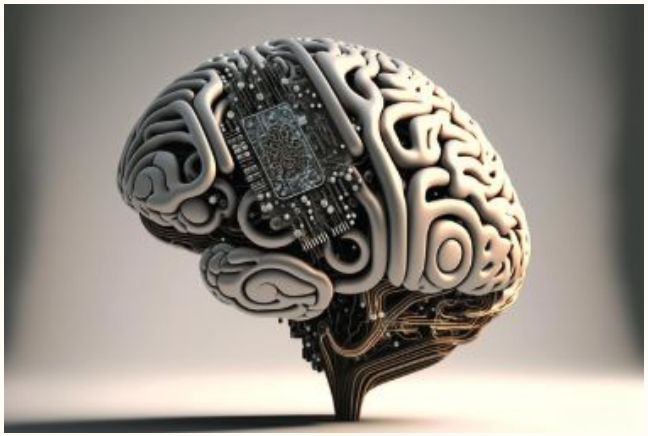
Team Brainiacs: Dementia Diagnosis



Matt Le
Ingrid Blankevoort
Patrick McCourt
Spencer Gerritsen
Vijay Srinivasula

Project Overview

This project uses deep learning to analyze MRI brain scans to determine whether a patient shows signs of **dementia**. By processing uploaded images through a trained classification model, our app provides a rapid, and humane screening result to support early detection and clinical decision-making.

Goal

To create an AI-powered tool that combines symptom input and MRI analysis to detect **dementia** and assess its severity, aiding early diagnosis and supporting clinical decision-making.

Objectives

- Build an image recognition model using a Convolutional Neural Network or CNN
- Train a Large Language Model or LLM using Google Gemini 2.0
- Connect the two models for a single output (diagnosis)

Resources

- Tensorflow.keras
- Gemini 2.0 Flash
- Langchain_google_genai
- Kaggle datasets

What is Dementia?

Dementia is a general term for a decline in cognitive function severe enough to interfere with daily life. It includes memory loss, impaired reasoning, and difficulty with language and problem-solving.

Alzheimer's Disease is the leading cause of **Dementia** accounting for 60 - 70%

55 million worldwide
10 million cases per year
139 million by 2050 projected

Genetics, family history, and conditions like cardiovascular disease, diabetes, and high blood pressure

Age is greatest risk factor especially after 65 as well as lifestyle such as physical inactivity, poor diet, and smoking

Women are disproportionately affected, making up nearly two-thirds of cases

Four Main Categories of Dementia

Or how our model classifies each image

01

Non-Demented

- No sign of dementia

02

Very Mild

- Memory lapses
- Difficulty with complex tasks
- Able to live independently
- Personality changes

03

Mild

- Pronounced memory loss
- Difficulty recognizing people
- Trouble with language
- Needs help with daily tasks

04

Moderate

- Loss of ability to communicate
- Physical decline
- Requires full-time care
- Difficulty swallowing, incontinence, and unresponsiveness

