

Introduction to deep learning

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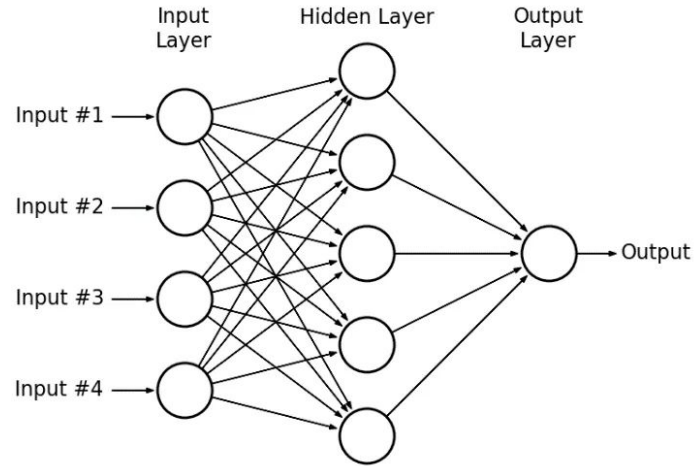
Deep learning

- Deep learning is a subfield of machine learning
- Some consider it as a separate field
- Deep learning is not always a solution to every problem
- Most common/basic architecture based on the source of data:
 - Tabular data: Deep Neural Network (DNN)
 - Imaging data: Convolutional Neural Network (CNN)
 - Video data: CNN, Recurrent Neural Network (RNN)
 - Time series data: RNN, Long Short-Term Memory (LSTM), Gated Recurrent Units (GRU)
 - Text data: RNN, LSTM, GRU, Transformer-based models (e.g., BERT, GPT)

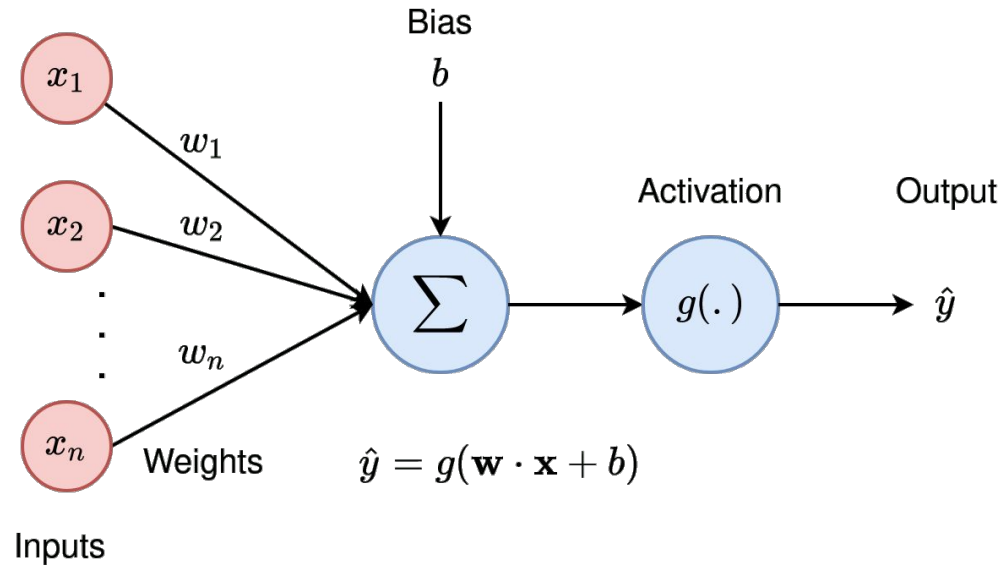
- Classification and regression in DL:
 - Binary classification
 - Multiclass classification
 - Single label classification
 - Multilabel classification
 - Scalar regression
 - Vector regression

Revision - ANN

- Neural network is the basis of deep learning
- ANN can be used for regression and classification
- Simple ANN = single layer, feed-forward neural network = multilayer perceptron (MLP) = shallow neural network
- ANN is formed of:
 - Input layer
 - Hidden layer
 - Output layer

