GSFC UNIVERSITY
EDUCATION RE-ENVISIONED
An ISO 9001:2015 Certified

REPORT

Machine Learning-Based Forecasting of the Progression of Alzheimer's Disease

Degree of Bachelor of Science (BSc)

Submitted By

Dhruv Verma

23SC06007

School Of Science

Submitted To : Department of data science, School of science,

GSFC University, Vadodara

Faculty mentor: Dr. Dhaval Thakkar

Date of Report Submission: 18 March 2025

ACKNOWLEDGEMENT

I express our heartfelt gratitude to the inventors and researchers behind the patent *Machine Learning-Based Forecasting of the Progression of Alzheimer's Disease* for their valuable contribution to the advancement of artificial intelligence in healthcare.

We also thank the faculty of **GSFC University**, whose academic insights and encouragement have played a key role in enhancing our understanding of patent analytics and AI applications in medicine.

A special note of appreciation goes to **Dr. Dhaval Thakar**, our mentor, for his unwavering support, valuable feedback, and mentorship throughout this project.

Thank you for your guidance and support.

Sincerely,

Dhruv Verma

Enrollment No.: 23SC06007

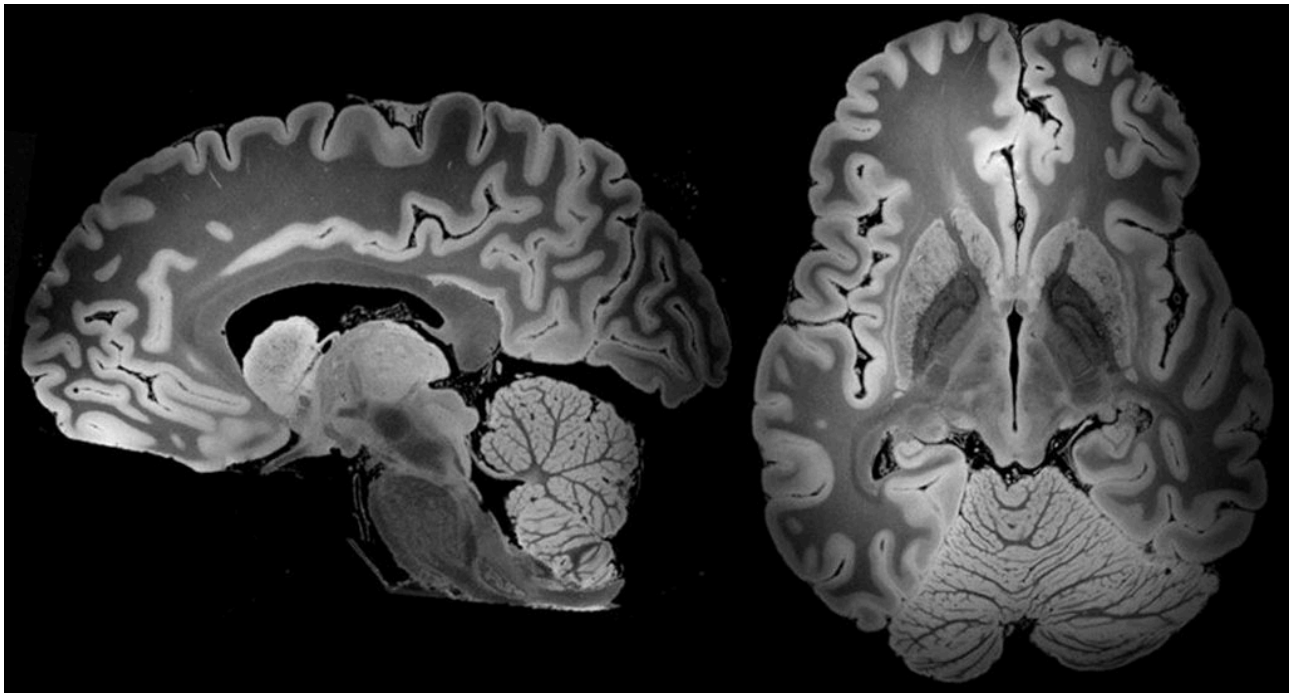
TABLE OF CONTENT

1. Introduction to Project

Alzheimer's disease (AD) is a chronic, progressive neurodegenerative disorder that significantly impairs cognitive functions such as memory, reasoning, and communication. It is among the most common causes of dementia in the elderly population.

