

Fussil Design

Cellular Automation of Cohesion Between Nature and Algorithms



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#visual communication
#cellular automata
#morphogenetic design
#parametric design
#creative coding
#3D printed artefacts
#algorithm
#fussil

Abstract

The central focus of the master's thesis is research into the elementary elements of nature, cellular automata and their influence on design processes. Through practical experiments and a theoretical research of various cellular automata, a new design tool is created that serves to create with nature and enables the implementation of newly created artifacts in various spheres of design. The new cellular automata that are created in the process are called *fussils*, from the Latin words *fossus* (excavated) and *futurus* (about to be, future).

The fundamental principle for creating and evaluating research is creative programming, which I also use for experiments and the realization of design tools.

The results and their design artefacts are presented in an analogue and digital environment, which also shows the large range of patterns and shapes created in the new tool.

With the cohesion of nature and algorithm, I want to contribute to the development of new visual systems and design processes. These processes are a key part of understanding nature as a key factor in shaping new practices and artefacts of the future.

1. Introduction

Emergence. Existence. Death. Suddenly all that is around us is the constant notion of nature; one that has been following us, shaping us, creating the known surroundings from a simple matter to a complex term that we call – *life*. Our relations with it have been changed and shaped by many centuries of intertwined existence; searching for the nature of nature.

Inspired by it, not only did existence allow us to explore the macro- and microcosmos of nature, but to define our culture, identity, and design, exploiting its patterns, forms, resources, and behaviour. Nevertheless, as a part of it, yet as a separate being, we developed our own nature; numbers, letters, means of communication, and today digital systems.

Today, automation, data, and artificial intelligence have become extensions of natural evolution, mimicking and accelerating its mechanisms. These algorithmic systems, like nature itself, rely on patterns of interaction, adaptation, and feedback. Thus, the central question emerges: What is the algorithm of nature? And further: Can we design alongside it, or even within it?

The fine line may seem untouchable, yet it is crucial for designing a future that is more knowledgeable and evolves with our surroundings. This research investigates these questions by studying cellular automata – computational models that simulate the self-organizing behavior of living systems – and transforming them into

design tools. The goal is not only to represent nature through computation but to co-design with it. This concept of co-designing with nature shifts the focus from imitation to collaboration: the designer becomes a facilitator of emergent processes rather than their sole author.

The interdisciplinary nature of this work spans philosophy, biology, mathematics, and design. Concepts from Darwinian evolution, Alan Turing's morphogenesis, and John Conway's Game of Life are reinterpreted through creative programming to explore the shared logic of growth and adaptation. Each experiment is visualized both digitally and physically, emphasizing that design thinking and biological thinking are not opposites — they are parallel systems seeking form and coherence.

Rather than presenting algorithms as abstract code, the research translates them into visual and tactile experiences. Each algorithm becomes a living sketch — a designed organism capable of changing, reacting, and coexisting within its environment. These explorations culminate in the creation of the Fussil Design Tool, a platform that allows designers to interactively generate and manipulate evolving patterns, bridging the digital and natural realms.

This research progresses from philosophical reflection to practical application, gradually weaving together theory, computation, and design. It begins by positioning nature as an intelligent designer and explores how biological evolution parallels algorithmic logic. From there, it moves into visual and computational experiments that translate these ideas into generative systems, forming the foundation of the Fussil Design approach. The later sections introduce the Fussil Design Tool itself, demonstrating its use as a creative instrument that allows designers to collaborate with evolving digital organisms. Finally, the study concludes by reflecting on the broader implications of co-designing with nature — rethinking authorship, creativity, and the future of design practice.

2. Nature as Intelligent Designer

2.1. Living Organism of Artefact?

To understand how nature and algorithms might be connected, the first step is to examine the very systems that nature itself produces — living organisms. By studying how life forms are structured, replicated, and evolved, we can begin to recognize the inherent logic behind their creation. These or-

ganisms act as nature's own design experiments, embodying principles of efficiency, adaptation, and self-organization. Observing them allows us to trace parallels between natural formation and algorithmic construction, offering the first insight into how design can emerge without a conscious designer.

Beyond its appearance as a familiar fruit, the orange encapsulates nature as an advanced design system [1]. Introduced to the European people in the 10th century by the Moors or Sicilian agriculture in the 9th century, we found first evidence of complex irrigation systems for growing oranges already then.

If we look at the orange, we can see that this design package [2] is carefully packed in a membrane that can sustain a bigger fall. Opened once, the membrane is soft, containing a sweet liquid substance that gives us energy, vitamins and in the end, it gives us a small package containing all the necessary ingredients to have more of it; the seed, a resource that can be reproduced an unlimited number of times — as long as the circumstances for its growth are met. This is the most advanced design system that nature has been developing over 3.8 billion of years, the systems of self-reproduction.

This natural design parallels the human act of designing: intentional composition, material optimization, and embedded purpose. Over centuries, humans have selectively bred plants and animals, altering their genetic makeup in ways that resemble industrial design processes. The orange, therefore, can be seen both as an organism and an artefact — a product of nature's evolution shaped by human intervention.

Biologist Tim Lewens captures this duality by noting that biology “finds itself in the strange position of using the vocabulary of design without recognizing an intelligent designer” [3]. In this light, natural evolution functions as a continuous process of research and development — a system of prototyping, testing, and refining, much like the work of designers.

Thus, we can say: an orange is an artefact of living nature — an outcome of countless iterations of natural design.

2.2. The Ignorant Mind

If organisms behave like designed objects, who — or what — is their designer? The answer

lies not in divine intelligence but in process itself. To answer it, we may here conceive the search with four formal causes that also present points towards the research.

- **Material cause: What is it made of?**
- **Formal cause: How is it structured or shaped?**
- **Efficient cause: Where did it originate?**
- **Final cause: What purpose does it serve?**

Applied to both artefacts and organisms, these causes help describe not only what something is but why it exists. This framework becomes a foundation for exploring how design — whether human or natural — emerges from necessity, context, and adaptation. The main contributor to this thinking was Charles Dawrin who underlined the basic foundation behind main premises that connect nature to algorithms.

2.3. Darwin's Dangerous Idea

By Darwin's revolution, his radical idea will change the course of our understanding the living world. His main idea, mostly concentrated in two primal factors of adaptation and diversity, has been described in his Origin of Species. Much like empirical reasoning, he takes the world as such and slowly digs out all the mechanisms of the past and the future. Therefore, his theorem on one side is set to prove that species are evolving, and on the other, how these processes have occurred.

Evolutionary change is driven by selective pressures. A primary example is resource limitation, where a population's size exceeds the carrying capacity of its environment, creating a competitive struggle for survival. The "crunch" time [4] presents a game of survival in which two logical points have been made by Darwin.

1. If there are no variations among the population then they will stay in equilibrium.

2. If there was a significant variation among the population then any advantages enjoyed by that population would bias the sample.

These advantages can be seen on very small scales, and an absolute tiny change would make a difference. Subsequently, if there is any strong principle of inheritance, as such that a population is more like their parents and not parents' contemporaries, these can also create traits that would be amplified over time.

The process of evolution by natural selection [5], is what will define the future centuries of all sciences. The simple principle of preservation would set a question of scale. If natural selection occurred as such, what are the smallest elements of its application?

2.4. Nature and Algorithms

The arguments Darwin proposes have two sorts of demonstrations, logical and empirical. His theory of evolution is suggesting that Design can be made without conscious designer. Instead, design arises from repetition, variation, and selection.

Nevertheless, David Dennett by the end of the 20th century, gives these logical operations a term that would best suit Darwin's explanations, calling them algorithms.

"Algorithms are not new and were not in Darwin's day ... What is relatively new – permitting us valuable hindsight in Darwin's discovery – is the theoretical reflection by mathematicians and logicians on nature and power of algorithms." [4]

Dennett's reflection on Darwin led to a critical insight: evolution operates algorithmically. An algorithm — a step-by-step procedure for solving a problem — does not need intelligence to create intelligent outcomes. It requires only three conditions:



1. **Substrate neutrality:** The same logic can run on any medium — digital or organic.
2. **Mindlessness:** The process has no understanding of its results; it simply follows rules.
3. **Guaranteed results:** If the steps are followed, the outcome is consistent.

These qualities define both natural evolution and computational processes. In this way, algorithms become nature's double — its abstract reflection in human-made systems. Something purely mechanical can produce something seemingly intelligent, just as random mutations produce life.

The purely mindless mechanical steps of the algorithm are therefore purely automatic. These processes can only be done, by definition, as: “the workings of automaton” [4].

2.5. Nature, design without designer

For automata, evolution is triggered by “on-off” switches that create the next version of themselves. But if the nature operates through algorithmic processes, then every organism is both product and producer of design. From this perspective, humans are not outside nature, but active participants in its algorithmic unfolding.

The philosopher David Hume used a watch as an example: a pile of watch parts can't assemble itself into a working watch; it needs a designer. So, who is the designer in nature?

