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Digitalisation of subjetive sleep assessment methods

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Abstract

Sleep is a crucial aspect of human well-being, with significant implications for overall health and quality of life. In response to the growing concern over sleep-related issues and the need for innovative solutions, this paper presents Sleep Sheep, a groundbreaking system designed to monitor sleep and promote healthy sleep habits. The motivation behind Sleep Sheep stems from the recognition of the vital role sleep plays in our daily lives. Inadequate sleep has been associated with various health problems, including cognitive impairments, mood disorders, and compromised immune function. Thus, addressing sleep-related concerns has become a pressing priority. To achieve its objectives, Sleep Sheep utilizes advanced monitoring techniques and state-of-the-art technology. The system employs a smartphone application to collect and analyze comprehensive sleep data, including sleep duration, sleep stages, and sleep disturbances. The collected data is then processed using algorithms to provide valuable insights into sleep patterns and quality. Preliminary results from Sleep Sheep demonstrate its potential to positively impact sleep quality and overall well-being. By providing users with personalized sleep reports and actionable recommendations, Sleep Sheep empowers individuals to adopt healthier sleep practices. This, in turn, can lead to improved sleep duration, enhanced sleep efficiency, and a better overall sleep experience. The significance of Sleep Sheep lies in its potential to address the widespread issue of poor sleep quality and promote healthier lifestyles. By fostering awareness about the importance of sleep and providing individuals with the tools to monitor and improve their sleep, Sleep Sheep has the potential to make a substantial impact on public health. Ultimately, this innovative system aims to contribute to the well-being and quality of life of individuals by encouraging healthy sleep habits and optimizing sleep outcomes.

Keywords: sleep monitoring, sleep quality, daily life impact, subjective sleep measurement

1. Introduction

Sleep quality plays a pivotal role in overall well-being and health. Adequate and restful sleep is crucial for physical, mental, and cognitive functioning, allowing individuals to maintain optimal performance and overall quality of life[1]. However, a significant proportion of the population, particularly individuals aged 40 and increase with more years

above, face challenges in achieving restorative sleep, and this prevalence tends to increase with age, also with people with physical and mental health problems[2]. Poor sleep quality is a prevalent issue among older adults, as well as those living alone. It is important to address this issue comprehensively, as the consequences of inadequate sleep extend far beyond mere annoyance.

The ramifications of poor sleep encompass various aspects of health and well-being. Sleep deprivation and disrupted sleep patterns have been associated with decreased cognitive performance, impairments in memory consolidation, reduced attention span, and impaired decision-making abilities. Furthermore, inadequate sleep is linked to an increased risk of developing chronic conditions such as cardiovascular diseases, obesity, diabetes, and compromised immune function. Moreover, sleep disturbances have been associated with psychological disturbances including anxiety, depression, and decreased overall mental well-being[3]. In severe cases, chronic sleep problems can even contribute to premature mortality[4].

Given the profound impact of sleep on individuals' health and quality of life, it is imperative to develop effective measures to assess and monitor sleep quality. Various digital questionnaires and tools have emerged to facilitate the measurement and evaluation of sleep quality[5]. These tools enable individuals to self-report their sleep patterns, identify potential sleep disorders, and gain insights into their sleep-related habits.

The objective of this study is to introduce Sleep Sheep, a groundbreaking system designed to monitor sleep and promote healthy sleep habits. In this paper, we aim to provide a comprehensive overview of the motivation behind this work, emphasize the importance of sleep and its measurement, review the current state of the art in digital questionnaires available for assessing sleep quality, and present the clear objectives of our study.

2. Methodology

The Sleep Sheep system consists of two main components: the user interface (frontend) and the processes carried out on the servers (backend).

