Analysis of Structural MRI Data for the Localisation of Focal Cortical Dysplasia in Epilepsy

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Abstract. Focal Cortical Dysplasia (FCD) is an anatomic malformation of the cortex that gives rise to epilepsy and in most cases can be treated surgically. The precise pre-surgical localisation of FCD is pivotal for a successful intervention that will lead to seizure freedom. The most useful brain imaging method is MRI, but the specificity of its localisation remains a challenging task. In this work multiple features intended to represent intensity, texture and form are extracted from \(T_1\)-weighted and FLAIR images of normal and patient data. A final probability map is performed to highlight FCD lesion(s). The data from 11 most recently visited patients in our clinic and 20 controls have been acquired and examined. In all patient cases the probability map highlights the lesions with high accuracy and improved compared to other methods.

Keywords: Focal Cortical Dysplasia, Epilepsy, MRI.

1 Introduction

A major cause of refractory epilepsy is Focal Cortical Dysplasia (FCD) which is a developmental abnormality of the brain cortex leading to its abnormal stratification. Epilepsy has a prevalence of approximately 1%. In such cases surgical treatment can be performed which achieves seizure freedom in approximately 80% of the cases. The precise pre-surgical localisation and complete surgical removal of the dysplastic tissue is pivotal for a successful outcome and for the avoidance of any additional interventions. The development of high quality brain imaging methods and in particular MRI has enabled the routine treatment of epilepsy.

There has been a considerable amount of work for the localisation of FCD lesions with a variety of image features. Intensity information has been used primarily from the \(T_1\)-weighted \((T_1\)-w\) contrast image, and to a lesser extent from

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the FLAIR image \cite{8}. Additional features used to identify FCD lesions in structural $T_1$-w images include the higher cortical thickness and the lower grey matter to white matter tissue contrast that decreases the definition of the boundary between these two tissues \cite{11}. The characterisation of the FCD lesions has also included texture features such as from grey value co-occurrences and run-length in a window surrounding every voxel, followed by an SVM classification \cite{11}. An FCD lesion develops within one of the hemispheres that results in a left to right asymmetry that has also been used to characterise it \cite{3}. The explicit segmentation of FCD lesions to identify their boundary has been performed voxel based with a fuzzy C-Means clustering method \cite{13}, with the graph cuts method \cite{6}, as well as with analysis of feature based classification together with level sets \cite{4, 5}.

A set of control images has also been used for reference of normals together with an intensity feature resulting from white and grey matter tissue segmentation \cite{16}. In a more general context to our knowledge the reference for the normal appearing tissue statistics thus far has been exclusively intra-image. This may introduce a statistical bias due to the limited image size and the possible presence of multiple FCD lesions in a single brain image.

We propose a method that is based on an extended set of image features in a probabilistic framework. The probabilistic framework also considers statistics of normal tissue from a database. The features are extracted from the $T_1$-w and the FLAIR images. A feature is extracted from the intensities of both the FLAIR and the $T_1$-w while texture and form features are only extracted from $T_1$-w. The features are used to characterise both controls and patients. The reference for normal statistics is obtained voxel based from the set of co-registered control images and is used to infer the probability of FCD. The FCD lesions are identified with high confidence and increased sensitivity compared to the commonly used clinical method \cite{16}. The reference for the validation is a visual evaluation by an expert physician as well as the resected region that results in seizure freedom.

2 Method

A variety of intensity based, texture based, and form based features are extracted from the $T_1$-w and the FLAIR images. The various features are first calculated for all the controls providing a spatial voxel based reference for the normal appearing statistics. The statistic for a feature $f_i$, where $i$ is an index over the features, are the mean $\mu(f_i(x))$ and the standard deviation $\sigma(f_i(x))$ from which the probability of being normal is given by a Gaussian distribution $G(f_i(x), \mu(f_i(x)), \sigma(f_i(x)))$, where $x = (x, y, z)$ indexes a voxel in 3D space. The various features are also calculated for each patient data, and the FCD probability is taken to be the complement of the probability of being normal. An example of an axial slice of a patient with a typical FCD lesion enclosed in the yellow circle is shown in figure \ref{fig:1} on the left in a $T_1$-w image and on the right in a FLAIR image.