ENHANCING THE EFFICIENCY OF DIAGNOSING AND MANAGING MENTAL DISORDERS USING MACHINE LEARNING

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Bachelor of Science in Information Technology Specialized in Data Science

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Declaration

We declare that this is our own work, and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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The supervisor/s should certify the proposal report with the following declaration. The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

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....22/08/2024

Signature of the supervisor Date

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Signature of the Co-Supervisor Date

Dr. Kapila Dissanayaka.

ABSTRACT

Alzheimer’s disease has been identified as a severe threat to the humanity. Identification management and treating the patients have become more challenging due its severe symptoms such as memory loss. Starting immediate treatments for control the disease status, Helping the family and closest people of the patients to plan their future and securing the patient’s environment are being considered as the benefits of the immediate identification. MRI scan report-based patient severity classification and patient’s general medical information related machine learning models are integrated to fulfil the task of feeding possibilities and patient status information predictions to the doctor’s dashboard. Making the doctors diagnosis more efficient can be identified as the main goal of this proposed system. Observing MRI scans to identify Alzheimer’s levels is identified as a very time-consuming task for doctors. The proposed system is integrated with an MRI classification machine learning model. The whole system consists with a mobile application and a web application. The mobile application is supposed to be used by the medical staff in gathering and feeding patients information such as general information and MRI scan images to the machine learning models. Then the web application is supposed to be used by the doctors in order to monitor the patient’s status and predictions of the machine learning models throughout the time. Therefore, Implementation of this system carries out the goal of making Alzheimer identification efficient.

Keywords: Machine-Learning, MRI scan, Alzheimer’s detection, Efficient diagnostics, Patient management, Memory loss.

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LIST OF ABBREVIATIONS

Abbreviation	Description
MRI	Magnetic resonance imaging
CNN	Convolutional Neural Networks

INTRODUCTION

Background & Literature survey

Alzheimer's disease is a severe, chronic neurodegenerative disease mainly targeting the senior population, and its key features are a remarkable decrease in cognitive abilities, memory loss, and behavioural changes. As one of the most common forms of dementia, it becomes an enormous burden for the patient, family, and various health systems throughout the world. It is estimated that the number of people with dementia will increase to 82 million by the year 2030; 60-70% of these cases are caused by Alzheimer's disease, according to the World Health Organization [1]. Appropriate care and management strategies delay the worsening of symptoms, thus early detection and diagnosis of Alzheimer's disease are central to the effective management of this condition. The diagnostic process, on the other hand, is normally compromised by symptomatic overlap with other forms of dementia and the general lack of unequivocal disease-specific biomarkers. Recent advances in neuroimaging, with the recent developments in magnetic resonance imaging in particular, have shown important details in regard to the structural cerebral changes associated with Alzheimer's disease. MRI is apparently the only means by which early atrophy can be detected in the hippocampus and other memory- and cognitive-related parts of the brain, so it is a highly important diagnostic tool. In contrast, when MRI is manually examined, the process is time-consuming and demands a degree of specialization that is generally not found in all hospitals or clinical setups. This has led to great interest in developing some automatic tool and machine learning models to help with neuroimaging data analysis. Machine learning algorithms, especially deep learning models, have shone in the area of medical image analysis. With the same findings, convolutional neural networks have widely been applied in the field of image classification and have been very accurate in the detection of Alzheimer's disease in MRI scans [3]. Very impressively for their very high performance in 2015 study, Payan and Montana presented a deep learning framework that made use of 3D CNNs to classify the stages of Alzheimer's disease from MRI [4]. Another work by Suk et al. (2016) proposed a deep learning-based feature learning method from multimodal neuroimaging combining the MRI and PET images in the classification of Alzheimer's disease, further accentuating the potential of deep learning in this area. Going further than neuroimaging, many studies have since exploited the potential for combining such brain imaging features with other related patient data, allowing for even more complex machine learning approaches in order to maximize the predictive accuracy of cognitive test scores, demographic information, and lifestyle factors. In 2019, Lee et al. demonstrated that the use of MRI information, alongside clinical and demographic variables, conferred a model with strong predictive value in modelling MCI progression to AD [6]. This multidimensional approach insists on including all sorts of patient information for developing sturdy diagnostic tools. Similarly, mobile and web applications have also sought a way forward in health processes for the purposes of data collection and improvement of patient monitoring. mHealth applications have been used in collecting patient-reported outcomes to monitor disease progression and give suggestions for personalized care [7]. In applications in the case of Alzheimer's disease, this could automate the collection of patient data with regard to lifestyle and behavioural information that was largely left aside in traditional clinical diagnosis. The proposed system in this research further extends these developments by building MRI-based machine learning models within mobile and web application frameworks. This automates the time-consuming job of MRI analysis and provides a holistic view concerning the health of the patient, hence increasing accuracy and effectiveness in the diagnosis of Alzheimer's. Through the application of the latest machine learning algorithms and the convenience of mobile technology, this enables the delivery of timely and effective healthcare to Alzheimer's patients.