2.1. *Technologies and tools: backend*

One of the crucial aspects of any application is the management and persistence of data. To achieve this goal, we utilized the MongoDB database, a non-relational database that stores information in the form of documents. The use of MongoDB provided us with flexibility and ease of implementation for the application. Although MongoDB lacks native support for transactions, we mitigated this limitation by utilizing the Object-Relational Mapping (ORM) tool, Prisma. Prisma enabled us to incorporate the essential properties of transactional databases, such as Atomicity, Consistency, Isolation, and Durability (ACID).

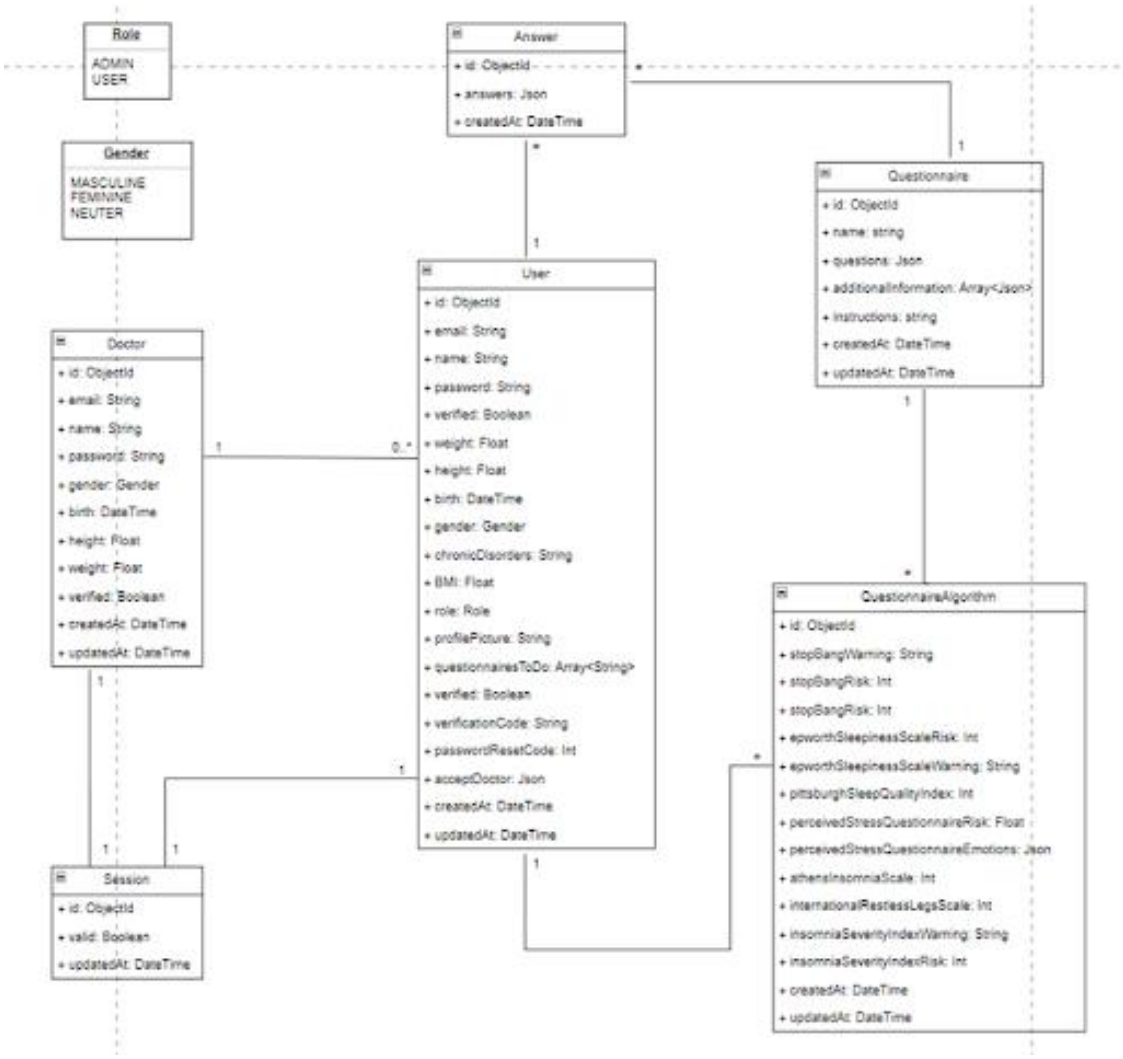

Fig. 1. Database Diagram

For the development of the backend, we chose the TypeScript programming language, a superset of JavaScript that adds static typing. TypeScript offered better coherence between the backend and frontend of the application, reducing complexity and providing a smoother development experience. Additionally, TypeScript addressed many of the challenges associated with JavaScript, enhancing the overall robustness of the system.

