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Pneumonia Detection from Chest X-Ray Images

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Abstract

New test text.

Contents

1 Introduction

Pneumonia is swelling (inflammation) of the tissue in one or both lungs. It is usually formed at the end of bronchial tubes of the lungs and cause these tubes to inflame and fill up with fluid. In the UK, pneumonia effects around 8 in 1000 adults each year [11]. Global economic cost of pneumonia has estimated at $17 billion annually [9]. Currently detecting pneumonia cases heavily relies on chest X-ray image examination which requires expert radiologists to diagnose. Building intelligent system to diagnose the pneumonia can help health care services to increase efficiency, reduce costs and could help increase early diagnoses in countries with inadequate access to healthcare.

1.1 Related work

There are number of research has been published about lung diseases related detection. Most preeminent ones are the CheXNet [12] and ChestX-ray8 [14], both of these research carried out by training on same dataset ChestX-ray8 [14]. ChestX-ray8 comprises of approximately 100,000 frontal view chest X-ray images labelled by extracting information from the accompanied radiologists notes with using variety of different NLP (Natural language processing) techniques from the OpenI [10] database. ChestX-ray8 authored by researchers from National Institute of Health (NIH) and published at 2018. Most profound effect of this paper is the creation of the ChestX-ray8 dataset which has become one of the widely used dataset in computer vision research related to lung diseases. More detailed information about the dataset can be found in dataset section of this proposal.

CheXNet is another related article authored by researchers from Stanford University ML group. Prediction of lung diseases achieved by 121 layer convolutional neural network and designed to predict 14 pathologies in the ChestX-ray8 dataset. One of the major importance of this paper is the setting benchmark for human level detection for chest X-ray images. One of the most fundamental difference of the X-ray related disease prediction is the definition of human level accuracy. Due to the nature of required expertise in X-ray images leaves general public out of the scope when it comes to human level performance of these pathologies. Anyone who have not been trained in radiology will not be able to detect any lung diseases in the Chest X-ray images. For example the figure 1.1 is sample of two chest X-ray images almost indistinguishable to general audience.

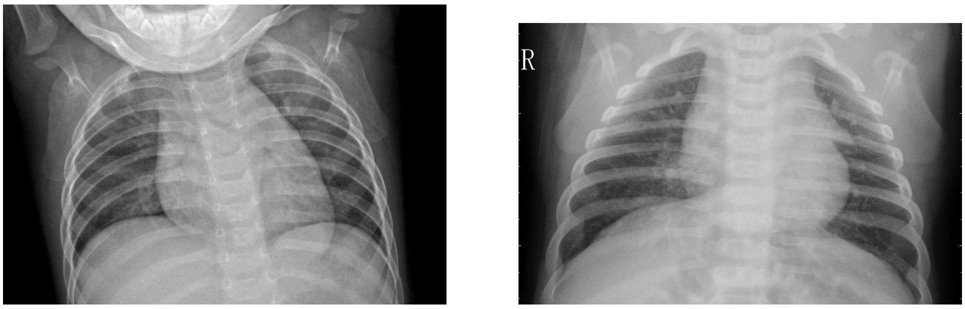

Figure 1.1: Two sample X-ray Chest images with and without pneumonia.

Given this challenge authors of the CheXNet conduct a test to establish benchmark for radiologists. They have collected 420 frontal chest X-rays and asked practicing radiologists in Stanford University to label them for all 14 pathologies. Radiologists selected with different range of experience, and had 4, 7, 25 and 28 years of experience. X-ray images presented to radiologists without any patient information or any symptoms experienced by patients and their diagnoses predictions measured based on underlying state of the X-ray patients. Fallowing is the table showing the summary statistic of this test for the 4 radiologists participated to test on F1 score, which is harmonic average of precision and recall.[12]:

	F1 Score (95% CI)
Radiologists 1	0.383 (0.309, 0.453)
Radiologists 2	0.356 (0.282, 0.428)
Radiologists 2	0.365 (0.291, 0.435)
Radiologists 4	0.442 (0.390, 0.492)
Radiologists Avg	0.387 (0.330, 0.442)

Table 1.1: Radiologist prediction performances from CheXNet [12].

