NAAN MUDHALVAN IBM PROJECT FINAL REPORT

COGNITIVE CARE
EARLY INTERVENTION FOR ALZHEIMER'S DISEASE

ANNA UNIVERSITY REGIONAL CAMPUS COIMBATORE

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

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1. INTRODUCTION

1.1 PROJECT OVERVIEW

This project focuses on the development of an AI-based MRI classification system for the early detection and diagnosis of Alzheimer's disease. By leveraging advanced machine learning techniques, the system aims to analyze MRI scans and provide accurate predictions regarding the presence and progression of Alzheimer's disease in patients. The primary purpose of this project is to enhance cognitive care by enabling early intervention, improving patient outcomes, and contributing to the advancement of Alzheimer's research and treatment. By harnessing the power of AI, we strive to provide healthcare professionals with a reliable tool that can aid in the early identification and management of Alzheimer's disease, ultimately leading to improved patient care and quality of life.

1.2 PURPOSE

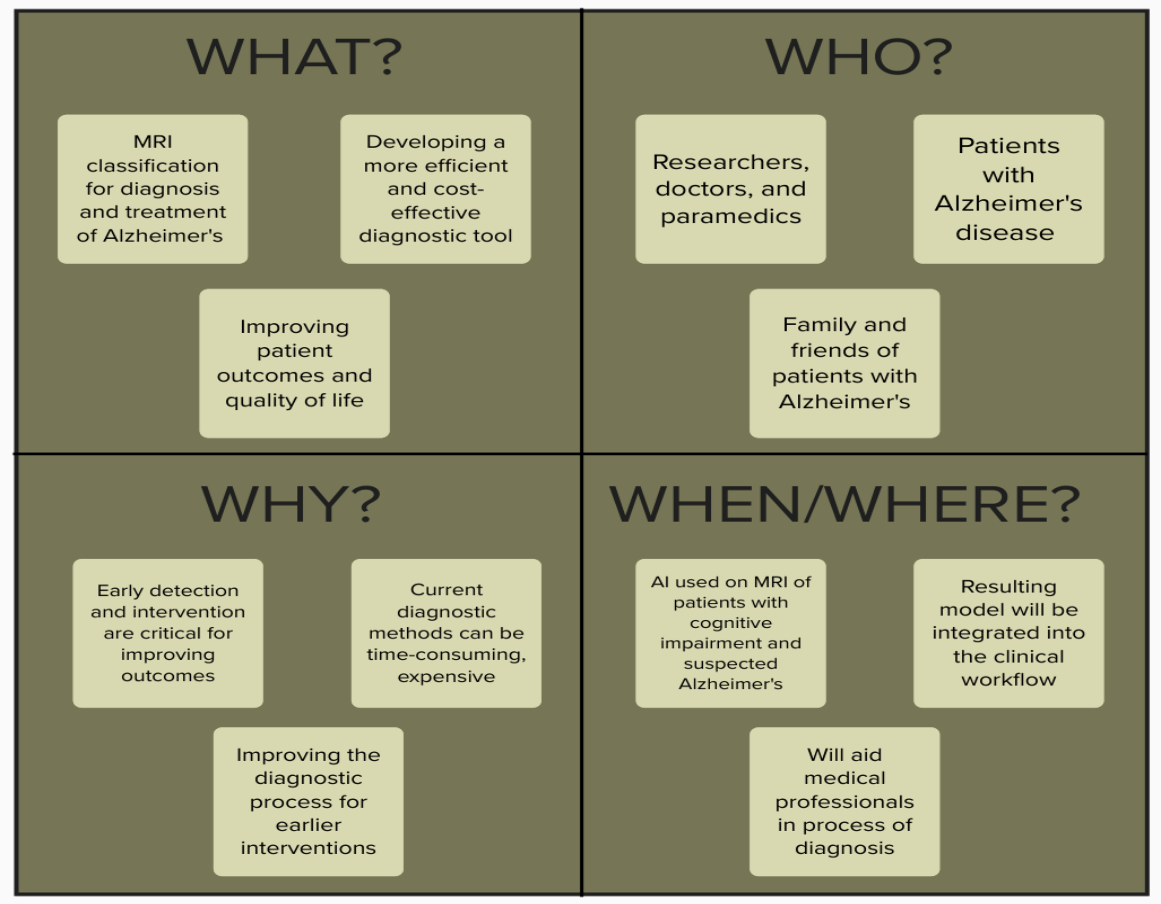
The purpose of this project is to develop an AI-based MRI classification system for Alzheimer's disease with the primary goal of enabling early detection and diagnosis. By leveraging advanced machine learning techniques, the solution aims to assist healthcare professionals in accurately identifying the presence and progression of Alzheimer's disease in patients. This project aims to contribute to the field of cognitive care by providing a reliable and efficient tool that can aid in the early intervention, personalized treatment planning, and improved management of Alzheimer's disease. The ultimate purpose is to improve patient outcomes, enhance healthcare efficiency, and contribute to the advancement of Alzheimer's research and understanding.

2. IDEATION & PROPOSED SOLUTION

2.1 PROBLEM STATEMENT DEFINITION

THE 5 W's

The 5 W's Of the Project - The 'Who','What','Why','When' and 'Where' have been summarized and presented below to get a comprehensive understanding of what this project entails.



