Stochastic Self-Assembly with Magnetically Re-programmable Voxels

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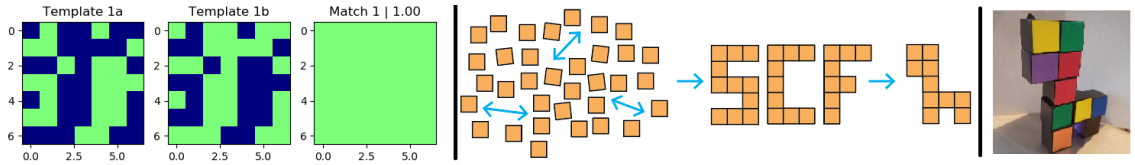

Fig. 1. (Left) Mating pairs of magnetic signatures can be programmed onto soft magnetic material as QR codes. (Middle) By programming the faces of voxels in this manner using a CNC-based magnetic plotter, an external force can then be used to perturb the set of cubes to assemble stochastically. (Right) A 3D object self-assembled from physical voxels.

This abstract introduces a method to magnetically "program" physical components to stochastically self-assemble. Previously, researchers have programmed soft magnetic material with permanent magnets to build haptic interfaces (Magnelayer [5, 6]). Separately, Hacohen et al. [1] developed ways to build modules capable of stochastic assembly using mechanically interfacing faces, while Tolley et al. manipulated external forces via fluids to direct the assembly of both passive [3, 4] and active [2] physical modules.

In this work, we combine these ideas by encoding re-programmable magnetic signatures into the faces of cubic building blocks that guide these voxels to self-assemble. We build a platform that plots specific magnetic signatures onto the faces of a set of cubes covered in a soft magnetic material. The faces of these cubes are this way "programmed" to uniquely mate with the face of one other cube in the set, while remaining agnostic to all others. The cubes can thereby self-assemble given some agitation by an external stimulus. These magnetic signatures and the final 3D prototype are therefore programmable, reusable, and not power-consuming during operation. Furthermore, target shapes are not limited by the resolution of the cubes as cubes can be programmed to mate *across* two other cube faces, and can also be used to encode visual textures onto the magnetic surfaces that can be viewed through magnetic viewing film.

By coating 3D objects such as cubes with soft magnetic material, the faces of these cubes can be “programmed” with custom magnetic signatures, such as QR codes, in which the binary values of pixels correspond to regions of material with oppositely polarized magnetizations. These faces can thus be made to attract or repulse each other to different degrees, or remain agnostic to each other. We leverage this insight to permit stochastic self-assembly in four steps. First, we begin with a target 3D model and voxelize it to create a set of discrete cubes. Second, we generate pairs of QR codes for the faces between adjacent cubes that meet two criterion. First, that the codes within the pair are the inverse to each other, and thus form a maximally attractive pair, and second, that they are maximally agnostic to all other QR code pairs in the set. Third, we translate these QR codes to G-code for use on a magnetic plotter housing a pair of magnets mounted onto a 3-axis CNC which we use to stamp the faces of cubes to acquire these magnetic signatures. Finally, a collection of magnetised cubes are made to stochastically self-assemble given some external force that continuously perturbs the cubes. This force could be provided via manipulation by a user, in a water tank under agitation, or in an enclosed chamber in microgravity.

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