Demystifying Medical Image Analysis and Visualization using Machine Learning

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Introduction

Medical Imaging

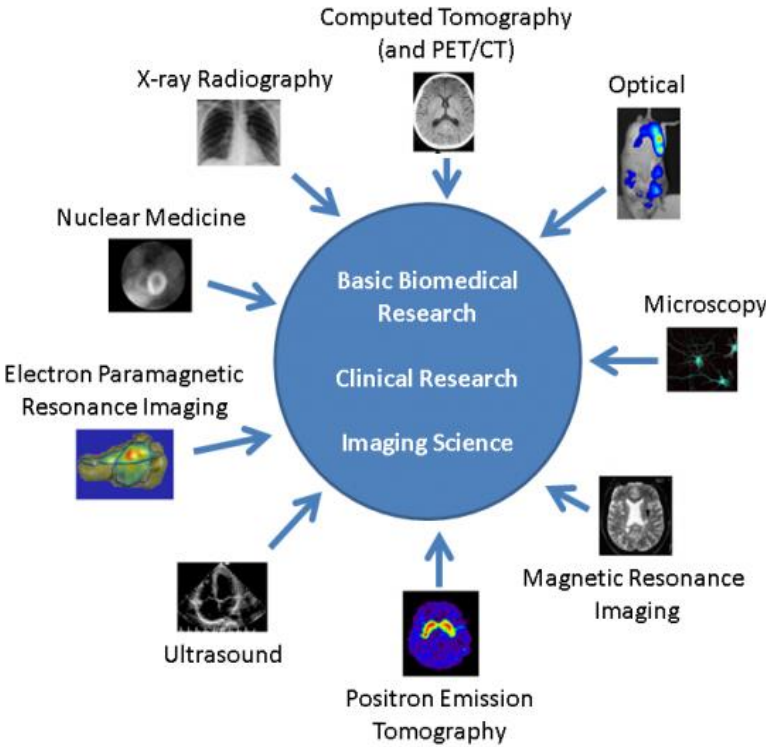
- Medical imaging is often perceived to designate the set of techniques that noninvasively produce images of the internal aspect of the body

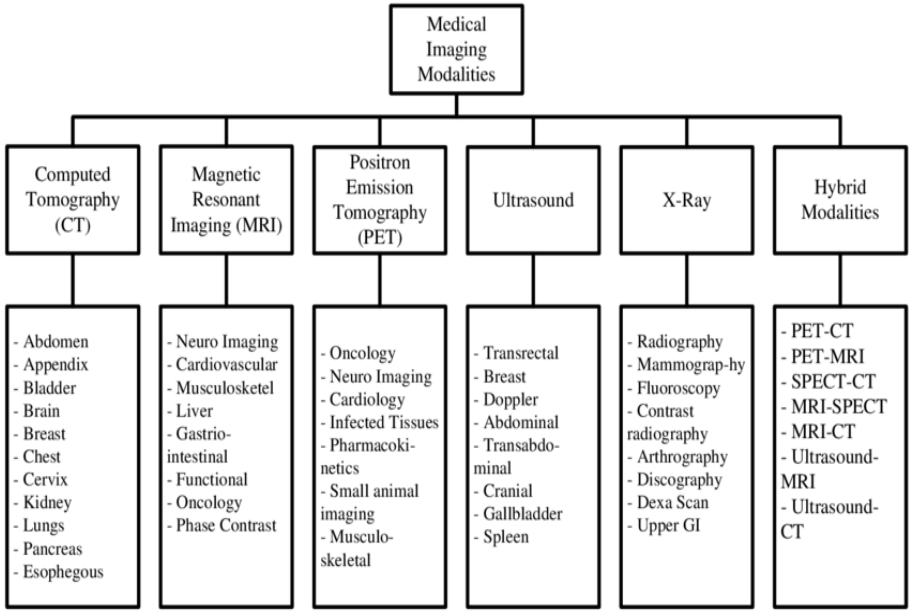
- As a discipline and in its widest sense, it incorporates radiology, tomography, endoscopy, thermography, medical photography and microscopy

Introduction

Imaging Modalities

- Span orders of magnitude in scale, ranging from molecules and cells to organ systems and the full body
- Each imaging modality is primarily governed by the basic physical and biological principles which influence the way each energy form interacts with tissues





Source: The University of Chicago

Introduction

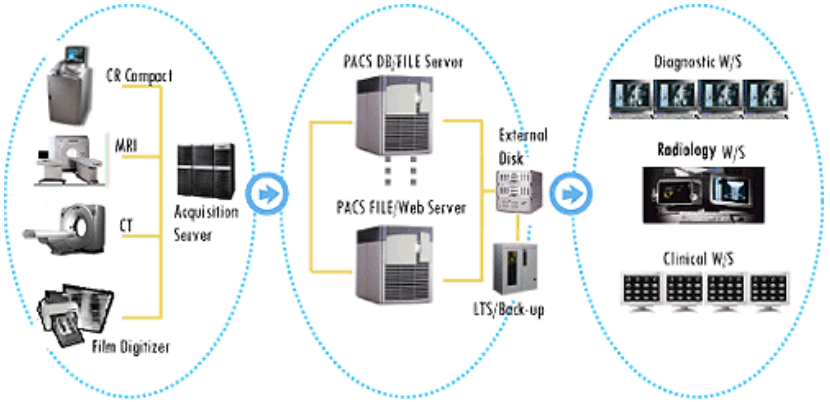
Picture Archiving and Communication system (PACS)

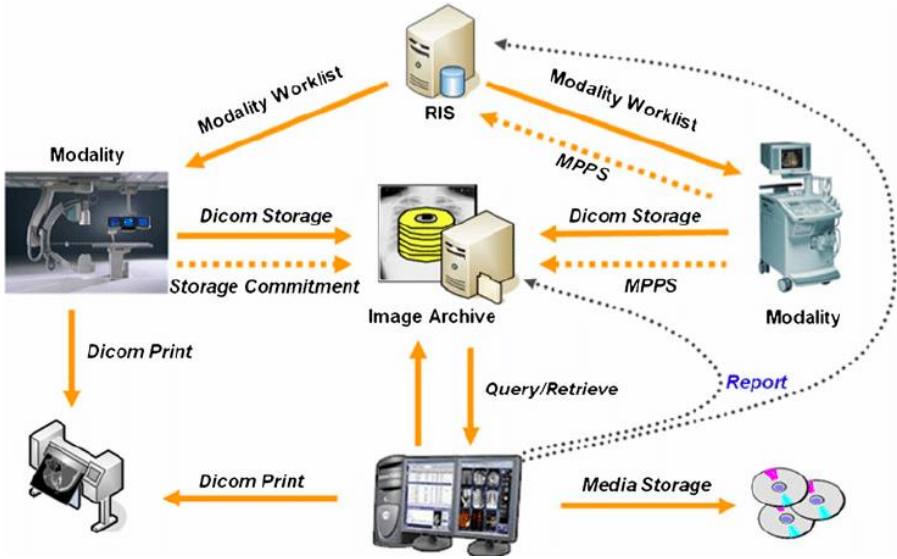
- PACS consists of the following:
  - Digital acquisition (Picture)
  - Storage devices (Archiving)
  - Display workstations
  - Components are interconnected through an intricate network (Communication)

