Information Systems Engineering and Management 12

Mohammed Serrhini
Kamal Ghoumid *Editors*

Advances in Smart Medical, IoT & Artificial Intelligence

Proceedings of ICSMAI'2024, Volume 2

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Editors

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Preface

This book includes a selection of articles from the First International Conference on Smart Medical, IoT & Artificial Intelligence – ICSMAI'24, held in Saidia, Morocco, from April 18 to 20, 2024.

This first edition aims to bring together students, researchers, and experts in the field of Smart Medical, IoT, and artificial intelligence to share their latest research findings, exchange ideas, and discuss challenges and opportunities in the field.

The Program Committee of ICSMAI'24 was composed of a multidisciplinary group of experts and those who are intimately concerned with, artificial intelligence, Internet of Things, Smart Medical, Information & communication technologies and security. They have had the responsibility for evaluating, in a 'blind-review' process, the papers received for each of the main themes proposed for the conference.

The main topics covered are:

Smart Healthcare/Smart Technologies/Smart Industry; AI, Machine Learning and Deep Learning; Parallel/concurrent/distributed algorithms and programming; Neuromorphic Systems; Distributed database, embedded and operating systems; Cloud/Fog/Edge Computing; Distributed ledgers and blockchain technologies; Internet of Things - IoT, 5G, URLLC; Robotics, Electrical and Electronics Engineering; Mobile, wireless, ad-hoc and sensor networks; Low-Power Wide-Area Networks; Virtual and augmented reality; Graph and Image Processing; Static and dynamic analysis and testing; Collaborative intelligent systems; Information/Network Security and privacy; Web of Things and Semantic Interoperability; Game Theory, mechanisms/hardware design; Computer Vision; Ethics and Cybercrime; Cryptocurrencies, Biometric, Cryptography, Authentication and Access Control; Fuzzy/Agents/Multi-agent Systems; Natural Language Processing; Data Analysis and Big Data; High Performance Computing; Scientific Calculation, Environment and Renewable Energy; Numerical modelling; AI-Optimized Medical Supply Chain in Smart Transportation; Emerging Technologies in Smart Medical Supply Transportation.

The book is aimed at all those dealing with Smart Medical, Internet of Things & artificial intelligence issues, including practitioners, researchers, and teachers as well as undergraduate, graduate, master's and doctorate students.

ICSMAI'24 received contributions from 14 countries around the world. The papers accepted for presentation and discussion at the conference are published by Springer (this book) and will be submitted for consideration in the Web of Science, Google Scholar, among others. Extended versions of selected best papers will be published in relevant journals, including WoS and Scopus indexed journals.

We acknowledge all those who contributed to the staging of ICSMAI'24 (authors, committees, and sponsors); their involvement and support was very much appreciated.

April 2024 Mohammed Serrhini

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Mohammed Serrhini is a professor with decades of academic and research experience in the Department of computer science at Faculty of Sciences, Mohamed First University, Oujda, Morocco. Mohammed Serrhini finished his engineering degree in computer science in 1996 from Polytechnic Institute of Applied Mathematics and Computer Science at Tula State University and PhD in 2012, at the Faculty of Sciences of the University Mohamed Premier of Oujda. He leads innovative research in artificial intelligence (AI) and cyber-security. His research interests are in the areas of computer vision, image processing, brain–computer interface in education, IA security; his works have appeared in several prestigious journals. He has served as General Chair of more than 15 international conferences and has delivered a number of keynote talks on AI and cyber-security. Serrhini receives many awards such from UNESCO in 2022 among others.

Kamal Ghoumid received his PhD degree from the Institut TELECOM, TELECOM Sud-Paris, Evry, France, and Institute FEMTO-ST of the Franche-Comté University (Besançon, France), in 2008. He previously graduated as an engineer in electronics and telecommunications at CNAM-Paris (France), received his Masters in communication systems from Paris-Est University (France) and specialized Masters in technics of radio communications. He has worked as a post-doctoral researcher at Jean Lamour Institute of Henri Poincaré University (Nancy, France) from 2008 to 2009, and the Institut FEMTO-ST of the Franche-Comté University, Besançon as well. He is also an Assistant Professor in the National School of Applied Sciences (ENSAO), Mohammed Premier University of Oujda (Morocco), where he is the head of the research team on Signals, Systems and Information Processing. His research interests are mainly in signal processing and integrated optic components in the fields of telecommunications, wireless and networks Communications, radio over fiber and communications systems.

