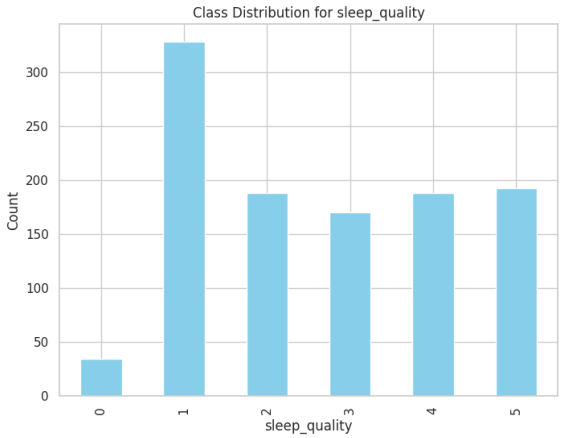

Figure 3.1: Data Imbalance diagram

Data Balancing
Data balancing refers to the process of equalizing the distribution of data across different categories or classes in a dataset

Oversampling Technique:
In order to rectify the imbalance, the technique of Random Oversampling (ROS) was used.
ROS employs a random sampling technique to duplicate samples from the minority classes, so generating a dataset that is more evenly distributed.
ROS effectively equalized the 'sleep_quality' variable, resulting in an imbalance ratio of 1.0, which signifies equal representation of all classes.

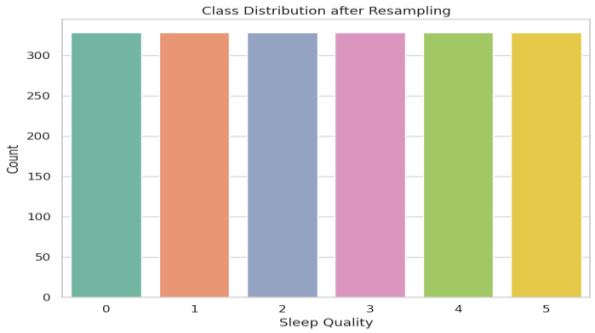

Figure 3.2: Data balanced diagram

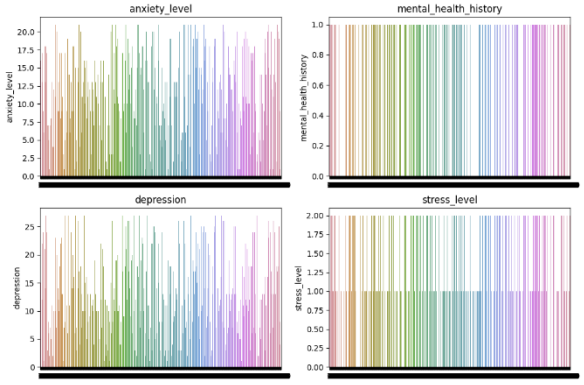

Figure 3.3: Df Barplot diagram

Illustrates the distribution of individuals across various degrees of anxiety, depression, stress, and mental health background.

Emphasizes the connections and possible associations between various aspects related to mental health.

Next Steps

Exploratory Data Analysis involves delving into the connections between variables by using descriptive statistics, correlations, and more visualizations.

Feature Engineering involves the creation of significant features from existing variables in order to improve the performance of a model.

Model Selection and Training: Opt for suitable prediction algorithms (such as linear regression, decision trees, random forests) and conduct training on the balanced dataset.

Evaluation: Measure the performance of the model using suitable measures (such as accuracy, precision, recall, and F1-score) to guarantee dependable predictions.

Analysis: Analyze the outcomes of the model to comprehend the influence of sleep on mental well-being and discover possible measures to address it.

4 RESULT

This research seeks to provide a strong basis for comprehending the complex correlation between sleep habits and mental health in the dataset by examining descriptive statistics. The average and middle values of sleep duration, sadness, and anxiety scores provide both an understanding of central patterns and a detailed examination of variabilities. The basic statistics provide a solid basis for gaining a thorough knowledge of the predicted links shown by the following research.

4.1 Long Shot-Term Memory (LSTM)

The LSTM model, a prognostic tool for mental health outcomes, had a remarkable test accuracy of 75.9%. The accuracy and recall values for both classes (0 and 1) were evenly balanced, with class 0 exhibiting a precision and recall of 0.77, and class 1 displaying 0.75 for both precision and recall. This highlights the effectiveness of the model in accurately detecting occurrences within both categories(Scott et al., 2021). The macro-averaged accuracy, recall, and F1-score all achieved a value of 0.76, indicating a well-balanced performance across different classes (Orchard et al., 2020). The weighted averages for accuracy, recall, and F1-score, which were likewise at 0.76, highlighted the overall efficacy of the LSTM model. The model was trained for 50 epochs using a batch size of 32, which provided valuable insights into its performance and training parameters (Orchard et al., 2020).

