Symbiotic Encounter:

SHAPE MEMORY ALLOY

ACTUATORS IN ARCHITECTURE

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ABSTRACT

Symbiotic Encounter: Shape Memory Alloy Actuators in Architecture

Mitra Bagheri

This thesis explores the innovative integration of Shape Memory Alloys (SMAs) into architectural design, emphasizing their potential to create dynamic, responsive structures. SMAs, known for their unique properties of shape memory and superelasticity, offer transformative capabilities for kinetic architecture. The research investigates how SMAs can enhance sustainability, user-centric design, and material innovation in architectural applications.

By examining the interplay between architectural theory and practical implementation, this work provides a comprehensive reference for utilizing SMAs in creating adaptive facades, responsive shading systems, and interactive installations. The thesis addresses existing gaps in knowledge by consolidating insights from materials science, mechanics, and fabrication processes. Through extensive prototyping, a final responsive wall piece is designed, demonstrating SMA's ability to interact with users and respond to environmental stimuli.

This research contributes to the advancement of architectural design by proposing new methodologies for incorporating smart materials, thereby fostering interdisciplinary collaboration and inspiring future innovations. The practical applications of SMAs presented in this study highlight their potential to revolutionize architectural practices, creating structures that are not only aesthetically appealing but also functionally adaptive and environmentally responsive.

GENERAL AUDIENCE ABSTRACT

Symbiotic Encounter: Shape Memory Alloy Actuators in Architecture

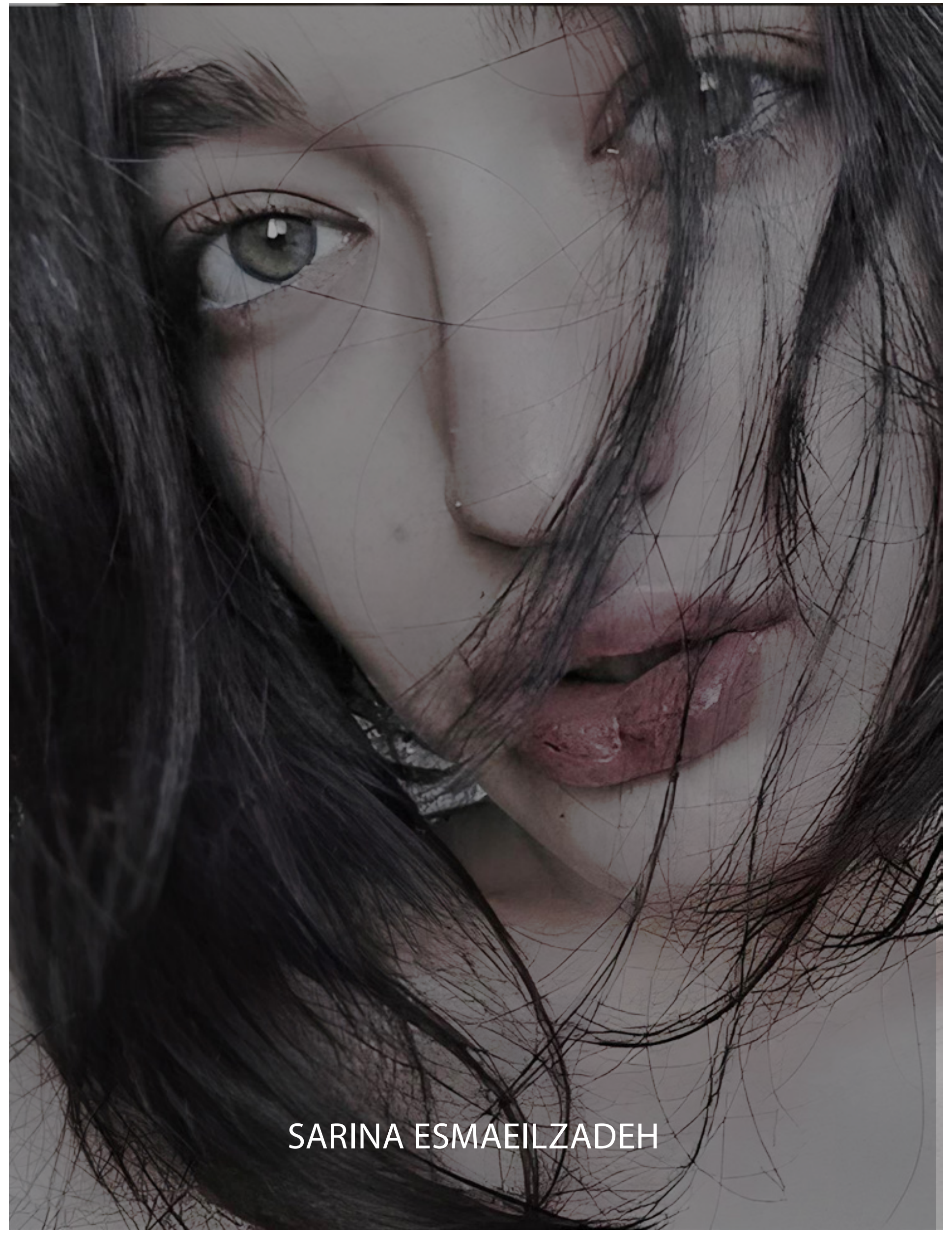
Mitra Bagheri

This thesis explores how new materials called Shape Memory Alloys (SMAs) can be used to make buildings more dynamic and responsive to their environment. SMAs are special because they can change shape when heated and return to their original form when cooled, much like magic metal.

The research shows how SMAs can be used in architecture to create structures that move and adapt in response to changes in their surroundings. For example, building facades made with SMAs can automatically adjust to control sunlight and temperature, making buildings more energy-efficient and comfortable for people inside.

A significant part of this study is a project where SMAs are used to create a wall that reacts to touch and other stimuli, bringing the wall to life in a way that interacts with people nearby. This work aims to inspire architects and designers to think beyond static structures and consider how buildings can become more interactive and environmentally friendly.

Overall, this research opens up exciting possibilities for the future of building design, making our living and working spaces smarter and more in tune with our needs and the natural world.



Dedicated to Sarina,

Sarina Esmaeilzadeh was A 16-year-old bright and talented girl that was brutally beaten to death September 23, 2022. She is one of more than 70 children killed with impunity by Islamic Republic security forces in connection with the Woman, Life, Freedom movement in Iran after the murder of Mahsa Amini in Tehran by islamist security forces for her loose Hijab.

. . .


DESIGN
PROCESS
BIOPHILIA
MATERIAL

Schulz in his renowned book Architecture: Presence, Language, Place(Norberg-Schulz, 2000) discusses The concept of language in architectural design, not in a literal sense, but as a communicative medium that expresses cultural, historical, and existential meanings. Norberg-Schulz explores how architectural design conveys a sense of identity, reflecting the values and narratives of a particular culture or society.

Place, as a fundamental aspect of architectural design, is explored in terms of both physical and existential dimensions. The author investigates how the built environment contributes to the sense of place, creating a connection between individuals and their surroundings. He underscores the significance of understanding architectural design beyond its functional attributes, emphasizing its role in creating meaningful places that resonate with human experience.

SMA CAN BE USED AS A COMMUNICATIVE MEAN

INTRODUCTION

Architecture as a communicative mean

Norberg-Schulz's exploration of these themes lays the groundwork for a profound understanding of architectural design as a lived experience, deeply intertwined with human presence, cultural expression, and the creation of meaningful places. The subsequent chapters likely further elaborate on these foundational concepts, providing a comprehensive exploration of the philosophical underpinnings of architectural design.

Architecture plays a pivotal role in providing users with a sense of orientation and identity within a place, contributing significantly to the human experience of the built environment. The spatial configuration, formal language, and symbolic elements inherent in architectural design collectively serve as communicative mediums that guide users in navigating and interpreting their surroundings. Through careful attention to spatial organization and the establishment of distinct landmarks, architectural design facilitates a legible and comprehensible environment, enabling users to orient themselves within a given space. Furthermore, the integration of cultural, historical, and contextual references in architectural elements fosters a sense of identity, anchoring users to the place and reinforcing a connection with the broader cultural narratives embedded in the built environment.

Architecture plays a pivotal role in providing users with a sense of orientation and identity within a place, contributing significantly to the human experience of the built environment.

KINETIC ARCHITECTURE

Kinetics holds potential to reaffirm architectural design's role as a meaningful cultural expression.

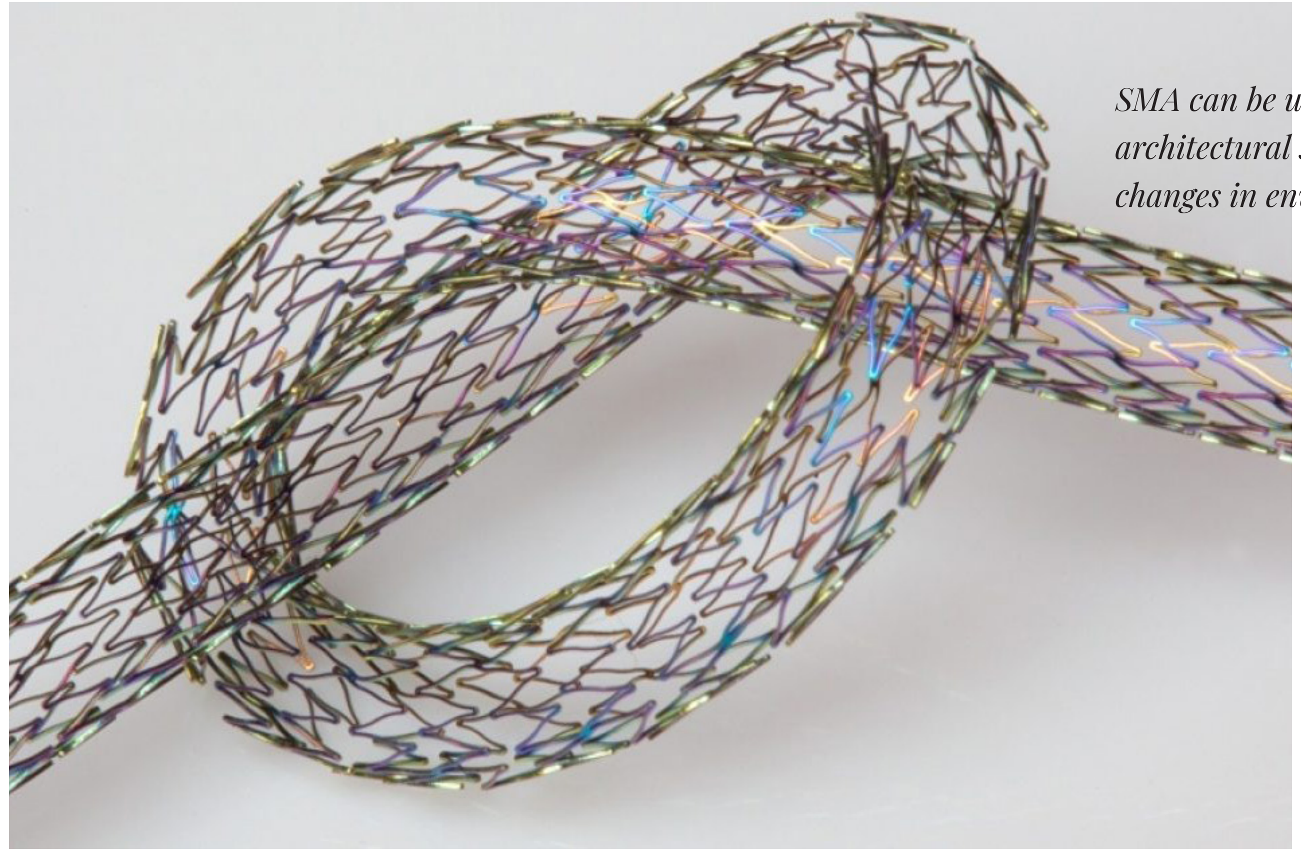
Kinetic architectural design that incorporates dynamic construction elements capable of movement has emerged as an important paradigm in contemporary architectural discourse and practice. There are several underlying motivations that render motion and transformative capacity in the built environment aspirational and advantageous. On a basic functional level, incorporating kinetics enables structures to actively adapt to fluctuating external stressors and changes in their surroundings. For example, facades that passively track solar orientation like sun-following louvers or shading systems constructed using flexible materials can enhance thermal comfort and energy efficiency. Kinetics allows modulation of light, ventilation, insulation and other environmental factors in response to diurnal and seasonal variations. This capacity for self-regulation improves construction performance.

Conceptually, kinetics aligns with the ontology of architectural design, which rejects notions of constructions as static objects and embraces their inherent relationality to inhabitants and changing contexts.

Socially and psychologically, motion signals life and invites participation. Kinetic structures exhibit vitality akin to natural organisms and prompt interaction

Technologically, embedding kinetics requires innovating structurally performative systems and smart materials. This drives progress in design methodologies, manufacturing techniques and sustainable technologies.

Architectural design that is functionally responsive, experientially stimulating, culturally communicative and materially progressive.



SMA can be used to create dynamic architectural structures that respond to changes in environmental conditions.

While some industrial efforts have introduced ideas and techniques for responsive shading in constructions, leading to the development of adaptive shading facades like those in the Al Bahr tower or Q1 headquarters (Alotaibi, 2015), it is essential to reevaluate current practices in responsive construction design due to several observed challenges:

(i) The fabrication of mechanisms and components required for configuring movable parts and linkage systems is intricate and costly.

(ii) Electromagnetic motor-based kinetic systems often generate disruptive noise and vibrations within the construction interior, necessitating regular maintenance for reliable operation.

(iii) Reported performance assessments of kinetic designs in construction simulations often fail to adequately consider actuation efficiency (output force/energy or output force/weight), neglecting the additional electricity consumed by large-scale motors and components.

Shape Memory Alloy (SMA) actuators offer a promising solution to address the existing gap in the body of knowledge within the field of architectural design.

