110061133 王立皓 HW4

Task A:
I choose ResNet18 and ResNet50 in this mini project.
The reasons are as follow:

ResNet18:

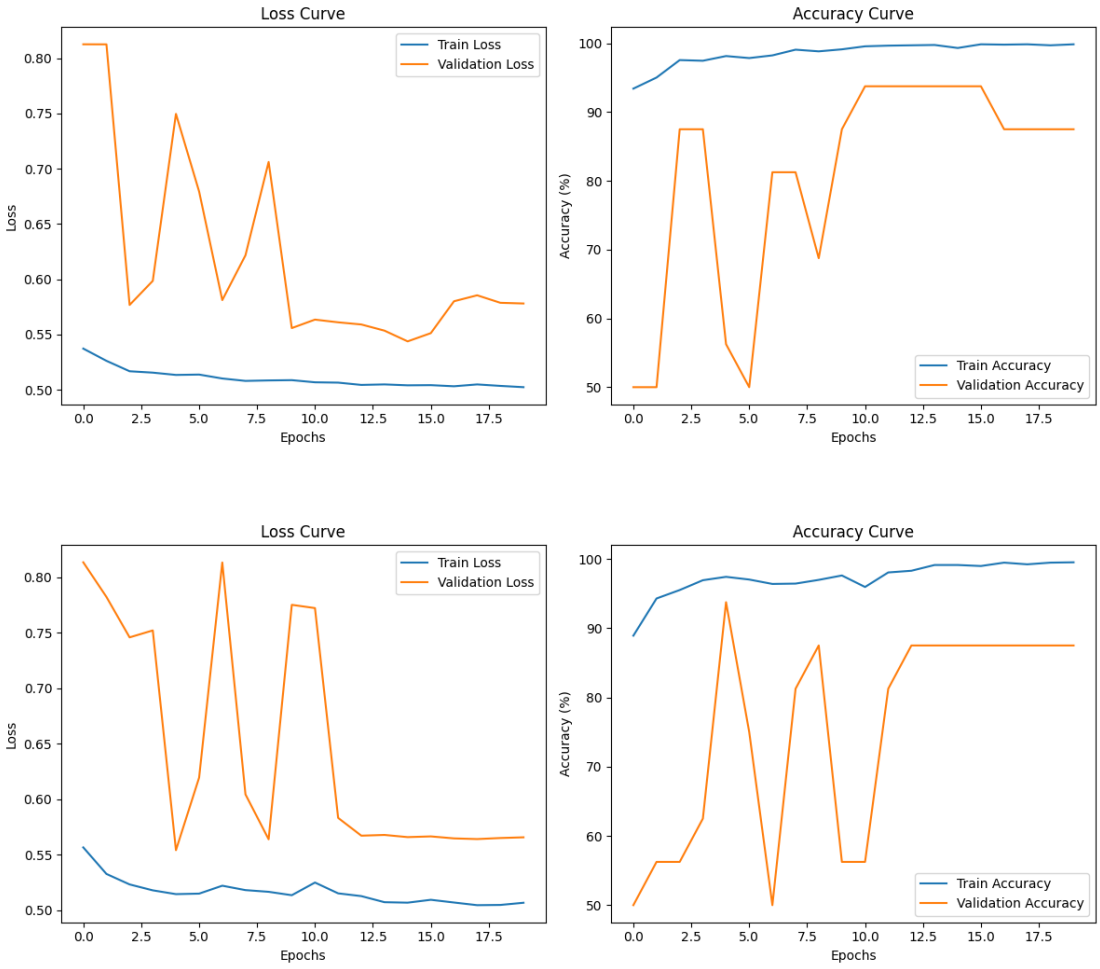
- **Model Characteristics**:
  - ResNet18 is a lightweight convolutional neural network with only 18 layers.
  - Its architecture makes it computationally efficient and well-suited for environments with limited processing power or memory.
- **Why Suitable**:
  - **Small to Medium Dataset Size**: Its smaller size reduces the risk of overfitting on limited datasets.
  - **Efficiency**: Ideal for tasks requiring faster training or inference, especially when computational resources are constrained.
- **Use Case**:
  - Tasks where speed and generalization are more critical than capturing finer-grained features.
  - Analyzing datasets with clear, distinguishable patterns that don't require extensive depth for representation.

2. ResNet50:

- **Model Characteristics**:
  - ResNet50 has 50 layers, making it significantly deeper than ResNet18.
  - Equipped with bottleneck blocks, allowing it to process more complex features effectively without prohibitive computation increases.
- **Why Suitable**:
  - **Complex or Large Datasets**: Its depth helps in identifying intricate patterns and finer details that ResNet18 might miss.
  - **High Feature Representation**: It excels in tasks requiring nuanced feature extraction and differentiation.
- **Use Case**:
  - Scenarios where high accuracy is essential, and computational resources are adequate.
  - Applications involving subtle, high-dimensional data patterns, such as medical imaging or fine-grained object classification.

ResNet18, being a lightweight model with 18 layers, is expected to provide fast training and inference, making it ideal for smaller or less complex datasets, though it may sacrifice accuracy for efficiency in cases requiring intricate feature extraction. In contrast, ResNet50, with its deeper architecture and 50 layers, is anticipated to yield higher accuracy and better performance on complex datasets due to its superior capacity for capturing fine-grained patterns. However, this comes at the cost of increased computational demands and longer training times. Both models offer complementary trade-offs, enabling their selection based on dataset complexity and resource availability.