Overview of Methodology

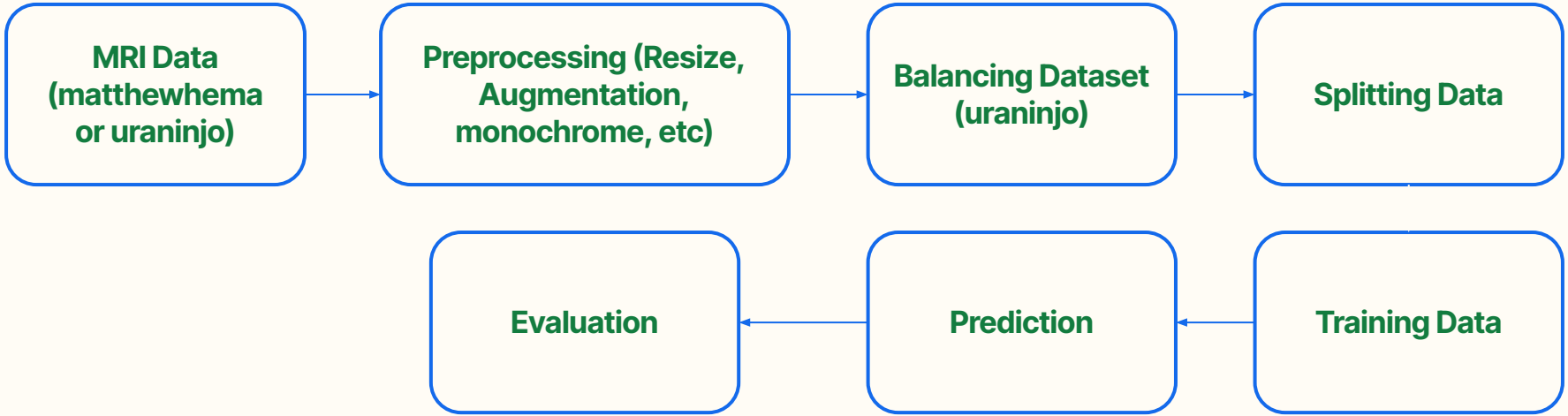
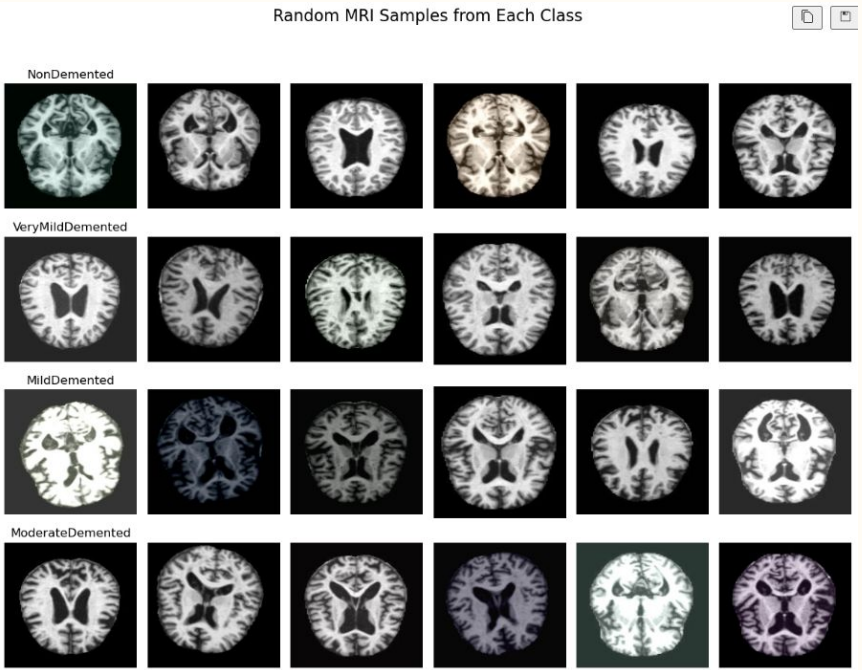


Image Processing & Visualization



‘Quality of life’ functions leveraged from Keras

- **ImageDataGenerator()**
  - Pass all image processing parameters (rescale, normalization, rotation, etc)
- **train_datagen.flow_from_directory()**
  - Large batch process images from a structured directory

Categorical Encoding

- 0 : Mild Demented
- 1 : Moderate Demented
- 2 : Non-Demented
- 3 : Very Mild Demented

Note: Data set from Uraninjo came pre-augmented to balance data (rotated and color washed)

MRI Dataset (Uraninjo) - Generators Comparison

Split MRI Data	Train Generator (70%)	Validation Generator (15%)	Test Generator (15%)
Purpose	Train the CNN model	Monitor performance during training	Final model evaluation
# of Images	23,788	5097	5099
Image Size	224x224 or 240x240 pixels		
Pixel normalize	Rescaled to 0-1 range		
Batch Size	32 images		

To ensure consistency: all 3 generators apply the same normalization and image sizing, data augmentation (rotation, flipping, etc), use ‘categorical’ (NOT ordinal) class mode to create one-hot encoded target vectors for multi class classification (softmax output).

CNN Model from Scratch

```
# Build the CNN Model from scratch
model = Sequential([
    # Input Layer
    Conv2D(32, (3, 3), activation='relu', kernel_regularizer=l2(0.001), input_shape=(240, 240, 3)),
    BatchNormalization(),
    MaxPooling2D((2, 2)),

    # Hidden Layers
    Conv2D(64, (3, 3), activation='relu', kernel_regularizer=l2(0.001)),
    BatchNormalization(),
    MaxPooling2D((2, 2)),

    Conv2D(128, (3, 3), activation='relu', kernel_regularizer=l2(0.001)),
    BatchNormalization(),
    MaxPooling2D((2, 2)),

    # Flattening Layer and Dense Layers
    Flatten(),
    Dense(256, activation='relu'),
    Dropout(0.5),
    Dense(512, activation='relu'),
    Dropout(0.5),
    Dense(4, activation='softmax')
])

# Compile the model
model.compile(optimizer=Adam(learning_rate=1e-4),
              loss='categorical_crossentropy',
              metrics=['accuracy'])
```

