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# Integrated Sustainability in Developing Smart Clothing Based on Bionic Design Process

**Hao Zhang** [1], **Xiaoping Zhou** [2*]

[1] Xiamen University of Technology, Xiamen 361024, China
[2] Xiamen Institute of Technology, Xiamen 361021, China
*Correspondence: zhouxiaoping925@163.com

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**Abstract:** ***Background:*** The recent coronavirus epidemic over the past three years has significantly impacted people's perspective worldwide. People have become more attentive, specifically on environmental protection issues. ***Purpose:*** This paper aims to develop smart clothing through the biomimetic design process to increase sustainability in the garment industry. ***Methods:*** The literature review analyzes the reasons why smart clothing is difficult to design and develop, as well as the reasons why consumers are hesitant to wear it from their perspective. ***Results:*** The results of the survey show that dynamic simulation of smart clothing can increase the sustainability of clothing in terms of its time of use and aesthetic appeal. In this study, the reactions and morphologies of two natural plants, pine nuts and mimosa, were studied in relation to external changes. Through data inquiry and simulation, the results that can be reproduced in the change process were determined. The significance and value of this study is highlighted through structural changes. The weight and volume of such smart devices are reduced by the use of shape memory alloy (SMA) metal in the design, which minimizes energy consumption during change and movement. Based on the principle of biological change structure and dynamic morphological change process, the dynamic biomimetic design method is intended to mimic morphological and dynamic changes. Finally, 3Dclo software simulates the effect, thereby saving a lot of time and resources. ***Conclusion:*** Dynamic intelligent clothing design based on biomimetic design process can be realized, and it can be applied to the sustainability of clothing.

**Keywords:** Bionic design process, Sustainability, Smart clothing, 3Dclo, Shape Memory Alloy (SMA), Transformable design

## 1. Introduction

### 1.1 Research Background

"Green", the so-called "bionics" refers to the imitation of information extracted from the living organisms' functions, structures, and movement principles. "Biomimicry" is a discipline in which bionics experts systematize bionic knowledge through careful observation and selective extraction (Wan-Ting, 2009). Green plants are considered the most important structural and functional elements in terrestrial ecosystems. Therefore, many plant structures or forms are used as bionic elements by scientists or artists. In the fields of art and design, the term "bio decoration" refers to decorative elements that are non-functional but visually appealing. This quote shows the origins of biology by providing a variety of biological examples. Barthlott's statement provides a theoretical basis for the bionic design of smart clothing (Barthlott, 2016). Through research on regional fashion trends, we conduct an in-depth analysis of the design features and consumer responses of smart fashion products. This approach deeply integrates the focus and core values of wearable research into users' daily lives and demands. The harmonious combination of functionality and design allows the users to communicate emotionally with those around them. The aesthetic perspective in smart fashion is also taken into account, and it developed into the most natural fashion item (Sung-E, 2015).

The production of traditional clothing produces large amounts of water pollution and carbon emissions, while the disposal of large amounts of clothing at the end of their useful life generates land pollution, air pollution, and greenhouse gases. The shortage of raw materials and energy resources and the diversification of customer needs have led to the need to optimize multiple criteria within a sustainable range when selecting materials. Systematic and holistically sustainable product processes are needed (Pascal, 2017). The field of smart clothing also requires sustainable processes, and the spread of sustainable concepts can even accelerate the spread of smart clothing. Using bionic fashion design can fully stimulate people's interest in endangered plants and ecological changes. At the same time, through the integration of bionic and smart clothing, the practicality and artistry of clothing can be increased, resource consumption can be reduced, and fashion can become the core of smart clothing. Most materials today can be recycled. The design of bionic clothing is more artistic than traditional clothing even without smart clothing components.

Clothing bionic design principles include the following processes: determining the prototype, selecting the bionic design angle, formulating a detailed plan, and establishing a design sequence for executing the plan (Chang, 2017). This paper identifies two biologically inspired design processes. A pinecone bionic design was created using bionic morphological imitation. The bionic design of Mimosa is based on bionic functional mimicry.

### 1.2 Research Purpose

This study aims to illustrate that the study of various parts or systems of organisms is a necessary means to imitate biological data. On the other hand, imitating biological behavior is also positive for biodiversity. This has huge implications for the sustainability of smart clothing. First, the lack of research on dynamic aesthetics based on bionics makes this research important and can arouse people's interest and inspiration through dynamic imitation. Second, how technology and scientific cognition satisfy aesthetic emotions through the bionic design process to express integrated sustainability in fashion design.

