NEURAL NETWORKS

LEARNING OBJECTIVES

- Understand various types of neural networks
- Applications of neural networks
- Apply a neural network model for regression
- Apply a neural network model for classification

OPENING

ARTIFICIAL NEURAL NETWORKS

OPENING

- Neural networks were first studied in the 1940s (!) as a model of biological neural networks
- Many advances since then have improved the ability to train and apply neural networks
- Good for both classification and regression but difficult to interpret model behaviors
- Deep learning in the past few years has been highly successful for otherwise difficult problems

OPENING

- Today we will focus on types of neural networks and their applications, and skip some of the more technical details

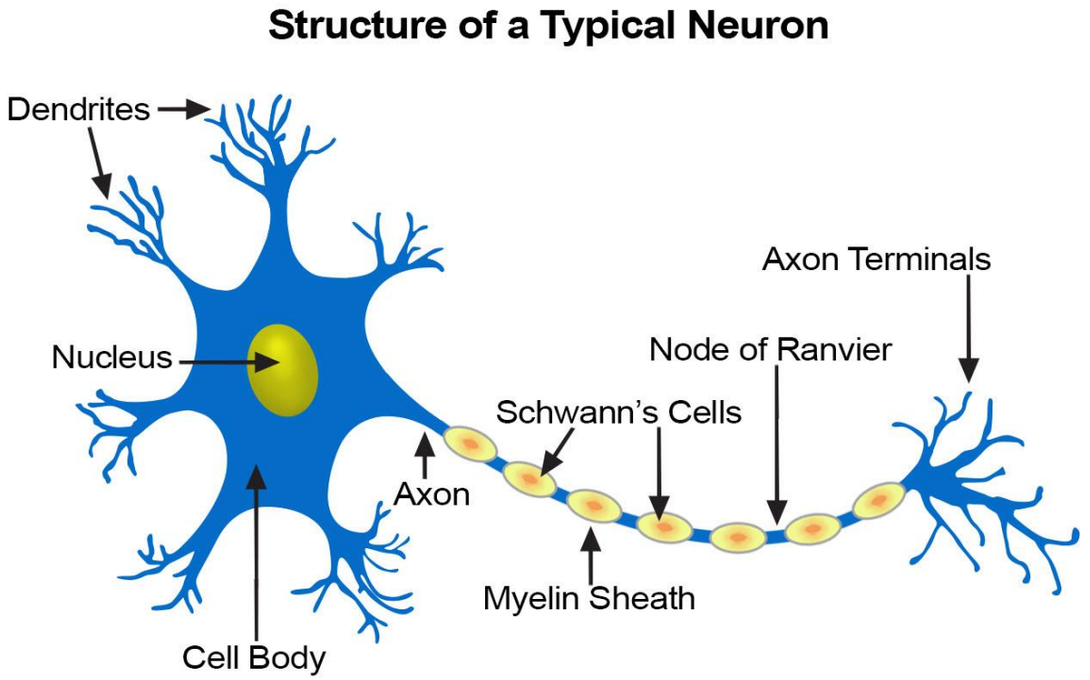
- Specifically we'll skip training neural networks -- there are many methods in various situations and the details can be tedious (but not particularly difficult)

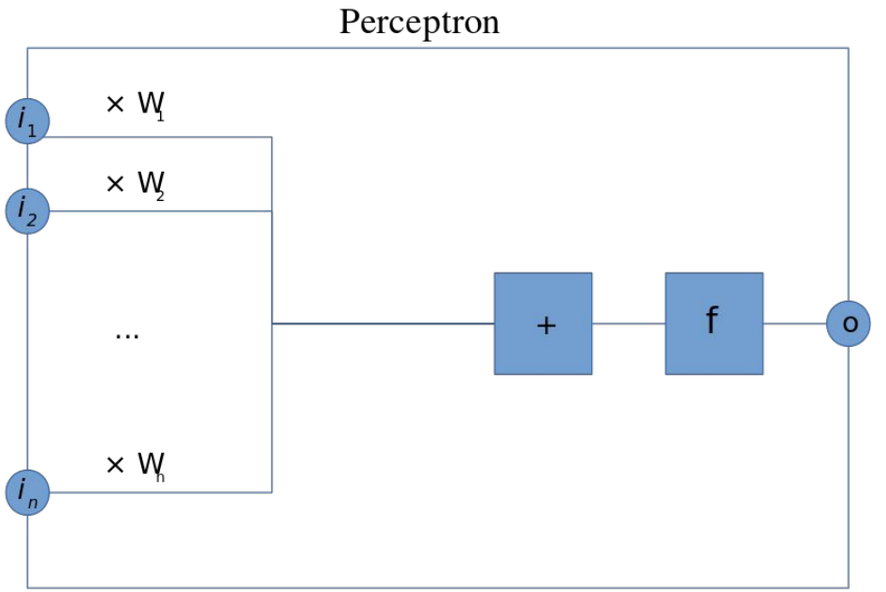
- Methods include backpropagation, gradient descent, and Hessian-free learning

PERCEPTRON

PERCEPTRON

- Perceptrons are the simplest example of a neural network
- The idea is to emulate a single neuron