Computer Vision, NLP, LLMs and Data Analysis

Comparative Analysis of Machine Learning Methods for Enhancing Sleep Efficiency and Prediction

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Abstract. Sleep efficiency corresponds to the fundamental aspect of human well-being in the context of improving health, productivity, education, and overall quality of life (QoL) for individuals and the community. This study presents a comprehensive analysis of sleep efficiency by evaluating various influential factors. We analyze the impact on sleep efficiency by considering age, gender, sleep duration, percentages of Rapid Eye Movement (REM) sleep, deep sleep, light sleep, awakenings, caffeine consumption, alcohol consumption, smoking status, and exercise frequency. The findings highlight the potential of predicting sleep efficiency and offer valuable insights. Many Unseen patterns emerged from the analysis, e.g., women in their 50s and men in their 60s exhibited increased sleep efficiency. Surprisingly, caffeine consumption did not significantly affect sleep efficiency, while higher alcohol consumption and smoking status were correlated with lower efficiency. Exercise frequency shows a slight positive correlation with sleep efficiency. This paper uses machine learning algorithms, including Linear Regression, Decision Tree, Random Forest, and Gradient Boosting Regressor to predict sleep efficiency. Among these, the Random Forest model outperformed the others, demonstrating the highest sleep efficiency prediction accuracy based on the factors considered.

Keywords: Sleep Efficiency · Machine Learning · Health Care · Sleep Quality · Sleep Analysis

1 Introduction

The World Health Organization (WHO) has realized sleep as one of the most significant global health challenges of the present day [1]. Addressing sleep issues could significantly impact our healthcare and education systems by cutting healthcare costs in half and doubling the funds available for education. Untreated sleep problems can lead to many immediate and future physical and mental health issues and educational and societal problems. Sleep deprivation is a challenging issue that needs to be dealt with sooner

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rather than later. Sleep efficiency is defined as the ratio of total sleep time to time in bed [2]. It is crucial for overall well-being as it ensures optimal restorative benefits within the limited time we spend asleep, promoting physical and mental health, and it has been the focus of numerous studies.

In the existing studies, most of these investigations have primarily focused on sleep duration, bedtime, and wake-up times as the main determinants of sleep efficiency [3]. Recent studies have shed light on the significant role of age and gender in sleep quality, but their specific impact on sleep efficiency remains under-explored [4]. Similarly, the relationship between caffeine and alcohol consumption and sleep quality has been investigated. However, the application of machine-learning techniques for sleep efficiency prediction is still in its infancy [5]. Several studies have employed machine learning models to analyze sleep stages [6], yet they have yet to mainly focus on predicting sleep efficiency considering such a broad spectrum of factors. Our research extends this domain by applying machine learning models for predicting sleep efficiency based on various lifestyle and biological factors. Thus, it contributes significantly to individual well-being and healthcare, underlining the importance of lifestyle modifications for improved sleep efficiency.

Our research fills this gap, applying machine Linear Regression, Decision Tree, Random Forest, and Gradient Boosting Regressor to predict sleep efficiency based on these factors. Our research aims to broaden the perspective by examining a more comprehensive set of factors through machine learning models. We have incorporated sleep duration and ten additional features into our analysis. Unique phases of sleep, the number of awakenings during sleep, as well as some lifestyle habits including. By considering these diverse factors, we hoped to understand their individual and combined impact on sleep efficiency comprehensively.

Our findings emphasize that many factors, including lifestyle and biological factors, influence sleep quality. We used different machine learning algorithms to study how these factors interact. Instead of looking at when people go to bed and wake up, we examined ten specific factors that can help us predict how well someone sleeps. We reveal meaningful insights from the data contributing to the existing knowledge about sleep and inspiring further research on this topic.

2 Methodology

Our methodology of the considered study can be articulated as a flow that encapsulates seven key levels, as presented in Fig. 1. These levels are Data Collection, Preprocessing, Data Analysis, and Visualization, splitting data into Testing and Training sets, Applying Machine Learning Models, Classification, and Prediction.

