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Report: Impact of Activation Functions on CNN Performance

Introduction

Activation functions play a critical role in the performance of Convolutional Neural Networks (CNNs). They introduce non-linearity, enabling the network to learn complex patterns. This report analyzes the impact of five activation functions—**ReLU**, **Sigmoid**, **Tanh**, **Softmax**, and **Linear**—on the performance of 10 popular CNN architectures using classification accuracy as the evaluation metric.

Evaluated CNN Models

1. VGG16
2. VGG19
3. MobileNetV2
4. ResNet50
5. DenseNet121
6. NASANetMobile
7. ResNet101
8. Xception
9. InceptionV3
10. ConvNeXtBase

Each model was evaluated with each activation function independently, and classification accuracy was recorded.

Activation Function Overview

- **ReLU (Rectified Linear Unit):** Most commonly used due to its simplicity and efficiency in deep networks.
- **Sigmoid:** Squashes input into a [0,1] range, can cause vanishing gradients.
- **Tanh:** Similar to Sigmoid but maps inputs to [-1,1], often performs better than Sigmoid.
- **Softmax:** Converts outputs into probabilities; typically used in final layers.
- **Linear:** Identity function; often used in regression but included here for comparison.

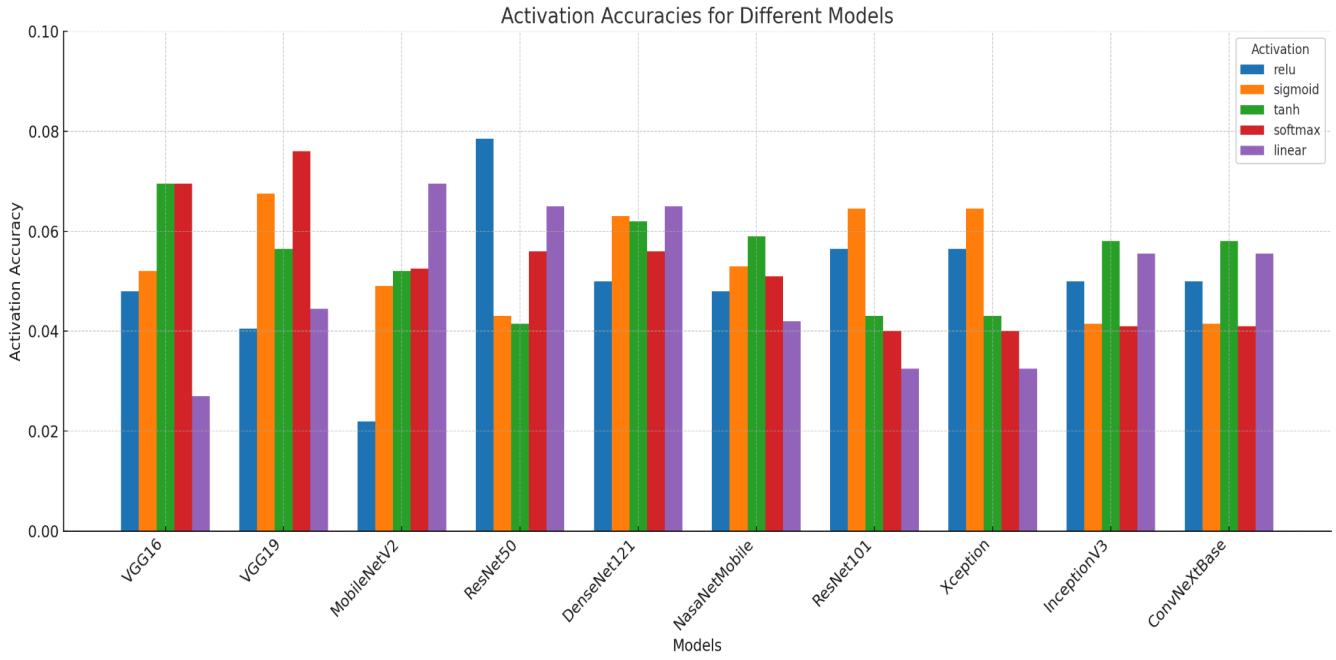
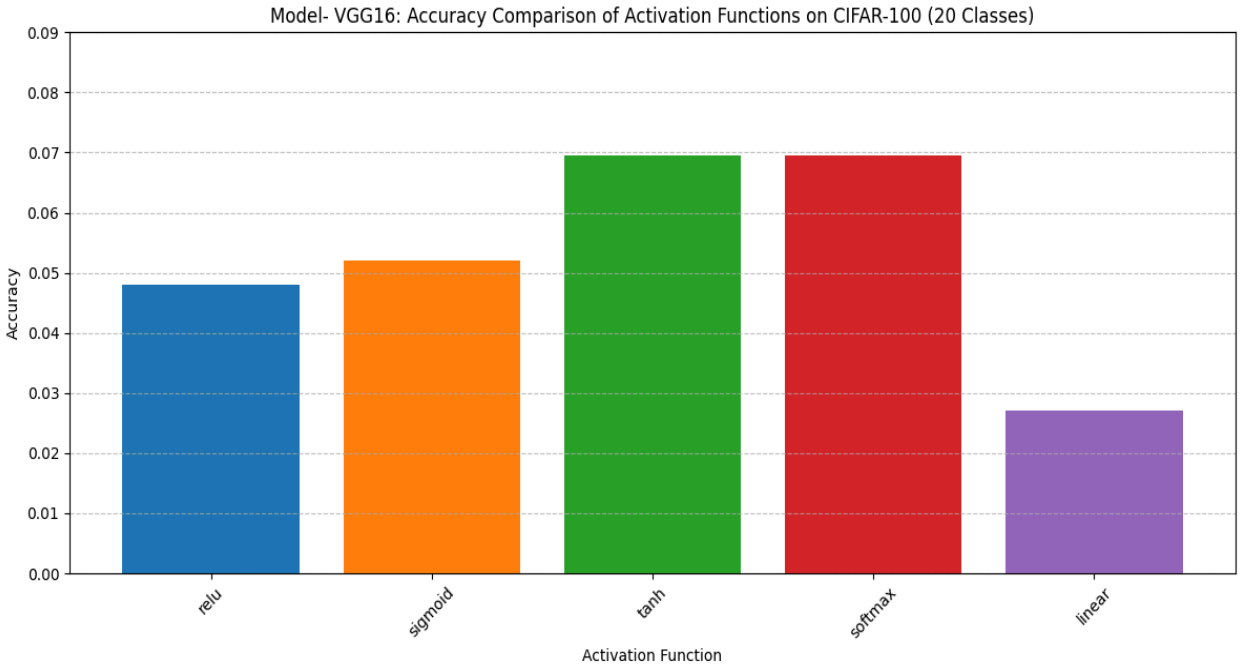


