Abstract

Objectives: Every year millions of babies born preterm and it is a serious issue in developed countries. Preterm birth is worldwide problem of young children. Methods/Statistical analysis: Advances in Magnetic Resonance Imaging (MRI), comprehensive images of the newborn brain is visualized non-invasively. Here we are focusing on the early assessment of brain development in neonates and premature infants using multi stage segmentation and classification approach with quantitative analysis. To achieve higher segmentation and classification accuracy neural network classifier are used. Findings: The accurate segmentation and classification of brain tissues is very much useful in evaluating the brain development of newborn and premature in-fants. Therefore, newborn brain MRI forms a crucial part in analytical neuro-imaging; principally in the neonatal stage. Our method gives higher dice similarity index values and higher computational speed as compared to existing methods. Application: Resulting segmentations are used for volumetric analysis and quantification of cortical descriptions. This analysis plays vital role for neonatologists in early detection and diagnosis of neural impairments.

Keywords: Classification, MRI, Multi-kernel Support Vector Machine, Newborn, Preterm, Segmentation

1. Introduction

The premature infants born every year are around 15 million and rising day by day. This is more than 10% in births1. In last two decades, ratio of preterm births has increased drastically. In developed and developing countries, premature birth is prime crisis of young children. Annually more than 1 million young children die due to the difficulties of premature birth. Babies with preterm birth frequently face severe and lifetime health issues, including cerebral palsy, vision loss, breathing problems, jaundice, and neurological impairments. As per the National Centre for Health Statistics, United States acquired a “C” on the 8th annual report with a preterm birth rate of 9.6% in 2014.

The main reason of newborn infant’s death is preterm birth, which is generally before 37 weeks of pregnancy. Premature infants are frequently at a higher level of risk, disability and health issues. World Health Organization (WHO) has defined the stages of preterm birth:

- Tremendously premature: < 28 weeks
- Extremely premature: from 28 to < 32 weeks
- Late premature: from 32 to < 37 weeks

MRI is non-invasive technique used for acquiring the brain images of infants. MRI is a harmless method to obtain the brain images of infants without ionized radiations. Due to these advantages of MRI, paediatric neuro-imaging has reformed the health care system. MRI of the new born brain helps to identify abnormalities such as hydrocephalus, congenital malformations, hypoxic ischemic encephalopathy, infections and infarction3. Thus
brain MRI forms a fundamental part in diagnostic neuro radiology, particularly in the neonatal stage. MR brain images are generally used for evaluation of brain development in preterm infants. This MR brain images provides complete analysis based on surface, area, volume and morphology, this supports to identify the complications and risk issues in the children due to premature birth. Studies of anatomy of developing brain is vital to depict normal development and investigate factors that affect brain growth. So quantitative neuroimaging studies using MRI are increasingly being used to assess brain growth and development in this vulnerable population. In this paper we are focusing on the early assessment of brain development in neonates using multi stage segmentation and classification approach with quantitative analysis.

Potential challenges in neonatal brain MR image segmentation are as follows:
- Low CNR (Contrast to Noise Ratio)
- Intensity Inhomogeneity
- Variable imaging parameters
- Overlapping intensities
- Partial volume effect
- Non-intensity based borders
- Shape Complexity
- Susceptibility artifacts
- Normal anatomical variations

The brain development in neonatal stage is crucial and significant changes occur in this interval. The major challenges to assess brain development of neonates are size and structure variations of infants. In brain tissue high level of water content is present, which causes overlapped intensity values and inconsistency among the brain structures.

2. Material and Methodology

The primary intention of my research is to design and develop an approach for automatic segmentation and classification of neonatal brain MRI.

Objectives
- Study and analysis of different variants of techniques meant for improving performance in Neonates and Premature Infants Brain segmentation process.
- Design and develop an efficient Neonates and Premature Infants Brain segmentation approach with the aid of supervised classification techniques.