The human designer, by making a watch, takes his time and energy, with which he first researches the object. From ontological questions to historical, functional and esthetical ones, designers, based on research, make developments on the product and create the designed object. This research and development, as though we have first applied them to human designed products, are the basis of all organisms.

Every tiny adaptation in an organism — every change made over mil-

lions of years — is a form of natural research and development. Charles Darwin realized that this is how „design” appears in nature, not from a single dogmatic act, but through the slow, costly accumulation of small changes. This is known as the Principle of Accumulation of Design.

These accumulations appear firstly in disordered environments, where from basic rules and randomness emerged simple algorithms that started building order. The nature is ultimately a game of “order from chaos” that uses this principle of accumulation.

All of this suggests that life didn't arise from a simple mechanical process alone. It depends on the very specific laws and constants that define our universe. We might be living in a rare, perfect moment in the cosmos — a „Goldilocks zone” with just the right conditions to turn randomness into the skilled, designed appearance of life. Or perhaps it's the only kind of life we can recognize.

To visualize this complex understanding of nature, I have created a “Cosmic Glass” (Fig. 1). This glass represents our universe and contains all essential “ingredients”, from simple rules that create automata to the evolution of life.

3. Evolutionary Algorithm, the Nature Doppelganger

The idea of cohesion between nature and algorithms has been experimented within the 20th century to understand nature better and its evolutionary algorithms. Trying to make these algorithms possible, Alan Turing proposed an equation that will give us insights into the important knowledge of natural patterns. Forty years later, the same question, yet in a different perspective, will be answered by John Horton Conway. By examining how evolution and self-organization can be expressed through algorithms, it becomes possible to reinterpret biological creativity as a design methodology.



To translate visually how these algorithms are being conducted, here I will be using a simple automated cell, called cellular automata. In simple terms, a cellular automaton is a mathematical model used to simulate complex systems through simple, rule-based interactions. It consists of a grid made of individual cells, each following a set of basic rules that determine how it changes over time. Although each cell behaves independently, their collective behaviour produces intricate and often life-like patterns. This principle – where simple local rules generate global complexity – forms the foundation of generative design and serves as a bridge between natural and algorithmic evolution.

Here I will be conducting visual experiments that will follow the practical-empirical scenarios of cellular automata. In this regard, the visual experiments are programmed in Java Script language – p5.js, with the help of data visualisation language, known as d3.js. These two programming languages allow us to create more complexity and present the constraints, leading to new discoveries.

3.1. The Cellular Automata

The basic logical mechanism of evolution was explored by the creation of Game of Life by John Horton Conway. The game reflects basic algorithmic choices that present the most important values of cellular automata [6]. The Game is constructed on a two-dimensional plane of pixels, where each pixel represents a single cell. Each cell in the grid has two states – on or off. These states retrospectively present the states of whether the cell is alive or dead. To contribute to its state level, each cell interacts with its neighbours in all directions.

Imagine a boundless grid composed of small cells, each capable of being in one of two states: alive or dead. At every step of the simulation, each cell looks at its eight immediate neighbours and follows these simple rules:

1. If a living cell has fewer than two neighbours, it dies – representing **isolation**.
2. If a living cell has two or three neighbours, it survives – representing **stability**.
3. If a dead cell has exactly three neighbours, it becomes alive – representing **reproduction**.

This is the only law that can be seen in Convey's game, simple enough that expresses tons of varia-

tions on form, conditions of life and movement.

To demonstrate these aspects, I created a row of cells, in which three cells are put on a horizontal line. The cell in the middle stays always alive, as it recognises two cells around it. However, the cells that are upward and downward, change their state as each one of them recognises only one neighbour alive. This formulation creates a flashing effect, as it changes itself in every next step, mo-

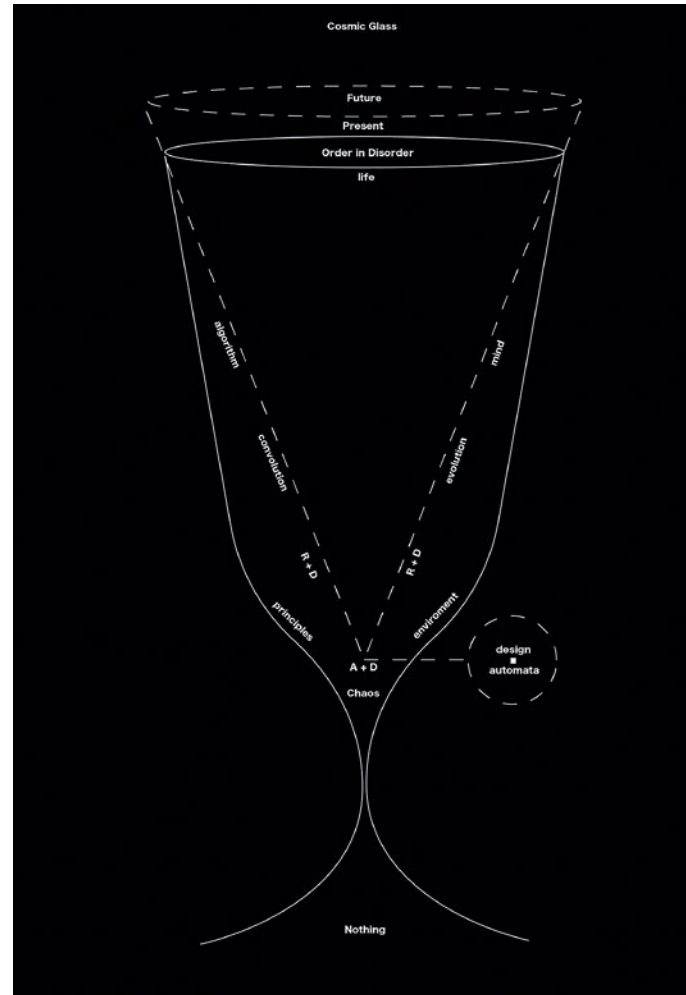


Fig. 1 Cosmic Glass, Infographic illustration. Source: Own study, Inspiration from David Dennet and Steven Hawking's Big Bang Theory.

ving from horizontal to vertical row. The flasher (Fig. 2a), in this way, represents a unique cellular automaton, that can live forever, or until some other cells disturb the system.

The flasher is a set of cellular automata that belong to the larger group called oscillators. These oscillators can vary in size and type of oscillations.

Some of the cellular automata produce organisms that do not show any behaviour, or in Con-