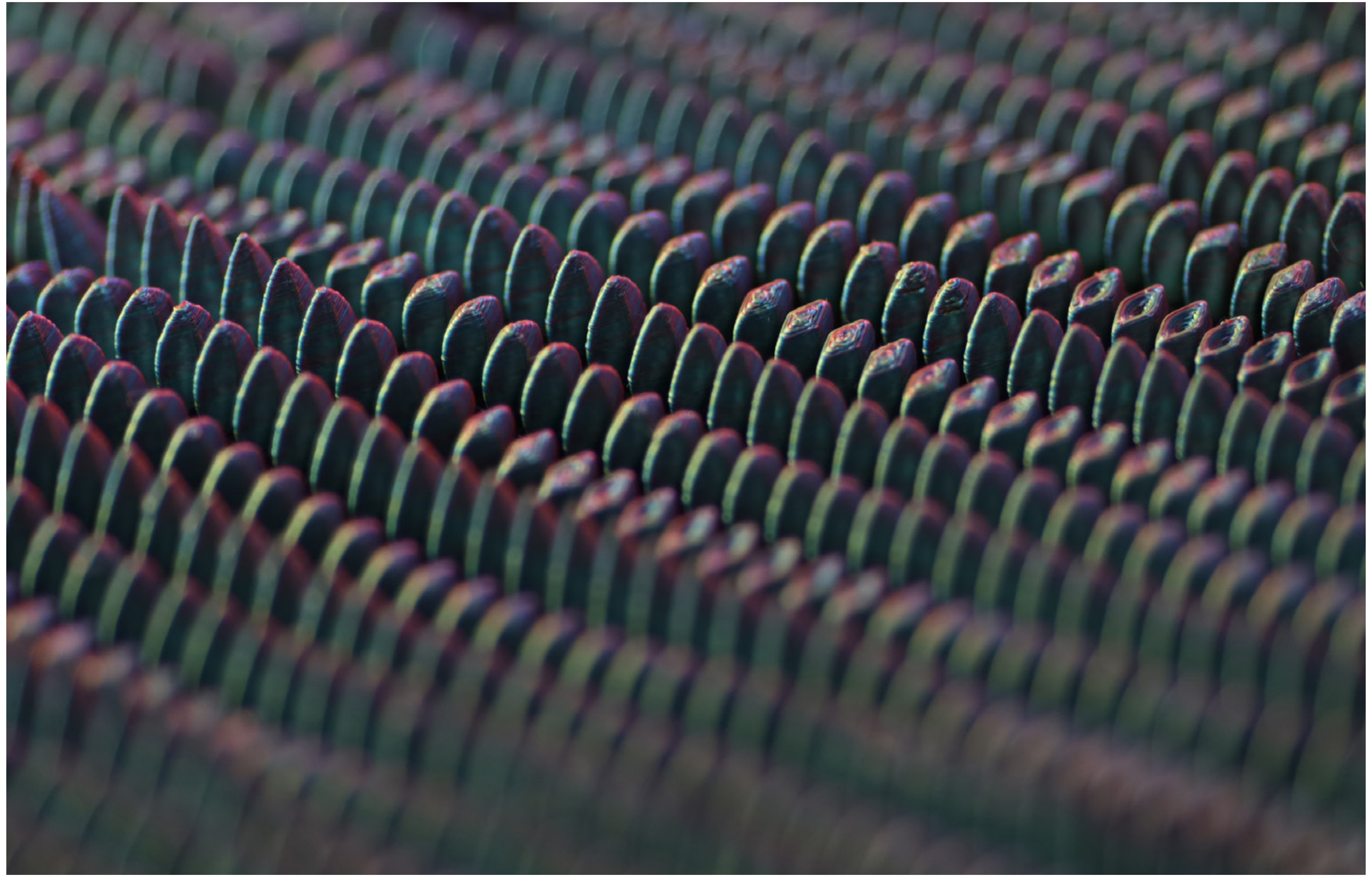
1. Sustainability and Energy Efficiency: SMAs have the potential to enhance sustainability in architectural design by enabling responsive construction components, such as facades and shading systems. These components can dynamically adapt to changing environmental conditions, optimizing energy usage and improving thermal comfort.

2. User-Centric Design: The use of SMAs in kinetic architectural elements can introduce user-centric design principles by creating interactive and adaptable spaces. This addresses the gap in providing architectural designs that respond to occupants' needs and preferences in real-time.

3. Reduced Noise and Maintenance: Unlike traditional electromagnetic motors, SMA actuators have the potential to operate silently and require less frequent maintenance due to their simplified mechanical structure. This addresses the gap in minimizing noise pollution within constructions and reducing the operational costs associated with maintenance.

4. Material Innovation: The utilization of SMAs introduces a new dimension of material innovation in architectural design. These smart materials can change shape in response to external stimuli, enabling the creation of dynamic, adaptable, and aesthetically pleasing construction components. This bridges the gap in materials research and application within architectural design.

5. Environmental Responsiveness: SMAs can contribute to the creation of constructions that are more in tune with their surroundings. By responding to environmental cues, such as sunlight, temperature, or wind, SMA-based elements can optimize energy use and reduce the ecological footprint of architectural designs.



CONTRIBUTION TO EXPANDING AND CONSOLIDATING KNOWLEDGE

on implementing shape memory alloys (SMAs) in architectural and design applicationsdolupitatum ipsae occatem harchiciur?

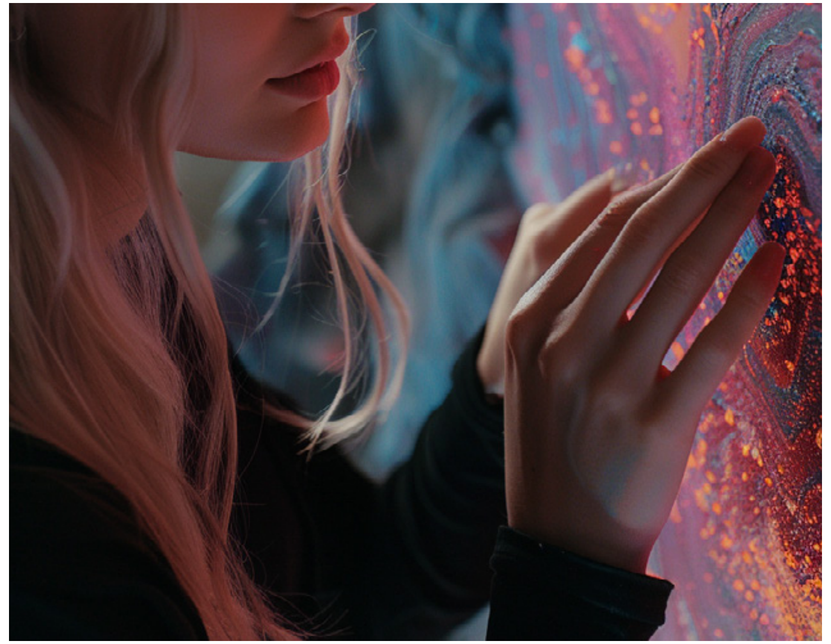
This thesis aims to provide a comprehensive reference on the effective integration of shape memory alloys into architectural design and design. Despite growing interest in SMAs for kinetic structures and adaptive facades, there is currently a fragmented understanding of how to leverage their unique properties in the built environment. Designers lack consolidated resources that map the capacities and limitations of different SMA materials and configurations with respect to functional objectives, manufacturing constraints, and performance goals. My research will gather dispersed knowledge across materials science, mechanics, and fabrication processes relevant to architectural SMAs. After conducting extensive research and different stages of prototyping, a final responsive wall piece will be designed and built that interacts with users responding to different stimuli including touch, sound, or distance.

The outcome of this research on the integration of shape memory alloys (SMAs) into architectural design and construction can contribute significantly to designers and the field of architecture in several ways like

- Unlocking new design possibilities:
- Facilitating interdisciplinary collaboration
- Developing design guidelines and tools
- Advancing responsive architecture
- Inspiring future research and innovation

Incorporating SMAs into architectural designs requires specialized knowledge and expertise, which may not be widely available among architects and engineers.




"THE PARADOX OF MODERN SOLITUDE: EXPLORING THE ACHE OF ABSENCE"

Architecture, as the physical embodiment of human thought and experience, plays a pivotal role in shaping our perception of solitude and the sense of absence in modern life.

In the vast tapestry of contemporary existence, a paradox emerges: despite the interconnectedness facilitated by technology and global networks, many individuals find themselves grappling with a profound sense of isolation. This existential solitude, exacerbated by the absence of familial or communal bonds, casts a poignant shadow over the human spirit.

At the heart of this paradox lies the poignant reality that the modern human, despite being surrounded by a cacophony of voices and digital connections, often traverses life's journey alone. The traditional structures of familial support and communal belonging, once pillars of solace and security, have undergone seismic shifts in the wake of societal evolution.

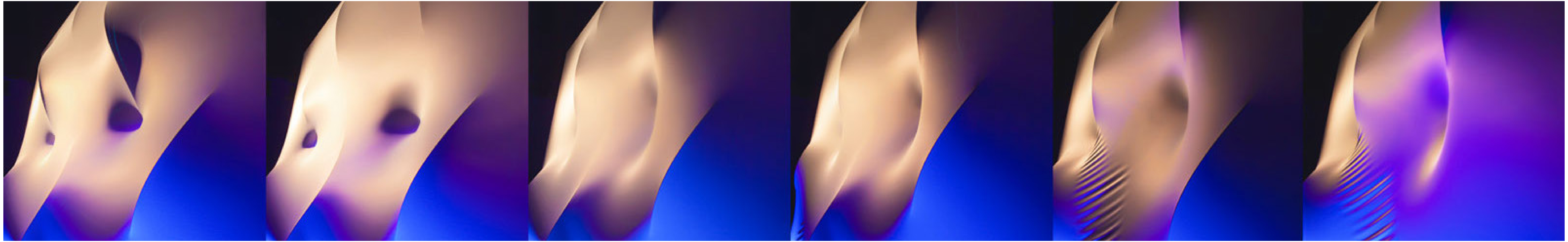
In the sanctuaries we call home, the absence of awaiting souls can reverberate with a disquieting echo. The empty spaces, devoid of the warmth and familiarity of loved ones, serve as poignant reminders of the transient nature of human connection. In a world where solitude is both ubiquitous and pervasive, the ache of absence can carve deep fissures in the human spirit, leaving behind scars that linger long after the physical void has been filled.

This solitude, however, is not merely a consequence of physical separation, but a manifestation of a deeper existential yearning for belonging and connection. In the absence of familial ties or communal bonds, individuals are confronted with the stark reality of their own solitude, navigating the labyrinthine corridors of existence with only their own thoughts and reflections for company.

"How much I turn the key in the lock
And take a step toward a dark home?
I am enslaved by bright houses."

-Ghazaleh Alizade

Iranian Poet



BACKGROUND

SMA can be used to create dynamic architectural structures that respond to changes in environmental conditions.

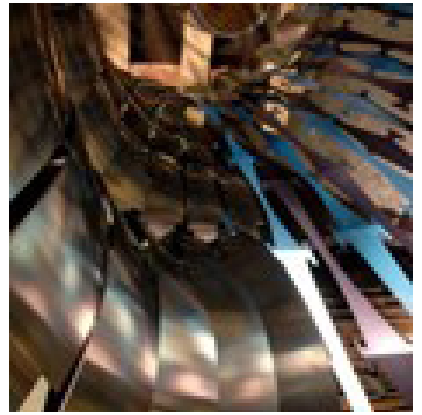
In a notable application, shape-memory alloy devices were employed in the restoration of the bell tower of San Giorgio church in Trignano, Italy, which had been extensively damaged during a 1996 earthquake. These devices were connected in series with steel bars within the bell tower to limit horizontal movement, thus improving its earthquake resistance and structural integrity (Indirli et al., 2001).

In structural systems, incorporating shape-memory alloys into a bracing system is highly effective in addressing the pinching observed in the hysteretic loop of a structure following significant deformation. This integration enhances the structure's capacity for robust re-centering.

In architecture, the 'Pixelskin02' project by Sachin Anshuman (Sachin, 2008) in 2006 utilized shape-memory alloy wires as a non-motorized method for operating a facade. In this innovative project, each pixel tile consisted of four triangular panels activated using 200 mA shape-memory alloy wires. These wires enabled controlled opening and closing of the panels by regulating the electric current supply.

Loonen's work (Loonen, 2014) suggests a novel approach using strips of shape-memory alloy that expand or contract based on carbon dioxide concentration. This concept allows for achieving an optimal balance between facade opening, pressure difference, and immediate ventilation needs.

Behnaz Farahi has extensively worked with shape-memory alloys in her design projects. One of her most notable projects is the "Caress of the Gaze" installation (Farahi, 2016), an interactive installation that used SMA-based actuators to create a dynamic, responsive surface. The surface would change shape in response to people's movement, creating an immersive environment. Another notable project is the "Breathing Wall," which uses SMA actuators to create a responsive façade for a building (Farahi, 2021). The facade responds to environmental conditions, such as temperature and humidity, by changing its shape and creating different patterns of light and shadow.



Philip Beesley is also another Designer renowned for his innovative projects incorporating shape-memory alloys (SMAs). "Hylozoic Ground," a standout installation initially showcased at the Venice Biennale of Architecture in 2010, features a floor adorned with thousands of SMA-based actuators. These actuators respond to the presence and movement of people, creating an immersive and interactive environment that encourages exploration(Beesley, 2009). Another notable project, "Luminous Veil," employs SMA-based actuators in an adaptive façade that adjusts louvers in response to changing light and temperature conditions, enhancing both energy efficiency and the building's connection with its surroundings. Beesley's exploration of SMA-based actuators extends to projects like the "Hylozoic Series," which delves into the potential of SMAs to create dynamic and responsive architectural designs (Beesley, 2023).

Architect Doris Sung has introduced innovative building envelope designs in several projects, such as "eXo," by incorporating NiTi sheets, also known as self-shaping structures. These responsive designs showcase the use of NiTi sheets in creating dynamic and adaptable building envelopes (Sung, 2014).

