Anomalies detection in Chest Radiographs using Deep Learning Approach

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***Abstract*—Medical imaging has led to improvements in the diagnosis and treatment of numerous medical conditions in patients. X-ray imaging can help medical world in various ways especially in making diagnosis a lot easier for doctors. A chest X-ray is one of the most recurrently available radiological scanning for visualizing and diagnosis of many diseases. In year 2017, a tremendous number of Chest X-ray images ha~~ve been~~ ~~provided by NIH, National Institute of health, to the re~~searches ~~all over the world. Since then, the urge to find answer to~~ ~~the question of how to use this type of knowledge containing~~ ~~scattered invaluable imaging informatics to open the door for~~ ~~data-hungry deep learning models in building a comprehensive~~ ~~computer aided diagnosis (CAD) system, has seen catching fire.~~ Several researchers have worked on detection of diseases related to chest. Our focus is to present a model which can help us detect chest anomalies using deep learning so as to avoid the lethal damage. ~~Radiology is as of now the key indicative~~ ~~gadget for various diseases and has a basic part in checking~~ ~~treatment and expecting result. The underlying foundations of~~ ~~specialization can be followed back to the specific idea of X-~~ ~~beam picture catch and the difficulty of revealing, shipping, and~~ ~~making pictures on sensitive glass plates. Pneumonia kills about~~ ~~1.5 million youngsters under 5 consistently and just in 2013,~~ it ~~was assessed that million individuals passed on of tuberculosis.~~ ~~In clinical focuses, the picture translation has been generally~~ ~~performed by human specialists and it is viewed as a long~~ ~~and muddled interaction. New frameworks consolidate AI and~~ ~~information mining procedures to take advantage of tremendous~~ ~~measure of data given by patients’ records and research center~~ ~~information. Radiologists have needed to adjust their way to~~ ~~deal with how they survey clinical inquiries. There are sorts of~~ ~~chest abnormalities that are being seen more regularly in chest x-~~ ~~beams. Radiologists should have the option to utilize new imaging~~ ~~strategies, for example, X-beam and CT checks, to recognize these~~ ~~kinds of infection~~.**

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**Over the last decade, various machine learning and deep learning algorithms have been used to diagnose various chest anomalies using different modalities for instance, X-ray, CT, etc. However, the more efficient approach and modality is still an open problem. This research is directed towards development of a computational framework to classify as well as locate fourteen chest anomalies using chest radiographs with maximum accuracy and optimum modality.**

***Index Terms*—Chest anomalies Classification, CAD, Modalities**

1. INTRODUCTION

~~One of the biggest advantages of the intermediary world of~~ ~~sciences is the invention of some of the innovative technolo-~~ ~~gies, instruments, and equipment that have led to enormous~~ ~~improvements in the world of medicine~~. Diagnostic imaging,

commonly referred to as radiology, is one of the most rev- olutionary innovations in the medical world. ~~Radiology has~~ ~~revolutionized how physicians and patients view health and~~ ~~diseases. Radiology allows medical professionals to peer into~~ ~~the interior of a living human body without having to cut it~~ ~~open. It is the paradigmatically visual discipline of the medical~~ ~~community and as such, extremely important to the growth and~~ ~~development of the field. The benefits of radiology to health~~ ~~and life (in general) cannot be overestimated. In fact, without~~ ~~radiology, it’d be impossible to recognize most contemporary~~ ~~medical fields.~~

The diagnosis of chest anomalies is relatively a new research area because the world of research has become aware of large datasets that are being provided to the research world. The classification problem of predicting chest anomalies Moreover, it is also important to know the relationship between different diseases and their effect on one another. Depending on the reviewed literature we focus on understanding how many diseases can be diagnosed at early stage via chest x-rays data. More analysis w~~ill be~~ attached later on in the project.

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The objective of the current research is to identify different chest diseases using chest radiographs. This research ~~will~~ help in predicting whether a patient have chest diseases and their impact on one another, so that appropriate decisions for proper medication can be made by radiologists. This problem will be addressed by using deep learning and survival analysis techniques based on heterogeneous data. Therefore, the problem statement of the proposed research is as follows: “With the enhancements in medical imaging field, chest related issues have witnessed considerable attention these days by the research community. This work is aimed towards development of a deep learning-based algorithm for prediction and classi- fication of different chest anomalies.”