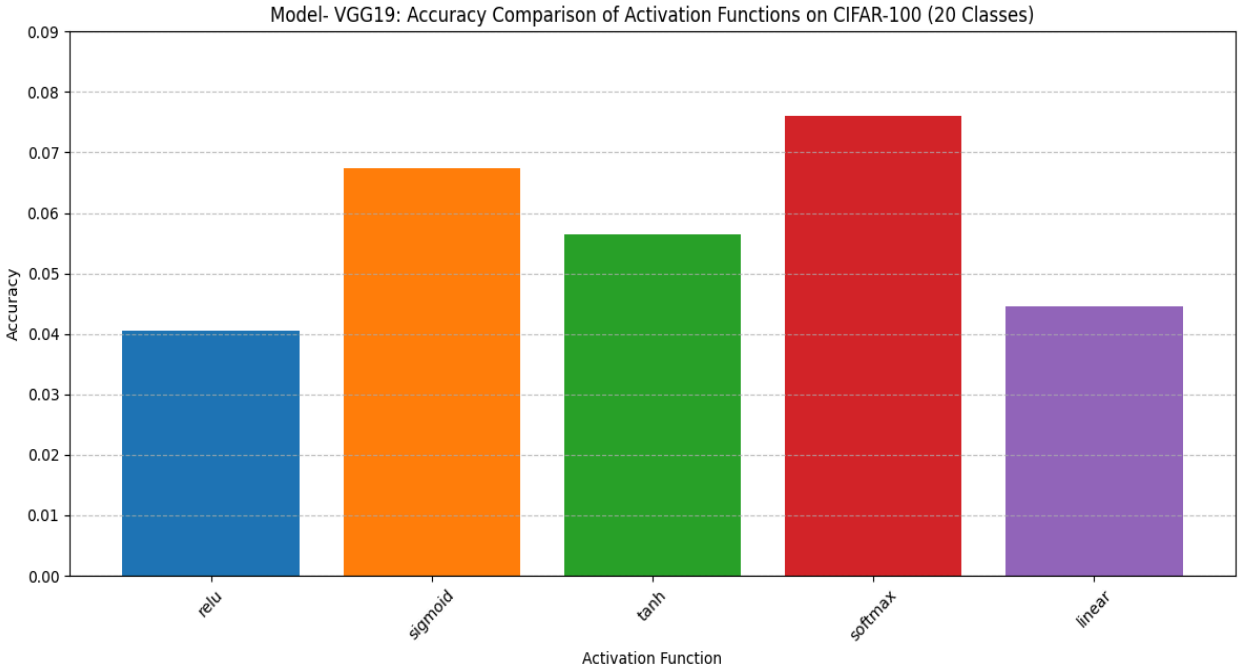
Fig : Activation accuracy for Different Models

