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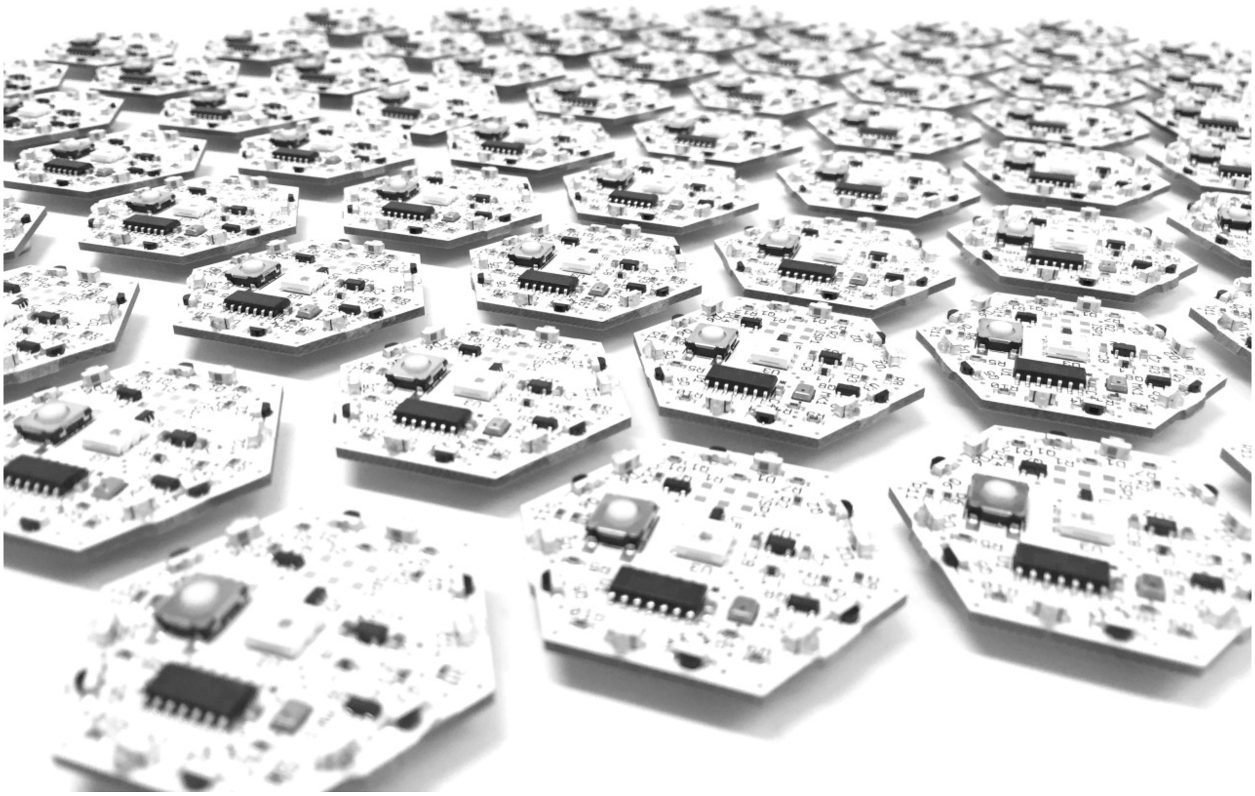


AutomaTiles

Tangible Cellular Automata for Playful Engagement with Systems Thinking

The exploration of complex systems, emergent behavior, and system dynamics have largely been left to mathematicians, physicists, economists, and computer scientists, with a new tool and interface I propose a new approach with the goal of creating a more aware society of systems thinkers. The old model of science with a mechanistic viewpoint has been replaced in the last century with a more systemic or holistic approach, but what does that mean for the general public through art, learning, and play? If Legos are the great for playing and building with static systems, then AutomaTiles are wonderful for dynamic systems.

What are AutomaTiles?