### 1.3 Research Objective

Based on bionic fashion design, it can fully arouse people's interest in endangered plants and ecological changes. At the same time, the integration of bionic and smart clothing can increase the practicality and artistry of clothing, reduce resource consumption, and promote fashion to become the core of smart clothing. Most of today's materials can be recycled. Even without smart clothing components, bionic-based clothing design is more artistic than conventional clothing design.

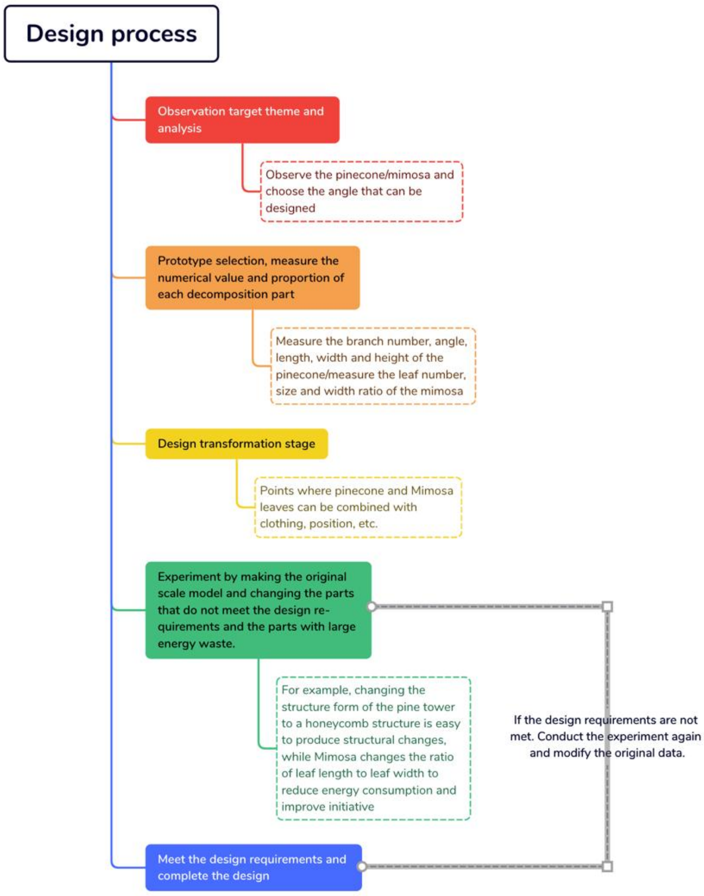


Figure 1: Design process.

### 1.4 Research Methods

Based on observing the target theme of pinecone and mimosa and analyzing it, we choose the angle that can be designed. The second step is to select the prototype and measure the values and proportions of each decomposed part. Such as the number of branches, angles, length, width, and height of the pinecone as well as the number, size, and width ratio of the mimosa leaves. Next, the design transformation stage is initiated, during which pinecones and mimosa leaves can be combined with clothing, postures, and other elements.

Afterward, experiments were carried out by making original scale models to modify the parts that did not meet the design requirements and consumed a lot of energy. For example, changing the pinecone to a honeycomb structure is likely to cause structural changes, while the mimosa changes the leaf length and leaf width ratio to reduce energy consumption and increase initiative. The design is finalized if the design requirements are met; otherwise, the experiment is repeated, and the original data is modified.

The bionic engineering design process is applied in the field of fashion design, with a specific emphasis on the development of smart clothing designs that are deformable. In the development of fashion designs, the aesthetic aspects are given importance, while the scientific and analytical aspects are given less attention than any other engineering research paper. This is the human factor in design.

## 2. Literature Review

### 2.1 Research Trends

The initial design plan was based on the characteristics of memory metal itself, but we consistently failed or encountered the problem of insufficient aesthetics. From an aesthetic perspective, we conducted numerous article searches using tools such as Scopus, easy Scholar, and Google Scholar.

Transformation refers to "a change or modification in shape or form". Although it can be used to modify the form, it is a vague image that encompasses a range of ideal types that are different from the original object or universal image. After the modernist era of mass production, postmodernist society has reached a stage where it is difficult to create new styles and new types due to the development of diversified aesthetic consciousness. The "Cross Over" is an active form that adapts to the situation and the style change process, combining multiple styles (Lim, 2015).

Transformable clothing is more sustainable than other clothing designs, and given its versatility, clothing that is designed to easily change its appearance may encourage consumers to buy fewer items of clothing. Furthermore, giving users the ability to influence the design of clothing may make them more attached to the clothing, thereby delaying their psychological obsolescence (Osmud, 2016).