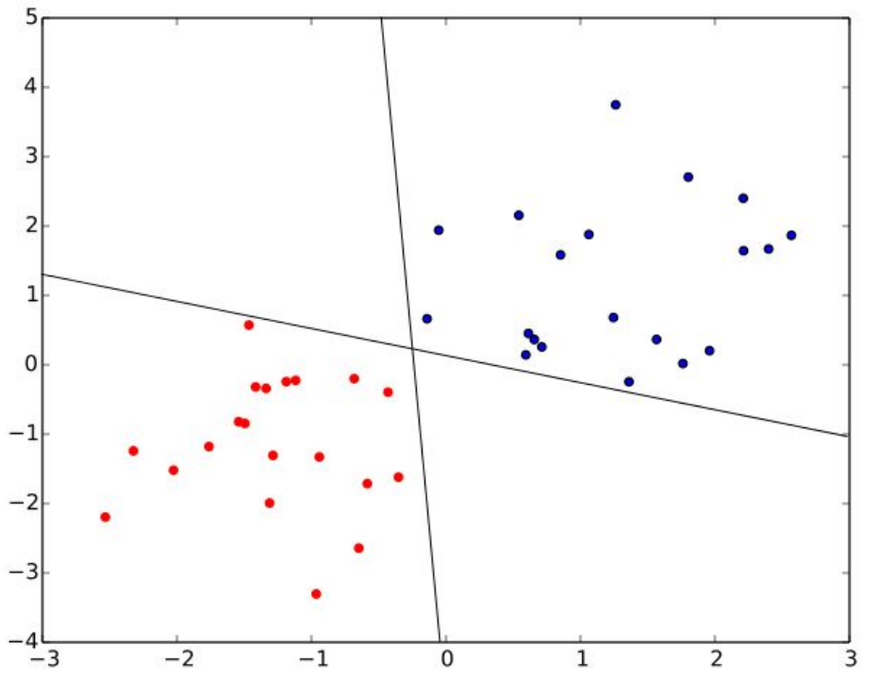


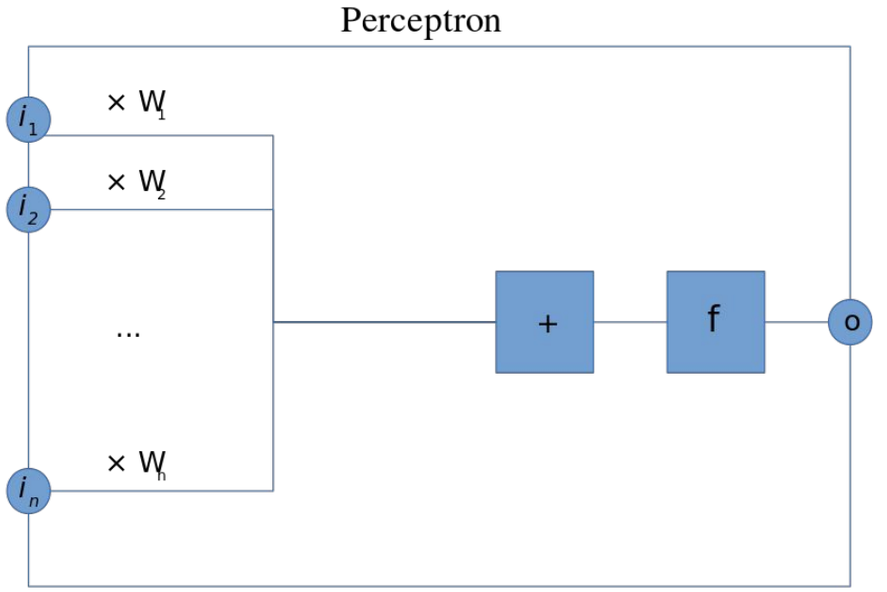


$$o = f\left(\sum_{k=1}^{n} i_k \cdot W_k\right)$$

PERCEPTRON

- Perceptrons are the simplest example of a neural network
- Given n inputs and an activation or link function f
- The perceptron computes a linear separating curve

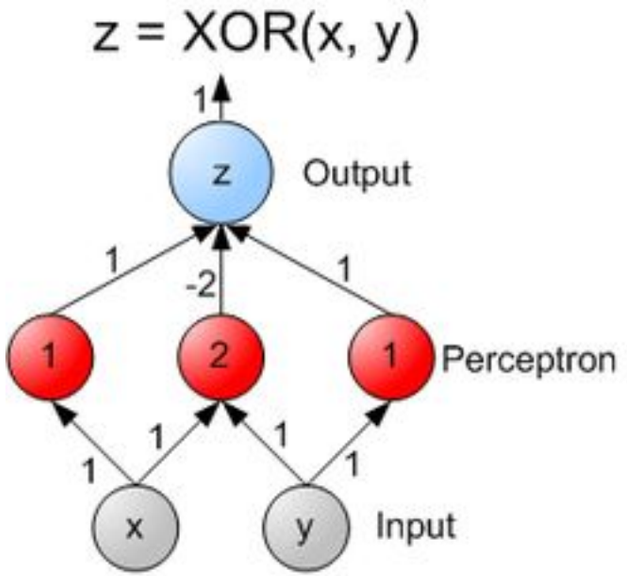




$$o = f\left(\sum_{k=1}^{n} i_k \cdot W_k\right)$$

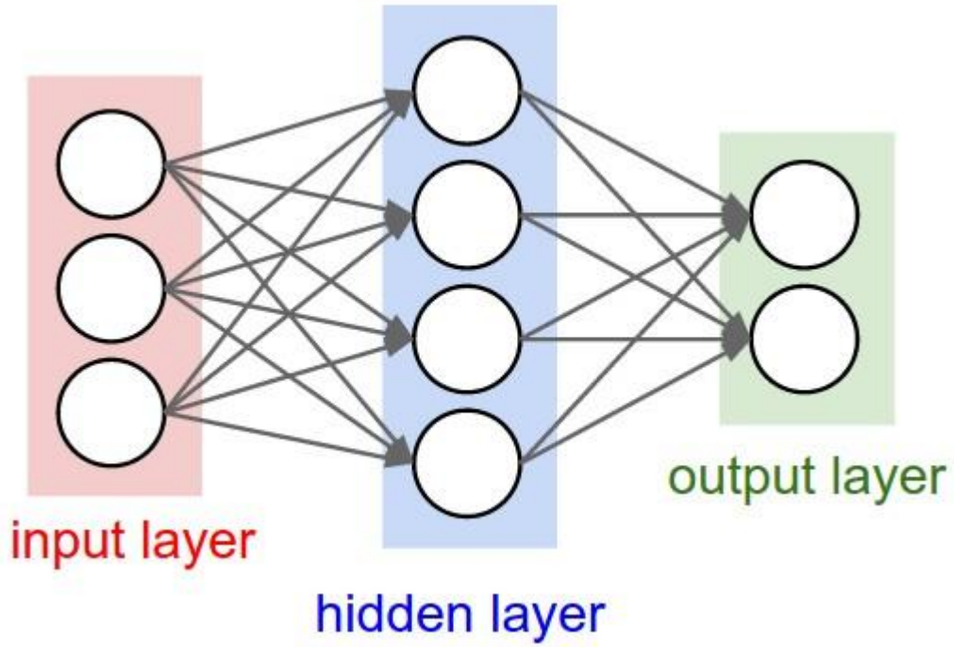
PERCEPTRON

- Common activation functions are linear, logistic, tanh, and softmax
- We'll see shortly that some are better for classification, some for regression
- Perceptrons can be combined into multilayer perceptrons or feed-forward network