Research Gap

It is evident that there is a gap in research on Alzheimer's disease diagnosis and management from the analysis of the literature. While different studies have contributed to specific areas regarding this field of study, gaping holes still exist, which the proposed solution seeks to fill comprehensively.

Research [8] by Ebrahimi-Ghahnavieh et al. (2019) focuses on Alzheimer's detection using MRI images based on applicability, which in this case, is transfer learning. This research most pointedly dwells on the most important dimension of Alzheimer's diagnosis: MRI-based predictions. While this study about applying machine learning techniques to analyzing MRI scans is successful in its methodology, it overlooks other critical variables that could impact the conditions of the patients by focusing only on lifestyle factors, sleeping quality, and background information. It also does not integrate such MRI-based predictions into a more holistic and user-friendly system for continuously tracking the patient by the doctors and to plan treatment.

Research [9] by Kuo et al. (2017) proposes a wearable device for sleep quality assessment, which is very important, as sleeping problems are typical early symptoms of most neurodegenerative diseases like Alzheimer's. Although this research adds to the understanding of sleep patterns in patients, no direct link toward the prediction of Alzheimer's using sleep quality was achieved, nor is it integrated with other diagnostic tools. The wearable technology only serves to measure sleep quality and not to correlate data with any other factors such as MRI readings or background information.

Research conducted by Simon et al [10]. (2016) contributed an overview on machine learning applications, covering it for use in the prediction of Alzheimer's based on some background information. Though this research covers the integration of Machine Learning and user data, it doesn't get down into visualization of such predictions or in what manner it can be used for the benefit of a long-term patient. Moreover, it does not think of developing a full-scale system to bind these varied data points into one platform accessible by healthcare providers.

Solution Proposed: Many such parameters can be integrated under one system, including analysis of MRI scans, sleep quality data from wearable devices, and patient background information. It increases the accuracy of Alzheimer's disease prediction and provides a visualization tool for medication reports to allow doctors to track treatment over time and know how to adjust it. The solution presented brings these different elements together into a holistic approach toward the management of Alzheimer's disease, hence filling the gaps left by previous research efforts within this area of study.

Research Gap

Research	Research [8]	Research [9]	Research [10]	Proposed Solution
MRI scan related prediction	✓	✗	✗	✓
Smart wearable for sleep quality measuring.	✗	✓	✗	✓
Alzheimer's prediction based on user background information.	✗	✗	✓	✓
Alzheimer's medication report visualization.	✗	✗	✓	✓

Figure 1 Research Gap Diagram

Research problem

The problem statement of the research in this project comes in with the increasing need for efficient and correct diagnosis and management of Alzheimer's disease, which is a challenge to the global healthcare system. Increase in aging population is followed by increased prevalence of AD, thereby putting immense pressure on the healthcare experts for the early diagnosis and best management of the disease. Early diagnosis is essential for intervention at a point in the illness when there is maximum opportunity to slow progression, improve quality of life for patients, and provide information that allows families to plan for the future. However, current methods for the diagnosis of Alzheimer's are shot through with limitations.