- Radiology information system (RIS)
  - RIS is a networked software system for managing medical imagery and associated data
  - RIS is integrated with PACS

- Digital Imaging and Communications in Medicine (DICOM)
  - Standard that establishes rules that allow medical images and associated information to be exchanged between imaging equipment from different vendors, computers, and hospitals

Source: eHealth Network



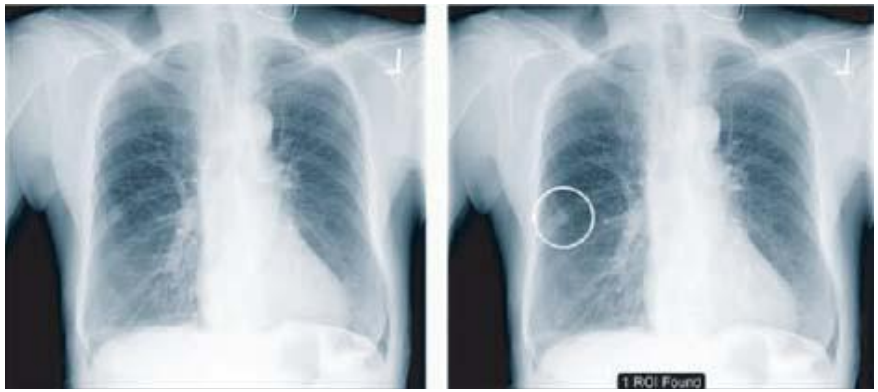


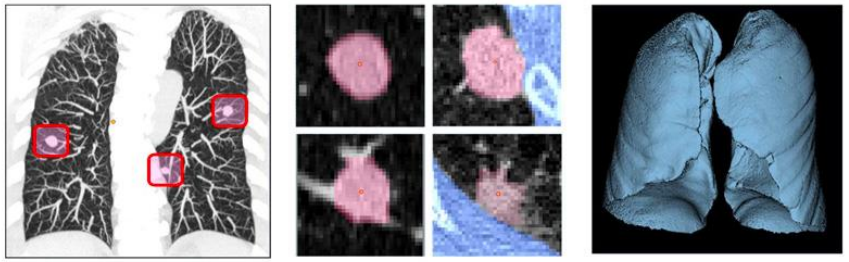
Source: Journal of Digital Imaging

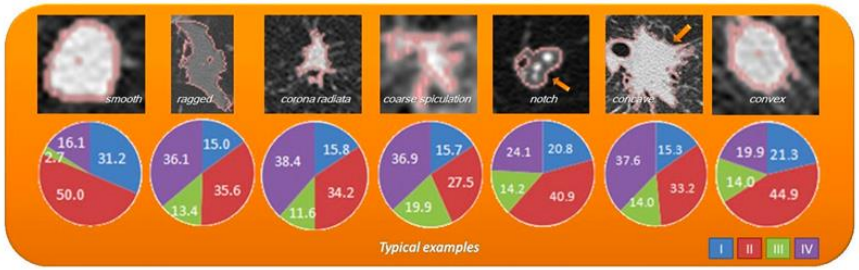
Introduction

Computer-Aided Detection and Diagnosis (CAD)

- A CAD system is a class of computer systems that aim to assist in the detection and/or diagnosis of diseases
- The goal of CAD systems is to improve the accuracy of radiologists with a reduction of time in the interpretation of images
- Computer-aided detection (CADe)
  - Used with “Screening Radiology”
  - Identify and mark suspicious areas in an image
  - Goal of CADe is to help radiologists avoid missing a cancer
- Computer-aided diagnosis (CADx)
  - Used with “Clinical Radiology”
  - CADx help radiologists decide if a woman should have a biopsy or not
  - Report the likelihood that a lesion is malignant





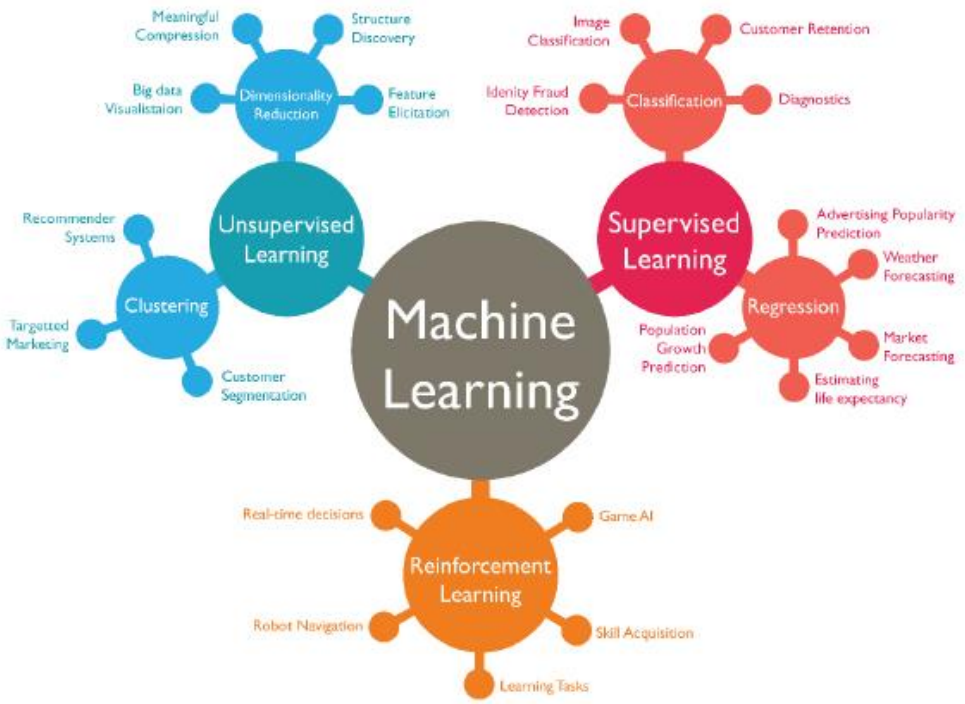


Machine Learning

How Do Machines Learn?

