Deep Learning in Medical Image Analysis

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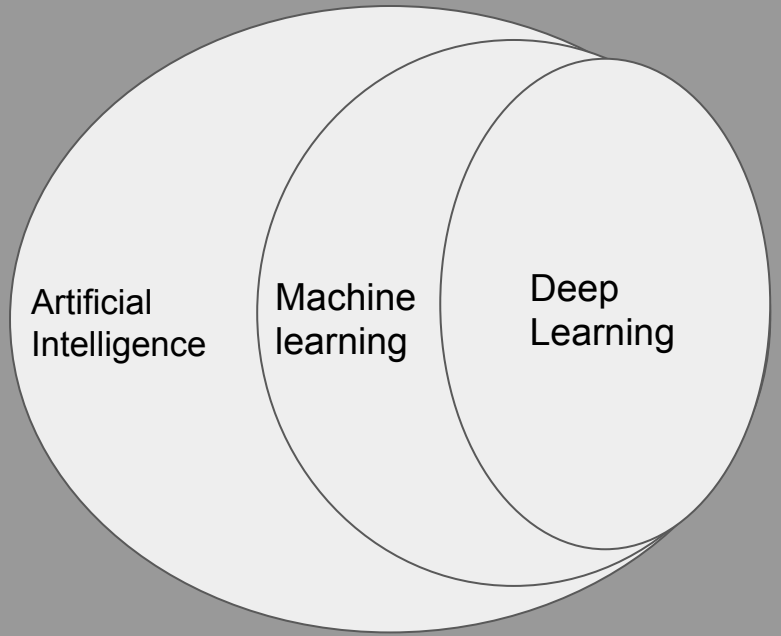
Overview

- Artificial Intelligence - “a system that acts intelligently”
- Machine Learning
  - Supervised
  - Unsupervised
  - Semi-supervised
  - Reinforcement
- Deep Learning is a technique for implementing Machine Learning.

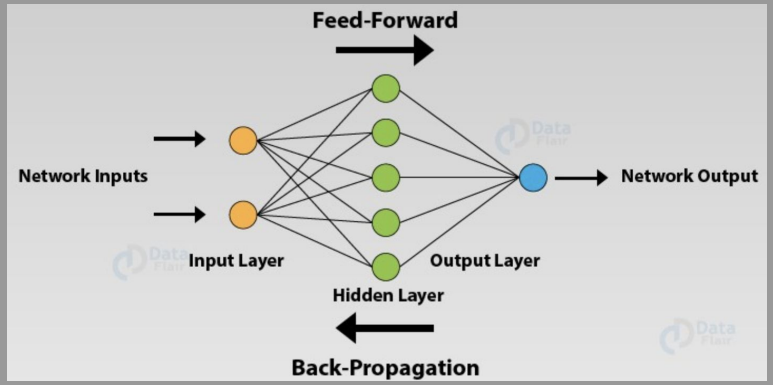


Relevance

- Deep learning can be used to
  - Classification or Computer-Aided Diagnosis (CADx)
    - CNN to detect lung nodules on chest X-ray in 1995
    - CNN to diagnose diabetic retinopathy by using digital photographs of the fundus of the eye
  - Localization
  - Detection or Computer-Aided Detection (CADe)
    - cancerous lung nodules on CT lung scans
    - malignant skin cells from dermatological photographs and dermoscopic images
  - Segmentation
    - brain MRI segmentation
    - prostate MRI segmentation
  - Registration