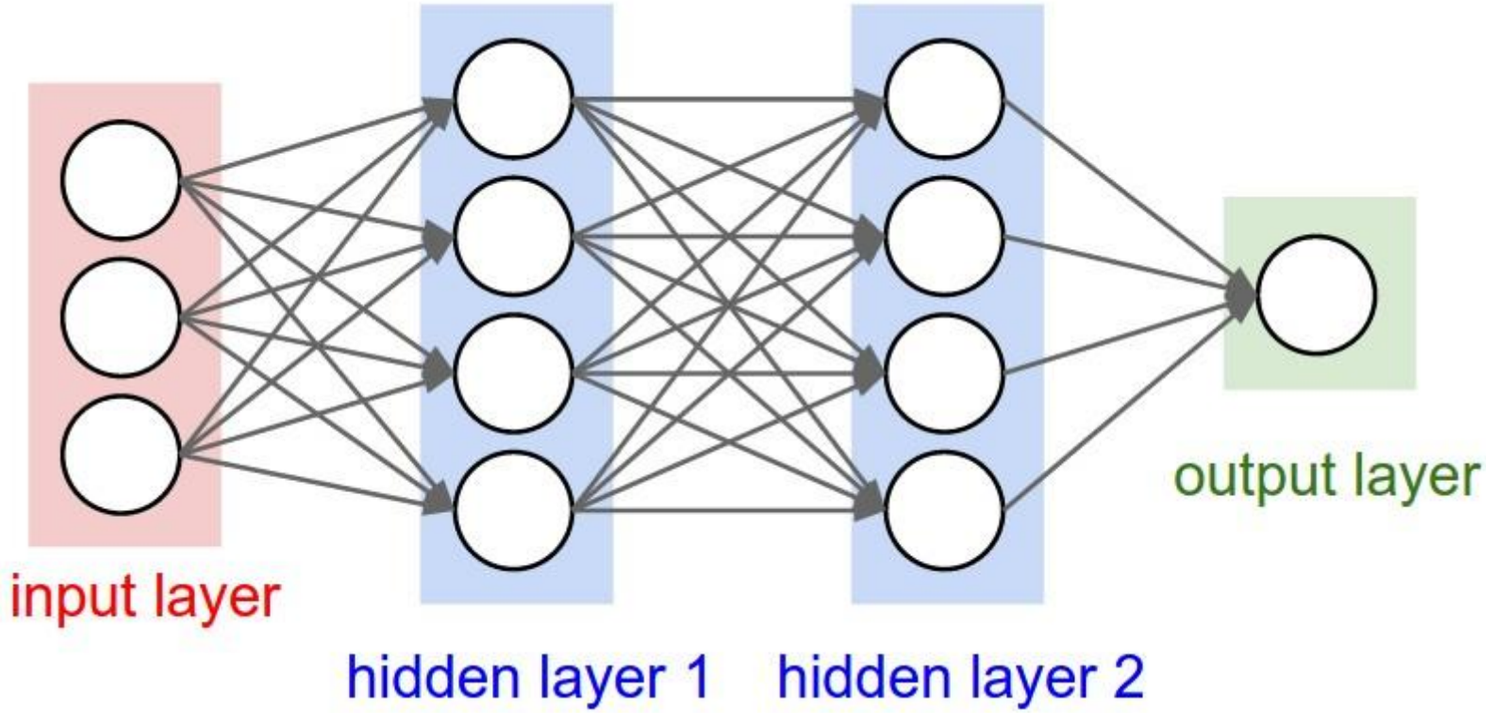
FEED FORWARD NN

- Source



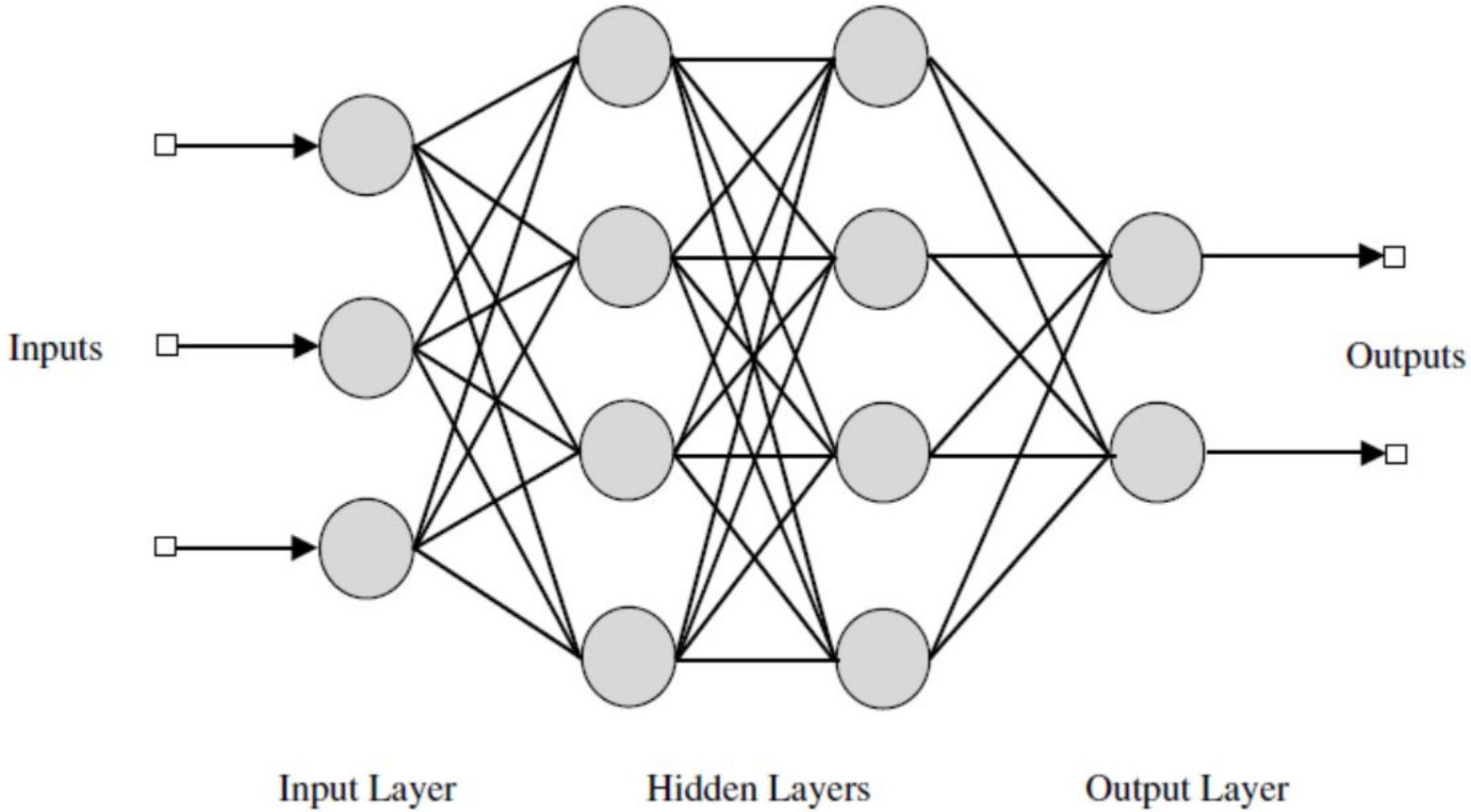
FEED FORWARD NN

- Source



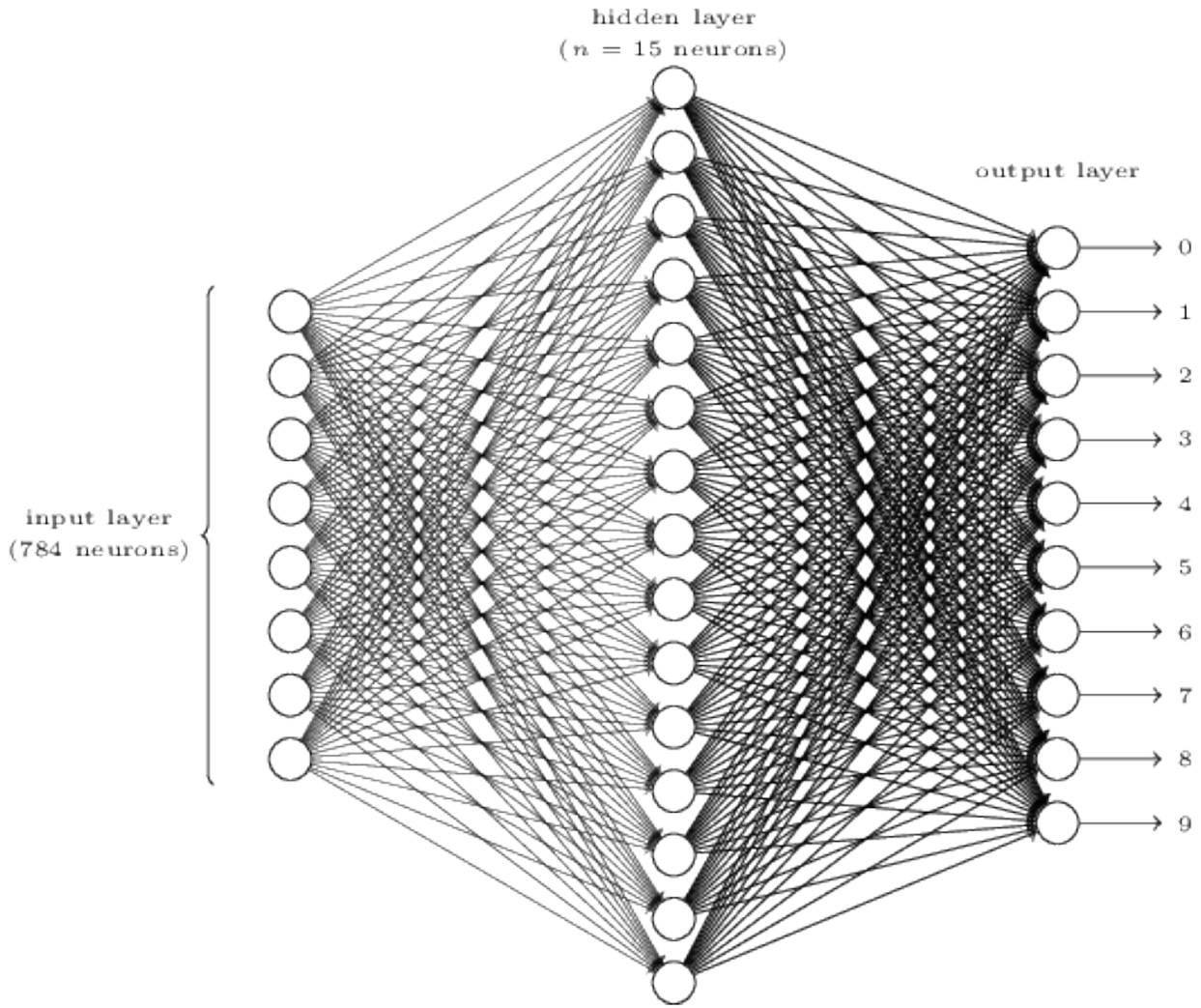
FEED FORWARD NN

- Source



FEED FORWARD NN

- Source



FEED FORWARD NN

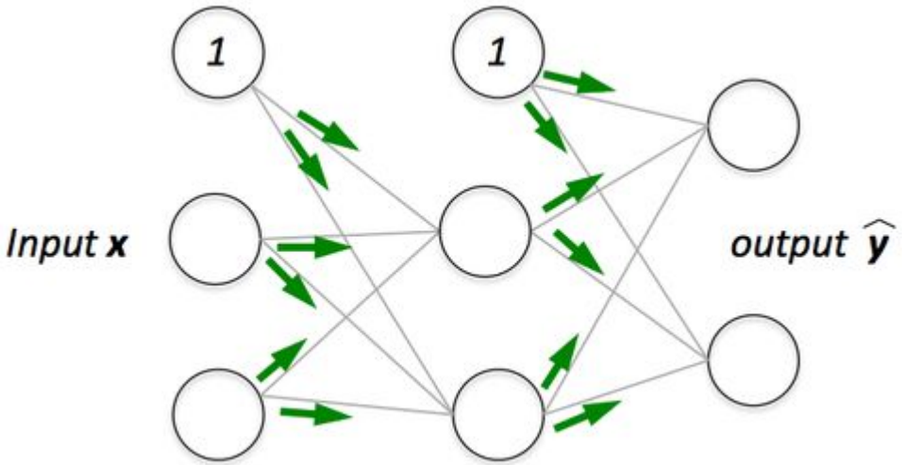
- Typically we use
  - Tanh or logistic layers for input
  - Linear layers for regression output
  - Logistic or Tanh for binary output
  - Softmax for n-class output (yields probabilities)

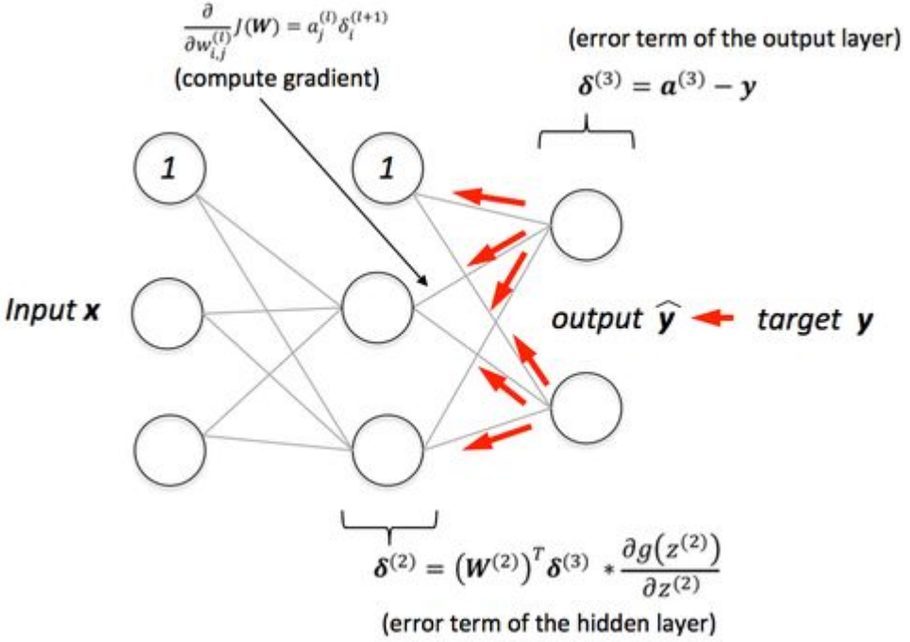