- "Machine learning is the field of study which gives the computers the ability to learn without being explicitly programmed"- Arther Samuels 1959

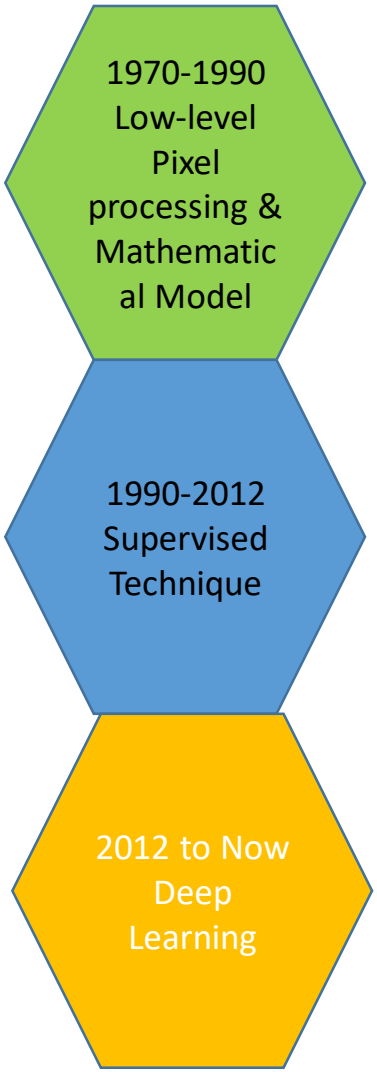
> A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E.
>
> -Tom M. Mitchell



Machine Learning

Progress in Medical Image Analysis

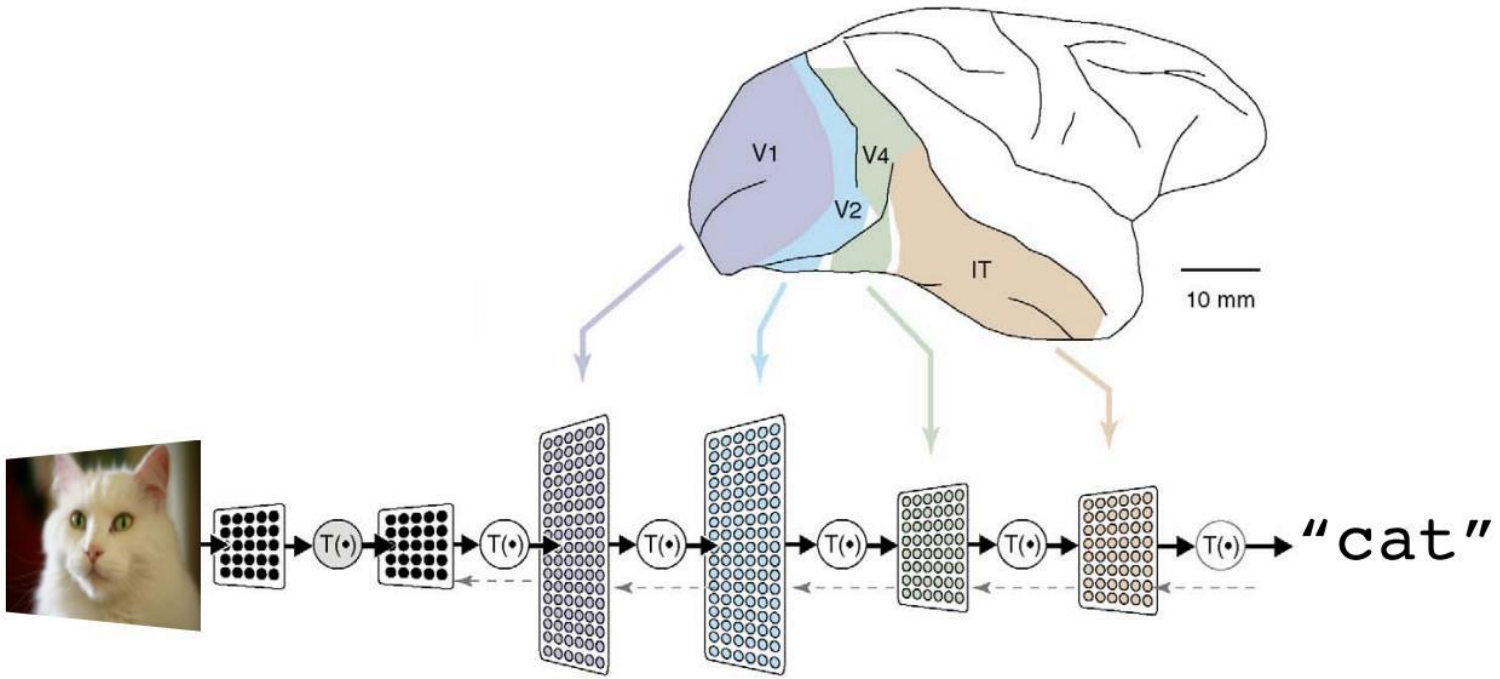
- Initially, medical image analysis was done with sequential application of low-level pixel processing and mathematical modeling
- At the end of the 1990s, supervised techniques, where training data is used to develop a system
- Deep learning algorithms, in particular convolutional networks, have rapidly become a methodology of choice for analyzing medical images



Deep Learning

Basics

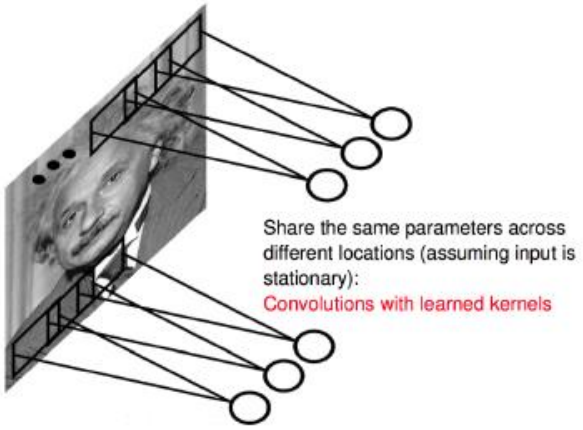
- A deep neural network consists of a hierarchy of layers, whereby each layer transforms the input data into more abstract representations (e.g. edge -> nose -> face)
- The output layer combines those features to make predictions



