December 6, 2025

Learning Goal

Diagnose and prevent common training problems using learning curves.

This slide establishes the learning objective for this topic

Key Concept (1/2)

Underfitting occurs when a model is too simple to capture patterns in the data. Both training and test error remain high. The solution: increase model complexity.
Overfitting occurs when a model is too complex, memorizing training data rather than learning generalizable patterns. Training error is low but test error is high. The solution: reduce complexity, get more data, or use regularization.

Understanding this concept is crucial for neural network fundamentals

Key Concept (2/2)

The **ideal model** captures genuine patterns without memorizing noise. Both training and test error converge to similarly low values.
Learning curves plot training and validation loss over training epochs. The shape reveals the problem: - Both high, not improving: Underfitting - Training drops, validation rises: Overfitting - Both converge to similar low values: Good fit

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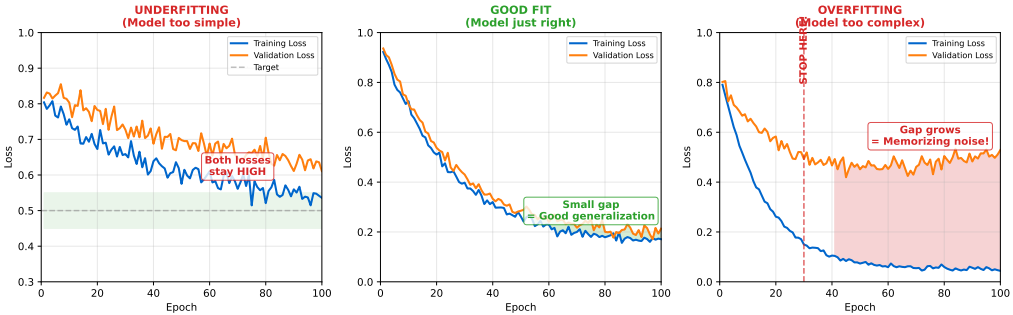
Understanding this concept is crucial for neural network fundamentals

Visualization



Visual representations help solidify abstract concepts

Key Formula

Bias-Variance Tradeoff:

$$\text{Total Error} = \text{Bias}^2 + \text{Variance} + \text{Irreducible Noise}$$

- **High bias (underfitting)**: Model too simple, misses patterns - **High variance (overfitting)**: Model too sensitive to training data - **Goal**: Minimize both bias and variance

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Mathematical formalization provides precision

Intuitive Explanation

Imagine memorizing vs understanding:
- **Underfitting**: A student who barely studies. They don't understand the material and fail both homework and exams.
- **Overfitting**: A student who memorizes answers verbatim. They ace homework but fail exams with new questions they've never seen.
- **Good fit**: A student who understands the concepts. They perform well on both homework and exams because they've learned generalizable knowledge.

The goal is understanding (generalization), not memorization.

Intuitive explanations bridge theory and practice

Practice Problem 1

Problem 1
Training loss = 0.15, Validation loss = 0.65. What is the diagnosis, and what should you try?

Solution

Diagnosis: Overfitting
Evidence: - Training loss is low (0.15) - model fits training data well - Validation loss is high (0.65) - model fails on new data - Gap: 0.65 - 0.15 = 0.50 (large gap indicates overfitting)
Solutions to try:
1. **More data**: If possible, collect more training examples
2. **Regularization**: Add L2 (weight decay) or dropout
3. **Simpler model**: Fewer layers or neurons
4. **Early stopping**: Stop training when validation loss starts rising
5. **Data augmentation**: Create variations of existing data
6. **Cross-validation**: Ensure result isn't due to unlucky train/validation split

Practice problems reinforce understanding

Practice Problem 2

Problem 2
Training loss = 0.55, Validation loss = 0.58. What is the diagnosis, and what should you try?

Solution

Diagnosis: Underfitting
Evidence: - Training loss is high (0.55) - model doesn't fit training data well - Validation loss is similar (0.58) - Small gap (0.03) but both values are high
Solutions to try:
1. **More complex model**: Add layers or neurons
2. **Train longer**: More epochs might help
3. **Better features**: Engineer more informative inputs
4. **Reduce regularization**: If using dropout/L2, reduce it
5. **Lower learning rate**: Current rate might be preventing convergence
6. **Check data quality**: Ensure labels are correct and features are meaningful

Practice problems reinforce understanding

Key Takeaways

- Underfitting: Model too simple, high train and test error
- Overfitting: Model memorizes, low train error but high test error
- Learning curves diagnose the problem visually
- Solutions: Adjust complexity, regularization, data, early stopping
- Goal: Low error on both training and test sets

These key points summarize the essential learnings