Basic Features of CNN Model

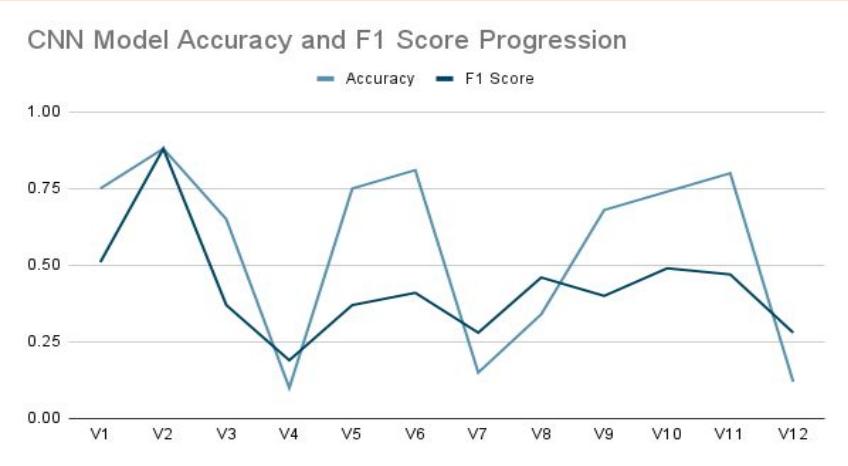
- Attempt to prevent overfitting
  - Regularizer()
  - BatchNormalization()
- 2 to 3 Hidden layers with MaxPooling()
- 2 to 3 Dense layer with 0.2 to 0.5 dropout
- Activation: Relu
- Classification: Softmax - 4

Matt

CNN Model Tuning - Lots of Trial and Error!

	Model	Accuracy	F1 Score
V1	CNN Sequential (base model)	0.75	0.51
V2	CNN Sequential (doubled neurons)	0.87	0.88
V3	CNN Sequential (Grayscale)	0.65	0.37
V4	CNN Sequential (back to RGB)	0.10	0.19
V5	VGG-16 (applied on matthehema)	0.75	0.37
V6	VGG-16 (doubled neurons)	0.81	0.41
V7	CNN Sequential (ordinal encoded)	0.15	0.28
V8	CNN Sequential (back to categorical)	0.34	0.46
V9	CNN Sequential (applied on matthehema)	0.68	0.40
V10	CNN Sequential (run w/out validation)	0.74	0.49
V11	CNN Sequential (increased layers)	0.80	0.47
V12	RESNET	0.12	0.28

- We produced 12 total models (scratch, VGG-16, RESNET)
- Over 33 hours of processing time with Apple Silicon M1
- All history and models saved (.keras and .pkl)
- Trial and error included alternating between different data sets, adding additional dense and hidden layers, trying different data sets, ordinal encoding, etc.



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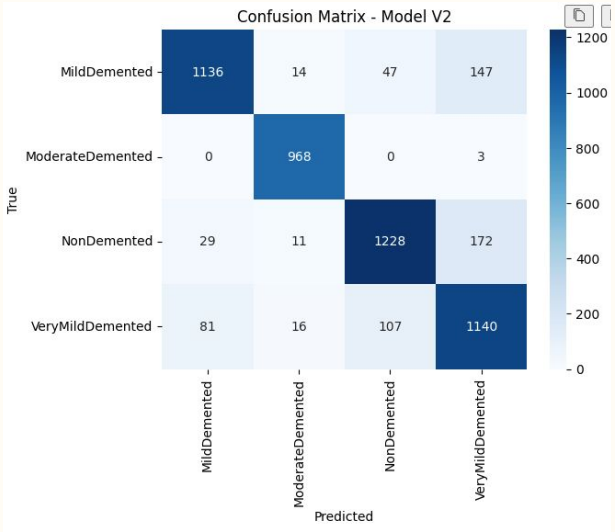
Best Performing Model - CNN Sequential V2