Smart clothing has relative advantages such as visibility, complexity, health utility, manageability, stability, comfort, aesthetics, and fun (Jeong, 2016). Smart clothing is defined as textiles that combine IT technology with cutting-edge textiles and use sensing and response systems to respond to environmental or human body stimuli. Other terms such as wearable computers, digital clothing, and smart clothing are used interchangeably (Kwon, 2017). In various interviews conducted in the United States, women expressed interest in the ability to effortlessly transform from one type of clothing to another (Peter, 2018). Although the safety and functionality of these smart garments have been demonstrated, consumers refuse to use them. Usability refers to the extent to which consumers can use a product or service as well as an important factor affecting the resistance to smart clothing innovation. Consumers have also observed that refusing to use smart clothing is an act of resistance to innovation; many people say they will not buy smart clothing unless there is a reliable brand that produces smart clothing with appropriate functions and at a lower price. Some refuse to buy smart clothing because of aesthetic dissatisfaction, despite improvements in quality and performance. These results suggest that manufacturers or designers should consider which features or technologies are suitable to use in clothing while ensuring the availability and style of multiple designs (Ju, 2020).


Figure 2: Research trends in deformable smart clothing

### 2.2 Classification of Research on Changeable Clothing

A search was conducted on internet websites and foreign academic journals to study how deformable clothing design has changed. The search obtained, electric models, air pump closed space movement types, and shape memory alloys that undergo thermal deformation, chemical changes, and other methods. Shape memory alloys have attracted attention due to their excellent response to speed, extremely lightweight, and extremely small size.

Since the electric motor and air pump require separate external equipment, the weight and volume must be greater than those of the base alloy and chemical reaction. A rotating motor moves a skein of thread in an electromechanical device, and the motor's speed determines the rate at which the other end of the thread moves to change a variable part. The air injection device uses an electric motor to drive fan-shaped blades to inject air into a closed space (such as an Air Pack, PVC, or 100% PVC Monogram canvas), expanding the originally dry space, and causing spatial and visual changes. Shape memory alloys have relatively fast reaction rates because of direct heating.

Changeable clothing can translate its aesthetics and functionality into a variety of looks and functions, catering to a variety of consumer needs and providing a potential paradigm shift. Increased versatility in the design and use of changeable tops is a key variable in increasing changeability and clothing life cycle sustainability. By analyzing the aesthetic attributes of clothing, designers can expand their understanding of variable design, and comprehend the content and types of variability in consumers' wardrobes, as well as the content and usability of clothing. Dresses were another type of clothing that attracted the interest of participants. Further research into transformable clothing will accelerate its development and consumer adoption (Helen Sumin Koo, 2014).

Variable garment design is an ongoing fashion option that reduces overall garment consumption by changing, reorganizing, or exchanging garment components. It can act as an active agent of ecological change by allowing consumers to directly participate in the design process (new design) and engage in sustainable practices (Osmud, 2016).

The technology acceptance model for adopting modern innovations in clothing, proves the importance of the multi-dimensionality of smart clothing, focusing on functionality, expressiveness, and aesthetics, combined with consumer needs, emphasizing the shift from technical issues to user-centeredness (Chanmi, 2016). Smart clothing must have clear aesthetic characteristics, be attractive, and be compatible with current fashion styles so that consumers do not lose their sense of fashion while using advanced technology.

By identifying the differences between user needs, consumer needs set by designers, and design purposes, it is concluded that non-cumbersome, fashionable, and comfortable are the most important user needs, and attract participants' attention from the aesthetic point of view, which is a form of participant intelligence. The most important factor in clothing purchases, but also an important reason, suggests that designers' inaccurate market research and academic bias in subsidized pursuits that fail to understand consumer needs can distance participants. Many academic journals focus too much on academics, and the intermediate logic is biased towards function and technology, causing conflicts between academia and the market, and is not conducive to the transformation of fashion and technology (Anna, 2017).