Now I will provide an accuracy bar chart for each model one by one .

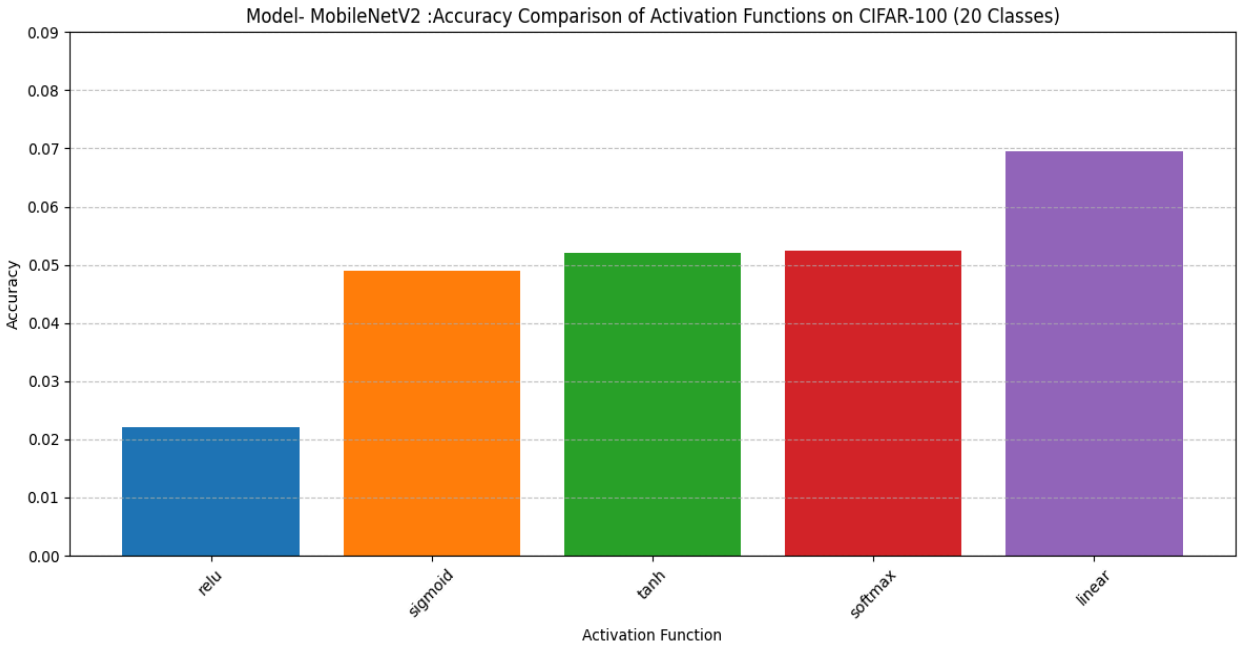
Model-1 : VGG16



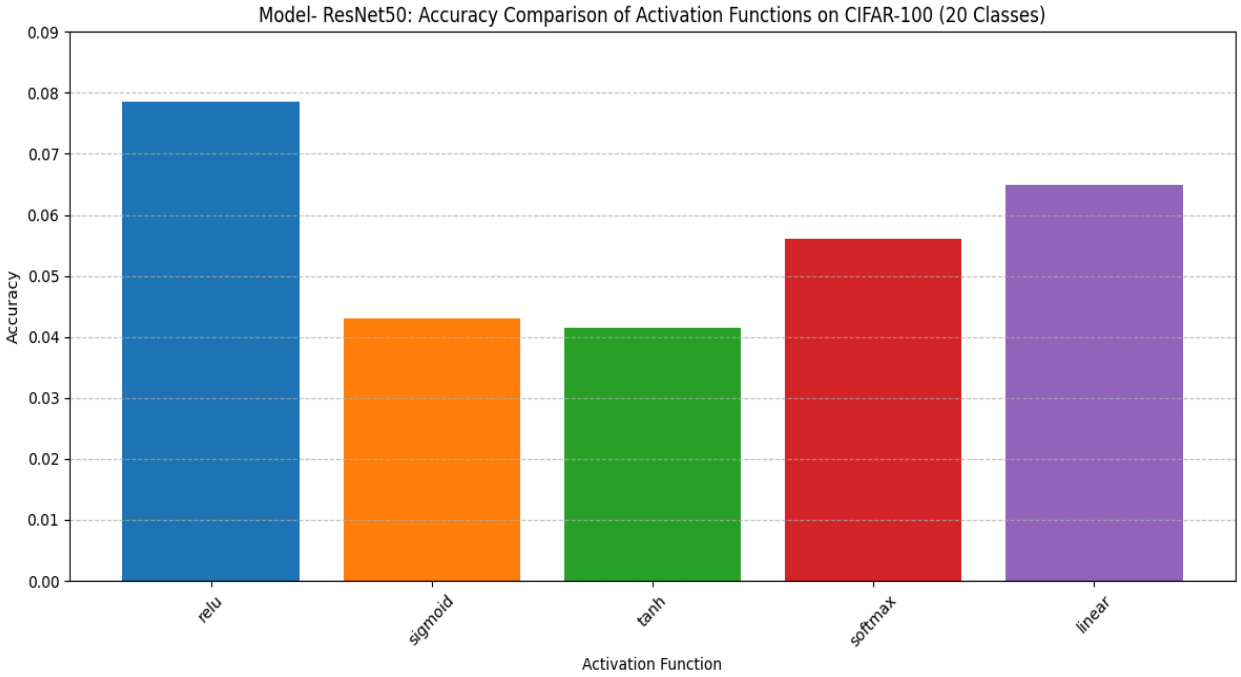
Model-2: VGG19



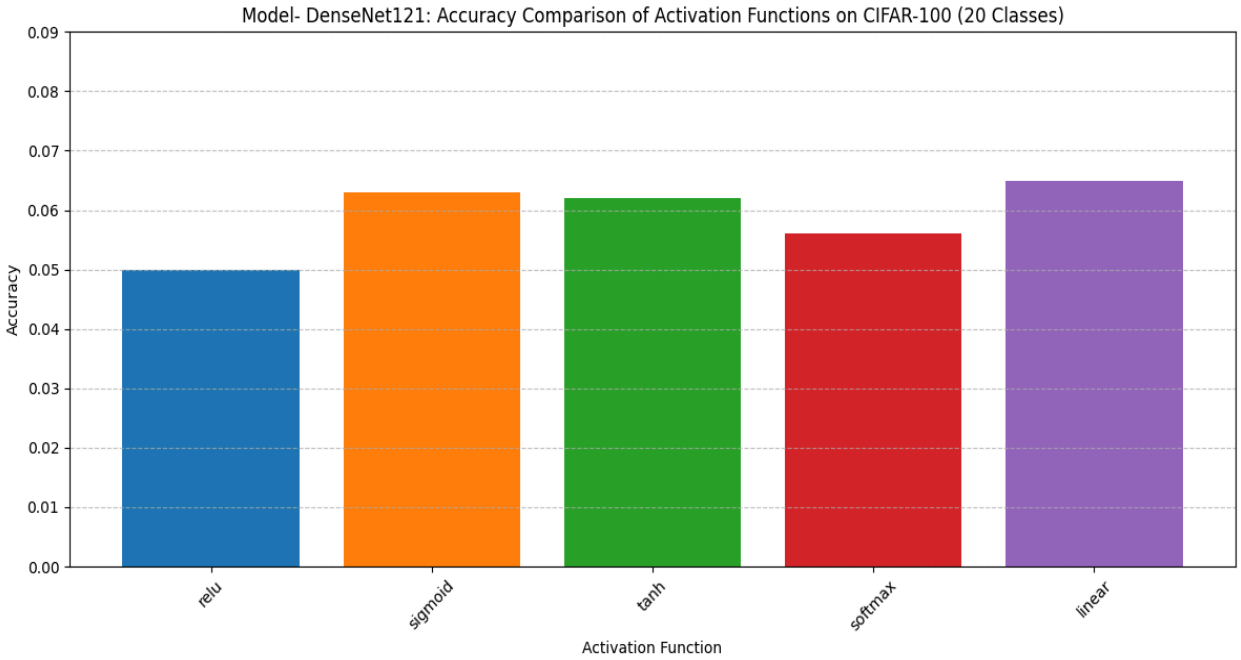
Model-3: MobileNetV2



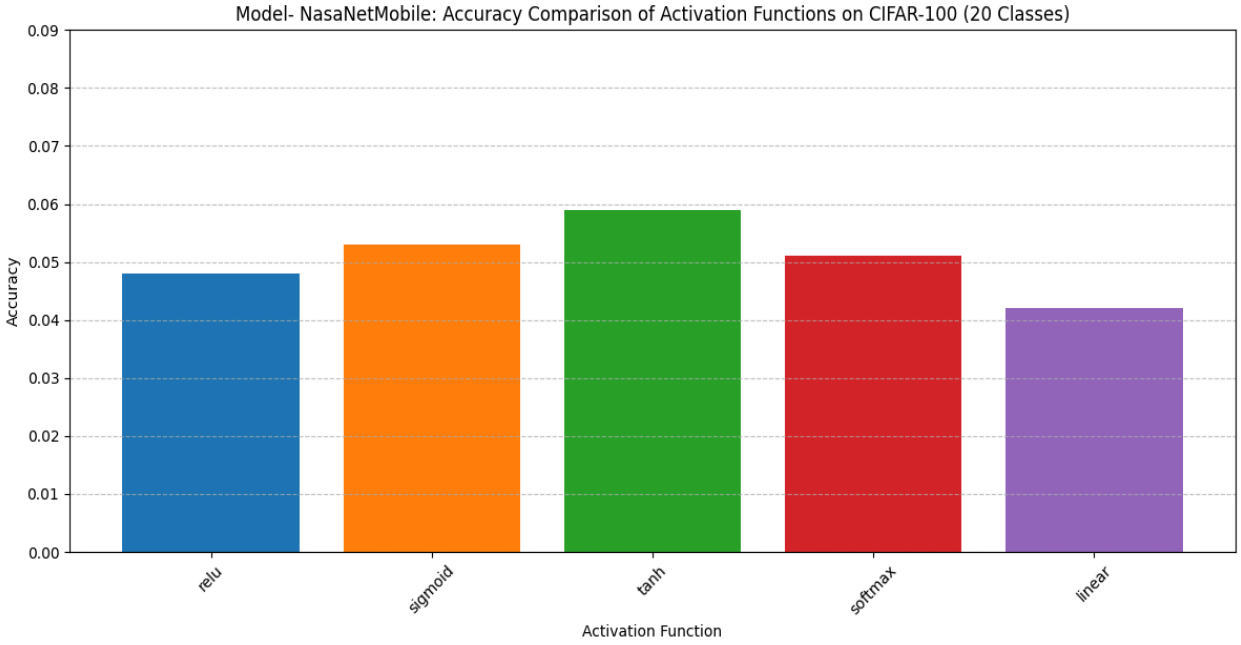
Model -4: ResNet50



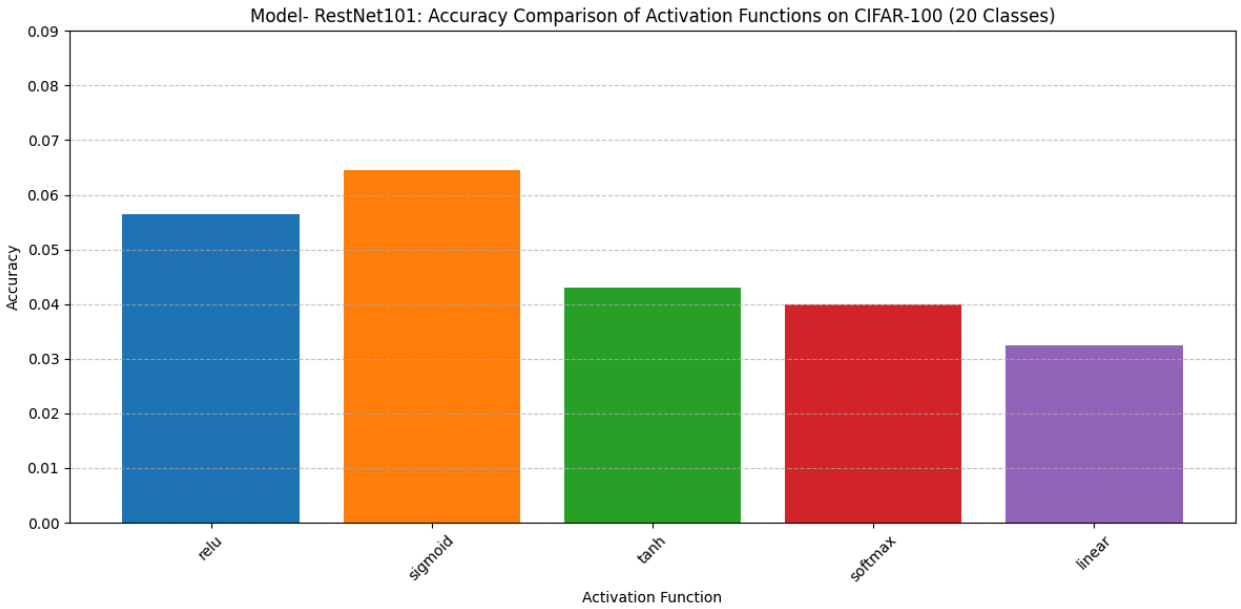
Model-5: DenseNet121