Task B:

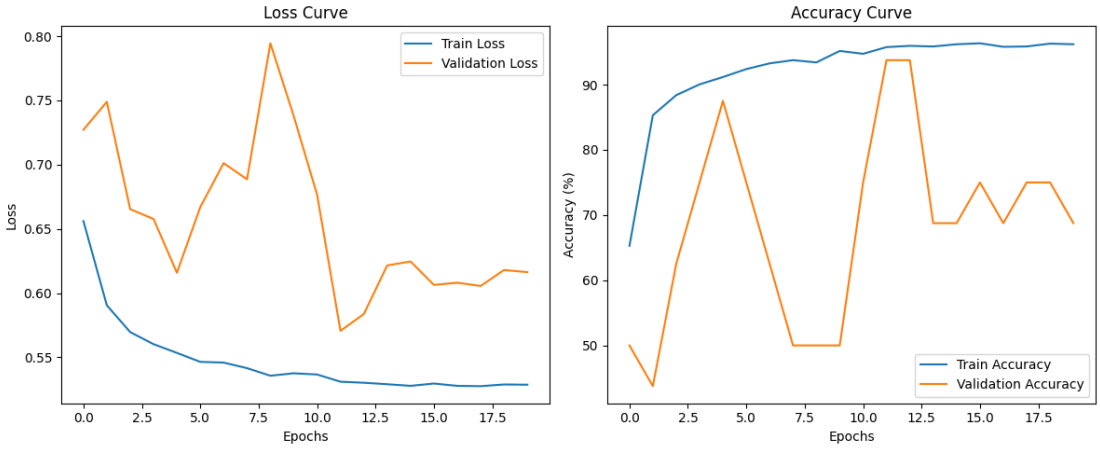


The above figures show the result of ResNet18 (top) and ResNet50 (bottom) without freezing. Each model is trained with 20 epochs, raw data will be given in the txt file in GitHub.

Both ResNet18 and ResNet50 achieves an **87.5%** validation accuracy in this part. However, it takes ResNet50 more than twice the time to obtain the same results.

The result assumes that increasing the layer in solving the pneumonia/no pneumonia problem may not help when using ResNet architecture. Interestingly, the ResNet18 model seems to overfit after 15 epochs, this is not expected since a simpler model should reduce the risk of overfitting.

Task C:



The above figures show the result of ResNet50 (bottom) freezing the layers. I accidently deleted the result image of ResNet18, but I kept the raw data, so discussion can still be done in this report. Each model is trained with 20 epochs, raw data will be given in the txt file in GitHub.

The results show that the ResNet18 achieves **68.75%** accuracy while the ResNet50 achieves **81.25%** accuracy. This means that a bigger size makes a difference when we freeze the layers.

The time it took for the two models to train also differs. It to about 10% more time for ResNet50 to complete training.

Task D and E:

Unfrozen Layers (Full Training):

- Both ResNet18 and ResNet50 achieve **87.5% validation accuracy**, but ResNet50 takes over twice the time to achieve the same result.
- ResNet18 **overfits after 15 epochs**, which is unexpected as simpler models typically generalize better.

- **Frozen Layers (Transfer Learning)**:
    - ResNet18 achieves **68.75% accuracy**, while ResNet50 achieves **81.25% accuracy**, suggesting that ResNet50's larger capacity better leverages frozen feature extractors.
    - ResNet50 takes about **10% longer** to complete training than ResNet18, a smaller difference compared to full training.

Explanations:

1. **Full Training Observations:**
    - Both models reach the same accuracy, indicating that the pneumonia classification task does not benefit from the increased capacity of ResNet50. The task may not be complex enough to require the deeper architecture.
    - ResNet18's overfitting after 15 epochs could result from **data limitations**, where the simpler model is more sensitive to insufficient or imbalanced training samples. Regularization techniques like dropout or data augmentation might address this issue.
2. **Frozen Layers Observations:**
    - The performance gap (68.75% vs. 81.25%) reflects the **importance of feature extraction quality** in transfer learning. ResNet50's deeper architecture extracts more robust features, which improves results even when layers are frozen.
    - The smaller time difference suggests that freezing layers mitigates the computational load difference between the two architectures, as fewer parameters are updated during training.

Conclusions:

1. **Full Training:**
    - ResNet18 is more efficient for achieving **87.5% accuracy**, making it suitable when computational resources are limited.
    - The unexpected overfitting of ResNet18 highlights the need for careful data preprocessing and regularization techniques, even with simpler architectures.
2. **Frozen Layers (Transfer Learning):**

- ResNet50 is preferable due to its higher accuracy (81.25%) despite a modest increase in training time, as its deeper architecture better leverages pre-trained features.
- The performance improvement underscores the benefit of using larger models for transfer learning, especially in tasks like pneumonia classification where nuanced feature representation is critical.

3. **Conclusion**:
    - Conventionally, for scenarios with limited resources or real-time constraints, ResNet18 is a good choice, particularly with careful mitigation of overfitting. For scenarios prioritizing accuracy, especially in transfer learning, ResNet50 is a more robust option.
    - Given the trade-off of time and resource, I would prefer ResNet18, full training and ResNet50, freezing layers over the other two cases. Since ResNet18 and ResNet50 can obtain the same results in this problem, it is more appropriate to choose the simpler model which is faster and less resource consuming; comparing the two cases of freezing layers, I believe it is a better option to choose ResNet50 instead of ResNet18 because the significantly improves the learning with only a 10% time trade-off. Therefore the case considering full training or not, for scenarios with limited resources or real-time constraints, ResNet50, freezing layers would be a great choice while for scenarios prioritizing accuracy, ResNet18, full training would be better in this case because a bigger size simply doesn’t help.