### 1. Introduction

Transfer learning leverages pre-trained deep learning models to adapt to new tasks with limited data. This report explores two prominent CNN architectures, **ResNet50** and **MobileNet**, both pre-trained on ImageNet, and fine-tuned on the **TF Flowers** dataset. We evaluate the performance of these models using different unfreezing strategies—layer-based and block-based—and assess trade-offs in terms of accuracy and efficiency.

### 2. Dataset Overview

The TF Flowers dataset contains 3,670 images of five flower categories: daisy, dandelion, roses, sunflowers, and tulips. We used an 80-10-10 split for training, validation, and testing. Images were resized to 224×224 pixels and normalized to the [0, 1] range to prepare them for the models.

### 3. Model Architectures

#### 3.1 ResNet50

ResNet50 is a deep residual network that introduces identity shortcuts to improve gradient flow, allowing very deep networks to train efficiently. It's known for its high accuracy but is relatively heavy in computation and parameters.

#### 3.2 MobileNet

MobileNet is designed for mobile and embedded vision applications. It employs depthwise separable convolutions, dramatically reducing the number of parameters and computational cost while maintaining strong performance.

### 4. Transfer Learning Implementation

#### 4.1 General Workflow

For both models:

* Pre-trained weights from ImageNet were loaded (include\_top=False).
* Base models were initially frozen.
* A custom classification head was added:
* GlobalAveragePooling2D → Dense(128, ReLU) → Dense(5, softmax)
* Optimizer: Adam
* Loss: Sparse Categorical Crossentropy
* Epochs: 10 (initial) + 5 (fine-tuning)
* Early stopping based on validation accuracy.

### 5. Layer Unfreezing Strategies

Two strategies were explored:

#### Strategy A – Unfreezing Last N Layers:

ResNet50: 5, 20, 30 layers

MobileNet: 5, 15, 20, 30 layers

#### Strategy B – Unfreezing Blocks:

* ResNet50: Final 1 to 3 residual blocks
* MobileNet: Final 1 to 3 depthwise-pointwise convolutional blocks

### 6. Results and Model Comparison

The following tables summarize **test accuracy** and **inference time per image (on CPU)** for each model and strategy across multiple configurations:

#### ResNet50 Summary

| **Strategy** | **Layers/Blocks Unfrozen** | **Test Accuracy** | **Inference Time** |
| --- | --- | --- | --- |
| Blocks | 2 blocks | **91.83%** | 84.12 ms |
| Layers | 20 layers | **92.92%** | 79.24 ms |
| Blocks | 1 block | **91.83%** | 102.82 ms |
| Layers | 20 layers | **93.73%** | 78.92 ms |
| Blocks | 3 blocks | **92.37%** | 103.10 ms |
| Layers | 30 layers | **94.01%** | 71.64 ms |
| Blocks | 1 block (shallow) | **92.64%** | 102.93 ms |
| Layers | 5 layers (shallow) | **92.10%** | 102.81 ms |

#### MobileNet Summary

| **Strategy** | **Layers/Blocks Unfrozen** | **Test Accuracy** | **Inference Time** |
| --- | --- | --- | --- |
| Blocks | 3 blocks | **90.74%** | 39.99 ms |
| Layers | 15 layers | **91.01%** | 31.69 ms |
| Blocks | 1 block | **90.74%** | 51.74 ms |
| Layers | 20 layers | **91.83%** | 38.60 ms |
| Blocks | 3 blocks | **91.01%** | 32.55 ms |
| Layers | 30 layers | **90.46%** | 52.01 ms |
| Blocks | 1 block (shallow) | **89.65%** | 51.86 ms |
| Layers | 5 layers (shallow) | **91.28%** | 52.03 ms |

### 7. Analysis of Strategies

#### Which Strategy Performed Best?

* **ResNet50** achieved highest performance with **Layer Strategy (30 layers)**, reaching **94.01% test accuracy**.
* **MobileNet** also peaked with **Layer Strategy (20 layers)**, achieving **91.83% test accuracy**.

#### Performance Trends

**Layer strategies generally outperformed block strategies** in both models.

* **ResNet50** had higher variance in inference time depending on layers/blocks unfrozen.
* **MobileNet** remained consistently faster, with lowest inference time under **Layer Strategy (15 layers)**.

#### Overfitting & Stability

Shallow unfreezing (5 layers or 1 block) yielded lower performance gains.

Deeper unfreezing provided gains but at risk of longer training and possible overfitting if not regularized.

### 8. Optimal Strategy Recommendations

| **Model** | **Recommended Strategy** | **Test Accuracy** | **Inference Time** |
| --- | --- | --- | --- |
| ResNet50 | Unfreeze last **30 layers** | **94.01%** | 71.64 ms |
| MobileNet | Unfreeze last **20 layers** | **91.83%** | 38.60 ms |

These combinations gave the best accuracy/inference trade-offs in our tests.

### 9. Conclusion

Transfer learning proved highly effective for flower classification using the TF Flowers dataset. **ResNet50** achieved the highest accuracy but at a computational cost. **MobileNet**, though slightly behind in accuracy, was significantly faster and more lightweight.

Your choice between these models should depend on the deployment environment:

For **high accuracy** tasks: ResNet50 with 30 unfrozen layers is optimal.

For **speed and efficiency**: MobileNet with 20 unfrozen layers offers excellent performance at a lower resource cost.