**1. Unbalanced:**

*1.1. Cross Entropy:*

loss='sparse\_categorical\_crossentropy'

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Model** | **Space Complexity** | **Time Complexity (hrs)** | **LR** | **Accuracy** | **Precision** | | | | **Recall** | | | | **F1 Score** | | | |
| **P** | **M** | **G** | **NT** | **P** | **M** | **G** | **NT** | **P** | **M** | **G** | **NT** |
| CNN | 440k | 0.091 | 0.001 | 0.8125 | 1.00 | 0.67 | 0.73 | 0.98 | 0.48 | 0.91 | 0.51 | 0.96 | 0.65 | 0.77 | 0.60 | 0.97 |
| VGG16-CNN | 15.7M | 0.26 | 0.0001 | 0.83 | 0.73 | 0.66 | 0.94 | 0.99 | 0.73 | 0.66 | 0.41 | 1.00 | 0.60 | 0.78 | 0.57 | 1.00 |
| EfficientNetB0-CNN | 4.05M | 0.27 | 0.001 | 0.37 | 0.00 | 0.17 | 0.00 | 0.39 | 0.04 | 0.04 | 0.00 | 0.86 | 0.00 | 0.07 | 0.00 | 0.54 |
| EfficientNetB3-CNN | 10.8M | 0.47 | 1.6e-5 | 0.60 | 0.50 | 0.60 | 0.38 | 0.65 | 0.06 | 0.46 | 0.27 | 0.96 | 0.11 | 0.52 | 0.31 | 0.78 |
| ResNet50-CNN | 23.5M | 0.31 | 0.001 | 0.78 | 1.00 | 0.87 | 0.60 | 0.83 | 0.39 | 0.59 | 0.82 | 0.97 | 0.56 | 0.70 | 0.69 | 0.90 |
| DenseNet201-CNN | 51.8M | 0.57 | 0.001 | 0.47 | 0.33 | 0.43 | 0.67 | 0.49 | 0.23 | 0.32 | 0.05 | 0.82 | 0.27 | 0.37 | 0.10 | 0.61 |
| MobileNet-CNN | 3M | 0.126 | 0.001 | 0.30 | 0.00 | 0.30 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.46 | 0.00 | 0.00 |
| GoogleNet-CNN | 6M | 0.14 | 0.0001 | 0.77 | 0.71 | 0.64 | 0.58 | 0.97 | 0.65 | 0.67 | 0.56 | 0.96 | 0.68 | 0.65 | 0.57 | 0.97 |
| XceptionNet-CNN | 25M | 0.15 | 0.0001 | 0.83 | 0.90 | 0.66 | 0.89 | 0.99 | 0.61 | 0.95 | 0.42 | 0.99 | 0.73 | 0.78 | 0.57 | 0.99 |

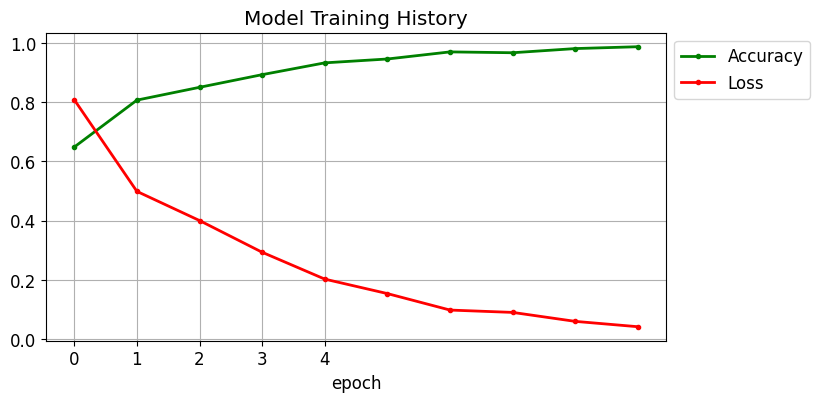


Figure 1. CNN

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Figure . VGG 16

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Figure . EfficientNetB0

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Figure . EfficientnetB3

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Figure . ResNet50

Chart, line chart

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Figure . DenseNet201

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Figure . MobileNet

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Figure . GoogleNet

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Description automatically generated