Neural Network

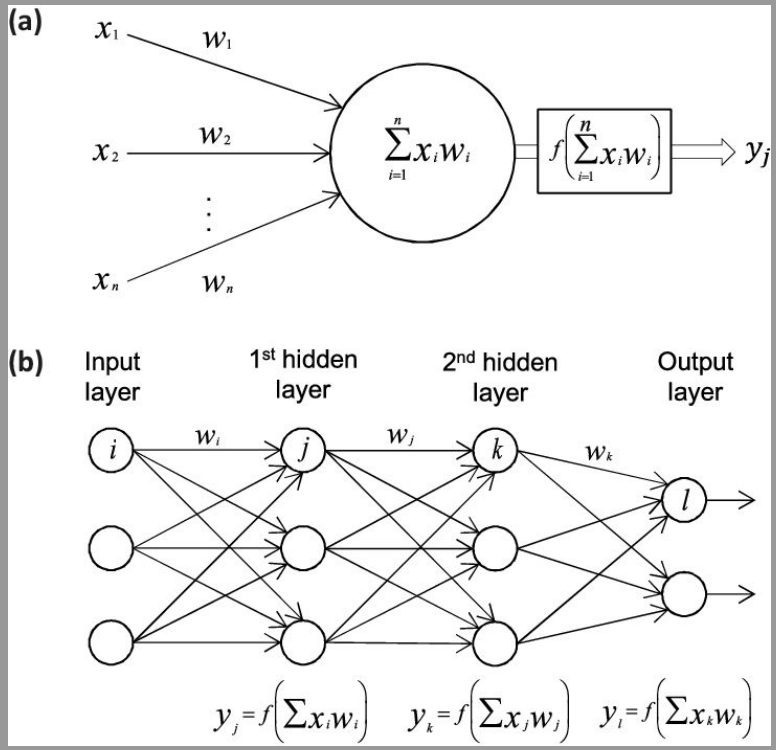
- Used in this cases for recognition and classification
- Has highly structured layers
  - The first layer: Input Layer
  - The last layer: Output Layer
  - All in between layers: Hidden layers
- Forward propagation is the term that describes how starting from the input layer the activation is passed on to each layer to classify inputs



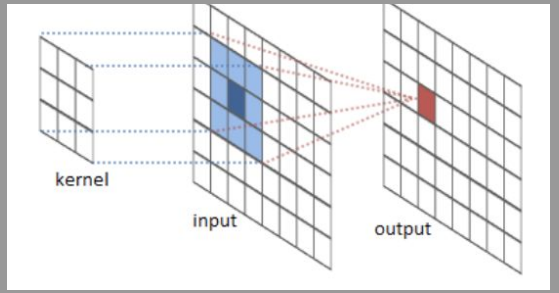
Deep Neural Network

Deep refers to the number of hidden layers in the neural network. Traditional neural networks only contain 2-3 hidden layers deep networks can have as many as 150.

Trained by using large sets of labeled data and neural network architectures that learn features directly from the data.



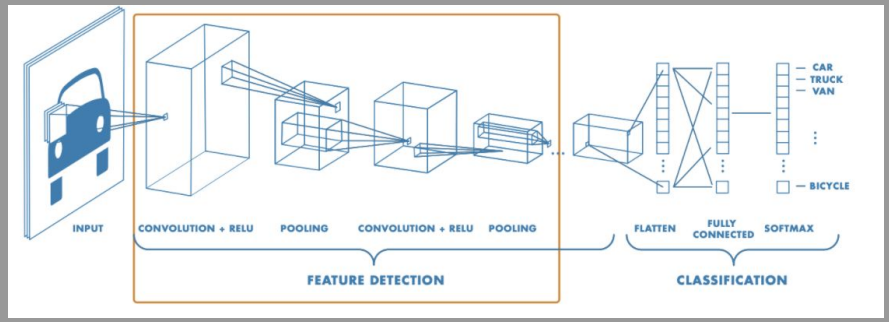
Convolutional Neural Network



- A class of deep learning that...
  - Reduces the number of parameters by reducing the number of interaction between neurons
  - Reduces the amount of training data needed
  - Reduces the likelihood the model is overfitted
    - This is done by disconnecting some of the internal interactions between neurons
- Normally used in visual analysis problems
  - Inspired by the patterning and organization of the animal visual cortex
- A deep neural network that specializes in Image recognition
- Processes data with a grid like topography- 2D images
- Two major sections: Feature Learning and Classification