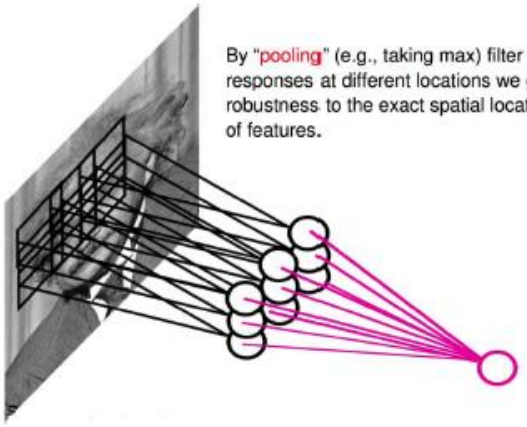
Deep Learning

Elements of Convolution Neural Networks (CNN)

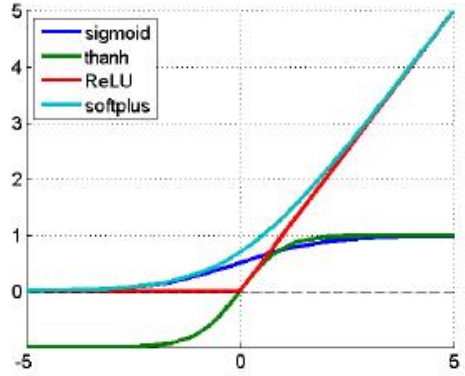
- Local Connectivity
- Parameter Sharing → Convolution Layer
- Pooling/Subsampling → Pooling Layer
- Nonlinearity → Activation Function



Convolution



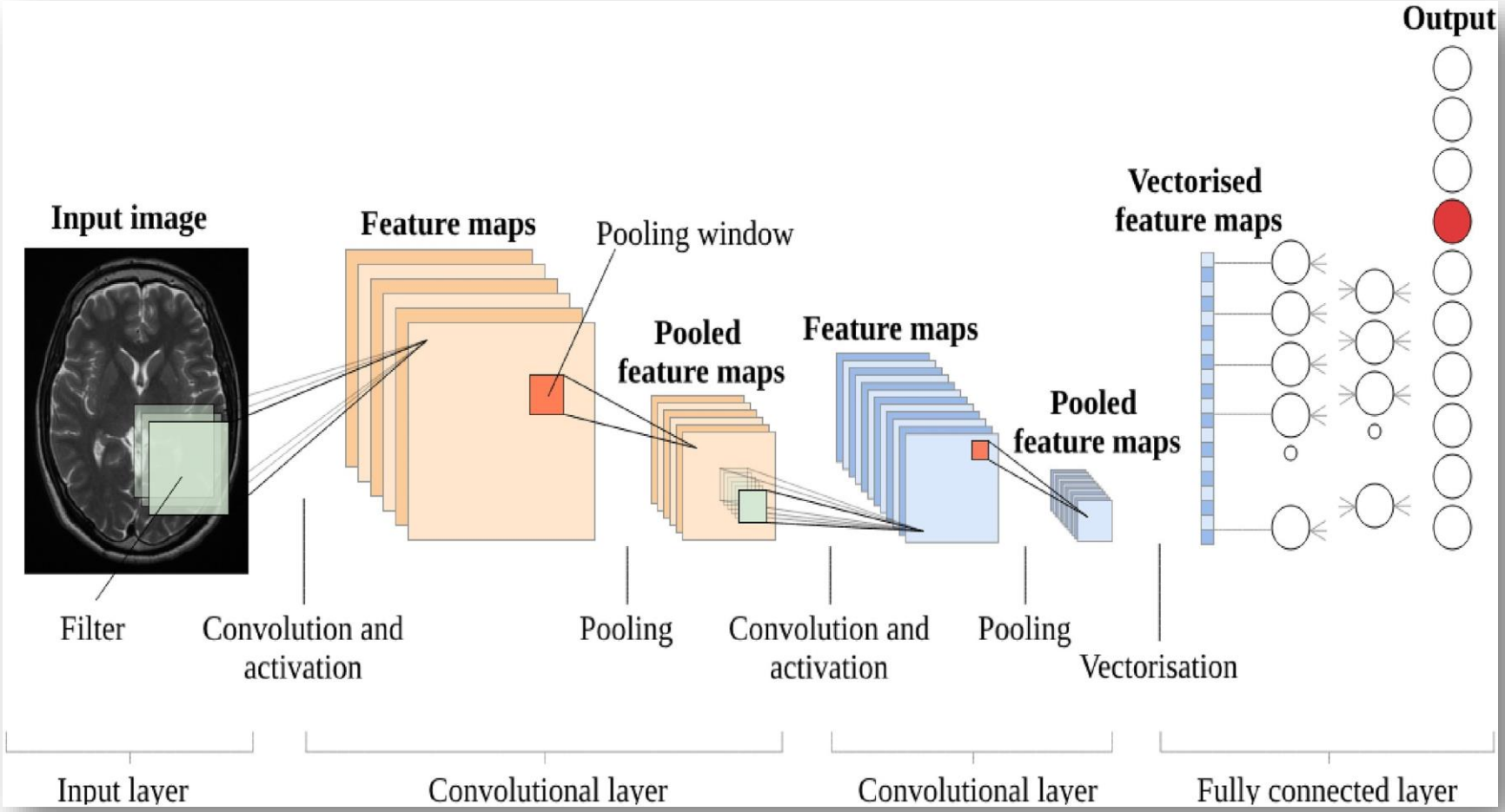
Pooling



Activation Function

Deep Learning

CNN: Putting it Together



Deep Learning

CNN Hyper-parameters (knobs)

- Convolution
  - Number of features
  - Size of features
- Pooling
  - Window size
  - Window stride
- Fully Connected
  - Number of neurons

