FRACTAL FLUENCY

IN THE

BUILT ENVIRONMENT

FRACTAL FLUENCY IN THE BUILT ENVIRONMENT

ART AND SCIENCE OF FRACTALS

DESIGNING WITH FRACTALS

FRACTAL LIBRARY

ARCHITECTURAL APPLICATIONS

ScienceDesignLab by 13&9 Design and Fractals Research in collaboration with Mohawk Group

CONTENTS

FOREWORD

What do we see in the wispy edges of clouds, in the intricate branches of trees, and in the jagged peaks of a snowy mountain range? For many years, scientists assumed these images were a haphazard mess devoid of any pattern. However, the past fifty years have seen a remarkable revolution in the way scientists study nature's scenery, which has brought scientific inquiry and artistic views of nature closer together. At the heart of this revolution lies the discovery of intricate patterns called fractals. Dramatically referred to as 'the fingerprint of life', fractals have been shown to be the basic building block of many of nature's patterns, ranging from clouds and trees to mountains. People's eyes have evolved to observe these fractals and looking out at nature's scenery triggers a remarkable reduction in stress and mental fatigue. This booklet takes the reader through the basic facts about fractals and why they trigger such positive effects in the observer. It also tells the story of the formation of the ScienceDesignLab and its mission to create science-informed, human-based fractal designs for the built environment. Strategies for integrating fractals into building designs will be discussed, including diverse examples such as the Fractal Library collection, ceiling, perforated screen, window blinds, wallpaper print, curtain, glass film and flooring developed in the collaboration between the ScienceDesignLab and the Mohawk Group.

13&9 Design and Fractals Research in discussion with Mohawk Group at University of Oregon.

MISSION STATEMENT

Nature’s visual beauty is profound. Yet, it is surprisingly under-utilized when building the environments in which we work and live. In 1975, architect Christopher Alexander published The Oregon Experiment which described his famous approach to campus planning at the University of Oregon in Eugene, Oregon. Declaring that human aspirations and needs should be the primary driver when creating community spaces, The Oregon Experiment became a powerful demonstration of human-centered design.

Today, the University of Oregon is home to a scientific project that uses state-of-the-art techniques such as eye-tracking, EEG and MRI testing to investigate the psychology and neuroscience behind the human need to enjoy nature’s beauty. Over the course of twenty years, experiments conducted at the University of Oregon and with collaborators at the University of New South Wales in Australia have quantified the positive impact of human exposure to nature’s fractal patterns and confirmed that analogous effects can be induced by computer-generated fractal patterns.

In 2017, the ScienceDesignLab was formed with the mission to create science-informed, human-based fractals for application in the built environment. The lab features an international collaboration between the Fractals Research team in Eugene, Oregon which uses software to generate and analyze patterns, and 13&9 Design team in Graz, Austria, which developed fractal patterns. Togehter they developed and optimized the software to create designs that are based on scientific parameters. The time-differences at the two locations allow around the clock activities when necessary. Phase One designs were informed and influenced by the research performed previously by the University of Oregon scientists, whereas Phase Two designs are actively studied by these scientists and designers. To ensure robust results, the UO experiments are also carried out in parallel at the University of New South Wales.

13&9 Design and Fractals Research in discussion with Mohawk Group at University of Oregon.

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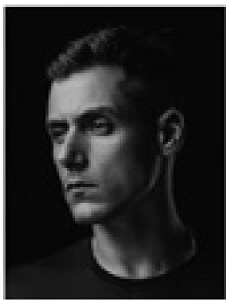

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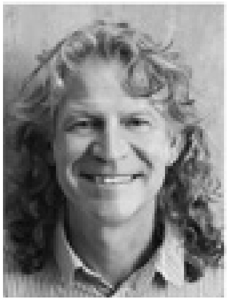

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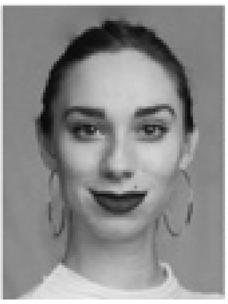

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PROF. TAYLOR´S RESEARCH AND MOTIVATION

Richard Taylor is a Professor of Physics, Psychology, and Art, holding a Ph.D. in physics and a degree in art theory. He has published over 300 articles across a diverse range of fields and has taught 10,000 students. Taylor also uses his interests in nature's patterns to encourage and promote public awareness of science-art collaborations. His work has been the subject of television documentaries (including ABC's The Art of Science, PBS's Hunting the Hidden Dimension and the BBC's The Code), many popular press articles (for example, in The New York Times and The London Times) and magazine articles (for example, in Scientific American, Time, The New Yorker, New Scientist and Discover). He regularly gives lectures around the world, commissioned by organizations as diverse as the Nobel Foundation, the Royal Society and national art galleries such as the Pompidou Centre in Paris and the Guggenheim Museum in Venice. In addition to being head of the Physics Department at the University of Oregon, he is also director of the research company Fractals Research.

WHAT ARE FRACTALS

“The beautiful thing about fractals is that they’re very simple. You take this pattern and repeat it at different size scales. This repetition generates an enormous amount of very rich intricate structure and that’s what our visual systems get drawn towards.”

Richard Taylor

FRACTALS RESEARCH: BIOINSPIRATION

Richard Taylor’s research uses his unique background in science and art to address fundamental questions about natural patterns called fractals. His main focus is bioinspiration – exploring the favorable properties that make fractals so prevalent in nature and applying them to artificial systems. Adopting an interdisciplinary approach, he has studied fractals in physics, psychology, physiology, geography, architecture, and art. The diverse applications of his research range from predicting the collapse of Antarctic ice shelves to studying the deteriorating brain structure of Alzheimer’s patients. His main projects focus on applying bioinspiration to visual science and visual art. His team (Figure 1) is developing bio-inspired electronics for bionic eyes that feature the same fractal shapes as the neurons they interface with. The goal is for these bionic eyes to restore sight to people with retinal diseases. Taylor’s fascination with the human eye extends to the psychology and neuroscience of how we respond to viewing fractal patterns in art and in nature. This research has led to a crucial question for art, science, and society: do the visual qualities of fractal scenery explain the origin of people’s biophilic tendencies?

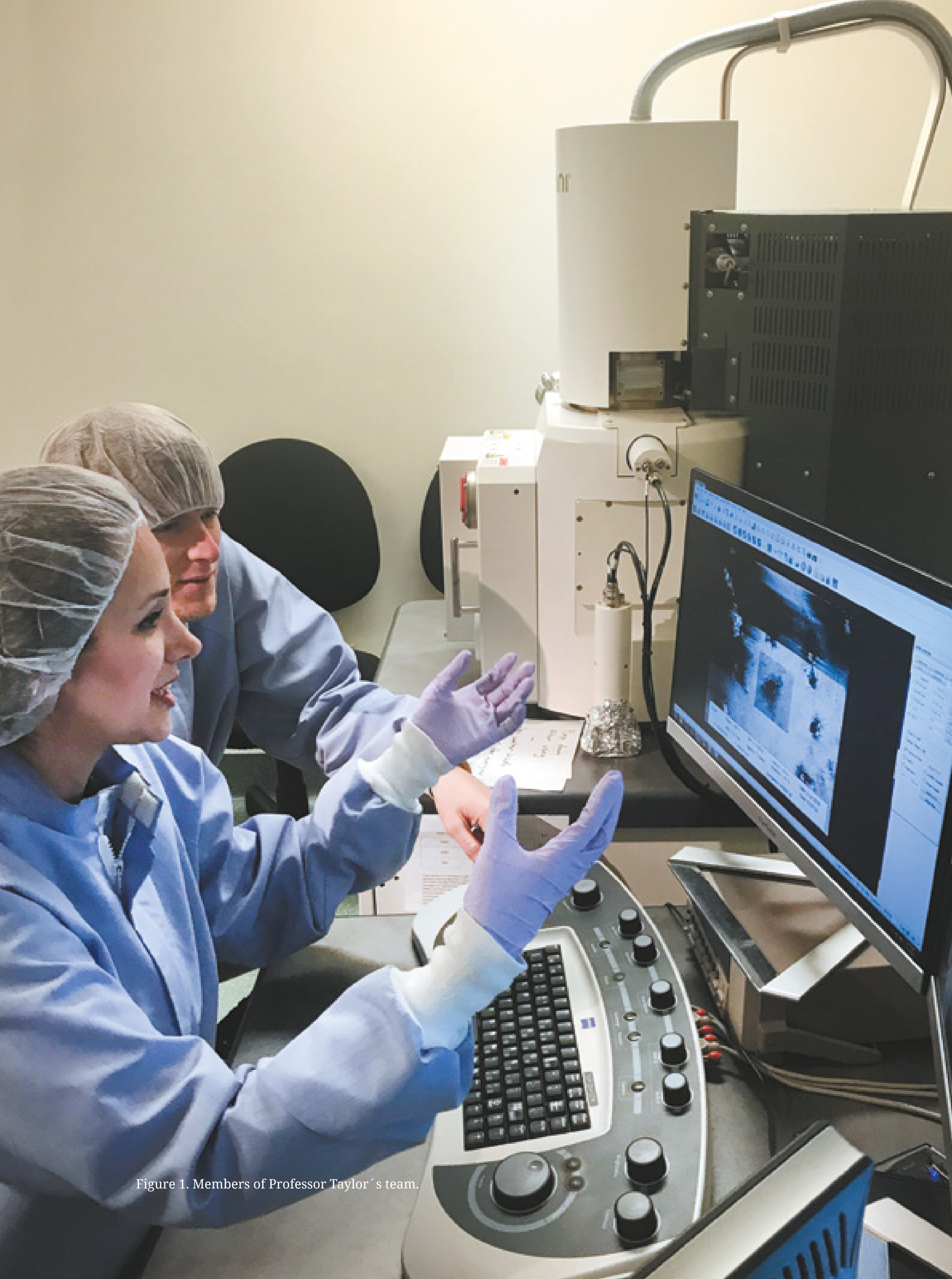

Figure 1. Members of Professor Taylor´s team.

BIOPHILIA AND FRACTAL FLUENCY

The biophilia movement gained momentum in the 1980s when naturalist Edward Wilson promoted his Biophilia Hypothesis. Biophilia—nature-loving—recognizes the inherent need of humans to connect with nature. Around this time, pioneering psychology experiments by Roger Ulrich showed that exposure to nature's scenery induced positive changes in people, including significant stress reduction. This even accelerated the recovery of patients from major surgery. In their book from the same era, The Experience of Nature: A Psychological Perspective, Rachel and Steven Kaplan introduced Attention Restoration Theory which explores our inherent fascination for viewing nature. They proposed that the 'soft' attention induced by nature differs from the 'hard' attention required for unnatural tasks (like reading books and looking at artificial objects such as buildings) and restores depleted mental resources rather than exhausting them. Consequently, nature's restorative power could reduce mental fatigue and refresh the ability to concentrate, and in doing so prevent occupational burn-out.

Over the past two decades, experiments performed by Taylor and his collaborators have confirmed that fractals are responsible for the aesthetics of nature's scenery. This hypothesis was inspired by the prevalence of fractal objects in nature. Common examples from our daily lives include clouds, trees, and mountains (Figure 2). Further emphasizing their visual impact, fractals have also permeated the artistic expression of cultures spanning many centuries. As painter Jackson Pollock famously declared "My concerns are with the rhythms of nature" and concluded, "I am nature". Whether natural or created, fractals represent a profound ingredient of our visual experiences. The fractal fluency model declares that human vision has become fluent in the visual language of nature's fractals and can process their features efficiently. The model predicts that the increased performance of basic visual tasks during this 'effortless looking' will create an aesthetic experience accompanied by significant reductions in stress and mental fatigue. The World Health Organization views stress to be the "Health epidemic of the 21st Century," with associated illnesses ranging from depression to schizophrenia. As people increasingly find themselves surrounded by urban landscapes, they risk becoming disconnected from the relaxing qualities of nature's fractals. In response, designers and architects will need to rise to the interdisciplinary challenges and rewards of creating fractal designs informed by the art and science of fractal aesthetics.

Figure 2. Fractal Fluency: Typical fractal scenes contain trees, clouds and mountains.

HISTORY OF FRACTALS: KEY DEVELOPMENTS

300 BCE: Fractal qualities emerge in artworks (eg Hellenic friezes)

800: The Borobudur Temple is built incorporating fractal characteristics

1830s: Psychologist Gustav Fechner introduces psychophysics – experimental investigations of the psychological impact of objects' visual properties

1860s: Mathematicians such as Karl Weierstrass start to generate and study shapes that will later be known as fractals

1930s: Mathematician George Birkhoff introduces the concept of Aesthetic Measure – that aesthetic appeal can be linked to an object's mathematical shape

1950s-60s: Clues that fractals appear in Nature are published - Harold Hurst's studies of the Nile (1951) and Lewis Fry Richardson's study of the British coastline (1961)

1964: Psychologist Eric Fromm introduces the term Biophilia to describe the inherent psychological need of humans to connect with living entities

1975: Mathematician Benoit Mandelbrot introduces fractal as an umbrella term to unite the earlier mathematical studies of repeating patterns with the emerging examples in nature

1975: Architect Christopher Alexander launches The Oregon Experiment, emphasizing the importance of human-centered design for the built environment

1979: Medical sociologist Aaron Antonovsky proposes salutogenesis - the medical approach of focusing on factors that promote well-being through the management of stress, health, and coping

1982: Mandelbrot publishes The Fractal Geometry of Nature cataloging the prevalence of fractals in nature's scenery

1980s: Biologist-naturalist Edward Wilson proposes the Biophilia Hypothesis – that society needs to accommodate the inherent need of humans to connect with nature. Pioneering psychology studies quantify the positive impacts of viewing nature (Roger Ulrich's studies of stress reduction, Rachel and Steve Kaplan's studies of mental fatigue reduction)

1999: Physicist Richard Taylor publishes the first fractal analysis of art, triggering 20 years of psychophysics research of fractal aesthetics. This research leads to The Fractal Fluency Model which states that the human visual system has evolved to look at and appreciate fractals.

2017: Formation of the ScienceDesignLab to implement fractal fluency in the built environment

FRACTAL FACTS: SCIENTIFIC HISTORY

In Figure 3, a prevalent form of a fractal — a tree — is used to highlight their intrinsic visual properties. Fractals fall into two families — exact (left image) and statistical (right image). Exact fractals are assembled by repeating a pattern precisely at many scales. Randomness disrupts this repetition for statistical fractals and only the pattern's statistical qualities repeat. Statistical fractals therefore simply appear similar at different scales leading to the term self-similarity.

Exact fractals have been studied by mathematicians since the 1860s: famous examples were introduced by Weierstrass (1861), Cantor (1883), Peano (1890), Hillbert (1891), von Koch (1904), and Sierpinski (1915). All of these mathematicians have their fractal creations named after them and are collectively known as the 'classic' fractals because of their historic status. Exact fractals are scarce in nature because a small degree of randomness inevitably creeps in. Consequently, natural examples of exact fractals, such as snowflakes and romanesco broccoli (Figure 4), lack the cleanliness of the mathematical versions.

Figure 3. The branch patterns of an artificial tree repeat exactly at different magnifications (left column). In contrast, only the statistical qualities repeat for a real tree (right column).

Figure 4. Romanesco broccoli: A rare example of an exact fractal occurring in nature.

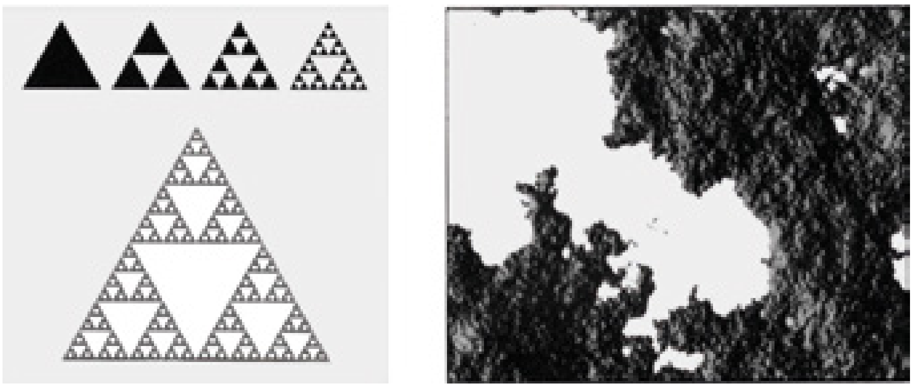

Figure 5. A Sierpinski Fractal compared to nature's fractal coastline.

The large degree of randomness within statistical fractals provides the organic signature commonly on display in nature's scenery. The relative subtly of nature's version of fractality explains why it took a century for mathematicians to fully appreciate that nature shared the same underlying geometry as the early exact fractals. The early mathematicians thought their creations were superior to nature's patterns and even labeled them as 'pathological.' They believed that the complexity of nature's patterns (e.g. coastlines) was the result of a haphazard mess – in sharp contrast to the complexity generated by the careful layering of their mathematical patterns (Figure 5). It wasn't until Benoit Mandelbrot's 1982 book The Fractal Geometry of Nature that the prevalence of fractal objects in nature was cataloged.

The left column of Figure 6 employs a coastline to further demonstrate that introducing randomness morphs the cleanliness of the exact fractal into the subtle statistical version.

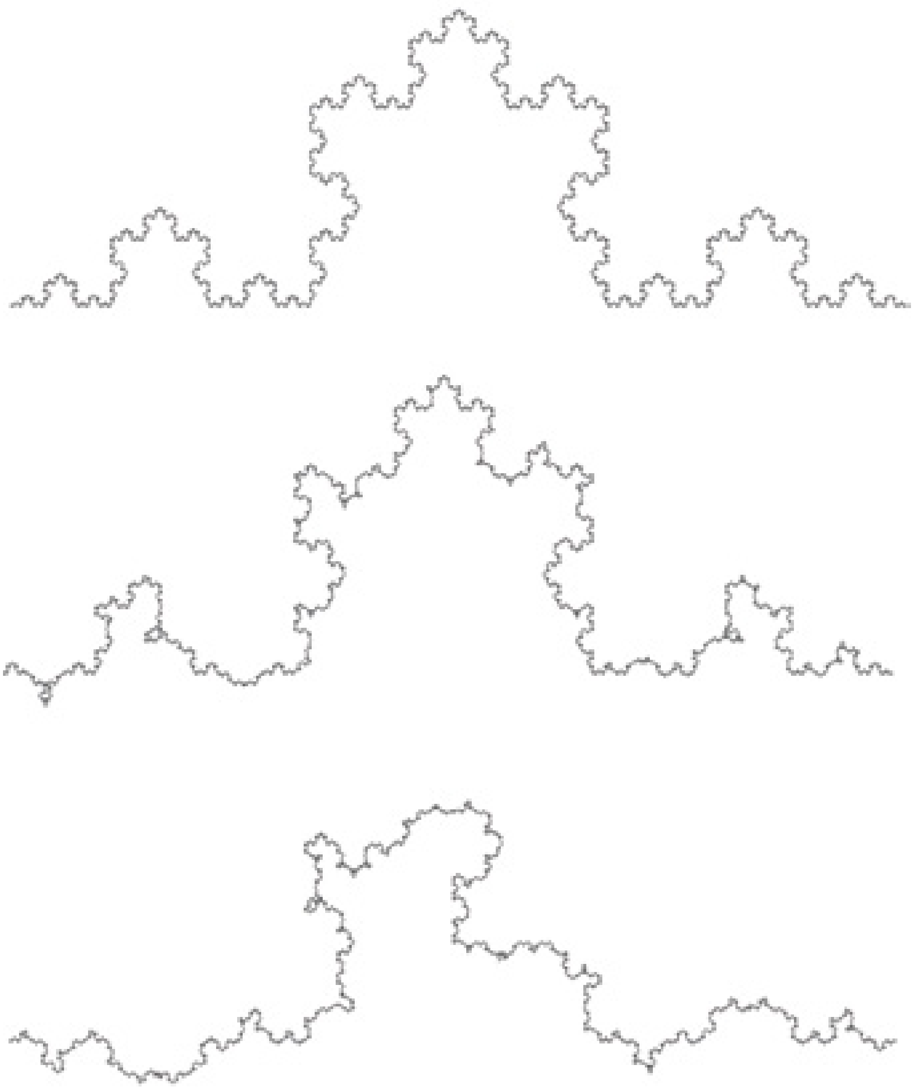

Figure 6. A computer-generated coastline based on exact fractals (top) is morphed into a statistical fractal coastline (bottom) by introducing randomness. For the top fractal, all of the headlands point upward. For the bottom fractal, half point downward, and the positions of the up and down headlands are randomized.

FRACTAL FACTS: ARTISTIC HISTORY

Intuitive artistic creation of fractals often pre-dates its conscious mathematical 'discovery'. For example, the repeating triangles found in the Koch Curve (1904) were actually first used to illustrate waves in Hellenic friezes (300 B.C.E.). The Book of Kells (circa 800 C.E.) and sculpted arabesques in India's The Jain Dilwara Temple (1031 C.E.) also display remarkable examples of exact fractals. Repeating triangles appear in the 12th century pulpit of Italy's The Ravello Cathedral. Similarly, in the 13th century, triangles within Cosmati mosaics created a fractal shape that 7 centuries later became celebrated in mathematics as the Sierpinski Triangle (Figure 5). More recent examples include the Ryoan-ji Rock Garden in Japan (15th century) along with the artistic works of Leonardo da Vinci (eg The Deluge, 1500), Katsushika Hokusai (eg The Great Wave, 1833), Salvador Dali (eg Visage of War, 1940), Jackson Pollock (e.g. Lavender Mist, 1950) (Figure 7) and Mauk Escher (eg Circle Limit III, 1959).

In addition to fractal art, there have been stunning cases of architecture that incorporate repeating layers. The Borobodur temple (Figure 8d) constructed in Java during the 8th century is an early example. Built by the Holy Roman Emperor Frederick II in the 13th century, the layout of the Castle del Monte features several sizes of octagons. The Gothic cathedrals of Europe (12–16th century) also exploit fractal repetition of shapes (arches, windows, and spires) while the repetition of triangles in Frank Lloyd Wright's Palmer House in Ann Arbour (1950–1951) and the bubble patterns of the Beijing Olympics' Water Cube (2008) add to their appeal. Moving beyond individual buildings, some African villages follow a fractal plan and fractals appear in the skylines and boundaries of modern cities.

Figure 7. Five examples of nature fractals compared to an example of Jackson Pollock's fractals.

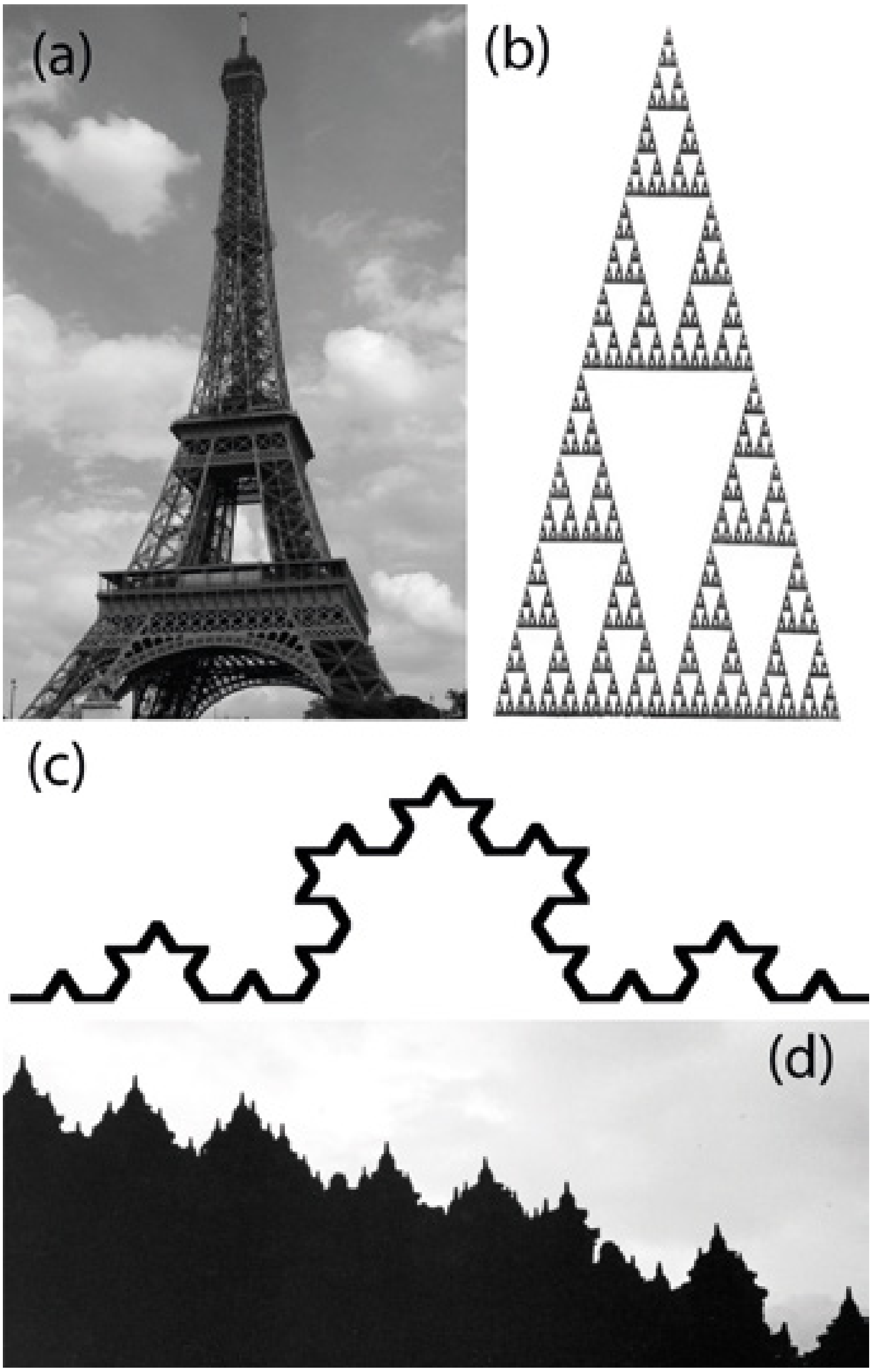

Figure 8. The Eiffel Tower (a) compared to a Sierpinski Triangle (b) and a Koch Curve (c) compared to the Borobodur Temple (d).

