09. Network Architecture

Neural Networks - From Brain to Business

Learning Goal

Design and understand the structure of a multi-layer neural network.

Key Concept (1/2)

A neural network is organized into **layers** of neurons. The **input layer** receives raw features (like price, volume, sentiment). **Hidden layers** transform these features into increasingly abstract representations. The **output layer** produces the final prediction.

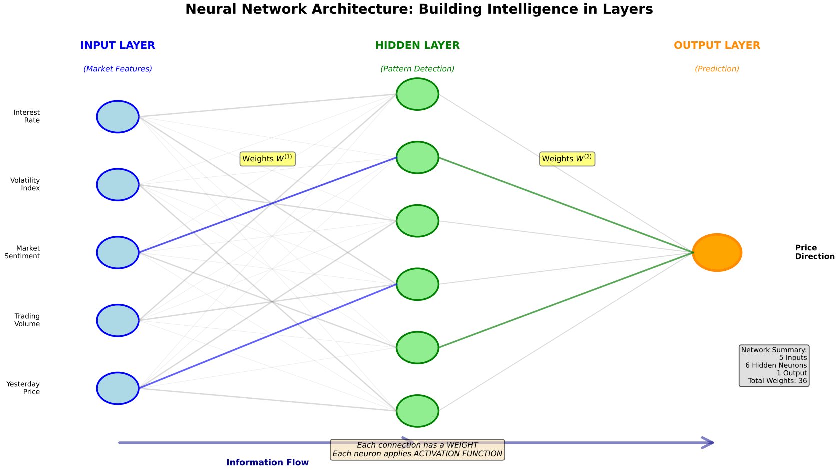
Each connection between neurons has a **weight**, and each neuron (except inputs) has a **bias**. The total number of parameters (weights + biases) determines the network's capacity to learn complex patterns.

Key Concept (2/2)

For a network predicting stock direction with 5 input features, 6 hidden neurons, and 1 output neuron: - Input to hidden: 5 x 6 = 30 weights + 6 biases = 36 parameters - Hidden to output: 6 x 1 = 6 weights + 1 bias = 7 parameters - **Total: 43 learnable parameters**

The architecture choices (number of layers, neurons per layer) are **hyperparameters** that we set before training. Too few neurons = underfitting. Too many = overfitting or slow training.

Visualization



Key Formula

Parameter counting for a fully connected layer:

$$\text{Parameters} = (\text{inputs} \times \text{outputs}) + \text{outputs}$$

Where: - inputs x outputs = number of weights - outputs = number of biases (one per neuron)
For multiple layers:

$$\text{Total} = \sum_{\text{layer } l} (n_{l-1} \times n_l + n_l)$$

Intuitive Explanation

Think of a neural network as a factory assembly line:
- **Input layer**: Raw materials arrive (stock price, volume, etc.) - **Hidden layer 1**: Workers detect simple patterns (is price rising? is volume high?) - **Hidden layer 2**: Supervisors combine simple patterns (rising price + high volume = momentum) - **Output layer**: Manager makes final decision (BUY or SELL)
Each worker (neuron) has different skills (weights) for evaluating the incoming information. During training, workers learn which signals matter most for making good predictions.

Practice Problem 1

Problem 1
A network has architecture [10, 8, 6, 1]. How many total parameters does it have?

Solution

Layer by layer: - Input (10) to Hidden1 (8): $10 \times 8 + 8 = 80 + 8 = 88$ - Hidden1 (8) to Hidden2 (6): $8 \times 6 + 6 = 48 + 6 = 54$ - Hidden2 (6) to Output (1): $6 \times 1 + 1 = 6 + 1 = 7$
Total: $88 + 54 + 7 = 149$ parameters

Practice Problem 2

Problem 2
You have 1,000 training samples. A colleague suggests a network with architecture [50, 100, 100, 50, 1]. Calculate the number of parameters. Is this a good idea?

Solution

Parameter count: - 50 to 100: 50 x 100 + 100 = 5,100 - 100 to 100: 100 x 100 + 100 = 10,100 - 100 to 50: 100 x 50 + 50 = 5,050 - 50 to 1: 50 x 1 + 1 = 51

Total: 20,301 parameters

With only 1,000 training samples and 20,301 parameters, the network has **20x more parameters than data points**. This will almost certainly overfit - the network will memorize training data rather than learn generalizable patterns.

Recommendation: Use a much smaller network, like [50, 20, 1] with 1,041 parameters, or get more training data.

Key Takeaways

- Networks have input, hidden, and output layers
- Each connection has a weight; each neuron has a bias
- More neurons = more capacity, but also risk of overfitting
- Architecture is a hyperparameter chosen before training
- Rule of thumb: parameters should be less than training samples