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IDENTIFYING GLOMERULI IN HUMAN KIDNEY TISSUE IMAGES USING PATTERN RECOGNITION METHODS

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ABSTRACT

Glomerular disease is the result of conditions that affect a particular part of your kidneys called glomeruli. Glomeruli is a small network of blood vessels that are the "cleansing units" of your kidneys. They filter the waste and remove excess fluid from your bloodstream. “an approximate of one million glomeruli in each human kidney”. Normal glomeruli typically range from 100-350μm in diameter with a roughly spherical shape when glomeruli are damaged and unable to function properly, it is called glomerular disease or glomerular malfunction. Glomerular malfunction can damage your kidneys which could also eventually lead to kidney failures. Therefore, this paper presents a convolutional neural network model for image segmentation which uses pattern recognition methods to identify the position of glomeruli in the human kidney tissue images. The paper aims at the comparison between neural networks namely faster region based convolutional neural network and mask region based convolutional neural network for effective identification of glomeruli in human kidney tissue images.

Keywords: Glomeruli, Region based convolutional neural networks, kidney tissue images,Faster Region based convolutional neural networks, Mask region basedconvolutional neural networks

1. INTRODUCTION

Health care is the most important need of the modern era. Health care means improving a person's health by preventing, treating, diagnosing, recovering from a health risk caused. Therefore, improving the health status of human system technologies, such as machine learning, in-depth learning and artificial intelligence has begun to work. The integration technology with the health sector has had a huge impact and success in the world. Healing millions of diseases, analysis of various diseases, providing accurate diagnostic results and advanced nutrition testing are now possible with the advent of technology. The word glomeruli is derived from greek which means filters. According to a study quotes that around million glomeruli are present in each kidney

Glomeruli gets damaged due to the glomerular disease the glomerular membrane gets damaged and the protein and blood present in the blood stream passes through the glomerular membrane resulting in decreased levels of protein’s in the blood stream .In the second case toxic substances present in the blood does not pass through glomeruli resulting the toxic substances and urine gets deposited inside the blood stream itself and the level of urine in the blood builds up in the blood stream.Glomerular disease are the disease which are caused in the cellular level hence the tests which are performed should be performed in the cellular level itself .To identify the abnormalities in the cellular level renal biopsies are carried out in which a small piece of kidney tissue is extracted with the help of needle and is observed under the microscope to observe the changes in the shape of glomeruli which comes in handy while identifying the disease caused in the glomerular level.Observing manually with the help of traditional process such as utilization of microscope to observe the slides under the microscope is time consuming.

Therefore, this paper presents a Convolutional neural network model for image segmentation which uses pattern recognition methods to identify the position of glomeruli in the human kidney tissue images. There are several neural network based models were built to identify the glomeruli. This paper aims at a comparison between the two Region based convolutional neural network and proposes a comparatively best Region based convolutional neural network as a result.

2. LITERATURE SURVEY

Many researcher's took part in the task of detecting and classifying glomeruli in human kidney tissue images. Here are some of the researches took place in past few years.

In 2021, N Bouteldja[1] in their paper "Deep Learning-Based Segmentation and Quantification in Experimental Kidney Histopathology". Proposed a convolutional neural network which had a architecture which aimed at the segmentation of kidney tissue images obtained from an healthy mice was obtained to train the neural network with healthier glomeruli and another five diseased samples were been taken from unhealthier species. The convolutional neural network were trained for six models one model being healthier and other five models being diseased. The neural network was been trained to identify and segment various renal structures such as glomeruli, bowman's capsule, veins, arteries, nephrons. The neural network was trained with more than 70,000 samples to get more accurate results. While computational feature extraction was performed on the diseased model it showed that the diseased model was found to be having various symptoms such as interstitial expansion, tubular dilation and atrophy, and glomerular size variability

In 2021 Cascarano GD [2] in their work "A neural network for glomerulus classification based on histological images of kidney biopsy" has proposed a Computer aided design model which was manly based on machine learning and image processing technique which aimed at classifying the glomeruli based on diseased condition namely sclerotic and non-sclerotic images which helps in nephropathology to determine the glomerular irregularities. The dataset on which the model was trained consisted of 29 slide images which was obtained by kidney autopsies of 19 patients the slides were stained with periodic acid Schiff. The slides were annoted manually. on the above annotations feature extraction was performed and the obtained patterns were made as a classifier features which helped the artificial neural network to discriminate between the glomeruli class. The results were excellent obtaining precision of 0.98 and recall of 0.93.