To run the TypeScript code, we utilized Node.js as the runtime environment. Node.js is widely used and extensively tested, making it the ideal choice for executing the application's backend code on a server.

The backend server was launched using the Fastify framework, a powerful web framework inspired by Hapi and Express. Fastify is known for its exceptional performance, extensibility through hooks, plugins, and decorators, and its reliance on JSON Schema for endpoint validations. The use of Fastify ensured a seamless and efficient server-side implementation, providing an excellent developer experience.

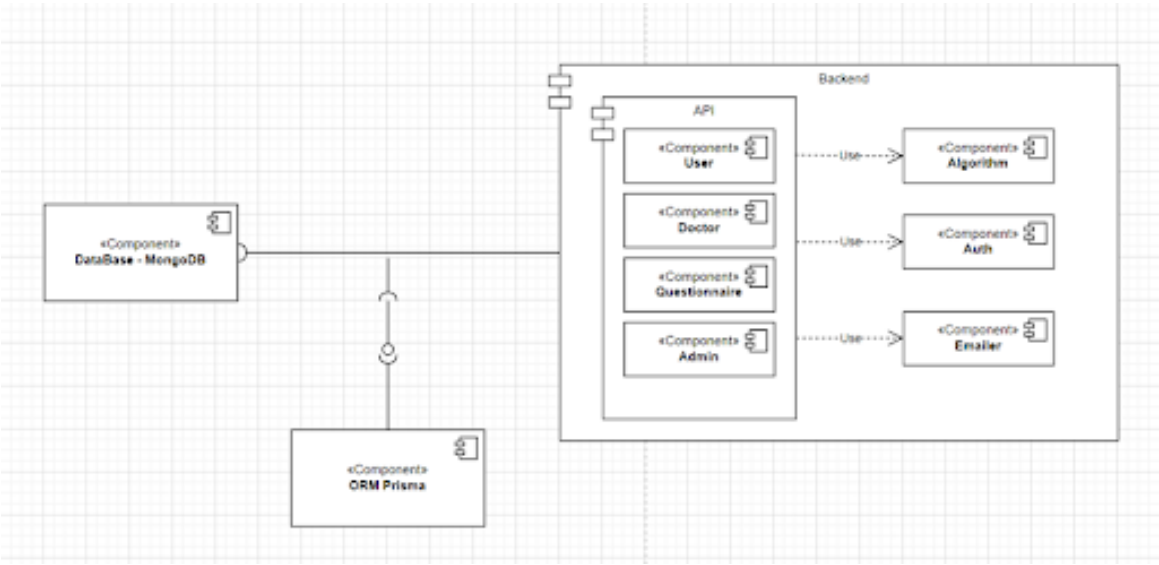

Fig. 2. Backend Diagram

2.2. T*echnologies and tools: frontend*

The user interface of the Sleep Sheep application is built on React Native, an open-source JavaScript framework designed for cross-platform app development. React Native allows us to develop applications that work seamlessly on multiple platforms, including iOS, Android, and web, by utilizing the same codebase. React Native was our preferred choice for the frontend development due to our prior experience with ReactJS and its ability to build native-like applications.

To implement navigation functionality within the React Native application, we integrated React Navigation, a standalone library that facilitates efficient navigation between different screens. By leveraging React Navigation, we implemented a Stack navigation structure, enabling smooth transitions between screens.

