

Metric Learning: Triplet-Loss

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I. THE TRIPLET-LOSS PIPELINE

In this supervised similarity or metric learning, the Triplet-Loss pipeline consists of

- 1) Retrieve images from CUB200_2011 dataset within `TripletCUBDataset` class
- 2) Transform images into tensors and apply additional augmentations to the training set only
- 3)
- 4)

II. TRAINING HYPER-PARAMETERS

We conducted 4 experiments using two pre-trained models: ResNet18 and ResNet34

ResNet18 contains approximately 11.4 million parameters

ResNet34 contains approximately 21.5 million parameters

- 1) epochs: 20, learning rate: 0.001, batch size: 32
 - 2) epochs: 20, learning rate: 0.002, batch size: 32
 - 3) epochs: 20, learning rate: 0.001, batch size: 64
 - 4) epochs: 20, learning rate: 0.002, batch size: 64
- Extended Training with ResNet18*
- 5) epochs: 60, learning rate: 0.001, batch size: 32
 - 6) epochs: 60, learning rate: 0.001, batch size: 64

III. TRAINING CURVES

A. ResNet18

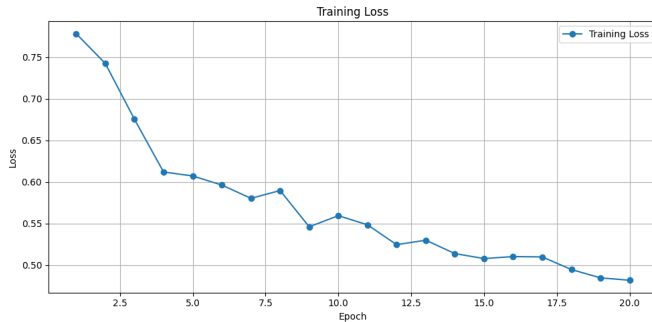


Fig. 1. Experiment 1 with ResNet18



Fig. 2. Experiment 2 with ResNet18

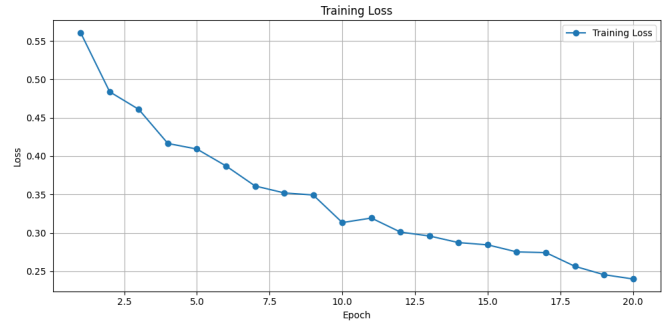


Fig. 3. Experiment 3 with ResNet18