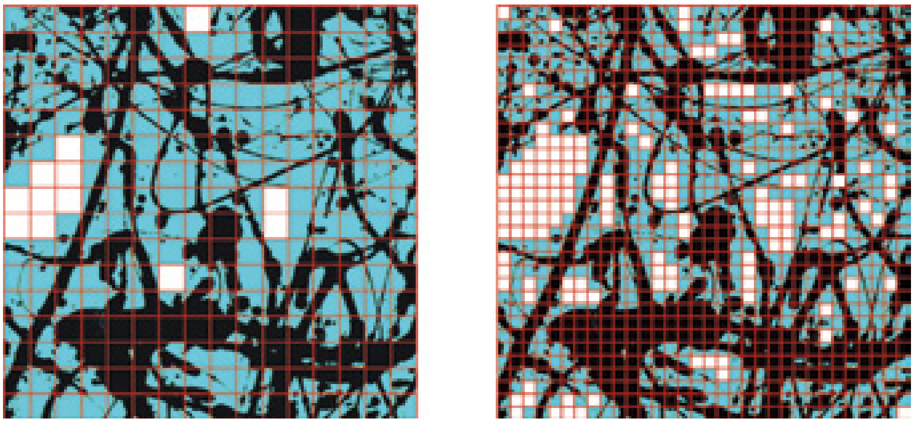

Figure 9. The box-counting technique is used to measure the D value of a fractal pattern.

Figure 10. Examples of natural fractals with their D values: clouds (left), mud cracks (middle) and forests (right).

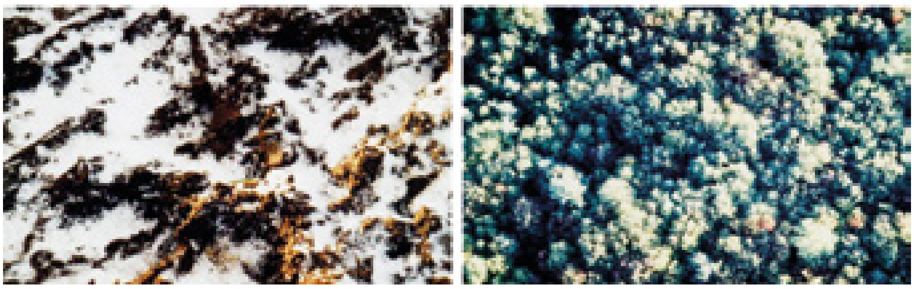

Figure 11. Nature's fractals displaying fractal scaling and fractal displacement.

THE FINGERPRINT OF NATURE: VISUAL IMPACT OF FRACTALS

Psychologists employ a parameter developed by mathematicians to assess the visual intricacy resulting from the fractal pattern repetition. The fractal dimension D quantifies how the patterns at different scales assemble into the fractal image projected on the retina. For simple (i.e., non-fractal) shapes, D matches what we would expect for dimension: a smooth line has a D value of 1 while a completely filled area has a value of 2. The repeating patterns embedded in a fractal line cause it to begin to occupy space. Accordingly, its D value lies between 1 and 2. When the contribution of fine structure to this fractal mix is increased, the line gradually fills in the 2-dimensional surface of the retina and the fractal's D value therefore approaches 2.

To calculate the D value of a pattern, a computer covers the fractal image with a grid of identical squares (red in Figure 9). The computer then detects which squares are occupied by the pattern (blue) and which are empty. This is repeated for finer and finer squares, allowing the computer to confirm that the patterns are repeating at different scales and also to calculate the relative amounts of coarse and fine scale structure.

The low content of fine structure within the low D fractals builds a very sparse and simple shape (Figure 10). However, as the D values move closer to 2, the increase in fine structure content creates a much more intricate, detailed shape (Figure 10). Because D charts the ratio of fine to coarse structure, it measures the visual complexity produced by the repeating patterns. Behavioral research confirms that people's perception of complexity increases with D.

This shared complexity is responsible for how fractals came to be named. Looking for a term to unite the exact and statistical patterns, Mandelbrot noted that their complexity created a fractured appearance and so took the Latin for fracture ('fractus') and altered it to the now famous name. This complexity is also responsible for two commonly experienced tell-tail signatures of fractals. While 'fractal scaling' refers to the fact that fractal objects look similar when viewed near to and far away (picture the snowy ground of Figure 11), 'fractal displacement' conveys their spatial uniformly (picture the forest in Figure 11).

THE FRACTAL EYE: HOW WE LOOK AT FRACTALS

Although there are examples of natural fractals with D values from 1.1 to 1.9 (Figure 10 shows some examples), the most common fractals lie in the narrower range between 1.3 to 1.5. As examples, many clouds and trees lie in this range. This informs the fluency model, which proposes that humans have adapted to efficiently process these mid-complexity patterns using a cascade of automatic (i.e., not consciously driven) processes evident at many levels of the visual system. To examine the entry level of the visual system, eye-motion studies followed the observer's gaze when they looked at fractal images displayed on a monitor. The eye trajectories traced out fractal patterns described by D = 1.4 (Figure 12). This result was true for all images observed even though they varied across the wider range from D = 1.1 to 1.9. Participants with and without neurological conditions revealed the same fractal gaze dynamics, suggesting that the fractal motion is intrinsic to eye motion and is not modified by higher level processing in the visual system.

The eye searches through the scenery to confirm its fractal character. If the gaze concentrates on just one location, the peripheral vision lacks the resolution to detect fine scale patterns in regions further away from the gaze's focus. The gaze, therefore, moves so that the eye's fovea can sample the fine patterns at many locations. The eye then experiences the full distribution of coarse and fine scale patterns necessary for confirming the scene's fractality. The answer to why the eye follows a fractal trajectory during this search can be found in foraging behavior. Animals benefit from fractal searches when exploring their natural terrains. The mathematical efficiency of these multi-scaled searches provides the explanation for why they are exploited both by animal searches for food and the eye's search for visual information. The mid-D trajectory is optimal during this fractal search because it matches the D values of prevalent fractal scenery. The trajectories then match the fractal mix of coarse and fine structure found in the scenery, so facilitating an efficient sift through its visual information. Pupil dilation also varies in a fractal manner as the eye moves over the fractal images, suggesting further refinements to the search mechanism.

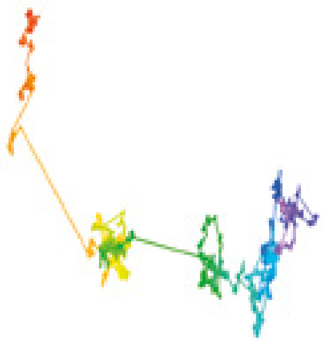

Figure 12. A simulation of fractal eye movements.

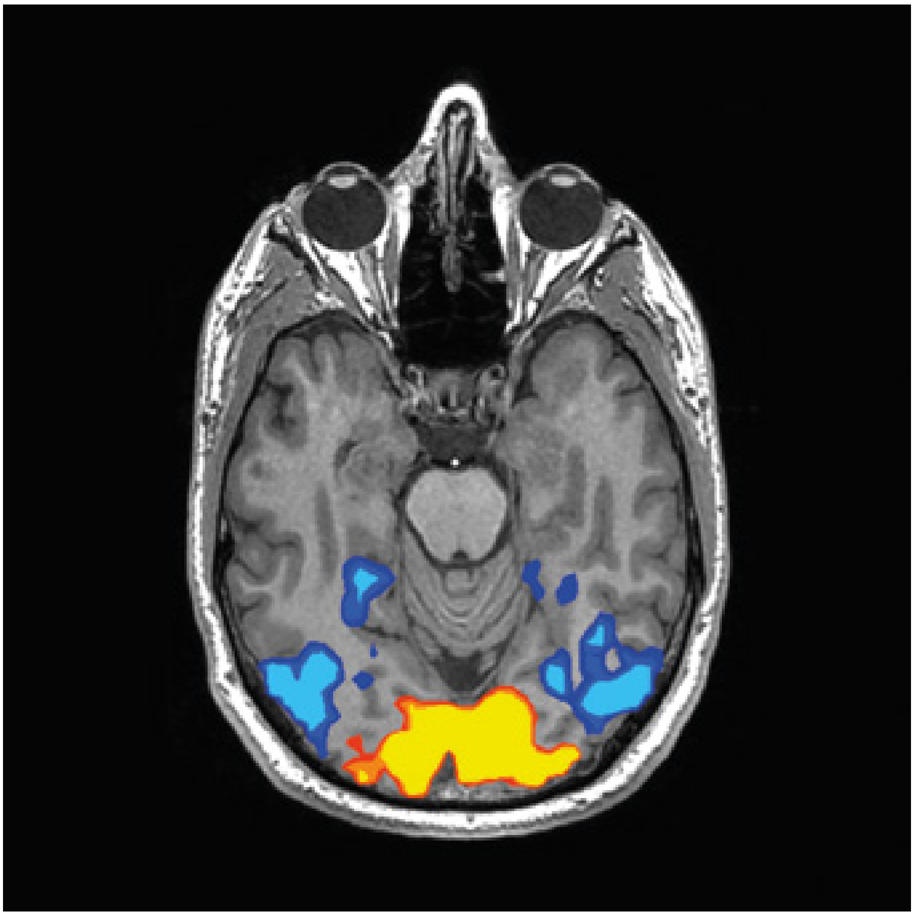

Figure 13. A fMRI study of the brain while the observer views fractal patterns.

Evidence for the enhanced processing of mid-D fractals can also be found at later stages of the visual system. The brain's visual cortex can be modeled as a system of virtual pathways that process scenic information. The number of pathways dedicated to processing objects of a particular size has been shown to be proportional to the relative number of objects of that size within the scene. Through evolution, the distribution of pathways has therefore matched the D values that dominate the environment. Fractal processing also makes use of fractal images stored in our memories by utilizing simultaneous synthesis (an integration of current perceptual information with long-term memory). As the eye searches efficiently through the image to confirm its fractal content, the brain is calling on fractal memories to help in this confirmation process. As to why this confirmation of fractality is so important, such a strategy would, for example, have allowed our ancestors to identify the non-fractal forms of animals within fractal scenery—so promoting their survival. Once a non-fractal element is detected then the fractal search is suspended and the effortless looking switches to focused attention on the element of interest.

Employing quantitative EEG, peaks in alpha waves are associated with wakefully relaxed states while peaks in beta waves indicate heightened attention. Strikingly, the D = 1.3 fractals induced the largest changes in both alpha and beta responses. This ability of stimuli to simultaneously relax and arouse is unusual and points to the unique role of nature's fractals for the visual system. Studies employing fMRI to examine which regions of the brain are being utilized also reveal D-dependent responses. On-going fMRI studies (Figure 13) will consider the role of the parahippocampal region (which is known to be involved in memory retrieval and scene recognition) and the default mode network (a large brain network associated with wakefully restful activities such as daydreaming and mind-wandering).

CONSEQUENCES: THE POSITIVE IMPACTS OF VIEWING FRACTALS

A cascade of automatic processes in our visual systems enhance our capability to process the visual information of mid-D fractals. The peak in the qEEG beta response emphasizes that the viewer's attention is being engaged by mid-D fractals. While engaged, fractal fluency improves the performance of visual tasks. For example, participants in behavioral studies exhibit increased sensitivity to mid-D fractals. To demonstrate this experimentally, the pattern contrast of fractals shown on a monitor was gradually decreased until the monitor displayed uniform luminance. When observing mid-D images, participants could see these fractals under lower contrast conditions and could distinguish their D values more accurately.

Pattern recognition capabilities also heighten for mid-D fractals. For example, associated improvements in spatial awareness led to superior navigation through environments containing mid-D fractals. When participants were instructed to navigate an avatar to find an object randomly placed within a virtual landscape, accuracy and completion speeds peaked for the mid- complexity landscapes predicted by the fluency model. Imaginary objects induced by clouds serve as another example of heightened pattern recognition processes. The visual system becomes trigger happy when viewing these mid-D fractals and so we perceive objects that don't actually exist (pareidolia). Research confirms that mid-D fractals induce large numbers of percepts and that they activate the visual cortex's object perception and recognition regions. This is supported by studies of Rorschach inkblots. Perception of shapes in the fractal blots peaks in the lower D range and declines when the fractal structure is electronically removed from the blot images.

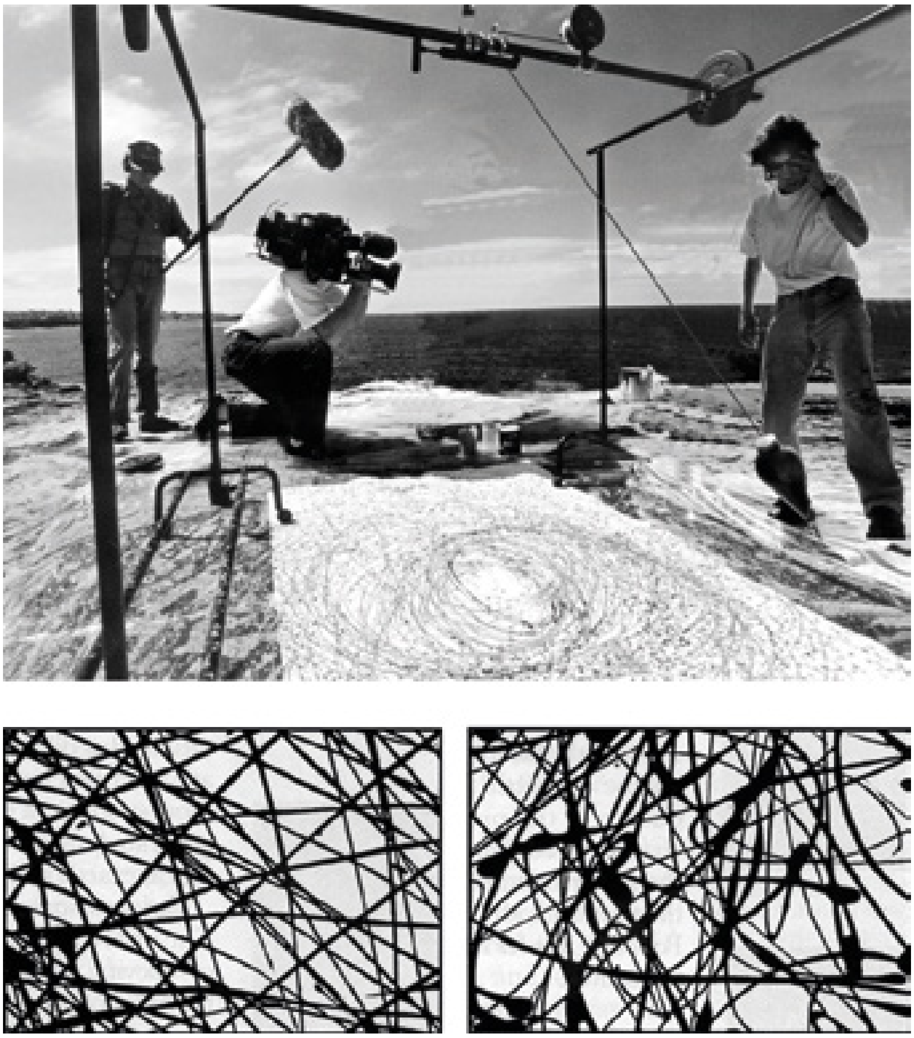

Figure 14. Richard Taylor uses a machine called the Pollockizer to generate non-fractal (left) and fractal (right) art for aesthetics experiments.

Because people find mid-D fractals so easy to process, fractal fluency is accompanied by a powerful aesthetic experience. Behavioral experiments investigating fractal art (Figure 14) show that ninety-five percent of people prefer fractal images over ones which have had their fractal content reduced. Fractal aesthetics experiments also confirm that preference for mid-D complexity occurs for a wide variety of fractal images and that this preference is already evident by the age of two. Notably, winter skylines have a higher D and are less preferred than their summer mid-D equivalents (Figure 15), perhaps contributing to seasonable affective disorder.

This universal peak preference for mid-D statistical fractals shifts to higher D values when viewing exact fractals. This is expected from the fractal fluency model. When morphing from statistical fractals to their exact equivalents, the removal of randomness results in a lower complexity pattern (Figure 6). The preferred D value, therefore, has to rise to regain the optimal complexity set by exposure to nature's statistical fractals. In other words, the simplicity introduced by exact repetition increases the tolerance for higher fractal complexity. Fractal Solar panels serve as a practical example of an exact fractal with high D.

Consistent with the alpha wave study, a NASA-funded project shows that aesthetic resonance induces a state of relaxation. The study examined the stress levels of participants in a mock-up space laboratory. While exposed to images, participants performed a sequence of stress-inducing mental tasks separated by recovery periods, thus creating a sequence of alternating high and low stress periods. The physiological response to the stress was recorded using the skin conductance method employed in Ulrich's original stress studies of nature. The stress saw-tooth was found to dampen when participants viewed mid-D fractals, indicating a stress reduction of 60%.

Figure 15. Trees have higher D values in the winter when they lose their leaves and expose the fine details of the branches.


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TRANSLATING FRACTALS INTO DESIGN

13&9'S TRANSDISCIPLINARY APPROACH AND MOTIVATION

The evolution of 13&9 Design`s transdisciplinary collaborative intent began during study periods of its Co-Founders, Dr. med. univ. Anastasija Lesjak (graduation in 2012 at the Medical University of Graz) and Architect Martin Lesjak, INNOCAD architecture CEO (graduation in 2006 at the University of Technology Graz), where they would gather with experts each in their own study discipline, assembling of different approaches, and discussing the cognitive effects of the physical and psychical connection between humans and human-made environments.

Driven by interests to explore this relationship in a practical sense, together with their partners and team, Anastasija and Martin started in 2013 to develop a medium through which various characters, talents, and expertise fuse into a single organism-like structure – embarking on a creative process from the concept phase to project fulfillment. They puzzled the essence of transdisciplinary action to form new, unexpected solutions in fields of practical architecture, interior, and product design to establish their human-centered design philosophy.

The value of their working methodology resulted in many international projects with artists, media designers, strategists, and scientists to bypass the boundaries of classical architecture and design practices by contributing to a multilayered think tank and skilled hub guided by a unified goal. Their work has since come to be defined by nonconformism leading to questioning each design task, by way of inserting compound perspectives into the process and outcome in aim to use creativity for a better future.

”This emerging new approach, blurring the boundaries between disciplines and categories, results in “new hybrids.”

Anastasija Lesjak

The concepts benefiting from complex challenges which require careful assimilation of context to people, places, and technology, can offer new narratives and experiences, overtaking a perception of something that is seen as “physical” outcome of design. Furthermore, understanding design as a responsible link to users and their surroundings, merging even more the private and public, individual, and social, artificial, and natural aspects, results in a quest for objects and spaces with physical, psychical, cognitive, and social performance.

Today’s continuous exposure to technology, globalization, urbanization, environmental issues, rapid social shifts, and especially in how we live, work, and interact, poses many challenges on physical, mental, and cognitive levels that echo the necessity of putting human needs in focus to create holistic environments independent from the confines of the space – where participants experience personalization, creativity, innovation, well-being, biophilia, and social connectivity.

Thus, “New Holism”, an approach to design blurs the boundaries between disciplines and categories resulting in “New Hybrids” in architecture, interior, and product design, to create an interface between science, art and design. Furthermore, this strategy uses design as an aid to navigate through the complexities of our daily life and goes far beyond the decorative tasks, offering solutions that are emotionally sustainable, functionally significant, and relevant to individuals as well to society. “New Holism” tries to find answers to the rapid shifts in our society and how it can improve people’s well-being and their built environment.

”An initial question: ‘What is the relevance behind surroundings and content?’ Many design efforts in the creative industry are based on solving short-term requirements rather than a holistic analysis of the task’s content and its relations for more extended design thinking that aims to create sustainable solutions.

Our goal is not only to deliver functional and aesthetically pleasing outcome only - furthermore, understanding design as a responsible link to users and their surroundings, merging even more the private and public, individual and social, artificial, and natural aspects, results in a quest for objects and spaces with flexible / transformative performance.“

Martin Lesjak

HOW TO DESIGN WITH FRACTALS

DESIGN METHODS

The success of the fractal design strategy lies in the development of software operated both by the scientists in Eugene and the designers in Graz. At times, this allowed patterns to be developed on a 24-hour schedule – when designs were completed at the end of the Austrian day, the patterns were sent over at the start of the Oregon day. It is also worth emphasizing the expertise of the three teams – the “design police,” the “fractal police,” and the “manufacturing ‘police” which ensured that there were no weak links as the designs progressed towards their completion. As with all great inter-disciplinary endeavors, creativity was an emergent phenomenon beyond the capabilities of the individual teams.

The design of the Relaxing Floors collection centered on the fact that natural scenes display ‘fractal composites’ whereby individual fractal objects (trees, mountains, clouds, etc) visually merge to form the overall fractal pattern. In addition to more closely capturing the essence of nature, fractal composites provided more flexibility to develop patterns that are appealing from a design perspective.

To visualize the compositional principle underlying these fractals, the design team explored the analogy of individual fractal trees combining to generate a fractal forest. Fractal trajectories called Lévy flights were used as the basis of the designs and these flights featured a fractal mix of trajectories with many different flight lengths (Figure 16a). Much like a bird dropping a seed whenever it lands, the seeds then grew into fractal trees at the locations between the flight trajectories. A second motivation for the ‘bird flight’ composition strategy is that it is known that eye movements follow fractal trajectories when viewing fractal patterns (see Figure 12 earlier). These designs, therefore, placed the tree locations using the same fractal statistics that the eye adopts when viewing them.

For simplicity, the seeds shown in Figure 16b-d have a circular shape. The seed’s size can then be scaled relative to the length of the previous flight trajectory so that the flight trajectories’ scaling properties can be transferred to the seed (Figure 16d).

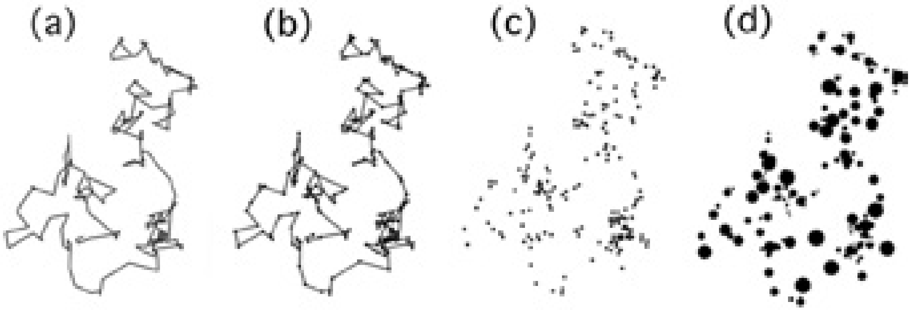


Figure 16. Fractal Flights. (a) Lévy flight trajectories; (b) Circular seed patterns are added to the landing locations between these trajectories; (c) the trajectories are removed; (d) the sizes of the circles are scaled based on the length of the previous flight trajectories.

Figure 17 shows the process that was used to grow each seed into a tree. This involved replacing each circle in Figure 16 with a tree pattern based on the traditional Sierpinski fractal. This fractal grew from a square-shaped seed by repeating the square at multiple size scales. Figure 17b shows three levels of repetition for demonstration purposes. However, designers can select the number of desired iterations and the patterns used in the Relaxing Floors typically featured two levels. In principle, the square-shaped seeds can also be replaced with any shape, providing designers with considerable flexibility for the appearance of the resulting trees. Similarly, the black background can be replaced by various pattern textures including the lines used in the tree shown in Figure 17d.

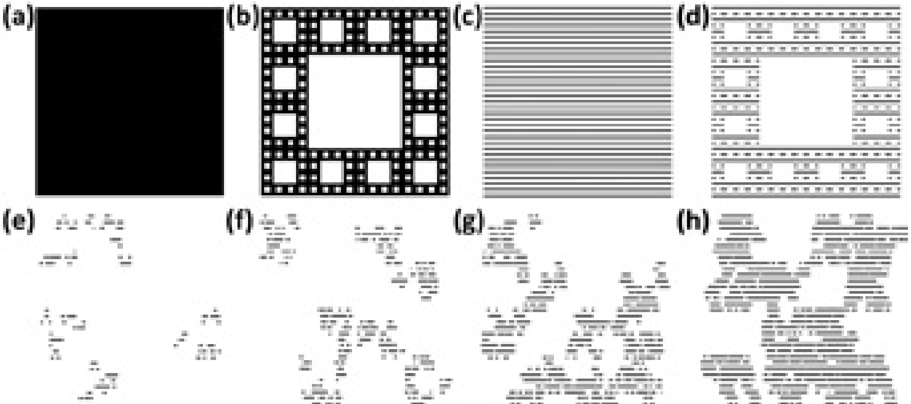
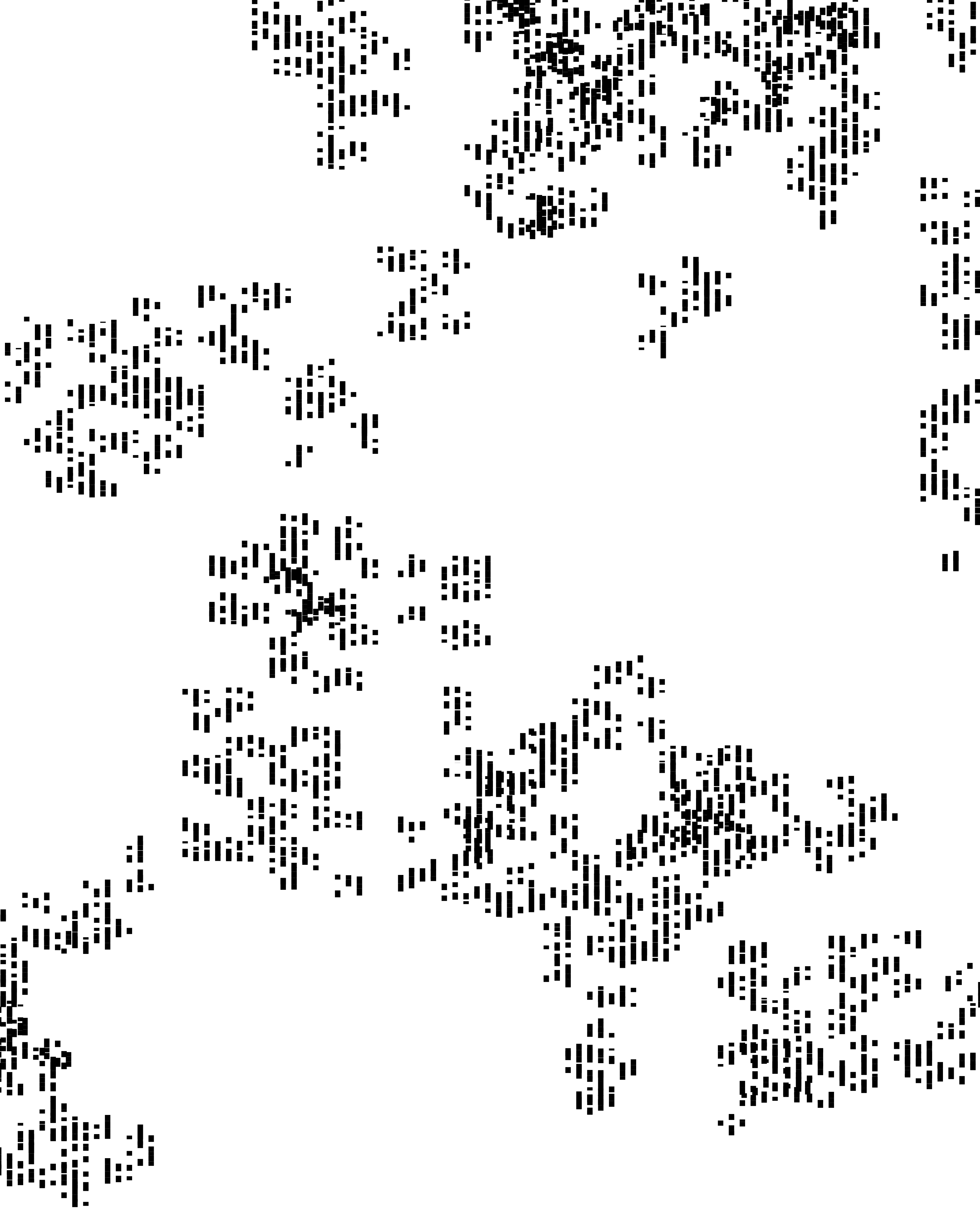


Figure 17. Fractal trees. (a) The seed growth starts with a filled square; (b) a square-shaped seed is used to grow a Sierpinski fractal pattern (the shown pattern has D = 1.8) (c) the black background is replaced with a line construction; (d) a square-shaped seed is used to grow a Sierpinski pattern superimposed on this lined background. The patterns are then randomized to morph the exact fractal into a statistical fractal. The D value of the final fractal is inputted during this growth process. Four examples are shown here: (e) 1.2, (f) 1.4, (g) 1.6 and (h) 1.8.



