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Classification of Pap smear images for Cervical cancer using Convolutional Neural Network

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Abstract: ***Classification of Pap smear images for cervical cancer consists of two types namely, normal and abnormal cancerous cells. The dataset involves 7 sets of classes of cancerous images which have 3 sets of normal cancerous images and 4 sets of abnormal cancerous images. The proposed work performs two stages of classification. The first stage of the work is classifying the data as normal or abnormal cancerous cells. In the second stage of the work, the class of the cancer as normal columnar, normal intermediate, normal superficial, light dysplasia, moderate dysplasia, severe dysplasia and carcinoma_in_situ are classified. The proposed work gives good results for classifying images for 3 sets of classes and 4 sets of classes for normal cells and is able to classify and detect normal and abnormal cell accurately.***

Keywords: ***Deep Learning, Convolutional Neural Network, Cervical Cancer, Pap smear images***

I. INTRODUCTION

Image processing, one of the fields of digital signal processing has made tremendous progress in the field of medical science. Image analyzing and processing techniques has given solutions to many of the problems in this field. The study for optimizations in finding out solutions for problems has been going on from past few years. The study on deep learning and machine learning has given a lot of scope for researchers in finding out the solutions for new concepts in this field [1].

The processing of images along with machine learning or deep learning have been already used to detect many types of cancers namely breast cancer, lung cancer, etc., The cancer can be detected and classified using images as dataset or text as dataset [1].

The detection of cervical cancer in early stages is a challenging task because the test results do not provide appropriate results (symptoms of disease) for analysis of cancer. The cervical cancer is clinically tested using a test called "Pap test or cervical test or screening test". Cervical cancer is the world's fourth most commonly found type of cancer in women [2].

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The diagnosis of cancer is the first step. After detecting the cancer, next step is to detect the class or type of cancer depending on the classes namely normal or abnormal. It also indicates whether the patient has the chances of developing cancer or not in future and treat them properly as per results. Some of the results may not require treatment and can be cured by itself as in classes of abnormal namely light dysplasia, moderate dysplasia. The results showing abnormality of cells may require further treatment.

II. CERVICAL CANCER

A. Cervical Cancer

Cervical cancer is one of the types of cancer mainly found in only females. This cancer is detected in the cervix part of uterus which connects to the vagina. Consuming birth control pills, multiple sexual partners, smoking, early sexual contact and sexually transmitted virus called Human Papillomavirus (HPV) which causes infections in vagina are the main causes of cervical cancer [3]. During the early stages of the cancer, there will be no symptoms found.

B. Pap smear Images

The images obtained from the screening test of the cervix part are called pap smear images. These are also called as cervical images or papanicolaou images. The cervix part will be screened for any cancerous or non-cancerous results. The images mainly focus on the cells in the cervix which are called as cervical cells or shortly cervix cells. Depending on cells we consider it has normal (Squamous) or abnormal cells as shown in fig 1 and fig 2[4].

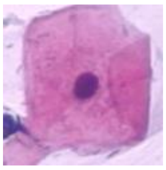

Fig 1:Normal cell image.

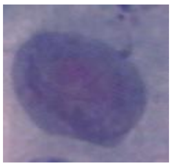

Fig 2:Abnoraml cell image

C. Convolutional Neural Networks

In the past few years computers have been the conventional tool of approaching a problem. This means computers are made to follow a set of instructions provided by the user. The problem here was that the user used to know how to solve a problem even without computers. Hence the new concept called "Neural Networks" came into existence. Neural Networks work similar to human brain. They learn from examples and modify themselves to neutralize the problems.

The term “neurons” are inspired from biological word. The neurons are made to learn from a huge set of data and are trained to solve the problems. It has Artificial neural networks and Convolutional Neural networks. The more advanced architecture to define neural networks can be used by deep convolutional neural networks..

Convolutional Neural Networks feed forward the artificial neural network in which the connectivity pattern is inspired by the organization of the animal visual cortex. Visual cortex is a small region in brain which is sensitive to specific regions of visual field. Basically, when a human sees an image, he just can see it through naked eyes and not be able to interpret the image. But when the same image is processed by the computer, it uses primary colors to interpret the image and gives results in the form of different pixels.