DEFINING END USER PROBLEM STATEMENT

Below is a visual representation of the beneficiaries of the project and their respective needs analyzed and presented as our problem statement

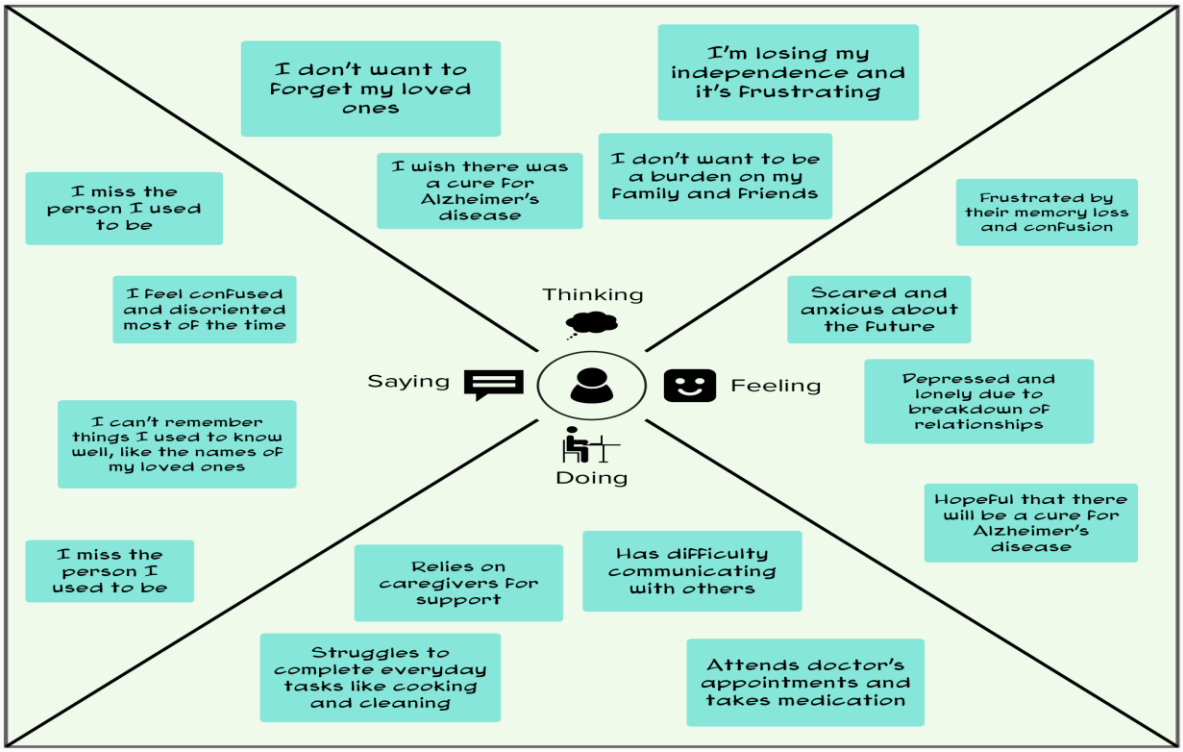
2.2 EMPATHY MAP CANVAS

EMPATHY MAP

Alzheimer's disease is a prevalent and devastating neurodegenerative disorder that affects millions of people worldwide. Patients with Alzheimer's disease often experience significant changes in their thoughts, feelings, and behaviors, which can be challenging for caregivers and loved ones to understand and manage.

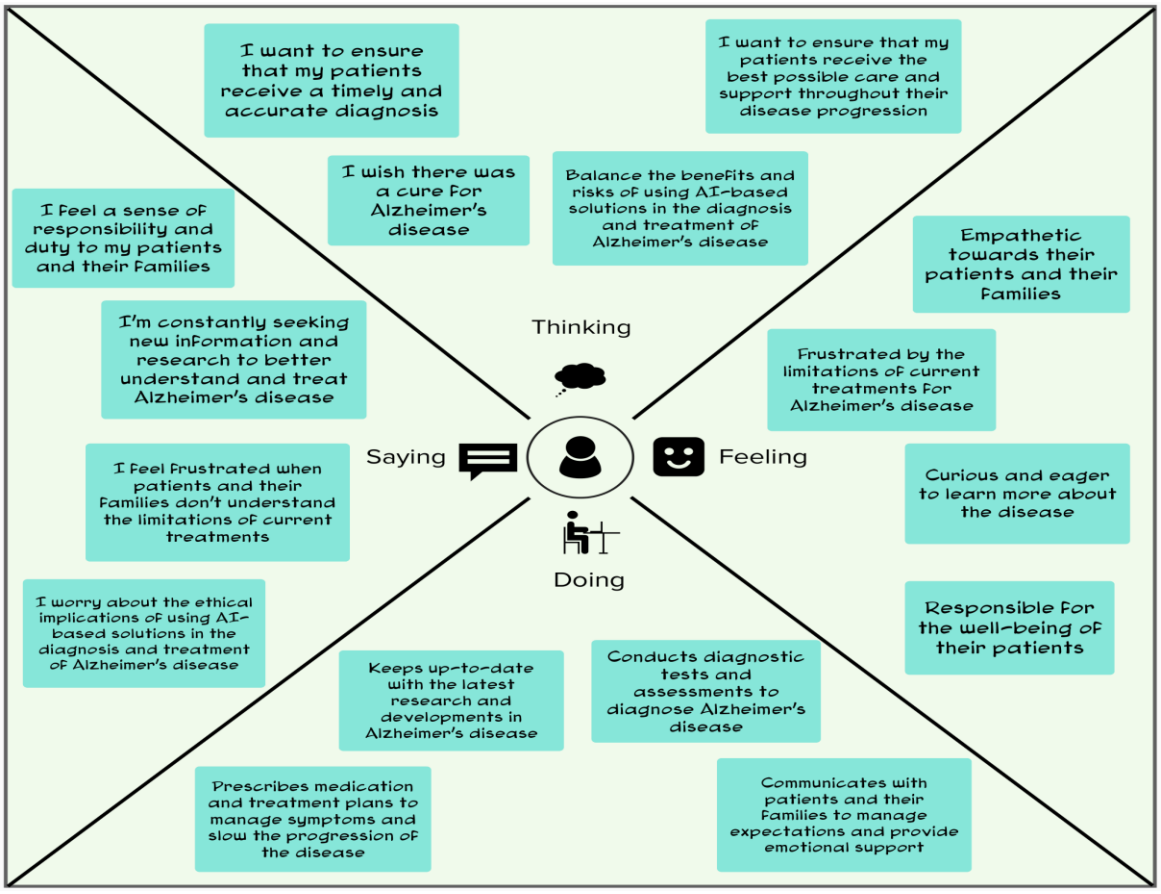
PATIENT PERSPECTIVE

By understanding the experiences of patients with Alzheimer's disease, we can develop more empathetic and effective solutions to improve their quality of life and support their caregivers and loved ones.