Figure . XceptionNet

*1.2. Unbalanced Focal Loss:*

loss=SparseCategoricalFocalLoss(gamma=3)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Model** | **Space Complexity** | **Time Complexity (for 5 epochs) (hrs)** | **Learning Rate** | **Accuracy** | **Precision** | | | | **Recall** | | | | **F1 Score** | | | | |
| **Pituitary** | **Menigioma** | **Glioma** | **No Tumor** | **Pituitary** | **Menigioma** | **Glioma** | **No Tumor** | **Pituitary** | **Menigioma** | **Glioma** | **No Tumor** |
| CNN | 440k | 0.084 | 0.001 | 0.80 | 0.88 | 0.68 | 0.61 | 0.99 | 0.45 | 0..81 | 0.56 | 0.98 | 0.60 | 0.74 | 0.59 | 0.98 |
| VGG16-CNN | 15.7M | 0.267 | 0.0001 | 0.85 | 0.93 | 0.68 | 0.88 | 1.00 | 0.87 | 0.98 | 0.37 | 0.98 | 0.90 | 0.81 | 0.52 | 0.99 |
| EfficientNetB0-CNN | 4.05M | 0.27 | 0.001 | 0.42 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.59 |
| EfficientNetB3-CNN | 10.8M | 0.47 | 0.000016 | 0.32 | 0.00 | 0.22 | 0.18 | 0.37 | 0.00 | 0.14 | 0.09 | 0.62 | 0.00 | 0.17 | 0.12 | 0.46 |
| ResNet50-CNN | 23.5M | 0.31 | 0.001 | 0.62 | 0.69 | 0.45 | 1.00 | 0.97 | 0.71 | 0.95 | 0.17 | 0.59 | 0.70 | 0.61 | 0.29 | 0.73 |
| DenseNet201-CNN | 51.8M | 0.57 | 0.001 | 0.66 | 0.57 | 0.50 | 0.24 | 0.96 | 0.39 | 0.68 | 0.15 | 0.94 | 0.46 | 0.58 | 0.19 | 0.95 |
| MobileNet-CNN | 3M | 0.13 | 0.001 | 0.42 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.59 |
| GoogleNet-CNN | 6M | 0.14 | 0.0001 | 0.78 | 0.73 | 0.62 | 0.74 | 0.97 | 0.61 | 0.88 | 0.33 | 0.97 | 0.67 | 0.72 | 0.46 | 0.97 |
| XceptionNet-CNN | 25M | 0.20 | 0.0001 | 0.81 | 0.83 | 0.62 | 0.84 | 1.00 | 0.61 | 0.92 | 0.33 | 1.00 | 0.70 | 0.74 | 0.48 | 1.00 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Model** | **Space Complexity** | **Time Complexity (hrs)** | **LR** | **Accuracy** | **Precision** | | | | **Recall** | | | | **F1 Score** | | | |
| **P** | **M** | **G** | **NT** | **P** | **M** | **G** | **NT** | **P** | **M** | **G** | **NT** |
| CNN | 440k | 0.084 | 0.001 | 0.80 | 0.88 | 0.68 | 0.61 | 0.99 | 0.45 | 0..81 | 0.56 | 0.98 | 0.60 | 0.74 | 0.59 | 0.98 |
| VGG16-CNN | 15.7M | 0.267 | 0.0001 | 0.85 | 0.93 | 0.68 | 0.88 | 1.00 | 0.87 | 0.98 | 0.37 | 0.98 | 0.90 | 0.81 | 0.52 | 0.99 |
| EfficientNetB0-CNN | 4.05M | 0.27 | 0.001 | 0.42 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.59 |
| EfficientNetB3-CNN | 10.8M | 0.47 | 1.6e-5 | 0.32 | 0.00 | 0.22 | 0.18 | 0.37 | 0.00 | 0.14 | 0.09 | 0.62 | 0.00 | 0.17 | 0.12 | 0.46 |
| ResNet50-CNN | 23.5M | 0.31 | 0.001 | 0.62 | 0.69 | 0.45 | 1.00 | 0.97 | 0.71 | 0.95 | 0.17 | 0.59 | 0.70 | 0.61 | 0.29 | 0.73 |
| DenseNet201-CNN | 51.8M | 0.57 | 0.001 | 0.66 | 0.57 | 0.50 | 0.24 | 0.96 | 0.39 | 0.68 | 0.15 | 0.94 | 0.46 | 0.58 | 0.19 | 0.95 |
| MobileNet-CNN | 3M | 0.13 | 0.001 | 0.42 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.59 |
| GoogleNet-CNN | 6M | 0.14 | 0.0001 | 0.78 | 0.73 | 0.62 | 0.74 | 0.97 | 0.61 | 0.88 | 0.33 | 0.97 | 0.67 | 0.72 | 0.46 | 0.97 |
| XceptionNet-CNN | 25M | 0.20 | 0.0001 | 0.81 | 0.83 | 0.62 | 0.84 | 1.00 | 0.61 | 0.92 | 0.33 | 1.00 | 0.70 | 0.74 | 0.48 | 1.00 |

