Maximum Likelihood Conjoint Measurement in R

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Conjoint measurement is a psychophysical method that allows the assessment of separate contributions of two (or more) attributes (dimensions, factors) to *perceived* differences in stimuli (Luce & Tukey, 1964).We present a parametric model of difference judgments and statistical methods that allow maximum likelihood estimation (MLE) of the relevant parameters as well as testing of hypotheses concerning the parameters. We describe the model and its implementation in R using glm and show how to use it to determine the separate contributions of surface irregularity (bumpiness) and surface gloss to perceived bumpiness and glossiness.

The stimuli were computer-rendered surfaces that varied in physical glossiness and physical bumpiness (Figure 1, left). In one condition, observers viewed every possible pair of the 25 surfaces in Figure 1 (left) and judged which one was bumpier. In a second condition, a different group of observers judged which one was glossier. Ho *et al.* (2008) developed a model of the judgment process by assuming that physical gloss level g_i and bump level b_j of surface S_{ij} contribute to perceived bumpiness and perceived glossiness after scaling by unknown functions $B^g(\cdot), B^b(\cdot)$ and $G^g(\cdot), G^b(\cdot)$, respectively.

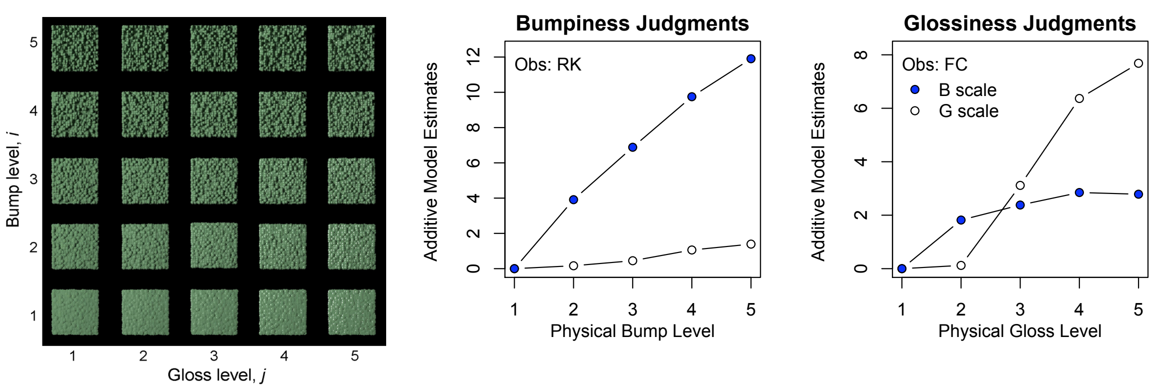

Figure 1

Perceived bumpiness B^A_{ij} for the *Additive Model* is modeled as the sum of contributions (cues) from physical bumpiness $B^b(b_j)$ and physical gloss $B^g(g_i)$,

$$B^A_{ij} = B^g(g_i) + B^b(b_j) = B^g_i + B^b_j,$$

with a parallel formulation for perceived glossiness. In comparing the bumpiness of surfaces S_{ij} and S_{kl}, we assume that the observer forms the noise-contaminated decision variable, $\Delta = B^A_{ij} - B^A_{kl} + \epsilon, \quad \epsilon \sim \mathcal{N}(0, \sigma^2)$ and judges surface S_{ij} as bumpier precisely when $\Delta > 0$. The parameter σ represents the observer's precision in judgment. We estimate σ and the remaining free parameters $B^g_2, \ldots, B^g_5$ and $B^b_2, \ldots, B^b_5$ using MLE. We fit a similar model to gloss comparisons. The MLE estimates are easily obtained using the function glm with a binomial family. The decision variable serves as the linear predictor which is related to the observer's judgments via a probit link. Results from two observers are shown in Figure 1 right . In the additive model, we can test whether the two surface properties influence one another (if not, then B^g_i (and G^b_j) should equal zero for all i, j). We also tested this simple additive model against more complex, non-additive models. We discuss the bias, variability and robustness of the method as well as methods for testing the underlying assumptions of the model (Luce & Tukey, 1964).

References

Ho, Y.-H., Landy. M. S. & Maloney, L. T. (2008). Conjoint measurement of gloss and surface texture. *Psychological Science*, 19, 196–204. New York: Academic Press.

Luce, R. D., & Tukey, J. W. (1964). Simultaneous conjoint measurement. *Journal of Mathematical Psychology*, 1, 1–27.