The practical application of Shape Memory Alloys (SMAs) in architectural design encounters several limitations, as seen in existing examples. For instance, designs like Sung's SMA-clad facades are environmentally inefficient due to the high cost of utilizing large quantities of NiTi. Additionally, the complexity of programming the material for on-site construction and the potential for solar-heated SMA shading panels to introduce excessive heat into building interiors pose significant challenges. Moreover, the work of Formentini and Lenci lacks validation regarding the building performance of SMA-actuated cladding systems. Issues such as distracting metallic surface glare and limited movability of SMA sheets and wires have also been observed. Crucially, both approaches fail to clearly model the mechanical behavior of SMA deformation and its relationship with building geometry.

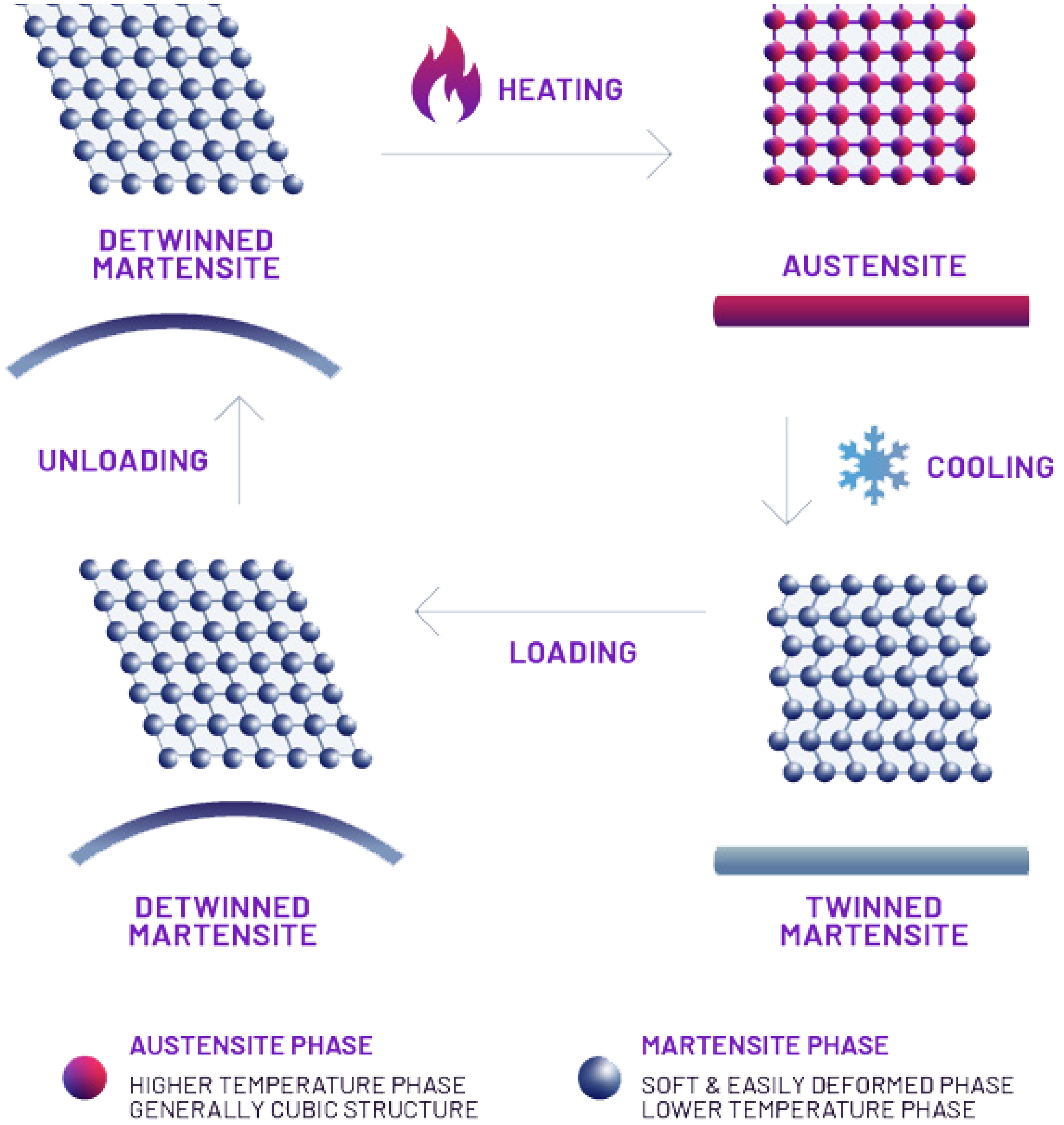
High Cost and Implemention Complexity are main reasons that limits SMA use in design.

WHAT IS SHAPE MEMORY ALLOY?

A metal that remembers.

Shape-memory alloys (SMAs) are unique materials known for their two remarkable properties: shape memory and superelasticity. The shape memory effect allows these alloys to return to their original shape when heated, while superelasticity enables them to undergo significant deformations without permanent strain. Compared to conventional metallic materials, SMAs offer superior energy dissipation capabilities during repeated phase transformations. Often referred to as "smart metals," SMAs provide a lightweight, solid-state alternative to traditional actuators and switches such as hydraulic, pneumatic, or motor-driven systems.

SMAs are ferroelastic materials characterized by their ability to exhibit the shape memory effect (SME). This phenomenon arises from thermomechanical behaviors within the material, leading to a sequence of crystalline structural deformations that allow it to memorize and subsequently recover its original shape. SMAs have two distinct solid-state phases: martensite (M) and austenite (A), which determine the material's elastic properties and geometric patterns. When an SMA is heated above the transformation temperature As, it becomes rigid and begins to revert to its initial shape, continuing this change as the temperature rises to Af. Conversely, cooling the SMA below Ms leads to a softer crystalline state known as twinned martensite. If the temperature decreases further to Mf while an external load is applied, the SMA undergoes hysteresis and remains in a detwinned martensite state. Nickel-titanium (NiTi) is the most widely used and industrially manufactured SMA, accounting for approximately 90% of all SMA applications (Yi et al., 2020).



To operate effectively, SMAs require a process known as "training" to enable them to revert to a previous shape when subjected to heating.

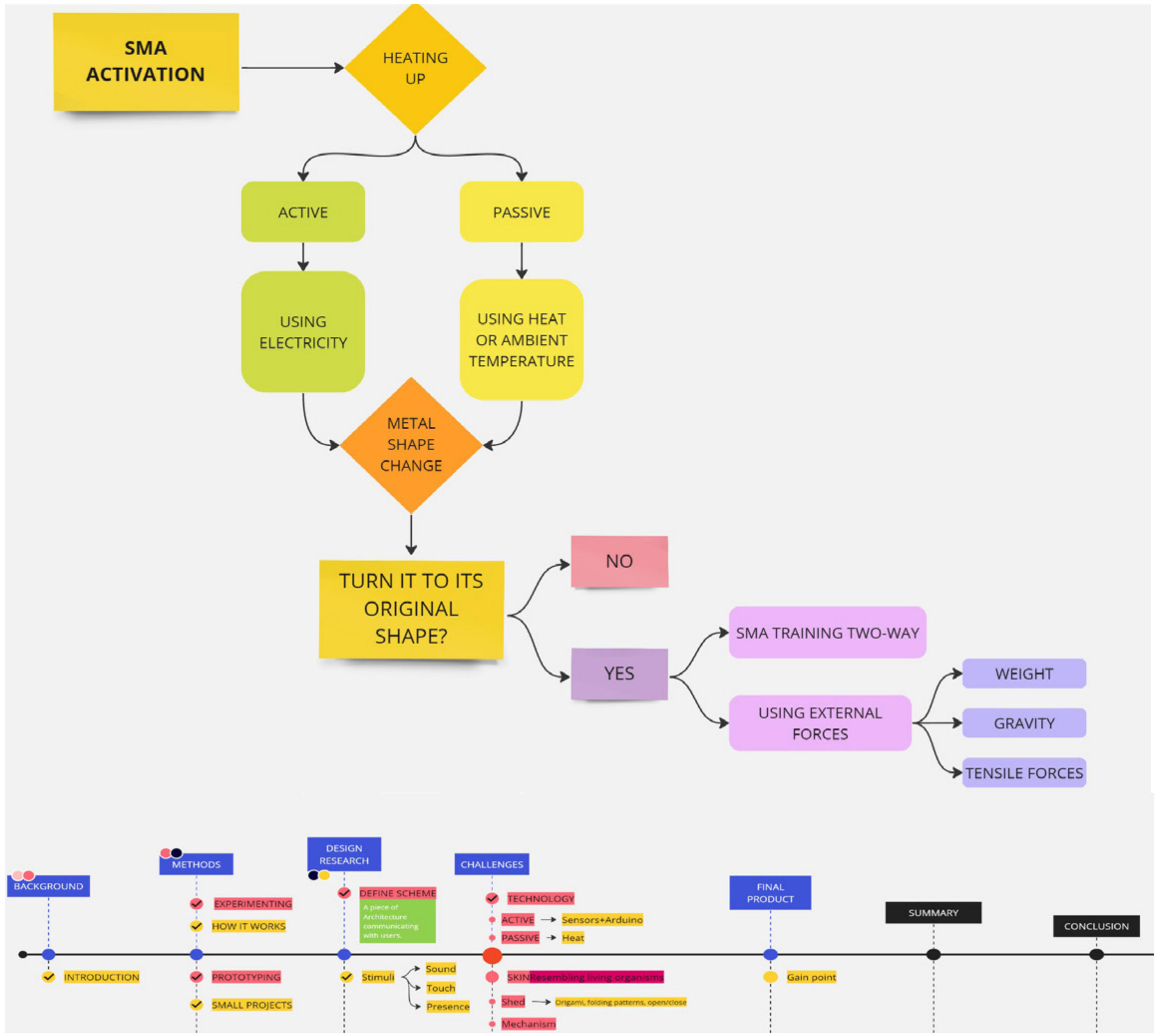
Shape-memory alloys exhibit different shape-memory effects, with two common types known as one-way SMA and two-way SMA. These effects follow similar procedures, typically beginning with the martensite phase, introducing a deformation, heating the material, and then cooling it once more.

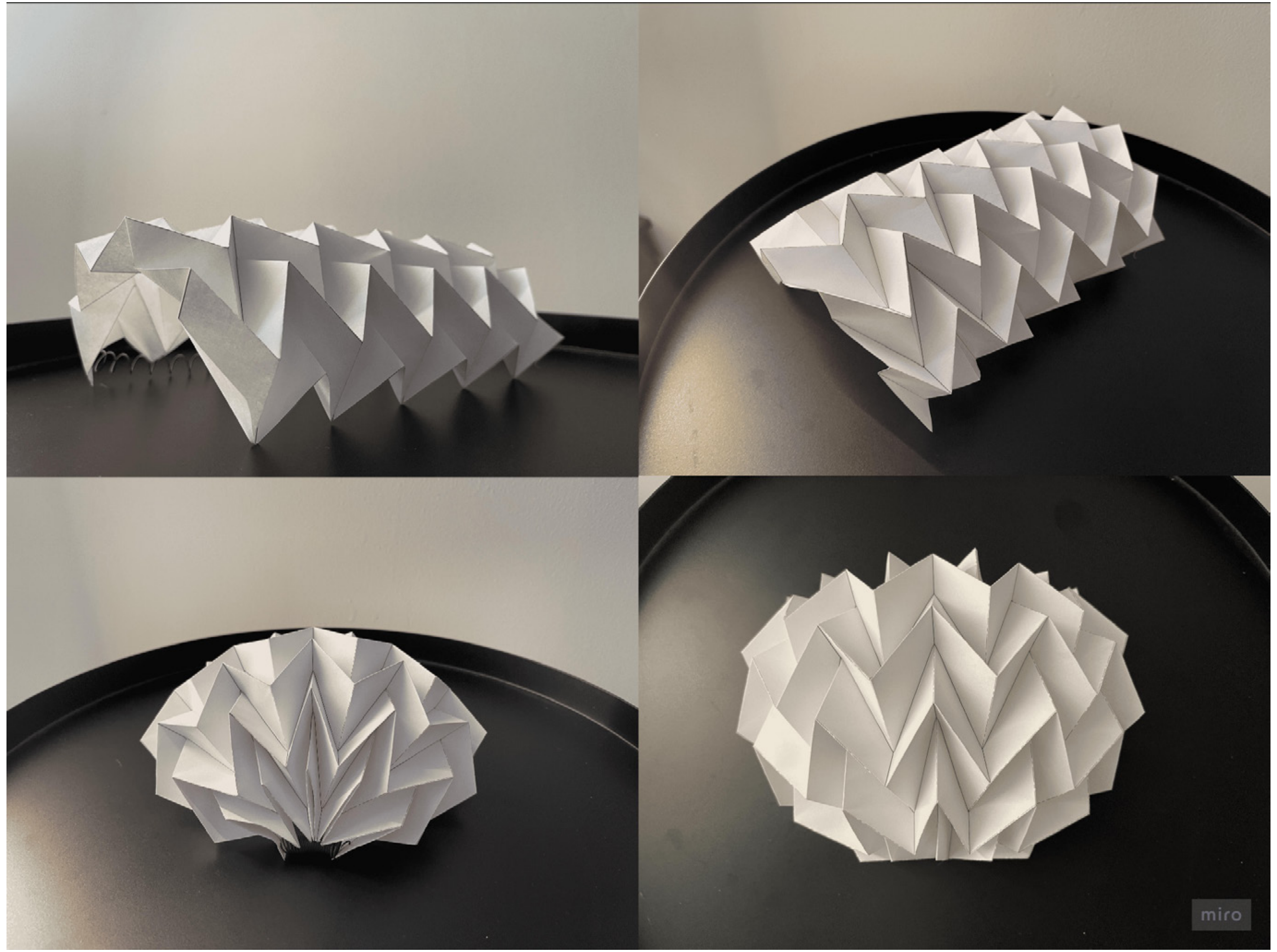
Superelasticity is the remarkable ability of certain alloys to undergo substantial, fully recoverable strain when subjected to stress. Different families of shape-memory alloys find applications across diverse contexts due to their distinct transformation temperature ranges. For example, aluminum-manganese and iron-nickel-cobalt-aluminum shape-memory alloys are well-suited for seismic applications because their operational temperature range spans from -50°C to 50°C. Each shape-memory alloy family comes with its own set of advantages and disadvantages.

