Deep Convolutional Neural Networks

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Deep Convolutional Neural Networks

A **Deep Convolutional Neural Network** is a **Machine Learning** algorithm that allows to map a considerably large input data to a desired number of outputs by implementing a **Deep Neural Network**, which processes the given input by applying different **Convolutional** layers in order to extract the most important features of the input data.

Deep Convolutional Neural Networks

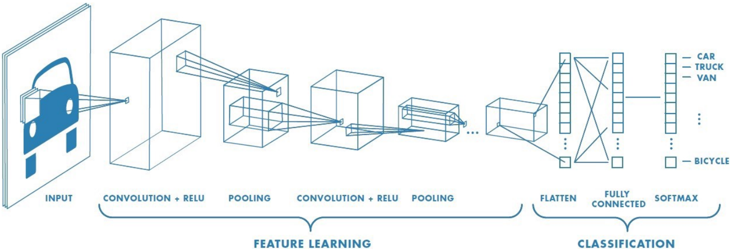


Figure: Representation of a Convolutional Neural Network application for vehicle classification.

But what's Machine Learning?

In general terms, Machine Learning is devoted to developing and using algorithms that learn from raw data in order to make predictions. This algorithms have the faculty of idenifying patrons and learn from given input data (learning data) so that they can adjust their architecture and internal parameters with the objective of predicting a specific output given a set of new unseen inputs (test data).

Machine Learning Systems Applications

Machine Learning Algorithms are used for multiple purposes including:

- Data prediction (airplane ticket price).
- Data Transformation (Written date to numerical value).
- Data Classification (Cat or Dog).
- Data Recognition (Face Detection).
- Etc...

A change in paradigms...

Common computational algorithms follow a established paradigm:

Given a defined input, a specific algorithm is designed in order to process this input data and generate the desired output.

However with Machine Learning Algorithms this paradigm changes:

Given a set of inputs and the desired output (training data) expected for this values, Machine Learning Systems generate the desired algorithm required to obtain this desired output given different new input data (testing data).

Neural Networks

A Neural Network is a type of Machine Learning system that models itself after the human brain (neurons). These systems consist of a multilayered architecture, where multiple inputs can be mapped to a specific number of outputs by computing and passing the input data through different inner conversion layers (hidden layers).

Neural Networks

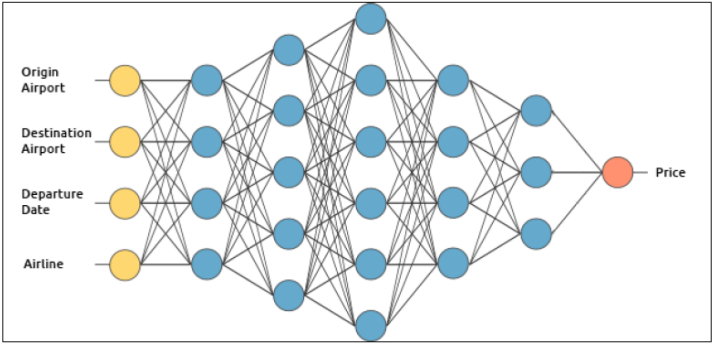


Figure: Representation of a Neural Network application for airplane tickets price prediction.

Neural Networks vs Human Brain

A general overview on Neurons:

- Each Neuron is basically a computational unit that takes input signals (dendrites) that are channeled to outputs (axons).
- This outputted data is passed through a function (activation function) that allows to modify this data in some manner so that it can be then outputted or introduced to a new neuron(synapse)
- A specific weight or importance is assigned to the generated outputs of the activation allowing the network to learn which signals are most important than others.

Neural Networks vs Human Brain

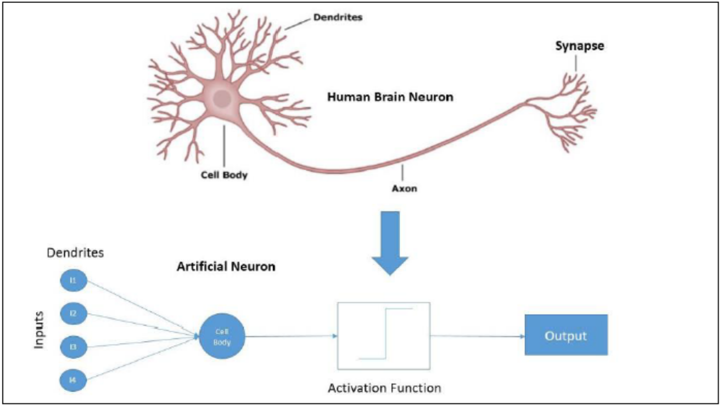


Figure: Human vs Artificial Neuron Comparisson.

