# VGG-19 :

Found 4123 images belonging to 3 classes.

Found 1031 images belonging to 3 classes.

Class weights: {0: 1.528735632183908, 1: 0.6632882882882883, 2: 1.1929976851851851}

Downloading data from <https://storage.googleapis.com/tensorflow/keras-applications/vgg19/vgg19_weights_tf_dim_ordering_tf_kernels_notop.h5>

**80134624/80134624** ━━━━━━━━━━━━━━━━━━━━ **0s** 0us/step

**Model: "functional"**

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━┓

┃ **Layer (type)** ┃ **Output Shape** ┃ **Param #** ┃

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│ input\_layer (InputLayer) │ (None, 224, 224, 3) │ 0 │

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│ block1\_conv1 (Conv2D) │ (None, 224, 224, 64) │ 1,792 │

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│ block1\_conv2 (Conv2D) │ (None, 224, 224, 64) │ 36,928 │

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│ block1\_pool (MaxPooling2D) │ (None, 112, 112, 64) │ 0 │

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│ block2\_conv1 (Conv2D) │ (None, 112, 112, 128) │ 73,856 │

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│ block2\_conv2 (Conv2D) │ (None, 112, 112, 128) │ 147,584 │

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│ block2\_pool (MaxPooling2D) │ (None, 56, 56, 128) │ 0 │

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│ block3\_conv1 (Conv2D) │ (None, 56, 56, 256) │ 295,168 │

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│ block3\_conv2 (Conv2D) │ (None, 56, 56, 256) │ 590,080 │

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│ block3\_conv3 (Conv2D) │ (None, 56, 56, 256) │ 590,080 │

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│ block3\_conv4 (Conv2D) │ (None, 56, 56, 256) │ 590,080 │

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│ block3\_pool (MaxPooling2D) │ (None, 28, 28, 256) │ 0 │

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│ block4\_conv1 (Conv2D) │ (None, 28, 28, 512) │ 1,180,160 │

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│ block4\_conv2 (Conv2D) │ (None, 28, 28, 512) │ 2,359,808 │

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│ block4\_conv3 (Conv2D) │ (None, 28, 28, 512) │ 2,359,808 │

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│ block4\_conv4 (Conv2D) │ (None, 28, 28, 512) │ 2,359,808 │

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│ block4\_pool (MaxPooling2D) │ (None, 14, 14, 512) │ 0 │

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│ block5\_conv1 (Conv2D) │ (None, 14, 14, 512) │ 2,359,808 │

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│ block5\_conv2 (Conv2D) │ (None, 14, 14, 512) │ 2,359,808 │

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│ block5\_conv3 (Conv2D) │ (None, 14, 14, 512) │ 2,359,808 │

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│ block5\_conv4 (Conv2D) │ (None, 14, 14, 512) │ 2,359,808 │

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│ block5\_pool (MaxPooling2D) │ (None, 7, 7, 512) │ 0 │

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│ global\_average\_pooling2d │ (None, 512) │ 0 │

│ (GlobalAveragePooling2D) │ │ │

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│ dense (Dense) │ (None, 1024) │ 525,312 │

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│ batch\_normalization │ (None, 1024) │ 4,096 │

│ (BatchNormalization) │ │ │

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│ re\_lu (ReLU) │ (None, 1024) │ 0 │

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│ dropout (Dropout) │ (None, 1024) │ 0 │

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│ dense\_1 (Dense) │ (None, 512) │ 524,800 │

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│ batch\_normalization\_1 │ (None, 512) │ 2,048 │

│ (BatchNormalization) │ │ │

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│ re\_lu\_1 (ReLU) │ (None, 512) │ 0 │

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│ dropout\_1 (Dropout) │ (None, 512) │ 0 │

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│ dense\_2 (Dense) │ (None, 3) │ 1,539 │

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**Total params:** 21,082,179 (80.42 MB)

**Trainable params:** 10,493,955 (40.03 MB)

**Non-trainable params:** 10,588,224 (40.39 MB)

/usr/local/lib/python3.11/dist-packages/keras/src/trainers/data\_adapters/py\_dataset\_adapter.py:121: UserWarning: Your `PyDataset` class should call `super().\_\_init\_\_(\*\*kwargs)` in its constructor. `\*\*kwargs` can include `workers`, `use\_multiprocessing`, `max\_queue\_size`. Do not pass these arguments to `fit()`, as they will be ignored.

self.\_warn\_if\_super\_not\_called()

Epoch 1/25

/usr/local/lib/python3.11/dist-packages/keras/src/models/functional.py:237: UserWarning: The structure of `inputs` doesn't match the expected structure.