The development of shape-memory alloys has been ongoing since the early 1960s. These alloys have found successful applications in various fields, including medicine, robotics, aerospace, and the automotive industry.

HOW DOES SMA WORK?

A unique class of alloys that have ability to 'remember' their shape





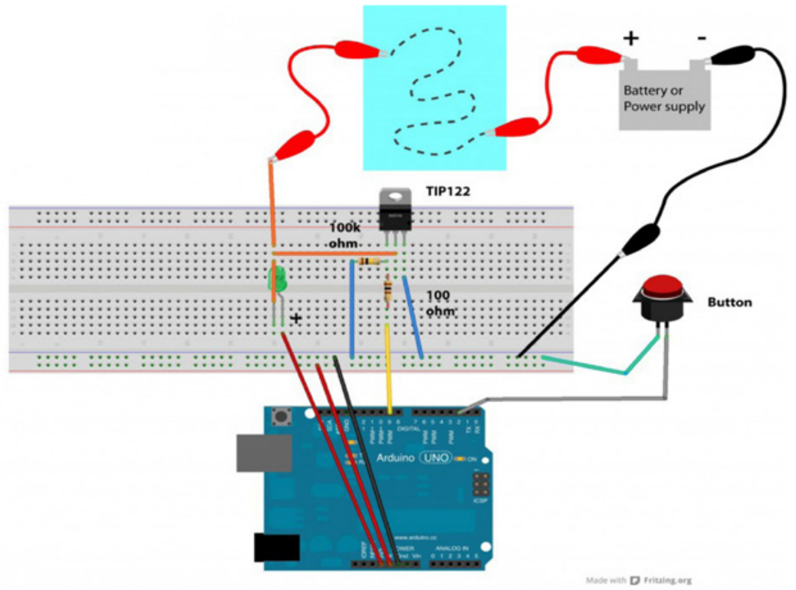
SHAPE-MEMORY ACTIVATION

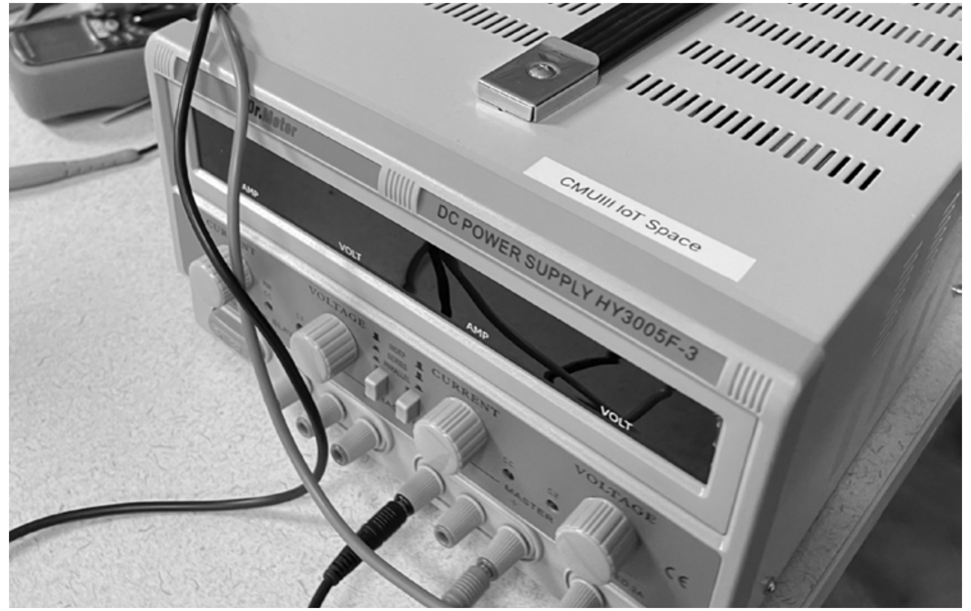
From a design perspective, there are still open questions regarding how to intricately program and control the complex thermomechanical behaviors of SMAS at an architectural scale.

Shape-memory effect allows SMAs to change shape in response to changes in temperature. There are two primary methods for activating SMAs:

- 1. Temperature Change: The temperature change can be achieved by exposure to ambient temperature changes or by actively heating the SMA using external heat sources.
- 2. Electrical Activation: Another common method to activate SMAs is by passing an electric current through the material. This approach relies on Joule heating, where the resistance of the SMA to the electric current generates heat. This heat raises the temperature of the SMA, causing it to transition from the martensitic phase to the austenitic phase, which results in a change in shape. Electrical activation provides precise control over the activation process and allows for rapid shape changes.
- Both methods have their advantages and are used in various applications based on the specific requirements of the SMA actuator. Temperature change activation is more passive and relies on external temperature variations, while electrical activation offers active and precise control over the SMA's response which can also include circuits using Arduinos and different sensors.

Incorporating SMAs into architectural designs requires specialized knowledge and expertise, which may not be widely available among architects and engineers.





It takes several steps to build an Arduino circuit that can move a shape-memory alloy (SMA) actuator. As a general introduction, the following should be considered:

Supplies required:

Arduino board (such as the Arduino Uno or Nano)

SMA actuator or wire

MOSFET or H-Bridge motor driver, In order to manage the high current required by the SMA

Power supply (SMA-dependent demand for voltage and current)

Resistors, diodes, and capacitorIn order to protect the circuit

Breadboard and jumper wires (for prototyping)

SMA activation technique (either electrical current or temperature control)

1. Identify Your Sensor: Determine the type of sensor that is being used using and its pinout. Refer to the datasheet or documentation for the sensor to understand its electrical characteristics.

2. Connect the Sensor: Connect the sensor to the Arduino as follows:

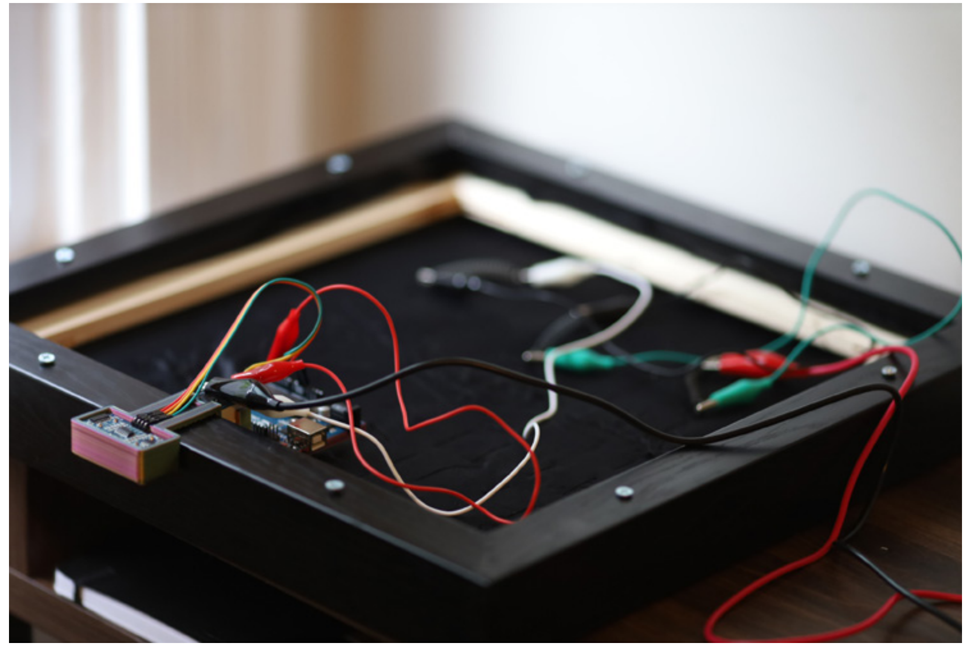
- Connect the sensor's power (VCC) pin to the Arduino's 5V pin or 3.3V pin, depending on the sensor's voltage requirements.

- Connect the sensor's ground (GND) pin to the Arduino's ground (GND).

- Connect the sensor's signal (OUT) pin to one of the Arduino's analog input pins (A0 to A5) or digital input/output pins (2 to 13). The choice of pin depends on the sensor and its interface (analog or digital).

3. Install Necessary Libraries (If Required): Some sensors may require specific libraries to communicate with the Arduino. These libraries can be found in the Arduino IDE's Library Manager or on platforms like GitHub. Install the appropriate library if needed.

4. Write Arduino Code: Write an Arduino sketch (code) to read data from the sensor. Use the Arduino IDE for this purpose. The code will depend on the type of sensor is being used for each project's purpose. Here's a basic example for reading data from an analog sensor connected to analog pin A0:




```
const int trigPin = 9;
const int echoPin = 10;
const int signalPin = 7;
float duration, distance;
unsigned long signalStartTime = 0;

void setup() {
  // put your setup code here, to run once:
pinMode(trigPin, OUTPUT);
pinMode(echoPin, INPUT);
pinMode(signalPin, OUTPUT);
Serial.begin(9600);

}

void loop() {
  // put your main code here, to run repeatedly:
digitalWrite(trigPin, LOW);
delayMicroseconds(2);
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);
duration = pulseIn(echoPin, HIGH);
distance = (duration*.0343)/2;
Serial.print("Distance: ");
Serial.println(distance);
if (distance<20) {
  digitalWrite(signalPin, HIGH);
  signalStartTime = millis();
// do stuff if the condition is true
} else {
  if (millis() - signalStartTime >= 5000) { // If 25 seconds have passed
    digitalWrite(signalPin, LOW); // Turn off the signal
   }
// do stuff if the condition is false
}
```

ARDUINO PROGRAMMING

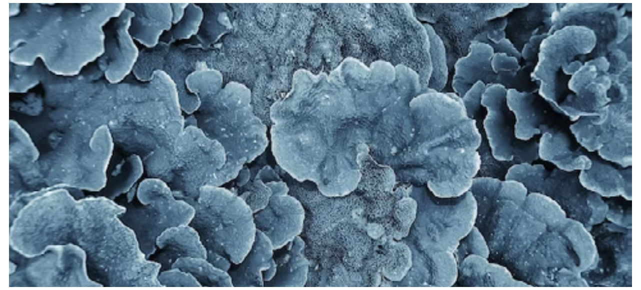
thye code used for triggering sma using ultra-sonic sensor

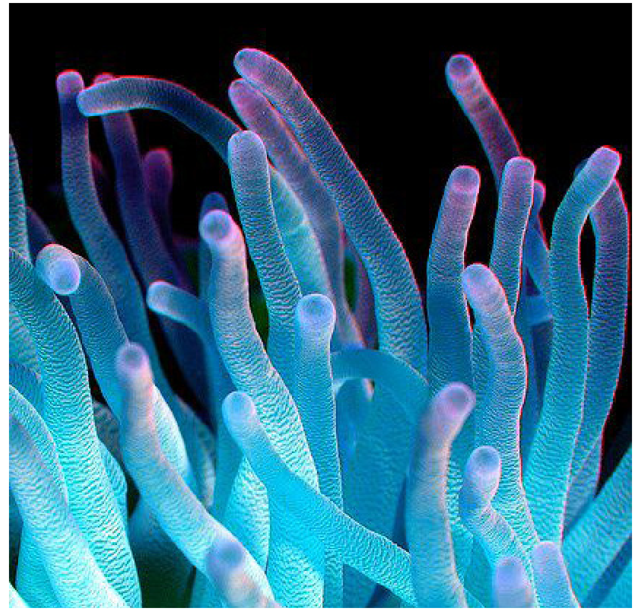
NATURE AS THE BIGGEST SOURCE OF INSPIRATION

The fusion of nature's wisdom and architecture

Exploring the intricate textures and forms found in the marine realm can unveil a treasure trove of inspiration for architectural designs. The underwater world is teeming with mesmerizing creatures that have evolved over millions of years, adorned with captivating patterns, shapes, and structural elements. These natural wonders offer a wealth of insights that can be translated into innovative architectural solutions.