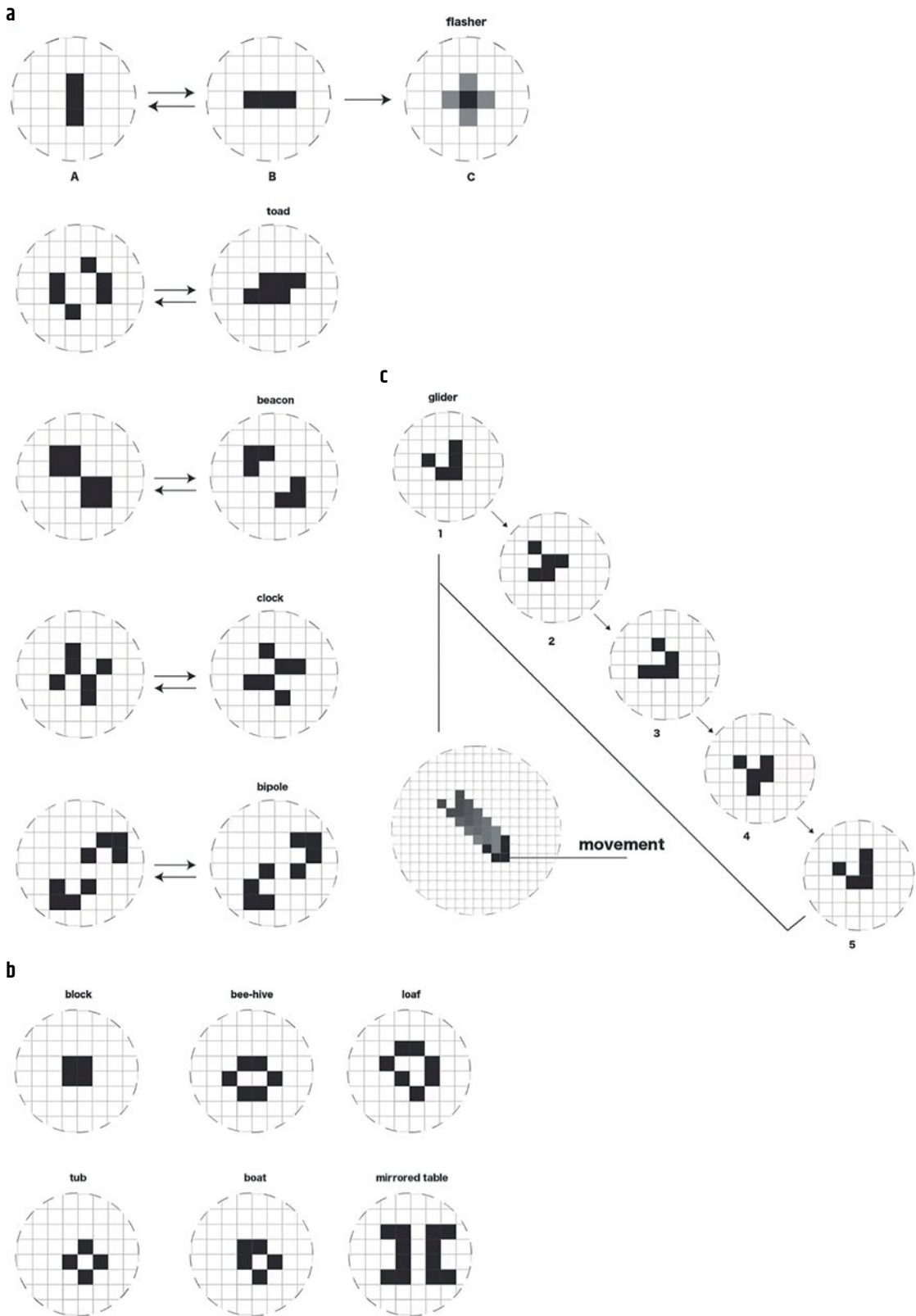


Fig. 2 John Horton Conway: Game of Life - Representation of various cellular automata. Source: Own study, Digital Infographic.

ways example, they present special cellular automata called – still lives [6].

These are completely stable cellular automata. If they are not disturbed, they don't change their shape, nor move. The simplest type of these objects is the block. The block (Fig. 2b) is a cellular automaton created by four cells, each one of them placed next to each other in a square shape.

We have seen that these forms can be still, stable, but also, they can be unstable. By being unstable forms, they are in constant movement, changing their shape through the defined grid, until they come to an end, or are in collision with some other specimen.

These have been discovered over the decade in various forms and can be separated into a large number of subcategories. The most known version of such is a glider (Fig. 2). With five periodic oscillations, the glider can move by one pixel in a destined direction. The movement of this cellular automaton is unique as it is moving by investigating the surrounding area in each direction, more like an amoeba-like organism would move.

What is interesting about the glider and its basic shape of five cells is that no matter at what direction it moves the continuum of five cells is always following them. Belonging to the subcategory of spaceships, glider is the most basic one.

Proving that there are indefinite patterns, by which a designed object can make designs, was a crucial point in understanding Game of Life. There are communicative methods, by which cellular automata can exchange their information, thus providing new cellular automata.

Why is the Game of Life so important? Because it not just proves similarities between nature and algorithms, but because these digital systems can create their own systems. As such, a glider, by moving in one direction, can create a counter that would offer more logical gates, such as “and”, “or”, “not”. These logical gates can make a finite state machine that would work beyond any further computation – by themselves.

Conway's Glass (Fig. 3), therefore, is a representation of how designed law creates an environment for basic mechanisms to form. It has its own life, infinity, and uncertainty.

3.2. Turing Reaction-Diffusion Systems

If Conway offered a digital logic of life, Alan Turing provided its chemical counterpart. In 1952, Turing's

paper *The Chemical Basis of Morphogenesis* [7] sought to explain how biological forms – such as stripes, spots, and spirals – emerge from apparently uniform beginnings. His insight was that complex organic structures could result from simple chemical interactions between two or more substances, which he called morphogens. Here morphogens are representing the cellular automata, which embody the basic rules and constraints to the system.

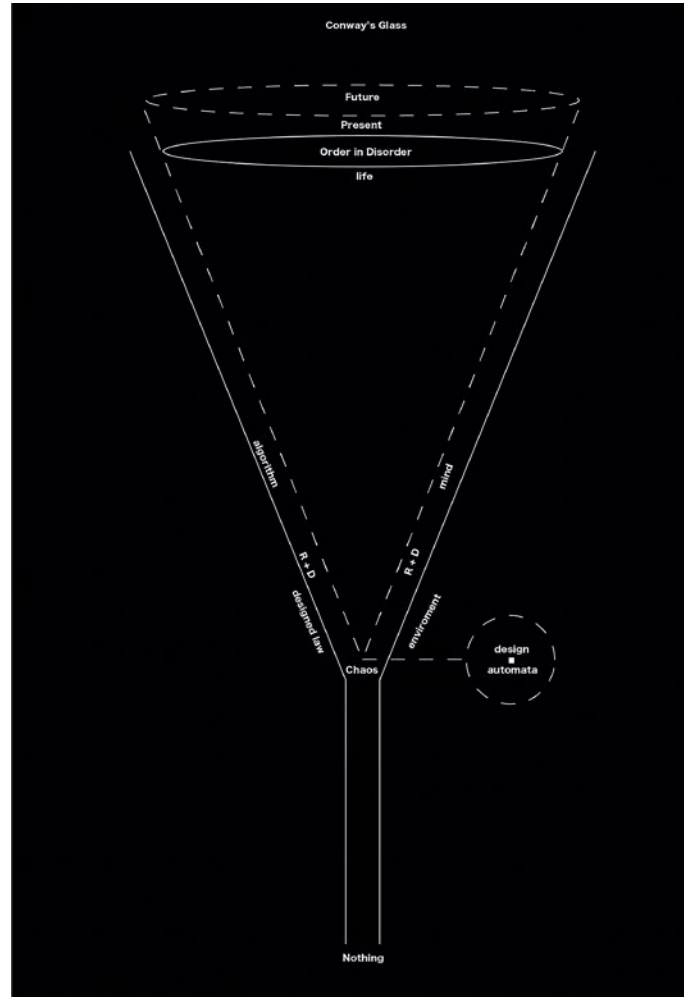


Fig. 3 Conway's Glass. Source: Own study, Infographic illustration.

The principle of application is simple: one morphogen acts as an activator, promoting growth, while another functions as an inhibitor, limiting it. The balance between these two forces – reaction and diffusion – creates stable but intricate patterns. Over time, these concentrations organize themselves into forms reminiscent of animal skins, coral reefs, or leaf arrangements.

The paper describes both mechanical and chemical processes that account in various exam-

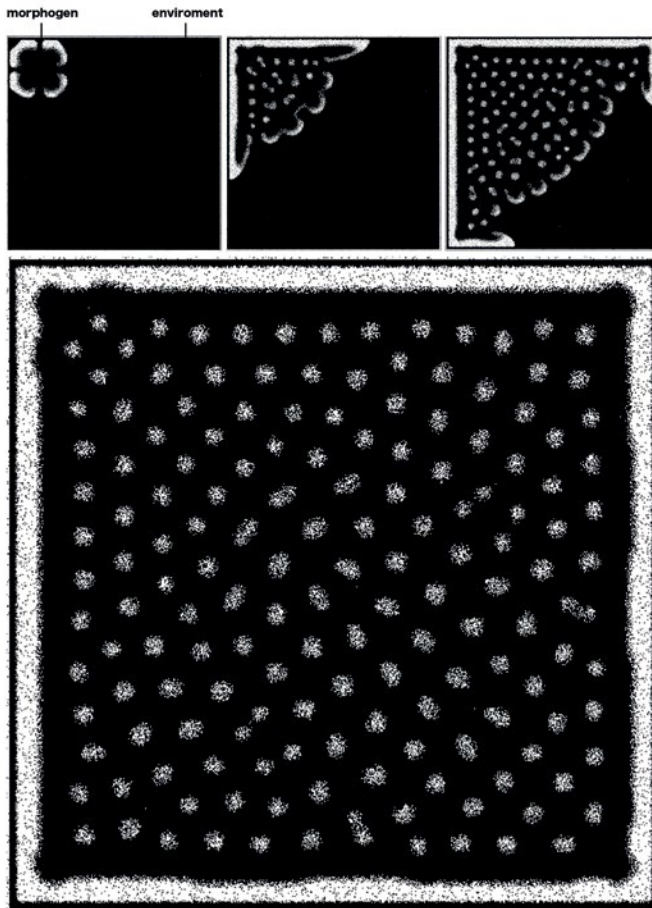


Fig. 4 Turing's Reaction-Diffusion system.
Source: Own study, digital experiment with p5.js

ples. Though it is necessary to understand that his theory, as he has written it, works in an idealistic environment, which cannot be a measure of real nature. But it gives a very basic idea of how a cellular automata can react with environment.

Here we can see that Turing was evaluating all necessary conditions that can produce more accurate results: chemical and mechanical. This is also the main distinction from Conway's cellular automata. Turing was researching not just basic automata, but rather their evolution over time with the environment.

"In this paper it is proposed to give attention rather to cases where mechanical aspects can be ignored and the chemical aspect is the most significant" [7].