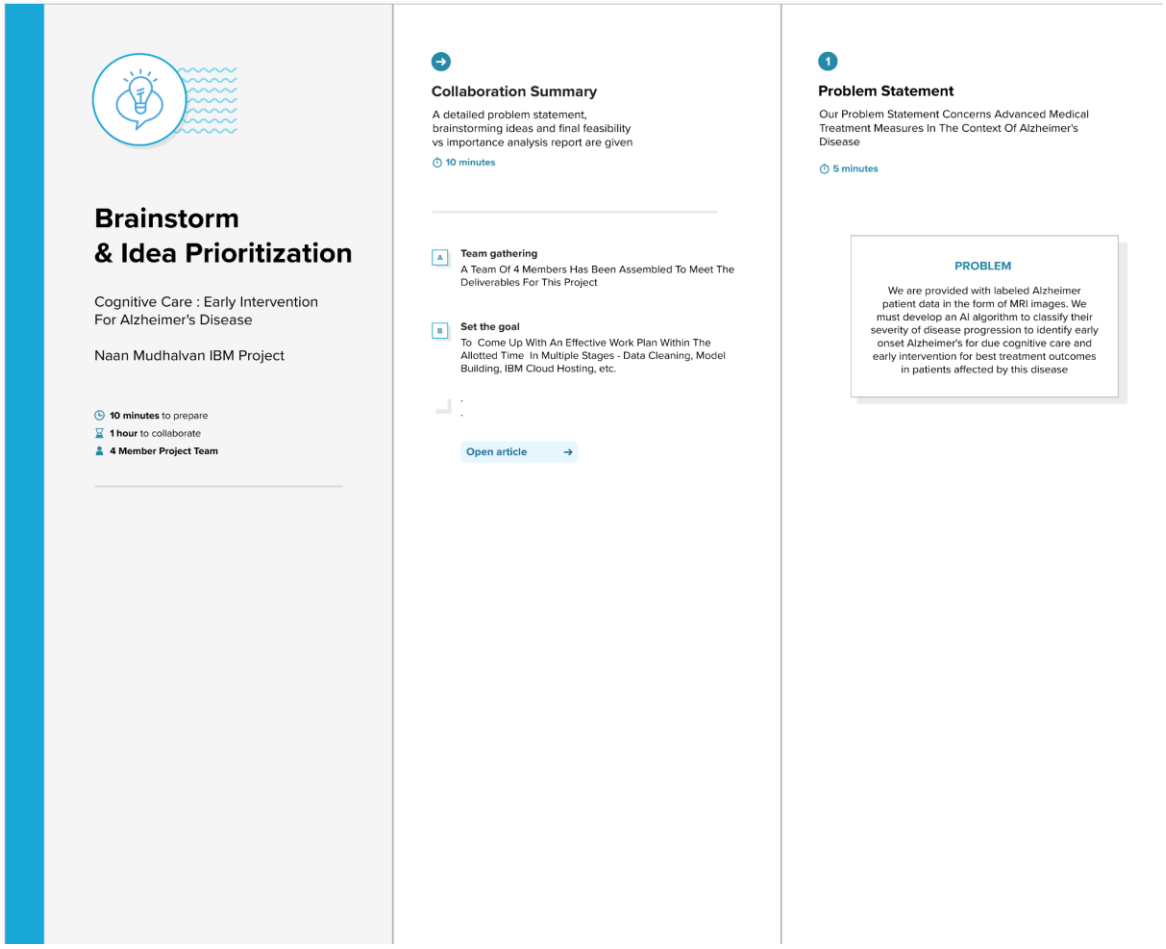
DOCTOR'S PERSPECTIVE:

The doctor empathy map highlights the challenges and responsibilities that healthcare providers face when caring for patients with Alzheimer's disease. Doctors want to provide the best possible care for their patients, but they can feel frustrated by the limitations of current treatments and worried about the ethical implications of using AI-based solutions in the diagnosis and treatment of Alzheimer's disease.



2.3 IDEATION & BRAINSTORMING

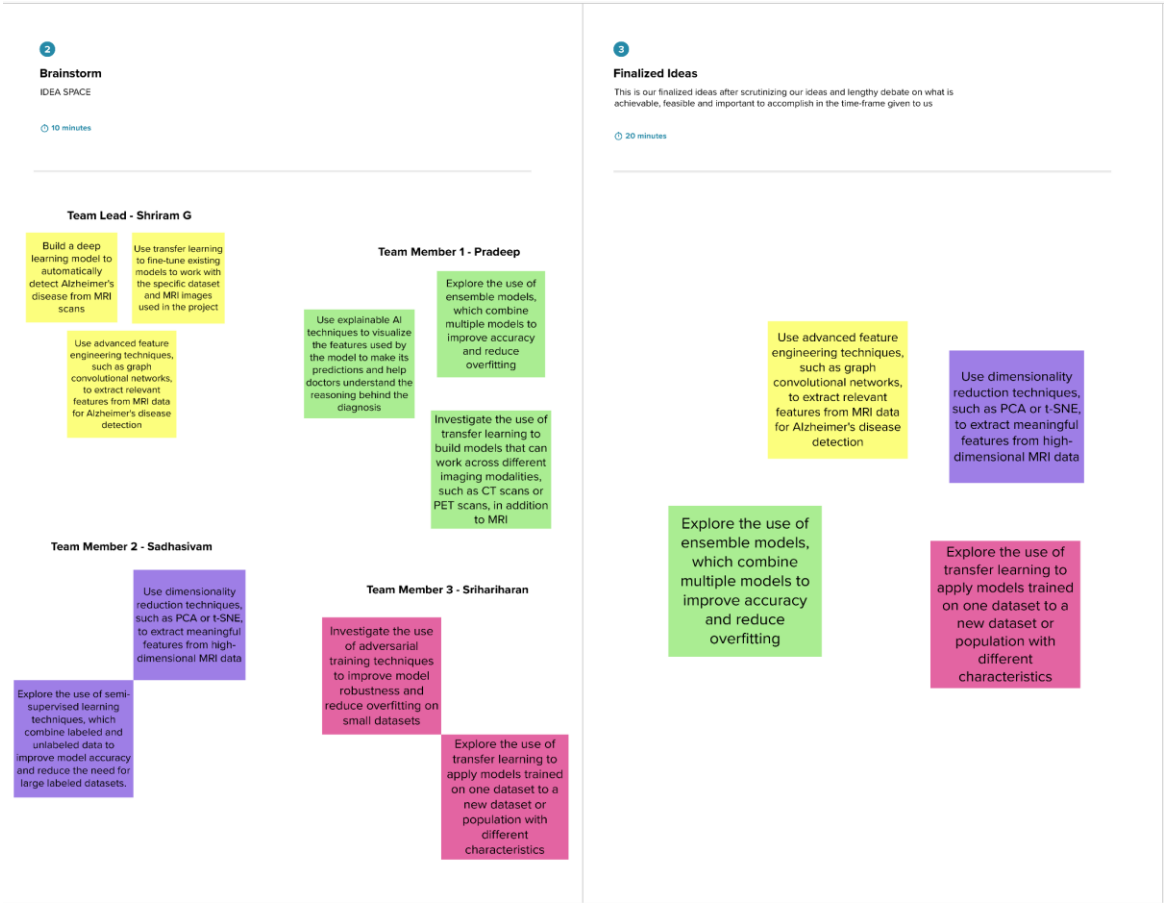
Our team's collaboration summary, the result of a collaborative brainstorming effort to generate ideas for AI-based model building for Alzheimer's disease detection and diagnosis is presented in this report



