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Bezier Control Points Image: A Novel Shape Representation

Approach for Medical Imaging

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The geometry of the human cerebral cortex is very complex and variable across individuals. An essential characteristic of cortical geometry is its folding. Though the mechanisms of cortical folding are still largely unknown [1], it was reported that cortical folding pattern is a good predictor of brain function [2]. Hence, development of cortical folding pattern descriptors could potentially contribute to automated segmentation and recognition of brain anatomies, as well as the mapping of brain structure and its function. There already exist a couple of cortical folding descriptors in the literature, e.g., curvature [3], gyrification index [4], and spherical wavelet [5]. These folding descriptors have their own advantages and are already applied in many research and clinical studies [6,7].

This paper presents a parametric folding pattern descriptor for the cortex at the meso-scale of primitive surface patch. The key idea of this descriptor is that we intend to encode geometric shape pattern information of surface patch by the parametric Bezier surface representation. Figure 1 provides an overview of the proposed method. Main steps are followed:

Step 1: we reconstruct geometrically accurate and topologically correct cortical surfaces from volumetric brain MRI images. Fig. 2 shows a visualization of the cortical surface and an extracted patch.

Step 2: A meso-scale triangulated surface patch is re-parameterized by the Bezier surface [8], which has been widely used in the computer graphics and computational geometry communities. We use a local approximation method to estimate the control points. The basic idea is very straightforward: We use n parallel planes to cut the brain patch and we will get n 2-D curves defined in the space of planes. We transform the problem of estimation control points of a surface to a set of curves. We use linear system to calculate m control points of each curve and arrange them according to the order of planes cut. Thus we construct an $N \times M$ matrix of the control points. We use this matrix to approximate the real surface control points.

Step 3: The coordinates of the estimated Bezier Control Points (BCP) are used to generate an image, called BCP image, to encode the surface patch shape. Based on the intensity patterns of the BCP image, cortical surface patches can be classified into different primitive patterns.

An important contribution of the BCP image representation is that the analysis of surface patch folding pattern is converted into the problem of image pattern classification, which has been extensively studied in the computer vision and pattern recognition community and there are many readily usable algorithms and tools for image pattern analysis [9,10]. In our experiments we use Locality Preserving Projections (LPP) method. The essence of this approach is to map the original BCP images space to a subspace expanded by the eigenfunctions of the Laplace Beltrami operator on the BCP manifold. Using above pipeline

we make the classification on synthesized dataset, random sulci and gyri patches and different sulci regions extracted from human cortical surfaces. The correctness of classification is very satisfied. Figure 4 and figure 5 show the examples of our manually extracted patches.

In summary, the major contribution of this paper is the development of BCP image as a folding shape pattern descriptor. In this method, the variable shapes of surface patches are compactly and effectively encoded by the regular grids of BCP images. The classification of surface folding pattern problem is converted to a regular image pattern classification problem using the LPP projection method. Though this work and its results are preliminary, we believe this methodology has great potential to be extended for more complex cortical folding analysis in the future. This effective folding pattern representation methodology could be potentially used for many applications in cortical surface analysis such as automated parcellation and recognition of cortical surface, computational neuroanatomy, and clinical studies of brain diseases with abnormal cortical folding patterns.

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Figure 1.
The flowchart of the proposed method.

Figure 2.
An example of the triangulated cortical surface reconstructed from brain MRI image (left) and an extracted surface patch (right).

Figure 3.

Illustration of 8 primitive folding patterns and their corresponding Bezier control points and BCP images. Here, Control represents Control Points.

Figure 4.
Examples of the extracted cortical gyri and sulci patches and their corresponding BCP images.

Figure 5.
Examples of the extracted sulci patches: central sulcus, post central culcus and superior temporal sulcus.