Expected: ['keras\_tensor']

Received: inputs=Tensor(shape=(None, 224, 224, 3))

warnings.warn(msg)

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 632ms/step - accuracy: 0.3397 - auc: 0.4949 - loss: 1.6308 - precision: 0.3407 - recall: 0.2687

Epoch 1: val\_accuracy improved from -inf to 0.47042, saving model to Alzheimer\_Detection/models/vgg16\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **123s** 782ms/step - accuracy: 0.3398 - auc: 0.4951 - loss: 1.6304 - precision: 0.3409 - recall: 0.2688 - val\_accuracy: 0.4704 - val\_auc: 0.6391 - val\_loss: 1.6696 - val\_precision: 0.4830 - val\_recall: 0.4539 - learning\_rate: 1.0000e-04

Epoch 2/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 541ms/step - accuracy: 0.3870 - auc: 0.5757 - loss: 1.4903 - precision: 0.4029 - recall: 0.3081

Epoch 2: val\_accuracy improved from 0.47042 to 0.50242, saving model to Alzheimer\_Detection/models/vgg16\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **83s** 644ms/step - accuracy: 0.3870 - auc: 0.5757 - loss: 1.4902 - precision: 0.4028 - recall: 0.3081 - val\_accuracy: 0.5024 - val\_auc: 0.6867 - val\_loss: 2.6267 - val\_precision: 0.5024 - val\_recall: 0.5024 - learning\_rate: 1.0000e-04

Epoch 3/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 528ms/step - accuracy: 0.4195 - auc: 0.6036 - loss: 1.4119 - precision: 0.4351 - recall: 0.3285

Epoch 3: val\_accuracy did not improve from 0.50242

**129/129** ━━━━━━━━━━━━━━━━━━━━ **81s** 626ms/step - accuracy: 0.4195 - auc: 0.6037 - loss: 1.4118 - precision: 0.4351 - recall: 0.3285 - val\_accuracy: 0.4074 - val\_auc: 0.6479 - val\_loss: 1.6520 - val\_precision: 0.4083 - val\_recall: 0.3996 - learning\_rate: 1.0000e-04

Epoch 4/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 528ms/step - accuracy: 0.4693 - auc: 0.6499 - loss: 1.3246 - precision: 0.4979 - recall: 0.3749

Epoch 4: val\_accuracy improved from 0.50242 to 0.50339, saving model to Alzheimer\_Detection/models/vgg16\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **82s** 631ms/step - accuracy: 0.4691 - auc: 0.6498 - loss: 1.3247 - precision: 0.4978 - recall: 0.3747 - val\_accuracy: 0.5034 - val\_auc: 0.7380 - val\_loss: 1.9033 - val\_precision: 0.5034 - val\_recall: 0.5034 - learning\_rate: 1.0000e-04

Epoch 5/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 528ms/step - accuracy: 0.4792 - auc: 0.6610 - loss: 1.2863 - precision: 0.5119 - recall: 0.3774

Epoch 5: val\_accuracy improved from 0.50339 to 0.50727, saving model to Alzheimer\_Detection/models/vgg16\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **84s** 649ms/step - accuracy: 0.4793 - auc: 0.6610 - loss: 1.2863 - precision: 0.5119 - recall: 0.3774 - val\_accuracy: 0.5073 - val\_auc: 0.7290 - val\_loss: 1.5086 - val\_precision: 0.5078 - val\_recall: 0.5073 - learning\_rate: 1.0000e-04

Epoch 6/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 531ms/step - accuracy: 0.5034 - auc: 0.6882 - loss: 1.2334 - precision: 0.5265 - recall: 0.4017

Epoch 6: val\_accuracy improved from 0.50727 to 0.54704, saving model to Alzheimer\_Detection/models/vgg16\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **139s** 626ms/step - accuracy: 0.5033 - auc: 0.6882 - loss: 1.2335 - precision: 0.5264 - recall: 0.4017 - val\_accuracy: 0.5470 - val\_auc: 0.7482 - val\_loss: 1.0913 - val\_precision: 0.5902 - val\_recall: 0.4539 - learning\_rate: 1.0000e-04

Epoch 7/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 537ms/step - accuracy: 0.5106 - auc: 0.7113 - loss: 1.1841 - precision: 0.5524 - recall: 0.4186

Epoch 7: val\_accuracy did not improve from 0.54704

**129/129** ━━━━━━━━━━━━━━━━━━━━ **81s** 626ms/step - accuracy: 0.5106 - auc: 0.7113 - loss: 1.1840 - precision: 0.5523 - recall: 0.4186 - val\_accuracy: 0.5315 - val\_auc: 0.7297 - val\_loss: 1.4578 - val\_precision: 0.5457 - val\_recall: 0.4976 - learning\_rate: 1.0000e-04

Epoch 8/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 528ms/step - accuracy: 0.5473 - auc: 0.7485 - loss: 1.1146 - precision: 0.5878 - recall: 0.4619

Epoch 8: val\_accuracy improved from 0.54704 to 0.59069, saving model to Alzheimer\_Detection/models/vgg16\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **80s** 623ms/step - accuracy: 0.5474 - auc: 0.7486 - loss: 1.1145 - precision: 0.5880 - recall: 0.4621 - val\_accuracy: 0.5907 - val\_auc: 0.7796 - val\_loss: 1.2150 - val\_precision: 0.6130 - val\_recall: 0.5655 - learning\_rate: 1.0000e-04

Epoch 9/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 535ms/step - accuracy: 0.5681 - auc: 0.7658 - loss: 1.0760 - precision: 0.6129 - recall: 0.4924