The basic aim of proposed research work is to segment brain at global and tissue level. At global level major brain areas such as brainstem, cerebellum and two hemispheres are segmented. Gray Matter (GM), White Matter (WM), and Cerebrospinal Fluid (CSF) are segmented at tissue level.

In concern with newborn infants further segmentation of Gray matter as cortical and subcortical GM is needed. Myelination is a very important process and infant continuously goes through myelination, so it is essential for evaluation to segment myelinated and unmyelinated white matter. Overall process of segmenting different brain structures at different levels in newborn and premature infants is really exigent task.

From the approach, two challenges are identified to improve their approach further. The first one is the inclusion of multi-kernel support vector machine (MKSVM) instead of SVM in the second stage. The inclusion of MKSVM could improve the classification accuracy of SVM for both linear and non-linear dataset. Here, radial basis function (RBF), polynomial function and quadratic will be used as kernel to improve the SVM performance further. The second one is the Levenberg-Marquardt based neural network taken into consideration for classification instead of multiclass k-nearest neighbor (MCNN) in the third stage. In KNN, the main disadvantage is that it does not learn anything from the training data and which can be slow if there are a large number of training samples. Therefore, neural network based classifier is exploited to improve the performance.

Proposed approach for segmentation of Brain MR Images involves the following steps:
(1) Preprocessing,
(2) Region Segmentation.

T1-weighted (T1w) and T2-weighted (T2w) brain MR images of a newborn are used as input for first step of proposed algorithm. Then this MR image goes through various pre-processing steps to improve the quality of images which is beneficial for efficient segmentation. The various steps involved in pre-processing are de-noising, affine registration, intensity homogeneity correction and alignment to the radiological orientation. Gaussian filter is used for noise removal.

In the second step, the region of interest (ROC) will be extracted by using three stages.
Stage I: K-Nearest Neighbor (KNN) will be used for assigning voxels to one of the tissue classes are labelled.

Stage II: Dedicated analysis of the remaining voxels will be performed using multi-kernel support vector machine (MKSVM).

Stage III: Finally, the segmented region will be identified using Levenberg-Marquardt based neural network.

Finally, various brain MR images will be collected from benchmark database and subjected to developed technique for performance evaluation of segmentation. MATLAB is used as development tool for implementation.

3. Results and Tables

Table 1 gives us the quantitative analysis of brain MR images for different subjects. For this analysis we used dataset of 30 images. Various parameters are calculated like precision, dice similarity index, computational speed. The result shows the improvement in these parameters as compared to existing methods.

Figure 1 shows the graphical representation of dice similarity index. The higher DC value indicates good segmentation accuracy. The matching between manual segmented images and our segmented image is given by DC.

The Figure 2 shows the different operations performed on input brain MR images. Figure 2 (a) shows the T1 w & T2w input Brain MR Images. (b) Shows the pre-processed image which is obtained using Gaussian filtering. (c) Shows the contouring of brain portion by using this brain portion is extracted and skull portion is removed. (d) Shows the segmentation of different brain tissues and finally (e) shows the classification of brain tissues using multi classification approach.

Table 1. Quantitative analysis

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<th>Subject</th>
<th>Precision</th>
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<th>Recall</th>
<th>DC</th>
<th>Time</th>
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<tr>
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<tr>
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Figure 1. Graphical representation of dice similarity index.

Figure 2. (a) Input T-1 w & T2-w MRI image. (b) Pre-processed images (c) Intracranial cavity contour (d) Segmented output (e) Tissue classification.
4. Conclusion

Accurate segmentation and classification of prime tissues of brain like GM, WM, and CSF is presented using multi-stage classification technique. Resulting segmentations is used for volumetric analysis and quantification of cortical characteristics. This analysis plays vital role for neurologist and neonatologist in early detection of neural disorders and neural impairments. Proposed work will provide imperative information to neuprophysicians for diagnosis and better treatment planning of newborn babies. The pre and better treatment planning of neural impaired infants will help society to decrease count of mentally challenged infants.

5. References