CNN Model V2

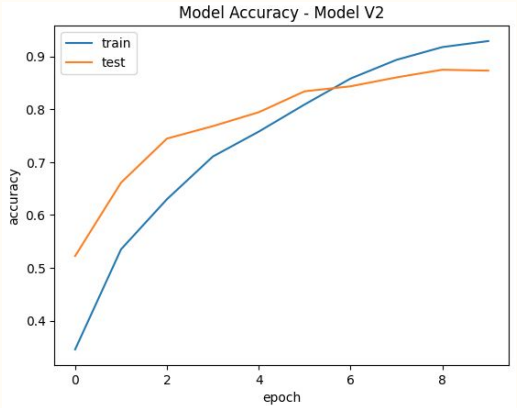
Accuracy
0.87

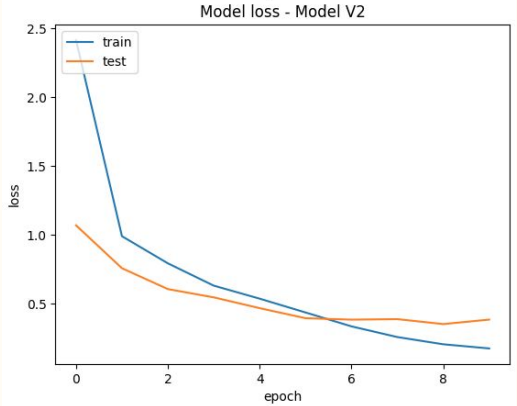
F1 Score
0.88

A simpler model overall was best as it didn't over complicate the complex nuances of MRI imagery.

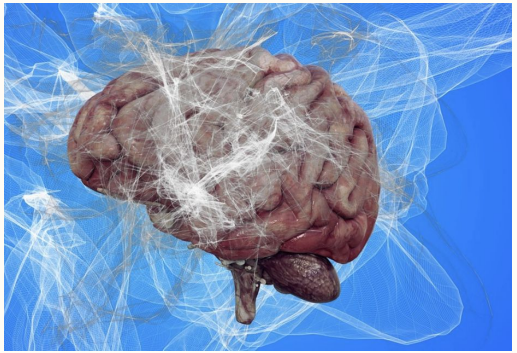


	precision	recall	f1-score	support
MildDemented	0.91	0.85	0.88	1344
ModerateDemented	0.96	1.00	0.98	971
NonDemented	0.89	0.85	0.87	1440
VeryMildDemented	0.78	0.85	0.81	1344
accuracy			0.88	5099
macro avg	0.88	0.89	0.88	5099
weighted avg	0.88	0.88	0.88	5099





LLM Google Gemini 2.0 Flash for Dementia Symptom Analysis



- LangChain for prompt engineering
- Gradio for interactive web UI
- Temperature setting of 0.2 (more deterministic than creative)
- How it works:
  - User enters patient symptoms or health data
  - Chatbot answers whether patient systems fall into one of these 4 categories:
    - Non-Dementia
    - Very Mild Dementia
    - Mild Dementia
    - Moderate Dementia

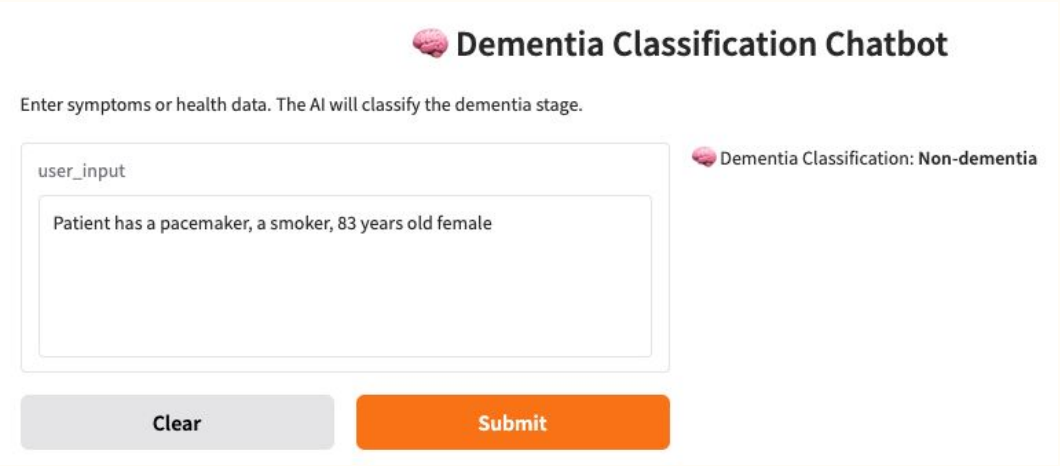
DISCLAIMER: this tool is assistive only, not to replace a doctor's or clinical diagnosis