Deep Learning for CAD

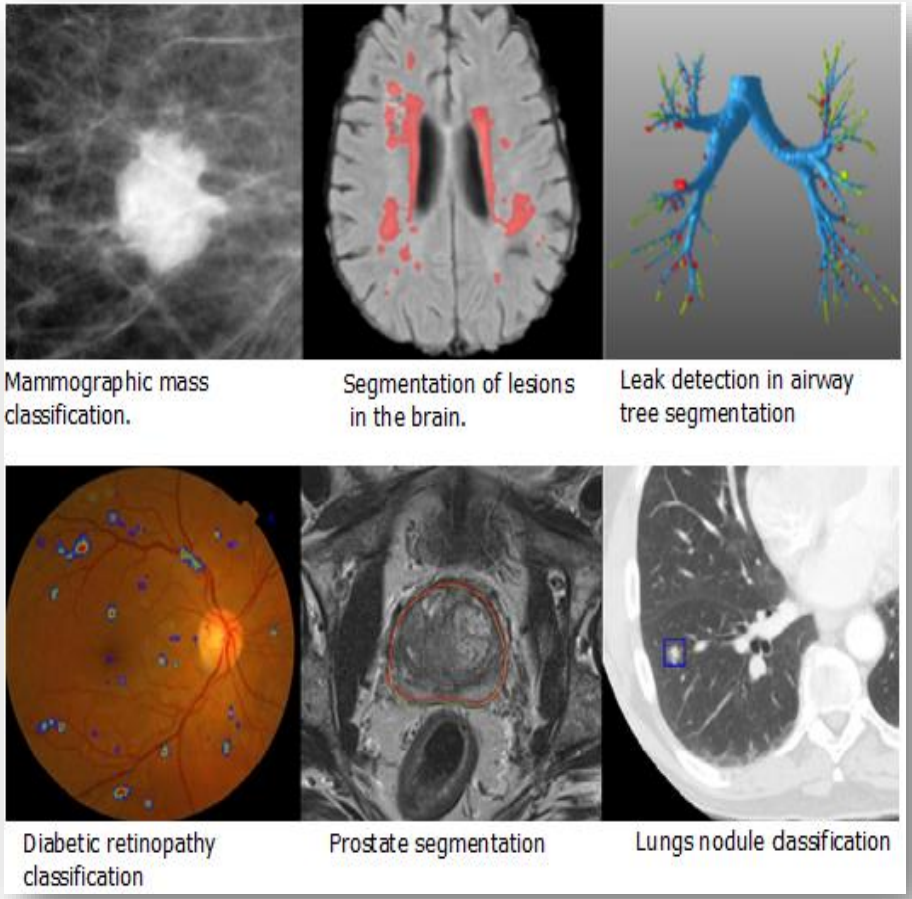
Towards Precision and Automated Diagnosis

- The deep learning techniques could potentially change the design paradigm of the CAD framework for several advantages over the old conventional frameworks
- Deep learning can directly uncover features from the training data, and hence the effort of explicit elaboration on feature extraction can be significantly alleviated
- The neuron-crafted features may compensate and even surpass the discriminative power of the conventional feature extraction methods
- Feature interaction and hierarchy can be exploited jointly within the intrinsic deep architecture of a neural network
- The three steps of feature extraction, selection and supervised classification can be realized within the optimization of the same deep architecture
- The performance can be tuned more easily in a systematic fashion

Deep Learning

Medical Imaging Tasks

- Classification
  - Object or lesion classification
  - Image/exam classification
- Detection
  - Organ, region and landmark localization
  - Object or lesion detection
- Segmentation
  - Organ and substructure segmentation
  - Lesion segmentation
- Registration
  - Multi-view
  - Multi-modal
  - Pre-Post Treatment Change



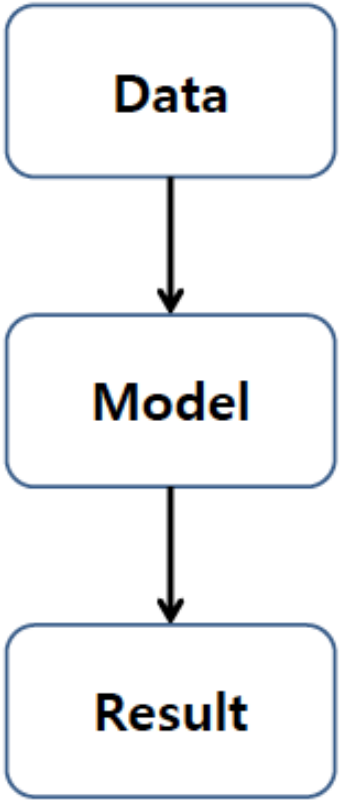
Deep Learning

Common Challenges in Medical Image Processing

- **Data Collection**
  - Dataset Size
  - What if we don't have enough data?
  - Not enough Labels

- **Model Selection**
  - Do we really need 'deep' models?
  - How to choose a model?
  - Can we accelerate training?
  - Do we require custom model?

- **Result Interpretation**
  - Can we visually interpret the result?
  - Does it help the doctors?



Deep Learning

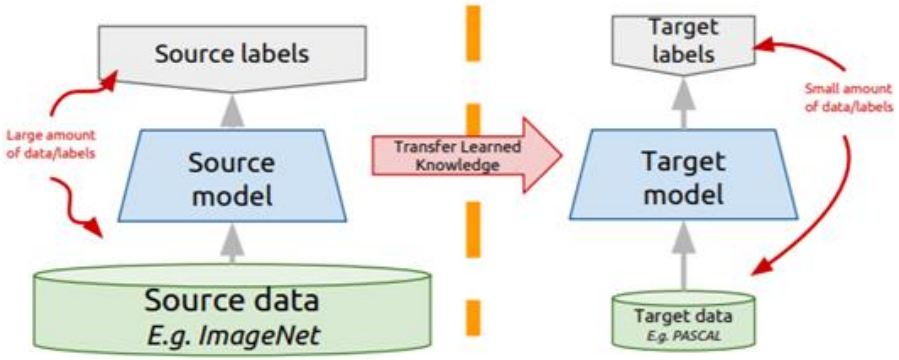
What If We Don't Have Enough Data?