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~~Medical imaging has altered the processes of diagnosing,~~ ~~treating and studying diseases and ailments, opening up the~~ ~~range of possibilities for patients. Due to the increase in~~ ~~the ratio of people’s trust in digital media, authenticity of~~ ~~multimedia becomes essential. Detecting the forgery in images~~ ~~is the primarily step and tracking the original source is an~~ ~~area of advance research. Prior efforts has considered forgery~~ ~~detection and provenance ltering as separate problems. How-~~ ~~ever, in our contribution we aim to combine previous efforts~~ ~~as a single problem of detecting fourteen anomalies in chest~~ ~~radiographs altogether~~. We aim to solve this problem through

state of the art deep learning techniques.

paper outline missing?

1. LITERAURE SURVEY

To recognize abnormal locations and look at the influence of preprocessing for input plans on the show of the structure, a method based on neural connections was built employing a one-dimensional numeric game plan using chest X-pillar images. Another dataset of chest x-pillar images has been handled by the Public Center for Biotechnology Information, National Library of Medicine, and National Institutes of Health, Bethesda.

Natural Language Processing was used to analyze 108,948 forward-looking viewpoint X-light emissions from unusual patients (NLP) This study shows how a poorly regulated multi-mark image classification and contamination restriction may be used to spatially organize thoracic illnesses that occur often [7]. Strain pneumothorax, gigantic hemothorax, and mediastinal hematoma are among the hazardous diseases most perceived by chest x-radiates, according to studies. X- bar images of the chest are the most well-accepted imaging method for surveying children’s patients with unpolished tho- racic damage.

Methods for dealing with images have a positive influence on clinical images and aid in the early detection of illness. The Tottori University Electronic Display Research Center has proposed a framework to check for abnormalities. A three- layered architecture that can correctly identify aspiratory han- dles. This estimation shows 75 percent accuracy when using the Rotation Forest collecting computation. P.B. Sagamihara and S. Govindarajan [**?** ] propose utilizing a central channel to remove excess noise from an image and make it more result driven.

[limitation of this work like dataset, technique, results and performance measure]

The depiction of chest x-bar photos on the network is done. The lungs’ destructive structure of septum cells may be ordered with unusual precision, and the treatment of cell breakdown in the lungs can be simplified. Investigators have demonstrated revenue in semi-supervised computations to work on PC-based plans for the prediction of recent illnesses. One of these investigations provides us with an estimate for the number of requests for lung abnormalities. Individual assump- tions have a larger role in projecting a polling form theory for convincing self-stamped assessments. Changes in social affair techniques in the semi-supervised learning framework might be used to estimate the ENSL.

[limitation of this work like dataset, technique, results and performance measure]

To form the group, the specialists utilized self-planning, Co- getting ready, and Tri-planning. The Friedman Aligned Ranks nonparametric test, like the Finer postdoc test, found that the suggested estimate of ENSL’s capacity and gathering precision were genuinely attested. In today’s world, significant learning approaches have been a focal point for disease depiction and image division efforts. In 2017, Pranav Rajpurkar and Jeremy Irvin of Stanford Center for Artificial Intelligence in Medicine released Chex Net, a computer that recognizes pneumonia using chest x-pillar with substantial findings that declare to deliver preferred outcomes above radiologists.

[limitation of this work like dataset, technique, results and performance measure]

On the largest uninhibitedly public data provided by NIH,

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ChestX-ray14, which comprises close to 100,000 chest X-shaft images, the calculation employed a 121-layered convolutional neural association. CXNet-m1 is an association suggested by Beijing Normal University’s College of Information Sci- ence and Technology. For ChestXray14, they created a new convolutional neural association (CNN) framework. In 2017, the National Institutes of Health (NIH) released one of the most comprehensive open datasets for chest radiography. By progressively establishing Convolutional Neural connections over altering important associations, it improves depiction accuracy. For early disclosure reasons, neighborhood equal model (LBP) characteristics were employed in partitioned images to organize normal vs disease on Chest X-Rays in [18]. The dataset utilized in this analysis includes 48 images that were excluded because they were private.

