NEURAL NETWORK MODELS

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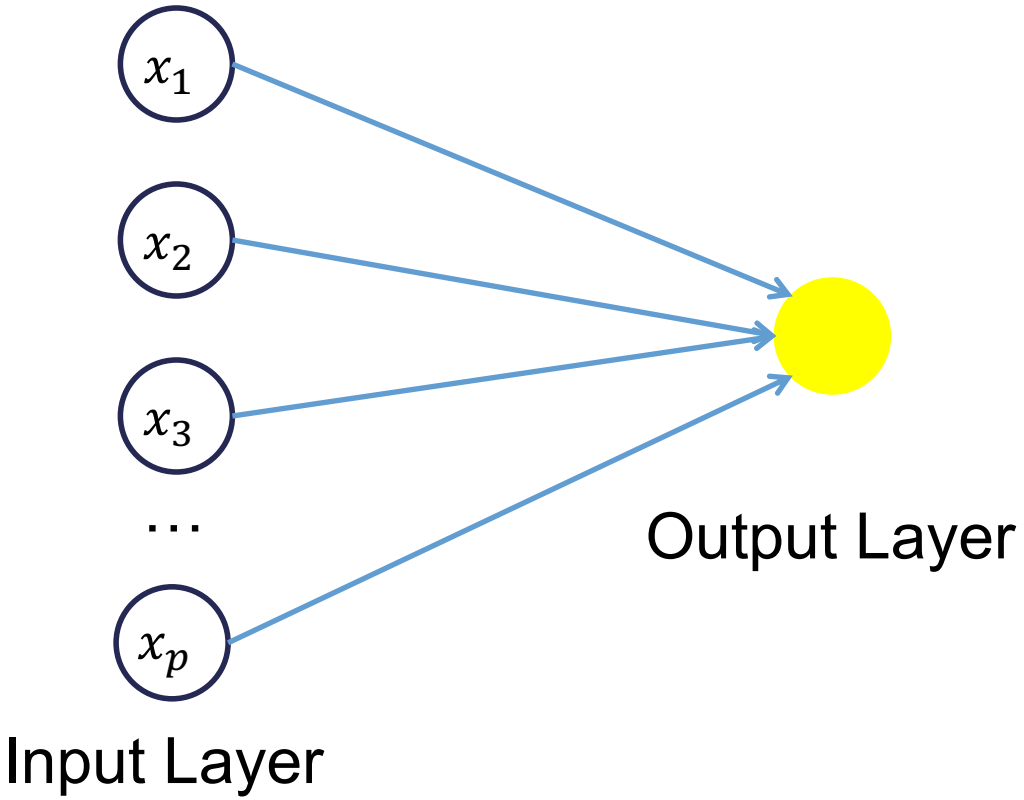
NEURAL NETWORK STRUCTURE

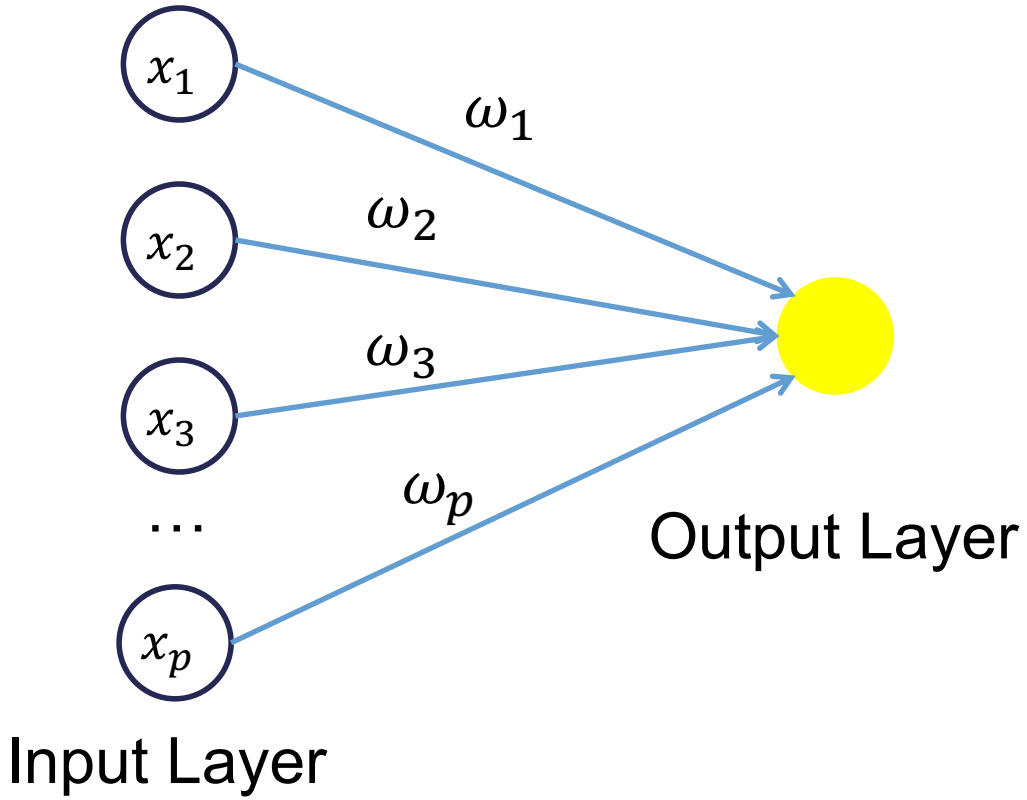
Neural Networks

- Neural network models are models based on mathematical models of how the brain functions.
- They are organized in a network of **neurons** through **layers**.
- The input variables are considered the neurons on the **bottom layer**.
- The output variable is considered the neuron on the **top layer**.
- The layers in between, called **hidden layers**, transform the input variables through non-linear methods to try and best model the output variable.

Neural Network Structure



Neural Network Structure



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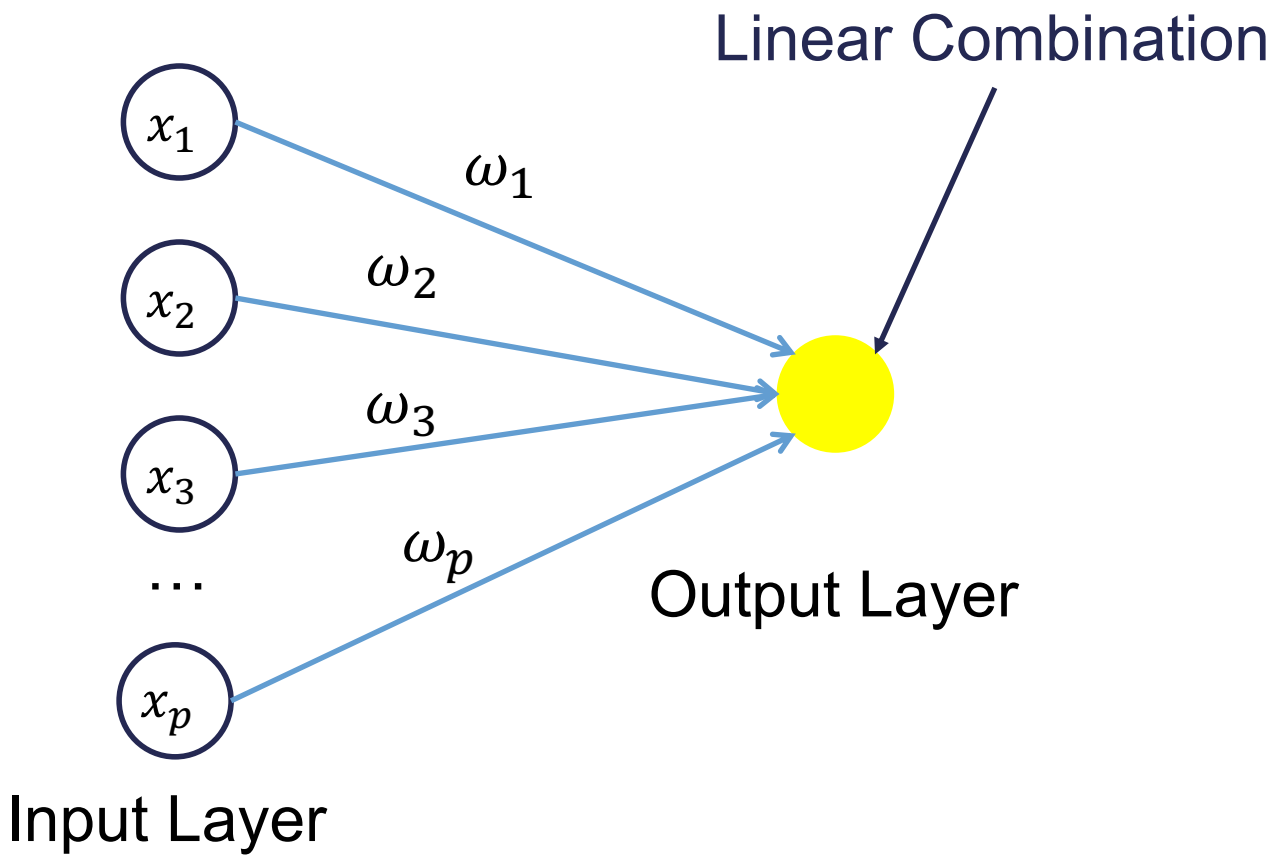