- Data Augmentation for Effective Training Set Expansion

Random thin-plate Spine Deformities in 2D to generate slight variations

H. R. Roth et. al., MICCAI, 2015

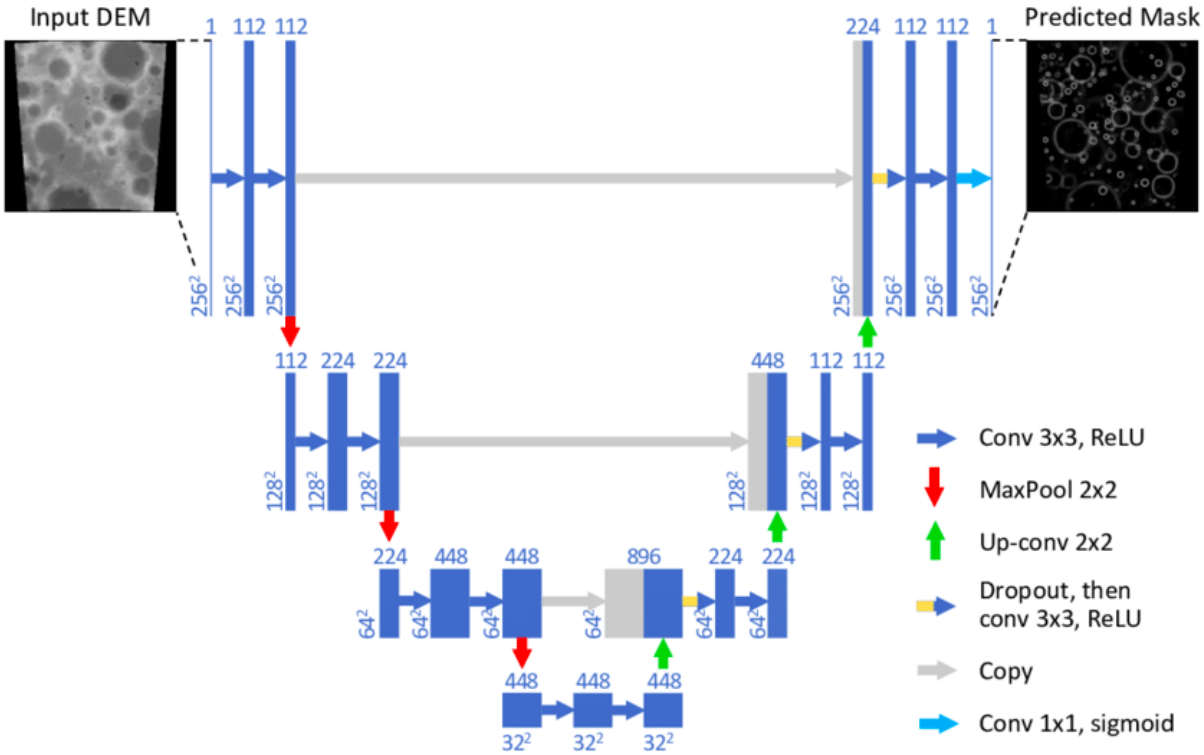
- Transfer Learning from Other Domains
  - Initializing deeper network with transferred feature leads to better performance



Deep Learning for CAD

U-net

- Winner of various image segmentation tasks
- Shows stable performance even with small annotated images

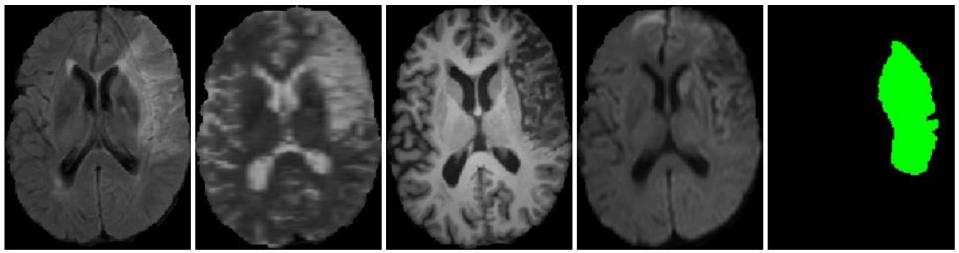


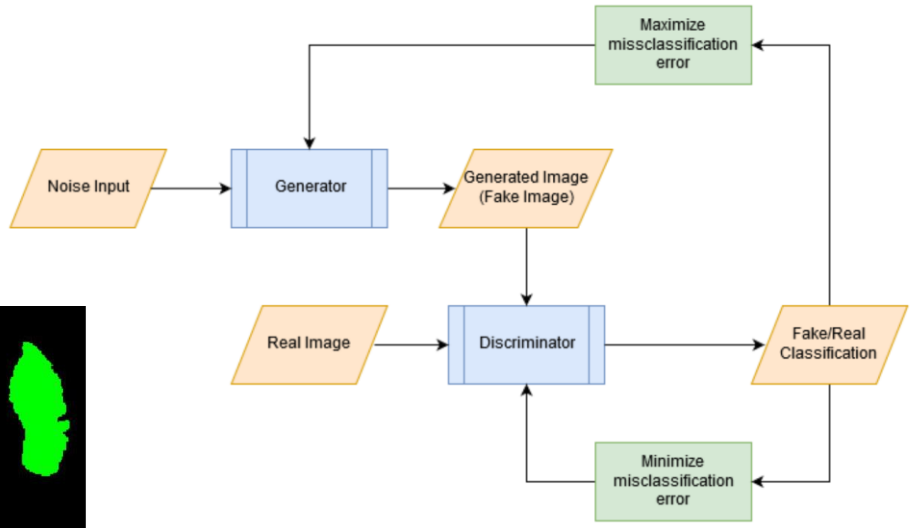
O. Ronneberger et al. 2015

Deep Learning for CAD

Brain Lesion Detection using Generative Adversarial Network (GAN)