These traditional diagnostic techniques are based on manual MRI image analysis, cognitive evaluations, and history, making them time-consuming and expertise-driven, hence usually delayed. In particular, the manual interpretation of the MRI scan forms a significant bottleneck in diagnosis. Even with advances in neuroimaging, subtle changes in brain structure associated with Alzheimer's still require expert radiologists for identification, and this is a problem in resource-poor settings. Current diagnostic processes also do not integrate all other important factors about the patient, such as lifestyle, sleep patterns, and demographic data, which otherwise have vital clues to risk and progression in Alzheimer's disease.

This is further compounded by a lack of a system that can unify the different types of patient data—MRI images, quality of sleep, background information, and so forth—into one platform for complete analysis and long-term monitoring. The absence of such a system, however, not only restrains the capability of healthcare providers to make informed decisions but also deters optimum continuous management of the disease from being maintained, much less improved, with respect to changing therapies.

The objective of this study is to solve these very critical issues by developing an integrated system that uses machine learning models in MRI scan analysis, includes the effects of data from wearables in terms of sleep quality, and integrates relevant background information on the patient for increased accuracy in prediction. In return, there will be a fully diagnostic tool that will explanatively provide diagnosis concerning the brain, enabling efficient diagnosis and management of Alzheimer's for better patient outcomes and more efficient use of healthcare resources.

RESEARCH OBJECTIVES

Main Objective

This research works on the development of an integrated system that would boost the efficiency of diagnosis and management in Alzheimer's disease using advanced machine learning models and wearable technology. This system will automate the analysis of MRI scans and the integration of data concerning the lifestyle of a patient while real-time sleep quality metrics are collected from a custom-designed smart wearable. This help will streamline the entire process and result in a significant help to healthcare professionals in increasing their diagnostic a***cy and improved management of patients overall. This holistic approach must not only encompass disease detection but rather long-term disease monitoring and personalized treatment planning, which in the end yields better patient outcomes and ultimately reduces the burden on healthcare systems.

Specific Objectives

Develop Machine Learning-Based MRI Analysis Model

Design and implementation of a machine learning model for MRI scans that can diagnose Alzheimer's disease and grade the severity of the disease is, thus, one of the most target critical points in this research. The model will be trained by a large quantity of data on MRI recognition of diagnostic patterns associated with various stages of Alzheimer's: from mild cognitive impairment to severe dementia. The goal is to automate the time-consuming manual MRI analysis and thereby speed up the diagnostic process to reduce the general health system that currently depends on expert radiologists.

Design and Development of a Smart Wearable System for Sleep Quality Monitoring

This work proposes a new component: development of a smart wearable that monitors patient sleep quality metrics. Sleep disturbances, therefore, are very frequent early symptoms of neurodegenerative diseases, such as Alzheimer's. It tracks data such as sleep duration, cycles, and sleep disturbances, which provide information regarding neurological health. Such data will be integrated into the general diagnostic system and deliver therefore more comprehensive information about the patient's state.

Integrate information about the patient's background into the diagnostic model

This research is geared to apply a great deal of information on patient background, including demographic and details pertaining to lifestyle, and medical history to the diagnostic model. The latter would enable the system to assess the personal risk in a more graded way and subsequently increase the accuracy of predictions for Alzheimer's. This objective, in turn, realizes that AD is multifactorial and can just be optimally managed through a multi-dimensional approach in diagnosis.

Create a Single Platform for Data Integration and Visualization:

One more dedicated aim is to make a web-based platform that integrates MRI, smart wearable, and patient background data. This will work as a central point from which healthcare providers will be able to access and view patient data in real time. The system will be endowed with intuitive dashboards through which doctors can monitor the progress in the development of the disease, the treatment being meted out to the patient, and, in turn, make decisions pertaining to patient care.

Validate the System Through Clinical Trials

Validation of the proposed system through clinical trials shall provide assurance of the system's effectiveness and reliability. The goals are linked to tests of the system within real-world conditions using actual patients with Alzheimer's in order to affirm its accuracy, usability, and impact on the clinical process. The feedback of healthcare professionals will be taken to incorporate the necessary modifications for solving practical problems that may come up while the system is being implemented.