Convolutional neural networks do not need any pre-processing techniques. They use the trained data and classify the data. The images taken as data are nothing but a matrix of pixel values. The CNN captures the spatial and temporal dependencies in images through operations called “filters”.

Convolutional neural networks work in many layers. They are namely:

1. Input layer
2. Convolutional layer
3. Pooling layer
4. Fully connected layer

Apart from this, ReLU layer, softmax function and flatten layers are seen in CNN as shown in fig 3.

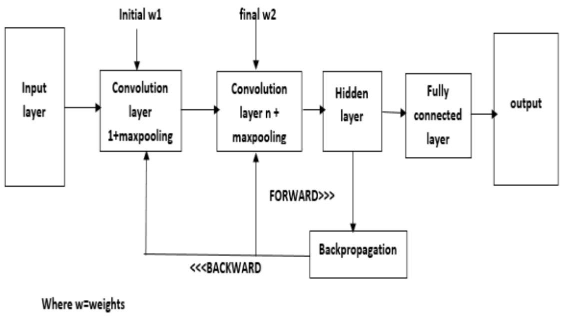

Fig 3: CNN Architecture

The input layer takes images(data) as the input and converts into matrix form and reads the values present in each pixel.

The convolutional layer is used to reduce size of images which is easy to understand and process without losing any features of images. Convolution layer consists of filters called as convolutional filters used for isolating image and mapping them one by one for analysis. These filters can also be used in dimensionality reduction.

mathematical equations. The mathematical equation given below illustrates how an image is processed in CNN algorithm using filters and channels. The analogy can also be applied for image classification comparing the results for different sets of classes of images.

The CNN module can be depicted using the parameters represented as filter f, and input image is I, kernel k, x and y are rows and columns of matrix of image,

Then dataset is represented as:

$$G[x,y] = €\{I(x*k)+(y*k)$$

The image is applied with certain number of filters and channels. The pooling layer applies certain number of stride and padding to the image. This can be interpreted as: m as image size, b as filter size, n as number of channels in the image, p as padding, s as stride, c as number of filters then:

$$[m,n]*[b*n]=\{([m+p-b/s]+1),\ldots\ldots\ldots\ldots\ldots..,c\}$$

The processing of image using CNN can be analyzed for a particular image considering image size and applying filter size, channel size for extracting features must be equal to a image applying padding which is dividing image in some part of matrix by stride, applying the number of filters.

The next layer is pooling layer which is used to reduce the spatial size of the image. The size reduction can also be done by reducing dimensionality or by extracting specific dominant features. There are two types of pooling layers max pooling and average pooling. Max pooling gives the max value of all the values in the image portion whereas average pooling takes the average of all the values of images portion and gives the value. The max pooling is used most of the time as it gives maximum value and is used mainly in dimensionality reduction and noise suppression. The ReLU stands for Rectified linear unit which is used as activation function. The softmax is also a type of activation function used instead of ReLU function in the last layer of CNN. The flatten layer is used to convert the data into single dimensional value as shown in fig 4.

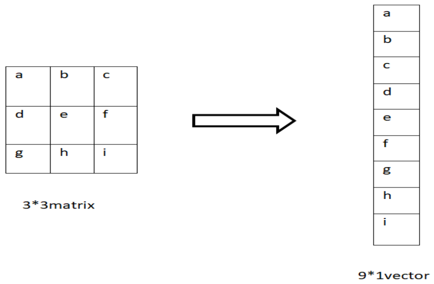

Fig 4: Dimension reduction in flatten layer

The fully connected layer is the last layer of the CNN architecture and is used to connect all the other layers of the network. If the data requires more layers to define and needs more accurate results, deep convolutional neural networks can be used [5].

III. LITERATURE SURVEY

The Cervical cancer can be treated at an early stage if the symptoms are observed at pre-cancer stage. The screening test results in normal and abnormal cells. The normal cells can further turn to abnormal cell depending on the class of normal cell. The abnormal cells may sometimes require proper treatment to cure them from converting to cancerous cells [6]. One of the methods in classifying images is by cell segmentation[7]. The proposed work consists of three steps. The first step is for cell segmentation which uses patch based fuzzy C-means clustering. The input image consists of cells taken from microscopic lens, which is used for processing, is converted from color scale to greyscale and then median filters are applied to reduce noise and to smooth the image. The FCM (Fuzzy C-means clustering) algorithm is then applied to the converted greyscale image.