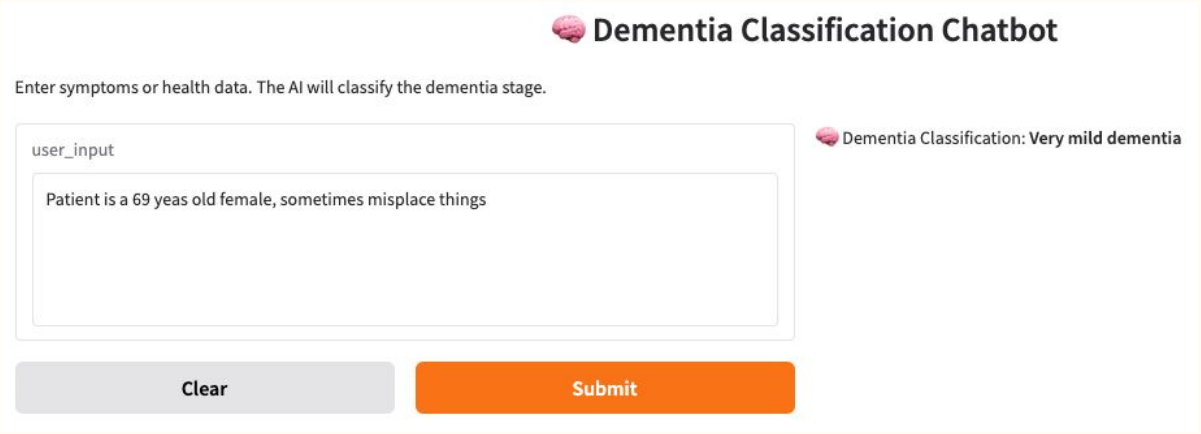
```python
# Test with sample inputs
example_1 = "Patient is healthy, no cognitive issues, and has no memory problems."
example_2 = "Patient has difficulty with complex tasks, often forgets names and faces, but can still live independently."
example_3 = "Patient forgets recent events, has trouble finding words, but still can manage daily tasks."
example_4 = "Patient requires assistance for dressing, frequently confused about time and place."


print("Example 1:", classify_dementia(example_1))
print("Example 2:", classify_dementia(example_2))
print("Example 3:", classify_dementia(example_3))
print("Example 4:", classify_dementia(example_4))
```

