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Accuracy of Empirical Multifractal Analyses

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The moment-based box counting method of multifractal analysis is widely used for estimating generalized dimensions, D_q, from 2-dimensional grayscale images. An evaluation of the accuracy of this method is needed to establish confidence in the resulting estimates of D_q. We estimated D_q from q = -10 to +10 for 23 random geometrical multifractal fields with varying levels of grayscale heterogeneity, different grid sizes, and known analytical D_q versus q functions.

Comparison of the estimated and analytical functions indicated the moment-based box counting method overestimates D_q by as much as 6.9% when $q \quad << 0$. The root mean square error, RMSE, for the entire range of q values examined ranged from 7.81x10^{-6} to 1.35x10^{-1}, with a geometric mean of 6.50x10^{-3}. The RMSE decreased with increasing grayscale heterogeneity and decreasing grid size.

Variations in the slope of the log-transformed partition function, $\tau(q)$, as a function of box size were responsible for the overestimation of D_q when q is negative. An alternative procedure for estimating $\tau(q)$ was developed based on the numerical first derivatives of the log-transformed partition function. Using this approach the maximum deviation in D_q values was only 1.2%, while the RMSE varied from 3.11x10^{-6} to 2.72x10^{-2}, with a geometric mean of 2.57x10^{-4}.

Our results indicate an order of magnitude increase in accuracy in the estimation of generalized dimensions when $\tau(q)$ is calculated numerically as instead of using standard linear regression analysis. The theoretical origins of the discrepancy are the normalization of the mass fractions in order to simulate pixel values in an image.

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