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Based on the paper **“Deep Learning Approach for Early Detection of Alzheimer’s Disease”**, here is a **detailed explanation of how the VGG19 model** was used:

🧠 Overview of the VGG19 Model in the Paper

🎯 Goal:

To detect and classify Alzheimer's disease (AD) across four stages:

- NC (Normal Control)
- EMCI (Early Mild Cognitive Impairment)
- LMCI (Late Mild Cognitive Impairment)
- AD (Alzheimer's Disease)

The **VGG19 model** was part of the **second approach** (Method 2) that utilizes **transfer learning** for medical image classification.

- **Two-phase training**:
    - First with the VGG base frozen (transfer learning)
    - Then fine-tune last 10 layers (as done in the paper)
- **Added callbacks** like `EarlyStopping` for better model generalization.
- Matches the exact concept used in the Alzheimer’s paper: **VGG19 + Transfer Learning + Fine Tuning**.

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🧱 Model Architecture: Fine-tuned VGG19

🔹 Structure:

- **Base model**: VGG19 (pre-trained on ImageNet)
- **Top layers**: Replaced for medical image classification
- **Trainable parameters**: 25,433,540
- **Non-trainable parameters**: 0 (meaning the entire model was fine-tuned)

🔧 Added Layers (after VGG19 base):

Layer Type	Output Shape	Parameters
Flatten	(None, 4608)	0
Dense (1024)	(None, 1024)	4,719,616
Dense (512)	(None, 512)	524,800
Dense (256)	(None, 256)	131,328
Dropout	(None, 256)	0
Dense (128)	(None, 128)	32,896
Dropout	(None, 128)	0
Dense (4)	(None, 4)	516

✅ **Final Output Layer**: Softmax (for 4-class classification)

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✅ Transfer Learning + Fine-Tuning

🔹 Transfer Learning (used first)

- The VGG19 model was **pre-trained on ImageNet** — a large-scale dataset of natural images.
- The authors **used the pre-trained convolutional layers** to leverage the model's ability to extract general visual features (edges, textures, shapes, etc.).
- These layers acted as a **feature extractor** for the MRI images.

This is classic **transfer learning** — reusing knowledge from a different domain.

🔧 Fine-Tuning (also applied)

- Instead of freezing all the pre-trained layers, the model was **fine-tuned**, meaning **all layers were trainable**:

"Trainable parameters: 25,433,540 — Non-trainable parameters: 0"

- They **replaced the top layers** with new dense layers suited to the Alzheimer classification task:
    - Dense(1024) → Dense(512) → Dense(256) → Dropout → Dense(128) → Dropout → Dense(4) (Softmax for 4 classes)
- Fine-tuning allowed the model to **adjust the pre-trained features to the new medical domain** (MRI scans), which is quite different from natural images.

✅ **Both techniques were combined** to maximize performance — and it worked: **97% accuracy** on multi-class AD classification.

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🏁 Performance

Model	Accuracy
Fine-tuned VGG19	**97%** (Best result in paper)
3D-M2IC CNN	95.17%
2D-M2IC CNN	93.6%

🔬 Dataset & Preprocessing Details

- **Dataset**: 2D MRI scans from the ADNI dataset
- **Total images after augmentation**: 48,000 (balanced across 4 classes)
- **Image size**: Resized to 100×100 pixels
- **Normalization**: Pixel values rescaled to [0, 1]
- **Augmentation**: Rotation, flipping
- **Split**: 80% train, 10% validation, 10% test

📊 Evaluation Metrics

The VGG19 model was evaluated using:

- Accuracy
- Loss
- F1 Score
- Recall
- Precision

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- ROC-AUC
- Confusion Matrix
- Matthews Correlation Coefficient (MCC)

It **achieved the best results across nearly all metrics** compared to other proposed and existing models.

🧾 Conclusion

- The fine-tuned **VGG19** served as a **highly effective deep learning model** for **multi-class classification** of Alzheimer's stages.
- Its **transfer learning capability**, coupled with a well-designed dense head, **achieved 97% accuracy**, outperforming both 2D and 3D CNN models built from scratch.
- Its success illustrates the power of **pre-trained architectures**, especially in domains like medical imaging where datasets are often small.

Would you like help adapting this VGG19 architecture for your own dataset like RAD, or comparing it to models like ResNet or MobileNet?

🔍 Challenges :

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Problems Faced during this phase :

The transfer Learning training part took so much long time because of the size of dataset first I made it 10 epochs and it was almost finished but unfortunately the runtime disconnected so I was forced to restart session again and all the results wer gone but it reached epoch 9 with accuracy 0.78 , then I changed it to 5 epoch but I was running out of time so the prediction and plotting and the lime i didn't have the time to run it to know the output .