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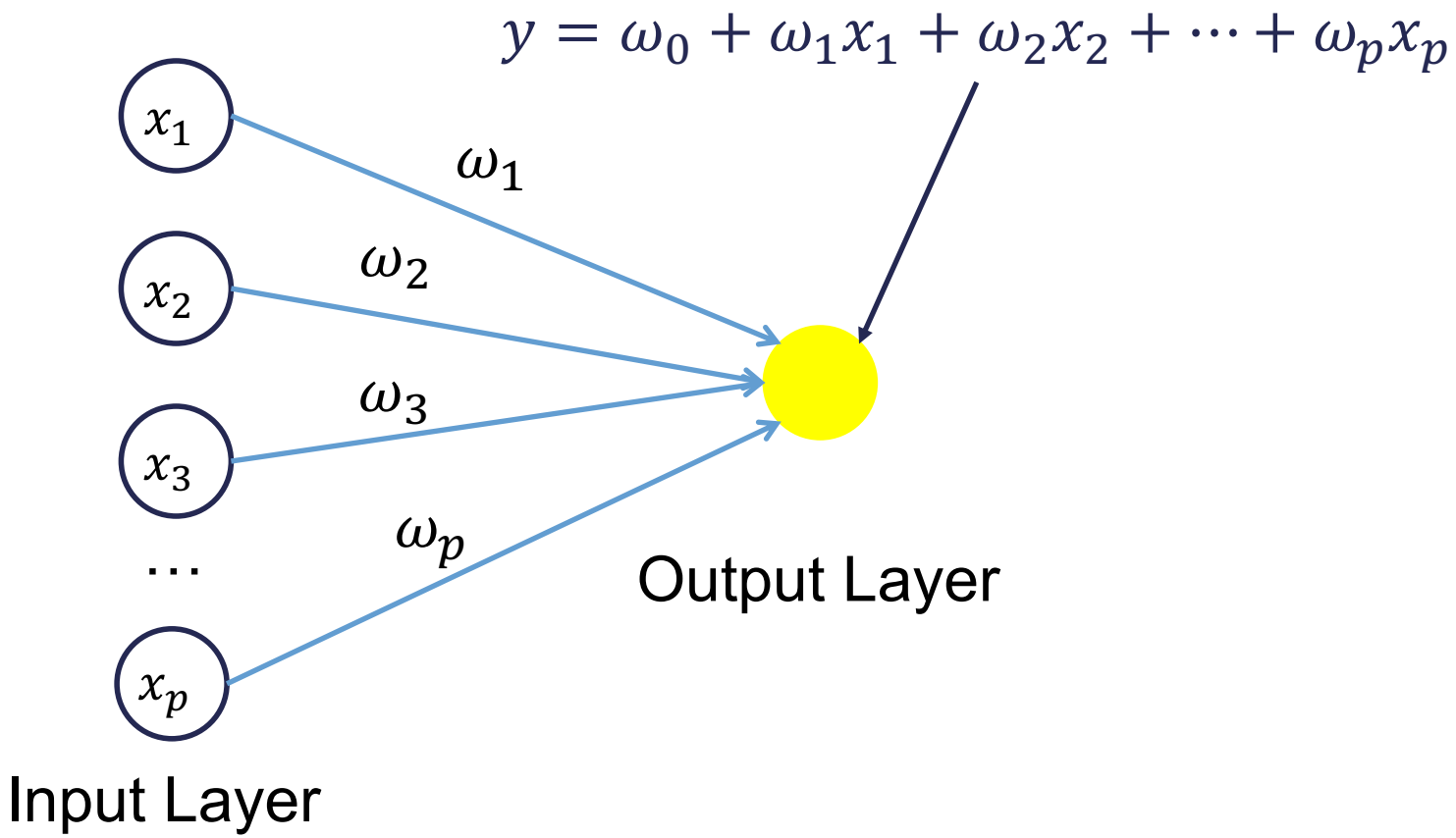

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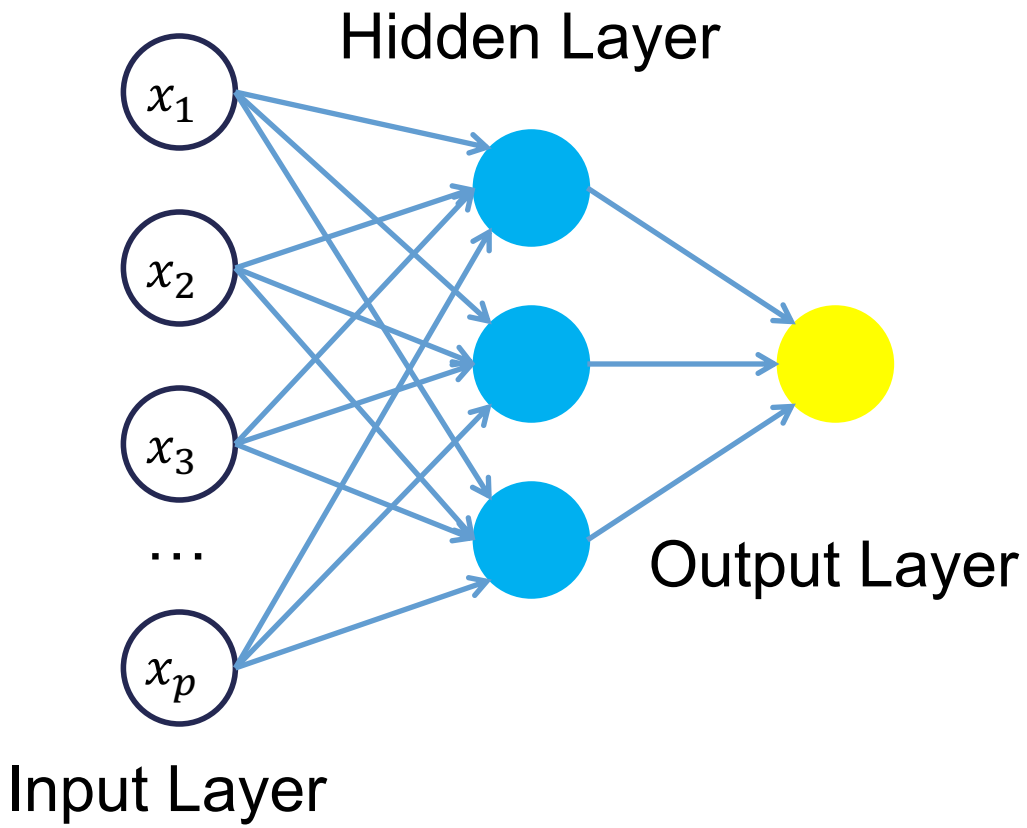

