Understanding Convolutional Neural Networks Made Easy

Department of RadiologyTulane University School of Medicine

Jeremy Binh Nguyen, MD

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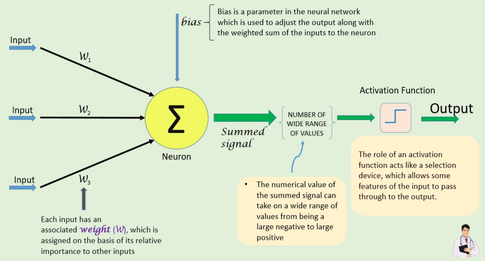
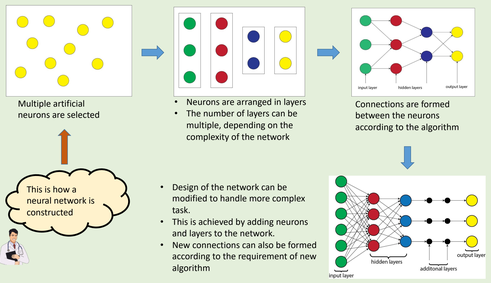
Goals and Objectives

- Describe the structure and operation of an "artificial neuron" in a neural network.
- Discuss the basic architecture of a deep learning neural network including the input, hidden and output layers.
- Describe the architecture of a Convolutional Neural Network (CNN).
- Explain the intuitive meaning of convolution.
- Discuss how a convolutional neural network can extract features of an image though the Convolution Layer, Rectified Linear Unit Layer (ReLU), and Pooling.
- Explain how a convolutional neural network can classify an image through the Fully Connected Layer and Softmax Function.
- Describe an intuitive design of a Convolutional Neural Network, with the integration of the feature extraction and image classification components.

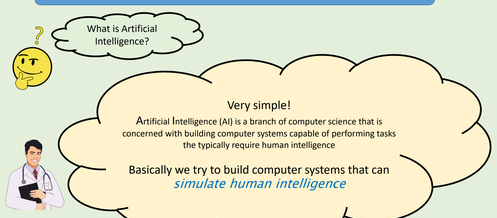
Functional Artificial Neuron



Assembling a Neural Network



Artificial Intelligence



What is machine learning?

- Machine learning is a SUBSET of artificial intelligence
- ***MACHINE LEARNING*** is an application of AI that can automatically learn and improve from experience
- MACHINE LEARNING is built upon an ALGORITHM that uses computational methods to "learn" information directly from data without relying on a predetermined equation as a model
- MACHINE LEARNING algorithms adaptively improve their performance as the data available for learning increases

What is Deep Learning?

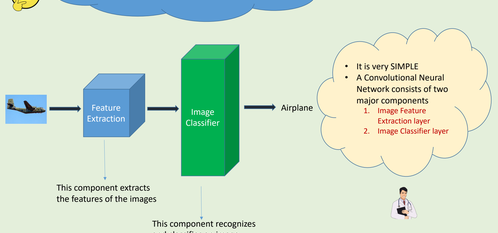
- Deep learning is an artificial intelligence function that mimics the workings of the human thought process
- Deep learning is a subset of machine learning
- The fundamental functional unit of a deep learning neural network is an ARTIFICIAL NEURON node
- Deep learning neural networks are built with artificial neuron nodes connected together to form a topological structure
- The hierarchical neural network reflects the ALGORITHM of the network in processing/transforming the data

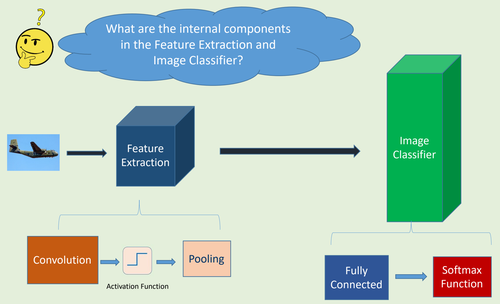
- The word "***deep***" in "deep learning" refers to the number of layers through which the data is processed
- Deep learning algorithms propagates data through multiple layers of neurons, each of which passes a simplified representation of the data to the next layer
- Deep learning algorithm is capable of learning from the input data to improve its performance

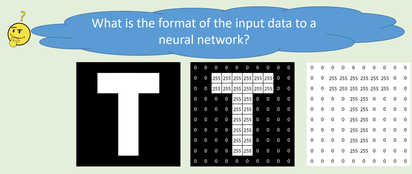
What is a Convolutional Neural Network (CNN)?

- Convolutional Neural Networks are a special type of deep learning network
- A CNN is designed for processing structured arrays of data such as images
- CNN is a type of deep learning model for processing data that has a grid pattern, such as images
- CNN modeling is inspired by the organization of human visual cortex and designed to automatically and adaptively learn spatial hierarchies of features, from low- to high-level patterns
- CNN are excellent at picking up on patterns such as lines, gradients, circles, or even eyes and faces
- Convolutional neural networks have become the state of the art for many visual applications such as image classification

What is basic organization of a Convolutional Neural Network?