Neuron Basic Architecture

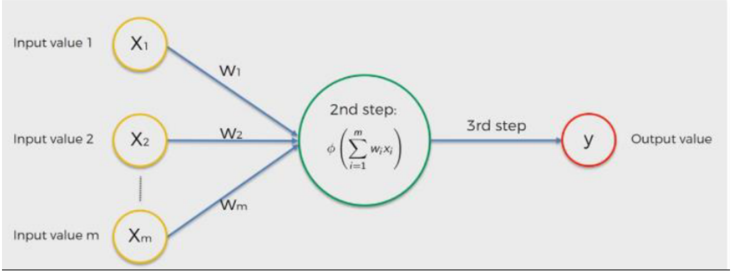


Figure: Basic Neuron Architecture.

n	:	Number of the current input value (n : 1, 2, ..., m)
x_n	:	Single input value of the network.
W_n	:	Assigned weights of the current connection.
Y	:	The predicted Output of the Neuron.
ϕ	:	Activation Function.

Machine Learning Development Process

A Machine Learning development is normally conformed of three phases:

- Training
- Validation
- Testing

Training

- The ML System is trained by using a defined training data set.
- Each training set is conformed of a vector of input values used to predict a desired output.
- The system evaluates how well its predictions were in comparisson with the real output obtained from the training set.
- Finally, the model modifies its inner parameters in order to learn how to make a better prediction.

Validation

- The trained system is evaluated with a new set of previously unseen data called validation set.
- This evaluation allows to conclude how well the training predictions can be scaled to different inputs that the system has not previously worked with.
- This phase is highly important as it allows to approximate the accuracy of the system's predictions or to decide if any major modifications must be made in the design of the ML System.

Testing

- The trained and validated system is now faced with test case data.
- At this point the data set only contains the vector of input data but the output is unknown.
- The Machine Learning System is now responsible of predicting an output for each of the given inputs.

Neural Networks Training

The training of a Neural Network can be described in different phases:

1. Define a Training Data Set.
2. Decide the Network architecture and set the initial connection weights W "randomly".
3. Start the training of the network with the training sets, applying the ϕ activation function to the input values. (Forward Propagation)
4. Generate the output value y.

Neural Networks Training

5. Calculate the Cost Function which allows to compare the predicted output value with the real output of the training set and evaluate the error of the current prediction.
6. Based on the feedback from the calculated Cost Function, reassing all the weights (Backward Propagation).
7. Repeat the training process until a better Cost is obtained.

Neural Networks Validation

1. Using a new validation data set, test the trained neural network and calculate the overall Cost Function of the system.
2. If a non-desired behavior is achieved, then certain modifications to the network can be made in order to improve its accuracy.
3. If required change the model architecture, reducing or increasing the number of hidden layers of the network, changing the activation function of the network, etc.
4. Train the network again and validate it once again until a better result is obtained for the validation set.

Neural Networks Testing

Once the Neural Network has been trained and validated, it can be used to predict any new unseen input data sets in order to make a prediction of the desired output.

Deep Neural Networks

Deep Neural Networks is a concept used to describe all Neural Network implementations that require to process a big ammount of input data, that in general causes the architecture of the model to be large or to present a big number of hidden layers. (Image processing, Audio Processing, etc.)

Deep Neural Networks

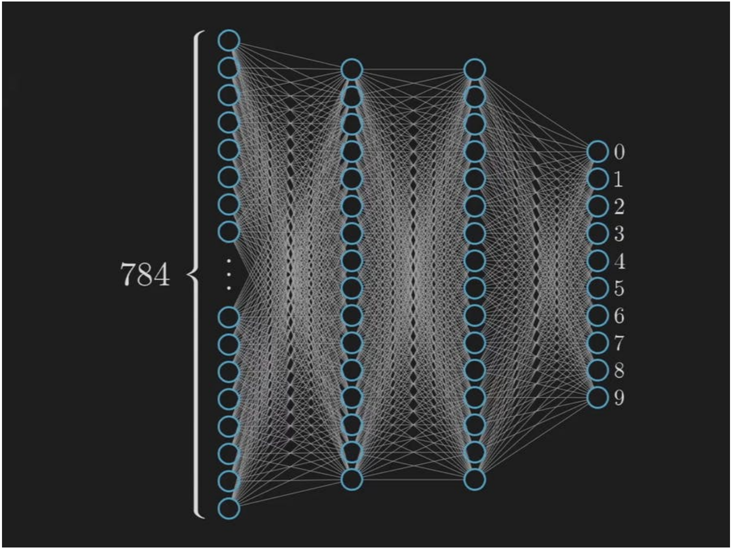


Figure: Example of a DNN architecture.