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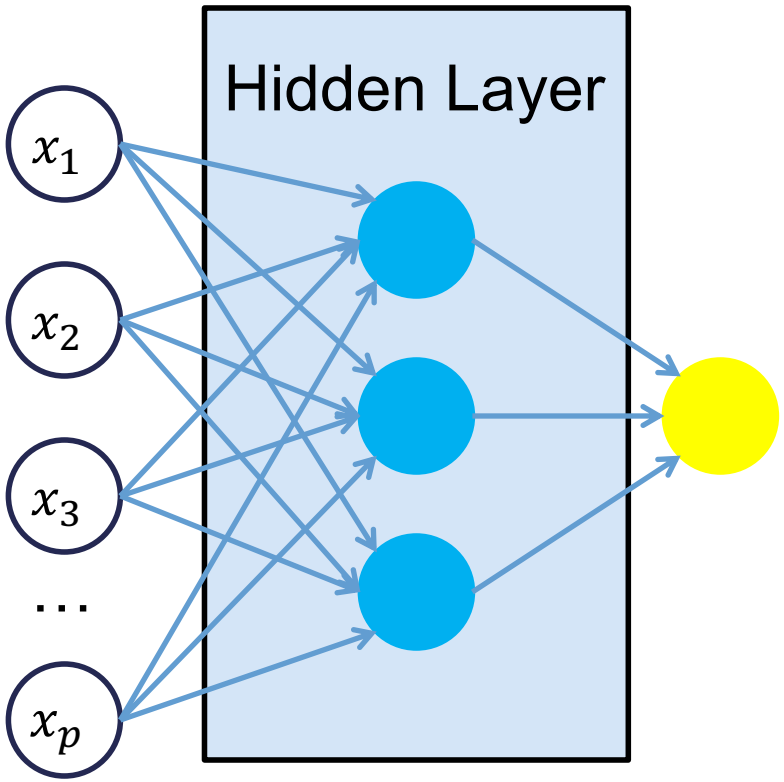
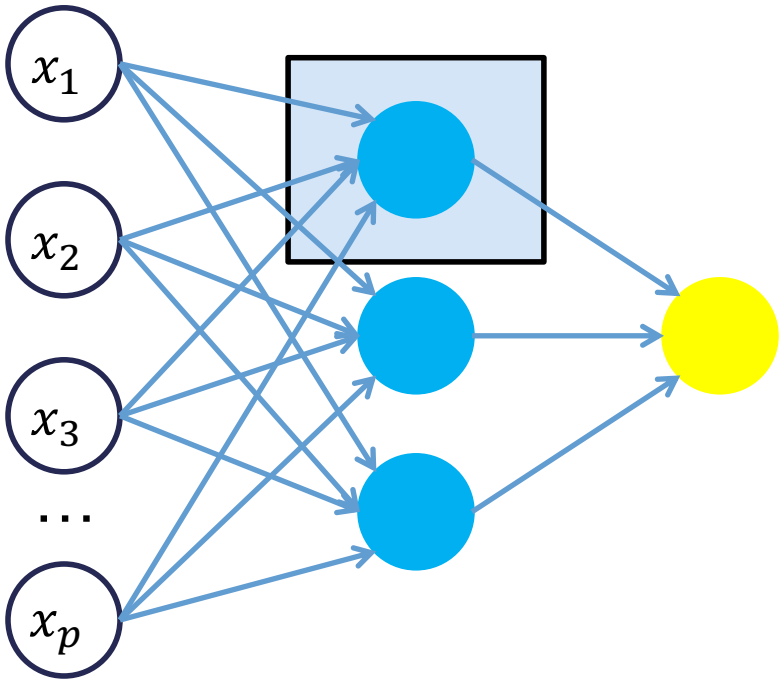


All of the nonlinearities and complication of the variables get added to the model here.

Neural Networks



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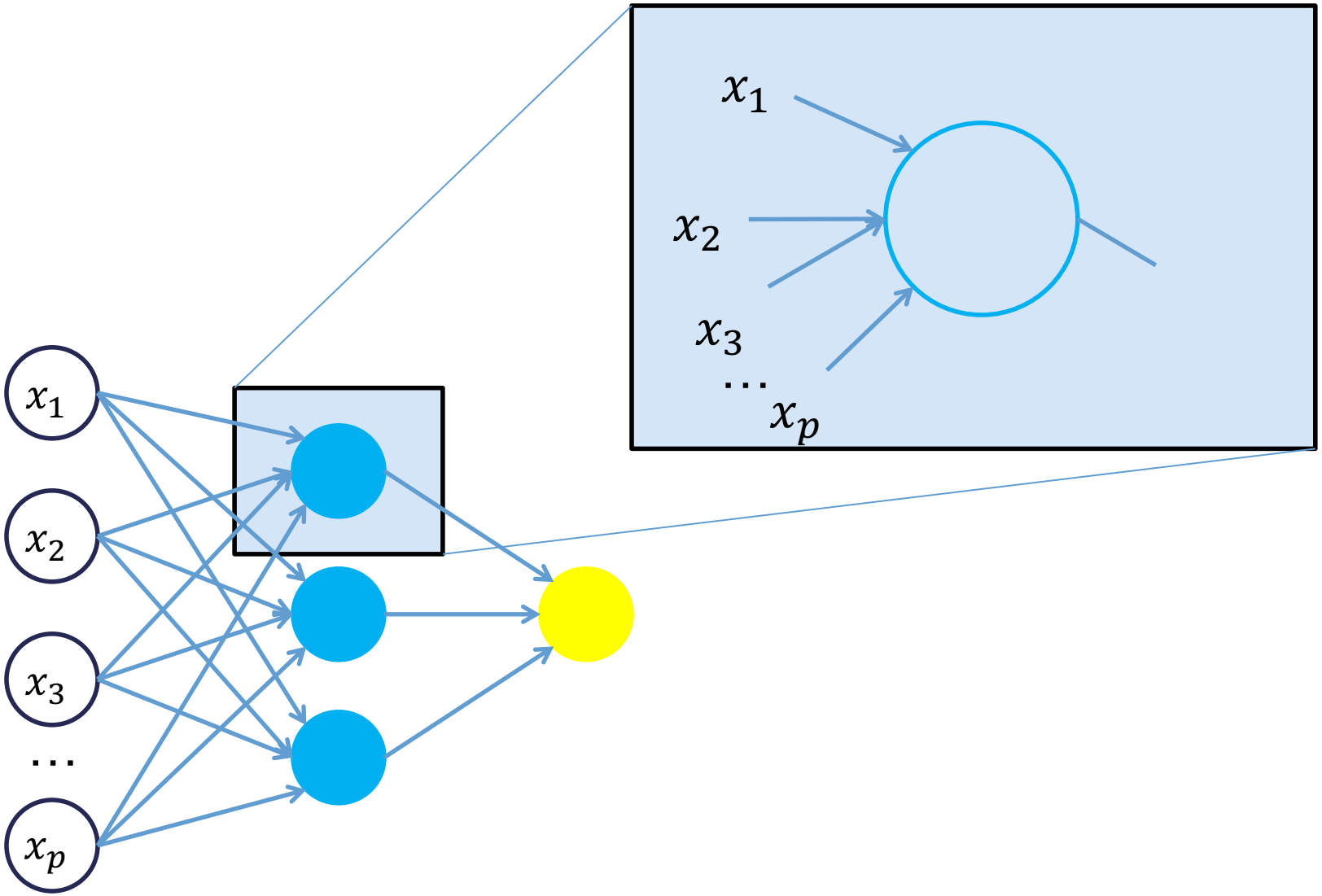