For making HTTP requests to the backend API, we utilized Axios, a JavaScript library commonly used for handling network requests. Axios enabled us to communicate with the backend seamlessly, ensuring smooth data exchange between the frontend and backend components.

To store essential data such as access tokens and refresh tokens, we employed React Native Async Storage. This library provides an unencrypted, asynchronous, persistent, key-value storage system accessible throughout the application. React Native Async Storage proved instrumental in securely storing important data for future use.

To streamline the development process and facilitate testing on various devices, we relied on Expo, a free and open-source platform. Expo allowed us to rapidly build the application using JavaScript and React Native, ensuring compatibility and functionality across different platforms.

2.3. Q*uestionnaires*

To monitor the users' sleep condition and assess sleep quality, we utilized eight different questionnaires within the Sleep Sheep system. Each questionnaire serves a specific purpose in evaluating sleep patterns, identifying sleep disorders, and measuring related factors. The questionnaires employed are as follows:

Consensus Sleep Diary (CSD)[6]: A comprehensive tool for assessing sleep patterns and quality, consisting of two parts completed twice a day. The CSD serves as a valuable resource for testing, refining, and validating sleep research methodologies.

STOP-BANG[7]: A screening tool for obstructive sleep apnea (OSA) that identifies high-risk individuals. It evaluates snoring history, daytime sleepiness, observed nighttime apnea, and other related factors.

Epworth Sleepiness Scale (ESS)[8]: A questionnaire that measures daytime sleepiness by assessing the likelihood of dozing off or falling asleep in different daily life situations.

Pittsburgh Sleep Quality Index (PSQI)[9]: A questionnaire that assesses sleep quality and disturbances over a one-month period. It includes questions about snoring, sleep apnea, and other sleep-related disorders.

Perceived Stress Questionnaire (PSQ)[10]: An assessment tool for stressful life events and circumstances that trigger or exacerbate disease symptoms, helping to understand the relationship between stress and health outcomes.

Athens Insomnia Scale (AIS)[11]: A questionnaire specifically designed to evaluate the severity of insomnia symptoms and their impact on daily life. It is effective in assessing functional impairment, increased healthcare costs, and the risk of depression associated with insomnia.

International Restless Legs Scale (IRLS)[12]: A tool developed to assess the severity of Restless Legs Syndrome (RLS) symptoms. It measures the frequency and severity of sensory and motor symptoms related to RLS.

Insomnia Severity Index (ISI)[11]: Used to evaluate the nature, severity, and impact of insomnia symptoms on daily life. Clinicians and researchers employ ISI to assess insomnia in various contexts and monitor treatments.

By utilizing these questionnaires and implementing the algorithms proposed by each, we are able to analyze the user's sleep data and provide them with the corresponding results. This comprehensive approach allowed us to gain valuable insights into sleep quality and related factors for each user.

3. Results

After conducting the necessary investigation and implementing the software system, including both frontend and backend components, we successfully developed the Sleep Sheep application. The application provides users with an intuitive interface for monitoring and assessing their sleep quality. In this section, we will present an overview of the screens and their functionalities within the Sleep Sheep application.

Login Screen:

The login screen allows users to log in as either a patient or a doctor. By selecting the appropriate login type, users can access their respective accounts. Additionally, options such as "Don't have an account?" and "Forgot password?" provide further functionality for new users and account recovery.

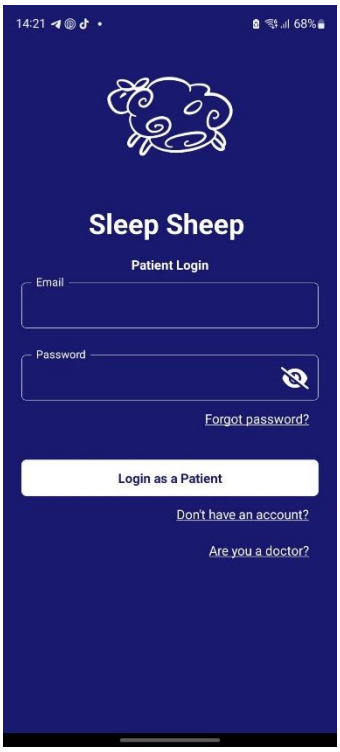

Fig. 3. Login Screen

Register Screen:

The register screen enables users to create a new account by entering their details. Upon successful registration, users receive a verification email. Clicking the verification link redirects users to the login screen.