Enhance treatment personalization and monitoring:

Ultimately, the goal of the research is to develop tools inside that system for the facilitation of customized treatment plans, using the integrated data. Ongoing analytics of patient data, in terms of quality of sleep, MRI results, and other background details, may suggest modification strategies for a given therapy in the course of time. This objective aims to give more dynamical management of the processes of Alzheimer's and be more responsive to changes in the patient's condition, to result in better outcomes in the long term.

METHODOLOGY

Methodology steps

Data Collection and Preprocessing

Train and validate machine learning models on data that is apt to be collected and integrated from smart wearable devices, such as the MRI scans and a patient's background information and sleep quality metrics. Required MRI scans will be tapped into from public databases like the Alzheimer's Disease Neuroimaging Initiative or through clinical partnerships. Information related to patients can be demographical data, previous medical history, and lifestyle data, that shall be derived from questionnaires and electronic health record systems. The sleep duration, sleep cycles and sleep disturbances shall be recorded for an ultra-long time using the smart wearable device.

This is an important point to mention that during such a stage, data preprocessing itself plays an important role. First, MRI images are normalized to suppress any noise that might be coming in and segmented to bring out the meaningful parts of the brain. Then, missing data in the patient's background information shall be filled using corresponding imputation techniques, and categorical variables will be converted to encodings compatible with the model. The sleep quality data obtained from the wearable device will also be filtered and cleaned from any artifacts and anomalies. Then, cleaned and prepared data will be divided into three sets which will let us to correctly develop machine learning models: training, validation and testing.

Development of the MRI-Based Machine Learning Model

In this step, the MRI scan will be analysed with a machine learning model for the classification of different stages involved in Alzheimer's disease: mild, moderate, severe, and no indication. As MRI data is highly dimensional and complex in structure, in this paper, a deep learning technique, more specifically, Convolutional Neural Networks (CNNs), will be exploited. CNNs effectively operate on spatial hierarchies and image data for nearly all forms of recognition tasks.

The model will be developed through the selection of the correct network architecture from within available libraries, for instance, ResNet and VGG, which will be trained over the pre-processed MRI data set. Transfer learning-related techniques harness pre-trained models as a starting point in furthering the model performance related to the Alzheimer's-specific dataset. The hyperparameters of the model—the learning rate, batch size, and the number of epochs—will be optimized with cross-validation to bring out the best performance. The accuracy and generalizability will be tested based on the evaluation using a test dataset.

Design and Development of the Smart Wearable Device

The smart wearable device can be designed and developed in this stage, which should be capable of continuously monitoring patient sleep quality. The device will be equipped with sensors for movement tracking, sensors for heart rate monitoring, and probably even brain activity, realized by means of EEG sensors. Proper components are to be selected, such as microcontrollers, sensors, and batteries, yielding light weight, comfort, and support for long-term data collection.

Also embedded in the software of the wearable device are the real-time data processing and transmission algorithms to the central database or the patient's mobile device. This will be followed by testing the device in a controlled environment to ensure that sleep data is accurately captured and transmitted. Following validation, the wearable devices will be deployed in a field study on real patients to collect the requisite sleep quality data needed for integration into the greater system.

Data and System Integration

At this stage, data from all the sources can be integrated: the MRI images, the background information about the patients, and the sleep quality metrics. The system will be web-based, hence offering one central location for access by healthcare professionals and analyses on the patients. A backend that can handle large data should be developed to support smooth communication among the components of the system—like the developed machine learning model, wearable device, and electronic health records of the patient.

It will also have a user-friendly interface where this developed machine-learning model is run. The outcome will be a web application comprising numerous dashboards; among them will be results regarding the MRI analysis, information on the sleep trend, or any other data relevant to the patient at that instance. The system will possess visualization tools to allow doctors to follow the disease progression over time, compare patient data to population norms, and make decisions regarding a treatment strategy. In addition, the designed system architecture will also be developed to consider scalability and accommodate more facilities and data load features.

Clinical Trials and Validation

This will also validate the system with respect to accuracy, usability, and effectiveness in a real clinical setup. The testing will also involve clinical trials by partnering with health professionals through deployment of the system with actual Alzheimer's patients. Testing of the machine learning model and the wearable device through such use will be done to establish the accuracy in diagnosing patients and following up on their health status over time.