AutomaTiles are a tangible cellular automata, which means that each AutomaTile responds to it's neighboring AutomaTiles and determines its next state based on it's current state and conditions. I like to start with this image of a murmuration of Starlings. A familiar image to many, each one of these birds is not very interesting on

its own, but when thousands of them fly together, the kinds of patterns that emerge are beautiful, mesmerizing, and captivate the minds of scientists and artists alike. With each bird following a few simple rules, these patterns emerge(Reynolds, 1987 [1]). Each bird flies in a similar direction as the birds around it, keeping distance so as not to clip each others' wings, and staying close enough to be part of the flock. While this system results in great beauty, Donella Meadows, a former researcher at MIT in Jay Forrester's System Dynamics group, is quick to point out that not all emergent properties are beautiful. In fact, the worlds biggest problems, war, hunger, poverty…

> **"No one deliberately creates those problems… because they are intrinsically systems problems…"**
>
> *Donella H. Meadows, Thinking in Systems [2]*

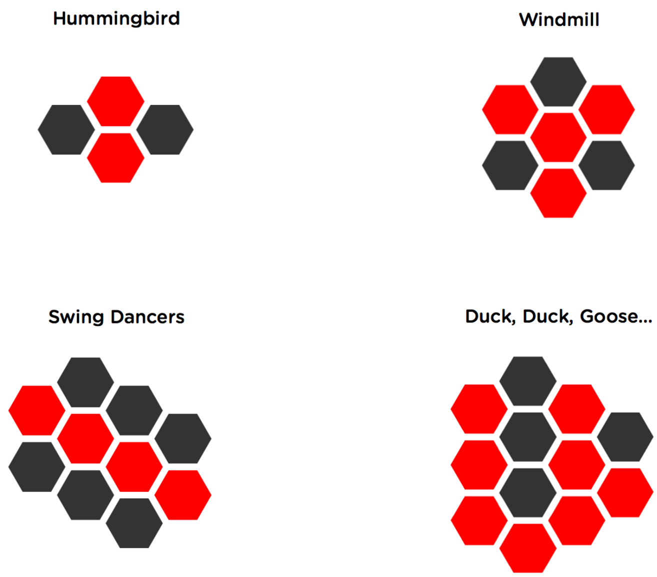
are all properties that no single person wants to exist, yet they persist besides this fact. She states that these are "unintended consequences" and that solving these kinds of problems requires a different kind of thinking, systems thinking.

Cellular Automata

In the early 1970s, a mathematician by the name of John Conway can be credited largely with popularizing the notion of Cellular Automata through his simple ruleset called Game of Life. Conway's Game of Life can be easily simulated on a computer screen, since it is played on a square grid, where each square decides whether to be white or black, on or off, based on the 8 neighboring squares. Again, through 3 simple rules, patterns emerge that appear to show lifelike complexity, and when simulated fast enough, animate into almost biological forms. For the past 45 years, these kinds of systems have been simulated and played with amongst a community of scientists and hobbyists.

AutomaTiles embody the cellular automata in physical form allowing kids and adults to easily intuit their individual properties and puzzle over their collectively complex behaviors. While AutomaTiles are hexagonal, to allow for the most edge connected neighbors, a life-like ruleset was a good place to start. Implementing the lifelike ruleset on AutomaTiles is simply and the parameters can be adjusted by allowing the tiles to "gossip" the new rules. Just like in Conway's Game of Life, it didn't take much imagination to begin naming the patterns and looking for dynamic equilibria, static equilibria, or divergent conditions.

By naming different emergent patterns, the tiles begin to take on a life of their own. Character emerges and does more than simply demonstrating simple rules leading to complex behavior.

