Recognition and Classification of Fetal Brain Abnormalities

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Abstract: In today's world, not only adults, children, teenage suffer from different diseases but also the yet to be born babies suffer from various abnormalities. We hear many cases that the child was born with some disability and because of the delay in the discovery and operation of the disability, the disability becomes permanent. Out of one thousand, three women are pregnant with abnormal child. If somehow, we detect the abnormality in the child when it is in the fetal stage and operate and medicate according to that then the abnormality can be treated very effectively and efficiently. Our paper deals with the same concept of detecting and classifying the brain abnormalities in the fetus using various deep learning techniques and algorithms. There have been previous works on the same but the technique used by others included machine learning and it had some drawbacks which can be resolved using deep learning techniques. Deep learning has greater efficiency and advantage over machine learning. In our method of detection, we take the help of MRI (Magnetic Resonance Imaging) technique to first capture the brain image of the fetus. Then we perform various preprocessing steps to extract the ROI (Region of Interest). Then we use feature extraction and reduction techniques to obtain more developed and detailed image of the fetus. We compare the image with the normal fetal brain images to classify and detect abnormalities. We make the use of CNN (Convolutional Neural Network) classifier algorithm of the deep learning technique to achieve high level of accuracy. CNN algorithm is better than k means clustering and SVM classifier algorithm of machine learning techniques. Our work has shown higher accuracy than previous models and our future work will involve increasing of classification and data.

Keywords: MR Image, CNN Classifier, Fetal brain, DWT, Preprocessing, Segmentation.

1. Introduction

Today, Deep learning is a man-made consciousness work that mirrors the operations of the human brain in preparing information and making designs for use in dynamic operations and images. Deep Learning is a subset of machine learning that has systems equipped for taking information that is unstructured or unlabeled. Deep learning uses Neural Networks which process the visual image information at different layers or levels. The lower levels process small information and higher levels process complex information. Distinguishing and grouping fetal brain abnormalities using magnetic resonance imaging (MRI) is significant, as according to a research approximately three among every thousand ladies are pregnant with abnormal brain. Early discovery of fetal brain variations from the norm utilizing ML methods (deep learning) can improve the nature of determination and treatment arranging. We found that majority of the work done regarding detection of brain abnormalities was done after the child was born and not during the fetal stage. Magnetic Resonance Imaging (MRI) is an important tool in for brain abnormality detection. Magnetic Resonance Imaging (MRI) in early periods of the cerebral improvement during incubation offers bits of knowledge into the rise of brain abnormalities, their qualities and fluctuation over the populace. We have proposed a method for the detection of any abnormality or disease in the brain when the child is in the fetal stage so that if any strange phenomenon is observed, it can be treated and operated accordingly and can be rectified at an early stage.

We use the deep learning techniques and algorithms unlike other research work done using machine learning. These algorithms are fast and much more efficient than machine learning techniques Firstly, we take a raw image and it which helps in reducing any noise occurrence in the image and highlights the image features more. After this the frequency of the image is measured using DWT (Discrete Wavelet Transform) algorithm which classifies the image as rough or smooth according to the frequency. If frequency is high image is rough whereas if it is low image is smooth. DT-CWT (Dual- Tree Complex Wavelet Transform) is a much more enhanced version of DWT. Here, we will use DT-CWT. The next step is the feature enhancement and texture analysis which is done using Grey Level Co-occurrence Matrix (GLCM) algorithm. At last the image is passed through the CNN (Convolution Neural Network) classifier which helps in classifying the image as normal image or abnormal image by comparing the result to the large data set of images. The main advantage of our proposed system is that we make use of the CNN algorithm which has much greater efficiency in medical image processing than the algorithms used in machine learning such as k-means clustering and support vector machine (SVM). Using this algorithm, we achieved higher accuracy results and our method is much faster and more efficient and uses a larger data set to compare images.

