Experiment Run

Experiment Run Report

Experiment Title: Numerosity-Based Categorization - Experiment Run 4

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1. Experiment Details

Parameter	Value
Seed	42
Dataset Size	5000 samples
Image Size	128x128 pixels
Categories	Few (1-5), Medium (6-15), Many (>16)
Batch Size	256
Learning Rate	0.0002
Epochs	20
Optimizer	AdamW
Dropout Rate	0.3
Weight Decay	5e-4
Loss Function	CrossEntropyLoss
Early Stopping	Yes (Patience = 5)
Device Used	GPU – NVIDIA L4
eps	1e-6
betas	0.9, 0.98

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2. Experiment Setup

- **Dataset:** Synthetic Dot Patterns
- **Model Architecture:** Residual CNN with three convolutional layers and fully connected layers.
- **Training Strategy:**
    - Train on 70% of data.
    - Validate on 15%.
    - Test on 15%.
- **Evaluation Metrics:**
    - Accuracy
    - Loss Curves
    - Confusion Matrix
    - Precision, Recall, and F1-Score

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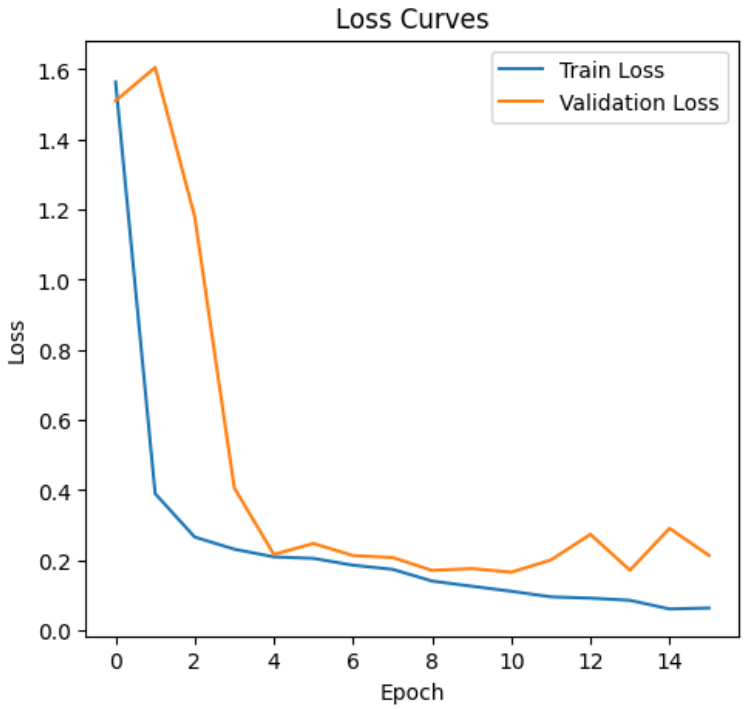
3. Training & Validation Performance