The nucleus is focused and differentiated into nucleus and non-nucleus images using threshold frequency. The threshold of the nucleus is obtained by considering percentage of patch (darker part) at the centers of nucleus. After differentiating the cell images, cell segmentation of the image is performed by using hard C-means clustering and watershed segmentation. In the next step feature extraction is performed by considering features like area of cell, axis of cell, ratio of cell etc., depending of the aspects required to analyze the image. In the last step, the image is classified using SVM, ANN, K-nearest neighbor, and the results are compared.

The other proposed method for classification of images is by using Convolutional Neural Network[8]. The method acquired only limited samples of images. The method uses DCNN (Deep Convolutional Neural Network) algorithm. The image preprocessing is performed which modifies the image size. After image preprocessing, the image augmentation methods namely image rotation, image flipping, and image enhancement methods are applied. Finally, the images are trained, and algorithm is applied. The results are compared for original images and augmented images.

The classification of Pap smear images can be done by various methods like soft computing which works on knowledge-based network analysis with Genetic algorithm, automatic detection using comparison detector, cell segmentation by feature extraction. The classification also can be done by algorithms using Artificial Neural Networks (ANN), Support Vector Machine (SVM), K-means, fuzzy means, Decision trees. Out of these, Neural networks give good results in achieving classification of images[9].

IV. PROPOSED WORK

A. Classification

The data used in the processing is taken from the MDE-lab site which includes 7 sets of classes of more than 200 images. The dataset is taken as data1 and data2.The data1 includes all 7 sets of classes datasets whereas data2 will have 2 classes namely normal and abnormal classes having same 7 sets of classes divided into 3 sets of classes as normal classes (normal columnar, normal intermediate, normal superficial) and 4 set of classes as abnormal(light dysplasia, moderate dysplasia, severe dysplasia, carcinoma_in_situ) from the process of image. The processing of the concept takes place as shown in fig 5. The number of images required for training process can be defined separately.

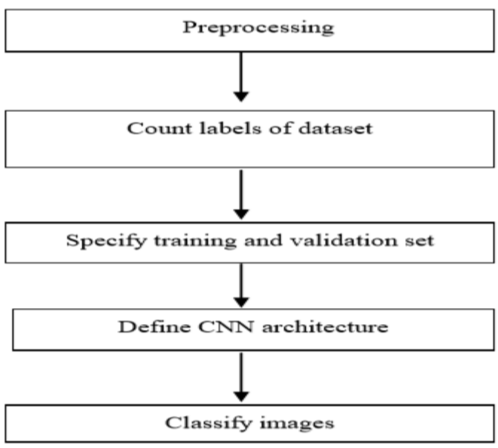

Fig 5: Workflow model

The CNN layer workflow is as shown in fig 6. The remaining images in the dataset is taken for validation process. After defining the dataset for training and validation, CNN architecture is defined for the dataset. Input layers are used to define the image given image size for the processing.

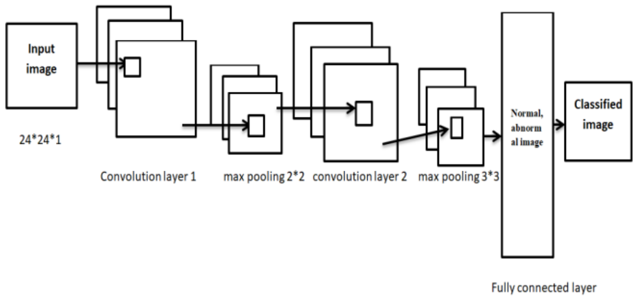

Fig 6: Workflow of image classification in CNN

Next the convolutional layer defines the number of filters required and value of filter size. In the first Convolutional Network 8 layers are used as shown in fig 7 and in the second network 16 layers are used as shown in fig 8. The pooling layer uses only maxpooling layer which gives maximum value of the value of the image in pixels. In the fully connected layer, the rest of the other layers are connected.