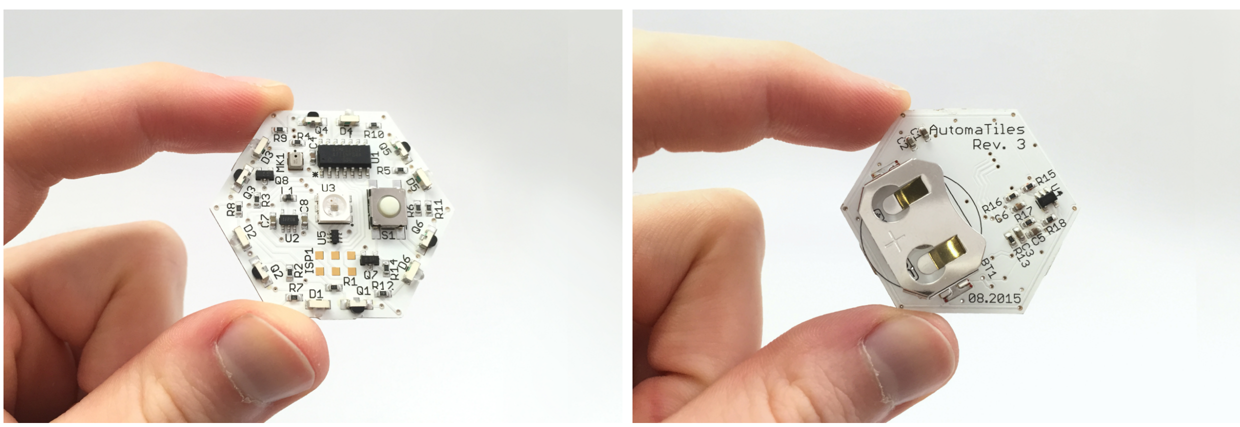


Animated gifs can be seen at http://automatiles.tumblr.com/post/129871033941/simulation-in-parallel-to-the-design-and-technical

Life-life rules is just where AutomaTiles began their life, but the goal is to make them a familiar framework for systems thinking, and so we went about creating an easy way to deploy new rulesets and have only just scratched the surface with implementing a few and exploring the potential through the physical affordances of AutomatTiles. The second ruleset implemented was a forest fire simulation, a

common system dynamics demo, which utilized our C-based API, much like an Arduino library, https://github.com/jbobrow/AutomaTiles/tree/master/CodeSketches/API. Each AutomaTile represents a plot of land, seeded to grow a tree with a certain probability. If the user touches the tree, they strike lightning, starting a fire, which continues to spread through adjacent trees. To prevent the entire forrest from igniting quickly in flame, different arrangements of trees could be beneficial, or perhaps some controlled burning.

Using only a single RGB light source, the AutomaTiles could display 4 states meaningfully. Flashing bluish white would show the lighting, which is not a persistent state, but shows response to a users input. Covers on the AutomaTiles, with 3 colors printed, red, green, and black, displayed the other 3 states with the help of flooded lighting. When illuminated green, the tree appears to have foliage, red removes the leaves and replaces it with a trunk encased in flames. When dimly lit, the trunk remains and neither the flames nor the leaves dominate visually. By relying on simply cases for the tiles, the cost of the tiles remains low, the transparency of the tech remains high, and so the goal of simple singular actions resulting complex systems dynamics is maintained while adding more legible or representational state.



AutomaTile Rev. 3 is a 2cm edged hexagonal board with a low power IC, ATtiny84 for all logical control, 6 pairs of IR emitters and phototransistors (used as receivers) to talk to neighboring AutomatTiles, an RGB LED for displaying state or other information to a user, a MEMS microphone, and a push button for touch input. All components are set lower than the push button so when encased, it receives any force applied to the surface of the AutomaTile. The ISP pads are exposed on the top of the board for low level control and experimentation with new firmware.

Technical Specifications

Designed with simplicity in mind, AutomaTiles are distributed computational toys, which have transparency and interconnectedness as a design principle from the start. While they are preceded by distributed computation toys such as the commercial Sifteo or research based BodaBlocks (Schweikardt, 2007), AutomaTiles have some key design differences that set them apart and also allow engagement with systems in a way never before possible. Sifteo, or Siftables, communicate with neighboring Sifteo tiles but each tile represents a complex system in itself, with a high resolution screen, the information on the tile can easily take focus away from the whole being greater than the sum of its parts. Additionally, the added cost of higher fidelity information per cell makes it difficult to implement a with hundreds or thousands of tiles. BodaBlocks explore cellular automata in 3 dimensional space, which quickly results in occlusion of tiles, which leads my conclusion to exploring 3D automata in virtual space much more engaging.

AutomaTiles rely on a minimum amount of components and affords communication with transparency. The form of a hexagon tessellates regularly providing a direct edge to edge connection with any neighboring tiles, an intuitive understanding of who is next to who. Two magnets on each side of the tile self align the tiles and maintain a soft hold, one to keep a lattice regular, an often problem that plagues hexagonal tabletop games(think of the various solutions to keep Settlers of Catan boards together). Infrared light emitters and phototransistors allow for communication to neighbors through plastic cases, and allow hands or other dividing objects to easily block communication. The tiles broadcast the same information in all directions but read each of its sides individually, so orientation based rulesets are possible.