Lung division was conducted using 247 JSRT models, 138 Montgomery models, and 397 models from the India dataset solely in [5] and [6], with division correctness of 95.4 percent,

94.1 percent, and 91.7 percent, respectively. For early TB screening, Jaeger et al [7] split lungs utilizing the graph cut approach and employed colossal abilities from the domain of article revelation and content-based picture recuperation. (TB) The Image Clef dataset was used to categorize the various forms of X-Rays found in the dataset. In any event, they didn’t notice anything unusual about the document. They find anything unusual. Tuberculosis [8] has a precision

didn’t

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of 97 percent in recognizing aspiratory edema with a single CXR. The public datasets have been used to organize several projects. No test precision was provided, and no correlation with past findings was examined. It was difficult to assess the effectiveness of the outcomes. It has been tried to use a pre-arranged Decaf model in a two-classifier scheme of reg- ular versus pathology, cardiomegaly, mediastinum, and right pleural spread. Because the work was represented on a private dataset, no link could be established. ~~The results of this study~~ ~~were published in the Journal of the American College of~~ ~~Cardiologists.~~

1. PROPOSED METHODOLOGY

Detection of diseases from x-ray images is quite challenging task that require high level of domain expertise. To address the dependency of domain expert, machine learning researchers are focusing on automatic feature extraction for training the model. While the major advancement in automatic feature extraction using deep learning, research community is moving rapidly towards convolution neural network for classification and detection. We have employed state-of-the-art method for disease detection, Faster R-CNN (Region Convolution Neural Network) for detection of diseases from x-ray images. In our selected network, feature extraction is performed implicitly. Furthermore, Faster R-CNN provides detection results quite faster than traditional methods **(author?)** [1].

1. BACKBONE NETWORK

There is ever increasing demand in medical world and radiologists for efficient detection and diagnosis of chest

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concluding remarks on the existing approaches, what it lacks?

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section III is very small.

It needs to extend or combine with section IV.

anomalies to save human lives and help contribute in the advancement of clinical ways. This can be done by developing a model which can serve in detection of different chest anomalies, its clinical diagnosis and treatment. Proposing regions from the images requires deep convolution features, extracted from the image. These features are extracted using a separate neural network that is called as backbone network [3]. Currently object localization and classification problem is primarily dependent on the features extraction method that can eventually control the quality of the results produced. With the increasing popularity of the residual network, most of the re- searchers have shifted towards the automatic feature extraction using residual connectivity. We have utilized residual neural network (ResNet-50) [8] for the purpose of feature extraction. There are two basic benefits of the residual connectivity,

this section can be combined with othe one.

* The deeper network tend to create vanishing gradient problem because of the fact that when we go more and more deeper the changes in features become negligible that causes vanishing gradient problem. Residual connection pro- vide shortcut connections for gradient to flow that eventually lead towards learning more beneficial patterns. • The residual network also enables the network to have more insight of global and local features at the same time, as the local features concatenates with the global features in the deeper layers. In any residual network connection can be of two types. 1) Concatenating two same dimensions features to feed into next layer as defined by the equation 1. 2) Concatenating the two different dimension features for passing to next layer.

O=F(f,w*i*) + *xO* = *F* (*f, wi*) + *wjx*

/diagram/

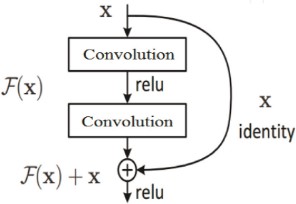


Fig. 1. Region Proposal Network

Taking features as input from previous module of backbone network, this module proposes the anchors in the image which have high probability of containing the objects. For finding the areas of possible objects, sliding window approach is utilized. A window is slided over the feature set to generate the anchors. The n\*n window is utilized with n=3 for sliding over the image. For each feature point, nine different anchors are generated having same central location (a,b) with different ratios and angles. Following figure 1 depicts the nine different

anchors with multiple resolutions and sizes on the same feature pixel. Anchors having similar color have same aspect ratio with multiple resolutions [9]. Nine different anchors for the same pixel location make number of anchors quite large. Different methods like Intersection over Union (IoU) and non- max suppression is used to reduce the number of proposals. Anchors are dropped having IoU value less than a threshold value of 0.7 as depicted by equation:

IoU =Anc *∩Gt Anc∪Gt>*0*.*7=*Object*

give the Eq No.

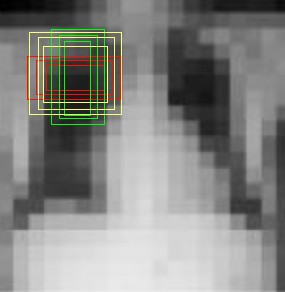


Fig. 2. Generation of nine different anchors at the same pixel feature map

1. LOSS FUNCTION

The chased number of proposals are learned by fine-tuning of weights using the different types of loss functions at the end of RPN. A simple network is utilized for this task which is responsible for two functions: classification and regression in parallel. The classification task achieved here is binary classification which identifies that a proposal contains an object or not (background) . The result of the regressor is the actual position of the bounding box with width, height and initial point. The loss function used here is shown in following equation,

Give Equ no.

