Image Processing Concepts for Brain Tumor MRI Image Classification

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Abstract*-- The current generation is witnessing a radical change in technology with the rise of artificial intelligence. The application of artificial intelligence on different domain indicates the widespread involvement of this technology in the years to come. One such application is on medical image classification such as brain tumor classification. The process of medical image classification involves techniques from the image processing domain to process set of MRI image data in order to extract prominent feature that eases the classification process. The classifier model learns the MRI image data to predict the occurrence of the tumor cells. The objective of this paper is to provide knowledge pertaining to various approaches implemented in the field of machine learning applied to medical image classification as preparation of the MRI dataset to a standard form is the key for developing classifier model. the paper focus to analyses different types of preprocessing methods, image segmentation, and feature extraction methodologies and inscribes to points out the astute observation for each of techniques present in image processing methodologies. As predicting tumor cells is a challenging task because of its unpredictable shape. Hence emulating an appropriate methodology to improve the accuracy and efficiency is important as it aids in constructing a classifier model that can accelerate the process of prediction and classification for the brain tumor MRI imagery.

***Keywords*: brain tumor, image processing, image segmentation, preprocessing methods, feature extraction methods, GLCM, PCA**

I. INTRODUCTION

A human body is accustomed to cell division, cell growth, old cells are replaced, and the damaged cells are repaired which is a part of the natural process. However, if such a natural process remains unchecked by the human body's natural defense mechanism then it results in abnormal cell growth that causes tumors. Primary brain tumor develops within the brain cells whereas, secondary brain tumor develops at a different part of the body and then reaches to the brain. The grade 1 and 2 are low-grade tumor has a fewer growing tendency compared to grade 3 and 4 high-grade tumors, these tumors grow in a hasty fashion. Tumor detected using clinical imaging mechanisms such as CT scans and MRI scans being the recent one. The magnetic resonance imaging employs powerful magnetic fields and radio waves in order to obtain visuals inside the body. Earlier, the health care professionals employed manual ways of detecting cancer by visualizing the clinical images. Since then, there is a major advancement in automating the entire process of detection with the help image processing mechanism. Digital image processing is a domain in computer science that implements suitable algorithms to enhance the image in a way that prominent information is extracted to summarize the image. Digital image processing has varied use cases which has a great impact on the present world we live in. With image processing being the fast-growing technology and machine learning acquiring major emphasis, a combination of these there two technologies can have great potential for improvising decision making and diagnosis of brain tumors. Although practically the machine learning model for the medical field is not implemented for now, the future is promising for the use of a machine learning model that eliminates human intervention to classify the tumor to benign or malignant. The reason for employing a machine learning model in brain tumor classification is to accelerate the entire classification process with accuracy.

Revised Manuscript Received on July 20, 2020.

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II. PREPROCESSING

When today's world is taken into consideration, there is enormous data that is been collected over the decade whether it is numerical data, image data, textual data, and whatnot. These data are resource weapons and act as a backbone to train a machine learning model. The extracted data may not be clean data. In other words, it may not be normalized data. There may be missing values, data may be unstructured, and many other abnormalities exist. When we speak about image data, there may be inconsistency in dimensions, size, high pixel rates, etc. These extracted data are subjected to filtration [2]. As the goal for any machine learning algorithm is not only to focus on prediction and classification but also it aims in increasing the efficiencies and accuracies along with prediction and classification. For this reason, different preprocessing methods are proposed in recent studies. This section debates on widely used preprocessing methodologies and where it can be applied.

A. Wiener filtering

The image under investigation can be a real-time image or it can be a raw image. The spatial relation between the pixel is timely and each pixel represents the intensity of a stationary point. However, in a mere state of events on an account of unfocused optics, the image will occur blur. This is due to poor sampling according to signal processing. Wiener filter is one of the image restorations tools which manages to de-blur the image.

Ramesh Babu Vallabhaneni et al, in 2018 employed Wiener filtering to have adaptive denoise filtering, the edges of the resultant images are seen to be preserved using this methodology [2]. Mamun, Md. Al & Hossain in 2018 also implemented this filtering mechanism along with image morphology, it is seen that the output images are clearer with this approach, the acquired images from this process are subjected to SVM classification that provides an accuracy of 83% [3]. Baselice, Ferraioli, Pascazio, & Schirinzi, 2017, used the Wiener filtering mechanism to denoise ultrasound images [4]. It uses mathematical formulation associated with the least square method to automatically find an ideal version of the image. In absence of this filter, de-blurring a motioned image would involve a manual trial and error method to find a de-blurring function. This type of preprocessing method is suitable for linear images. It minimizes the mean square error and its capable of de-noising linear images.

