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Real Second-Order Freeness

The second-order statistics of large random matrices may be studied in a noncommutative probability space equipped with a bilinear function modelling the covariance of traces. As in the first-order case, second-order freeness may be defined so that fairly general classes of random matrices are asymptotically second-order free. However, the definition satisfied by real random matrices is different from that satisfied by their complex analogues. We present a topological approach to the matrix calculations, in which the real matrices are distinguished from their complex analogues by the appearance of twisted gluings and the resulting nonorientable surfaces. This motivates a different definition of second-order freeness in the real case, which is satisfied by a number of important matrix models, and in fact by any independent matrices which are orthogonally in general position.