L(pi,ri)=1NclsiGcls(pi,pi)+1NregiPiGreg(ri,ri)

combine

1. ACTUAL ROI CLASSIFICATION

Feature maps from RPN are first resized using ROI-pooling. ROI-pooling is responsible for making feature size consistent to be used in next stage of object classification. Now consistent sized features or RoIs resulted in RoI-pooling stage are passed to CNN network to categorize the actual object into natural class instead of object and background. This network performs two tasks: bounding box categorization and regression. Loss for each task is calculated separately and optimized. The response time of Faster R-CNN is fairly low than previously developed systems for performing similar task. Following

figure 2 provides the detailed overview of all steps involved in Faster R-CNN [5].

1. DISEASE HEATMAP GENERATION

Detection of disease is followed by segmentation of the disease to show heatmap of the diseased area. For this we have used the attention based abnormality detection. Learned feature maps from backbone network are exploited in this stage to find pathological abnormalities in chest X-ray images. We extracted the features of last layer from backbone network as an input to the attention mechanism.

The network composition of the segmentation is fairly simple as it contains only six convolution layers. Initial three layers use kernels of 1,3 and 1, respectively. Each convolution contains ReLU layer as an activation function for introducing non-linearity in the features. Output features from third convo- lution layer are used in finding discriminative localization map for each class. This localization map acts as the input of the next convolution layer. Final three layers contain fourteen 1\*1 kernels in fourth followed by 512 kernels of size [1\*1] and in the last layer a kernel of 14\*14. All the layers use ReLU activation function except last layer, which uses sigmoid. At the end of the network, we have employed class activation mappings (CAM) for finding the most reactive area for disease in abnormal image **(author?)** [2].

For generation of activation maps (CAM), we passed the image in the classification network trained for disease detec- tion. For understanding, let’s consider the feature map f is the output of the l layer and weight matrix wc,l is the learned weights for the class c in all the diseases in layer l. We used last convolution layer features for extracting CAM. This map indicates the most reactive features for a particular disease c. A map Ml is extracted by summing the dot product of the weight and features of respective layer. We can formally right using equation,

Σ

Eq. no.??

Ml = *kwl,kfl.*

Extracted map is of low dimensions as compared to the actual image because the feature size reduces as we move deep in CNN. For up-scaling the activation map dimensions, we used the scipy python library.

The overall process of the complete system is shown in figure 3. Initially input image is passed from Faster R-CNN to detect the area of the disease based on extracted deep features. We have trained proposed Faster R-CNN on fourteen different diseases that can be detected from x-ray images. Faster R-CNN provides the bounding box on the localized region for each respective disease. As from the figure it can be seen that image is passed from five different modules starting from DenseNet based backbone network. Following this, RPN network extracts regions from the image that are further passed to classification network. The last network in the Faster R- CNN categorize the region and make concise boundaries of the box. After actual selection of the disease area, the image is passed from separate CNN to find the class activation maps (CAM).

*A. Dataset Preprocessing*

1. EXPERIMENTS AND RESULTS

In this chapter results of deep learning algorithms used for classification are reported. The performance measures of the algorithms found better for classification and prediction of chest anomalies. Each deep learning algorithm mentioned in the previous chapter has been applied on the training data set. It is clear from the results that faster RCNN has proved to be the best in providing the most accurate results.

1. PERFORMANCE MEASURES

Some basic performance measures can be derived using the confusion matrix. The confusion matrix is a five by five table that contains twenty-five outcomes produced by a classifier. Several measures, such as accuracy, error-rate, sensitivity, specificity and precision are calculated from the confusion matrix. Moreover, some advanced performance measures are based on them e.g. ROC and precision-recall.

1. *True Positive*

True positives are the correctly predicted positive values which de- picts that the value of actual class is true and the value of predicted class is also true which verifies the prediction. E.g. if actual class value indicates ‘yes’ that a passenger survived and predicted class also gives the same result.

This can be presented in better way

1. *True Negative*

These are the correctly predicted negative values which means that the value of actual class is no and value of predicted class is also no,e.g. if actual class indicates ‘no’ that is a passenger did not survive and predicted class also gives same results i.e. ‘no’ which mean the same thing.