On 2020, Gloria Bueno [3] in their work "glomerusclerosis identification in whole slide images using semantic segmentation". A convolutional neural network were proposed to detect the glomeruli present in the whole slide images .in this work there was a comparision between U-net and seg-net which are popular convolutional neural network mainly meant for segmentation of medical images were employed to identify the glomeruli in the whole slide images and to classify them based on the dieseases. The images were obtained in the form of 47 whole slide images which was derived from human renal autopsies and all the slides were stained with periodic and Schiff the comparision between both the algorithms resulted in signet - alexnet being superior with the results in comparision with U-and the results were good with 98.16% of accuracy.

Zeng C, [4] in his work "Identification of glomerular lesions and intrinsic glomerular cell types in kidney diseases via deep learning" proposed a deep convolutional neural network was to identifiy the glomeruli and also to identify the glomerular lesions which enabled to identify various glomerular cells which helped to give treatment instructions and evaluating kidney diseases. The renal biopsy samples obtained in the form of whole slide images were subjected to a segmentation with the help of deep convolutional neural network and trained to identify the glomeruli and glomerular lesions and also to detect the decomposition of glomerular. In this computer aided diagnosis of glomeruli nearly 360 whole slide images with more than 41000 patches with Periodic acids Schiff stained images which were obtained from patients were used for training and 41 whole slide images were used for testing and the permance of the model was evaluated with the various parameters such as precision and recall whose result was found to be having a precision of 0.931 and average recall of 0.949 for all the variants of the glomerular disease based slides.

On 2019, S Kanan [5] in their work "segmentation of glomeruli within trichrome images using deep learning" proposed a convolutional neural network to identify and classify the glomeruli within trichrome images which were cropped manually. The images were classified into three classes namely "No glomeruli", "normal or partially sclerolised glomeruli" and "globally sclerolised Glomeruli". the dataset consisted of trichrome stained images of renal biopsies performed on 170 patients in the Boston medical center were analyzed. The images were cropped into many slices

resulting in 751 non glomerular region, 611 images with partially sclerolized glomeruli .The cropped and labelled images are fed into the glomeruli resulting in the accuracy of 92.67 and kappa score of 0.86.

In 2019, M. Hermsen [6] in their work "Deep-learning based histopathologic assessment of kidney tissue" aimed at the usage of neural network for computer aided analysis of whole slide image of kidney glomeruli which was stained with the help of periodic acid schiff were subjected to training the neural network. The 40 images of kidney tissues which was obtained from "Radboud university medical center, Netherlands" was labelled for multi class classification and introduce to four separate data sets and subjected to multi class segmentation with the help of neural networks and was evaluated for various parameter such as glomerular detection rates and dice coefficient and the neural network found to have very excellent result such as 0.94 dice coefficient.

In 2019. Sheehan S [7] in their work "Detection and classification of novel renal histologic phenotypes using deep neural networks" has proposed a deep neural network to analyze periodic acid Schiff stained whole slide images of renal biopsy which was obtained from the renal biopsy performed on the mice of different genotypes. The main objective of the work was to show that the deep neural networks performs excellently in medical image processing tasks. The deep neural networks were trained to perform automatic segmentation to show the presence of the glomeruli in the histologic images. The work made use of Alex-net to obtain various patterns from the input image and Alexnet was trained with thousand samples for classification and to obtain the final confidence score and classification Support vector machine was used and was found to have excellent results against the glomeruli segmentation.

In 2018, Simon O [8] in their work "multi radial LBP features as a tool for rapid glomerular detection and assessment in whole slide histopathology images" proposed a method for training the machine learning algorithm Support vector machine with the help of feature vectors known as "local binary patterns" which was caluculated with the help of " multi radial color local binary pattern" which will be formed by analyzing the RGB values of the histopathological image. The local binary pattern was used to train the support vector machine and to caluculate the likelihood of presence of glomeruli in the human kidney tissue image and thus detection of glomeruli would have been taken place. The work resulted in having a precision of 90% and a recall of 70%.