Deep Neural Networks

Deep Neural Networks present a high utility and power for Computer Vision Applications such as Image and Video Recognition, Image Analysis, Classification, Media Recreation, etc. In general these systems have been primarily developed with a particular and powerful algorithm called Convolutional Neural Networks.

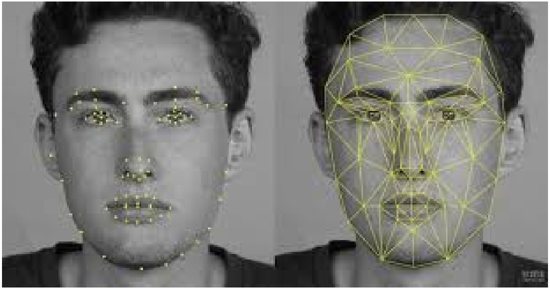


Figure: Example of a Face Recognition Implementation.

Convolutional Neural Networks

- Consider a Computer Vision Implementation where an RGB image of a high resolution, say 8K (7680x4320 px) is going to be processed using a Neural Network.
- These type of implementations will require the Network to process each and every pixel value for the three color channels.
- This procedure would cause the architecture of the network to be considerably large, resulting in an intensive computational resource usage specially for the training phase of the development of the model.

Convolutional Neural Networks

A Convolutional Neural Network takes an input image and assigns importance to various aspects/objects in the image, being capable of differentiating one from other, and having the ability to learn these filters autonomously with enough training.

These concepts allow CNNs to be capable of capturing the Spatial and Temporal dependencies in an image through the application of relevant filters.

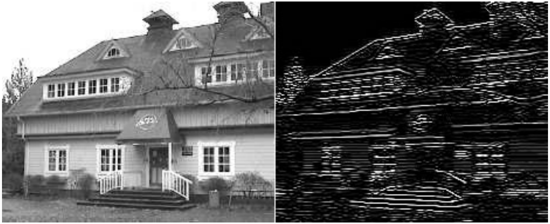
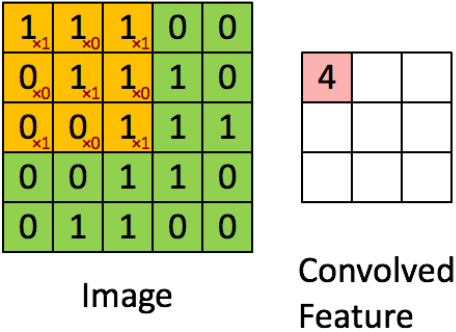


Figure: Example of a horizontal line convolutional filter Output.

Convolutional Neural Networks



Convolutional Neural Networks

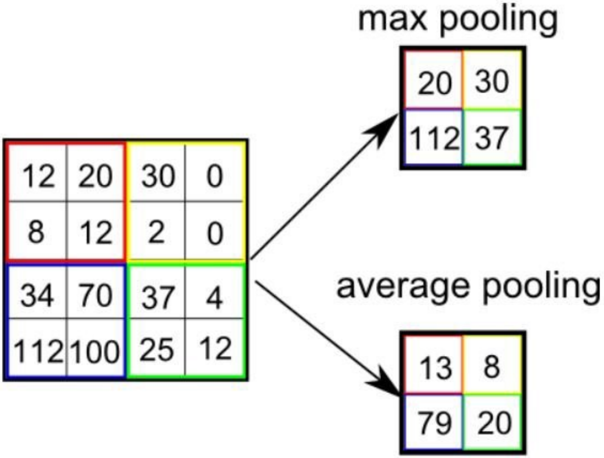


Figure: Pooling Operation Example.

Convolutional Neural Networks

This Convolutional operation allows to extract the most important features of an image in a reduced size. In other words, we can express a large amount of pixels in an image more compactly.