1. *False Positive*

When actual value of class is depicting ‘no’ and predicted class is giving ‘yes’. E.g. if actual class says about a passenger who did not survive but predicted class gives you ‘yes’ that means passenger will survive, such case is called False positive.

1. *False Negative*

When actual class is yes but the class predicted by the model is no. e.g. if predicted class indicated that passenger will die and in actual class the same passenger survived. FP (False Positives) and FN (False Negatives occur when the actual class contradicts with the predicted class in the model.

1. ~~ACCURACY~~

Accuracy is the most important performance measure and it is sim- ply a proportion of truly predicted measures to the total observations measured. It concludes that if we have higher accuracy then our model is better. Accuracy is considered as a great measure for performance evaluation. For ANN model, we have got 0.937 which means our model is approx. 93.7 accurate. Accuracy of Classifier = (TP+TN)/(TP+FP+FN+TN)

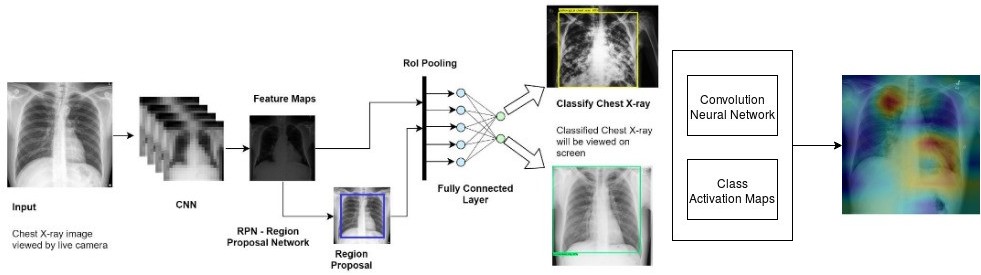


Fig. 3. class activation maps (CAM)

TABLE I: Results obtained after applying data mining algorithms.

|  |  |  |
| --- | --- | --- |
| Classifier | Accuracy on cross-validation | Accuracy on unseen data |
| C4.5 | 72.78 | 71.68 |
| Rule induction | 71.90 | 70.09 |
| Naive Bayes | 86.85 | 85.70 |
| SVM | 91.10 | 89.51 |
| ANN | 95.55 | 93.79 |

TABLE II: Benchmark of proposed work with existing Techniques

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Study | Number of Anomalies | Data set | Classification techniques | Result |
| X.Wang et al.(2017)[1] | 8 | Chest X-rays8 | 90 | 90 |
| M.Bindi et. al [40] | MCI/Dementia MCI/NC | Tadpole | Fuzzy NN | 76,91 |
| Proposed Solution | CN,MCI,AD | tadpole | Random Forest NaiveBayesian | 96.62,91.05 |
| Proposed Solution | CN,EMCI,LMCI,SMC,AD | tadpole | SVM,ANN | 89.55,93.79 |

1. PRECISION

Precision refers to the closeness of two or more measure- ments to each other. Using the example above, if you weigh a given substance five times, and get 3.2 kg each time, then your measurement is very precise. Precision is a measure of result relevancy Precision is defined as the number of true positives samples over the sum of total number of true positives samples false positives samples.

Precision of Classifier = TP/(TP+FP) Precision attempts to answer the following question: What proportion of positive identifications was actually correct? It is an important perfor- mance measure. A model that produces no false positives has a precision of 1.0.

1. SENSITIVITY

Sensitivity or Recall is the fraction of truly predicted positive measures to the all values measured in the actual class. What proportion of actual positives was identified correctly? Recall = TP/(TP+FN)

1. LOSS

In mathematical optimization, statistics and machine learn- ing a loss function maps an event or instance of one or

more variables onto a real values naturally demonstrating some “cost” related to the event. The lower the value of loss, the better is the performance of the model but model should not be over-fitted to the training data. The loss is calculated from training and validation accuracy. The interpretation that how well is the model is working for testing and training sets. Loss of model is not a percentage. It is a sum of all the errors made for each sample in training or validation data-sets.

1. COMPARISON WITH EXISTING TECHNIQUES

A lot of research is being carried out on chest diseases in the past years. The classification problem of predicting chest anomalies has shifted from two class problem of distinguishing healthy control subjects from Alzheimer’s patients to a far more challenging classification problem of predicting multiple anomalies during its progression root causing one another [6]. This research field has clinical applications as radiologists can not only effectively diagnose chest disease but also identify the different types of diseases the patient is suffering from and whether the subject will progress to next anomaly. This will allow them to make well suited decisions for patients such as prescribing proper medication and psychological interventions.