GUIDED PRACTICE

TRAINING

TRAINING

- Feed forward neural networks can be trained with backpropagation
- Source





TRAINING

- Key Parameters
  - Learning Rate (gradient descent for training)
  - Epochs: number of backpropagation passes (over entire dataset)
  - Batch size: how many training points used at a time to update weights

- Model others behaves as usual with
  - model.predict
  - model.predict_classes

TRAINING

- Tips
  - If the error jumps around per epoch, decrease the learning rate
  - Taking too long to train: use higher learning rate or batch_size
  - High error after convergence?
    - More hidden layers / neurons
    - Normalize data or use PCA

UNIVERSAL APPROXIMATION THEORY

UNIVERSAL APPROXIMATION

- One major reason that neural networks are useful is the Universal Approximation Theorem

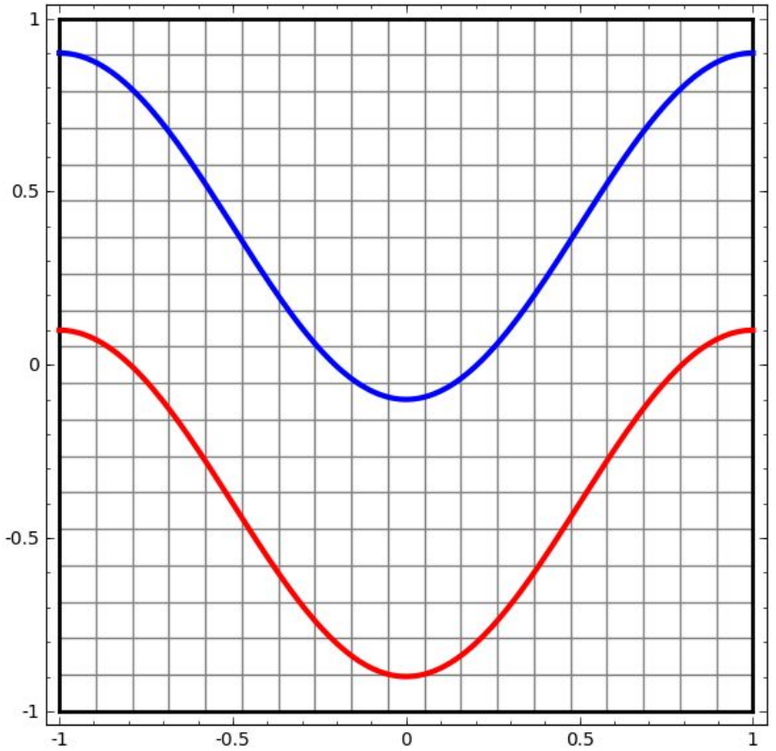
- The result basically says that many real vector-valued functions can be approximated arbitrarily well with *some* feed-forward neural network