To visualise these aspects, I have created a programmed visualizations that will explain the Turing theorem further (Fig. 4). To model his reaction in my research I will be using the Gray-Scott [8, 9] model of his theory. Therefore, the tissue in our example is the environment; the grid of cells that is filling the whole space. The cellular automata that are in these environments can be put in various concentrations and are reactive with it.

By concentrations, the cellular automata are here in constant reaction with the environment, therefore exhibiting different patterns based on their diffusion and reaction rates.

"To determine the part of the rate of change of one of these numbers due to diffusion, at any moment, one only needs to know the amounts of the same morphogen in the cell and its neighbours" [7].

By this, what Turing is suggesting is that if we have a small concentration of cellular automata, through time, this cellular automata will be spread equally in the grid forming a stable system.

In opposition to Conway, who is using a designed law, Turing has based his theory on a mathematical equation which allows a form to accumulate over time. Therefore, we are here not talking about the mechanical properties of the cell, but rather their underlying step – the communication with the environment.

The Turing's Reaction-Diffusion theory will be a part of long research after his death, proving that his mechanism doesn't just form patterns in nature, but explains how embryos and parts of the organisms are formed [10].

To translate this into computational design, we can imagine a digital canvas where each pixel represents a container of chemicals. As the simulation runs, cellular automata react, spread, and stabilize into unique formations. The pattern depends on two main parameters:

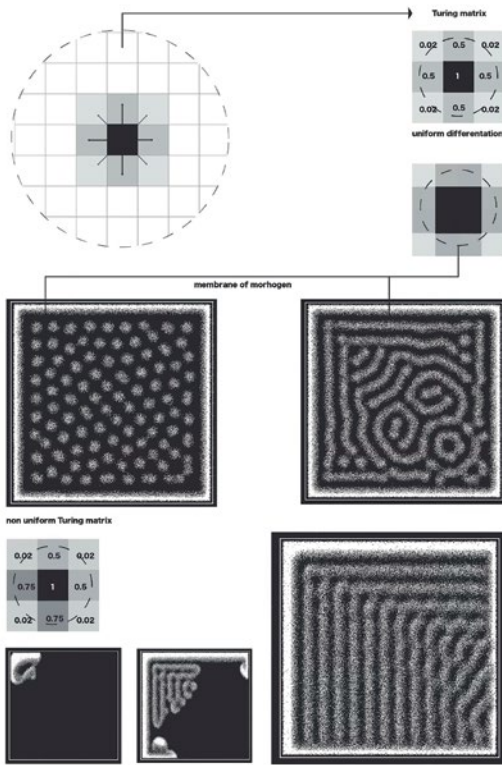


Fig. 5 Turing's uniform and non-uniform patterns. Source: Own study, digital experiment with p5.js

1. **Feed:** how much new cellular automata are introduced to the system.
2. **Kill:** how quickly existing cellular automata are removed.

The feed and kill rate are based on the reaction that is happening in the system [11]. Therefore, in this system a play of small differentiations of the rates produces various patterns in the system. These patterns are called Turing patterns. (Fig. 5)

From a design perspective, the reaction – diffusion system offers a new understanding of material agency. Instead of dictating form, the designer creates conditions under which form self-organizes. This transforms the act of design from one of control to one of collaboration – working with a system that possesses its own logic and creativity [12].

The Turing Glass (Fig. 6) forms another space [13] of observation, where the main focus is given to accumulating the right properties for making various patterns. Turing's insight, therefore, is not only a scientific one. It offers a new aesthetic paradigm: form as the outcome of feedback with environment.

4. Morphogenetic Design

Whether we describe Turing's or Conway's cellular automata, they all now represent an algorithm that possesses some designed law and principles of accumulation. As designers, these theories represent the basis of exploration on two levels, on the first level, as a designer of these algorithmic laws and on the second, a designer who controls the outcomes of these designs. The experiments that were introduced in the first and second chapter, now represent the basic core of explorative research.

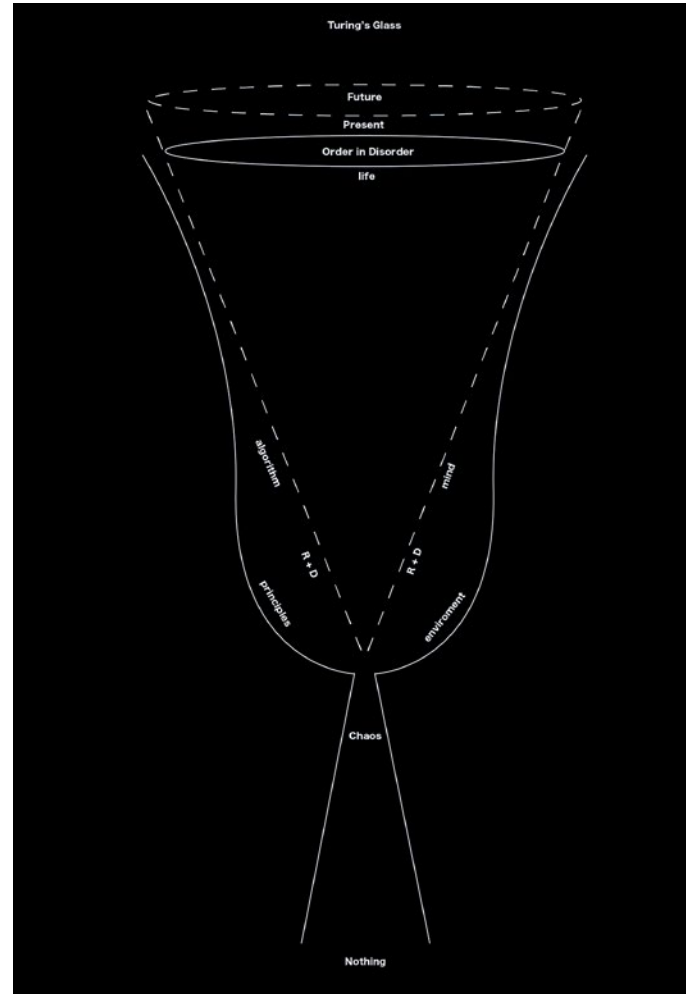


Fig. 6 Turing's Glass. Source: Own study, Infographic illustration.

Turing and Conway's system may seem very close together, but their main core is very different. The Conway's automata have a designed law, by which they detect the living cells around it, therefore observing not the actual environment but the objects inside that environment. On the other hand, Turing's automata have all components of observing the environment itself, pro-

ducing accumulative a designed pattern, but not with other objects on the environment.

To approach the complexity of natural ecosystems, the next step is to allow multiple automata to coexist and interact. To form a new general cellular automata that would present both of these components, these theories have to merge together, forming a new “morphogenetic algorithm”.

In 2005, Jamie Davies proposed some key remarks on how to understand these morphogenetic algorithms and the key terms it conveys:

1. **Feedback** – Continuous exchange of information between a cell and its surroundings.
2. **Self-assembly** – Spontaneous formation of structure from initially disordered components.

3. **Adaptive self-organization** – System’s ability not only to form patterns but to modify them in response to changing conditions.

“Morphogenetic mechanisms of biology generally have another “layer” to them that provides negative feedback and adjusts morphogenetic processes to optimize them for a specific function.” [14]

This algorithm is the sum of all products, presenting an cellular automaton that is defined by feedback, self-assembly and adaptive self-organization. Given the factor of all principles, here the complexity of such an algorithm rises to a new level. With experiments, here I propose a new system of unification.

4.1. Multi-automata design system

In both Conway’s and Turing’s models, each automaton operates in isolation. To approach the complexity of natural ecosystems, the next step is to allow multiple automata to coexist and interact. This multi-automata design system draws inspiration from the Belousov-Zhabotinsky chemical reaction, where several substances oscillate between states of activation and inhibition [15].

When implemented digitally, the system simulates a microscopic world of competing organisms. Each type of cellular automata has its own diffusion and reaction properties, and together they form evolving ecologies (Fig. 7). Depending on their parameters, three outcomes typically emerge:

1. **Dominance:** one automaton overpopulates and eliminates the others.
2. **Equilibrium:** multiple automata coexist in balance.
3. **Inertia:** no significant interaction occurs, and the system stabilizes.