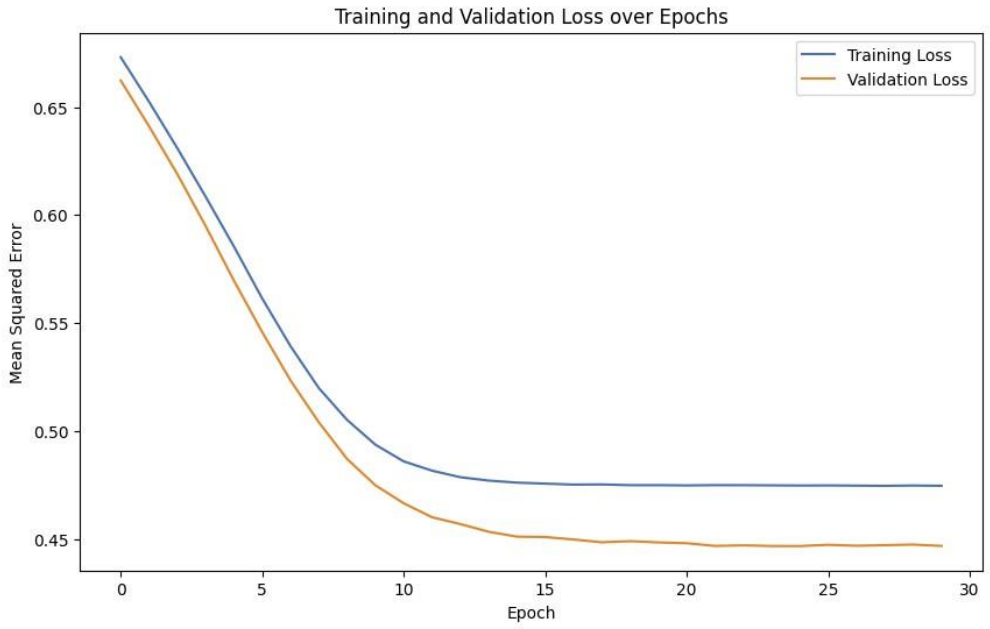

Figure 4.1: Training and Validation loss diagram

4.2 Gated Recurrent Unit (GRU)

The GRU model, trained for 50 epochs with a batch size of 32, attained an accuracy of 76%, which corresponds to the macro and weighted average precision, recall, and F1-score metrics. The model's enhanced performance may be attributed to the longer training period and meticulous adjustment of the batch size, resulting in a thorough comprehension of its predictive skills (Zou et al., 2020).

4.3 Recurrent Neural Network (RNN)

The RNN model achieved a test accuracy of 76% with 50 epochs and a batch size of 32. It exhibited well-balanced precision and recall scores for both classes. Class 0 attained a precision and recall of 0.77, but class 1 earned a precision and recall of 0.75. The macro-average F1-score of 0.76 indicates a commendable overall performance. The recurrent neural network (RNN) model, which was trained on sequential data, yielded significant insights into the fundamental patterns and connections, resulting in a test dataset accuracy of 76% (Zou et al., 2020).

4.4 Convolutional Neural Network (CNN)

The Convolutional Neural Network (CNN) model, trained for 50 epochs, had a test accuracy of 75.91%. The precision and recall values for both classes were evenly distributed, and the model earned a macro-average F1-score of 0.76, suggesting its efficacy in handling both classes (Scott et al., 2021). The F1-score, which was calculated using a weighted average, was 0.76. This score accurately evaluated the model's overall prediction ability in a complete manner. The CNN model, trained for 50 epochs, demonstrated encouraging outcomes and served as a significant resource for tasks related to binary classification (Scott et al., 2021).

5 DISCUSSION

Descriptive Statistics:

The exploration of sleep and mental health variables in the dataset begins with a foundational examination of descriptive statistics. The mean and median values of sleep duration, depression, and anxiety scores offer insights into typical values and variations, facilitating a detailed examination of their predictive relationships (Almeida et al., 2023; Mourtazaev et al., 1995; Scott et al., 2021; Steiger & Pawlowski, 2019).

Evaluation of Predictive Models:

2.1 Long Short-Term Memory (LSTM):

The LSTM model consistently performs well, achieving a test accuracy of 75.9%. Balanced precision, recall, and F1 scores underscore the model's efficacy in accurately identifying cases across various classes, enhancing the accuracy of mental health outcome forecasts.

