MR Image Analysis of Neonatal Brain using Adaptive Mathematical Morphological Processing and Region based Segmentation

B.sridhar, S.Sridhar, V.Nanchariah

Abstract**:** ***In the study of evaluation of infant brain development, the segmentation of obtained MR images is an important step. When compared with the MR images of adult brain it is difficult to identify the different regions in infant brains with that of the methods used for the analysis of adult brains. This is due to the size difference of the brain and the differences in the properties of the brain tissues. So, for analyzing these MR images it requires manual interaction with the images resulting in the bias of the results. For this problem we propose another approach for the segmentation of neonatal brain MR images. This method doesn't require any manual interaction and produces unbiased results. Our algorithm segments the different layers (right hemisphere, left hemisphere, cerebellum, brain stem) and the different tissues like sub cortical gray matter, Militated & un mylinated gray matter and cerebrospinal fluid, resulting in the better understanding of the development of different parts of the brain. Our algorithm can be used for the analysis of MR images of infant brains of age as less as 3to6 months.***

Keywords **:** ***Neonatal brain, Magnetic Resonance Imaging, Mathematical morphology, Watershed macro controlled segmentation.***

I. INTRODUCTION

In the development of brain the neonatal stage has gained its own importance as it is the most critical stage in the development of brain. The analysis of this stage helps in preventing and better understanding of the different problems that may rise in the growth of brain in the infant stage. For this process of analysis of neonatal brain we make use of region based watershed segmentation.

The main aim of this segmentation process is to differentiate the different regions in the brain with the help of watershed segmentation. Each and every segment in the brain is assigned with different colors. Initially the MR images obtained from the MRI are obtained and these images are considered as inputs for our process and these obtained images are then processed to find out the different regions.

In the segmentation of neonatal brain the MRI posses additional challenges when compared to that of an adult brain as the imaging process involves the movement of baby.

Revised Manuscript Received on November 30, 2019.

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So, it requires high resolution images with low artifact and all these lead to low signal to noise ratio and lower contrast to noise ratio as it is difficult to distinguish the different regions of the infant brain.

For the better understanding of the image initially the intensity levels of the obtained images are modified using image enhancement techniques .a large amount of work and development has done for the analysis of adult brains. But these techniques cannot be used for the analysis of neonatal brains due to the large structural differences between the adult and infant brains. In the past few years lot many technologies came into existence for the imaging of neonatal brains.

Many of these techniques involved manual selection of the regions or the manual segmentation of the training images for obtaining image intensity models. This may lead to some bias in the results. Our process involves coloring of each and every region in the neonatal brain with the help of watershed segmentation. Firstly the image enhancement techniques are used to increase the contrast of the image. This technique makes the inputs a lot better understandable when compared to the original input images.

The input data for our algorithm are the scanned MR scans of a new born infant brain between the age groups of 38 and 44 weeks. Before applying these inputs to the algorithm the inputs are to be preprocessed. To enhance the quality of the image we apply some preprocessing techniques like image enhancement techniques so as to increase the contrast of the image for better segmentation. We correct the intensity in homogeneities as mentioned in the method by Mangin (2000)[1].

Most of the authors used their own style of templates and atlases to guide the segmentation process, recently few authors have developed specific brain atlases for the study of neonatal brain (Kuklisova-Murgasova et al., 2011; Oishi et al., 2011; Shi et al., 2011b)[2].In order to overcome the problems that are faced during the segmentation process most of the authors introduced strong prior knowledge into the segmentation process.

More over the obtained segmentation results are often used to investigate the structural difference between the different people. In this paper we have proposed a different approach for the segmentation of the neonatal brain. This is based on the general and widely acceptable knowledge of Neonatal brain morphology.

Before presenting our algorithm we offer a brief description about few techniques that we have used like watershed segmentation and mathematical morphological operations, which are involved in our algorithm.

More details can be found in Beucher and Meyer (1993)[3], Lotufo and falcao (2000) and soille (2010)[4].
The details related to the segmentation of the neonatal brain and its segmentation are considered from the works of Laura Gui et al., (2012)[5].
Our paper is organized in the following pattern. Section II consists of the theoretical background i.e., Mathematic morphological operators followed by watershed transform is discussed. In section III It consists of the proposed method which is explained further. In section IV The results, related discussions are enclosed. The section V consists the conclusion of this method.