2.1 Data

The basis for this research is a dataset titled ‘Sleep Efficiency’, available for public use on Kaggle [7]. This dataset incorporates 452 data points and 15 features, each featuring diverse aspects of sleep and lifestyle, such as age, gender, bedtime, wakeup time, sleep duration, percentages of Rapid Eye Movement (REM) sleep, deep sleep, light sleep, the

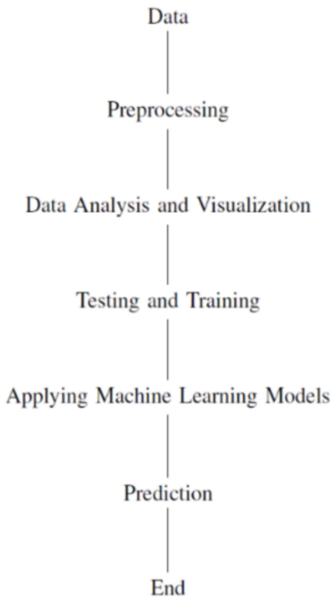

Fig. 1. Overview of our approach to the machine learning models used to predict sleep efficiency.

number of awakenings during sleep, caffeine consumption (in mg), alcohol consumption (in oz), smoking status, and exercise frequency (per hour daily). Additionally, the dataset includes information about each subject's caffeine and alcohol consumption in the 24 h prior to bedtime, their smoking status, and their exercise frequency.

The 'Sleep Efficiency' dataset is not only known within the academic community but also holds recognition in the commercial sector. Unmoved, a renowned company dedicated to sleep studies, has notably utilized this data for their work [8].

2.2 Preprocessing

During the preprocessing stage, specific variables, namely 'bedtime', 'wakeup time', and 'sleep duration', were removed from the dataset. This decision was made based on the study's objective, which aimed to investigate sleep efficiency in a broader context rather than focusing on these specific variables used to calculate sleep efficiency. In order to predict sleep efficiency accurately, Missing values were imputed using the K-Nearest Neighbors algorithm with a parameter setting of n = 2, ensuring that the dataset is complete while preserving its integrity.

2.3 Data Analysis and Visualization

In our Data analysis phase, various statistical methods and visualizations were used to identify patterns and relationships in the data. We used Python-based libraries such as Matplotlib and Seaborn for data visualization. The sleep parameters were analyzed against the different lifestyle factors and demographic features to evaluate their impact on sleep efficiency. The data visualizations including correlation matrix, histograms, box plots, and bar plots were instrumental in illustrating the patterns and correlations identified during data analysis.

2.4 Splitting Data/Testing and Training

The preprocessed dataset was partitioned into training and testing subsets. The training set comprised 80% of the data (361 samples), while the testing set constituted the remaining 20% (91 samples). The data splitting was performed randomly to ensure that both training and testing sets were representative of the overall dataset. This division facilitated the effective training and evaluation of the machine learning models used in the study.

2.5 Applying Machine Learning Models

Four machine learning models were utilized in the study: Linear Regression, Decision Tree, Random Forest, and Gradient Boosting Regressor from Scikit-learn [9]. Each model was trained on the training data and subsequently evaluated on the testing data. The performance metrics used for evaluation were R-squared (R2), Mean Squared Error (MSE), and Student's T-test for Linear Regression.

2.6 Prediction Accuracy

The final stage of the research methodology involved using the selected machine learning model to predict sleep efficiency based on the selected features. The results of the prediction stage offer valuable insights and findings relevant to the study of sleep efficiency. Upon evaluation, each machine learning model's performance was compared, and the model with the best performance was chosen for prediction. The choice of the best model was based on the accuracy score and MSE values, with a preference for a higher accuracy score and a lower MSE. The formulas for MSE and R2 scores are:

$$MSE = \frac{1}{n}\sum_{\{i=1\}}^{\{n\}}\left(y_i - \widehat{y_i}\right)^2 \tag{1}$$

$$R^2 = 1 - \frac{\sum_{\{i=1\}}^{\{n\}}\left(y_i - \widehat{y_i}\right)^2}{\sum_{\{i=1\}}^{\{n\}}(y_i - \overline{\mathrm{y}})^2} \tag{2}$$

3 Results

This section discusses the results and the corresponding analysis of the considered data. The performance metrics in regard to the machine learning algorithms are also evaluated. We provide the parameter values of the machine-learning techniques in Table 1. These models include Linear Regression, Decision Tree, Random Forest, and Gradient Boosting Regressor, as shown in Table 1. The parameters listed for each model indicate the specific settings used during training. The training and testing data were divided into an 80% training set and a 20% testing set.