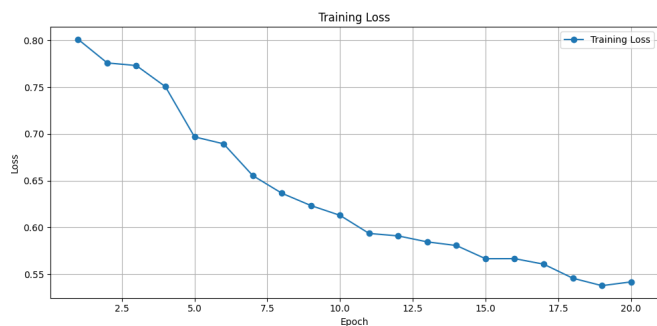


Fig. 4. Experiment 4 with ResNet18

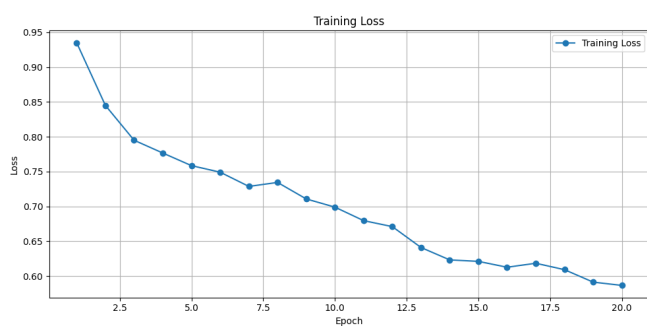


Fig. 8. Experiment 4 with ResNet34

B. ResNet34

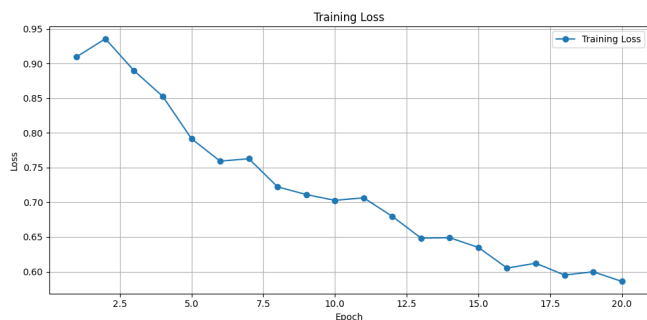


Fig. 5. Experiment 1 with ResNet34



Fig. 6. Experiment 2 with ResNet34

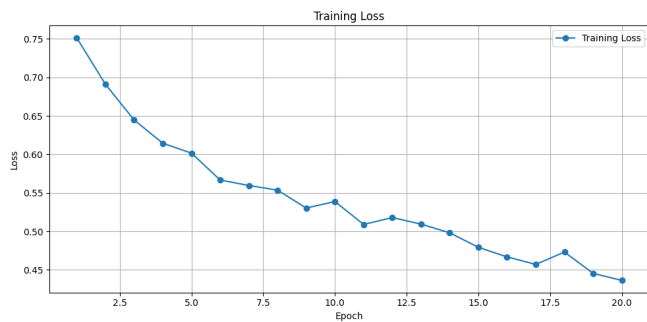


Fig. 7. Experiment 3 with ResNet34

IV. EMBEDDING VISUALIZATIONS

A. ResNet18

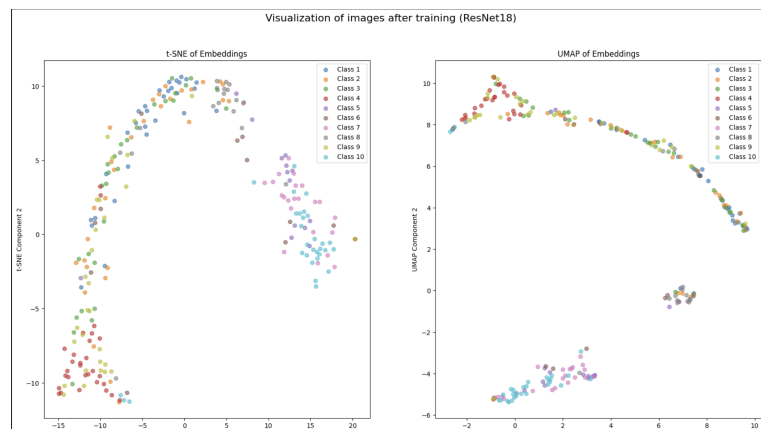


Fig. 9. Experiment 1 with ResNet18



Fig. 10. Experiment 2 with ResNet18

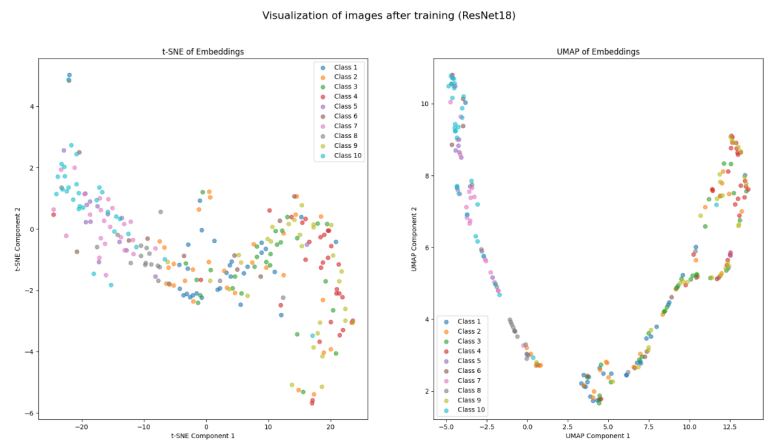


Fig. 12. Experiment 4 with ResNet18

B. ResNet34

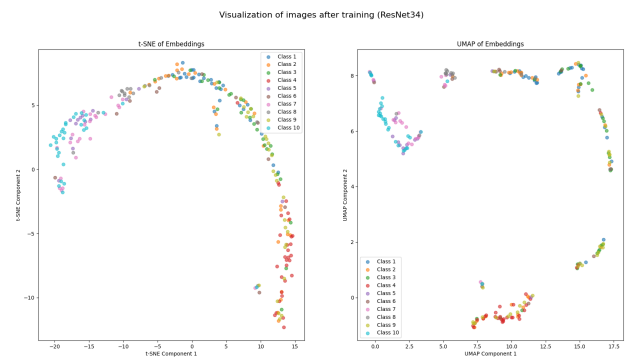


Fig. 13. Experiment 1 with ResNet34

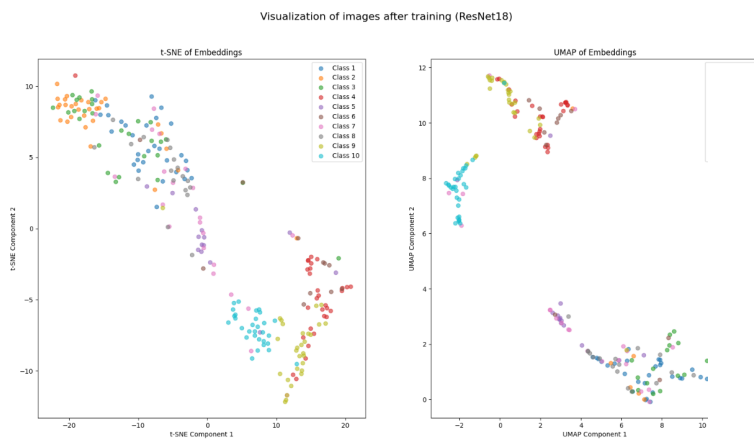


Fig. 11. Experiment 3 with ResNet18

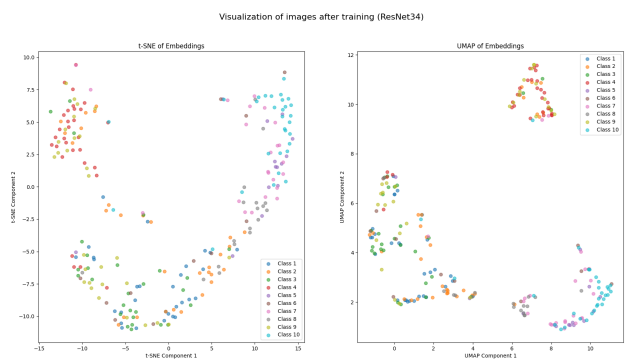


Fig. 14. Experiment 2 with ResNet34

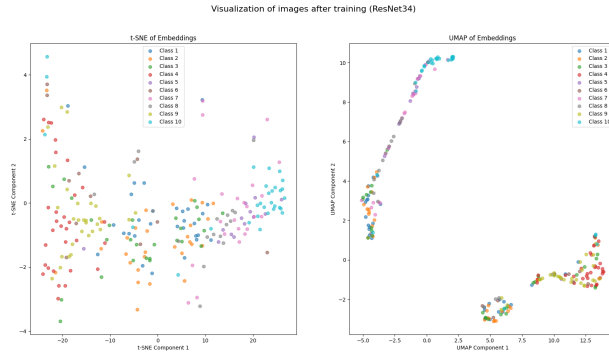


Fig. 15. Experiment 3 with ResNet34

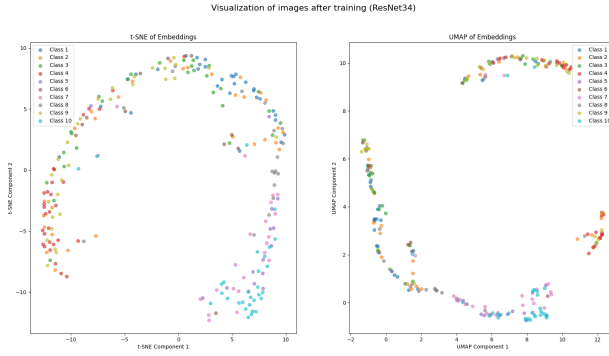


Fig. 16. Experiment 4 with ResNet34

V. EVALUATION RESULTS

A. ResNet18

TABLE I
LOSS AND ACCURACY METRICS FOR EXPERIMENT 1

| Metric (Average) | Value |
|-----------------------------------|--------|