Given the absence of a definitive cure, **early detection** of Alzheimer's is vital. Traditional diagnostic tools involve neuroimaging, cerebrospinal fluid analysis, and cognitive testing, which may be costly and require expert interpretation. This scenario has encouraged the integration of **Machine Learning (ML)** for analyzing large medical datasets and predicting disease progression.

This report provides a comprehensive study of a patented invention that introduces a machine learning-based approach to forecast the progression of Alzheimer's disease. The study covers the technical description, novelty, application potential, and the broader relevance of the patent.



2. Title & Field of Invention

1. **Patent Title:** Machine Learning-Based Forecasting of the Progression of Alzheimer's Disease

2. **Patent Number:** US 11,101,039 B2

3. **Inventor:** Jack Albright

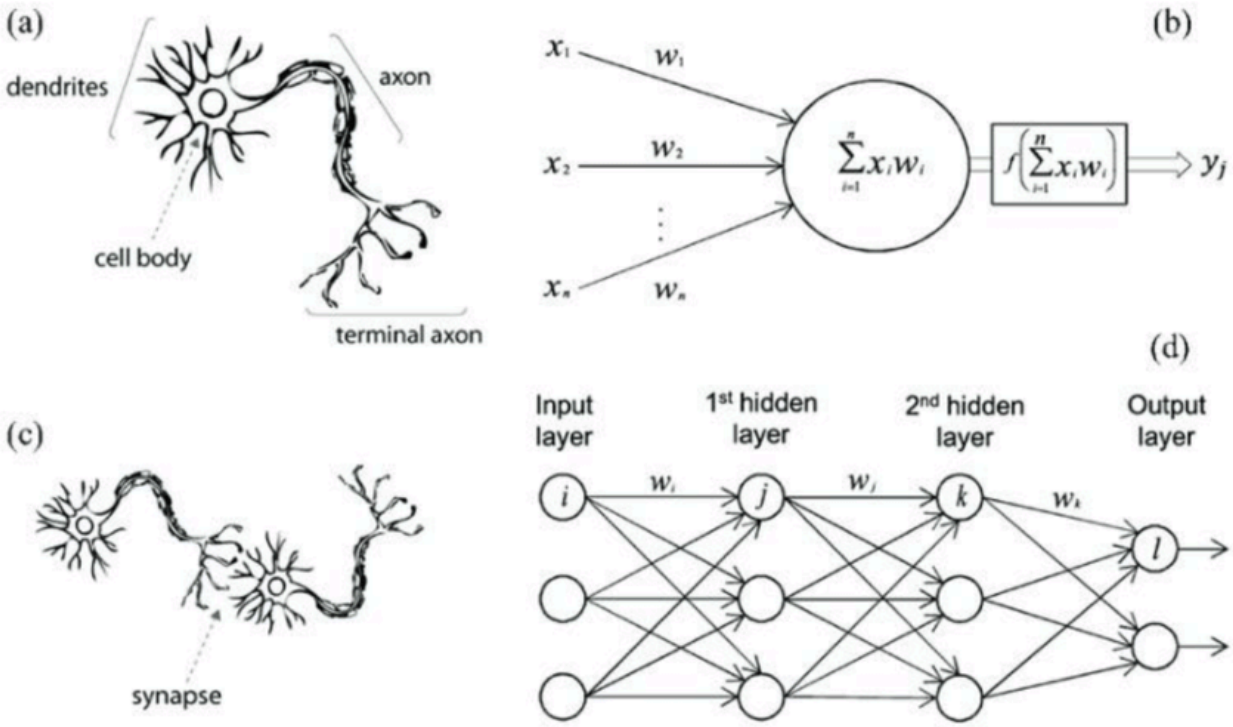
4. **Field of Invention:** Artificial Intelligence and Healthcare Analytics

This patent belongs to the intersection of healthcare and computer science, particularly applying AI to neurodegenerative disease diagnosis and management.