In 2018 ,Buckwoy JD's [9] work " Region based convolutional neural nets for localization of glomeruli in trichrome stained human kidney tissue images" proposed a "machine learning based image classification algorithm" to examine the morphology of the kidney tissue image. The whole slide images which had a kidney tissue image of rats and the size of the tissue was about 4 micro meters was obtained. A dataset consisting of 74 training images and 13 text images in which about 28000 glomeruli was manually localized was fed into the neural network resulting that the neural network achieved an average precision of 96.94 and average recall of 96.74.

In 2017, Pedraza [10] in their work "Glomeruli classification with convolutional "neural networks" proposed a convolutional neural network to perform a classification on the whole slide image which was obtained during human renal autopsy . The whole slide images had two classes namely "glomerulus" and "Non glomerulus" the convolutional neural network which was used here was Alex Net . the results obtained here showed that the neural network was suitable for glomerular classification and the robustness was high .

3. PROPOSED SYSTEM

The project aims at comparison between the two convolutional neural networks namely faster region based convolutional neural network and mask region based convolutional neural network which is employed to overcome the above defined disadvantages of the existing methodologies.

Faster Region based convolutional neural network

The paper proposes faster region based convolutional neural network to detect the glomeruli in the human kidney tissue image by encapsulating the glomeruli present in it with the help of bounding boxes and the performance measure of the faster region based convolutional neural network is measured in terms of ground truth values. The ground truth values of the prediction are calculated by evaluating whether the bounding box of the prediction overlaps the given bounding box.

Higher the area of overlapping higher the ground truth values. And lesser the area of overlapping lesser the ground truth values. Even though faster region based convolutional neural network is slower while compared to other neural network the performance of faster region based convolutional neural network is higher while compared to other convolutional neural networks since faster region based convolutional neural network which does not restrict the size of the input image given to it we can perform operation on large sized images.

Faster region based convolutional neural network consist of two parts namely "region proposal network (rpn)" and "network that classifies objects in the proposed region"

The input image is processed with a convolutional neural network the convolutional neural network has two layer one convolution and one pooling layer. The function of the CNN is to extract the feature from the input image and pass them to the region proposal network and hence the convolutional neural network is known as feature extractor.The extracted features from the feature extractor is scanned with the help of sliding window present in the RPN to calculate the presence of object and to detect whether object is a background or not. With the sliding window of fixed size it's complicated to detect various shapes and hence anchor boxes containing different scales and aspect ratios are introduced. Anchor boxes contain multiple k windows which retrieves 4k parts of information about the area and 2k parts of information about the class. Which results in the candidate region which are extracted from the RPN being redundant due to the proposal of multiple regions by the region proposal network to the same object. To solve the above problem with the help of "Region of interest pooling" the ROI's are pooled down to fixed size windows which in turn is given as a input to "fully connected layer". In the final stage "bounding box regression" and "object classification" is done in a supervised Manner.

Mask Region based convolutional neural network

Mask Region based convolutional neural network is an extended version of Faster region based convolutional neural network where the segmentation is carried out in a pixel level. The main goal of Mask Region based convolutional neural networkis to predict the masks of the given object. The architecture of Mask Region based convolutional neural network is similar to faster region based convolutional neural network additional to that a mask predictor is present along with classifier and object detector. Each region of interests segmentation mask is predicted in a pixel to pixel manner with the help of mask branch. Since prediction of masks is a pixel level segmentation task and has much more refined alignment while compared to bounding boxes based prediction the RoI layer is upgraded to "RoI align layer which is designed to fix the location misalignment caused by the quantization in the RoI pooling.

4. SYSTEM DESIGN

The system which has been proposed to detect the glomeruli consists of various steps

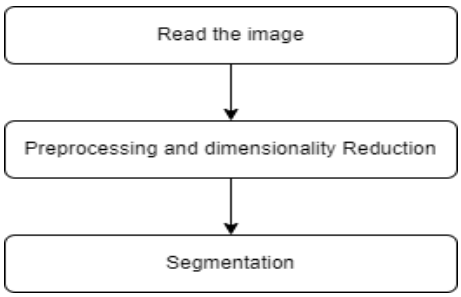

FIGURE 1: System Design

a) Read the image

The image obtained from the dataset for training and testing consist of the images which are saved in the form of tag image file format is a large sized file which is unable to be read by traditional image viewer but can be read with the help of a python library named tiffile. The Unique names of the images is appended to the list and a path which leads to images is specified and a function is called which reads unique names of the images present in the list and retrieves the images which is present in the specified folder and reads it with the help of the library tiffile.

b) Preprocessing and dimensionality reduction.