Table 1: Summary of Literature Features

| Research Direction | Reference Content | Trait |
|---|---|---|
| Kinetic energy | Summarizes the advantages and disadvantages of various kinetic energy devices or materials. | A comprehensive summary of various kinetic energy devices or materials. In terms of reaction rate and shape, memory alloys are excellent. |
| Aesthetics | Analyzing aesthetic attributes expands designers' understanding of variable design. | Discussed the variable types of clothing from a consumer perspective, such as tops, dresses, etc. |

| | | |
|---|---|---|
| Sustainable | Transformable clothing as a sustainable fashion option | Involve consumers in the design process to increase the positive factors of ecological change |
| Technical | Demonstrating the importance of multi-dimensionality in smart clothing using the Technology Acceptance Model. | User-centered and requires clear aesthetics. |
| Marketability | Identifying user needs based on aesthetics is an important factor in purchasing | It elaborates that logic is biased towards function and technology, causing conflicts between academia and the market, which is not conducive to the transformation of fashion and technology. |

## 3. Methods and Materials

The possibility of creating new structures is much lower than the benchmark structures in nature. Biological or organic design is a popular approach that refers to the advantages and functions of organic organisms in nature. It is the natural behavior of human beings to observe, recognize, utilize, integrate, and imitate man and nature. At the same time, human beings observe nature, imitate natural curves and natural geometric shapes as a form of worship, and thus produce a natural form of imitation. The characteristics are that human beings are not satisfied with the simple imitation and reproduction of nature, but seek the laws of nature, as well as abstract changes in abstract forms, irregularities after artificial processing, nonlinearity, post-structuralism, multiplicity, and other characteristics. Dimensional characteristics can be summarized into four characteristics as per the advancement of geometry: functional and fluid characteristics beyond natural forms; the relationship between man and nature caused by human problems such as environmental problems, natural disasters, and diseases; interaction with peaceful thinking; and spiritual calmness.

Except for Ying Gao, all the organic fashion designers currently available are stagnant in the stage of imitating nature. Like Guo Pei Couture SS18 Paris, although the Organic-botanic baroque designs mimic the form of plants very well and combine with Baroque artistic techniques to add artistic value to clothing, it also lacks the visual sense of biological movement (Figure 3).

However, this inflatable concept gives life to clothing and gives people a visual impact similar to Ying Gao's work from 'Walking City' (Figure 3). Design methods have been developed for transformer styles that aim to summarize organic design characteristics. Like living organisms, the imitation of nature, the purification of function, the change of form, and the response to the surrounding environment are all sustainable.

Figure 3: Organic-botanic baroque designs at Guo Pei Couture SS18 Paris. (Left)And “Walking City” of Ying

Gao by 2009s

Figure 4: Anouk Wipprecht Robotic Spider Dress, 2013 (left). And Ying-Gao, Super Organza Dress, 2013

Produced in collaboration with engineer Daniel Schatzmayr Anouk Wipprecht's latest techno-couture dress spied on the wearer's shoulders. Figure 4 illustrates the robot wearing a spaid dress. Something is applied to a model that looks like it is in a sitting position. The robot's limbs move, to see the wearer when you approach too closely. People dance around the wearer's body with abrasions while shouting. It stimulates curiosity (Wipprech, 2013).

The series, consisting of two dresses made with a light-emitting thread and nested eye-tracking technology, reacts to the gaze of viewers (Figure 4). Although the picture is "torn" by the flickering eye, the concept of existence and the concept of extinction are questioned because the experience of light-dark distribution consists of an unfixed gaze (Ying-Gao, 2013).

In human factors research, guardians and teachers of children with Autistic Spectrum Disorders (ASD), Seasonal Affective Disorder (SAD), and other diseases immediately change the appearance of their clothing to attract the child's attention when the child cannot control their emotions, which can be helpful for the child's emotional stability. The order can be changed multiple times according to the intelligent programming method. The duration of use may be extended by the therapeutic effect (Duvall, 2016). The usability and functionality of SMA in this article have been fully certified, and numerous modifications can be achieved by using only the natural physical properties of SMA. In this article (Wang, 2020), a fashionable dynamic effect is generated by the combination of two memory alloys that move up and down on a plane.

### 3.1 Design 1. Pinecone-inspired Design

After examining several plants and animals in nature, I found that pinecones and mimosas have similar characteristics. Among the plants that I was familiar with as a child, the one that impressed me most was the pinecone that changed shape after planting. Furthermore, I often encountered these plants in my living environment. The shape of pinecones before and after they fall is also very different (Figure 5). Upon closer examination, the layers are discovered to be entangled. This form is very similar to a honeycomb structure. I wondered if the honeycomb shape could be applied to the shape of pinecones.

Figure 5: The shape and structural extension design of the pinecone before and after falling.

