

# Preface

The statistical community has shown an increased interest in shape analysis in the last decade, in particular with reference to the development of robust inferential statistical methods. In this book we present an extension of NonParametric Combination (NPC) methodology (Pesarin, 2001; Pesarin and Salmaso, 2010) to shape analysis. At first we introduce basic concepts and terms that will be used throughout the book. In particular we provide a brief overview of statistical shape analysis and geometric morphometric techniques, focussing on landmark and semilandmark-based representations of shapes (Chap. 1). Then we face with inferential aspects in the field of shape analysis. In particular, we review inferential methods known in the shape analysis literature, highlighting some drawbacks of using Hotelling's  $T^2$  test statistic, and we introduce NPC methodology for the analysis of shape configurations. Multiple Aspect (MA) procedures and domain combinations are also illustrated (Chap. 2). The case of heterogeneous variation and nonzero correlation among landmarks is also investigated, along with the effects of superimposition on the power of NPC tests (Chap. 3). Permutation tests have been evaluated also in the particular case in which the number of variables is larger than the cardinality of permutation sample space. We have performed a simulation study to evaluate the power of multivariate NPC tests, showing that the power for the proposed tests increases when increasing the number of the processed variables provided that the noncentrality parameter increases, even when the number of covariates is larger than the permutation sample space (Chap. 4).

These preliminary results allowed us to extend the notion of *finite-sample consistency* for permutation tests combination-based to the shape analysis field. Sufficient conditions are given in order that the rejection rate converges to one, for fixed sample sizes at any attainable  $\alpha$ -value, when the number of variables diverges, provided that the noncentrality induced by test statistics also diverges (Chap. 5).

The last chapter is mainly devoted to practical applications. In particular we present an application concerning the facial expression of emotion along with a case study aimed at analyzing aortic valve morphology. Moreover we also introduce two innovative topics: biometric morphing and nonparametric iterated combination for paired data (Chap. 6).

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Permutation Tests in Shape Analysis

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