The data preprocessing step involves various processes such as

a. Converting RLE encodings to masks

The run length encodings of the image are converted from vector form to the image form. The images which are generated from the run length encoded values consist of white patches above the dark back ground called masks. The white patches represent the position of the glomeruli.

b. Resizing the images and the masks.

The train images along with their mask are resized to a definite proportion the resized image and the resized mask of the corresponding image consist of the same size in terms of scale and the test images are also resized into a definite scale. The reason behind the resizing of images is dimensionality reduction which reduces the computational time.

c. Converting the images into grey scale.

As a part of dimensionality reduction the images are converted to greyscale. The Colored image consist of three layers RGB which contributes to a three dimensional tensor certainly requiring more computational power. When the images are converted to Grayscale the images have only one layer which contributes to a matrix of 2 dimensional data form which requires less computational power while compared to the RGB image.

d. Slicing the image.

The greyscale converted images of both training and testing are converted into small partitions of a similar size and proportions .One single grey scaled and resized images is sliced into several portion of small sized tiles so that there are large number of image samples to train the neural network and slicing improves the image segmentation task and also more the training samples more accurate the results, hence image slicing is done so as to view the smaller part of a larger image in a larger view point which enables the neural network to train efficiently. Hence, the gray scaled images are sliced into smaller part for efficient training of neural network.

e. Slicing the masks

The masks of the corresponding images are sliced down into the same sized slices as of the images. The sliced tile of a mask should be of the same size as of the corresponding image slice which is sliced earlier if a mask differs slightly in size when compared to the training images leads to misleading the information given to the neural network which might resulting in the decrease in performance of the neural network .

c) Segmentation.

The images are subjected to segmentation with the help of two region based convolutional neural network models namely faster region based convolutional neural network and Mask region based convolutional neural network. During the process the glomeruli present in the kidney is distinguished with the help of masks or the bounding boxes. A brief comparison between the models are done to propose a best model among both the models for the image segmentation tasks.

Dataset

The data set is derived from hubmap .The dataset is comprised of very large (>500MB - 5GB) TIFF files. The training set has 8 images meant for training, and the test set has 5 images. The training set includes annotations which are present in the form of Run Length encoding (RLE).Run-length encoding (RLE) is a data compression technique which contains sequences in which the same data values present in consecutive data elements which are stored in the form of single data value and count. Run length encoded values in the dataset is present in the Comma Separated Value file. Each image has a unique ID and also the Run Length encoded representation of the mask for the objects in the image[11-14].

The images are in TIFF (Tagged Image File Format) which was earlier used format to save the scanned images. The images consist of the cross sectional view of human kidney tissue images which was obtained during human renal autopsy of the diseased human beings.Since the images were unable to be opened using the traditional image viewers, we used python to check the size of the images and also the Run length encoding was not been able to be viewed using excel .the comma separated values file was opened in the jupyter notebook with the help of read_csv command. The comma separated value file named as train.csv consists of the unique identity names of each image and also the run length encodings of the masks which enables to generate the masks using python programming. The masks which are generated by preprocessing these encoding values consists the position of the glomeruli present in the human kidney tissue images in the form of light patches present above a black ground the white patches are similar to spherical shape which represent the position of glomeruli present within the image of the kidney[15-16].

5. SYSTEM IMPLEMENTATION

After the data preparation part now, we can push the data into both the neural network to obtain the results and compare against one another. Thetraining process is given below

Specify the path for the image and data path.

The path of the files where the images are stored are specified as image path and path of the csv file where co-ordinates of the glomeruli present is stored as the data path.

Convert data frame of co-ordinate into array of bounding boxes

The co-ordinates of the glomeruli which is found using cv2.countour function and stored in the form of data frame. Is converted into array of bounding boxes helps in comparison between the actual results and obtained results.

Create a helper function to get the model

A helper function is created to get the model. The function named get model is defined with number of classes as a input. The function imports a previously trained model of faster Region based convolutional neural network and takes several input features such as class scores, and returns a Faster Region based convolutional neural network model which predicts the boxes. The function is shown in the figure given below.

Glomeruli Class dataset.