B. Median Filter

The median filter is a preprocessing method whose functionalities involve de-noising a corrupted image. This type of filtering method is considered to be a non-linear filter which typically means that convolution operation does not take place, unlike linear filtering. It possesses edge-preserving property and it is also applicable for signal processing. Telrandhe, Swapnil et al in 2016 implemented median filtering to preprocess the image data. their implementation involved classifying brain tumor MRI images using SVM classifier [5]. This is the most popular filtering or preprocessing technique due to its potential in preserving the edges while it negates the noise from the subjected image. Kamil Dimililer, Ahmet İlhan, 2016 in their paper employed this technique in order to enhance the medical images that were provided to a neural network classifier. the resultant image was accurately enhanced without losing the edge properties [6]. A comparison between the Gaussian filter and median filter reveals that, when the image under investigation has a moderate level of noise, the median filter delivers better results than gaussian filters whereas, when the image under investigation associated with salt-and-pepper noises gaussian filter takes the lead. Manisha & Bansal, 2018 improvised median filtering in their work by focusing only on the noisy pixels and applying filtering only on the corrupted pixels. using this approach leaves the image features unharmed [7].

C. Mean Filter (Average Filter)

The mean filter is a preprocessing method which is also proposed to de-noise a corrupted image. This type of filter follows a separate methodology compared to the median filtering. A. Sehgal, S. Goel, P. Mangipudi, A. Mehra, and D. Tyagi, 2016 made used of mean filtering along with C-fuzzy segmentation to derive a dice score of 0.73[8]. The mean filtering replaces the individual pixel intensity with an average pixel intensity of an image. Galiano & Velasco, 2014, employed mean filtering mechanism that behaves asymptotically as a shock filter. that allows equivalent distribution of contrast [9]. The properties possessed by the mean filtering are similar to that of median filtering methodology however, the approach that is been followed is different. It promotes edge-preservation solution and reduces variance. Although it is applicable to an image that is associated with impulsive noise, it is not as effective as compared to any other method as the impulsive noise is not completely eradicated.

D. Gabor Filter

Gabor filter coined after Dennis Gabor is a preprocessing method that utilizes the concept of linear filtering. This type of preprocessing method is designed to explicitly concentrate on the frequency domain in the region of interest of the image. The frequency-domain in image processing refers to the rate of change of the pixel color channels which may change gradually or rapidly depending upon the frequency strength. G. Mirajkar and B. Barbadekar, 2010 used gabor filtering on the resultant images that were subjected to wavelet approximation to extract features that gave the entropy of the image and variation coefficient[10]. Gobar filtering mechanism is prominently used textual rich image processing and finds its application in facial expression recognition. This filtering mechanism is noted for its uniqueness and utilizes a fast Fourier transform. However, it fails to accurately preserve the edges of the image contents.

E. Image Normalization

Image Normalization is another preprocessing mechanism that is intended to emphasize the features of the image by increasing the contrast of the image in order to facilitate better feature extraction. Xue, Mou, Zhang, Bovik, & Feng, 2014. promoted adaptive normalization of the gradient magnitude map and laplacian of gaussian map [11]. The absence of black pixels and a huge amount of white pixel can showcase a poorly contrasted image can be, this indicates that the grayscale image is not appropriately balanced. In such cases, the image normalization preprocessing step is taken into consideration. Where linear normalization will ‘stretch’ the range of pixel intensity. G. Singh and M. A. Ansari in 2016 also employed a normalization technique along with k means clustering. for classification, the naive bayes algorithm was adapted [12]. This type of preprocessing method can also result in intensifying noise in the image.

F. Morphological Operation

Morphological operation uses pre-defined kernels (filters) to process an input image using a suitable method. The predefined filters are called a structuring element that denotes a pattern. These filters are a small matrix that is applied to the input image. There is two main morphological operation, those are dilation and erosion. Erosion works by reducing the pixels near the boundaries of the foreground image by applying minimum function. Whereas, dilation works in contrary to that of the erosion method. The dilation increases the pixel intensity near the boundaries for the foreground by applying a maximum function. Kumari, Sahdev, & Sahoo, 2015, used morphological operation to enhance the contrast of real-time images at a faster rate. With speed as such, real-time sensing images could achieve better clarity [13]. However, morphological operation fails when applied to an image that contains intricate and minute detail Hence it is not suitable for textual image analysis whereas, it may find its application in preprocessing an image that will further be subjected to segmentation.