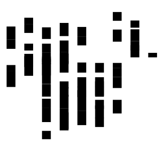


Figure 18. A fractal forest integrating the seed design of Figure 17 into the flights of Figure 16 by placing the trees at each of the landing sites. This forest is called MellowD and has a measured value of D=1.6.

To convert from an exact to the statistical pattern, randomness is introduced into the lengths of the black lines and also into the positions of the white squares (Figure 17e-h). The rate at which the seed changes size between the repetition levels can then be adjusted using D. Figure 17e-h shows examples of different D values, each with a different randomization.

The resulting fractal trees are then embedded at the landing sites between the fractal flights. The resulting forest shown in Figure 18 was named MellowD and used in the Relaxing Floors collection. This design strategy has the potential to incorporate fractal scaling in three key ways: 1) the fractal spacing between the trees (determined by the flights), 2) the distributions of the tree sizes (again set by the flights) and 3) the fractal growth of the seeds into trees. The D-values of the fractal forests were set by inputting the appropriate scaling parameters when generating both the fractal flight trajectories and the trees, and then a box-counting technique (see Figure 9 earlier) was used to analyze the completed forest pattern to confirm that it scales according to the target D-value.

Fractal scaling was confirmed from the minimum pattern size of 0.2 inches (0.5cm) up to 24 inches (61cm). The box-counting method cannot confirm fractal scaling at scales larger than 24 inches due to a limited number of boxes at these scales. However, based on the fractal input parameters, it is expected that fractal scaling continues beyond the confirmed range. Even this restricted range of confirmed fractal scaling exceeds the magnification factor for typical physical fractals, for which the coarsest pattern is 25 times larger than the smallest. Crucially, this factor of 25 was used for the stimuli used in most of the previous research that revealed the positive observation effects. The scaling ranges of our designs, therefore, exceed those known to induce the positive effects.

The forest used for the Relaxing Floors had a D value of 1.6 (Figure 18), whereas Figure 19 demonstrates the ability to tune the D value. For manufacturing demands, the 6ft (15cm) by 12ft (30cm) pattern of Figures 18 and 19 had to be divided into either 2ft by 2ft ‘tiles’ or 1ft by 3ft ‘planks’, which were then randomly re-assembled when installed. The team, therefore, had to simulate this division process to ensure that it did not disrupt the design aesthetic (in particular, that any discontinuities at the tile or plank edges fit well within the overall pattern) nor the fractal aesthetic (that the discontinuities didn’t alter the forest fractal’s D value). Figure 19 shows examples of the randomized flooring pattern.

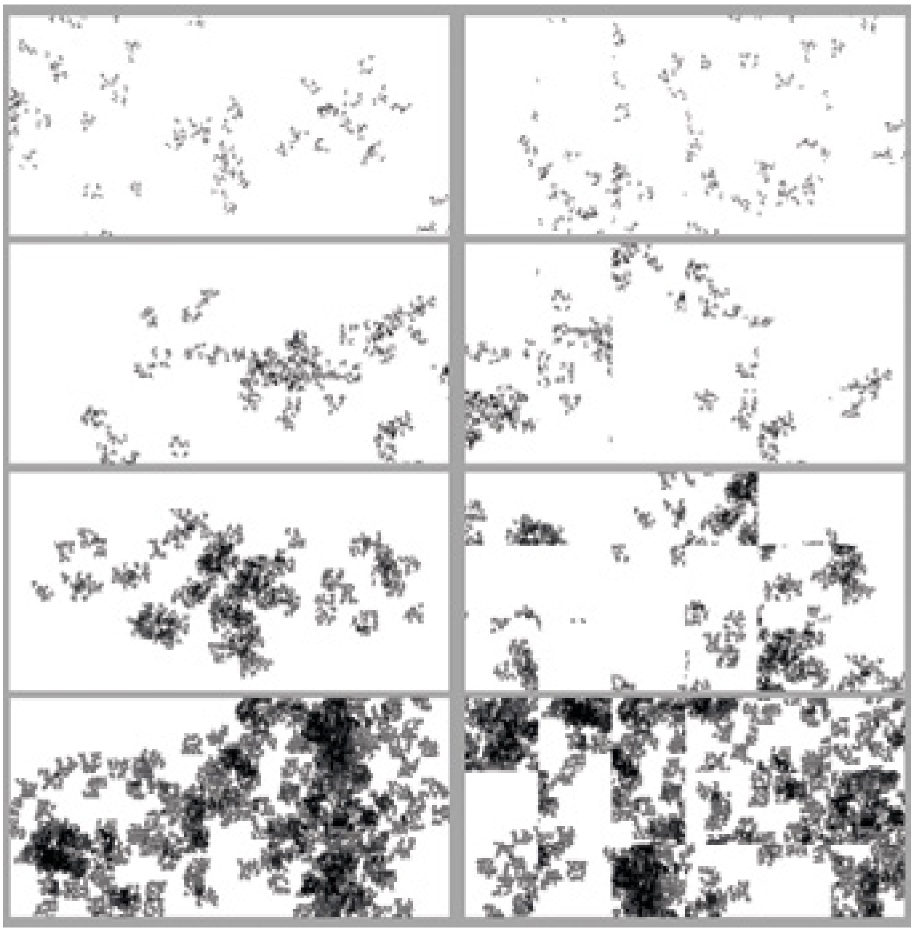


Figure 19. Fractal patterns with different D values: D=1.2 (top), 1.4, 1.6, and 1.8 (bottom). On the left side of each panel are images of the original forest pattern. On the right side are images of randomized versions of the original forest patterns, where the same forest has been divided into tiles and the tiles randomized.

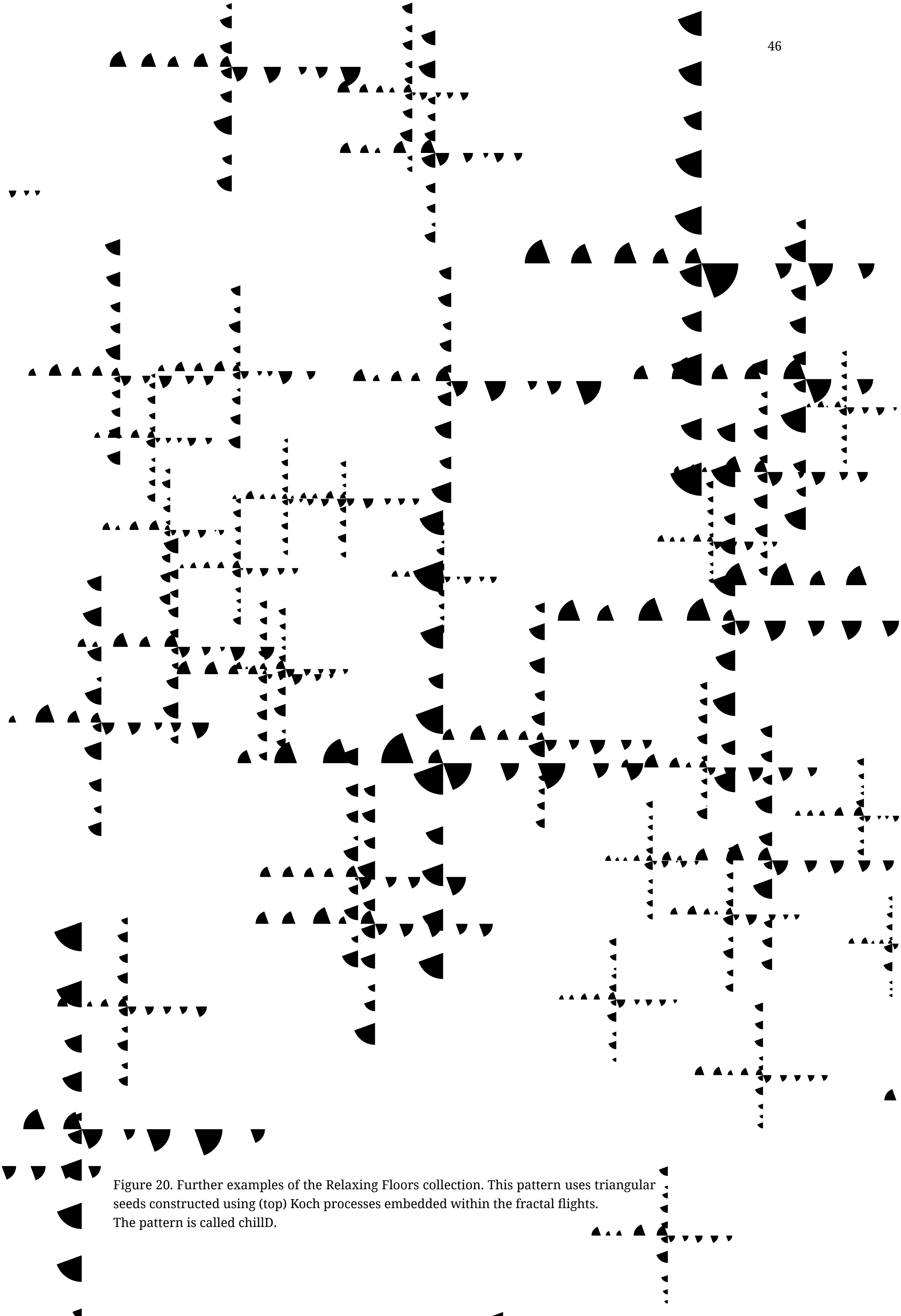


Figure 20. Further examples of the Relaxing Floors collection. This pattern uses triangular seeds constructed using (top) Koch processes embedded within the fractal flights.
The pattern is called chillD.

In addition to the mellowD forest, the Relaxing Floors collection featured two other fractal forest designs generated using the above principles, each with an overall D value of 1.6. The two other forests - chillD, and calmD – are shown In Figures 20 and 21. The three designs differed in the number of repeating levels within the tree, the shapes chosen to build the tree, and also the extent to which the tree size was set relative to the flight trajectory. In the case of this flooring tiles, the tufted carpet background had to be textural enough to hide the tile edges without creating a pattern that would alter the intended D-value. New tufting techniques which hide unused yarns to create controlled texture were used to achieve an optimized construction for aesthetics.

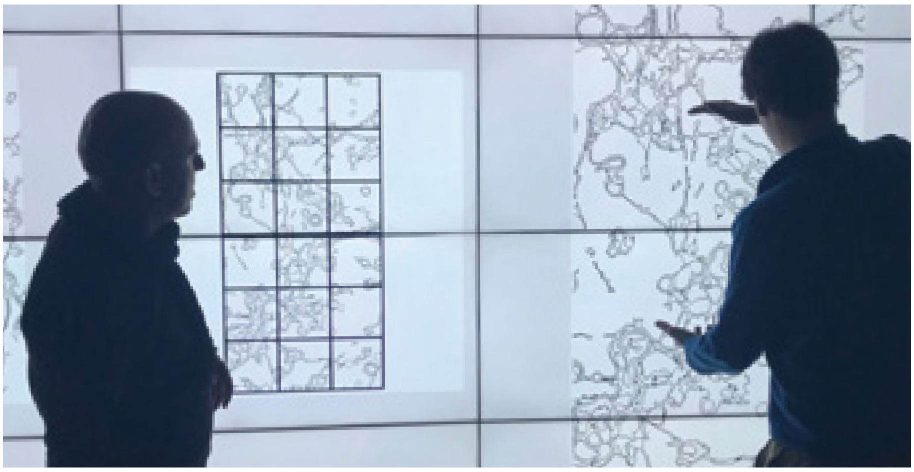


Figure 21. Further examples of the Relaxing Floors collection. This pattern uses triangular seeds constructed using Sierpinski processes embedded within the fractal flights.
The pattern is called calmD.

A second flooring design employed images of nature's fractals—retinal neurons—as the starting point (Figure 22). These images were obtained as part of a research project which develops retinal implants to restore vision to patients with diseases such as macular degeneration. Fluorescence microscopy was used to acquire detailed images of the retinal neurons in order to quantify parameters such as their D values (Figure 22 (left)). For the floor designs, the images were converted into grayscale versions and then contoured (Figure 22 (middle)). We initially expected to use software to manipulate the D values of the neuron contours but, fortuitously, the selected image's D value of 1.7 fell within the D = 1.6–1.7 target range.

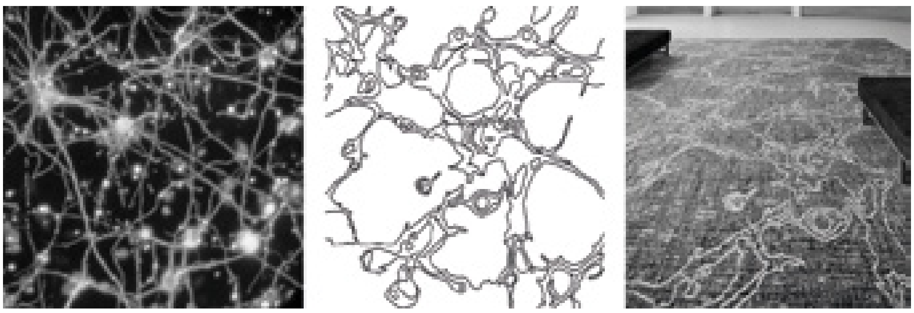


Figure 22. (left) Fluorescence image of retinal neurons, (middle) contours extracted from the greyscale image of the neurons, (right) an image of the installed carpet.

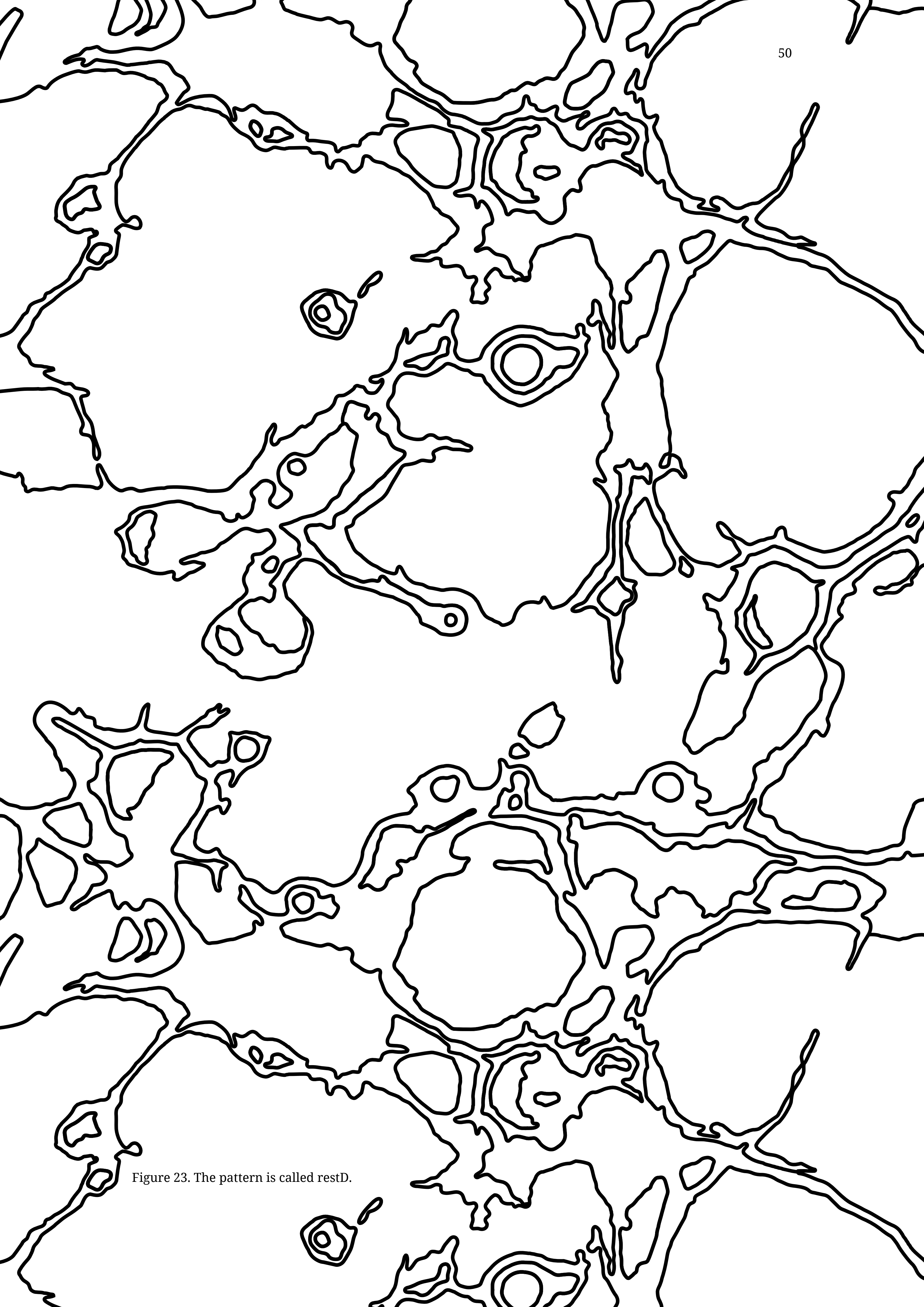


Figure 23. The pattern is called restD.


ADAMS & STRATFORD

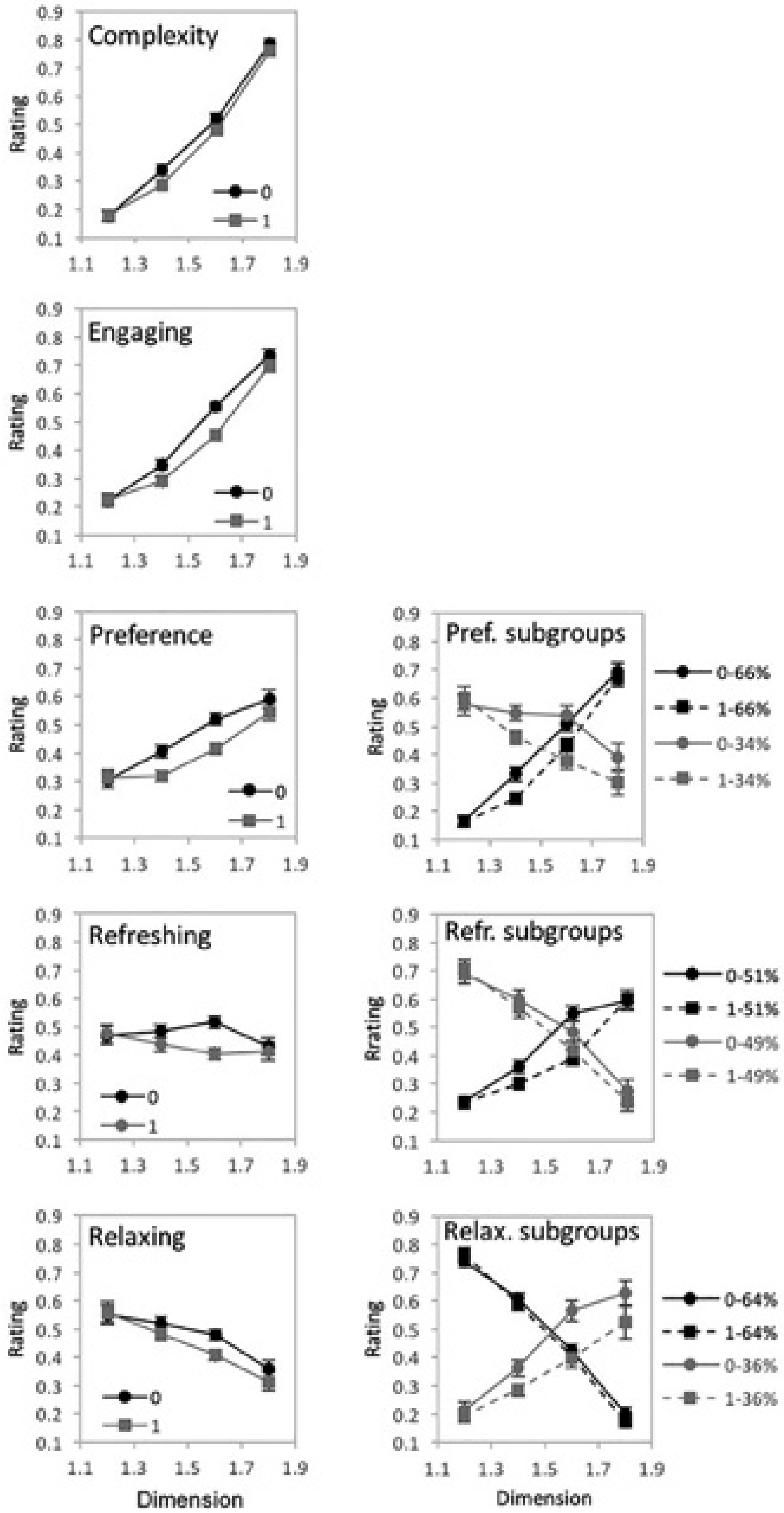
PSYCHOLOGY EXPERIMENTS

The ScienceDesignLab performed psychology experiments to confirm the positive impacts expected when the team developed the fractal designs for the Relaxing Floor collection. For installations to be effective without altering the overall aesthetics of the space, patterns must balance desirable levels of preference and engagement with relaxing and refreshing qualities. The results, published in a special edition on Biophilic Design Rationale in the journal Frontiers in Psychology, show the Relaxing Floors mid-complexity fractal designs to be very effective at balancing engagement, preference, refreshment, and relaxation qualities for a broad group of observers. Specifically, these patterns have the greatest agreement across individuals in terms of their preference, engagement and refreshment while also maintaining relaxing effects.

Furthermore, computer analysis of the fractal patterns showed that dividing the patterns into tiles and randomly re-arranging them had little mathematical impact on the fractal character of the patterns. The psychology studies confirmed that this robustness to randomization applies to viewers' positive experiences.

Lastly, the experiments were performed in Oregon, USA, and Sydney, Australia, to highlight that the positive effects are not impacted by the geographical location of participants. The findings indicate that perceptions of fractal patterns are not altered by the diverse natural environments where participants reside. This result supports our earlier findings that preference for fractal complexity forms early in human development (sometime prior to three years of age) and is not further altered by life experience. These results suggest that Relaxing Floors will have a positive impact on a broad range of building occupants.

Figure 24. Experiment results for “global forest” (Figure 19) fractal patterns for 5 different judgment conditions (how complex, engaging, preferred, refreshing, and relaxing).(A–E) shows plots of mean ratings as a function of fractal dimension (D) and 2 pattern arrangements (not randomized “0,” randomized “1”) for the different judgment conditions (error bars represent standard error). (F–H) shows plots of mean ratings as a function of fractal dimension (D) and 2 pattern arrangements (not randomized “0,” randomized “1”) for each subpopulation identified with cluster analysis (error bars represent standard error).


