Multiscale Self-Similarity in the Structure and Evolution of Complex Networks

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The renormalization group in physics provides a rigorous way to analyze systems across different length scales. Applying this ideas to complex networks, however, is challenging because the small-world property introduces correlations between coexisting scales. To address this, we have developed geometric renormalization methods for both unweighted and weighted networks. The technique builds on mapping networks into hyperbolic space and reveals multiscale self-similarity as a pervasive organizing principle in real-world networks.

Notably, when applied to human brain connectomes, our renormalization protocols reproduce the multiscale self-similarity observed in their anatomical organization, including the ordering of weak ties. Multi-scale self-similarity also appears in the growth patterns of certain networks, whose evolution can be described as a reverse renormalization process. Beyond methodology, these results enable practical applications, including the development of scaled-down and scaled-up network replicas valuable for studying size-dependent processes and advanced simulations, and the implications extend to broader questions, such as the origin and interpretation of critical-like states in networked systems.