Seattle, July 10, 2023

Dear MorphMetters,

This is a followup to my email of January 15, which directed you to a preprint posting on arXiv of a manuscript I had just submitted to my favorite journal, Evolutionary Biology. The text has changed somewhat since then, mainly in response to a very constructive journal review. The revision was accepted and has just been posted to the internet on the journal's website as

https://doi.org/10.1007/s11692-023-09607-2

The article is Open Access, so you are free to download it if you want.

The title remains "Reworking geometric morphometrics into a methodology of transformation grids." Its basic thrust is that now is the time to totally rethink the combination of Procrustes analysis and thin-plate splines, the two foundations of today's most common GMM toolkit, as we apply them in studies of shape differences at large scale (growth gradients, for example, or the kind of processes that used to be called "orthogenesis"). This requires three major changes of method, each one reanimating the spirit of contributions far earlier than my own. A first change, echoing D'Arcy Thompson (1917), restores the reading of the deformation grid per se -- the bending and spacing of its collection of curves -- to the report of a morphometric contrast, cause, or effect. For that purpose (this is the second change), the rotation steps in the Procrustes procedure should be set aside in favor of the two-point shape coordinates of Francis Galton (1907). And the third change, echoing Peter Sneath (1967), complements the thin-plate spline with polynomial regression grids and the residuals from them, in order to expedite our understanding of the deformations these diagrams are intended to illustrate.

A fourth stage in this methodological metamorphosis, a novel and (by me, at least) unanticipated multivariate analysis for large-scale features of landmark configurations, is the topic of a later preprint of mine, DOI:10.1101/2023.03.23.533997, that I announced in an email to you all on March 25. A revised version of _that_ has just been submitted to this same journal, Evolutionary Biology, and of course if it is published I'll let you know.

As always, I welcome any comments you may have, positive or negative, on these ideas. You may send them to me at either of my academic addresses (below) or post them to this Google group.

Here is the abstract of 11692-9607 as published:

Today's typical application of geometric morphometrics to a quantitative comparison of organismal anatomies begins by standardizing samples of homologously labelled point configurations for location, orientation, and scale, and then renders the ensuing comparisons graphically by thin-plate spline as applied to group averages, principal components, regression predictions, or canonical variates. The scale-standardization step has recently come under criticism as unnecessary and indeed inappropriate, at least for growth studies. This essay

argues for a similar rethinking of the centering and rotation, and
then the replacement of the thin-plate spline interpolant of the
resulting configurations by a different strategy
that leaves unexplained residuals at every landmark individually in
order to simplify the interpretation of the displayed grid as a whole,
the "transformation grid" that has been highlighted as the true
underlying topic ever since D'Arcy Thompson's celebrated exposition of 1917.
For analyses of comparisons involving gradients at large
geometric scale, this paper argues for
replacement of all three of the Procrustes conventions by a version
of my two-point registration of 1986 (originally
Francis Galton's of 1907). The choice of the two points interacts
with another non-Procrustes concern, interpretability of the
grid lines of a coordinate system deformed according to a fitted
polynomial trend rather than an interpolating thin-plate spline.
The paper works two examples using previously published midsagittal cranial
data; there result new findings pertinent to the interpretation of
both of these classic data sets.
A concluding discussion suggests that the current
toolkit of geometric morphometrics, centered on Procrustes shape
coordinates and thin-plate splines, is too restricted to suit many of the
interpretive purposes of evolutionary and developmental biology.

(The "previously published data" the abstract mentions are the
familiar Vilmann rodent neurocranial octagons and a subset of the
hominid cranial data resource from the Vienna paleoanthropology group of
twenty years ago.)

Thanks for reading this.

Fred Bookstein

fred.bookstein@univie.ac.at, flbookst@uw.edu