III. SEGMENTATION

The most renowned method in image processing is called segmentation. Tons of study on segmentation indicates its various application which accords with image data. Whether it is on retrieval of contents of the image, medical imaging, facial recognition or video processing, the list keeps expanding. Segmentation is a technique that dissociates the foreground image with a background image by partitioning an image into a number of salient objects. The partitioning of the image depends on the complexity of an image (Yazdani, Yusof, Karimian, Pashna, & Hematian, 2015) [14]. If the image has more salient object to be recognized the segmentation of the image should be of a higher order. The segmentation analyzes the nature of the bond of the pixels and group them together, according to the pixel values. This way grouped pixel formulate an object and the object becomes a foreground. This process of segmentation is different from object detection as object detection only detects an object. Whereas segmentation can also be used for object detection. The most popular segmentation is given below.

A. Edge Based Image Segmentation

Edge detection is one of the most profound methods of segmentation which is directed to discover the edges of an object in the image. The process of detection of edges is one way to ease the feature finding step. The edges of an object in an image give out a piece of significant information that is useful to the investigation. This also helps in reducing the amount of computation required for additional filters without losing structural and temporal properties of an image. Edge detection under image processing domain is highly evolved throughout time. The images is partitioned into different areas where the object exist. And the boundaries of the image object represent shape of the object residing in the image. This approach is helpful where the shape of the object is a crucial characteristic. It also finds its application in forensic study of fingerprint analysis. The edge detection stand as a foundation on top of which other segmentation technique are aligned.

There are instances where the edges in an image are found to be incoherent. In order to segment the object of the image choosing the closed region boundaries are advisable. These figures or object which appear as closed region are called as spatial taxons. In other words, the spatial-taxons are described as information granules which tend to include the foreground objects, groups of objects, and salient object. Hiralal & Menon, 2016 [15] have done a comprehensive study in their research work for edge segmentation.Asra Aslam, Ekram Khan, M.M. Sufyan Beg, improvised edge detection segmentation which is based on sobel edge detection to find closed region using closed couture algorithm[16]. J. Canny's, 2015, edge detection algorithm[17] finds the image gradient by initially smoothening the edges. with this approach, the noise in the image is eliminated. S. Beucher, F. Meyer implemented the watershed transform [18][19], is used along the edges o avoid over-segmentation. it helps in visualizing an image in 3 dimensions where the 3rd dimension accounts to intensity.

B. Threshold Based Image Segmentation

One of the straightforward methods of segmentation in image processing is threshold-based segmentation [14]. Every pixel in an image has an assigned value. In threshold Based Image segmentation a constant threshold value is predetermined and fixed. Each pixel values are compared to the fixed threshold value. If each pixel value is smaller than the threshold value, the smaller pixel value is substituted by black pixel. As a result, the pixel value which is very low remains to be the same. Thresholding is more suitable to an image that is converted to grayscale. Converting to grayscale maintains the pixel value between the range of black (High) and white (Low). The resultant image from the threshold-based segmentation is a binary image. Dealing with binary images it becomes straightforward to classify and recognize the segmented areas of the image. The key for a good threshold-based segmentation is the selection of the threshold value. Mostly the threshold values are selected automatically by calculating the mean value. J. Canny's, 2015, combined threshold segmentation after applying edge detection segmentation in order to carry out border thinning although this is a complex task and can incur relatively higher execution time[17]. M. Sujan implemented otsu thresholding segmentation that yielded 84.1 % accuracy [20] in comparison with that Umit Ilhan, Ahmet Ilhan (2017) [21] implemented a threshold-based segmentation in which threshold was calculated by defining unique pixel values, thereby using this average threshold value to convert to a binary image.

C. Clustering-based Image Segmentation

The clustering algorithm is put forth when the dataset is unlabeled and is the most classic algorithm for unsupervised learning problems (Verma, Gupta, Agrawal, & Cui, 2009) [22]. One of the most popular clustering algorithms use is k-means Clustering. Clustering can be depicted as grouping set of datapoints which are similar in their properties (Muneer & Joseph, 2018). K-means clustering uses an iterative approach to cluster the datapoints. The 'K' in the K-means clustering refers to the number of clusters intended by the problem statement. The centroids are determined using distance formula that is suitable for the problem statement. The datapoints that is close to the centroid values of the cluster is grouped in the same. The value of the centroid of the clusters are updated iteratively until the values does not change. For the K-means clustering segmentation to be successful, the selection of the number of cluster 'k' is the crucial part. In terms of images, each pixel values is grouped with respect to the closeness of the pixel values. This may create few clusters, in which each cluster would represent a range of pixel values. Then the segmentation process is carried out.