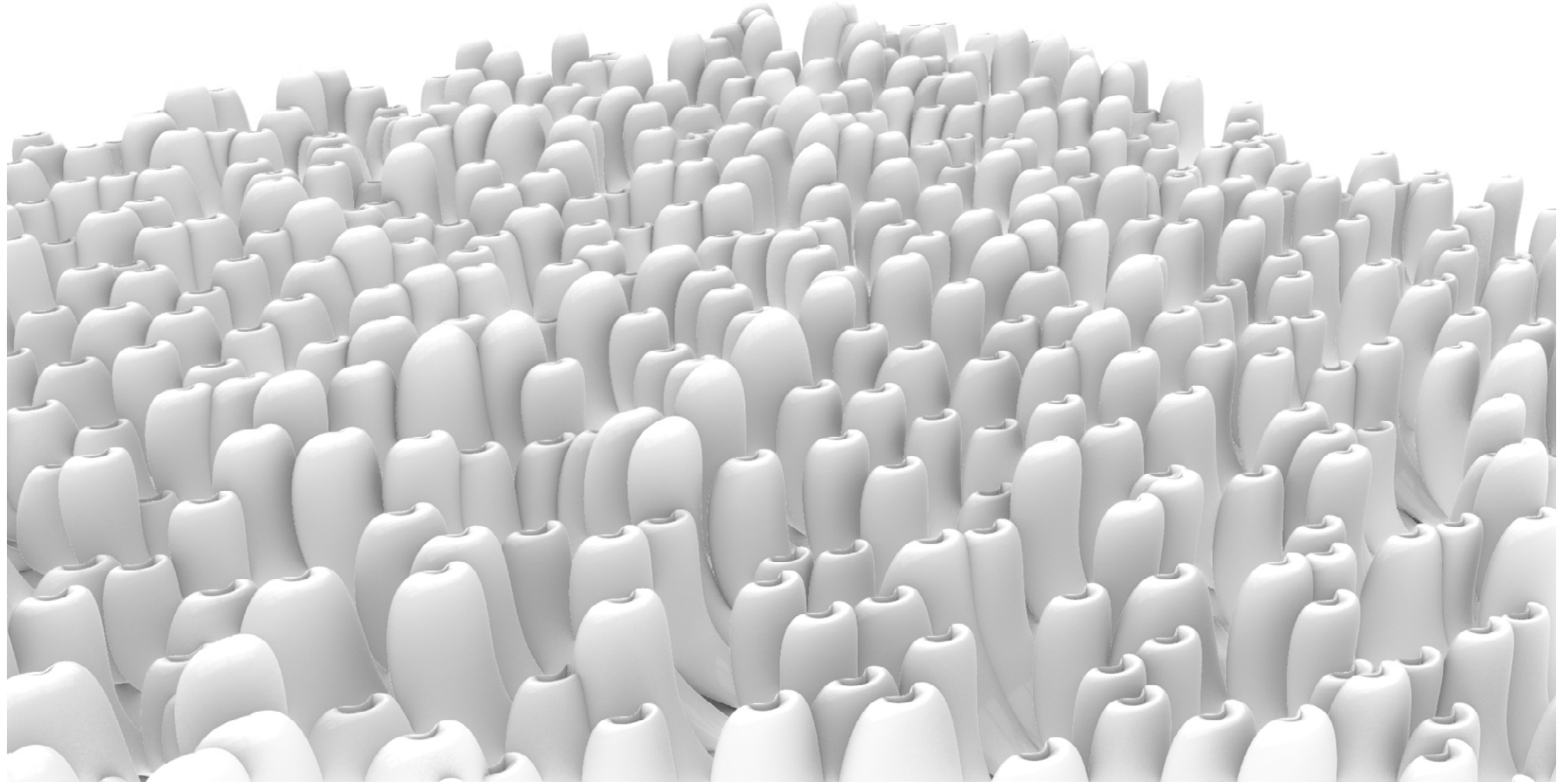
Tthe graceful movements and fluid forms of marine creatures like jellyfish, cephalopods, and rays can influence the design of organic shapes and flowing lines in architectural compositions. Their undulating motions and the way they interact with their aquatic environment can inspired me to take an innovative approaches to creating dynamic and responsive structures that harmonize with their surroundings.

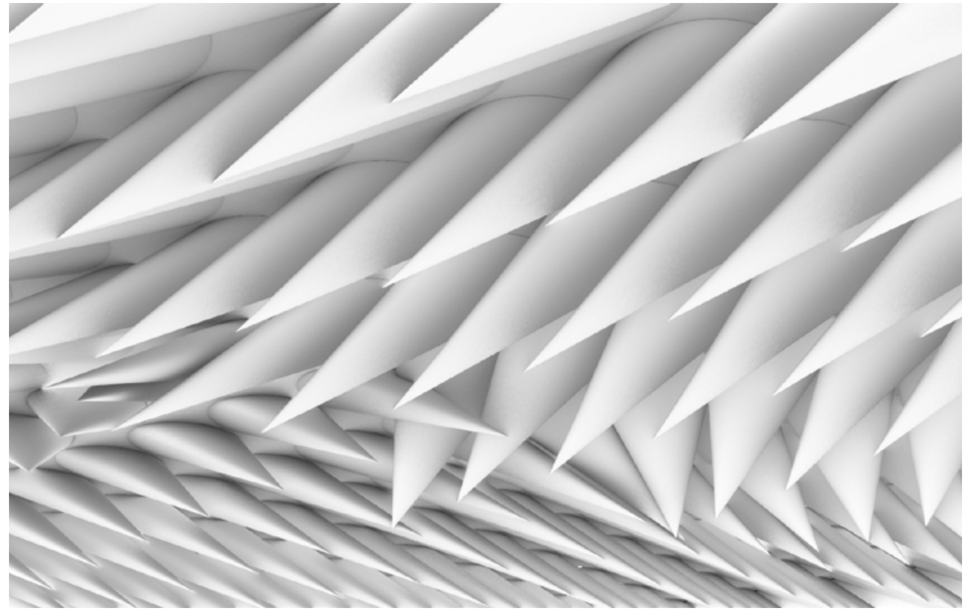




KINETIC ART INSTALLATIONS

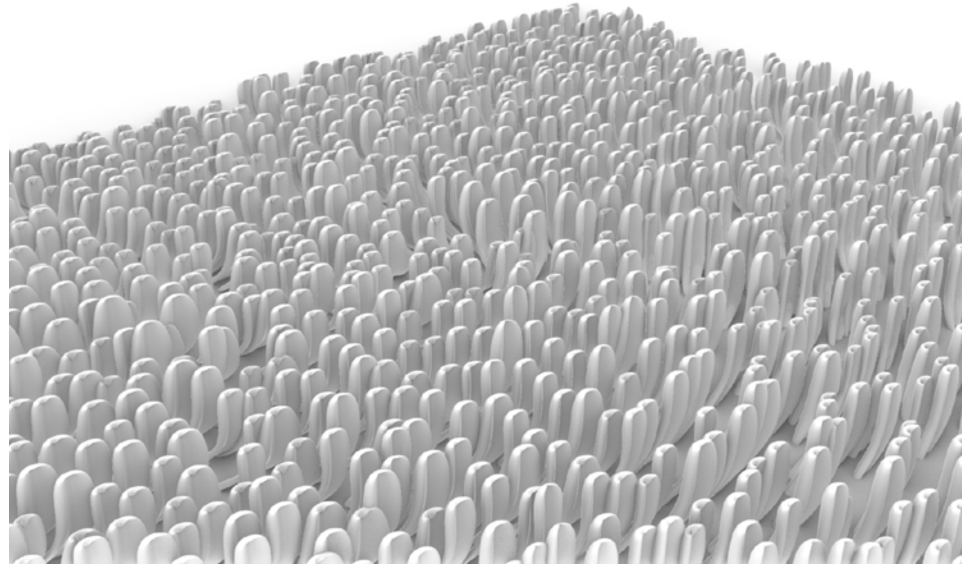
Architects often incorporate kinetic art installations into buildings to enhance aesthetics and create dynamic spaces.

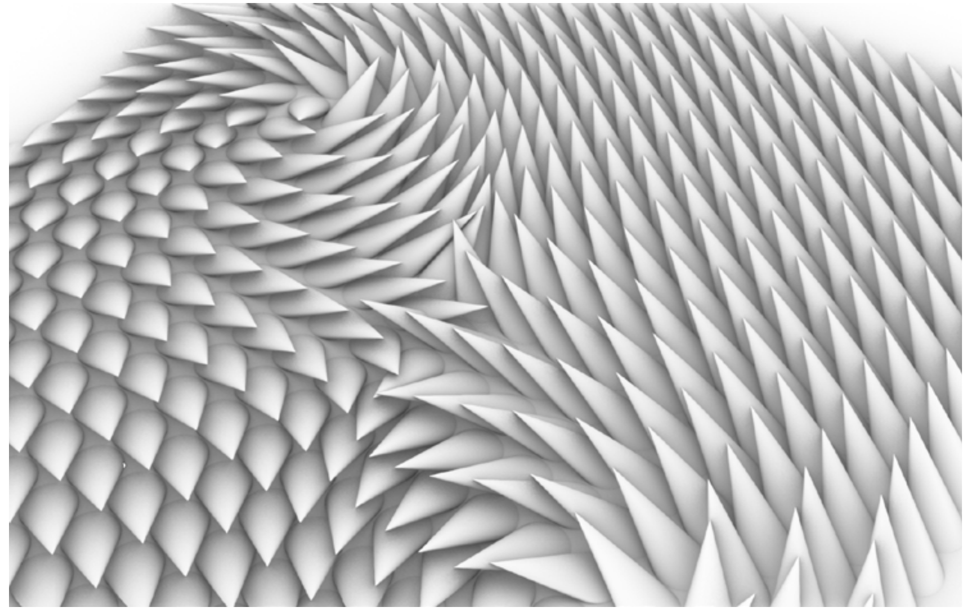


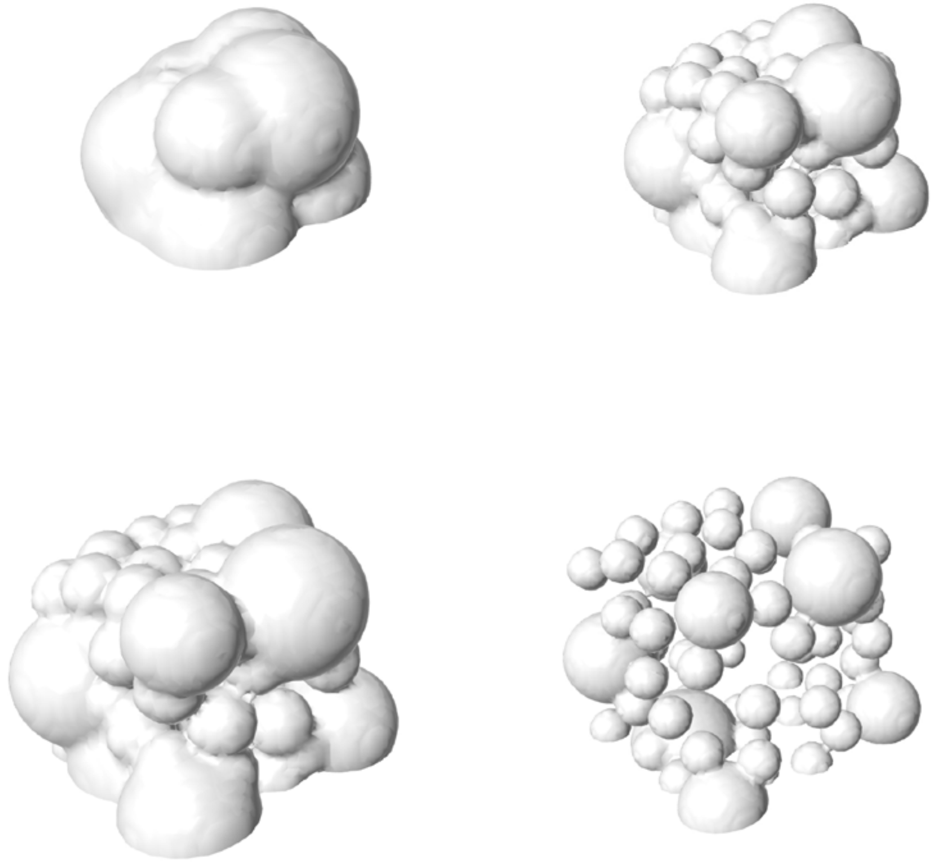


SMA wires can be used in such installations to create moving elements that respond to environmental stimuli or user interaction, adding an interactive and visually engaging aspect to architectural design.

SMA offers architects and designers a versatile and innovative material option that can be tailored to meet specific design requirements, ranging from dynamic façades to smart building systems and interactive installations. Its unique properties enable the creation of adaptive, responsive, and visually striking architectural solutions.