2. Related Work

The greater part of the past work that utilized fetal brain images concentrated on segmenting fetal brain images to distinguish irregularities or isolating the fetal brain from the remainder of the body. Fewer examinations

considered the utilization of Machine Learning strategies to distinguish defects existing in the fetal cerebrums [1,2]. As far as we could possibly know, past investigations that applied classification strategies to fetal brain MRI pictures are restricted to References [3–5]. In spite of the fact that the first two investigations performed classification on fetal MRI brain pictures, the creators just classified a mind imperfection in babies called small for gestational age (SGA).

They first accepted that textural examples of fetal mind MRI pictures are related with newborn. At that point, they developed a support vector machine (SVM) for foreseeing the SGA variation from the norm after the introduction of the baby (turning into a neonate). These strategies have a few restrictions. [11]To begin with, these methodologies just utilized fetal images of 37, rather than applying a wide scope of fetal. Second, their strategies just arrange one kind of variation from the norm; specifically, SGA for babies. Third, mapping the fetal MRI to its relating MRI after birth is a basic speculation expected to characterize the SGA variation from the norm. Also, the creators utilized two little data sets which just have ninety-one (91) and eighty-three (83) pictures, individually. Ultimately, the cerebrum of the baby was cut in a manual way, which is a period squandering process. The creators of Reference [5] classified a few baby irregularities, however the most elevated classification exactness accomplished was restricted to 80%.

Most of the work on done on identifying and grouping cerebrum anomalies in early age was limited to only after the birth of the child i.e. neonates and preterm babies as opposed to fetuses. Ball et al. [6] utilized the autonomous segment investigation system with an SVM to distinguish mind surrenders in preterm newborn children. et al. [7] utilized help vector relapse to anticipate the GA of babies. They additionally utilized SVM to identify chemical imbalance. Comparable work was finished by et al. [8] to distinguish newborn children with mental imbalance.

In this Reference [9], the MR images are classified to binary images and is used to the MRS (Magnetic Resonance Spectroscopy) prior to feature selection with Bayesian Neural Network. The drawback of this paper is that Wavelet fails to provide details curved edges. The authors stated that to distinguish between normal and abnormal MR images and to increase the classification rate. In this they used method [10]. In this, we found that less accuracy in image classification.

3. Proposed System

In our proposed framework, we take the raw MRI image, then we train some of the raw images in order to classify between abnormal brain and normal brain. So, after taking the raw image we first the image in order to remove the noisy data and resizing of the image. Then the image will go to DT- CWT phase in order to extract the structure and features. Then The image will pass through the GLCM phase in order to extract texture features of the image like Energy, Entropy, Contrast, Homogeneity etc. Then the CNN classifier is there to distinguish the image between the classes. The block diagram of proposed framework is presented in Fig. 1.

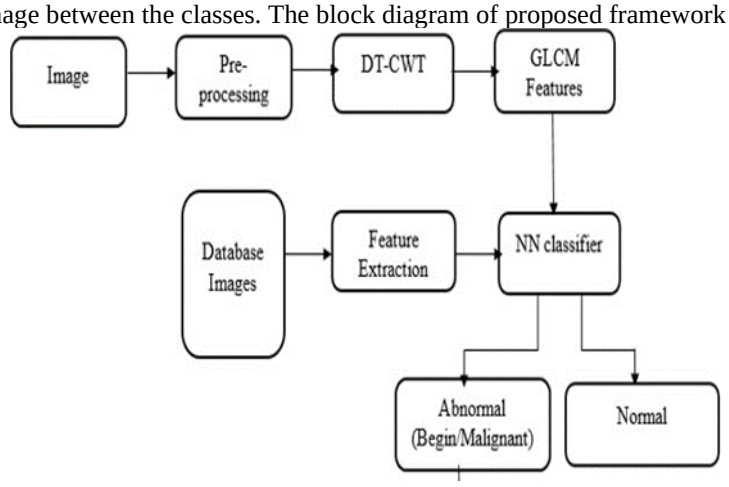

Fig. 1. Block diagram of Proposed Algorithm

Then the database image will be directed to the classifier after the feature extraction phase in order to classify between the classes. The database images are the test images that we have not trained. Each module of the proposed system is explained in the following sections.