Complexity
Engaging
Preference
Pref. subgroups
0-66%
1-66%
0-34%
1-34%
Refreshing
Refr. subgroups
0-51%
1-51%
0-49%
1-49%
Relaxing
Relax. subgroups
0-64%
1-64%
0-36%
1-36%
Rating
Rrating
Dimension
0
1

HOW TO INCORPORATE FRACTALS IN THE BUILT ENVIRONMENT

THE FRACTAL LIBRARY

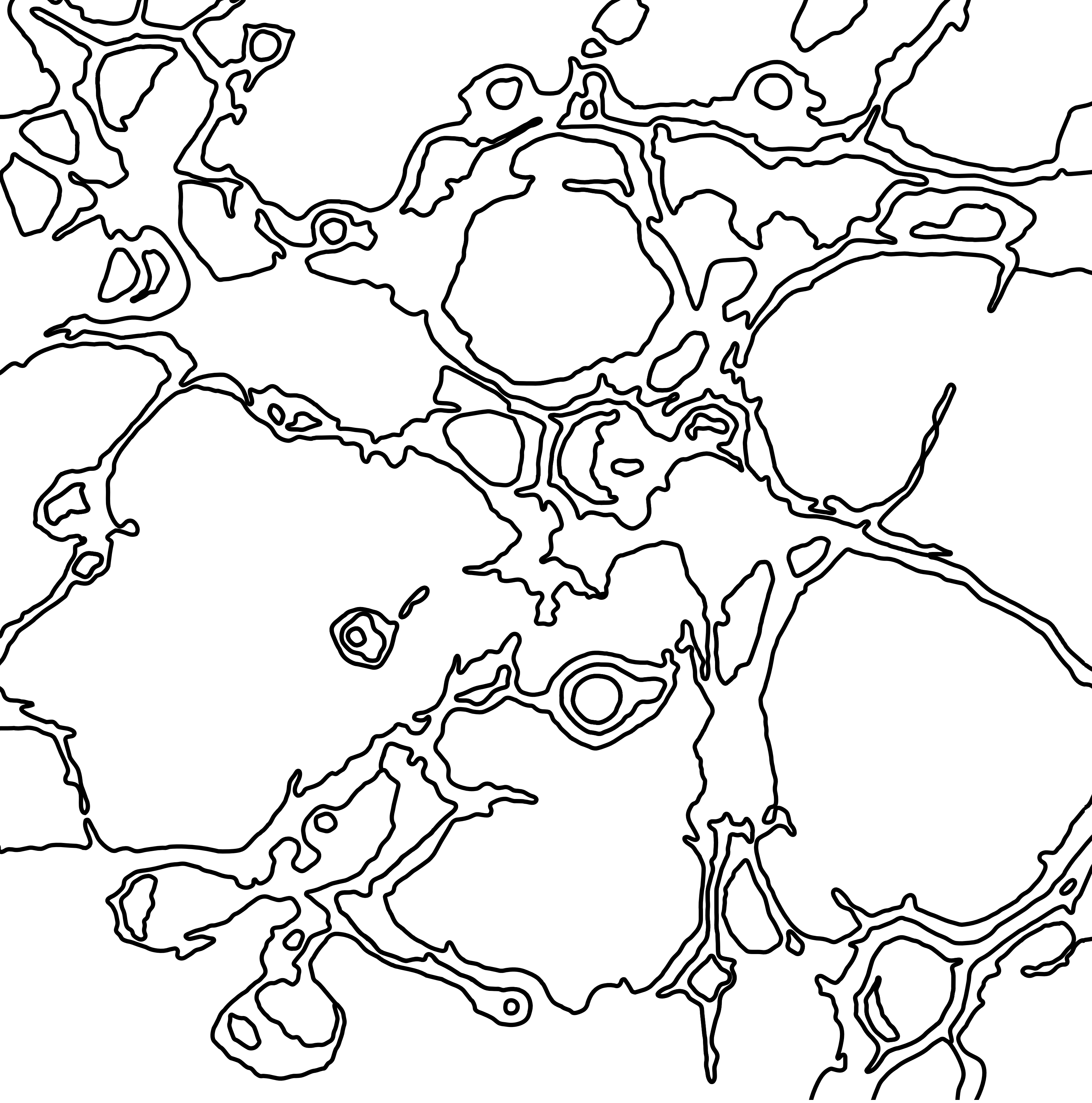
The recently developed Fractal Library allows our team to dive deeper into exploring the diverse capabilities of the Fractal Software. The design parameters for Relaxing Floors limited us to relatively simple geometric shapes based on squares, circles, and lines. For the Fractal Library, the deisgners were able to think out of the box and create refined patterns for broader applications.

The Fractals Research team refined the Fractal Software with feedback of the 13&9 Design team to maximize its flexibility. The extended functionality included the ability to use any vector file as the seed. This was inspired by the rich variety of patterns found in nature, architecture, and art, especially the intricate gestures within Jackson Pollock’s paintings. The new generation of seeds ranges from bird traces, leaves and brush strokes to rectangular formations. Powered by the capabilities of the Fractal Software, simple patterns could be readily refined to become perfect seeds.

The patterns in the Fractal Library evolved through a trial-and-error process. In the initial exploratory phase of development, the 13&9 Design team generated a vast variety of patterns by exploring how a range of seeds looked when combined with different types of fractal growth. The most aesthetically pleasing patterns from the design perspective were selected and then adapted based on single, double or multiple repetition. All of the optimized patterns were then analyzed by the Fractals Research team to confirm their fractal quality and D-Value.

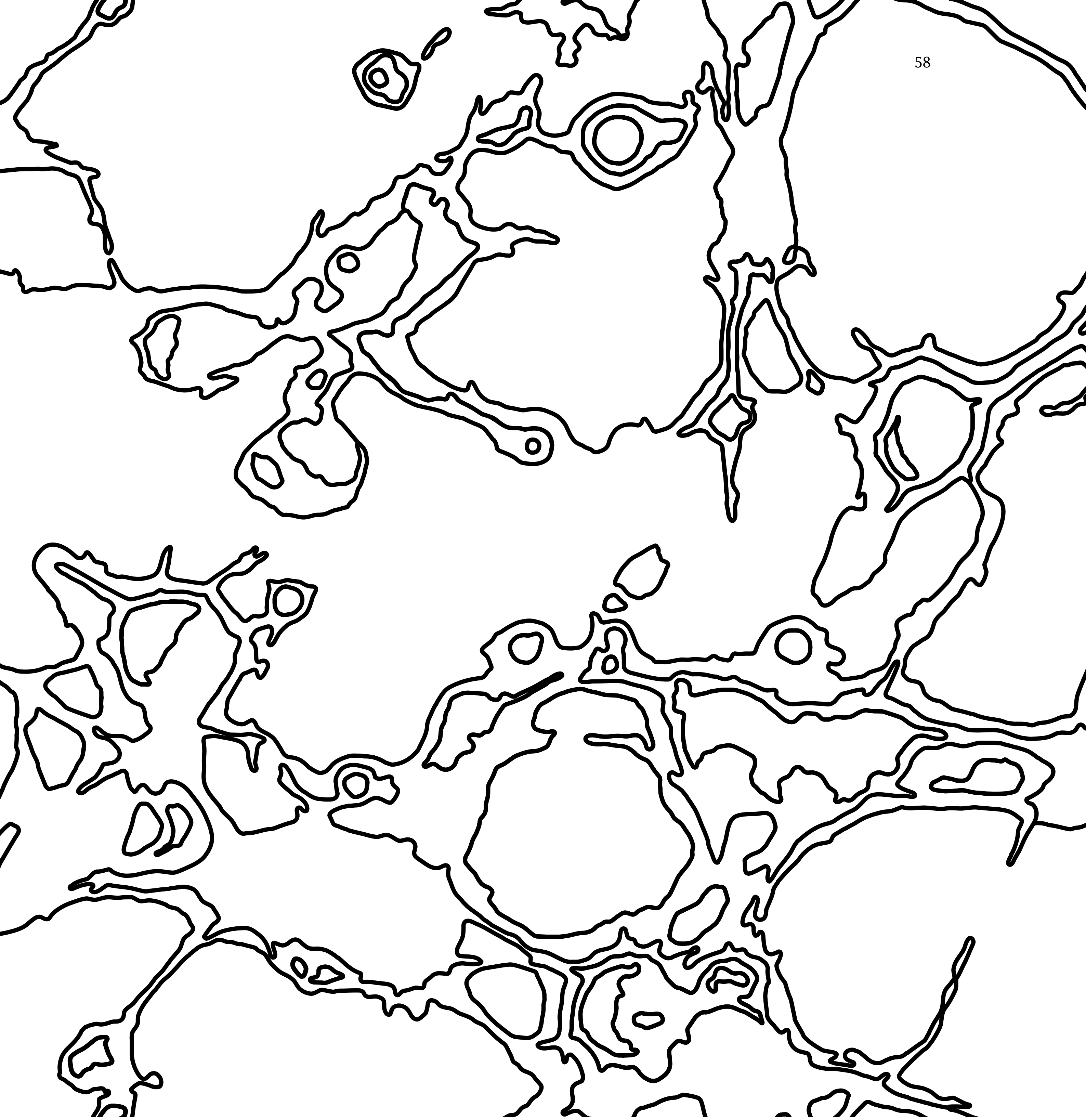
The Fractal Library serves as a versatile resource for Designers and Architects to customize a pattern in collaboration with the ScienceDesignLab. Different colors, textures, and applications (printing, milling, carving, weaving, etc.) can be selected for each of the basic patterns, leading to almost endless possibilities for stress-reduction surfaces such as carpets, walls, windows, and facades.

The following patterns are just some examples from the Fractal Library. For more detailed information visit www.13and9design.com or contact info@13and9design.com.



restD

Pattern Repeat D value - 1.63



LINES

Pattern Repeat D value - 1.47

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

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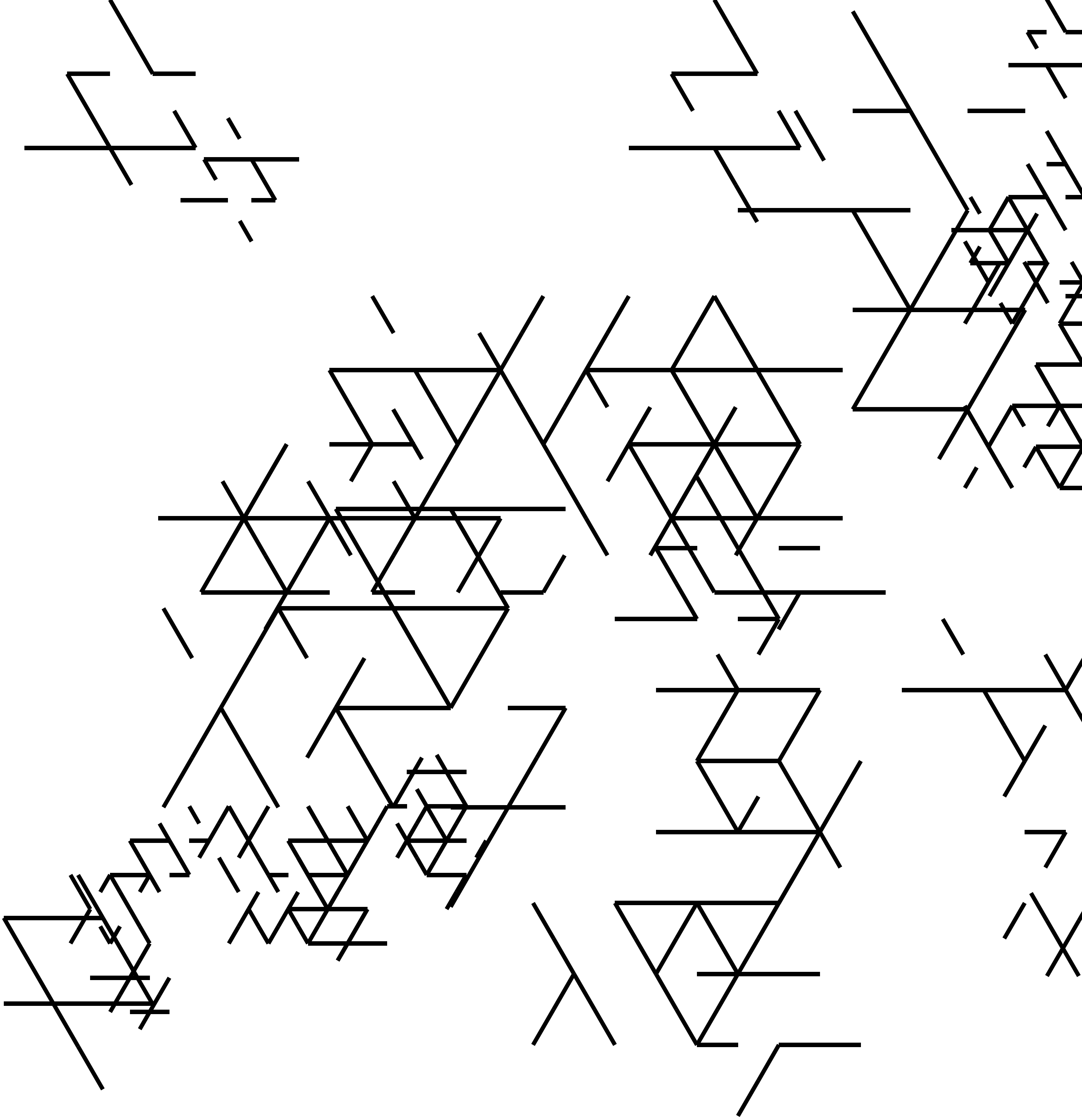
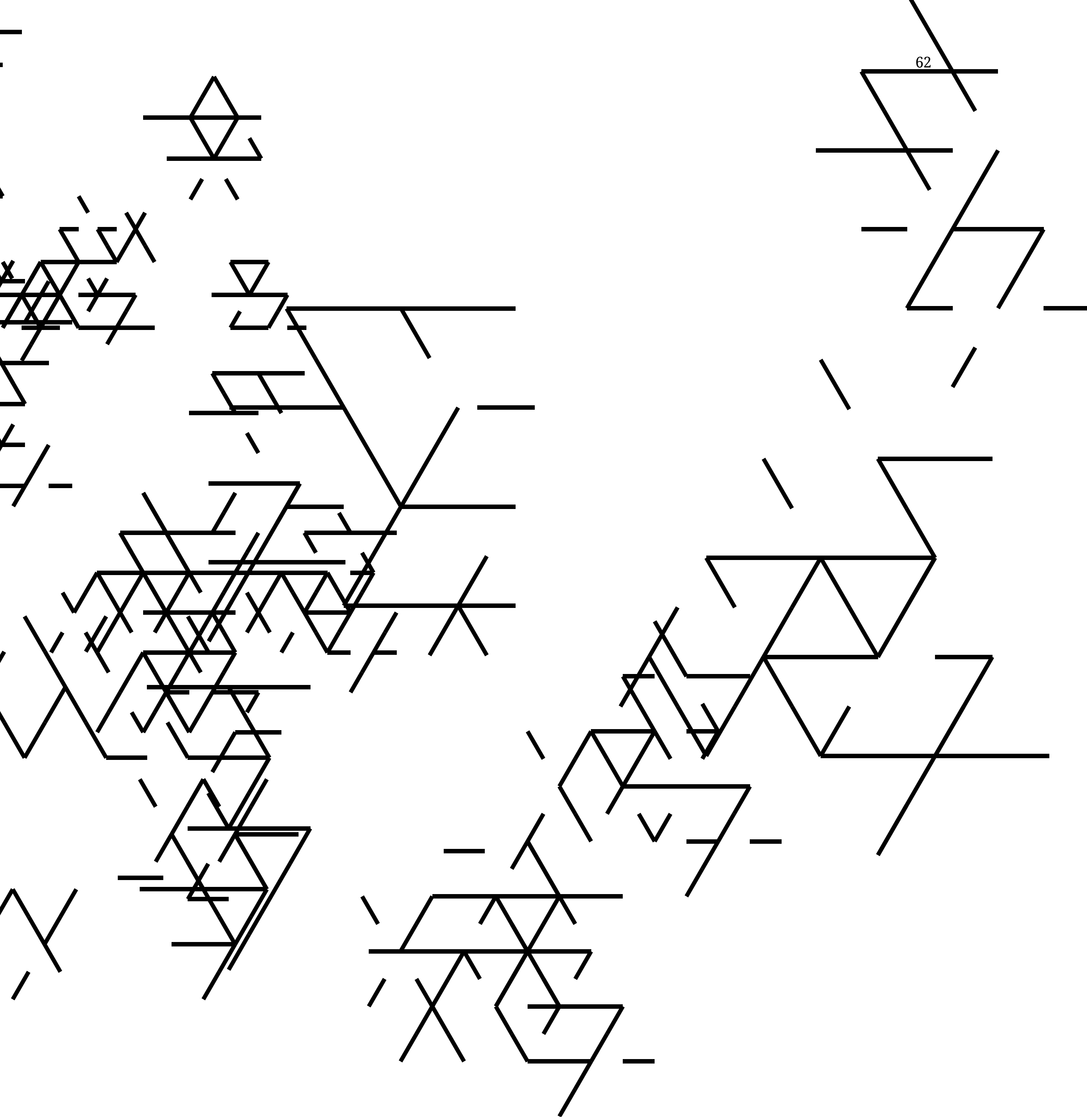
[redacted]

[redacted]



