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Structure and Complexity in Rule Ensemble Cellular Automata
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Individual elementary cellular automata (ECA) rules are attractive models for a range of non-equilibrium physical systems, but rule ensembles remain poorly understood. This paper presents the first known analysis of the equally weighted ensemble of all ECA rules. Ensemble dynamics reveal persistent, localized, non-interacting structures strongly correlated by velocity and reminiscent of solitons, instead of equilibration. Dispersion from a single initial site generates peaks traveling at low-denominator fractional velocities, some of which are not discernable in individual rules, implying collective excitation. Principal component analysis of the rule space shows the ECA are dense (with $\sim$111 eigenrules out of 128 ECA rules, up to symmetry), but can be transformed to a simple basis set that is quasi-linear in initial conditions. These results suggest that the ECA, often considered to be the simplest nontrivial set of "short program" models for self-assembly, might be approximated well by computationally simpler models. This work also shows, surprisingly, that structure can develop without favoring a single evolution rule.

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