A. Data Set

The fetal brain images that is used in this paper is sourced from fetal brain atlas [11]. It included more than 300 images (around 120 images of healthy brain and around 180 images of abnormal brain) with GA (Gestational

Age) ranging from 14 weeks to 39 weeks. The also included various abnormal brain also such as cerebellar, Dandy–Walker variant/malformation, cerebellar hypoplasia etc. Fig 2. Present some abnormal brain.

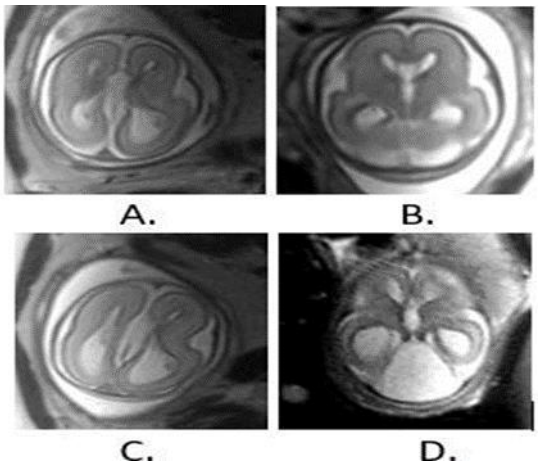

Fig. 2. Abnormal Brain Images with diseases A. Agnesis of the corpus callosum (23 Week) B. Cerebeller hypoplasia (26 Week) C. Colpocephaly (23 Week) D. Dandy-Walker variant malformation (25 Week)

Some of the normal fetal brain images are there.

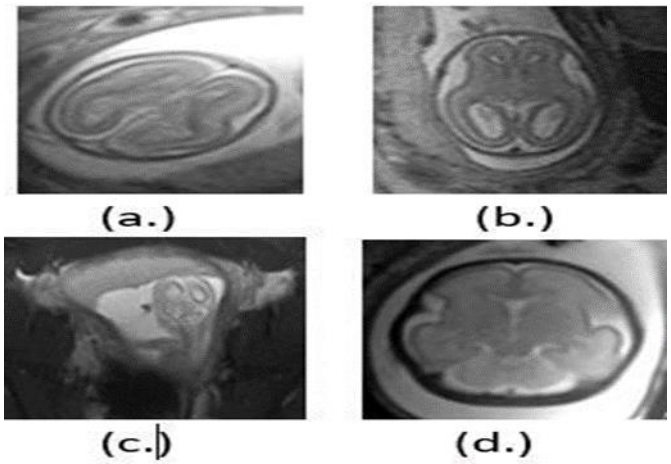

Fig. 3. Normal Brain Images (a). 20 Week Fetal (b). 22 Week Fetal (c). 15 Week Fetal (d). 26 Week Fetal

B. Preprocessing

The data or the image that is fed into the system for processing or analyzing is usually complex and is from various sources. This unclear data needs to be properly cleaned and organized for analyzing. Thus, preprocessing is used. Preprocessing is an operation that is involved in the image classification and processing and deals with performing of operation on images at the very first level of image processing. It involves conversion of colored images to grey scaled images. This is done as colored image contains more image information which can hinder and slow the pace of image processing as the image turns complex to analyze. The role of preprocessing is to enhance and amplify the image features which might be helpful in further processing of the image and this is done by suppressing any unwanted disfigurement. There are several techniques involved in the preprocessing of the image such as intensity adjustment, color adjustment, morphological operations etc. the image is fed into the system. After reading the image, resizing of the image is done. Resizing is done for the purpose that the images that our fed into the deep learning algorithms are of same size. Contrast enhancement and adjustment is performed to reduce image complexity.

The next step is to denoise the picture. We remove any unwanted noise and smoothen the image using spatial filter. Next technique is the segmentation phase where the image with the ROI (Region of Interest) is separated out from the rest of the image. Now the image becomes clearer and more refined and is sent to further stages.