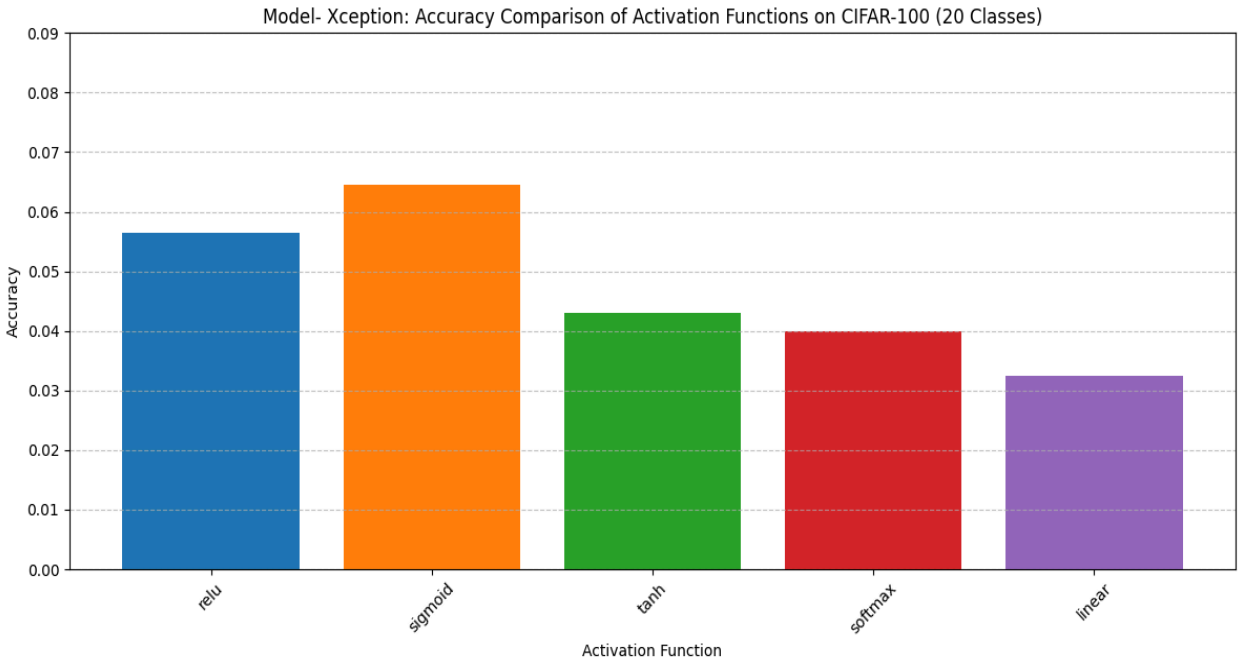
Model-6 : NasaNetMobile



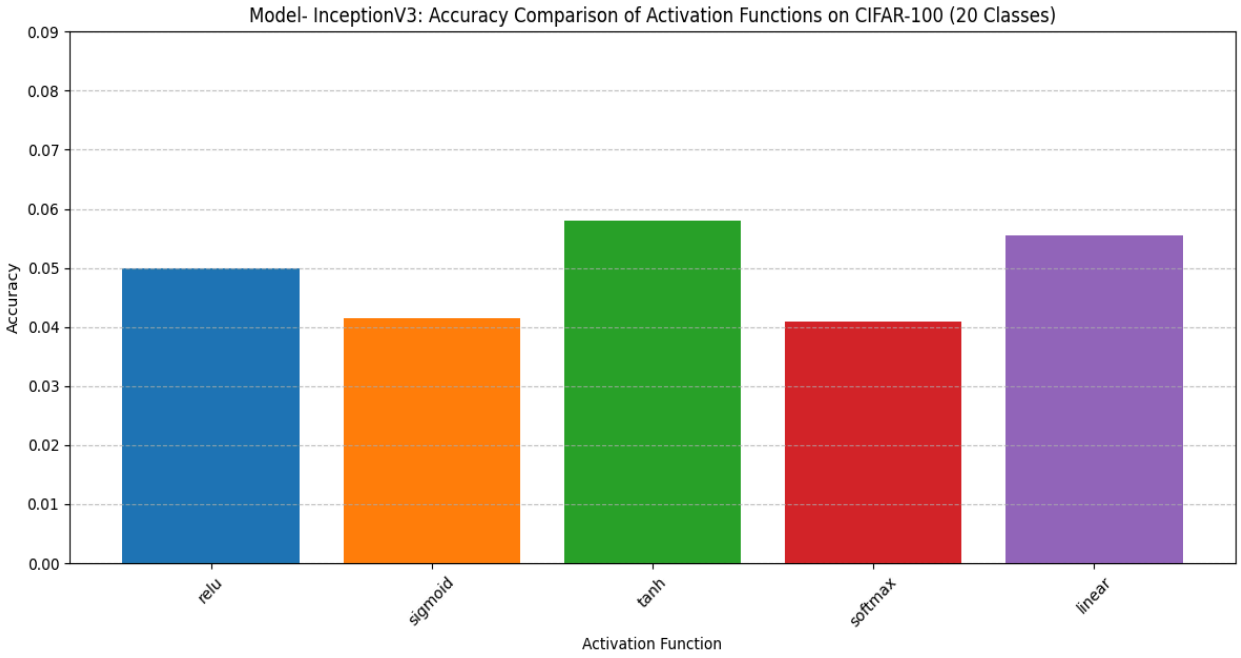
Model-7: ResNet101



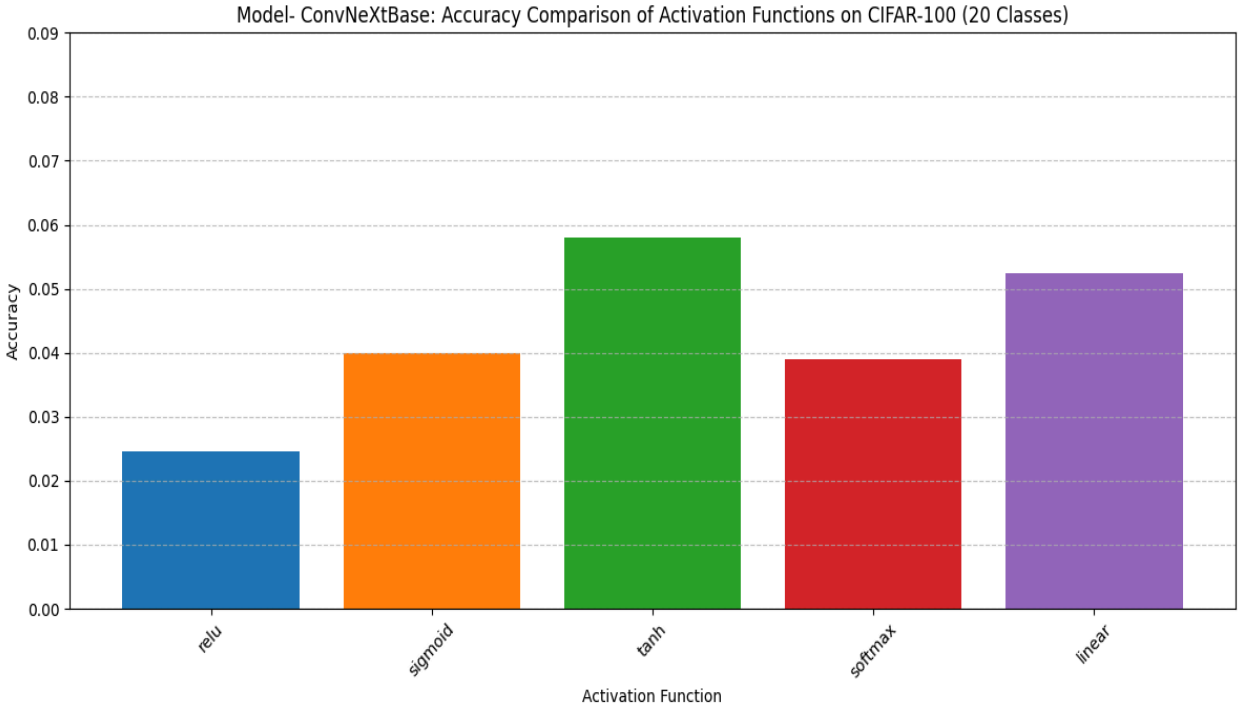
Model-8 : Xception



Model-9 : Inception



Model-10 : ConvNeXtBase



Analysis

1. ReLU

- ReLU showed strong performance only on **ResNet50**, where it achieved the highest accuracy (0.0785).
