Machines making other machines: new twist on self-replication

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How can we best build self-replicating machines? The past few decades have witnessed self-replicating virtual automata, ranging from the benign Game of Life by Conway to malicious computer viruses. Self-replicating physical constructs are, however, currently both delicate and rare. The work of mathematicians such as John von Neumann and Roger Penrose, around the birth of automata theory in the middle of the past century, revealed no limits in principle to constructing such devices. The main obstacles appear to be the substantial engineering challenges.

Engineers at the Massachusetts Institute of Technology recently tackled a key challenge: how can a machine replicate properly if its components appear at random? Living cells face a similar problem when duplicating their DNA from randomly diffusing chemical components. To address this issue, the group fabricated a simple self replicating machine that dealt robustly with randomly available input components.

The MIT design consists small robotic blocks which link to one another using actuated hooks. A specific ordered linkage of blocks makes up a correctly formed device. A large number of individual blocks sit on a low-friction air-table, which shakes to move them about randomly. Each block carries both sensors to identify blocks around it and a program specifying which blocks to attach to and which to ignore. Blocks which pair correctly by chance stick together, while incorrect pairs fail to stick. With appropriate rules, certain structures can catalyze the formation of equivalent structures out of the random blocks. Thus correct structures that initially appear by chance will duplicate exponentially in a positive feedback loop.

A key requirement for this engineering approach (and indeed for living cells) is good error control. Living organisms, for example, utilize clever chemical and kinetic techniques for minimizing errors in their copying processes. Incorrectly incorporated blocks in the MIT setup are excised using a clever set of error detection and correction rules. The total rule set is surprisingly small, making this work a nice demonstration of self-replication in the face of environmental randomness. This work paves the way in principle for smart materials which can self assemble into structures of interest, with minimal assistance on the part of humans.