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Floatiles: Self-Assembly Based On Cheerios Effect and Aperiodic Monotiles

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`https://karegeo.github.io/floatiles/`

Cheerios effect: examples in nature

Floating objects on a liquid surface tend to come together due to surface tension and buoyancy. This phenomenon is known as the Cheerios Effect (1) because those breakfast cereals clump together. It can be used for self-organization (2) of small floating objects as an active matter.
In nature, this aggregation happens with:

- Common duckweed (L. minor) and fungal spores (3)
- Mosquito eggs (4)
- Rafts of fire ants (5)
- Nematodes (6)

Structures can resemble diffusion-limited aggregation simulations (7–9). This project is a simple macroscopic physical experiment that can be later used for constructing complex systems with emergent properties, such as the self-replication of structures (10–15).

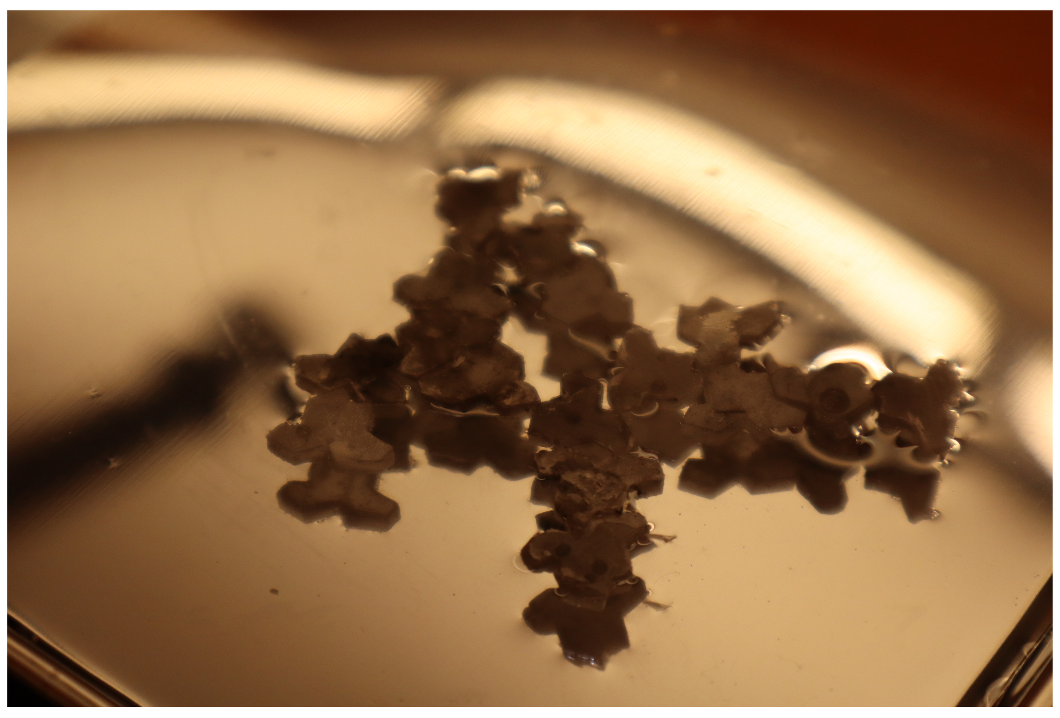

Figure 1: Self-assembly experiment using wax tiles based on the Hat shape.

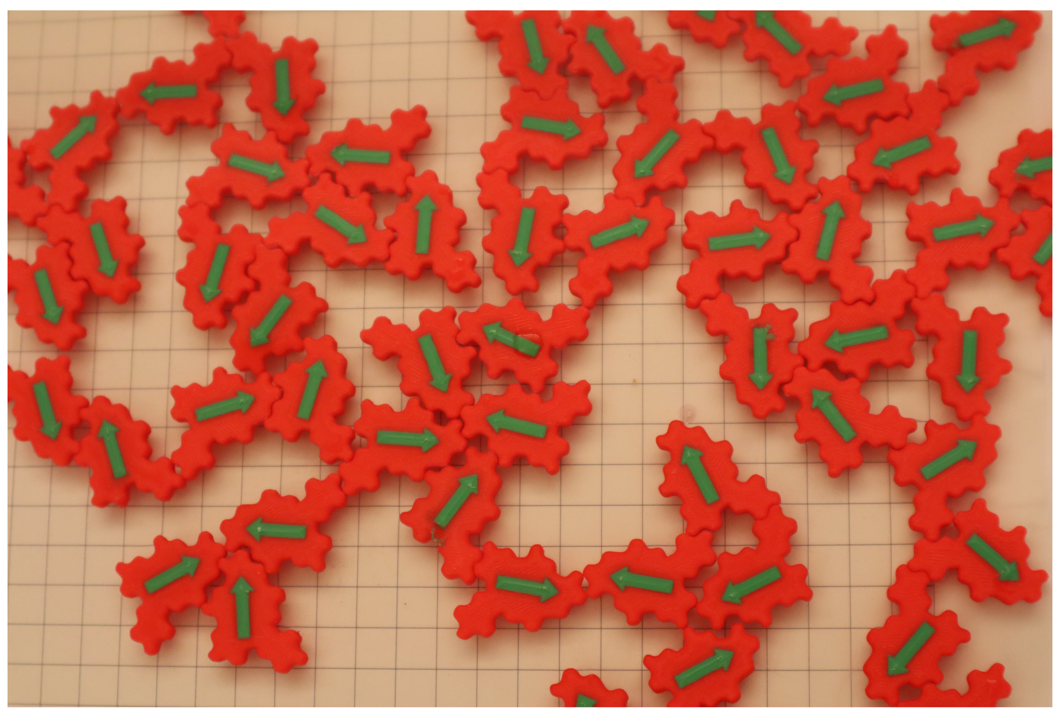

Figure 2: Example of aggregation of Spectre tiles.