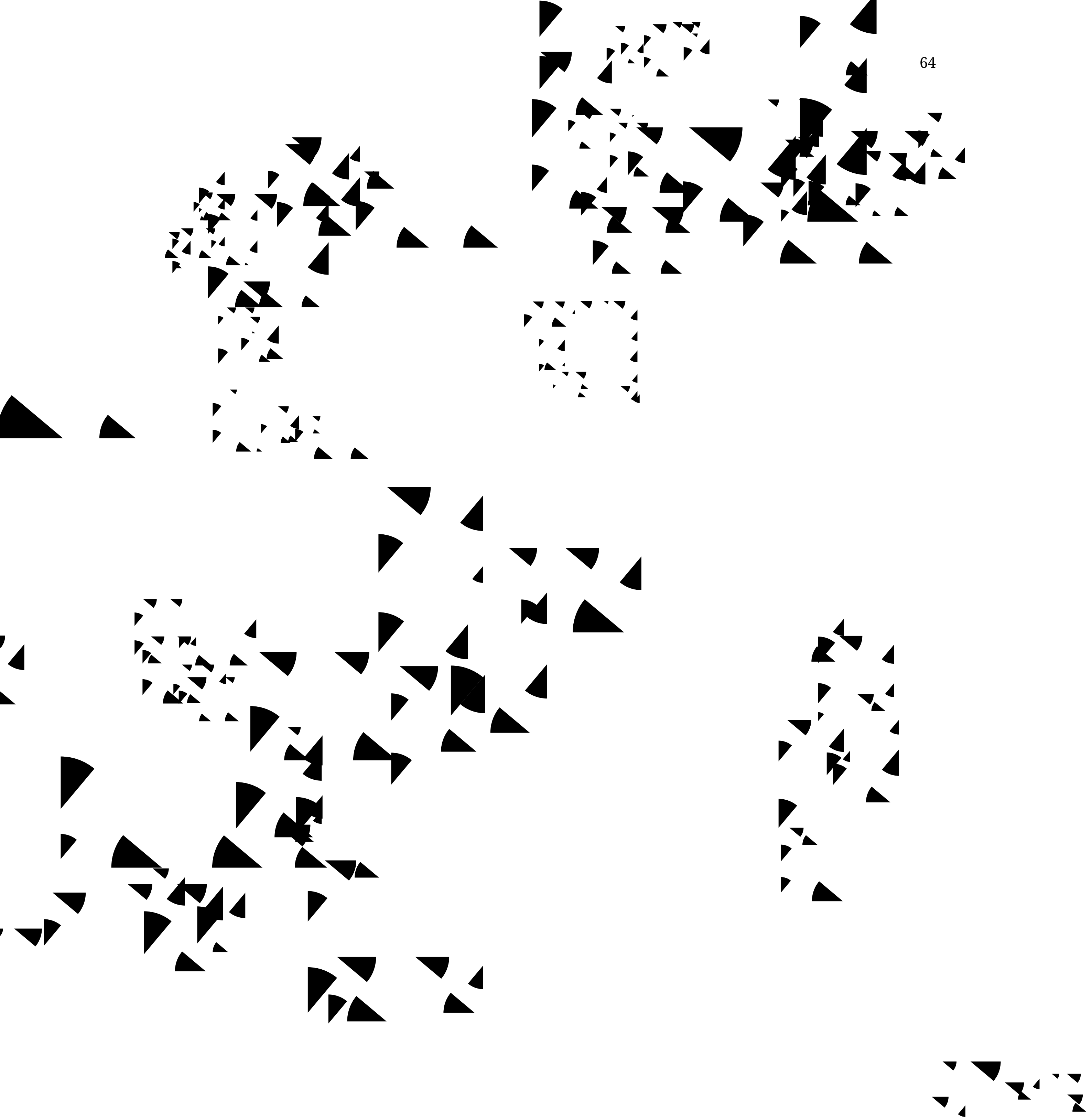
LINES DIAGONAL

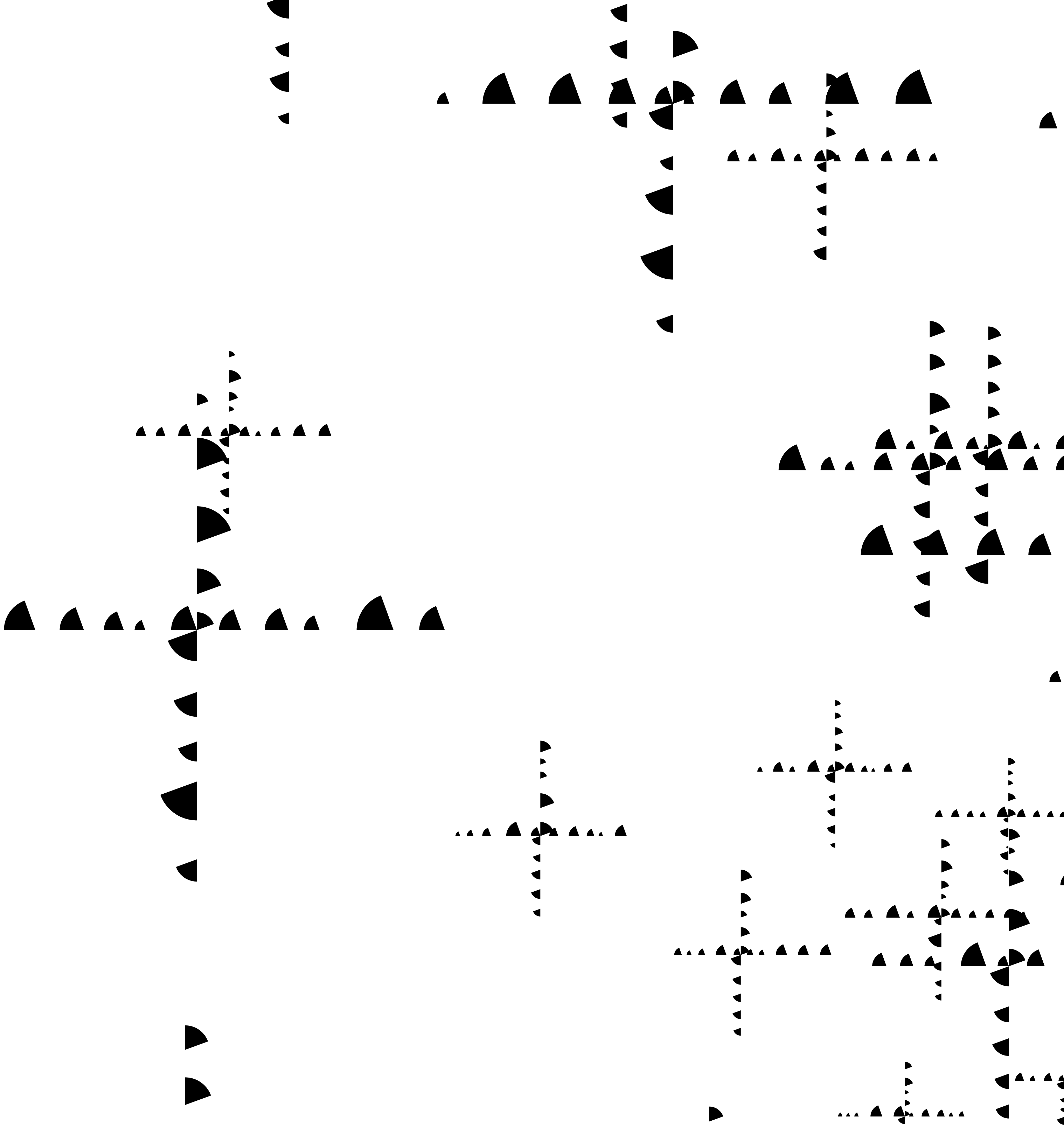
Pattern Repeat D value - 1.56



calmD

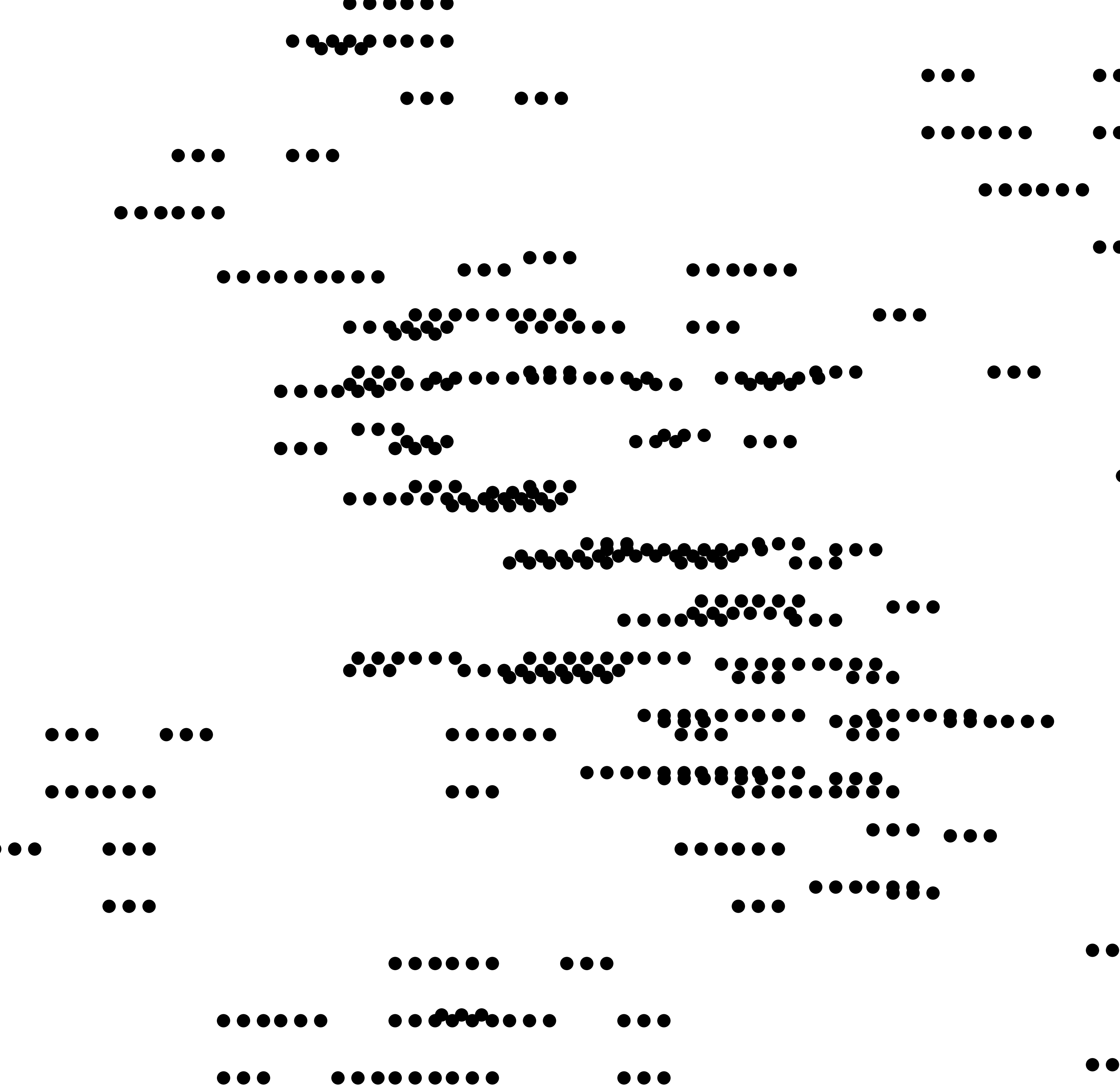
Pattern Repeat D value - 1.55





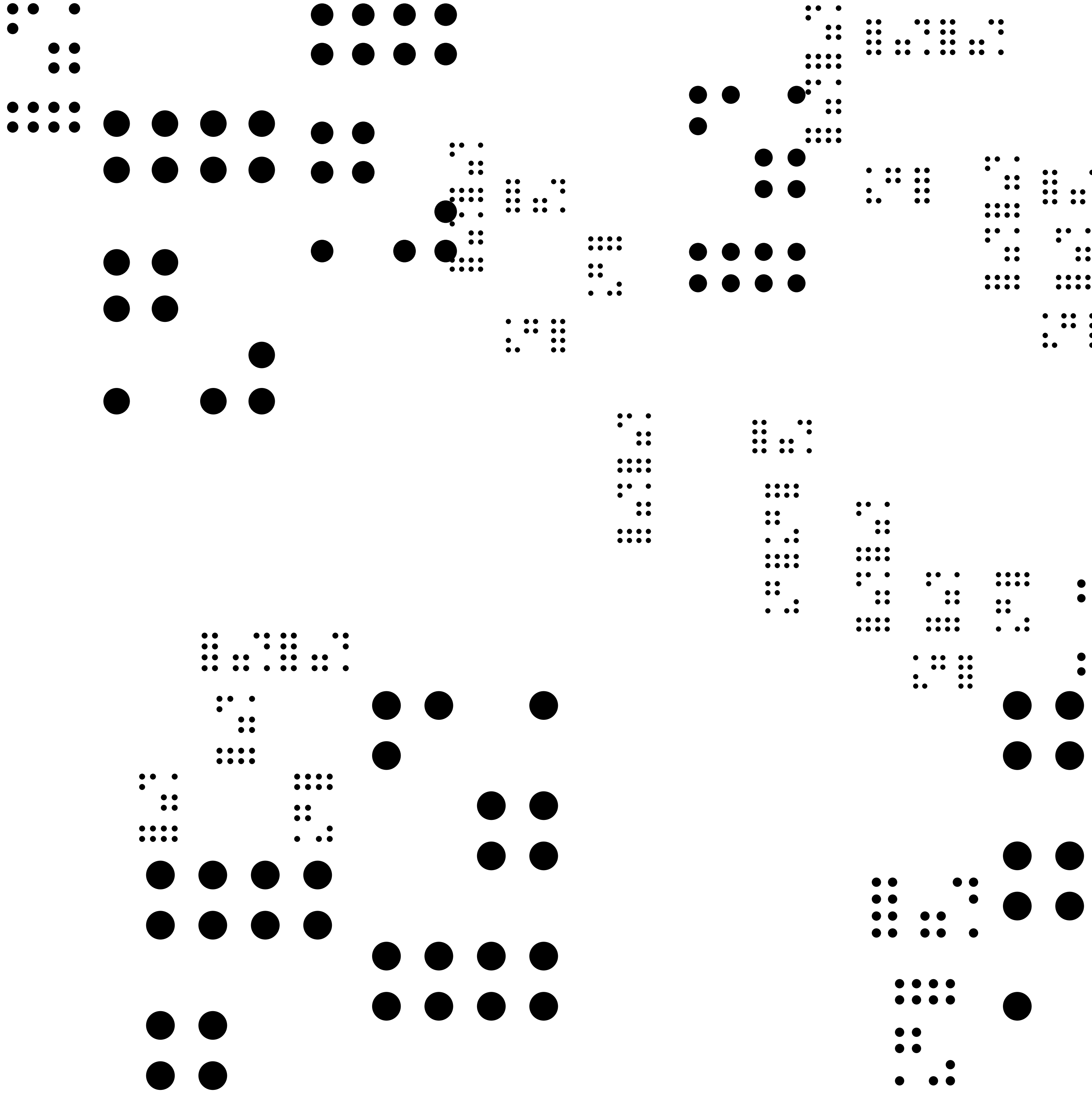
chillD

Pattern Repeat D value - 1.47



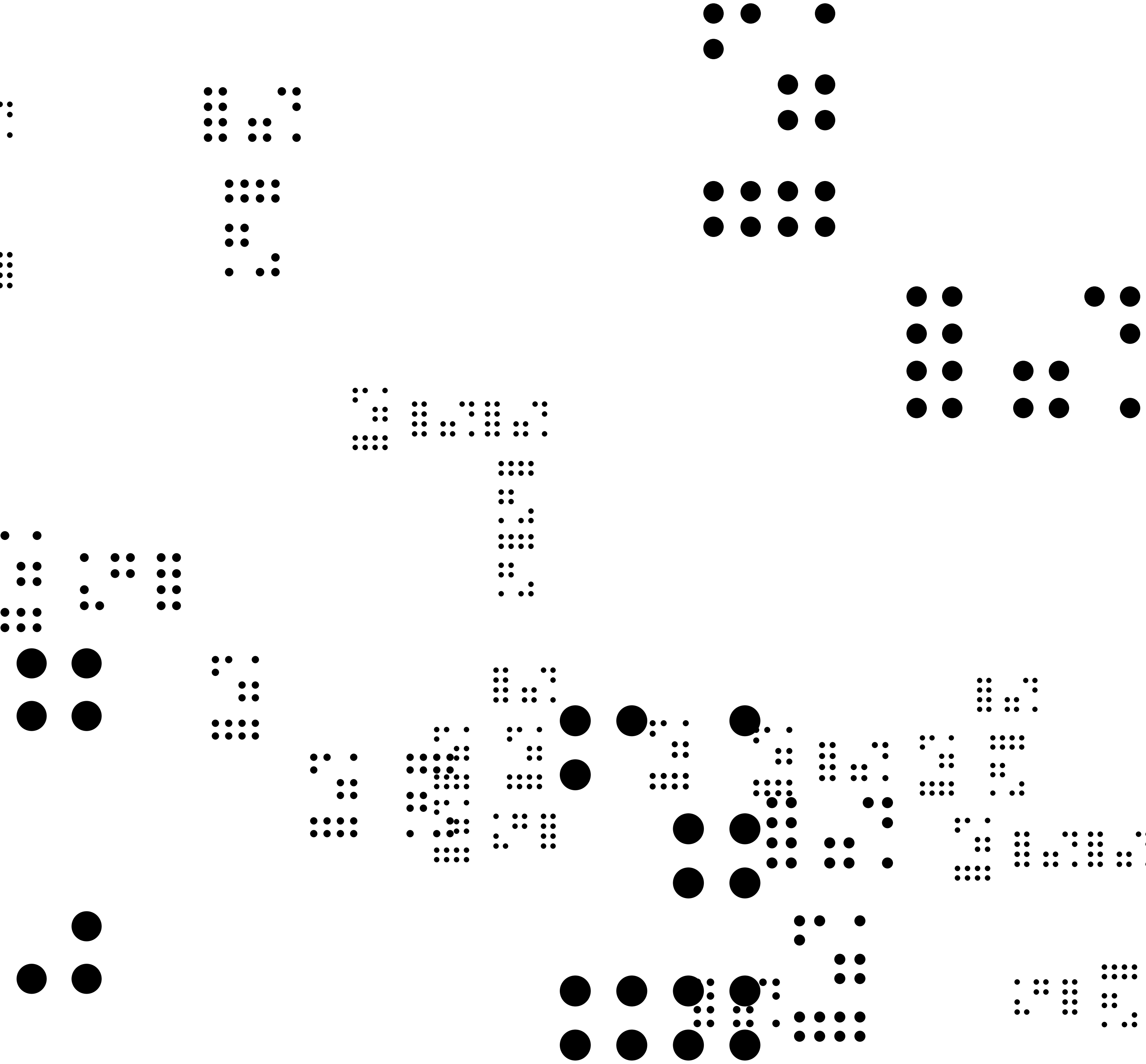
DOTS

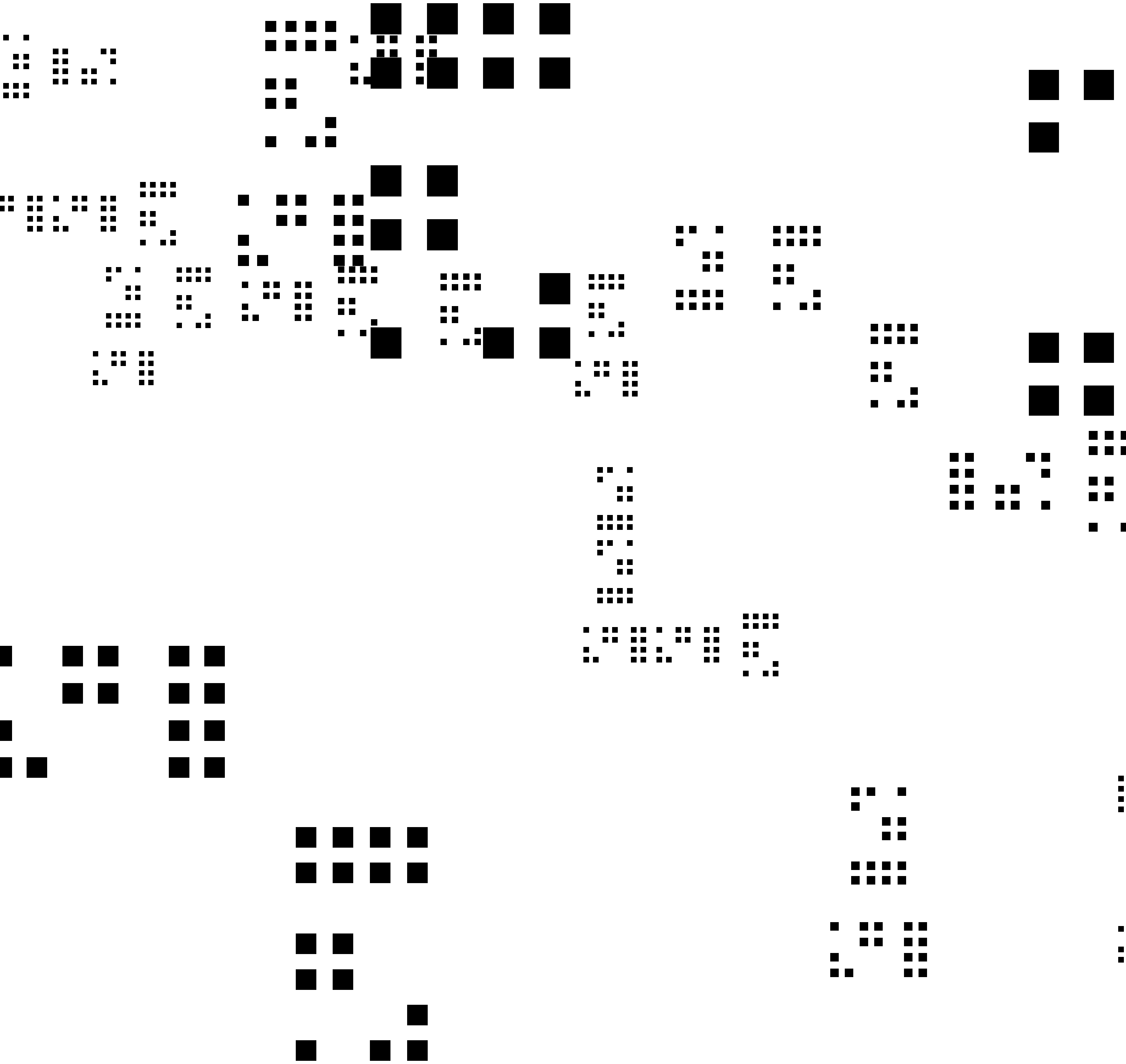
Pattern Repeat D value - 1.50



BINARY CIRCLES

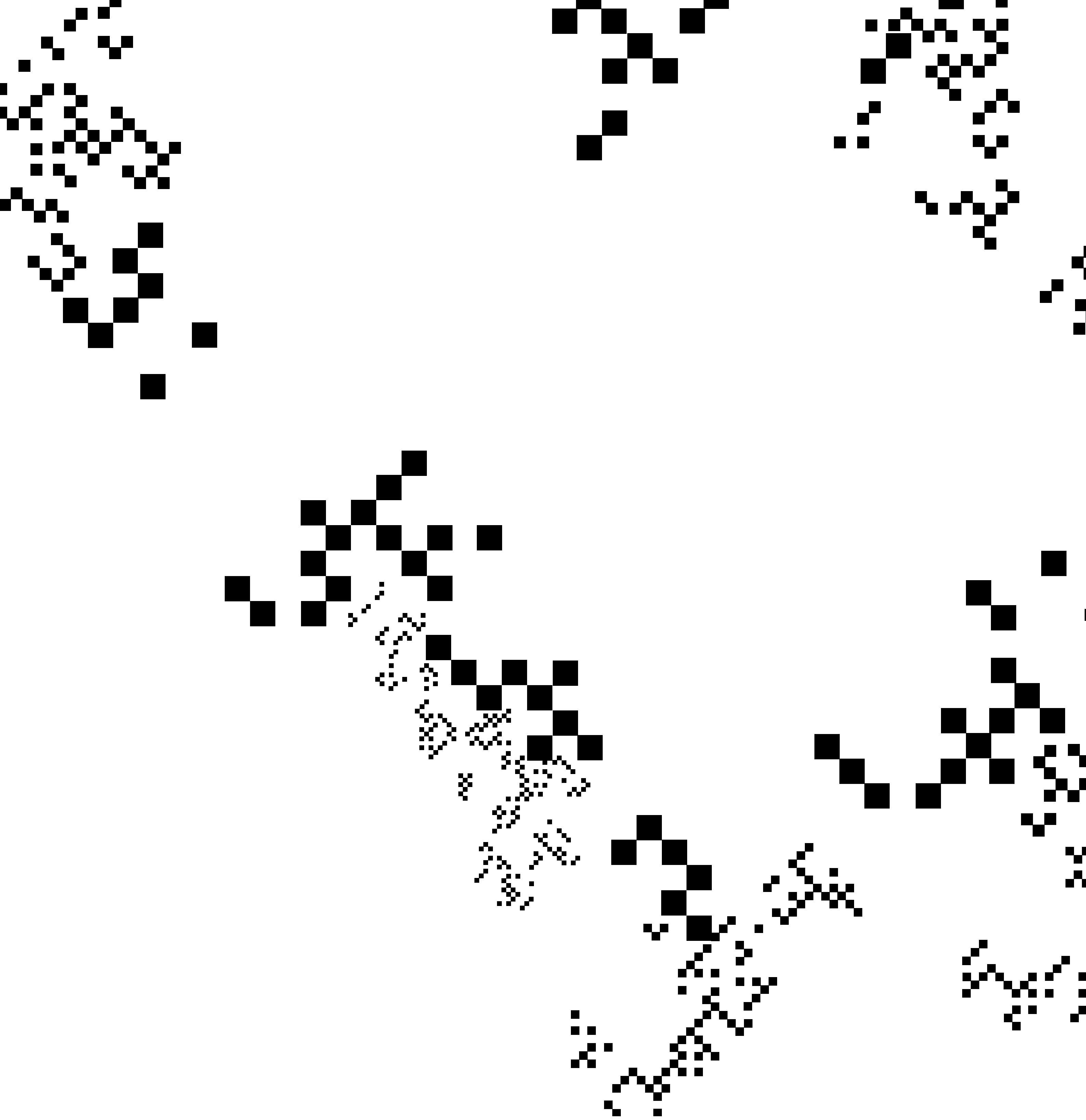
Pattern Repeat D value - 1.44





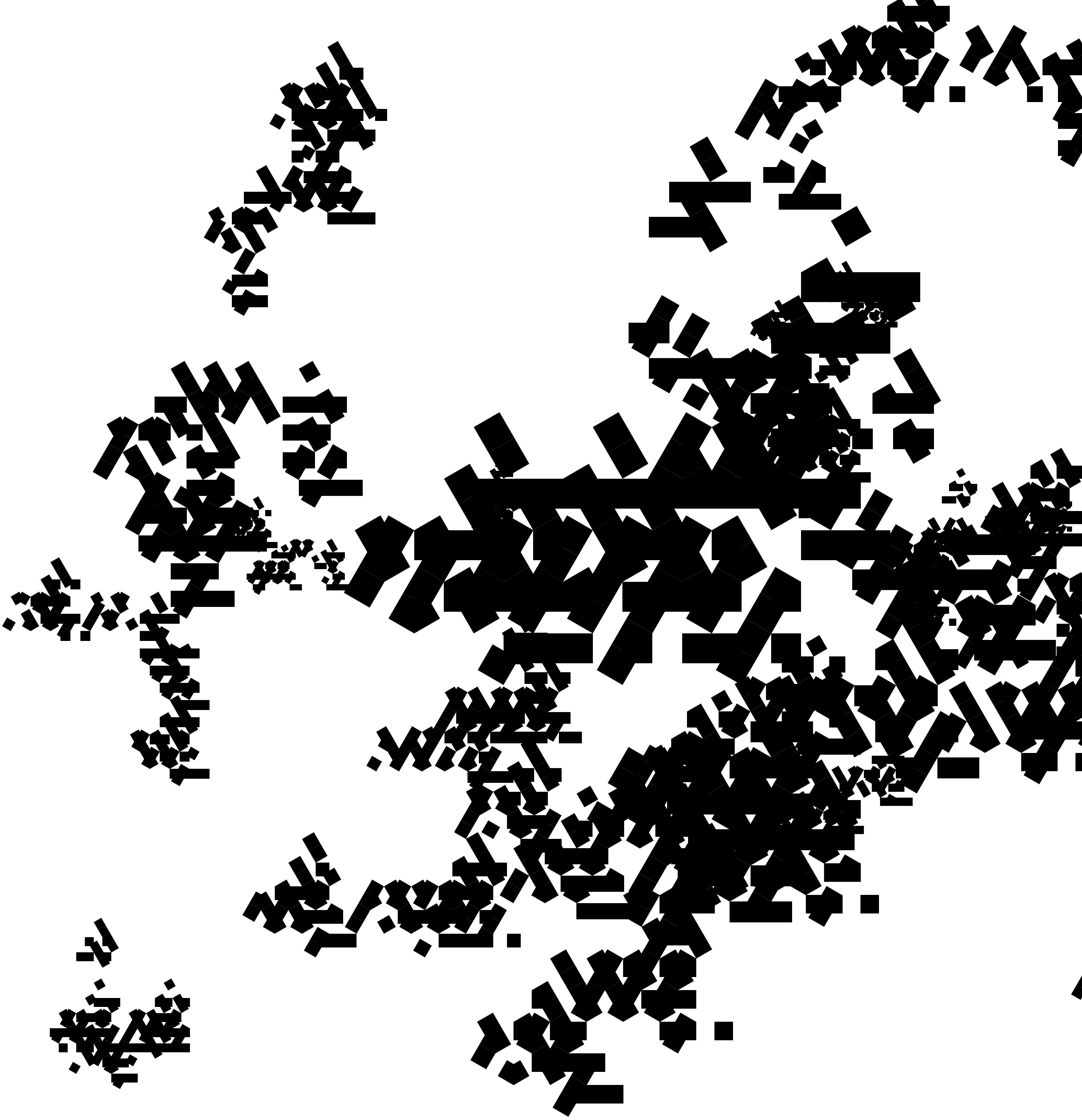
BINARY SQUARES

Pattern Repeat D value - 1.44



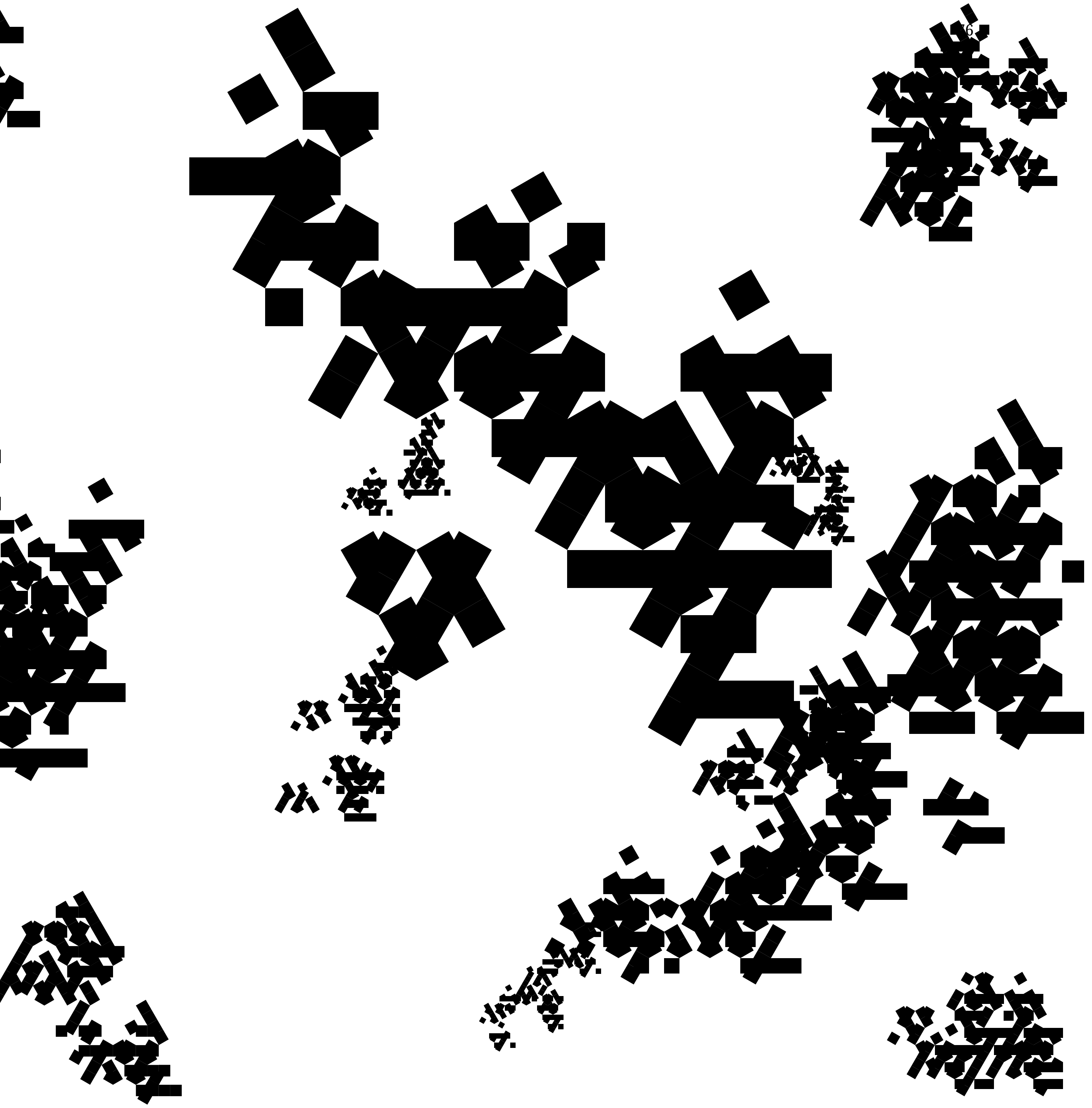
DIAMONDS

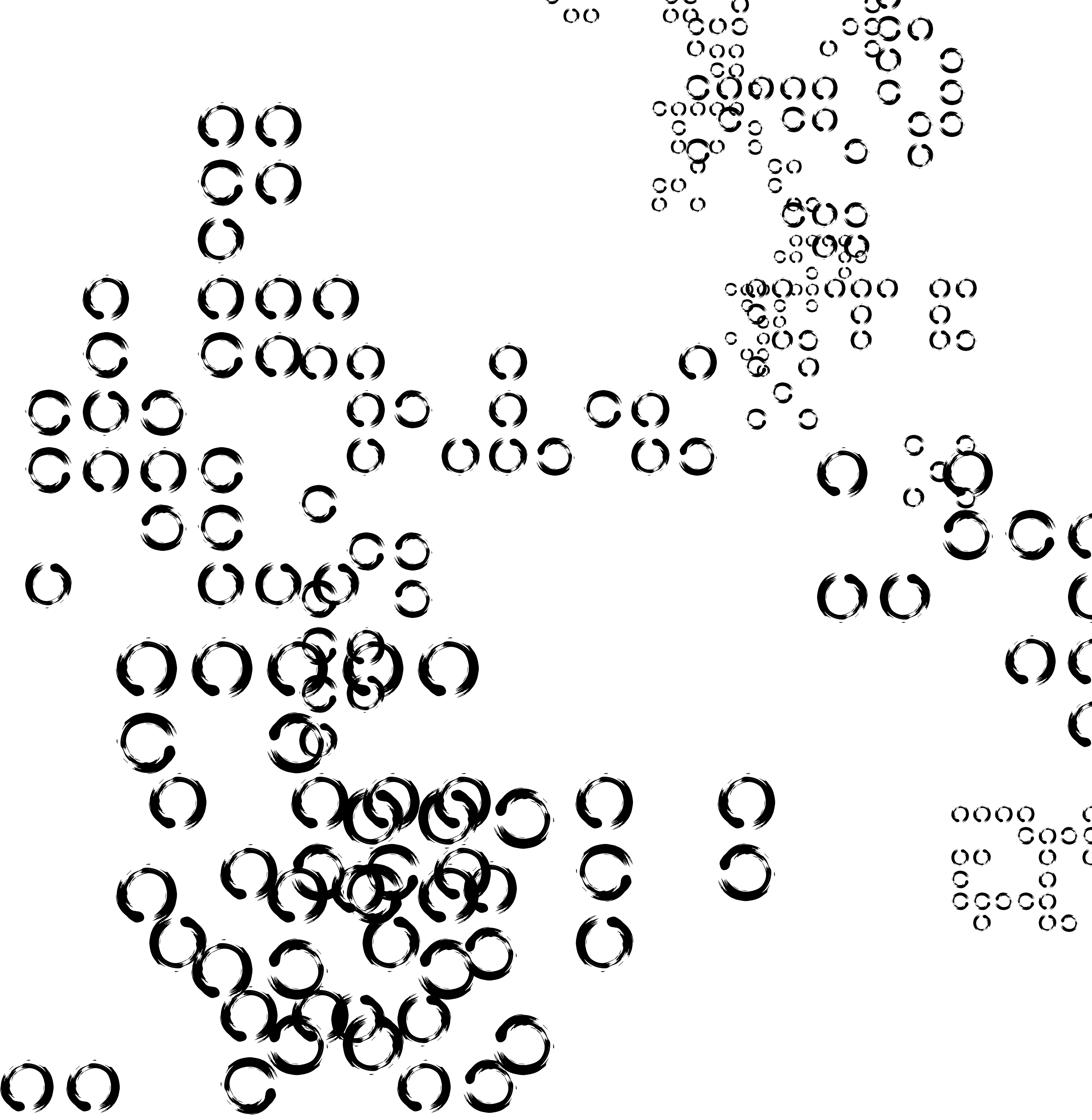
Pattern Repeat D value - 1.43



WEAVE

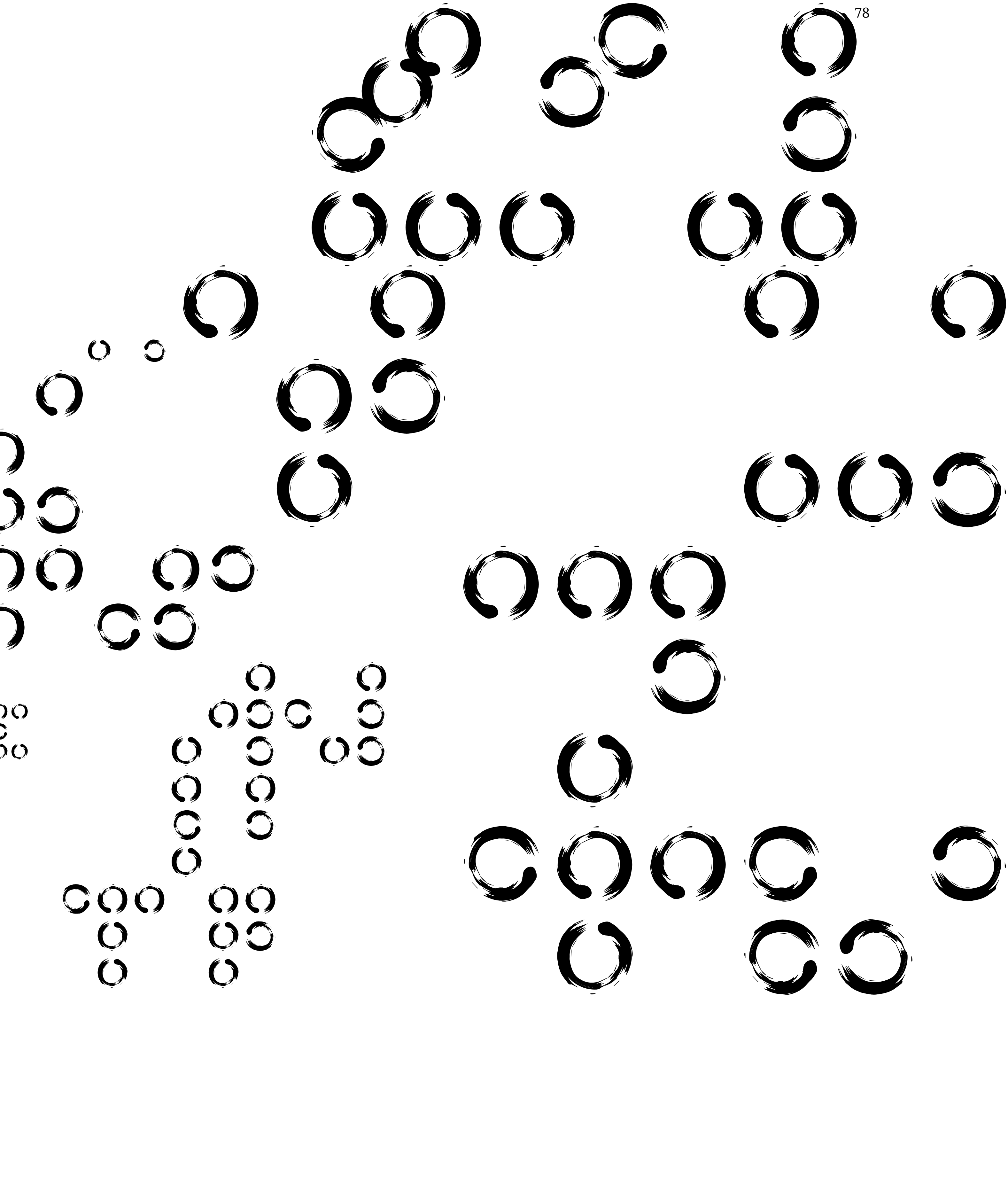
Pattern Repeat D value - 1.68





BRUSH STROKES DOTS

Pattern Repeat D value - 1.55

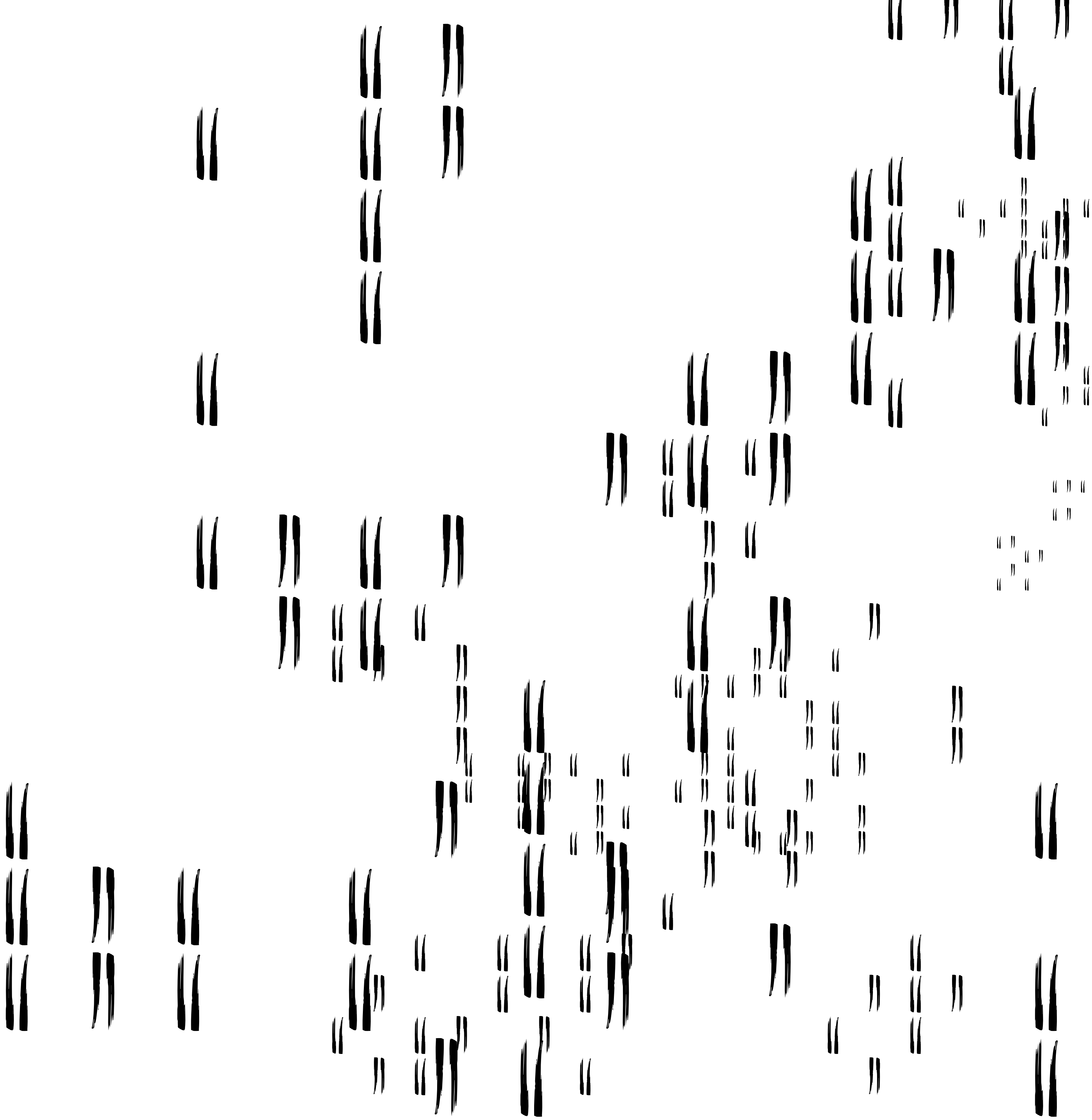


BRUSH STROKES TREE

Pattern Repeat D value - 1.71

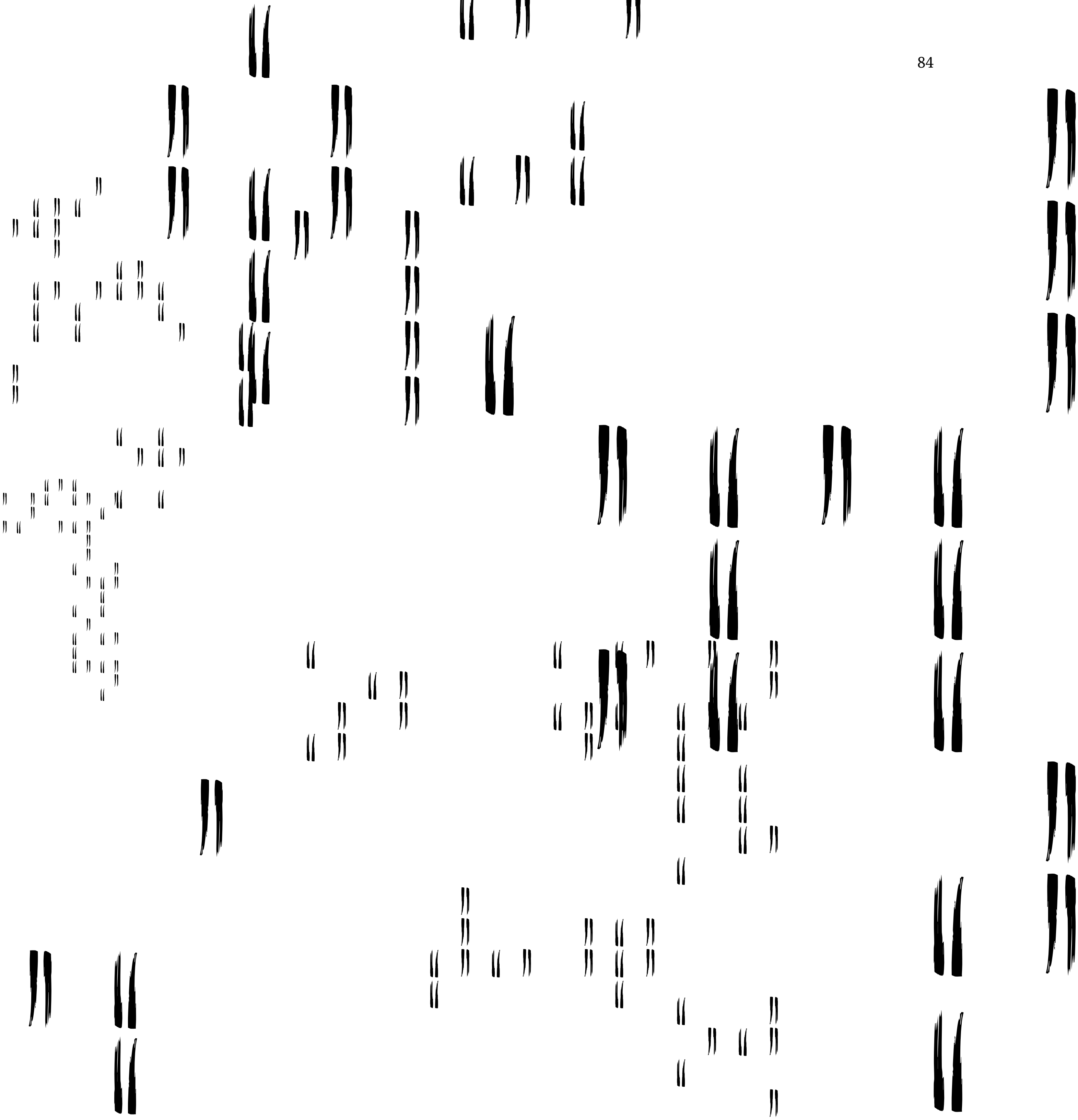
BRUSH STROKES CROSS

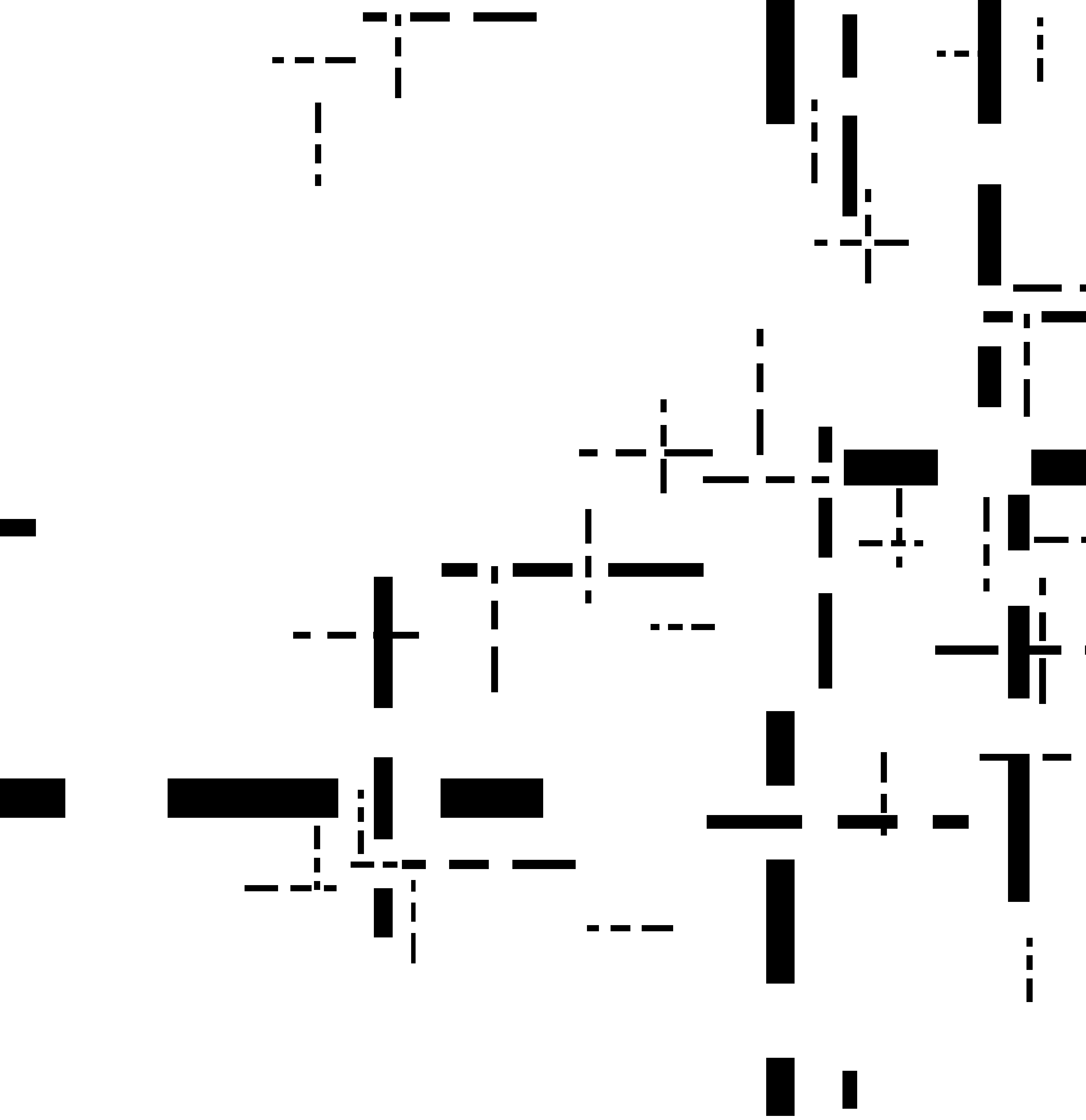
Pattern Repeat D value - 1.57



BRUSH STROKES VERTICAL

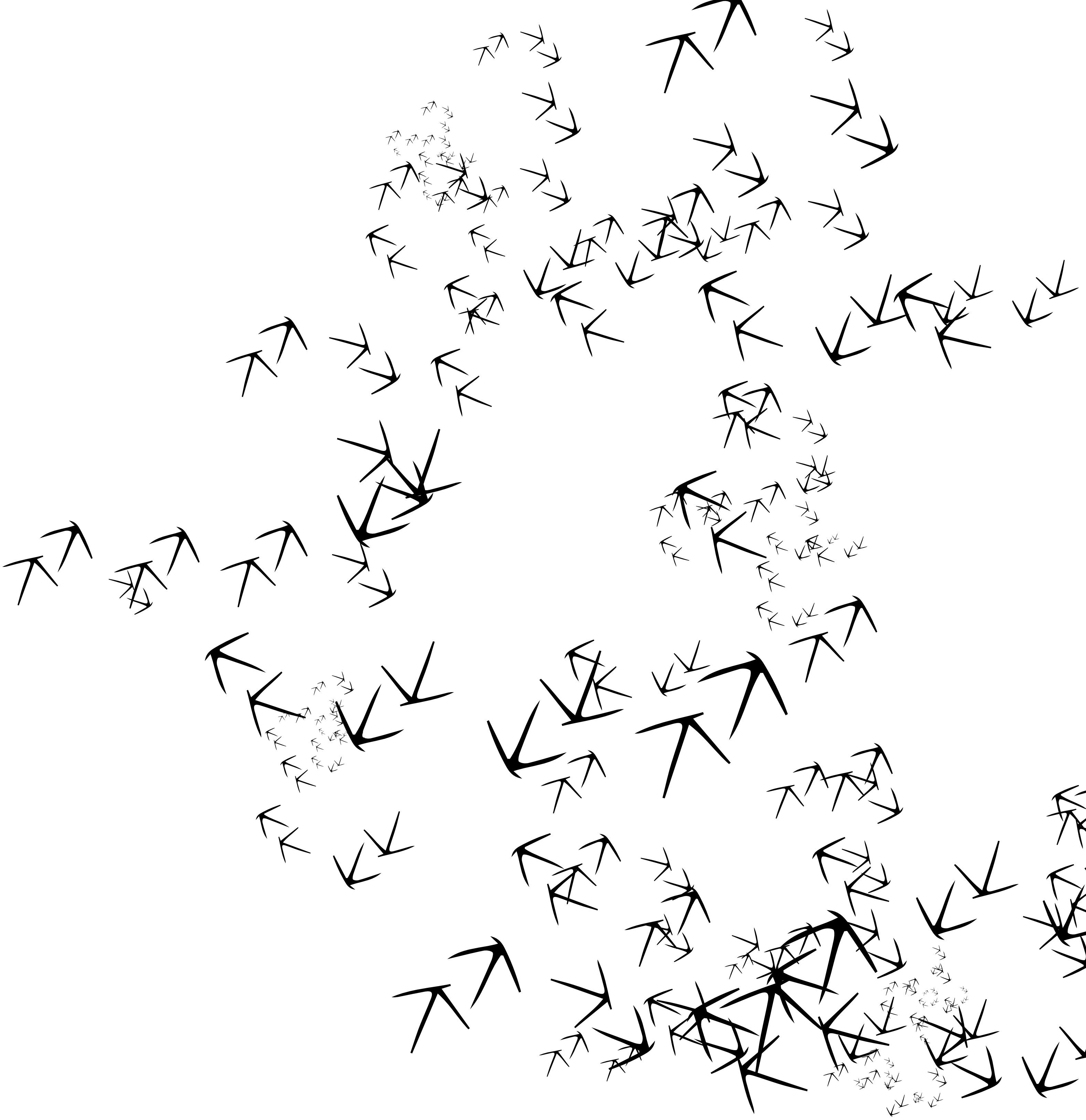
Pattern Repeat D value - 1.39





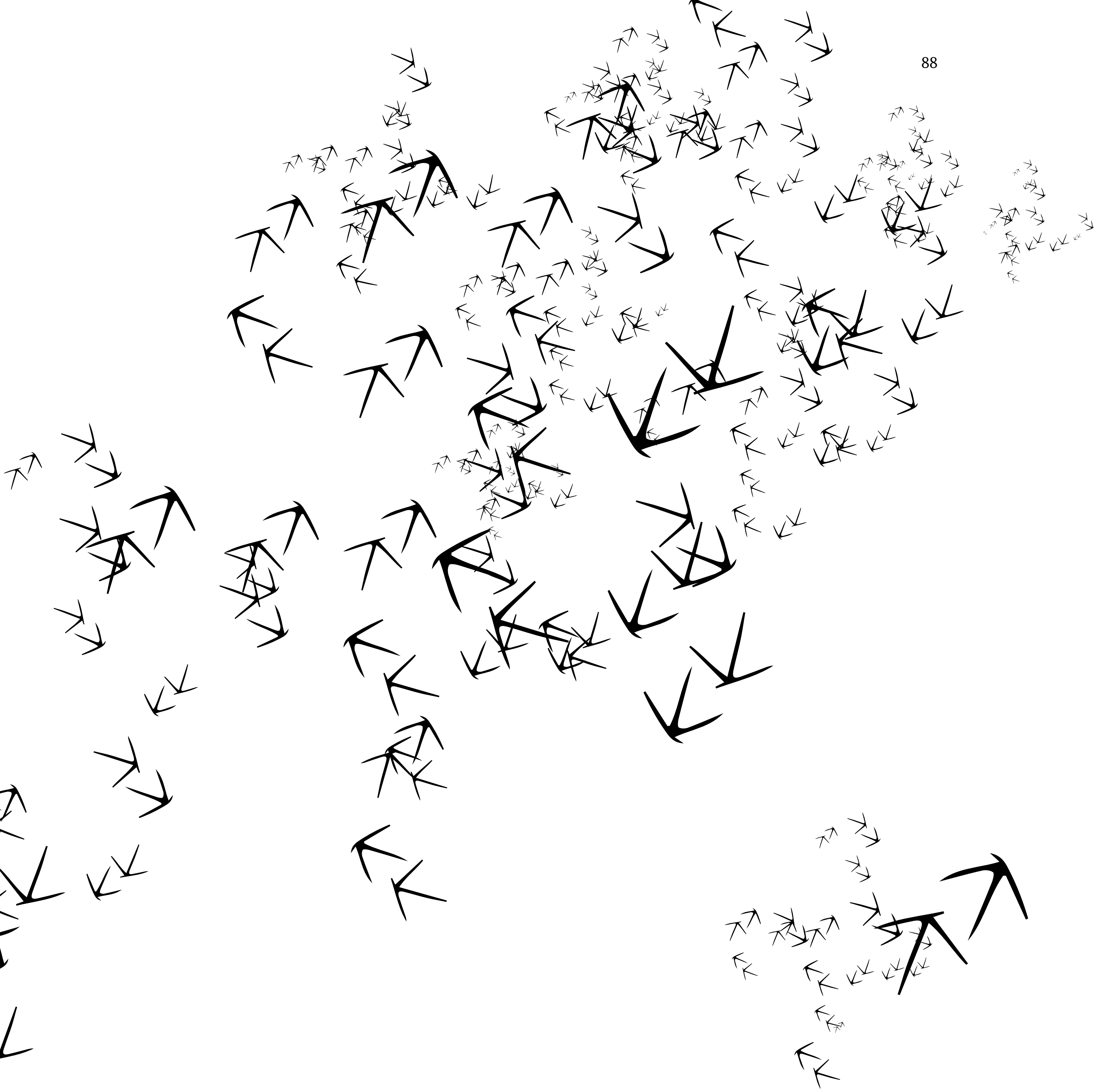
MATRIX

Pattern Repeat D value - 1.35



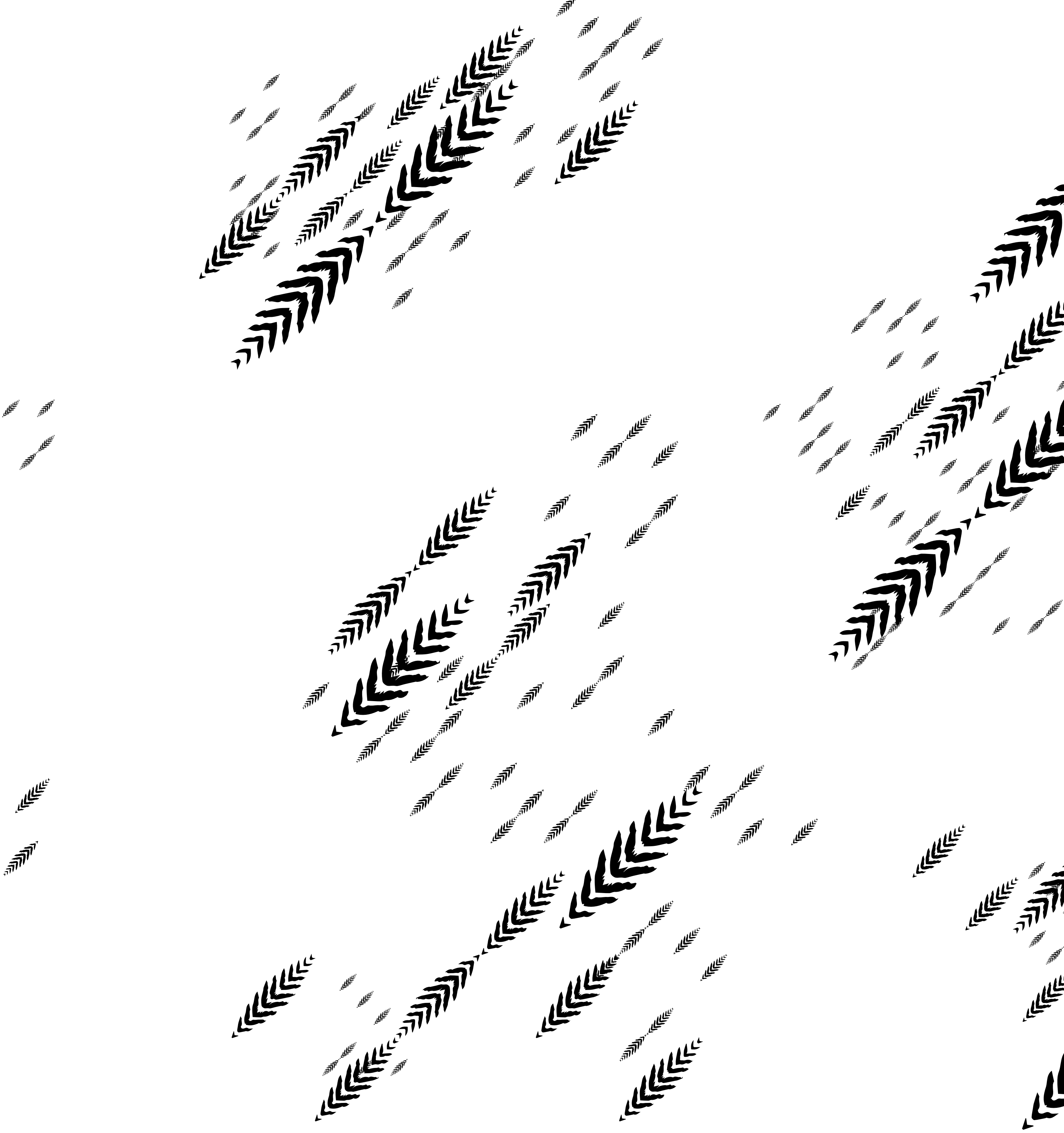
BIRD TRACES

Pattern Repeat D value - 1.51



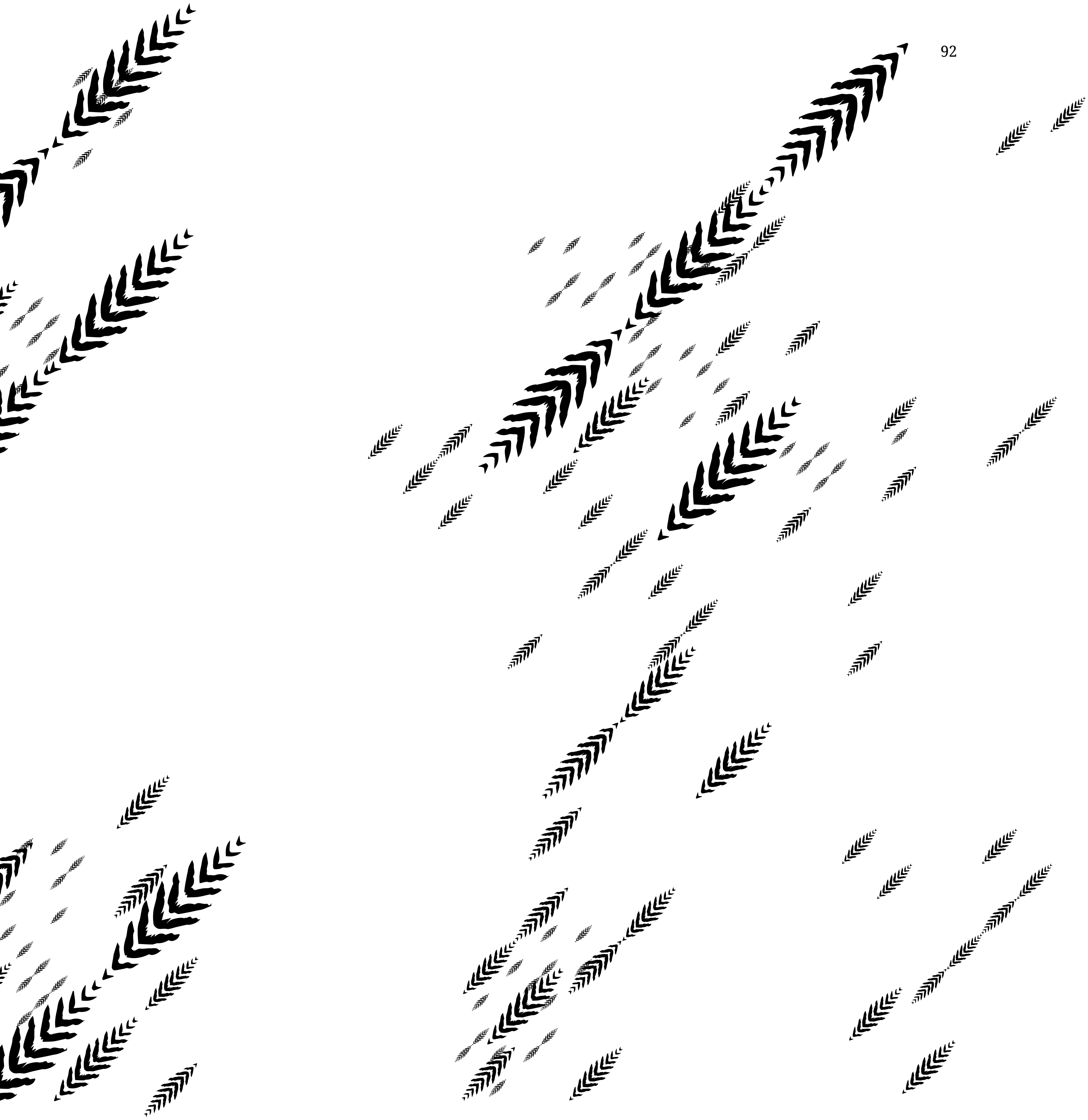
LEAVES

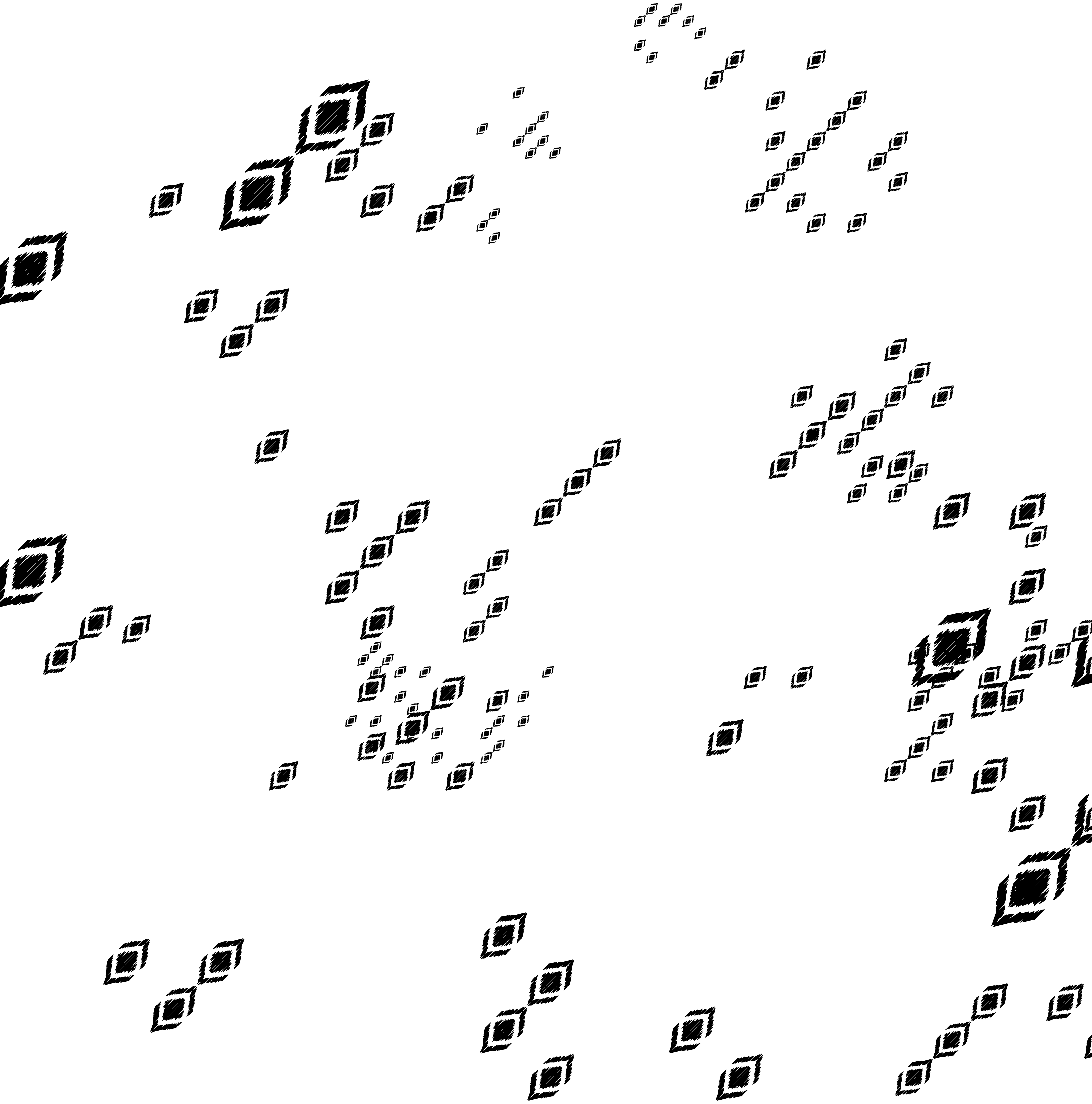
Pattern Repeat D value - 1.61



IKAT 01

Pattern Repeat D value - 1.45





IKAT 02

Pattern Repeat D value - 1.35

Figure 25. Fractals displayed on a screen.

CREATING SPACES THAT REDUCE STRESS

HOW TO INCORPORATE FRACTALS INTO THE BUILT ENVIRONMENT

Because practical applications will embed fractals within artificial environments, they will have to be adapted (bio-inspiration) rather than simply copied (biomimicry). When fractal images are projected into a room rather than displayed on monitors (Figure 25), the preferred D shifts to higher values (D ~ 1.6–1.7). The observer then sees the fractal surrounded by the blank surface of the wall. This introduction of Euclidean simplicity increases the tolerance for high fractal complexity. When sat in a room, the preferred D value will be higher than when the observer walks through a forest and is engulfed by other fractals. Experiments investigating the importance of matching city skylines to the backdrop of fractal mountains further emphasize the importance of viewing context on the preferred D value. Similarly, dynamic fractals are expected to have different preferred D values than static fractals. Examples of dynamic fractals include water ripples moving on a river, flickering flames, branches swaying in the breeze, and clouds moving across the sky. Artificial dynamic fractals are expected to maintain the viewer's attention longer than the static equivalents.

Figure 26. Fractal Room with Fractal Sounds for Mohawk Group's Waterways Project.

Building on the core principles of human-centered design, it is also important to acknowledge differences between individuals. Although the overall population prefers mid-D values when viewing fractals on a monitor, there are 3 sub-groups which exhibit distinct preferences. Whereas the majority's preference peaks at mid-D, just under 25 percent of observers are instead 'sharpies' (preferring high D) and a similar number are 'smoothies' (preferring low D). One recent study proposed that genetic factors might influence the fractal aesthetics of individuals. It has also been suggested that creative people might have a preference for higher D values. Some studies show that urban versus rural living along with aging can shape fractal preference, indicating that adaptation during our lifetimes might also be a factor.

During the transition from fundamental to applied research, the specifics of the individual spaces along with the needs of the individuals who occupy them will be crucial. Nevertheless, the basic requirements look favorable for applications. The amount of fractal repetition required to trigger the positive effects can easily be achieved. Set by typical magnification ranges of nature's fractals, the largest pattern needs to be just a factor of twenty-five larger than the smallest. Furthermore, participants typically took less than a few seconds to rate aesthetics (and much of this time was spent recording their judgment). Consistent with automatic processes, long exposure times are not necessary.