Epoch 9: val\_accuracy did not improve from 0.59069

**129/129** ━━━━━━━━━━━━━━━━━━━━ **82s** 624ms/step - accuracy: 0.5681 - auc: 0.7659 - loss: 1.0760 - precision: 0.6129 - recall: 0.4924 - val\_accuracy: 0.5907 - val\_auc: 0.7919 - val\_loss: 1.0441 - val\_precision: 0.6300 - val\_recall: 0.5170 - learning\_rate: 1.0000e-04

Epoch 10/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 541ms/step - accuracy: 0.5971 - auc: 0.7862 - loss: 1.0372 - precision: 0.6349 - recall: 0.5142

Epoch 10: val\_accuracy did not improve from 0.59069

**129/129** ━━━━━━━━━━━━━━━━━━━━ **82s** 632ms/step - accuracy: 0.5972 - auc: 0.7863 - loss: 1.0371 - precision: 0.6350 - recall: 0.5144 - val\_accuracy: 0.5238 - val\_auc: 0.7447 - val\_loss: 1.2837 - val\_precision: 0.5458 - val\_recall: 0.4966 - learning\_rate: 1.0000e-04

Epoch 11/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 541ms/step - accuracy: 0.6326 - auc: 0.8163 - loss: 0.9849 - precision: 0.6789 - recall: 0.5625

Epoch 11: val\_accuracy did not improve from 0.59069

**129/129** ━━━━━━━━━━━━━━━━━━━━ **83s** 637ms/step - accuracy: 0.6326 - auc: 0.8163 - loss: 0.9849 - precision: 0.6790 - recall: 0.5626 - val\_accuracy: 0.4433 - val\_auc: 0.6771 - val\_loss: 2.4584 - val\_precision: 0.4465 - val\_recall: 0.4374 - learning\_rate: 1.0000e-04

Epoch 12/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 533ms/step - accuracy: 0.6636 - auc: 0.8448 - loss: 0.9246 - precision: 0.7029 - recall: 0.6045

Epoch 12: val\_accuracy did not improve from 0.59069

**129/129** ━━━━━━━━━━━━━━━━━━━━ **141s** 631ms/step - accuracy: 0.6636 - auc: 0.8448 - loss: 0.9247 - precision: 0.7028 - recall: 0.6045 - val\_accuracy: 0.5606 - val\_auc: 0.7726 - val\_loss: 1.3876 - val\_precision: 0.5697 - val\_recall: 0.5470 - learning\_rate: 1.0000e-04

Epoch 13/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 535ms/step - accuracy: 0.6825 - auc: 0.8588 - loss: 0.8849 - precision: 0.7182 - recall: 0.6279

Epoch 13: ReduceLROnPlateau reducing learning rate to 1.9999999494757503e-05.

Epoch 13: val\_accuracy did not improve from 0.59069

**129/129** ━━━━━━━━━━━━━━━━━━━━ **82s** 634ms/step - accuracy: 0.6825 - auc: 0.8588 - loss: 0.8850 - precision: 0.7182 - recall: 0.6279 - val\_accuracy: 0.5044 - val\_auc: 0.7268 - val\_loss: 1.3164 - val\_precision: 0.5305 - val\_recall: 0.4724 - learning\_rate: 1.0000e-04

Epoch 14/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 525ms/step - accuracy: 0.7350 - auc: 0.8933 - loss: 0.8080 - precision: 0.7820 - recall: 0.6767

Epoch 14: val\_accuracy did not improve from 0.59069

**129/129** ━━━━━━━━━━━━━━━━━━━━ **80s** 623ms/step - accuracy: 0.7350 - auc: 0.8932 - loss: 0.8080 - precision: 0.7820 - recall: 0.6768 - val\_accuracy: 0.5422 - val\_auc: 0.7591 - val\_loss: 1.3728 - val\_precision: 0.5460 - val\_recall: 0.5179 - learning\_rate: 2.0000e-05

Epoch 15/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 533ms/step - accuracy: 0.7351 - auc: 0.8990 - loss: 0.7866 - precision: 0.7798 - recall: 0.6835

Epoch 15: val\_accuracy improved from 0.59069 to 0.71387, saving model to Alzheimer\_Detection/models/vgg16\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **83s** 631ms/step - accuracy: 0.7352 - auc: 0.8990 - loss: 0.7865 - precision: 0.7798 - recall: 0.6836 - val\_accuracy: 0.7139 - val\_auc: 0.8897 - val\_loss: 0.8350 - val\_precision: 0.7473 - val\_recall: 0.6712 - learning\_rate: 2.0000e-05

Epoch 16/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 523ms/step - accuracy: 0.7564 - auc: 0.9111 - loss: 0.7443 - precision: 0.7975 - recall: 0.7090

Epoch 16: val\_accuracy did not improve from 0.71387

**129/129** ━━━━━━━━━━━━━━━━━━━━ **79s** 614ms/step - accuracy: 0.7564 - auc: 0.9111 - loss: 0.7443 - precision: 0.7975 - recall: 0.7090 - val\_accuracy: 0.7032 - val\_auc: 0.8752 - val\_loss: 0.9014 - val\_precision: 0.7300 - val\_recall: 0.6634 - learning\_rate: 2.0000e-05

Epoch 17/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 530ms/step - accuracy: 0.7742 - auc: 0.9200 - loss: 0.7268 - precision: 0.8046 - recall: 0.7238