3. Abstract of Invention

The invention presents an AI-based forecasting system that uses clinical data from patients across multiple time points to predict the onset and progression of Alzheimer's disease. The core innovation lies in the **"All-Pairs" data analysis technique**, which compares features from every possible pair of patient visits to identify patterns and transitions between disease stages.

The system employs advanced neural network architectures (MLP, RNN) trained on the Alzheimer's Disease Neuroimaging Initiative (ADNI) dataset to predict outcomes like Mild Cognitive Impairment (MCI) and Dementia.



4. Prior Art & Problem Statement

Prior Art

Previous solutions for AD diagnosis primarily included:

1. Neuroimaging (MRI, PET)
2. Cognitive testing (MMSE, CDR)
3. Genetic and biomarker analysis

Machine learning models have also been introduced, but they mainly focus on classification (i.e., identifying whether a patient has AD or not), rather than predictive forecasting.

Problem Statement

There is a gap in AI tools capable of accurately forecasting the progression of AD across months or years. Clinicians need decision-support systems that go beyond detection and assist in longitudinal disease management. The patent fills this gap with an innovative forecasting technique.

5. Objectives of the Invention

1. To build a machine learning system that **predicts the timeline** of Alzheimer's disease progression.
2. To use historical clinical data from patients for **temporal pattern analysis**.
3. To aid clinicians in **early diagnosis** and **personalized treatment planning**.
4. To improve the accuracy and interpretability of AI models in healthcare.

6. Patent Eligibility Criteria

6.1 Novelty

1. First-of-its-kind **All-Pairs comparison** technique across patient visits.
2. Combines structured time-series data with neural networks for forecasting, not just classification.

6.2 Inventive Step

1. Applies a new feature engineering strategy enabling **pairwise temporal comparisons**.
2. Demonstrates significant improvements in forecasting accuracy for MCI and AD onset.

6.3 Industrial Application

1. Deployable in hospital settings, research labs, and pharmaceutical trials.
2. Can integrate with Electronic Health Records (EHR) systems for real-time predictions.

7. Specification

1. **Input Data:** Clinical test results, medical history, and other patient data collected at multiple visits.

2. **Feature Engineering:** Uses the All-Pairs technique to generate feature vectors that reflect differences between visits.

3. **Algorithms:** Trains Multilayer Perceptron (MLP) and Recurrent Neural Networks (RNN) models for sequence learning and forecasting.

4. **Output:** Probabilistic predictions of disease stages over time.

8. Detailed Description/Working of Invention

Step 1: Data Collection

Patient records from the **ADNI database** include imaging results, test scores (MMSE, ADAS-Cog), and lab biomarkers. Data from multiple visits are collected.

Step 2: Feature Extraction

The system generates feature vectors by comparing every pair of visits. This **All-Pairs method** captures dynamic changes in a patient's health over time.

Step 3: Model Training

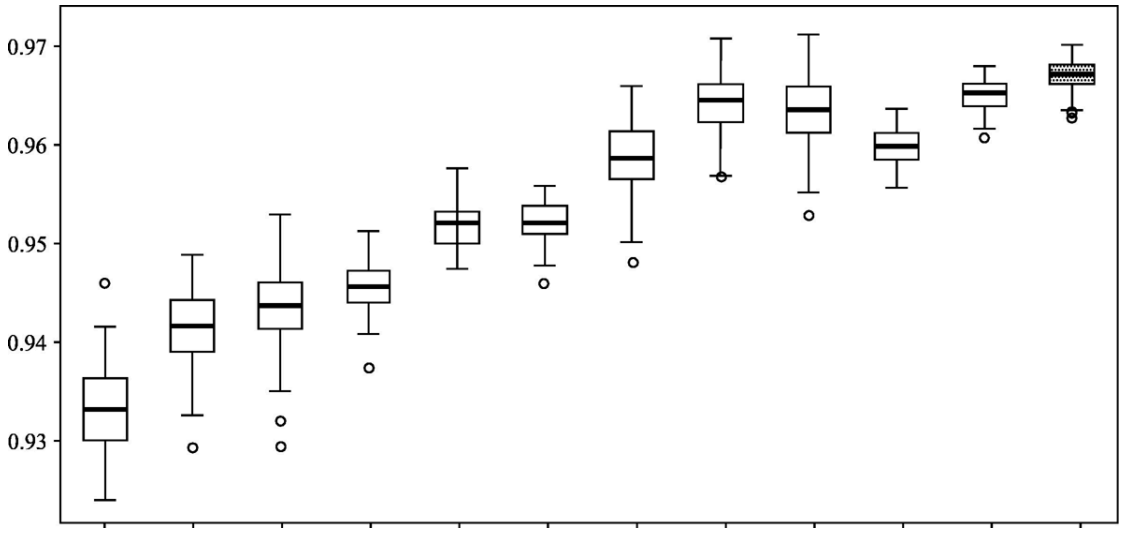
MLP and RNN models are trained on these features. The RNN, in particular, is adept at learning from sequential, time-dependent data.