II. ADAPTIVE MORPHOLOGICAL OPERATORS

The classical morphological process analyses the shape by matching it with the so called structuring element, a bounded set $B \subset IR^2$. The different shapes that can be used for B are disc, square, line, ball etc. For better results here we made use of square with five as side[7].
The mathematical equations for these dilation and erosion operators are as follows.

$$dilation \; : \; (f \oplus B)(x) = \sup\{f(x-y), y \in B\}$$
$$erosion \; : \; (f \ominus B)(x) = \inf\{f(x+y), y \in B\} \quad (1)$$

The name itself clearly indicates that the dilation process blows up its boundaries, while erosion shrinks them. Dilation and erosion form the basic mathematical morphologic operations. These dilation and erosion form the basic functions for few other morphological operations like opening and closing.

$$opening \; : \; (f \circ B)(x) = ((f \ominus B) \oplus B)(x)$$
$$Closing \; : \; (f \bullet B)(x) = ((f \oplus B) \ominus B)(x) \quad (2)$$

In the watershed segmentation process the input image is considered as a topographic surface. This algorithm is introduced by Luc Vincent and Pierre soille which is based on the concept of "immersion". The individual local minima on the surface of a gray–scale image can be regarded that the surface has a hole and is immersed into water. Starting with the low intensity value the water will progressively fill the different catchment basins of image (surface). Conceptually the algorithm then builds a dam so as to avoid a situation that the water coming from the different minima are merged. At the end of this process the each local minima is totally enclosed by dams corresponding to the watersheds of images. This informal analysis of the immersion process can be established mathematically by the definition of 'geodesic distance' and 'geodesic influence zone'. 'Geo desic influence zone' deals with the expansion of the plateau from each local minimum for watersheds transformation.
Suppose A contains a set B consisting of several connected components B1, B2… Bk. The geodesic influence that is A(Bi) of a connected component Bi of B in A is the locus of the points of A whose geodesic distance to Bi is smaller than their geodesic distance to any other component of B.

$$A(B_i) = \{p \in A, \forall j \in [1,k]/\{i\}, d_A(p, B_j)\} \quad (3)$$

The immersion process and is results are described in terms of the geodesic influence zone.
Similarly the morphological opening if applied on a gray level image, removes the bright features on the image whose spatial support is much smaller than the structuring element. The morphological opening, closing and the different morphological operators are applied so as to modify the different attributes of the input image.
Adaptive mathematical morphological operators (AMM)
Let f is a weighted structure element with convolution of a nonlinear filter masks, such a type of filters are min, max and median filters, A is the input image, x is a element of each set of 'f'. Dilation and erosion operators are expressed as

$$\mathrm{D(f)} = (\mathrm{f} \oplus \mathrm{A})(\mathrm{x}) = \bigvee \mathrm{y} \epsilon\, \mathrm{A(x)}\; \mathrm{a(x-y)}$$
$$\mathrm{E(f)} = (\mathrm{f} \ominus \mathrm{A})(\mathrm{x}) = \wedge \mathrm{y} \epsilon\, \mathrm{A(x)}\; \mathrm{a(x+y)} \quad (4)$$

Level AMM is a fixed operators, which is on the intensity level I then weight family can be a function of intensity is denoted a $\{\Psi I\}$. Then adaptive operator can be expressed as in equation

$$\Psi v = \vee v \, \Psi v(X(f)) \quad (5)$$

X(f) is indication operator. Here Ψv is decreases with increasing the operator.

III. PROCESS INVOLVED

Our proposed algorithm consists of six steps as shown in Fig. 1, whose details are described in the further sections. The different steps involved in it are: obtaining high contrast images using image enhancement techniques, Detection of edges by using morphological gradient of the image, Morphological processing to highlight the different regions in the image, Thresholding the image, calculating the watershed label matrix of the input image, Detection of the different regions in the neonatal brain.
In this paper we propose a different and widely acceptable approach for the segmentation of neonatal brain, based on the use of widely acceptable neonatal brain morphology. In this process we consider that the gray matter, White matter and all the remaining constituents of the brain are connected tissues. This in turn is surrounded by cerebro spinal fluid.
The images obtained from the magnetic resonance imaging are considered as inputs for our analysis. The images are considered in the form of '.png' files. These images are in the form of RGB for our analysis we convert them into gray scale. To improve the clarity and contrast of the image initially we apply the required image enhancement techniques