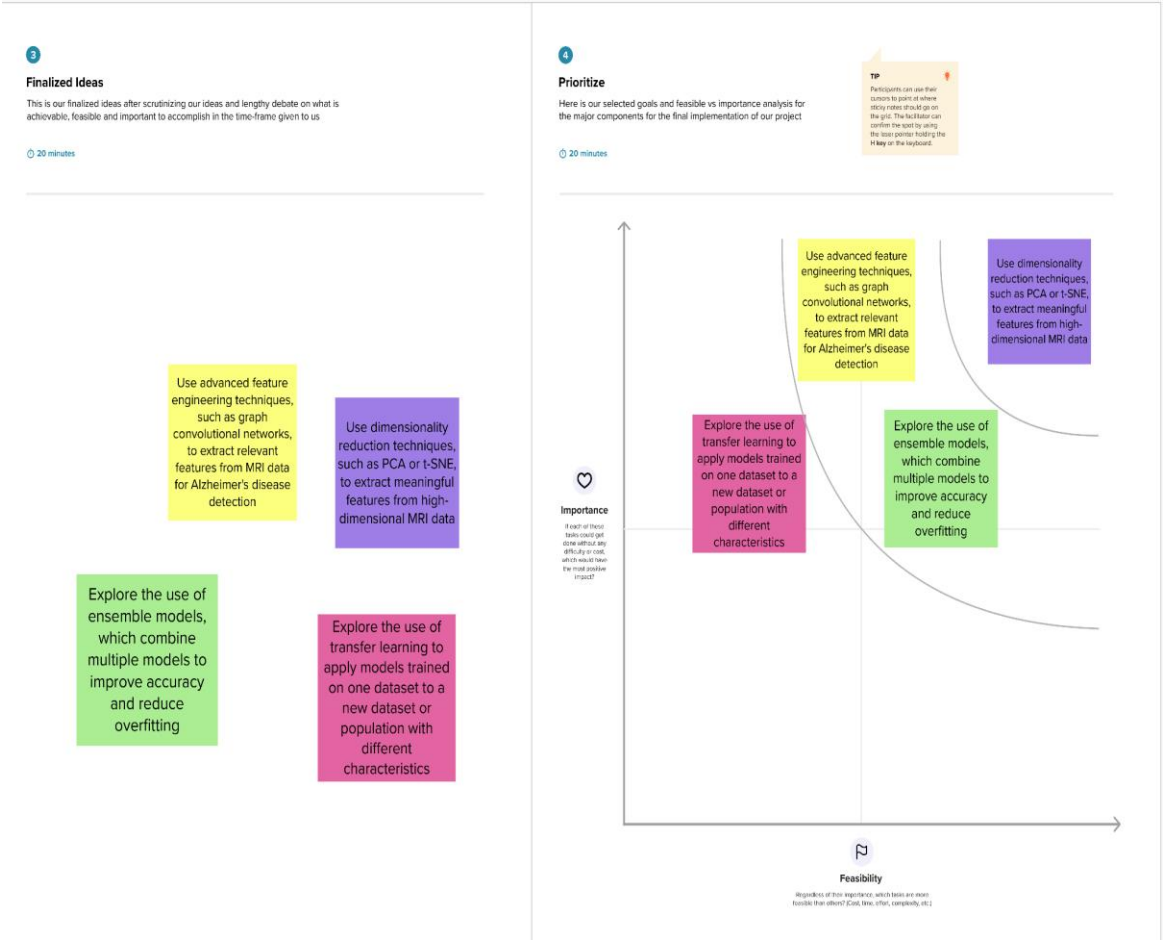
Above is our summary page.

Below is our brainstormed ideas vs our finalized ideas with contributions from each teammate which would aid in building our solution.

The ideas were selected on the basis of feasibility of implementation with the allocated timeline for completion of the project versus maximal number and efficiency of the outcomes that could be achieved in the project.



Below is our selected ideas from our brainstorming session along with our feasibility vs importance chart to help us approach the project and implement our solution in a neat and timely fashion, on a priority basis.