The quantitative analysis of pinecone morphology refers to the method (Liu, 2016) to obtain the average value of spherical pinecone morphology. According to the 5 groups of pinecone morphology modeling data, the average values of D+E are 18mm+7.4mm=25.4mm, (Figure 6). The 5 groups of pinecone morphology radius and pinecone morphology average values are (a: 22/40 b: 24/42 c: 25.2/52 d: 27.7/46 e: 27.7-27.7) sample size, calculated by the method. The aspect ratio is 0.55. In addition, it is found that the number of angle structures between the pinecone leaves and the core is 7 (Figure 6). The reference scale (calculation explains why the sample is sewn into 7 rows of horizontal stripes), the angle structure spacing is set to 5cm (Figure 6), the length of part C should be between 9 and 14, and when the structure length is set to 40cm, the longest structure radius (1/2A) is designed to be 22cm, and the plan view of the structure is determined.

The pine tower consists of eight angle structures, each angle 45 degrees (Figure 9) and 180 degrees 4 angles, should be sewn test, every 45 degrees angle at least 4 planes. To expand 180 degrees, there must be at least 16 planes.

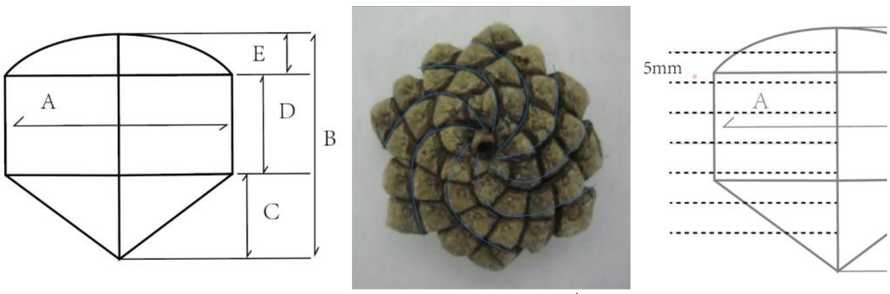


Figure 6: Quantitative analysis of pine cone morphology. (Left) Number of pinecone angles. (Middle) Angular structure space spacing diagram.

The production method is to sew 16 pieces of the same shape of cloth 40cm long and 22cm wide in a straight line with 5cm spacing in one layer order and adjust the sewing position spacing to make it appear like a honeycomb. Therefore, the honeycomb model is first made using coarse cloth.

After the sample is expanded to less than 180 degrees, the coarse cloth amount is increased to 16 pieces, which can be easily expanded to 180 degrees. The rectangular fabric is then cut into 1/4 of the cross-section of the loose ball and the sample is made again. The 3D effect was first simulated in 3Dclo, and the result was that the composition method could achieve the effect of opening into the shape of a pinecone shell (Figure 7); then it involved the testing of memory alloys, such as the sewing and fixing method of the installation position, etc., and the experiment was carried out on white cloth (Figure 7).

In the process of making the sample, apply the same method as outlined in the program, rotating the simulation until it naturally loosens to form the pinecone and copy the 1/4 section of the pinecone. It is a time and fabric-saving measure, and it takes about a day to make samples. At the same time, you can make a prototype and try it everywhere. As a result of the experiment, pinecones were constructed in the chest and opened well near the back shoulder blades and clavicles. During the test, a 2mm line is placed in the center of the first and last piece of the structure, indicating the shape memory metal, and when the strength is applied, the structure movement starts. At the same time, on the other side of the final chapter of the structure, a 2mm line is placed on the garment surface intersecting the structure, which is used as a reverse force (strengthen), and the structure is closed.

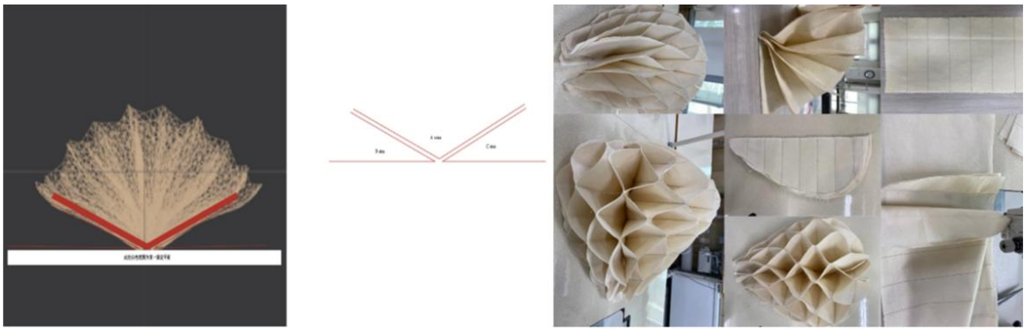

Figure 7: Expand effect 3D virtual.（Left）Expand effect 2D virtual.（Middle）Pinecone structure production diagram.