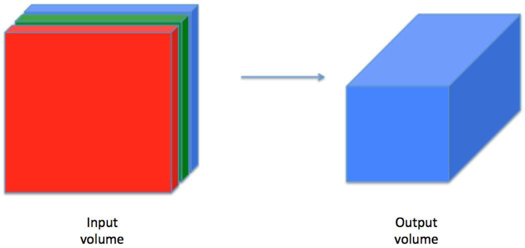
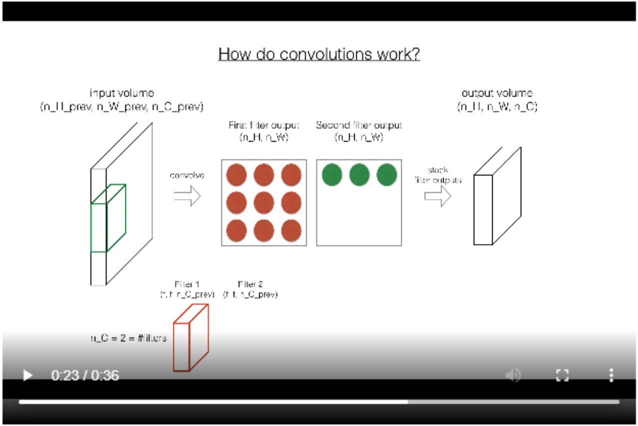


Figure: Convolution Process Example.

Convolutional Neural Networks

To achieve this volume reduction task, we apply multiple convolution operations to obtain fundamental elements of the input volume, for example edge detection, color filtering, horizontal lines, etc.



Convolutional Neural Networks

The deeper we go in our network the more complex features our model is capable of detecting in a smaller volume, thus it's easier to extract the fundamental features of the input and feed them to a fully connected set of layers.

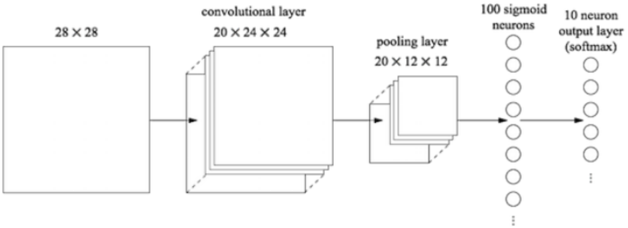


Figure: Convolutional Neural Network Example.

Convolutional Neural Networks

Figure: DNN Layer 1 Activation Outputs.

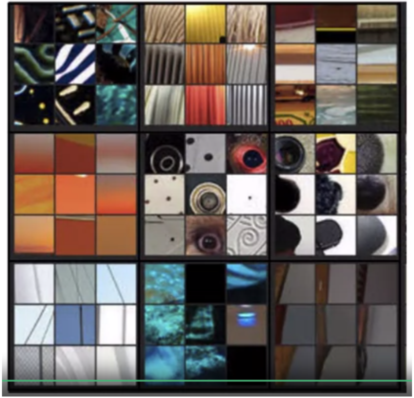


Figure: DNN Layer 2 Activation Outputs.

Figure: DNN Layer 3 Activation Outputs.

Figure: DNN Layer 4 Activation Outputs.

Convolutional Neural Networks

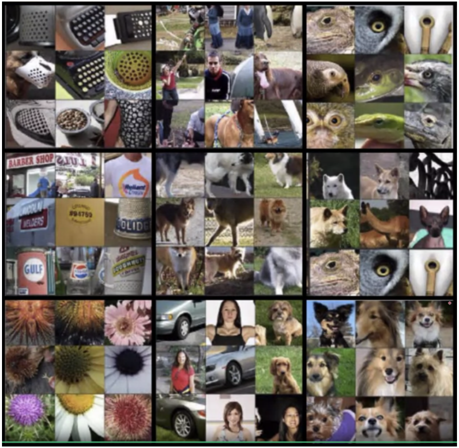


Figure: DNN Layer 5 Activation Outputs.

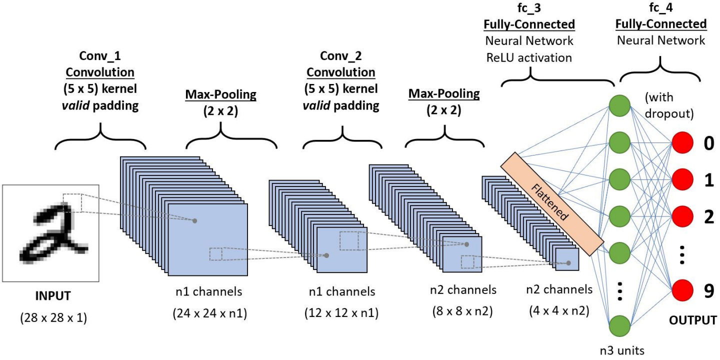


Figure: DCNN Architecture for Hand Written Number Classificaction.

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