C. DWT (Discrete Wavelet Transform)

The filter banks are one-dimensional so in order to compress the image that is two- dimensional image we have to use a special way to do this. So, here discrete wavelet transforms (DWT) is used. The main objective of DWT is used to extract the localization. So, here by localization mean spatial and frequency localization. So, from here we have found out that at what spatial locations we have high frequencies and what locations we have lower frequencies.

The image is of two-dimensional (2-D) i.e. rows and columns. So, first we will pass the original image i.e. rows data to low pass filter and high pass filter then down samplers will be there after that again columns data will give to the low pass filter and high pass filter then we obtain four types of data i.e. LL, LH, HL and HH. Low pass filter will give the approximate image and high pass filter will give the edges of the images. This is 1-level decomposition.

In DWT, we compress the image but not lose any information of the image by means of Nyquist algorithm. The disadvantage with the Fourier transform is with temporal resolution that it cannot obtain frequency and space information but with other wavelet transform we can capture both information. The finer image will be converted to the coarser image. So finally, versatile mathematical tool is provided by wavelet representation to analyze transient signals that are not found out at the discontinuous regions. DT-CWT (Dual- Tree Complex Wavelet Transform) is the enhanced version of DWT. In this, tree will be made like passing every image to the low-pass filter and then record the image. DT-CWT is shift- invariant.

D. GLCM (Grey- Level Co- Occurance Matrix)

It is a mathematical strategy to find out the textures in an image. It is a second order approach. It shows relationship between the pixels of the image. It creates the matrix representing the no. of combinations of pixels i.e. gray levels co-occur. It is done in the whole image or sometimes in image section. Sometimes it also known as co-occurrence distribution. It is very known method for deep texture analysis and features extraction from grey-level images. After the normalized matrix, we can extract different features like contrast, homogeneity, energy, entropy.

Texture Features

1. Energy: It is used to measure the homogeneity or uniformity i.e. repetitions of the pixels.

$$J = \sum_{i=1} \sum_{j=1} (p(i,j))^2$$

2. Entropy: It basically measures disorder of an image. If the image is not uniform, then the entropy will be higher. And it inversely related to Energy.

$$S = -\sum_{i=1} \sum_{j=1} p(i,j) \log(p(i,j))$$

3. Contrast: It is used to measure the difference between the lowest and the highest data of the set of pixels. So, it defines the local variations of an image.

$$I = \sum\sum (x-y)^2 p(x,y)$$

4. Homogeneity: As the name suggests, so if the area is homogenous, same gray values will be there and homogeneity will be higher. In normalized matrix, the diagonal elements have higher homogeneity.

$$\text{Homogeneity} = \sum_i \sum_j \frac{1}{1+(i-j)^2} P_{i,j}$$

where p(i,j) is co-occurrence matrix.

E. CNN Classifier

The Convolutional Neural Network (CNN) is a deep learning algorithm and techniques which has many underlying layers. It has a multilayered architecture and because of the presence of so many layers we are able to achieve high accuracy in the classification of different images by passing and processing the image through multiple layers. It helps in determining and distinguishing even the complex features. The CNN classifier works by comparing the image fed to a large dataset of normal images. It is a type of self- learning algorithm as the images that are fed are processed and CNN remembers these image features and uses it to further classify and in comparison, with other images. The first layer is the convolution layer which is used for feature extraction of

image with the help of various filters. The next layer is the pooling layer which is used for dimensionality reduction in the image by using different views of the image.it reduces the amount of information in the image. This helps in reducing the computational power which is required to process data. Fully connected layer is the next layer whose input is the image output of the pooling layer. It is a type of feed forward neural network which means that the data will move only forward in one direction and not in a loop. It flattens the image. The next layer is the ReLU (Rectified Linear Unit) which is used to increase the non-linearity of the image. It helps in removing the black elements from the image and highlighting the features of image. The last layer is the classifier layer which is ultimately used to distinguish between different classes.