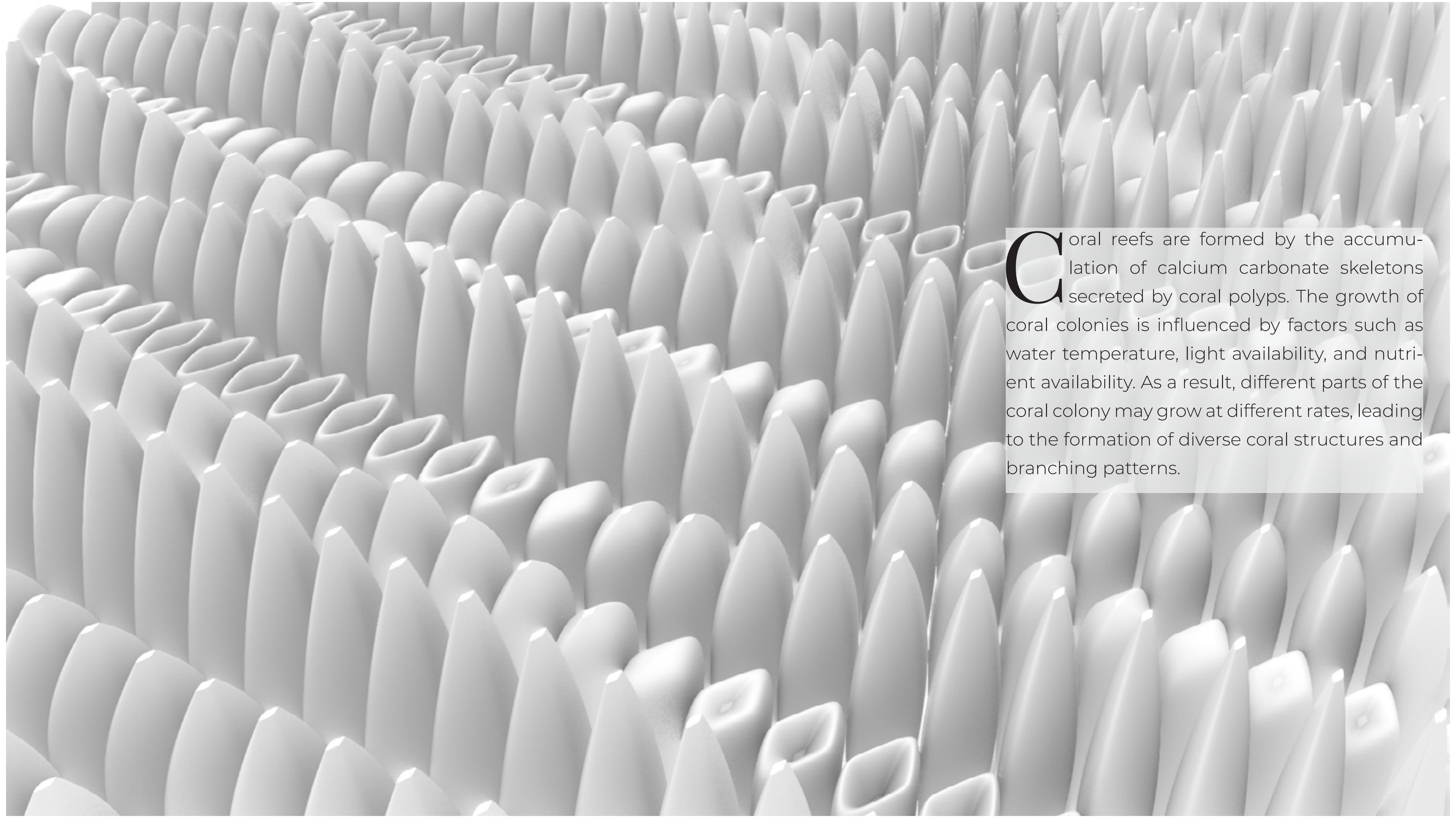




DIFFERENTIAL GROWTH

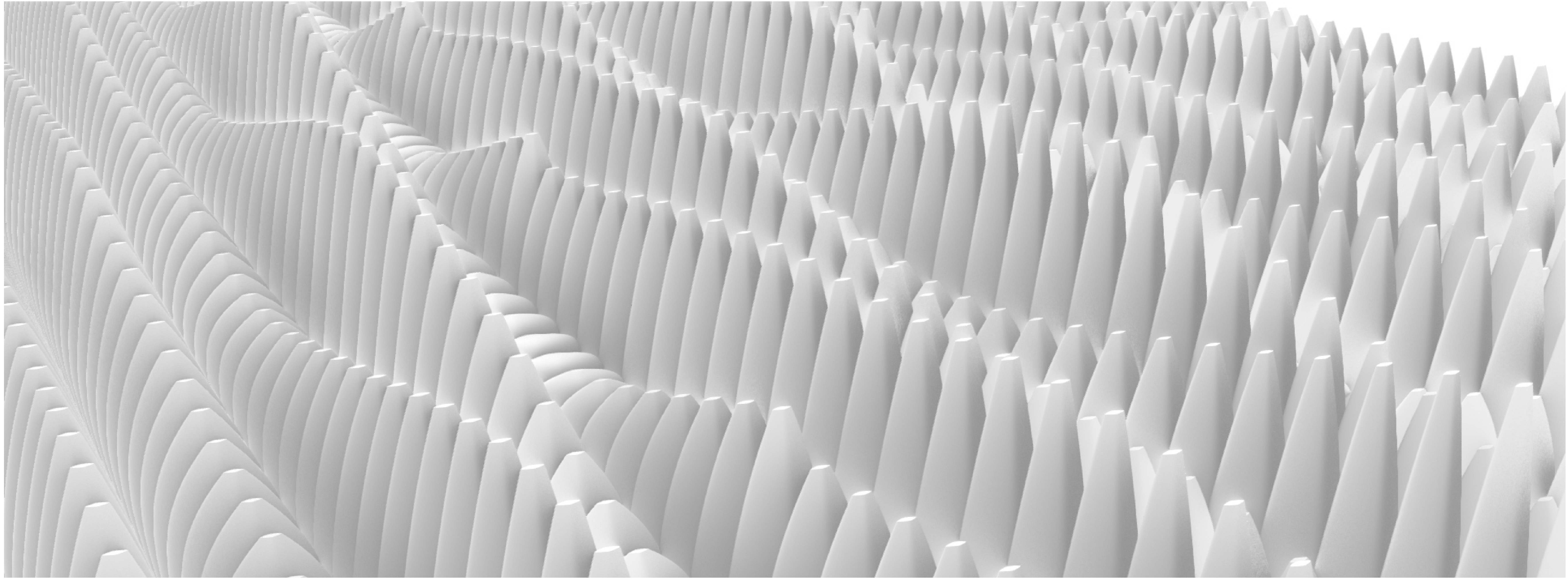
differential growth gives rise to the characteristic shapes and architectures seen in various plant species.

Differential growth is a phenomenon observed in nature where different parts of an organism grow at different rates, resulting in various shapes, patterns, and structures. This process is fundamental in the development of many organisms and plays a crucial role in their adaptation to their environment.



Coral reefs are formed by the accumulation of calcium carbonate skeletons secreted by coral polyps. The growth of coral colonies is influenced by factors such as water temperature, light availability, and nutrient availability. As a result, different parts of the coral colony may grow at different rates, leading to the formation of diverse coral structures and branching patterns.

Inspired by the intricate branching patterns and fractal-like geometry found in coral reefs, I developed an innovative architectural system that seamlessly blends natural inspiration with technology. Through meticulous computational design using Grasshopper, I generated intricate scale-like surfaces with varying z-axis depths, mimicking the intricate textures and layered growth of coral formations. This sculptural skin serves as a 3D printed facade element that not only captures the captivating aesthetics of the underwater realm but also harbors an ingenious integration of shape memory alloys (SMAs). By strategically embedding these smart materials beneath the biomimetic skin, we can unlocked the potential to imbue the structure with dynamic, lifelike qualities akin to the rhythmic movements and adaptability of living coral colonies, blurring the boundaries between the natural and the built environment.



While some industrial efforts have introduced ideas and techniques for responsive shading in constructions, resulting in the development of adaptive shading facades like those seen in the Al Bahr tower or Q1 headquarters (Alotaibi, 2015)[1], it is imperative to reevaluate current practices in responsive construction design due to several observed challenges:

(i) The fabrication of mechanisms and components required for configuring movable parts and linkage systems is intricate and costly.

(ii) Electromagnetic motor-based kinetic systems often generate disruptive noise and vibrations within the construction interior, demanding regular maintenance for reliable operation.

(iii) Reported performance assessments of kinetic designs in construction simulations often do not adequately consider actuation efficiency (output force/energy or output force/weight), neglecting the additional electricity consumed by large-scale motors and components.

Shape Memory Alloy (SMA) actuators offer a promising solution to address the existing gap in the body of knowledge within the field of architectural design.

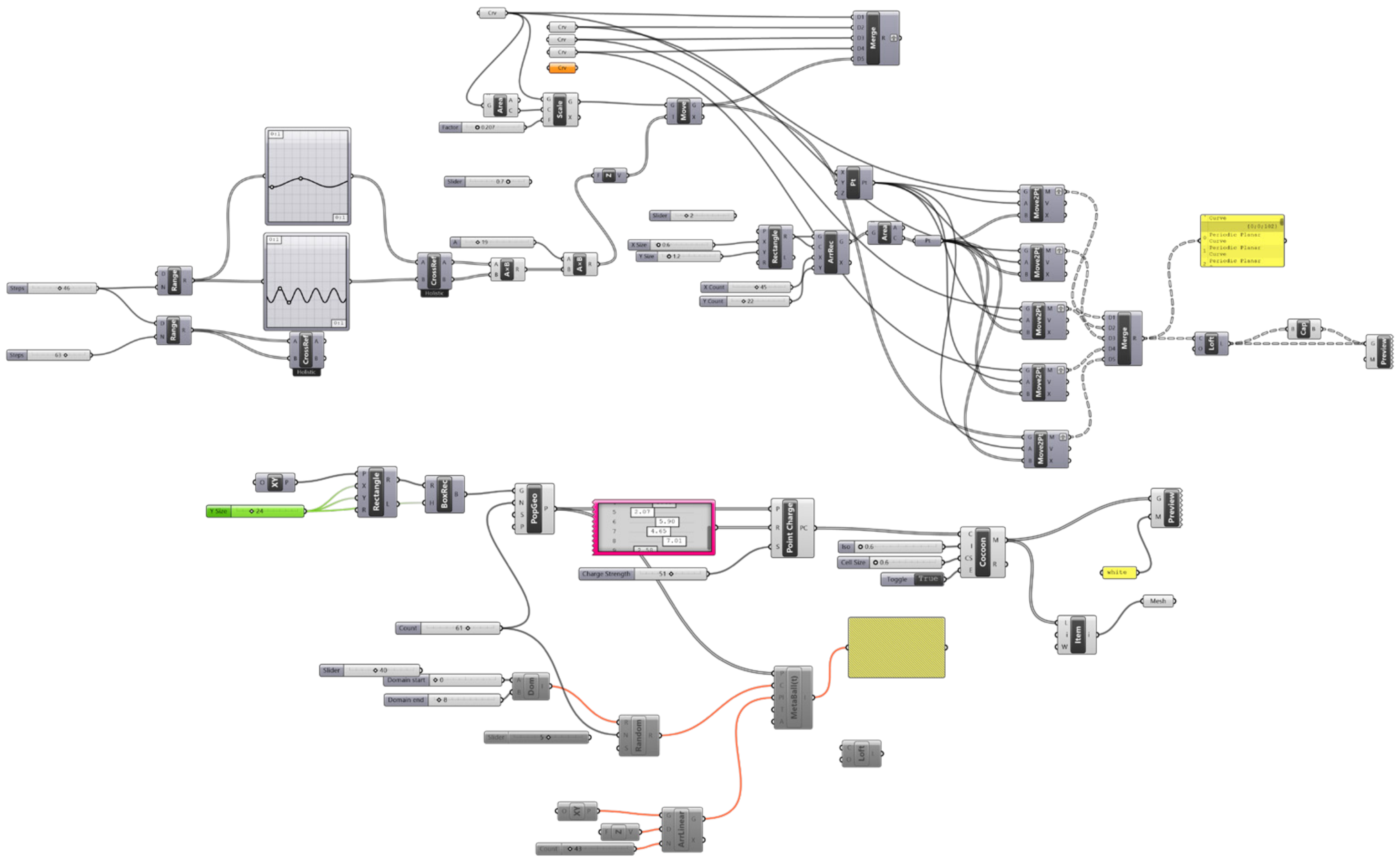
1. Sustainability and Energy Efficiency: SMAs have the potential to enhance sustainability in architectural design by enabling responsive construction components, such as facades and shading systems. These components can dynamically adapt to changing environmental conditions, optimizing energy usage and improving thermal comfort.

2. User-Centric Design: The use of SMAs in kinetic architectural elements can introduce user-centric design principles by creating interactive and adaptable spaces. This addresses the gap in providing architectural designs that respond to occupants' needs and preferences in real-time.

3. Reduced Noise and Maintenance: Unlike traditional electromagnetic motors, SMA actuators have the potential to operate silently and require less frequent maintenance due to their simplified mechanical structure. This addresses the gap in minimizing noise pollution within constructions and reducing the operational costs associated with maintenance.

4. Material Innovation: The utilization of SMAs introduces a new dimension of material innovation in architectural design. These smart materials can change shape in response to external stimuli, enabling the creation of dynamic, adaptable, and aesthetically pleasing construction components. This bridges the gap in materials research and application within architectural design.

5. Environmental Responsiveness: SMAs can contribute to the creation of constructions that are more in tune with their surroundings. By responding to environmental cues, such as sunlight, temperature, or wind, SMA-based elements can optimize energy use and reduce the ecological footprint of architectural designs.

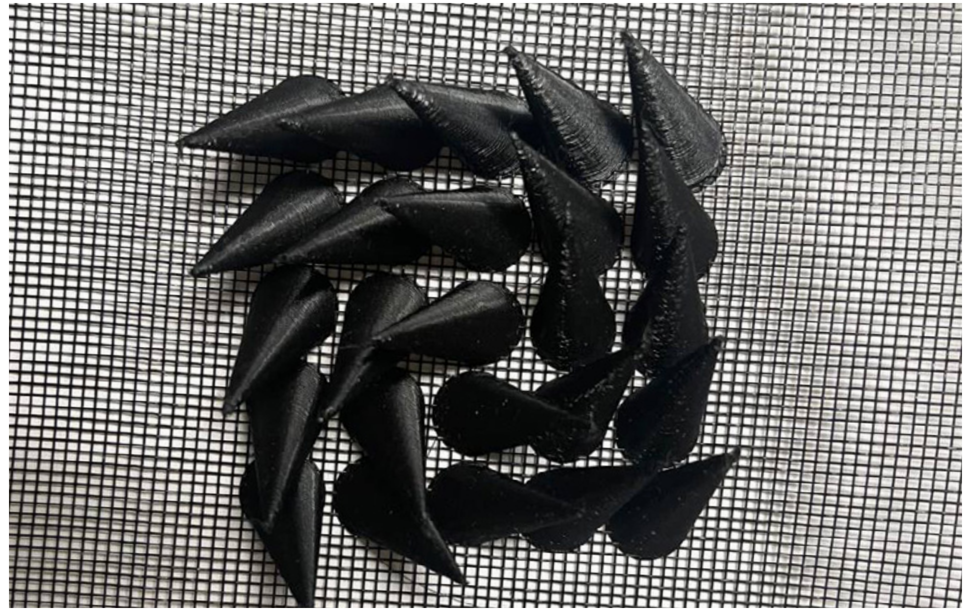


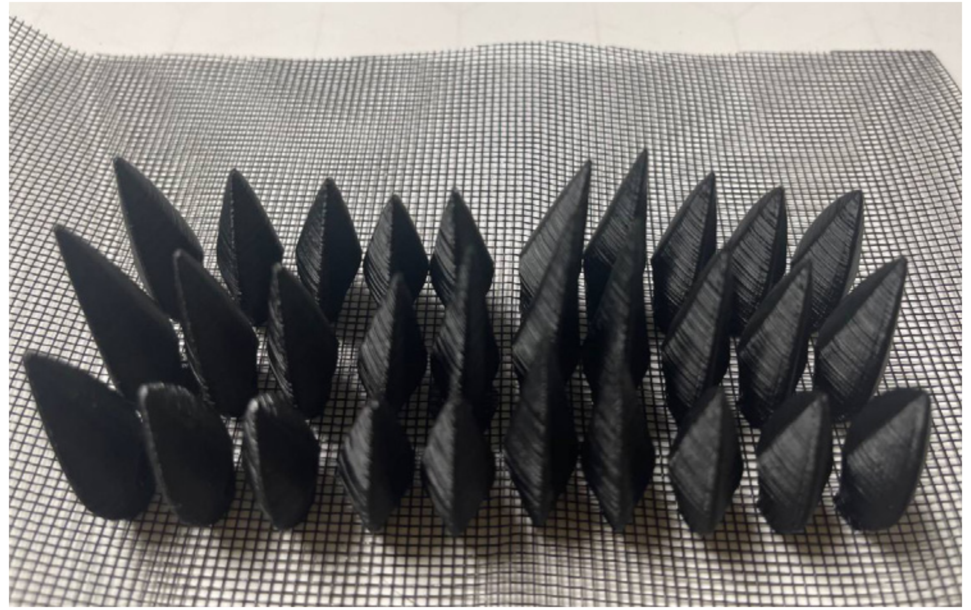
My exploration of translating nature's intricate forms and textures into architectural designs through the use of Grasshopper for Rhino demonstrates my profound understanding of the symbiotic relationship between the natural world and the built environment. By harnessing the power of computational design tools, I have embarked on a journey to capture the essence of the underwater realm and manifest it into tangible architectural expressions.

