Complexity from simple form: 3D-printed aperiodic monotiles and Cheerios effect

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This project aims to build a simple physical experiment of macroscopic scale that can be later used for constructing complex systems with emergent properties, such as the self-replication of structures [1, 2]. As requirements, the experimental setup should be safe, affordable, and use easily obtainable materials and equipment. Therefore, two simple ideas from physics and mathematics were used.

The first idea is the 'Cheerios' effect [3], named so because breakfast cereals (and many other small objects) in milk tend to come together. This effect is also seen in water and other liquids with high surface tension. When an object floats on the water's surface, it flexes the surface around it slightly due to its weight, creating a 'pit' around it. This bending of the water surface can be seen in Fig. 1 and Fig. 2 due to the reflection of lightning. This bowing of the water surface, or deformation, causes forces that pull objects towards each other. Current work uses those forces to assemble structures from elements. Objects of specific shapes placed on the surface of the water are mutually attracted by this effect, forming a variety of configurations. Different shapes were used, such as modified pentagons with spikes, puzzle-piece-shaped objects, and others. Plastic bottle caps were used for the first experiments, but they created a simple hexagonal grid due to their circular shape. Shape modifications allow control of the binding force between blocks. More irregular shapes will make different structures possible. Those structures can resemble the result of diffusion-limited aggregation simulations [4].

The second idea is to use aperiodic tiles as the primary form for building blocks. This problem has been solved recently, and an aperiodic tile has been found [5, 6]. At the current moment, subjectively best results were achieved with curved 'Spectre' shape. 3D printers were used to create hollow buoyant objects based on that 'einstein'. The size of the blocks is in centimeters range due to the limited resolution of 3D printers. In the future, the size of the blocks could be reduced, allowing hundreds of objects in the meter-sized container. Other manufacturing options, such as the laser cutting of buoyant wooden material, can remove the need for the hollow structure. Vibration applied by eccentric electric motors and manual intervention can be applied to speed up the aggregation process. This is similar to an increase in temperature and helps the system to achieve a minimal energy state faster. Mobile microbots in work by [7] are much more sophisticated but have a simple shape.

In conclusion, the floating aperiodic monotiles, influenced by the Cheerios effect, can illustrate the concept of complex systems. The tiles represent individual components of the system, and the Cheerios effect represents the interaction between those components. The resultant aperiodic pattern that emerges is an example of emergent behavior. Moreover, suppose blocks are constructed to have certain behaviors (like attraction, repulsion, or changes in shape).

In that case, observing even more complex emergent phenomena will be potentially possible. It could be a great model to study the origins of novelty and aperiodic order.

Fig. 1. 'Dense' stable configuration

Fig. 2. 'Sparse' stable configuration

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