Chart, line chart

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Figure . CNN

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Figure . VGG16

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Figure . EfficientNetB0

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Figure . EfficientNet B3

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Figure . Resnet50

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Figure . Desnet201



Figure . Mobilenet

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Figure . GoogleNet

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Description automatically generated

Figure . XceptionNet

*1.3. Unbalanced SMOTE (with cross\_entropy):*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Model** | **Space Complexity** | **Time Complexity (hrs)** | **Learning Rate** | **Accuracy** | **Precision** | | | | **Recall** | | | | **F1 Score** | | | | |
| **Pituitary** | **Menigioma** | **Glioma** | **No Tumor** | **Pituitary** | **Menigioma** | **Glioma** | **No Tumor** | **Pituitary** | **Menigioma** | **Glioma** | **No Tumor** |
| CNN | 440k | 0.11 | 0.001 | 0.82 | 0.86 | 0.71 | 0.71 | 0.93 | 0.77 | 0.83 | 0.45 | 0.99 | 0.81 | 0.76 | 0.55 | 0.96 |
| VGG16-CNN | 15.7M | 0.52 | 0.0001 | 0.86 | 0.96 | 0.71 | 0.83 | 0.99 | 0.81 | 0.96 | 0.50 | 0.97 | 0.88 | 0.81 | 0.62 | 0.98 |
| EfficientNetB0-CNN | 4.05M | 0.45 | 0.001 | 0.47 | 0.00 | 0.38 | 0.00 | 0.51 | 0.00 | 0.41 | 0.00 | 0.82 | 0.00 | 0.39 | 0.00 | 0.63 |
| EfficientNetB3-CNN | 10.8M | 1.04 | 0.000016 | 0.50 | 0.00 | 0.39 | 0.00 | 0.88 | 0.00 | 0.97 | 0.00 | 0.51 | 0.00 | 0.55 | 0.00 | 0.64 |
| ResNet50-CNN | 23.5M | 0.77 | 0.001 | 0.66 | 1.00 | 0.97 | 0.37 | 0.96 | 0.19 | 0.27 | 0.95 | 0.89 | 0.32 | 0.42 | 0.54 | 0.92 |
| DenseNet201-CNN | 51.8M | 2.08 | 0.001 | 0.86 | 0.96 | 0.70 | 0.97 | 0.99 | 0.77 | 0.98 | 0.45 | 0.99 | 0.86 | 0.82 | 0.61 | 0.99 |
| MobileNet-CNN | 3M | 0.27 | 0.001 | 0.42 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.59 |
| GoogleNet-CNN | 6M | 0.14 | 0.0001 | 0.79 | 0.88 | 0.68 | 0.57 | 1.00 | 0.74 | 0.66 | 0.72 | 0.93 | 0.81 | 0.67 | 0.64 | 0.96 |
| XceptionNet-CNN | 25M | 0.27 | 0.0001 | 0.83 | 0.91 | 0.66 | 0.82 | 1.00 | 0.68 | 0.94 | 0.41 | 0.99 | 0.78 | 0.78 | 0.55 | 1.00 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Model** | **Space Complexity** | **Time Complexity (hrs)** | **LR** | **Accuracy** | **Precision** | | | | **Recall** | | | | **F1 Score** | | | |
| **P** | **M** | **G** | **NT** | **P** | **M** | **G** | **NT** | **P** | **M** | **G** | **NT** |
| CNN | 440k | 0.11 | 0.001 | 0.82 | 0.86 | 0.71 | 0.71 | 0.93 | 0.77 | 0.83 | 0.45 | 0.99 | 0.81 | 0.76 | 0.55 | 0.96 |
| VGG16-CNN | 15.7M | 0.52 | 0.0001 | 0.86 | 0.96 | 0.71 | 0.83 | 0.99 | 0.81 | 0.96 | 0.50 | 0.97 | 0.88 | 0.81 | 0.62 | 0.98 |
| EfficientNetB0-CNN | 4.05M | 0.45 | 0.001 | 0.47 | 0.00 | 0.38 | 0.00 | 0.51 | 0.00 | 0.41 | 0.00 | 0.82 | 0.00 | 0.39 | 0.00 | 0.63 |
| EfficientNetB3-CNN | 10.8M | 1.04 | 1.6e-5 | 0.50 | 0.00 | 0.39 | 0.00 | 0.88 | 0.00 | 0.97 | 0.00 | 0.51 | 0.00 | 0.55 | 0.00 | 0.64 |
| ResNet50-CNN | 23.5M | 0.77 | 0.001 | 0.66 | 1.00 | 0.97 | 0.37 | 0.96 | 0.19 | 0.27 | 0.95 | 0.89 | 0.32 | 0.42 | 0.54 | 0.92 |
| DenseNet201-CNN | 51.8M | 2.08 | 0.001 | 0.86 | 0.96 | 0.70 | 0.97 | 0.99 | 0.77 | 0.98 | 0.45 | 0.99 | 0.86 | 0.82 | 0.61 | 0.99 |
| MobileNet-CNN | 3M | 0.27 | 0.001 | 0.42 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.59 |
| GoogleNet-CNN | 6M | 0.14 | 0.0001 | 0.79 | 0.88 | 0.68 | 0.57 | 1.00 | 0.74 | 0.66 | 0.72 | 0.93 | 0.81 | 0.67 | 0.64 | 0.96 |
| XceptionNet-CNN | 25M | 0.27 | 0.0001 | 0.83 | 0.91 | 0.66 | 0.82 | 1.00 | 0.68 | 0.94 | 0.41 | 0.99 | 0.78 | 0.78 | 0.55 | 1.00 |