Epoch 17: val\_accuracy improved from 0.71387 to 0.72260, saving model to Alzheimer\_Detection/models/vgg16\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **88s** 686ms/step - accuracy: 0.7742 - auc: 0.9199 - loss: 0.7268 - precision: 0.8045 - recall: 0.7238 - val\_accuracy: 0.7226 - val\_auc: 0.8963 - val\_loss: 0.8204 - val\_precision: 0.7622 - val\_recall: 0.6809 - learning\_rate: 2.0000e-05

Epoch 18/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 534ms/step - accuracy: 0.7769 - auc: 0.9217 - loss: 0.7230 - precision: 0.8064 - recall: 0.7376

Epoch 18: val\_accuracy improved from 0.72260 to 0.72551, saving model to Alzheimer\_Detection/models/vgg16\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **83s** 638ms/step - accuracy: 0.7769 - auc: 0.9217 - loss: 0.7231 - precision: 0.8064 - recall: 0.7376 - val\_accuracy: 0.7255 - val\_auc: 0.8952 - val\_loss: 0.8249 - val\_precision: 0.7503 - val\_recall: 0.6848 - learning\_rate: 2.0000e-05

Epoch 19/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 542ms/step - accuracy: 0.7905 - auc: 0.9309 - loss: 0.7064 - precision: 0.8203 - recall: 0.7553

Epoch 19: val\_accuracy improved from 0.72551 to 0.76140, saving model to Alzheimer\_Detection/models/vgg16\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **145s** 664ms/step - accuracy: 0.7905 - auc: 0.9309 - loss: 0.7063 - precision: 0.8203 - recall: 0.7553 - val\_accuracy: 0.7614 - val\_auc: 0.9115 - val\_loss: 0.8048 - val\_precision: 0.7827 - val\_recall: 0.7371 - learning\_rate: 2.0000e-05

Epoch 20/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 531ms/step - accuracy: 0.8011 - auc: 0.9331 - loss: 0.6854 - precision: 0.8254 - recall: 0.7692

Epoch 20: val\_accuracy did not improve from 0.76140

**129/129** ━━━━━━━━━━━━━━━━━━━━ **80s** 620ms/step - accuracy: 0.8011 - auc: 0.9331 - loss: 0.6854 - precision: 0.8254 - recall: 0.7692 - val\_accuracy: 0.6693 - val\_auc: 0.8514 - val\_loss: 1.0645 - val\_precision: 0.6805 - val\_recall: 0.6508 - learning\_rate: 2.0000e-05

Epoch 21/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 535ms/step - accuracy: 0.8099 - auc: 0.9414 - loss: 0.6647 - precision: 0.8392 - recall: 0.7807

Epoch 21: val\_accuracy did not improve from 0.76140

**129/129** ━━━━━━━━━━━━━━━━━━━━ **81s** 624ms/step - accuracy: 0.8100 - auc: 0.9414 - loss: 0.6647 - precision: 0.8392 - recall: 0.7807 - val\_accuracy: 0.7507 - val\_auc: 0.9101 - val\_loss: 0.7867 - val\_precision: 0.7756 - val\_recall: 0.7139 - learning\_rate: 2.0000e-05

Epoch 22/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 531ms/step - accuracy: 0.8056 - auc: 0.9410 - loss: 0.6578 - precision: 0.8327 - recall: 0.7737

Epoch 22: val\_accuracy did not improve from 0.76140

**129/129** ━━━━━━━━━━━━━━━━━━━━ **80s** 621ms/step - accuracy: 0.8057 - auc: 0.9410 - loss: 0.6579 - precision: 0.8327 - recall: 0.7738 - val\_accuracy: 0.7342 - val\_auc: 0.9055 - val\_loss: 0.8016 - val\_precision: 0.7552 - val\_recall: 0.7090 - learning\_rate: 2.0000e-05

Epoch 23/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 546ms/step - accuracy: 0.8311 - auc: 0.9523 - loss: 0.6330 - precision: 0.8528 - recall: 0.8000

Epoch 23: val\_accuracy did not improve from 0.76140

**129/129** ━━━━━━━━━━━━━━━━━━━━ **84s** 639ms/step - accuracy: 0.8311 - auc: 0.9523 - loss: 0.6331 - precision: 0.8527 - recall: 0.7999 - val\_accuracy: 0.7401 - val\_auc: 0.9046 - val\_loss: 0.8276 - val\_precision: 0.7590 - val\_recall: 0.7148 - learning\_rate: 2.0000e-05

Epoch 24/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 538ms/step - accuracy: 0.8300 - auc: 0.9559 - loss: 0.6237 - precision: 0.8620 - recall: 0.8064

Epoch 24: val\_accuracy improved from 0.76140 to 0.78274, saving model to Alzheimer\_Detection/models/vgg16\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **83s** 643ms/step - accuracy: 0.8300 - auc: 0.9559 - loss: 0.6237 - precision: 0.8619 - recall: 0.8064 - val\_accuracy: 0.7827 - val\_auc: 0.9184 - val\_loss: 0.7760 - val\_precision: 0.7961 - val\_recall: 0.7614 - learning\_rate: 2.0000e-05

Epoch 25/25

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 542ms/step - accuracy: 0.8412 - auc: 0.9559 - loss: 0.6027 - precision: 0.8603 - recall: 0.8142

Epoch 25: val\_accuracy did not improve from 0.78274

**129/129** ━━━━━━━━━━━━━━━━━━━━ **142s** 639ms/step - accuracy: 0.8412 - auc: 0.9559 - loss: 0.6027 - precision: 0.8603 - recall: 0.8142 - val\_accuracy: 0.7013 - val\_auc: 0.8797 - val\_loss: 0.9002 - val\_precision: 0.7234 - val\_recall: 0.6673 - learning\_rate: 2.0000e-05

Restoring model weights from the end of the best epoch: 24.