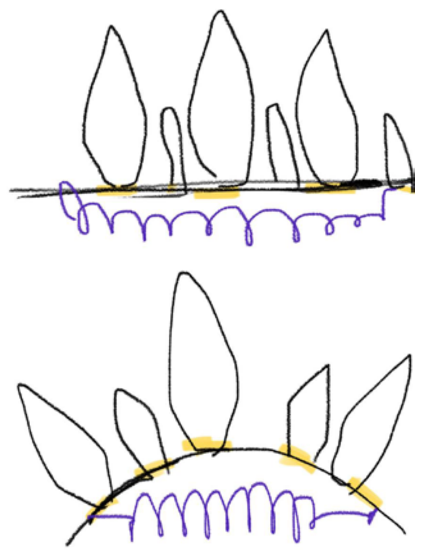
Through the creation of complex algorithms and generative scripts within Grasshopper, I have unlocked the ability to replicate the intricate branching patterns found in coral reefs, the spiraling geometries of nautilus shells, and the fluid movements of marine creatures. These algorithms serve as digital blueprints, allowing me to manipulate parameters and variables to generate a vast array of architectural forms, each imbued with the organic beauty and structural complexity of their natural inspirations.

By utilizing Grasshopper's fractal components, particle-spring systems, and agent-based modeling techniques, I have effectively bridged the gap between the digital and the physical realms, enabling me to simulate and visualize the growth patterns, interactions, and self-organizing principles observed in the underwater world. This integration of computational power and natural principles has opened up new avenues for me to create responsive, adaptive, and sustainable architectural solutions that not only captivate the senses but also harmonize with their environment.

A good bed for implementing shape memory alloys







Different growth and fractal patterns have been studied to create elements that resembles the living creature dynamics at its best..

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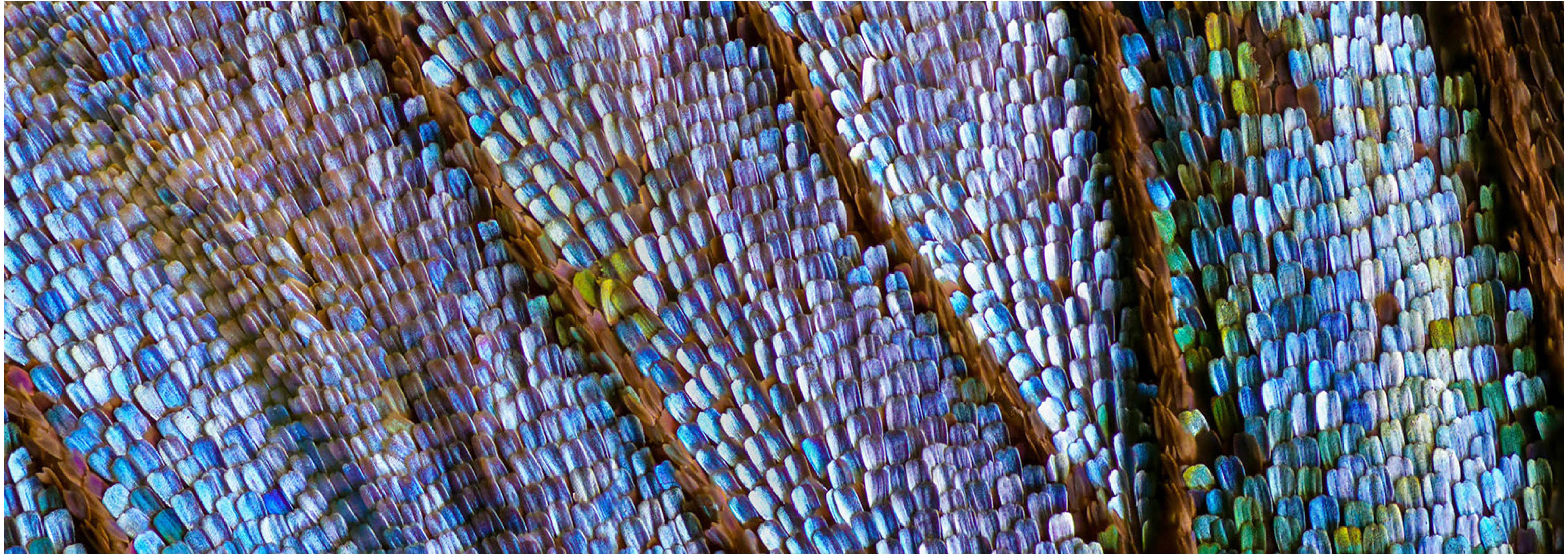
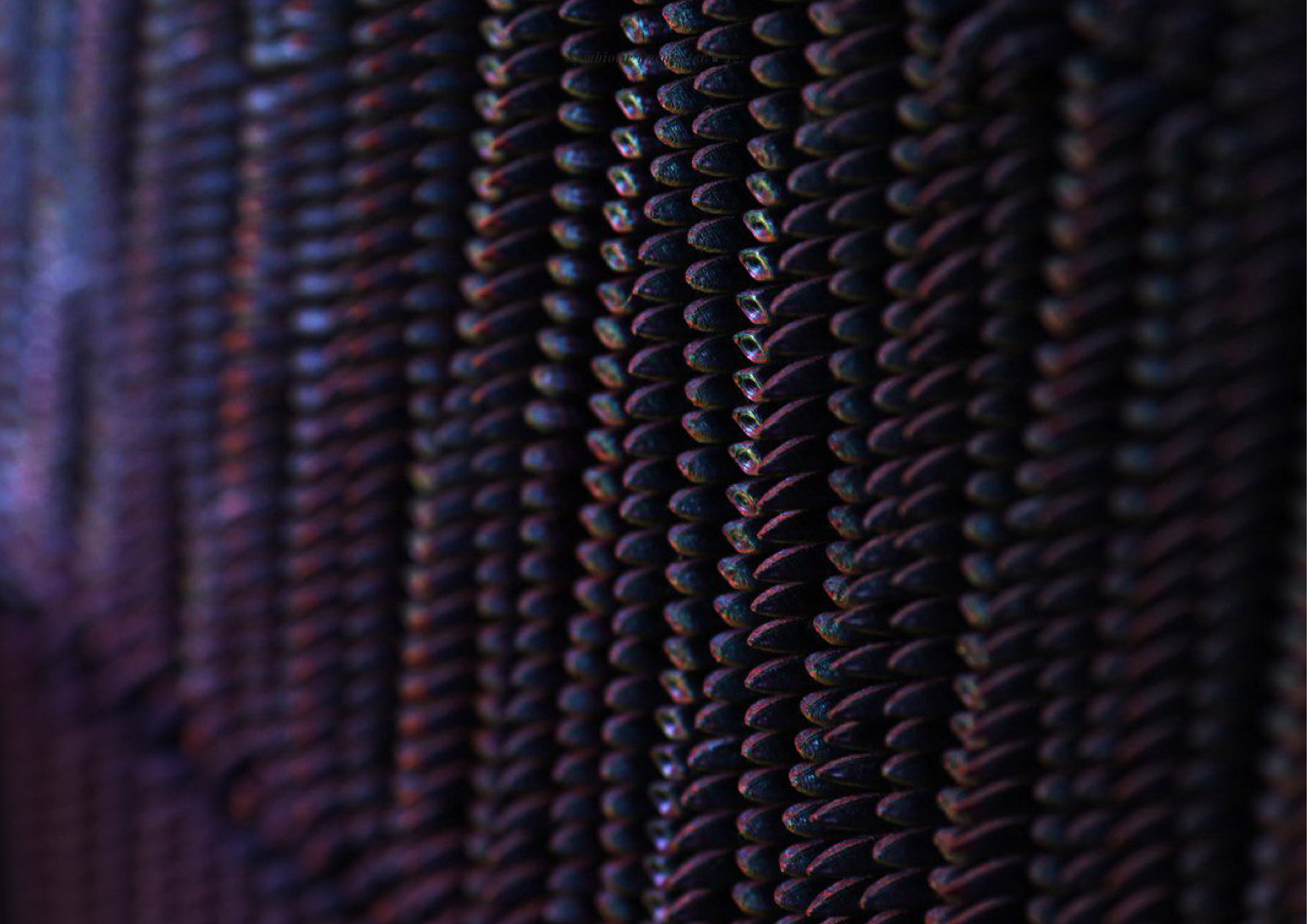
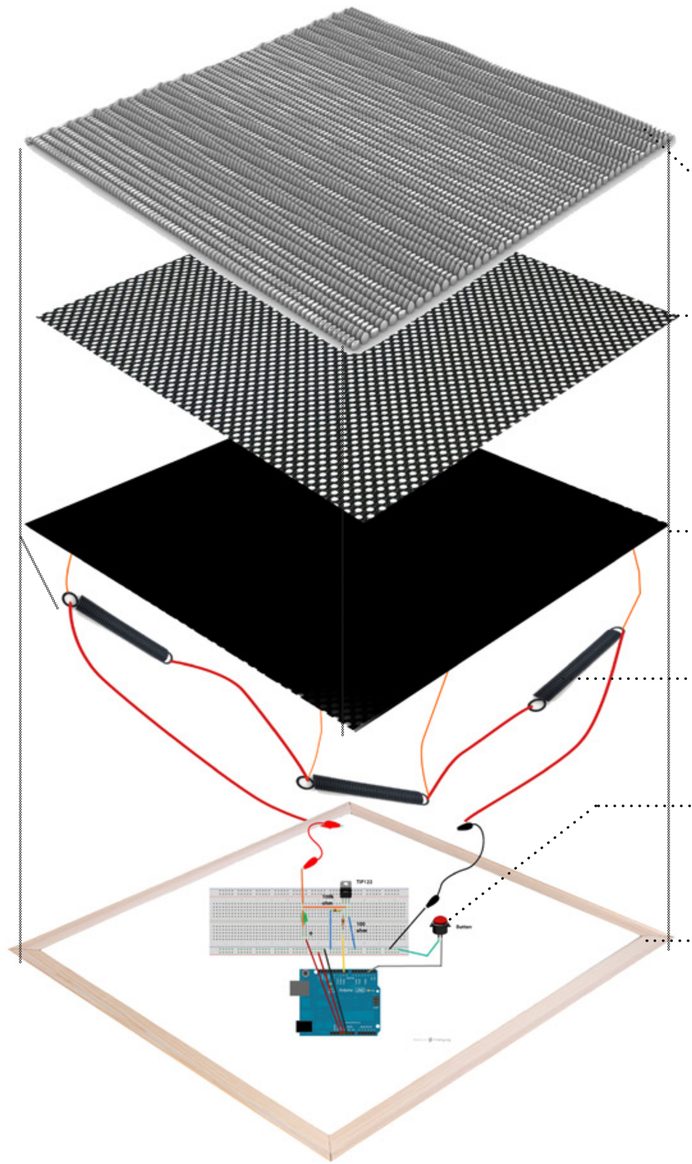


SMA can be used to create dynamic architectural structures that respond to changes in environmental conditions.