Importance of this test is that it gives us a rough estimate for human level accuracy benchmark to assess the model performance for new detection models.

2 | Computer Vision

Importance of X-ray image analysis in pneumonia diagnoses clearly highlights that this is a computer vision problem. In essence computer vision is a scientific field aims to automate vision task usually performed by humans. Vision on earth begin approximately 543 million years ago when trilobites developed basic vision system [6]. Development of vision helped increase the specie variation and development on earth significantly in respect to reproduction, finding food and many other reasons. Largely due to this very important nature of vision, research in how vision performed in species and how to automate the vision task gained a lot of attraction. Early research in this field inspired by the biological vision system. More specifically model of mammal neural system in respect to vision was the center point. In 1959 experiment on cat visual system by Hubel and Wiesel [4] highlighted the inner functioning of vision by discovering effect of dark edges causing activation in visual cortex. They also concluded that visual cortex passing this signals from detected edges to later centers of the brain where those edges are combined to represent more complex shapes. This idea of simple to more complex neural structure inspired Japanese computer scientist Kunihiko Fukushima to propose system he called *Neocognitron* [2]. In the article he laid out simple to complex neural architecture which was very similar to todays convolutional neural network (CNN).

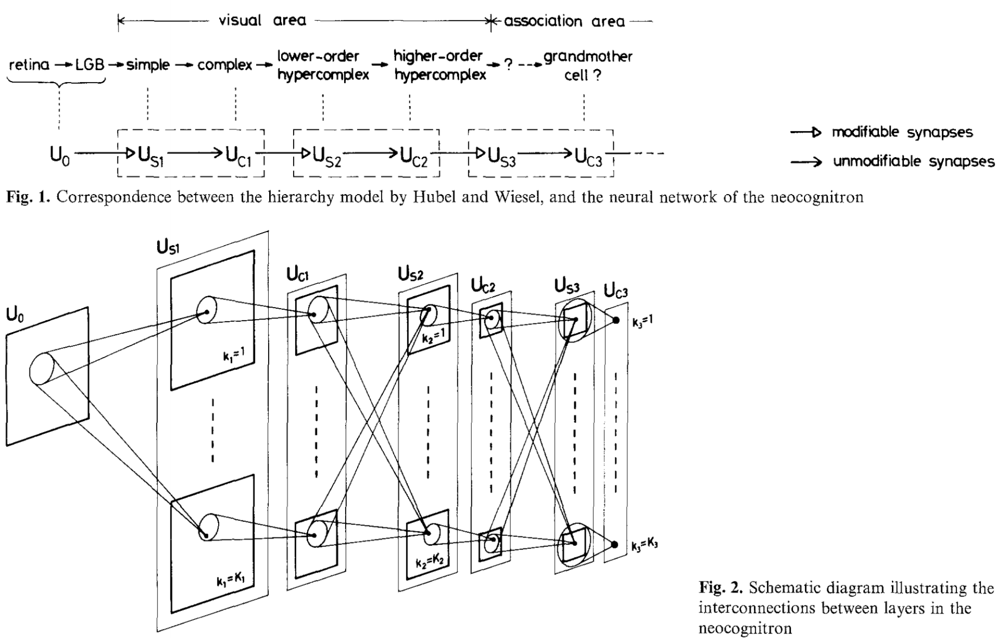

Figure 2.1: Network architecture from Neocognitron.

2.1 Convolutional neural networks (CNN's)

Although Neocognitron formed the general idea of the convolutional neural networks, it did not used the method called backpropagation that CNN's use today. Backpropagation is technique used in neural networks to propagate errors through the layers of neural network. First CNN that have the attributes same as current CNN's was build in Bell Labs in 1989 to recognize the hand written digits of the zip codes [7]. Convolutional neural network name indicates that network uses mathematical operation called **convolution**. Explaining in a simple way using definition from the Deep Learning book [3]:

> "Convolutional networks are simply neural networks that use convolution in place of general matrix multiplication in at least one of their layers."