Starting fine-tuning phase...

Epoch 26/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 673ms/step - accuracy: 0.8429 - auc\_1: 0.9570 - loss: 0.6034 - precision\_1: 0.8617 - recall\_1: 0.8179

Epoch 26: val\_accuracy improved from -inf to 0.80213, saving model to Alzheimer\_Detection/models/vgg16\_ft\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **122s** 798ms/step - accuracy: 0.8428 - auc\_1: 0.9570 - loss: 0.6036 - precision\_1: 0.8616 - recall\_1: 0.8178 - val\_accuracy: 0.8021 - val\_auc\_1: 0.9342 - val\_loss: 0.7184 - val\_precision\_1: 0.8192 - val\_recall\_1: 0.7779 - learning\_rate: 5.0000e-06

Epoch 27/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 568ms/step - accuracy: 0.8576 - auc\_1: 0.9628 - loss: 0.5826 - precision\_1: 0.8775 - recall\_1: 0.8318

Epoch 27: val\_accuracy improved from 0.80213 to 0.82153, saving model to Alzheimer\_Detection/models/vgg16\_ft\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **86s** 666ms/step - accuracy: 0.8575 - auc\_1: 0.9628 - loss: 0.5826 - precision\_1: 0.8774 - recall\_1: 0.8317 - val\_accuracy: 0.8215 - val\_auc\_1: 0.9433 - val\_loss: 0.6772 - val\_precision\_1: 0.8373 - val\_recall\_1: 0.7934 - learning\_rate: 5.0000e-06

Epoch 28/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 569ms/step - accuracy: 0.8435 - auc\_1: 0.9584 - loss: 0.5958 - precision\_1: 0.8620 - recall\_1: 0.8212

Epoch 28: val\_accuracy did not improve from 0.82153

**129/129** ━━━━━━━━━━━━━━━━━━━━ **141s** 660ms/step - accuracy: 0.8436 - auc\_1: 0.9584 - loss: 0.5958 - precision\_1: 0.8621 - recall\_1: 0.8212 - val\_accuracy: 0.8070 - val\_auc\_1: 0.9379 - val\_loss: 0.7118 - val\_precision\_1: 0.8282 - val\_recall\_1: 0.7808 - learning\_rate: 5.0000e-06

Epoch 29/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 573ms/step - accuracy: 0.8473 - auc\_1: 0.9591 - loss: 0.5875 - precision\_1: 0.8661 - recall\_1: 0.8236

Epoch 29: val\_accuracy did not improve from 0.82153

**129/129** ━━━━━━━━━━━━━━━━━━━━ **143s** 668ms/step - accuracy: 0.8473 - auc\_1: 0.9591 - loss: 0.5875 - precision\_1: 0.8661 - recall\_1: 0.8236 - val\_accuracy: 0.7827 - val\_auc\_1: 0.9281 - val\_loss: 0.7282 - val\_precision\_1: 0.8043 - val\_recall\_1: 0.7614 - learning\_rate: 5.0000e-06

Epoch 30/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 570ms/step - accuracy: 0.8650 - auc\_1: 0.9682 - loss: 0.5523 - precision\_1: 0.8810 - recall\_1: 0.8399

Epoch 30: val\_accuracy improved from 0.82153 to 0.82347, saving model to Alzheimer\_Detection/models/vgg16\_ft\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **90s** 695ms/step - accuracy: 0.8650 - auc\_1: 0.9682 - loss: 0.5523 - precision\_1: 0.8809 - recall\_1: 0.8399 - val\_accuracy: 0.8235 - val\_auc\_1: 0.9452 - val\_loss: 0.6711 - val\_precision\_1: 0.8427 - val\_recall\_1: 0.8002 - learning\_rate: 5.0000e-06

Epoch 31/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 580ms/step - accuracy: 0.8676 - auc\_1: 0.9646 - loss: 0.5610 - precision\_1: 0.8812 - recall\_1: 0.8456

Epoch 31: val\_accuracy did not improve from 0.82347

**129/129** ━━━━━━━━━━━━━━━━━━━━ **138s** 670ms/step - accuracy: 0.8676 - auc\_1: 0.9647 - loss: 0.5610 - precision\_1: 0.8812 - recall\_1: 0.8456 - val\_accuracy: 0.7362 - val\_auc\_1: 0.9031 - val\_loss: 0.9466 - val\_precision\_1: 0.7435 - val\_recall\_1: 0.7255 - learning\_rate: 5.0000e-06

Epoch 32/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 569ms/step - accuracy: 0.8601 - auc\_1: 0.9665 - loss: 0.5521 - precision\_1: 0.8779 - recall\_1: 0.8418

