or planar) used for each surface. Intriguingly, similar variational approaches, using Beltrami flows, have been used for image restoration [144], and related covariant PDEs can assist in structure extraction and statistical applications (see [29, 31–34, 38–40] for a discussion).

17.8 Cortical averaging

The warping fields deforming one cortex into gyral correspondence with another can also be used to create an $average$ cortex (Fig. 17.14). First, all 38 gyral curves are transferred to the cortical parameter space, uniformly reparameterized, and averaged to create an *average curve template* (*curves*, Fig. 17.13). This serves as a target for alignment of individual cortical patterns (cf. [137]). Each individual cortical pattern is transformed into the average curve configuration using a flow field in the parameter space [Fig. 17.13(a),(b)]. By carrying a color code (that indexes 3D locations) along with the vector flow that aligns each individual with the average folding pattern, information can be recovered at a particular location in the average folding pattern (Fig. 17.13) specifying the 3D cortical points mapping each subject to the average. This produces a new coordinate grid on a given subject's cortex [Fig. 17.13(f)] in which particular grid-points appear in the same location across subjects relative to the mean gyral pattern. By averaging these 3D positions across subjects, an average 3D cortical model is constructed for the group (Fig. 17.14, *bottom row*). The resulting mapping is guaranteed to average together all points falling on the same cortical locations across the set of brains and ensures that corresponding features are averaged together.

17.8.1 Cortical variability

By using the color code [Fig. 17.13(d)] to identify original cortical locations in 3D space [Fig. 17.13(f)], displacement fields are recovered mapping each patient into gyrus-by-gyrus correspondence with the average cortex (Fig. 17.15). Anatomic variability is then defined at each point on the average cortex as the root mean square (r.m.s.) magnitude of the 3D displacement vectors, assigned to each point, in the surface maps driving individuals onto the group average (based on 20 subjects) is visualized as a color-coded map in Fig. 17.16 (a),(b). Overall, variability values rise sharply from 4-5 mm in primary motor cortex to localized peaks of maximal variability in posterior perisylvian zones, in the vicinity of visual area MT (or V5), and superior frontal association cortex (16-18 mm). Caution is therefore necessary when referring to functional activation foci or metabolic changes in this important area using stereotaxic coordinates, unless a nonlinear registration approach is employed, otherwise structural differences may be interpreted as functional differences. The patterns also suggest a greater morphologic individuality in cortical regions that are phylogenetically more recent.