These states correspond directly to dynamics observable in natural ecosystems – growth, balance, and stasis – and illustrate how algorithmic design can mimic ecological reasoning. The system does not produce a single fixed output but a spectrum of possible

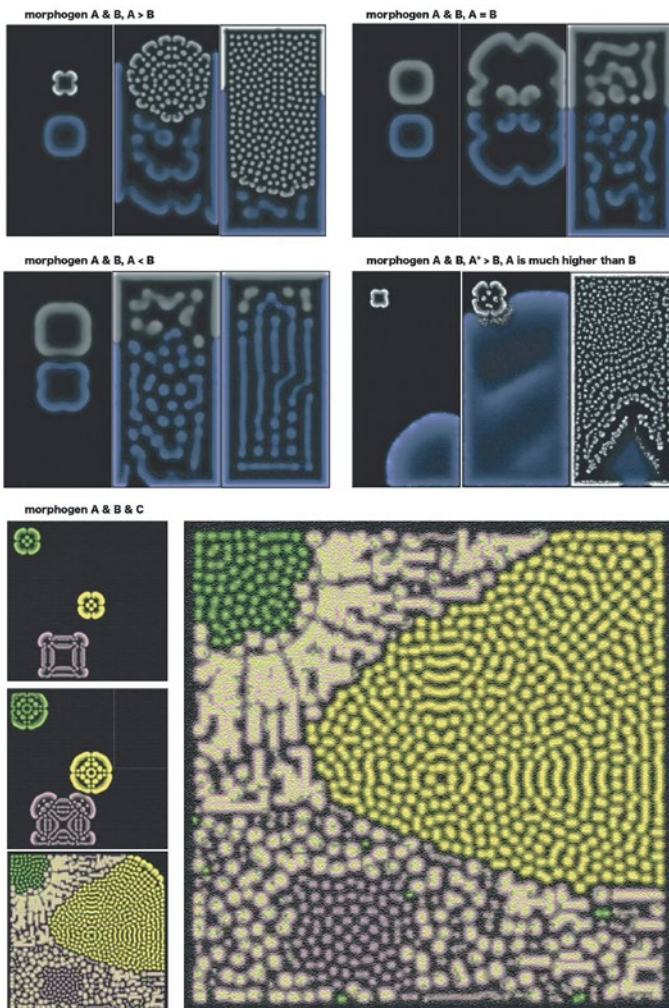


Fig. 7 Turing’s uniform and non-uniform patterns. Source: Own study, digital experiment with p5.js

worlds, each representing a cross-communication between digital species of cellular automata.

For design research, this model provides a framework for morphogenetic thinking: understanding design not as the creation of isolated objects but as the cultivation of relationships. Each cellular automata becomes an actor in a broader system, and the designer's role becomes curatorial – defining initial conditions and observing how complexity unfolds (Fig. 7).

4.2. The Haptic Membrane

Nature perceives its surroundings through layers of sensitivity: skin, bark, cell wall. In computational systems, a similar function can be simulated through a haptic membrane – a zone of awareness that extends around each cellular automaton. This concept expands the classic neighbourhood model of cellular automata by introducing a variable sensing radius.

The Conway's designed law is based on eight pixels that surround a certain cellular automaton, however, to achieve a bigger radius, we use a convolutional kernel. This kernel represents a pattern of influence for each pixel around an observing cellular automaton. By controlling the scale factor of this kernel we create a larger field of perception which can form new versions of Conway's Game of Life, such as Smooth Life [16] and Lenia [17].

The scale factor determines how big the area around the cell should be considered and then the program determines the new states.

The new idea is shown, as follows:

1. If the gradient value is higher than the average, it takes the new value.
2. If the gradient is just in the middle, its state is determined by the previous value.
3. If the gradient value is below the average, it dies.

The haptic membrane transforms the grid from a rigid framework into a responsive environment. Each automaton becomes aware of gradients of change, adjusting its behaviour according to subtle variations in its surround-

ings. The simulation thus evolves into a living field of digital matter – sensitive, reactive, and self-organizing (Fig. 8).

This notion resonates with design practice. Just as a craftsman senses resistance in clay or tension in fabric, the haptic membrane allows the algorithm to sense and respond to contextual forces. It introduces an element of tactility into computational space – turning code into a haptic material.

5.1. The Fussils

By creating a new haptic membrane and multi-automata design system, this chapter brings the research into its design-oriented phase. Introduced by new cellular automata, the Fussils.

These cellular automata have all principles of what Dennet would describe as the principle of randomness, skill and accumulation of design, and in a new theory proposed by Davies: feedback, self-assembly and adaptive self-organisation.

To introduce fussils to the environment, I have experimented first with scale factors. The outco-

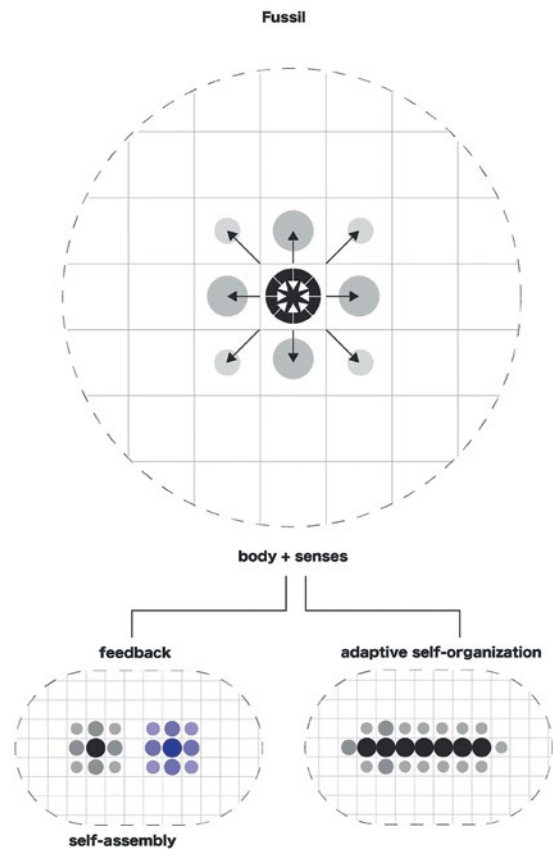


Fig. 8 Diagram representing the new cellular automata. Source: Own study, Infographic illustration5. Fussils.

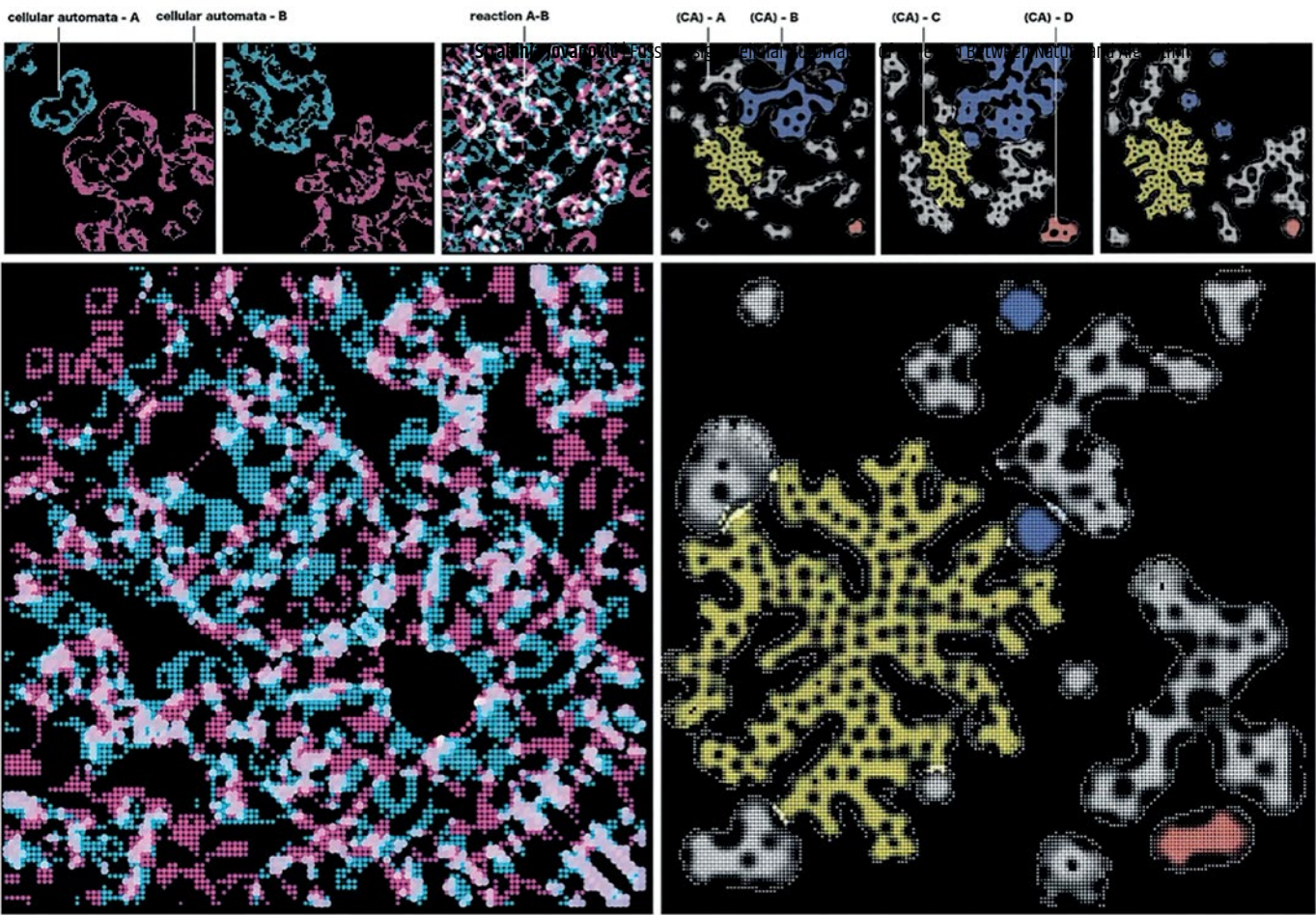


Fig. 9 Experiments with unified cellular automata, introduction of Fussils.
Source: Own study, digital experiment with p5.js

me is now very different from other automata created, as we can see more complex organisms forming. Each Fussil is not merely an element of a design, but an autonomous agent that both shapes and is shaped by its environment.