Chart, line chart

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Figure . CNN

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Figure . VGG16

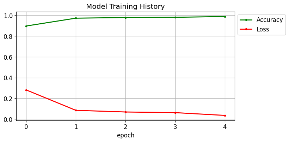


Figure . EfficientNetB0

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Figure . EfficientNetB3

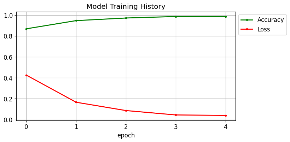


Figure . Resnet50

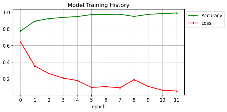


Figure . DenseNet201



Figure . MobileNet

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Figure . GoogleNet

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Figure . XceptionNet

*1.4. Unbalanced ADASyn (with cross\_entropy):*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Model** | **Space Complexity** | **Time Complexity (hrs)** | **Learning Rate** | **Accuracy** | **Precision** | | | | **Recall** | | | | **F1 Score** | | | | |
| **Pituitary** | **Menigioma** | **Glioma** | **No Tumor** | **Pituitary** | **Menigioma** | **Glioma** | **No Tumor** | **Pituitary** | **Menigioma** | **Glioma** | **No Tumor** |
| CNN | 440k | 0.12 | 0.001 | 0.83 | 0.83 | 0.75 | 0.64 | 0.97 | 0.77 | 0.77 | 0.59 | 1.00 | 0.80 | 0.76 | 0.61 | 0.98 |
| VGG16-CNN | 15.7M | 0.60 | 0.0001 | 0.87 | 0.91 | 0.75 | 0.81 | 1.00 | 0.94 | 0.92 | 0.54 | 0.99 | 0.92 | 0.82 | 0.65 | 0.99 |
| EfficientNetB0-CNN | 4.05M | 0.63 | 0.001 | 0.42 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.59 |
| EfficientNetB3-CNN | 10.8M | 1.11 | 0.000016 | 0.52 | 1.00 | 0.36 | 0.33 | 0.86 | 0.13 | 0.15 | 0.87 | 0.69 | 0.23 | 0.21 | 0.48 | 0.69 |
| ResNet50-CNN | 23.5M | 0.83 | 0.001 | 0.42 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.59 |
| DenseNet201-CNN | 51.8M | 1.67 | 0.001 | 0.90 | 1.00 | 0.85 | 0.94 | 0.85 | 0.77 | 0.90 | 0.76 | 1.00 | 0.87 | 0.87 | 0.84 | 0.95 |
| MobileNet-CNN | 3M | 0.30 | 0.001 | 0.42 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.59 |
| GoogleNet-CNN | 6M | 0.15 | 0.0001 | 0.77 | 0.82 | 0.66 | 0.49 | 1.00 | 0.74 | 0.58 | 0.63 | 0.97 | 0.78 | 0.62 | 0.55 | 0.98 |
| XceptionNet-CNN | 25M | 0.31 | 0.0001 | 0.86 | 0.96 | 0.70 | 0.90 | 0.99 | 0.81 | 0.97 | 0.45 | 0.99 | 0.88 | 0.81 | 0.60 | 0.99 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Model** | **Space Complexity** | **Time Complexity (hrs)** | **LR** | **Accuracy** | **Precision** | | | | **Recall** | | | | **F1 Score** | | | |
| **P** | **M** | **G** | **NT** | **P** | **M** | **G** | **NT** | **P** | **M** | **G** | **NT** |
| CNN | 440k | 0.12 | 0.001 | 0.83 | 0.83 | 0.75 | 0.64 | 0.97 | 0.77 | 0.77 | 0.59 | 1.00 | 0.80 | 0.76 | 0.61 | 0.98 |