Step 4: Forecasting

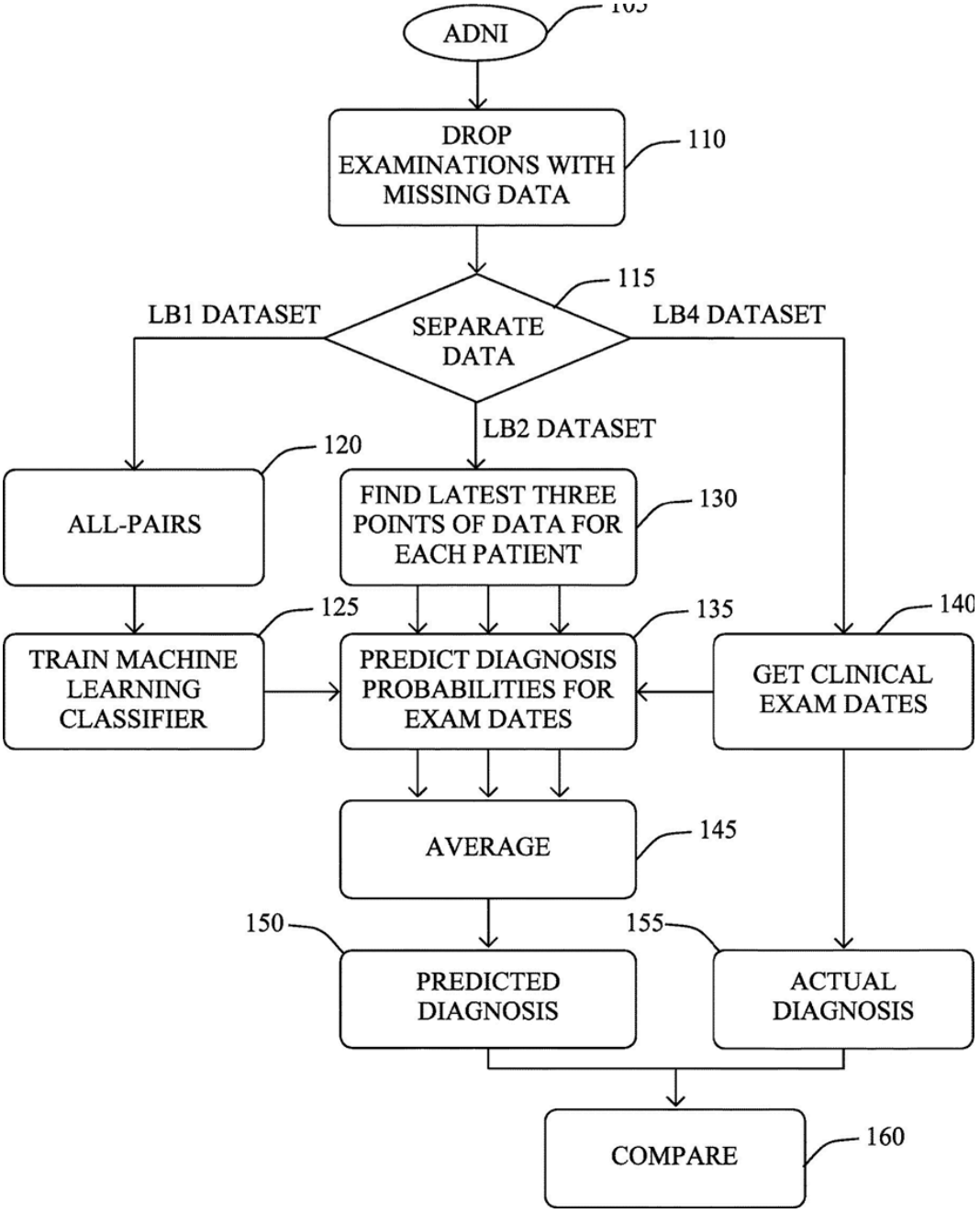
The trained model predicts the **probability distribution** of a patient transitioning into MCI or AD at future time points (e.g., in 6 months or 1 year).