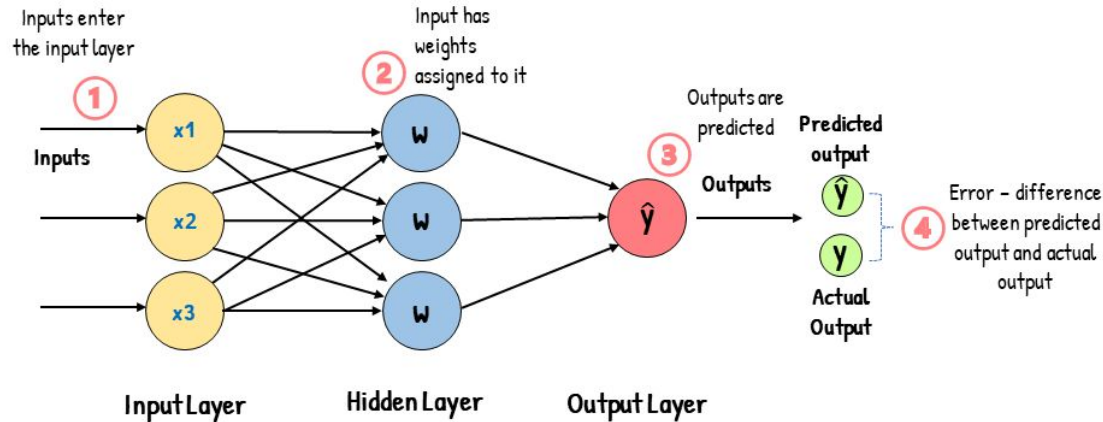


- Breakdown of ANN:



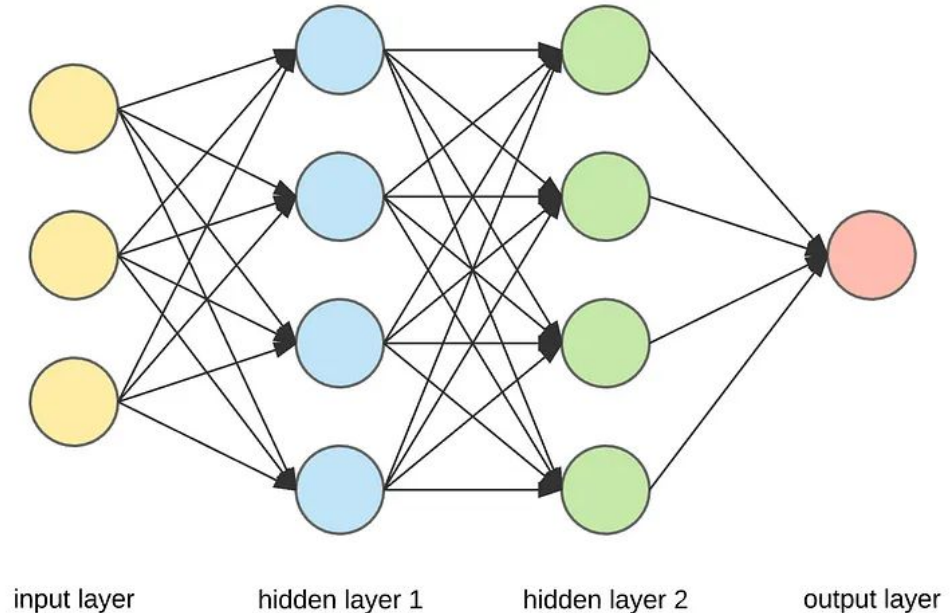
- Simple ANN uses feed-forward neural network approach

Feed-Forward Neural Network



Deep Neural Network (DNN)

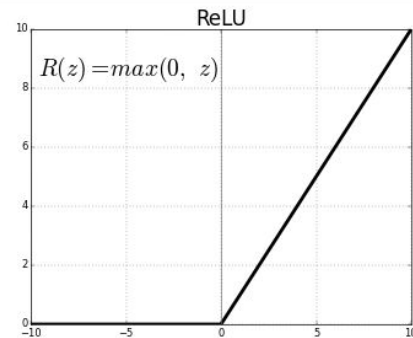
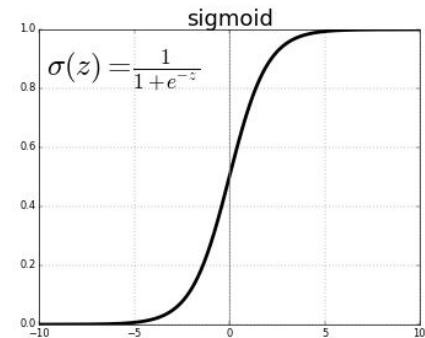
- Shallow neural network/ simple ANN, at most has 3 layers (input, output, and hidden layer)
- DNN has more than 3 layers:
 - “Deep” \approx more layers