| VGG16-CNN | 15.7M | 0.60 | 0.0001 | 0.87 | 0.91 | 0.75 | 0.81 | 1.00 | 0.94 | 0.92 | 0.54 | 0.99 | 0.92 | 0.82 | 0.65 | 0.99 |
| EfficientNetB0-CNN | 4.05M | 0.63 | 0.001 | 0.42 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.59 |
| EfficientNetB3-CNN | 10.8M | 1.11 | 1.6e-5 | 0.52 | 1.00 | 0.36 | 0.33 | 0.86 | 0.13 | 0.15 | 0.87 | 0.69 | 0.23 | 0.21 | 0.48 | 0.69 |
| ResNet50-CNN | 23.5M | 0.83 | 0.001 | 0.42 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.59 |
| DenseNet201-CNN | 51.8M | 1.67 | 0.001 | 0.90 | 1.00 | 0.85 | 0.94 | 0.85 | 0.77 | 0.90 | 0.76 | 1.00 | 0.87 | 0.87 | 0.84 | 0.95 |
| MobileNet-CNN | 3M | 0.30 | 0.001 | 0.42 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.59 |
| GoogleNet-CNN | 6M | 0.15 | 0.0001 | 0.77 | 0.82 | 0.66 | 0.49 | 1.00 | 0.74 | 0.58 | 0.63 | 0.97 | 0.78 | 0.62 | 0.55 | 0.98 |
| XceptionNet-CNN | 25M | 0.31 | 0.0001 | 0.86 | 0.96 | 0.70 | 0.90 | 0.99 | 0.81 | 0.97 | 0.45 | 0.99 | 0.88 | 0.81 | 0.60 | 0.99 |

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Figure . CNN

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Figure . VGG16

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Figure . EfficientNetB0

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Figure . EfficientNetB3

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Figure . Resnet50

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Figure . DenseNet201

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Figure . MobileNet

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Figure . GoogleNet

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Figure . XceptionNet

Table. Accuracy Comparison on Unbalanced Dataset

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model | CE | Focal Loss | Augment CE | SMOTE CE | ADASYN CE |
| CNN | 0.8125 | 0.80 | 0.91 | 0.82 | 0.83 |
| VGG16-CNN | 0.83 | 0.85 | 0.96 | 0.86 | 0.87 |
| EfficientNetB0-CNN | 0.37 | 0.42 | 0.31 | 0.47 | 0.42 |
| EfficientNetB3-CNN | 0.60 | 0.32 | 0.32 | 0.50 | 0.52 |
| ResNet50-CNN | 0.78 | 0.62 | 0.80 | 0.66 | 0.42 |
| DenseNet201-CNN | 0.47 | 0.66 | 0.94 | 0.86 | 0.90 |
| MobileNet-CNN | 0.30 | 0.42 | 0.23 | 0.42 | 0.42 |
| GoogleNet-CNN | 0.77 | 0.78 | 0.80 | 0.79 | 0.77 |
| XceptionNet-CNN | 0.83 | 0.81 | 0.94 | 0.83 | 0.86 |

|  |  |
| --- | --- |
| **Name** | **Values** |
| Mini Batch Size | 20 |
| Number of Epochs | 5 to 12 |
| Learning Rate(s) | 0.001 to 0.0001 |
| Shuffle | True |
| Steps Per Epoch | Train Size (1600) / 20 |
| Dense Activations | RELU |
| Optimizer | ADAM |