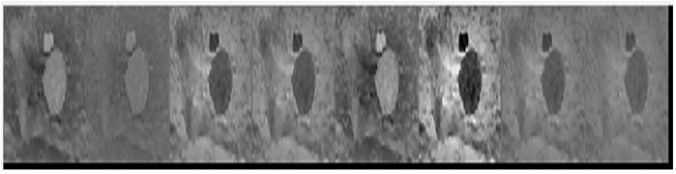

Fig 7: 8 layers of images obtained using CNN

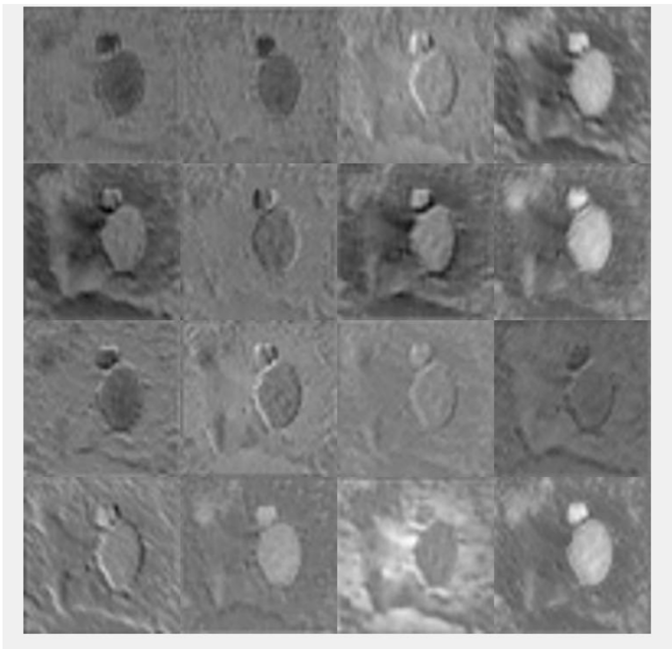

Fig 8: 16 layers of the image obtained using CNN

The number of cycles to be trained (epochs) and the validation frequency is defined manually and can be changed as per requirements.

In the training network, the activation function is used to analyze the complicated functional mappings in the convolutional layer as shown in figure 6 and it provides results applying the required function are taken for layer 1, layer 5 and layer 16 from all 16 layers. Mainly the activation concept is used to investigate features of images by observing the areas in which the convolution layer activates on an image. Further it compares with the corresponding areas in the original images. The module of work of activation function is as shown in fig 9. In the next step, the 2D image is converted to 3D mainly to restore the original important features of the images without losing any feature of the image. In the 2D image the values will be height and weight (row*column). In 3D image we have height, weight and channel value on the layers. Then the image is taken in 4D dimension which includes values to be height, weight, channel value and image color. The proposed work uses max function in activation function to get the strong value which gives the required image feature which classifies the image using image features.

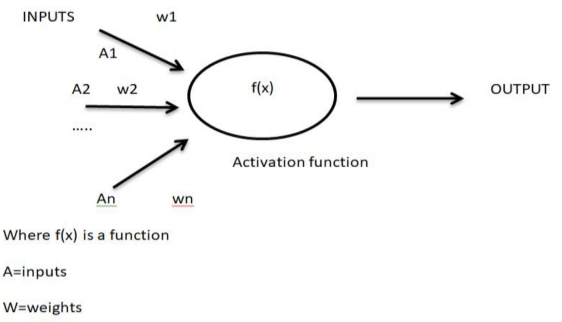

Fig 9: Model of activation function in neural networks

B. Testing

To predict the class of a image, the steps are used as shown in fig 10.