Epoch 32: val\_accuracy did not improve from 0.82347

**129/129** ━━━━━━━━━━━━━━━━━━━━ **86s** 664ms/step - accuracy: 0.8601 - auc\_1: 0.9666 - loss: 0.5521 - precision\_1: 0.8780 - recall\_1: 0.8419 - val\_accuracy: 0.7895 - val\_auc\_1: 0.9288 - val\_loss: 0.7287 - val\_precision\_1: 0.8045 - val\_recall\_1: 0.7662 - learning\_rate: 5.0000e-06

Epoch 33/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 575ms/step - accuracy: 0.8719 - auc\_1: 0.9690 - loss: 0.5396 - precision\_1: 0.8916 - recall\_1: 0.8512

Epoch 33: val\_accuracy did not improve from 0.82347

**129/129** ━━━━━━━━━━━━━━━━━━━━ **86s** 667ms/step - accuracy: 0.8719 - auc\_1: 0.9690 - loss: 0.5396 - precision\_1: 0.8916 - recall\_1: 0.8512 - val\_accuracy: 0.8196 - val\_auc\_1: 0.9460 - val\_loss: 0.6826 - val\_precision\_1: 0.8362 - val\_recall\_1: 0.8021 - learning\_rate: 5.0000e-06

Epoch 34/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 576ms/step - accuracy: 0.8791 - auc\_1: 0.9731 - loss: 0.5367 - precision\_1: 0.8975 - recall\_1: 0.8551

Epoch 34: val\_accuracy improved from 0.82347 to 0.82444, saving model to Alzheimer\_Detection/models/vgg16\_ft\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **142s** 673ms/step - accuracy: 0.8791 - auc\_1: 0.9731 - loss: 0.5367 - precision\_1: 0.8974 - recall\_1: 0.8551 - val\_accuracy: 0.8244 - val\_auc\_1: 0.9473 - val\_loss: 0.6666 - val\_precision\_1: 0.8416 - val\_recall\_1: 0.8089 - learning\_rate: 5.0000e-06

Epoch 35/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 573ms/step - accuracy: 0.8813 - auc\_1: 0.9714 - loss: 0.5339 - precision\_1: 0.8952 - recall\_1: 0.8633

Epoch 35: val\_accuracy did not improve from 0.82444

**129/129** ━━━━━━━━━━━━━━━━━━━━ **140s** 662ms/step - accuracy: 0.8813 - auc\_1: 0.9714 - loss: 0.5338 - precision\_1: 0.8952 - recall\_1: 0.8633 - val\_accuracy: 0.7934 - val\_auc\_1: 0.9314 - val\_loss: 0.7718 - val\_precision\_1: 0.8032 - val\_recall\_1: 0.7837 - learning\_rate: 5.0000e-06

Epoch 36/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 569ms/step - accuracy: 0.8745 - auc\_1: 0.9722 - loss: 0.5327 - precision\_1: 0.8924 - recall\_1: 0.8526

Epoch 36: val\_accuracy did not improve from 0.82444

**129/129** ━━━━━━━━━━━━━━━━━━━━ **142s** 659ms/step - accuracy: 0.8746 - auc\_1: 0.9722 - loss: 0.5327 - precision\_1: 0.8924 - recall\_1: 0.8526 - val\_accuracy: 0.7226 - val\_auc\_1: 0.8939 - val\_loss: 0.8847 - val\_precision\_1: 0.7343 - val\_recall\_1: 0.7051 - learning\_rate: 5.0000e-06

Epoch 37/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 569ms/step - accuracy: 0.8910 - auc\_1: 0.9755 - loss: 0.5084 - precision\_1: 0.9025 - recall\_1: 0.8693

Epoch 37: val\_accuracy did not improve from 0.82444

**129/129** ━━━━━━━━━━━━━━━━━━━━ **142s** 659ms/step - accuracy: 0.8910 - auc\_1: 0.9755 - loss: 0.5084 - precision\_1: 0.9025 - recall\_1: 0.8694 - val\_accuracy: 0.8244 - val\_auc\_1: 0.9536 - val\_loss: 0.6347 - val\_precision\_1: 0.8473 - val\_recall\_1: 0.8128 - learning\_rate: 5.0000e-06

Epoch 38/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 571ms/step - accuracy: 0.9013 - auc\_1: 0.9787 - loss: 0.4870 - precision\_1: 0.9148 - recall\_1: 0.8907

Epoch 38: val\_accuracy did not improve from 0.82444

**129/129** ━━━━━━━━━━━━━━━━━━━━ **143s** 668ms/step - accuracy: 0.9012 - auc\_1: 0.9787 - loss: 0.4871 - precision\_1: 0.9147 - recall\_1: 0.8906 - val\_accuracy: 0.7992 - val\_auc\_1: 0.9323 - val\_loss: 0.7995 - val\_precision\_1: 0.8114 - val\_recall\_1: 0.7847 - learning\_rate: 5.0000e-06

Epoch 39/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 587ms/step - accuracy: 0.9048 - auc\_1: 0.9829 - loss: 0.4888 - precision\_1: 0.9212 - recall\_1: 0.8871