Layers

- Convolutional Layer generates feature maps; normally the first layer of the CNN where the image is convolve using filters
  - Filters
  - Activation functions
- Pooling Layer reduces the dimensions of the feature maps
  - Max Pooling
- Fully Connected Layer uses the results from convolutional and pooling processes to determine the outputs.
  - Fully connected input layer
  - Fully connected output layer



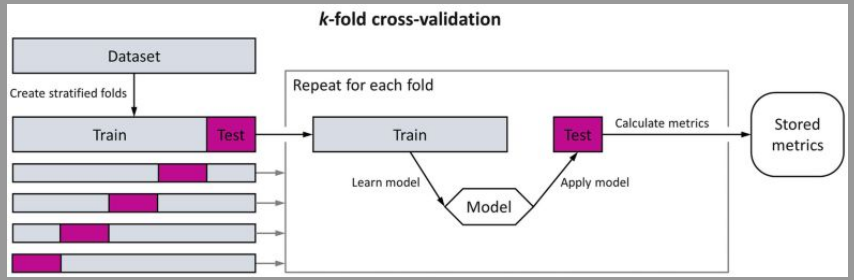
Transfer Learning

When a model that has been trained for a task is reused to as the beginning model for a different task.

- Load a pretrained network to use as a starting point of a new task
  - The early layers are used to distinguish low level features: edges, colors, etc.
- Replace the last layers
  - The final layers of the network are tuned to distinguish features specific to your data set
- Train the network
  - Import the new images into the network
- Test the network
  - Using a different set of images, test the accuracy
- Utilize results
  - Use the results to improve the network by fine tuning the parameters of the final layer

Validation of a Prediction Model

- Internal validation
  - using random split
  - k-fold cross-validation

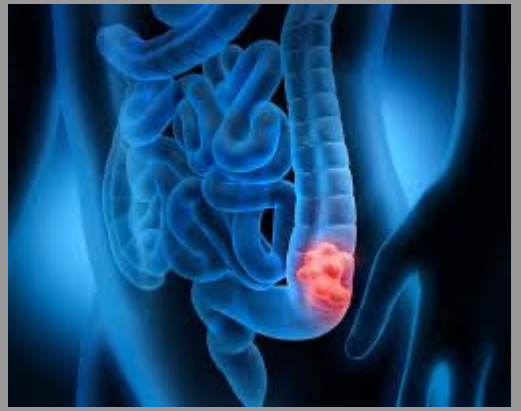


- External validation
  - one complete data set is used for model generation
  - different data set is used for model validation
  - true test to evaluate the performance of a prediction model

Challenges

- Require a lot of data for highly accurate result
  - Lack of high quality labelled data set
- Computational expensive
- Hard to tune and not transparent
  - many options of the architecture and learning algorithm
  - choices of parameters and hyperparameters
  - “the black box problem"

Colon Cancer



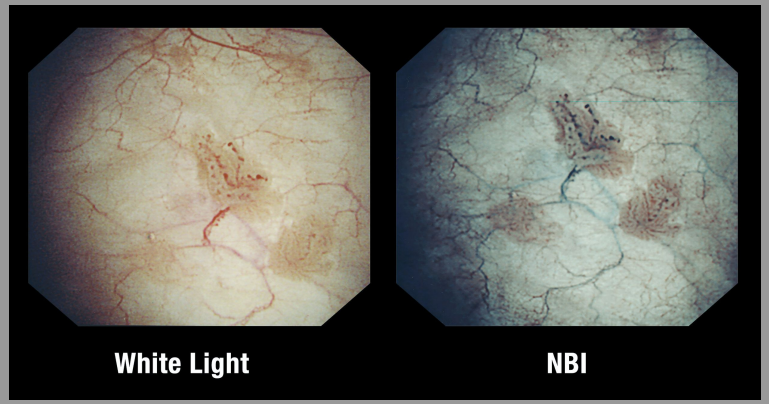
- Second leading cancer killer of both men and women in the United States
- Accounts for 50,000 American deaths per year
- Treatment is most effective when the cancer is its earliest stages
- Some polyps can become cancerous, making distinguishment vital