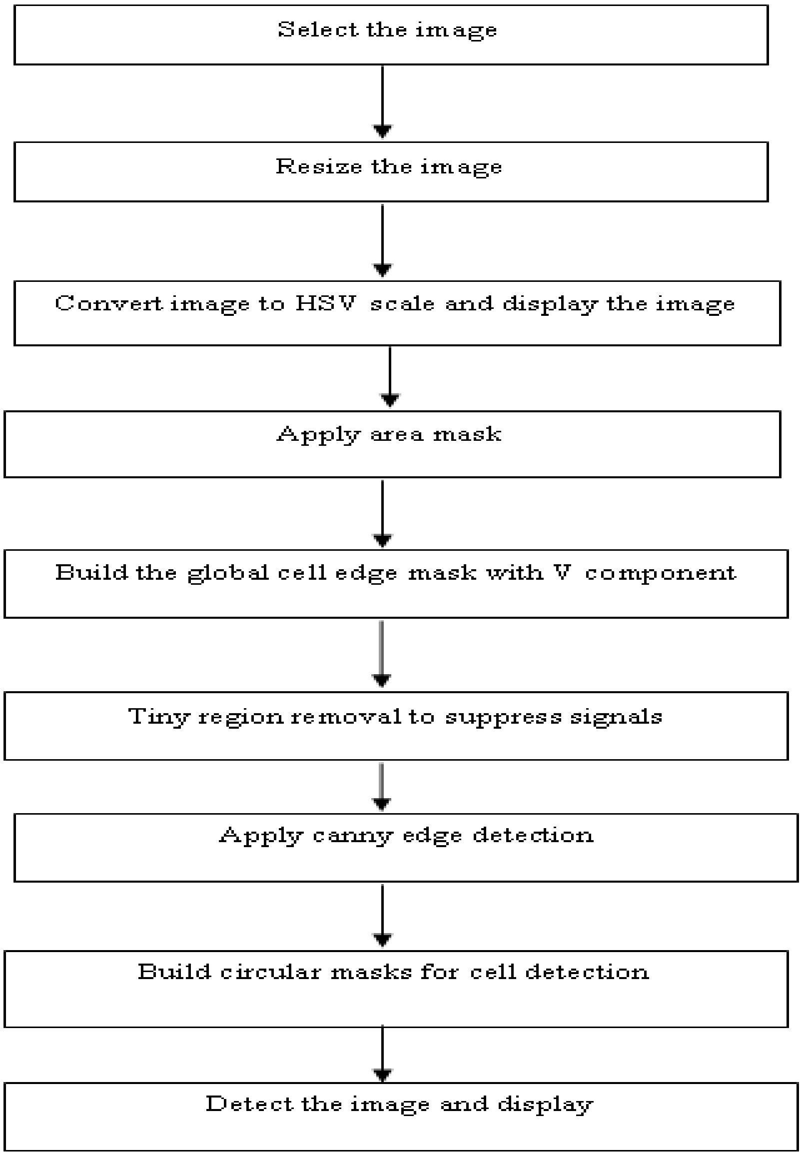

Fig 10: Workflow model for testing process

The testing process takes place only to a manually selected particular image in the algorithm. The image must be selected manually which is loaded from the set of provided dataset. Further resizing is done only for proper output. The image is converted to HSV scale. The filter is applied pixel to pixel to the image at the edges to extract images called "global cell edge mask" and then connected component is applied to convert the image to identify the image, pixel by pixel to detect the image. Some unwanted tiny signals are removed and canny edge detection method is applied to predict the image by analyzing its edges of the resulting image. The resulting image displays the name and class of the image. it displays the name and class of the image to which the image belongs.

V. RESULTS AND DISCUSSION

The results are shown for different classes taken at each time separately. The overall procedure in getting results for all the classes.

The table-I shows the results obtained for classifying images separately for 3 set of classes, 4 set of classes, 5 set of classes, 6 set of classes and 7 set of classes respectively. The epochs is varied from 50-60 and frequency is kept constant from when comparing results for different classes.