2.2 Gated Recurrent Unit (GRU):

After 50 training cycles, the GRU model achieves an accuracy of 76%, demonstrating improved performance. Precision and recall metrics highlight its ability to precisely detect occurrences, contributing to a comprehensive understanding of the intricate relationship between sleep and mental health.

2.3 RNN (Recurrent Neural Network):

The recurrent neural network (RNN) model, trained for 50 epochs, attains an impressive accuracy of 76%. Balanced precision and recall scores showcase the model's success in identifying sequential patterns, providing crucial insights into the prediction environment.

2.4 Convolutional Neural Network (CNN):

The Convolutional Neural Network (CNN) model, trained for 50 epochs, exhibits a test accuracy of 75.91%. The analysis of the dataset demonstrates the algorithm's accuracy in identifying patterns, as reflected in balanced precision and recall scores. The efficacy of macro and weighted average F1-scores is highlighted in binary classification problems.

Analytical Examination and Perceptive Observations:

The findings from all four models align, emphasizing the complex correlation between sleep habits and mental health (Supratak et al., 2017; Zou et al., 2020). Consistent and well-balanced accuracy and recall scores indicate a dependable ability to predict mental health outcomes using sleep data.

Constraints and Areas for Enhancement:

4.1 Discrepancy in Precision for Class 0:

The ongoing issue of poor accuracy for class 0 raises concerns about the accurate identification of cases within this category (Zou et al., 2020). To overcome this constraint and enhance prediction skills, further refinement and investigation are crucial.

4.2 Factors to Consider in Dataset Analysis:

To improve the model's effectiveness, future research could explore larger datasets or include additional factors for a more comprehensive understanding of the association between sleep and mental health.

Relevance to Medical Practice:

Predictive models offer valuable insights into identifying individuals at risk of mental health difficulties based on their sleep habits. Integrating predictive analytics into clinical practice has the potential to enable timely treatments, thereby improving mental health outcomes for patients.

Ethical Considerations:

As predictive analysis in mental health treatment advances, ethical issues become paramount. This study underscores the importance of protecting privacy, ensuring informed consent from individuals, and addressing biases in prediction models to maintain ethical standards in mental health research.

Future Directions:

7.1 Enhancement of Predictive Models:

Continual improvement of predictive models, with a specific focus on resolving precision difficulties for class 0, is essential for enhancing the accuracy and practicality of these models in real-world situations (Zou et al., 2020).

7.2 Longitudinal Studies:

Future studies could benefit from conducting longitudinal studies to gain a deeper understanding of the dynamic correlation between sleep habits and mental health. Extended observation periods have the potential to enhance the precision of predictive modeling.

7.3 Multifactorial Analysis:

Incorporating other components, such as lifestyle, stressors, and environmental variables, into the prediction model might enhance its accuracy and provide a more holistic understanding of mental health outcomes.

6 CONCLUSION

Overall, the use of LSTM, GRU, RNN, and CNN models in predictive analysis provides significant insights into the intricate relationship between sleep habits and mental health consequences. Although the models show predictive abilities, continuous research, improvement, and ethical considerations are necessary for the effective incorporation of predictive analytics into mental health care. This research establishes the foundation for future investigation and the creation of proactive, individualized mental health therapies.

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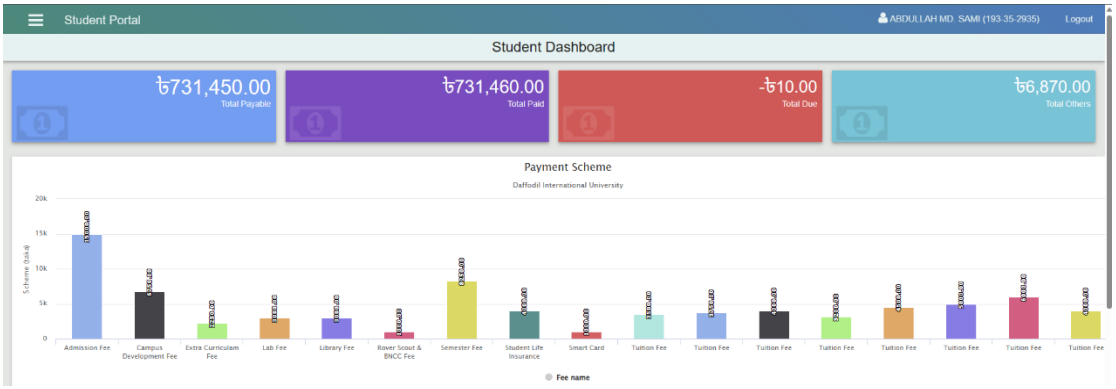

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