Basic concepts in DNN

Activation function

- To restrict the overall output values
- Example:
 - Sigmoid: for binary classes
 - Softmax: for multiclass
 - Rectified linear unit (ReLU)
 - Solve the issue of vanishing gradient (faster convergence)
 - Introduce non-linearity into the network - enabling the network to learn a complex pattern in the data



Loss/cost function

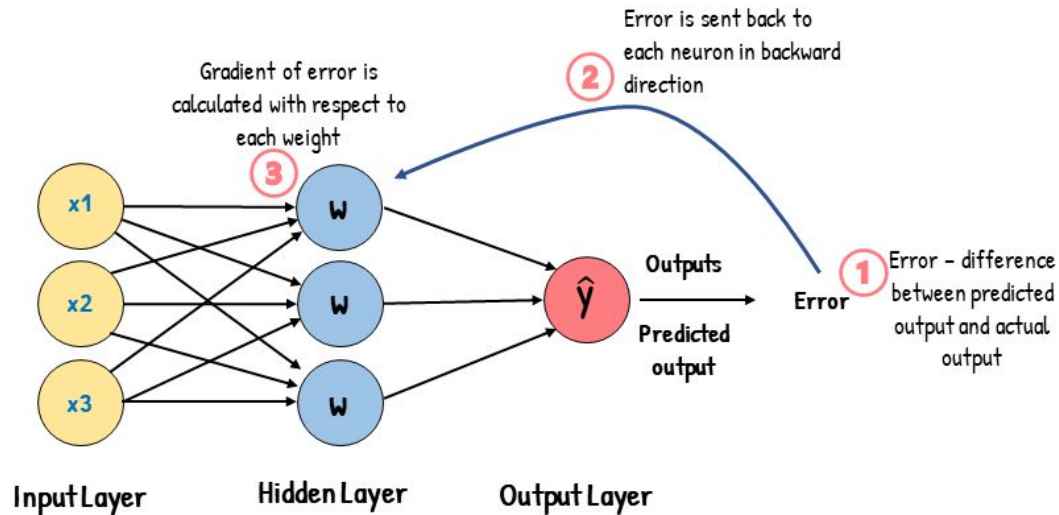
- A value to be minimised during the training process

Problem type	Last-layer activation	Loss function
Binary classification	sigmoid	binary_crossentropy
Multiclass, single-label classification	softmax	categorical_crossentropy
Multiclass, multilabel classification	sigmoid	binary_crossentropy
Regression to arbitrary values	None	mse
Regression to values between 0 and 1	sigmoid	mse or binary_crossentropy

Backpropagation

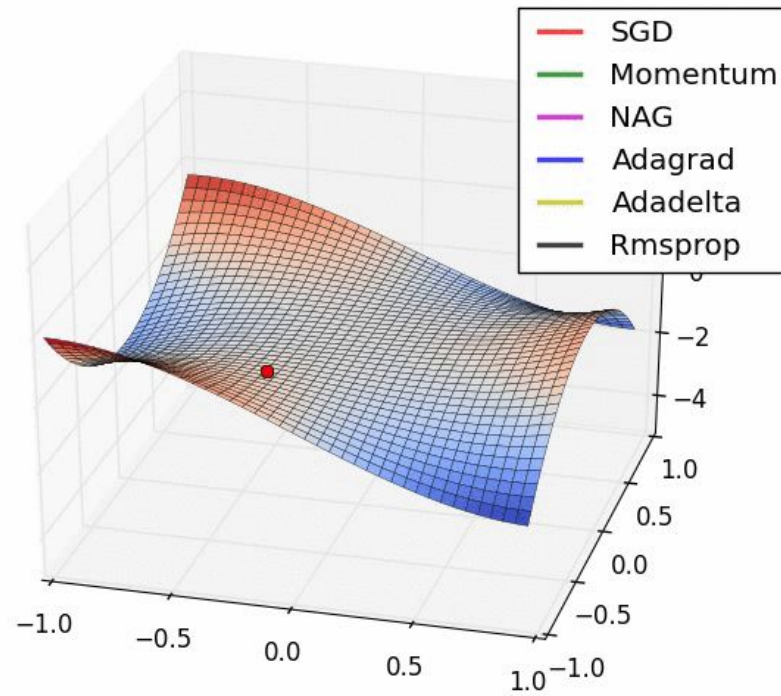
- This an iterative process of fine-tuning the weights of the network using gradient descent (an optimisation algorithm)
- Process: It operates in two phases:
 - Forward Pass:
 - The input data is passed forward through the network, layer by layer, producing an output
 - The output is compared with the desired output to compute the error
 - Backward Pass:
 - The error is propagated backward through the network, adjusting the weights to minimize it