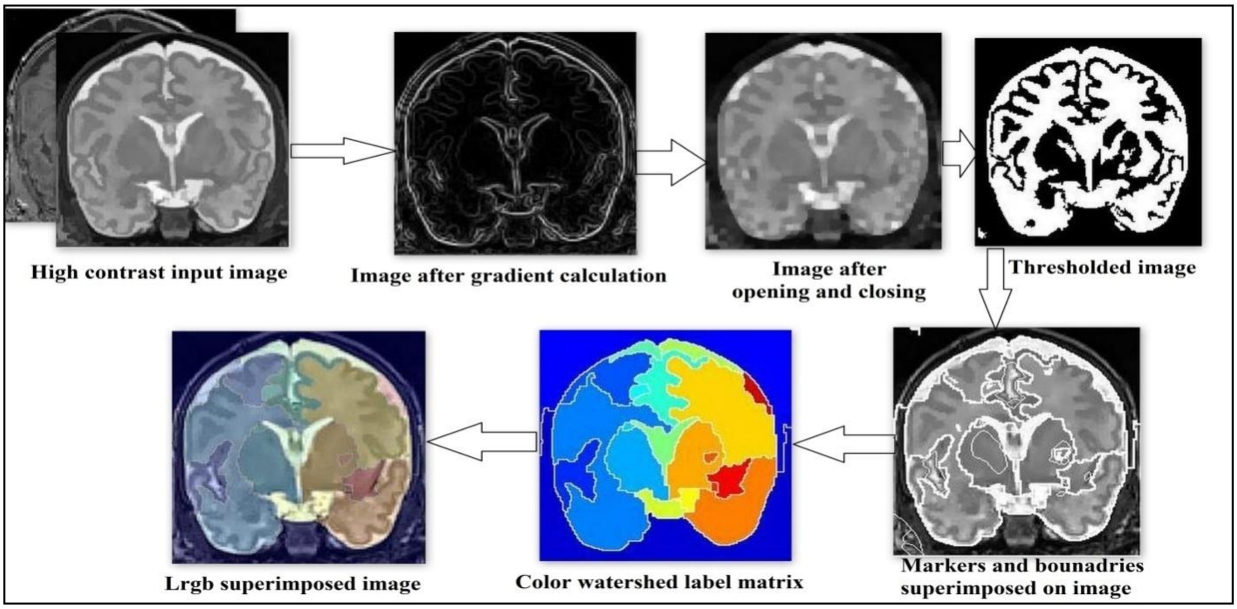

Fig 1) Outline of segmentation process

By applying these techniques we will obtain a high contrast image. Initially for detecting the edges of the image we apply the gradient operator,

which in turn highlights the edges of the image. There are several functions which we can use for this gradient operator but after applying all we have noticed that the better results are obtained using the prewitt operator. Then we make use of watershed function to compute a label matrix identifying the watershed regions of the input matrix. The image pixels are divided into different regions. Without any additional processing this process may lead to over segmentation. To overcome this process we make use of morphological techniques like “opening by reconstruction” and “closing by reconstruction” which cleans up the image. These functions will create regional maxima inside each and every region and by using the function called imregional max we can find out the different regions in the neonatal brain.

The image opening is an erosion process followed by dilation and opening by reconstruction is a process which is an erosion process followed by a morphological reconstruction. Similarly closing an image can remove the dark spots from the image. Similarly the closing by reconstruction is a process of closing followed by image reconstruction. As known the opening by reconstruction and closing by reconstruction are more effective than the techniques like opening and closing and so we make use of these techniques. Soon after we have computed the watershed transform of the image. The foreground markers, background markers and segmented object boundaries are super imposed on the original image.

To our knowledge the proposed algorithm is best suitable for the segmentation of the neonatal brain and to identify the different regions present in the brain. The robustness of our algorithm is confirmed by testing it on several images with variable quality.

IV. Results and Discussions

We have tested our segmentation on different test samples of neonatal brains between the age groups of 38 and 44 weeks.

Our algorithm was implemented in MATLAB, using the image processing toolbox for MATLAB (2011) for the watershed algorithm and morphological operations.

A. obtaining high contrast input image using image enhancement techniques

For the process of segmentation initially the inputs that we have took for processing are to be preprocessed so as to increase the quality of the image for the better segmentation. For this purpose we apply several image enhancement techniques like contrast adjustment using the ‘imadjust’ function of Mat lab.

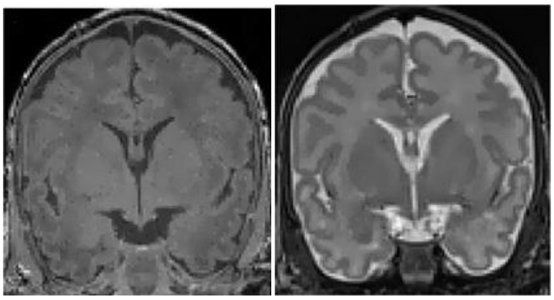

Fig 1.2 a) low contrast image, b) high contrast image

In this way by using the image enhancement techniques we have converted the low contrast image into high contrast image and are given as the input for our algorithm.