Liu et al [23] implemented adaptive method of fuzzy segmentation and k-nearest neighbour segmentation framework which perform segmentation depending upon the pixel similarities. Eman Abdel-Maksoud, Mohammed Elmogy, Rashid Al-Awadi(2015) [24] integrated k-means and fuzzy segmentation which showcased powerful performance compared to k means segmentation and mean shift segmentation individually. Kaus et al. [25] combined spatial prior knowledge with k-NN classifier. to perform segmentation.

D. ANN Based Image Segmentation

Artificial neural network segmentation is a recent trend with the emerging popularity of artificial intelligence. With multiple segmentation algorithm discovered and investigated over the years choosing any segmentation algorithm depends mostly on the type problem that is being solved. Although they are proven to be more accurate for the suitable problems, there still exist challenges in image processing that needs an optimized way of handling. Research have integrated various segmentation algorithm with the neural network. This integration will involve segmentation process to function at a faster pace. H. E. M. Abdalla and M. Y. Esmail 2018, [27] implemented a feed forward neural network with back propagation to segment brain tumor images and thereby classify them appropriately. Most suitable neural network for image segmentation is convolutional neural network. The convolutional neural network uses convolutional operation which is basically a mathematic operation on a image pixel value. Kernels are key in convolutional neural network as these are considered to be the feature detectors. A filter or the kernel is a smaller matrix. The values of the kernel grid can be selected to segmentation and the number of kernels that is to be used is not restricted. (Li, et al., 2015) have integrated k-means clustering algorithm with the neural network architecture. Sharma, Minakshi and Mukharjee (2013) implemented genetic algorithm to selected features and made a comparative analysis on the performance of fuzzy and neural segmentation [28]

IV. FEATURE EXTRACTION METHODS

Feature extracting and selection paradigms of machine learning model is a procedure of extracting and selecting the most rewarding feature or variable that aids in prediction of the outcome for the datasets. The dataset required to train any machine learning model is usually enormous data. Computing these enormous dataset forces the physical machine to utilized huge amount of resources which leads to maximum time consumption. Apart from the technical hinderance, it also forces the machine learning model to learn all the details of the dataset. As a result, the anomalies of the dataset is learnt along with the actual data. The trained model without having a effective preprocessing, feature extraction and feature selection mechanism may yield an inaccurate machine learning model.

A. GLCM

Gray level co-occurrence matrix is one of a highly implemented statistical procedure that is used to inspect texture of the image data. these textures describe statistical relationship between the pixels pair. the GLCM first discovers the texture in the image data depending on the intensities of the gray levels. then creates a GLCM matrix by calculating a pair of pixels that exhibits spatial relationship between the pair of pixels. the matrix so obtained is called as graycomatrix. the features such as contrast, correlation, energy, and homogeneity metrics are then extracted by computing the graycomatrix. Minakshi and Mukharjee (2013) [28] used GLCM feature extraction mechanism to obtain 20 features, further applied genetic algorithm to select the most prominent feature. Zulpe, Nitish & Pawar, V. (2012) used GLCM feature extraction to extract feature of four class of brain tumor images thereby feeding into 2-layer feed forward network [29]

B. GLRLM

The gray level run length matrix is another approach for feature extraction that is largely implemented. It shows it major inclination on statistical properties of MRI images. It uses the statistical distribution on the spatial relationship between the pixels. These features of the GLRLM can be incorporated with neural network model to identify the textural patterns between the pixel relationship. Feature extraction mechanism when applied to the images before the preprocessing can consummate longer duration as the image possess high resolution and have intricate regions of interest. Arunadevi & Deepa implemented GLRLM to categorize the brain tumor 3D MRI image data [31]. Study suggest that time consumption on taken on the raw image can be minimized my parallelising GLRLM mechanism in order to generate GLRLM matrix. Zhang, Hanyu & Hung, Che-Lun implemented a mature way of accelerating GPU to support parallel GLRLM mechanism [30].