Epoch 39: val\_accuracy did not improve from 0.82444

**129/129** ━━━━━━━━━━━━━━━━━━━━ **144s** 685ms/step - accuracy: 0.9047 - auc\_1: 0.9829 - loss: 0.4887 - precision\_1: 0.9211 - recall\_1: 0.8871 - val\_accuracy: 0.7148 - val\_auc\_1: 0.8943 - val\_loss: 0.8582 - val\_precision\_1: 0.7298 - val\_recall\_1: 0.6993 - learning\_rate: 5.0000e-06

Epoch 40/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 567ms/step - accuracy: 0.8986 - auc\_1: 0.9790 - loss: 0.4897 - precision\_1: 0.9110 - recall\_1: 0.8822

Epoch 40: val\_accuracy did not improve from 0.82444

**129/129** ━━━━━━━━━━━━━━━━━━━━ **85s** 657ms/step - accuracy: 0.8986 - auc\_1: 0.9790 - loss: 0.4897 - precision\_1: 0.9110 - recall\_1: 0.8822 - val\_accuracy: 0.8167 - val\_auc\_1: 0.9452 - val\_loss: 0.6734 - val\_precision\_1: 0.8300 - val\_recall\_1: 0.7953 - learning\_rate: 5.0000e-06

Epoch 41/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 569ms/step - accuracy: 0.9003 - auc\_1: 0.9808 - loss: 0.4888 - precision\_1: 0.9120 - recall\_1: 0.8831

Epoch 41: ReduceLROnPlateau reducing learning rate to 2.499999936844688e-06.

Epoch 41: val\_accuracy did not improve from 0.82444

**129/129** ━━━━━━━━━━━━━━━━━━━━ **147s** 693ms/step - accuracy: 0.9003 - auc\_1: 0.9808 - loss: 0.4888 - precision\_1: 0.9120 - recall\_1: 0.8831 - val\_accuracy: 0.8050 - val\_auc\_1: 0.9358 - val\_loss: 0.7330 - val\_precision\_1: 0.8224 - val\_recall\_1: 0.7905 - learning\_rate: 5.0000e-06

Epoch 42/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 574ms/step - accuracy: 0.9061 - auc\_1: 0.9823 - loss: 0.4837 - precision\_1: 0.9194 - recall\_1: 0.8915

Epoch 42: val\_accuracy improved from 0.82444 to 0.83123, saving model to Alzheimer\_Detection/models/vgg16\_ft\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **140s** 676ms/step - accuracy: 0.9062 - auc\_1: 0.9824 - loss: 0.4835 - precision\_1: 0.9195 - recall\_1: 0.8915 - val\_accuracy: 0.8312 - val\_auc\_1: 0.9492 - val\_loss: 0.6726 - val\_precision\_1: 0.8388 - val\_recall\_1: 0.8177 - learning\_rate: 2.5000e-06

Epoch 43/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 576ms/step - accuracy: 0.9173 - auc\_1: 0.9862 - loss: 0.4528 - precision\_1: 0.9294 - recall\_1: 0.9060

Epoch 43: val\_accuracy did not improve from 0.83123

**129/129** ━━━━━━━━━━━━━━━━━━━━ **141s** 669ms/step - accuracy: 0.9172 - auc\_1: 0.9862 - loss: 0.4528 - precision\_1: 0.9294 - recall\_1: 0.9060 - val\_accuracy: 0.8264 - val\_auc\_1: 0.9493 - val\_loss: 0.6645 - val\_precision\_1: 0.8378 - val\_recall\_1: 0.8118 - learning\_rate: 2.5000e-06

Epoch 44/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 570ms/step - accuracy: 0.9159 - auc\_1: 0.9863 - loss: 0.4547 - precision\_1: 0.9268 - recall\_1: 0.9044

Epoch 44: val\_accuracy improved from 0.83123 to 0.84481, saving model to Alzheimer\_Detection/models/vgg16\_ft\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **87s** 668ms/step - accuracy: 0.9159 - auc\_1: 0.9863 - loss: 0.4547 - precision\_1: 0.9268 - recall\_1: 0.9044 - val\_accuracy: 0.8448 - val\_auc\_1: 0.9607 - val\_loss: 0.6178 - val\_precision\_1: 0.8549 - val\_recall\_1: 0.8341 - learning\_rate: 2.5000e-06

Epoch 45/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 565ms/step - accuracy: 0.9189 - auc\_1: 0.9873 - loss: 0.4444 - precision\_1: 0.9308 - recall\_1: 0.9013

Epoch 45: val\_accuracy did not improve from 0.84481

**129/129** ━━━━━━━━━━━━━━━━━━━━ **85s** 655ms/step - accuracy: 0.9189 - auc\_1: 0.9873 - loss: 0.4445 - precision\_1: 0.9308 - recall\_1: 0.9013 - val\_accuracy: 0.8235 - val\_auc\_1: 0.9442 - val\_loss: 0.7049 - val\_precision\_1: 0.8348 - val\_recall\_1: 0.8138 - learning\_rate: 2.5000e-06

Epoch 46/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 577ms/step - accuracy: 0.9241 - auc\_1: 0.9869 - loss: 0.4538 - precision\_1: 0.9309 - recall\_1: 0.9100

Epoch 46: val\_accuracy improved from 0.84481 to 0.85936, saving model to Alzheimer\_Detection/models/vgg16\_ft\_best.keras