After the literature review, it was found that Larmour, Saunders, and Bell (16) used a similar approach for smaller particles to form sheets. It has also been applied for robots (17).

Geometry: aperiodic monotiles

The shape of the emergent pattern depends on the shape of the floating particles (18). Initial trials using regular plastic bottle caps resulted in simple hexagonal grids due to their circular shape. Other shapes can lead to more complex patterns, even if the shape is always the same.
Recently discovered aperiodic monotiles can cover a plane without repeats and gaps (19, 20). The Hat and Spectre were used for current experiments.
Before aperiodic monotiles, an experiment in December 2022 - January 2023 utilized spiked pentagons to create complex floating structures. Regular pentagons, the simplest non-tiling regular polygons, were modified with spikes and corresponding cavities to introduce irregularities and strong capillary connections when interlocked.

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Materials and production

- Water was used for safety
- FDM 3D printing of hollow buoyant plastic pieces
- Acrylic laser cutting for paraffin molding
- Two PLA filaments (green and red) for visual directional marks
- Vibrational platform for introducing perturbations (18)

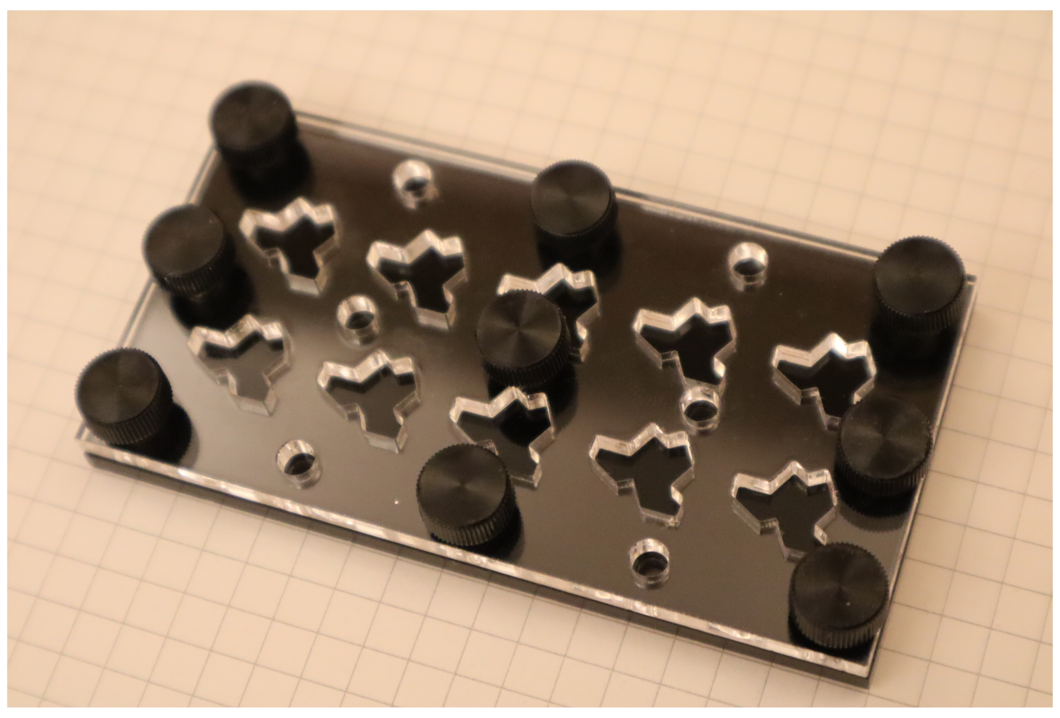

Figure 3: Laser-cutted acrylic casting for wax molding.

Agitation: effects of perturbations

The formation of patterns could be altered by introducing perturbations and non-equilibrium conditions (21). Without additional energy, tiles will form smaller clusters instead of more complex formations.
Three available options for agitation:

1. Vibrational motion of the whole container (22)
2. Wave generation by perturbation of the water surface
3. Aeration with air bubbles (23, 24)

This is a simplified toy example of antifragility (25). Variable agitation coupled by feedback to current pattern state can make a trivial model of open-ended evolution (26). The interplay of agitation and particles may achieve complex behavior as in Cejková et al. (27), Virgo et al. (11), and Toyota et al. (28).

Preliminary results and potential future plans

- **Moderate agitation can lead to more complex patterns**
- Recordings will be analyzed with specialized algorithms for pictures (29) and spatiotemporal videos (30, 31)
- Entropy analysis to measure complexity as in (32–34)
- Spatial entropy analysis (35) and compressed video file size (36) for complexity measurement
- Automated object detection as in (37)
- Complexity measurement using entropy and neural networks similat to (38, 39)
- Modified Active Floatiles could be used as building blocks for self-organizing floating robots and swarms

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