2.4 PROPOSED SOLUTION

S.No.	Parameter	Description
1.	Problem Statement (Problem to be solved)	The current methods for diagnosing Alzheimer's disease rely heavily on clinical assessments, neuropsychological tests, and manual analysis of brain imaging techniques. However, these methods can be time-consuming, costly, and may not provide accurate results in early stages of the disease. In addition, there is a shortage of trained healthcare professionals to perform and interpret these tests. There is a critical need for new approaches that can improve the speed, accuracy, and accessibility of Alzheimer's disease diagnosis.
2.	Idea / Solution description	We propose to develop an AI-based model that can accurately classify MRI brain scans to aid in the detection of Alzheimer's disease. The model will be trained on a large dataset of MRI scans from patients with and without Alzheimer's disease, using machine learning/deep learning algorithms to identify patterns in the data that are predictive of the disease. The model will be designed to provide a classification of Alzheimer's Disease progression in the patient from mild to severely demented stage with 4 classes of classification.
3.	Novelty / Uniqueness	1. Improved accuracy: The AI-based model can identify subtle patterns in MRI scans that may be difficult for human radiologists to detect, leading to more accurate and reliable diagnoses. 2. Faster diagnosis: The AI-based model can process MRI scans quickly, leading to faster diagnosis and treatment.

		3. Non-invasive: MRI scans are a non-invasive and widely available diagnostic tool, making this proposed solution accessible to a broad range of patients. 4. Cost-effective: The proposed solution has the potential to reduce the need for expensive and time-consuming diagnostic tests, making Alzheimer's disease diagnosis more cost-effective.
4.	Social Impact / Customer Satisfaction	By enabling early detection of the disease, patients can receive earlier treatment and support, potentially leading to better outcomes and quality of life. Furthermore, the proposed solution has the potential to reduce the financial burden on patients and healthcare systems, making Alzheimer's disease diagnosis more cost-effective and accessible to a broader range of people.By providing a faster and more accurate diagnosis, patients and their families can receive a timely diagnosis and begin planning for their future care needs. This can reduce the anxiety and uncertainty that often accompanies a long and drawn-out diagnostic process. Additionally, the non-invasive nature of MRI scans makes this proposed solution more comfortable and accessible for patients, improving their overall experience with the healthcare system
5.	Business Model (Revenue Model)	The proposed solution for Alzheimer's disease diagnosis through AI-based MRI classification can have a revenue model that includes both one-time and recurring revenue streams. One-time revenue streams may include revenue generated from the sale or licensing of the software to healthcare institutions or diagnostic centers. Recurring revenue streams may include

		maintenance fees for the software and potentially ongoing service fees for healthcare institutions. To generate revenue through the sale or licensing of the software, we can develop a pricing model based on the market's willingness to pay. This depends on competitor pricing. Additionally, we can explore the possibility of revenue-sharing models with healthcare institutions that use our software. To generate recurring revenue, we can offer maintenance and support services for the software. This will include software updates and troubleshooting services. Furthermore, we may explore offering ongoing service fees to healthcare institutions to support the integration of the software into their existing systems
6.	Scalability of the Solution	1. The AI-based model can be easily integrated with existing healthcare systems, allowing for seamless integration and scalability. 2. The solution is highly adaptable and can be customized to meet the specific needs of different healthcare institutions and patient populations. 3. New data can be easily incorporated into the model, improving its accuracy and scalability over time.

3. REQUIREMENT ANALYSIS

3.1 FUNCTIONAL REQUIREMENT

FR No.	Functional Requirement	Sub Requirement
FR-1	MRI Classification Model	The model must classify Alzheimer MRI in at least 4 classes. Must not be too big in size. But not take up too much memory to run. Must be flexible to load and run on any platform.
FR-2	Alzheimer MRI Upload	A neat HTML Page with a nimble backend. Form to upload patient MRI images to be predicted.
FR-3	Alzheimer MRI Prediction Result View	Result view must contain prediction for uploaded MRI Must have a description of the predicted class. Must contain guideline recommendations on care to be provided at that stage of disease progression.
FR-4	IBM Cloud Storage For Reconfiguration	Model must be hosted on IBM Cloud Storage Must be in the Dallas-South region for anywhere anytime accessibility with no service failures.

3.2 NON-FUNCTIONAL REQUIREMENT

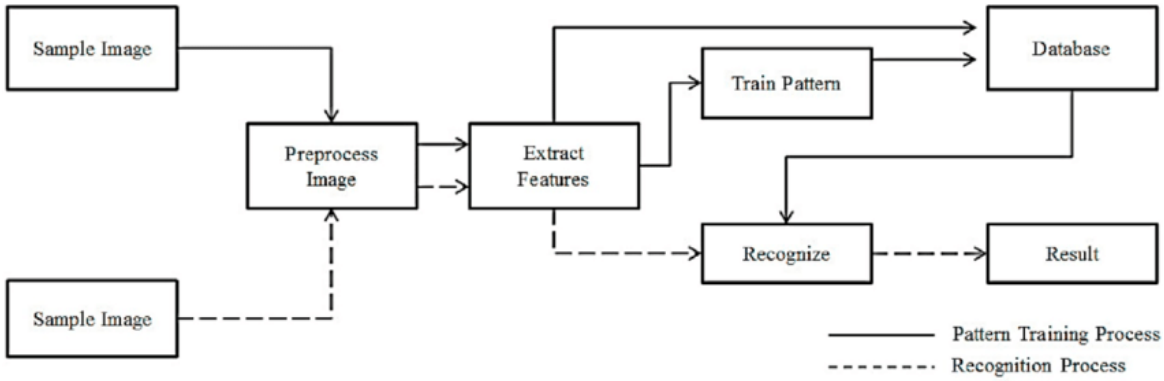
FR No.	Non-Functional Requirement	Description
NFR-1	Usability	The solution should have an intuitive user interface that is easy to navigate and understand. The solution should have a short learning curve, allowing healthcare professionals to quickly grasp how to use the software effectively.
NFR-2	Security	Adhere to strict data privacy regulations, such as General Data Protection Regulation (GDPR) or Health Insurance Portability Laws, depending on the jurisdiction.

		Can be deployed on healthcare institution servers to ensure maximal safety to prevent data breach.
NFR-3	Reliability	The model must have a reasonable accuracy score of at least 90 percent.
NFR-4	Performance	The model must run with minimal latency to give a result upon feeding the input.
NFR-5	Availability	The model must be available on a needs basis of the institution's functioning hours. This need not run on an emergency basis as it is not an immediate life-threatening illness.
NFR-6	Scalability	The solution must be easily scalable and adaptable to integration with all other softwares used by the medical institution and rapidly adapt to other technologies.