| Loss | 0.5020 |
| Top-1 Accuracy (%) | 79.60 |
| Cosine Similarity Anchor-Positive | 0.6735 |
| Cosine Similarity Anchor-Negative | 0.0359 |

TABLE II
PRECISION METRICS FOR EXPERIMENT 1

| Metric | Value (%) |
|--------------|-----------|
| Precision@1 | 33.74 |
| Precision@5 | 33.83 |
| Precision@10 | 32.55 |

VI. EXPERIMENT 2 - RESNET18

TABLE III
LOSS AND ACCURACY METRICS FOR EXPERIMENT 3

| Metric (Average) | Value |
|-----------------------------------|---------|
| Loss | 0.3277 |
| Top-1 Accuracy (%) | 89.11 |
| Cosine Similarity Anchor-Positive | 0.7762 |
| Cosine Similarity Anchor-Negative | -0.0004 |

TABLE IV
PRECISION METRICS FOR EXPERIMENT 3

| Metric | Value (%) |
|--------------|-----------|
| Precision@1 | 39.92 |
| Precision@5 | 44.03 |
| Precision@10 | 42.51 |

TABLE V
LOSS AND ACCURACY METRICS FOR EXPERIMENT 4

| Metric (Average) | Value |
|-----------------------------------|--------|
| Loss | 0.5633 |
| Top-1 Accuracy (%) | 76.53 |
| Cosine Similarity Anchor-Positive | 0.6284 |
| Cosine Similarity Anchor-Negative | 0.0632 |

TABLE VI
PRECISION METRICS FOR EXPERIMENT 4

| Metric | Value (%) |
|--------------|-----------|
| Precision@1 | 31.69 |
| Precision@5 | 28.48 |