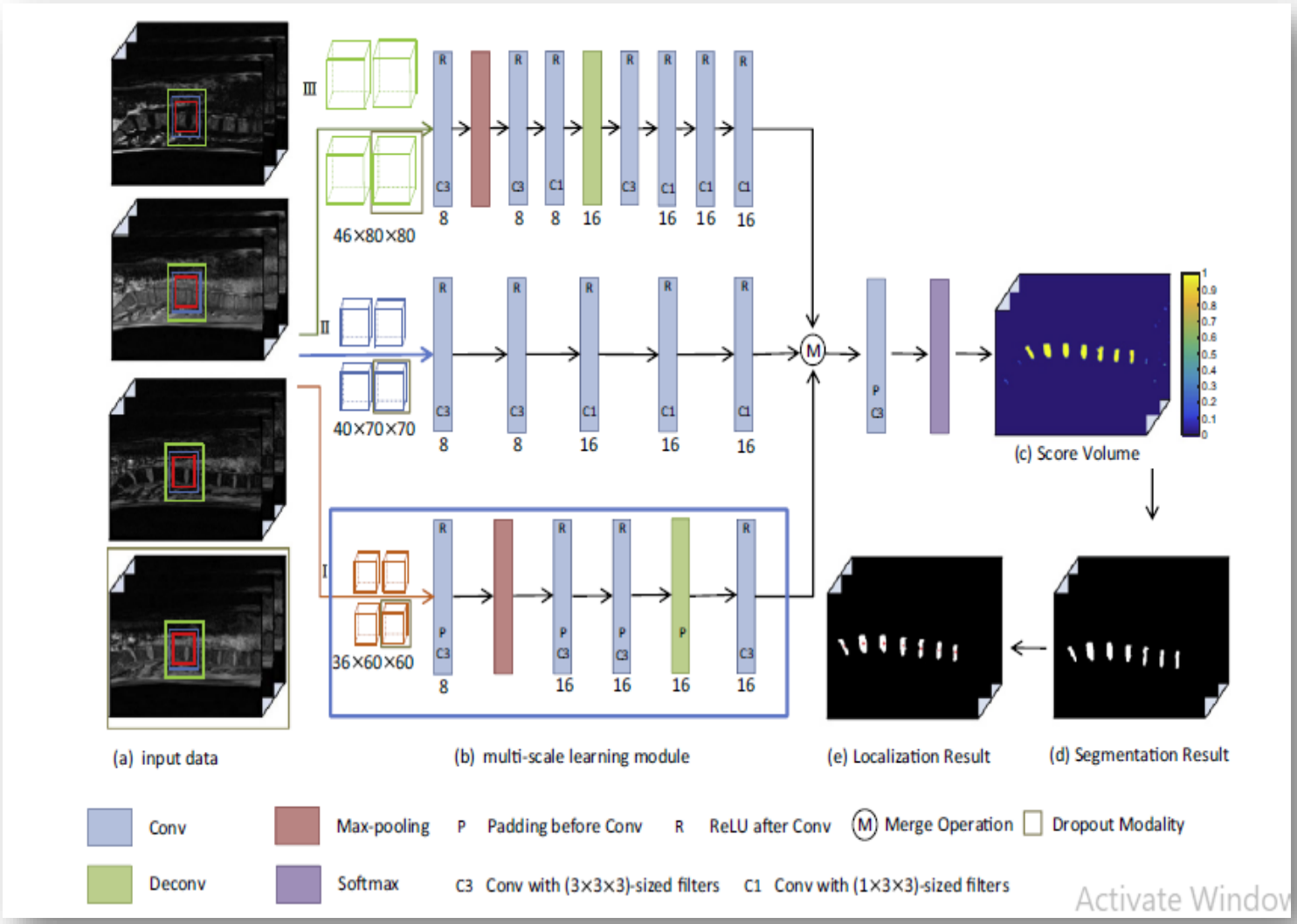
- Detect lesion in the multi modal brain images using patch wise classifier trained with GAN
- Generator generates fake non lesion patches while discriminator distinguishes real patches from fake non lesion patches





Deep Learning for CAD

3D multi-scale FCN Intervertebral Disc detection and localization

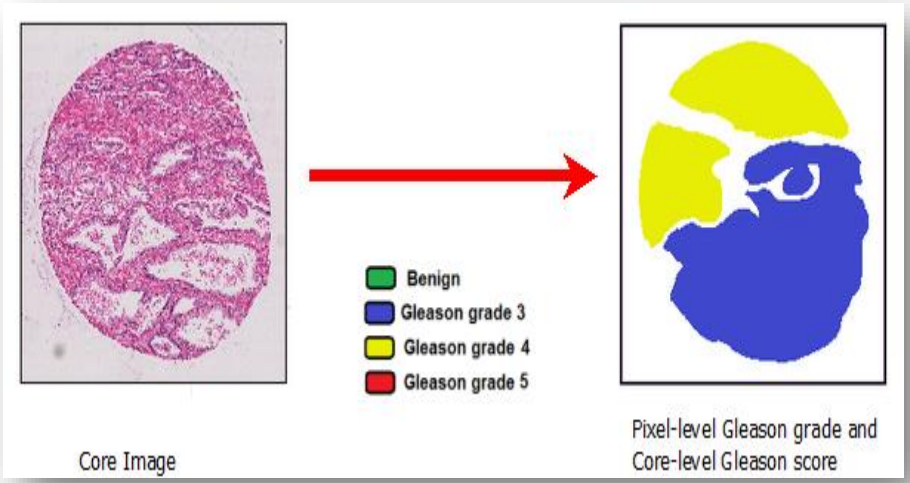


3D multi-scale FCN with random modality voxel dropout learning for Intervertebral Disc Localization and Segmentation from Multi-modality MR Images, Xiaomeng Li, Qi Dou, Hao Chen, Chi-Wing Fu and Xiaojuan Qi et al., Medical Image Analysis, 45, 2018.

Our Recent Research

MICCAI Gleason 2019 Challenge

- Automatic Gleason Grading of Prostate Cancer in Digital Histopathology Image
- The challenge involves two separate tasks:
  - **Task 1: Pixel-level Gleason grade prediction**
  - **Task 2: Core-level Gleason score prediction**
- Dataset
  - Dataset consists of 260, 4K images.
  - Approved by the Clinical Research Ethics Board of the University of British Columbia (CREB #H15-01064).
  - Annotate TMA cores as benign, and Gleason grades 3, 4, and 5 tissue.
  - Augmentation by GAN and AE