Convolutional neural networks are generally a good option for image or time series data problems because of the sliding window approach capturing the underlying signal.

2.2 Prominent computer vision architectures

In this project I will be taking advantage of the well known network architectures for computer vision for general benchmarking purposes. These architecture generally known for their good performance in image classification competitions hence, any new design should perform better than these designs to be considered.

2.3 LeNet-5

LeNet-5 [8] is 7 layered neural network build for classifying hand written digits in checks. Numbers in checks turned into 32×32 pixel images and feed into the network for image classification task. LeNet-5 is the first successful application for combination of CNN and backpropagation. Network representation illustration and full specification of the network outlined below.

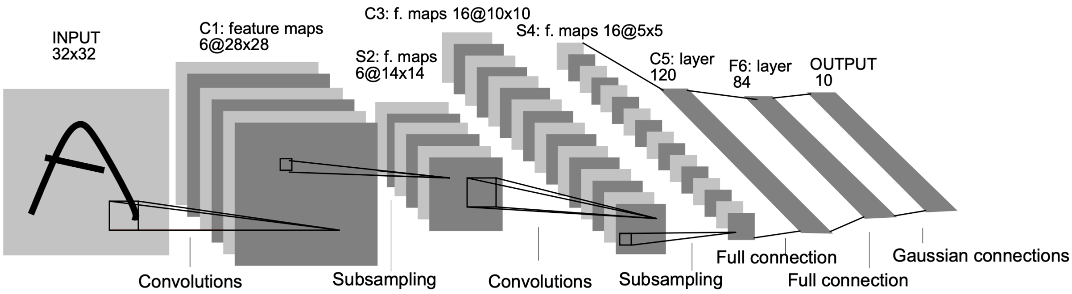

Figure 2.2: Network architecture of LeNet-5.
Credit: LeNet-5 [8]

2.4 AlexNet

AlexNet [5] designed and named after Alex Krizhevsky, and published with collaboration of Ilya Sutskever and Geoffrey Hinton (advisor). It was designed for ImageNet challenge [1] and utilized the idea of combining neural networks with graphics processing units (GPU) for high performance. This combination overcome the restriction of high computational demanding nature of neural networks and proved that current computational techniques are sufficient for training neural networks in even very large dataset such as the ImageNet. Another important implication is that AlexNet brought neural networks back to spotlight for research community after long break from LeNet-5's results.

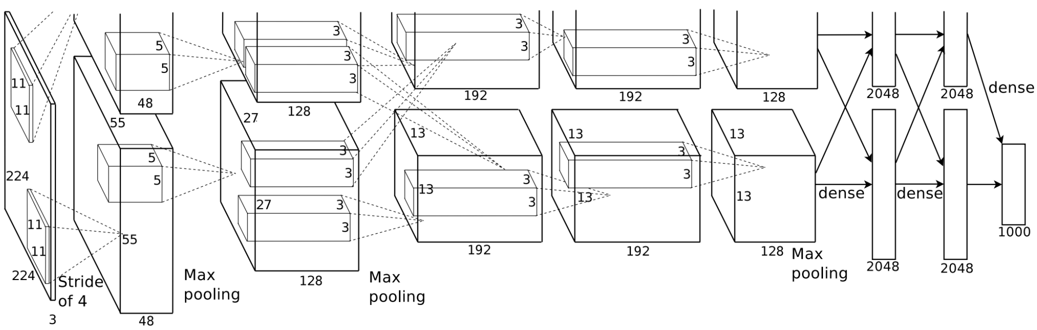

Figure 2.3: Network architecture of AlexNet.
Credit: AlexNet [5]

2.5 VGGNet

VGGNet [13] designed by Visual Geometry Group (VGG) from University of Oxford, this architecture also participated in ImageNet challenge [1] for the year 2014. This research investigated the depth of the convolution neural networks effect on their accuracy. Doing so article walks through their general layout for experimenting different depth and characteristic of neural networks with comparison. Trial error approach they assumed, presents useful methodology for network prototyping this project will use. After obtaining high accuracy from this new deeper neural network inspired many similar high depth neural network architectures to be build. Success of these deep neural networks also get popular which lead the new popular term *Deep Learning*.