| Precision@10 | 27.04 |

A. ResNet34

TABLE VII
LOSS AND ACCURACY METRICS FOR EXPERIMENT 1

| Metric (Average) | Value |
|-----------------------------------|--------|
| Loss | 0.5902 |
| Top-1 Accuracy (%) | 75.85 |
| Cosine Similarity Anchor-Positive | 0.6200 |
| Cosine Similarity Anchor-Negative | 0.0994 |

TABLE VIII
PRECISION METRICS FOR EXPERIMENT 1

| Metric | Value (%) |
|--------------|-----------|
| Precision@1 | 31.69 |
| Precision@5 | 30.12 |
| Precision@10 | 30.37 |

TABLE IX
LOSS AND ACCURACY METRICS FOR EXPERIMENT 2

| Metric (Average) | Value |
|-----------------------------------|--------|
| Loss | 0.5829 |
| Top-1 Accuracy (%) | 75.63 |
| Cosine Similarity Anchor-Positive | 0.6727 |
| Cosine Similarity Anchor-Negative | 0.1282 |

TABLE X
PRECISION METRICS FOR EXPERIMENT 2

| Metric | Value (%) |
|--------------|-----------|
| Precision@1 | 26.34 |
| Precision@5 | 29.14 |
| Precision@10 | 29.42 |

TABLE XI
LOSS AND ACCURACY METRICS FOR EXPERIMENT 3

| Metric (Average) | Value |
|-----------------------------------|--------|
| Loss | 0.4440 |
| Top-1 Accuracy (%) | 83.28 |
| Cosine Similarity Anchor-Positive | 0.7201 |
| Cosine Similarity Anchor-Negative | 0.0272 |