Polyp Distinguishment

- Majority of polyps are benign
  - 80% of all polyps are diminutive (5mm)
- Benign polyps can be divided into two categories: Hyperplastic vs. Adenomas
  - Hyperplastic polyps rarely become cancerous
  - Adenomas can be precursors to colorectal cancer

Narrow Band Imaging

- Enhances endoscopic images
- Improves detection of lesions and distinguishment between vascular structures



White Light NBI

Polyps project

- 264 unique polyps 224 patients
  - 46 cases - alternating capture mode
  - 89 cases - sequential capture mode
- Goals:
  - archive ≥ 95% net percentage value of detection for adenoma
  - archive ≥ 95% agreement between the system-based and the standard, pathology-based recommendations

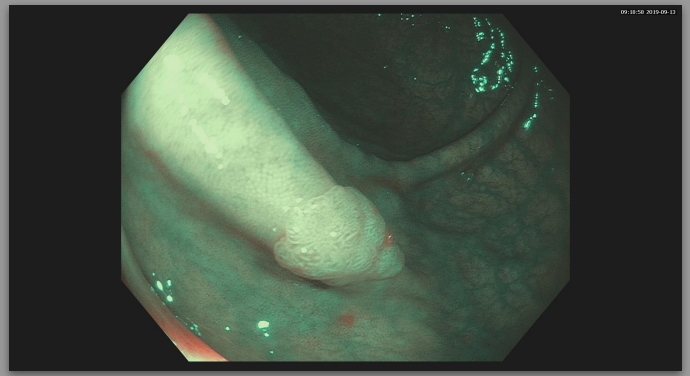
Polyps project

- 264 unique polyps are divided into 5 data sets
  - 4 sets are for training, 1 set is for validation
- Convolutional neural network is trained to
  - detect polyps
  - classify them into certain categories
  - Using ResNet50 for transfer learning model
- Result
  - Average accuracy is 97.3%

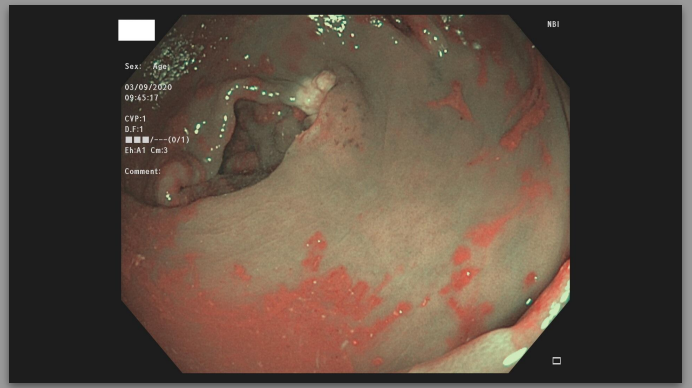
Absence Training

Up to present the models have been trained to classify polyp types in images

Next, models can be trained to distinguish between scans with no polyps present and scans with polyps



NBI, Tubular Adenoma polyp



Empty frame with no polyp

Conclusion

- Deep Learning has numerous usages such as
  - classification, localization, detection, segmentation, and registration.
  - Neural Networks, Deep Neural networks and Convolutional Neural networks are utilize this technique to train and validate its prediction model.
- CNNs are utilized to train the model to identify polyp types in colonoscopy images, both in white light and NBI settings.
  - Similar model can be train for pCT and X-ray data

Future direction

- Accuracy Improvement of the Model
  - Size estimation
  - Pattern extraction

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