CHD Fetal Brain Analysis using Combined Quantitative MRI Features and Custom-build Loss Functions

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Abstract

Background:

Fetal magnetic resonance imaging (MRI) is a crucial tool in prenatal care, aiding in understanding early brain development and detecting potential abnormalities, including those associated with congenital heart disease (CHD) [1-3]. Notably, quantitative MRI (qMRI) features have had statistical significance when compared to typically developing (TD) [3]. Further combining multiple cortical qMRI features might provide a more comprehensive and accurate characterization of fetal brain development, revealing subtle abnormalities in CHD that may be overlooked by single-feature analysis. The RandomForest algorithm, employed in this approach, constructs several decision trees and offers robust classification while mitigating overfitting [4]. Its ability to assess the importance of features makes it valuable for identifying significant biomarkers in medical imaging analysis.

Objective:

The objective of this study is to gather insights into differentiating between CHD and TD brain development by identifying unique and biologically relevant MRI biomarkers.

Material and Methods:

The study received approval from the local Institutional Review Board at Boston Children's Hospital. The cohort comprised 126 CHD subjects (mean = 27.8 weeks, sd = 5.97) and 80 TD MRI (mean = 26.53 weeks, sd = 3.95). qMRI features (area, depth, gyrification index, volume) were feature engineered to create combined features via non-linear transformations, weights, and Principal Component Analysis [5] (Figure 1); evaluated using a custom-built loss function to determine the most discriminative features, based on same class proximity and different class farness. To select features, the Mean Decrease in Impurity method within the RandomForest algorithm and non-linear feature transformations [6] were employed.

Results, Discussion, and/or Key Learning:

Preliminary results (Figure 2) show a promising differentiation between TD and CHD; future directions would include the evaluation of all features using the loss function, to quantitatively measure discriminative power. The biologically-relevant features would lay the groundwork for group classification between CHD and TD, aiming to validate their diagnostic utility and integrate them into clinical practice.

Keywords: machine learning, CHD, MRI, feature analysis

Figures

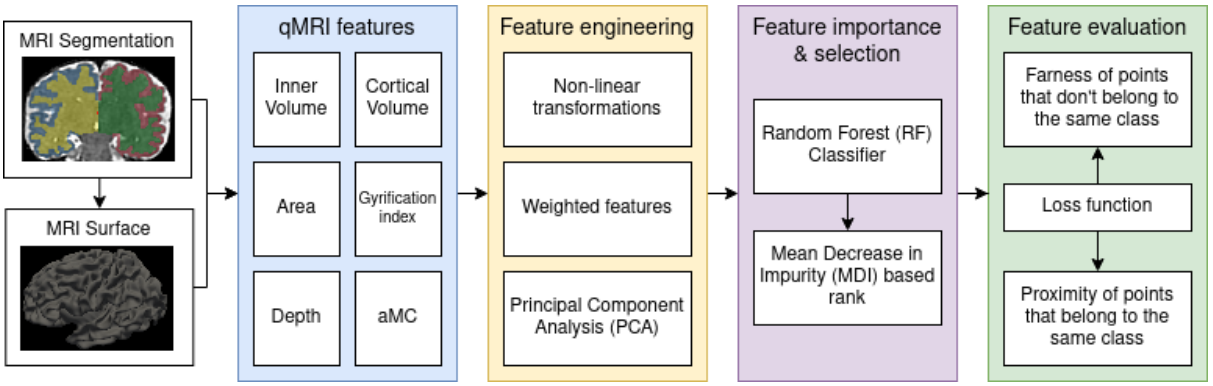

Figure 1. Automatic pipeline for fetal quantitative MRI (qMRI) segmentation and quantitative surface features. Features would be engineering using non-linear transformations, weights, and PCA, further ranked based on RF's MDI, and lastly evaluated based on their discriminative power using custom-build loss functions that evaluate farness of points of non-belonging class and proximity of points of belonging class.

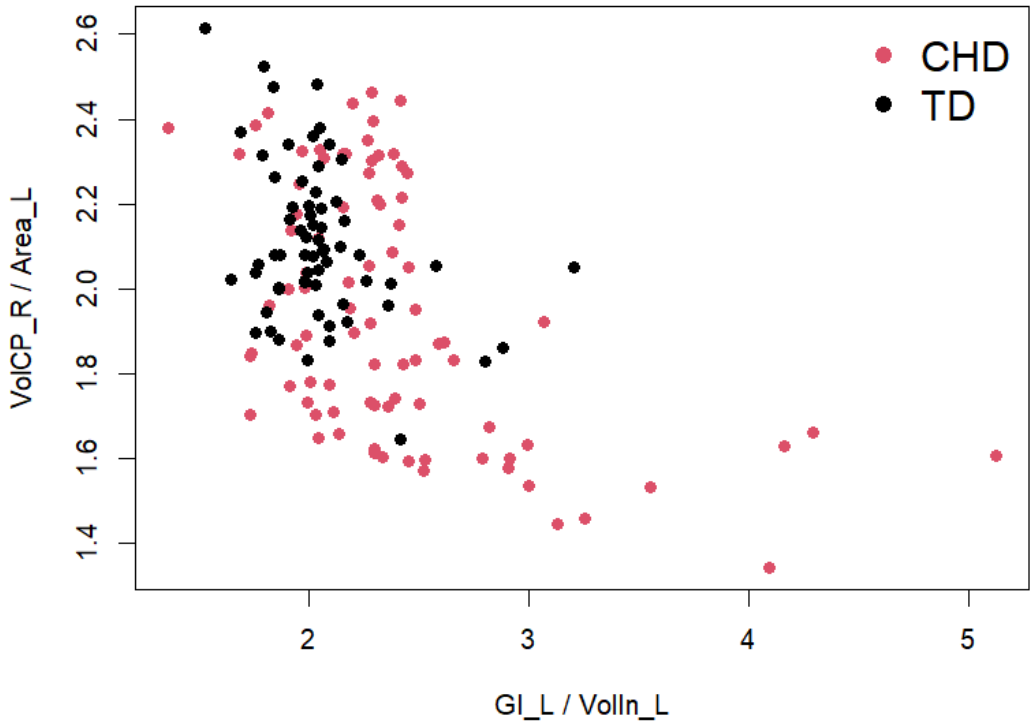

Figure 2. Preliminary results using the best two discriminative features after non-linear transformations, based on CHD dataset and a Random Forest Classifier's Mean Decrease in Impurity. On the x-axis is the gyrification index on the left hemisphere divided by the inner left hemisphere volume, while on the y-axis is the cortical right hemisphere volume divided by the left hemisphere area. Each point represents a different subject.

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