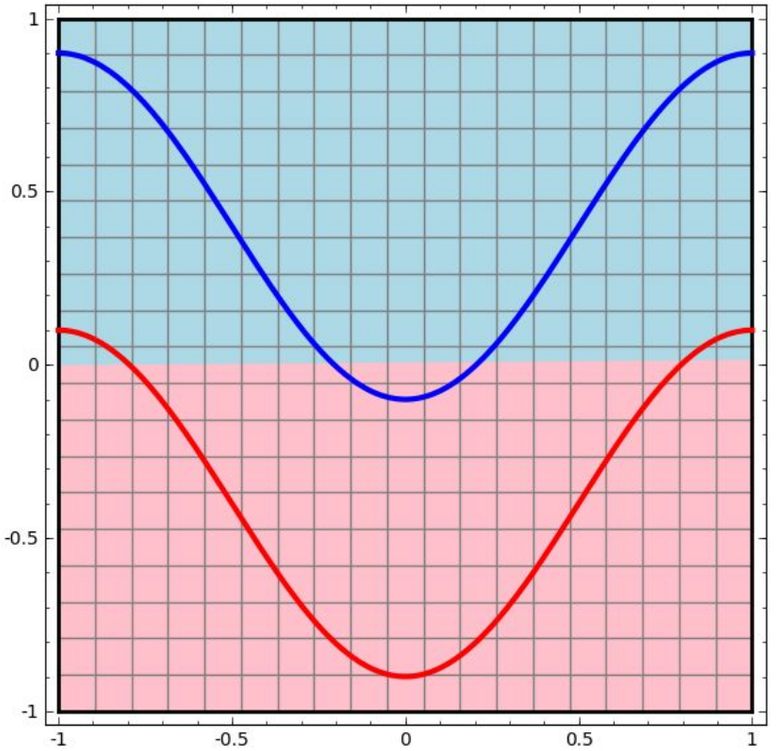
- This is why neural networks are useful for regression -- given enough data and the right network structure they can fit many common data sets

CLASSIFICATION WITH NEURAL NETWORKS

CLASSIFICATION

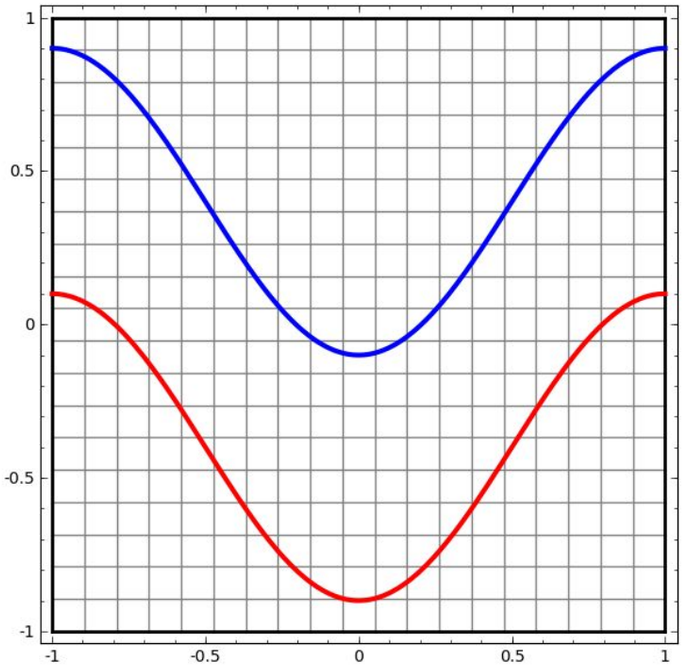
- Neural Networks are also extremely useful for classification (source)
- No hidden layers:

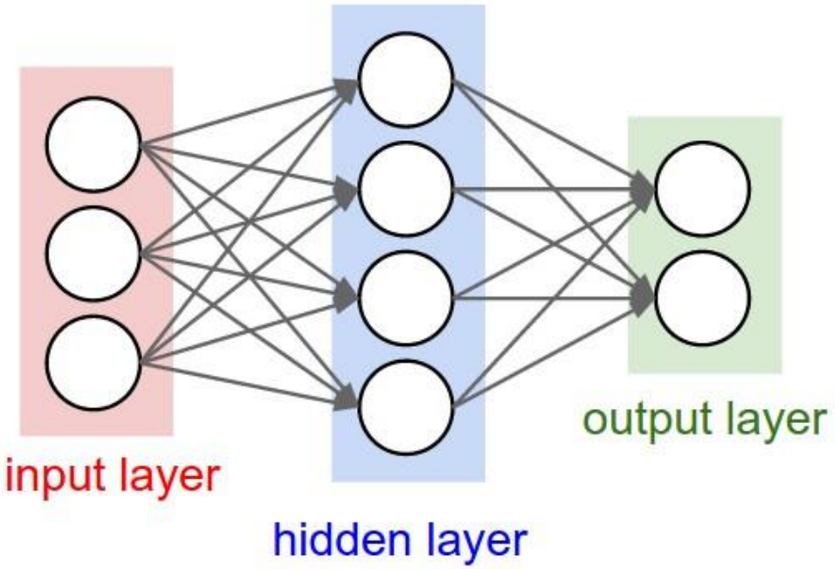


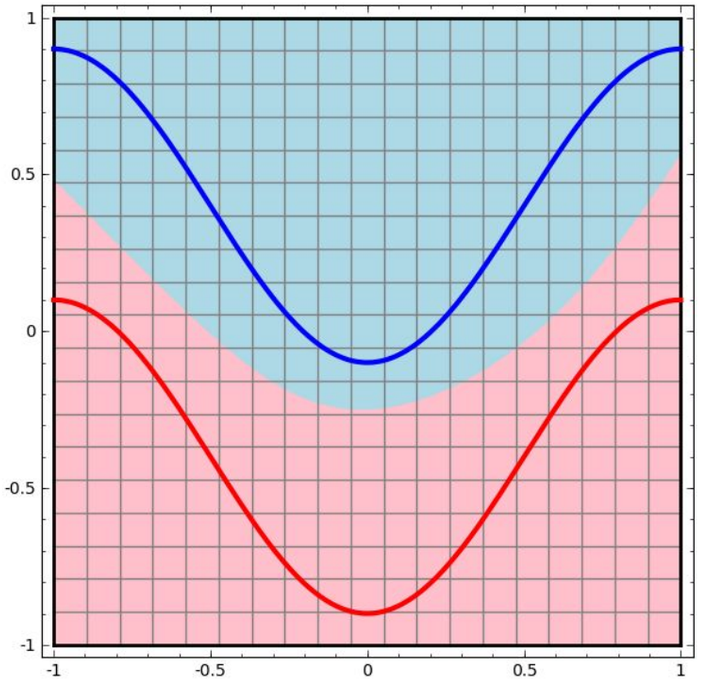


CLASSIFICATION

- Neural Networks are also extremely useful for classification (source)
- One hidden layer:

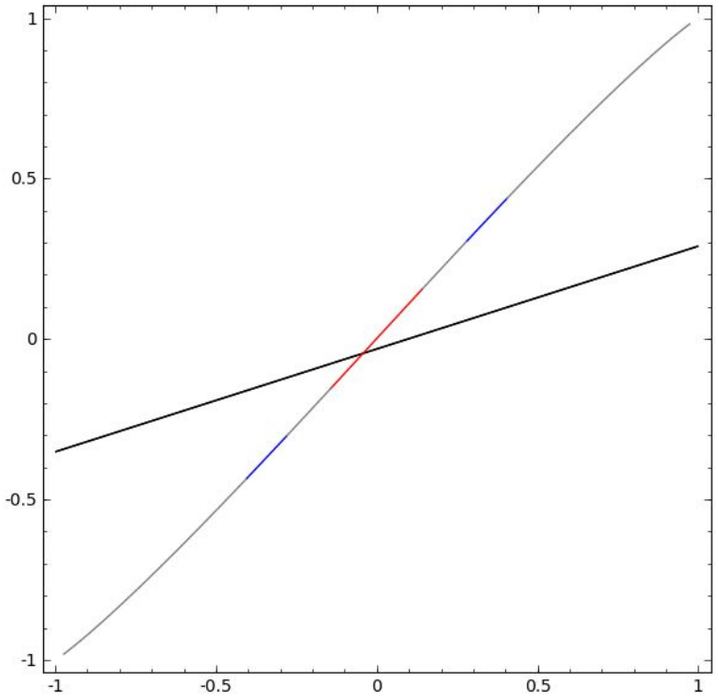






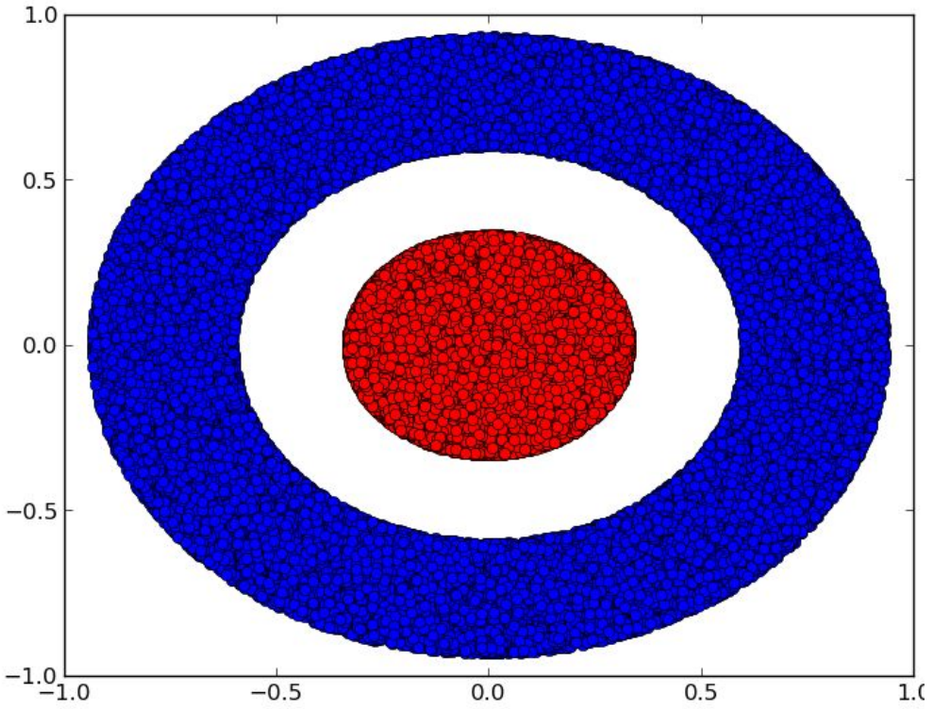
CLASSIFICATION

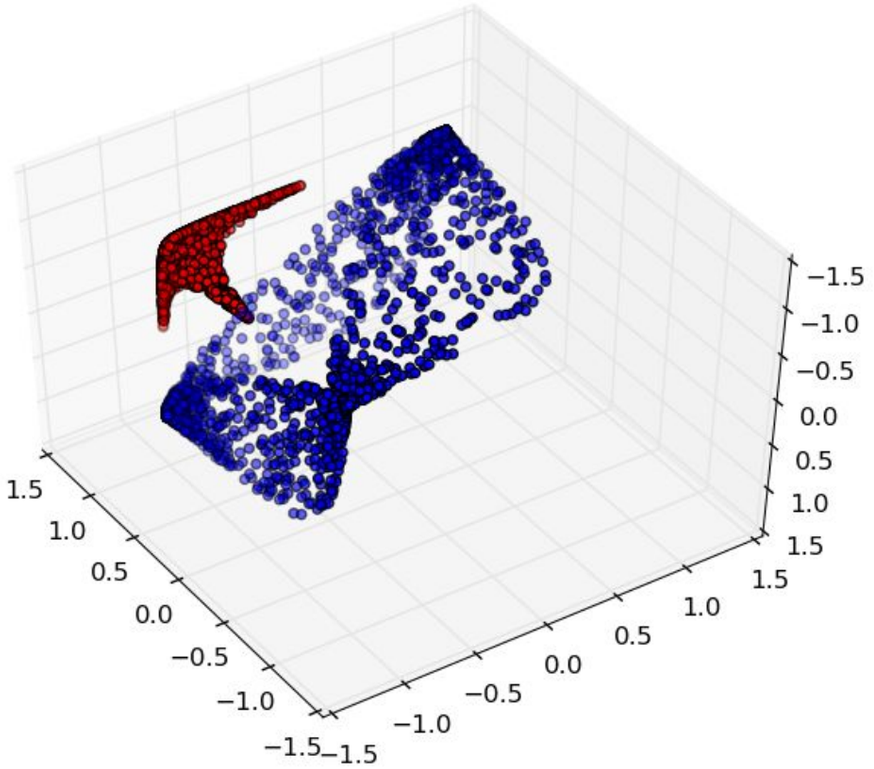
- Neural Networks are also extremely useful for classification (source)



CLASSIFICATION

- Neural Networks are also extremely useful for classification (source)





CLASSIFICATION

- The neural network transforms the data topologically (no tears or breaks) and then separates the data with a hyperplane

- NNs are capable of handling difficult data sets, including:
  - Image processing: recognizing hand-written characters
  - Image compression
  - Financial forecasting
  - Many others

GUIDED PRACTICE

NEURAL NETWORKS IN PYTHON

NN IN PYTHON

- There are many NN libraries for python and other languages
- Python
  - Theano
  - Keras
  - Lasagne
  - TensorFlow
  - Scikit Learn support for NN coming in 0.18
- Lua
  - Torch

- Some of these libraries utilize GPUs for (much) faster training

NN IN PYTHON

- Let’s look at some examples in Keras
  - Regression
  - Classification

GUIDED PRACTICE

DESIGNING NEURAL NETWORKS

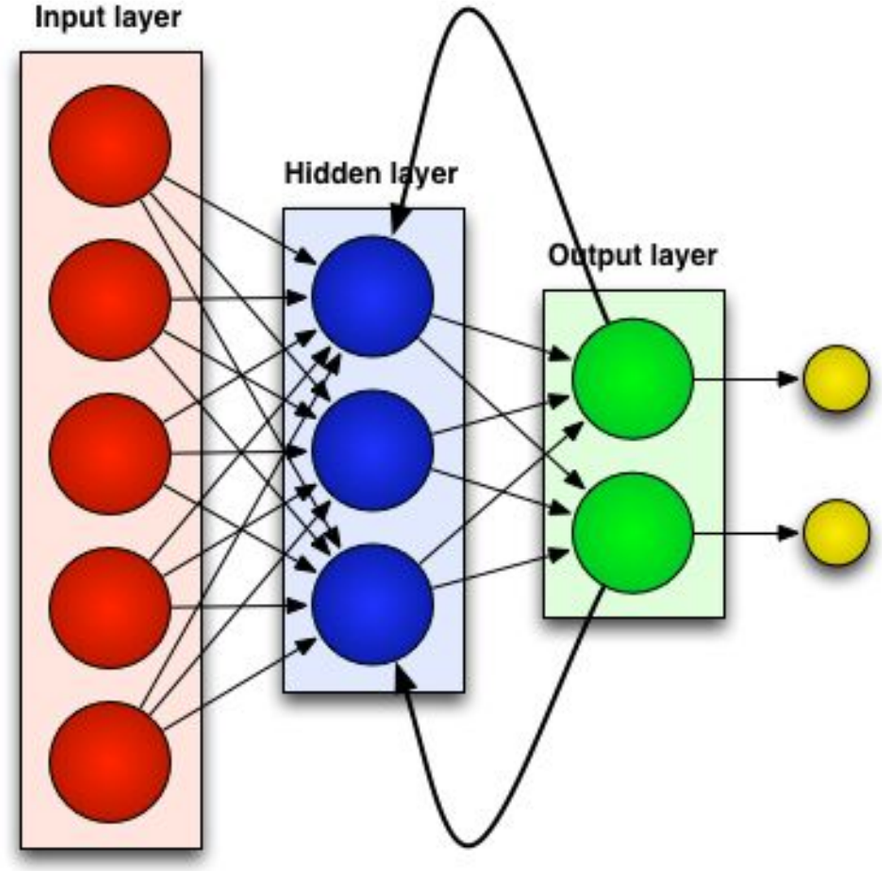
NN IN PYTHON

- Network design is a hard problem
  - Experience helps
  - Evolutionary algorithms are useful for design
  - Nice (free) book available

RECURRENT NEURAL NETWORKS

RECURRENT NEURAL NETWORKS

- Recurrent Neural Networks contain loops (source)



RECURRENT NEURAL NETWORKS

- Recurrent Neural Networks contain loops
- This implements feedback and gives neural networks “memory” or context
- Particularly good for predicting sequences, translating text, recognizing objects in images, speech translation
- Commonly referred to as **deep learning**, involving both feature extraction and modeling
- Nice intro here

RECURRENT NEURAL NETWORKS

- RNN font analysis

RECURRENT NEURAL NETWORKS

- Automatic Colorization with CNN

RECURRENT NEURAL NETWORKS

- RNN font analysis
- Automatic Colorization with CNN
- Automatic translation
- Deep Learning Applications

TOPIC REVIEW

CONCLUSION: Neural Networks

Pros:

- Flexible
- Good for a variety of tasks
- Good for many types of data

Cons:

- Can require a lot of data
- Training may be slow
- Many parameters to tune
- Many layer types and activations
- Black Box model

CONCLUSION

- Many more examples for Keras available
- Recommended articles: Convolutional NN,
- Advanced machine learning methods you should explore include Bayesian methods and deep learning

THANKS!

NAME

- Optional Information:
- Email?
- Website?
- Twitter?