**129/129** ━━━━━━━━━━━━━━━━━━━━ **146s** 683ms/step - accuracy: 0.9241 - auc\_1: 0.9869 - loss: 0.4538 - precision\_1: 0.9309 - recall\_1: 0.9099 - val\_accuracy: 0.8594 - val\_auc\_1: 0.9616 - val\_loss: 0.6118 - val\_precision\_1: 0.8739 - val\_recall\_1: 0.8468 - learning\_rate: 2.5000e-06

Epoch 47/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 565ms/step - accuracy: 0.9186 - auc\_1: 0.9864 - loss: 0.4525 - precision\_1: 0.9286 - recall\_1: 0.9053

Epoch 47: val\_accuracy did not improve from 0.85936

**129/129** ━━━━━━━━━━━━━━━━━━━━ **85s** 656ms/step - accuracy: 0.9187 - auc\_1: 0.9864 - loss: 0.4524 - precision\_1: 0.9287 - recall\_1: 0.9054 - val\_accuracy: 0.8506 - val\_auc\_1: 0.9632 - val\_loss: 0.5896 - val\_precision\_1: 0.8638 - val\_recall\_1: 0.8303 - learning\_rate: 2.5000e-06

Epoch 48/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 568ms/step - accuracy: 0.9294 - auc\_1: 0.9892 - loss: 0.4358 - precision\_1: 0.9355 - recall\_1: 0.9191

Epoch 48: val\_accuracy did not improve from 0.85936

**129/129** ━━━━━━━━━━━━━━━━━━━━ **142s** 657ms/step - accuracy: 0.9294 - auc\_1: 0.9892 - loss: 0.4358 - precision\_1: 0.9355 - recall\_1: 0.9191 - val\_accuracy: 0.8409 - val\_auc\_1: 0.9568 - val\_loss: 0.6198 - val\_precision\_1: 0.8556 - val\_recall\_1: 0.8274 - learning\_rate: 2.5000e-06

Epoch 49/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 578ms/step - accuracy: 0.9301 - auc\_1: 0.9874 - loss: 0.4533 - precision\_1: 0.9411 - recall\_1: 0.9196

Epoch 49: val\_accuracy did not improve from 0.85936

**129/129** ━━━━━━━━━━━━━━━━━━━━ **87s** 675ms/step - accuracy: 0.9301 - auc\_1: 0.9874 - loss: 0.4532 - precision\_1: 0.9411 - recall\_1: 0.9196 - val\_accuracy: 0.8535 - val\_auc\_1: 0.9583 - val\_loss: 0.6297 - val\_precision\_1: 0.8624 - val\_recall\_1: 0.8390 - learning\_rate: 2.5000e-06

Epoch 50/50

**129/129** ━━━━━━━━━━━━━━━━━━━━ **0s** 583ms/step - accuracy: 0.9263 - auc\_1: 0.9885 - loss: 0.4341 - precision\_1: 0.9363 - recall\_1: 0.9142

Epoch 50: val\_accuracy did not improve from 0.85936

**129/129** ━━━━━━━━━━━━━━━━━━━━ **87s** 673ms/step - accuracy: 0.9263 - auc\_1: 0.9885 - loss: 0.4342 - precision\_1: 0.9363 - recall\_1: 0.9142 - val\_accuracy: 0.8535 - val\_auc\_1: 0.9610 - val\_loss: 0.6051 - val\_precision\_1: 0.8586 - val\_recall\_1: 0.8419 - learning\_rate: 2.5000e-06

Restoring model weights from the end of the best epoch: 46.

A graph of a graph of a graph of a graph of a graph of a graph of a graph of a graph of a graph of a graph of a graph of a graph of a graph of

AI-generated content may be incorrect.

**33/33** ━━━━━━━━━━━━━━━━━━━━ **7s** 208ms/step - accuracy: 0.7860 - auc\_1: 0.9185 - loss: 0.7760 - precision\_1: 0.8036 - recall\_1: 0.7708

Final validation results: {'loss': 0.6117828488349915, 'compile\_metrics': 0.859359860420227}

/usr/local/lib/python3.11/dist-packages/keras/src/models/functional.py:237: UserWarning: The structure of `inputs` doesn't match the expected structure.

Expected: ['keras\_tensor']

Received: inputs=Tensor(shape=(32, 224, 224, 3))

warnings.warn(msg)

**32/33** ━━━━━━━━━━━━━━━━━━━━ **0s** 215ms/step

/usr/local/lib/python3.11/dist-packages/keras/src/models/functional.py:237: UserWarning: The structure of `inputs` doesn't match the expected structure.

Expected: ['keras\_tensor']

Received: inputs=Tensor(shape=(None, 224, 224, 3))

warnings.warn(msg)

**33/33** ━━━━━━━━━━━━━━━━━━━━ **9s** 238ms/step

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AI-generated content may be incorrect.

Classification Report:

precision recall f1-score support

AD 0.88 0.71 0.79 225

CMI 0.90 0.88 0.89 518

CN 0.78 0.93 0.85 288

accuracy 0.86 1031

macro avg 0.86 0.84 0.84 1031

weighted avg 0.86 0.86 0.86 1031