Table- I: Results obtained for classifying different classes

DATASET (Normal+ Abnormal)	Efficiency/Accuracy= (TP+TN)/(TP+TN+FP+FN)	Epochs (defines one complete cycle of dataset)	Frequency
3 classes	89.4%	50-55	100
4 classes	72.94%	50-55	100
5 classes	57.76%	50-55	100
6 classes	45.47%	50-55	100
7 classes	44.68%	50-55	100

The efficiency results are shown in the form of graph in figs 11,12,13,14 and 15 respectively below:

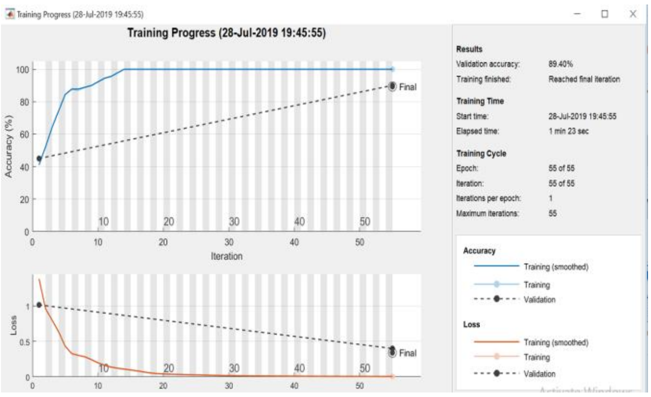

Fig 11: Accuracy results obtained for 3 classes

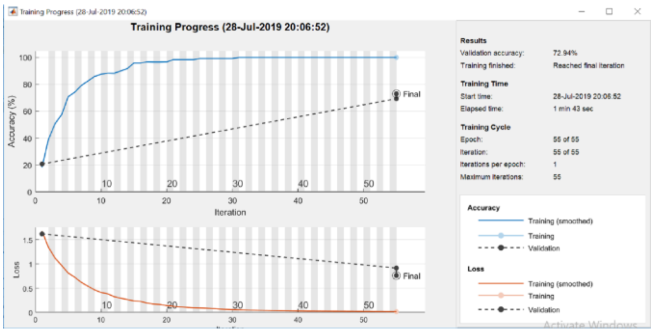

Fig 12: Accuracy results obtained for 4 classes

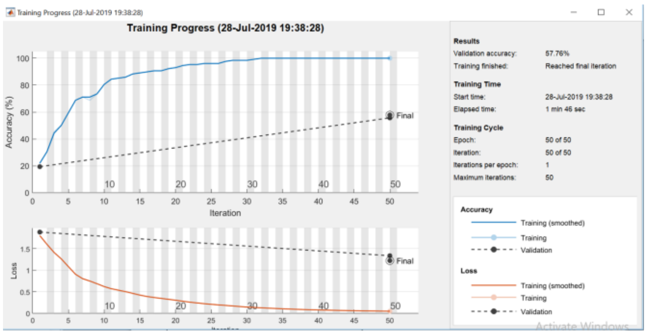

Fig 13: Accuracy results obtained for 5 classes

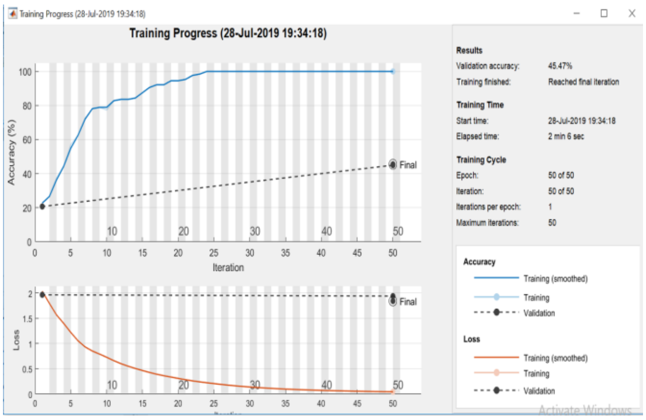

Fig 14: Accuracy results obtained for 6 classes

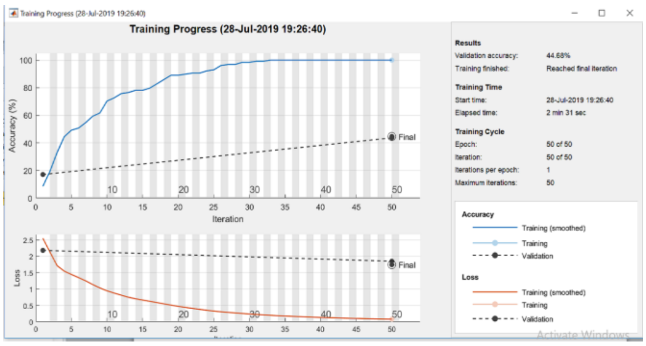

Fig 15: Accuracy results obtained for 7 classes

The results obtained are clearly indicating that the accuracy obtained for classifying for 3 classes and 4 classes is good and efficient. Hence the experiment is successful in classifying images when we have 3 classes and 4 classes of images which are the results of early stages of cancer.