Backpropagation



Gradient descent

- An optimization algorithm used in DL to minimize the error between predicted and actual results
- Example:
 - RMSprop (Root Mean Square Propagation)
 - Usually works for most tasks
 - Some suggestion: γ to be set to 0.9, while a good default value for the learning rate η is 0.001
 - ADAM (Adaptive Moment Estimation)
 - Some suggest to always use ADAM (Adam usually outperforms the rest)
 - Some suggestion: 0.9 for β_1 , 0.999 for β_2 , and 10^{-8} for ϵ

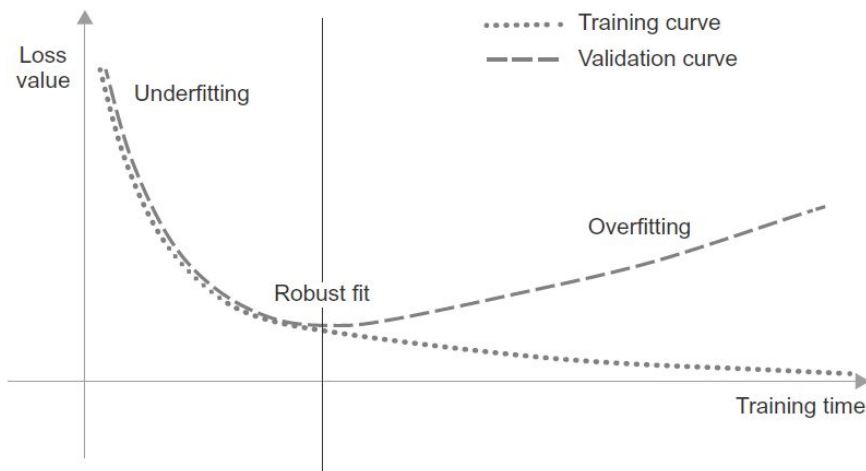


Validation approaches

- Hold-out validation - when we have a large dataset
- k-fold cross-validation - when we have a small dataset
- Iterated k-fold cross-validation with shuffling - when we have a small dataset and we need to evaluate the model as precise as possible

Approach to DL

- Set a baseline to beat
- Overfit the network on the training data first
- Then, reduce the overfitting by improving the generalisation



- How to overfit?
 - Add more layers
 - Make the layers bigger
 - Train for more epochs
- How to improve generalisation?
 - Reduce the layers
 - Use regularisation methods
 - Improve the data:
 - Develop better features - feature engineering
 - Remove uninformative features
 - Collect more data