From a designer's perspective, working with Fussils is like cultivating a digital ecosystem. Rather than sketching or modelling a form, one sets initial parameters – rules of survival, growth, and exchange – and observes how they evolve into visual and structural complexity. The process resembles nurturing coral or tending a garden: outcomes are guided but never fully controlled.

The Fussils grow in real time, their structures pulsing, dividing, and recombining. Some reach stable forms; others mutate endlessly. This quality of becoming – of always being in transition – captures the essence of generative design. It mirrors nature's way of designing: through continuous iteration and feedback, not through static completion.

Visually, the Fussils can appear as swirling vortices, branching veins, or soft organic membranes. Each configuration reflects a different equilibrium between order and chaos, between attraction and repulsion. The designer, observing these forms, begins to recognize in them a digital echo of natural evolution – a reminder that computation, too, can be alive.

5.2. Fussil Reaction Design Interface

To make the system accessible to designers without requiring programming knowledge, the Fussil Reaction Design Interface was developed in p5.js and d3.js. It translates the complex mathematics of reaction – diffusion and automata into a visual and interactive environment (Fig. 10).

Here, every automaton is represented by a circle within a digital field. Its behaviour – diffusion, reaction, and energy – is controlled through sliders and buttons that modify real-time para-

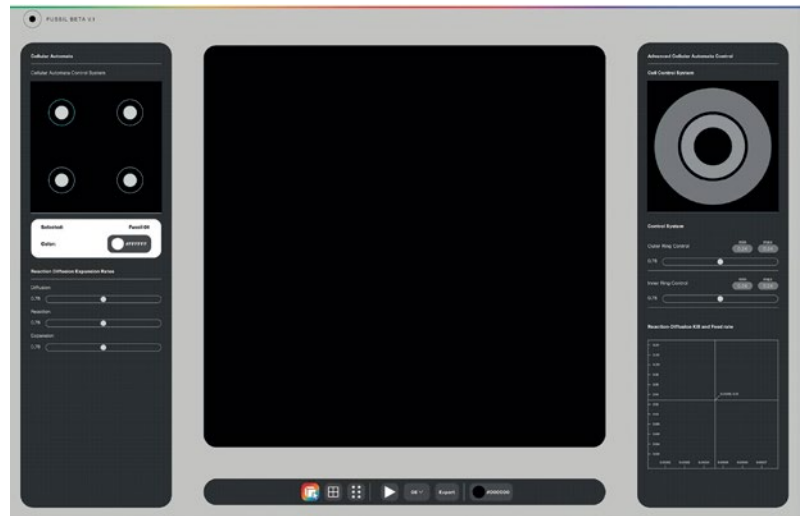


Fig. 10 Fussil Design Tool.
 Source: Digital program with p5.js and d3.js



Fig. 11 Fussil Design Tool, example of cellular automata with haptic membrane. Source: Own study, digital experiment with p5.js

meters. The designer thus interacts directly with the generative process, observing how each change transforms the evolving system.

The main parameters are:

1. **Diffusion rate (D)**: defines how far and how fast an automaton spreads its influence. A higher diffusion produces smooth gradients; a lower one preserves sharp boundaries.
2. **Reaction rate (R)**: determines how strongly it interacts with other automata. High reaction rates create turbulent, energetic behaviour, while low ones result in calm and stable structures.
3. **Expansion (E)**: regulates the size of the cellular automata.

By altering these values, designers perform a kind of digital choreography. Each gesture, each adjustment, sends ripples through the system, changing its rhythm and balance. The act of designing becomes temporal – more akin to conducting a piece of music than composing a static form.

The interface also allows the linking of multiple automata, enabling the creation of multi-species ecosystems within the digital field. As these entities interact, they form complex visual landscapes that resemble organic processes. The designer's role shifts from maker to observer, from controlling to listening to what the system wants to become. The Fussil interface thus becomes more than a computational tool; it is a medium of dialogue between hu-

man and algorithm, between intention and emergence (Fig. 11).

5.3. Fossil Design Tool

It is through here that we return to our primary questions, the four causes of matter, form, effi-

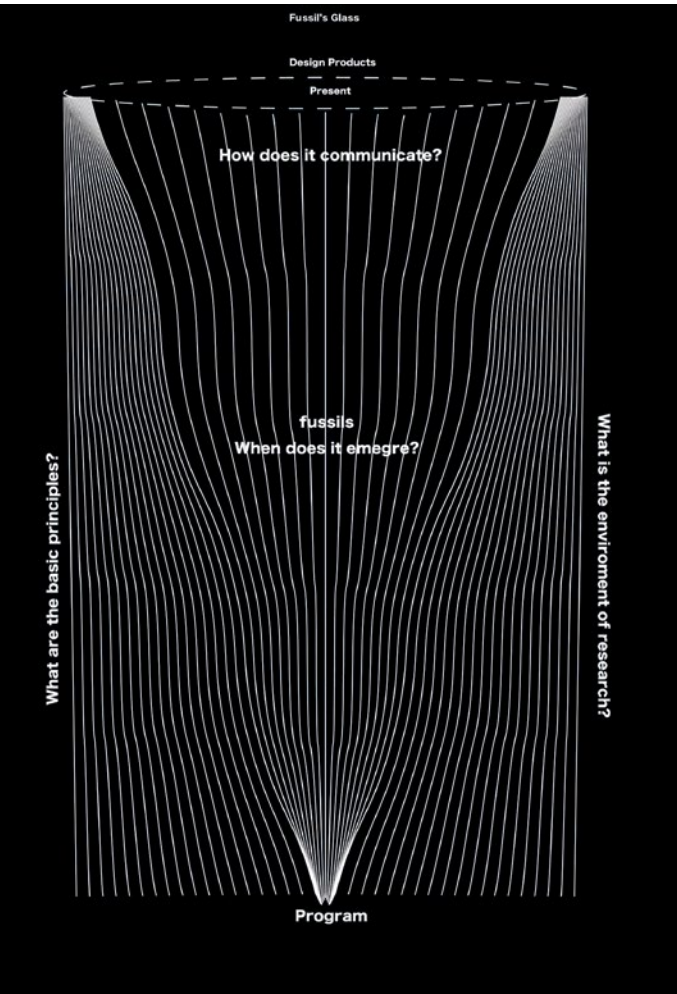


Fig. 12 Fossil Glass. Source: Own study, Infographic illustration.

ciency, and purpose. These causes determine the parameters of our Fossil Glass.

What is the environment of our glass? What are the basic principles of it? When does it emerge? How does it communicate?

Fossil Glass is not deterministic, but rather explorative. We are not given the perfect conditions that will give an organism, but rather to set these conditions by ourselves and explore the designed results (Fig 12).

The designer is put on a stage of play with parameters and factors. Some factors will produce a very narrow environment, therefore fewer outcomes, and some will produce a wide range of organisms. In some cases, the environment will be overpopulated, in some cases chaotic. However, by controlling these factors we can get certain outcomes that can be implemented in our purposeful cause.

5.4. Fossil Patterns

5.4.1. Coral Fossils

The first fossil we can create is a species of coral fossils (Fig. 13). The coral fossils are set by a body and extremities that go in each direction of the environment. As time passes, they are gradually diffusing and their further shape can be observed by change in diffusion rates. For example, not only do they form a uniform body, but they can separate from one another and form a variety of automata that are populating the environment. Exploring the environment, we can see that production of new automata here is not homogenous like in Turing and Conway's example, but their process of mitosis is quite amoeba-like.

If their parameters are changed, they can transform their shapes. By lowering diffusion, the coral fossils can also form stable states over time.

5.4.2. Guppy Fossils

With the change of a few parameters, we can also explore other types of fossils. With changes in matrix and convolution we can develop more Turing oriented patterns with breathable automata. By this, the fossils are not dissolving with the environment, but are duplicating themselves to such an extent to create various natural patterns. As they resemble a lot of patterns that can be observed on guppy fishes, these fossils are named guppy fossils (Fig. 14).

One of the very interesting forms it can take is a guppy fish scale fossil. These fossils have a specific formation that can form a breathable fish scale like pattern. Constantly moving, we can see that this pattern has developed pores purely from parametric design.