The fractal patterns described here are increasingly referred to as biophilic fractals because they are likely responsible for biophilia's well-known effects, including the reductions in mental fatigue and stress observed in the pioneering psychology experiments that examined exposure to nature. Taylor's own research has demonstrated significant increases in detection sensitivity, attention, visual performance (e.g., pattern recognition and navigation), aesthetic appeal. and stress reduction. Conversely, the lack of fractal aesthetics in unnatural (man-made) environments puts a strain on the visual system, inducing negative responses such as headaches.

INTRODUCING THE MOHAWK GROUP‘S RELAXING FLOORS

This collection is the culmination of art, science, and human-centered design based on fractal patterns. Relaxing Floors utilizes fractals to tap into our innate affinity for nature and activate our bodies’ stress-relieving response to similar patterns.

Much of our world is digitized and urban. People cannot simply disconnect or remove themselves completely. But there are strategies to help counter the continuous exposure to technology and the many physical and psychological challenges it imposes.

The Relaxing Floors collection shows respect for nature and an understanding that it can be our partner. The designs are informed by the natural world and adapted for the interior environment. As a result, the flooring fulfills the deep-seated preferences that humans have developed over millions of years, such as our response to fractals.

The creators of Relaxing Floors work holistically, seeking to create environments that balance people-place-technology. The designs that they create are helping to navigate the complexity of our modern world.

In the Relaxing Floors collection, designers have a choice of several designs all arranged in a fractal pattern. These patterns are available as carpet tiles, which can be cut and arranged randomly where the seam is hardly recognizable. Even randomized, these carpets maintain their fractal quality.

“As we’ve worked on our collaboration, we’ve really learned a lot about the reason why people respond to different patterns in their surroundings.

Understanding the science behind the design is part of our commitment to create spaces for decompressing and getting away from that overload of technology that we’re living with every day.”

Jackie Dettmar

mellowD

mellowD is one of two styles within the 12”x 36” carpet plank collection that mimic eye movements that occur as observed in a natural landscape. Style mellowD utilizes a line-shaped seed which repeats at different magnifications.

chillD

The second style within the 12”x 36” carpet plank collection, chillD, incorporates patterns using a computerized growth process to design fractals that reduce stress, as discovered during scientific studies. The plank visual is grounded by triangular segment-shaped seeds.

restD

Neurons are the electrical wires of the human body. They carry the signals that allow us to see, feel, and move.
Through sophisticated imaging techniques, people can visualize these microscopic conductors. It is these images that form the basis for the Relaxing Floors restD plank style and a coordinating Connecting Neurons Definity broadloom style.
Under a microscope, these neurons look like miniature trees with fractal branches and glow red due to a fluorescent dye.
Starting from a high-resolution neuron image, the designers selected an area with a pleasing pattern, a balanced spread of neurons and good properties for a seamless pattern match. The neuron formations were then reduced to their outlines to create a literal visualization of the fractals that exist in our own bodies.

Figure 1. Fractals displayed on a monitor

RELAXING SCREENSAVERS

The fractal fluency model proposes that the 'soft' attention induced by nature's fractals differs substantially from the 'hard' attention required for unnatural tasks such as reading text. Soft attention restores depleted mental resources rather than exhausting them and is accompanied by stress reduction. Consequently, the restorative power of fractal patterns could reduce mental fatigue and refresh the ability to concentrate, and in doing so prevent occupational burn-out.