References

[1] J. Deng et al. "ImageNet: A Large-Scale Hierarchical Image Database". In: *CVPR09*. 2009.

[2] Kunihiko Fukushima. "Neocognitron: A Self-Organizing Neural Network Model for a Mechanism of Pattern Recognition Unaffected by Shift in Position". In: *Biological Cybernetics* 36 (1980), pp. 193–202.

[3] Ian Goodfellow, Yoshua Bengio, and Aaron Courville. *Deep Learning*. `http://www.deeplearningbook.org`. MIT Press, 2016.

[4] David H. Hubel and Torsten N. Wiesel. "Receptive Fields of Single Neurons in the Cat's Striate Cortex". In: *Journal of Physiology* 148 (1959), pp. 574–591.

[5] Alex Krizhevsky, Ilya Sutskever, and Geoffrey E Hinton. "ImageNet Classification with Deep Convolutional Neural Networks". In: *Advances in Neural Information Processing Systems 25*. Ed. by F. Pereira et al. Curran Associates, Inc., 2012, pp. 1097–1105. URL: `http://papers.nips.cc/paper/4824-imagenet-classification-with-deep-convolutional-neural-networks.pdf`.

[6] E. N. K LARKSON. "The visual system of trilobites". In: *Palaeontology* 22 (1979), pp. 1–22.

[7] Y. LeCun et al. "Backpropagation Applied to Handwritten Zip Code Recognition". In: *Neural Comput.* 1.4 (Dec. 1989), pp. 541–551. ISSN: 0899-7667. DOI: `10.1162/neco.1989.1.4.541`. URL: `http://dx.doi.org/10.1162/neco.1989.1.4.541`.

[8] Yann Lecun et al. "Gradient-based learning applied to document recognition". In: *Proceedings of the IEEE*. 1998, pp. 2278–2324.

[9] Girish B. Nair and Michael S. Niederman. "Community-Acquired Pneumonia: An Unfinished Battle". In: *Medical Clinics of North America* 95.6 (2011). Pulmonary Diseases, pp. 1143–1161. ISSN: 0025-7125. DOI: `https://doi.org/10.1016/j.mcna.2011.08.007`. URL: `http://www.sciencedirect.com/science/article/pii/S0025712511000927`.

[10] *Open Access Biomedical Image Search Engine*. `https://openi.nlm.nih.gov/`. Accessed: 2019-03-12.

[11] *Pneumonia*. URL: `https://www.nhs.uk/conditions/pneumonia`.

[12] Pranav Rajpurkar et al. "CheXNet: Radiologist-Level Pneumonia Detection on Chest X-Rays with Deep Learning". In: *CoRR* abs/1711.05225 (2017).

[13] Karen Simonyan and Andrew Zisserman. "Very Deep Convolutional Networks for Large-Scale Image Recognition". In: *3rd International Conference on Learning Representations, ICLR 2015, San Diego, CA, USA, May 7-9, 2015, Conference Track Proceedings*. 2015. URL: `http://arxiv.org/abs/1409.1556`.

[14] Xiaosong Wang et al. "ChestX-ray8: Hospital-scale Chest X-ray Database and Benchmarks on Weakly-Supervised Classification and Localization of Common Thorax Diseases". In: *CoRR* abs/1705.02315 (2017). arXiv: `1705.02315`. URL: `http://arxiv.org/abs/1705.02315`.