Doctors and other medical personnel will give feedback during testing about the interface problems, accuracy of data, and usability issues faced while dealing with the machine learning model. The model's output will also be compared with expert diagnoses to test for reliability. The cross validated by the wearable device will hence be cross validated with the traditional assessment of sleep to establish its accuracy.

Any necessary adjustments to the system will be made, as per the results from trials, in view of its high standards needed for clinical use.

Deployment and Continuous Improvement

Finally, the system will be deployed in a more general clinical environment and a framework for continuing improvement established within it. The system will be implemented in numerous healthcare facilities where it is used by doctors and medical staff to diagnose and manage cases of Alzheimer's disease. Some training will be needed to familiarize health providers with the features of the system and take them through how to use it effectively.

The performance of the system will be monitored continuously post-deployment, and updates will be made according to feedback from the users and integration of new technologies. Periodic updating of the machine learning model with new data from the wearable devices and MRI scans will help maintain its accuracy. This system will also facilitate an accurate evaluation of how the system affects patient outcome, workflow efficiency, and health-related costs, thus serving to provide invaluable lessons for further enhancements in the future.

In other words, these six steps represent an attempt to build a solid, integrated approach that could bring improvements in Alzheimer's disease diagnosis and management, better patient care, and improved use of, presumably, health care resources.

System Architecture Diagram.

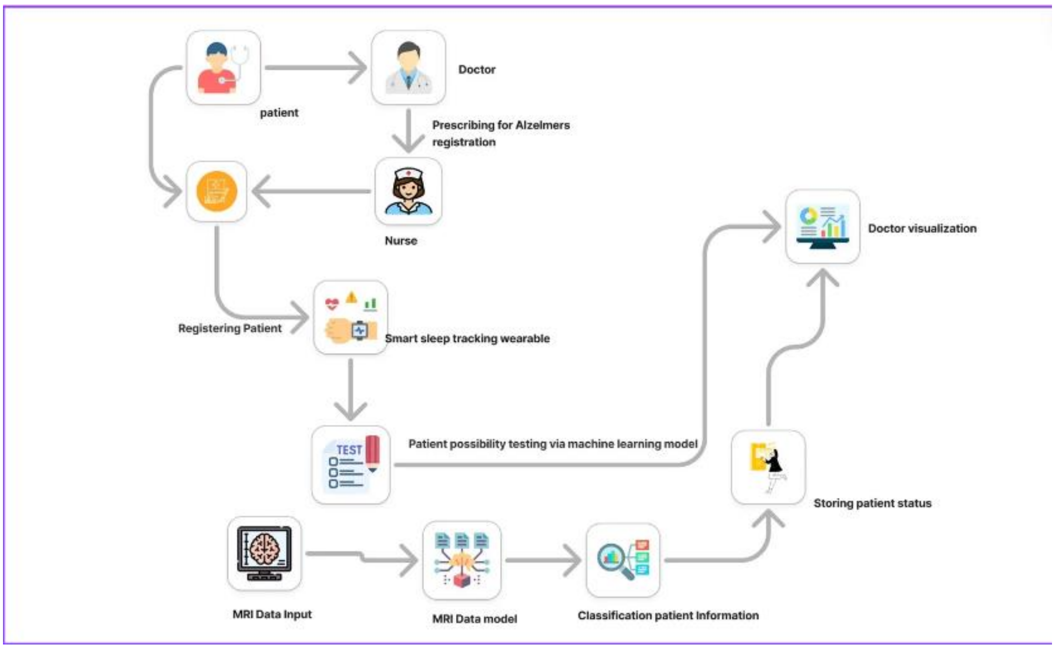


Figure 2 System architecture diagram

Project Requirements

Functional Requirements and Non-Functional Requirements

Functional Requirements	Non-Functional Requirements
• Identifying patients' possibility of having the disease using general information inputs. • Identify and classify the patient's disease status using MRI scans • Visualizing patients' medical history to the doctor.	• Create easy to use user interfaces. • Fast user interaction. • Reliable and stable application behaviour.

System Requirements

The “MentCare” project aims to provide an efficient Alzheimer’s detection feature using contextual data and machine learning. The effective functioning of this system depends on certain software and user needs being satisfied.