Because this 'effortless looking' requires only environmental exposure, fractals could be embedded into the visual background and they will still be effective. Accordingly, someone could be directing their hard attention towards text on a computer screen and the associated mental depletion will be countered by the restorative effects of fractals displayed in the background. Fractals, therefore, have the potential to serve as the ideal screensaver.

The stress induced by the pandemic is amplified through the many hours that people spend on remote calls - staring at electronic devices instead of nature's scenery. More than ever, fractal screensavers could have a dramatic, positive impact on society. As a humanitarian response to the pandemic, the ScienceDesignLab adapted the Relaxing Floors patterns into screensavers. The goal is to trigger subconscious relaxation mechanisms by displaying the fractal screensavers on a range of devices that people use when working.

Download the Relaxing Screensavers under:
https://info.mohawkgroup.com/newsletter-fractals

VISUAL CASE STUDIES

ARCHITECTURAL, INTERIOR, AND PRODUCT APPLICATIONS

Imagine a future in which designers immerse building occupants in synesthetic fractals — a “fractal atmosphere” of visual, sonic, thermal, and tactile experiences. This would induce a positive, emergent experience that humans subconsciously appreciate. Manufacturers, designers, and architects have the possibility of applying a fractal approach starting with the outside facade of a building through to the shapes of furniture and the way they are arranged in everyday work spaces. Occupants could walk into a room in which the fractal ceilings dampen the noise, the fractal window shades provide an optimal breeze, the fractal solar panels deliver efficient energy to the fractal lighting, and all of their patterns combine to create a stress-reducing visual environment analogous to the complex scenes of nature. In this way, fractal designs offer the potential to combine the power of aesthetics with other favorable functions.

Office furniture that incorporates fractal variations in surface heights is both visually appealing and allows for fractal qualities of human motion (Figure 27). This promotes an interactive space that encourages social and work collaborations while reducing physical strain on the body.

Figure 27. 360° LAB in Graz by INNOCAD architecture
MyWorld 360 is an innovation lab comprised of a series of integrative and flexible spaces meant to foster ingenuity and pioneering ideas.

Inspired by the prevalence of light patterns in nature, fractal window blinds (Figure 28) offer further possibilities for multi-functionality. The fractal pattern can be used to obscure an unattractive view, it can provide shade, and it can also cast a fractal shadow pattern across a room. For open windows, the shade can also generate a fractal breeze. In addition to the fractal variations in light, it can therefore provide analogous variations in heat and air currents for the room's occupants. The shades also offer the advantage of impacting the building's interior and exterior appearance simultaneously.

Most importantly, however, the shades can generate dynamic fractals, which are expected to maintain the observer's attention to a higher degree than their static equivalents. In this case, the shifting sun will move the fractal shadows across the room during the day and clouds will create extra variations on shorter time scales. This idea of projecting nature into rooms is central to the biophilia movement.

Figure 28. HOSPICE CARE UNIT AT STATE HOSPITAL in Deutschlandsberg by INNOCAD architecture has fractal window blinds at the hospital facade that create dynamic sun reflections in the room.

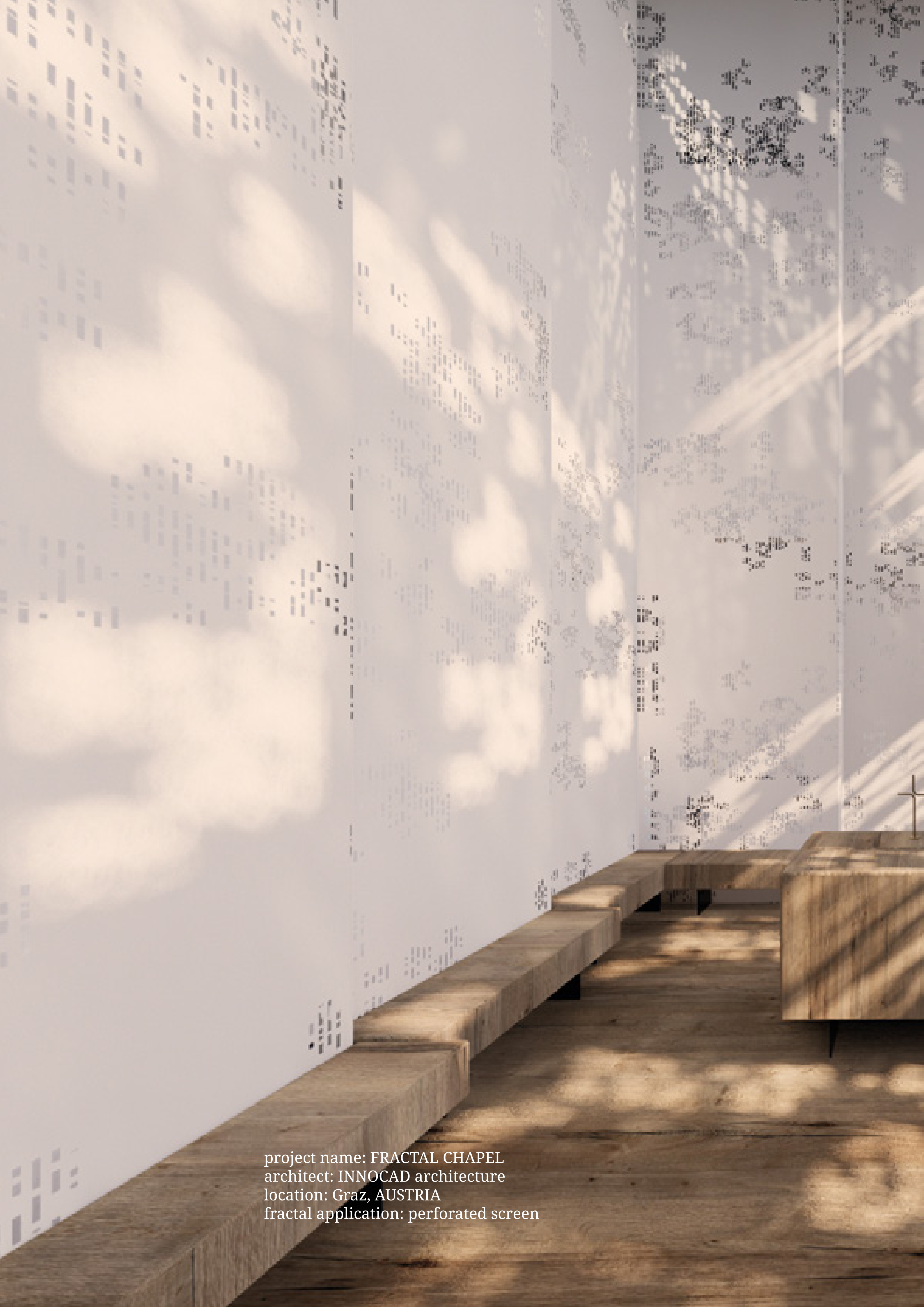
project name: WAG HEAD OFFICE AUSTRIA
architect: INNOCAD architecture
location: Linz, AUSTRIA
fractal application: flooring
Relaxing Floors by 13&9 Design in collaboration with Fractals Research for Mohawk Group

project name: THE ROCK
architect: INNOCAD architecture
location: Vienna, AUSTRIA
fractal application: flooring
Relaxing Floors by 13&9 Design in collaboration
with Fractals Research for Mohawk Group


221

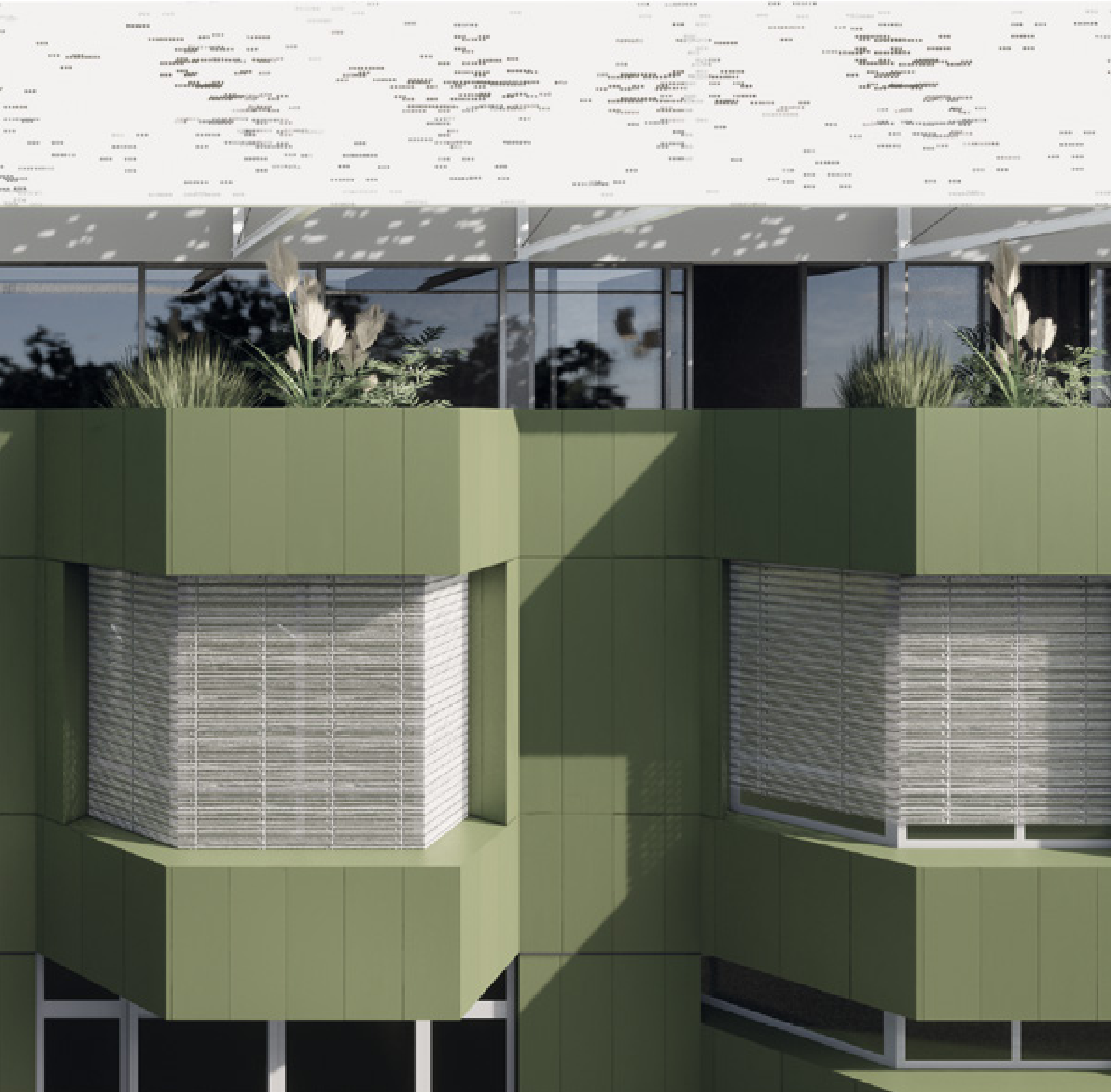
project name: CASA P
architect: INNOCAD architecture
location: Linz, AUSTRIA
fractal application: flooring
Relaxing Floors by by 13&9 Design in collaboration
with Fractals Research for Mohawk Group


project name: WAG HEAD OFFICE AUSTRIA
architect: INNOCAD architecture
location: Linz, AUSTRIA
fractal application: acoustic ceiling tiles
Calm Collection by 13&9 Design in collaboration
with Fractals Research for FACT Design