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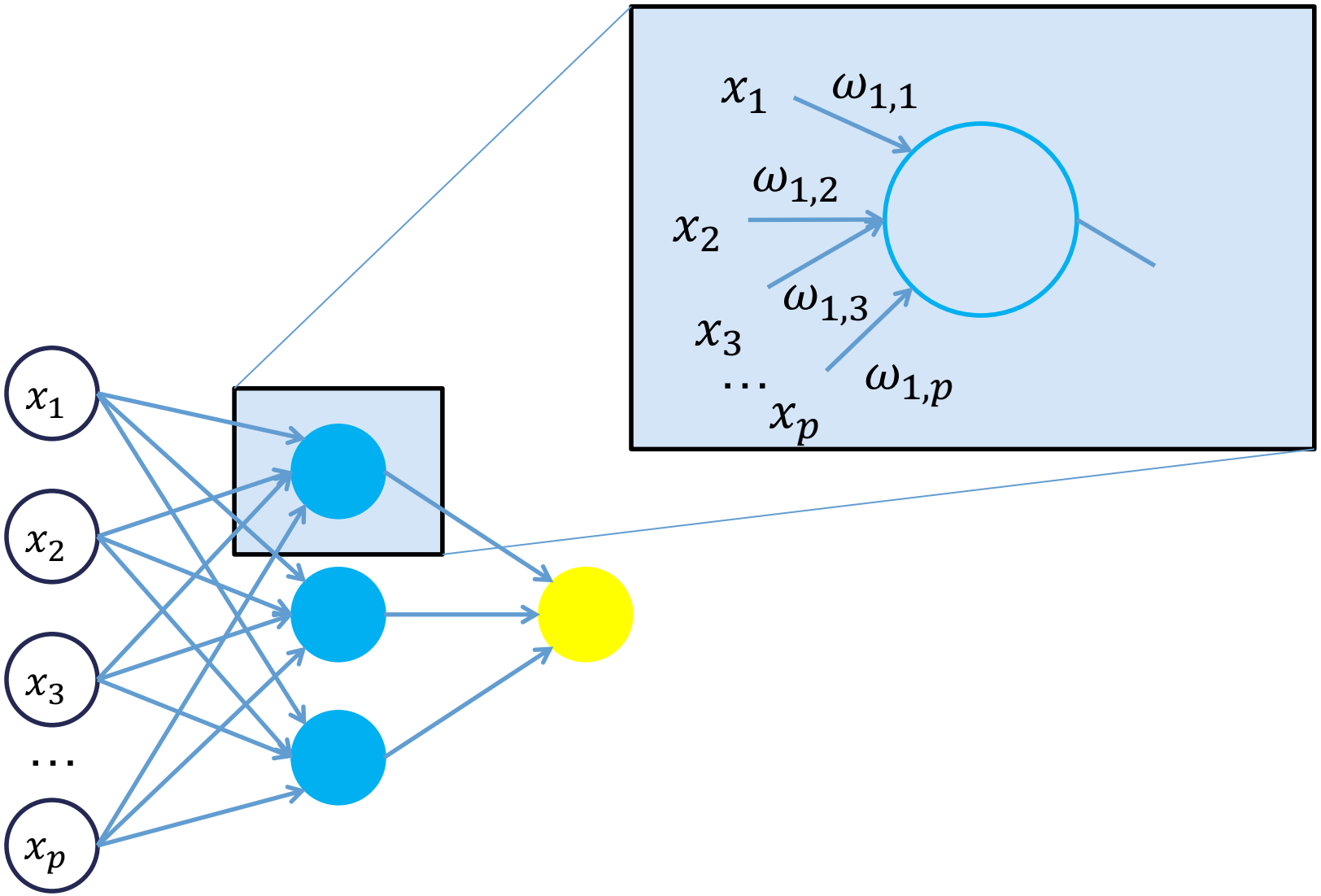

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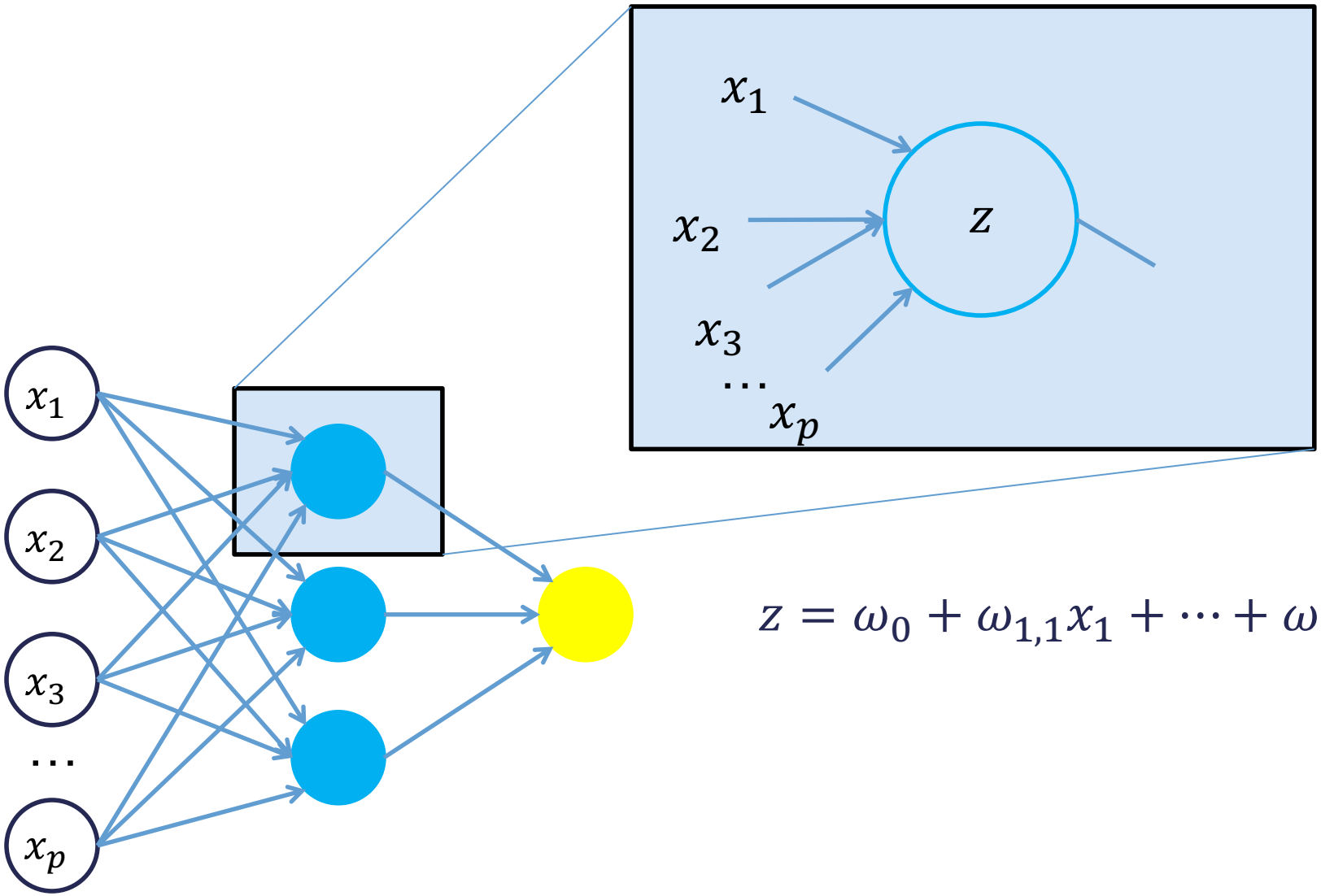
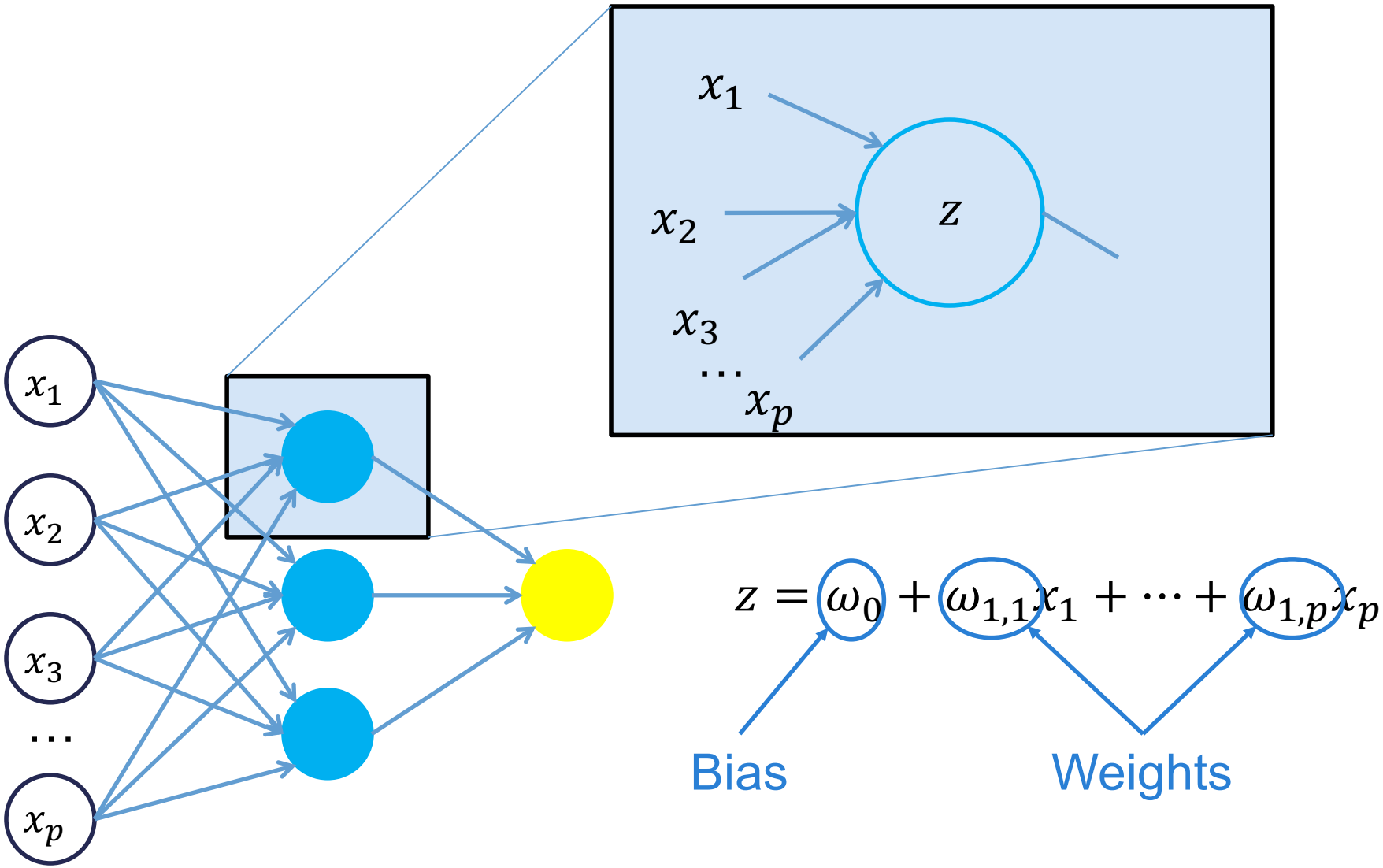