The experimentation with these types of patterns gives designers a broad play with parameters. Some of the results can be quite experimental, if the parameters are changed over time.

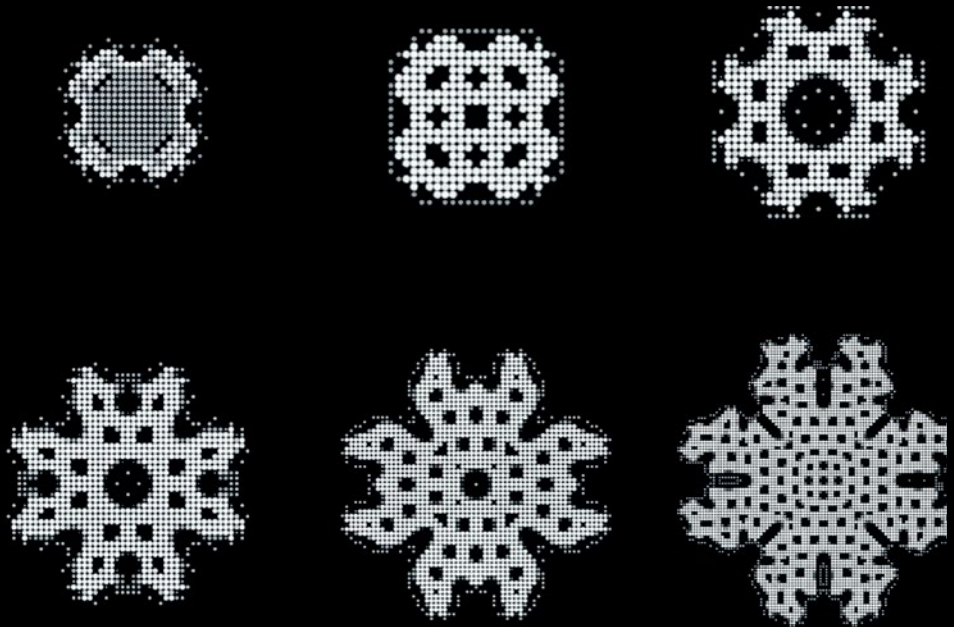


Fig. 13 Coral fussions.
Source: Own study, digital experiment with p5.js

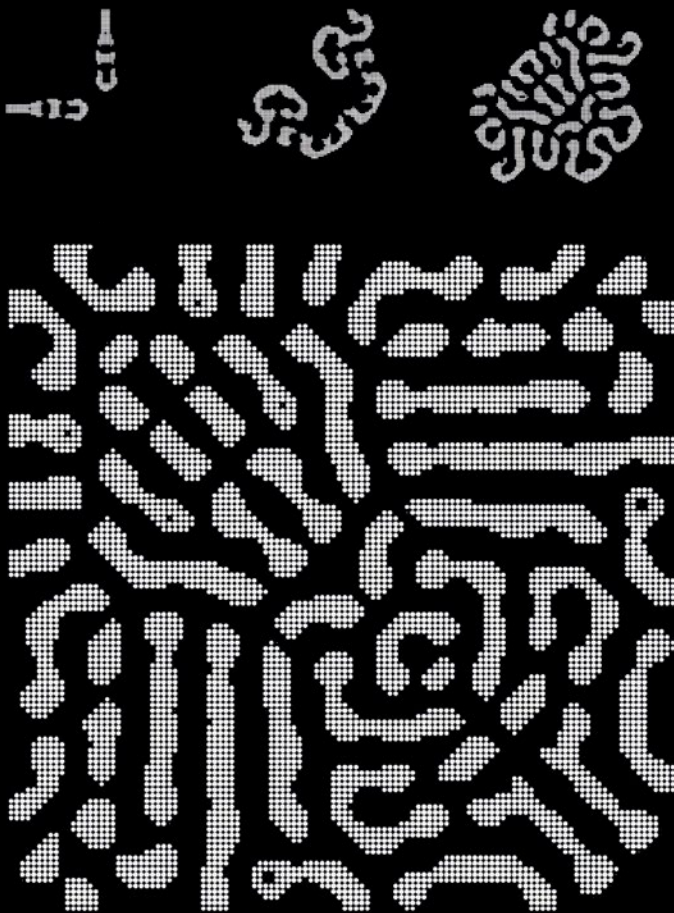


Fig. 14 Guppy textures with fussions.
Source: Own study, digital experiment with p5.js

5.4.3. Cheetah fussion

A more cohesive approach has been taken by building cheetah fussions. These fussions rapidly grow and form a uniform cheetah-like pattern. The interesting mark on these patterns is that they are indestructible. Once they grow inside the environment, they form a pattern that once disturbed it can regrow itself (Fig. 15).

Forming our matter, form and efficiency, we are now set with the final cause. Fussions enable us to explore the purpose in two extents. We can create an environment, explore how it emerges, convolves, thus our role here would be purely explorative to see the reactions, understand the basic principles, and build new algorithms from it. The general cellular automaton is not set as an immutable algorithm, but rather as developmental.

Here we are now taking a cycle in our examination and we embed a new process of a morphogenetic designer.

1. Designing from nature: Creating morphogenetic algorithms, principles and factors of parametric design.
2. Co-designing new nature: Creating our patterns, organisms that we can control, for our various purposes. This way we are creating morphogenetic designs – the seed.
3. Implementing design in nature: Creating textures, environment, buildings, clothes with new aim and visual complexity.

5.5. The Fussil Modular Grid

While the Fussil Glass explores organic emergence, the Fussil Modular Grid reintroduces order and structure, linking generative behaviour with compositional design principles. Each pattern generated by the system can be encapsulated within a modular unit – essentially, a tile that retains its internal dynamics while connecting seamlessly with others.

When arranged in a grid, these modules interact at their boundaries, producing a secondary layer of complexity: a dialogue between local variation and global coherence. This mirrors how cells form tissues, or how individual components assemble into architectural structures [18, 19].

Designers can manipulate these modules through rotation, mirroring, or scaling, creating tessellations that shift between uniformity and diversity. Unlike conventional tiling systems, the Fussil modules are not static – they continue to evolve within their cells, generating ever-changing surfaces.

This adaptability opens pathways for numerous applications: generative textiles that never repeat, architectural panels responsive to environmental data [20, 21], or jewellery that subtly transforms over time [22]. Each outcome retains the living quality of its origin

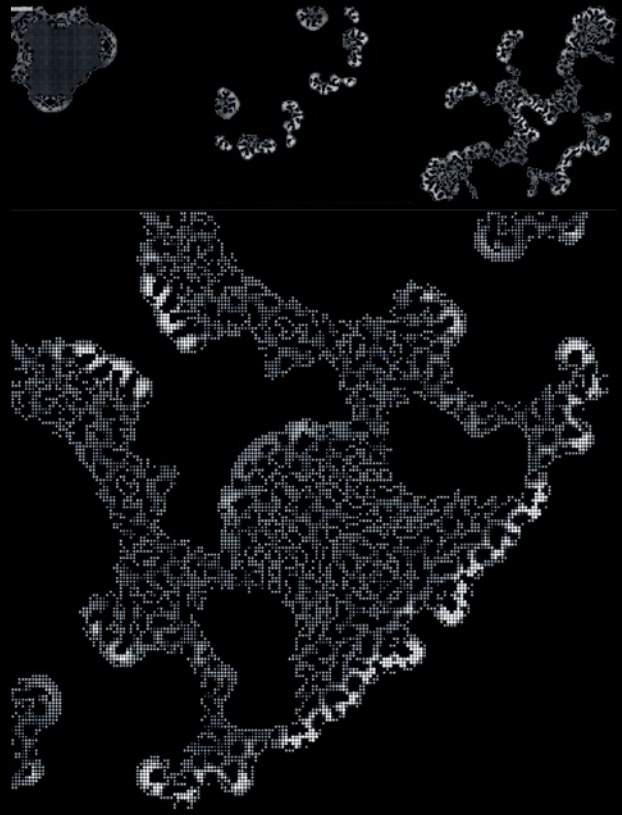


Fig. 15 Cheetah textures with fussils.
Source: Own study, digital experiment with p5.js



Fig. 16 The grid system of Fussil Design Tool.
Source: Own study, digital experiment with p5.js

Fig. 17 Textile design with fussil patterns.
 Source: Photography by Hana Podvršič.