4. PROJECT DESIGN

4.1 DATA FLOW DIAGRAMS

A Data Flow Diagram (DFD) is a traditional visual representation of the information flows within a system. A neat and clear DFD can depict the right amount of the system requirement graphically. It shows how data enters and leaves the system, what changes the information, and where data is stored.



4.2 SOLUTION & TECHNICAL ARCHITECTURE

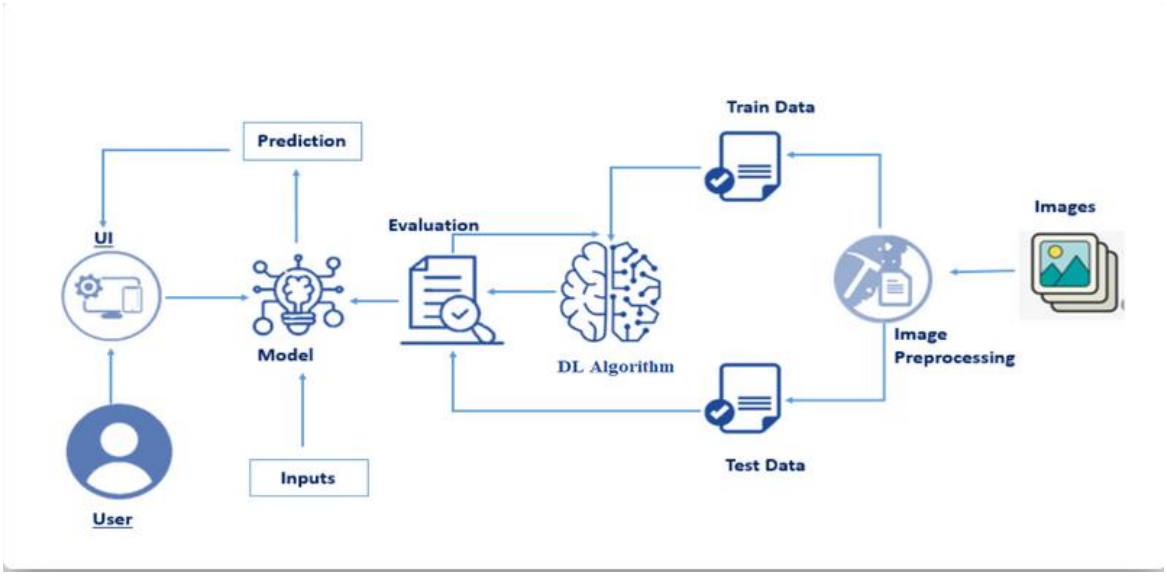
General Solution Architecture

The solution architecture for an AI-based MRI classification model typically includes the following components:

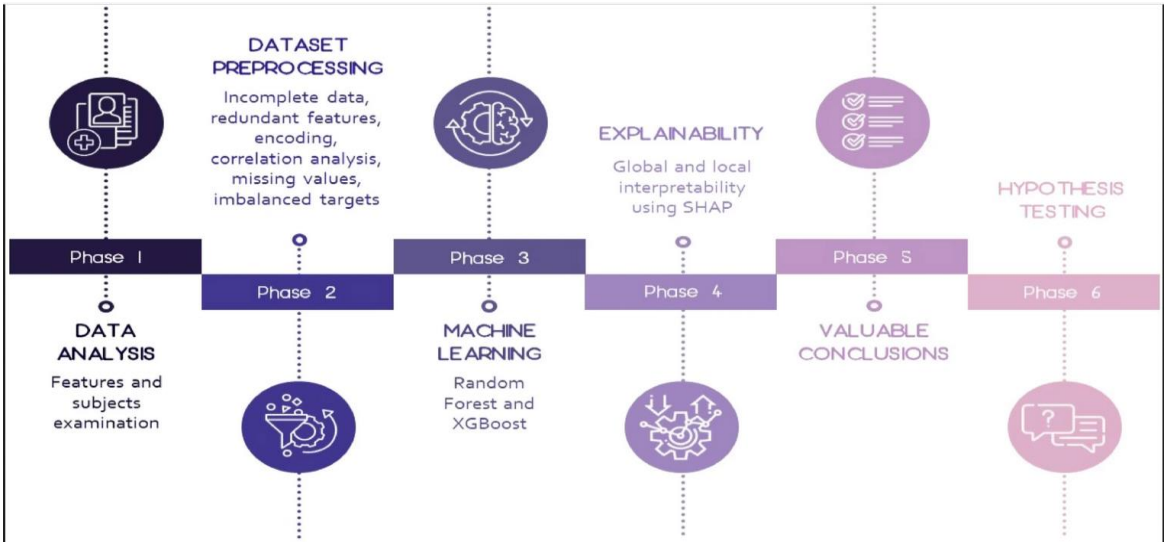
1. Data collection and preprocessing
2. Feature extraction
3. Model development
4. Model evaluation
5. Model deployment
6. Continuous learning

A Block Diagram Visualization Of Our Solution Architecture is presented below

Simplified Model:


Prediction
UI
Model
Evaluation
Train Data
DL Algorithm
Images
Image
Preprocessing
Test Data
Inputs
User

MLWorkflow:


DATASET
PREPROCESSING
Incomplete data, redundant features, encoding, correlation analysis, missing values, imbalanced targets
EXPLAINABILITY
Global and local interpretability using SHAP
HYPOTHESIS
TESTING
Phase 1
Phase 2
Phase 3
Phase 4
Phase 5
Phase 6
DATA
ANALYSIS
Features and subjects examination
MACHINE
LEARNING
Random Forest and XGBoost
VALUABLE
CONCLUSIONS

Software Architecture:

The software architecture will consist of a client-server model, with the client application running on a healthcare professional's device and the server application running on a cloud-based platform. The client application will provide an intuitive interface for the user to upload patient MRI scans and view the AI-generated diagnosis results. The server application will house the AI models for MRI classification and provide the necessary compute power to process the large amounts of data generated by the client application.
The solution will be developed in multiple phases, starting with the design and development of the AI models for MRI classification. The models will be trained on large datasets of MRI scans to ensure high accuracy in diagnosis. The client-server application will then be developed, integrating the AI models into the server application and designing the user interface for the client application. In the final phase, rigorous testing and quality assurance measures will be implemented to ensure the software's reliability and accuracy.