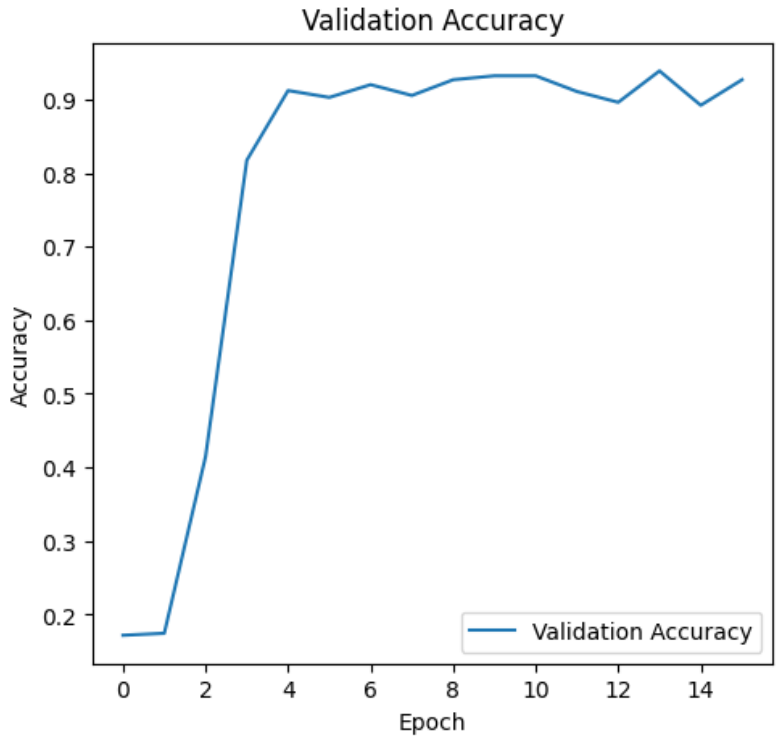
3.1 Loss and Accuracy Trends

Epoch	Train Loss	Validation Loss	Validation Accuracy (%)
1	1.5640	1.5103	17.20%
2	0.3902	0.6055	17.47%
3	0.2664	0.1795	41.47%
4	0.2319	0.4067	81.73%
5	0.2099	0.2170	91.20%
6	0.2056	0.2481	90.27%
7	0.1862	0.2137	92.00%
8	0.1744	0.2082	90.53%
9	0.1410	0.1712	92.67%
10	0.1263	0.1765	93.20%
11	0.1119	0.1662	93.20%

Epoch	Train Loss	Validation Loss	Validation Accuracy (%)
12	0.0960	0.2009	91.07%
13	0.0923	0.2743	89.60%
14	0.0861	0.1719	93.87%
15	0.0615	0.2913	89.20%
16	0.0641	0.2138	92.67%

3.2 Loss Curve & Accuracy Plot





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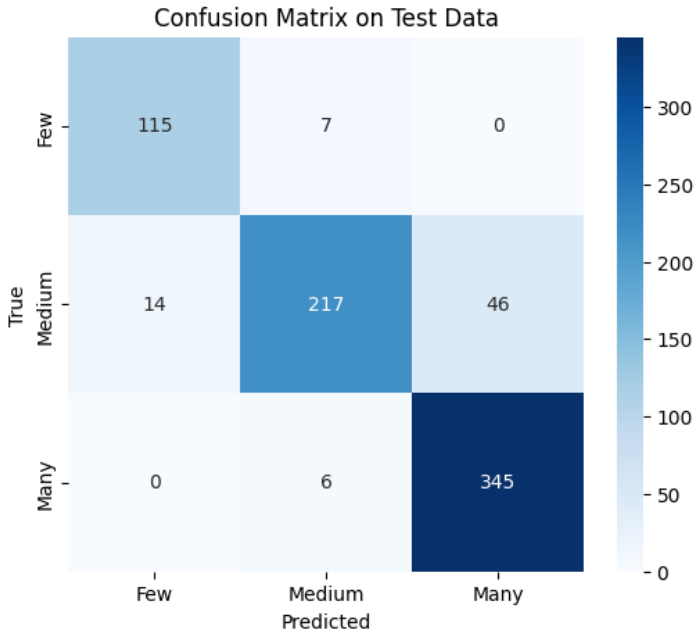
4. Test Set Evaluation

Final Test Accuracy: 90.27%

4.1 Confusion Matrix



4.2 Classification Report

Class	Precision	Recall	F1-Score	Support
Few	0.89	0.94	0.92	122
Medium	0.94	0.78	0.86	277
Many	0.88	0.98	0.93	351