Create a Glomeruli dataset class which returns the values of boxes , image id , labels, the area encapsulate by the boxes. And whether the segmented part is glomeruli or not. The dataset is mainly used to plot the original bounding box and to compare between the predicted box and give ground truth values.

Function to flip the images while training

Define a function using transforms to flip the images while training which helps the neural network to give good results against the test images.

Set up the training and test data set:

The training and test data set is set up initially by loading the dataset followed by splitting up of the dataset for training and testing. After the dataset is split into train and test parts the training and validation data models are defined. The images are horizontally flipped using transforms function to train the neural network efficiently.

Implement the model

Both The models are executed.The number of epochs is set as 10 and the model is executed. The learning parameters will be already pre-defined in the previous function the value of momentum is set as 0.9, and the optimizer is set as stochastic gradient decent and central processing unit as the device since graphical processing unit is not available and the print frequency is given as 200. And the model is subjected to training with ten epochs.

6. RESULTS

The Faster Region based convolutional neural network yielded a mean average precision 0.576. network took 1 hour 48 minutes to train and the highest ground truth value was observed to be 0.9976. The faster Region Based Convolutional Neural Network also yielded an average recall of 0.656.

The mask region based convolutional neural network obtained the average precision of 0.588, the highest ground truth value was observed to be 0.9973. The faster Region based convolutional neural network also yielded an average recall of 0.658.

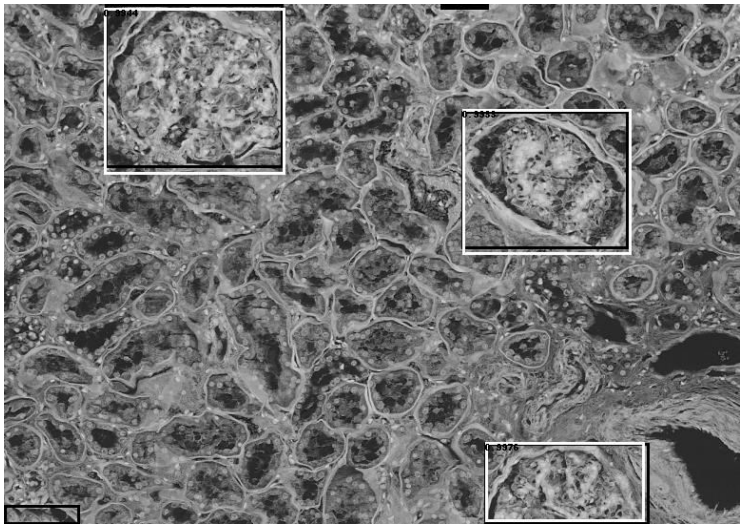

FIGURE 2: Faster RCNN Results

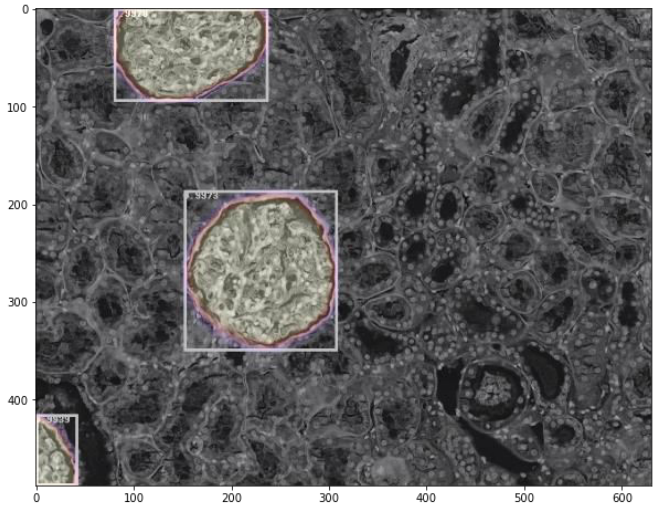

FIGURE 3: Mask RCNN Results

7. CONCLUSION AND FUTURE WORK

On comparing the results obtained by both the algorithms mask region based convolutional neural network has obtained higher accuracy in comparison to Faster Region Based Convolutional Neural Network. In case of time constraints the Faster Region Based Convolutional Neural Network work efficiently while compared to Mask Region Based Convolutional Neural Network.In the further work the algorithms could be trained with the various learning parameters and also with various optimizer techniques and also along with increased number of epoch the algorithms may expected to have better results. Improvement in results can also be done by finding efficient slicing methods.

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