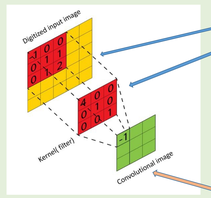


- We must remember that the network does not see the image data like an human eye
- The image must be ***digitized*** prior to input into the network
- Digitization involves creating a matrix of numbers representing pixel brightness
- The brightness of each pixel is assigned a number ranging from 0 to 255, depending on the degree of brightness
- You can see an example of a digital representation of a letter **T** above

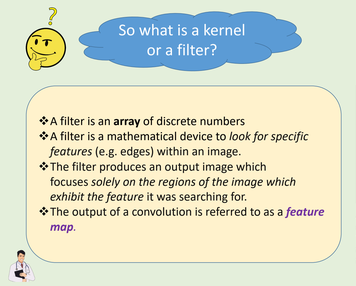
What does the convolution layer do to the input data?

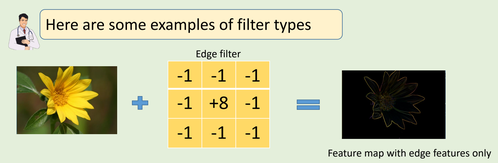
- Convolution is a mathematical operation
- Convolution could be conceptually thought of as the ***mixing*** of information of two datasets
- The mixing can be utilized to extract some features of the datasets
- In convolution neural networks, convolution is utilized for extracting features of the input image

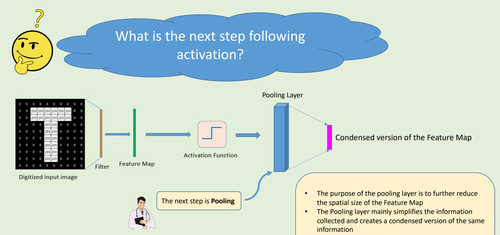
Performing convolution on an input image



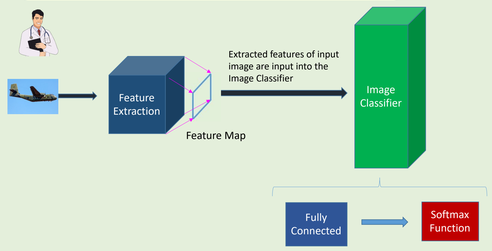
- Convolution operates on two datasets
  - one being an **input** image
  - one being a **kernel** acting as a ***filter*** on the input image
- The convolution operation involves multiplying the values in the filter with the corresponding pixel values of the input image.
- The operation yields a ***convolutional*** image, usually smaller dataset reflecting the extracted features of the input dataset

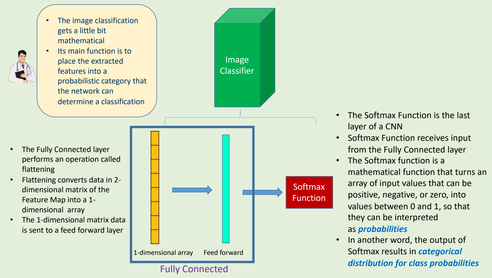


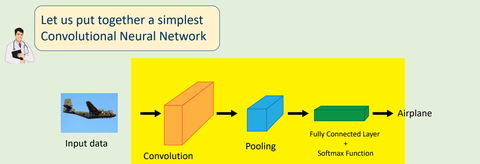




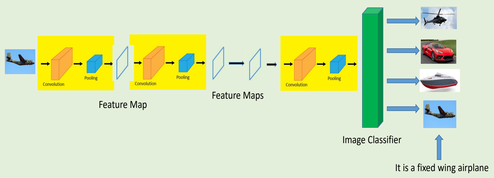
- Now that feature extraction is complete, the information will be forwarded to the Image Classifier for image classification
- The Image Classifier consists of the Fully Connect Layer and the Softmax Function



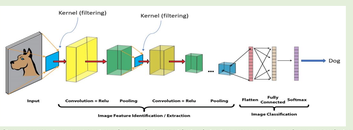




- The actual design of a CNN is much more complex
- Typically numerous convolutions are performed on the input data
- Each convolution uses a different filter which results in different Feature Maps
- All of these Feature Maps are then assembled as the final output of the convolution layer
- The final convolutional data is forwarded to the Image Classifier for image classification



Basic building blocks of a convolutional neural network (CNN)



CNN consists of two major subsystems, one subsystem is for image feature identification/extraction and one subsystem is for image classification

Image feature identification/extraction subsystem

- **Convolution** of the input image and a kernel, acting as a filter can result in various effects (e.g. extracting edges, blurring, sharpening, outlining, embossing, etc.)
- **Rectified Linear Activation Function (ReLU)**, introducing the non-linearity to the data, which enable the network to train a faster without making a significant difference to the accuracy
- **Pooling** layer makes the CNN translation invariant in terms of the convolution output

Image classification subsystem

- **Flattening** converts the matrix data into a 1-dimensional array for inputting it into the image classification system
- **Fully Connected** layers will combine features learned by different convolution kernels and produce different activation patterns based on what features are present in the input images
- **Softmax** is a mathematical function, which allows the transformation of arbitrary real values from the **Fully Connected layer** into probability distributions of a list of potential image classification

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Contact Information

Jeremy Nguyen, MD, MS. Associate Professor of Radiology at Tulane University Medical Center

Email: jnguye2@tulane.edu

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