TABLE XII
PRECISION METRICS FOR EXPERIMENT 3

| Metric | Value (%) |
|--------------|-----------|
| Precision@1 | 34.98 |
| Precision@5 | 30.86 |
| Precision@10 | 29.55 |

TABLE XIII
LOSS AND ACCURACY METRICS FOR EXPERIMENT 4

| Metric (Average) | Value |
|-----------------------------------|--------|
| Loss | 0.6131 |
| Top-1 Accuracy (%) | 73.66 |
| Cosine Similarity Anchor-Positive | 0.6504 |
| Cosine Similarity Anchor-Negative | 0.1431 |

TABLE XIV
PRECISION METRICS FOR EXPERIMENT 4

| Metric | Value (%) |
|--------------|-----------|
| Precision@1 | 25.51 |
| Precision@5 | 28.31 |
| Precision@10 | 27.08 |

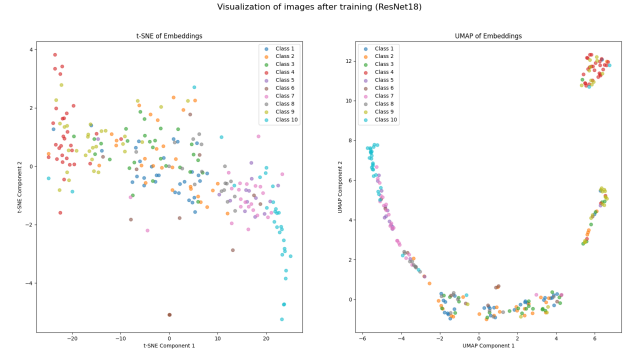


Fig. 18. Experiment 5 with ResNet18

TABLE XV
LOSS AND ACCURACY METRICS FOR EXPERIMENT 5

| Metric (Average) | Value |
|-----------------------------------|--------|
| Loss | 0.4344 |
| Top-1 Accuracy (%) | 83.53 |
| Cosine Similarity Anchor-Positive | 0.7268 |
| Cosine Similarity Anchor-Negative | 0.0781 |

VII. Extended Training with ResNet18

A. epochs: 60, learning rate: 0.001, batch size: 32

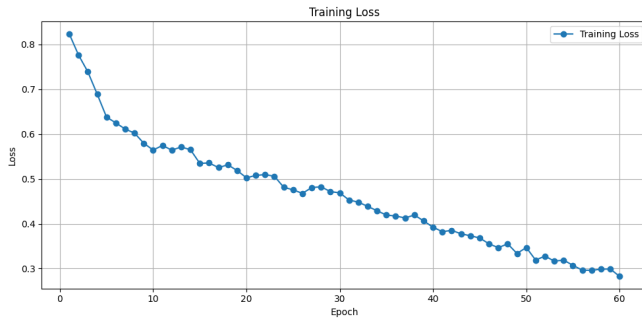


Fig. 17. Experiment 5 with ResNet18

TABLE XVI
PRECISION METRICS FOR EXPERIMENT 5

| Metric | Value (%) |
|--------------|-----------|
| Precision@1 | 33.74 |
| Precision@5 | 35.97 |
| Precision@10 | 34.86 |

B. epochs: 60, learning rate: 0.001, batch size: 64



Fig. 20. Experiment 6 with ResNet18

TABLE XVII
LOSS AND ACCURACY METRICS FOR EXPERIMENT 6

| Metric (Average) | Value |
|-----------------------------------|-------|
| Loss | |
| Top-1 Accuracy (%) | |
| Cosine Similarity Anchor-Positive | |
| Cosine Similarity Anchor-Negative | |

TABLE XVIII
PRECISION METRICS FOR EXPERIMENT 6

| Metric | Value (%) |
|--------------|-----------|
| Precision@1 | |
| Precision@5 | |
| Precision@10 | |



Fig. 19. Experiment 6 with ResNet18