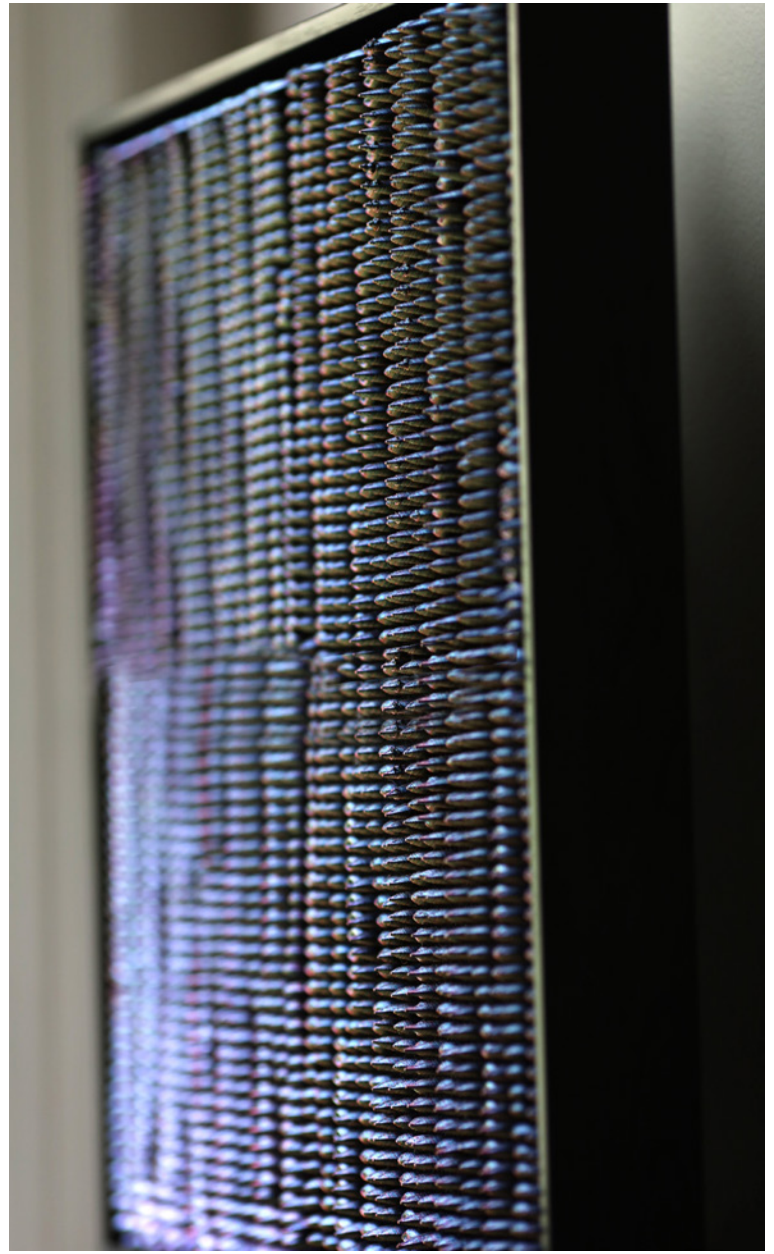
ISOMETRIC DIAGRAM

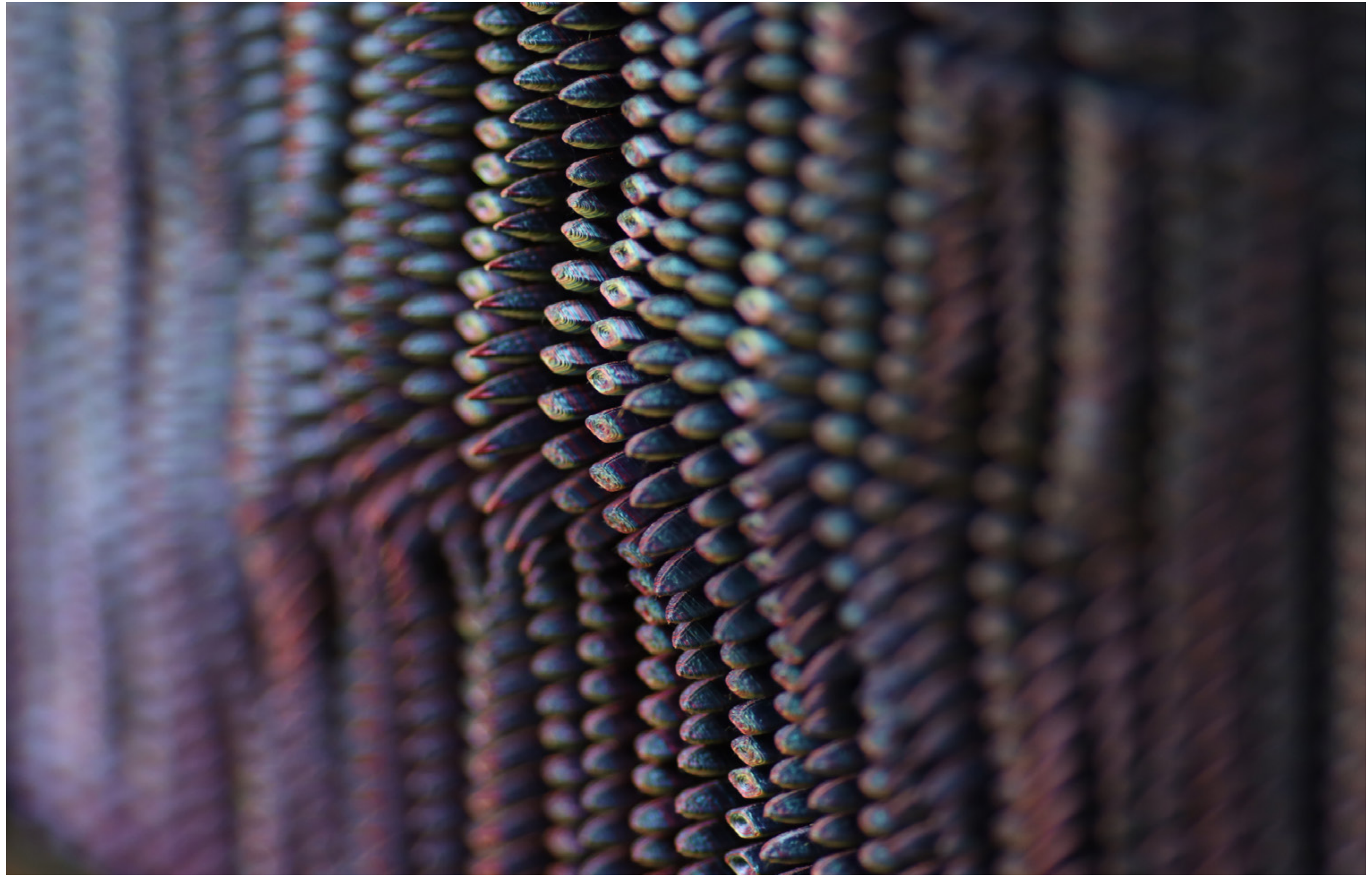
The diagrams shows layers attached to eachother to function properly

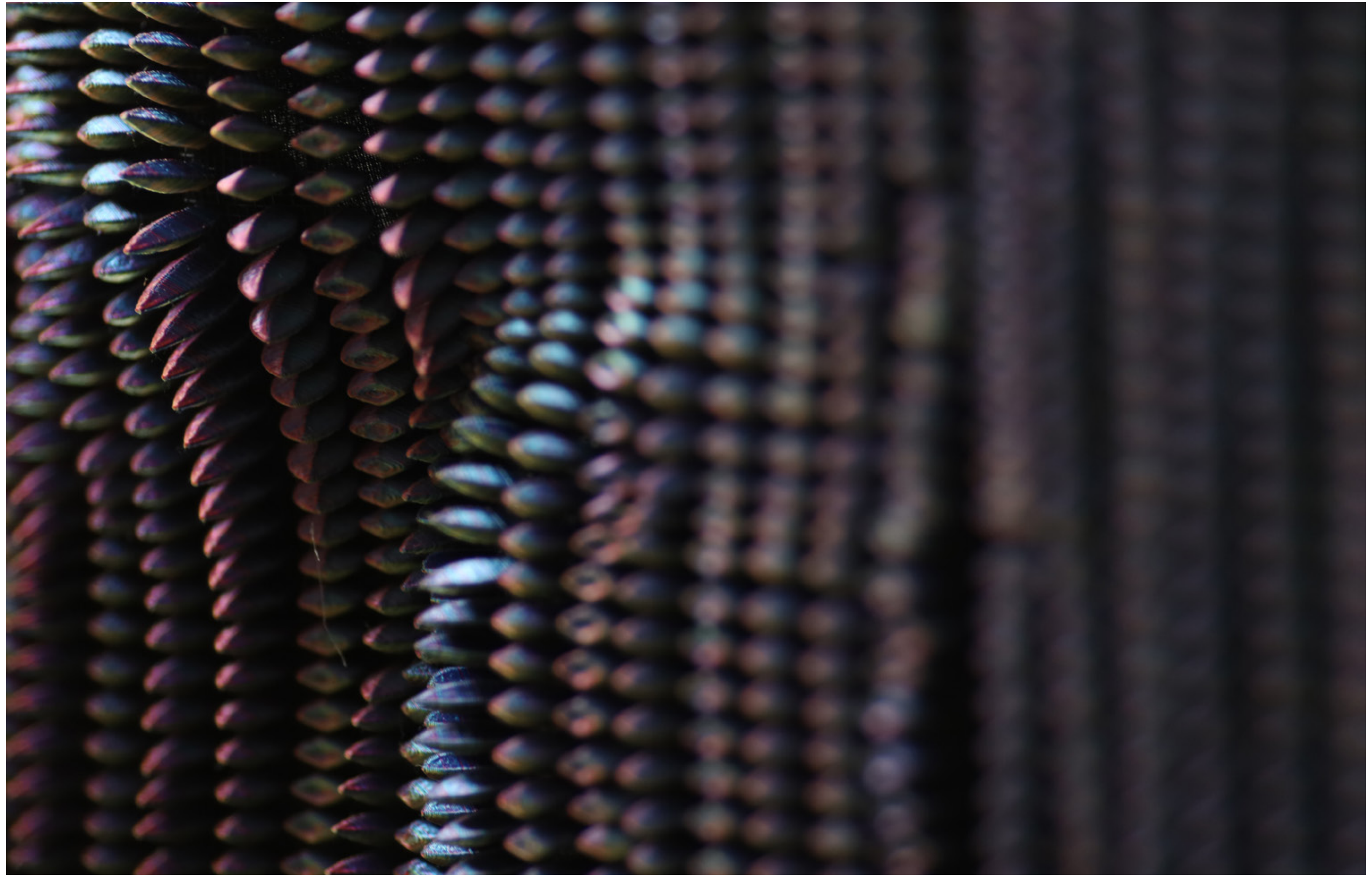
Symbiotic Encounters: A Dynamic Wall Art Installation.

The central theme of the installation revolves around the concept of symbiosis, where the boundaries between art and observer blur into a harmonious exchange. At its core is a textured surface reminiscent of sea creatures' delicate tentacles, each movement orchestrated in response to the presence of passersby.

Utilizing Shape Memory Alloy (SMA) technology, the surface of the artwork comes alive with subtle shifts and ripples, as if imbued with a lifelike vitality.







Kinetic architecture has the potential to address feelings of loneliness and solitude by creating dynamic, responsive environments that acknowledge and engage with individuals in meaningful ways. By fostering a sense of presence, enhancing emotional connection, promoting social interaction, and encouraging mindfulness, these interactive architectural elements can play a transformative role in shaping more inclusive and supportive built environments.

A responsive wall that detects and reacts to the presence of individuals can create a sense of acknowledgment and validation. As individuals approach the wall, its movement or greeting serves as a tangible response to their presence, affirming their existence and fostering a sense of connection with the space.

Interactive architectural elements that greet individuals upon their arrival home can evoke feelings of warmth, comfort, and welcome. By acknowledging individuals as they enter a space, these gestures imbue the environment with a sense of hospitality and companionship, mitigating feelings of loneliness and isolation.

SMAs could be employed in responsive interfaces that interact with occupants in a more nuanced manner. For instance, SMA-based surfaces could detect changes in temperature or pressure, allowing them to adjust their texture or curvature to provide tactile feedback or enhance comfort. Such responsive interfaces could create immersive and engaging environments that foster emotional connection and well-being.

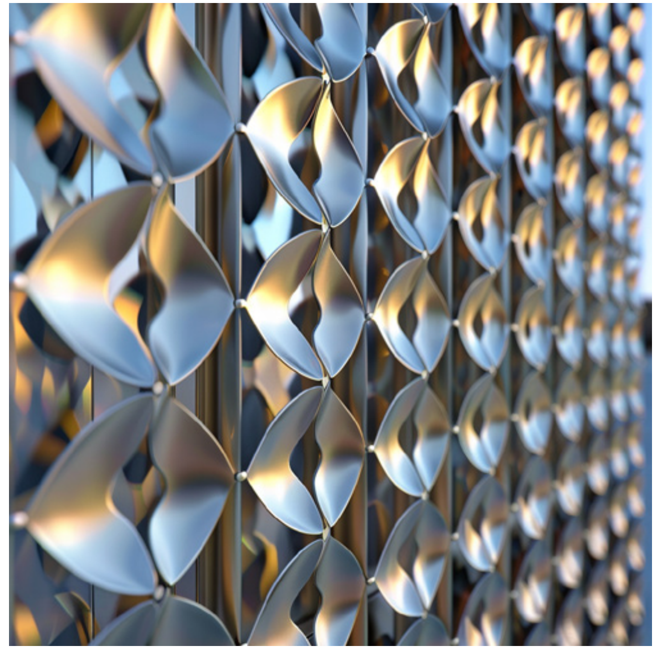
a dynamic wall empowered by Shape Memory Alloys (SMAs) and equipped with sensors that keenly detect human presence. This innovative wall not only perceives your arrival but responds with subtle movements, gracefully adjusting its form as you approach. Picture it as a personalized greeter, welcoming you home by name, an empathetic gesture that transcends the conventional boundaries of architecture. This interactive integration of SMAs and sensor technology serves as more than just a physical entity; it becomes a companion, alleviating the sense of loneliness by acknowledging and engaging with you in a meaningful and intimate way.

WALL ART PIECE IN THE HALLWAYS OF A HOSPITAL

FALSE CEILING IN AN AIRPORT

EHIBITION

CEILING ARTPIECE IN A CONFERENCE ROOM



RESPONSIVE PASSIVE SHADING REACTING TO TEMPERATURE

TENSILE EMBODIMENT

THE WAYS SMA ACTUATORS CAN COME TO ARCHITECTURE

SMA characteristic enables different uses in built environments.

Shape Memory Alloy (SMA) holds immense potential in revolutionizing architectural design by seamlessly integrating dynamic functionality with aesthetic appeal. In urban landscapes, SMA can be employed in exterior facades to create passive shading systems that delicately adjust in response to temperature changes, optimizing energy efficiency while enhancing occupant comfort. Furthermore, SMA actuators can be utilized to sculpt light and shadow across minimalist facades, transforming static buildings into dynamic, interactive structures that engage with their environment. Whether it's through the creation of mesmerizing kinetic installations inspired by natural phenomena or the implementation of sustainable shading solutions, SMA represents a paradigm shift in architecture, where buildings become not just inert structures, but living, adaptive entities that harmonize with their surroundings.

"Symbiotic Encounters." This creation seamlessly merges technology with organic aesthetics, inviting viewers into a captivating dialogue with the artwork itself.

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