$$z = \omega_0 + \omega_{1,1}x_1 + \cdots + \omega_{1,p}x_p$$

Neural Networks



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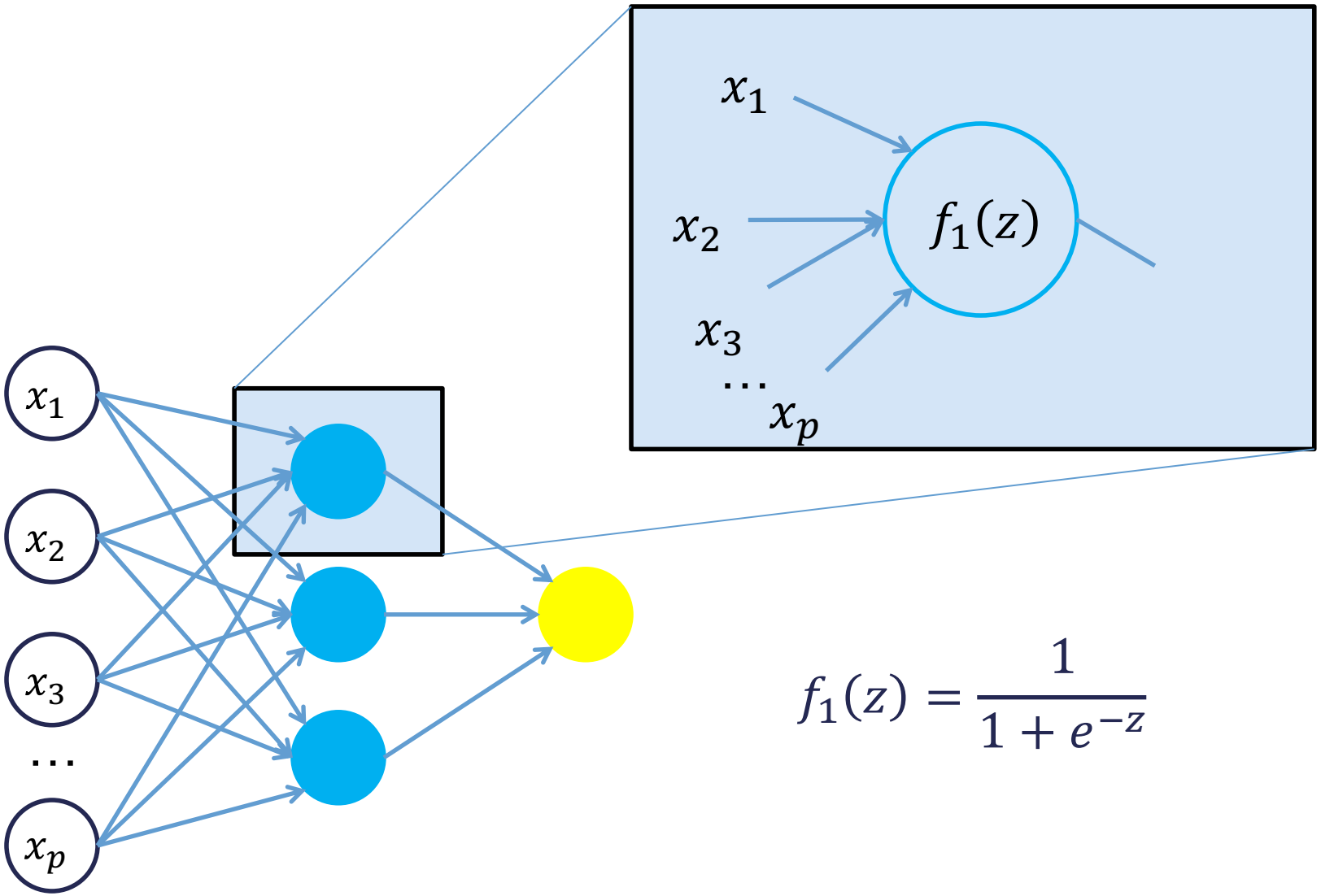
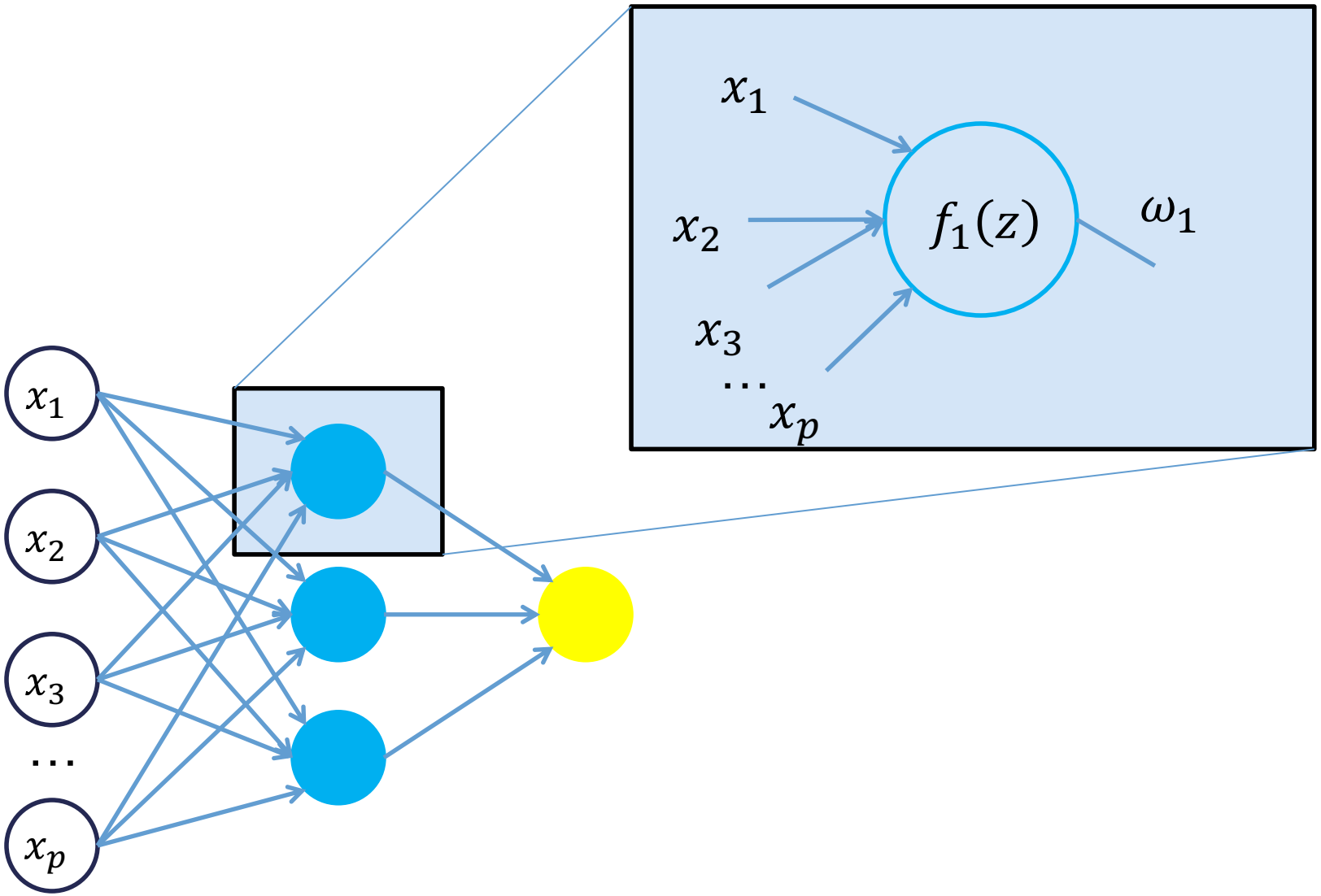