B. Edge detection of the image using gradient operation

The gradient of an image is nothing but differentiating the input image. By differentiating the input image we can obtain the edges of the regions in the images. Here in the process of gradient calculation different kinds of functions are being used out of which few are Prewitt, sobel, Laplacian, Gaussian etc.,

But after analyzing the different results we have observed that better results are being observed when we make use Prewitt and sobel function. So, we make use of this function in our algorithm and the results obtained are as shown below

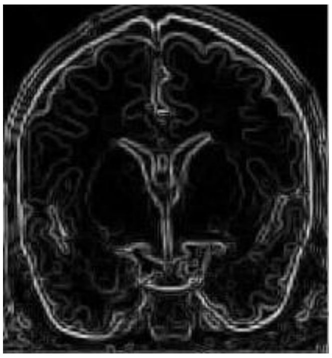

Fig 1.3) representing gradient magnitude of input image

In this way the edges of an input image are being highlighted. It is further used for the process of region marking using morphological operators.

C. Morphological processing for highlighting different regions in the input image

A different variety of procedures can be used to find the foreground markers, which can be like the connected blobs of pixels found inside the different regions. In this process we are making use of different morphological techniques like "opening-by-reconstruction" which is generally used to clean up the image. These operations that we are using will create flat maxima in each and every region of the neonatal brain. The opening process followed by closing removes the dark spots present in the region. We have observed that reconstruction based opening and closing are more effective than the ordinary opening and closing functions.

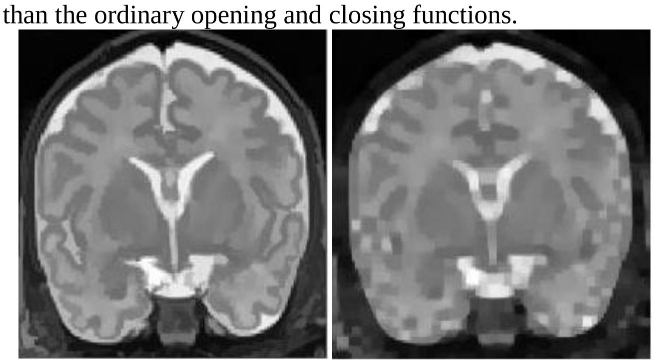

Fig 1.4 a) opening and closing by reconstruction, b) opening and closing

After performing these operations the regional maxima in each and every region are calculated. In the process of opening by reconstruction and closing by reconstruction we basically make use of two primary mathematical morphological operators called dilation and erosion.

As we have known the opening process smoothes the shape of the image by breaking narrow isthmuses and by eliminating small islands, where as the closing process smoothes the image by closing small holes in the images of neonatal brain.

D. Thresholding the image and calculating the boundaries and markers of image

Thresholding the image is nothing but converting a gray level into binary image. The boundary value for this is nothing but the threshold value is set as required. The threshold image is as shown in the figure.

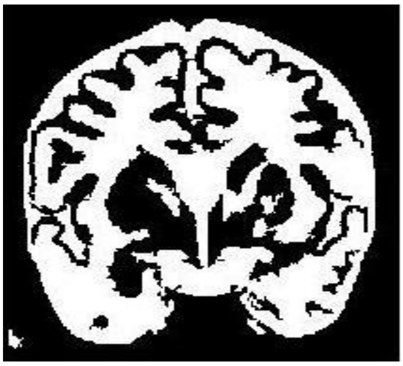

Fig 1.5) Threshold image of input image

In this way by thresholding the image the image is converted into binary image which consists of zeros and ones. This binary image is useful for detecting the different regions present in the neonatal brain.

Now the boundaries and markers obtained are superimposed on the original image as shown below.

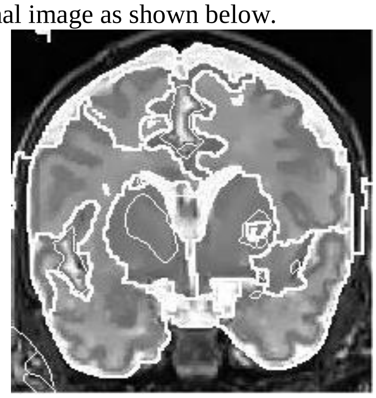

Fig 1.6) image with markers and boundaries

E. Calculating the watershed label matrix

The label matrix is calculated for each and every region and the label matrixes are converted into RGB colors and these colors are assigned to them using an inbuilt function in MATLAB called label2rgb. This process is used for the purpose of visualizing the labeled regions.

In order to distinguish the different regions of the neonatal brain this process is used and the label matrix is calculated and the colored regions of the brain are filled with colors.