- For most other models, especially **MobileNetV2**, it underperformed significantly, indicating that ReLU might not generalize well across all architectures when used as a replacement in all layers.

2. Sigmoid

- Performed well in **Xception** and **ResNet101**, achieving the highest accuracy in both.
- Still lagged behind other activations in some models, such as **MobileNetV2** and **InceptionV3**, likely due to vanishing gradient issues.

3. Tanh

- Consistently competitive, often appearing in the top two activation functions.
- Showed best performance in **VGG16**, **NASANetMobile**, **InceptionV3**, and **ConvNeXtBase**.

4. Softmax

- Excelled in **VGG19**, indicating its suitability in classification-focused architectures.
- However, it performed poorly in **ConvNeXtBase** and **InceptionV3**, which may be due to inappropriate use in internal layers rather than just the output layer.

5. Linear

- Surprisingly effective in **MobileNetV2** and **DenseNet121**, outperforming other nonlinear functions.
- Generally the weakest in models like **VGG16**, **NASANetMobile**, and **ResNet101**, reaffirming its limited utility in deep classification networks.

**** Mentioning at least three CNNs which use regular kernel, deformable kernel, dilated kernel, depthwise separable kernel, modified depthwise-separable kernel, pointwise kernel :**

Kernel Type	Models
Regular	VGG16, VGG19, ResNet50
Deformable	No
Dilated	Xception, InceptionV3, ConvNeXtBase
Depthwise Separable	MobileNetV2, Xception, NASANetMobile
Modified Depthwise-Separable	MobileNetV2, Xception, NASANetMobile
Pointwise (1x1 Conv)	ResNet50, MobileNetV2