A Trapping Perspective on the Sokoban Random Walk

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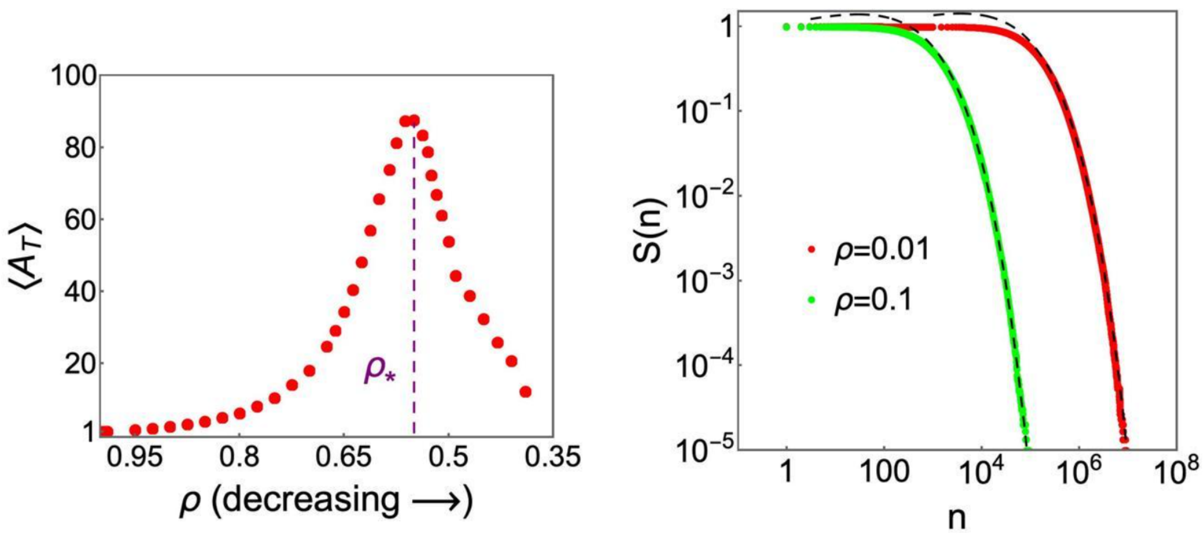
The 'Ant in a Labyrinth' (AIL) model, introduced by de Gennes, is a canonical model in percolation theory describing a random walker moving through a disordered medium with obstacle density ρ. The AIL walker exhibits a percolation transition in two dimensions at a critical density $\rho_c \approx 0.407$; for $\rho \leq \rho_c$, the walker can percolate, *i.e.*, escape to infinity, while for $\rho > \rho_c$, walker is confined in a finite cluster of vacant sites. Motivated by experiments on bristle robots, Reuveni and co-workers recently introduced a generalization of this model, known as the Sokoban random walk [1]. In this model, the walker is capable of pushing some of the obstacles that block its path and therefore induce some modifications to its local environment. Surprisingly, even a limited pushing ability leads to a loss of the percolation transition. This means that at low obstacle densities, where escape is easy, the walker's ability to modify its surroundings leads to a localization that eliminates the long-range transport. Thus, even a small departure from de Gennes' model yields a fundamentally different low-density behavior, eliminating the percolation transition.

Questions then arise – What physical principle governs the low-density transport of the Sokoban walk? How does it dynamically relax toward the localized state induced by its pushing ability? And are these principles robust against variations in the model properties? In this talk, I will provide systematic answers to these key questions by analyzing the trapping behavior of the Sokoban random walk [2,3]. We use tools from the large-deviation to show that the Sokoban model belongs to the Balagurov-Vaks-Donsker-Varadhan universality class of the classical trapping theory. The survival probability that the Sokoban has not yet been trapped inside a cage exhibits stretched-exponential relaxation at late times. We then show that the pushing dynamics leads to the emergence of a dynamical crossover between two trapping mechanisms, which, unlike the percolation transition, is smooth and explains the different low-density physics of the model. Quite remarkably, this crossover is completely robust against variations in the pushing strength of the walker and disappears only for the de Gennes' model, where pushing is absent.



References:

[1] O. L. Bonomo and S. Reuveni, Loss of percolation transition in the presence of simple tracer-media interactions, Phys. Rev. Res. 5, L042015 (2023).

[2] P. Singh, D.A. Kessler and E. Barkai, Sokoban random walk: From environment reshaping to trapping crossover, Phys. Rev. Res., 8, L012023 (2026)

[3] P. Singh, D.A. Kessler and E. Barkai, The Sokoban Random Walk: A Trapping Perspective, arxiv (2026)