The results obtained for testing a particular selected image is shown in figures 16, 17,18 respectively:

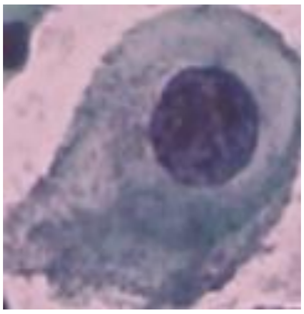

Fig 16: Original pap smear image

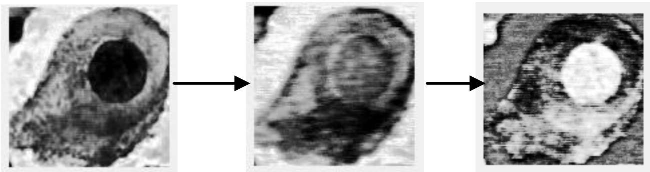

Fig 17: Conversion of image from RGB to greyscale and applying image mask results screenshots

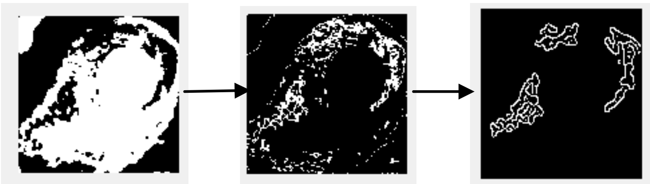

Fig 18: Screenshots of results obtained when applied edge detection

The image loaded here is a random one from dataset and can be detected for all images separately.

The confusion matrix obtained for classifying 3 set of classes is as shown in fig 19. The accuracy can be calculated manually using the formulae:

$$Accuracy = (TN + TP)/(TN + TP + FN + FP)$$

$$\begin{bmatrix} 60 & 6 & 2 \\ 0 & 38 & 1 \\ 0 & 10 & 34 \end{bmatrix}$$

Fig 19: Confusion matrix for classifying 3 set of classes

By calculating manually using the values obtained,
Accuracy can be calculated as:

{38 + (60 + 0 + 2 + 34) / (60 + 6 + 38 + 10 + 34 + 1 + 2)}*100
= 88.74 %

which is approximately equals to 89%.

VI. CONCLUSION

The proposed approach gives more accurate efficiency in predicting and classification the early stages of cervical cancer. The paper also gives information about classifying the different classes of normal and abnormal cells. The proposed method is a easier way of classifying the images and the advantages of the proposed methodology is that it gives good results in classifying and predicting early 3 and 4 classes of the disease as it is first been classified through different classes and then compared with the results. Next the random image is been tested to predict the early stage of disease. It not only predicts the normal or abnormal cell, it can also predict the categorical class of the image hence providing good results.

FUTURE SCOPE

The experiment was conducted in classifying only for 7 set of classes of images and predicting for 2 set of classes of normal and abnormal. Further the experiment can be explored to predict all the 7 set of classes separately.The efficiency can also be compared in classifying by varying the epochs and frequency. The experiment conducted uses image processing technique using images. The prediction and classification of images using cell segmentation can also be done and compared with the results. Deep Convolutional neural networks can be used for good results

APPENDIX

The dataset used for the experiment is taken from MDE-lab: "smear2005.zip" new pap smear images database, Management and decision Engineering Lab(MDE),Business school, University of Aegean,23-July-2008, "http://mde-lab.aegean.gr/downloads".

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AUTHORS PROFILE

Manasa Ungrapalli N S has successfully completed Bachelor's degree in the field of Computer Science and Engineering from Malnad College of Engineering. She has been awarded best paper award for the experiment conducted on IOT. Presently she is pursuing her Masters in the field of Software Engineering in MSRIT.

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