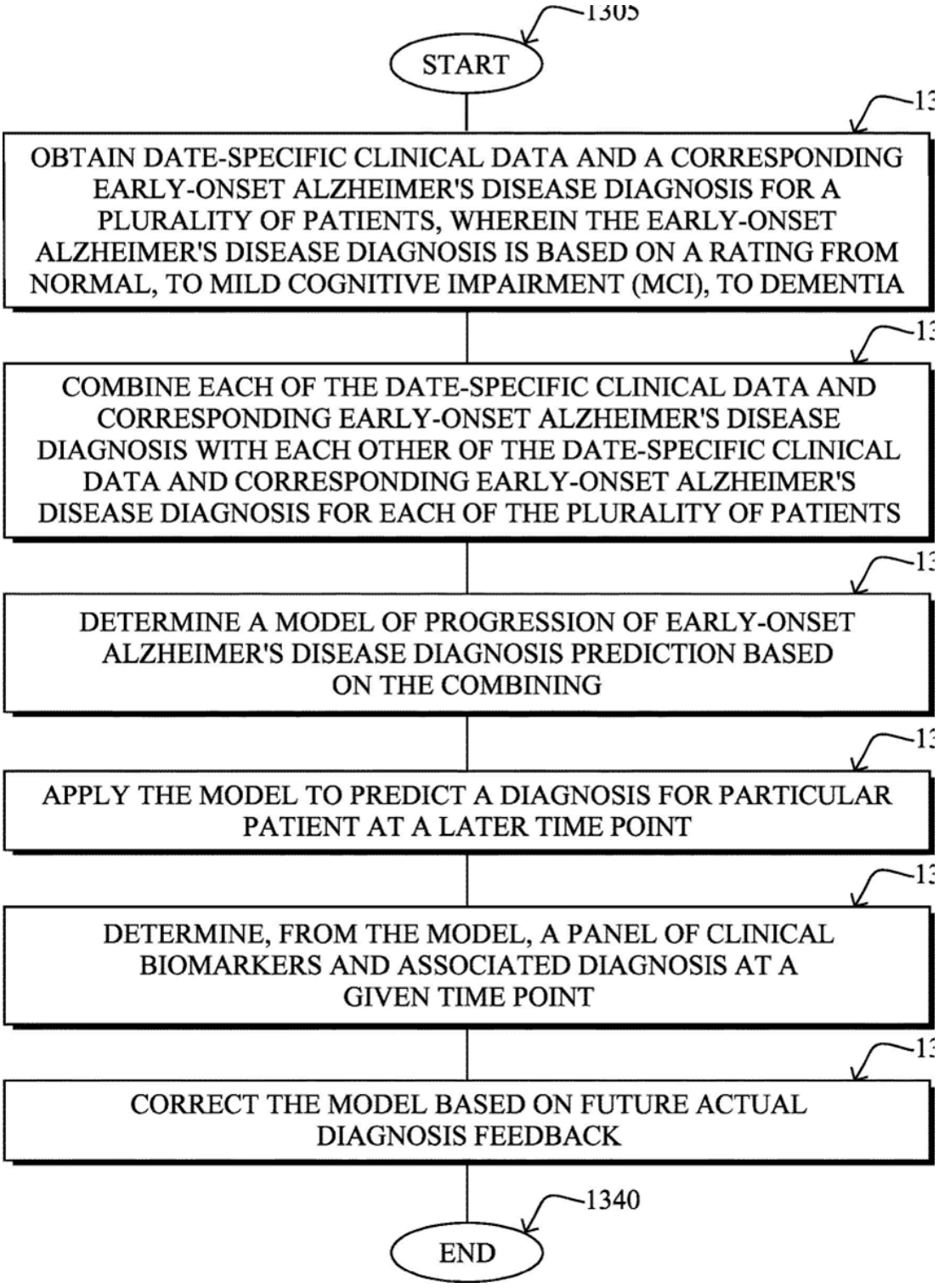
9. Diagrams & Illustrations

1. **System Architecture Diagram** of the AI framework.
2. **Data Flow Chart** from clinical records to prediction output.
3. **Graphical Comparison** of model accuracy (MLP vs RNN).
4. **Confusion Matrix** and ROC curves illustrating model performance.



Accuracy scores of MLP and RNN model


ADNI
105
DROP EXAMINATIONS WITH MISSING DATA
110
SEPARATE DATA
115
LB1 DATASET
LB4 DATASET
LB2 DATASET
ALL-PAIRS
120
FIND LATEST THREE POINTS OF DATA FOR EACH PATIENT
130
TRAIN MACHINE LEARNING CLASSIFIER
125
PREDICT DIAGNOSIS PROBABILITIES FOR EXAM DATES
135
GET CLINICAL EXAM DATES
140
AVERAGE
145
PREDICTED DIAGNOSIS
150
ACTUAL DIAGNOSIS
155
COMPARE
160


1305
START