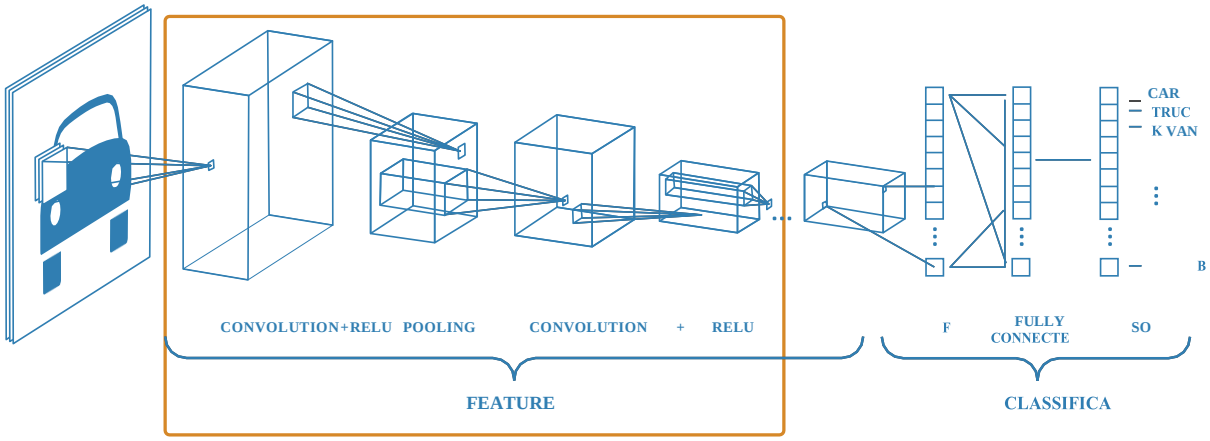

Fig. 4. CNN Architecture

4. Software System

As per programming framework proposed at the present time, the working standard and the basic point of view in the use of eye-flickers controlled virtual reassure rely upon Divide an Conquer perspective. This approach was in like manner the starting stage for organizing practically identical virtual consoles reliant on a mind PC interdental. According to the past logical composition, MATLAB has been every so often used to make a reasonable figuring concentrated on these sorts of uses. Thus, it should be focused on that the novel MATLAB based course of action proposed right presently be used by understudies as critical material to reinforce the data instructed by their instructor.

A. MATLAB

MATLAB is a programming platform which can be used for building models for the deep learning techniques. Its advantage is that it uses very less coding and large computation problems can be solve in less time. Using MATLAB, deep learning techniques and algorithms can be used with great ease and efficiency. It can manage large datasets. It also has specific tools for working with deep learning and image processing.

The IPT (Image Processing Toolbox) in MATLAB is an assortment of capabilities that broadens the ability of the MATLAB numeric registering conditions. It tends to be utilized to perform image division, image improvement, commotion decrease, image enlistment, geometric changes and 3D image handling activities. It gives an exhaustive arrangement of reference standard calculations and work process applications for image preparing, investigation, representation and calculation improvement. A two- dimensional image is just a two-dimensional array of pixels. Manipulation of this two-dimensional data is used to perform some common image operations. It is used for image processing as it offers a wide range of functions for matrix manipulation.

The main parts of MATLAB are namely: The MATLAB programming which is a high-level programming, the working environment for the MATLAB, MATLAB library (Mathematical functions) and the MATLAB API.

5. Results and Simulation

We run the proposed framework in MATLAB, and we get the simulation results in GUI (Graphical User Interface) of MATLAB. Fig 5 shows the full simulation result of proposed framework. Firstly, the raw MR image will be browsed then the step of the image will be done. In image, segmentation part will be done. Fig 6 presents segmentation phases of the image. After, DWT phase is there i.e. to compress the image.