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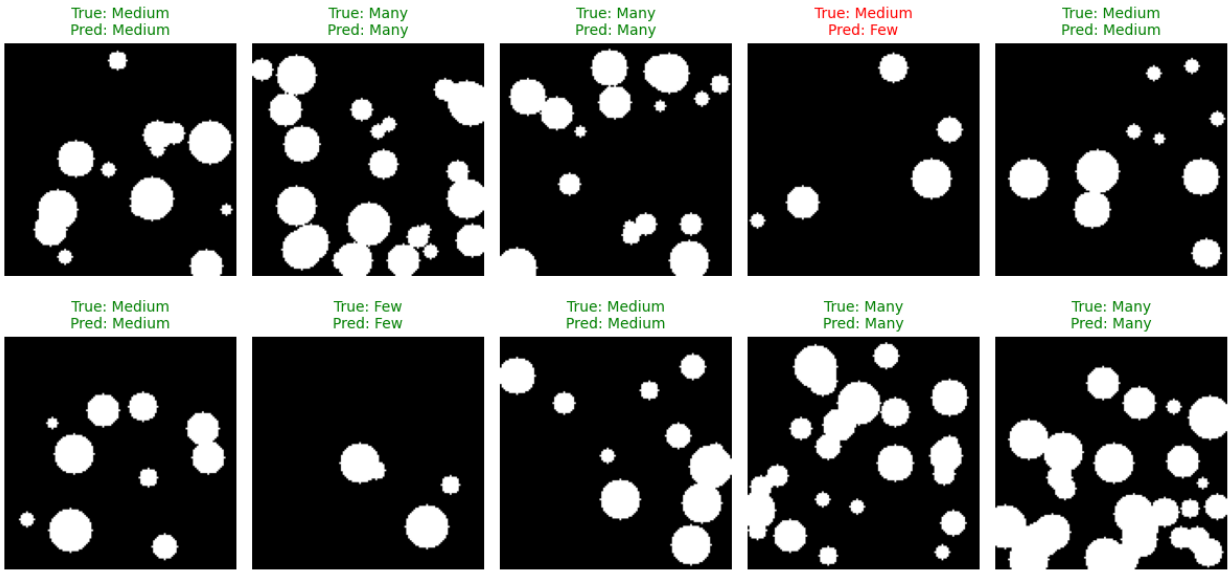
5. Observations & Insights

- **Key Findings:**
    - Improved stability, lowering the learning rate to 0.0002 resulted in smoother loss curves and more stable training.
    - Better generalization, increasing the batch size to 256 improved validation accuracy and helped the model generalize better.
    - Addition of eps and betas to the optimizer:
        - Epsilon(eps=1e-6) - It is a small constant added to the denominator of the Adam update formula to prevent division by zero.
        - Betas((0.9, 0.98)) - beta1 (0.9): Controls the exponential moving average of past gradients (momentum term) while beta2 controls the exponential moving average of squared gradients (second-moment estimate).
    - The training loss remained relatively stable, but validation loss showed fluctuations, especially in the later epochs.
    - The validation accuracy peaked early and then slightly declined, indicating possible early stopping effectiveness.

- **Error Analysis:**



- Confusion between 'Medium' and 'Many' Classes: The model misclassified 45 instances of 'Many' as 'Medium', suggesting some difficulty in distinguishing between high numerosity levels.
- 'Few' Class is Well Learned: Precision and recall for 'Few' are both high meaning the model identifies this class very well.
- Some Overfitting Still Present: Even with increased dropout and weight decay, the validation loss fluctuates in later epochs, meaning further regularization might still be needed.

- **Next Steps:**
  - Evaluate alternative dropout rates (e.g., 0.35) to balance regularization and performance.
  - Fine-tune weight decay to minimize unnecessary penalization.
  - Increase dropout to regularize the model further.

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6. Conclusion

This experiment successfully improved generalization by reducing the learning rate, increasing batch size, and strengthening regularization techniques. The model has achieved stable training, high classification performance, and better validation trends. However, misclassification between 'Medium' and 'Many' remains a challenge, and slight overfitting persists. Future experiments will further refine generalization strategies before moving into shape-based numerosity testing.

7. Additional Notes

- Reproducibility was ensured by setting a fixed random seed and using pre-saved datasets.
- This run also followed the structured experiment template, making future runs easy to compare.
- Some variability in validation loss was observed, which may indicate the need for better regularization techniques.
- Early stopping was applied, preventing overfitting, but further adjustments may be needed.