OBTAIN DATE-SPECIFIC CLINICAL DATA AND A CORRESPONDING EARLY-ONSET ALZHEIMER'S DISEASE DIAGNOSIS FOR A PLURALITY OF PATIENTS, WHEREIN THE EARLY-ONSET ALZHEIMER'S DISEASE DIAGNOSIS IS BASED ON A RATING FROM NORMAL, TO MILD COGNITIVE IMPAIRMENT (MCI), TO DEMENTIA
COMBINE EACH OF THE DATE-SPECIFIC CLINICAL DATA AND CORRESPONDING EARLY-ONSET ALZHEIMER'S DISEASE DIAGNOSIS WITH EACH OTHER OF THE DATE-SPECIFIC CLINICAL DATA AND CORRESPONDING EARLY-ONSET ALZHEIMER'S DISEASE DIAGNOSIS FOR EACH OF THE PLURALITY OF PATIENTS
DETERMINE A MODEL OF PROGRESSION OF EARLY-ONSET ALZHEIMER'S DISEASE DIAGNOSIS PREDICTION BASED ON THE COMBINING
APPLY THE MODEL TO PREDICT A DIAGNOSIS FOR PARTICULAR PATIENT AT A LATER TIME POINT
DETERMINE, FROM THE MODEL, A PANEL OF CLINICAL BIOMARKERS AND ASSOCIATED DIAGNOSIS AT A GIVEN TIME POINT
CORRECT THE MODEL BASED ON FUTURE ACTUAL DIAGNOSIS FEEDBACK
1340
END