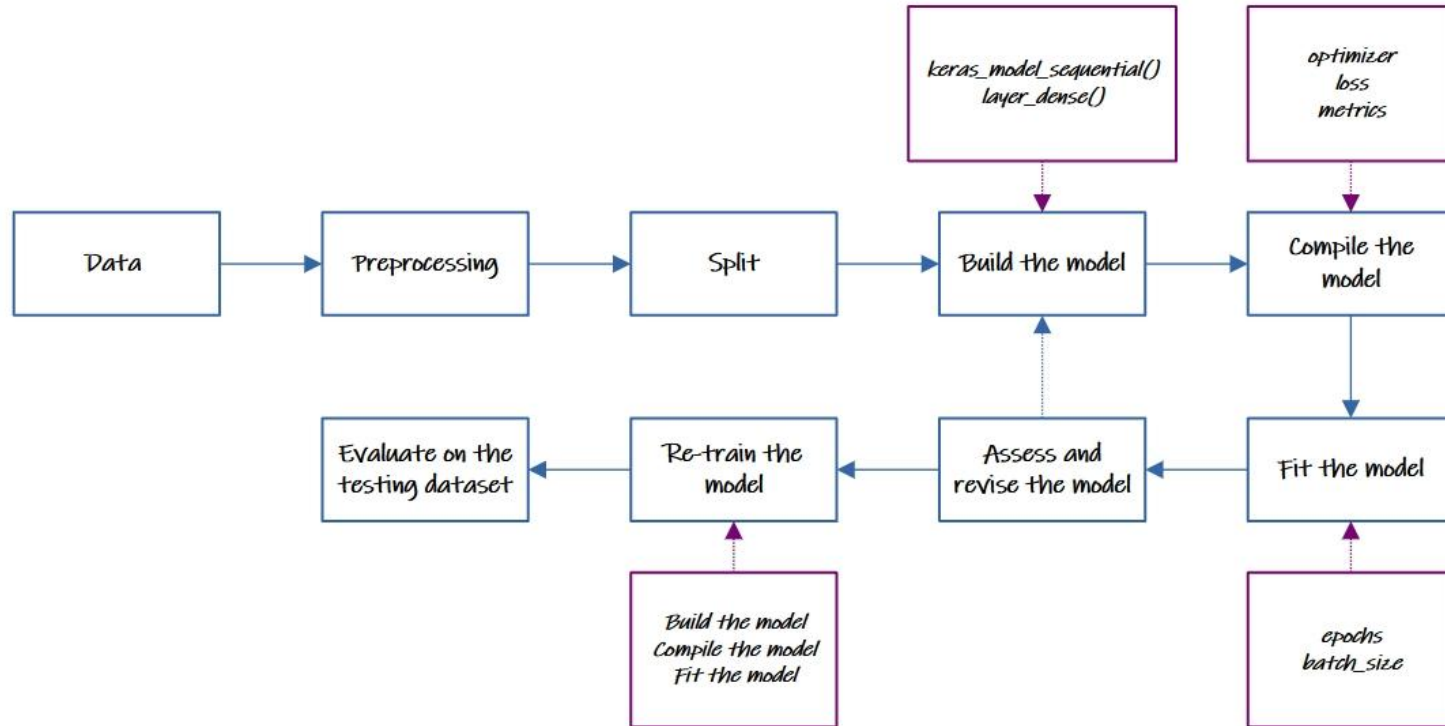
Regularisation methods

- Regularisation methods are applied to avoid overfitting
- Methods:
 - Reduce the network size
 - Weight regularisation - for small deep learning model
 - L1 regularisation
 - L2 regularisation
 - Dropout layer - for large deep learning model
 - Usually between 0.2 - 0.5

DL packages in R

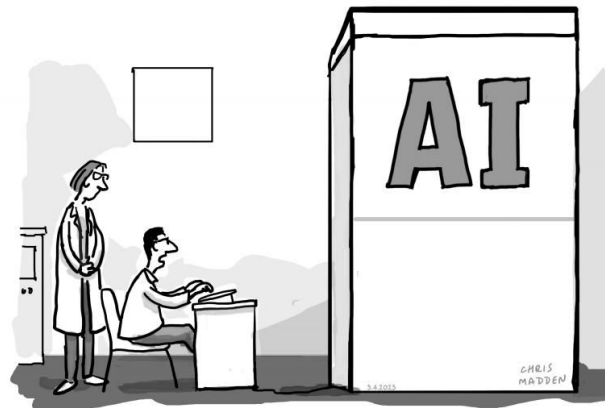
- Keras
- Tensorflow
- Torch

DNN workflows in keras



Running a DL analysis

- Bigger data
- Computational resources:
 - Laptop/PC with GPU
 - Cloud
 - [SaturnCloud](#)
 - [AWS Amazon](#)
 - [Google Colab](#)
 - Etc



"We've got a problem. I've turned it on
but I can't turn it off again."

Suggested readings/references

- Chollet, F., Kalinowski, T., & Allaire, J. J. (2022). Deep learning with R (Second edition). Manning.
- Kalirane, M. (2023, April 5). Gradient Descent vs. Backpropagation: What's the Difference? Analytics Vidhya.
<https://www.analyticsvidhya.com/blog/2023/01/gradient-descent-vs-backpropagation-whats-the-difference/>
- Ruder, S. (2020, March 20). An overview of gradient descent optimization algorithms. Ruder.io. <https://www.ruder.io/optimizing-gradient-descent/>



Any question?



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