Fracture, a game developed for AutomaTiles in mid-game.

As shown above with multiple states displayed, the RGB LED serves to visually indicate state through color or animation. A quickly pulsing light will communicate differently than a slow pulsing one, perhaps urgency versus calm or excitement and boredom. Attention can be drawn with the temporal aspect of the lighting and the API allows for any kind of light transitions thinkable.

Often times clocks for computers are obscured away. While AutomaTiles are not restricted to discrete time, they have a nice way of playing with it. The on board microphones allow each tile to listen for when to step forward in time. A traditional metronome can used to step the tiles forward at any given speed. There is a very intuitive understanding of time as it steps forward, and simply pausing the metronome pauses the cellular automata in their current state.

Fracture, 4 player setup (left), with all colors segregated, and a game in progress (right).

Games

Understanding abstract systems is difficult, so having incentive to play with them lowers the barrier for entry. AutomaTiles were designed as a platform and so implementing games on them was a natural progression. In fact, AutomaTiles address some of the biggest hurdles in advancing tabletop games. Their collective intelligence can provide insight into gamestate, i.e. take care of all of the bookkeeping usually associated with a tabletop or board game, which allows for more focus on strategy and interacting with the system rather than calculating it. Another aspect is adding an element of an AI to a tabletop game. Computer games have NPCs or Non-Playable Characters all of the time, and board games like Pandemic rely on a dice roll to simulate a sort of NPC, the epidemic itself, but AutomaTiles have the potential to embed a smart board to play against.

To test this theory, a group lead by Celia Pierce at Northeastern University visited my lab and in a short session, we brainstormed, sketched out, coded and started play testing a game around the concept of desegregation. The rules are simple, tiles can be one of n colors, and they glow brighter with more diversity. Diversity is calculated by dividing the number of diverse tiles (not the same color) over the potential diversity (number of neighbors a tile has). The resulting game became a competitive game towards diversity. You, the player, has a single color of tiles, starting out completely segregated, and your goal is to get all of your tiles to touch only other color tiles first. Players take turns moving, and a legal move is to split the board or fracture it into 2 pieces, and then rearrange the 2 pieces to snap back together into one continuous piece. While the game could be played with cardboard, the kind of bookkeeping necessary to play would greatly reduce the amount of fun had in playing the game.

A video of gameplay can be seen here: http://automatiles.tumblr.com/post/138293217571/fracture-a-competitive-game-towards-diversity

AutomaTiles update in realtime to blink brightly when they have achieved full diversity and glow proportionate to how diverse they are in any state less than fully diverse. Players in the lead are revealed by their blinking tiles, and other players with strategically try to keep them from winning while moving to put their tiles in a better position. In watching over a dozen games and interviewing players, it is quite clear that there is a type of thinking happening with hands.

Systems Tinkering

Through this new type of distributed hardware we have been able to explore systems in playful ways. The kinds of intuition that Donella Meadows hoped not only scientists could acquire seems achievable by inventing tools that allow for exploration and expression through emergent behavior. Simply by engaging people with toys or art installations that reveal how the whole is somehow greater than the sum of its parts can be a valuable start. Lowering the barrier of entry to play with systems provokes a different type of thinking, and allows for what Mitchel Resnick refers to as *systems tinkering*. AutomaTiles are a technology to focus on what happens not alone, but when they are together.

Citations

1. Reynolds, C. W. (1987) Flocks, Herds, and Schools: A Distributed Behavioral Model, in Computer Graphics, 21(4) (SIGGRAPH '87 Conference Proceedings) pages 25-34.

2. Meadows, Donella H., and Diana Wright. Thinking in Systems: A Primer. White River Junction, VT: Chelsea Green Pub., 2008. Print.

3. Schweikardt, Eric, and Mark D. Gross. "A Brief Survey of Distributed Computational Toys." 2007 First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL'07) (2007): n. pag. Web.