Lattice gases with a point source and a tourist walk in one dimension

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Exploration of surrounding territory from a point source is ubiquitous in nature, such as in foraging for food by a colony of social insects. In emerging applications of nanotechnology to health, we envisage large numbers of synthetic molecular walkers being released from an artificial capsid to explore their environment, e.g., the interior of a cell.

Random walks on a lattice are a common abstraction for processes involving particle diffusion. The symmetric exclusion process (SEP) is a random walk of multiple particles subject to the exclusion constraint: no two particles can simultaneously occupy the same site.

We studied [1] the symmetric exclusion process with an infinitely strong, unbounded source: whenever the origin is clear, a new particle is injected thereinto. We also studied the analogous process with the exclusion constraint removed. Using a combination of analytical results and extensive numerical simulations, we derived asymptotic expressions for the number of particles in the system for all dimensions d. Furthermore, we derived expressions for the number of distinct visited sites (the size of the explored territory) and the total visit activity, which are of interest in models of foraging and spreading. In many cases these quantities converge to their asymptotic behaviour exceedingly slowly, especially in experimentally relevant dimensions $d = 2, 3$, therefore simulations should be used to predict them in short-time applications.

We then turned to a more general process inspired by our interest in catalytic molecular walkers [2,3], a symmetric exclusion process with a localized source and with sites capable of catalytic slowdown once per particle. The hopping rate of a particle visiting a site for the first time is $r \leq 1$, and the hopping rate of a particle revisiting a site is 1. In 1D, the model describes the traffic flow of tourists in certain single-file scenarios, or foraging for an information resource. Using extensive numerical simulations, we found that macroscopic variables, viz., the number of walkers and the number of sites visited, exhibit distinct behaviors depending on r, including a superdiffusive phase. Moreover, average particle density exhibits phases with respect to r, and so does the density profile.

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