Title:	Emergent activity networks in a model of punctuated equilibrium
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Abstract:	We revisit the simple, yet very influential Bak–Sneppen model of biological evolution known to yield a self-organized state exhibiting features of punctuated equilibrium. We consider a variant of the model with varying degrees of random links in the underlying connection network of biological niches, mimicking a scenario that is expected to be more typical than the strictly nearest neighbour interactions. First, we investigate the robustness of self-organized criticality under random links and demonstrate that the randomly rewired system also attains a self-organized critical state, for probability of random rewiring ranging from p∼0 (i.e. close to a ring as in the Bak–Sneppen model) to p∼1 (where the underlying connection graph is almost completely random). The robustness of the self-organized state under random links is manifested in the emergent power-law scaling of the frequency of mutation distances as defined by the path length between mutating sites, irrespective of the extent of randomness in the network of niches. The critical fitness in the system is also found to decrease as a power-law with increasing random links. We then explore a new way to understand the activity of the system through the characteristics of the emergent network of active sites, which we denote as an “activity network”. We demonstrate how the structure of this activity network is significantly different from the network of the niches, thus lending a different understanding of the system’s activity in general. Interestingly, the mean path length of the activity network has a weak dependence on the presence of random links, while in contradiction the network of niches changes sensitively with respect to the probability of random rewiring in the small-world limit. More importantly, the system evolves to an activity network whose mean path length is typically 2 orders of magnitude smaller than the network of niches. This implies that the system self-organizes to a network of active nodes where there is a very efficient transfer of information. The size of the activity network is also very weakly dependent on random links and time of evolution. More surprisingly, it has a markedly small characteristic size, independent of the system size. This indicates that, counter-intuitively, the set of niches where mutation takes place is always very small, irrespective of system size, with most niches in evolutionary stasis over significantly long times, interspersed by small sub-sets of nodes that undergo repeated mutations.
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