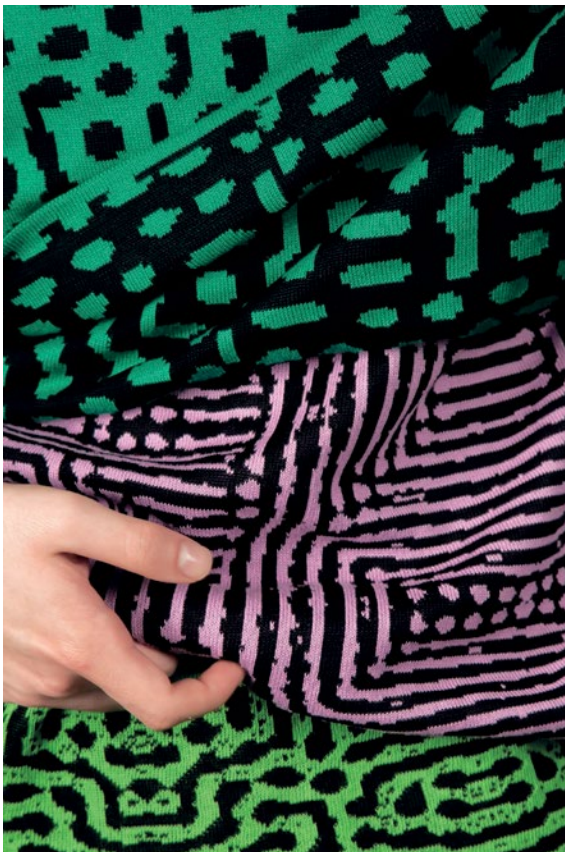
— the sense that form is in motion, perpetually negotiating its own existence.

The Fussil Modular Grid thus bridges computational generativity and design pragmatism, demonstrating how living algorithms can inform not only aesthetics but also fabrication, function, and tactility.

5.6. Fussil Product

Inspired by organic architecture and cyclic processes of nature, the possibility not only lies in modular patterns, but in materials and products that incorporate these processes.

The cheetah fussil was one of the main components that lead to creation



of flexible material. What makes it flexible are the holes inside the patterns that have relatively stable openings equally distributed along all axes. Therefore, when such a pattern is 3D printed, it can give more flexibility, yet not break that easily. The outcomes of such patterns can also be traced in textile materials (Fig. 17, 18).

Every seed is represented by some growth. Throughout the research and experiments, this growth has been mostly transferred to two-dimensional design space. However, as our seed contains all processes of morphogenesis, we can put all these layers on a new axis – the third axis of space. Therefore, the

Fig. 18 Textile design with fussil patterns.
 Source: Photography by Hana Podvršič.



Fig. 19 Fussil Vase: Turris.
Source: Photography by Hana Podvršič.

Fussil Tool incorporates a new design element of space-time. In this system, the layers are defined by the development of our initial design. They present the layers of time, where we embody elements of emergence, evolution and death. Put on the z-axis vertically, they now create a new space of observation, a fussil product.

There is a large variety of these products that can be created from the initial seed of design. Some of them are quite simple and uniform and some show objects of tremendous complexity. One of these forms translated into a fussil product is a vase (Fig. 19, 20). These vases,

initially conceived in a virtual environment, are translated into physical reality using clay – a sustainable material that connects contemporary design with the earth itself. As both medium and metaphor, clay anchors the digital in the organic, grounding abstract algorithms in tactile form. They serve a dual purpose: as sculptural explorations of biological aesthetics and as functional objects designed for everyday life. In this way, the project reimagines the relationship between technology and tradition, proposing a future where design not only mimics nature, but meaningfully collaborates with it.

6. Conclusion

The Orange never knew what it left behind. Or maybe, it always knew what it wanted [23, 24], giving us the seed, the knowledge of its complexity, emergence, evolution, grasping into our instincts of research and creativity that would lead to investigating the primordial natural parts and its algorithm.

The 20th century was a century of pure investigation of these processes. Conway and Turing had essentially cre-



Fig. 20 Fussil Vase: Tripedala. Source: Photography by Hana Podvršič.



ated all necessary components for further examination of morphogenetic processes. The processes that would question my research and create a new way of thinking of nature. “Everything is a machine,” would be argued by Gilles Deleuze and Felix Guattari in 1983 [25]. However, the information is a mutual category that can be shared by algorithms and nature, making a cohesive thought. As everything is a machine, everything is also nature.

Through the lens of cellular automata, reaction – diffusion, and evolutionary computation, Fussil Design demonstrates that the mechanisms of life and the logic of algorithms share a common ground – the generative potential of feedback.

By uniting these mechanisms into the Fussil Design Tool, this work proposes a new paradigm of creation: design as cohabitation. The designer no longer acts as a master of form, but as a collaborator with digital organisms that possess their own agency. Through interaction with the Fussil Tool, designers can explore new relationships between control and emergence, intention and surprise, authorship and evolution.

This opens new possibilities for the future of design research: responsive materials, adaptive architectures, and self-organizing artefacts that embody ecological intelligence. Each Fussil becomes a small manifesto for a new kind of making – one that acknowledges the agency of both code and matter.

To design with nature, is to recognize that we are not outside its logic but expressions of it. The orange, the algorithm, and the artefact all belong to the same continuum of evolution.

Ultimately, Fussil Design is not only a system for generating form – it is a philosophy of participatory creation, where human and non-human intelligence meet in the shared pursuit of growth, adaptation, and beauty. ■

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References

- Xu Q., Nature genetics: The draft genome of sweet orange (*Citrus sinensis*), 2023, <https://www.nature.com/articles/ng.2472> [access: 29.08.2024].
- Munari B., *Design as Art*, Penguin Classic, 2019.
- Lewens T., *Organisms and Artifacts: Design in Nature and Elsewhere*, MIT Press, Cambridge (MA), 2004.
- Dennet C. D., *Darwin’s Dangerous Idea: Evolution and the Meanings of Life*, Penguin Books Ltd, 1995.
- Darwin C. *On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life*. New York: D. Appleton & Company; 1946. Quoted in: Dennett DC. Darwin’s dangerous idea: evolution and the meanings of life. London: Penguin Books; 1995. p. 50.
- Gardner M., *Mathematical Games – The fantastic combinations of John Conway’s new solitaire game “life”*, Scientific American No. 223, 1970
- Turing A., *Chemical Basis of Morphogenesis*, Philosophical Transactions of the Royal Society of London. Series B Vol. 237, No. 641, 1952, pp. 37-72.
- Pearson J., *Complex Patterns in a Simple System*, Science Vol. 261, 1993, p. 189.
- McGough J. S., Riley K., *Pattern Formation in the Grey-Scott Model*, Nonlinear Analysis: Real World Applications Vol. 5(1), 2004, pp. 105-121.
- Murray J. D., *Mathematical Biology II: Spatial Models and Biomedical Applications*, 3rd Edition, Springer, 2003.
- Sims K., *Reaction-Diffusion*, 2013, <https://www.karlsims.com/rd.html> [access: 20.10.2023].
- Minsky M., Papert S., *Symbolistic Concept Towards Understanding Machine Learning*, MIT Press, 1988.
- Siegle E., *Did the Universe have zero entropy when it first began?*, Big Think, 22.02.2024, <https://bigthink.com/starts-with-a-bang/universe-zero-entropy/> [access: 20.03.2024].
- Davies J., *Mechanisms of Morphogenesis: The Creation of Biological Form*, Elsevier Academic Press, Edinburgh, 2005.
- Turner A., *A Simple Model of Belusov-Zhabotinsky Reaction from First Principles*, Bartlett School of Graduate Studies, University College London, 2009.
- Rafler S. *Generalization of Conway’s “Game of Life” to a continuous domain – SmoothLife*. arXiv preprint arXiv:1111.1567. 2011. Available from: <https://arxiv.org/abs/1111.1567>
- Chan BWC. *Lenia: Biology of Artificial Life*. *Complex Systems*. 2018;28(3):251-86. Available from: https://www.complex-systems.com/abstracts/v28_i03_a01/
- Owen J., *Grammar of Ornament*, Princeton University Press, New Edition, 2019.
- Studio Filippo Nasseti, *Body Architecture*, Parametric Architecture, 2022, <https://parametric-architecture.com/body-architecture-studio-filippo-nasseti/> [access: 29.08.2024].
- Conti M., *The incredible inventions of intuitive AI*, 2016, https://www.ted.com/talks/maurice_conti_the_incredible_inventions_of_intuitive_ai [access: 29.08.2024].
- Pietila R, Pietila R. Dipoli [Internet]. Architectuul. 2019 Apr 12 [cited 2024 Mar 17]. Available from: <https://architectuul.com/architecture/dipoli>
- Oxman N., *A visionary of 3-D-printed fashion*, MIT Press, 2014, <https://neri.media.mit.edu/press/article/a-visionary-of-3-d-printed-fashion.html> [access: 29.08.2024].
- Harman G., *Object-Oriented Ontology: A New Theory of Everything*, Penguin Books, St Ives, 2017.
- Latour B., *Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts*, in Bijker W., Law J. (eds), *Shaping Technology/Building Society: Studies in Sociotechnical Change*, MIT Press, 1992.
- Deleuze G., Guattari F., *Anti-Oedipus: Capitalism and Schizophrenia*, University of Minnesota Press, 1983.