Home Screen:

The home screen serves as the central hub of the application. It features a navigation menu with buttons to access the user's profile and the calendar page. Additionally, the home screen provides a table displaying information from the Consensus Sleep Diary Morning Questionnaire. Days without questionnaire responses are marked as "No Data." A list of available questionnaires is also presented, allowing users to navigate to the questionnaire screen and complete the selected questionnaire. The content displayed on the home screen varies depending on the user role. For administrators, an input field is available to convert an existing user account into a doctor account. For doctors, an input field allows them to add patients by their email address, and a list of their assigned patients is displayed. Clicking on a patient redirects the doctor to the UserInfo Screen for that patient.

EmailVerification Screen:

The email verification screen facilitates the password reset process. Users can enter their email address and, if it matches a user in the database, receive an email containing a verification code. Once the code is provided, users can create a new password, which grants access to their account. The EmailVerification Screen includes the ForgotPassword and PasswordChangeVerificationComponent.

Calendar Page Screen:

The calendar page screen presents a list of all available questionnaires in the database. Patients can select a questionnaire to view their answers, which redirects them to the AnswerList Screen. For doctors, a message is displayed, indicating that this feature is only available for patients. Additionally, patients accessing the application via the web interface can export their data from the questionnaires and algorithms.

AnswerList Screen:

The AnswerList screen displays a list of all previous answers submitted for a selected questionnaire. Information such as the date, time, and algorithm results are presented. Clicking on an answer opens a pop-up window containing the questions and the corresponding answers. Patients accessing the application via the web interface can export their data from the selected questionnaire and algorithms.

Profile Screen:

The profile screen allows users to log out, view and update their profile information, and delete their account. For patients, there is an option to update their height, weight, gender, and chronic disorders.

DeleteAccount Screen:

The delete account screen provides users with the option to permanently delete their account from the application by clicking a designated button.

Questionnaire Screen:

The questionnaire screen enables users to fill in the selected questionnaire. Once completed, users can submit their responses. Additionally, the screen includes a "See Instructions" button that provides users with instructions specific to the chosen questionnaire.

UserInfo Screen:

The user info screen is accessible to doctors and allows them to view all information related to their patients. From this screen, doctors can assign new questionnaires to patients and navigate to the UserInfoAnswers Screen, which functions similarly to the Calendar Page Screen.

By providing an overview of the various screens and their functionalities, we have demonstrated the user interface and navigation flow within the Sleep Sheep application. These features allow users to effectively monitor their sleep quality and provide doctors with access to their patients' information and questionnaire results.