C. PCA

Principal component analysis was first coined by Karl Pearson. This exploratory tool has gained popularity for it's potential to covert the image dataset to a coordinate matrix. While establishing a machine learning model, the bigger challenge faced is curse of dimensionality. The model trained on the feature set involving the feature of least importance tend be overfitted model. Hence, the feature of least importance should be eliminated. This can be a challenging process as the feature vector consist of n number of vectors which are statically independent. Although all feature of the feature vector may be inclined to each other, this is not a straightforward method to visualize the data. PCA is a solution for this problem. PCA suspects the most prominent feature is the feature with biggest variance. Using this hypothesis, it concludes that feature with higher variance is equivalent to that of entropy that the algorithms looks for. Feature with the larger entropy corresponds to the feature containing exclusive information. Jolliffe, I. T., & Cadima, J. (2016) has researched comprehensively on PCA [34]. Palki, Patil, Kumar, Perur, & Kumar compared PCA with the SVM on their model classifier that classifies brain tumor to be malignant or benign [32]. The results show that SVM classifies with better accuracy. Irem Ersöz Kaya et al (2017)[33] provided comparative study on five type of PCA namely conventional PCA, Probabilistic PCA (PPCA), Expectation Maximization Based PCA (EM-PCA), Generalize Hebbian Algorithm (GHA), and Adaptive Principal Component Extraction (APEX) and concluded that PPCA gave better results when applied to the brain tumour MRI images.

D. LDA

Linear discriminant analysis is yet another statistical tool appropriate in detecting the linearity of the features and recognition of the patterns. It is often compared to other feature extraction methodologies such as PCA and SVM. Saravanan, S.

Karthigaivel, R. Magudeeswaran in 2020 combined LDA with ICA to have automated way of enhancement of the brain tumor images image [35]. LDA has a smaller pace compared to PCA yet it is more commonly used feature extraction mechanism. Unlike analysis of variance statistic tool LDA operates on continues independent features and categorical dependent features. Along with this feature, the base hypothesis of the linear discriminant analysis is that the image data or any data is normalized [36]. Unlike the PCA, the LDA attempts to examine the dissimilarity between the clusters. Hence feature coordinates are built based on the dissimilarities rather than the similarities of the clusters.

V. RESULTS SUMMARY

The approaches under image processing are been discussed in the above section. Using the above information, the features pertaining to the different methodologies under image processing are been in listed down in the table-I. The goal of this section is to provide comprehensive knowledge to build brain tumor classification model using the correct methodologies.

Table-I Methodology Summary

Sl. No.	*Methods*	*Category*	*Features*
1	Wiener Meathod	Preprocessing	Image restoration De-blurring tool Realtime images
2	Median Filtering	Preprocessing	De-nosing tool Non-linear Edge preserving
3	Mean Filtering	Preprocessing	De-nosing tool Linear Edge preserving
4	Gabor Filtering	Preprocessing	Region oriented Suitable for texture rich images
5	Image Normalization	Preprocessing	Intensify noises White balance Maintains contrast
6	Image Morphology	Preprocessing	Patters define filters Dilation Erosion Suitable for textual images
7	Edge-Based Segmentation	Segmentation	Looks for pixel dis-continuation Gives shape of the object Considers closed region
8	Threshold-Based Segmentation	Segmentation	Sets threshold Binary segmentation Slow speed
9	Clustering-Based Segmentation	Segmentation	Segments based on similarities No of Segments defined by ‘k’
10	GLCM	Feature Extraction	Texture analysis Based on pair of pixels Used to describe spatial analysis
11	GLRLM	Feature Extraction	Texture analysis Consumes more time Used to describe spatial analysis Mostly recommended for MRI
12	PCA	Feature Extraction	Statistical tool Gets variance rich features Gets features that have great entropy
13	LDA	Feature Extraction	Statistical tool Works on independent features Feature linearity

VI. CONCLUSION

Application of deep neural networks on medical image classifications is a cutting-edge technology of present times. As there are multiple factors involved in building an image classifier model, Innumerable developments and plenty state of art proposals in this domain has made it cumbersome to decide which methodology should be implemented while building a model. this paper showcases the features, positives and negatives of different methods involved in preprocessing, image segmentation and feature extraction. The paper further discusses different strategies that is been implemented in the recent years and the benefits of these strategies. In summary the paper culminates most widely used preprocessing methods is median filtering to denoise the image data. However, other preprocessing mechanism are implemented depending upon the characteristic of dataset that the model will use. Most of the research has shown the efficiency of k-means clustering and fuzzy-C means clustering goes head-to-head. However, fuzzy-C means clustering captures hidden features in order to segment the images whereas k-means clustering provides better accuracy. The threshold based and edge-based clustering are time consuming for complex dataset and it should be incorporated to with other methodologies to provide desired results. GLCM and GLRLM are one of most prominently used feature extraction methods for image data. These methods provide complete feature set for further processing. LDA and PCA has its own benefits nevertheless, PCA is preferred over LDA for solving curse of dimensionality. Accordingly, the research in this domain continues. The objective of the such research is to have an automated brain tumor classifier model that accurately predicts the presence of tumor cell without the human intervention.

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