The colored image after processing is as shown in the figure below

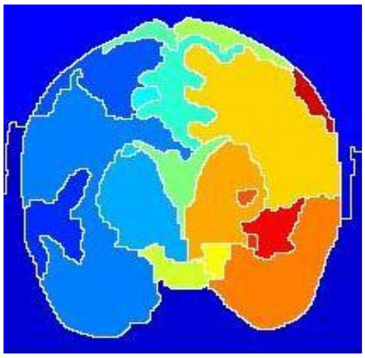

Fig 1.7) color watershed label matrix of the input image

Finally after the calculation of the regions they are superimposed on the original image.

F. Detection of the different regions of neonatal brain

The obtained label matrix is then superimposed on the original image the regions are then identified.

With the help of these regions we can identify the growth of the different regions in neonatal brain.

Finally the image is segmented using morphological operations and watershed segmentation. With the help of this label matrix is helpful in estimating the growth of different regions in the neonatal brain.

This tested results are as shown in the below figures. We can clearly see that the different regions present in the neonatal brain are segmented and are easily distinguishable

Fig 1.8) lrgb superimposed image of neonatal brain

Our segmentation is applied for different infant neonatal brains we can clearly see the differences in the size and shape of the images. The proposed algorithm is suitable for the neonatal brain of different children and it successfully achieved better results. Despite the differences in the shape and structure between different children our algorithm has yielded better results. The visual evaluation of our segmentation reflects good results for all the different inputs, showing that the algorithm can cope with significant anatomical variability.

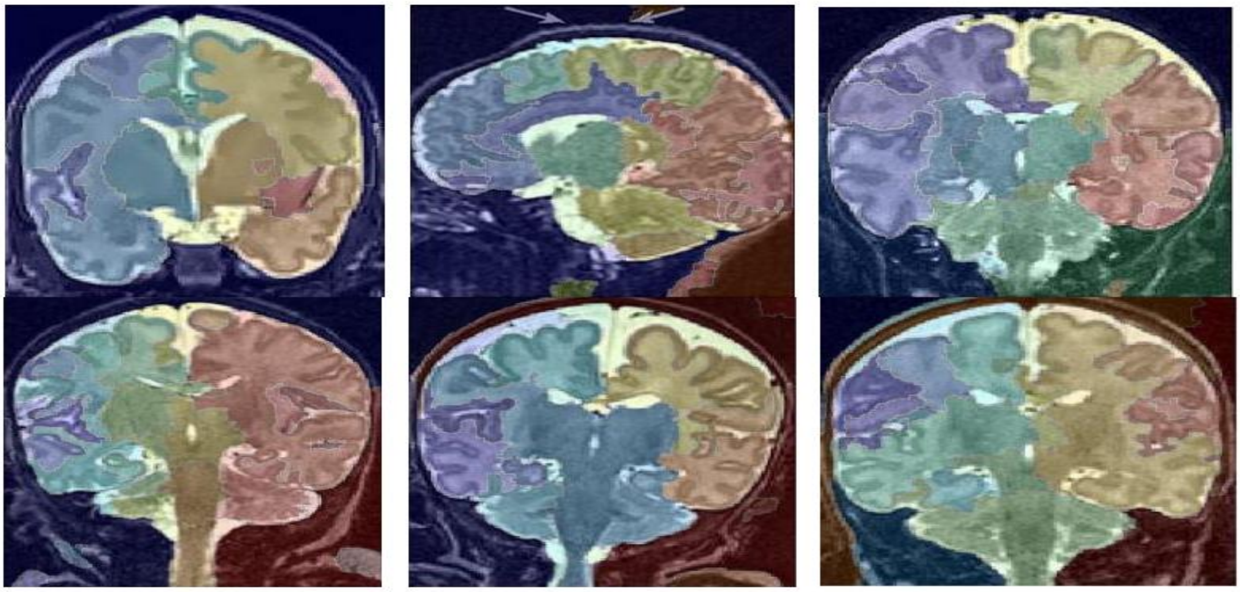

Fig 1.9) Representing the results of different infant brains with different anatomical features

V. CONCLUSION

The main contribution of this work is a segmentation algorithm suitable for newborn Brain MRI, Based on the knowledge of Morphological processing and watershed segmentation with a basic knowledge on the different attributes of brain.This method was successfully tested on the infant brains of 10 different children between the age groups of 38 and 44 weeks. This would enable the precise detection of the different regions present in the brain. We estimate that this algorithm can be applied for infant brains of different age groups.

ACKNOWLEDGEMENTS

Authors show the gratitude to the vizianagaram hospital management who are supporting progress this research work and also thankful our College management who were provided the financial support.

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