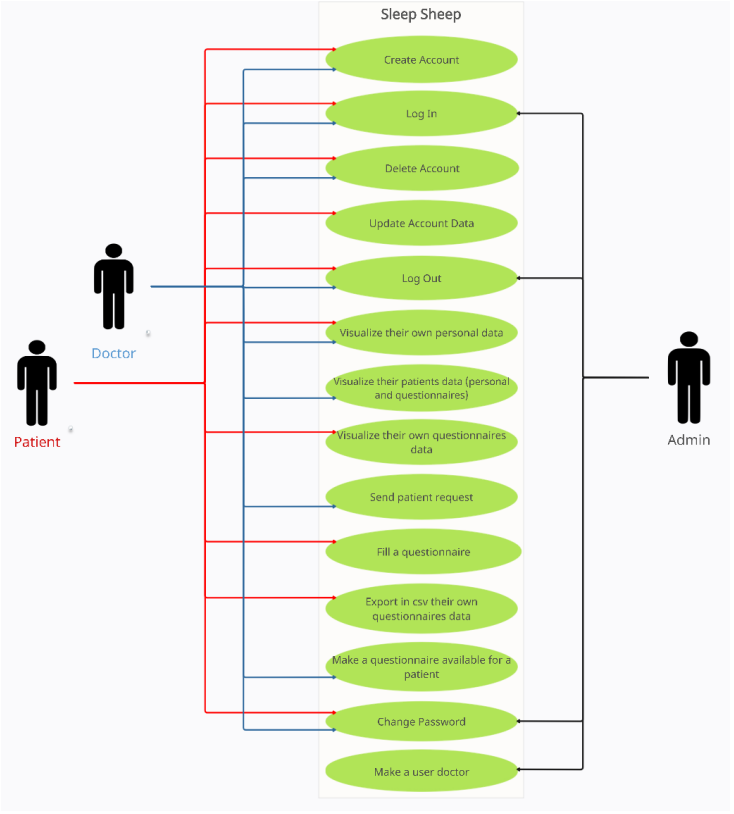

Fig. 4. Use Case Diagram

4. Discussion

Throughout the development of the system, we encountered several challenges and problems that needed to be addressed to ensure the smooth functioning of the application.

First, we will discuss the problems and challenges associated with the part of the application running on the servers (backend) and next will be the part running on the users' devices (frontend).

In the backend we had numerous challenges, creating an interface to link the backend and the frontend in a coherent and meaningful way, authenticating and authorizing all the different users that connect to the application: patients, doctors, and administrators. Preserve all collected data ensuring accuracy, consistency and persistence and deploy the application on the HTWG university infrastructure making the deployed application persistent to any unexpected failure.

On the other hand, there have also been several issues that have been fixed. The authentication and authorization of each user of the application, where we needed several levels of permissions, due to the presence of different types of users we had to implement a complex use of the web standard to authorize and authenticate JWT (Json Web Tokens). In the requests for the creation of new answers to the questionnaires by the patients there have been problems in the validation of these requests, where each questionnaire had very different answers, we had to establish very rigid requirements in the message sent to the server to validate it and ensure that there is no possible security breach. The emailer which was the part of the application that oversaw sending all the emails to our users has had problems due to the complexity of its configuration and set up for production deployment.

In the frontend we had a main challenge. We could not access to the files on Android using React Native. Therefore, we were not able to let the users have a profile picture or download the csv with the data by phone (This feature is only available in web).

5. Conclusion and outlook

Through comprehensive analysis of software solutions, as well as the system's architecture, we have successfully designed a robust sleep quality monitoring system. This involved defining the configuration of components and their requirements, as well as developing a data exchange model. By compiling a set of development requirements, we were able to compare and evaluate alternative solutions.

However, it is important to acknowledge the limitations of our analysis. Firstly, our investigation focused on three specific methods for measuring sleep quality (**sleep duration, sleep stages, and sleep disturbances**), potentially excluding other viable techniques. Further research could explore additional approaches to respiratory monitoring and the accurate detection of sleep-related issues. Additionally, although we conducted first practical tests on selected system components, it is necessary to acknowledge that real-world usage may uncover unforeseen challenges.

Moving forward, our next planned step is to conduct individual tests with the modules from our application, followed by a thorough evaluation of their performance. Subsequently, we will proceed with the development of a prototype for system integration testing. Finally, once the preliminary stages are completed, a medical evaluation of the developed system will be conducted to assess its accuracy, usability, security, and stability. This evaluation will provide valuable insights and enable us to refine the system further, ensuring its readiness for the market.

In conclusion, our research and development efforts have resulted in the design of a sleep quality monitoring system. While limitations exist, our planned future steps will allow us to address these concerns and advance the system towards a comprehensive and market-ready solution. By continually refining and evaluating the system's performance, we aim to contribute to the improvement of sleep quality monitoring and ultimately enhance overall well-being and health for individuals of all ages.

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