1. Software Requirements

The integrated Alzheimer's diagnosis and management system needs a software stack that must be very robust and flexible in order to provide functions in fluidity over several platforms and components. For the mobile application, Flutter will be used because it is cross-platform and assures seamless development on both Android and iOS devices with very consistent performance. The web application will be developed using ReactJS, which provides a flexible and efficient framework for the development of interactive and responsive user interfaces that are necessary to visualize data and perform user interactions.

The backend infrastructure will be provided by Firebase. This platform offers real-time database services, authentication, and cloud storage solutions that support safe and scalable management of data. The development and training of machine learning models, including Convolutional Neural Networks for the classification of MRI images and Random Forest algorithms for patient background data analysis, are to be done using Python with its broad range of libraries and frameworks that support machine learning and data science applications. Google Colab provides a collaborative environment for developing and training these models with strong computational resources and easy sharing.

To enable portability and maintain uniformity between the various deployment environments, the combination of applications and services using Docker will enable containerization, leading to easy deployment and maintaining the services. For effective data visualization, especially in the representation of complex scientific data and patterns, ChartJS will be a part of the dynamic and flexible charts integrated into the web application to provide reports directly impacting health decisions by professionals.

2. User Requirements

Therefore, it will meet various requirements of its primary users: medical staff, doctors, and patients. The nurses will be interested in a friendly mobile application for efficient and accurate information gathering on the patients, which will also include MRI scans, sleep quality data, and other important lifestyle habits. It has to enable smooth data entry, the ability to upload information and, at the same time, real-time synchronization with the back-end system to ensure that data is prepared for use.

Doctors need a comprehensive and user-friendly web application to integrate and visualize patient information through an interactive dashboard. Results of the diagnostics, for instance, MRI image classifications from a CNN model and risk assessments produced through Random Forest analyses of the patient's background information, should thus create lucid visualizations. Techniques for detecting sleep quality should also be exploited to enlighten the status of a patient's neurological health, thus helping doctors monitor the progress of disease and come up with effective treatment plans. It has real-time updates, historical data tracking, and predictive analytics that are key to advanced clinical decision-making and improved management of a patient's care.

Indirectly, it benefits the patients by increased diagnostic accuracy and more tuned care for the individual. In case of patient-oriented functionality—say feedback on sleep monitoring via the smart wearable—the system will present information in a user-understandable format that will, therefore, enable patients to be more active in managing their health by themselves. The data interaction occurs at very high levels of privacy and security in all forms of user interaction, to instill trust and conform to healthcare regulations.

3. Feasibility Study

The proposed system will be feasible technically, economically, and on an operational basis. From a technical perspective, the use of mature technologies such as Flutter, ReactJS, and Firebase ensures a strong foundation for development, drawing from proven tools that support scalability and maintainability. This will make the development and deployment of models very efficient. The current research backs up the chosen algorithms and techniques in image classification, like CNNs, and the methods for detection of sleep quality. It follows that the likelihood of successful implementation is highly risen, especially in similar applications.

Economically, this can easily be achieved by the fact that open-source technologies are cheaper in terms of their development cost and the use of resources with a wide adoption spread. It is envisioned to fast-track diagnosis and hence improve patient care, reducing costs for health institutions through reduced diagnosis time and improved treatment outcomes. Investing in the development of such an integrated system is, therefore, succoured because of the benefits that ought to be enjoyed in respect to efficiency, accuracy, and satisfaction from patients.

Operationally, it fits the flows of health professionals, enhancing rather than disrupting current practices. It requires minimal training and a minimal degree of training and induction because all user interfaces are simple, and a modular design enables gradual acceptance and integration into different healthcare settings. Aside from the potential issues that may arise concerning the task's completion, it assures data interoperability and maintains standards of security in its selection of technologies and best practices in software development and health data management.

Overall, the feasibility study shows that the proposed system is feasible and has great potential to enhance the diagnosis and management of Alzheimer's disease. Detailed further analysis and prototyping only solidify these findings and guide the successful execution of the project.