### 3.2 Design 2. Mimosa-inspired Design

Mimosa can also undergo large morphological changes due to external stimuli (Figure 8). If you search the Internet for mobile plants, mimosas will appear. The leaves of the Mimosa plant shrink when touched, which is a magical sensation that is particularly impressive for children. The leaves shrink side by side and move almost simultaneously.

The Mimosa fragrant moss is a long fan-shaped plant with 18 leaves on each side, with a single leaf length of up to 45mm.（Siddharth, 2007) The method did not measure the length and width of a single leaf. However, the aspect ratio of a single leaf is very significant in this paper.

Figure 8: Mimosa structural analysis and design expansion diagram

Therefore, two leaves are collected from four different specimens, each in a group, and three leaves are taken from each leaf to measure the length and width, respectively. The samples were collected from mimosa's 9th, 10th, and 11th leaves. The central lobe represents the wings of this part.

The mean ratio of the 4 groups was 0.290/0.268/0.283/0.316, and the blade aspect ratio was about 0.289. It was discovered that 0.289 could not meet the moving needs of SMA. It can be moved well by shortening the length, expanding the width, and attaching SMA. Since the actual mimosa middle vein is slightly thinner than the thickness of the SMA, the SMA ratio must be greater than 0.289 to be used like the actual mimosa vein. The exact force of the mimosa is the veins and the lower part of the leaf suspension, so the ratio of width to length of mimosa leaves is crucial for unilateral force to be applied to SMA. Each leaf is designed to move through a transparent fishing line connected to its lower SMA. This is how mechanical reactions mimic the emotional movement of beauty.

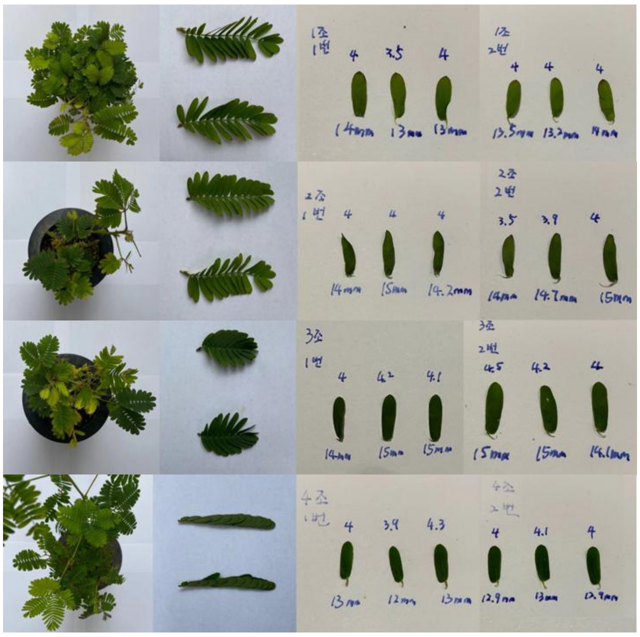

Figure 9: Comparison of extraction and determination of 4 groups of mimosa samples

Table 2: Unit and Category Name (US: 0617): Width/Length (Bottom: Ratio -0.285)

| Scale | Sample measurement value | | | | | | Average ratio |
|---|---|---|---|---|---|---|---|
| First set of test subjects | 4/14 | 3.5/13 | 4/13 | 4/13.5 | 4/13.2 | 4/14 | |
| Ratio value | 0.285 | 0.269 | 0.307 | 0.296 | 0.303 | 0.285 | 0.290 |
| Second set of test subjects | 4/14 | 4/15 | 4/14.2 | 3.5/14 | 3.9/14.7 | 4/15 | |
| Ratio value | 0.285 | 0.266 | 0.281 | 0.250 | 0.265 | 0.266 | 0.268 |
| The third group of test subjects | 4/14 | 4.2/15 | 4.1/15 | 4.5/15 | 4.2/15 | 4/14.1 | |
| Ratio value | 0.285 | 0.280 | 0.273 | 0.30 | 0.280 | 0.283 | 0.283 |
| The fourth group of test subjects | 4/13 | 3.9/12 | 4.3/13 | 4/12.9 | 4.1/13 | 4/12.9 | |
| Ratio value | 0.307 | 0.325 | 0.330 | 0.310 | 0.315 | 0.310 | 0.316 |

Make the base end by using a 20cm wide and 60cm long thin wood, which is set 5cm long and 17cm long (width/length ratio of 0.289). Ten pieces of thin wood are sewn every 5cm and poured into mimosa leaves. The shape memory metal is fixed to the first blade of the structure so that different blades move at the same time, all blades must be connected, so that the first blade successfully pulls the rear blade under the power of the shape memory metal. As a result, part of the structure of pinecone and mimosa has been imitated and artistically transformed, and combined with functionality, the structure can be changed to stimulate the human visual senses.