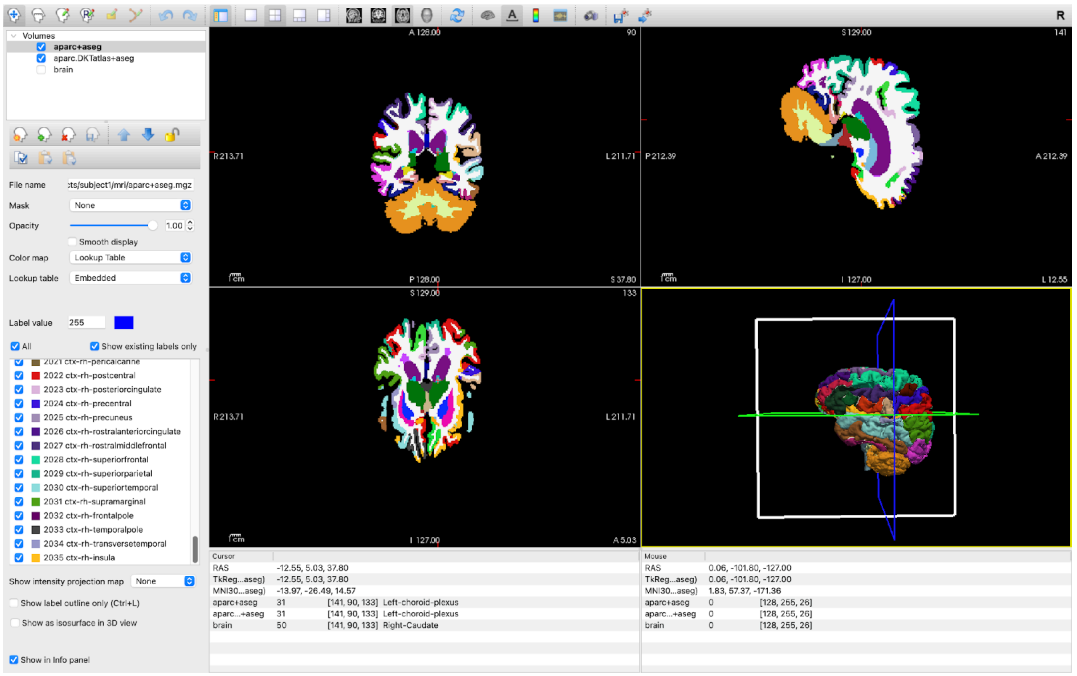


Figure: Human Brain MRI data in 3D space

10. Advantages & Applications

1. **Clinical Decision Support:** Helps physicians monitor at-risk patients with greater precision.
2. **Research Utility:** Can stratify patient cohorts for trials based on predicted disease trajectory.
3. **Scalability:** Deployable in any clinical setting with digital patient records.
4. **Cost Reduction:** Less dependence on invasive tests and high-cost imaging.
5. **Personalized Medicine:** Enables more accurate, patient-specific treatment strategies.

Table: Advantages and Disadvantages of MLP and RNN

Aspect	MLP (Multi-Layer Perceptron)	RNN (Recurrent Neural Network)
Architecture	Feedforward neural network with one or more hidden layers	Neural network with recurrent connections that maintain memory of previous inputs
Data Handling	Works best with fixed-size input data	Designed for sequential and time-series data
Temporal Awareness	No understanding of sequence or time dependency	Remembers previous inputs using internal memory (hidden state)
Application in Forecasting	Can detect patterns but lacks contextual understanding over time	Ideal for predicting changes over time, such as disease progression from visit-to-visit
Training Complexity	Simpler and faster to train	More complex to train due to recurrent dependencies and risk of vanishing gradients
Accuracy in AD Forecasting	Moderate—good for static comparison tasks	High—captures temporal progression better, making it more suitable for Alzheimer

11. Claims of the Patent

The patent makes the following legal claims:

1. An AI system that predicts future onset of cognitive impairment using historical patient data.
2. A unique method for generating All-Pairs feature vectors from temporal clinical data.
3. Implementation of a forecasting engine using MLP/RNN architectures.
4. Application of the model in a diagnostic or prognostic healthcare environment.

12. Learning from Patent Study

From this study, the following insights were gained:

1. The immense potential of AI in **preventive healthcare**.
2. How **feature engineering and data preprocessing** significantly impact model performance.
3. The value of patents in **protecting technological innovation**, particularly in interdisciplinary fields.
4. The growing relevance of **interdisciplinary knowledge**—combining AI, medicine, and IP law.
5. Importance of structured research, reproducibility, and ethical deployment in health AI.

13. Patent Filing Trends in India

Trends

1. Rapid rise in AI-healthcare patents in India over the last decade.
2. Increased participation from academic institutions and startups.

Supportive Policies

1. **Startup India, Digital India** encourage tech-enabled healthcare.
2. **National IPR Policy** promotes awareness and filing of patents among researchers.

Implications

1. Indian innovators are entering the AI-medical diagnostics space.
2. Greater collaboration between AI researchers and clinicians is expected.

14. Conclusion

This patent study emphasizes the transformative role of machine learning in tackling complex health issues like Alzheimer's disease. By offering a robust forecasting system, the patented model demonstrates how AI can go beyond classification to provide **dynamic, longitudinal insights**.

The All-Pairs approach and neural network implementation represent a leap in AI diagnostics, holding promise for real-world clinical use. This study not only contributes to our technical knowledge but also inspires responsible innovation in healthcare AI.