Work Breakdown Structure

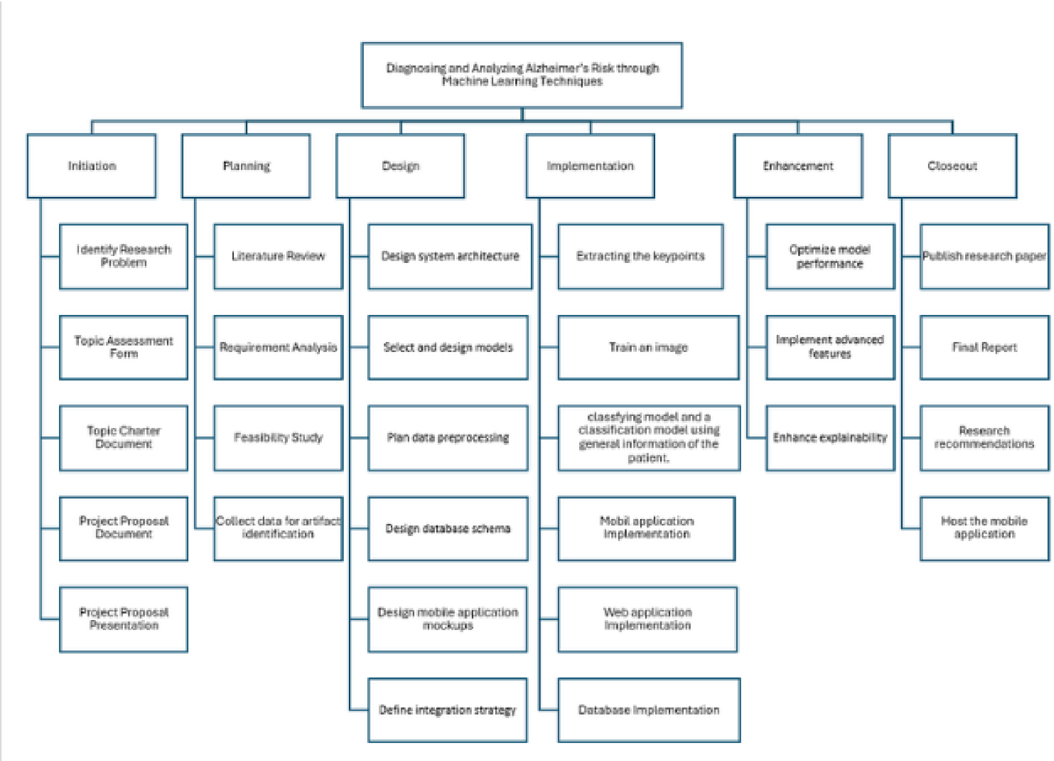
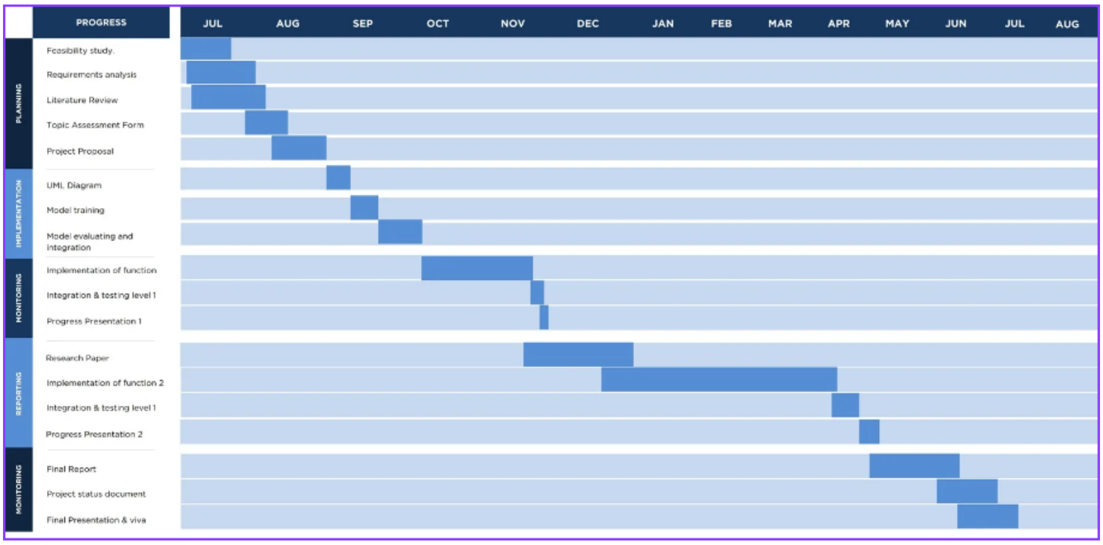


Figure 3 Work breakdown structure.