Project Stages :

1. Data collection and Pre-processing: In this step, MRI scans of patients are collected and pre-processed to remove any unwanted artifacts and noise. This is an important step as it ensures that the quality of data used for model training and development is of high quality. Pre-processing techniques may involve filtering, noise reduction, and image enhancement techniques to improve the accuracy of the MRI scans.
2. Feature extraction: Once the MRI scans are pre-processed, AI algorithms are used to extract features from them. These features can include shape, size, texture, and intensity of different regions of the brain. Feature extraction is a crucial step in the development of the AI model, as it determines the predictive power of the model. Different algorithms and techniques can be used for feature extraction, such as Principal Component Analysis (PCA), Independent Component Analysis (ICA), and Wavelet Transform.
3. Model development: In this step, the extracted features are used to train and develop an AI model using machine learning algorithms such as deep learning. The choice of algorithm and architecture depends on the nature of the problem and the type of data. Deep learning

algorithms, such as Convolutional Neural Networks (CNNs), are commonly used for MRI classification problems due to their ability to extract hierarchical features from data.

4. Model evaluation: The developed model is evaluated to ensure that it meets the desired performance criteria. Evaluation metrics such as accuracy, sensitivity, specificity, and area under the curve (AUC) are used to assess the performance of the model. The model may need to be fine-tuned and optimized based on the evaluation results.
5. Model deployment: The developed model is then deployed in a healthcare institution's IT infrastructure to process new MRI scans and make diagnostic predictions. The model may be integrated with existing electronic health record systems for seamless data exchange and processing.
6. Continuous learning: As new data becomes available, the model can be re-trained and updated to improve its accuracy and reliability. This process of continuous learning is essential to ensure that the model remains up-to-date with the latest data and trends.

4.3 USER STORIES

User Type	**Functional Requirement**	**User Story Number**	**User Story / Task**	**Acceptance criteria**	**Priority**	**Team Member**
Doctor	Access In Any Device	USN-1	As a user, I can access the application from a phone, tablet or laptop	I can access the interface	High	Shriram
Doctor	MRI Upload	USN-2	I should be able to upload the MRI image	MRI image upload	High	Pradeep
Doctor	MRI Prediction	USN-3	The MRI status prediction must be received	There is good accuracy in the predictions	High	Sadhasivam
Doctor	Description	USN-4	The proper description of the state must be given for the prediction	Description should be clear and concise	High	Sriharihara n

5. CODING & SOLUTIONING

5.1 ALZHEIMER CLASSIFICATION MODEL

An Deep Learning Model was developed to classify MRI images of Alzheimer's patients into 4 classes of Non-Demented, Mildly Demented, Very Mildly Demented and Moderately Demented. It was trained with an Xception model as the baseline and multiple Convolution Neural Network Architecture based layers. ImageDataGenerator was used for preprocessing before feeding the data into the model. The Tensorflow library was used to code the solution along with the Open Computer Vision Library (OpenCV) and the Keras Tensorflow (API).The model was developed on Google Colaboratory and the model file was stored in IBM Watson Studio's Cloud Object Storage, using the IBM Watson Machine Learning Client Library in python.

```
custom_inception_model = Sequential([
    xcep_model,
    Dropout(0.5),
    GlobalAveragePooling2D(),
    Flatten(),
    BatchNormalization(),
    Dense(512,activation='relu'),
    BatchNormalization(),
    Dropout(0.5),
    Dense(256,activation='relu'),
    BatchNormalization(),
    Dropout(0.5),
    Dense(128,activation='relu'),
    BatchNormalization(),
    Dropout(0.5),
    Dense(64,activation='relu'),
    BatchNormalization(),
    Dropout(0.5),
    Dense(4,activation='softmax'),
],name="inception_cnn_model")
```

The general code has been attached in the Training Folder.

5.2 FLASK WEB INTERFACE

The Flask Web Microframework was used to develop and implement a flexible, scalable and simple web interface for using the Deep Learning Model with a Graphical User Interface (GUI).

Jinja2 was used for templating the interface. The official Flask Project Directory structure was used in the backend. Bootstrap was used for styling our HTML pages.

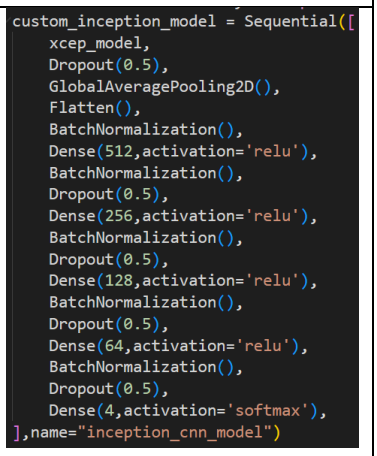
```python
@app.route('/', methods=['GET'])
def index():
    # Main page
    return render_template('alzheimers.html')

@app.route('/predict', methods=['GET','POST'])
def upload():
    if request.method == 'POST':
        # Get the file from post request
        f = request.files['image']
        basepath = os.path.dirname(__file__)
        file_path = os.path.join(
            basepath, 'uploads', secure_filename(f.filename))
        f.save(file_path)
        img = load_img(file_path, target_size=(180,180,3))
        x = img_to_array(img)
        x = np.expand_dims(x,axis=0)
        # image_data = preprocess_input(x)
        #with graph.as_default():
        #    set_session(sess)
        preds = model.predict(preprocess_input(x))
        preds = np.argmax(preds, axis=1)
        print(preds)
        index = ['MildDemented','ModerateDemented','NonDemented','VeryMildDemented']
        text = str(index[preds[0]])
        print(text)
        return render_template('predict.html', text=text)
    return render_template("predict.html",text='Please upload an image first')
```