$$f_1(z) = \frac{1}{1 + e^{-z}}$$

Neural Networks



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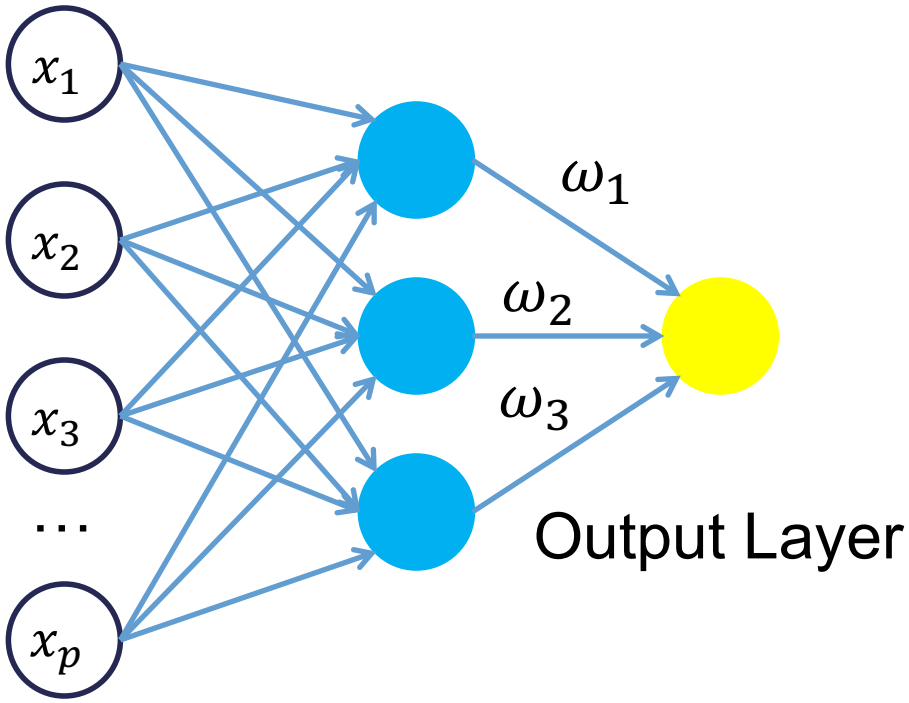

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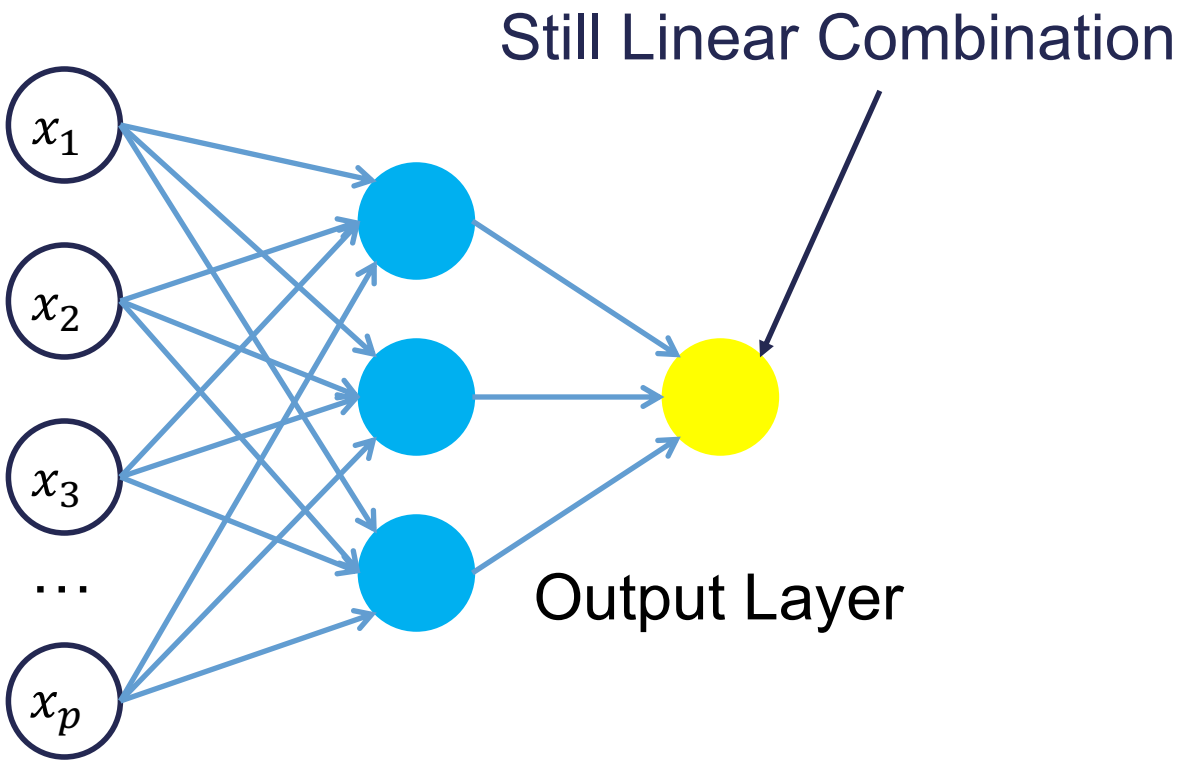