GANTT CHART



DESCRIPTION OF FACILITATORS

Supervisor:

Ms. Wishalya Tissera – Sri Lanka Institute of Information Technology.

Co-Supervisor:

Dr. Kapila Dissanayaka - Sri Lanka Institute of Information Technology.

COMMERCIALIZATION

Mental health disorders, affect a significant portion of the global population, making this a large and critical market to address. Traditional methods of diagnosing and managing mental disorders involve in-person consultations, which can be time-consuming and costly for patients. Our solution aims to bridge this gap by providing a convenient and cost-effective tool for diagnosing and managing mental disorders through a mobile application and web application. This approach not only reduces the challenges associated with traditional healthcare methods but also offers continuous monitoring and personalized insights.

We plan to introduce multiple subscription plans for different user segments:

- Monthly Subscription: Rs. 500

- Annual Subscription: Rs. 4,500

Our Target Market is General Practitioners of the MOH centers, Institutes who learn about mental disorders, General population who wish to take self-mental care. We will offer the initial mental disorders diagnosis feature free of charge, allowing users to assess their mental health at no cost. However, to access more detailed reports, continuous monitoring, and personalized treatment plans, users will need to subscribe to one of the available plans. This model ensures accessibility while also generating revenue to sustain and enhance the platform. By offering flexible pricing and targeting a wide range of users, including partnerships with community clinics, we aim to create a scalable and impactful solution in the mental health space, addressing a critical global need.

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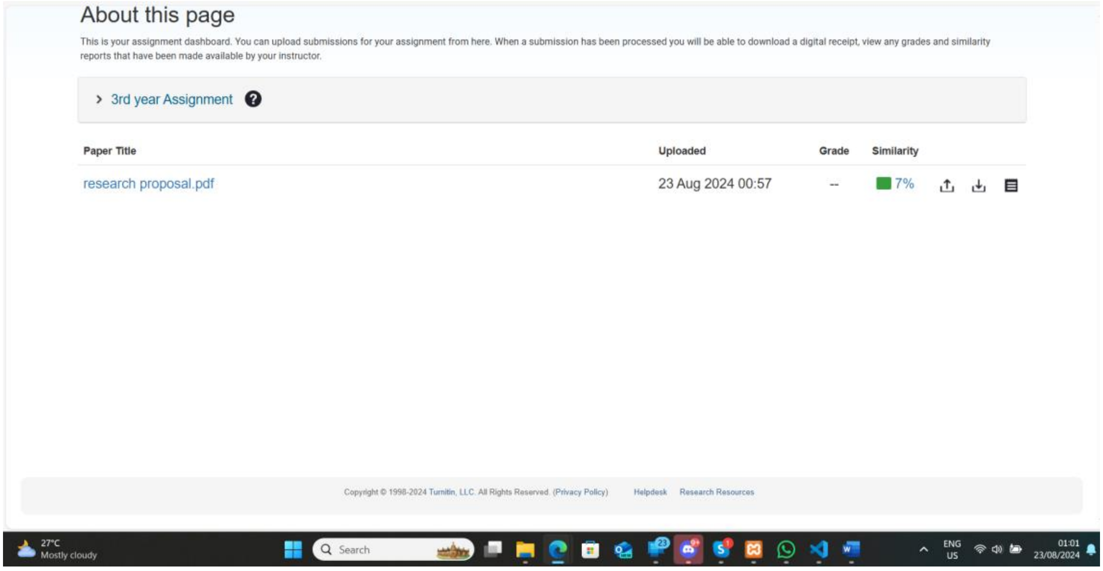
APPENDIX



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