Our proposed methodology is able to classify and predict fourteen different chest anomalies with accuracies better than any other existing studies.

A comparison benchmark of our proposed work is made with the existing techniques available in literature, on the same data- set is shown in the Table below. The classification models found in re-

search system used only 2 or 3 number of classes on TADPOLE data-set. P. J. Moore, et. al used random Forest technique and could give an accuracy of 82 percent only. When we performed this three class classification, Naive Bayesian approach gave an accuracy of 91 percent and Random Forest gave an accuracy of 96 percent. In this research the classifica- tion problem is refined to fourteen classes for better diagnosis and prediction of disease. Our system gave an accuracy of

92.79 percent for Faster RCNN.

Section V

1. CONCLUSION

This research presented a different approach for diagnosis and classification of anomalies present in chest radiographs that are with different organs associated with chest for in- stance, lungs, ribs, diaphragm, stomach etc. and locating the type of anomaly in the chest radiograph. After data analysis, different deep learning algorithms are employed for classifi- cation of fourteen chest anomalies of chest. The maximum accuracy of 92.79 percent is achieved using Convolutional Neural Networks on unseen data which is found to be higher than any existing research. Therefore, it has been concluded that CNN is a better detection of chest anomalies in x-rays. The use of deep learning in medical support system need to be more investigated and applied in numerous biological fields [4]. The proposed system is designed for detecting fourteen chest anomalies which can be further extended to more anomalies ranging from lesser to greater severity in hopes that more fatal condition could be detected earlier. This will help in early diagnosis of the specific stage and better treatment can be proposed according to the exact condition of the patient. Proposed system is designed using SVM and CNN, it may be improved using other algorithms of deep learning for more classes and better results for diagnosis and prognosis. Also, the classification accuracy can be a focus of future work.

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1. Aurelia Bustos, Antonio Pertusa, Jose-Maria Salinas, and Maria de la Iglesia-Vaya´. Padchest: A large chest x-ray image dataset with multi-label annotated reports. *Medical image analysis*, 66:101797, 2020.
2. Xi Cheng, Youhua Zhang, Yiqiong Chen, Yunzhi Wu, and Yi Yue. Pest identification via deep residual learning in complex background. *Computers and Electronics in Agriculture*, 141:351–356, 2017.
3. Kaiming He, Xiangyu Zhang, Shaoqing Ren, and Jian Sun. Deep residual learning for image recognition. pages 770– 778, 2016.
4. Chang Liu, Yu Cao, Marlon Alcantara, Benyuan Liu, Maria Brunette, Jesus Peinado, and Walter Curioso. Tx- cnn: Detecting tuberculosis in chest x-ray images using convolutional neural network. pages 2314–2318, 2017.
5. Christiane Mo¨ller, Yolande AL Pijnenburg, Wiesje M van der Flier, Adriaan Versteeg, Betty Tijms, Jan C de Munck, Anne Hafkemeijer, Serge ARB Rombouts, Jeroen van der Grond, John van Swieten, et al. Alzheimer disease and behavioral variant frontotemporal demen- tia: automatic classification based on cortical atrophy for single-subject diagnosis. *Radiology*, 279(3):838–848, 2016.
6. Barath Narayanan Narayanan and Russell C Hardie. A computationally efficient u-net architecture for lung seg- mentation in chest radiographs. In *2019 IEEE National Aerospace and Electronics Conference (NAECON)*, pages 279–284. 2019.
7. Adrien Payan and Giovanni Montana. Predicting disease with 3d convolutional neural networks. *arXiv preprint arXiv:1502.02506*, 2015.
8. Jue Wang, Sheng Luo, and Liang Li. Dynamic prediction for multiple repeated measures and event time data. *The annals of applied statistics*, 11(3):1787, 2017.

some more recent paper can be added. `

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REFERENCES

[1] Hamed Behzadi-Khormouji, Habib Rostami, Sana Salehi, Touba Derakhshande-Rishehri, Marzieh Masoumi, Siavash Salemi, Ahmad Keshavarz, Ali Gholamrezanezhad, Majid Assadi, and Ali Batouli. Deep learning, reusable and problem-based architectures for detection of consolidation on chest x-ray images. *Computer methods and programs in biomedicine*, 185:105162, 2020.