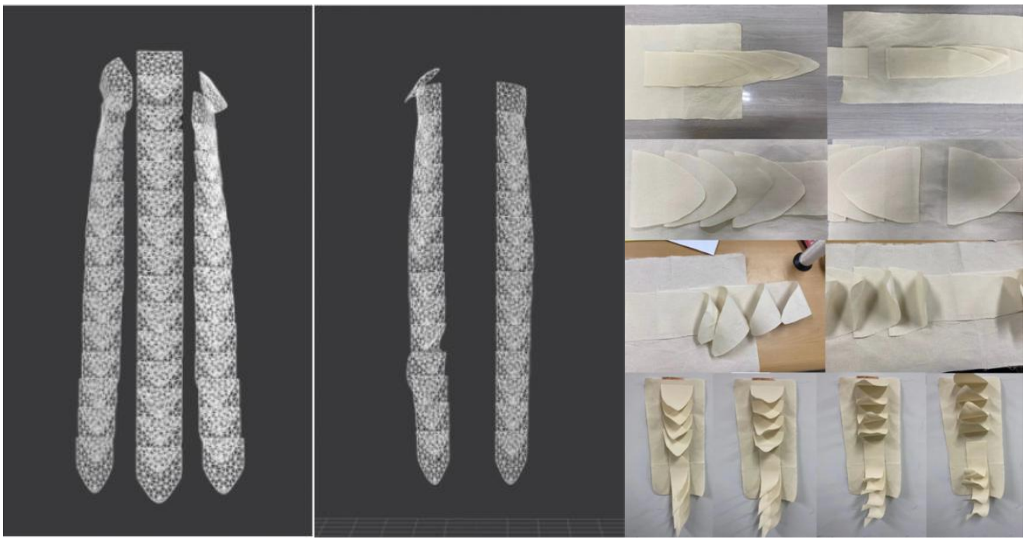

Figure 10: Simulation effect made by 3Dclo (Left); Sample preparation process

It can be seen from Figure 15 that when model 1 is first made in the proportion of the leaves of the mimosa, the common monomer fabric cannot support the blade movement of this length. Consequently, the length should be reduced to 50% and 30%. This will minimize the waste of energy. The designed model 2 and model 1 were sewn to 5 cm, and the test method was to connect each leaf with a fishing line, and the length of the fishing line between each leaf was the same. In the same group with a larger shadow area, it took about an hour to produce pinecones and mimosas in 3Dclo software (Figure 10). After the transparent fishing line is connected, the SMA metal is inserted in a leaf located on the top of the clothing store, so that the leaf structure is made into 3 sections, and one shape memory alloy is attached to the front and back of the middle cover paper. The blade rises when the front surface shape memory alloy is deformed by heat, and the blade moves with the fishline involved when the back surface shape memory alloy is also heated.

## 4. 3D Costume Design Process and Rendering

### 4.1 Work One

First, the bionic design of deformable clothing is formed by the shape of pine nuts, which is in line with the clothing. The effect of opening and closing was produced by selecting three positions that can be adjusted normally following the 3D simulation experiment and physical structure test. The three positions are as follows: anterior chest extension to the abdomen; shoulder to chest; shoulder to back shoulder blades. It is concluded that the response speed will be faster with lightweight fabrics such as Eugen yarn; after selecting the location, determining the style and layout of the garment, and then selecting the fabric to simulate, it is then rendered in 3D (Figure 11). After confirming the effectiveness of the production of the actual clothing, the main fabric is designed which is made of silk, and attached to the surface of the Eugen yarn（Figure 12). Two 10cm-long SMA metals are used by each of the three pinecones groups. These metals are regulated by a power control motherboard connection, which is connected to the mobile phone via a Bluetooth module. The change of clothing is remotely controlled through channel energization.