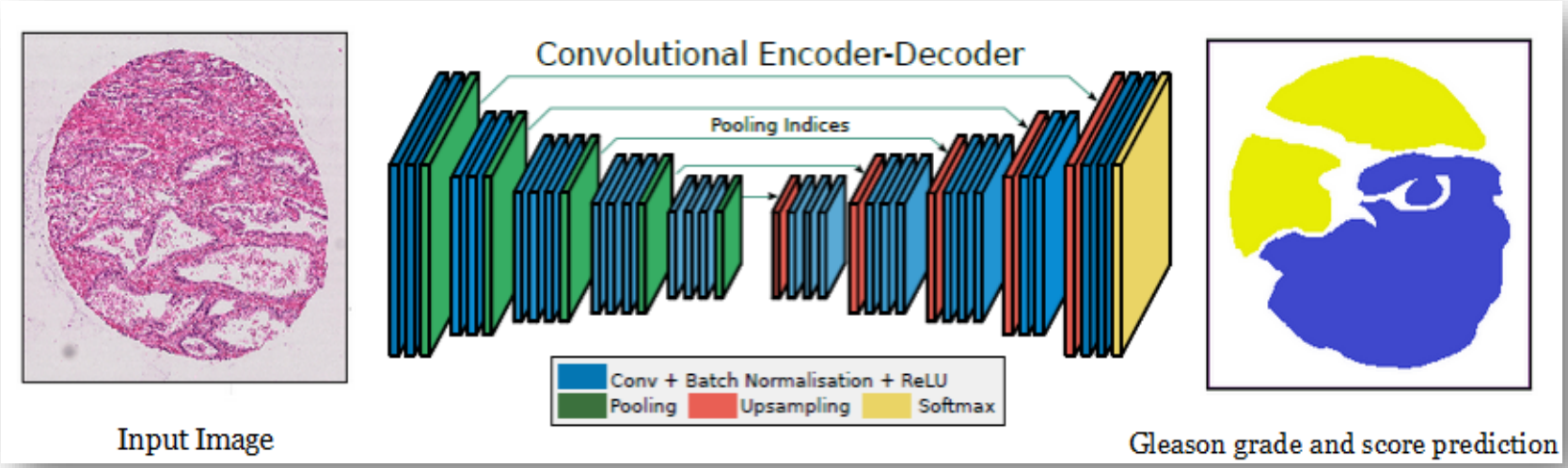


Source: https://gleason2019.grand-challenge.org/

Our Recent Research

MICCAI Gleason 2019 Challenge: Our Proposed Model

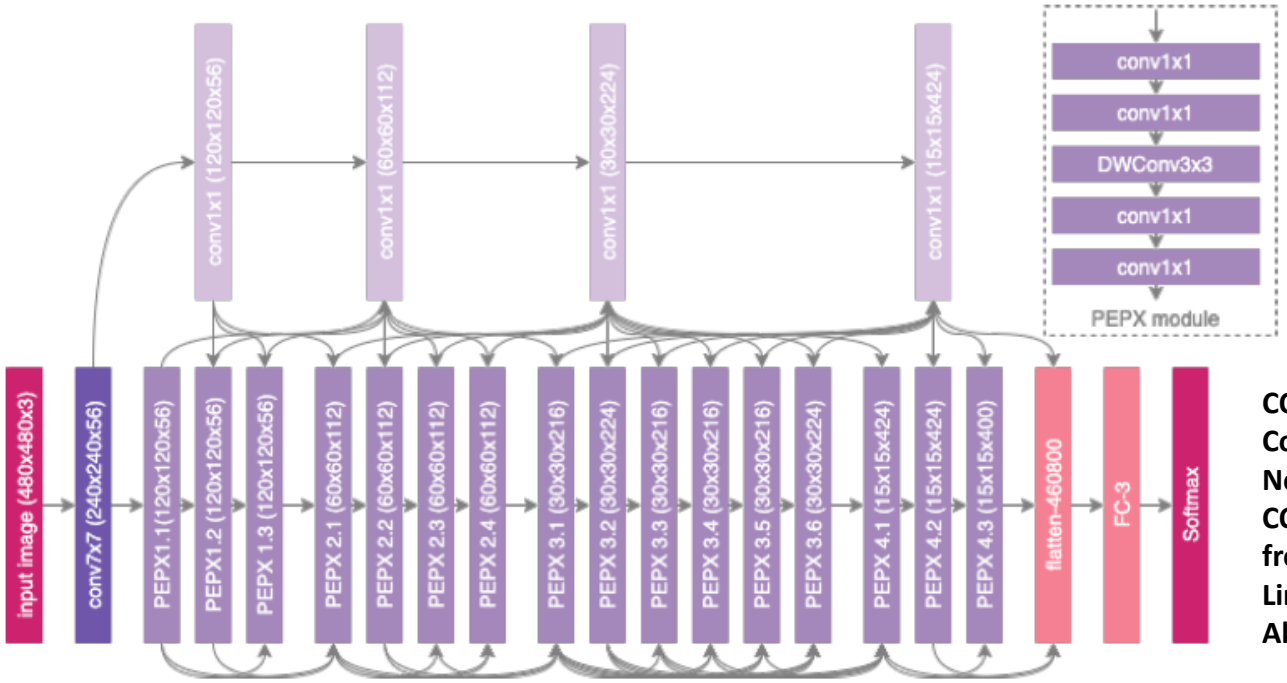
- Network
  - Fed into two branches. (RoI and a binary mask for RoI.)
- Transfer Learning
  - The MS COCO dataset contains more than 200,000 images with pixel-level annotations.



 # https://gleason2019.grand-challenge.org/Results/

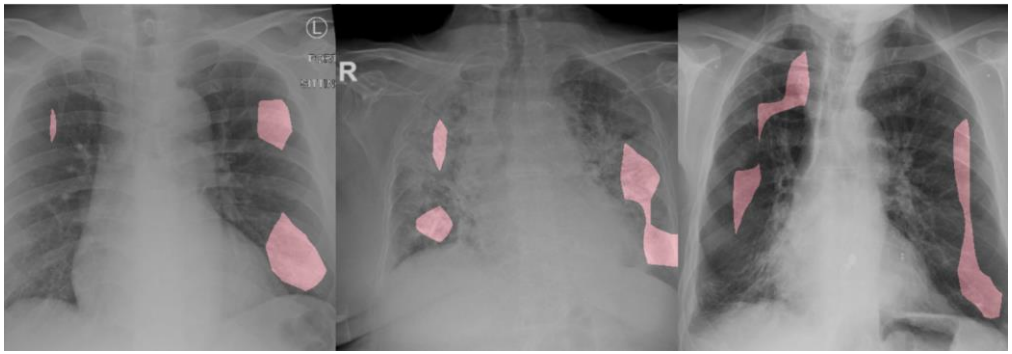
COVID-Net

Neural Network Design for Detection of COVID-19 Cases from Chest X-Ray Images



13,975 CXR images across 13,870 patient cases

COVID-Net: A Tailored Deep Convolutional Neural Network Design for Detection of COVID-19 Cases from Chest X-Ray Images
Linda Wang, Zhong Qiu Lin, and Alexander Wong



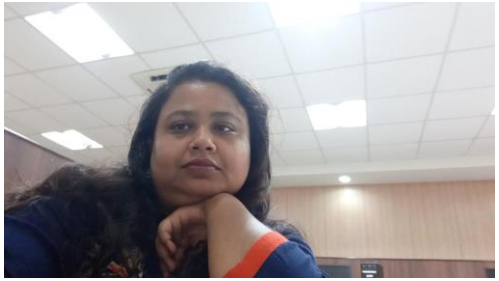
https://github.com/lindawangg/COVID-Net

Conclusion

- Deep learning based medical image analysis has shown promising results for data driven medicine
- By adopting recent progress in deep learning, many challenges in data driven medical image analysis has been overcome
- Deep learning has the potential to improve the accuracy and sensitivity of image analysis tools and will accelerate innovation and new product launches

Computer Aided Detection and Diagnosis

My Research Group @ University of Calcutta



Ms. Jhilam Mukherjee
Area: Lung Nodule Detection & Risk Prediction (X-Ray/CT)

Ms. Raka Kundu
Area: Automatic Estimation of Spinal Deformity (X-Ray/CT)

Ms. Pubali Chatterjee
Area: Brain Segmentation (MRI)

Mr. Pabitra Das
Area: Vertebra Segmentation(MRI/CT)

Ms. Somoballi Ghoshal
Area: 3D Reconstruction and Visualization (MRI/CT)


Thank You!