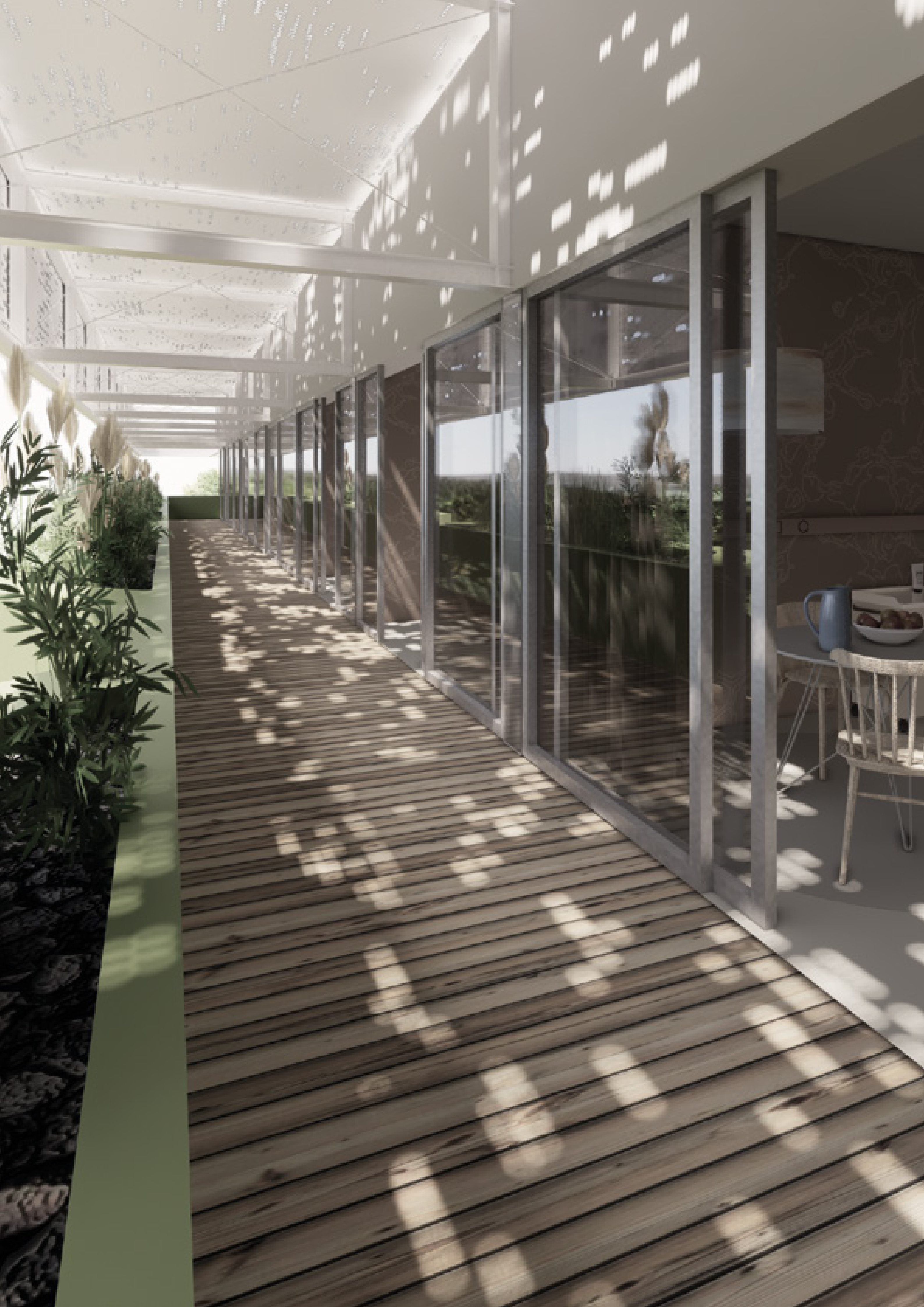
project name: FRACTAL CHAPEL
architect: INNOCAD architecture
location: Graz, AUSTRIA
fractal application: perforated screen

project name: HOSPICE CARE UNIT AT STATE HOSPITAL
architect: INNOCAD architecture
location: Deutschlandsberg, AUSTRIA
fractal application: window blinds



project name: HOSPICE CARE UNIT AT STATE HOSPITAL
architect: INNOCAD architecture
location: Deutschlandsberg, AUSTRIA
fractal application: wallpaper print / curtains

project name: SUPERNOVA HEADQUARTERS
architect: INNOCAD architecture
location: Graz, AUSTRIA
fractal application: glass film



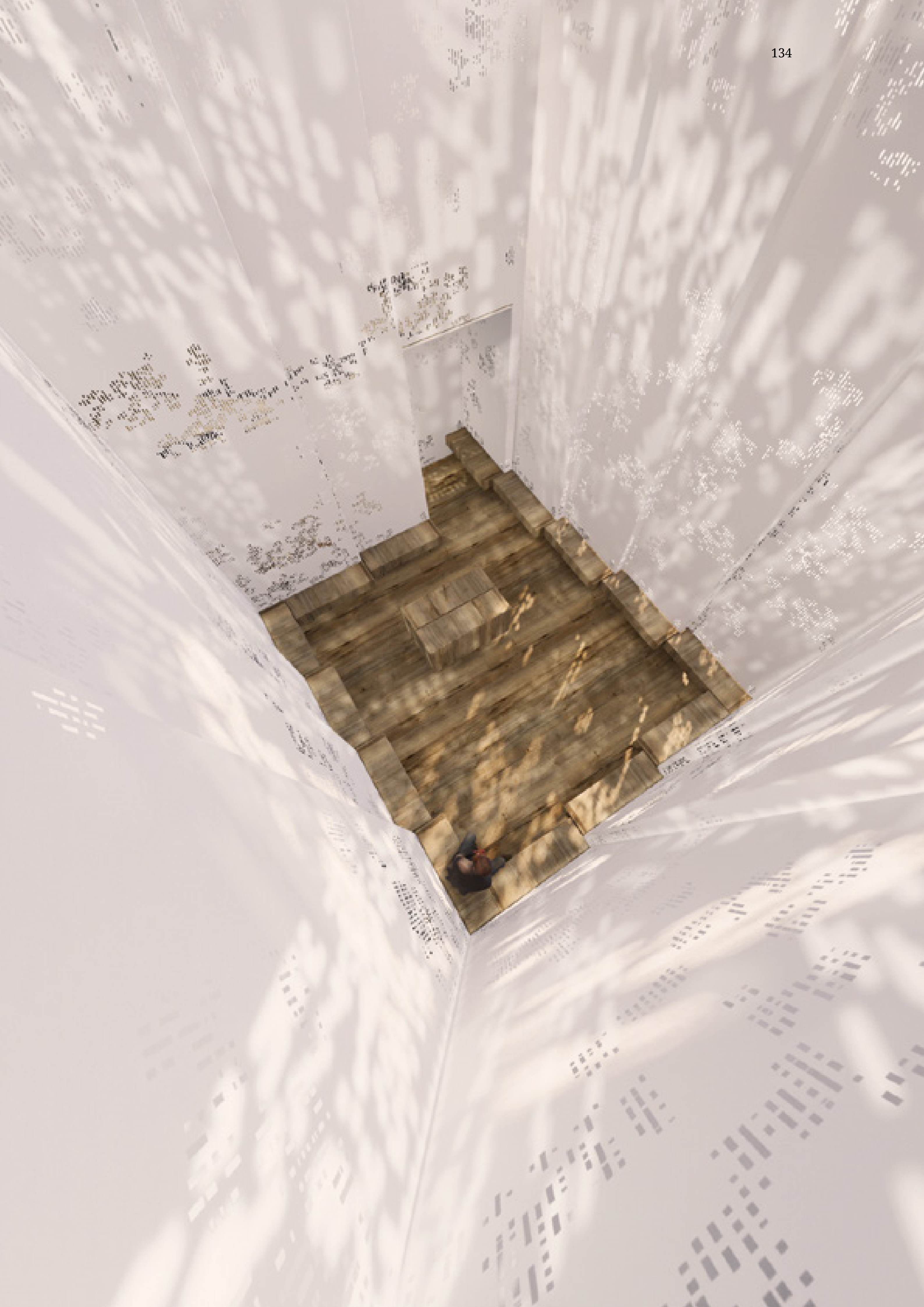
CONCLUSION

”In the field of architecture and interior design, fractal patterns offer a wide range of possibilities. There are already ongoing projects in healthcare and office design including fractal facades, room dividers, shading structures, customized curtains and wallpapers.“

Martin Lesjak

“The aim is to generate further patterns in the form of the Fractal Library that will find applications with architects, interior designers and product manufacturers in diverse environments such as the workplace, public, educational and healthcare facilities. We hope that through this commitment to fractal design, we will encourage well-being and improve diverse task performances through concentration restoration.”

ScienceDesignLab



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“Relaxing Floors: Fractal Fluency for the Built Environment”
J.H. Smith, C. Rowland, S. Moslehi, R.P. Taylor, A. Lesjak, M. Lesjak, S. Stadlober, L. Lee, J. Dettmar, M. Page and J. Himes
Published: The Journal of Nonlinear Dynamics, Psychology, and Life Sciences, 24 127-141 (2020)

“The Potential of Biophilic Fractal Designs to Promote Health and Performance: A Review of Experiments and Applications”
R.P. Taylor, Published: Journal of Sustainability: Special edition ”Architecture and Salutogenesis: Beyond Indoor Environmental Quality“ 13, 823 (2021)

“Aesthetics and Psychological Effects of Fractal Based Design”
K.E. Robles, M. Roberts, C. Viengkham, J.H. Smith, C. Rowland, S. Moslehi, S. Stadlober, A. Lesjak, M. Lesjak, R.P. Taylor, B. Spehar and M.E. Sereno
Frontiers Environmental Psychology, special edition on Biophilic Design Rationale: Theory, Methods, and Applications, 12, 699962 (2021)

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Contract Magazine (US)

i+D Magazine (US)

1st Look (KOR)

100 Future Objects (AT)

Interior & Sources (US)

Healthcare Design (US)

wohninsider (AT)

Floor Trends (US)

Floor Covering Weekly (US)

Pubmed Health (US)

Buildings Magazine (US)

McMorrow Reports (US)

Around the O (US)

Archiproducts (IT)

Indesign Live (APAC)

AAHID (US)

Officeinsight (US)

formfaktor (AT)

Surface Magazine (US)

architektur.aktuell (AT)

LECTURES

”Fractal Design Panel“
Panel at NYCxDESIGN hosted by Metropolis Magazine and Mohawk Group
May 19th, 2019

”Neuroscience Applied to Architectural Design“
Lecture as part of the Master Program NAAD in Venice
January 13th – 17th, 2020

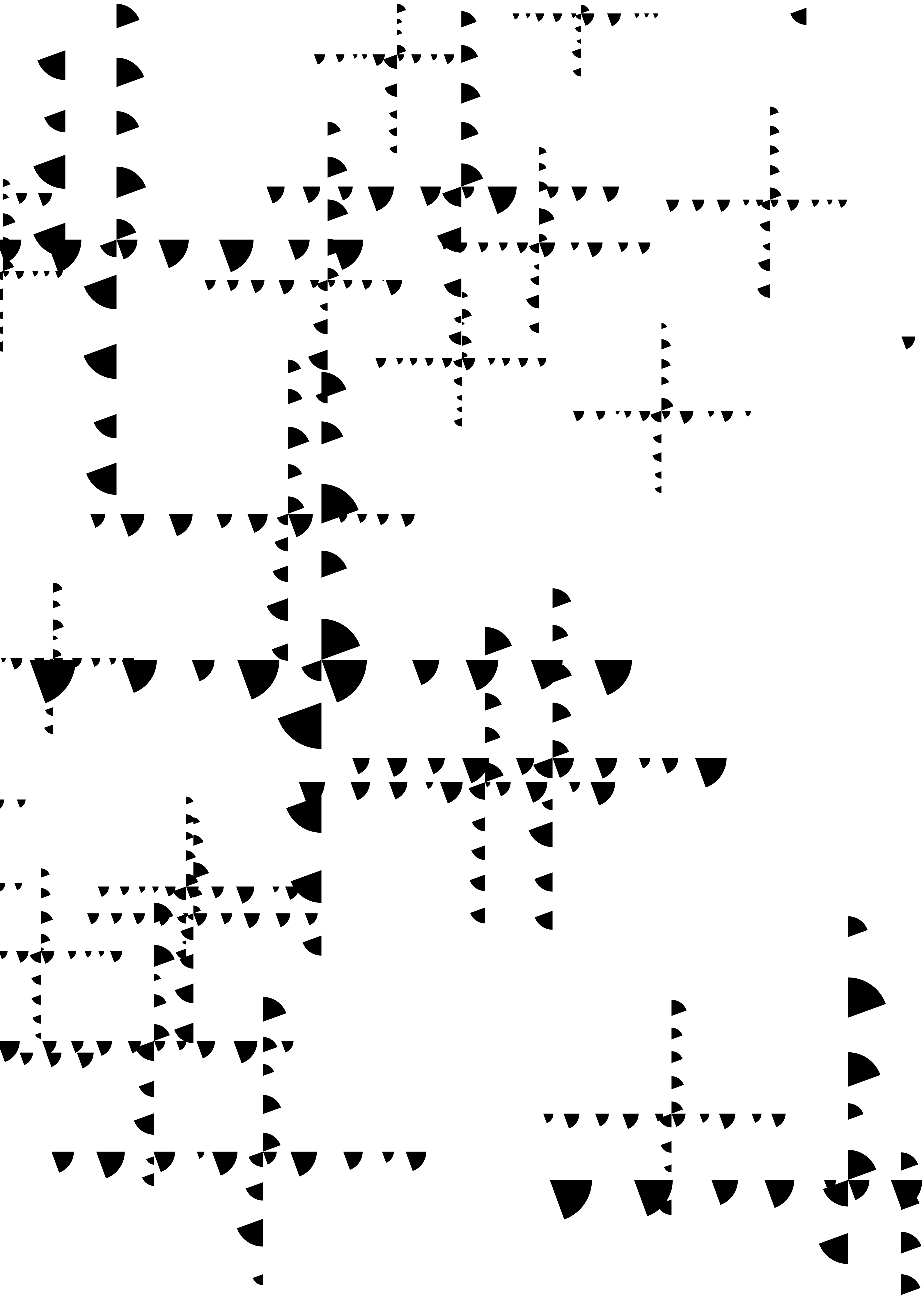
“Fractal Fluency in the Built Environment“
Presentation as part of Mohawk´s Resourceful CEU series,
September 16th, 2020

“Design Relevance for a Changed World - Part 1”
FROM THE EDGE webinar,
September 22nd, 2020

“Cognitive Architecture”
Panel at the Classic Planning institute meeting,
February 26th, 2021

“Your Brain on Fractals”
Yale School of Architecture, Whitney Humanities Center,
April 14th, 2021

“Design Relevance for a Changed World - Part 2”
FROM THE EDGE webinar,
April 28th, 2021



AWARDS

2019 Good Design® Award
by The Chicago Athenaeum International Museum

Best Surfacing Products 2019 Award
by Architectural Record

Best of Year 2019
by Interior Design Magazine

Gold Nightingale Award 2019
by Healthcare Design Magazine

Product Innovations 2019 at Merit Award
by Buldings Magazine

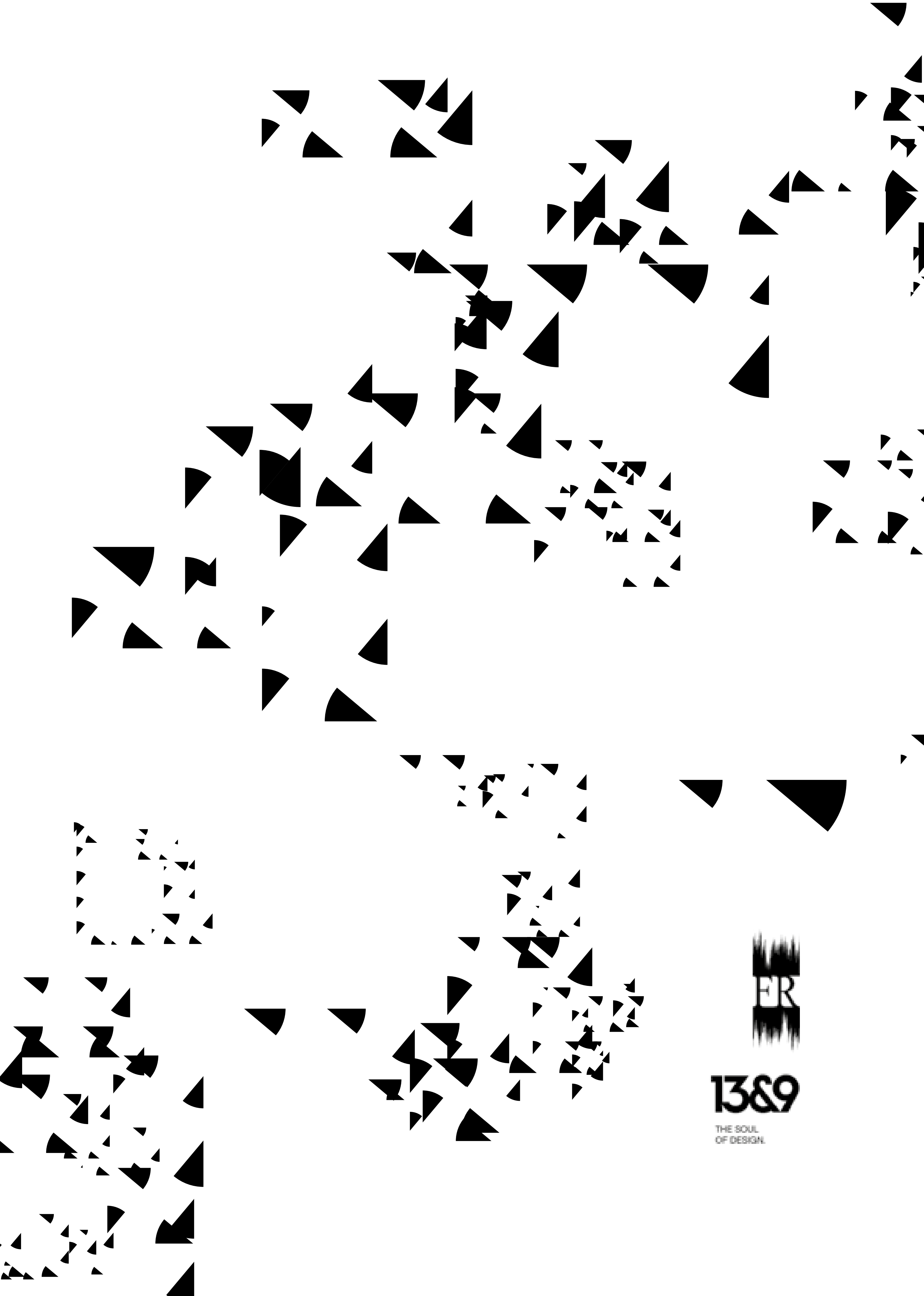
HiP Awards 2019
by Interior Design Magazine

Best of NeoCon Innovation Award 2019
by Contract Magazine

Metropolis Likes
by Metropolis Magazine

Honoree: NYCXDESIGN Awards 2019
by Interior Design Magazine

Honoree: Best of Year 2019
by Interior Design Magazine



13&9

THE SOUL
OF DESIGN.

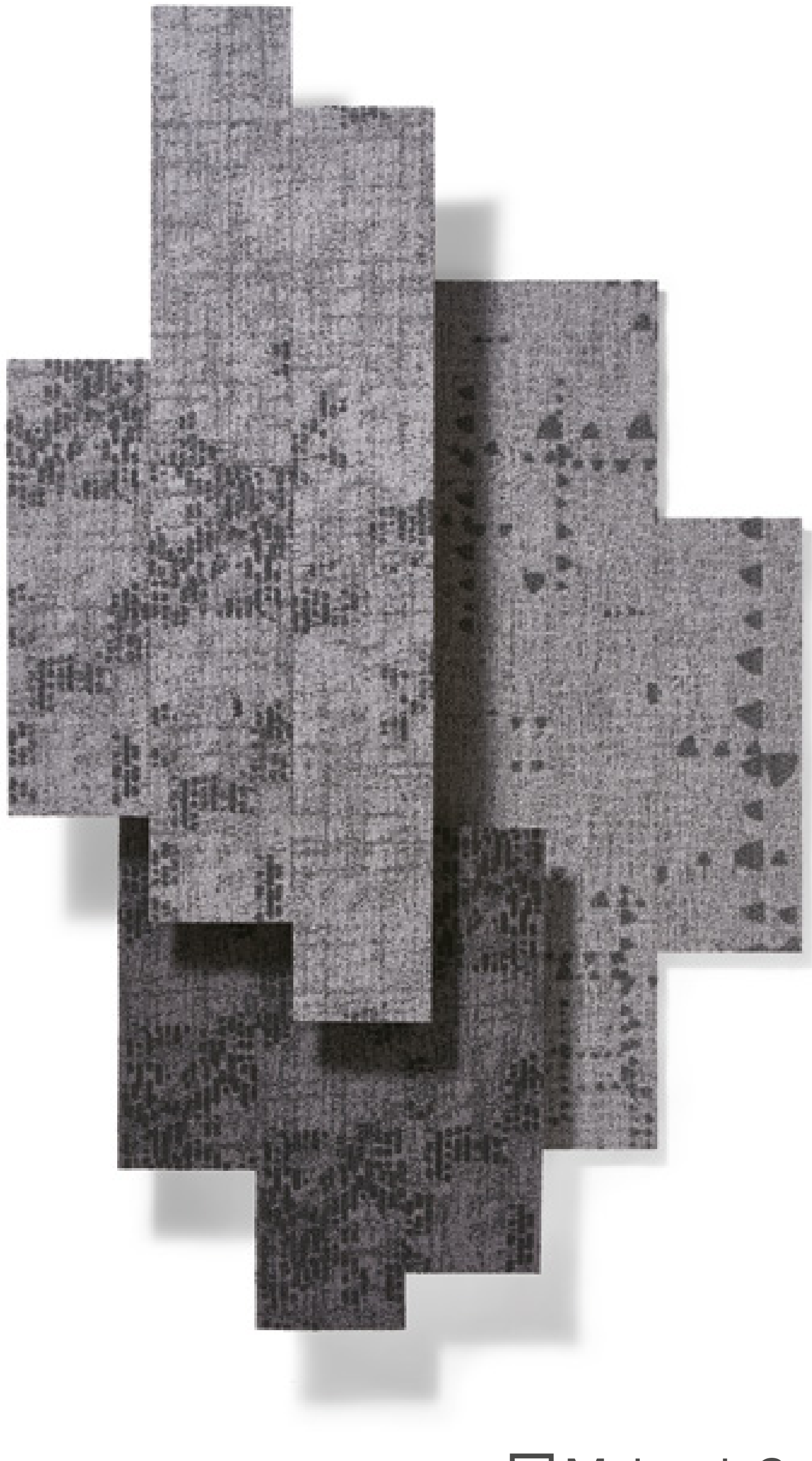
ABOUT FRACTALS RESEARCH

Fractals Research is a research company based in Eugene, USA, which specializes in integrating scientific and artistic inquiries of natural patterns called fractals. It was founded to develop and apply computer analysis techniques to understand the visual impact of art works and became well-known for authenticity research on abstract artists such as Jackson Pollock. In addition to analyzing art works, Fractals Research also develops computer programs for generating fractal patterns for applications in art, design and architecture. The company also publishes documents focusing on fractal research.

ABOUT 13&9 DESIGN

In 2013, Anastasija and Martin Lesjak founded the product design studio 13&9 in Graz, Austria. The team has developed numerous collections from concept to production together with specialized partners in a variety of spaces including furniture design, lighting, acoustics, textile design, accessories, exhibitions, and sound design. This creative community is both a design studio for international companies such as BuzziSpace, Mohawk Group, FACT Design, Quinze & Milan, Lande, Wever & Ducré, XAL, and VITEO Outdoors, and its own label. The transdisciplinary approach extends across all concepts and development processes and includes various external partnerships, cooperations with manufacturers, and regional production to support an environmentally responsible business model. In collaboration with scientists (e.g., ScienceDesignLab / Prof. Dr. Richard Taylor, University of Oregon) and different creative disciplines, the team holistically develops products with multiple uses that combine form, function, and individual and social added value in one identity - the soul of 13&9.

The label‘s innovative projects and products have received awards worldwide and have been published in the international press in the fields of architecture, design, and research.



Mohawk Group

ABOUT MOHAWK GROUP

As the world's leading producer and distributor of quality commercial flooring, Mohawk Group believes that better floor coverings emerge from better design, innovation, sustainability, project solutions and operational excellence. Mohawk Group addresses the unique challenges and opportunities in contract interiors with a comprehensive carpet and hard surface portfolio of all types and price points. As the commercial division of Mohawk Industries, the company has a heritage of craftsmanship that spans more than 130 years. To learn more about our full line of flooring products, please visit MohawkGroup.com.

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IMPRINT

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INNOCAD architecture
115-132, 135

Mohawk Group
52, 96, 97, 100, 105, 107, 109, 110, 146

Paul Ott
113

Richard Taylor
15, 20, 22, 23, 24, 25, 26, 27, 29, 30, 33, 35, 43, 46, 48, 50, 52

Rūdolfs Klintsons
21

Sabrina Stadlober
17

Sandra Mulder
8, 10, 12, 39, 40, 99, 103, 136, 138, 140

ScienceDesignLab
6, 44, 47, 49, 51, 56, 58-95, 142, 144

Sebastian Kapfhammer
36

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Lisa Nett, INNOCAD architecture
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