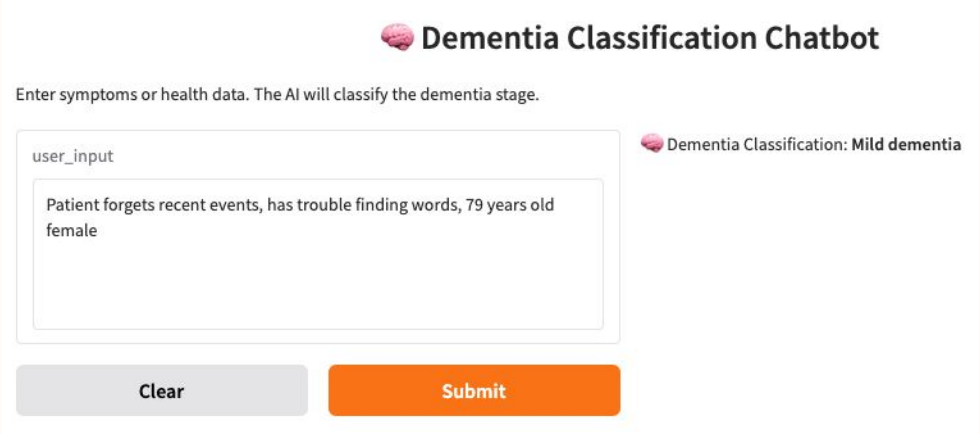
✓ 2.0s

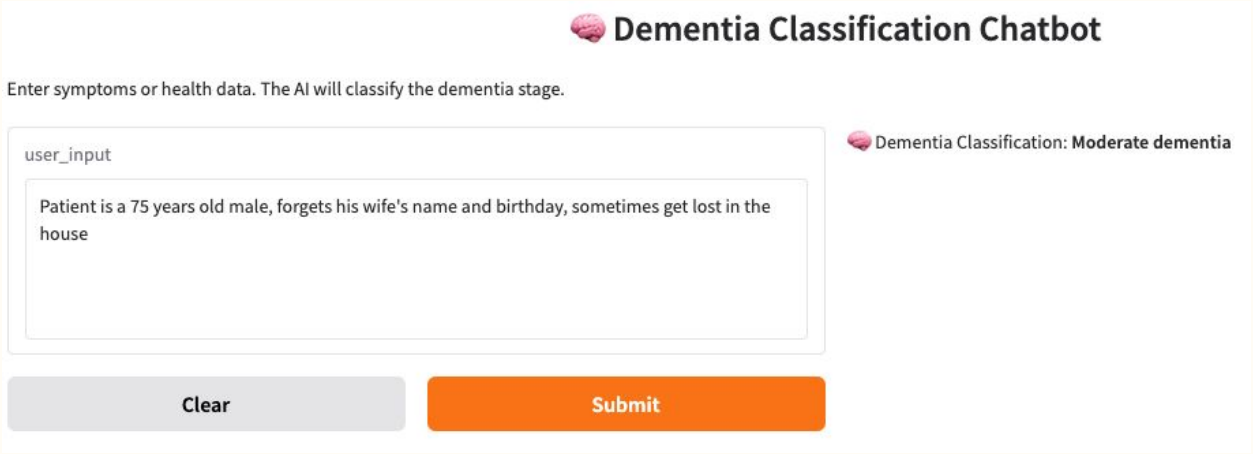
```
Example 1: - Non-dementia
Example 2: Very mild dementia
Example 3: Mild dementia
Example 4: Moderate dementia
```

```python
# Create a chain to classify dementia stages
prompt = PromptTemplate.from_template("""
    You are a dementia diagnostic assistant trained to classify cognit

    Classify the dementia stage based on the symptoms or health descri

    Use these specific criteria for classification:

    - Non-dementia: No significant memory problems. May have occasiona

    - Very mild dementia: Subtle but noticeable memory lapses (like mi

    - Mild dementia: Clear memory deficits affecting recent events. Pr

    - Moderate dementia: Significant memory loss including personal hi

    Patient Symptoms or Health Data:
    {input_text}

    Analyze the information carefully and respond ONLY with one of the
    - Non-dementia
    - Very mild dementia
    - Mild dementia
    - Moderate dementia
    """)
```


Dementia Classification Chatbot
Enter symptoms or health data. The AI will classify the dementia stage.
user_input
Patient has a pacemaker, a smoker, 83 years old female
Dementia Classification: Non-dementia
Clear
Submit


Dementia Classification Chatbot
Enter symptoms or health data. The AI will classify the dementia stage.
user_input
Patient is a 69 yeas old female, sometimes misplace things
Dementia Classification: Very mild dementia
Clear
Submit


Dementia Classification Chatbot
Enter symptoms or health data. The AI will classify the dementia stage.
user_input
Patient forgets recent events, has trouble finding words, 79 years old female
Clear
Submit
Dementia Classification: Mild dementia


Dementia Classification Chatbot
Enter symptoms or health data. The AI will classify the dementia stage.
user_input
Patient is a 75 years old male, forgets his wife's name and birthday, sometimes get lost in the house
Clear
Submit
Dementia Classification: Moderate dementia

Multi Modal Dementia Diagnostics Analysis

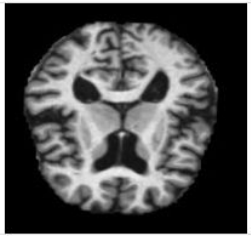
- 60% weight to MRI Brain Scan Analysis
- 40% weight to symptom text analysis
- Pre-trained neural network model utilizing dementia_cnn_sequential_4_model_V2.keras
- Hybrid text analysis system: dual approach combining rule-based-pattern matching with sentiment analysis using pre-trained BERT model
- Image upload is required, text is optional
- Gradio link (expires on 5/24/2025): https://5526421984f64cd7ea.gradio.live/

DISCLAIMER: this tool is assistive only, not to replace a doctor's or clinical diagnosis

🧠 Dementia MRI Chatbot (MRI + Text Analysis)

Upload a brain MRI and optionally describe symptoms. MRI contributes 60%, and combined rule-based + sentiment text classification contributes 40% to the final result.