6. RESULTS

6.1 PERFORMANCE METRICS

Model Performance Testing:

S.No.	Parameter	Values	Screenshot
1.	Model Summary	• It uses a Custom Xception Model while keeping a pre-trained Xception model with frozen weights as the base model upon which our model architecture is extended. • Pre-trained CNN model as a Feature Extractor. • Sequential Layers of GlobalAveragePooling2D, SeperableConv2D, BatchNormalization are used. • ReLu activation function has been taken in the dense layers. • Softmax in the output layer. • It is trained for 30 epochs. • RMSPROP is the optimizer. • The Loss Function is Categorical Cross Entropy	
2.	Accuracy	Accuracy Score = 0.9060 Loss = 0.2810 AUC = 0.9846 Validation loss = 0.3822 Validation Accuracy = 0.8621 Validation AUC = 0.9761	Not Applicable (N/A). Colab Jupyter Notebook Submissions may be referred.

7. ADVANTAGES & DISADVANTAGES:

Advantages:

1. Early Detection: The AI-based MRI classification system offers the advantage of early detection and diagnosis of Alzheimer's disease. By accurately analyzing MRI scans, healthcare professionals can identify the disease at an early stage, allowing for timely intervention and personalized treatment plans.
2. Improved Accuracy: The use of advanced machine learning techniques enables the system to provide more accurate predictions compared to traditional diagnostic methods. This can lead to improved diagnostic accuracy, reducing the chances of misdiagnosis and providing more reliable information for healthcare professionals.
3. Efficient and Time-saving: The automated nature of the AI system streamlines the diagnostic process by quickly analyzing MRI scans and providing diagnostic predictions. This saves valuable time for healthcare professionals, allowing them to focus on patient care and treatment decisions.
4. Personalized Treatment: With accurate diagnosis, the system can contribute to personalized treatment planning for Alzheimer's patients. By understanding the specific stage and progression of the disease, healthcare professionals can tailor treatment strategies to individual patients, potentially improving therapeutic outcomes.

Disadvantages:

1. Dependence on Quality of MRI Scans: The accuracy and reliability of the AI system heavily rely on the quality of the MRI scans. Inaccurate or low-quality scans may result in misleading or incorrect predictions, emphasizing the importance of acquiring high-quality scans for optimal performance.
2. Ethical Considerations: The use of AI in medical diagnostics raises ethical concerns regarding patient privacy, data security, and the responsible use of AI algorithms. Safeguards and strict protocols must be in place to protect patient data and ensure ethical practices are followed throughout the system's implementation.

3. Limited Scope: The AI system focuses specifically on MRI-based classification of Alzheimer's disease. It may not address other aspects of the disease or consider complementary diagnostic modalities, potentially limiting its overall utility in comprehensive Alzheimer's diagnosis and management.
4. Technical Challenges: Developing and deploying an AI-based system requires technical expertise and infrastructure. Challenges such as model training, integration with existing systems, and system maintenance may arise, requiring dedicated resources and support for successful implementation.

It is important to consider these advantages and disadvantages in the context of the project to ensure that the benefits outweigh the limitations and challenges, and that the solution can effectively contribute to the early detection and management of Alzheimer's disease.

8. CONCLUSION

In conclusion, the development of an AI-based MRI classification system for the early detection and diagnosis of Alzheimer's disease holds immense potential in revolutionizing cognitive care. By leveraging advanced machine learning techniques, the system can accurately analyze MRI scans and provide timely predictions regarding the presence and progression of Alzheimer's disease. This technology offers several significant advantages, including early detection, improved accuracy, efficiency, and personalized treatment planning.

The implementation of this AI solution has the potential to significantly impact patient outcomes by enabling early intervention and tailored treatment strategies. By detecting Alzheimer's disease at an early stage, healthcare professionals can initiate appropriate interventions and therapies, potentially slowing down the progression of the disease and improving the quality of life for patients.

9. FUTURE SCOPE

1. Enhanced Diagnostic Capabilities: The AI system can be further improved to incorporate additional diagnostic modalities, such as genetic markers, cerebrospinal fluid analysis, and cognitive assessments. Integrating multiple sources of data can enhance the accuracy and reliability of Alzheimer's disease diagnosis, leading to more comprehensive and precise patient evaluations.
2. Multi-Class Classification: Currently, the focus of the AI system is on binary classification, distinguishing between Alzheimer's disease and healthy individuals. Future research can explore the expansion of the classification model to include multiple disease subtypes and cognitive conditions, allowing for a more nuanced diagnosis and tailored treatment approaches.
3. Longitudinal Monitoring: The AI system can be extended to enable longitudinal monitoring of Alzheimer's disease progression. By analyzing a series of MRI scans over time, the system can provide insights into disease progression patterns and assist in tracking the effectiveness of interventions and therapies.
4. Integration with Electronic Health Records (EHR): Integrating the AI system with EHR systems can enable seamless data exchange and facilitate real-time decision support for healthcare professionals. This integration can enhance the efficiency of the diagnostic process and ensure the integration of AI-based predictions into routine clinical workflows.
5. Collaboration and Data Sharing: Collaboration among research institutions, healthcare organizations, and data-sharing initiatives can significantly contribute to the development and improvement of AI-based MRI classification systems. Sharing anonymized MRI datasets and collaborating on model development can lead to more robust and generalizable AI models with better diagnostic performance.
6. Expansion to Other Neurological Disorders: The AI system's framework and methodology can be applied to other neurological disorders beyond Alzheimer's disease. This includes conditions such as Parkinson's disease, multiple sclerosis, and stroke, where MRI plays a vital role in diagnosis and monitoring. By adapting and expanding the AI model, it can be extended to cater to the specific characteristics of these disorders, aiding in their early detection and management.

10. APPENDIX

SOURCE CODE AND GITHUB PROJECT REPO LINK :
https://github.com/naanmudhalvan-SI/PBL-NT-GP--1610-1680518166.git
DEMO LINK :
https://drive.google.com/file/d/1vGx_24yNLQLfYrukCXnJiHn5mQWwbJio/view?usp=share_link