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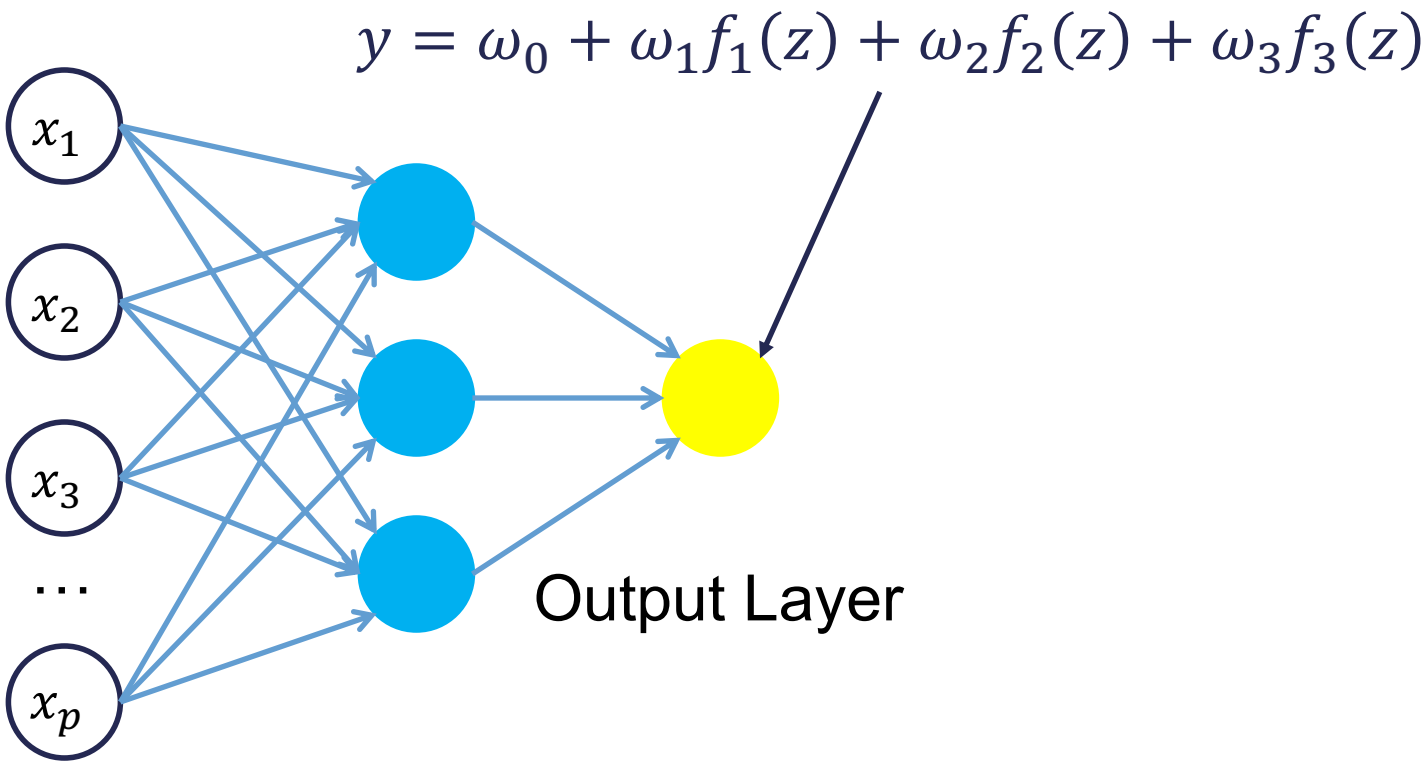
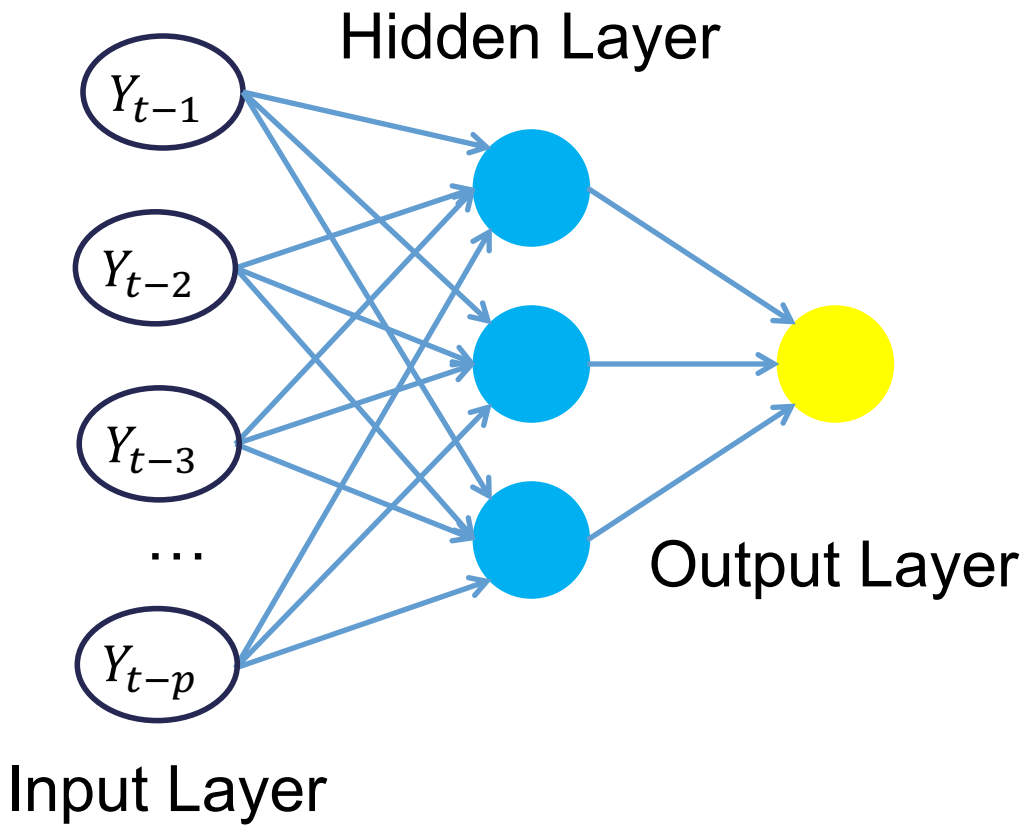


AUTOREGRESSIVE NEURAL NETWORKS

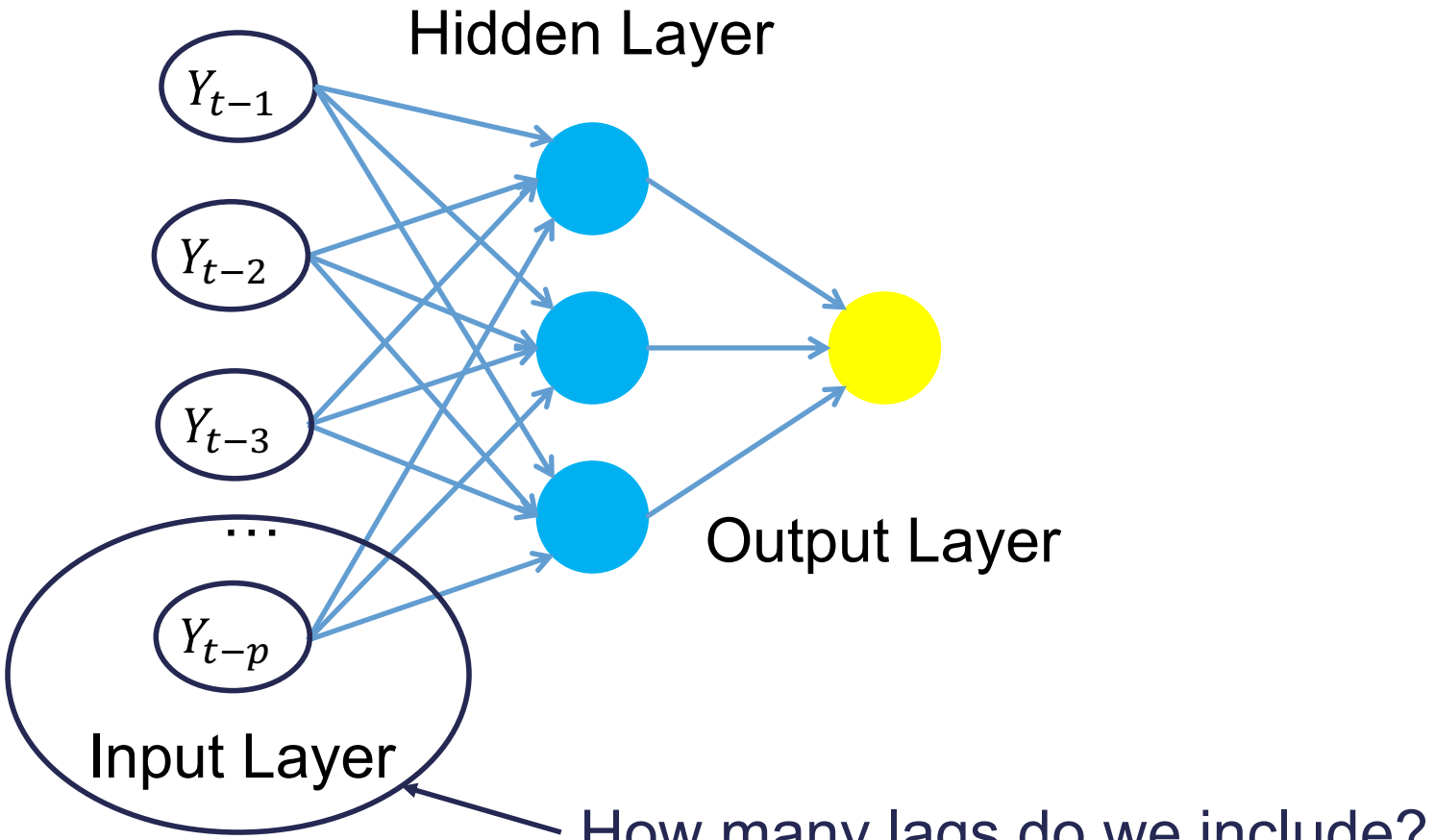
Autoregressive Terms

- Neural network models used for forecasting in time series, just have lags of Y in the bottom layer (inputs) along with (or in place of) other X variables.

