

io-port 04131516**Bookstein, Fred L.****Principal warps: Thin-plate splines and the decomposition of deformations.**

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Author's summary: One conventional tool for interpolating surfaces over scattered data, the thin-plate spline, has an elegant algebra expressing the dependence of the physical bending energy of a thin metal plate on point constraints. For interpolation of a surface over a fixed set of nodes in the plane, the bending energy is a quadratic form in the heights assigned to the surface. The spline is the superposition of eigenvectors of the bending energy matrix, of successively larger physical scales, over a tilted flat plane having no bending energy at all. When these splines are paired, one representing the x-coordinate of another form and the other y-coordinate, they aid greatly in the modeling of biological shape change as deformation. In this context, the pair becomes an interpolation map from R^2 to R^2 relating two sets of landmark points. The spline maps decompose, in the same way as the spline surfaces, into a linear part (an affine transformation) together with the superposition of principal warps, which are geometrically independent, affine-free deformations of progressively smaller geometrical scales. The warps decompose an empirical deformation into orthogonal features more or less as a conventional orthogonal functional analysis decomposes the single scene. This paper demonstrates the decomposition of deformations by principal warps, extends the method to deal with curving edges between landmarks, relates this formalism to other applications of splines current in computer vision, and indicates how they might aid in the extraction of features for analysis, comparison, and diagnosis of biological and medical images.

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Keywords: biharmonic equation; biomedical image analysis; deformation; principal warps; quadratic variation; shape; surface interpolation; scattered data; thin-plate spline; quadratic form; bending energy matrix; affine transformation; diagnosis of biological and medical images

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