**Title:** Adventures with random walks: from counting birds to searching for global maxima on fitness landscapes

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**Abstract:** Large-scale networks represent a broad spectrum of systems in nature, science, technology, and human societies. Computer networks such as the World Wide Web and the Internet, social networks such as Twitter/X and Facebook, and online knowledge-sharing platforms such as Wikipedia have become part and parcel of our lives. These networks tend to be very large and time-dependent, making predictions of their properties a challenging task. I will describe a novel methodology, based on random walks, for the inference of various properties of complex networks. I will show that our formalism yields reliable estimates of global network properties, such as the network size, after only a small fraction of its nodes has been explored. I will also introduce a novel algorithm for partitioning network nodes into non-overlapping communities - a key step in revealing network modularity and hierarchical organization. I will apply this algorithm to various benchmarks, including a large-scale map of roads and intersections in the state of Colorado. Next, I will demonstrate how these ideas can be extended to global optimization - the search for a global maximum or minimum on fitness or energy landscapes. Finally, I will describe a Monte Carlo sampling technique which can be used to infer key thermodynamic quantities in systems with discrete states from small, non-equilibrium samples. Thus, random walks can be used to reveal modular organization and global structure of complex networks, find global optima, and infer thermodynamics of physical systems such as spin glasses.

**Keywords**: Random walks (1); Monte Carlo sampling (2); Bayesian inference (3); Global optimization (4)

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