Source: https://icloths.mysxl.cn/

Figure 11: 3Dclo production process and effects

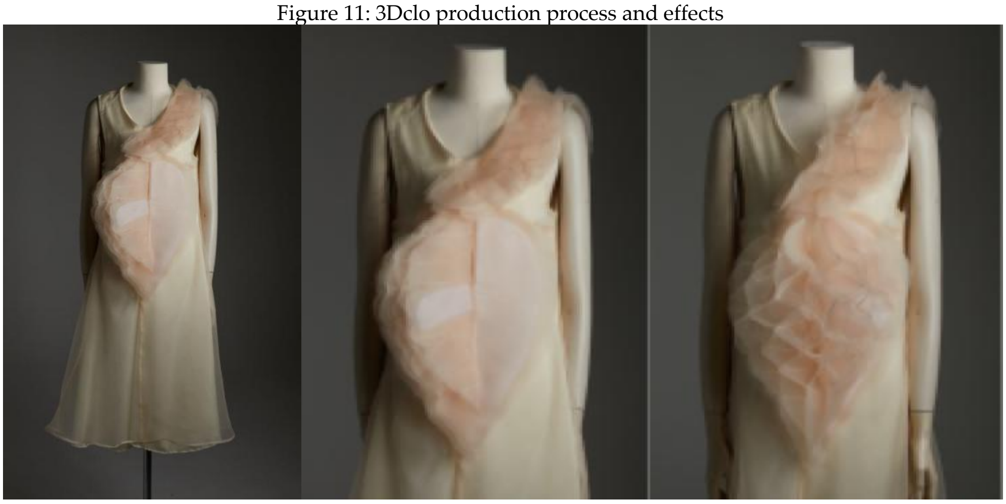

Figure 12: Photograph of the actual production of the work 1

**4.2 Work Two**

This garment is a biomimetic design that has been transformed into the shape of a mimosa plant. First, the modified mimosa 3D structure is placed on the garment. In this instance, five positions were selected, which could be adjusted normally after 3D simulation and physical structure testing, resulting in an on-off and off-off effect. Five positions are set around the waist, three at the front and two at the back extending toward the back of the body centered on the present. After selecting the location, determine the style and layout of the garment, the fabric to simulate is then selected. Additionally, using lightweight fabrics such as the responsive Eugen yarn, the upper body added natural leather material suitable for soil color as a shawl. It is then presented as a 3D effect (Figure 13). After confirming the effectiveness of the actual garment, the main fabric that is made of silk was attached to the surface in a layer of Eugen yarn (Figure 14). The 5 groups of mimosas were composed of 14 leaves, with SMA metal fixed inside the top leaf, and a total of 10 SMA metals to make the leaves move up and down. SMA metal is controlled by the power control motherboard connection, connected to the mobile phone through the Bluetooth module, and remotely controlled clothing through the channel power.

Figure 13: Mimosa 3Dclo production process

Figure 14: Mimosa transformed clothing physical production.

## 5. Production Details and Precautions

### 5.1 Selection Criteria

When selecting clothing materials, choose the fabric that meets the characteristics of the shape base alloy (cotton, linen, silk, transparent hard yarn, denim, spandex, etc.), and then choose a transparent hard yarn that has been aesthetically recognized and tested. In addition, the adhesion of the fabric increases when it comes into contact with the alloy (Figure 15), which in turn increases the corresponding support force. Consequently, the silk showing the sagging characteristics of the fabric is chosen.

### 5.2 The Role of Memory Shape Alloys

The underlying principle is that the body requires physical contact to function well. Only by attaching a device to the body's joints and muscles can the alloy move in the memory's shape; it can be operated better by pushing it in the opposite direction.

### 5.3 Battery Type and Clothing Location

Battery type and location on clothes. The number of cycles and the duration are dependent on the battery type. Currently, the rechargeable battery installed in clothing has a capacity of 8,000 mAh and measures 5cm by 3cm by 1.5cm for ease of research and test experiments, so smaller batteries can be used. The wire is inserted into the joints of the two patterns, while the position on the garment is placed in a dark bag on the back of the second layer of fabric.

Figure 15: Fabric material selection and interior details

## 6. Conclusion

This paper focuses on the comprehensive sustainability of the development of smart clothing based on the bionic design process. From the historical development of biomimicry and the core value composition of smart fashion to the relationship between bionic design and smart clothing, we summarize the methods of extracting design elements from the bionic design process. Firstly, it is demonstrated that the development of intelligent clothing should be based on aesthetics from the perspective of user demand, aesthetics, and the research of intelligent clothing design. Secondly, through the investigation of other biomimetic designers' works, it is determined to simulate the response of organisms to the surrounding environment as the center of design. This response and change to the environment are reminiscent of the plant environment and sustainability. Through the decomposition, simulation, experiment, and reconstruction design of two natural biological structures, the effect of the change can be successfully demonstrated. The use of 3Dclo software during the simulation stage results in significant time savings as well as a significant quantity of white cloth that is required during the early stage of garment production. This approach is practical and sustainable. A biomimetic design process can be used to create dynamic intelligent clothing designs that can be applied to enhance the sustainability of clothing.

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