Upload Brain MRI Image



Symptom Text

Enter symptoms or previous diagnosis (optional)

Clear Submit

output

🧠 **Predicted Dementia Stage**: Very Mild Demented (Confidence: 0.28)
📊 **Combined Probabilities**:
Mild Demented: 0.25
Moderate Demented: 0.20
Non Demented: 0.27
Very Mild Demented: 0.28

🧬 **Gemini MRI Interpretation:**
Okay, let's break down what "MRI indicates: Very Mild Demented with 0.28 confidence" means in simple clinical terms:

* **MRI:** This refers to a Magnetic Resonance Imaging scan of the brain. It's a type of imaging that provides detailed pictures of the brain's structure.

* **Very Mild Demented:** This suggests that the MRI scan shows some features that are often associated with the very early stages of dementia. "Very mild" implies that any cognitive or functional impairments are likely subtle at this point.

* **with 0.28 confidence:** This is the most important part to understand. It means that the interpretation of the MRI scan suggesting "very mild demented" is only 28% confident. In other words, the MRI findings are not strongly

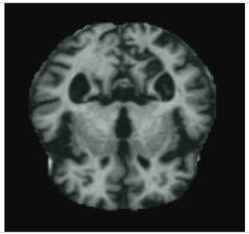
Flag

Use via API · Built with Gradio · Settings

🧠 Dementia MRI Chatbot (MRI + Text Analysis)

Upload a brain MRI and optionally describe symptoms. MRI contributes 60%, and combined rule-based + sentiment text classification contributes 40% to the final result.

Upload Brain MRI Image



Symptom Text

Patient is 89 years old female, not in the best health condition, constantly forget the names of her family members

Clear | Submit

output

🧠 **Predicted Dementia Stage**: Moderate Demented (Confidence: 0.30)
📊 **Combined Probabilities**:
Mild Demented: 0.22
Moderate Demented: 0.30
Non Demented: 0.23
Very Mild Demented: 0.25
💬 **Entered Text Analysis**: Combined rule-based + BERT sentiment (40% weight).

🧬 **Gemini MRI Interpretation:**
Okay, let's break down what "MRI indicates: Moderate Demented with 0.30 confidence" means in simple clinical terms:

1. MRI (Magnetic Resonance Imaging):

* Think of this as a detailed picture of the brain. It uses magnets and radio waves to create images that show the brain's structure. Doctors use it to look for changes or abnormalities.

2. Moderate Demented:

* This suggests that the MRI scan shows brain changes that are *consistent* with a moderate level of dementia.

Flag

Conclusion

Problem Recap: Dementia diagnosis often comes too late due to lack of accessible, early-stage screening tools.

What we Built

- Successfully developed an AI-powered application that can classify dementia stages using both MRI scans and patient symptom descriptions.
- Combined a deep learning CNN model and a Gemini-powered LLM for dual input analysis

Key Achievements

- Achieved 60% test accuracy using a dataset of over 33,000 MRI images (60% weight on the image, 40% weight on the text based chatbot diagnosis).
- Designed an interactive chatbot using Gradio and Gemini 2.0 Flash
- Successfully demonstrated the power and value of AI in healthcare diagnostics.

Important Insight:
Throughout development, we emphasized that this tool is designed to assist, not replace, medical professionals. Our goal is to support clinicians in making faster, more informed diagnostic decisions.

Spencer

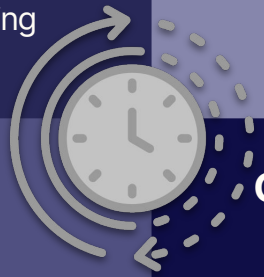
Future Work & Stretch Goals

Enhancing Model Precision

- ➔ Further train on more diverse MRI datasets (e.g. other types of dementia)
- ➔ Address confusion between Non-Demented and Very Mild cases using better image preprocessing

Expanding LLM Functionality

- ➔ Fine-tune Gemini with clinical notes or real-world symptom descriptions
- ➔ Introduce multilingual support for broader accessibility



Clinical Integration

- ➔ Collaborate with healthcare professionals for more real world and up to date symptom descriptions
- ➔ Align AI predictions with clinical assessment workflows

Our Stretch Goal

Multi-Modal Diagnosis

- ➔ Combine MRI scan input and symptom text to provide holistic diagnosis.
- ➔ Use both CNN and LLM outputs in a unified prediction model.

Demo Time

Thank You