Autoregressive Terms



Autoregressive Terms



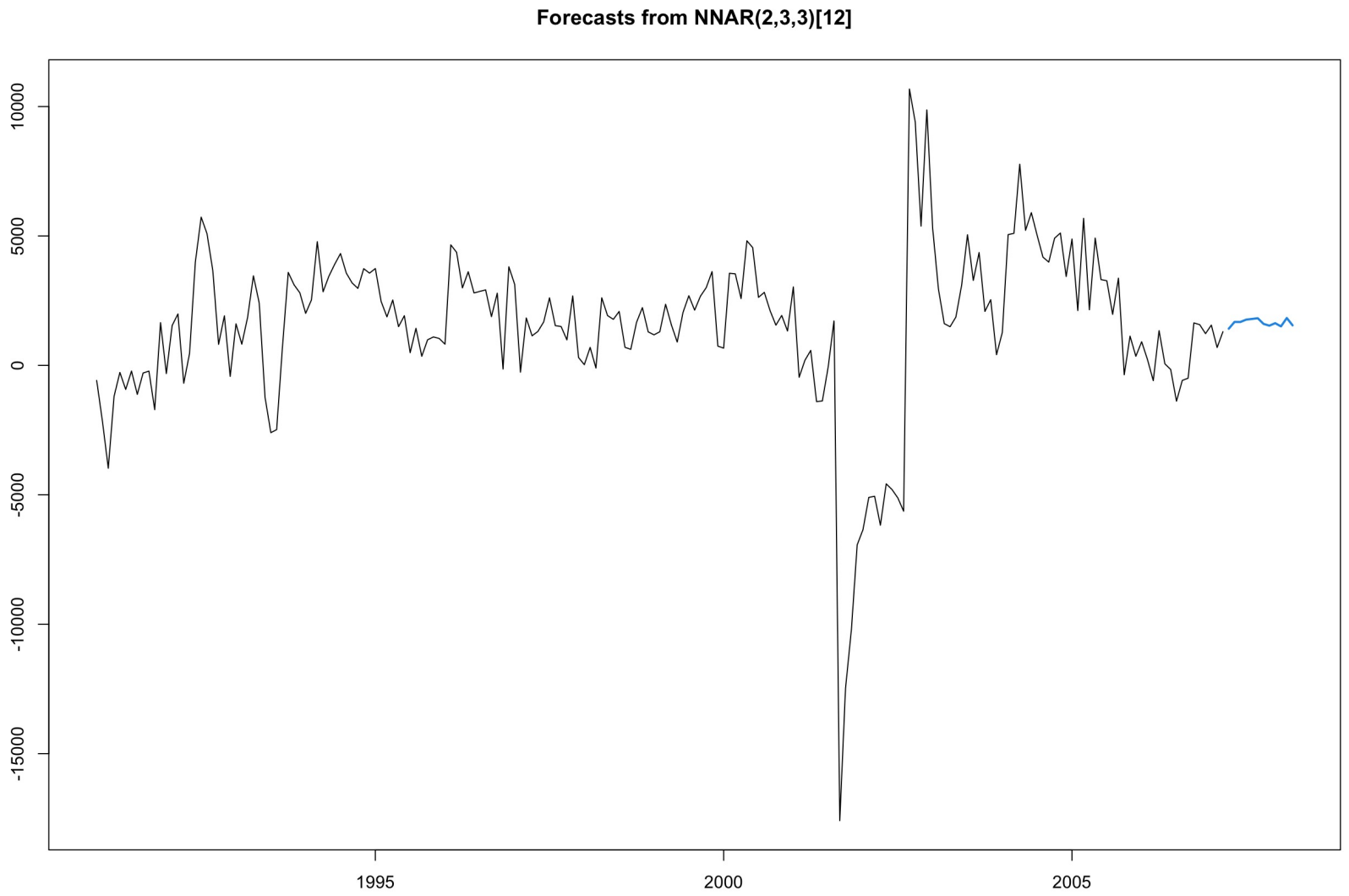
Number of Autoregressive Lags

- Explore with correlation plots or automatic selection techniques.
- Focus primarily on the AR components of the model.
- For **seasonal data** we typically include all lags up through one season unless correlation plots say you only need specific ones.
- STILL WANT TO MAKE DATA STATIONARY FIRST!

Neural Networks

```
NN.Model <- nnetar(diff(training, 12), p = 2, P = 3)

NN.Forecast <- forecast::forecast(NN.Model, h = 12)

plot(NN.Forecast)
```

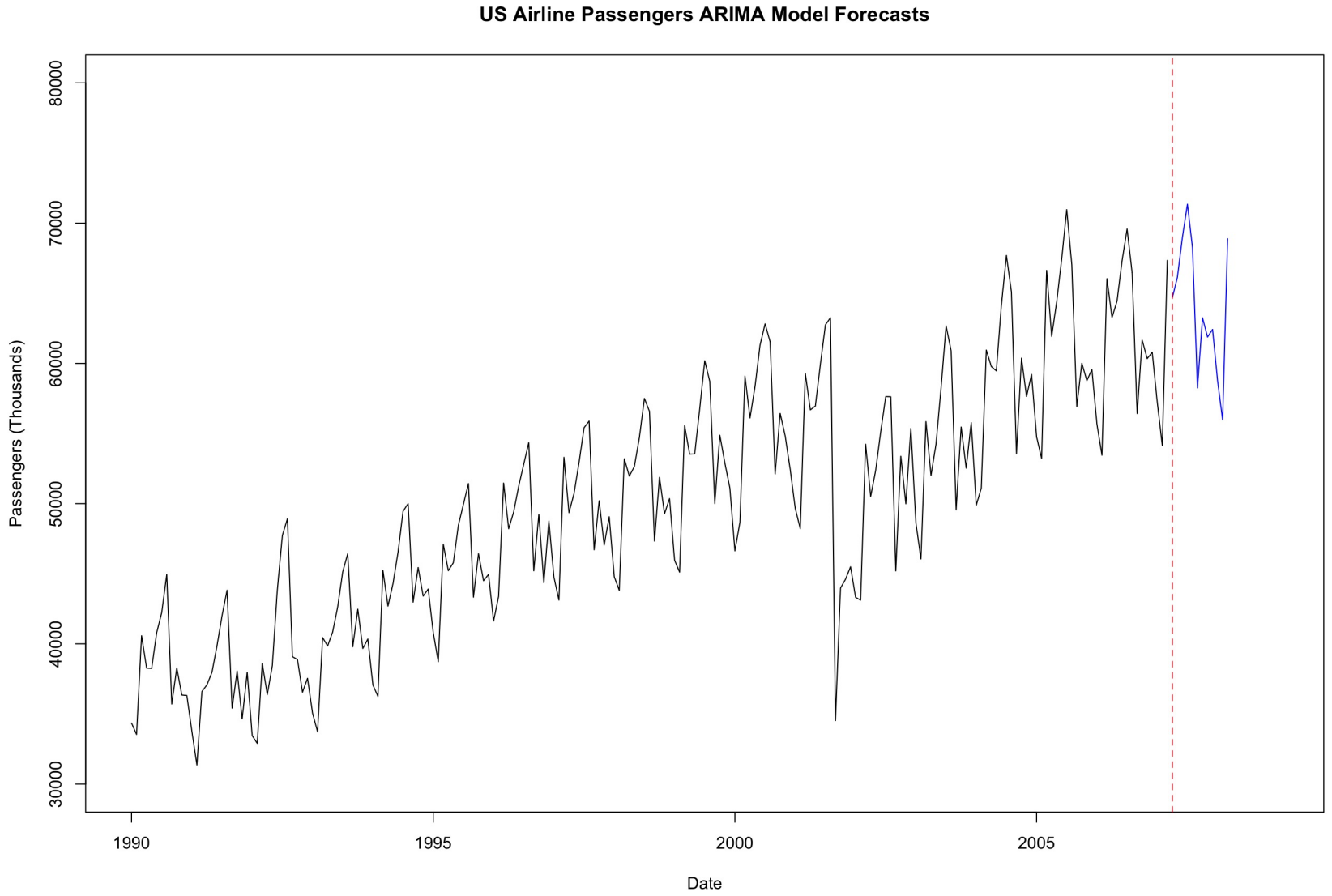
Neural Networks



Neural Network Forecasts

```
Pass.Forecast <- rep(NA, 12)

for(i in 1:12){
  Pass.Forecast[i] <- Passenger[length(Passenger) - 12 + i] +
  forecast::forecast(NN.Model, h = 24)$mean[i]
}

Pass.Forecast <- ts(Pass.Forecast, start = c(2007, 4), frequency = 12)

plot(training, main = "US Airline Passengers ARIMA Model Forecasts",
               xlab = "Date", ylab = "Passengers (Thousands)",
               xlim = c(1990, 2009), ylim = c(30000,80000))
lines(Pass.Forecast, col = "blue")
abline(v = 2007.25, col = "red", lty = "dashed")

NN.error <- test - Pass.Forecast

NN.MAE <- mean(abs(NN.error))
NN.MAPE <- mean(abs(NN.error)/abs(test))*100
```

Neural Network Forecasts



Model Evaluation on Test Data

Model	MAE	MAPE
HW Exponential Smoothing	1134.58	1.76%
Seasonal ARIMA	1229.21	1.89%
Dynamic Regression ARIMA	1180.99	1.80%
Prophet	1449.85	2.25%
Neural Network AR	1087.85	1.67%