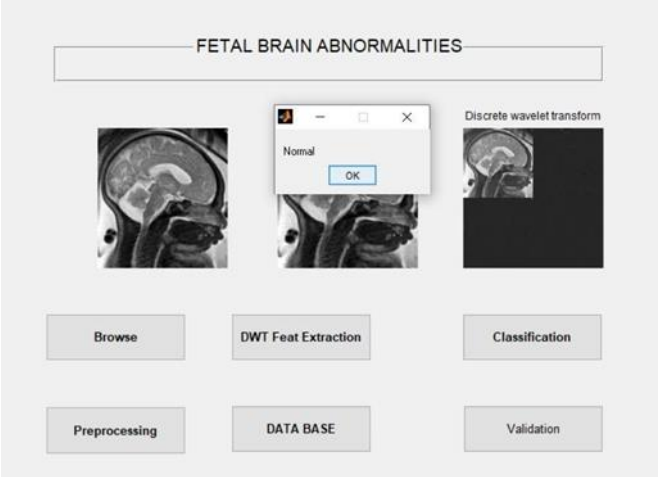

Fig. 5. Result of the browse MR image

Then the GLCM features will be extracted like entropy, contrast etc. After clicking DATABASE button, the test image will be checked with the training images then after classification button the result will come i.e., the fetal image is normal or abnormal.

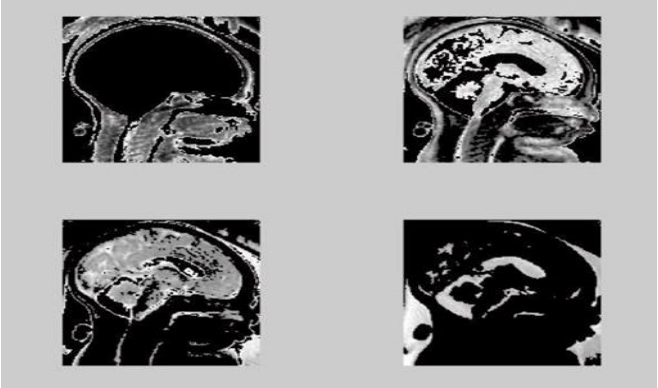

Fig. 6. Segmentation of browse image

Once we get the classification, then we have to check for the efficiency, Fig 7 will show the accuracy, sensitivity and specificity.

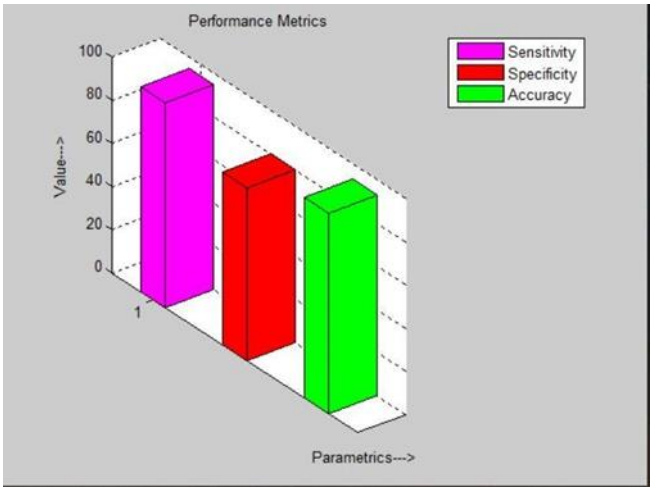

Fig. 7. Efficiency Graph

6. Conclusion

We proposed a method for the recognition and classification of brain abnormalities in the fetus. We used deep learning techniques and algorithms for this purpose such as the CNN algorithm. Unlike other researches that used machine learning techniques and algorithms for the same purpose, our proposed work has shown higher accuracy and efficient results. We achieved accuracy of around 92%-93% which is higher than any other previous work.

Also, we were able to predict and identify different brain abnormalities with images of different gestational ages. The CNN classifier, we used here has outperformed any other algorithm in terms of decreasing computational cost and increasing image processing speed. We want to achieve more efficiency in the future work. And we will also increase the data sets. And we will classify different abnormal diseases like tumor, cerebellar hypoplasia etc.

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